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# U.S. Department of Energy's Wind Program—Lasting Impressions

## State of the Industry

1980–Today

Wind power has the potential to provide vast amounts electricity for the nation with more than 66,000 MW of installed power capacity delivering clean energy to homes and businesses. Wind power is expanding across the United States with utility-scale turbines deployed in 39 states and territories. Texas alone has more installed wind power than all but five countries around the world.

Throughout the past decade, the U.S. wind industry has grown significantly and represents 31% of newly installed generating capacity since 2009. Wind energy will continue to be a fundamental component of the next era of energy projects that connect to the electricity grid. Interest in wind power continues to grow as next-generation technologies continue to make wind an affordable clean energy solution.

The U.S. wind industry isn't just generating clean electricity for American homes, it also employs more than 73,000 professionals nationwide. These jobs include those at more than 500 manufacturing facilities across the United States, including dedicated wind facilities in every region that manufactures turbine components such as towers, blades, and assembled nacelles.

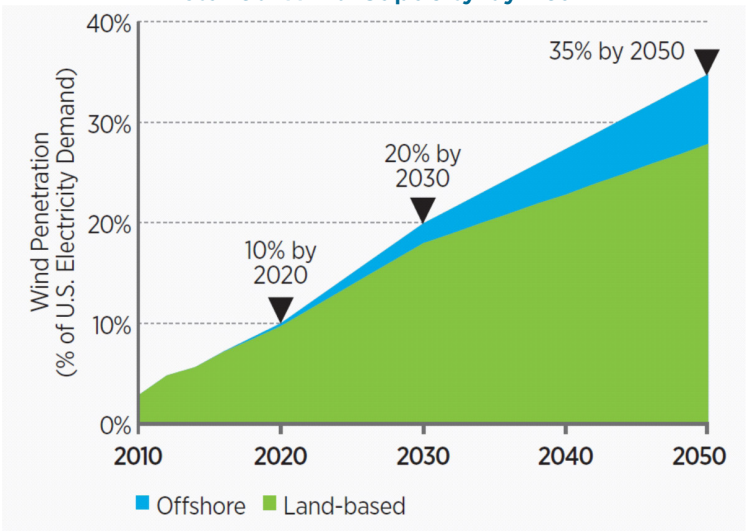
### A New Vision for U.S. Wind Power

The U.S. Department of Energy's (DOE) Wind Program, in close cooperation with the wind industry, revisited the findings of the 2008 DOE 20% Wind Energy by 2030 report to develop the *Wind Vision Report*, a renewed vision for U.S. wind power research, development, and deployment through 2050. The Wind Vision Report quantifies a scenario where wind energy supplies 10% of the country's electricity in 2020, 20% in 2030, and 35% in 2050. Included in the *Wind Vision Report* are:

- A characterization of industry progress to date, and how recent developments and trends have impacted wind industry growth
- A quantification of the social, economic, and environmental benefits of a robust wind energy future
- A roadmap addressing the challenges to achieving high levels of wind as a part of the country's clean energy mix.

The Wind Vision Report can be found at *energy.gov/windvision*

### Installed Wind Capacity by Year



# The Wind Program's Role in Innovation—Moving the Nation's Power Dial

Plugging into the nation's abundant wind resources for electric power generation will stabilize energy costs, help secure energy independence, and improve our environment. DOE's Wind Program recognizes that wind is a clean, domestic, renewable, and plentiful energy resource. For almost four decades, the Wind Program has led the nation's efforts to improve performance, lower costs, and accelerate deployment of wind technologies on land and offshore. The cost of energy from wind power, in areas with good wind resources, has decreased from over $0.55/kWh in 1980 (current dollars) to under $0.03/kWh today in the interior region of the United States. The Wind Program partners with national laboratories, industry, universities, and other federal agencies to conduct research and development activities aimed at increasing wind energy deployment throughout the country. As creative and scientific minds gather, DOE is there to invest in technology breakthroughs by following through on long-term commercialization strategies that evolve to meet growing market demand.

## Simulation Codes and Design Tools

The Wind Program developed turbine simulation codes to streamline design development and reduce costs of technology commercialization. These codes allow designers to build virtual models of blades and full systems to predict performance in different environments before prototypes are even constructed.

- Publicly available codes such as FAST and AeroDyn are now widely used by universities, government agencies, and industry.
- The NuMaD blade software tool significantly reduces development time compared to conventional tools; a blade model previously requiring 15 hours to complete can now be completed in less than an hour.

## Next-Generation Component Design and Fabrication

The Wind Program facilitates the development of next-generation wind turbine components such as rotor blades, drivetrains, generators, power electronics, and towers. Research and development in this area includes advanced design studies, design competitions, industry collaboratives, and materials characterization studies. Many of these innovations have been incorporated by industry into modern commercial wind turbines.

- Advanced airfoils led to new turbine blade designs that produced 30% more energy than previous designs, and are now the industry standard.
- Researchers fabricated a 1.5 MW single-drive, permanent-magnet drivetrain, that reduced the total cost of production by 12.8%. A planetary gearbox and a medium-speed (190 rpm), permanent-magnet generator reduced tower-head weight and total drivetrain costs.

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- The Structural and Mechanical Adaptive Rotor Technology (SMART) project developed a wind turbine rotor with integrated tailing-edge flaps, designed for the control of rotor aerodynamics. Blades outfitted with a trailing edge flap, running along roughly 20% the blades total length, exhibit fewer microstrains and stressors as the turbine operates.

## Turbines

Modern wind turbines are increasingly cost effective, reliable, and have scaled up in size to multi-megawatt power ratings. Since 1999, the average turbine generating capacity has increased by 170% to 1.88 MW for turbines installed in 2013. Wind Program research has helped facilitate this transition, through the development of longer, lighter rotor blades, taller towers, more reliable drivetrains, and performance-optimizing control systems. Furthermore, improved turbine performance has led to a more robust domestic wind industry that saw wind turbine technology exports grow from $16 million in 2007 to $421 million in 2013.

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- Wind turbine initiatives, including *WindPact* and *Low Wind Speed Turbine*, supported innovative prototypes and early commercial growth of turbines that reach higher wind classes and capture much more energy.
- Wind Program researchers worked with GE to design and test components such as blades, generators, and control systems that resulted in GE's 1.5 MW commercial wind turbine. The GE 1.5 constitutes approximately half of the nation's installed commercial wind energy fleet, and is a major competitor in global markets.
- In an effort to expand the role of wind power in communities across the county, DOE is investing in distributed wind technologies—wind turbines that are installed at or near the point of end-use for the purposes of meeting onsite energy demand or supporting the operation of the existing distribution grid. DOE is assisting small wind turbine manufacturers in lowering the cost of energy from their turbines and achieving international certifications.

Simulation Codes and Design Tools | Next-Generation Component Design and Fabrication | Turbines

**1990:** Turbine research and development realizes new materials for components

**1991:** Advanced blade designs produce 30% more energy

**1995-2006:** First-in-industry wind turbine systems are demonstrated

**1996:** National Wind Technology Center opens

**1999:** Wind Powering America kicks off nationwide efforts

1990

2000

## Testing and Demonstration

The Wind Program supports testing centers across the nation that enable researchers and industry partners to conduct a wide range of system, component, and field tests to identify and resolve technical design issues.

- The Utility-Industry Wind Turbine Verification Program tested and evaluated prototype utility-scale wind turbines prior to deployment. This program expanded the market for wind power by introducing the benefits of wind to several electric utilities that today are key wind players.
- DOE's National Wind Technology Center in Colorado employs field, drivetrain, and blade test facilities to test next-generation turbine designs and components.
- The Wind Technology Testing Center in Boston, Massachusetts is the nation's first large wind blade test facility, with the capability to test blades up to 90 meters in length and suitable for wind turbines up to 15 MW, as anticipated for offshore installations.

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- In 2012, America's largest and one of the world's most advanced drivetrain test facilities opened at Clemson University in Charleston, South Carolina. Funded in part by DOE, the Clemson facility can currently test drivetrains up to 7.5 MW and will also have a 15 MW test rig.

## Market Acceleration and Barrier Reduction Activities

In the 1990s, wind development had largely occurred at a few sites in California and had not established a foothold elsewhere in the country. DOE-funded market acceleration and environmental initiatives, such as Wind Powering America, were critical in enabling wind to break out of California and develop in markets across the country. In 2014, DOE announced WINDExchange, a new hub for stakeholder engagement and outreach.

- WINDExchange helps communities weigh the benefits and costs of wind energy, understand the deployment process, and make wind development decisions supported by the best available fact-based information. *http://energy.gov/eere/wind/windexchange*

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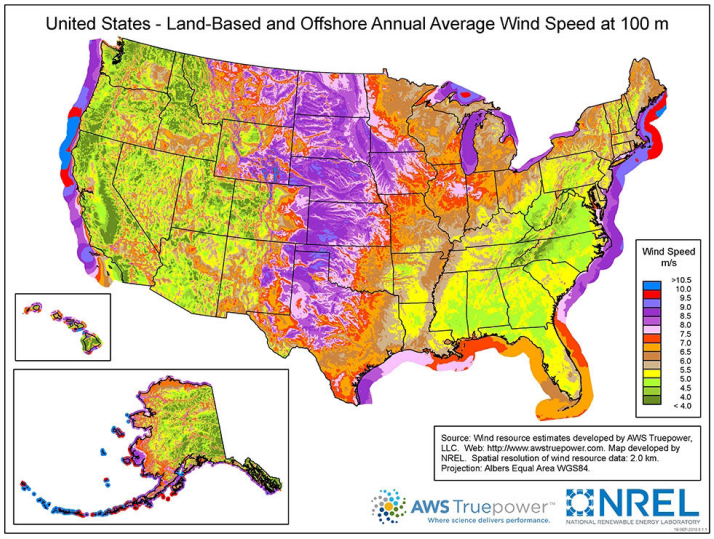
- DOE's past initiative, Wind Powering America helped establish the first 40 GW of wind energy in the United States by supplying state and local policymakers with objective information and tools such as the Jobs and Economic Development Impact (JEDI) model to promote sound decision making about wind energy policies and deployment in their jurisdictions.

## Resource Characterization and Integration

Wind Program efforts in resource characterization have given energy planners an understanding of the wind's resource potential, and have allowed manufacturers to design more cost-effective and reliable turbines, helping grid operators integrate electricity from the nation's wind resources.

- The TurbSim code provides designers with realistic wind inflow for turbine simulation models, yielding higher confidence in the performance and reliability of new turbine systems.
- Utility power system simulations using high resolution time-synchronized wind data have become the world standard for conducting wind and solar integration studies.
- The WindSENSE project increases awareness of wind conditions and energy forecasts so grid operators can make informed scheduling decisions, especially during extreme events such as wind ramps. By working closely with Western utilities and system operators, WindSENSE improves integration of wind generation into the grid while maintaining grid reliability.
- Wind resource maps help developers and policy makers identify areas of significant resources for wind farm planning. The web-based maps attract over 15,000 page views each month.

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## Wins in Wind: 1990–Today

Testing & Demonstration | Resource Characterization & Integration | Market Acceleration & Barrier Reduction Activities

**2003:** NuMAD software is introduced

**2004:** 1.5 MW permanent magnet drivetrain reduces cost of production 12.8%

**2005:** STAR curved blade tips debuts

**2007:**
First plug and play 1.8 kW Skystream
GE 1.5 MW is commercialized
Wind resource maps available

**2008:** *20% Wind Energy by 2030* report is released

2010

**2011:** Nation's first large blade test facility opens

**2011:** *National Offshore Wind Strategy* report is released

**2013:** Clemson drivetrain test facility opens

**2014:** WINDExchange is launched

2015: *Wind Vision Report* is released


# Where the Wind is Blowing—DOE is Going

Developing our nation's vast energy resources is an important part of President Obama's blueprint for a clean energy future. DOE's Wind Program is dedicated to driving down the cost of wind energy with more efficient, more reliable, and more predictable wind energy systems. The Wind Program is leading the nation's path toward capturing more wind than ever before through the installation of innovative offshore wind turbines and systems in U.S. waters, the Atmosphere to Electrons initiative which analyzes the complex physics of wind farms, and market acceleration and deployment activities. The Wind Program is mobilizing efforts across the nation to ensure the United States remains competitive in this growing global industry.

- **The Country's Emerging Offshore Wind Market** is expanding to capture the strong, consistent, and abundant winds off the United States' lengthy coastlines in order to provide a clean, domestic, and renewable source of power for the nation. The Wind Program's ongoing Advanced Technology Demonstration is helping catalyze the development of offshore wind resources through the installation of optimized turbines and systems in U.S. waters. From 2006 to 2014, DOE's Wind Program announced awards totaling more than $300 million for 72 projects focused on offshore wind. These projects focus largely on removing market barriers to deployment and developing innovative technologies to meet the demands of this growing market. As part of the National Offshore Wind Strategy, DOE supports collaborative partnerships between government and innovators to design and demonstrate next-generation wind energy technologies.

- **The Atmosphere to Electrons Initiative** will play a major role in the future optimization of wind plant systems that produce more power. DOE is partnering with government, academia, and industry to improve the reliability of next-generation wind turbines and wind plant systems that address the complex dynamics of winds created by turbulent weather, variable terrain, and wakes.

- **Market Acceleration and Deployment** efforts will continue to address wind power market and deployment barriers, centering on activities that reduce the cost of energy in environmental assessments and permitting, operations, installations, and maintenance over the full lifecycle of a wind system.

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