U.S. DEPARTMENT OF ENERGY

Proceedings from the Wind Manufacturing Workshop

Achieving 20% Wind Energy in the U.S. by 2030

Wind and Hydropower Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

August 27-28, 2008
Washington, D.C.

May 2009

About the Wind and Hydropower Technologies Program

The Wind and Hydropower Technologies Program (WHTP) within the Department of Energy's Office of Energy Efficiency and Renewable Energy (DOE-EERE) is leading the nation's efforts to improve the performance and operability of wind energy technologies and lower the costs, to investigate emerging water power technologies, and to enhance the environmental performance and efficiencies of conventional hydropower technologies. To find more information about the Wind and Hydropower Technology program, please visit http://www1.eere.energy.gov/windandhydro/wind_mvg.html

Program Vision

One team managing the public investment in wind and water power technologies to maximize energy security, economic vitality, and environmental quality.

Program Mission

Responsible stewardship of national resources to increase the development and deployment of reliable, affordable, and environmentally sustainable wind and water power and realize the benefits of domestic renewable energy production.

This document presents the breakout session results at the August 2008 DOE-sponsored stakeholder workshop held to collect comments from all participants on research and development priorities and analytical pathways to achieve the scenario outlined in DOE's *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply* report. The information provided herein is a documentation of the discussions held at the workshop and does not reflect any particular analyses or endorsement by the DOE.

Table of Contents

Executive Summary

On August 27–28, 2008, more than 80 wind and manufacturing experts participated in the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Wind and Hydropower Technologies technical workshop to discuss what is needed to strengthen the U.S. wind manufacturing sector in order to reach 300 GW of installed wind by 2030. The purpose of the workshop was to collect comments from all participants on possible solutions and actions to address U.S. wind component manufacturing challenges, building on the recommendations made in DOE's *20% Wind Energy by 2030* report[1].

Recurring Themes

Comments suggested that:

- To achieve the 20% Wind Scenario, wind turbine systems and components are currently projected to be larger: on average in the 3 MW size range for land-based machines in the out years to 2030, up from today's popular 1.5 MW size. This is required to generate much-needed boosts in power and energy output, increase capacity factors, increase efficiencies, and lower overall capital costs. Yet this trend poses several challenges in scaling up blade and rotor manufacturing production capacity. For example, significant ramp-up issues exist for casting, bearings, gears, forging, fiberglass, and carbon fiber. Also, steel plate for towers is in high demand globally, not only for wind energy development but for a variety of other products and components. While global competition could reduce materials availability for blade manufacturers, the high costs of materials will also be a challenge. While there is a high likelihood that businesses will make the necessary investments to expand production of these and other materials and components for wind energy, a robust supply chain is critical for the 20% Wind Scenario to be achieved. For this reason, greater certainty in government policies, regulations, and incentives is required to help ensure that the level of private capital needed for the wind sector is made available. A stable investment horizon could help mitigate supply chain problems.

- Attaining the 20% Wind Scenario will require wind machine component production volumes on unprecedented scales. Annual production volumes for many components will need to meet 2030 levels (i.e., enough components to manufacture 7,000 3 MW wind machines per year) by 2018. The manufacture of most wind turbine systems and components is currently a labor-intensive process. "Lean manufacturing" techniques must be incorporated to reduce the labor intensity of current blade production processes and their associated costs. Improved manufacturing techniques and a robust supply chain are critical factors in achieving the 20% Wind Scenario.

- As blades get larger and designs more complex, maintaining blade quality becomes more challenging. Automation is needed to increase manufacturing precision and process control. The development of automated and repeatable production techniques including greater use

[1] *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*, U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), May 2008. The Wind Scenario outlined in the report evaluates how wind energy can achieve a level of 20% of the nation's electricity by 2030. It is not a suggested national policy, but only a study of the feasibility of one scenario for achieving 20% wind by 2030.

of robotics and process controls for lamination, blade finishing, trimming, grinding, painting, materials handling, pultrusion, and inspection would not only improve quality control but reduce production costs.

- Design innovations will be necessary across the manufacturing sector for wind turbine systems and components. For example, because taller towers for some projects would help to achieve the 20% Wind Scenario, tower design and construction methodologies need improvements, and methods and designs for crane-free operations may become attractive. Manufacturing challenges specific to drive trains include the need to improve gearbox reliability through more accurate simulations and testing of loading conditions for complex wind environments. Simulation and modeling of various drive train configurations assist in determining which ones will be the most effective. In addition, simulations optimize the design and limit the number of full scale tests so as to be cost efficient. Another step is to model bearing responses under various load conditions which can then be measured in a dynamometer and in the field. This process allows for the verification of design assumptions and basic design process. To address gearbox maintenance issues and related failures, extensive dynamometer testing of new gearbox configurations to prove durability and reliability before serial production should be expanded. In order to reduce weight and cost and improve reliability in the future, larger test facilities will be required, as current test facilities are not adequate for the larger machines currently in development. Additional research and development is needed on improving surface engineering treatments as well as on quality verification for bearings and gears. In addition, more resources should be devoted to testing facilities to improve access for designers and accelerate testing schedules and improve manufacturability[2]. This step is essential to ensure that advanced drive train designs are moved into production and deployed to the field as rapidly as possible.

- Manufacturing costs for small wind[3] components are still too high per unit of output, particularly the costs of tower production. Development of integrated manufacturing design processes and tools is needed to reduce manufacturing cost per unit. Manufacturing processes should be optimized and automated, and small wind companies should work together to design common parts. The high cost and low availability of raw materials, such as fiberglass and carbon fiber, is also a challenge in the manufacturing of small wind components; thus, more cost-effective, advanced materials are needed.

- More small wind resource assessments are needed. Because investment capital is still not competitively available for small wind, steps should be taken to better educate investors about small wind markets to increase their comfort level with small wind technologies, to convey the benefits of this low carbon technology, and to encourage further investments. In addition, more education and outreach to local authorities and rural electric cooperatives is needed to increase deployment of small wind systems and help overcome market entry barriers associated with new technologies. Implementation of small wind systems is most likely to occur in more rural areas, where energy supply options are limited. Lessons learned from other industries, particularly regarding the development of advanced tower designs

[2] Drive train designs currently include a number of different components. Several options for less complex designs are currently being tested, including such options as reducing the number of stages in a gearbox to moving to a direct-drive power train, which eliminates the gearbox altogether. Testing these options is essential to moving these advanced and simplified designs into production and deployment. Simpler designs will help improve manufacturability.

[3] Note: Discussions in the *Small Wind: Entire Systems* breakout group was limited to residential wind systems between 90 W and 25 kW because manufacturers representing other size ranges were not present at the workshop.

(e.g., wireless telecommunications towers), should be captured for small wind manufacturers.

- The available workforce for the production of wind turbines, blades, rotors, towers, castings, and bearings is insufficient, and a shortage of trained engineers, technicians, and factory workers already exists. One of the solutions to this challenge is a focused government and industry effort to build education and training capabilities for wind energy development. The establishment of a skilled workforce ranging from trades and crafts to advanced university degrees should begin immediately. Curricula should be modified and training and education centers in several wind manufacturing areas should be established. University-based centers of excellence for wind components could be established in the near term and continue to operate beyond 2030 to address this workforce issue.

- Transportation logistics issues—if unresolved—are potential showstoppers to achieving the 20% Wind Scenario. Taller, wider towers and larger, heavier blades will likely exceed the current transportation envelope for both rail and highway systems. Vehicles capable of transporting larger components will be needed, as will skilled drivers. In addition, inconsistencies among state permitting policies for transport of these components need to be addressed. New manufacturing approaches are also needed to allow for component assembly closer to job sites and portable manufacturing systems that can be set up at one site, broken down, and reassembled at another site.

Suggested Next Steps[4]

Comments received suggested the following actions as "next steps":

- Evaluate other aspects of the 20% Wind Scenario to determine technology development, market, and policy needs that are related to expanding wind component manufacturing capability to a gigawatt-scale level.

- Evaluate plans and strategies for wind energy development by government and industry to determine if the barriers to expanding wind manufacturing capabilities are being adequately addressed, and if not, address these barriers quickly.

- Collaborate with and step up education of federal and state policy makers about the need for a stable, long-term business environment for wind energy development to attract capital and labor and bolster the domestic supply chain of raw materials.

- Address transportation logistics challenges to ensure safe and timely delivery of components to wind sites. Zoning regulations and permitting policies will need to be discussed among several parties, including federal and state agencies, regional entities, and local jurisdictions.

- Dramatically increase the number of skilled workers across the U.S. wind manufacturing sector in order to support industry growth. Initiate conversations with states and universities to modify curricula and explore the idea of establishing training and education centers in several wind manufacturing areas.

[4] For the complete list of suggestions regarding Next Steps, see page 33.

Introduction

On August 27–28, 2008, the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Wind and Hydropower Technologies Program hosted a technical workshop to discuss what is needed to strengthen the U.S. wind manufacturing sector to reach 300 GW of installed wind by 2030. This *U.S. Wind Manufacturing Workshop: Achieving 20% Wind Energy by 2030* brought together 83 wind and energy storage experts, including representatives from wind turbine component manufacturers, materials and other supply chain manufacturers, wind engineering firms, wind project developers, nongovernmental organizations, state and federal government agencies, and national laboratories.

The main purpose of the workshop was to receive input from all participants regarding possible solutions and actions to address U.S. wind component manufacturing challenges, building on the recommendations made in DOE's *20% Wind Energy by 2030* report[5]. In addition to identifying specific manufacturing actions, workshop participants also suggested solutions to crosscutting issues that affect all aspects of wind energy design, development, manufacturing, and deployment.

The one-and-a-half day workshop began with an opening plenary session in which DOE officials welcomed attendees and set the stage for the workshop by presenting the following wind component manufacturing "vision":

In 2030, the U.S. manufacturing base for wind power systems will be transformed—with capabilities to produce up to 7,000 large wind turbines per year.[6]

In the plenary session, entitled "Wind Manufacturing—Perspectives on Where We are Today and Future Scenarios," a panel comprising wind industry experts provided updates on:

- Large Wind: Blades and Rotors—Peggy Baehmann, GE Global Research
- Large Wind: Towers and Transportation—Lars Moller, Broadwind Energy
- Large Wind: Drive Trains—Ed Hahlbeck, Power Train Engineering
- Small Wind: Entire System—Andy Kruse, Southwest Windpower

Workshop participants in four breakout groups[7] identified key manufacturing challenges and suggested what technology changes may be required to overcome them. Chapters 1 through 4 provide detailed summaries of the discussions and suggestions from individual participants that resulted from the four breakout sessions. Appendix A provides the workshop agenda. Appendix B

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[5] *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply,* U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), May 2008. The Wind Scenario outlined in the report evaluates how wind energy can achieve a level of 20% of the nation's electricity by 2030, an addition of 293 GW of installed wind capacity.

[6] Does not represent a consensus opinion of the wind industry nor of the workshop participants regarding installed capacity goals for the small wind industry.

[7] While various industry representatives were invited, not all were able to attend the workshop. For example, in the *Small Wind: Entire Systems* breakout group, only one small wind manufacturer was able to attend. Furthermore, in the *Large Wind: Drive Trains* breakout group, no bearing suppliers or representatives from the generator and power electronics areas were present. This may have resulted in limited input in some areas. The U.S. Department of Energy welcomes additional comment.

provides a full list of workshop participants. Appendix C provides contact information for the workshop coordination team. The opening and closing plenary session presentations are available for download on the following website:
http://www1.eere.energy.gov/windandhydro/wind_mfg_workshop.html.

1. Large Wind: Blades and Rotors

Over the last several decades, wind turbines, rotors, and blades have become larger and their designs more complex. For example, designs common in the 1980s involved blades that were about 8 meters long; but today they can reach 40 meters (or more) for land-based applications and 60 meters (or more) for offshore applications. To achieve the 20% Wind Scenario, it is projected that this trend toward larger blade sizes and design complexity will need to continue in order to boost power and energy output, increase capacity factors, increase efficiencies, and lower overall capital costs.

This trend poses challenges in scaling up blade and rotor manufacturing production capacity. For example, the use of larger blades requires lighter-weight materials to increase efficiency and performance and decrease weight, which in turn reduces load-carrying requirements for towers and other structural components; however, tower designs may be dictated by aerodynamic loads at the greater heights and swept areas. Lightweight materials such as fiberglass and carbon fiber are in high demand globally, not only for wind energy development but for a variety of other products and components. While there is a high likelihood that businesses will make the necessary investments to expand production of these and other materials and components for wind energy, a robust supply chain would be critical for the 20% Wind Scenario to be achieved. Comments suggested that for this reason, greater certainty in government policies, regulations, and incentives is required to help ensure that the level of private capital needed to flow into the wind sector is indeed made available.

Key Blade and Rotor Manufacturing Challenges

- Improving quality with increasing blade lengths, design complexity, and use of lighter-weight advanced materials
- Lack of adequate testing facilities for perfecting advanced blade designs to improve efficiency, performance, and manufacturability, while reducing weight and cost
- Lack of adequate analysis tools for integrating design and manufacturing
- Cost and availability of raw materials for advanced blade designs
- Addressing workforce shortages that affect all aspects of wind energy design, development, manufacturing, and deployment
- Addressing the high costs and logistical problems of transporting blades to construction sites for assembly

One of the technical challenges in mass producing larger blades with more complex designs and lighter-weight advanced materials is quality control. Faults and defects add to overall costs, can detract substantially from wind turbine performance and efficiency, and can lead to later problems in the field with operation, maintenance, and blade life. The need for better blade quality creates added burdens in ramping up manufacturing capacity for some of the supply-chain industries, such as forging, casting, fiberglass, carbon fiber, and bearings. In addition, existing production processes are also highly labor intensive, which adds to costs and increases the difficulties in achieving high levels of manufacturing precision and process control.

One of the solutions to this challenge is the development of automated and repeatable production techniques, including greater use of automation and process controls for lamination, blade finishing, trimming, grinding, painting, materials handling, pultrusion, and inspection. Such techniques should improve quality control and lower production costs. This development effort needs to begin right away if automated blade and rotor factories and assembly facilities are to be built and operational in the next 10 years. Comments suggested that this effort should be led by the wind manufacturing sector, but financial support from the government for research and development will be needed, along with technical support from universities and national laboratories. Comments further suggested that this effort must also focus on the development of "lean manufacturing" techniques to reduce the labor intensity of current blade production processes and their associated costs.

Key Blade and Rotor Manufacturing Needs

- Automated, repeatable, and lower-cost blade manufacturing processes (e.g., for lamination, blade finishing, trimming, grinding, painting, materials handling, pultrusion, and inspection), including "lean" manufacturing processes that reduce labor intensity and production costs and increase quality and process control
- Integrated modeling, data acquisition, and analysis tools for assessing advanced blade designs and improving manufacturability and production process controls
- More resources to develop new testing facilities to improve access for blade designers and accelerate testing schedules
- Greater standardization and lower costs for all materials, constituents, and forms/formats
- Education and training programs for wind energy engineers, technicians, and factory personnel

Another technical challenge to improving blade quality is the lack of adequate analysis tools for integrating design and manufacturing. Trade-offs need to be better understood between blade design complexity (i.e., design enhancements for larger sizes, lighter weights, and improved efficiency and performance) and the ability to manufacture blades in ever-increasing quantities. Existing analysis tools are not accurate, particularly as blade designs get more complicated and the need for manufacturing precision increases. There is also a lack of testing facilities to hone advanced blade designs and refine new concepts for improving efficiency, durability, and manufacturability, and reducing weight.

One of the solutions to this challenge is the development of models and data acquisition systems for blade manufacturing. These models and systems can be used in the design phase to ensure the manufacturability of advanced concepts and in the manufacturing phase to ensure that the blades themselves are being made to the highest possible quality standards. This development effort needs to begin right away so that the tools are in place and available when they are needed in the next 5–10 years. Individuals commented that the effort should be led by the wind manufacturing industry, with financial support from government and technical support from universities and national laboratories.[8] In addition, suggestions include that more resources from government and industry must be devoted to developing new testing facilities to improve access for blade designers and

[8] For example, TPI Composites, Inc., Scottsdale, Ariz., currently has an agreement with Sandia National Laboratories to work together on advanced manufacturing techniques for blades.

accelerate testing schedules. This step is essential to ensure that advanced blade designs are moved into production and deployed to the field as rapidly as possible.

Another blade and rotor manufacturing challenge lies in the pricing and availability of some of the key raw materials for advanced blade designs. Manufacturers are experiencing global competition from other industries for materials with the same lightweight and fatigue-resistant properties as those sought for blades. For example, designers today are working on lighter and stronger materials, such as carbon fibers, to improve fatigue resistance while reducing weight. Supply, price, and availability problems also exist for fiberglass, balsa, foam, resins, and rotors as well as other turbine components that require forging and casting (such as bearings) and use pig iron and steel. In addition, a lack of standardization for composite materials is also an issue.

One of the solutions to these blade and rotor manufacturing scale-up and supply chain issues lies in creating a more stable and predictable policy framework and a more favorable business environment to attract and sustain private capital investment in manufacturing capacity. It will be extremely difficult for the 20% Wind Scenario to be achieved without a reliable and stable manufacturing supply chain in place for making and delivering blades and rotors. In fact, this manufacturing capacity needs to be in place and producing thousands of blades and rotors per year at least 10 years before 2030 for the 20% Wind Scenario to be realized. Another solution lies in developing greater standardization for composites and other types of materials to improve quality and reduce production costs. Input received suggests that this effort should begin right away so that the standards are put in place in the next 5–10 years. Comments further suggested that the effort should be led by the wind manufacturing industry, with financial support from government and technical support from universities and national laboratories.

Another identified manufacturing challenge involves enhancing America’s workforce for the production of wind turbines, blades, and rotors. There is already a shortage of trained engineers, technicians, and factory workers. This challenge crosscuts every aspect of wind energy manufacturing.

One of the solutions to this challenge is a focused government and industry effort to build education and training capabilities for wind energy development. Trade groups, such as the American Wind Energy Association (AWEA), can play an important role in this effort. Comments suggested that the strengthening of wind energy education and training capabilities needs to begin right away and is likely to take 10 years or more to implement. Suggestions include that centers for wind engineering need to be created at major universities, and programs need to be established at the community college level and in technical schools to train technicians, repair personnel, and factory workers.

Another manufacturing challenge involves the transport of blades from factories to wind resource sites. As blade size and weight increase, truck bed and roadbed limits for blade delivery will soon be exceeded. New manufacturing approaches are needed to move blade production and assembly closer to job sites and to create more portable manufacturing systems that can be set up and reassembled from site to site. One aspect of this challenge is the need to ensure that uniform state regulations are in place for transportation rules and logistics. There are also important siting, permitting, and electric grid integration policies and regulations that likely need to be addressed by federal, regional, and state agencies.

Table 1.1. Breakout Group List of Participants

Name	Organization
Rashid Abdul, Group Spokesperson	Gamesa Technology Corporation
Peggy Baehmann	GE Global Research
Cliff Eberle	Oak Ridge National Laboratory
Gary Kanaby	Knight and Carver Wind Group
Bob Krystyniak	PPG Industries
Daniel Laird	Sandia National Laboratory
Timothy McCarthy	Zoltek Carbon Fibers
Bill McCormick	MAG Cincinnati Automation & Test
David Neil	ATI Casting Service
James Payant	Janicki Industries
Frank Peters	Iowa State University
Stefan Sanner	DeWind
Joseph Simko	Hodge Foundry Inc.
Scott Schreck	National Renewable Energy Laboratory – National Wind Technology Center
Yetsunori Ueda	Mitsubishi Heavy Industries
Kyle Wetzel	Wetzel Engineering Inc.
David Willett	Clipper Windpower
Geoffrey Wood	Profile Composites, Inc.
Rich Scheer, Facilitator	Energetics Incorporated

Table 1.2. Vision of Blade and Rotor Manufacturing in 2030

Key Characteristics
Supply Chain • Manufacturing is integrated with the supplier base • Material in and product out are just-in-time • Vertically integrated • Specifications exist (as for “6061-T6”) • Domestic and international supply chain issues have matured and “settled out” • Additional suppliers of low cost commercial grade carbon fiber have emerged **Manufacturing Process** • Plants are automated with <1% waste • Automation for lay-up, composites, finishing • Greater use of robotics • Automated, accurate, and repeatable • More on-site and regional plants • Labor resources minimized • Ample testing facilities and resources • Only three domestic foundries can produce large ductile iron castings for turbines, involves major expansions **Workforce** • Trained workforce available **Blade Production** • World’s top quality blades made in the U.S. • Factories produce three blades per day at 10-20 facilities across the country • Existing blade production capacity increased three-fold • Capacity for casting large iron rotors increased ten-fold **Transportation** • Advanced concepts and effective systems in place

TABLE 1.3. TECHNICAL AND OTHER CHALLENGES TO BLADE AND ROTOR MANUFACTURING

Manufacturing Processes	Materials and Supply Chain	Testing	Workforce	Business Processes	Public Policies
• Lack of automated processing technologies, particularly for composites • Difficulties in producing blades that consistently meet standards for quality • Lack of technologies for automated fiber lay-up applied to blade shapes • No techniques for quality control for portable manufacturing systems • There are risks involved in automating dry fiber placement; significant research and development investment required • Lack of robotics for robotic lamination and finishing • Lack of effective material application • Current processes are very labor intensive • Lack of design and manufacturing tools • No clear, economical automation solutions; challenges in achieving quality, repeatability, and speed of blade production • Large blades need longer curing times and quality problems increase as blade length goes up	• Availability and pricing of raw materials – e.g., pig iron, steel, resins, etc. • Lack of common specifications • Lack of materials (e.g., carbon, balsa, foam), factories, and transportation systems • Lack of consistency of input materials from competing manufacturers – e.g., resins, fibers, cores • Common understanding of casting specifications on the part of both suppliers and customers • Supplies of pitch bearings • Scale up of the manufacture of component parts • Supplies of balsa	• Lack of models for design and facilities for testing • Lack of ability to perform dynamic testing under real life loads	• Lack of trained and available workers – e.g., engineers, operators, and technicians • Technical staffing for design, manufacturing, floor staff, and automation for all areas – e.g., turbines, blades, rotors, and bearings	• Costs of capital for scale-up given risks about the production tax credit • Mind set favors status quo • Recyclability of the blades • Investment costs for automation • "Not in my backyard" • Uncertainty of the business environment • Lack of standards for composites	• Lack of long-term Federal/State commitment to tax credits and other incentives • Environmental siting and permitting differ for each State • Regulations for lightning strikes and icing • Integration/ interconnection with the electric grid, principally electric transmission • Safety regulations and the risks of human injury and accidents

TABLE 1.4. BLADE AND ROTOR MANUFACTURING NEEDS TO ADDRESS BARRIERS AND REACH 20%

Manufacturing Processes	Materials	Blade Design and Testing	Workforce Training	Business Process Improvements	Public Policy
• Lower cost, repeatable, and automated manufacturing processes – Mid-term – Industry led; government financial support and university and national lab tech support – Includes "lights-out" composite manufacturing process – Includes developmental path for dry fiber automation – Includes cost-effective robotics for finishing machines for blades – Automation cover ply kitting, vacuum-assisted resin transfer molding and resin transfer molding, finish trimming/grinding • Develop "lean manufacturing" processes to reduce labor intensity Near term – Industry led; government financial support and university and national lab tech	• Develop lower cost, standardized composite materials applied to constituents and formats – Mid-term – Industry led; government financial support and university and national lab tech support • Develop easy-to-cure materials for on-site/ nearby manufacturing – Long term – Government led; industry support and university and national lab tech support • Develop processes/ techniques for getting more lower cost and adequate quality carbon – Near term – Industry led • Develop environmental friendly resins for on-site/nearby manufacturing	• Build and validate models and data acquisition systems for quality control and validation – Near to mid term – Industry led; government financial support and university and national lab tech support – Includes addressing need to evaluate advanced blade designs for manufacturability – Includes analysis tool to evaluate design-manufacturability trade-offs – Includes designs for more fault tolerant blades • Fund more and better test facilities – Near term – Industry led; government financial support and university and national lab tech support • Develop technologies for quality and life assessments – Near term – Industry led; government financial support and university and national lab tech support • Develop "foundry friendly" designs that increase throughput – Near term – Industry led; government financial support and	• Implement technical education programs – Long term – Government led; industry, trade association, national lab, university, and community college support – Includes engineering schools – Includes community colleges and trade schools for factory workers and technicians • Develop an industry training center(s) and library – Near term – Trade association led; government, industry, national lab, university, and community college support	• Develop an industry organization/ process to establish common standards and specifications – Near term – Trade association led; government, industry, national lab, university, and community college support • Take steps to attract capital investments to increase domestic carbon and fiberglass capacity – Near term – Industry led	• Create a business environment that sustains private investment and public incentives to address technical problems • Develop a Federal program for automation of blade manufacturing

Manufacturing Processes	Materials	Blade Design and Testing	Workforce Training	Business Process Improvements	Public Policy
support • Develop in-process inspection and data collection techniques – Near term – Industry led; government financial support and university and national lab tech support • Develop lower cost for manufacturing with carbon fiber – Near term – Industry led; government financial support and university and national lab tech support • Develop pre-impregnated composite fibers techniques		university and national lab tech support • Develop meaningful and consistent certification processes – Near term – Industry led; government financial support and university and national lab tech support • Develop advanced manufacturable designs for more efficient blades – Near term – Industry led; government financial support and university and national lab tech support			

Table 1.5. Crosscutting Issues to Blade and Rotor Manufacturing

Transportation & Logistics Issues	Federal/State Policy Issues	Training and Education
Getting uniform state regulations • Document existing state and local rules • Can American Wind Energy Association (AWEA) help with this? • Is federal legislation needed to achieve uniformity?	**Production tax credits (PTCs)/government policies** • Make them long term and predictable • Lack of them is a game breaker in near term • Affects investment/jobs across the entire supply chain • Non-PTC approaches include Renewable Portfolio Standards (RPS) or carbon taxes/cap and trade	**Top priority need for the entire supply chain**
Weights exceeding trucking capacities • Use more rail, but site access limited • Need for new options	**Environmental permitting for foundries and fiberglass and carbon fiber plants** • Mostly state but also the Environmental Protection Agency • New Occupational Safety and Health Administration regulations for blade finishing	**Tremendous lack of engineers with wind and related expertise** • Federal emphasis and funding (e.g., National Science Foundation, Department of Energy, Department of Commerce) to universities can help • Few universities offering wind energy concentration/degree/program, e.g., composites engineering • AWEA can replicate programs like American Foundry Society
Blade lengths getting longer for larger MW capacity • Trucking may not be possible to reach remote resources • Need for new options	**Electric transmission permitting, grid reliability and expansion** • Load balancing concerns at 20% – continuing need for studies	**Need for technicians and field personnel** • Local community college level
Is regional manufacturing the way to go? Can manufacturing facilities be short lived and portable?	**Streamlined siting and permitting for wind farms** • States, counties • e.g., "renewable energy zones" • "not in my backyard" (land-based and offshore)	
Offshore transport by boat is attractive	**End of life disposal for blades** • Recycling strategies needed • Regulations on the horizon	

2. Large Wind: Towers and Foundations

In today's wind turbine, the tower configuration used almost exclusively is a steel monopole on a concrete foundation that is custom-designed for the local site conditions. A turbine is generally placed on a 60-meter to 80-meter tower, but 100-meter towers are becoming more prevalent. Depending on the wind characteristics at the site, the tower height is selected to optimize energy capture with respect to the cost of the tower. Efforts to develop advanced tower configurations that are less costly and more easily transported and installed are ongoing.

To achieve the 20% Wind Scenario by 2030, the design and manufacture of taller (perhaps up to 140 meters in height) and wider towers is expected to be necessary. The U.S. manufacturing capacity for wind towers would need to be greatly increased, with some of this capacity ideally located at the tower-construction site. The towers will be built from steel plate, and some may be hybrid steel/concrete. Some could be flexible ("soft") towers. Some retooled stranded assets in the Midwest may be utilized for wind tower manufacturing. Firms in the wind turbine sector (including tower manufacturing firms) may be vertically integrated and may be located regionally near the installation site.

Key Tower and Foundation Manufacturing Challenges

- Complicated transportation and logistics issues created by the manufacture and transport of taller and wider towers, including inconsistencies among State permitting policies
- Lack of qualified workers in all aspects of production and manufacturing and lack of drivers for tower transport
- Lack of innovative manufacturing methodologies to develop cost-effective, on-site manufacturing for towers
- Concern as to whether existing international standards and regulations are suitable for U.S. operating environments and industrial practices
- High cost of raw materials (including steel and alternative choices)

The major technical challenges to achieving the wind manufacturing vision for towers and foundations[9] are likely led by the logistical constraints of transporting and erecting towers of 100 meters and taller. With larger and wider towers, transporting the components would be an ever-increasing challenge, and these components may exceed the transportation envelope for both rail and highway systems. Today's tower manufacturing technology may be augmented by on-site manufacturing. In addition, there are no cost-effective, lighter towers.

The logistics issues are further complicated by inconsistencies among state permitting policies. Staging and transfer capabilities for oversized loads are likewise inconsistent. In addition, there are not enough drivers or vehicles capable of transporting the towers. A lack of sufficient cranes

[9] The *Large Wind: Towers and Foundations* breakout group did not specifically discuss manufacturing issues related to *foundations* in this session, although it was generally acknowledged that a detailed discussion of offshore systems would necessitate work in this area.

capable of erecting these tall towers exists, as well as a lack of qualified personnel to produce, manufacture, and construct the towers in the quantity needed by 2030.

Key Tower and Foundation Manufacturing Needs

- Improvements in tower design, including the development of innovative manufacturing methodologies for cost-effective, on-site manufacturing of towers
- Improvements in tower construction methodologies, including the development of crane-free operations
- Coordinated permitting for transportation of large towers
- More streamlined government permitting approval processes
- Incentives for workforce training, and proactive recruitment, to ensure a large increase in the number of qualified workers in all aspects of production and manufacturing
- Enhancement of U.S. design standards for land-based wind turbines
- Long-term tax credits and manufacturing incentives, as well as substantial research and development funding for tower innovation, to reduce high materials costs

To address the difficulties of erecting the needed taller towers, commentors suggested that design and construction methodologies must be improved, and methods and designs for crane-free operations must be developed. This is a mid-term need for land-based systems and a longer-term need for offshore turbines. Comments suggested that this should be a combined DOE and industry-led effort. In addition, individuals commented that a study of onsite manufacturing potential and challenges should be performed and that this would be a near-term, industry-led effort.

One near-term method for addressing tower transportation and logistics issues would be to establish coordinated permitting for transportation of large towers. This effort could be led by industry and state governments. U.S. Department of Transportation assistance would also be vital to success in this area.

Input received suggested that governmental permitting approvals, some of them quite stringent, are needed for taller structures. Issues include safety for low-flying aircraft and radar interference. One solution would be for DOE to lead an interagency effort that will help to establish a more streamlined and transparent approval process to address tall tower issues, including those involving radar.

Another urgent challenge in tower and foundation manufacturing is the lack of qualified personnel. The lack of an adequate workforce can be alleviated by creating incentives for workforce training programs and by proactive recruitment. The near-term development of a larger qualified workforce to design, build, and erect taller towers could be led by industry and state governments, with support from the U.S. Department of Commerce, the U.S. Department of Education, and the American Wind Energy Association. In addition, establishing university centers of excellence could be very beneficial. A university-based center of excellence for wind towers (or a tower section of an overall wind center) could be established in the near term (by 2012) and continue to operate at least through the period 2012–2030. Individual participants suggested that this effort could be university-led, and could be funded by DOE, state governments, and industry, with additional support from AWEA.

The current situation of European design rules and materials specifications being applied in the U.S. leads to significant design, sourcing, and inspection problems and costs. There is also a shortage of certifying agencies for towers. Thus, individuals suggested that there is an urgent need for consensus U.S. design rules, materials specifications, and inspection procedures for the tower industry. This may be enabled by a joint industry/DOE initiative with support from national laboratories and nongovernmental organizations. Individuals suggested that a similar program should be in place in the long term (by 2030) for offshore wind turbines, with similar responsibilities for DOE, industry, national laboratories, and nongovernmental organizations, and that the program should also have additional support from universities.

While steel plate is generally available for the manufacture of towers, cost is an issue. Individuals suggested that long-term tax credits and manufacturing incentives are needed, as well as funding for tower innovation. Stability in federal policies, including carbon legislation and the production tax credit, would also be helpful.

Table 2.1. Breakout Group List of Participants

Name	Organization
Shinji Arinaga	Mitsubishi Heavy Industries
Tom Ashwill	Sandia National Laboratories
P.J. Dougherty	SMI Inc./Helios Strategies
Fred Fletcher, Group Spokesperson	ArcelorMittal
Lanny Kirkpatrick	Siemens
Sree Harsha Lalam	ArcelorMittal USA
Tom Maves	Ohio Department of Development
Lars Moller	Broadwind Energy
Mike Robinson	National Renewable Energy Laboratory – National Wind Technology Center
Mamoru Tanaka	Mitsubishi Heavy Industries
Paul Veers	Sandia National Laboratories
Tom Vinson	American Wind Energy Association
Ed Skolnik, Facilitator	Energetics Incorporated

Table 2.2. Vision of Tower and Foundation Manufacturing in 2030

Key Characteristics
• Increased tower manufacturing capacity • Vertically integrated tower/turbine firms, regionally located near installation sites • Re-tooled stranded assets in Midwest (auto industry, steel, etc.) • Steel welding and assembly in plants/transportation and erection on site • 140-meter tall towers • Some hybrid concrete/steel towers • Alternative materials possible including flexible (soft) towers • Life cycle costing including decommissioning costs • Some on-site manufacturing

TABLE 2.3. TECHNICAL AND OTHER CHALLENGES TO TOWER AND FOUNDATION MANUFACTURING

Policy	Personnel Issues	Service and Transport	Design	Manufacturing Materials	Manufacturing Methods
• Siting and permitting	• Abundant skilled workforce (construction, welding, etc.) • Shortage of wind engineers (structural, mechanical)	• Lack of crane capacity or self-erection strategies • Increase size/ transportability track-off • Lack of crane availability	• Innovative design to get to 140m with logistic constraints • New structure • Construction method, machine (erection) • Decreasing weight of nacelle/gear box • North American-specific design (e.g., low-level jet impact on high towers) • Lack of experience with offshore wind • Integrated turbine/tower load control • Young's modulus (buckling) of light-weight towers >100m	• Cost-effective lighter towers • Access to cost-effective raw and manufactured materials • Alternate material technical certification	• Construction period • Cost-effective on-site joining (e.g., laser-hybrid) process

TABLE 2.4. TOWER AND FOUNDATION NEEDS TO ADDRESS BARRIERS AND REACH 20%

University/Education	Policy	Certification	Manufacturing	Demonstration	Design
• University Center of Excellence for towers – Near-Term (Ongoing), Universities – lead, Federal Government (Department of Energy [DOE])/State Government/Industry/ American Wind Energy Association (AWEA) support • More qualified workers – Near-Term (Ongoing), Universities – lead, Federal Government (DOE)/State Government/Industry/ AWEA support • DOE and industry to create educational centers and funding to add to workforce – Near-Term – (Ongoing), Universities/Federal Government (DOE) lead, State Government/ Industry/AWEA support • Investment in joining and testing centers • Partner with underutilized shipyards, contractors, and apprentice schools • DOE to fund wind university scholarships	• Regional logistics solutions (permitting, short-term) – Near-term, Industry/State Government joint lead, Federal Government (Department of Transportation) support • Set up U.S. transportation corridors for large loads (towers) • Federal manufacturing incentives for expanding, retooling, entering wind industry supply chain • DOE/industry-funded solicitations to facilitate innovations	• Enhance U.S./North American design standards and certification program – Mid-Term (Land-based towers), Industry/Federal Government (DOE) joint lead, nongovernmental organization (NGO)/ National Labs support – Long Term (Offshore towers), Industry/Federal Government (DOE) joint lead, NGO/National Labs/ Universities support	• Study of on site manufacturing potential and challenges – Near-Term, Industry (only) • Explore ship building joining methods • In-line ultrasonic testing of tower plates at mills	• Full-scale demonstration project for alternative tower design • Prototype scaled demonstration projects – Mid-Term, Industry/Federal Government (joint lead), Universities support	• Erection tower design and construction method – Mid-Term, Industry (only) • Create methods and designs for crane-free operations. – Mid-Term, Industry (only) • Substantial research, development, and demonstration funding for innovative towers and foundations • Design concept tower studies targeting innovation (Windpact) • Design, fabrication, testing of tower concepts with alternative materials • Flexible tower design • Dynamic analysis for blade, drive train and tower (modal dynamics) • Consideration of transport limitations in design phase • Develop airships for transport

Table 2.5. Crosscutting Issues to Tower and Foundation Manufacturing

Transportation & Logistics Issues	Federal/State Policy and Regulatory Issues	Workforce & Education	Standards & Certification
• Physical dimensions of taller towers (diameter and length) exceed the transportation envelope for both rail and highway systems • Inconsistency of permitting from state to state for oversized loads • Inadequate staging and transfer capabilities/material handling • Lack of cost-effective onsite manufacturing and erection techniques • Forced design innovation (including materials) • Not enough trailers or truck drivers • Not enough cranes	• Inconsistency of permitting from state to state for oversized loads • More streamlined and transparent approval processes for radar issues (currently Federal Aviation Administration [FAA], National Oceanic and Atmospheric Administration, Department of Homeland Security, and Department of Defense are involved) • Height of 500 feet and above requires more stringent government approvals (FAA, environmental, etc.) • Lack of stable Federal policy (e.g., long-term production tax credit, carbon legislation, manufacturing incentives) • Inadequate Federal research and development funding for tower innovation	• Establishing university Centers of Excellence • Federal and state incentives for workforce training programs • Proactive recruitment process for wind industry workers	• Question of suitability of existing international standards for U.S. operating environments • Question of suitability of existing international standards for U.S. industrial practices • Lack of certifying agency in U.S.

3. Large Wind: Drive Trains

As wind turbine capacity increases, so does the size of the machine and its components. The demand for larger turbine components has an impact on the manufacturing supply chain. There is increasing interest in more innovative gearbox designs that can reduce the number of parts, cost, and logistics of installation and maintenance. The availability of raw materials and manufacturers with capabilities to produce large quantities of high-quality and reliable drive train components likely is critical for meeting the 2030 manufacturing goal.

Key Drive Train Manufacturing Challenges

- Shortage of capable suppliers to manufacture drive trains and components to meet U.S. demand for megawatt-scale models
- Poor drive train reliability; limited understanding of gearbox bearing dynamics and reliability
- Limited domestic casting, steel, and forging capacity
- Shortage of well-trained and educated personnel
- Lack of facilities to adequately test turbine components
- Lack of basic research and development information in the public domain
- Lack of simple, efficient, and cost-effective manufactured drive train concepts/designs

One of the technical challenges in drive train manufacturing is that wind turbine gearboxes do not meet their design life. Drive train reliability is a significant long-term research and development activity. A number of field operation problems occur as a result of gearbox bearing failure. This type of failure is believed to be linked to poor lubrication and lack of routine maintenance. Bearings in wind turbine gearboxes undergo extremely high loads and the bearing performance will differ throughout the gearbox. Bearing dynamics and reliability are not well understood.

One of the solutions to this challenge is to improve bearing reliability through higher-resolution simulation and testing of loading conditions for complex wind environments. Commentors suggested that additional research and development is necessary to enable better surface engineering of treatments and coatings for gears and quality verification for bearing and gear steel. In addition, comments suggested that more technical information sharing is needed in the public domain about the research and development of these components. Because of intellectual property concerns, manufacturers are hesitant to make information about their products publicly available. Stronger collaboration among industry, government, and academia on research and development for drive train components would likely be beneficial.

Comments made further suggested that more resources from government and industry should be devoted to testing facilities to improve access for designers, accelerate testing schedules, and improve manufacturability. Individuals commented that this step is essential for moving advanced drive train designs into production and deploying them to the field as rapidly as possible and that this activity needs to be completed in the near term to support the 20% Wind Scenario's manufacturing goals. Participants suggested that universities should take the lead in this effort, with support from national laboratories. One activity currently underway that could help with this challenge is the wind turbine Gearbox Reliability Collaborative led by the National Renewable

Energy Laboratory. The Collaborative is working to understand how gearbox loads translate to bearing response, stress, slip, and other problems.

Key Drive Train Manufacturing Needs

- Marketing and recruitment program to raise public awareness of long-term job opportunities in the wind industry
- A revival of manufacturing capabilities of supporting industries (bearings and castings)
- Consistent funding for research and development
- Improvement in reliability through the understanding of bearing dynamics and actual operating environments
- More testing facilities to improve access for designers, accelerate testing schedules, and improve manufacturability
- Cooperative development with research community and knowledge integrated from aerospace and automotive industries

Another challenge in drive train manufacturing is the limited domestic casting, steel, and forging capacity available for the construction of wind turbine components. In addition, not enough wind turbine gearbox manufacturers have been able to ramp up their production lines quickly enough to accommodate new megawatt-scale models. Most of the existing supply chain shortages have occurred with gearbox components. Increasing the U.S. capacity for gearbox manufacturing is not trivial because it is capital-intensive and requires new equipment for gear-cutting machines and heat-treating facilities. In addition, it can take several years to tool up and test gearboxes for larger-size turbines. Given the global increase in demand for wind turbine components and for broader heavy industry in general, shortages of large bearings used in gearboxes, main shafts, generators, and other components have resulted.

One of the solutions to drive train manufacturing scale-up and supply chain challenges is to have a clear, stable, and long-term federal policy to support industry (including the production tax credit and cap and trade programs). Commentors stated that stability in how to treat capital expenditures such as investments in equipment and production facilities is also necessary. A steady and reliable manufacturing supply chain for making and delivering drive trains is paramount for achieving the 20% Wind Scenario. Another solution to the supply chain challenges could be to foster cooperative development within the research community and integrate knowledge from the aerospace and automotive industries. In addition, tools and techniques that can help to fully automate the manufacturing process in the future would help to meet supply-side issues. Reducing the number of components and design complexity would also help to balance the demand for raw materials in the future, and research should be conducted to review global best practices for reducing design complexity. Several comments suggested that this activity should start immediately, so that in the next 5–10 years the infrastructure is in place for meeting 2030 manufacturing goals, and that this effort should be led by the federal and state governments, with support from industry.

Another challenge is the shortage of well-trained and educated workers for wind turbine—or even renewable—energy jobs. One of the reasons for this shortage is that the number of students receiving degrees in math, science, and engineering is on the decline in the U.S. Convincing qualified workers to seek tradesman jobs is often challenging, given the limited available information about these professions and existing misconceptions about what these positions entail.

One of the solutions to this challenge is to develop a marketing campaign and recruitment program that raises public awareness of long-term career opportunities and improves the image of "green" jobs. Participant suggestions indicated that this should be a broad-based effort that ranges from the recruiting of computer numerical control (CNC) machinists to academics with PhDs. A "paint by numbers" package could be developed to attract qualified workers to the wind industry. Commentors further suggested that incentives should also be developed to encourage highly skilled foreign workers to relocate to the U.S., and that this activity needs to start immediately, and it should be completed in the near term. Comments suggested that state and local governments should lead this activity, and that industry groups would need to support communications and outreach efforts. Moreover, comments suggested that universities should also play a supporting role by helping to develop programs and classes on wind turbine development and renewable energy, and that the federal government can also play a supporting role by assisting with and funding outreach efforts.

Table 3.1. Breakout Group List of Participants

Name	Organization
Peter Blau	Oak Ridge National Laboratory
Wayne Braun	Bradken - Americas (AmeriCast Technologies)
J. Ross Bushman	Cast-Fab Technologies, Inc.
Sandy Butterfield	National Renewable Energy Laboratory
Claus Kurt Christensen	Vattenfall Wind Power A/S
Ali Erdemir	Argonne National Laboratory
Pedro Guillen	Ricardo
Edwin Hahlbeck, Group Spokesperson	Powertrain Engineers Inc
Joe Jongewaard	Iowa Department of Economic Development
Thomas Prucha	American Foundry Society
Dan Radomski	NextEnergy
Dennis Roy	GE
Elizabeth Salerno	American Wind Energy Association
Charles Schultz	Beyta Gear Service
Michael Skovgaard	Vestas Wind Systems
Julius Steiner	Gamesa Technology Corporation, Inc.
Jonathan Wang	Mitsubishi Power Systems
Edwin Weston	Great Lakes Wind Network
Sally Wright	Garrad Hassan
Yuji Yatomi	Mitsubishi Power Systems
Stephen Zwolinski	Gerdau MACSTEEL - Jackson
Brian Marchionini, Facilitator	Energetics Incorporated

Table 3.2. Vision of Drive Train Manufacturing in 2030

Key Characteristics
• Design and manufacture of fail-proof, maintenance-free drive train components • Surface engineering – treatments • Widespread availability of durable, low-friction smart bearings that integrate condition sensors • Size of the gearbox is minimized and optimized with high reliability and long durable life • Material improvement for machinability and hardenability leads to reliability • Two-stage gear-driven 4MW permanent magnet machine carbon/glass-reinforced plastic active pitch, full inverter design and 99% reliability with fluid film bearings that are serviceable • Reduction in component count, reduced weight of system • Common nacelle architecture across turbine original equipment manufacturers to reduce cost and supply chain complexity • Reduction in supply chain complexity • Increased reliance on suppliers to provide critical components, subassemblies, integrated systems • Educational system adapts to give students technical knowledge as a base level • Access to engineering expertise • Well-trained people • Recruitment programs for new tradesmen • Fully automated plants for improved throughput • Advanced gearboxes–hydraulic systems, magnetic, low cost single stage • High efficiency power electronics and advanced controls • Drive trains with prognostics and diagnostics • Load patterns are well understood; reduced drive train dynamics and transients • Manufacturers supported by testing and research and development resources from partnerships of government and industry • Standards are developed for component testing • Offshore turbines will have direct drive permanent magnet generators

Table 3.3 Technical and Other Challenges to Drive Train Manufacturing

Supply Chain	Reliability	Simulation and Analytical Tools	Scale-Up	Other
• Shortage of capable suppliers for drive trains • Do not have the ability to manufacture components in the U.S. to meet demand • Lack of available steel mills in the U.S. • Limited domestic casting and forging capacity • Too much governmental involvement in a supply base that needs to exponentially grow	• Do not fully understand bearing dynamics • Bearings are not robust enough • Gearboxes and power electronics are not reliable • Not doing a good job of load control (abnormal starts and stops)	• Do not know how to simulate loading conditions for various wind fields • Lack of experience with field validation • Do not know how to fully use analytical tools	• Downsizing the drive train can cause issues • Scaling knowledge from smaller units to larger systems	• There is not enough basic research and development information in the public domain • Lack of well-trained and educated workforce • Lack of capital • Lack of facilities to test turbine equipment

Table 3.4: Drive Train Needs to Address Barriers and Reach 20%

Workforce	Capacity	Research and Development	Funding	Collaboration
• Need to have industry training—manufacturing program and raise public awareness of long-term opportunities (computer numerical control [CNC] machinists to PhDs) – Near Term – Lead – local government; Support – industry, academia, Federal government • Need a significant increase in math, physics, chemistry, etc through the educational system – Near Term – Lead – State and Federal governments depending on educational requirements; Support - Academia • Need to communicate the opportunities of green jobs and green money – Near Term – Lead – nongovernmental organizations (NGOs); Support – Federal and State governments, industry • Need funding for training – graduate engineering, windsmiths and trades – Near Term – Lead – Federal and State government; Support – Academia	• Foundries need to have the capability to supply raw materials in both quality and quantity, have a robust infrastructure to handle large pieces of materials, and have the melt capability – Short-term to Mid-Term – Lead – Industry; Support – State governments • Need more capacity to build bearings – Mid-Term – Lead – Industry • Need to have machine tool builders that are U.S. based – Mid-Term – Lead – Industry; Support – Federal and State government	• Need to link understanding of bearing dynamics and real operating environments to requirements for materials, surface treatments, and lubes – Mid-Long Term – Lead- Federal government; Support – National Laboratories, industry • Need industry data (size, weight, materials) of key components collected from original equipment manufacturers (OEMs) to accelerate interest and commitment of competent suppliers – Short-term – Lead – Independent third party; Support – Academia • Need better surface engineering/treatment/ coating methods – Mid-Long Term – Lead – Federal government; Support – national laboratories and industry • Need high precision manufacturing equipment and educated operators for gears and shafts and housings • Need automation process to speed time to market of key components and nacelle assembly operations	• Need a consistent energy policy to bring in $ • Need consistent funding for research and development – Near-Term – Lead – Federal and State government; Support – American Wind Energy Association (AWEA), trade associations	• Need to revive manufacturing capabilities of supporting industries (bearings and castings) – Near Term – Lead – Federal and local government; Support – Industry • Need strong collaboration among industrial, government and academia research and development people – Near-Term – Lead – Federal government; Support – Industry, academia • Need cooperative developed with wind turbine generator designers and gear box designers • Need to use automotive/aerospace knowledge to enhance wind power production levels – Near Term – Lead – Federal and State government; Support – Industry • Need cooperation among suppliers and OEMs to move turbines to the marketplace • Need to think strategically about locating facilities to machine turbines – could locate with another facility

Workforce	Capacity	Research and Development	Funding	Collaboration
		• Need good load data and address intellectual property issues to allow cooperation • Need to enhance the quality verification of steel/bearings • Need improved quality and reliability geared toward jobbing shop – approaches, controls, non-destructive examination • Production needs to have a steep learning curve to bring 20+ GW production facility into place by 2030 • Need a larger dynamometer test stand than currently available that can do torque loads • Need more research in material science and design • Need to better understand the role of third-bodies (grit) in bearings • Need improved bearing tests that include spectrum loads that simulate actual operation (vibration, etc.)		

TABLE 3.5. CROSSCUTTING ISSUES TO DRIVE TRAIN MANUFACTURING

Workforce	Federal/State Policy Issues	Testing Capabilities and Materials
• Do not have a plan or leader for increasing awareness and interest in energy efficiency/renewable energy jobs • Students graduating with math, physics, science etc. is diminishing • Lack of people in skilled trades and engineering • There are not as many apprentice programs as there used to be • Opportunities for green jobs are not well-known among graduates • Students (and parents) are not attracted to trades (need campaign to change the image of trades)	• Clear, stable, and long term federal policy to support industry (include production tax credit, cap and trade) • Need for consistent research and development funding • Stability in how to treat capital expenditures (investments in equipment, production facilities) • Transmission policy • No incentives for skilled workers to come to the U.S. from other countries	• Do not have facilities to adequately test turbine components • Need more support for participation in international standards development • Steel mill supply (must be bearing quality)

4. Small Wind: Entire System[10]

Small wind systems—particularly residential wind systems in the size range of 90 W to 25 kW—are poised to become a major part of the distributed energy industry. Residential wind systems allow consumers to supplement their monthly energy bills by generating their own energy at its point-of-use while minimizing transmission losses, reducing their carbon footprint, and protecting themselves from the effects of future electric rate hikes.

Modern small wind systems consist of specially designed fiberglass composite blades that use the latest airfoils, communications systems that allow users to track performance and run diagnostics wirelessly, integrated utility grade inverters, corrosion-resistant aluminum die castings, unique stator designs that allow for low-wind start-up and high torque for control, and sound isolators that minimize sound emissions. These and other manufacturing enhancements will be addressed in the near-, mid-, and long-term to add simplicity and reliability and to lower the cost of current small wind system designs.

An estimated 13 million homes[11] in the U.S. have sufficient land to sustain a small wind system in a Class 2 or greater wind, and more than 13 million businesses have sufficient land and are located in a Class 2 or greater wind area. Growth in the small wind business will likely depend on a number of key factors, including integration of simple, easy-to-maintain parts; improved high-volume manufacturing and better distribution channels; localized resource assessments and follow-up dealer training on certified products; attention to interconnection and net metering policy at the state level; national and local zoning policies; and availability of investment tax incentives.

Key Small Wind* Challenges

- Design, manufacturing, installation, and maintenance costs that are still too high
- Manufacturing costs that are still too high per unit of output, particularly the cost of tower production, as well as the high cost and low availability of raw materials such as fiberglass and carbon fiber
- Lack of competitively available investment capital
- Lack of available, well-trained manufacturing and installation personnel; workforce lagging behind growing demand for wind power
- Lack of available energy storage that is cost-effective, life-cycled, efficient, and integrated is a strategic issue; it is an R&D problem not only for small systems that can be used to sell power back onto the grid, but for large wind machines as well

** For this purpose, "small wind" is defined as residential wind systems in the 90 W–25 kW size range*

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[10] This breakout group consisted of a small number of manufacturers, including only one manufacturer with more than ten years of experience in small wind manufacturing, sales, and service. For this reason, the key issues identified herein will need to be supplemented with input from additional, longer term small wind industry members. In addition, it should be noted that energy storage was only briefly discussed as part of this breakout group due to program design constraints and space limitations. Energy storage may be a useful strategy when looking at the entire system, but not necessarily at the wind plant level.

[11] According to *The U.S. Small Wind Turbine Industry Roadmap*, American Wind Energy Association, 2002, (http://www.awea.org/smallwind/documents/31958.pdf) it is projected that 13 million homes will be potential sites for a small wind turbine by 2010, with 15.1 million homes projected to be potential sites by 2020.

Achieving growth in the small wind marketplace creates challenges, the most important of which is the cost of energy. For wind power to become more competitive, the cost of generating wind power on a life-cycle cost basis must be lowered, while at the same time reliability must be maintained and improved. There is a need to validate and integrate predictive tools and design for manufacturing and assembly, both of which would likely bring down the cost of designing, manufacturing, and installing wind systems.

To address this challenge, programs would need to be developed and validated to model integrated system components, including turbines and other key elements of small wind systems. Individuals commented that a library of these components and models should be developed; wind engineering and manufacturing firms need to become better engaged in optimizing machine components, as well as supporting technical standards of efficiency; and that these efforts should begin immediately, in order to be completed for the midterm. Commentors further suggested that the national laboratories, federal government, industry, and universities should all be involved in this effort.

Key Small Wind Needs

- Development and validation of a library of component models to perform system operation and optimization; models for turbine design must be validated to better design integrated systems
- Development of integrated manufacturing design processes and tools
- Development of advanced materials for system components that can be cost-effectively manufactured
- Optimization and automation of manufacturing processes, resulting in equal or lower costs per volume of output
- A detailed analysis on energy storage opportunities for small wind systems, followed by development of incentives
- Education for investors on small wind markets and technologies, and encouragement of that investment

Another challenge in small wind is that manufacturing costs are still too high per unit of output, including the cost of towers and cost and availability of raw materials such as fiberglass and carbon fiber. An ancillary challenge is the lack of a robust supply chain; components are not widely available to average consumers, which results in both higher costs and custom design and installation for each unit.

To address these challenges, advanced materials that are more easily manufactured would likely be needed. Input received suggested that automated manufacturing processes that will lower production costs per volume must also be developed. Increasing the production of domestic raw materials, primarily iron and steel, is a challenge for many U.S. industries today, one which comments suggest must be addressed on a national basis. Comments also suggested that identification and support for vendors and subcontractors who are skilled, trained on wind technology, and available to support component manufacturers is a critical need. Comments suggested that national laboratories, supported by industry, should lead these efforts, which should begin in the near term and be completed in the midterm. In addition, individual participants suggested that a fully functioning workforce must be ready and able to expand the wind power supply chain and grow the market.

Although small residential systems are used primarily for on-site energy needs (rather than for grid power), excess power—if stored efficiently and cost-effectively—could provide value to small wind consumers. However, DOE analysis shows that a 20% wind penetration level is possible without the utilization of storage options. Storage may be a useful strategy when looking at the entire system, but not necessarily at the wind plant level. As renewable energy penetration levels increase, storage will be most effective with large regional electric markets. DOE is exploring an integrated strategic plan for long term options to enable an aggressive ramp up of wind power concurrent with substantial expansion in other renewables such as solar and geothermal power. These options include the potential for developing storage technologies on several DOE programs that would take advantage of synergies among programs, technologies, and applications. The integrated strategic plan will include the technology and institutional needs for both transmission and distribution grid integration.

Small wind turbine companies need better capitalization and more low-cost funding at attractive interest rates to grow. This is a key challenge in today's weakened economy but one that likely would need to be addressed if residential wind systems are to capture a larger market share. One solution to this challenge is to improve investors' comfort level by better educating them about small wind technology, market opportunities, and the cost-effectiveness of wind.

Support for technology solutions; institutional and investment actions; and education, outreach, and training would be expected to grow the small residential wind market. Comments suggested that small wind companies must work together to design common parts and to explore and develop cross-cutting, packaged solutions for widespread market development. Individuals suggested that development of international standards for small turbines and labeling practices, as well as consistent national, state, and local regulatory policies such as interconnection and feed-in tariffs, will support market growth and promote U.S. manufacturing. Additionally, comments suggest that better education, training, and outreach will be critical to success. Further, comments suggested that educating all supply-chain workers; designing aggressive and engaging public and trade relations programs; and conducting outreach to federal, state, and local government officials and investor-owned and public utilities will provide needed support to the small wind market. Comments indicated that these efforts should start immediately and continue into the long term by the community of nongovernmental organizations, the small wind industry, the federal government, and national laboratories.

TABLE 4.1. BREAKOUT GROUP LIST OF PARTICIPANTS

Name	Organization
Daniel Dedrick	Sandia National Laboratories
Kevin Dennis	ZBB Energy Corp.
Trudy Forsyth	National Renewable Energy Laboratory (NREL)
Kevin Harrison	National Renewable Energy Laboratory (NREL)
Jamie Holladay	Pacific Northwest National Laboratory (PNNL)
Andrew Kruse, Group Spokesperson	Southwest Windpower, Inc.
Dennis Lin	U.S. Department of Energy Wind Program
Brian Ross	Janicki Industries
Paul Smith	3TEX, Inc.
Ron Stimmel	American Wind Energy Association
Robert Thresher	National Renewable Energy Laboratory – National Wind Technology Center
Zhenguo "Gary" Yang	Pacific Northwest National Lab (PNNL)
Wendy Wallace, Facilitation Assistant	Energetics Incorporated
Jan Brinch, Facilitator	Energetics Incorporated

TABLE 4.2. VISION OF SMALL WIND IN 2030

Key Characteristics
• Costs of \$0.06/kWh in a Class 2 wind resource (12 mph) • Vertical-axis and horizontal-axis wind turbine systems targeted to different cost entry point • Improved kWh/kW for increased market capture • Reliable, autonomously monitored operation and performance such that only periodic maintenance is required • Architecturally integrated machines that are quiet, reliable, and attractive • Designed for maximized manufacturing and assembly • Maximized manufacturing techniques for high-volume, lean "plug and play" production • Optimized manufacturing techniques for blades (material selection) and foil design • Lower cost, higher quality tooling • Integrated with power electronics that optimize system topologies • A Just-In-Time supply chain, less vertically integrated • Set of predictive simulation tools for research assessment in place • Integrated energy storage technologies and power electronics systems in place

TABLE 4.3. TECHNICAL AND OTHER CHALLENGES RELATED TO SMALL WIND MANUFACTURING

Design	Manufacturing	Energy Storage	Investment	Education
• Cost of energy power • Lack of validated and coupled predictive tools (computational fluid dynamics, grid, etc.) • Lack of technical standards • Modeling tools for designing different small wind turbines over speed control • Need for better product design and tooling for high volume production • Lack of understanding for integrated systems	• Manufacturing cost too high per unit of output (M^2) • Towers cost too high • Material cost/availability too high • Lack of understanding of manufacturing improvements and $ to change • Lack of robust supply chain • Lack of raw materials (fiberglass and carbon fiber)	• Cost effective, life-cycled efficient and integrated storage not yet available • Need for technical analysis on energy storage for small wind systems	• Capitalization of SWT companies	• Need for better trained manufacturing personnel

TABLE 4.4. SMALL WIND MANUFACTURING NEEDS TO ADDRESS BARRIERS AND REACH 20%

Design of Small Wind Components and Systems	Manufacturing	Energy Storage (Small and Large)	Education, Training, and Outreach
• Program to develop and validate library of component models to perform system operation – Near to mid term – National laboratory led, federal government, industry and university support – Validated models for design of turbines and manufacturing methods • Development of integrated manufacturing design/process tools – Mid to long term – Industry led, federal government, national laboratory and state government supported • Engage redesign manufacturing engineering firms to help with optimization – Near term – Industry led and federal government, specifically the commerce department, supported. • Products designed around technical standards that reduce manufacturing costs – Mid to long term – Industry led with state government support/involvement • Published set of industry standards; minimum efficiency requirements – Long term – Industry led with nongovernmental organization (NGO) support	• Advanced materials for system components/more manufacturable components – Near to mid- term – National laboratory led and industry supported • Automated manufacturing processes (Lower cost/volume) – Near term – Industry led with support from federal government national laboratories, and state government involvement • Increased production of domestic raw materials (iron and steel) – Long term – Federal government led and state government supported • Need to identify and establish lower tier vendors/subcontractors – Start in the mid term and go into the long term – Industry led and state government supported	• Qualify storage like wind ($) to increase volume, decrease cost – Near term for the large wind – Long term for the small wind – Federal government led, national laboratory supported • Design cost effective active materials for energy storage/ manufacturing – Near, mid, and long term – National laboratories led, federal government and industry supported • Sponsor research and analysis on storage for small wind systems – Near term – Federal government led and national laboratory supported	• Educate investors on small wind markets/technology – Near, mid, and long term – NGO led, industry, federal government, and national laboratory involvement

TABLE 4.5. CROSSCUTTING ISSUES TO SMALL WIND MANUFACTURING

Education, Outreach, Training	Institutional and Investment Issues	Technology Solutions
• Workforce development – having trained workers, installers, designers • Better education pathways • Targeted public relations campaign • Aggressive trade show presence • Global small wind organization/group • Outreach to local authorities and jurisdictions • Outreach to rural electric coops • Outreach to federal and state government officials	• Development of international standards • Development of international labeling practices • Development of consistent national, state, and local policies (investment tax credit, system benefits charge, and feed-in tariffs) • Interconnection • Outreach to investment community • Recognize and promote land-based manufacturing	• Small wind companies working together to design common parts • Resource assessment • Explore and develop crosscutting technology solutions that design for marketplace • Availability of metals and composites • Packaged solutions for distribution • Learn from other industries, i.e. wireless telecommunications towers

Next Steps

The following actions were recommended by the various participants as next steps:

- Increase research and development funding commensurate with today's wind challenges and align research and development priorities to address manufacturing needs.

- Evaluate other aspects of the 20% Wind Scenario to determine technology development, market, and policy needs that are related to expanding wind component manufacturing capability to a gigawatt-scale level.

- Evaluate plans and strategies for wind energy development by government and industry to determine if the barriers to expanding wind manufacturing capabilities are being adequately addressed, and if not, address these barriers quickly.

- Build more testing facilities and demonstration centers, including dynamometers.

- Accelerate collaboration among universities, government, national laboratories, and industry in order to utilize the knowledge and capabilities available among all parties.

- Dramatically increase the number of skilled workers across the U.S. wind manufacturing sector in order to support industry growth. Initiate conversations with states and universities to modify curricula and explore the idea of establishing training and education centers in several wind manufacturing areas.

- Reach a consensus on installed capacity goals for the small wind industry; information provided in the American Wind Energy Association's small wind industry roadmap[12] should be used as a starting point. A reclassification of small and large wind (e.g., small commercial, farm, community) should be considered as a result of the evolvement of the wind industry over the past 20 years.

- Collaborate with and step-up education of federal and state policy makers about the need for a stable, long-term business environment for wind energy development to attract capital and labor and bolster the domestic supply chain of raw materials.

- Address transportation logistics challenges to ensure safe and timely delivery of components to wind sites. Zoning regulations and permitting policies will need to be discussed among several parties, including federal and state agencies, regional entities, and local jurisdictions. Such interagency conversations should be initiated now so specific actions can be identified and implemented.

[12] *The U.S. Small Wind Turbine Industry Roadmap*, American Wind Energy Association, 2002. http://www.awea.org/smallwind/documents/31958.pdf.

Appendix A. List of Acronyms and Abbreviations

AWEA – American Wind Energy Association

CNC – computer numerical control

coops – cooperatives

DOE – U.S. Department of Energy

EERE – Office of Energy Efficiency and Renewable Energy

FAA – Federal Aviation Administration

GW – gigawatt

kW – kilowatt

kWh – kilowatt-hour

m – meter

mph – miles per hour

MW – megawatt

NGO – nongovernmental organization

NREL – National Renewable Energy Laboratory

OEM – original equipment manufacturer

PNNL – Pacific Northwest National Laboratory

PTC – production tax credit

R&D – research and development

RPS – renewable portfolio standard

SWT – small wind turbine

U.S. – United States

USA – United States of America

W – watt

WHTP – Wind and Hydropower Technologies Program

Appendix B. Agenda

U.S. Wind Manufacturing Workshop:
Achieving 20% Wind Energy by 2030

August 27-28, 2008
Omni Shoreham Hotel
Washington DC

Agenda

PURPOSE The purpose of this workshop is to collect comments from all participants on possible solutions and actions to address U.S. wind component manufacturing challenges, building on the recommendations made in DOE's *20% Wind Energy by 2030* report to strengthen the U.S. wind manufacturing sector to reach over 300 GW by 2030. The workshop will address strategies and innovations that may ease the supply chain issues globally as well as create a sustainable manufacturing sector domestically. The workshop will collect individual comments focusing on the level of production needed over the next 22 years and beyond and the roles of the various stakeholders in carrying out these needs. It will also address transportation and logistics, materials, policies, and workforce requirements.

DAY ONE: WEDNESDAY, AUGUST 27, 2008

7:30 a.m. **Registration and Continental Breakfast**

8:30 a.m. **Opening Remarks**
Andy Karsner, Assistant Secretary for Energy Efficiency and Renewable Energy for the U.S. Department of Energy (DOE)

8:50 a.m. **Overview of DOE's Wind Energy Program**
JoAnn Milliken, Acting Program Manager, DOE Wind and Hydropower Technologies Program

9:10 a.m. **20% Wind Energy by 2030: A Vision of Our Manufacturing Sector**
Steve Lindenberg, Technology Application Team Leader, DOE Wind and Hydropower Technologies Program

9:45 a.m. **Break**

10:15 a.m. **Wind Manufacturing – Perspectives on Where We are Today and Future Scenarios**
Moderator: Lisa Barnett, DOE Wind and Hydropower Technologies Program
Panelists:

- Large Wind: Blades and Rotors—*Peggy Baehmann, GE Global Research*
- Large Wind: Towers and Transportation—*Lars Moller, Broadwind Energy*
- Large Wind: Drive Trains—*Ed Hahlbeck, Power Train Engineers, Inc.*
- Small Wind: Entire System—*Andy Kruse, Southwest Windpower*

11:45 a.m. **Breakout Session Instructions**
Bonnie Ram, Energetics Incorporated

12:00 p.m. **Lunch**

For the **Breakout Session** portions of the workshop, all workshop participants will be pre-assigned to one of four smaller breakout groups (see below) on each of the manufacturing components listed. Each of the four groups will address the session topics in parallel.

1:15 p.m. **Breakout Session #1 – Determining the Characteristics of the Manufacturing Sector in 2030**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

2:00 p.m. **Breakout Session #2 – Identifying the Technical Barriers to Achieving the Vision**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

2:45 p.m. **Breakout Session #3 – Determining the Technical Needs to Address the Barriers and Achieve the Vision**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

4:15 p.m. **Break**

4:30 p.m. **Breakout Session #4 – Discussion of Timeframes (Long-, Mid-, and Near-Term) and Roles (Government, Industry, Universities, and Others) for Addressing the Needs and Achieving the Vision**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

5:30 p.m. **Adjourn Day 1**

DAY TWO: THURSDAY, AUGUST 28, 2008

7:30 a.m. **Continental Breakfast**

8:30 a.m. **Breakout Session #5 – Identifying Crosscutting Issues (e.g., Transportation and Logistics Issues, Policy Issues, Other Issues)**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

9:45 a.m. **Breakout Session #6 – Preparation of Breakout Session Summary Reports**

- Large Wind: Blades and Rotors—*Red Group, Congressional A*
- Large Wind: Towers and Foundations—*Yellow Group, Congressional B*
- Large Wind: Drive Trains—*Green Group, Council Room*
- Small Wind: Entire System—*Blue Group, Cabinet Room*

10:30 a.m. **Break**

10:45 a.m. **Closing Plenary Session**

- Breakout Session Summary Reports
- General Discussion of Gaps and Overlaps
- Final Thoughts and Next Steps

12:30 p.m. **Adjourn**

Appendix C. Final Participant List

U.S. Wind Manufacturing Workshop:
Achieving 20% Wind Energy by 2030
August 27-28, 2008
Omni Shoreham Hotel
Washington, DC

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Gamesa Technology Corporation

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U.S. Department of Energy

Shinji Arinaga
Mitsubishi Heavy Industries

Tom Ashwill
Sandia National Laboratories

Peggy Baehmann
GE Global Research
Structural Mechanics and Dynamics Lab

Lisa Barnett
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Peter Blau
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Wayne Braun
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Jan Brinch
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Sandy Butterfield
National Renewable Energy Laboratory

Claus Kurt Christensen
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Noel Davis
JGC Industries

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ZBB Energy Corp

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Appendix D. Contact Information

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Appendix E. Public Comments Sought under February 26, 2009 Request for Information on Draft Proceedings

The Department of Energy (DOE) Wind and Hydropower Technologies Program (WHTP) sought additional input from the public regarding the 20% Wind Energy by 2030 Workshop and the Wind Manufacturing Workshop proceedings under Request for Information DE-PS36-09GO039008-RFI. Public comments were submitted under the Request for Information (RFI) from February 26 through April 3, 2009.

The WHTP solicited comments and suggestions on all key topics, findings, themes, and suggestions found in the Proceedings of the two workshops. Input was encouraged on possible analytical and R&D pathways which could contribute to the achievement of the 20% Wind by 2030 scenario, particularly in the following areas:

1. Design and manufacture of large wind components
2. Modeling and prediction tools for large wind performance and reliability
3. Design and manufacture of distributed wind systems
4. Offshore wind: reliability, system design and optimization
5. Models and analysis, forecasting tools, and flexible system management technologies for grid system interconnection
6. Integrated risk assessment framework for environmental and siting challenges

The Program received almost 80 responses under the RFI from various entities including developers, investors, industry, other federal and state governments, renewable energy equipment suppliers, electric utilities, independent power producers, environmentalists, academics, and public, private, or non-profit entities.

The information collected may be used for internal DOE planning and decision-making to align future activities under the WHTP with President Obama's goals for increased use of renewable energy and the creation of domestic jobs.

The full text of the RFI is below.

Request for Information
DE-PS36-09G039008

Program Manager / Area: Megan McCluer, Program Manager, Wind & Hydropower Technologies Program

Information Requested on: Input from the public regarding the proceedings of the 20% Wind Energy by 2030 Workshop and the proceedings of the U.S. Wind Manufacturing Workshop.

Description: The Wind and Hydropower Technologies Program (WHTP) within the Department of Energy's Office of Energy Efficiency and Renewable Energy (DOE-EERE) is leading the nation's efforts to improve the performance and operability of wind energy technologies and lower the costs, to investigate emerging water power technologies, and to enhance the environmental performance and efficiencies of conventional hydropower technologies. To find more information about the WHTP, please visit http://www1.eere.enewpov/windandhydro/wind mvg.html.

The WHTP led the preparation of the *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply* report. The report, which was released in May 2008, illustrates the feasibility of integrating 20% wind energy with the U.S. electrical grid. The report outlines a scenario in which the United States could reach over 300 gigawatts (GW) of installed wind power by 2030. The scenario presented in the *20% Wind Energy by 2030* report for achieving 20% wind energy by 2030 is by no means a suggested national policy. Given the scale of the scenario and the challenges discussed in this report, the WHTP decided to host two workshops to collect additional individual comments and to build on the recommendations. On August 27-28, 2008, more than 80 wind and manufacturing experts participated in a DOE-EERE WHTP technical workshop on what is needed to strengthen the U.S. wind manufacturing sector in order to support the machines and components for 300 GW of installed wind power by 2030. This workshop addressed challenges for manufacturing large wind blades, rotor s, tower s, foundations, and drive t rains, as well as manufacturing entire systems for distributed wind. The second DOE-EERE WHTP workshop occurred on October 6-7, 2008 with more than 130 wind energy professionals discussing possible research and development (R&D) technology areas and analytical pathways to achieve the scenario outlined in the *20% Wind Energy by 2030* report. This workshop focused on six key wind energy issues: large land- based wind technologies, distributed wind technologies, offshore wind technologies and siting strategies, grid system interconnect ion, environmental risks and siting strategies, and market development and public policies.

The Department of Energy (DOE) is seeking additional input from the public regarding the proceedings of the 20% Wind Energy by 2030 Workshop and the proceedings of the U.S. Wind Manufacturing Workshop. The information presented in the workshops can be found, as attachments, on the IIPS cover page, under the "Supporting Documents/Amendments for this Financial Assistance Opportunity" heading.

The information collected may be used for internal DOE planning and decision-making to align future activities under the Wind & Hydropower Technologies Program with the Administration's goals for increased use of renewable energy and the creation of domestic jobs. Interested parties might include, but are not limited to: developers, investors, industry, Native American Tribes, renewable energy equipment suppliers, electric utilities, independent power producers, environmentalists, academics, and public, private, or non-profit entities.

Request for Information Guidelines: The sole purpose of this Request for Information (RFI) is to gain input from the public regarding the proceedings of the 20% Wind Energy by 2030 Workshop and the proceedings of the U.S. Wind Manufacturing Workshop. This does not constitute a request for specific project proposals. **DOE will not pay for information provided under this RFI, and there is no guarantee that future funding opportunities or other activities will be undertaken as a result of this RFI.**

Please send your response (one attachment only) via email, with the title, "RFI Response" to WindRFI@go.doe.gov. Your response should be limited to 3 pages, submitted in Microsoft Word as an email attachment to the address above and received **no later than 8:00 PM Eastern Daylight Time on 4/03/2009.**

Please include as part of your response, contact name(s), phone number(s), email addresses, organization name, address, and type of business or institution.

RESPONSES WILL NOT BE CONSIDERED CONFIDENTIAL. DO NOT INCLUDE ANY CONFIDENTIAL OR PROPRIETARY INFORMATION IN YOUR RESPONSE.

Questions: Questions regarding the content of this RFI should be submitted via email to http://e-center.doe.gov at the location of this numbered RFI. "RFI Question" should be included as part of the subject line.

DOE reserves the right not to reply to any or all comments or questions submitted under this RFI.

Rationale or Justification: The main purpose of the two Workshops described above was to collect comments from individual participants on possible research and development (R&D) areas and analytical pathways to achieve the scenario outlined in the *20% Wind Energy by 2030* report. The documents from the two proceedings are compilations of these comments and opinions of the participants at these Workshops. More input is invited. The information being sought under this RFI is intended to assist DOE in further assessing barriers and opportunities to the 20% Wind Energy by 2030 scenario.

Requested Information: DOE-EERE WHTP invites comments and suggestions on all key topics, findings, themes, and suggestions found in the Proceedings of the subject workshops. Input is especially encouraged on possible analytical and R&D pathways which could contribute to the achievement of the 20% Wind by 2030 scenario, particularly in the following areas:

1 Design and manufacture of large wind components
2 Modeling and prediction tools for large wind performance and reliability

3 Design and manufacture of distributed wind systems
4 Offshore wind: reliability, system design and optimization
5 Models and analysis, forecasting tools, and flexible system management technologies for grid system interconnection
6 Integrated risk assessment framework for environmental and siting challenges

Thank you. The Department appreciates the time and effort you have put forth in responding to this Request for Information.’

Page 3 of 3