Wind Vision: A New Era for Wind Power in the United States

Enabling Wind Power Nationwide
2017 Wind Program Peer Review
February 2017

Jose Zayas, Director
Department of Energy
Wind Energy Technologies Office
DOE Mission
Enhance U.S. security and economic growth through transformative science, technology innovation, and market solutions to meet our energy, nuclear security, and environmental challenges

DOE Goal: Science and Energy
Advance foundational science, innovate energy technologies, and inform data driven policies that enhance U.S. economic growth and job creation, energy security, and environmental quality

DOE Strategic Objectives: Science and Energy
• Support prudent development, deployment, and efficient use of “all of the above” energy resources that also create new jobs and industries
• Support a more economically competitive, environmentally responsible, secure and resilient U.S. energy infrastructure
• Deliver the scientific discoveries and major scientific tools that transform our understanding of nature and strengthen the connection between advances in fundamental science and technology innovation

The priorities outlined in DOE’s strategic plan are critical to advancing the nation’s energy and security goals and strengthening our economy to provide a cleaner energy environment and a more secure and prosperous country for future generations
**EERE Vision**
A strong and prosperous America powered by clean, affordable, and secure energy

**EERE Mission**
To create and sustain American leadership in the transition to a global clean energy economy

**EERE Strategic Objectives**

- **Cost Reduction and Performance Improvement:** Applied research and development of components or whole technology systems

- **Technology Validation and Risk Reduction:** Confirming the performance of technologies, both in controlled laboratory and real world conditions, and providing benchmarks for performance and durability—all to reduce uncertainty for investors

- **Reducing Market Barriers:**
  Addressing specific gaps in market development such as a lack of reliable product information, inconsistent regulatory environments, or inadequate skill standards for the clean energy workforce
Wind Energy Programmatic Goals
The Wind Energy Technologies Office aims to accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality. Office RDD&D activities are applicable to utility-scale land and offshore wind markets, as well as distributed turbines—typically interconnected on the distribution grid at or near the point of end-use. Achieving LCOE goals will support deployment of wind at high penetration levels, sufficient to meet up to 20% of projected U.S. electricity demand in 2030, and up to 35% in 2050, compared to over 5.5% of demand in 2016.

Wind Energy Programmatic Priorities
• Optimize wind plant cost of energy reduction through complex aerodynamics R&D, advanced component development, wind plant reliability improvement and resource characterization
• Establish a competitive U.S. offshore wind industry through offshore system development and demonstration
• Optimize grid integration and transmission for wind systems through integration studies and operational forecasting tool development
• Eliminate and reduce market barriers through accelerated siting and deployment strategies

Wind Energy 2017 Targets Towards Programmatic Goals
• Reduce the unsubsidized market LCOE for utility-scale land wind energy systems from a reference wind cost of $.074/kWh in 2012 to $.057/kWh by 2020 and $.042/kWh by 2030*
• Reduce the unsubsidized market LCOE for offshore wind energy systems from a reference of $.20/kWh in 2010 to $.10/kWh by 2030*

*For Programmatic purposes, all costs are reported at a 7% discount rate.
DOE 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.

Sample DOE R&D Innovations

- Over 140 DOE-funded wind patents from 1978 through 2016
- 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

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

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

Untapped Wind Market Potential in All 50 States
- Land-based utility-scale wind
- Offshore wind (OSW)
- Land-based distributed-scale wind (DW)
The U.S. Wind Industry Today is Creating Significant Economic Value Across the States

Wind provides over 5.5% of the nation’s electricity and supports over 100,000 domestic jobs, including over 500 manufacturing facilities in 43 States.

Robust Industry
- $14.5 billion invested in 2015
- Utility-scale wind power in 41 states and distributed wind power in all 50 states
- 12 states ≥10% wind generation, with three states >25% generation
- Wind power represented 41% of capacity additions in 2015
- 30 MW Block Island (RI) first offshore wind project began producing power in 2016

Domestically Sourced Components and Raw Materials
- Over 80% of towers, 50-70% of blades and hubs, and 85% of nacelle assembly for turbines installed in 2015 were manufactured in the U.S.
- Today’s U.S. wind manufacturing capacity is 6-10 GW/year

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

Wind-Related Manufacturing Facilities and Installed Capacity by State, 2015
Wind Energy is a Valuable Option for Electricity Generation in all 50 States

The U.S. wind industry today creates economic value
- Wind provides over 5.5% of the nation’s electricity and supports over 100,000 domestic jobs, including over 500 manufacturing facilities in 43 States
- Over 80% of towers and 50-70% of blades and hubs installed in the U.S. in 2015 were made in America
- Wind is providing the lowest cost electricity—without subsidization—in some regions of the U.S. today. This lowest cost electricity is good for American business and consumers

Federal wind energy RDD&D investment is key to continued growth
- DOE plays a unique and valuable role in enabling the wind industry and its stakeholders meet core challenges to industry growth
- Innovation to reduce wind technology costs and mitigate market barriers enables deployment and drives U.S. economic growth

America can continue to be a world leader in wind power
- With continued science driven research, U.S. wind technologies can provide global leadership in the next generation of wind technology innovations, driving economic benefits for U.S. manufacturers, U.S. businesses and U.S. consumers

Wind energy provides significant state and national economic and security benefits
- U.S. industry growth and U.S. competitiveness
- U.S. energy security and independence
- Strengthened domestic manufacturing and local economic value

America is the world’s number one producer of electricity from wind

Wind turbine technician is America’s fastest growing profession

Wind energy received $110 billion in global investment in 2015
Wind Energy Technologies Office (WETO)

**Structure**

Wind Energy Technologies Office (WETO)

*Jose Zayas, Director*
*Jim Ahlgrimm, Deputy Director*

- **Wind Research and Development**
  *Mike Derby*
  - Manufacturing, Reliability, Testing, and Facilities
    *Megan McCluer*
  - Aerodynamics and Components
    *Vacant*
  - Distributed Wind
    *Patrick Gilman*

- **Modeling and Analysis**
  *Patrick Gilman*
  - Resource Characterization
    *Joel Cline*
  - Offshore Demos and R&D
    *Alana Duerr*

- **Market Acceleration and Deployment**
  *Jocelyn Brown-Saracino (acting)*
  - Siting, Radar, and Environmental
    *Jocelyn Brown-Saracino*
  - Stakeholder Engagement
    *Maggie Yancey*

- **Grid Systems Planning and Operations**
  *Charlton Clark*
  - Grid Systems Planning and Operations
    *Jian Fu*

- **Project Management and Operations**
  - Golden Field Office
    *Gary Nowakowski*
  - Operations
    *Shane Beichner*
Wind Energy Technologies Office
Funding History and Request

- Technology RD&T and Resource Characterization (Land, Offshore, Distributed)
- Technology Validation and Market Transformation
- Mitigate Market Barriers
- Modeling and Analysis
- Technology Application
- Technology Development and Testing
- NREL Site-Wide Facility Support

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<td>$ in millions</td>
<td>67</td>
<td>73</td>
<td>62</td>
<td>61</td>
<td>46</td>
<td>48</td>
<td>95</td>
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- Technology RD&T and Resource Characterization: 12, 19, 24, 18, 35
- Technology Validation and Market Transformation: 46
- Mitigate Market Barriers: 11, 5
- Modeling and Analysis: 10, 8
- Technology Application: 12
- Technology Development and Testing: 30
- NREL Site-Wide Facility Support: 4
Wind Energy Technologies Office
Accomplishments, FY 2014 – 2016

- In FY 2015, A2e conducted complex aerodynamics R&D and experimental testing campaigns to determine the effect of wakes on plant performance. Followed in FY 2016 by joint computational-experimental campaigns using high fidelity simulations of atmospheric physics and scaled experiments to study turbulent inflow and near-wake development.

- FOA work was conducted in FY 2015 and FY 2016 through a manufacturing initiative to address transportation and logistics barriers to further LCOE reductions thorough economies of scale and allow access to new U.S. geographic areas to wind turbine deployment.

- Both awardees of the FY 2014 Taller Towers FOA successfully completed tower design and testing tasks in FY 2015 and performed experimental validation and LCOE analyses in FY 2016.

- The third round of the Distributed Wind Competitiveness Improvement Project (CIP) was completed in FY 2015, supporting both existing and emerging small and medium-sized wind turbine manufacturing companies, and assisting them in improving component designs, improving manufacturing competitiveness, and system certification. The fourth round of CIP continued in FY 2016. The Annual Distributed Wind Market Report was published in FY 2015.

- The Wind Forecasting Improvement Project Phase 2 (WFIP-2) began analysis of data gathered in FY 2015 and continued in FY 2016. This three year project targeted at better understanding atmospheric phenomenon in complex terrain.

- In FY 2015, began work under the Bat Impact Minimization Technologies and Field Testing Opportunities FOA. Five awardees will: (1) conduct reliability tests and full-scale validation of the effectiveness of an electronic deterrent device at a wind plant; (2) develop and test an ultrasonic acoustic deterrent system; (3) develop a turbine-integrated, air-powered deterrent device; (4) develop and test coatings that alter the surface texture of wind turbines; and (5) develop a blade-mounted ultrasonic whistle.


- In FY 2016, completed a 19-month deployment of an highly instrumented buoy off the mid-Atlantic Coast and made the data publically available to help offshore wind industry partners optimize offshore wind farm development and design.
Wind Energy Technologies Office

Total Funding, FY 2014 – FY 2016

Congressional Appropriations by Subprogram
FY 2014 – FY 2016 ($291M)

- Resource Characterization & Technology RD&T: 30%
- Technology Validation and Market Transformation: 39%
- Mitigate Market Barriers: 11%
- Modeling and Analysis: 11%
- Technology Management: 10%
- SBIR/STTR: 1%
- NREL Site-Wide Facility Support: 6%
- Modeling and Analysis: 3%

Peer Reviewed Projects
FY 2014 – FY 2016 ($185M)

- Resource Characterization & Technology RD&T: 43%
- Technology Validation and Market Transformation: 44%
- Mitigate Market Barriers: 12%
- Modeling and Analysis: 1%

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<tr>
<th>($thousand)</th>
<th>FY 2014</th>
<th>FY 2015</th>
<th>FY 2016</th>
<th>FY 2014-16</th>
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<td>Wind Energy, Total Appropriations</td>
<td>88,126</td>
<td>107,000</td>
<td>95,450</td>
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<td>Resource Characterization &amp; Technology RD&amp;T</td>
<td>35,163</td>
<td>30,301</td>
<td>21,869</td>
<td>87,332</td>
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<td>Technology Validation and Market Transformation</td>
<td>20,054</td>
<td>46,250</td>
<td>47,650</td>
<td>113,954</td>
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<td>Mitigate Market Barriers</td>
<td>10,324</td>
<td>11,116</td>
<td>12,132</td>
<td>33,573</td>
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<td>Modeling and Analysis</td>
<td>3,261</td>
<td>2,853</td>
<td>2,618</td>
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<td>NREL Site-Wide Facility Support</td>
<td>9,000</td>
<td>4,700</td>
<td>2,450</td>
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<td>SBIR/STTR</td>
<td>1,091</td>
<td>1,064</td>
<td>750</td>
<td>2,905</td>
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<td>Technology Management*</td>
<td>9,233</td>
<td>10,716</td>
<td>7,981</td>
<td>27,931</td>
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*Technology Management includes laboratory and DOE HQ technology management support

$185M out of $244M in Direct Project Funding Peer Reviewed

Peer Review Addresses 76% of FY 2014 – FY 2016 Project Appropriations
Wind Energy Technologies Office

Peer Reviewed Budget by Core Area

### Resource Characterization and Technology RD&T

<table>
<thead>
<tr>
<th>Core Area</th>
<th>FY 2014 Funding</th>
<th>FY 2015 Funding</th>
<th>FY 2016 Funding</th>
<th>FY 2014-16 Total Funding</th>
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<tbody>
<tr>
<td>A2e, HPC, RC, Flow Field Analysis and Testing</td>
<td>9,208,439</td>
<td>12,619,686</td>
<td>8,930,000</td>
<td>30,758,125</td>
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<tr>
<td>Distributed Wind Research, Development, and Testing</td>
<td>1,797,110</td>
<td>5,356,600</td>
<td>735,000</td>
<td>7,888,710</td>
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<td>Innovation, Manufacturing, Reliability, Adv Components, &amp; Testing</td>
<td>14,721,406</td>
<td>10,140,079</td>
<td>8,830,224</td>
<td>33,691,709</td>
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<tr>
<td>Offshore Wind Unique RD&amp;T</td>
<td>19,319,526</td>
<td>33,191,333</td>
<td>35,066,666</td>
<td>87,577,525</td>
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<td><strong>Subtotal, Resource Characterization and Technology RD&amp;T</strong></td>
<td><strong>45,046,481</strong></td>
<td><strong>61,307,698</strong></td>
<td><strong>53,561,890</strong></td>
<td><strong>159,916,069</strong></td>
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### Market Acceleration and Deployment

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<th>Core Area</th>
<th>FY 2014 Funding</th>
<th>FY 2015 Funding</th>
<th>FY 2016 Funding</th>
<th>FY 2014-16 Total Funding</th>
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<td>Analysis, Modeling, COE, and Policy Impact</td>
<td>600,000</td>
<td>750,000</td>
<td>600,000</td>
<td>1,950,000</td>
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<td>Grid Systems Planning and Operation</td>
<td>2,280,816</td>
<td>2,000,000</td>
<td>200,000</td>
<td>4,480,816</td>
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<td>Siting, Radar and Environmental</td>
<td>5,389,779</td>
<td>3,364,845</td>
<td>1,200,000</td>
<td>9,954,624</td>
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<td>Stakeholder Engagement, Outreach, and Workforce Development</td>
<td>2,393,538</td>
<td>3,010,000</td>
<td>3,075,828</td>
<td>8,479,366</td>
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<tr>
<td><strong>Subtotal, Market Acceleration and Deployment</strong></td>
<td><strong>10,664,133</strong></td>
<td><strong>9,124,845</strong></td>
<td><strong>5,075,828</strong></td>
<td><strong>24,864,806</strong></td>
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<td><strong>Total, Peer Reviewed</strong></td>
<td><strong>55,710,614</strong></td>
<td><strong>70,432,543</strong></td>
<td><strong>58,637,718</strong></td>
<td><strong>184,780,875</strong></td>
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Enabling Wind Nationwide

**Enabling industry growth and U.S. competitiveness**

To expand U.S.-based wind manufacturing and improve U.S. competitiveness in the global wind market, government research is needed to support wind technology innovation and address key market barriers. Continued innovation and optimization can reduce electricity costs to U.S. businesses and consumers and allow wind deployment across America without subsidization.

- Wind plant optimization
- Resource assessment and characterization
- Reliability improvements
- Enabling access to better resources through tall wind
- Distributed wind R&D
- Next Generation component innovations

**Enhancing energy security and independence**

To empower states and regions to optimally choose and manage their own unique electricity mix, government research is needed to address transportation logistics, impacts on wildlife and human uses such as radar and shipping, and grid integration. By leveraging their land, offshore, and distributed wind resources, states can hedge against fuel price volatility and improve grid infrastructure security.

- Facilitating coexistence between wind energy and wildlife
- Offshore wind environments
- Information synthesis and dissemination
- Successful coexistence with radar systems
- Wind energy workforce and education development
- Advancing grid integration

**Strengthening domestic manufacturing and providing local economic value in all 50 states**

To create highly skilled jobs across all 50 states, government research is needed to provide certainty as to the risks, costs, benefits and opportunities presented by wind energy. Developing a domestic offshore wind manufacturing supply chain, training the next generation of workers for the wind industry, and increased state and local tax and land lease revenues from wind energy can help revitalize rural America.

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy
Next Generation Wind Technology
• The Atmosphere to electrons (A2e) initiative will continue to focus on improving the performance and reliability of next-generation “smart wind” plants by investigating systems-level interactions influenced by atmospheric conditions, variable terrain, and machine-to-machine wake interactions.
• The National laboratory high performance computing (HPC) capabilities will be extensively leveraged to model the complexity of wind plant flow physics and enable industry to take the next steps in developing both evolutionary and transformational innovation technologies.

Distributed Wind
• The Competitiveness Improvement Project (CIP) will continue to focus on making distributed wind energy more cost competitive with other distributed generation technology (PV) and increase the number of wind turbine designs tested to national certification standards.

Manufacturing
• Advanced manufacturing options, such as automation and 3-D printing, will be leveraged to enable innovation and rapid prototyping. Locally produced components enhance U.S. competitiveness and supports domestic jobs.
Resource Characterization and Technology Research, Development and Testing (cont.)

**Offshore Wind**
- Collection and dissemination of resource characterization data; development of advance standardized data collection methodologies; R&D to decrease technology costs and adapt to unique U.S. conditions; and evaluation of OSW supply chain bottlenecks and needed investments are needed to support Wind Vision deployment levels.

**Demonstrations**
- Offshore wind demonstration projects will showcase technologies to address U.S.-specific challenges such as hurricanes, deep water, and icing conditions.
- “Tall Wind” efforts will demonstrate the design, manufacturability and testing of full-scale technologies to address technical challenges and achieve cost performance needed to reach wind turbine hub heights between 110m and 140m economically.

**Test Facilities**
- The DOE national laboratories and other partners will continue to play a crucial role in providing world class test facilities capability for validating component designs and performing valuable wind energy research. Facilities include: blade testing, drivetrain testing, field testing, grid simulation, and high-performance computing (HPC) capabilities.
Siting, Radar and Environmental

- The concerns of interference of wind turbines on the nation’s air surveillance radars will be investigated and addressed through interagency coordination on wind-radar impacts, R&D, and field tests to identify, develop and deploy mitigation measures, with a focus on solutions that can be funded by industry.
- Development, refinement, and validation of technologies that minimize impacts on species of regulatory concern, including eagles, sage and prairie grouse, and bats.
- Continue broad collaboration with industry, NGOs, and others to support research on and identify solutions to human-use and environmental impacts of wind energy.

Grid Systems Planning and Operation

- Through the DOE Grid Modernization initiative, the office will continue to evaluate regional flexibility capabilities, conducts next generation integration studies utilizing newly developed 10-year wind data sets, and further develops wind-based transmission line planning tool architecture.
- The multi-year Pan-North American Renewable Integration Study, conducted in partnership with the Canadian and Mexican governments, focuses on the operational and planning impacts of higher penetration levels of wind power, hydropower, and potentially solar power.
Market Acceleration and Deployment (cont.)

Analysis, Modeling, COE, and Policy Impact

- **Strategic analysis prioritizes investment** on the highest impact program activities, and system engineering and reference models are continue to be used to identify the best opportunities for cost reduction.

- Wind-specific estimations of electricity production cost, electric sector capacity expansion, national energy-economy modeling, wind technical and economic feasibility analysis, and technology deployment analysis inform roadmap development.

Stakeholder Engagement, Outreach, and Workforce Development

- Wind stakeholders will continue to provide neutral, **state of the art information for wind deployment** decision-making and effective training of a robust and educated workforce to meet U.S. industry demand.

- **DOE’s Regional Resource Centers** provide accurate, impartial information about challenges facing wind deployment in their regions to aid in efforts to overcome or mitigate these challenges.

- Innovative and technical challenges like the **Collegiate Wind Competition** will facilitate the next generation workforce to real-world problems and solutions.

![Conceptual pathway to 50% LCOE reduction in a hypothetical 2030 wind plant located in an area with excellent (higher speed) wind resources by levelized cost of energy (LCOE) parameter.](image)

Wind turbine technician is America’s fastest growing profession.
America Can Continue to be a World Leader in Wind Power: *Wind Vision*

**DOE-led Wind Vision report provides a national roadmap for a future with high U.S. wind penetration that is both is achievable and beneficial**

The *Wind Vision* Study Scenario (35% of demand) results in significant cumulative benefits by 2050:

- 600,000 gross jobs created
- $149 billion in consumer cost savings
- $3.2 billion in annual local tax revenues
- 260 billion fewer gallons of water (23%) consumed
- $108 billion in reduced air pollution impacts (22,000 premature deaths avoided)
- 14% reduction in carbon-dioxide equivalent emissions

**Extensive DOE collaboration with industry stakeholders:**

The *Wind Vision* report was produced through DOE-led collaboration with **over 250 experts and more than 100 organizations** representing industry, electric power system operators, environmental stewardship organizations, state and federal governmental agencies, research institutions and laboratories, and siting and permitting stakeholder groups.

The *Wind Vision* Study Scenario—**35% of U.S. electricity demand met by wind by 2050**—results in broad geographic distribution of land-based and offshore wind energy across all 50 states.
Wind energy is a national asset that, with additional innovation, can be deployed cost-effectively and unsubsidized across all 50-states

- The science and research agenda that brought us to over 80 GW of installed capacity and over 5.5% of U.S. electricity generation today is **not the agenda needed** to achieve future Wind Vision levels
- **Continued innovation in RDD&D is needed** to enable wind in new areas—all 50 states—through new technologies and understandings
- A wide range of **market barriers will need to be overcome** to make this a reality
- All renewable generation technologies, including wind, solar, and water, **must work together** to create a stable, reliable, affordable, and secure domestic renewable energy future
- Wind and solar have grown at rates of about 20% annually in recent years, **creating jobs at a rate 12 times faster** than that of the rest of the U.S. economy
- Increasing demand from electrification of the U.S. transportation and industrial sectors will make the need for clean electricity generation **all the more important** in the future
Thank You!

Jose Zayas
Office Director
DOE Wind Energy Technologies Office

For more information please see:
wind.energy.gov