2016–2017 Status Assessment and Update on the *Wind Vision* Roadmap

Findings from Topical Working Sessions

April 2016—March 2017

Edgar DeMeo
Renewable Energy Consulting Services, Inc.
Palo Alto, California

U.S. Department of Energy Wind Energy Technologies Office
Liaison: Richard Tusing

NREL Technical Monitors: Christopher Mone and Eric Lantz

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Subcontract Report
NREL/SR-6A20-69026
October 2017

Contract No. DE-AC36-08GO28308

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Acknowledgments

Renewable Energy Consulting Services, Inc. appreciates the support for and interest in this project provided by the U.S. Department of Energy's Wind Energy Technologies Office (WETO). The overall guidance and insights offered by Richard Tusing (Allegheny Science and Technology, and senior advisor to WETO) have been particularly helpful.

Also appreciated are the substantial contributions from WETO staff leads with responsibility for the various topical areas addressed in this project. These include Charlton Clark, Joel Cline, Megan McCluer, Jocelyn Brown-Saracino, Maggie Yancey, Patrick Gilman, and Nick Johnson.

Several technical staff members from the National Renewable Energy Laboratory (NREL) provided important contributions to the overall effort. Christopher Mone served as technical monitor for the project during most of the period of performance. For the project's final stage, Eric Lantz assumed that role. For the topical areas of workforce development, education, and outreach, Ian Baring-Gould and Suzanne Tegen played lead roles. Brian Smith provided assistance on project strategy, identification of participants, and review of project documentation.

Offshore wind issues arose in most of the project's discussion sessions. Critical review of findings relative to these issues was provided by Alana Duerr (WETO) and Gary Norton (CSRA and WETO technical support).

In addition, this report benefitted substantially from editorial expertise provided by NREL and WETO communications staff. Contributions from Sheri Anstedt of NREL and Liz Hartman of WETO are particularly appreciated.

Finally, this work could not have been accomplished without those who participated in the various working sessions on which the assessments' findings are based. These individuals represented sectors relevant to wind power, including the wind industry, electric power, environmental stewardship, government and regulatory, and the national laboratories. Their contributions during and subsequent to the working sessions were substantial and conscientious, and are very much appreciated. Participant lists are included in this report as part of the working session summaries.

List of Acronyms

A2e	Atmosphere to electrons
ANL	Argonne National Laboratory
APPA	American Public Power Association
ASME	American Society of Mechanical Engineers
AWEA	American Wind Energy Association
AWWI	American Wind Wildlife Institute
BLM	Bureau of Land Management
BOEM	Bureau of Ocean Energy Management
CREZ	Competitive Renewable Energy Zone
DAP	Data Archive and Portal
DHS	U.S. Department of Homeland Security
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EDPR	EDP Renovaveis
EEI	Edison Electric Institute
ERCOT	Electric Reliability Council of Texas
EU	European Union
FERC	Federal Energy Regulatory Commission
FOA	Funding Opportunity Announcement
FWS	U.S. Fish and Wildlife Service
HVDC	high-voltage direct-current
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
LB	land-based
LLNL	Lawrence Livermore National Laboratory
MISO	Midcontinent Independent System Operator
NARUC	National Association of Regulatory Utility Commissioners
NASUCA	National Association of State Utility Consumer Advocates
NCAR	National Center for Atmospheric Research
NCSL	National Conference of State Legislatures
NEED	National Energy Education Development
NERC	North American Electric Reliability Corporation
NGO	non-government organization
NOAA	National Oceanic and Atmospheric Administration
NRECA	National Rural Electric Cooperative Association
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OEM	original equipment manufacturer
OSW	offshore wind
PJM	PJM Interconnection
PNNL	Pacific Northwest National Laboratory
PTC	production tax credit

RECS	Renewable Energy Consulting Services, Inc.
RTO	regional transmission organization
RUL	remaining useful life
SNLA	Sandia National Laboratories Albuquerque
SPP	Southwest Power Pool
SWiFT	Scaled Wind Farm Technology
T&D	transmission and distribution
USGS	U.S. Geological Survey
UVIG	Utility Variable-Generation Integration Group
WAPA	Western Area Power Administration
WETO	Wind Energy Technologies Office
WGG	Western Grid Group
WRISE	Women of Renewable Industries and Sustainable Energy
WTRIMWG	Wind Turbine Radar Interference Mitigation Working Group

Executive Summary

In March 2015, the U.S. Department of Energy (DOE) released *Wind Vision: A New Era for Wind Power in the United States* (DOE 2015), which explores a scenario in which wind provides 10% of U.S. electricity in 2020, 20% in 2030, and 35% in 2050. The *Wind Vision* report also includes a roadmap of recommended actions aimed at pursuit of the vision and its underlying wind-deployment scenario. The roadmap was compiled by the *Wind Vision* project team, which included representatives from the industrial, electric-power, government-laboratory, academic, environmental-stewardship, regulatory, and permitting stakeholder groups. The roadmap describes high-level activities suitable for all sectors with a stake in wind power and energy development. It is intended to be a "living document," and DOE expects to engage the wind community from time to time to track progress.

During 2016, DOE's Wind Energy Technologies Office (WETO) engaged the National Renewable Energy Laboratory and Renewable Energy Consulting Services, Inc. to help in assessing the roadmap's status and needs. Central to this assessment were several informal working sessions focused on key topical areas included in the roadmap. These sessions, listed here in chronological order (except as noted) based on the dates of the sessions, addressed all the action areas included in the 2015 roadmap, including:

- Wind Electricity Delivery and Integration
- Wind Power Resources and Site Characterization
- Supply Chain, Manufacturing, and Logistics
- Workforce Development
- Wind Siting and Permitting (with a separate session on wildlife issues)
- Wind Plant Technology Advancement (coupled with Wind Power Performance, Reliability, and Safety)
- Wind Power Performance, Reliability, and Safety (coupled with Wind Plant Technology Advancement)
- Collaboration, Education, and Outreach (addressed in all sessions)
- Policy Analysis (addressed in most sessions).

The working sessions focused on several key questions in relation to the *Wind Vision* and its implementation.

- To what extent are the specific action areas being addressed?
- Are there gaps that need to be filled?
- Have the needed groups and people become engaged? Are there others needed in addition?
- Are there areas of concern where more effort is needed to engage appropriate participants?

In general, the session discussions concluded that the actions in the 2015 published roadmap are comprehensive and appropriate. For some of these actions, the discussions indicate that important progress has occurred over the past several years. Comments from participants, however, suggest that some actions require a stronger response. Additionally, several new actions—beyond those identified in 2015—were suggested.

Major Recent Progress on Roadmap Actions

The working sessions began with a discussion of the status of the various actions included in the 2015 *Wind Vision* Roadmap. Comments from participants identified significant progress since the beginning of the *Wind Vision* initiative (nominally early 2013) on a number of the roadmap actions, including the following highlights. The specific relevant top-tier actions are shown in **underlined bold** type.

Wind Electricity Delivery and Integration

Action 5.1: Encourage Sufficient Transmission

New transmission lines have been added in several regions, increasing the ability to transport large blocks of energy over substantial distances, improving the reliability of the electricity network, and enabling the connection and integration of significant amounts of new wind power. Continued focus on prudent transmission is needed (see sections on Actions Requiring Stronger Response and Suggestions for Additional Actions, below).

Action 5.2: Increase Flexible Resource Supply

Substantial progress has been made in understanding the importance and value of adding sources of flexibility to the electric power system—such as five-minute dispatch for network generators, fast-ramping capability, and demand response. A great deal of experience has been obtained in applying these flexibility options, thereby aiding the integration of large shares of variable wind power in some regions of the nation. This information and experience should be shared widely (see sections on Actions Requiring Stronger Response and Suggestions for Additional Actions).

A new, very large area electric power system integration study—the North American Renewable Integration Study (NARIS)—has been initiated and includes all renewable energy sources as well as all traditional sources. This is responsive to a newly recommended action described in the Additional Actions section below.

Wind Power Resources and Site Characterization

Action 1.1: Improve Wind Resource Characterization

Much progress has been made in wind forecasting, with sufficient accuracy to allay historical power system operators' concerns about wind's impacts on reliability of electric service. Ranging from real-time to day-ahead, wind forecasts—when coupled with recent increases in overall power-system flexibility—have enabled reliable system operation with wind penetration levels of more than 30% on average, and at times more than 50%. Ongoing research is needed to increase forecasting accuracy and to add new capabilities, such as prediction of wind ramps and severe storm

events. Further benefits would accrue from improvements in seasonal and inter-annual forecasting (see section on Additional Actions below).

Some high-quality, long-term, high-resolution (spatial and temporal) wind resource data sets have been assembled, but these tend to be proprietary. Secure dissemination to researchers developing and validating wind models is needed. Some progress on this front has been made through the DOE-WETO Data Archive and Portal, funded under the Atmosphere to Electrons (A2e) initiative. This work requires increased attention (see Actions Requiring Stronger Response, below).

Supply Chain, Manufacturing, and Logistics

Action 3.1: Increase Domestic Manufacturing Competitiveness

For very tall towers—with heights significantly greater than those of typical U.S. turbines averaging approximately 80 meters—progress has been made in on-site manufacturing. Also, cross-fertilization is occurring among industry players from different and complementary manufacturing and construction disciplines, such as metal components production and concrete structures fabrication. Some states have successfully repurposed existing underutilized manufacturing facilities.

Innovative manufacturing technology for composites is progressing well for wind turbine blade production.

A great deal of "know-how" (i.e., knowledge and experience that is understood by skilled laborers and passed on by word of mouth, but which is not well documented) has been developed relative to wind equipment manufacturing. A key challenge is to capture this and document it for use in related academic and other educational programs (see section on Additional Actions).

Action 3.2: Develop Transportation, Construction, and Installation Solutions

The wind industry has developed an extensive proprietary experience base in transportation logistics that deals with the many variations in local, state, and regional requirements and restrictions. National or regional transportation policies would reduce complexities and wind energy costs (see section on Additional Actions).

Wind Siting and Permitting

Action 6.1: Develop Mitigation Options for Competing Use Concerns

The development of radar-activated turbine lighting has substantially reduced nighttime visual intrusion while effectively protecting aircraft.

Action 6.3: Develop Information and Strategies to Mitigate the Local Impact of Wind Deployment and Operation

The wind developer community has learned the importance of dealing carefully and sensitively with community relations. Successful mitigation strategies—ranging from avoidance of impacts, to minimization, and to compensatory measures—have been developed. Most developers are responsible in this respect, but occasional exceptions remain.

Extensive, effective documentation is publicly available on the public impacts of wind development. A comprehensive compilation of this information by an

authoritative body such as the National Academy of Sciences would be valuable (see Actions Requiring Stronger Response).

Action 6.4: Develop Clear and Consistent Regulatory Guidelines for Wind Development

Constructive results have been achieved through federal agency-to-agency communication and cooperation. Examples include: DOE and the Federal Aviation Administration (FAA) on wind plant lighting; DOE and the Bureau of Ocean Energy Management (BOEM) on offshore wind leasing and impacts, with 14 GW of offshore sites now leased by BOEM; and the Interagency Field Test and Evaluation (IFT&E) campaign, which brought together DOE, the Department of Defense, the FAA, and the Department of Homeland Security to begin to quantify and address radar impacts and has led to the Interagency Wind Turbine Radar Interference Mitigation Working Group.

Action 6.5: Develop Wind Site Pre-Screening Tools

The wind industry has developed effective deployment frameworks and pre-screening approaches for wind installations. Typically, these are proprietary. Little need is seen for developing generic tools of this type, with the possible exception of wind deployment on federal lands. Such tools have been developed by BOEM for offshore deployment in federal waters, which might provide useful guidance with respect to federal lands.

Wind and Wildlife

Action 6.2: Develop Strategies to Mitigate Siting and Environmental Impacts

The number of wildlife species providing cause for concern has been reduced considerably. Attention is now focused on the remaining few species, such as eagles, grouse, and several species of bats.

The wind industry has become successful at avoiding potentially problematic areas with respect to wildlife impacts. Some of the earliest wind developments—in particular the Altamont Pass installations in California—experienced significant unanticipated wildlife-related concerns that arose after construction. Much has been learned from that experience; to date there has not been another development accompanied by the level of concern associated with Altamont.

A great deal of data exists on wildlife impacts from wind development. Most of this is held confidentially by wildlife consultants and wind developers. Anonymizing these data and making them generally available would have substantial value in assisting future development. The American Wind Wildlife Institute Information Center database is a positive step in this direction.

Monitoring and analysis of wind's wildlife impacts over extended periods is ongoing—primarily by the wind industry. This work should be continued and be shared with relevant stakeholders.

Technology to reduce wind's impacts on wildlife is under active development with some encouraging success. Radar, visual, and auditory approaches are showing

promise for deterring wildlife and for adjusting wind plant operation when there is wildlife nearby.

Workforce Development

Action 8.1: Develop Comprehensive Training, Workforce, and Educational Programs

At the primary and secondary educational levels, the KidWind and Wind for Schools programs have been successful and effective. At the college level, the Collegiate Wind Competition, which is funded by DOE and administered by the National Renewable Energy Laboratory, also has been effective. However, these programs reach only a small number of students and teachers. Their expansion could be instrumental in motivating the wind workforce likely to be needed over the next 5 to 20 years (see Actions Requiring Stronger Response, below).

A few high-quality community college and higher-level collegiate educational programs in wind energy have been developed and are operating in the nation. These programs produce wind technicians as well as graduates with bachelor's, master's, and doctorate degrees in disciplines needed for wind power. They provide excellent models for use in establishing similar programs at additional academic institutions across the nation (see Actions Requiring Stronger Response, below).

Collaboration, Education, and Outreach

Action 7.1: Provide Information on Wind Power Impacts and Benefits

A large body of information has been produced that provides a compelling description of wind power's opportunities and value for the nation—including benefits, costs, jobs and career potential, and prospective contributions to the nation's economy and energy security. Although this information is well understood by some, it should be actively shared throughout all relevant sectors of our society to reach and engage more industrial firms, students who will comprise the future wind workforce, and government officials and energy and environmental regulators who affect decisions on wind power development (see Actions Requiring Stronger Response, below).

With respect to wind electricity delivery and integration—in particular, the importance and value of increased power system operational flexibility and regional interconnection—leading organizations within the electric sector have made great progress in demonstrating that large shares of wind generation can be incorporated economically into the power system without reducing system reliability. This understanding now needs to be shared widely and actively throughout the electric sector (see Actions Requiring Stronger Response, below).

Action 7.2: Foster International Exchange and Collaboration

Effective international collaboration on many wind-related topics, primarily through the International Energy Agency (IEA), is ongoing and produces substantial value. Both WETO's A2e and the European Union (EU) Horizon 2020 program are providing opportunities for important collaboration in which DOE, the national laboratories, and overseas organizations have partnered. Other areas of extensive collaboration through IEA include wind electricity delivery and integration, and wind cost-of-energy tracking and projection.

Wind Plant Technology Advancement; and Wind Power Performance, Reliability, and Safety

Action 2.1: Develop Next-Generation Wind Plant Technology, and Action 4.1: Improve Reliability and Increase Service Life

The wind industry maintains substantial activity to improve wind technology, reduce costs, increase reliability, and increase competitiveness. These efforts are complemented and augmented by DOE wind program activity aimed at taller and larger wind turbines, increased reliability of major turbine components, on-site manufacturing of very large components, deployment options for offshore turbines, and improved understanding of the underlying physics of wind energy conversion and the characteristics of the wind resource.

Advancements in turbine and plant control technologies and strategies have been achieved. These provide features such as increased energy capture, anticipation of and protection against extreme conditions, and improved reliability.

Turbine manufacturers have developed very large turbines (7 to 10 MW) for offshore deployment. Other advances—in some cases applicable to both land-based and offshore wind plants—include aeroelastically tailored blades, larger blades for low-specific-power turbines, and advanced composite structures and manufacturing methods.

Action 2.1: Develop Next-Generation Wind Plant Technology, and Action 2.4: Establish Test Facilities

Progress has been made with high-performance computer (HPC) simulation models for wind turbines and wind plants. Model validation efforts are underway at several federal test facilities.

Action 3.3: Develop Offshore Wind Manufacturing and Supply Chain

DOE and the Department of the Interior have jointly produced the *National Offshore Wind Strategy* (Gilman et al. 2016). This includes technical and institutional actions to develop a vibrant domestic offshore wind industry. Critical technical issues addressed range from floating platform foundation development to hurricane survival. This progress element also supports **Actions 2.1 and 4.1**.

The first domestic offshore wind plant—the Block Island Wind Farm in Rhode Island—has been installed and is operational. This has facilitated the beginnings of a domestic supply chain for offshore wind projects.

Action 4.1: Improve Reliability and Increase Service Life

The wind industry, with assistance from DOE national laboratories, has made considerable progress in turbine and component life extension.

The wind industry, with DOE national laboratories collaboration, is developing sophisticated data- and physics-based models to estimate remaining useful life for drivetrain components.

Action 4.4: Develop and Document Best Practices in Wind O&M

The wind industry has produced an O&M Recommended Practices document for its use.

Suggestions on Actions Requiring Stronger Response

Session participants suggested that several of the 2015 Roadmap actions require increased attention. Although no attempt was made to assign responsibilities to specific sectors—for example, electric, regulatory, wind industry, or environmental—one or more of these would have substantial roles in each case. In all cases, government programs could play an important role. The specific relevant top-tier actions are shown in **underlined bold** type.

Action 1.1: Improve Wind Resource Characterization

Development of long-term, high-quality public wind resource data sets for model development and validation.

Action 2.1: Develop Next-Generation Wind Plant Technology, and Action 2.5: Develop Revolutionary Wind Power Systems

Sustained focus on fundamental science promising major reductions in wind energy costs and development risks.

Action 3.2: Develop Transportation, Construction and Installation Solutions

Evaluation of trade-offs between large component transport and on-site manufacturing.

Action 5.1: Encourage Sufficient Transmission

Facilitation of transmission expansion to enable transport and sharing of renewable electricity and reliability responsibilities.

Action 5.2: Increase Flexible Resource Supply

Development of electricity markets that value and encourage overall power-system flexibility to aid in the integration of all energy sources.

Action 6.2: Develop Strategies to Mitigate Siting and Environmental Impacts

Formation of an expanded public-private fund pool for wildlife research to reduce uncertainties of impacts from wind plant development.

Action 6.3: Develop Information and Strategies to Mitigate the Local Impact of Wind Deployment and Operation

Compilation of extensive available information on the public impacts of wind development, conducted by an authoritative body such as the National Academy of Sciences.

Action 7.1: Provide Information on Wind Power Impacts and Benefits

Expanded outreach on wind benefits, costs, and other impacts.

Action 8.1: Develop Comprehensive Training, Workforce, and Educational Programs

Expansion of certified education and training programs aimed at wind careers at all levels.

Action 9.1: Refine and Apply Energy Technology Cost and Benefit Evaluation Methods

Comprehensive comparative evaluation of *all* sources of electricity.

No attempt was made to prioritize these needs, but all are considered critically important for the continued prudent expansion of wind power.

Suggestions for Additional Actions Not Included in the 2015 Roadmap

Session participants identified several new actions as suggested additions to an updated *Wind Vision* Roadmap, as follows. Relevant top-tier actions are shown in **underlined bold** type.

Action 1.1: Improve Wind Resource Characterization

Extend wind forecasting—both land-based and offshore–to include seasonal and interannual variations and extreme storms, to reduce wind-plant financing risks and increase wind energy value.

Action 3.1: Increase Domestic Manufacturing Competitiveness

Conduct full-scale demonstration of promising new manufacturing techniques to reduce commercial investment risks.

Document public-domain, wind-specific manufacturing knowledge; include design codes and standards; identify manufacturing knowledge gaps.

Action 3.2: Develop Transportation, Construction and Installation Solutions

Develop transportation best practices and national policy on interstate transport of wind equipment.

Action 4.1: Improve Reliability and Increase Service Life

Optimize decision making for maintenance, to reduce turbine downtimes and increase energy generation.

Action 5.1: Encourage Sufficient Transmission

Optimize use of the *existing* transmission system so that power-handling capacity and energy-transport capabilities are not underutilized.

Action 5.2 Increase Flexible Resource Supply

Conduct wind integration study for entire North American electricity network to examine opportunities and challenges associated with sharing energy services over very large regions.

Proactively engage in design of electricity markets that recognize and equitably compensate all energy and reliability services.

Action 6.2: Develop Strategies to Mitigate Siting and Environmental Impacts

Expand development of wildlife-deterrent technologies, to reduce harmful impacts on wildlife and reduce wind-turbine curtailment.

Action 7.1: Provide Information on Wind Power Impacts and Benefits

Conduct proactive outreach to policymakers and educators to promote balanced, objective information on wind energy costs, benefits, and other impacts, as well as attractive career opportunities in wind power.

Action 8.1: Develop Comprehensive Training, Workforce, and Educational Programs

Pursue workforce diversity to expose wind opportunities more broadly to minorities and across the gender spectrum.

Key Overall Messages from the Status Assessment and Update Effort

Several key themes gelled during the assessment and update activity. The themes arose in the general discussions during most of the working sessions and related follow-up activity. They illustrate concern over inadequate attention to key needs, and provide a basis for prioritization among the actions described above. These key themes follow.

- Extensive outreach is needed. Accurate, objective information about wind power's capabilities, opportunities, status, costs, benefits, and other impacts should reach a great many more people in the regulatory, electric power, and educational sectors. This information is also needed in response to misinformation often injected into local wind-plant siting and approval forums.
- Sustained fundamental research is needed on the interactions between the wind resource and wind turbines and wind plants. Without this research, major prospective reductions in wind energy costs and development uncertainties are at risk.
- Workforce expansion efforts are inadequate. Closer connection between the wind industry and academic institutions is needed to inform students of opportunities offered by wind power and to bring qualified graduates into the wind industry. Prospective career opportunities in wind power need to be communicated to educational programs at all levels, ranging from primary and secondary to vocational and university.

- The nation needs—and does not have—a complete spectrum of authoritative information on the comparative impacts of *all* energy technologies.

The topical working session summaries in the body of the full *Wind Vision Roadmap Status Assessment and Update* report provide amplification of the points included in this Executive Summary. Additionally, many of these points are presented in tabular form in the Summary of Key Findings table included in the full report.

Table of Contents

List of Tables

1 Project Background and Key Findings

In March 2015, the U.S. Department of Energy (DOE) released *Wind Vision: A New Era for Wind Power in the United States* (DOE 2015). The document includes a roadmap of recommended actions aimed at the pursuit of the vision. The roadmap was compiled by the *Wind Vision* project team, and describes high-level activities suitable for all sectors with a stake in wind power and energy development. The roadmap is intended to be a "living document," and DOE expects to engage the wind community from time to time to track progress.

DOE's Wind Energy Technologies Office (WETO) engaged the National Renewable Energy Laboratory and Renewable Energy Consulting Services, Inc. (RECS) to help in assessing the roadmap's status and needs. Central to this assessment have been several informal working sessions on key topical areas included in the roadmap. Most of these sessions involved a small group of about a dozen experts in the session's topical area.

Prior to each session, participants were sent the roadmap sections of DOE's *Wind Vision* report (DOE 2015), highlighting those portions focused on the session's topical area. Participants were asked to review the material relevant to the topical area and come to the session prepared to discuss questions such as:

- To what extent are the specific action areas being addressed?
- Are there gaps that need to be filled?
- Have the needed groups and people become engaged? Are there others needed in addition?
- Are there areas of concern where more effort is needed to engage appropriate participants?

Working sessions were held in the following topical areas, except as noted. Dates and locations for the sessions are indicated in parentheses.

- Wind Electricity Delivery and Integration (April 25, 2016, Sacramento, California)
- Wind Resources and Site Characterization (June 14, 2016, Boulder, Colorado)
- Supply Chain, Manufacturing and Logistics (June 22, 2016, Golden, Colorado)
- Wind Siting and Permitting (June 23, 2016, Boulder, Colorado)
- Wind and Wildlife (June 23, 2016, Boulder, Colorado)
- Workforce Development (May 23, 2016, New Orleans, Louisiana; June 22 and September 27, 2016, Boulder, Colorado)
- Collaboration, Outreach and Education (see text)
- Wind Plant Technology Advancement (September 27, 2016, Boulder, Colorado; see text)

- Wind Power Performance, Reliability, and Safety (September 27, 2016, Boulder, Colorado; see text)
- Policy Analysis (see text).

For two of the topical areas—Collaboration, Outreach and Education, and Policy Analysis—focused topical working sessions were not held. Collaboration, Outreach and Education status and needs, however, arose with emphasis in nearly all the other sessions. Key related points have been captured in this report. Similarly, though to a lesser extent, policy issues arose in several of the working sessions. Again, key related points have been captured.

For Wind Plant Technology Advancement, and Wind Performance, Reliability and Safety, a different approach was followed. Initial insights were gathered from officials of the federal wind program and the associated federal laboratories—based on their ongoing interactions with a broad cross section of the industry, periodic technical reviews of specific projects, and peer reviews of the entire federal wind program conducted with industry participation. These insights were then reviewed and augmented by other individuals within the wind program. With this approach, wind turbine and wind equipment manufacturers were not asked to share and discuss their activities for advancing wind technology with others in the industry—activities that might be proprietary and could provide competitive advantage.

In all topical areas, Renewable Energy Consulting Services coordinated closely with key DOE wind management staff having responsibility for the relevant topical area. These individuals were intimately involved with their respective working session through identification of participants, participation in the actual working session, critical review of session documentation, and assimilation of the findings. These individuals are well positioned to continue the roadmap update process on behalf of WETO and the wind community at large.

1.1 Report Organization

This background section closes with a tabular summary of key findings from the entire effort. These findings are based on the summaries of the working sessions and other discussions conducted over the course of the project. The section following the Key Findings table is composed of those session summaries. The report closes with a section describing a recommended procedure for updating the Roadmap on an ongoing basis, along with a section recommending next steps for WETO in implementing the update of the 2015 *Wind Vision* published Roadmap documents.

Table 1. 2016 Roadmap Update: Key Findings

2016 Roadmap Update: Key Findings

Questions Addressed	Electricity Delivery & Integration	Wind Resources & Site Characterization	Supply Chain, Manufacturing & Logistics	Siting & Permitting
Are actions appropriate?	Actions well-designed and relevant; greater emphasis needed on assembling individual findings into a broad understanding of wind's interactions with and roles in the electric power system.	Actions appropriate; offshore actions generally are well defined; greater detail is needed for land-based actions.	Actions generally appropriate and well-described; some participants recommend greater emphasis on on-site manufacturing as components increase in size; others are concerned about higher costs for manufacturing on site, and recommend greater attention to transport of very large components.	Actions are relevant and comprehensive. All identified action groups—including development of information on and strategies for mitigating local impacts (radar, aviation, marine shipping, and human impacts such as visual and audible), and development of clear and consistent regulatory guidelines—are high priority.
Are actions identified in the published roadmap being adequately addressed?	**Insufficient expansion of transmission**; full spectrum of benefits poorly described. **Importance and value of system flexibility** well-understood by a few; message needs to be spread much more widely. **Engagement with regional market design** efforts is inadequate.	**Forecasting work** on track, but expansion to broader range of time frames is needed as described below. **Remote measurement system** development (e.g., lidar) needs acceleration, especially for offshore. **Long-term, high-quality data set** development is inadequate. **Study of offshore wind characteristics**—particularly those affecting turbine loads—is inadequate.	**Composites manufacturing** development progressing well, but full-scale demonstrations will be needed. **Transportation best practices** have been developed by individual firms; these are largely proprietary. National transportation policies and practices would be valuable and are not being developed. **Innovative tower construction** is progressing, but innovative blade work (e.g., segmented blades) is lagging.	**Good progress on wind-radar** interactions. **Interactions between offshore** wind siting and commercial shipping routes hampered by inconsistencies in agency positions (e.g., USCG, BOEM). **Inadequate dissemination** of authoritative information on public impacts and benefits. **Minimal government and industry** attention to development hurdles on federal lands. **Good progress** with offshore leasing and permitting processes. **Reliable land-based visual simulation** tools are available, but **better tools are needed for offshore simulation**; tools for sound-level estimation need improvement.
What major actions are missing?	**Optimize** the use of the *existing* transmission system. **Conduct** integration study for the entire North American continent, including broad spectrum of low-carbon power technologies. **Expand** engagement with evolving market design activities.	**Add** land-based actions paralleling those included for offshore (this was done by session participants). **Improve** seasonal and inter-annual wind forecasting. **Develop** long-term, high-quality data sets needed for model development. Include extreme-storm observations and analysis aimed at reduction of financing risk .	**Document** public-domain manufacturing knowledge. **Update** 2012 competitiveness assessment. **Expand** outreach from federal projects to manufacturing and supply-chain sectors. **Conduct** full-scale demonstration projects for innovative manufacturing techniques. **Develop** a national policy on transportation requirements and practices.	None were identified. However, a **greatly expanded federal role in outreach** was recommended to actively communicate a balanced story on wind's benefits and impacts.
Should any of the actions receive less attention?	No new tools needed to accommodate distributed wind or offshore wind.	None considered low priority; concern expressed that land-based actions not be short-changed because of the prominence of offshore in the federal program	None considered low priority; difference of opinion on relative importance of on-site manufacturing compared to innovative transport approaches—as described above.	**Ongoing public impact research** and tracking will add important insights; but because much of the needed scientific assessment already has been conducted, support for establishment of a funding pool for this work is low. **Development of a model deployment** framework is of low priority for industry; however such a framework has been well received for offshore, and might facilitate development on federal lands.

2016 Roadmap Update: Key Findings

Questions Addressed	Electricity Delivery & Integration	Wind Resources & Site Characterization	Supply Chain, Manufacturing & Logistics	Siting & Permitting
Who else should be engaged?	Much broader cross section of regulators, legislators, and power system planners and operators.	Major public funding required for development of models and required data sets. In addition to DOE Wind, NOAA, OAR, NWS, NSF, DOD and the DOE Office of Science should be engaged.	**More industry players** in these sectors should be engaged; federal program should highlight the attractive, available business opportunities. **Engineering academic programs** in manufacturing and design should feature wind as an attractive career option.	**Engaging the National Academy of Sciences** was recommended to assemble, evaluate, and disseminate information on public impacts of wind plants. A meta-analysis might suffice, because much related work already has been conducted. **Corporate purchasers** of clean, renewable energy (e.g., Google, Apple, Walmart) might also be engaged to help in the approval process for new projects.
What major concerns were identified?	**Insufficient outreach** to decision makers and stakeholders is by far the key concern. **Workforce development** is also a major concern; the power sector workforce is aging; younger people need to become engaged.	Insufficient attention to obtaining long-term, high quality, publicly available data sets needed for model development and validation.	**A larger cross section of industry** in these sectors needs to be informed of business opportunities offered in the wind power arena. **Concern was expressed** about overdependence on European design codes for tower and foundation design and manufacturing. A legally binding U.S. standard is needed.	**Public concerns over wind expansion are increasing**—particularly in high-population regions. Misinformation is common in local forums where new projects are discussed. Countering unfounded myths with credible, authoritative information is a critical need. Greatly expanded outreach to local officials and the public is essential. **Some developers** have not grasped the importance of open and sensitive community relations.
Key message from session	Much of the information needed exists; it is understood by the experts; it needs to be conveyed to and internalized by many more regulators, legislators, system planners, and operators. Outreach from DOE and national labs, formerly extensive and effective, needs to be expanded greatly.	Roadmap actions aimed at offshore wind are in general described with greater depth and breadth than those aimed at land-based wind; many of the specific needs mentioned for offshore apply also to land-based actions.	Short-term (less than a year) needs in this arena are likely to be handled by industry players operating on their own. Over the longer term, more sharing and cooperation among industry players is possible—for example with innovative manufacturing technologies, and policy improvements in standards or transportation requirements. Government programs should focus on such longer-term activities with industry engagement.	Public resistance to new wind installations is increasing, particularly in densely populated regions in the Midwest and Northeast. Those fighting development, along with conventional energy interests, are playing a stronger role in local forums on new wind power projects. Outreach to the public—including students and children—and to local permitting officials is essential to present a comprehensive picture of wind's relative benefits and impacts. Government organizations, seen as credible, are well positioned to lead.

2016 Roadmap Update: Key Findings

Questions Addressed	Wind and Wildlife	Workforce Development	Collaboration, Outreach & Education
Are actions appropriate?	In general, participants feel that the Roadmap's wildlife-related actions—to the extent they are defined—are appropriate and cover the range of needed activity. However, the action descriptions tend to bundle species to a high level that masks important distinctions. The risks to each of these species and the corresponding management issues are different. Clarification along these lines should be added to the Roadmap text.	Actions are all relevant and important. Providing educational opportunities illustrating wind energy career options at all levels from primary schools through college programs is essential for developing the workforce required now and in the coming years for continued major expansion of wind power, both land-based and offshore.	Both action groups **Provide Information on Wind Power Impacts and Benefits**, and **Foster International Exchange and Collaboration,** are broadly viewed as appropriate and necessary. The first is viewed as critically important.
Are actions identified in the published roadmap being adequately addressed?	**The key need in the wildlife arena is to continue to develop a funding base to support the research needed to reduce uncertainties.** These funds could come from both industry and government sources. This is a key roadmap action, but requires greater attention. **Very little is known about bat populations**, and thus impacts on these populations from wind turbines are not well known. There is no consensus on the relative importance of focusing on (a) mortality reduction, or (b) quantifying populations and thus population impacts. **Little is known about offshore impacts.** More attention to these is needed as offshore installations proceed.	**Good models exist for educational programs** at the primary-secondary, community college-technician, and college levels. **Only a few programs are actually operating** at each of these levels. More are needed. There is no certification process in the United States. Europe is further along in technical training programs. **Overall, attention to these actions in the United States is inadequate**.	**On providing benefits and impacts information**, all working session discussion groups underscored the importance of assembling and communicating a comprehensive, objective story about wind's benefits, costs, and other impacts to a broad audience ranging from energy decision makers to the general public. A much stronger government and national laboratory role in this endeavor is recommended, including ongoing participation in energy policy- and decision-making forums. **International exchange and collaboration** appears to be proceeding satisfactorily.
What major actions are missing?	The Roadmap's wildlife section does not include **technology development that could be instrumental in reducing impacts**. Several examples were suggested: acoustic or visual deterrents to help eagles and other raptors and bats avoid turbines; tailored curtailment for bats, eagles, and raptors through use of radar or other sensors; development of a bat-friendly turbine; development of bird-friendly glass (for compensatory mitigation); and remote-sensing equipment to aid in wildlife studies.	**Increase diversity** in the wind energy workforce. The wind industry has lower-than-average diversity across a wide age spectrum. Most wind jobs are suitable for all, irrespective of gender, or of racial, cultural, and national background. This should begin at the primary and secondary education levels, and continue through programs including the Collegiate Wind Competition (CWC). The Women of Renewable Industries and Sustainable Energy (WRISE) program is aimed at this need.	None has been identified. However, in general the discussion groups recommended an **expanded federal role in outreach** in general and in engaging with key energy-sector stakeholders.
Should any of the actions receive less attention?	**No.** All identified actions are considered important.	**No.** All identified actions are considered important.	No. All identified actions are considered important.

2016 Roadmap Update: Key Findings

Questions Addressed	Wind and Wildlife	Workforce Development	Collaboration, Outreach & Education
Who else should be engaged?	**Industrial firms with relevant technological expertise** should be engaged to develop and commercialize technologies to minimize wildlife impacts. Investment in these technologies is underway worldwide and should be expanded, including third-party validation efforts. **Increased engagement of government, NGO, and communication entities** is recommended to assemble a balanced story on wind's impacts—positive and negative—and share that story widely.	**The education sector**, from primary through post-graduate levels, needs to be made aware of wind's career opportunities going forward. **Industry in general**, particularly sectors where career opportunities are shrinking, also needs to become more aware of wind. **This requires extensive outreach** from the wind industry and government programs.	Although major relevant sectors are currently involved, a stronger, more interactive engagement of national laboratory experts with various sectors is recommended—including the electric-power, academic and educational, siting and environmental, and local and regional planning sectors.
What major concerns were identified?	**The wildlife narrative in the Wind Vision Roadmap tends to convey a negative impression** within the otherwise very positive *Wind Vision* story. Participants encouraged the wind community and others in the energy sector to provide context for the wildlife discussion that includes the entire spectrum of wind's environmental impacts, both positive and negative, and that also describes those impacts relative to the environmental impacts of all energy generation technologies. Without this holistic view, it is not possible to fully understand wind energy's lifecycle impacts in comparison to other forms of generation.	**Wind community needs to identify** those jobs requiring additional training programs. These programs then need to be implemented and replicated to support workforce needs. **Job and career opportunities** in wind energy are relatively unknown and need to be communicated much more widely. **Teacher training and retention** is a key issue. Many more qualified teachers are needed, but salaries are low. Upon graduation, technicians can be paid twice as much as teachers.	In almost all working sessions, the critical importance of the outreach function was stressed. This stems from the need to convey widely a balanced story about wind's benefits, costs, and other impacts, and to counteract false, negative information when it appears. Much concern was expressed that greatly expanded federal outreach efforts are needed.
Key message from session	Over the past two decades, a great deal has been accomplished in the wind-wildlife arena. The number of species providing cause for concern has been reduced considerably, and the wind and wildlife community is focused on the handful of species that are of concern. Participants encouraged the formation of a public-private funding approach to support accurate, peer-reviewed science that enables timely resolution of the major remaining issues associated with the wind and wildlife intersection. Acceptance of that science and incorporation into relevant policy is essential.	Wind energy offers expanding and rewarding career opportunities over a broad age group. Wind energy career opportunities, however, are largely unknown in the educational sector and throughout the workforce. Both the wind industry and government should greatly expand their efforts to increase awareness of these opportunities. Because most opportunities are equally appropriate for all, irrespective of gender and cultural background, the nation should strive to encourage diversity in the wind workforce.	Although no focused working session was held in this topical area, it's actions arose in all of the sessions held. The key message is that education and outreach as described in the points above is critically important and that federal programs—because of perceived credibility—should be actively engaged in these efforts. Participants in some sessions commented on lack of diversity in the wind industry, and encouraged expanded efforts to communicate wind's opportunities to all racial, ethnic, and gender groups.

2016 Roadmap Update: Key Findings

Questions Addressed	Technology Advancement	Performance, Reliability & Safety	Policy Analysis
Are actions appropriate?	All identified actions are relevant and important.	All identified actions are relevant and important.	All identified actions are relevant and important.
Are actions identified in the published roadmap being adequately addressed?	Most actions appear to be progressing well. One exception is development of segmented blades for very large land-based turbines. Also, there is little if any activity on next-generation foundations and installation systems for land-based wind turbines, or on floating foundations for deepwater offshore turbines.	**Industry OEMs and DOE** have extensive testing facilities. **OEMs and third parties** are developing sophisticated, physics-based models to estimate remaining useful life for drivetrain components. **The national labs** are studying fundamental failure modes using dynamometers, full-scale turbines (the DOE/GE 1.5 MW machine), and blade-testing facilities. **NREL regularly maintains a failure database** with updated statistics. **SNL previously maintained** the Continuous Reliability Enhancement for Wind (CREW) database, but this has been discontinued.	No. The comparative evaluation of benefits, costs, and other impacts for all energy technologies is not being carried out. This action goes beyond the wind community. However, examination of impacts of various policy scenarios on wind deployment is being conducted.
What major actions are missing?	None has been identified.	None has been identified.	**Policies governing interstate transportation** of wind turbine components are needed. **Electricity market rules** are needed that value all elements of system flexibility, and that encourage the use of flexibility inherent in wind plants.
Should any of the actions receive less attention?	The need for distributed wind technology improvements depends on the projected contribution of distributed wind toward achieving the *Wind Vision* goals.	There is little if any activity in creating a distributed wind reliability database.	No.

2016 Roadmap Update: Key Findings

Questions Addressed	Technology Advancement	Performance, Reliability & Safety	Policy Analysis
Who else should be engaged?	In general, major entities needed for progress are involved, including industry and government programs both in the United States and overseas.	In general, major entities needed for progress are involved, including industry and government programs both in the United States and overseas.	Major players are involved. What's needed is active, ongoing engagement of the wind industry and the federal wind program with these players to ensure that wind's characteristics, benefits, costs, and other impacts are accurately understood.
What major concerns were identified?	The DOE A2e program is expected to advance the fundamental understanding of atmospheric physics, of the many factors affecting wind turbine and wind plant performance, and of the interactions between the wind and wind plants. To realize its potential, ongoing support will be needed.	Leading-edge erosion is a significant and growing concern for wind blades. Currently, there is uncertainty in how best to mitigate this issue. There is continued innovation in blade repair, both in method and extent. However, best practices are not well defined and could use improvement through standards efforts.	Authoritative information on the relative impacts of all energy technologies needs to be developed to enable informed decisions on energy choices.
Key message from session	The findings for these topical areas were developed in collaboration with wind experts from the DOE and national laboratory wind programs. In an overall sense, they can be summarized as follows. In general, expanding demand for clean renewable energy such as wind power is providing attractive commercial opportunities for the wind equipment industry—at least over the next five years. In response, the industry maintains substantial activity to improve the technology, reduce costs, increase reliability, and increase competitiveness. These efforts are complemented and augmented by federal wind program activity aimed at taller and larger wind turbines, increased reliability of major turbine components, on-site manufacturing of very large components, deployment options for offshore turbines, and improved understanding of the underlying physics of wind energy conversion and the characteristics of the wind resource.		No focused session was held on this topical area. The points above arose in sessions on several of the other topical areas.

2 Topical Working Session Summaries

2.1 Overview

The topical sessions were designed around the list of questions presented on page 1. Participants were chosen to represent a spectrum of relevant expertise and stakeholder communities. In general—and by design—some had been involved in development of the *Wind Vision* project (DOE 2015), and some were not. To encourage open, informal discussion, the group size was targeted at 10 to 15 members. Most groups were in this range, although one exceeded 20. The groups reviewed the actions related to their topic as published in Chapter 4 of the March 2015 *Wind Vision* report (DOE 2015), along with the more-detailed actions described in Appendix M of that report. Each of the questions posed was discussed in turn. Individual views were shared and then discussed. In some cases, general agreement emerged, and in others differences were expressed. No attempt was made to reach consensus. Instead, the various views were retained and documented.

In general, each session summary includes the following items.

- Summary of Major Discussion Points
- Revised Roadmap Actions Worksheet
- Original, As Published, Roadmap Actions Worksheet
- List of Session Participants
- Session Agenda.

Following each working session, RECS prepared a draft summary of major points from the discussion. Session participants then reviewed the draft and offered comments and additional relevant inputs. These comments were used in preparing a revised draft, which was also shared with the participants. In most cases, a few additional comments were received, which were used in preparing a final version of the summary. In one case, for the Workforce Development topic, the primary input for the session summary was provided by NREL staff members Suzanne Tegen and Ian Baring-Gould.

The discussion points summary aims to capture the key points from the rich and sometimes far-ranging discussion seeded by consideration of the various roadmap actions. For the individual roadmap actions, participants commented on the extent to which each fit into three specific categories:

- Good progress; well underway; enough momentum to keep going
- On Track: adequate activity; no cause for concern if activity maintained
- Poor or insufficient activity; cause for concern.

The revised roadmap actions worksheet captures commentary supporting the categorization of the specific actions—again with no attempt to force consensus but instead to include the basis for opinions expressed. Some groups voted on the categorization; others chose not to do this.

The session summaries follow in the order listed on pages 1 and 2. Because the Technology Advancement and Performance and Reliability topics were addressed in a manner different from that used for most of the topics, as described in Section 1, only the actions worksheets are included.

2.2 *Wind Vision* Roadmap—Status and Update: Working Session on Wind Electricity Delivery and Integration

On April 25, 2016, the Working Session on Wind Electricity Delivery and Integration was held at the Citizen Hotel in Sacramento, California.

2.2.1 Summary of Major Discussion Points

A key theme that surfaced many times in the discussion is that substantial information needed to enable expansion of wind power as part of a low-carbon future while maintaining power system reliability has been developed. Additional key insights will emerge from ongoing and planned investigations. Those involved with the related studies and those with wind power experience understand this information. However, this group constitutes a small portion of the electric-power sector; many more in this sector, including regulators, legislators, system planners and operators, and others need to engage this understanding and act on it. So far, the story is not being communicated to the others in the sector with sufficient clarity and repetition. Additionally, when these groups begin to understand the story, they will need more technical support to help them act on the understanding and put it into practice.

There is a critical need for outreach by technical leaders in the wind-integration space, including DOE, the national labs, the wind industry, and power-sector members with wind experience. Some power-sector members have now achieved a high level of understanding with considerable help from DOE-sponsored integration studies, NREL's wind-integration expertise, and the Utility Variable-Generation Integration Group (UVIG). Because utility and Regional Transmission Organization (RTO) members are understandably focused on their organizations and are not incented to provide outreach and education to other groups, however, this *Wind Vision* Roadmap working session identified an expanding need for additional outreach and technical support by national labs, DOE, or other technically competent groups. The UVIG provides an important and effective channel, but today cannot do this job alone.

A strong view emerged that DOE wind and solar integration experts should become part of the teams at RTOs and major balancing authorities to support them in transition planning, in justifying the changes that need to take place for the public good, and in providing the evidence for why these changes are appropriate. This implies that DOE should be more than a research organization.

Attached to this summary is (1) the revised actions worksheet that was used to focus the working session discussion and capture input from the participants. It amplifies the above key theme, and provides details about a number of the points that follow. Also attached are (2) the original actions worksheet, listing the actions as published in the 2015 *Wind Vision* Roadmap; (3) the list of participants in the session; (4) the session agenda; (5) a

set of follow-up questions asked of the participants as part of their review of the initial draft of this summary; and (6) a response from one of the participants that provides detailed amplification of the overarching message. One other participant provided detailed responses to the follow-up questions. These have been incorporated into the following text and the actions worksheet. Review input on the initial draft was received from several of the participants and is reflected in this summary. Although no attempt had been made to reach consensus on the key points from the session discussion, other participants indicated their general agreement with the content of this summary.

2.2.1.1 Discussion Highlights

- Most participants think that the *Wind Vision* Roadmap actions in Delivery and Integration are well thought out and relevant—with varying priorities as indicated below. Although the actions are individually important, most feel that the Roadmap should show how the actions as a group lead to an overarching, high-level understanding of wind power's interaction with and role in the electric power system. Then this high-level perspective, or "Big Picture," needs to be shared with energy-sector decision makers to actively convey the knowledge and insights developed. Participants think that this high-level outreach requires greater emphasis in the Roadmap and should be given a very high priority.
- An important part of the wind-integration story is about public benefit. It includes carbon emissions reduction and air pollution reduction, as well as economic benefits. As such, federal and state government programs have a responsibility to conduct outreach to tell this story.
- DOE and the wind industry need to engage in longer-term strategic discussions with energy-sector decision makers. The wind industry has been focused myopically on the Production Tax Credit (PTC) extension and short-term business profitability. DOE has not been able to provide sufficient resources or participation to fill the gap in decision-maker engagement. Wind's benefits extend well beyond the PTC horizon, and both DOE and the wind industry must help communicate that story to the public. This need includes reaching out to state-level organizations, as well as federal agencies, such as the Federal Energy Regulatory Commission (FERC) and North American Electric Reliability Corporation (NERC).
- Some participants expressed the view that too much of DOE's wind energy funding is devoted to offshore wind—albeit for demonstration projects rather than technology research. They also think that, in general, DOE is overemphasizing distributed generation. As a result, they feel that DOE is paying insufficient attention to improved power-system operational practices, revised market designs, and transmission expansion of the bulk power system. This undervalues the contribution that land-based utility-scale wind will make to a low-carbon future. It also undercuts the message that—even with significant shares of distributed renewables—transmission expansion is needed as a foundational part of the future power system. As an example, a substantial opportunity exists in Florida for growth in distributed PV, but it is likely that at times there will be an excess of PV energy in that region that will need to be either curtailed or exported. With

insufficient transmission, export is not possible. This situation already is a reality in California, where solar plants are seeing curtailment at midday.

- Most participants thought that no significant delivery and integration actions are needed for distributed wind. Tools already exist to analyze distributed wind system impacts. In general, the impacts are expected to be small, unlike with distributed PV for which penetrations can be much larger. This does not include direct purchase of wind energy by corporate buyers, which sometimes has involved kilowatt-scale wind turbines in the past but is now predominantly using MW-class turbines and purchases from large utility-scale wind plants.
- Most participants think that no substantial delivery and integration actions are needed over the next 5 to 10 years to analyze or enable offshore wind integration. Participants feel that connection of offshore wind plants to the land-based grid is straightforward and does not require new research.
- Workforce development is a significant issue. The power-sector workforce is aging and younger people need to become engaged.
- Cyber-security is an important general issue for the power sector. It is not wind-specific, however, and should be addressed at a higher administrative level.
- Although addressed in a different section of the Roadmap, wind forecasting improvement and use still require substantial attention.

2.2.1.2 Prospective New Actions to Add

- Optimize the use of the existing transmission system—including interactions with distribution systems that are evolving to accommodate the expansion of distributed generation—and modernize the entire power grid with the best available technologies.
    - Fix bottlenecks and constraints—both technical and institutional
    - Upgrade capacity on existing and new transmission corridors
    - Modernize rating calculations under the full range of operating conditions
    - Capitalize on changes in power flows as existing generators retire (e.g., older coal plants) and new resources come on line

There is no doubt that the existing transmission and distribution (T&D) system can provide more capacity and deliverability of renewable energy through such measures as improved modeling, state estimation, visibility (including strategically-placed telemetry and phasor measurement units), faster coordination of reserves and reliability services, and improvements at the seams for imports and exports. The Southwest Power Pool (SPP) territory is an excellent example of a region that will transition from a conventional view of designing and operating to serve load within the footprint to a radical new future where it is a huge exporter of clean energy. This is extremely difficult to do within the reality of an RTO stakeholder process, existing market rules, and state regulatory constructs and politics.

The FERC and regulatory drivers will have significant impact. Of equal and perhaps greater importance, there are many technical issues that must be studied, debated, and resolved. Many participants see a role for DOE and the DOE labs, particularly NREL, to drive the technical and market design issues with objective analysis and technical support. This is not the basic research that some DOE staff and lab directors prefer to do, but it's important to make sure that the research and analyses are actually understood and applied in the real world. This work is not expensive to fund; but even though such work makes a great difference, it is not presently being sufficiently funded or supported.

- Conduct very large system analysis of expansion and integration of a broad spectrum of clean, low-carbon power technologies
    - Examine North America in its entirety
    - Capitalize on the educational benefits this would provide for all involved
    - Secure the participation of the DOE Solar Energy Technologies Office, the Office of Electricity and Delivery, and others
    - Ensure a total system view of all sources of energy and reliability services.

Conducting a holistic North American study is an important first step, but that study should also lead to future work that brings in the energy integration perspectives that deal with the electrification of transportation and other sectors. Eventually, we must understand not just all generation technologies, but also their relationship with loads and energy consumers. During this working session, the participant from DOE's Wind Energy Technology Office reported that such a holistic study, the North American Renewable Integration Study (NARIS), recently was initiated.

- Expand and emphasize engagement with evolving market design activities
    - Encourage equitable valuation of reliability services and energy
    - Ensure equitable consideration of wind with respect to its need for and ability to provide reliability services.

Additional broad suggestions offered include (a) consolidate messaging with all relevant technologies that can contribute to de-carbonization of the electric power system; and (b) conduct analyses showing how the Power Marketing Administrations, electric cooperatives, and public power entities will be helped by de-carbonization (e.g., to a growing degree, their customers are in favor of reducing carbon emissions).

Table 2. Delivery and Integration Actions Wind Vision Roadmap
Revised Actions Worksheet—May 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
5.1: Encourage Sufficient Transmission						
• 5.1.1: Conduct cost-benefit analysis		0	0	9 Full spectrum of benefits poorly described and poorly understood.	X	
• 5.1.2: Analyze system dynamics		0	8	1	X	
• 5.1.3: Reduce jurisdictional barriers		0	0	9 States' views prevail; work toward a transmission authority?	X	
• 5.1.4: Develop and build systems to aggregate power from multiple offshore projects		8 No significant connection or integration issues expected.	1	0		X (even later)
• *5.1.0 NEW: Optimize use of existing T&D system and modernize it with the best available technology*		0	3 Progress in some regions.	6 Much more effort needed in most regions; operating guidelines are antiquated.	XX	

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
5.2: Increase Flexible Resource Supply						
• 5.2.1: Increase industry understanding *of flexibility needs and capabilities, and expand use of these capabilities throughout the electric power sector*		0	7 Much useful and actionable information exists and is understood by those involved in the analyses; outreach to regulators, system operators with little renewables experience, and other decision makers is critical.	2	X	
• 5.2.2: Develop flexibility methods and models		0	4.5	4.5	X	
• 5.2.3: Develop flexibility supply curves		0		9 This work has been qualitative so far; need quantitative understanding of how much flexibility specific options offer, in which time frames, and at what costs?	X	
• 5.2.4: Increase demand response		2	3 Regional variations (e.g., PJM a leader).	4	X	

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
• 5.2.5: Analyze new market designs *and encourage implementation of features that efficiently balance resource adequacy, reliability, revenue requirements, and decarbonization*		0	3 Some relevant work underway; but, as in 5.2.1, the results need to be shared with and internalized by power-sector regulators and decision makers.	6 Most participants concerned that effort related to this need is insufficient.	XX	
• 5.2.6: Evaluate direct and indirect economic benefits of offshore wind		7 Most participants feel that enough has been done to address near-term needs	1			X (even later)
• *5.2.0: New: Conduct comprehensive renewable energy integration study, including all energy technologies, for all of North America*. This relates to 5.1 and 5.2.		0	3 Work to date, however, hasn't included all technologies. North American Renewable Integration Study is being initiated; group strongly supports this work.	6 Little attention so far to such a comprehensive study.	XX	
5.3: Encourage Cost-Effective Power System Operation with High Wind Penetration						
• 5.3.1: Improve market and reliability rules		0	6 As in 5.2.1, however, the results need to be shared	3 Small balancing authorities and public power resisting change.	XX	

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
			with and internalized by power-sector regulators and decision makers.			
• 5.3.2: Improve understanding of wind integration issues		0		9 As in 5.2.1, the results need to be shared with and internalized by power-sector regulators and decision makers.	XX	
5.4: Provide Advanced Controls for Grid Integration						
• 5.4.1: Develop advanced active power controls		2 (Texas)	7 As in 5.2.1, however, the results need to be shared with and internalized by power-sector regulators and decision makers.		X	

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
5.5: Develop Optimized Offshore Wind Grid Architecture and Integration Strategies (Recommendation from OSW team: Retain this action and place 5.1.4 and 5.2.6 under it, renumbered 5.5.1 and 5.5.2, respectively)		7 Most feel this top-level action should be deleted; instead retain 5.1.4 and 5.2.6 (at lower priority as indicated above).	2			X (even later)
5.6: Improve Distributed Wind Integration						
• 5.6.1: Develop distributed system modeling tools		9 These tools exist (e.g., UVIG).				
• 5.6.2: Improve communication and control capabilities		7 Little need perceived.		2 Perhaps a need in rural areas with weak grids.		
• 5.6.3: Inform utilities of integration possibilities		9 Low priority as compared to PV.				

Additions to the original worksheet actions text are *indicated in italics*. XX indicates highest priority
Numerical entries indicate the number of participants placing the action in this category.

Table 3. Delivery and Integration Actions Wind Vision Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
5.1: Encourage Sufficient Transmission						
• 5.1.1: Conduct cost-benefit analysis						
• 5.1.2: Analyze system dynamics						
• 5.1.3: Reduce jurisdictional barriers						
5.1.4: Develop and build systems to aggregate power from multiple offshore projects						
5.2: Increase Flexible Resource Supply						
• 5.2.1: Increase industry understanding						
5.2.2: Develop flexibility methods and models						
• 5.2.3: Develop flexibility supply curves						
• 5.2.4: Increase demand response						
• 5.2.5: Analyze new market						

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
designs						
• 5.2.6: Evaluate direct and indirect economic benefits of offshore wind						
5.3: Encourage Cost-Effective Power System Operation with High Wind Penetration						
• 5.3.1: Improve market and reliability roles						
• 5.3.2: Improve understanding of wind integration issues						
5.4: Provide Advanced Controls for Grid Integration						
• 5.4.1: Develop advanced active power controls.						
5.5: Develop Optimized Offshore Wind Grid Architecture and Integration Strategies						
5.6: Improve Distributed Wind Integration						
• 5.6.1: Develop distributed system modeling tools						
• 5.6.2: Improve communication and control capabilities						
• 5.6.3: Inform utilities of integration possibilities						

Table 4. Working Session on Delivery and Integration, April 25, 2016
Confirmed Participants

Jay Caspary	SPP
Julia Matevosjana	ERCOT
Kris Ruud	MISO
Mark Ahlstrom	Next Era
Charlton Clark	DOE Wind
Brian Parsons	WGG
Charlie Smith	UVIG
Roby Roberts	EDPR
Aaron Bloom	NREL
Ed DeMeo	RECS

Table 5. *Wind Vision* Roadmap: Status and Update Working Session on Delivery and Integration, April 25, 2016

Agenda		
1:00 pm	Introductions and Session Overview; Discussion Ground Rules	Ed DeMeo, RECS, Inc.
1:15	Roadmap Purpose and Motivation: 2015 Baseline Actions	Ed DeMeo
1:30	Are revisions needed: Additions, deletions, gaps, other changes	All
2:30	Are the right organizations and people involved? Should others be engaged? Who?	All
3:15	Break	
3:30	Are needed actions being addressed? To what extent? Which are highest priorities now and after 2020? Are any of marginal importance?	All
4:30	Are there areas of particular concern?	All
5:00	Follow-Up Plans	Ed DeMeo
5:30	Adjourn	

2.2.1.3 Follow-Up Questions

Session participants reviewed and commented on a first draft of the discussion summary. They were then asked to provide additional input on several specific follow-up questions. Responses received were used in refining the summary. One of these responses was particularly effective in expressing major points voiced, and is included as Section 2.2.1.4. The specific questions were posed in the following note to the session participants:

In revising the summary, we'd like to add more detail in a few places—primarily to provide more specificity to those who might act on our input. A few of you already provided some of this detail, but I'd like to shake the tree once more.

Focusing on the actions identified as highest priorities (denoted XX), can we be more specific about suggested actions for both private-sector and government organizations? And if there's a specific federal role, what is that? This request pertains to Actions 5.1.0, 5.2.5, 5.2.0, 5.3.1, and 5.3.2, repeated below.

- 5.1.0: Optimize use of existing T&D system and modernize it with the best available technology
    - How can T&D use be optimized: operating rules, technology, what else?
    - Can we provide examples of best available technology?
    - Can we shine a national spotlight on this need? How? Is there a federal role?
- 5.2.5: Analyze new market designs and encourage implementation of features that efficiently balance resource adequacy, reliability, revenue requirements, and de-carbonization
    - Does the NREL-EPRI work Aaron Bloom described meet this need?
    - If not, what other actions are needed?
    - Is there a federal role? Or does this need to be addressed regionally?
- 5.2.0: Conduct comprehensive renewable energy integration study, including all energy technologies, for all of North America
    - Does the North American Renewable Integration Study fulfill this need?
    - If not, what else is needed?
- 5.3.1: Improve market and reliability rules
    - How can this be best addressed? What specific actions?
    - How can public power and small balancing authorities best be approached?
    - Does Order 1000 help with this? Do we need to go beyond Order 1000?
    - Is there a federal role? If so, what is it?

- 5.3.2: Improve understanding of wind integration issues
    - How should study results and experience be shared? With whom?
    - Is there a federal role? If so, what is it?
- Finally, with respect to our overriding message that the story is not getting out to many who need to hear it: What specific activities can you suggest that the federal program should carry out to reach power-sector decision makers?

2.2.1.4 Detailed Response from Charlie Smith, UVIG Executive Director

DOE has supported the best renewables integration work in the country, and among the best in the world. But it is not enough to do the studies and create the knowledge. If the people who need to hear it, and approve it, and use it, don't get the message, it is not of much use. UVIG has served as a conduit to help identify and stimulate the work that needs to be done, to monitor the progress and disseminate the results, but it is only one channel. There used to be a much stronger presence of NREL in the technology transfer world. NREL's presence is sorely missed. The work that DOE and NREL do needs to be translated into appropriate messages for different groups. There are many forums across the country at the local, state, regional, and national level that need to be touched. This includes individual utility companies; state legislative and regulatory bodies; RTOs, regional reliability entities, regional planning authorities, and regional associations; and at the national level, industry associations [Edison Electric Institute (EEI), American Public Power Association (APPA), National Rural Electric Cooperative Association (NRECA)], regulatory associations and authorities [National Association of Regulatory Utility Commissioners (NARUC), FERC, NERC], legislative associations such as the National Conference of State Legislatures (NCSL), consumer advocate associations such as the National Association of State Utility Consumer Advocates (NASUCA), professional associations such as the Institute of Electrical and Electronics Engineers (IEEE) and the American Society of Mechanical Engineers (ASME), and trade associations such as the American Wind Energy Association (AWEA).

There are technology-specific (wind and solar) messages and industry-specific messages which cut across technologies (e.g., market design and operation, transmission planning, interconnection requirements, regulatory matters) that need to be delivered. DOE wind and solar programs do a good job on the technology messages, but fall short on the cross-cutting integration messages. The wind program is aware of the need, but is short on the budget. They used to have a good program in this area at NREL before the budget cuts. The solar program seems much less aware of the need. The program seems to believe that if the cost of the technology is low enough, everything else will take care of itself. The fallacy of this belief might not be visible to the program until high levels of solar curtailment are reached. In the meantime, the solar program is riding on the coattails of the wind program in this area.

And even once this message has gotten across, there are related messages for which we have only scratched the surface on the necessary R&D work, never mind the messaging. This includes the increased participation of demand response in the market, and the integration of the electrical sector with the thermal and transportation sectors. Until we have a robust transmission system that is designed at the continental level, using high-

voltage direct-current (HVDC) equipment to span the interconnections and unlock the flexibility inherent in the diversity of the loads and resources from all sectors, we will not be able to successfully integrate the large volumes of wind and solar energy which are coming in the future.

We are talking about a generational transition here. The time constants of the industry we are dealing with are measured in years and decades, not weeks and months. We need an educational and information-dissemination effort that has objectivity, credibility, and staying power. Information dissemination in support of renewable energy programs is a public good, for which DOE support is entirely appropriate.

2.3 *Wind Vision* Roadmap—Status and Update: Working Session on Wind Power Resources and Site Characterization

The Working Session on Wind Power Resources and Site Characterization was held on June 14, 2016, at the National Center for Atmospheric Research (NCAR) Foothills Laboratory, 3450 Mitchell Lane, Boulder, Colorado, 80301.

2.3.1 Summary of Major Discussion Points

Most session participants expressed the view that the roadmap actions aimed at offshore wind are in general described with greater depth and breadth than those aimed at land-based wind, and that many of the specific needs mentioned for offshore apply also to land-based actions. In the Revised Actions Worksheet following this summary, most of the offshore actions have been recast as actions for both land-based and offshore applications. Where appropriate, the status of each action is addressed separately for both land-based and offshore. In retrospect, the drafting of the land-based portion of the original roadmap section was subjected to brevity constraints that were not applied to the drafting of the offshore portion.

2.3.1.1 Discussion Highlights

- Progress with wind forecasting and its incorporation into electric-power operating procedures has been substantial. A decade ago, concerns about the uncertainties of wind resources hampered the expansion of wind power. Today, through improved forecasting capability and extensive utility experience with the use of forecasts, such concerns are no longer a significant deterrent. Differing views about the value of increased forecasting accuracy were expressed. One participant thought that any additional value most likely would benefit the trading process in energy markets, and that decisions on whether to pursue a particular new wind project would not be influenced by improved forecasting accuracy. Instead those decisions will be influenced by such factors as access to transmission, access to energy markets with spatial and temporal diversity, and other elements of overall power system flexibility. In contrast, others expect significant additional value from improvements in forecasting capability (see, for example, the next bullet).
- Although power-system operational concerns stemming from wind resource uncertainties have been substantially reduced, uncertainties in energy production

predictions for prospective wind plants persist. As a result, financing terms for new wind plants tend to be less favorable than those for some other power plants. Reduction of these uncertainties would reduce financing risk, resulting in reduced energy costs from these plants. Additionally, improved ability to forecast wind ramps in the short term (minutes to a few hours) would provide value through increased operational efficiency of the electric power system—including its wind plants. Also, improved day-ahead forecasting allows power plant unit commitment decisions to be made with higher confidence—improving efficiency and reducing costs, as well as benefiting trading decisions as mentioned above. Improved seasonal forecasting also would benefit overall system operation by allowing better-informed decisions on scheduling of plant maintenance throughout the system, as well as more-accurate predictions of wind-plant revenues throughout the year. Finally, accurate multiyear forecasts over a decade or more not only would improve confidence in energy projections over the life of the wind plant but also could influence the location of the plant. They could also affect plant maintenance schedules and lifetime, as well as the selection of turbines and other plant equipment for the original wind power plant design.

- With respect to priorities, some participants think that the government program overemphasizes offshore wind. This is based on a belief that there is still great potential for additional land-based wind, and that there still is much to be done to fully understand the characteristics of land-based wind—characteristics that are important to energy production and equipment longevity. Conversely, other participants commented that the economics for offshore wind are improving, that major players are making commitments to develop offshore wind in U.S. waters, and that substantial activity in this arena is highly likely. This activity likely will result in significant economic and environmental benefits; the nation should not cede those economic benefits entirely to overseas players.
- The roadmap includes actions to develop and refine models for estimating wind characteristics over various time frames—including such features as energy content, shears, turbulence, impacts of topographical features, as well as the impacts of winds on wind turbines over time. For the land-based actions, however, there is little attention given to developing the extensive data sets that are needed to design and validate models. This need is addressed in the offshore actions, but should be extended to land-based actions as well. An additional benefit of validated models would be their use in decisions about plant life extension and repowering.
- The accuracy of these models will be increased substantially as the understanding of the physics of the atmosphere improves. Hence, it is important to continue and expand study of the underlying atmospheric physics. Without this understanding, forecasts must rely primarily on statistical methods and persistence modeling—which are backward-looking rather than forward-looking. These retrospective techniques are unable to predict major events such as extreme storms. Such storms can cause extensive economic loss, so advance warning can be very valuable in reducing losses through precautionary measures.

- Extreme-storm prediction capability requires data gathering and observations during actual extreme weather events, such as information obtained with hurricane-hunter aircraft dropsondes. Such information and related analysis are essential for the development of useful predictive models. The insights gained would also benefit the design and layout of offshore and near-shore wind turbines and wind plants.
- Most participants feel that wind power and wind resources should not be considered in isolation from other renewable energy resources. Synergies with other low-carbon resources, such as solar power and efficiency, should be considered and pursued. Wind should not appear to be in competition with such sources.
- Several participants recommended developing a visual representation of the Roadmap actions provided in Wind Resources and Site Characterization that conveys the breadth of the actions group and their degree of applicability to both land-based and offshore wind. Three participants agreed to pursue this concept further. However, with the recasting of actions described in Section 2.3.1 above, the benefit offered by such visual representations is likely reduced.
- To be useful to the entire wind community, the models and data sets described above should be publicly available. This requires major contributions of public funding. DOE Wind can provide some of this support, but larger contributions from other, more scientifically oriented government organizations are needed. Candidate agencies include the National Oceanic and Atmospheric Administration (NOAA), Office of Oceanic and Atmospheric Research (OAR), the National Weather Service (NWS), National Science Foundation (NSF), perhaps the U.S. Department of Defense (DOD), as well as the Office of Science within DOE. Participants indicated that the NSF has terminated funding of wind-related research of any kind, greatly reducing participation of the academic community in wind research in general.
- Models under development for use in optimizing wind plant layout and evaluating turbine wake effects will be the same for both land-based and offshore applications. However, the boundary conditions applied to land-based and offshore situations will differ substantially and will vary from site to site.
- The need for extensive, high-quality, long-term data sets, including high-resolution data for verification of computational fluid dynamics models, arose many times in the discussion. Apparently, much of this data exists but is proprietary. A repository and clearinghouse for such data is needed. These data could be combined and sanitized in a way that protects confidentiality. The National Oceanic and Atmospheric Administration has made progress in combining data from several wind plant operators to improve operational forecasts while maintaining data confidentiality. It was suggested that NREL could serve as a clearinghouse, especially for data needed in the design and verification of models used for loads prediction and turbulence intensities and effects. Some progress on securely disseminating proprietary data to researchers has been made with DOE's new Data Archive and Portal (DAP), funded under

A2e. Other data sets could be used in the development of models to improve the accuracy of dynamic transmission-line rating models.

- Some regions—for example, specific locations in the Pacific Northwest—are seeing suboptimal wind development in the sense that newer wind plants have reduced value because of the lack of geographic wind diversity. Wind plant output in these locations is often curtailed. Other locations that have lesser wind resources but less temporal coincidence of wind actually could have greater value. Methods are needed to more accurately evaluate the trade-offs in placement of newer plants so that maximum value of wind energy from these plants is achieved. This requires temporally synchronized wind resource data over large regions, as well as operational data for the electric power network. It was recognized, however, that robust transmission capacity from the wind-rich locations to distant regions would reduce concerns about overdevelopment in those locations. For example, the Texas Competitive Renewable Energy Zone (CREZ) transmission build-out has substantially reduced wind curtailment in Texas.
- International cooperation on wind resource research should continue. In general, participants feel that interactions through the IEA are valuable and are progressing well.

Table 6. Wind Power Resources and Site Characterization *Wind Vision* Roadmap
Revised Actions Worksheet—June 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track; adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
1.1: Improve Wind Resource Characterization *for Both Land-Based (LB) and Offshore (OSW) Applications*						
• 1.1.1: Improve wind *forecasting in minutes, hours, and days time frames*		LB 3 OSW not evaluated	8			
• *1.1.1a Improve seasonal forecasting for wind*		LB 1 OSW not evaluated		10	X	
• *1.1.1b: Understand inter-annual variations, such as those forced by non-linearities in the weather system, or by El Nino Southern Oscillation or similar phenomena*				11	X	
• 1.1.2: Develop models that predict the effect of climate change on wind resources*; couple this with assembly of comprehensive data sets needed for design and validation of the models*			1	9	X	X
• *1.1.3: Improve understanding of wind resource characteristics that affect loads on wind turbine components*			8	2		

Action		Good	On Track	Poor	Now	After 2020
• *1.1.4 Accelerate development and acceptance of innovative remote measurement systems (e.g., lidar)*			LB 7 OSW 2	3 7 Platform pitching increases difficulty offshore.	X	
• *1.1.5: Establish monitoring systems and conduct long-term collection of wind-characteristics data*		LB OSW	3	6 8	X	X
• *1.1.6: Develop data sets illustrating extreme events; include loading on turbine components*		LB OSW		8 9		X
• *1.1.7: Create archives and collaborative frameworks for data related to wind resources and their impacts*		LB OSW	7 1	3 8		
• *1.1.8: Enhance resource maps and related models*		LB 1 OSW	5 1	3 7		
1.2: Understand Intra-plant Flows						
• 1.2.3: Improve multi-scale complex flow models*; include wake modeling and intra-array effects*			3 The same models apply to both land-based and offshore installations.	4 Intra-plant flows, including wake effects, are poorly understood in complex terrain.	X	
• 1.2.2: Optimize the siting of turbines in a wind power plant		LB 1 OSW not evaluated	7			

Action		Good	On Track	Poor	Now	After 2020
1.3: Characterize Offshore-*Specific* Wind Resources						
• 1.3.1: Characterize offshore wind resource and external design conditions*, including turbine loads from winds, water, ice, and their interactions*				10		X
• 1.3.3: Create offshore monitoring for metocean data collection				8		X
• 1.3.6: Improve wake modeling		1 The same models apply to both land-based and offshore installations.	8 Because of the relatively flat sea surface, wake models do better offshore than on land.			

Additions to the original worksheet actions text are *indicated in italics*. LB: land-based wind OSW: offshore wind
Numerical entries indicate the number of participants placing the action in this category.

Table 7. Wind Power Resources and Site Characterization Wind Vision Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
1.1: Improve Wind Resource Characterization						
• 1.1.1: Improve wind characteristics forecasting						
• 1.1.2: Develop models that predict the effect of climate change on wind resources						
1.2: Understand Intra-plant Flows						
• 1.2.1: Improve remote sensing techniques						
• 1.2.2: Optimize the siting of turbines in a wind power plant						
• 1.2.3: Improve multi-scale complex flow models						
1.3: Characterize Offshore Wind Resources						
• 1.3.1: Characterize offshore wind resource and external design						

Action		Good	On Track	Poor	Now	After 2020
conditions						
• 1.3.2: Accelerate development and acceptance of innovative remote measurement systems						
• 1.3.3: Create offshore monitoring for metocean data collection						
• 1.3.4: Improve offshore data sets for extreme events						
• 1.3.5: Create archives and collaborative frameworks for data						
• 1.3.6: Improve wake modeling						
• 1.3.7: Enhance resource maps and other models for offshore wind						

Table 8. Working Session on Wind Resources, Tuesday Afternoon, June 14, 2016
Confirmed Participants

Jim McCaa	Vaisala
Branko Kosovic	NCAR
Julie Lundquist	University of Colorado
Alex Kapetanovic	RES-Americas
Drake Bartlett	Xcel Energy
Will Shaw	PNNL
Jeff Mirocha	LLNL
Rao Kotamarthi	ANL
Pat Moriarty	NREL
Caroline Draxl	NREL
Andy Clifton	NREL
Melinda Marquis	NOAA
Joel Cline	DOE
Brad Ring	DOE
Ed DeMeo	RECS

Table 9. *Wind Vision* Roadmap: Status and Update Working Session on Wind Power Resources and Site Characterization; June 14, 2016

Agenda		
1:00 p.m.	Introductions and Session Overview; Discussion Ground Rules	Ed DeMeo, RECS, Inc.
1:15 p.m.	Roadmap Purpose and Motivation: 2015 Baseline Actions	Ed DeMeo
1:30 p.m.	Are revisions needed: additions, deletions, gaps, other changes	All
2:30 p.m.	Are the right organizations and people involved? Should others be engaged? Who?	All
3:15 p.m.	Break	
3:30 p.m.	Are needed actions being addressed? To what extent? Which are highest priorities now and after 2020? Are any of marginal importance?	All
4:30 p.m.	Are there areas of particular concern?	All
5:00 p.m.	Follow-up Plans	Ed DeMeo
5:30 p.m.	Adjourn	

2.4 *Wind Vision* Roadmap—Status and Update: Working Session on Supply Chain, Manufacturing, and Logistics

On June 22, 2016, the Working Session on Supply Chain, Manufacturing, and Logistics was held at NREL's Research Support Facility, 15013 Denver West Parkway, Golden, Colorado, 80401.

2.4.1 Summary of Major Discussion Points

Short-term (less than a year) needs in the supply chain, manufacturing and logistics arena are likely to be handled by industry players—generally operating on their own. Over the longer term, more sharing and cooperation among industry players is possible—for example with innovative higher-risk manufacturing technologies and their demonstration, as well as with policy improvements that facilitate development of effective standards or uniform and equitable transportation requirements. Government programs should focus on such longer-term activities and promote the importance of industry engagement in these efforts. This message is supported by several of the discussion points below, and by the Revised Actions Worksheet.

A shortcoming of the June 22 working session is that representatives of the turbine manufacturer and project developer sectors were unable to attend because of schedule conflicts. Several of these parties expressed interest in participating. They were invited in September to take part in an October 4 conference-call discussion of the draft findings of

the June 22 session, and to provide comments and additions based on their perspectives. Their input is summarized in Section 2.4.2 below. Their comments also have been inserted *in italics* in the Discussion Highlights section below—in some cases these support the sense of the June 22 discussion and in other cases they present alternate views.

2.4.1.1 Discussion Highlights

- A competitive assessment addressing domestic manufacturing and supply chain capability (*U.S. Wind Energy Manufacturing and Supply Chain: A Competitiveness Analysis*) was published in 2014 (DOE 2014). This study identified components, systems, and expertise relevant to wind power plants that could be supplied competitively by domestic firms. It addressed both land-based and offshore wind applications. It would be valuable for this study to be updated and expanded.
- Many parties in the wind community and the industry in general are not aware of work funded by the federal wind program. Reports from that work should be publicized and distributed much more effectively, with focused attention on target audiences.
- Several participants expressed agreement in general with the roadmap's content and supporting commentary.
- Mainstream engineering education programs traditionally do not feature wind energy as an attractive career option. These programs tend to use illustrative examples from traditional engineering jobs such as the design of buildings and bridges, and vehicle and air transportation systems. Examples highlighting design, manufacturing, construction, and transportation of components of wind energy systems should be added. Students then would be exposed to an energy technology of the near future that can offer them attractive and relevant career paths. Some session participants, however, pointed to encouraging progress on this front based on personal experience.
- Engineering education programs should include an emphasis on design for manufacturability. Some industrial engineering programs already emphasize this and could add examples related to wind turbine components.
- Much of the information associated with wind equipment manufacturing is "know-how"; it exists in the experience base of manufacturing engineers, designers, researchers, and technicians, but is not formally documented or taught in educational programs. This information should be captured, documented, and presented as components of baseline engineering knowledge. Much of it will still be transferred through person-to-person interactions, but the learning process will be facilitated by documented educational materials. One participant pointed out that some European engineering colleges do offer courses of this type. These were sponsored originally by the European wind original equipment manufacturers (OEMs).

- Much support was expressed for the value of manufacturing innovation, including increased automation and use of "big data." However, participants thought that a solid, documented, and shared baseline of relevant manufacturing knowledge is a necessary prerequisite for innovation to occur. Without this, the impact and value of an innovation cannot be understood and quantified.
- Manufacturing standards are needed for wind components. Development of such standards is at an early stage. A blade manufacturing standard currently is under development.
- *In addition to manufacturing standards for wind components, engineering standards also are needed.*
- Participants thought that, with respect to wind tower and foundation design and manufacturing in the United States, there is an overdependence on European design codes. Participants recommended the development of a legally binding U.S. standard for the comprehensive design of foundations and towers. Without such a standard—one based on the knowledge of those with extensive relevant experience—concrete towers are likely to be based on U.S. building standards and European design codes. The resulting tower designs would be more complex and more costly than necessary.
- Transportation requirements and policies vary substantially from location to location—state to state, county to county, and in some cases from town to town. This greatly complicates the transport of components of wind power systems over great distances. A small industrial sector has emerged that specializes in the design of travel routes to minimize institutional and physical constraints. Some regions are beginning to pursue transportation-policy coordination on a regional basis. A federal policy would be helpful and would reduce costs associated with component transport.
- *National policy and standards on wind equipment transport—including permitting and routing considerations—would provide a substantial benefit. Currently, transport requirements vary from location to location which creates a significant burden and causes excess costs. Policy support on Federal Aviation Administration (FAA) height restrictions for the newer taller towers also would be welcomed. It is estimated that applying current procedures to structures reaching more than 500 feet vertically adds about a year to project-development time. In most cases, developers instead opt to make the structures less than 500 feet tall and accept the resulting lower performance.*
- The roadmap actions as published include some mention of onsite manufacturing of turbine components, but a much stronger focus on this is recommended. Much more involvement is needed from such sectors as the concrete and transportation industries.
- *The trend toward larger components is driving interest in on-site manufacturing. The comparative economics with other alternatives, however, require careful examination. On-site labor costs could be double those of a dedicated*

manufacturing facility. Maintaining suitable environmental conditions for manufacturing (e.g., appropriate temperatures) also could be challenging.

- *Considering the challenges noted, it might be more cost-effective to focus on means to ease transport of large components. Europeans successfully transport larger components than those found in the United States.*
- *The European wind industry has been driven to larger turbine sizes in part because plant construction is more challenging in Europe than it is in the United States. As an example, the construction time for a 200-MW wind plant in the United States might be about 10 months. In Europe, it could be 2 to 2.5 years, because this plant—affected by land constraints—actually would be 10 to 20 smaller installations. The desire to reduce the number of smaller installations—and thus total construction time—requires getting as much capacity as possible from each installation. This, in turn, drives the designs toward taller and larger machines. Those drivers are a lesser concern in the United States.*
- *Domestic manufacturing of large, heavy items—such as hub castings—would be beneficial. So far, the U.S. casting industry has not entered this business in volume because of policy and demand uncertainty. In contrast, China has invested in such production facilities.*
- *Items such as towers that require large quantities of steel generally use domestic steel. Imported steel could cost less, but current import tariffs make it uneconomic. If tariffs were reduced, lower-cost imported steel might be used, resulting in lower wind costs. The steel-tariffs issue, however, transcends the wind industry.*
- Successful scaling-up of onsite manufacturing techniques requires extensive engagement of new industrial players, such as the Precast/Prestressed Concrete Institute (PCI). The federal wind program should expand the list of industrial groups to engage. Session participants strongly recommended that DOE Wind actively inform relevant industry sectors that wind power presents an attractive business prospect. This can be done by publicizing data such as wind capacity addition projections for the next several years, and installation history during the last decade.
- Participants noted that turbine manufacturers and wind plant owners and operators were absent from this discussion. They recommended bringing those sectors into the discussion, but also appreciated the opportunity to focus on issues specific to the needs of their own industry segments.
- *Project developers are only indirectly connected to manufacturing and supply-chain considerations. They rely on the turbine manufacturers to manage the supply chain. However, project developers do directly influence—and are directly affected by—logistics considerations.*
- Going forward, emphasis on manufacturing for recyclability is needed.
- *Presently there is no incentive to design or manufacture for recyclability. There also is no economic driver to investigate how to recycle turbines retiring now or*

in the near future. However, significant work in turbine and component life extension is beginning.

- For offshore wind manufacturing, supply chain, and logistics, participants recommend expanded pursuit of synergies with the offshore oil and gas industries. A study comparing the needs of offshore wind with the capabilities of the oil and gas industry would be valuable.
- Participants recommend greater emphasis on repurposing of existing but underutilized manufacturing facilities. There appears to be little federal involvement with such activity, but some states—particularly Ohio—have exemplary programs of this type. One participant indicated that U.S. coastal manufacturing facilities could be ripe for repurposing to support offshore wind. As an example taken from European activities, the declining shipbuilding facilities in Bremerhaven, Germany, were repurposed for wind equipment manufacturing.
- *In the offshore arena, repurposing of coastal manufacturing and logistics facilities makes good sense. The long-term viability of the offshore market is not assured, however, which limits private investment. Very substantial opportunities still exist on land in the United States.*
- The group cautioned against siloing of wind manufacturing efforts. The Iowa State Hexcrete tower project funded under DOE's tall-tower initiative was identified as a good example of cross-fertilization among players from different manufacturing disciplines—although even this activity has not engaged a wide range of manufacturing capabilities.
- Most of the power-electronics technology used in wind plants comes from abroad. Participants recommend government efforts to increase domestic expertise and capabilities in power electronics.
- *Today, the majority of power-electronic equipment is imported—not just for wind power, but for many sectors that in aggregate far exceed the size of the wind business. There would likely be no advantage in increasing domestic production of power-electronic equipment—either for wind power alone or for all uses. This is a cost issue; foreign manufacturers can supply this equipment at lower cost than that of domestic industry.*
- Participants think that the WINDPACT studies were valuable for wind technology and manufacturing advancement; however, the studies are now roughly 15 years old. Support was expressed for a new round of such studies, which also could aid in furthering development of design standards.
- Participants encouraged the federal wind program to focus on actions over the longer time horizon—that is, beyond at least one year. Industry players generally are focused on six months or less; issues of importance over that time frame should be left to industry. Longer-term thrusts generally command much less industry attention. Over the longer term, innovative—as opposed to

incremental—technology advancements will be key. Government programs can play a significant role in fostering innovative technology.

- Participants expressed support for full-scale manufacturing demonstration projects. These are seen as good candidates for government-industry collaboration, because it is difficult to raise capital for the first production line employing a new process or approach.
- *Government-supported R&D in manufacturing would be helpful in areas such as:*
    - *Automation of blade manufacturing, where the labor component is large*
    - *Weight reduction for all major components*
    - *Taller towers, including manufacturing, assembly, and logistics*
- The group encouraged inclusion of manufacturing needs and issues as appropriate in other sections of the *Wind Vision* Roadmap, such as those dealing with technology development, environmental impacts, and education and workforce development.

Table 10. Supply Chain, Manufacturing and Logistics Actions *Wind Vision* Roadmap
Revised Actions Worksheet—June 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority	
					Now	After 2020
3.1: Increase Domestic Manufacturing Competitiveness						
• 3.1.1: Conduct competitiveness assessment: *update and expand 2012 DOE assessment*		1 Some effective government-industry collaboration; need to expand outreach to broader cross-section of prospective industry participants.	8 Incorporate market volatility; for example, tower imports are likely in 2018 when U.S. production capability might be exceeded; find areas where United States has a competitive edge.	Need better information dissemination from federal-program projects (quality, not quantity; target topic-specific primary audiences).		
• *3.1.15: Document public-domain, industry-specific manufacturing knowledge, including design codes and standards; identify manufacturing knowledge gaps. This provides a baseline for 3.1.2*				Numerical score not discussed, but identification of this need implies a significant deficiency.		
• 3.1.2: Develop innovative manufacturing technology; *include an expanded emphasis*		1.5 Composites manufacturing work is	7.5 Bench modeling projects are effective in	Full-scale demonstration projects are needed for innovative techniques; U.S.	X	

Action		Good	On Track	Poor	Top Priority	
					Now	After 2020
on on-site manufacturing		well underway in the United States.	the United States.	programs are generally weak in this respect.		
• 3.1.3: Scale manufacturing capacity: *increase production volume*			1 State-supported progress in Iowa (TPI) and Colorado (Siemens, Vestas).	8 Public-private collaboration needed; no federal emphasis to date.		
• 3.1.4: Improve supply chain efficiency through cross-industry synergies			5 IACMI provides a good example.	4 Ohio provides a good state model; federal emphasis is needed.		
3.2: Develop Transportation, Construction and Installation Solutions						
• 3.2.1: Develop transportation best practices		Individual firms have done this for their own proprietary use.	This is generally felt to be in AWEA's purview.	Publicly available best practices for regional, state, and county transport would reduce wind costs.		
• 3.2.2: Develop innovative transportation, construction and installation technologies		Good examples for towers (two federal projects underway).	6 Project opportunities exist. Industry activity level is unknown.	3 Blade work is lacking (canceled federal projects).	X	
3.3: Develop Offshore Wind Manufacturing and Supply Chain						
• 3.3.1: Establish offshore wind deployment levels sufficient to sustain the supply chain			Too early to score, but no cause for alarm at this point.			
• 3.3.2: Support *offshore*			Early industry work			X

Action		Good	On Track	Poor	Top Priority	
					Now	After 2020
manufacturing supply chain development and use			underway.			
• 3.3.3: Create a network of U.S. port facilities			Too early to score, but no cause for alarm at this point.			

Additions to the original worksheet actions text are *indicated in italics*
Numerical entries indicate the number of participants placing the action in this category.

Table 11. Supply Chain, Manufacturing and Logistics Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
3.1: Increase Domestic Manufacturing Competitiveness						
• 3.1.1: Conduct competitiveness assessments						
• 3.1.2: Develop innovative manufacturing technology						
• 3.1.3: Scale manufacturing capacity						
• 3.1.4: Improve supply chain efficiency through cross-industry synergies						
3.2: Develop Transportation, Construction and Installation Solutions						
• 3.2.1: Develop transportation best practices						
• 3.2.2: Develop innovative transportation, construction, and installation technologies						

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
3.3: Develop Offshore Wind Manufacturing and Supply Chain						
• 3.3.1: Establish offshore wind deployment levels sufficient to sustain the supply chain						
• 3.3.2: Support manufacturing supply-chain development and use						
• 3.3.3: Create a network of U.S. port facilities						

Table 12. Working Session on Supply Chain, Manufacturing, and Logistics
Wednesday Afternoon, June 22, 2016
Confirmed Participants

Todd Bell	Mortenson
David Dieter	Midstate Precast
Kirk Morgan	BARR Engineers
Patrick Fullenkamp	Great Lakes Wind Network (GLWN)
Sri Sritharan	Iowa State University
Derek Berry	NREL
Tyler Stehly	NREL
Christopher Mone	NREL
Jason Cotrell	NREL
Brian Naughton (remote)	Sandia National Laboratories Albuquerque (SNLA)
Eric Smith	Keystone Towers
Megan McCluer	DOE
Ed DeMeo	Renewable Energy Consulting Services

Table 13. *Wind Vision* Roadmap: Status and Update
Working Session on Supply Chain, Manufacturing, and Logistics
June 22, 2016

Agenda		
1:00 p.m.	Introductions and Session Overview; Discussion Ground Rules	Ed DeMeo, RECS, Inc.
1:15 p.m.	Roadmap Purpose and Motivation: 2015 Baseline Actions	Ed DeMeo
1:30 p.m.	Are revisions needed: additions, deletions, gaps, other changes	All
2:30 p.m.	Are the right organizations and people involved? Should others be engaged? Who?	All
3:15 p.m.	Break	
3:30 p.m.	Are needed actions being addressed? To what extent? Which are highest priorities now and after 2020? Are any of marginal importance?	All
4:30 p.m.	Are there areas of particular concern?	All
5:00 p.m.	Follow-up Plans	Ed DeMeo
5:15 p.m.	Adjourn	

2.4.2 Supply Chain, Manufacturing, and Logistics: Supplemental Input from Turbine Manufacturers and Project Developers

On October 4, 2016, a conference call was held with turbine manufacturers and project developers to discuss supply chain, manufacturing, and logistics issues from the *Wind Vision* Roadmap.

Participants were:

- Kevin Deters, Pattern Energy
- Stephen Johnson, GE
- Brian Choy, Vestas
- Megan McCluer, DOE
- Ed DeMeo, RECS.

2.4.2.1 Discussion Highlights

- Project developers are only indirectly connected to manufacturing and supply-chain considerations. They rely on the turbine manufacturers to manage the

supply chain. However, project developers do directly influence—and are directly affected by—logistics considerations.

- National policy and standards on wind equipment transport—including permitting and routing considerations—would provide a substantial benefit. Current variations in transport requirements from location to location cause a significant burden and excess costs. Policy support on FAA height restrictions for the newer taller towers also would be welcomed. It is estimated that applying current procedures to structures reaching more than 500 feet vertically adds about a year to project-development time. In most cases, developers instead opt to make the structures less than 500 feet tall and accept the resulting lower performance.
- In the offshore arena, repurposing of coastal manufacturing and logistics facilities makes good sense. The long-term viability of the offshore market is not assured, however, which limits private investment. Very substantial opportunities still exist on land in the United States.
- In addition to *manufacturing* standards for wind components, *engineering* standards also are needed.
- There is no incentive to design or manufacture for recyclability. There also is no economic driver to investigate how to recycle turbines retiring now or in the near future. However, significant work in turbine and component life extension is beginning.
- Today, the majority of power-electronic equipment is imported—not just for wind power, but for many sectors that in aggregate far exceed the size of the wind business. There likely would be no advantage in increasing domestic production of power-electronic equipment—either for wind power alone or for all uses. This is a cost issue; foreign manufacturers can supply this equipment at lower cost than domestic industry.
- Domestic manufacturing of large, heavy items—such as hub castings—would be beneficial. So far, the U.S. casting industry has not entered this business in volume—because of policy and demand uncertainty. In contrast, China has invested in such production facilities.
- Items such as towers that require large quantities of steel generally use domestic steel. Imported steel could cost less, but current import tariffs make it uneconomic. If tariffs were reduced, lower-cost imported steel might be used, resulting in lower wind costs. The steel-tariffs issue, however, transcends the wind business.
- The trend toward larger components is driving interest in on-site manufacturing. However, the comparative economics with other alternatives need careful examination. On-site labor costs could be as much as double those of a dedicated manufacturing facility. Maintaining suitable environmental conditions for manufacturing (e.g., appropriate temperatures) also could be challenging.

- Considering these challenges, it might be more cost-effective to focus on means to ease transport of large components. Europe successfully transports larger components than those found in the United States.
- The European wind industry has been driven to larger turbine sizes in part because plant construction is more challenging there than in the United States. As an example, the construction time for a 200-MW wind plant in the United States might be about 10 months. In Europe, it could be 2 to 2.5 years, because this plant—affected by land constraints—actually would be 10 to 20 smaller installations. The desire to reduce the number of smaller installations—and thus total construction time—requires getting as much capacity as possible from each installation. This, in turn, drives the industry toward taller and larger machines. Those drivers are a lesser concern in the United States.
- Government-supported R&D in manufacturing would be helpful in areas such as:
    - Automation of blade manufacturing, where the labor component is large
    - Weight reduction for all major components
    - Taller towers, including manufacturing, assembly, and logistics.

2.5 *Wind Vision* Roadmap—Status and Update: Working Session on Siting and Permitting

The Working Session on Siting and Permitting was held on June 23, 2016, at NREL's National Wind Technology Center, 18200 Colorado 128, Boulder, Colorado, 80303.

2.5.1 Summary of Major Discussion Points

As the density of wind development increases, particularly in highly populated regions of the nation such as parts of the Midwest and the Northeast, public resistance to new wind installations is increasing. The parties fighting development of any kind near where they live or vacation, along with the spokespeople for conventional energy interests, are playing a stronger role in local forums deliberating the fate of proposed new wind power projects. Hence, there is a growing need for outreach to the general public and local permitting officials to present a comprehensive picture of wind's benefits and impacts relative to other energy options, and to ensure effective stakeholder engagement during the development process for individual projects. Dispelling myths such as those based on rumored health effects of wind development is a key need. Government organizations are perceived as credible and authoritative sources of information on energy options, so these organizations should take a lead in conducting the needed outreach.

This message is supported by several of the discussion highlights below and by the subsequent Revised Actions Worksheet. Representation from the distributed-wind and offshore-wind communities was minimal, therefore these highlights primarily reflect perspectives of those involved with land-based utility-scale wind installations.

2.5.1.1 Discussion Highlights

- The session began with a discussion of overall reactions to the siting and permitting actions included in the Roadmap. Several participants commented that

the list of actions is comprehensive. Others agreed but recommended that the actions be prioritized. The issue of priorities was addressed later in the session and is discussed below.

- Public concerns with siting are likely to increase as installation rates increase. These concerns soon might become prominent in the central and eastern regions of the nation. For example, the development densities in Iowa and Indiana are becoming significant. Public resistance is likely to increase as the density of development grows. Some expressed the view that environmental issues associated with objections by humans (e.g., visual, sound, or health impacts) are harder to address than such issues associated with wildlife impacts. Some participants also commented that public opposition sometimes is related to the project itself and not to any specific issue. In those cases, opponents will latch onto any convenient environmental concern and then move to another once the current concern has been laid to rest.
- The wind development community has learned the importance of dealing carefully and sensitively with community relations. Nonetheless, some developers still have not grasped this message. Poor community-engagement practices cause significant problems for the industry in general, leading to a need for recommended stakeholder-engagement practices and broad education of the development community on adherence to these practices.
- A recurring theme emerged on the issue of how the DOE Wind Program can be most helpful in siting and permitting—particularly on federal lands. Many participants commented that agency-to-agency communication within the government is the most effective contribution. Examples offered include DOE to FAA, which has facilitated progress with lighting requirements and radar issues; DOE to BOEM, which has facilitated progress with offshore leasing and communication with stakeholders; and the Interagency Field Test and Evaluation (IFT&E), which brought together DOE, DOD, FAA, and the DHS to begin to quantify and address radar impacts, and has led to the Interagency Wind Turbine Radar Interference Mitigation Working Group (WTRIM WG). In some cases, different agencies have conflicting goals or requirements. Interagency working groups can be helpful in identifying and resolving issues arising from such conflicts.
- In general, the wind industry tends to avoid prospective development on public lands—owing to the relative difficulty of the permitting process and the resulting increases in development time, costs, and uncertainty. In view of DOE's successes in collaborating with FAA and BOEM, some asked why DOE hasn't become more connected with the Bureau of Land Management (BLM). It became clear that a main reason is that the industry has historically given a low priority to development on BLM lands, as opposed to a high priority industry-wide on lighting and radar issues, and priority on offshore for a segment of the industry. DOE tends to focus on agency interactions that correlate with industry priorities, so if wind developers placed a higher priority on public lands then DOE would likely engage with BLM to a greater extent. To a large degree, this is a chicken-

and-egg problem. Should the industry first demonstrate more interest in development on federal lands, or should DOE first expand interactions with BLM to facilitate project development on these lands? It was pointed out, however, that the fraction of developable wind resource in the nation associated with BLM lands is not well understood. Some suggested it is less than 10%, but this was disputed by others. At present, about 1.3% of all installed capacity is on public lands.

- Some participants commented that an appropriate role for federal and state government programs is to produce maps with suitability rankings for development. Such maps would indicate factors that restrict or exclude development, or would otherwise challenge development efforts. These maps are most useful to state and local planners and agency personnel who are assessing wind's potential on a macro level for their regions. They can also be useful to developers at an early stage, but can't include local-level details that become critically important as development efforts advance. Experienced project development teams are adept at finding this detailed information—more information than can be gleaned from any map. The great majority of government involvement in siting and permitting is related to the permitting process at the local level, with minimal if any role for state and federal government.
- The Roadmap includes an action to develop a model deployment framework (6.4.2) and another to support pre-screening efforts (6.5.1) that involves assessment tools. Participants acknowledged that the private sector already can meet these needs effectively, and that proprietary capabilities sometimes offer a competitive edge. Hence, government support of these actions is likely to be unnecessary. Conversely, one participant pointed out that BOEM and DOE have carried out similar actions to assist with offshore development. That process seems to have been effective and well received by prospective offshore developers, so it might also be appropriate for use with federal lands.
- A concern was expressed that in some cases permit issuance is handled by the same individuals or groups whose function it is to protect a particular location, animal, plant, or other feature. Participants would prefer that permitting be handled by people whose job is simply to deal with permits and who are not connected with any specific protection issue. The BLM Renewable Energy Coordinating Office was mentioned as a good example. The aim is to allow the most objective decisions possible.
- A concern was expressed about inconsistencies within agencies among national and regional offices and local chapters. In some cases, the national office develops and recommends a supportive position with respect to some siting consideration, but local chapters or field offices do not accept that recommendation. In such a case, federal program engagement with the national office is insufficient; sensitive engagement with specific local offices also might be needed.
- In general, the group believes that most of the agencies, organizations, and other entities with a role in wind siting and permitting are appropriately engaged;

however, others could be brought in to a greater degree. The BLM was mentioned again in this context, but the point raised previously is again relevant. Expanded outreach to Western Area Power Administration (WAPA) also was recommended, particularly regarding transmission siting. Along these lines, participants encouraged DOE to exercise to a greater degree its backstop authority under the Energy Policy Act of 2005 (EPAct 2005). Another sector mentioned in the discussion was Native American tribes; however a long-standing concern was raised: Contractual agreements reached with tribes can be canceled a year or two later when the tribal council membership changes.

- Another group that could be helpful in facilitating siting and permitting approval is the corporate buyers of wind energy that are becoming more prominent as an emerging and significant market segment—including Google, Apple, Amazon, Walmart, and others. Some of the early purchases of clean power were pursued primarily for public-relations purposes. These corporate players have moved well beyond that initial phase, however, and now want substantial amounts of clean energy to achieve corporate goals aimed at environmental responsibility. To acquire clean energy, such companies need suppliers to be successful at securing permits within reasonable time frames and with reasonable costs. Hence, they might be willing to help tell the "wind story" to permitting agencies and others as a means toward securing agency, nongovernmental organization (NGO), and public support.
- On the issue of outreach in general, participants strongly emphasized the importance of ongoing and expanded efforts to communicate widely the entire "wind story", including facts about its benefits without ignoring negative impacts. The group recommends a strong federal role in outreach. The industry also needs to be heavily involved, although the perceived objectivity of the government program provides a major advantage in communicating with entities and segments of society that are skeptical about wind power.
- A specific area where authoritative outreach is needed is health effects of wind power. Health Canada has conducted a study of wind's health effects, and the group discussed whether the U.S. Government should conduct such a study for wide distribution. The group reacted positively to this suggestion and recommended engaging the National Academy of Sciences (NAS) as an appropriate and credible entity for this activity. Because a great deal of work already has been done on this topic, much could be accomplished with a meta-analysis. Although additional insights might emerge from continued study, most parties expressed the view that little new original work is needed.
- There can be confusion about the meaning of the term "mitigation." It was agreed that the definition used by the U.S. Fish and Wildlife Service (FWS) should be used. The FWS defines **mitigation** to include **avoidance, minimization, and compensatory mitigation**. Historically, this term only included the last of these three actions. The *Wind Vision* Roadmap text should be modified to clarify the use of these terms.

- There was little discussion of actions related to distributed wind. Distributed wind applications span a broad range—from local installations addressing the electricity needs of a commercial or industrial customer with one or more megawatt-scale turbines, to residential installations with kilowatt-scale turbines. Although a few of the participants are engaged in the distributed wind arena, most are not. The sense of the discussion was that the prospective contributions of distributed wind are small relative to mainline utility-scale wind. However, this sense is likely based on the kilowatt portion of the distributed wind spectrum. To obtain a more informed perspective on distributed wind topics, the group recommended referring to the distributed wind community for inputs on the roadmap's distributed wind actions.[‡]
- The session closed with a discussion of priorities for siting and permitting actions. Most participants indicated that action groups 6.1, 6.3, and 6.4 are high priority now, with 6.3 and 6.4 needing the most attention. Some commented that actions 6.3.3 and 6.4.2 might be exceptions, as discussed above and in the Revised Actions Worksheet.

[‡] Subsequent to this working session, DOE/NREL released a major new analysis of distributed wind: *Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects*; available at https://energy.gov/sites/prod/files/2016/11/f34/assessing-future-distributed-wind.pdf

Table 14. Siting and Permitting Actions *Wind Vision* Roadmap
Revised Actions Worksheet—June 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
6.1: Develop Mitigation Options for Competing Use Concerns (e.g., radar, aviation, marine shipping, and navigation)					X	
• 6.1.1: Develop better understanding of wind turbine and radar interactions		LB 8 OSW Much progress for LB; ongoing government agencies' involvement needed.	6 OSW at early stage but on track.			
• 6.1.2: Reduce potential wind turbine and radar interactions		LB	9 LB progressing, but still see curtailments; much preliminary testing underway; good cooperation with FAA.	Too soon to evaluate for OSW, but some international experience exchange is underway.		
• 6.1.3: Address issues of aircraft safety and public perception		LB Adherence to FAA requirements is straightforward; radar-activated lighting is a helpful advance.	7 Taller turbines might require additional attention; emerging lighting and marking issues need to be			

Action		Good	On Track	Poor	Now	After 2020
			addressed.			
• 6.1.4: Alter existing or design new shipping routes*; address in the context of integrated ocean use planning*		OSW		6 Agencies have been inconsistent (e.g., BOEM, Coast Guard); need better understanding of relative risks.		
6.3: Develop Information and Strategies to Mitigate the Local Impact of Wind Deployment and Operation. *Mitigation includes avoidance, minimization, and compensatory mitigation*					X	
• 6.3.1: Document and disseminate public information on public impact		Documentation efforts have been extensive and successful.	Documentation is on track.	Dissemination (including uptake) is poor. Much active outreach—multigenerational and multimedia—is needed. NAS meta-study is recommended.		
• 6.3.2: Develop mitigation strategies		LB 1 Individual developers range from Good to On Track. Major developers generally handle this effectively.	5 Much regional variation; science has been developed.	1 More could be done.		
• 6.3.3: Establish a funding pool for public impact research		Much of the science has already been developed.	Ongoing analyses likely to add insights on human	What *is* needed is outreach (6.3.1).		

Action		Good	On Track	Poor	Now	After 2020
		This is not a high priority.	impacts.			
• 6.3.4: Continue monitoring public impact		LB	6 Some monitoring work is ongoing (e.g., an existing LBNL project). Comparing public attitudes both before a project is built and after it has become established would be valuable.	2+ More could be done. For example, wind impacts relative to other energy sources could be assessed.		
6.4: Develop Clear and Consistent Regulatory Guidelines for Wind Development					X	
• 6.4.1: Encourage regulatory process for wind development on federal lands		LB		7 Minimal industry and government attention to this; perceived barriers need to be addressed.		
• 6.4.2: Create a model deployment framework		Proprietary deployment frameworks are well-developed in the private sector for LB wind. This action is generally not needed for LB wind, but might be helpful with federal lands.	This tool would not get down to the local level, where there is much variation and where much of the effort is needed.	Some indicated that BOEM and DOE have developed a similar framework for OSW, and suggested doing this to facilitate development on federal lands.		
• 6.4.3: Create a streamlined leasing and permitting		OSW	6 BOEM making good	Need better interface between BOEM and other		

Action		Good	On Track	Poor	Now	After 2020
process for offshore wind			progress; process working well.	agencies such as the Coast Guard.		
• 6.4.4: Increase available sites to accommodate growth of offshore wind		OSW 4 14 GW already available.	3	Next round of sites (BOEM 2.0) will be a challenge; some states have not been receptive to OSW wind development.		
• 6.4.5: Implement a consistent, streamlined permitting process for distributed wind				Process not yet developed; recommend approaching the distributed wind community.		

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
6.5: Develop Wind Site Pre-Screening Tools						
• 6.5.1: Develop verified tools to support wind turbine siting and assessment		Good visual simulation tools exist. Project developers generally screen effectively with available tools—some proprietary; primarily industry responsibility.	9 Sound-level estimation is more difficult than visual simulation; new tools would be helpful. AWEA's Wind Siting Handbook offers a good starting point.			
• 6.5.2: Investigate challenging siting issues for complex or unique siting locations			Generally viewed as a lower priority.			
• 6.5.3: Develop offshore wind spatial planning tools and methods		OSW 1	5 BOEM process progressing well.			
• 6.5.4: Provide analysis and modeling tools for offshore wind *(e.g., radar)*		OSW	7			
• 6.5.5: Develop distributed wind resource and modeling tools				Recommend approaching the distributed wind community.		
• 6.5.6: Reduce the cost of distributed wind assessment and analysis tools				Recommend approaching the distributed wind community.		

Additions to the original worksheet actions text are *indicated in italics* LB: land-based wind OSW: offshore wind
Numerical entries indicate the number of participants placing the action in this category.

Table 15. Siting and Permitting Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
6.1: Develop Mitigation Options for Competing Use Concerns (e.g., radar, aviation, marine shipping, and navigation)						
• 6.1.1: Develop better understanding of wind turbine and radar interactions						
• 6.1.2: Reduce potential wind turbine and radar interactions						
• 6.1.3: Address issues of aircraft safety and public perception						
• 6.1.4: Alter existing or design new shipping routes						

Action		Good	On Track	Poor	Now	After 2020
6.3: Develop Information and Strategies to Mitigate the Local Impact of Wind Deployment and Operation						
• 6.3.1: Document and disseminate public information on public impact						
• 6.3.2: Develop mitigation strategies						
• 6.3.3: Establish a funding pool for public impact research						
• 6.3.4: Continue monitoring public impact						
6.4: Develop Clear and Consistent Regulatory Guidelines for Wind Development						
• 6.4.1: Encourage regulatory process for wind development on federal lands						
• 6.4.2: Create a model deployment framework						
• 6.4.3: Create a streamlined leasing and permitting process for offshore wind						
• 6.4.4: Increase available sites to accommodate growth of offshore wind						
• 6.4.5: Implement a						

Action		Good	On Track	Poor	Now	After 2020
consistent, streamlined permitting process for distributed wind						
6.5: Develop Wind Site Pre-Screening Tools						
• 6.5.1: Develop verified tools to support wind turbine siting and assessment						
• 6.5.2: Investigate challenging siting issues for complex or unique siting locations						
• 6.5.3: Develop offshore wind spatial planning tools and methods						
• 6.5.4: Provide analysis and modeling tools for offshore wind						
• 6.5.5: Develop distributed wind resource and modeling tools						
• 6.5.6: Reduce the cost of distributed wind assessment and analysis tools						

Table 16. Working Session on Siting and Permitting
Thursday Morning, June 23, 2016
Confirmed Participants

John Anderson	AWEA
Ian Baring-Gould	NREL
Sam Enfield	MAP Royalty
Patrick Gilman	DOE
Ben Hoen (remote)	LBNL
Ben Karlson	SNLA
Bryan Miller	SNLA Contractor
Suzanne Tegen	NREL
Jim Walker	EDF RE
Theresa Weber	RES Americas
Maggie Yancey	DOE
Ed DeMeo	RECS
Jocelyn Brown-Saracino	DOE
Raphael Tisch	DOE

Table 17. Wind Vision Roadmap: Status and Update
Working Session on Siting and Permitting
June 23, 2016

Agenda		
8:15 a.m.	Introductions and Session Overview; Discussion Ground Rules	Ed DeMeo, RECS, Inc.
8:30 a.m.	Roadmap Purpose and Motivation: 2015 Baseline Actions	Ed DeMeo
8:45 a.m.	Are revisions needed: additions, deletions, gaps, other changes	All
9:45 a.m.	Are the right organizations and people involved? Should others be engaged? Who?	All
10:30 a.m.	Break	
10:45 a.m.	Are needed actions being addressed? To what extent? Which are highest priorities now and after 2020? Are any of marginal importance?	All
11:45 a.m.	Are there areas of particular concern?	All
12:15 p.m.	Follow-up Plans	Ed DeMeo
12:30 p.m.	Adjourn	

2.6 *Wind Vision* Roadmap—Status and Update: Working Session on Wildlife and Wind Power

The Working Session on Wildlife and Wind Power was held June 23, 2016, at the NREL National Wind Technology Center, 18200 Colorado 128, Boulder, Colorado, 80303.

2.6.1 Summary of Major Discussion Points

Over the past two decades, a great deal has been accomplished in the wind-wildlife arena. The number of species providing cause for concern has been reduced considerably, and the wind and wildlife community is focused on the handful of species that are of concern. The wildlife narrative in the *Wind Vision* Roadmap, however, tends to convey a negative impression within the otherwise very positive *Wind Vision* story. Participants in this working session encouraged the wind community and others in the energy sector to provide context for the wildlife discussion that includes the entire spectrum of wind's environmental impacts—both positive and negative—and that also describes those impacts relative to the environmental impacts of all energy generation technologies. Without this holistic view, it is not possible for policy makers and the public to fully understand wind energy's lifecycle impacts in comparison to other forms of generation.

Participants also encouraged the formation of a public-private funding approach to support accurate, peer-reviewed science that enables timely resolution of the major remaining issues associated with the wind and wildlife intersection. Acceptance of that science and incorporation into relevant policy is essential.

2.6.1.1 Discussion Highlights

- In general, participants think that the Roadmap's wildlife-related actions—to the extent they are defined—are appropriate and cover the range of needed activity. The action descriptions, however, tend to bundle species to a level that masks important distinctions. For example, many species of bats interact with wind farms, but there are significant differences in their population levels, behavior and impacts—and therefore in the level of concern. Additionally, impacts with wind turbines appear to be a concern for only a few bat species. Eagles impacted includes both golden and bald. The risks to each of these and the corresponding management issues are different. Clarification along these lines should be added to the Roadmap text.
- In contrast with the generally positive *Wind Vision* story, the wildlife coverage is somewhat negative. Participants suggested augmenting the wildlife narrative in the Roadmap to provide context for the wildlife section as one part of a balanced story on wind power's impacts of all types. It is important to recognize that all generation sources impact wildlife to some degree, and that the wind power industry is proactively pursuing methods to identify, avoid, reduce, and mitigate wind's impacts. Additionally, because wind does not emit carbon or other pollutants and uses no water during operation, it provides many advantages not offered by traditional generation options. The messages in the earlier chapters of the *Wind Vision* report (DOE 2015) should also be reviewed from this perspective.
- Over the past two decades, a great deal of progress has been made on the wildlife front. Through extensive data collection and numerous analyses, the range of uncertainty has narrowed, and attention is focused on those relatively few species for which concern remains. Recognition of this fact could counter some of the concern about negativity mentioned in the bullet paragraph immediately preceding this one. Participants suggested preparing a "scorecard" of successes to date and summarizing what has been learned about impacts and mitigation measures. One related idea discussed is to conduct a workshop to develop this scorecard, and also to identify the issues still needing focused attention. As one broad example of progress resulting from industry experience, it was mentioned that there has been no second Altamont.
- Participants underscored the importance of evaluating wind's impacts on wildlife relative to the broad range of environmental benefits of wind, such as slowing climate change and improved air quality. One participant commented that we find birds that have been struck by a wind turbine blade, but we usually don't find those that have succumbed to air pollution.

- Participants also underscored the need to conduct a comparative analysis of the wildlife impacts from all energy technologies. This action is included generally in the Policy Analysis section of the Roadmap (which calls for a comparative analysis of all benefits, costs, and other impacts), but should be included here with a focus on wildlife. This also would help in addressing the negativity concern mentioned above.
- Though not specifically the topic of this session, several of the points listed above and much of the group's discussion underscore the need for outreach on many levels to tell the comprehensive story about wind's benefits, costs, other impacts, and needs. This requires active, sustained participation by government programs, as well as the NGO and private sectors. Although some of this activity is ongoing, much more is needed. The wind community was encouraged to use mass media, as the traditional energy sectors have successfully done.
- Wildlife-related uncertainties should be categorized by their relative risk of impacts. The community should then focus on those with the most serious impacts. For example, it is generally recognized that songbirds do not represent a major concern; population impacts from wind have not been found. Hence additional related research is not a priority. Conversely, specific species of bats—and in some cases golden eagles—have become a concern, therefore continued research to address issues with these species is a high priority. A related suggestion is to focus on those uncertainties for which resolution could enable the greatest amount of wind development. This would include grouse species such as sage grouse and lesser prairie chickens, because these are found in high-wind areas.
- Much concern was expressed that the relative importance of risk level is not understood in many cases. For example, with bats, mortality has been studied, but there has been little if any success in understanding whether the risk is at a population level. Hence the significance of the observed mortality is not clear. This issue led to a discussion—with no clear resolution—of whether resources should be focused on reducing mortality or instead on studying whether population impacts are occurring—and then concentrating on management mechanisms likely to be most effective in reducing the impacts.
- One participant emphasized that our understanding of interactions and risks is largely retrospective; we are beginning to understand the risks posed by past wind-energy technology that is in the ground now. As the technology evolves, with taller towers, longer blades, and wider spacing, the risks are likely to change as well—for example, low-flying species could become less affected and higher fliers could become more affected. Will this make future wind projects easier or harder to permit in areas with wildlife concerns today? Will different types of minimization be required than those that work today? The *Wind Vision* Roadmap also should look forward to addressing research needs retrospectively.
- Participants commented that a great deal of relevant wildlife-related data exist that are held confidentially by consultants and individual wind companies. The group suggested that some organization (a national lab, for example) collect these

data, analyze it, anonymize the results to remove proprietary concerns, and then make the results public. The consultants and wind companies should be brought into this effort as active participants. The inference is that such a process would significantly reduce uncertainties in some cases. The American Wind Wildlife Information Center database of pre- and post-construction studies is a step in the right direction.

- The Roadmap should clarify how the term "mitigation" is used in the *Wind Vision* report. In general, the wildlife community has adopted the definition employed by the U.S. Fish and Wildlife service: mitigation includes avoidance, minimization, and compensatory mitigation. In the past, the term sometimes included only the last of these three.
- With respect to compensatory mitigation, one participant expressed the view that it is not possible to breed bats. The implication is that providing alternative breeding opportunities for bats by creating or preserving habitat is not an appropriate compensatory-mitigation option. Others questioned this view on the basis that little related research has been conducted, thus this issue is unresolved. Investment in related research is needed to identify effective compensatory-mitigation opportunities for bats.
- The Roadmap's wildlife section does not include technology development that could be instrumental in reducing impacts. Several examples were suggested, including acoustic or visual deterrents to help eagles and other raptors and bats avoid turbines; tailored curtailment for bats, eagles, and raptors through use of radar or other sensors; development of a bat-friendly turbine; development of bird-friendly glass (for compensatory mitigation); and remote-sensing equipment to aid in wildlife studies.
- Development of technology to reduce impacts is a rapidly evolving endeavor that deserves significant investment. Projects involving biologists, engineers, and other experts are being initiated. Investment in these technologies is underway worldwide and should be expanded, including third-party evaluations of the effectiveness of the technologies. Experts anticipate that these technologies will become available as features incorporated into future wind turbines.
- In further discussion of the role of technology advancement in mitigation of wildlife impacts, participants emphasized the importance of pursuing advancements that actually reduce the identified impacts. As one example, the transition from lattice to tubular towers helped reduce raptor mortality by reducing perching opportunities. The push toward turbines designed for sites with lower winds, however, could increase the risk to bats, because curtailment at low wind speeds currently is the only readily available, cost-effective mitigation measure. The value of this measure would be greatly diminished if operation needs to be curtailed when wind speeds are in the range for which the turbine has been designed.
- Participants feel that the key need in the wildlife arena is to continue to develop a funding base to support the research needed to reduce uncertainties. These funds

could come from both industry and government sources. One idea proposed is to seek industry contributions based on the expectation that resolution of wildlife issues will open up substantial additional territory for wind development and reduce the legal risks associated with wildlife impacts during operation. Another is to approach corporate buyers of wind energy who have become serious about powering their operations with clean energy. To meet their objective of environmental responsibility, companies need assurance that the wind energy they purchase comes with minimal negative environmental impacts and will not be unduly impacted by wildlife-related curtailment. Additionally, these corporate buyers could be instrumental in encouraging legislators to provide sustained public funding contributions for the needed work. One participant pointed out that, similar to the approach of the wind industry, the solar industry has begun noting potential siting concerns and is approaching all relevant federal agencies to coordinate and collaborate in addressing solar power's environmental issues. Finally, it was generally recognized that the best way to ensure a long-term strategic funding commitment is to have a well-organized plan.

- Although effective mitigation tools exist or are under development that could be applied in specific cases, current policy does not allow for—or provide incentives for—their use. Application and effectiveness still are being addressed, resulting in reluctance among industry and regulatory agencies to use these tools. Some of the mitigation practices, such as curtailment during specific periods, are still coarse in their application and are actually dis-incentivized because of lost revenue. Participants feel that policy incentives should be developed that encourage the use of mitigation measures.
- Another important question is this: What level of impact reduction associated with deterrent technologies will be sufficient to avoid the need to obtain permits? This in turn would drive investment in the development of these technologies, and subsequently in their application. For example, there is a difference between (a) reducing impacts to common bat species because it is the responsible thing to do, and (b) trying to avoid 95% impacts to federally protected species to avoid the need for formal legal protection. Cost and perceived cost effectiveness also are factors in gaining acceptance of measures.
- It was noted that to conduct field studies to evaluate the effectiveness of mitigation measures, wind facilities hosting tests would need legal protection from potential enforcement related to the incidental loss of federally protected species associated with the studies. Additionally, the process to obtain a standard Eagle Take Permit or Endangered Species Act Incidental Take Permit takes a year or more—creating the necessity to develop alternate mechanisms (e.g., research permits or interagency memorandums of understanding).
- Understanding of offshore wind's wildlife impacts is at a very early stage. BOEM, DOE, and others have successfully conducted impact assessments for proposed offshore plants, but validation awaits actual experience. Also, as installation moves further offshore, impacts on birds and bats are likely to diminish in importance. The focus then will shift toward other species, such as

marine mammals and sea turtles. Today, very little is known about impacts on these species; but efforts to understand them are likely to assume a higher priority over the next 5 to 10 years.

Table 18. Wildlife-Related Environmental Impacts Actions *Wind Vision* Roadmap
Revised Actions Worksheet—June 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
6.2: Develop Strategies to Mitigate Siting and Operational Impacts (wildlife-related). *Mitigation covers the full range of avoidance, minimization, and compensatory mitigation. Where possible, avoidance is preferred.*						
• 6.2.1: Improve understanding of interactions between wind energy, wildlife and their habitats—*including the relative risks of these interactions*		Moderate understanding of impacts in some regions with wind development. Potentially significant levels of impact observed with respect to certain bat species (migratory tree bats), but others seem less impacted; total issue not well understood at present. Avian impacts have been narrowed down to a few		Little understanding of whether or why certain bat species are attracted to wind installations. To the extent they are attracted, the impacts on the bats are poorly understood. There is minimal data on which to base scientific studies. For offshore wind, there is no information yet in the United States to assess the status of this action, but European	X	

Action		Good	On Track	Poor	Now	After 2020
		species. And, so far, no population impacts have been found. AWWI has produced a document summarizing this status.		experiences can likely provide significant guidance. Little is known about impacts on species other than birds and bats. There is some experience with black bears in New England, and perhaps other species.		
• 6.2.2: Develop strategies to reduce wildlife impacts, *including avoidance, minimization, and compensatory mitigation*		Operating procedures to reduce impacts on bats have been successful for certain species in some locations (e.g., curtailment at low wind speeds), but the economic impact of these procedures varies considerably from site to site. Incentives to implement these procedures are lacking and are needed.	Deterrents for bats are under development and progressing. "Smart" curtailment strategies are needed that minimize lost revenue. For avian species of concern, such as eagles, work is underway to avoid problematic sites, and to develop detection and deterrent systems. Alternative	Compensatory mitigation measures for bats have not been identified.	X	

Action		Good	On Track	Poor	Now	After 2020
			compensatory mitigation methods for golden eagles show promise; funding for method validation is needed and is not assured.			
• 6.2.3: Develop a funding pool for wildlife research				Substantial additional funding is needed for FY 2017, and annually for the next several years. Long-term commitments from government and industry sources are needed.	X	
• 6.2.4: Perform strategic assessment of offshore wind environmental impacts		BOEM, DOE, and several states have given this high priority. Much has been accomplished; this work needs to be continued.		Techniques for assessing impacts are needed, such as integrative detection systems based on strike indicators, thermal video, or acoustic detectors.		
• 6.2.5: Continue monitoring environmental impacts; *include ongoing assessment of opportunities and risks*		Industry following through on this, at least to the extent required by regulators; addresses issues that arise.	Much data has been collected; analysis is underway; this could result in a "report card" on what is known and what has been accomplished. Ongoing support for this work is needed.	Investment in impacts of wind on various species of prairie grouse is needed to determine impacts. Long-term impacts on bats are also minimally understood. Typically, only a very few years of data are		X

Action		Good	On Track	Poor	Now	After 2020
				collected. Little is known about offshore impacts. Research on construction and operations will grow in importance by 2020 as installations proceed offshore.		

Additions to the original worksheet actions text are *indicated in italics*

Table 19. Wildlife-Related Environmental Impacts Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
6.2: Develop Strategies to Mitigate and Minimize Siting and Environmental Impacts (Wildlife Related)						
• 6.2.1: Improve understanding of wildlife and habitat impacts						
• 6.2.2: Develop strategies to reduce wildlife impacts						
• 6.2.3: Develop a funding pool for wildlife research						
• 6.2.4: Perform strategic assessment of offshore wind						
• 6.2.5: Continue monitoring environmental impacts						

Table 20. Working Session on Wildlife and Wind Power
Thursday Afternoon, June 23, 2016
Confirmed Participants

Abby Arnold	AWWI
Bob Thresher	NREL
Crissy Sutter	Normandeau
Dale Strickland	WEST
David Stoms	CEC
Ian Baring-Gould	NREL
Jim Walker	EDF RE
Jocelyn Brown-Saracino	DOE
John Anderson	AWEA
Julie Falkner	Defenders of Wildlife (now U.S. Department of Interior)
Karin Sinclair	NREL
Kevin Kritz	USFWS
Mary Boatman	BOEM
Mona Khalil	USGS
Mylea Bayless	BCI
Patrick Gilman	DOE
Paul Cryan	USGS
Raphael Tisch	Allegheny Science and Technology
Sam Enfield	MAP Royalty
Taber Allison	AWWI
Ed DeMeo	RECS

Table 21. Wind Vision Roadmap: Status and Update
Working Session on Wildlife and Wind Power
June 23, 2016

Agenda		
1:30 p.m.	Introductions; Session Context and Overview; Discussion Ground Rules	Jocelyn Brown-Saracino, DOE Ed DeMeo, RECS, Inc.
1:45 p.m.	Roadmap Purpose and Motivation: 2015 Baseline Actions	Ed DeMeo
2:00 p.m.	Are revisions needed: additions, deletions, gaps, other changes	All
3:00 p.m.	Are the right organizations and people involved? Should others be engaged? Who?	All
3:45 p.m.	Break	
4:00 p.m.	Are needed actions being addressed? To what extent? Which are highest priorities now and after 2020? Are any of marginal importance?	All
5:00 p.m.	Are there areas of particular concern?	All
5:15 p.m.	Follow-up Plans	Ed DeMeo
5:30 p.m.	Adjourn	

2.7 *Wind Vision* Roadmap—Status and Update: Working Session on Workforce Development

The Working Session on Workforce Development was held on May 23, 2016,[2] during the Wind Workforce and Education Summit, at the Morial Convention Center, in New Orleans, Louisiana.

2.7.1 Summary of Major Discussion Points

Wind energy offers promising and rewarding career opportunities for Americans over a broad age group. Students at the high school and community college levels can enter the wind workforce as wind operating and maintenance technicians or as skilled-labor manufacturing and production specialists, and can move to more advanced levels with the appropriate level of training and education. Those in baccalaureate and higher college-level programs can engage in a wide range of engineering, research, business, policy, and legal endeavors in the wind industry. Additionally, those in other fields with diminishing opportunities might well find opportunities in the wind industry that can extend their careers for many productive years. Although these opportunities will expand in the coming years as clean, renewable energy moves to center stage, wind-energy career opportunities are unknown in many educational arenas and in much of the emerging and

[2] Most input for this topic was obtained during the May 23 session. This input was refined, augmented and assembled as key findings during follow-up sessions at the National Wind Technology Center on June 22, 2016, and September 27, 2016, attended by the authors of this summary of discussion points.

existing workforce. Both the wind industry and government programs should greatly expand their efforts to increase awareness of these opportunities. Most of these opportunities also are equally appropriate for all, irrespective of gender and national or cultural background. Hence, programs to publicize the career opportunities in wind power should strive to encourage diversity in the wind workforce.

2.7.1.1 Discussion Highlights

- The foundational question is: What are the wind industry's workforce needs, and what do we need to do in the United States to provide a highly qualified workforce? This question needs to be addressed for all skill levels—including, for example, operations and maintenance, manufacturing and construction, public and government relations, business development, technology advancement, and fundamental research. AWEA has a subcommittee addressing this question for some skill levels, but it has just begun to meet after a period of inaction. A few states—notably Texas and Iowa—have been effective at defining and coordinating career pathways related to wind energy through engagement of industry partners and federal financial support. This is not the case in most states.
- In general, most participants commented that much more needs to be done to better understand the industry's needs, translate those needs into appropriate educational programs, and communicate these needs and opportunities to prospective members of the wind workforce. Specific needs identified include prioritization to identify those jobs most in need of training or educational programs; diversification of the workforce to include more women and minorities, as well as veterans retuning to the workforce; and outreach to improve marketing about wind power as an attractive career opportunity.
- Amplifying the point brought up in the previous bullet that outreach to improve marketing about wind power career opportunities is necessary, participants believe that it is very important to increase marketing for wind energy as a career choice in which graduates can be highly successful. Many students don't see wind as a viable career option; some are even completely unaware of careers in the wind industry. For example, even though there are more new jobs in wind than in coal mining, wind jobs sometimes don't have the same level of national recognition as coal jobs. DOE provides scholarships for students studying coal and nuclear power, but similar programs do not exist for wind power.
- At the primary- and secondary-school levels, KidWind and Wind for Schools offer effective and successful programs. These programs, however reach a very small number of students and teachers. Several—but only a few—science museums have a strong energy focus that includes wind. Programs such as these provide effective education models and should be replicated much more widely. Many participants commented that it is vital to train teachers as well as students to have a broader reach. Expanded internship programs for teacher training within industry and at national laboratories should be implemented, including activities for K–12 teachers.

- More must be done in the primary-secondary space if the nation is to have a well-qualified future wind workforce. Lack of awareness and knowledge at the primary-secondary level is viewed as a significant deficiency. Effective curricula exist and are improving [National Energy Education Development (NEED) Project, KidWind, and WindWise], but standards for these programs do not exist. Funding for active teacher training is very limited, so very few students are being reached. Also, the ability to keep programs current is severely limited. Perhaps most importantly, information and outreach mechanisms to inform young people about the wind industry barely exist.
- Wind technician training standards are well developed in Europe. In the United States, AWEA has begun to address the need for standards, but so far it only has begun working on an introductory program (Wind Tech 1). A domestic certification process also is needed to ensure consistency across U.S. wind installations. A small number of very high-quality community college programs are operating in the United States. These provide good models that other schools can apply.
- Instructor and teacher training infrastructure is inadequate. The best training programs do have access to equipment, but not the newest technology. It is difficult for teachers to keep current on technology. The rate of teacher retention is low, in part because of low salaries. Participants suggested that industry could partially fund wind energy technician (and other) instructor salaries, like many other industries do, to retain teachers and instructors instead of losing them to industry.
- Education models are available, especially at the undergraduate level, with a handful of high-quality university programs in wind-related subjects. These programs primarily are aimed at the undergraduate level, but some also address the master's and Ph.D. levels. These programs provide effective models for prospective programs at other schools. The North American Wind Energy Academy could play a strong role in bringing successful program models to additional schools, but it is unfunded and thus unable to engage at the level required. The DOE-NREL Collegiate Wind Competition provides an effective activity to engage students and industry, but only impacts a very small number of students.
- Although good models for college-level wind-education programs exist in the United States, the number of such programs is viewed as inadequate to meet the emerging workforce needs of the wind industry. In contrast, many more of these programs have been established in Europe. A critical part of establishing programs is development of motivated faculty. These individuals play a key role in introducing wind to students and pointing out the attractive career opportunities offered by wind. Toward this end, it is important to build bridges between industry and the university community. Industry representatives can contribute by bringing their experiences to the classroom and by serving as mentors for both students and teachers. Industry also could provide internships for teachers and serve on local college and university advisory boards. Without focused efforts to

expand wind educational programs, students will be attracted to other industries that benefit from relevant educational programs that already exist.

- The group had a brief discussion of distributed wind actions included in the roadmap. These cover training and certification for distributed wind assessors, and formalized training for distributed wind installers. Participants believe attention to these actions is adequate at present, but primarily because the distributed wind industry is not yet sufficiently developed to need these efforts. The group expressed the concern that, should this industry become more robust in the future, the needed educational structure would not be in place. Participants recommended further discussion of these issues with others more closely involved with distributed wind.
- The group briefly discussed offshore wind education and workforce needs, but recommended additional engagement with experts in the offshore space. Wind industry leaders have training programs for new hires, but there is very little formal education and training for offshore wind occupations. Industry efforts seem to be adequate given the current state of the U.S. market, but the need is anticipated to grow as offshore wind takes hold in the United States. A proactive approach to offshore wind education needs could determine whether new projects in the United States use domestic labor and suppliers, or import the work from abroad. Good programs are in place in Europe that can serve as models for offshore wind education. In the longer term, this area is expected to require a much greater emphasis.
- The group expressed concern about the minimal level of diversity in the wind workforce; employment of women and minorities is seen as inadequate. Organizations such as Women of Renewable Industries and Sustainable Energy (WRISE, formerly Women of Wind Energy) have elevated the discussion of women in the workforce, and several other programs actively work to increase participation by minorities. But the current level of engagement is insufficient given the present situation and trends within the industry. A new roadmap action is recommended focusing on this need.
- The wind industry has lower than average diversity across the spectrum from primary school programs through employment. Even projects such as the Collegiate Wind Competition have very little racial, ethnic, or gender diversity. Efforts so far to expose wind-industry jobs more broadly to women and minorities have been very limited.

Table 22. Workforce Development Actions *Wind Vision* Roadmap
Revised Actions Worksheet—June 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
8.1: Develop Comprehensive Training, Workforce, and Educational Programs						
• 8.1.1: Develop a foundation for a national wind workforce		An AWEA sub-committee is developing good ideas and plans, but progress has been slow.	Some states have defined coordinated educational pathways and programs (e.g., Texas, Iowa) but most have not.	Analysis is needed to determine priorities—for example, which jobs need additional programs or training. Needs include workforce diversification and improved marketing about wind-power education and wind power as a career. Unified curricula have only been completed at the lowest level and are not nationally shared or practiced. Skill ladders (between jobs and schools) do not exist, making it hard to advance through schooling while working in the industry. There is very limited engagement with returning veterans. Barriers to this process exist and need to be eliminated.	X	

Action		Good	On Track	Poor	Now	After 2020
• 8.1.2: Develop robust wind education programs for primary and secondary schools			There is great work in this area by KidWind and Wind for Schools, but it reaches a very small number of students and teachers. Several science museums have a good energy focus that includes wind, but very limited. Good education models are available.	More must be done in this space if we want a well-qualified future workforce. No one in the group thought we were on track or doing well as a nation. There are no standards but good curricula exist (NEED Project, KidWind, and WindWise). Funding for updating and active teacher training/engagement is very limited so only a handful of students are being reached. Information and outreach mechanisms to inform young people about the wind industry do not exist.	X	
• 8.1.3: Develop technical training programs for wind		Good education models are available from a few high-quality community college programs. Technical training programs are well-developed in Europe.	AWEA is planning to work on this, but only Wind Tech 1 has been developed. So far, there is no certification process in the United States.	Although a few teacher-training programs have been implemented, they cannot keep up with the needs of the educational institutions at all levels. Expanded internship programs for teacher training within industry and at national laboratories should be implemented. This should include activities for K–12 teachers. Defined standards exist only for entry-level wind technicians. Often these are not enforced; they are not uniformly accepted across the industry.	X	

Action		Good	On Track	Poor	Now	After 2020
				Training infrastructure is limited: good training programs do have access to equipment, but not the newest technology. Keeping current on technology is difficult for teachers. Retaining teachers is difficult, and low pay is an issue. A wide informational gap exists, with potential students not understanding the opportunities within the wind industry.		
• 8.1.4: Create a robust higher education infrastructure		Education models are available, especially at the undergraduate level. A handful of very high-quality university programs are now operating. DOE Collegiate Wind Competition has been very successful in engaging students, but could be expanded to include more activities and more schools.	The North American Wind Energy Academy could help support larger goals, but it is currently unfunded. The Symposium every other year is a good but small start. European wind education infrastructure is well developed and provides good examples.	Wind education infrastructure is at an early stage in the United States. Investment in training programs is insufficient; development of faculty and other educational personnel is also critically important. Bridges between industry and the university community are needed. Industry should contribute as mentors. Examples include NSF's Wind Tech Training Package and internships for teachers. There is a strong need for new training, outreach, and engagement techniques to entice students that are now being pulled into other industries. Because university programs are usually financially constrained, it is difficult to find professors willing to start new programs such as wind engineering.	X	

Action		Good	On Track	Poor	Now	After 2020
• *8.1.5: Develop and implement certified training programs and credentials for distributed wind workforce, including site assessors and installers. (This combines the original actions 8.1.5 and 8.1.6.)*		Some curricula have been developed.		Standardized training is needed, with certification included; work to date has focused on site assessors and installers. The market is not large enough to support certification processes, but as leasing models expand, the need for these processes is likely to increase. Initial curricula and certification programs have been developed for site assessors and installers, but are not being offered due to a lack of demand. Classes are being taught through informal channels.		X
• 8.1.7: Develop and implement offshore-wind workforce training programs		Good programs exist in Europe that can be built upon.	Industry training efforts seem to be adequate given the current state of the U.S. market.	The educational community has a long way to go in this area. As offshore deployments expand, a much larger effort will be needed that focuses on certification and training for technicians, specialty skills, and development of wind-related programs at schools with strong ocean-based educational programs.		X
• *NEW 8.1.8 Increase diversity in the wind energy workforce*		Organizations such as Women of Wind Energy (now WRISE) have elevated the discussion around women in the workforce.	Several programs actively work to expand diversity, but the level of engagement is insufficient.	The wind industry has lower-than-average diversity across the spectrum from primary school through the industry, even in areas where efforts are made. For example, students participating at the Collegiate Wind Competition have relatively little diversity.	X	

Additions to the original worksheet actions text are *indicated in italics*.

Table 23. Workforce Development Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
8.1: Develop Comprehensive Training, Workforce, and Educational Programs						
• 8.1.1: Develop a foundation for a national wind workforce						
• 8.1.2: Develop robust wind education programs for primary and secondary schools						
• 8.1.3: Develop technical training programs for wind						
• 8.1.4: Create a robust higher education infrastructure						
• 8.1.5: Train and certify distributed wind assessors						
• 8.1.6: Formalize distributed wind installer training						
• 8.1.7: Develop and implement offshore wind workforce training programs						

Table 24. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind Workforce Development and Education Summit

Last Name	First Name	Organization
Arquin	Michael	KidWind
Baring-Gould	Ian	National Renewable Energy Laboratory
Bramlett	Scott	EDF Renewable Energy
Butler	Barry	University of Iowa
Carp	Lisa	EDF Renewables
Clayson	Ed	Daktic, LLC
Croft	Katie	Renewable Energy Alaska Project
Cyre	Dan	Cloud County Community College
Daniels	Lisa	Windustry
DeGeorge	Elise	National Renewable Energy Laboratory
Eisenberg	Drew	Siemens
Enger	Doug	Iowa Lakes Community College
Flowers	Larry	G4 Wind
Gardner	John	Boise State University
Gengler	Michael	Iowa Lakes Community College
Gilman	Patrick	U.S Department of Energy
Graf	Kristen	Women of Wind Energy (now WRISE)
Hamilton	Bruce	Navigant
Hansen	Christopher	University of Massachusetts Lowell
Hudgins	Jerry	University of Nebraska
Jacobson	Mark	National Renewable Energy Laboratory
Jenkins	Jennifer	Distributed Wind Energy Association
Lamb	Rebecca	National Energy Education Development Project
Lamb	Shawn	Danish Wind Power Academy Americas
Loomis	David	Illinois State University
Mann	Claudia	Suzlon Wind Energy Corporation
Markfort	Corey	University of Iowa
McComb	Scott	Raisbeck Aviation High School
Mihelic	Michele	American Wind Energy Association
Miles	Jonathan	James Madison University
Miller	Paul	La DNR
Naughton	Jonathan	University of Wyoming
Pangle	Remy	James Madison University
Pitcher	Raymond	KidWind
Rife	Britton	Distributed Wind Energy Association
Rogers	Jolene	Iowa Lakes Community College
Stewart	Susan	Pennsylvania State University
Straw	Bethany	National Renewable Energy Laboratory

Last Name	First Name	Organization
Sturm	Philip	James Madison University
Summerville	Brent	Appalachian State University
Swift	Andy	Texas Tech University
Tegen	Suzanne	National Renewable Energy Laboratory
Vanderveen	Rich	Mackinaw Power
VanSlyke	Auston	Ecotech Institute
Veers	Paul	National Renewable Energy Laboratory
Wadsack	Karin	Northern Arizona University
Wegman	Steven	S. Dakota Renewable Energy Association
Williams	Scott	University of Wisconsin Madison
Willy	David	Northern Arizona University
Yancey	Maggie	U.S Department of Energy
Zayas	Jose	U.S Department of Energy
Zeitz	Alden	Iowa Lakes Electric Cooperative

Table 25. Wind Workforce Development and Education Summit
Shaping the Future Generation of Wind Energy: Inspiring the Next Workforce
May 22–23, 2016, Ernest N. Morial Convention Center, New Orleans, Louisiana

DAY 1 Sunday, May 22, 2016	
1:30–2:00 p.m.	Registration and Check In
2:00–2:30 p.m.	Welcome and Introductions
2:30–3:00 p.m.	The *Wind Vision* Roadmap and Next Steps
3:00–4:15 p.m.	Current Wind Energy Education Activities • Rebecca Lamb, National Energy Education Development Project • Mike Arquin, KidWind • Jon Miles, Wind for Schools • Jolene Rogers, Iowa Lakes Community College • Elise DeGeorge, Collegiate Wind Competition • Andy Swift, North American Wind Energy Academy
4:15–4:30 p.m.	Break
4:30–5:30 p.m.	Expanding the Workforce and Retraining Opportunities • Kristen Graf, Women of Wind Energy • Michele Mihelic, American Wind Energy Association • Auston VanSlyke, Ecotech Institute • Drew Eisenberg, Siemens
5:30–6:15 p.m.	Workforce and Education Roadmap Priorities
7 p.m.	No-Host Networking Dinner and Discussion—Legacy Kitchen
DAY 2	

Monday, May 23, 2016	
9:00–9:15 a.m.	Welcome and Introductions
9:15–10:30 a.m.	Breakout Session I • Option A: Moving DOE's *Wind Vision* Roadmap Forward • Option B: DOE's 2016 Wind for Schools Program Kick-off
10:30–10:45	Break
10:45–12:00 p.m.	Breakout Session II • Option A: Moving DOE's *Wind Vision* Roadmap Forward • Option B: Enriching the Wind Energy Workforce
12:00–12:30 p.m.	Closing Remarks
12:30 p.m.	Adjourn

2.8 *Wind Vision* Roadmap—Status and Update: Working Session Discussion Points Relevant to Collaboration, Education, and Outreach

2.8.1 Topic 1: Wind Power Resources and Site Characterization

- Most participants think that wind power and wind resources should not be considered in isolation from other renewable energy resources. Synergies with other low-carbon resources should be considered and pursued, such as solar power and efficiency. Wind should not appear to be in competition with such sources.
- International cooperation on wind resource research should continue. In general, participants feel that interactions through IEA are valuable and are progressing well.

2.8.2 Topic 2: Wind Plant Technology Advancements

- A2e and the Horizon 2020 (EU FOA) all offer excellent opportunities for collaboration among international stakeholders. DOE and the national lab complex have partnered on many successful and potentially impactful Horizon 2020 projects.
- DOE and the national labs continue to be engaged on many IEA Wind tasks that foster technical information exchange and advance research.
- There has been good progress on mitigation of ice loading, led by OEMs. However, DOE and industry have not been involved in IEA Wind's Task 19, which focuses on ice loading in cold climates.

2.8.3 Topic 3: Supply Chain, Manufacturing, and Logistics

- Many in the wind community and industry in general are not aware of work funded by the federal wind program. Reports from that work need to be

publicized and distributed much more effectively, with focused attention on target audiences.

- Mainstream engineering education programs traditionally do not feature wind energy as an attractive career option going forward. These programs tend to use illustrative examples from traditional engineering jobs such as the design of buildings and bridges, and vehicle and air transportation systems. Examples highlighting design, manufacturing, construction, and transportation of components of wind energy systems should be added. Students would then be exposed to an energy technology of the near future that can offer them attractive and relevant career paths. Some session participants, however, pointed to encouraging progress on this front based on personal experience.
- Engineering education programs should include an emphasis on design for manufacturability. Some industrial engineering programs already emphasize this and could add examples related to wind turbine components.
- Much of the information associated with wind equipment manufacturing is "know-how"; it exists in the experience base of manufacturing engineers, designers, researchers, and technicians, but is not formally documented or taught in educational programs. This information needs to be captured, documented, and presented as components of baseline engineering knowledge. Much of it will still be transferred through person-to-person interactions, but the learning process will be facilitated by documented educational materials. One participant pointed out that some European engineering colleges do offer courses of this type. These originally were sponsored by the European wind equipment OEMs.

2.8.4 Topic 4: Wind Power Performance, Reliability, and Safety

- No relevant points arose during focused consideration of this topic, but the points included above under Topic 2 apply here as well.

2.8.5 Topic 5: Wind Electricity Delivery and Integration

- Much information needed to enable expansion of wind power as part of a low-carbon future while maintaining power-system reliability has been developed. Additional key insights will emerge from ongoing and planned investigations. Those involved with the related studies and those with wind-power experience understand this information, but this group constitutes only a small portion of the electric power sector. Many more groups in this sector—including regulators, legislators, system planners, system operators, and others—need to embrace this understanding and act on it. So far, the story is not getting out to these groups with sufficient clarity and repetition. Additionally, when they begin to understand the story, they will need more technical support to help them act on the understanding and put it into practice.
- There is a critical need for outreach by technical leaders in the wind integration space, including DOE, the national labs, the wind industry, and power-sector members with wind experience. Some power-sector members have now achieved a high level of understanding with considerable help from DOE-sponsored integration studies, NREL's wind integration expertise, and UVIG. Because

utility and RTO members are understandably focused on their organizations and are not incented to provide outreach and education to other groups, however, this *Wind Vision* Roadmap working session identified an expanding need for additional outreach and technical support by national labs, DOE, or other technically competent groups. The UVIG provides an important and effective channel, but today cannot do this job alone.

- A strong view emerged that DOE wind and solar integration experts should become part of the teams at RTOs and major balancing authorities to support them in transition planning, in justifying the changes that should take place for the public good, and in providing the evidence for why these changes are appropriate. This implies that DOE needs to be much more than a research organization.
- An important part of the wind-integration story is about public benefit. It includes carbon-emissions reduction and air pollution reduction, as well as economic benefits. As such, federal and state government programs have a primary responsibility to conduct outreach on this topic.
- Workforce development is a significant issue. The power-sector workforce is aging and needs younger people to become engaged.

2.8.6 Topic 6: Wind Siting and Permitting

- On the issue of outreach in general, participants emphasized the importance of ongoing and expanded efforts to communicate widely the entire wind story—including facts about its benefits without ignoring negative impacts. The group recommends a strong federal role in outreach. The industry also needs to be heavily involved, although the perceived objectivity of the government program provides an advantage in communicating with entities and segments of society that are skeptical about wind power.
- A specific area where authoritative outreach is needed is health effects of wind power. Health Canada has conducted a study of wind's health effects, and the group discussed whether our federal government should conduct such a study for wide distribution. The group reacted positively to this suggestion and recommended engaging the National Academy of Sciences (NAS) as an appropriate and highly credible entity for this activity. Because a great deal of work already has been done on this topic, much could be accomplished with a meta-analysis. Although additional insights might emerge from continued study, most expressed the view that little new original work is needed.

2.8.7 Topic 6a: Wildlife and Wind Power

- Participants underscored the importance of evaluating wind's impacts on wildlife relative to the broad range of environmental benefits of wind, such as slowing climate change and improved air quality. One participant commented that we find birds that have been struck by a wind turbine blade, but we usually don't find those that have succumbed to air pollution.
- Participants also underscored the need to conduct a comparative analysis of the wildlife impacts from all energy technologies. This action is included generally in the Policy Analysis section of the Roadmap (which calls for a comparative

analysis of all benefits, costs, and other impacts), but should be included here with a focus on wildlife.

- Though not specifically the topic of this session, the points above and much of the group's discussion underscore the need for extensive outreach on many levels to tell the comprehensive story about wind's benefits, costs, other impacts, and needs. This requires active, sustained participation by government programs, as well as the NGO and private sectors. Although some of this activity is ongoing, more is needed. The wind community was encouraged to use mass media, as the traditional energy sectors have successfully done.

2.8.8 Topic 7: Collaboration, Education, and Outreach

- No separate session was conducted on this topic. Instead it arose in the discussions of nearly every topical session. In all cases, the need for ongoing outreach to present the wind story in an objective manner was underscored. Government programs were called upon to play a significant role in outreach because of perceived objectivity in contrast with industry advocacy efforts. The discussion groups called for a substantial increase in emphasis on such outreach. The last bullet under Topic 6a above is typical of the sense expressed by these groups.
- Several of the groups also underscored the value of international collaboration such as the work under the various IEA wind tasks. Participants familiar with that work generally thought that the work is proceeding on track and should be continued.

2.8.9 Topic 8: Workforce Development

- Wind energy offers promising and rewarding career opportunities for Americans over a broad age group. Students at the high school and community college levels can enter the wind workforce as operating and maintenance technicians or as skilled-labor manufacturing and production specialists, and can move to more advanced levels with the appropriate level of training and education. Those in baccalaureate and higher college-level programs can engage in a wide range of engineering, research, business, policy, and legal endeavors in the wind industry. Additionally, those in other fields with diminishing opportunities might well find opportunities in the wind industry that can extend their careers for many productive years. Although these opportunities will expand substantially in the coming years as clean, renewable energy moves to center stage, wind energy career opportunities are largely unknown to most in educational arenas or in the emerging and existing workforce. Both the wind industry and government programs need to expand their efforts to increase awareness of these opportunities. In addition, most of these opportunities are equally appropriate for all, irrespective of gender and national or cultural background. Hence programs to publicize the career opportunities in wind power also should strive to encourage diversity in the wind workforce.
- Participants believe it is very important to increase marketing for wind energy as a career choice in which graduates can be highly successful. Many students don't see working in the wind industry as a viable career option; some are even

completely unaware of wind-industry careers. For example, even though there are more new jobs in wind energy than in coal mining, wind jobs don't yet have the same level of national recognition as coal jobs.

- At the primary- and secondary-school levels, KidWind and Wind for Schools offer effective and successful programs. However, these programs reach a very small number of students and teachers. Several—but only a few—science museums have a strong energy focus that includes wind. Programs such as these provide effective education models and should be replicated much more widely. Many participants commented that it is vital to train teachers as well as students to have a broader reach and to inspire wind energy champions in schools and districts. Expanded internship programs for teacher training within industry and at national laboratories should be implemented, including activities for K–12 teachers.
- Instructor and teacher training infrastructure is inadequate. The best training programs do have access to equipment, but do not have access to the newest technology. It is difficult for teachers to keep current on technology. The rate of teacher retention is low, in part because of low salaries. Participants suggested that industry could partially fund wind energy technician (and other) instructor salaries—as many other industries do—to retain teachers and instructors instead of losing them to industry.
- The group expressed concern about the minimal level of diversity in the wind workforce; present employment of women and minorities is seen as inadequate. Organizations such as Women of Wind Energy (now WRISE) have elevated the discussion of women in the workforce, and several other programs actively work to increase participation by minorities. The current level of engagement, however, is insufficient given the current situation and trends within the industry. A new roadmap action is recommended focusing on this need.

2.8.10 Topic 9: Policy Analysis

- No focused session was conducted on this topic. However, *Action 9.1, Refine and Apply Energy Technology Cost and Benefit Evaluation Methods*, is central to the synthesis of the comprehensive comparative analysis of all energy technologies—placing wind energy in context—that arose as a critical need in many of the discussion sessions. Many participants expressed concern that this work is not being done.
- This project to assess the status of *Wind Vision* Roadmap activity addresses "Action 9.3, Maintain the Roadmap As a Vibrant, Active Process for Achieving the *Wind Vision* Study Scenario." Upon completion of the effort, outreach by the federal wind program will be needed to share the results with the wind and energy communities and ensure their ongoing participation in the roadmap's actions.

Table 26. Collaboration, Education and Outreach Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
7.1: Provide Information on Wind Power Impacts and Benefits						
• 7.1.1: Engage with key stakeholders						
• 7.1.2: Convene organizations to support engagement on local wind power issues						
• 7.1.3: Develop consensus-based organizations to support appropriate wind deployment						
7.2: Foster International Exchange and Collaboration						
• 7.2.1: Support wind turbine certification and improve wind turbine standards						

Action		Good	On Track	Poor	Now	After 2020
• 7.2.2: Continue international research collaboration						
• 7.2.3: Continue international collaboration to address wind deployment challenges						

2.9 *Wind Vision* Roadmap—Status and Update: Wind Plant Technology Advancement; Wind Plant Performance and Reliability

2.9.1 Insights from DOE Wind Headquarters and Laboratory Personnel September to October 2016

In conducting this roadmap status assessment, the approach followed for most of the topical areas was to hold informal working sessions attended by 10 to 20 experts on the topic and to gather insights from them. For two topical areas—wind plant technology advancement and wind plant performance and reliability—a different approach was used.

Initial insights were gathered from officials of the federal wind program and the associated federal laboratories—based on their ongoing interactions with a broad cross-section of the industry, periodic technical reviews of specific projects, and peer reviews of the entire federal wind program conducted with industry participation. These insights then were reviewed and augmented by other individuals within the wind program. In many cases general agreement emerged, but in others differences were expressed. With this approach, wind turbine and wind equipment manufacturers were not asked to share and discuss their activities for advancing wind technology with others in the industry—activities that might be proprietary and could provide competitive advantage.

In general, expanding demand for clean renewable energy such as wind power is providing attractive commercial opportunities for the wind equipment industry—at least over the next five years. In response, the industry maintains substantial activity to improve the technology, reduce costs, increase reliability, and increase competitiveness. These efforts are complemented and augmented by federal wind program activity aimed at taller and larger wind turbines, increased reliability of major turbine components, on-site manufacturing of very large components, deployment options for offshore turbines, and improved understanding of the underlying physics of wind energy conversion and the characteristics of the wind resource. These industry and government activities are discussed in more detail in the Actions Worksheets, and in the summaries of several of the other topical sessions conducted for this update.

Table 27. Wind Plant Technology Advancement Actions *Wind Vision* Roadmap
Revised Actions Worksheet—November 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
2.1: Develop Next-Generation Wind Plant Technology						
• 2.1.1: Develop cost effective turbine technology for very low wind speeds		The OEMs are developing large-blade technology for low specific power turbines (< 200 W/m2).				
• 2.1.2: Develop larger wind turbines		The OEMs are developing very large turbines for offshore (7–10 MW) and several of these are entering commercial production.	DOE and industry are investing in technology for increased hub heights greater than 80 m. Several promising technologies include on-site manufacturing of spiral welded towers and concrete towers. Towers with heights of 100 m to 120 m already are commercial options in some countries but may require subsidies for cost viability.	Land-based wind turbines have plateaued at 3–4 MW, in part, due to transportation and installation constraints. Segmented blades and on-site blade manufacturing are two promising technology options that could enable the use of very large wind turbines on land with reduced levelized cost of energy (LCOE). Additional research is required to overcome strength, fatigue, and aeroacoustic emission issues.	X	

Action		Good	On Track	Poor	Now	After 2020
				The costs associated with on-site blade manufacturing are uncertain and could present challenges.		
• 2.1.3: Develop advanced rotors		Advancement of rotor technology is occurring through OEM investment in aeroelastically tailored blades, as well as advanced composite structures and manufacturing methods. Advances such as these affect OEM's overall integrated system designs.	A modest level of investigation continues into active control devices for load alleviation and performance enhancements. There is uncertainty, however, about the ability of this type of technology to have significant impact.	Opportunities exist for more-novel rotors designed for low thrust, wake recovery, and other conditions. Such innovation will depend on better understanding of flow physics provided by A2e.		
• 2.1.4: Improve drivetrain and power electronics			Although many reliability issues exist with the current fleet of drivetrains and power electronics, there has been significant progress—especially on the topic of white etching cracking for high-speed bearings. Also, new drivetrain architectures are advancing, including direct-drive, permanent-magnet generators, and medium-speed drivetrains.	Further advances are needed for reliable, lightweight drivetrains such as those using superconducting generators at multimegawatt scales (8–10 MW) or novel gearbox and overall drivetrain topologies.		
• 2.1.5: Develop advanced control		Turbine control systems and wind plant control	Efforts involving advanced control systems coupled to	Field validation and demonstration of advanced		

Action		Good	On Track	Poor	Now	After 2020
systems		strategies are being developed by OEMs and third parties, in some cases through DOE-supported R&D projects. These systems are being integrated with system-level engineering tools to determine the optimal operating conditions for wind plants. The new features include wake steering, induction, lidar feed forward, offshore tower movement mitigation controls, and inter-process communication (IPC).	diagnostic and prognostic systems that can accurately predict remaining useful life (RUL) are nascent both in industry and the research community.	control strategies are needed on commercial wind plants in unique operating environments to reduce technical and financial risks. Novel control mechanisms, such as tilt control, require more fundamental technology changes (i.e., downwind turbine configurations) but hold significant promise for LCOE improvement. Many installations avoid using advanced controls due to reliability concerns. The reliability impact of dynamic turbine and plant controls is still unknown.		
• 2.1.6: Develop tall towers			DOE and industry are investing in increased hub heights above 80 m. Several promising technologies include on-site manufacturing of spiral welded towers and concrete towers.			
• 2.1.7: Develop next-generation foundations and			Presently, DOE-supported demonstrations are in progress for shallow water,	Little if any activity on next-generation foundations and installation systems for land-		

Action		Good	On Track	Poor	Now	After 2020
installation systems			fixed-bottom offshore wind applications: LEEDCo (Lake Erie) and Fishermen's Energy (New Jersey).	based wind turbines, or on floating foundations for deep-water offshore turbines.		
• 2.1.8: Deploy demonstration projects		Block Island offshore wind plant has been successfully installed.	Three potential DOE-supported offshore wind demonstration projects are progressing.	Permitting, power purchase agreements, and financing are major challenges for offshore wind deployment.		
• 2.1.9: Develop advanced support structures			Floating substructures have progressed substantially with innovations from OEMs, including spar, semi-submersible, and tension-leg-platform technologies. University of Maine concrete hull floating offshore wind project is on track.	Additional cost reductions in offshore structures and mooring technologies are possible with modern manufacturing practices and continued investments in R&D to define the in-situ operating environment.		
• 2.1.10: Develop new turbine technology systems		OEMs are moving towards a system-level approach for turbine and plant design, operation and maintenance. Digital tools and data analytics are being used for fleet control and asset management to optimize wind plant performance.	DOE continues to invest in the A2e initiative, which emphasizes resolving the underlying flow physics within wind farms and introducing technology advances to minimize plant losses and turbine loads.	Limited investment in fundamentally new turbine technology (except for the ARPA-e 50-MW palm-tree turbine concept).		
• 2.1.11: Evaluate solutions to ice		The OEMs are leading this work; good progress in		The IEA Wind Task 19 work focuses on blade icing and		

Action		Good	On Track	Poor	Now	After 2020
loading		mitigation of ice loading on blades.		operation in cold climates. DOE and industry have not been actively involved in this collaborative research. For offshore wind plants, ice loading on towers near the waterline is particularly important—especially for installations in the Great Lakes.		
• 2.1.12: Devise strategies to bolster offshore systems against hurricanes		The National Offshore Wind Strategy, developed jointly by DOE and DOI, identifies major action areas necessary for the development of an offshore wind industry, including wind systems that must survive hurricanes.		Some early investment by DOE and the R&D community focused on characterizing the extreme loads. Extreme loading must be addressed in standards and design practices. The acceptable risk associated with hurricane survival needs to be quantified based on economic considerations. New technologies (e.g., for blades and protective controls) also must be taken to greater technology readiness level before they can be successful. Advanced modeling and design capabilities that include		

Action		Good	On Track	Poor	Now	After 2020
				extreme load effects also are needed.		
• 2.1.13: Improve distributed wind technology			The OEM advanced turbine blade projects are underway with DOE support.	Increased investment is needed for distributed wind R&D to reduce costs, improve reliability, and certify new technologies for commercialization. A substantial segment of the wind community, however, thinks that wind turbines of 100 kW and less are not needed to meet *Wind Vision* deployment goals.		
2.2: Improve Standards and Certification Processes						
• 2.2.1: Create flexible certification processes			DNV-GL and OEMs are addressing need for flexible certification processes for the global marketplace.	DOE has a very limited but important role supporting the IEC TC 88 chairman and the reorganization of the IEC certification process. The A2e program and IEA wind research tasks, however, might lead to better standards by capturing atmospheric phenomenology and large wind plant array design drivers.		

Action		Good	On Track	Poor	Now	After 2020
• 2.2.2: Define actual operating conditions		A joint industry project is underway headed by DNV-GL with many international stakeholders to evaluate the most effective turbulence models and how to model wind inflow conditions.	Many steps are underway to better characterize wind inflow conditions. One main target for A2e is to more effectively couple meso-scale weather prediction models to wind-plant scale large eddy simulation (LES) models. This capability will be critical in understanding real-time effects of shear, turbulence, and veer, so that the stochastic nature of the atmospheric inflow can be well characterized.			
• 2.2.3: Foster international collaboration and consistency		.	The A2e and the Horizon 2020 (EU FOA) offer excellent opportunities for collaboration among international stakeholders. DOE and the national lab complex have partnered on many successful and potentially impactful Horizon 2020 projects. Recently DOE hosted an event to strengthen international collaborations with the European Energy Research Alliance (EERA).			

Action		Good	On Track	Poor	Now	After 2020
			DOE and the national labs continue to be engaged on many IEA Wind tasks that foster technical information exchange and advance research.			
2.3: Improve and Validate Advanced Simulation and System Design Tools						
• 2.3.1: Create a load validation campaign			Research is underway at the DOE Scaled Wind Farm Technology (SWiFT) facility to validate high-performance computer simulation models. This work employs a hierarchal approach by first developing wind tunnel data, then data from SWiFT, and then data from a full-scale working wind plant. Complementing this is a field-test campaign involving the DOE 1.5-MW turbine at the NWTC. Blade and dynamometer testing is also underway at the NWTC, as well as at Clemson (dynamometer) and Wind	There is a need for publicly available data from a modern, aeroelastically active turbine to validate the design tools being used to advance the aeroelastic capabilities necessary for continued technology advancement.		

Action		Good	On Track	Poor	Now	After 2020
			Technology Testing Center-Boston (blades).			
• 2.3.2: Develop a wind plant systems engineering design tool		The Systems Engineering tool developed by NREL has led to many significant studies on the optimization of parameters in a wind plant. This tool is influencing industry practice and serves as a catalyst for international collaboration in IEA Wind Task 37 and at the Technical University of Denmark.				
• 2.3.3: Develop aeroelastic analysis for wind plants		The OEMs have sophisticated aeroelastic design tools for the design of modern wind turbines. A2e's high-performance computing program is developing capability to perform the highest-fidelity simulations ever created for wind turbine and wind plant analysis. This capability includes blade-resolved fluid-structure interaction.	DOE has supported the development of FAST over the years and is now transitioning that NREL-developed tool into a community-based platform. This will allow stakeholders to contribute to the development and success of the tool over time.			

Action		Good	On Track	Poor	Now	After 2020
2.4: Establish Test Facilities						
• 2.4.1: Expand field test facilities		DOE has invested in SWIFT, and is also engaging with a large U.S. developer to use a full-scale wind plant for wake steering studies. DOE is actively collecting field data to validate system-level controls and provide uncertainty quantification and verification, and validation of the advanced high-fidelity models being developed by DOE.		Detailed atmospheric measurements concurrent with full-scale wind-plant implementation of advanced control technologies is still lacking.		
• 2.4.2: Establish component and subsystem testing laboratories		The DOE national lab complex has many component and systems level testing facilities. OEMs also have state-of-the-art testing facilities.	Atmospheric remote-sensing instrumentation (i.e., sodar, lidar and radar) is being used to obtain real-time high-fidelity data for analysis. Additional work is needed to expand lidar capability for improved spatial and temporal resolution.			
2.5: Develop Revolutionary Wind Power Systems						
• 2.5.1: Develop innovative designs			The OEMs and DOE continue to invest in innovative designs in components and systems. Examples include multirotor			

Action		Good	On Track	Poor	Now	After 2020
			concepts (OEM); towers and blades for tall and large turbines (DOE and OEMs); bladeless turbines, large downwind machines with 200 m blade technology, airborne kites, and vertical-axis wind turbines (ARPA-e). New technology development opportunities are expected from the detailed quantification of wind plant flow physics and large array interactions through the A2e initiative.			

Table 28. Wind Plant Technology Advancement Actions *Wind Vision* Roadmap
March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
2.1: Develop Next-Generation Wind Plant Technology						
• 2.1.1: Develop cost-effective turbine technology for very low wind speeds						
• 2.1.2: Develop larger wind turbines						
• 2.1.3: Develop advanced rotors						
• 2.1.4: Improve drivetrain and power electronics						
• 2.1.5: Develop advanced control systems						
• 2.1.6: Develop tall towers						
• 2.1.7: Develop next-generation foundations and installation systems						
• 2.1.8: Deploy demonstration projects						

Action		Good	On Track	Poor	Now	After 2020
• 2.1.9: Develop advanced support structures						
• 2.1.10: Develop new turbine technology systems						
• 2.1.11: Evaluate solutions to ice loading						
• 2.1.12: Devise strategies to bolster offshore systems against hurricanes						
• 2.1.13: Improve distributed wind technology						
2.2: Improve Standards and Certification Processes						
• 2.2.1: Create flexible certification processes						
• 2.2.2: Define actual operating conditions						
• 2.2.3: Foster international collaboration and consistency						
2.3: Improve and Validate Advanced Simulation and System Design Tools						
• 2.3.1: Create a load validation campaign						
• 2.3.2: Develop a wind plant systems engineering design tool						

Action		Good	On Track	Poor	Now	After 2020
• 2.3.3: Develop aeroelastic analysis for wind plants						
2.4: Establish Test Facilities						
• 2.4.1: Expand field-test facilities						
• 2.4.2: Establish component and subsystem testing laboratories						
2.5: Develop Revolutionary Wind Power Systems						
• 2.5.1: Develop innovative designs						

Table 29. Wind Power Performance, Reliability, and Safety Actions *Wind Vision* Roadmap Revised Actions Worksheet—December 2016

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

					Top Priority	
Action		Good	On Track	Poor	Now	After 2020
4.1: Improve Reliability and Increase Service Life						
• 4.1.1*: Enhance maintenance-based remaining useful life (RUL) predictions*		The OEMs and third parties are developing sophisticated, data- or physics-based models to estimate remaining useful life for drivetrain components based on specific failure modes.	The national labs are conducting R&D on improvements to physics-based, data-driven remaining-useful-life models. This knowledge will inform operators on best practices for trade-offs in component degradation, planned maintenance, and operation. Sandia National Laboratories is examining lifetime damage accumulation of blades to develop improved models aimed at more robust and more cost-effective designs.	Public-domain life-cycle data on turbine components is inadequate. Methods for estimating RUL for other failure modes of specific components are needed. Current uncertainty level of RUL predictions is too high to meet the needs of end users.	X	

Action		Good	On Track	Poor	Now	After 2020
• *4.1.2: Optimize decision making for maintenance*				Improved RUL information will provide opportunities to optimize decision making.		X
• *4.1.3*: Conduct design research and accelerated testing		The OEMs and national labs have extensive testing facilities for components and subsystems.	The national labs are studying fundamental failure modes (e.g., white etching cracking). This research is being conducted with dynamometers, blade testing facilities, and full-scale turbines (the DOE/GE 1.5-MW machine).	Some mitigation solutions have been developed, but have not been validated through operational testing.	X	
• *4.1.4:* Design offshore turbines and turbine systems for reliability			Maintenance is known to be more intensive for offshore installations due to the remote nature and specialized equipment needed. Much of the research into condition-based monitoring, fundamental failure modes, and remaining useful life will apply to both offshore and land-based applications. For land-based applications, it is often difficult to justify many condition-based monitoring	Offshore-specific failure modes such as saltwater corrosion, foundation scouring, and cabling issues are not well understood. Long-term reliability of direct-drive generators is not understood.	X	

Action		Good	On Track	Poor	Now	After 2020
			systems. For offshore applications, however, these systems might be cost-effective.			
4.2: Develop a World-Class Database on Wind Plant Operation Under Normal Operating Conditions						
• 4.2.1: Collect and analyze field data to understand the specific mechanisms that cause early failure and what those failures cost		The OEMs have developed many coatings (e.g. black oxide) and have extensive data to mitigate many of the extreme loads experienced during operation.	DOE has invested in understanding the white etching cracking phenomenon that plagues many drivetrain bearings. Field testing is underway on the DOE/GE 1.5-MW turbine to understand the loading these components experience. Work is also underway at the component and benchtop scale to replicate these failures and to gain a better understanding of the physical conditions that lead to failure.	Information on costs associated with these failures is minimal and is difficult to obtain. Leading-edge erosion is a significant and growing concern for wind blades. Currently, there is uncertainty in how best to mitigate this issue.		
• *4.2.2: Create and maintain national data sets on performance*		DOE is facilitating a large joint industry project to assess wind plant performance and identify deficiencies. Additionally, preconstruction estimates of energy production will be reconciled	Independent consultants and owners are developing internal capabilities for operational performance assessment.	There are no public databases of wind plant performance. High levels of uncertainties remain for operational	X	

Action		Good	On Track	Poor	Now	After 2020
		with operational performance data.		performance assessment. Performance assessment accuracy is hindered by the fidelity of reliability information on turbines and balance of plants.		
• *4.2.3: Create and maintain national data sets on reliability with periodic releases of updated statistics*			NREL regularly maintains a failure database with updated statistics.		X	
4.3: Ensure Reliable Operation in Severe Operating Environments						
• 4.3.1*: Understand issues related to high turbulence, lightning, and icing*		Labs have high-performance computing capability for turbulence modeling.	Some testing capabilities exist for lightning and icing.		X	
• 4.3.2: Create a distributed wind reliability database				Little related activity underway.		
4.4: Develop and Document Best Practices in Wind O&M						
• 4.4.1: Collaborate with		AWEA O&M recommended				

Action		Good	On Track	Poor	Now	After 2020
trade organizations and other agencies to improve workplace safety and *O&M* practices		practices were released and accessible by members. UVIG O&M users group is developing an operation guidance book.				
• 4.4.2: Identify and adopt O&M practices that reduce disruption to wind plant neighboring communities and wildlife						
4.5: Develop Aftermarket Technology Upgrades and Best Practices for Repowering and Decommissioning						
• 4.5.1: Create component retrofits and upgrades that enable improved performance and/or reliability		Many OEMs are developing sophisticated technologies to address the major component failures. For example, major bearing suppliers are developing procedures that allow up-tower main bearing replacements. Coatings developed by OEMs	There is continued innovation in blade repair, both in method and extent. Best practices are not well defined, however, and could use improvement through standards efforts.		X	

Action		Good	On Track	Poor	Now	After 2020
		provide improved reliability and extended lifetime of components. Blades can be repaired in the field.				
• 4.5.2: Create a body of knowledge on wind plant repowering and decommissioning practices		Many OEMs are entering the repowering market.	DOE is investing in research to understand how to extend the lifetime of turbines and components beyond 20 years.		X	

Additions to the original worksheet actions text are *indicated in italics*.

Table 30. Wind Power Performance, Reliability, and Safety Actions *Wind Vision* Roadmap, March 2015 Original, As Published, Roadmap Actions

Participants' Comments Worksheet

Green: Good progress; well underway; enough momentum to keep going
Clear: On Track: adequate activity; no cause for concern if activity maintained
Red: Poor or insufficient activity; cause for concern

Action		Good	On Track	Poor	Top Priority Now	Top Priority After 2020
4.1: Improve Reliability and Increase Service Life						
• 4.1.1: Update maintenance and replacement patterns						
• 4.1.2: Conduct design research and accelerated testing						
• 4.1.3: Design offshore turbines and turbine systems for reliability						
4.2: Develop a World-Class Database on Wind Plant Operation Under Normal Operating Conditions						
• 4.2.1: Collect and analyze field data to understand the specific mechanisms that cause early failure and what those failures cost						

Action		Good	On Track	Poor	Now	After 2020
• 4.2.2: Publish aggregated reliability statistics with regular updates						
4.3: Ensure Reliable Operation in Severe Operating Environments						
• 4.3.1: Create and maintain national data sets on performance and reliability						
• 4.3.2: Create a distributed wind reliability database						
4.4: Develop and Document Best Practices in Wind O&M						
• 4.4.1: Collaborate with trade organizations and other agencies to improve workplace safety and practices						
• 4.4.2: Identify and adopt O&M practices that reduce disruption to wind plant neighboring communities and wildlife						
4.5: Develop Aftermarket Technology Upgrades and Best Practices for Repowering and Decommissioning						

Action		Good	On Track	Poor	Now	After 2020
• 4.5.1: Create component retrofits and upgrades that enable improved performance and/or reliability						
• 4.5.2: Create a body of knowledge on wind plant repowering and decommissioning practices						

2.9.2 Contributors: Wind Plant Technology, Performance, Reliability, and Safety

Initial input for these two topics was provided primarily by DOE WETO's staff lead for wind technology during 2016, Nick Johnson. That input was reviewed, revised and augmented through subsequent interactions with key wind technology and performance staff members from NREL and SNLA. The complete list of participants follows. RECS compiled and summarized the input received.

Table 31. Contributors to the Technology and Performance Update Process

Lead Contributor: Nick Johnson	**DOE WETO**
Wind Plant Technology Advancement	
Christopher Mone	NREL
Brian Smith	NREL
Mike Robinson	NREL
Paul Veers	NREL
Katherine Dykes	NREL
Wind Power Performance, Reliability, and Safety	
Joshua Paquette	SNLA
Brian Naughton	SNLA
Brian Smith	NREL
Paul Veers	NREL
Jason Fields	NREL
Jon Keller	NREL
Shawn Sheng	NREL

3 Recommended Procedure for Periodic Roadmap Assessment

This section describes a procedure for assessing and updating the status and needs of the *Wind Vision* Roadmap and the actions included in that Roadmap. Renewable Energy Consulting Services, Inc. (RECS) recommends that WETO, in conjunction with the wind industry and the larger wind energy community, carry out such an assessment from time to time. The recommended process is structured around a series of modest activities focused on specific topical areas conducted on an ongoing basis—rather than major, complex, all-inclusive events held at intervals of 1 or 2 years or more.

RECS thinks that these updates should be conducted with three key objectives:

1. To help the wind power industry and broader energy communities maintain a focus on the findings of the 2015 *Wind Vision* initiative and major activities aimed at the prudent expansion of wind power
2. To help address the key needs identified in the Roadmap and in the 2016-2017 Status Assessment and Update on an ongoing basis
3. To update the Roadmap as needed and to assess progress in the major action areas described in the Roadmap.

In retrospect, it is clear that the 2016-2017 Status Assessment and Update addressed all three of these objectives. This occurred not only by considering the specific questions posed at the working sessions, but also—and perhaps to a greater extent—through the informal and often rich discussions that took place among the session participants. Some participants, for example, came to the sessions with (at best) a marginal awareness of the *Wind Vision* work, but left with a much better understanding of ways in which they and their colleagues might become involved in the wind power arena.

RECS recommends that WETO consider a dynamic approach along the following lines.

- Convene several informal discussion groups each year—similar to the working sessions conducted in 2016—each focused on a specific topic. It likely is not necessary to cover all topics each year. Addressing them all over a two- or even a three-year period would suffice. Holding some activity related to the *Wind Vision* each year, however, would help maintain community attention to pursuit of the vision and would reaffirm DOE's sincerity about wind advancement.
- For each of the informal sessions—and regardless of the specific topic—include discussion of two topics identified across the board as key needs during the 2016-2017 assessment effort: (1) outreach to tell a balanced story about wind's benefits, costs, and other impacts; and (2) workforce development to expand the labor pool needed for wind expansion. The aim is to increase participants' awareness of wind's potential and its employment opportunities, irrespective of their specific disciplines.
- The outreach function is so important that WETO should consider holding one or more public event each year specifically to tell the up-to-date wind story—based on such

documents as the Wind Technologies Market Reports and the many other key reports produced by WETO and the national laboratories. The authoritative information in those documents does get exposure at the AWEA conferences, but only in 15-minute time slots. The aim would be to engage decision makers and policy makers who aren't included on the traditional wind industry mailing lists. Workforce development also could be addressed at these events. And they also could provide indirect input useful in updating the Roadmap. Regional events organized through WINDExchange might provide an efficient means to address this need.

- Outreach is critically important in the areas of electricity delivery and integration, siting and permitting, and wildlife and other environmental issues. One of the recommended WETO sponsored annual outreach events could be focused on the first of these to emphasize the importance of transmission expansion and facilitation of power-system flexibility. Another could focus on the other topics noted, with the aim of presenting authoritative, balanced coverage of wind's benefits, costs, and other impacts relative to other electricity-generation options. One objective of these sessions should be to foster ongoing interactions among federal wind program and national laboratory personnel and those influencing wind deployment decisions at the local, state, and regional levels.
- The 2016 session on supply chain, manufacturing, and logistics provided an effective but limited opportunity to engage some new individuals from those sectors not necessarily involved in wind power. Information and education flowed freely in both directions. The wind industry would benefit from increased participation from these disciplines; but—as was learned from the session—the opportunities offered by wind are not widely recognized throughout the broader manufacturing industry. WETO should consider this topical area for one of the earliest sessions going forward. It would also be worthwhile to expand the scale of this session so that a greater number of potential industry players could be engaged. The group size, however, should remain small enough that informal discussion can occur. Alternatively, a larger group could be broken down into smaller discussion groups for a portion of the session.
- RECS also recommends a focused session with the wind industry on workforce development. The primary aim would be to encourage industry to contribute to a greater degree to the education of the future wind workforce. The industry could offer more internships and cooperative programs for promising students, with the expectation that some of these students would pursue careers in the wind sector. Industry also could encourage employees to interact with university programs to expose students to the wind business and to prospective careers in the wind-energy industry. One glaring problem exposed during the 2016-2017 assessment effort pertains to wind technician training. We learned that graduates of these training programs can command a salary that is double that of their teachers, making teacher retention a very serious issue. One possible solution to this problem could be for wind industry firms to help underwrite and thus augment the salaries of these teachers. This would likely improve teacher retention rates. Issues such as these could be explored and discussed at a carefully structured working session.
- The technology advancement, performance, and reliability topics cover a broad range and can easily encroach on proprietary information often associated with current or future competitive advantages. RECS' recommendation is to address these topics through the

technical review sessions and peer reviews that WETO routinely conducts. Consistent with the purpose of these sessions, a focused objective could be added to seek and digest input from the sessions relevant to updating the Roadmap. Manufacturing, supply chain, and logistics also could be handled in this manner, although the experience from the 2016 assessment session on these topics indicates that discussions outside the formality of organized peer reviews can be productive—as suggested in the recommendation described earlier.

- For the 2016-2017 assessment effort, wildlife was addressed separately from siting and permitting. Although these two sessions were effective and productive, many of the same participants were involved in both sessions and there was considerable overlap of discussion material. RECS thinks that these topics could be handled in a single session going forward. Again, however, the discussion is likely to be more open and productive with a relatively small group of perhaps 15 to 20 participants.
- With respect to policy actions and issues, no focused session was conducted in 2016. Instead, policy issues arose and were captured during discussions at the other sessions. Because many policy-level issues for wind apply also to some other renewable technologies, for future Roadmap assessments the WETO could consider a focused session on policy considerations organized at the EERE level.

4 Recommendation for Online Living Roadmap

The 2016-2017 Status Assessment and Update has in large measure served to validate the contents of the *Wind Vision* Roadmap published in 2015. The participants in aggregate found the Roadmap's actions to be comprehensive and appropriate. Participants, however, indicated that some of the actions require a stronger response from the appropriate sectors of the wind and energy communities. In several of the topical areas, additional actions were encouraged. Additionally, in some cases major concerns were expressed. Key points amplifying these general findings are included in each of the session summaries.

As next steps for WETO, RECS recommends the following actions.

- Initiate the dynamic update and outreach program outlined in Section 3 of this report.
- Revise the Roadmap sections of the 2015 *Wind Vision* report (DOE 2015; Chapter 4 and Appendix M) based on the findings from this 2016-2017 assessment effort. RECS recommends that the WETO Headquarters lead staff members manage the update process for their respective areas of responsibility. This would ensure ongoing compatibility between wind power's needs and the content of the respective programs. It also will provide a strong basis for staff interactions with the wind and energy communities to encourage action that needs to occur outside of the federal program.
- Post the revised and updated Roadmap online as a readily accessible and living document. Publicize the availability of the document.
- Develop a procedure and protocol for updating the Roadmap on an ongoing basis. This will require a "gatekeeping" function. The challenge is to maintain control of this process without excessive constraints.
- Lastly, a process should be developed to track progress in addressing and completing Roadmap actions on an ongoing basis.

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