U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EERE Wind: Program Overview

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Administration & DOE Priorities

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White House
- Generate 80% of the nations' electricity from clean energy sources by 2035
- Reduce carbon emissions 80% by 2050
- Stimulate jobs and economic recovery through RE development

DOE
- Promote energy security through reliable, clean, and affordable energy
- Strengthening scientific discovery and economic competitiveness through science and technology innovation

EERE
- Invest in clean energy technologies that strengthen the economy, protect the environment, and reduce dependence on foreign oil

WWPP
- Improve the performance, lower the costs, and accelerate deployment of innovative wind and water power technologies

The ***mission*** of the Wind Power Program is to enable U.S. deployment of clean, affordable, reliable and domestic wind power to promote national security, economic growth, and environmental quality

Wind Program Portfolio
Transformational Technology Innovation

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The Wind Program performs **Research and Development of Transformational Technology Innovation** in three markets:

Land Based Utility Wind
- 1-5+ MW turbines
- R&D Focus: Next generation turbine cost reductions, improved energy capture & conversion at an "Integrated Wind Plant" level, advanced controls, extended useful life of components

Offshore Wind
- 3-10+ MW turbines
- R&D Focus: Floating platforms (access higher winds); integrated systems designs (reduce full plant LCOE); optimized O&M strategies (reduce costs, extend life); turbine innovations (less constraints than on land) including rotor, next generation drivetrain and control systems

Small Wind
- < 1 MW turbines, Grid connected on the customer side of the meter
- R&D Focus: Optimized for low Class 3/Class 2 wind speeds, very low maintenance, LCOE reduction to compete with retail

Wind Program focus is on transformational innovations that the Wind Industry cannot achieve on their own

Wind Power Technology Evolution

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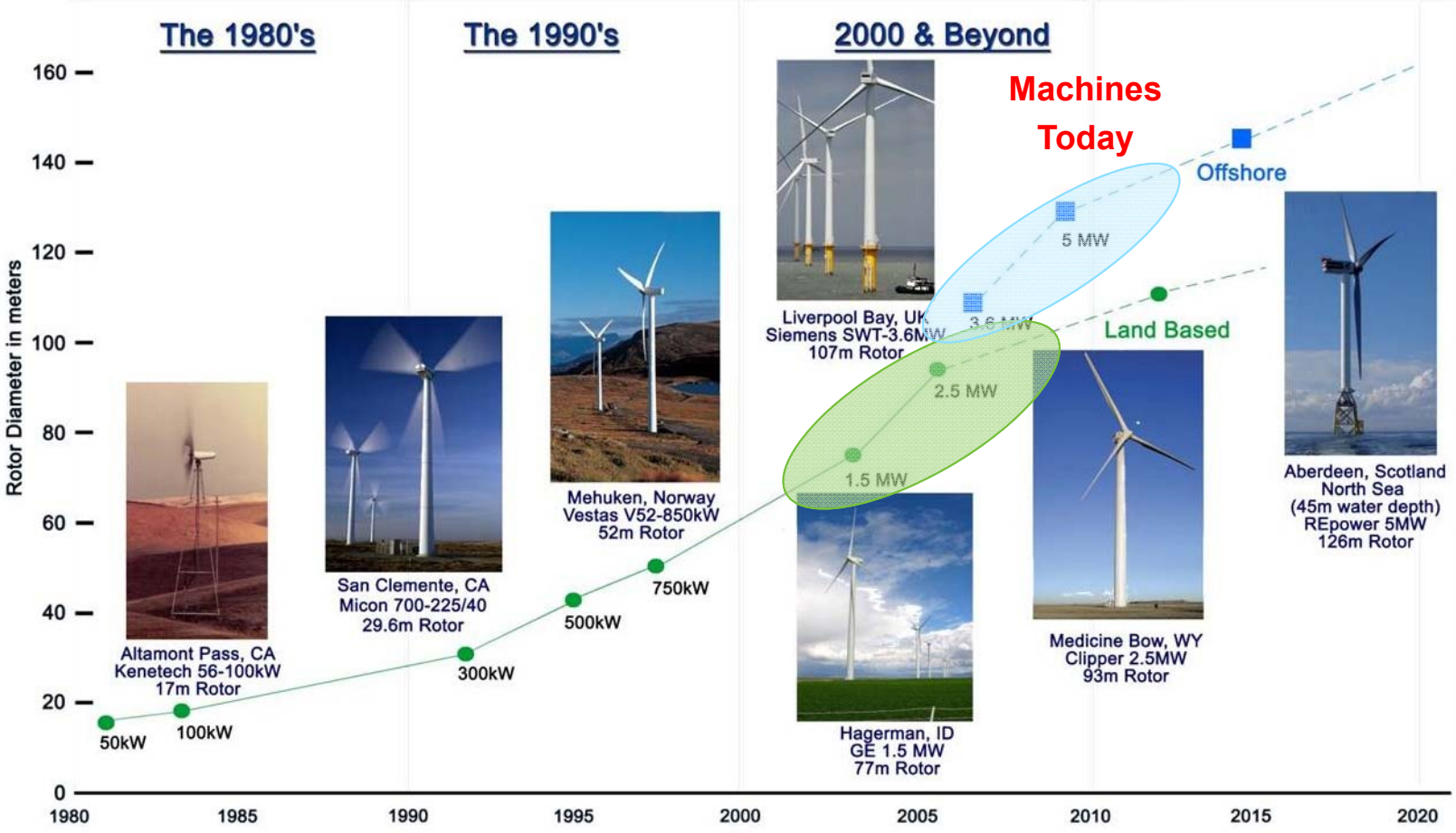

- **Land Based Technology > 2 MW; Turbine 50% Total Installation Cost**
- **Offshore Technology > 5 MW; Turbine 25% Total Installation Cost**
- **Land Based Turbine Size Constrained by Highway Transport**
- **Turbine Stiffness & Dynamic Coupling Driving Design Innovation**

Wind Technology major innovation shifts occurred at 100kw, 1.5MW, 3.5MW, beyond linear scaling. More paradigm shifts needed to achieve competitive parity with Natural Gas

Wind Program
LCOE and GW Goals

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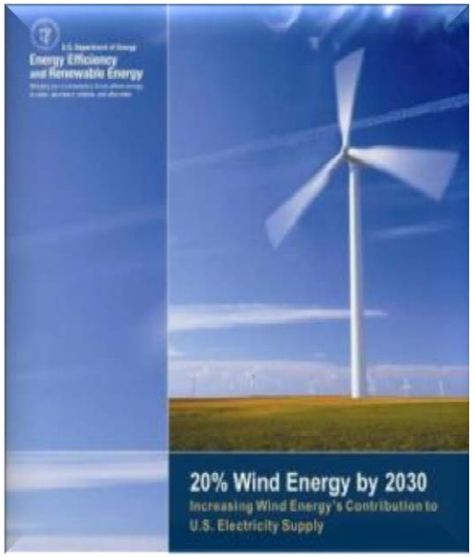
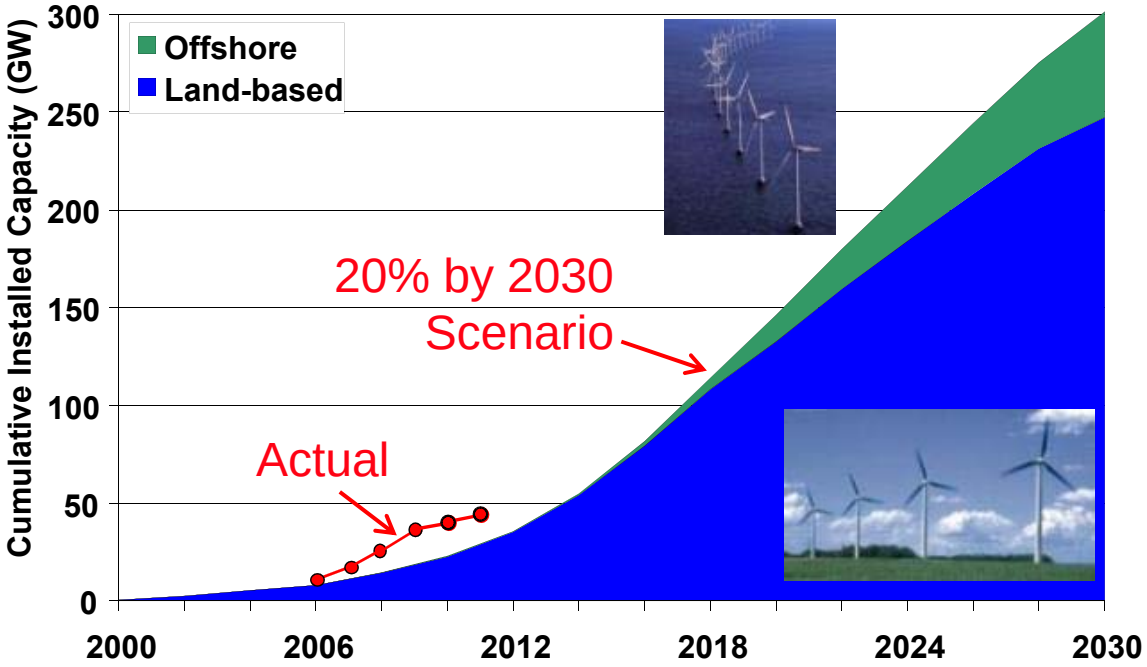


**Cumulative 2011 capacity includes 3,360 MW installed through Q3 2011 and assumes 33% of 8,482 MW under construction as of Q3 2011 in service by the end of 2011 for a total of 6,160 MW installed in 2011.*

20% Wind Scenario



Wind Program Goals	2010		2015		2020		2030	
Market Segment	COE (¢/kWh)	GW	COE (¢/kWh)	GW	COE (¢/kWh)	GW	COE (¢/kWh)	GW
Land-based Utility Target	8.2	40	6.8	75	5.7	125	4.2	250
Offshore Target (Fixed Bottom Foundation)	25.3	0	20.9	0	16.7	10	13.2	54

Aggressive Wind LCOE and GW goals are achievable with anticipated Wind Program impacts

Wind Power
Total U.S. Wind Resource Potential

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		Land Based Wind			Offshore Shallow Water (< 30 meters)			Offshore Deep Water (> 30 meters)		
Wind Class (@ 80 meters)	Velocity Range (m/s)	Resource Potential (GW)	Capacity Factor (Weibull)	Quads (Quadrillion BTUs)	Resource Potential (GW)	Capacity Factor (Weibull)	Quads (Quadrillion BTUs)	Resource Potential (GW)	Capacity Factor (Weibull)	Quads (Quadrillion BTUs)
III	6.4 - 7.0	4186	30%	37.5						
IV	7.0 - 7.5	3544	35%	37.0	249	35%	2.6	292	35%	3.1
V	7.5 - 8.0	1109	40%	13.2	365	40%	4.4	505	40%	6.0
VI	8.0 - 8.8	64	42%	0.8	294	42%	3.7	712	42%	8.9
VII	8.8 - 11.9	16	45%	0.2	164	45%	2.2	1569	45%	21.1
Total :		**8919**		**88.8**	**1072**		**12.8**	**3078**		**39.1**

- **Total Addressable U.S. Wind Energy Potential** **≈ 141 Quads (13,000 GW equivalents)**
- **Total U.S. Energy Use** **≈ 98 Quads (9,000 GW equivalents)**
- **Total U.S. Electrical Energy Use** **≈ 13 Quads (1,200 GW equivalents)**
- **20% by 2030 Goal** **≈ 3 Quads (300 GW equivalents)**
- **Current U.S. Wind Contribution** **≈ 0.4 Quads (40 GW equivalents)**

Source: NREL Wind Resource Database - Standard Version, April 2009

Significant SUSTAINABLE wind resource potential, greater than 10 times current total U.S. electricity consumption, supports high wind penetration scenarios

DOE Unique Role in Wind

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Interagency government coordination to accelerate deployment

- Collaboration on Permitting barriers with BOEM, FWS, DHS/DOD/FAA,…
- Collaboration on transmission planning and integration with FERC and Office of Electricity

Funding to benefit Industry 'commons'

- National Testing Facility infrastructure
- Certification and standards for small wind
- Publicly available national datasets for wind resource data
- Support and promote the workforce of tomorrow

WWPP Role in Wind Industry

Perceived High Risk/Long-term R&D Projects

- Offshore Demonstration project
- Next Generation drive-train
- Next Generation wind plants

Accelerate Administration priorities

- Investments in Manufacturing Innovation /U.S. Competitiveness
- R&D targeted on addressing renewables integration and transmission planning challenges

Wind Program tackles Priorities that Industry players cannot do alone

Wind Program Continuing Successes

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- **Development and demonstration of the first multi-megawatt wind turbines** (MOD series) setting the knowledge base and foundation for benefitting today's commercial industry **(1980s)**.
- **Wind turbulence field measurements and stochastic models development.** Established causal relationship between atmospheric turbulence and failure of large and small turbines deployed in the field. Provided fast and efficient methods for numerical simulation of turbulence in design codes **(1980 – present)**.
- **Development and validation of numerous structural, aerodynamic and controls codes** used extensively by industry in the design and development of innovative technology and commercial architectures **(1990s – present)**.
- **Next generation rotors and rotor material characterization and analytical modeling work**. Carbon-hybrid blades and creation of a composites materials database used extensively by industry for the commercial design of blades and rotors **(1990s – present)**.
- **Designation of the National Wind Technology Center (NWTC)**. Creation of a national center co-locating field, dynamometer, and blade test facilities with a national engineering center dedicated to advanced technology and model development **(1996)**.
- **Unsteady Aerodynamics Experiment (UAE).** Field and measurement campaigns conducted at the NWTC in conjunction with full turbine testing within NASA 80x120 Wind Tunnel establishing the world bench mark data set for codes validation of turbine aerodynamics and wakes leading to subsequent design innovation **(1990s)**.
- **Performance verification of turbines** emerging from DOE-industry turbine-development programs, resulting in design refinements and early entry of leading electric utilities into the commercial wind power arena **(1990s)**.
- **Wind turbine system and component development and demonstration**. Technology development programs including WindPact, and Low Wind Speed Turbine (LWST) supporting the development and demonstration of innovative prototypes leading to larger commercial wind turbines able to reach higher wind regimes and achieve greater energy capture; specific partners included Zond, GE, Northern Power Systems, et.al. **(1995 -2006)**.
- **Wind Powering America** drove RPS development in a number of key states, opening new markets **(2000-present).**
- **Wind Integration Studies**. Development of analytical and technical approaches to modeling power system behavior with various levels of wind and other variable generation deployment. Evaluation of grid reliability impacts in the near and long term. Evolution from a single utility to interconnection wide analysis **(2006-present).**
- **HydroDYN code development**. First integrated tool developed for modeling offshore deep water floating platform structures (barge, spar buoy, tension leg platform) incorporating coupled hydrodynamic and aeroelastic response to atmospheric turbulence and wave interaction. This model is becoming the standard tool and bench mark used in modeling innovative offshore concepts and designs **(2005-present)**.
- **Next Generation high efficiency rotor development** for increased energy generation **(2009-present)**.

The Wind Program – Three Decades of Demonstrated Success

Wind Program Balanced Portfolio

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	Barriers	Solutions	Program Activities
Technology Development	**Unsubsidized Wind LCOE is not "market competitive" with Natural Gas**	Target unsubsidized LCOE of 4.8-4.2/kWh (to offset transmission grid integration costs of 1.2-1.8/kWh) via improved turbine and wind plant efficiencies, cost effectively by FY 2020	INNOVATIONS: DRIVE TURBINE DESIGN AND PLANT DESIGN EFFICIENCIES
	Offshore Wind not "market competitive" with regional coastal pricing	Target unsubsidized Offshore LCOE < 9.3/kWh to enable regional competitive pricing	INNOVATIONS: DESIGN DEEPWATER SYSTEMS (PLATFORMS AND MARINE BASED TURBINES) TO ACCESS HIGH OFFSHORE WIND SPEEDS
	Distributed Wind not "market competitive" with regional retail rates	Target unsubsidized Distributed LCOE < 9.3/kWh to enable regional competitive pricing with retail rates	INNOVATIONS: REDESIGN 100KW-1MW DWT SYSTEMS WITH BEST DESIGNS FROM UTILITY SCALE
Market Acceleration	**Transmissions Barriers impacts to wind class (LCOE) and location. Perception that wind degrades grid system reliability**	Intra-Agency coordination with OE and FERC, and legislative policy to enable transmission capacity at high wind speed locations. Develop "frequency response", regulation support and voltage control capabilities	WIND TRANSMISSION AND INTEGRATION STUDIES, GRID TOOLS
	Market Barriers – Radar, Environmental, Permitting impacts to wind class and location	Produce and assemble new data to evaluate radar and environmental impacts. Identify key cost and time drivers for regulatory and permitting processes	RADAR AND ENVIRONMENTAL MITIGATION TECHNOLOGY DEVELOPMENT AND RESEARCH

125 GW deployed by 2020

GOAL:

Reduce Land COE to $0.057/kWh by 2020

Wind Program Priorities

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The Program seeks significant reductions in the Cost of Energy (LCOE) and rapidly accelerated Deployment. The offshore wind market is the primary focus of the Program, followed by the land-based and distributed wind markets.

Reduce Resource Uncertainty: • Improve wind power forecasting for utility operations • Increase precision of complex flow modeling for optimizing wind turbine design and plant operations	• Complete DOE-NOAA short term forecasting field project • Develop day ahead, multi day forecast R&D priorities • Validate current developmental complex flow models • Engage HPC assets for expanding model development
Grid Planning and Operations: • Facilitate/accelerate the development and adoption of successful strategies for planning and operating the power grid with variable generation	• High penetration integration studies • Improved utilization of existing transmission infrastructure • Reliability support using active power controls • Reserves impact analysis
Reduce Costs and Improve Performance: • Develop innovative and disruptive technologies • Reduce component and system level defects; • Characterize the effects of defects • Develop advanced installation and logistics strategies • Optimize plant infrastructure	• Develop advanced rotor and drivetrain architectures • Develop advanced active and passive control strategies • Investigate alternative materials and evaluate smart sensors for improved system health monitoring • Develop optimized micro-siting tools and plant level controls • Focused Offshore R&D and demonstrations
Reduce Siting & Permitting Barriers: • Accelerate/reduce the cost of project planning, siting and permitting • Coordinate gov't/industry Information Sharing • Develop cost effective wind radar and wildlife mitigation technologies	• Conduct baseline surveys and field assessments • Develop cost-effective wind radar mitigation technologies • Create Developer siting/permitting toolkit & mitigation menu
Leverage International Investments and Expertise: • Cooperative development of international standards • Share device performance data	• Participate in IEA Working Groups for standards development • Conduct cooperative research with European based laboratories (Risoe and ECN)

Every Wind Program Priority is linked to LCOE and GW Goals

Wind Program Strategic Backbone

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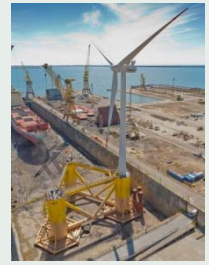
Establish a U.S. Offshore Wind Industry

Offshore System Development and Validation

- Improve financing terms for offshore wind plants through **offshore demonstration projects** and component testing
- Address offshore COE and reliability challenges through "cradle to grave" engineering including innovative turbine and foundation configurations, balance of system components and installation infrastructure
- Expand **open-source wind turbine design tool suite** to enable design and evaluation of next generation offshore turbines, both fixed and floating, leading to the most promising designs to lower system cost of energy



Market Barrier Removal

- Accelerate the siting and permitting process to reduce the cost of project planning and development
- Develop **cost effective wind radar and wildlife impact mitigation technologies**
- Facilitate government-government and government-industry cooperation and coordination
- Reduce Grid Integration costs through **wind integration studies, active controls analysis**, and Best Practices sharing

Optimizing Wind Plant Performance/Technology

Advanced Component Development

- Develop **advanced rotors, drivetrains**, support structures, and **prognostic health monitoring strategies**
- Investigate **active blade control**, **sensor technologies**, and control surfaces for enhanced energy capture
- Develop open-source wind turbine design tool suites for design and evaluation of wind plants and turbines

Wind Plant Performance Improvement

- **Reduce aerodynamics losses** resulting from turbulent inflow, wake interaction, and other complex flows
- Develop **HPC models** to improve wind forecasting and improve understanding of complex flow phenomena
- Investigate novel Integrated System Designs through systems engineering and analysis at the plant level

Wind Plant Reliability Improvement

- Improve the useful life of major components through gov't/university/industry **reliability collaboratives** (BRC & GRC)
- Develop advanced **offshore O&M strategies**, condition monitoring packages, and **sensor technology**
- Collect and report industry RAMS (Reliability, Availability, Maintainability, & Serviceability) data via the **CREW database**

Wind Program: ARRA Project Funding Summary

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ARRA impact creating new wind test facilities:

- Large Wind Blade Test Facility
  Boston, MA - **$24.7M**
- Large Dynamometer Test Facility
  Charleston, SC - **$44.5M**
- NWTC Dynamometer Upgrade
  National Wind Technology Center (at NREL)
  Golden, CO - **$9.5M**
- **University of Minnesota** – Siemens 2.3 MW Turbine
  Minneapolis, MN - **$7.9M**
- **Illinois Institute of Technology** – GE 1.5 MW Turbine
  Chicago, IL- **$7.9M**
- **University of Maine** – 1-3 Offshore Floating Platforms
  Orono, ME - **$7.1M**

Testing facilities across the country lay foundation for nextgen technological innovation

Investing in Tomorrow's Workforce

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Strategic Activity: Education

- Expand Wind for Schools K-12 education to allow wider application including new approaches and national competitions (KidWind Challenge)
- Integrate various university programs, including standardization of Wind Application Center activities, CDP's, ARRA University Consortia.
- Develop a National university wind competition, providing a workforce development opportunity that engages students, provides access to industry, and the impetus to choose careers in wind.

Strategic Activity: Research and Development

- Investments in technical solutions to improve technology and address deployment barriers
- Continue to work with and leverage key academic institutions

WIND POWERING AMERICA

Wind Program Summary

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I. **High confidence that U.S. wind industry has infrastructure, U.S. supply chain, and investment funds available to achieve:**
   - Land utility LCOE goals (Natural Gas competitive parity)
   - GW goals (20% by 2030)
   - Related Jobs and Economic stimulation

II. **Solving wind transmission and market barrier bottlenecks will not only unleash backlog of wind projects (275 GW), but will significantly lower LCOE via access to high wind speed sites**

III. **Wind strategy backbone is to develop highly efficient, integrated next generation wind plants and provide leadership for development of U.S. deepwater offshore wind industry**

IV. **The program is committed to developing the workforce of tomorrow**

V. **Stable, long term US policies are needed to optimize wind financial investment**

The Wind Program is confident to deliver LCOE and GW Goals, if Wind program Budget available to deliver next generation Wind Technology solutions and resolve Wind Market Barrier and Transmission solutions