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U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Wind Energy Technologies Office

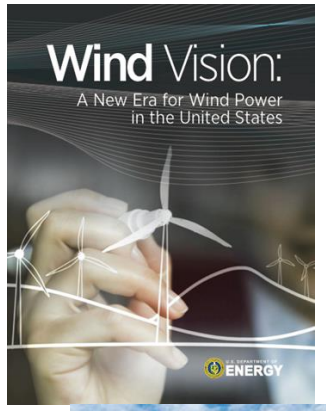
Research and Development efforts on Wind Energy Technologies

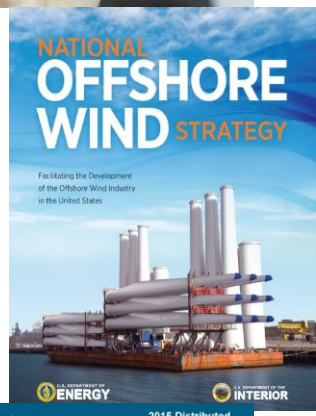
Michael Derby
Head of Research, Development, Demonstration and Testing
Oct 25, 2018

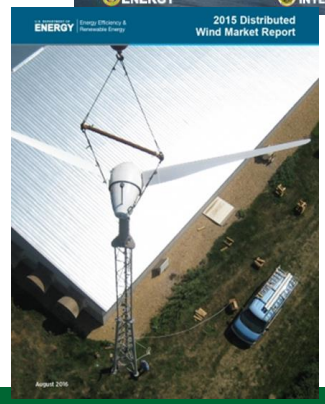
Wind Energy Program Overview

Wind Energy Program

- The Wind Energy Program invests in early stage applied energy science research, development, and validation activities for U.S. **land, offshore and distributed wind power** generation, manufacturing, and market barriers to lower wind energy costs, increase capacity, accelerate reliable and safe energy production, and address environmental and human use considerations.
- The Wind Energy Program supports wind as a sustainable domestic power source that currently **provides over 6% of generation, employs more than 100,000 Americans,** enables a robust domestic turbine component manufacturing sector, and has expansive potential for delivering affordable, reliable power across the nation.





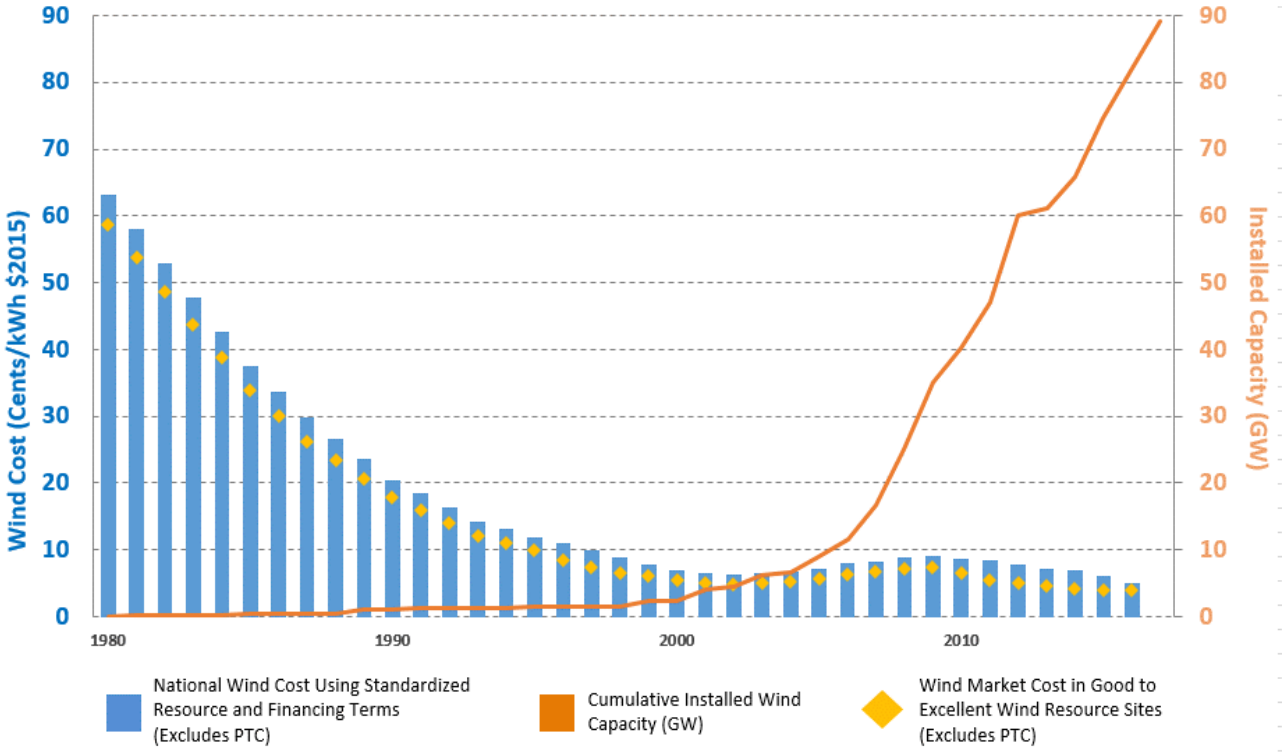


Focus Areas

- **Reducing Technology Costs and Risk**
  - Atmosphere to Electrons (A2e)
  - Technology Innovation Research, Development and Testing (RD&T):
    - Advanced components, reliability, and manufacturing
    - Offshore Wind
    - Distributed Wind
  - National Lab Facilities
- **Supporting Effective Stewardship**
  - Grid Integration and System Reliability
  - Wind/Radar Research and Testing
  - Wind Turbine Environmental Performance
  - Workforce Development and Stakeholder Engagement
- **Improving Understanding of the Costs and Benefits of Wind**
  - Analysis and Modeling

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

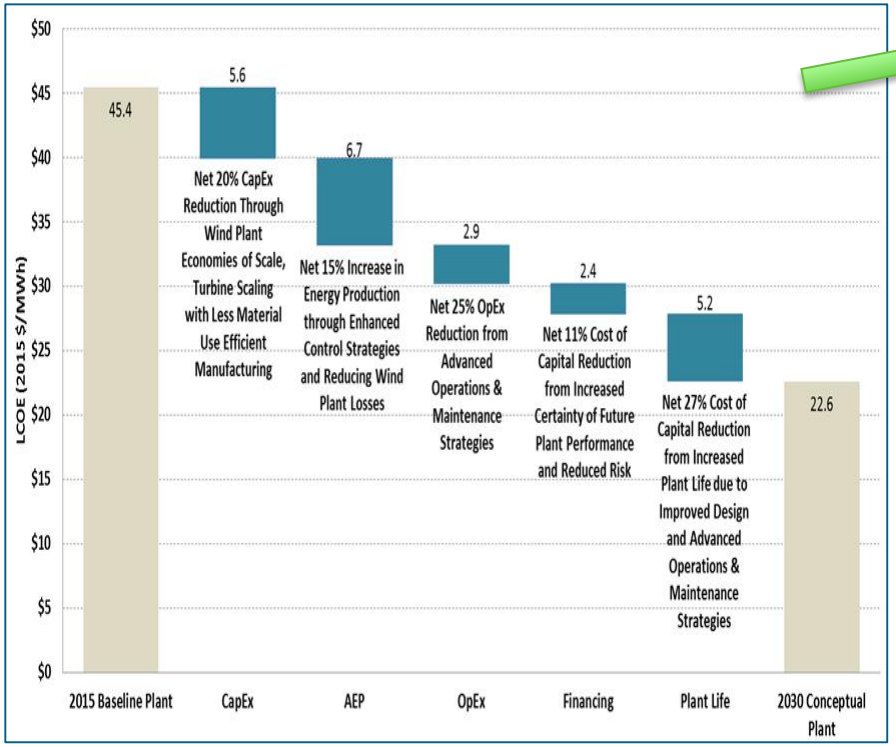


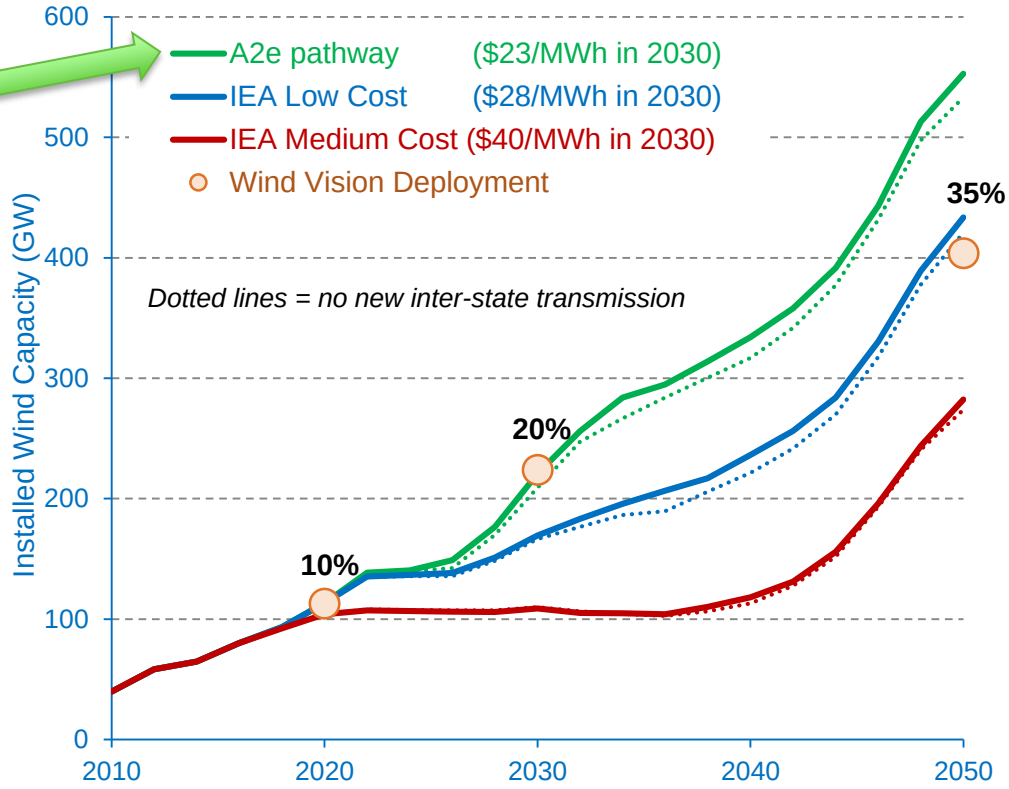
U.S. Wind Cost and Cumulative Deployment. The unsubsidized cost of wind energy in good to excellent wind sites dropped 90% from 1980 to 2016 – driven by DOE research and innovation. Industry has deployed a cumulative 89 GW as of 2017 year-end.

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

Cost Reduction Enables Increased Deployment





Dykes, K, et al., Enabling the SMART Wind Power Plant of the Future Through Science-Based Innovation. NREL 2017.

Mai, T., The Power of R&D as a Means for Continued Growth in a Post-PTC World. 2017 AWEA WINDPOWER

The collection of intelligent and novel technologies that comprise next-generation wind technology can be characterized as "System Management of Atmospheric Resource through Technology," or SMART strategies. SMART wind power plants will be designed and operated to achieve enhanced power production, more efficient material use, lower operation and maintenance and servicing costs, lower risks for investors, extended plant life, and an array of grid control and reliability features.

DOE's Strategy to Capture more Wind Energy

Tall Wind: Taller Towers & Bigger Blades

- Big Adaptive Rotor initiative to develop low-specific power rotors (larger swept area) for tall wind applications, with an improvement in energy capture of up to 15 percent.
- By increasing hub height from 80 meters to 140 meters, the area in the U.S. that has a minimum net capacity factor of 30% is increased by 68%

Wind Plant Optimization

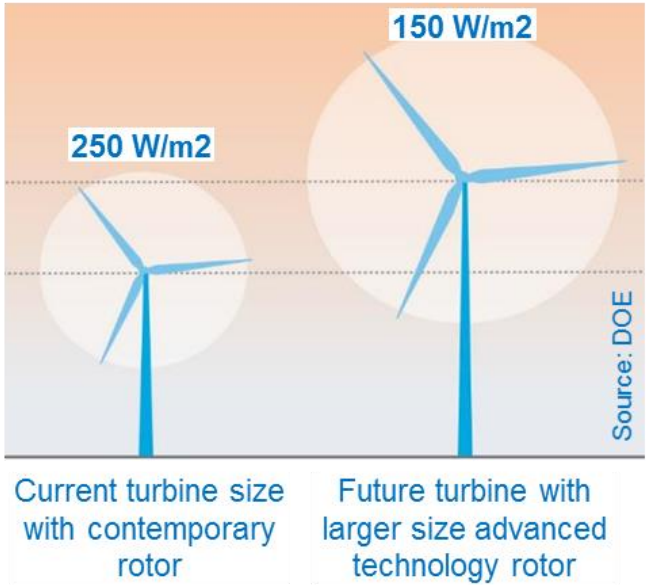
- R&D for next-generation wind plants to increase performance by reducing turbine-turbine wake interaction (current 20-30 percent energy reduction)
- Component and control innovations to reduce unsubsidized cost of wind energy by up to 50 percent by 2030.

Offshore Wind

- Collection and dissemination of wind and wave conditions data at U.S. offshore wind development sites.
- R&D to decrease technology costs and adapt to the unique U.S. conditions.
- Demonstration projects leveraging technologies that address U.S.-specific challenges.
- Evaluation of supply chain limitations.

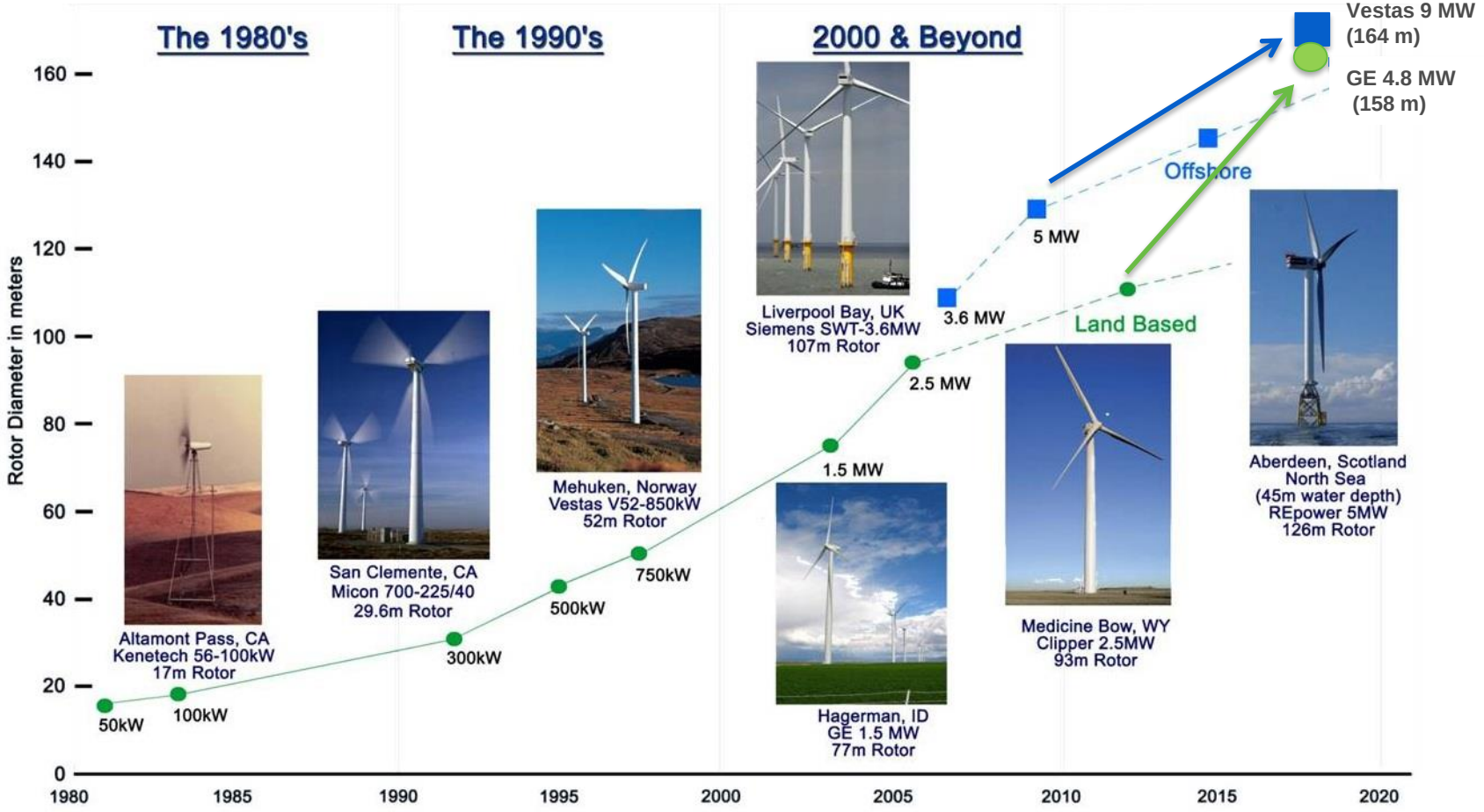
Distributed Wind Opportunities

- Integrated into microgrids



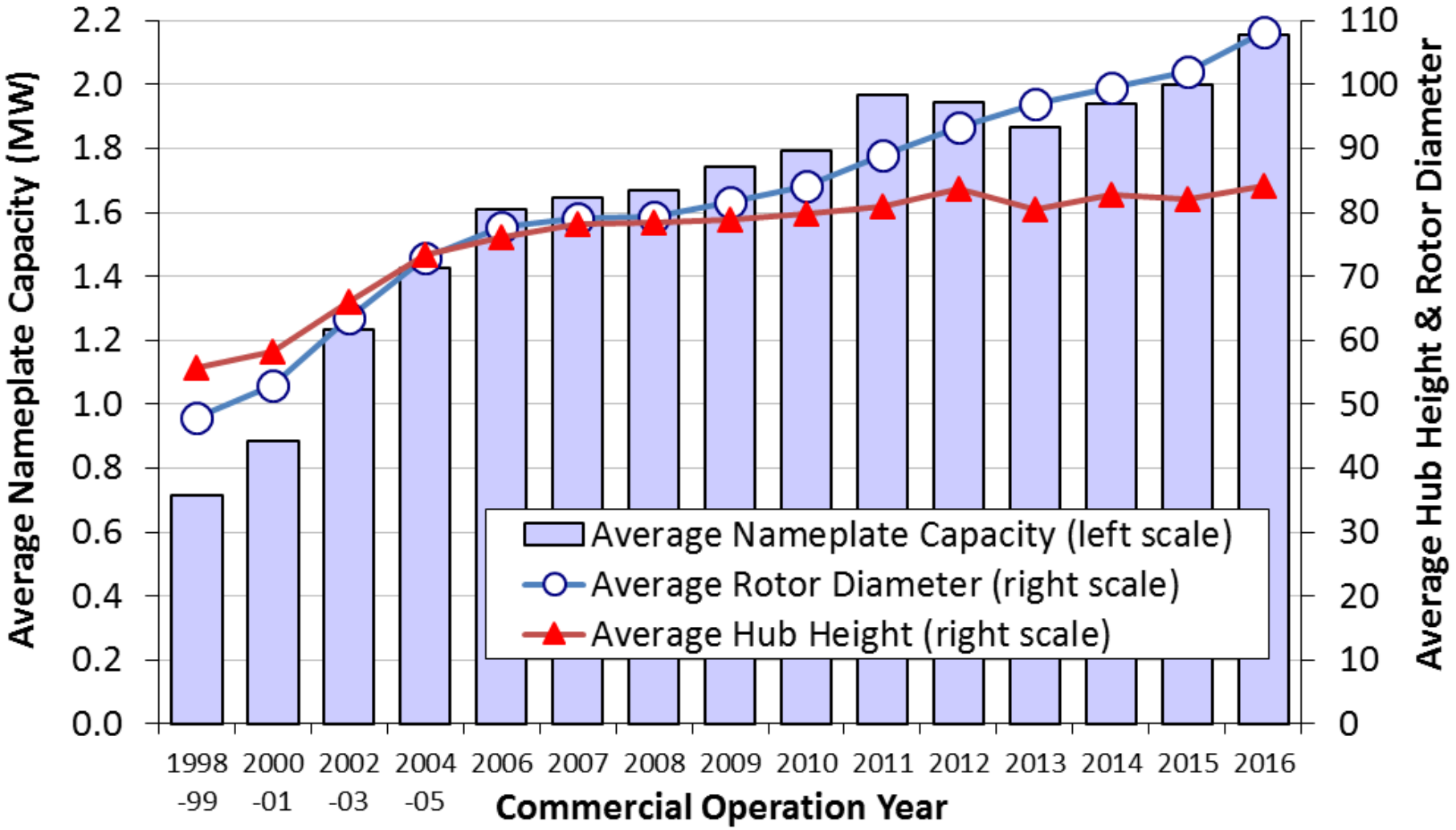
Wake Interaction at Horns Rev Offshore Wind Farm

Technology Evolutions



- Land Based Technology > 2 MW; Turbine 50% Total Installation Cost
- Offshore Technology > 5 MW; Turbine 25% - 35% Total Installation Cost
- Land Based Turbine Size Constrained by Highway Transport
- Turbine Stiffness & Dynamic Coupling Driving Design Innovation

Turbines Have Grown Larger in Diameter But Towers have remained around 80m



Source: DOE (2017), NREL (2017a); U.S. data
Courtesy of Dr. Ryan Wiser, LBNL

DOE Tall Wind Technology Development

Brief History – Towers, Drivetrains, and Blades

Wind Tower Systems/ Wasatch Wind – Space Frame Tower/Metal Lattice Structure — SBIR — 2002

Native American Technologies – 150m UltraTall Tower — SBIR — 2007; ARRA — 2009

GE – Acquires Space Frame Technology — 2011

GE – Fabric Based Wind Turbine Blades — ARPA - E — 2013

GE – Space Frame Tower Commercial Introduction — 2014

NREL – Hybrid design single stage gearbox and medium speed generator — FOA — 2015

EU — 2006

Gamesa – Segmented Blades (InnoBlades)

FOA — 2011

Advanced Magnet Lab/NREL – Superconducting Generator Design

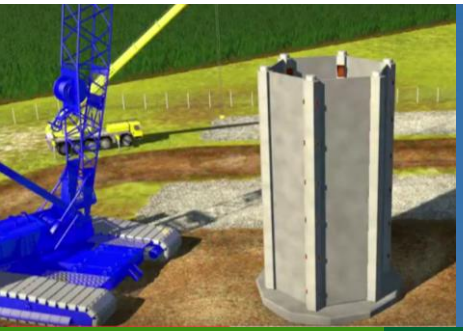
FOA — 2014

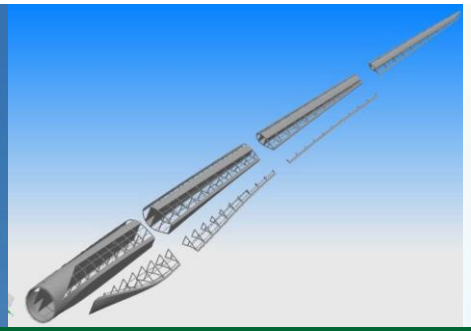
Keystone Tower Systems – Spiral Welded Tubular Steel Towers

Hexcrete Tower – High Strength Concrete Towers w/pre-stressed Steel Reinforcement

SBIR — 2015

Wetzel Engineering – Modular Blades

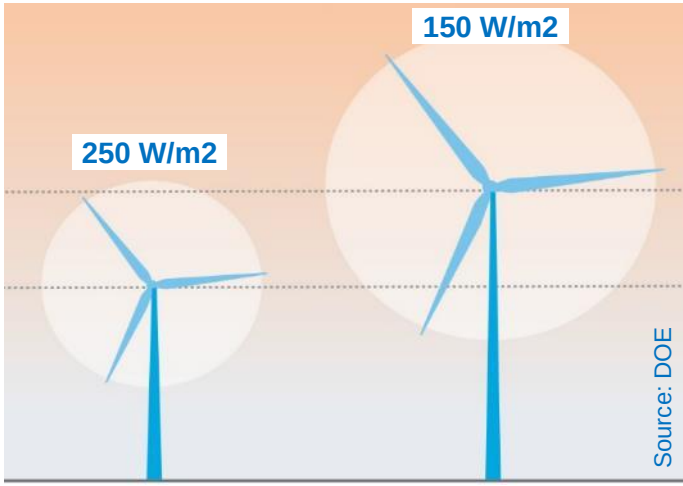




Big Adaptive Rotor Initiative

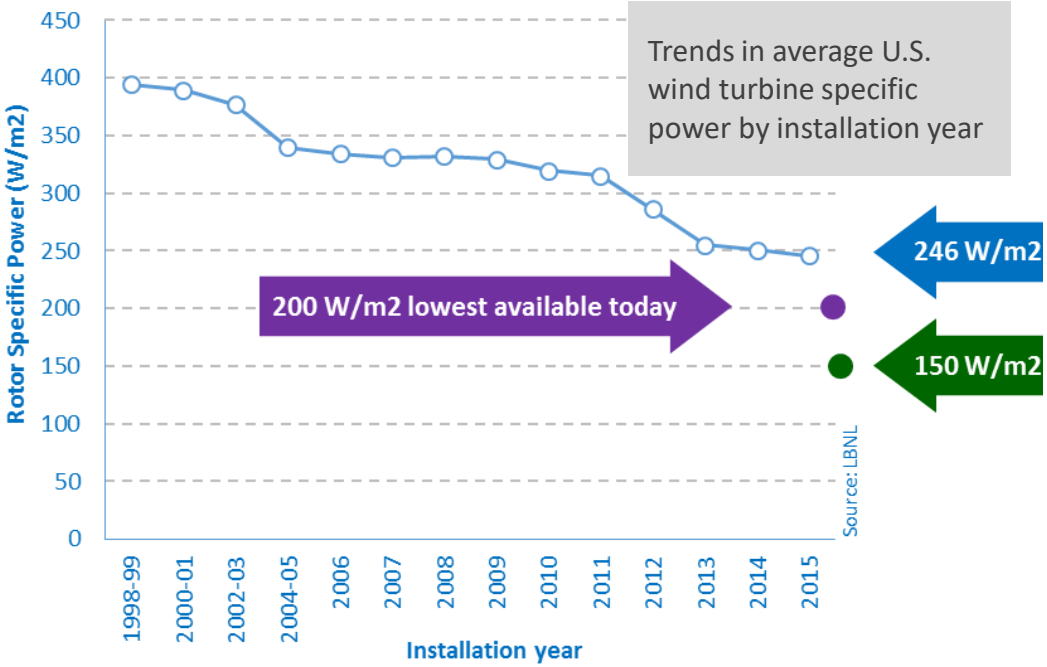
Technology Innovation and Testing

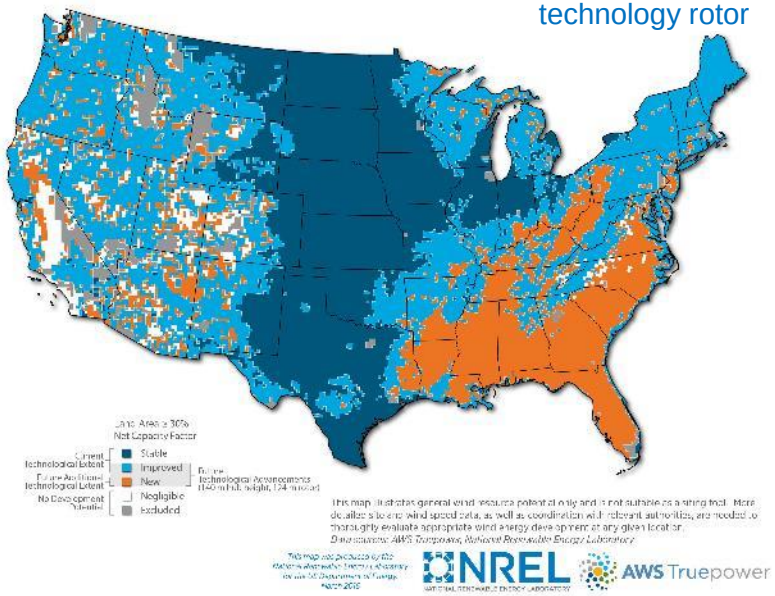
Advanced technology is required to design and manufacture very large low specific power density rotors that are lightweight, durable, and high-performing. In addition, transportation and other logistical challenges for tall wind applications must be addressed.



Current turbine size with contemporary rotor

Future turbine with larger size advanced technology rotor





Transportation and Logistics Challenges of Larger Blades

To maximize potential future cost reductions in wind technology, wind plants will require substantially larger turbine blades to achieve greater capacity factors and plant efficiencies

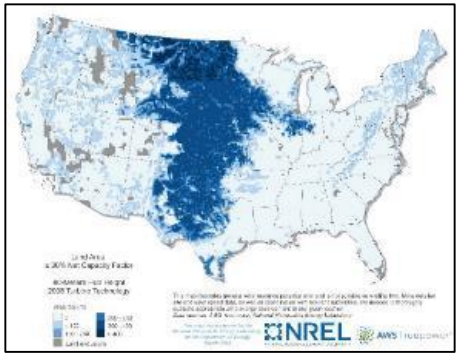
- Current U.S. **transportation limitations**, manufacturing and assembly methods, and materials all limit the widespread deployment of supersized blades around the country.
- Key transportation issues for large blades include:
  - Difficulty of transporting around turns, through narrow passages, and beneath overhead obstructions on U.S. roads and railways.
  - State Permitting Requirements
  - Coordination between transportation/logistics providers, state/federal agencies, and manufacturers

Photo credit: SSP Technology

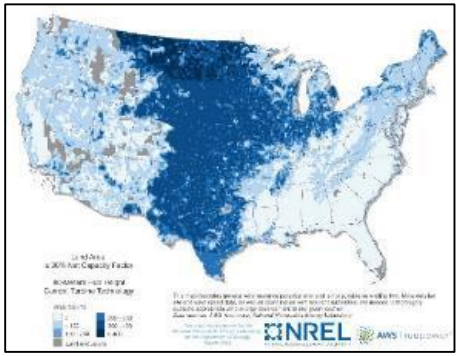
Taller Towers

Advancing wind turbine technology can unlock 700,000 more square miles of wind potential and make it a cost effective option in all 50 states

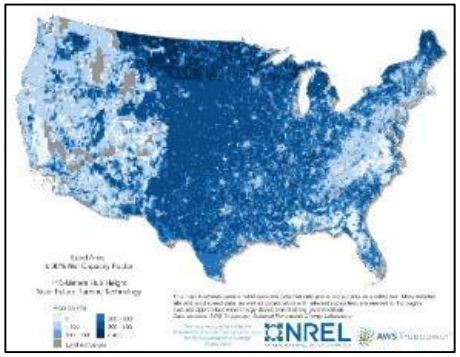
- By **increasing hub height from 80 meters to 140 meters**, the technical potential for land-based wind power expands by 67%
- **Tall wind technology** can unlock an additional area equivalent to roughly one-fifth of the United States
- Tall wind will allow wind energy to become an option in the Southeast, as well as facilitating further deployment in regions like the Midwest, Northeast, and West
- Relatively small **targeted investments** in grid infrastructure for grid reliability and resilience will enable states to take advantage of optimum local resources and energy needs
- Storage is not needed today, or in the near future, as utility forecasting and load balancing **are managed** at minimum costs with limited cycling of power plants



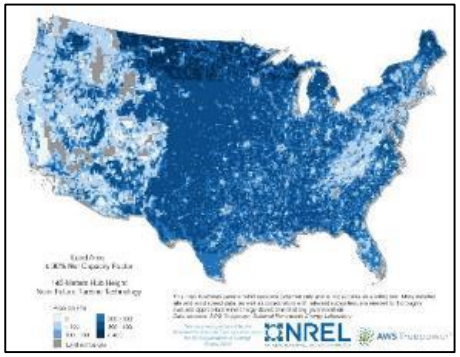
80M, 2008 Technology



80M Current Technology



110M Near Future Technology

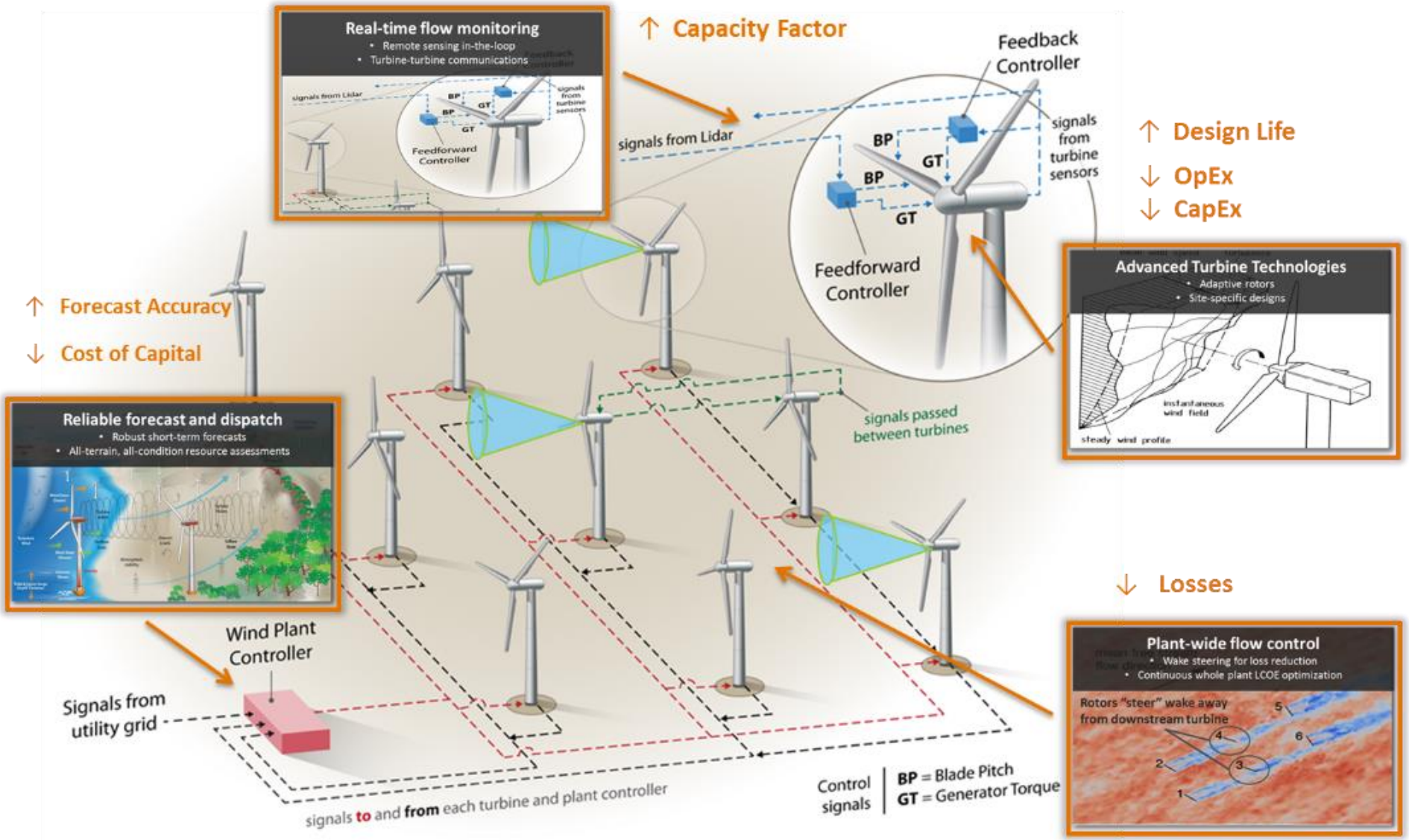


140M Near Future Technology

Atmosphere to Electrons (A2e)

Wind Plant Design Improvements

ATMOSPHERE TO ELECTRONS
U.S. DEPARTMENT OF ENERGY



National Offshore Wind Strategy

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

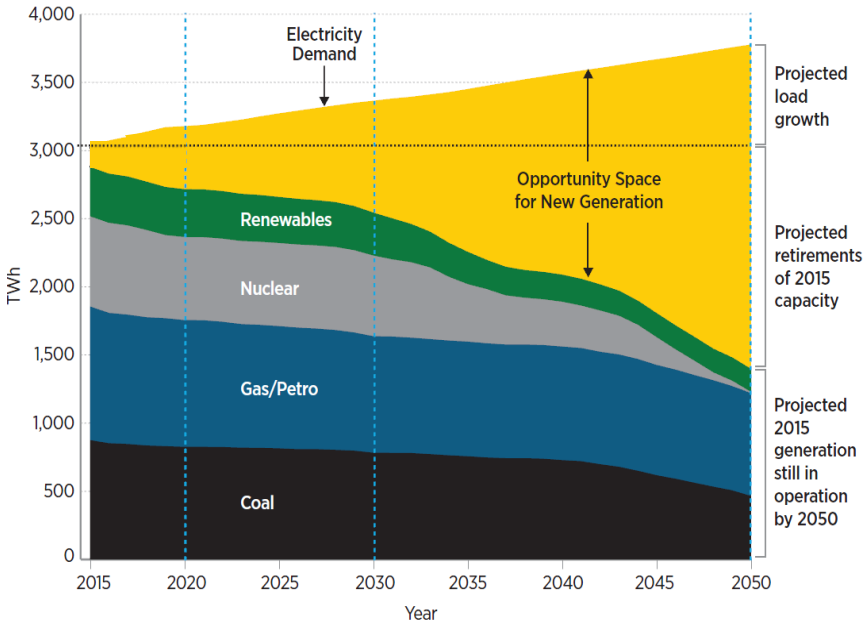
- Reducing technology and installation costs and risks
- Ensuring efficient, effective regulatory construct
- Supporting effective stewardship of the environment and public space
- Improving understanding of offshore wind's benefits

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.

DOE's Current Offshore Wind Efforts

Offshore Wind R&D Consortium ($41M total funding)

- NYSERDA selected as Administrator to establish an R&D consortium with matching industry funds to accelerate U.S. offshore wind by supporting fundamental R&D addressing:
  - **Offshore Wind Plant Technology Advancement** -- floating foundations R&D, innovations in components, controls, and electrical subsystems.
  - **Resource and Site Characterization** -- validation of innovative methodologies to collecting *in situ* data, improve understanding of extreme conditions such as hurricanes.
  - **Installation, O&M and Supply Chain Technology Solutions** -- reduction of onsite O&M needs, reduction in costs through improved foundation technology and installation processes.

Offshore Wind Advanced Technology Demonstration Projects

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

Offshore Wind Plant Optimization

- Improve the performance and reliability of next-generation optimized plants by investigating systems-level efficiency losses influenced by atmospheric conditions and turbine-turbine wake interaction in large arrays.

Offshore Wind Market Acceleration and Deployment by Supporting Early-Stage R&D

- Develop new technologies for monitoring wind-wildlife interactions in the offshore wind space, and information aggregation and dissemination through domestic and international collaborative partnerships.

Distributed Wind
Major Untapped Potential in Rural America

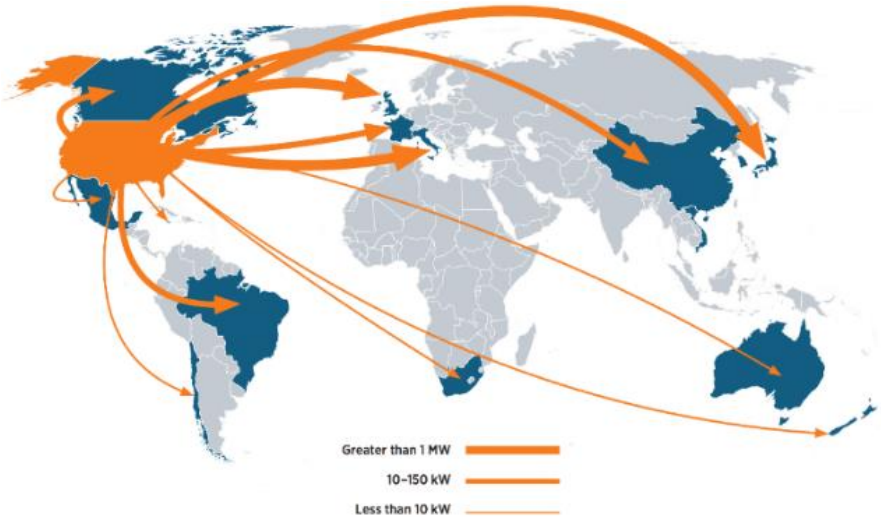
Significant Market Potential
- Technically feasible for approximately 49.5 million residential, commercial, and industrial sites nationwide.
- Market potential of nearly 4 GW by 2030 and 20 GW by 2050.
- Presently **over 75,000 wind turbines**, totaling 934 MW in cumulative capacity, deployed **across all 50 states**.

Made in America
- U.S. small wind (≤ 100kW) turbine manufacturers report domestic content levels ranging from 66% to 100%.
- U.S. distributed wind businesses support **jobs in 23 states.**
- U.S. small wind turbine manufacturers accounted for **nearly 98% of domestic sales** in 2016.

Global Leadership
- U.S. manufacturers accounted for nearly **75% of 2015 global small wind turbine sales**.
- U.S. small wind manufacturers doubled exports to international markets from 2014 to 2015.
- Since 2011 exports have accounted for more than half of U.S. small wind manufacturers sales.

Distributed wind is used to provide power to remote "off-grid" communities and to offset all or a portion of energy costs for retail power customers.

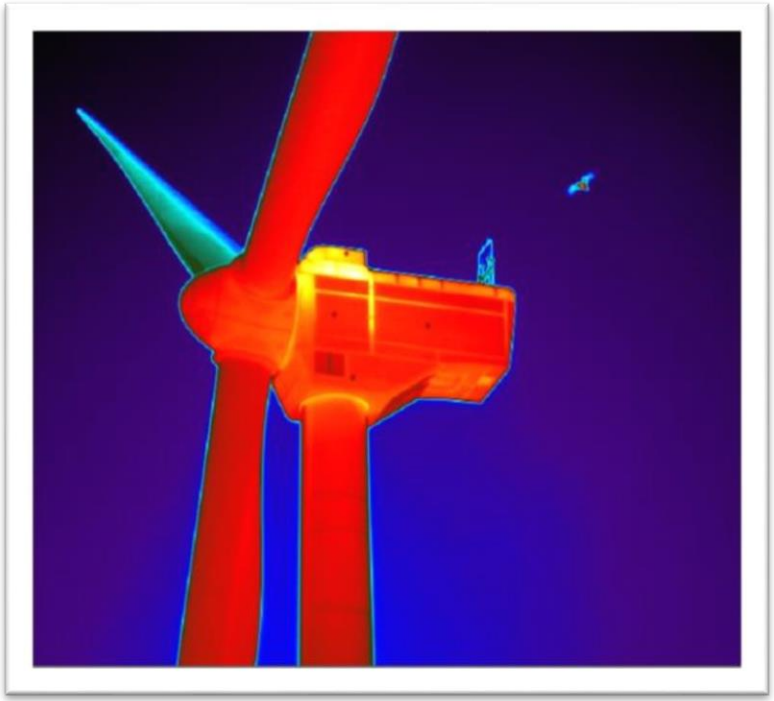
US Small Wind Exports, 2015



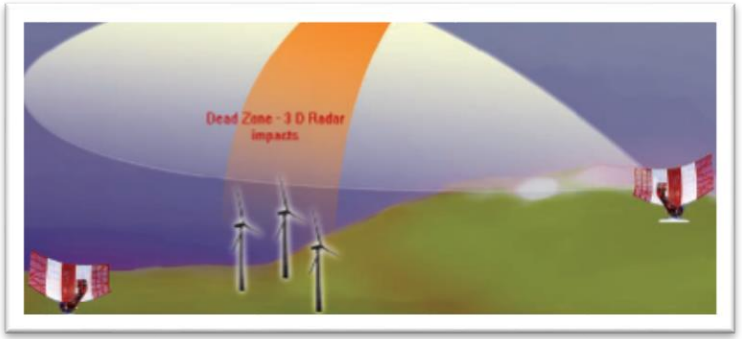
Siting and Environmental Research

Motivation: Develop technical solutions to allow for wind development in areas where regulatory restrictions associated with radar interference, wildlife impacts, or human use conflicts would otherwise prevent it.

Better understand and model risk

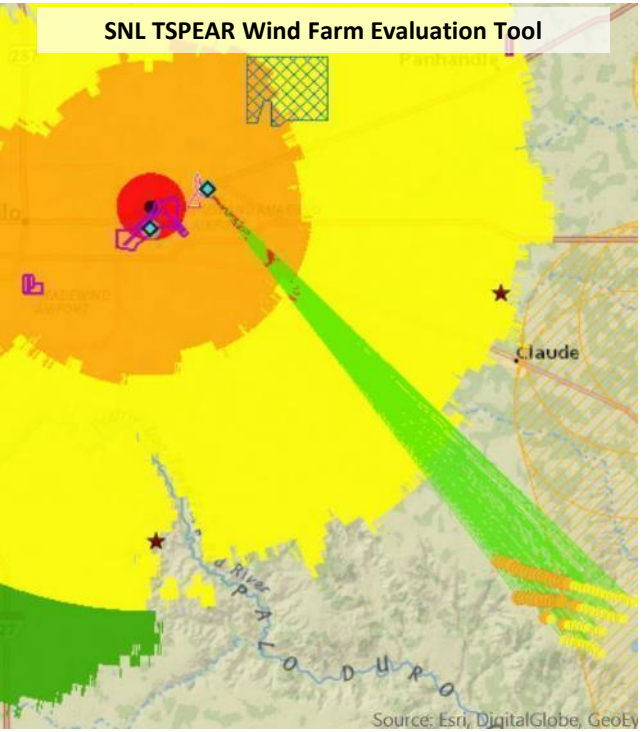


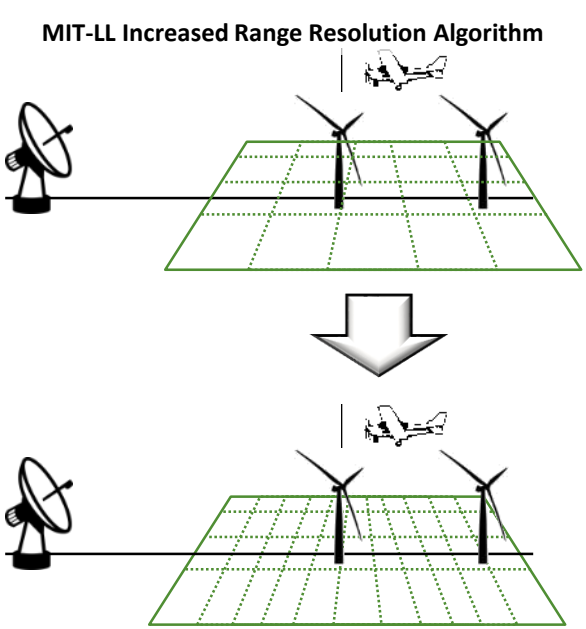
Develop mitigation solutions

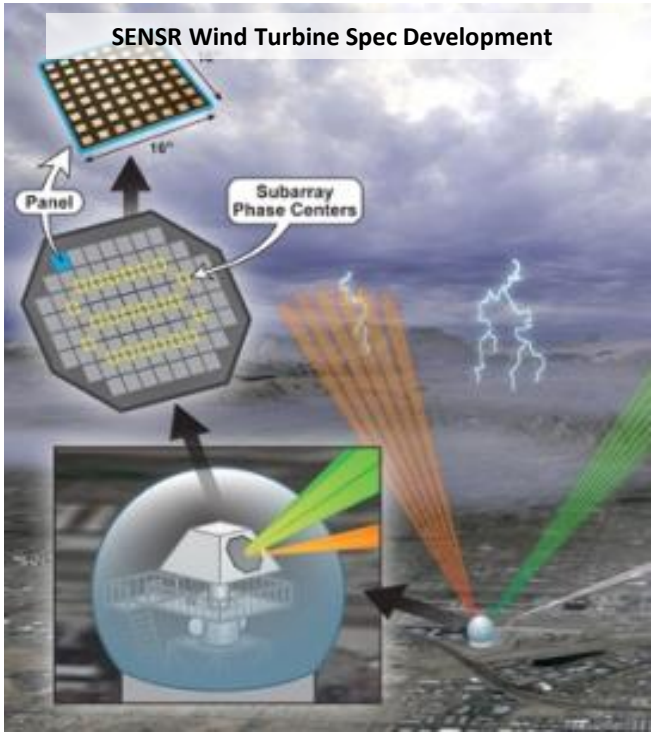


Wind Turbine Radar Interference Mitigation

Focus: Strong Federal Strategy and Collaboration







Strategic Theme 1:
Improve capacity to evaluate the impacts of wind energy on sensitive radars

Strategic Theme 2:
Develop and deploy mitigation measures to increase resilience of existing radars to wind turbines

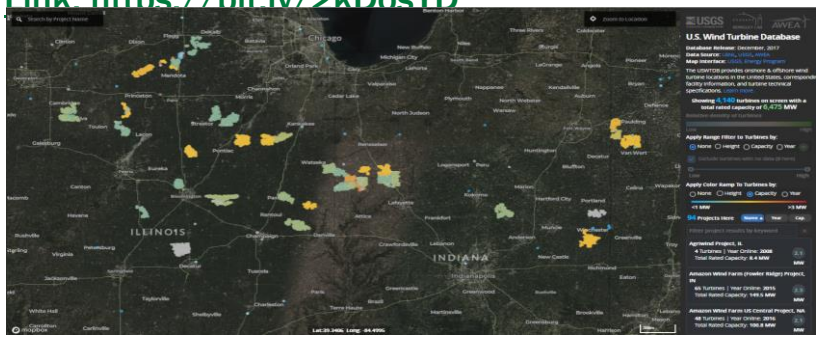
Strategic Theme 3:
Encourage the development of next-generation radars resistant to wind turbine interference

2015 Memorandum of Understanding (MOU) establishes working group (WTRIM WG) to collectively develop and deploy mitigation approaches, allows significant leverage of DOE funds

Key partners: DOD Siting Clearinghouse, FAA, NOAA, BOEM, DHS

Mitigating Market Barriers Tools & Resources

- **WREN**: WREN (Working Together to Resolve Environmental Effects of Wind Energy) is an international collaborative project focused on connecting wind energy practitioners from around the world around environmental issues.
- Link: https://tethys.pnnl.gov/
- **WINDExchange**: An online platform for neutral, fact based information on wind energy and development in the U.S.
- Link: https://windexchange.energy.gov/
- **US Wind Turbine Database:** Provides locations for land-based and offshore wind turbines in the U.S., corresponding wind project information and turbine technical specifications.
- Link: https://eerscmap.usgs.gov/uswtdb/
- **Understanding Wind Project Neighbors Through a National Survey of Attitudes:** First-ever nationwide quantitative assessment of the drivers of public acceptance and opposition to wind projects, largest-ever survey of wind farm neighbors (plus: national wind turbine mapping project).
- Link: https://bit.ly/2H6yfQ3
- **The DoD Preliminary Screening Tool:** Enables developers to obtain a preliminary review of potential impacts to Long-Range and Weather Radar(s), Military Training Route(s) and Special Airspace(s) prior to official FAA filing processes (OE/AAA)
- Link: https://bit.ly/2kDosYD



Close up of turbines located in IL & IN

Workforce Development

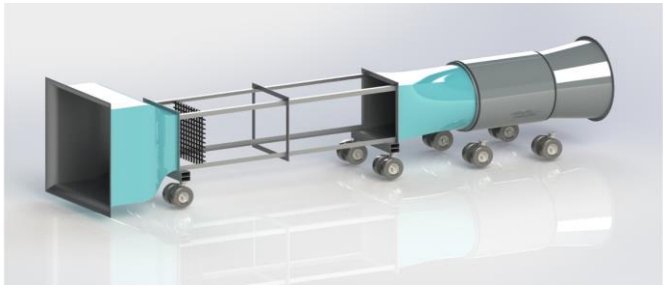
DOE helps ensure a robust domestic workforce

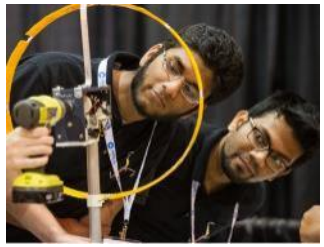
Wind for Schools

- **Introduces wind energy education** and careers to teachers and K-12 and post-secondary students, supporting the industry's need for a skilled and qualified workforce
- **Equips college students** with hands-on wind energy applications and education to provide the growing U.S. wind industry with a competitive workforce.

Collegiate Wind Competition (CWC)

- **Introduces students to the primary disciplines within the wind energy industry**, including engineering, project management, business, and stakeholder engagement
- **Prepares students from multiple disciplines to enter the wind energy workforce** by providing real-world technology and business plan development experience.

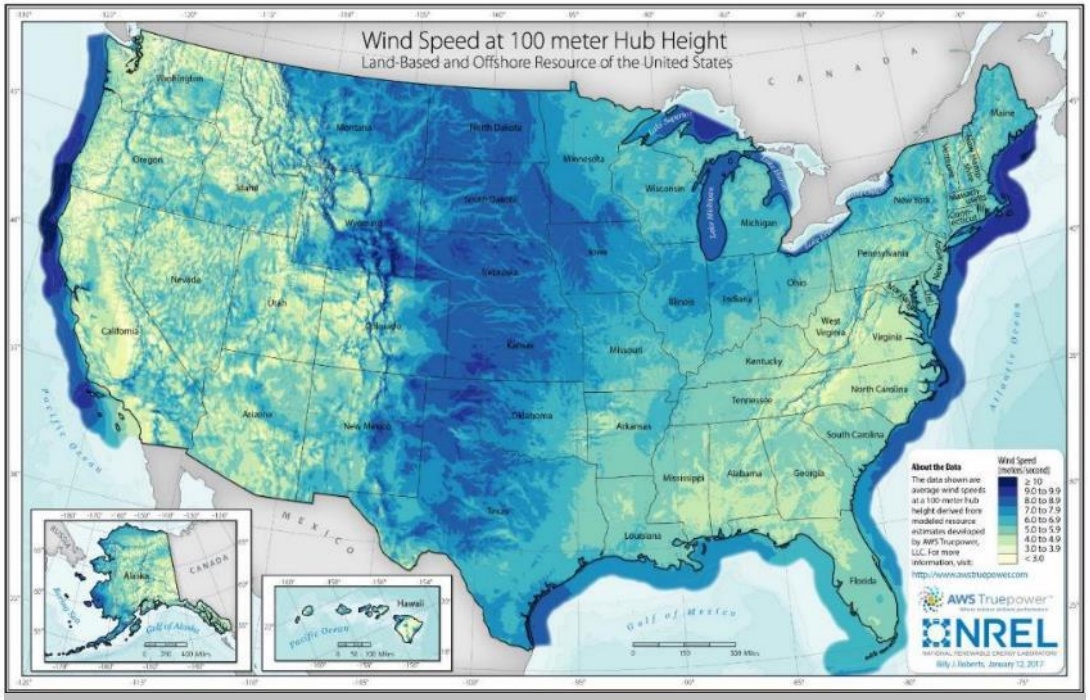




We Can Do More Across All Regions

U.S. Wind Resources are Among the Best in the World

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



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

Untapped Wind Market Potential in All 50 States

- Land-based utility-scale wind
- Offshore wind (OSW)
- Land-based distributed-scale wind

Barriers

- Wind turbine design
- Reliability
- Wind plant optimization
- Cost reduction
- Grid integration
- Mitigation of environmental impacts and human use impacts such as radar interference.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wind.energy.gov