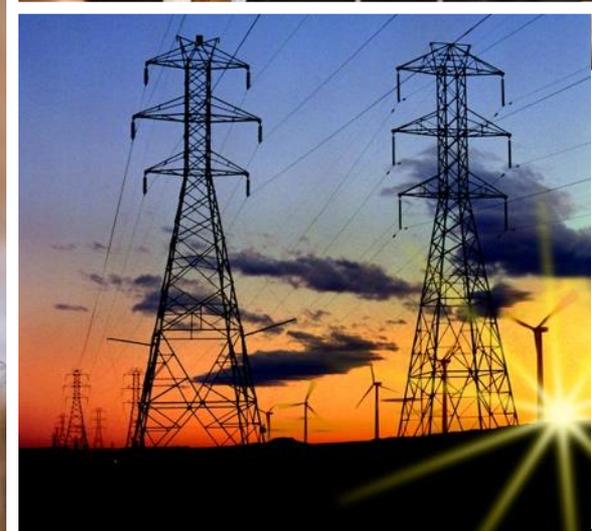
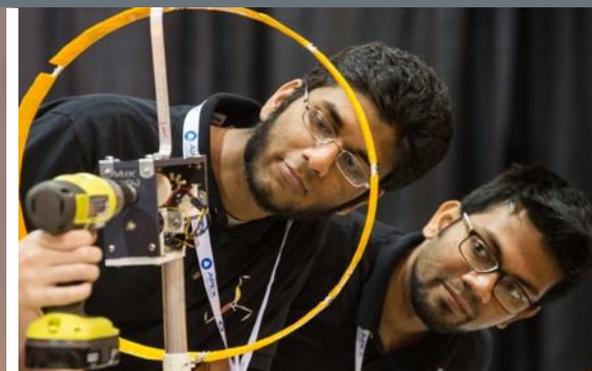
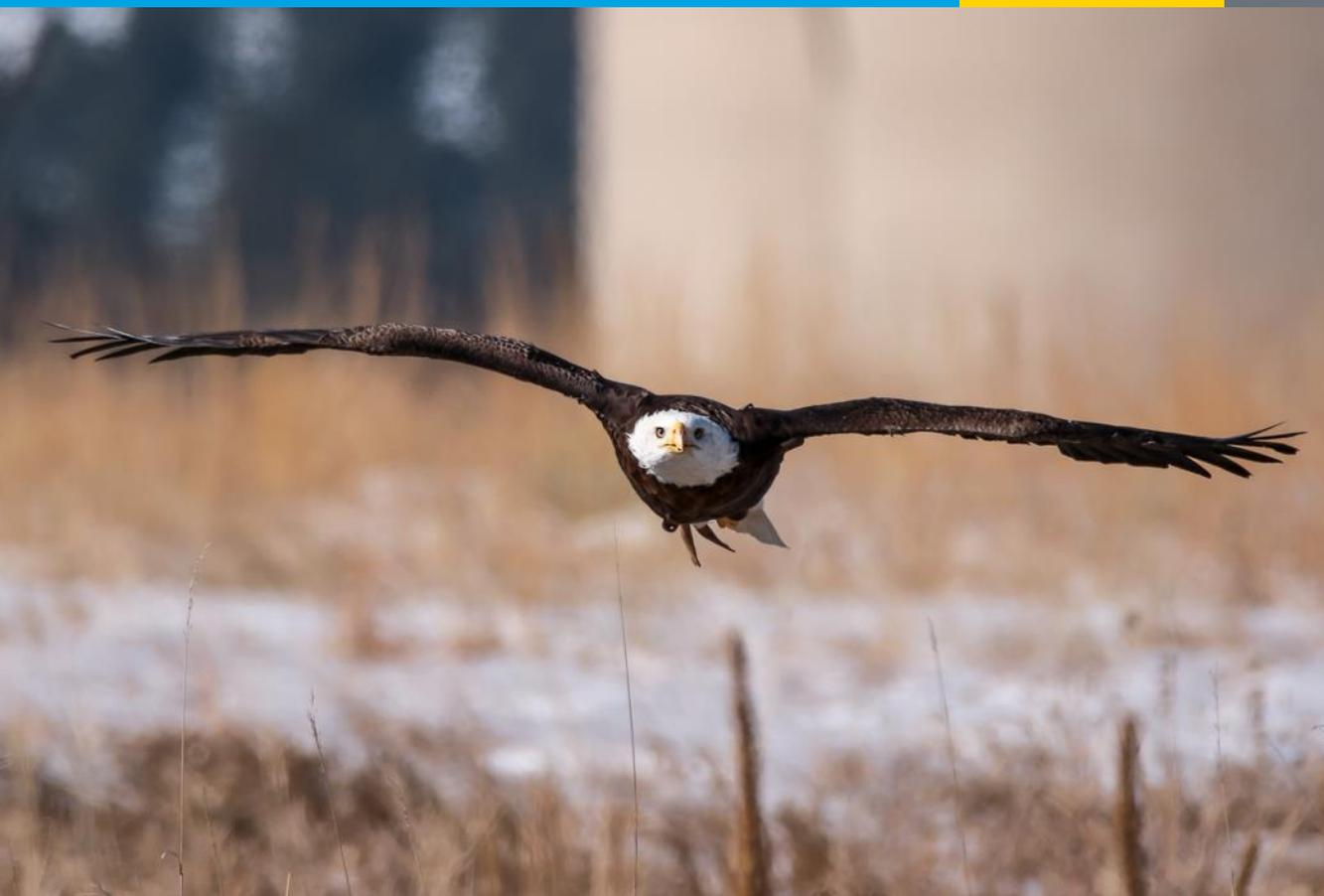


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Wind Market Acceleration and Deployment Track

Jocelyn Brown-Saracino
Acting Market Acceleration and
Deployment Program Manager

February 14, 2017

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- **GOAL:** Reduce the unsubsidized market levelized cost of energy (LCOE) for utility-scale land-based wind energy systems from a reference wind cost of \$0.074/kWh in 2012 to \$0.057/kWh by 2020 and \$0.042/kWh by 2030.
- **GOAL:** Reduce the unsubsidized market LCOE for offshore fixed-bottom wind energy systems from a reference of \$0.18/kWh in 2015 to \$0.15/kWh by 2020 and \$0.096/kWh by 2030.

Enhancing U.S. Energy Security and Independence

- **GOAL:** Accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality.

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- **GOAL:** Expand the geographic development potential of wind power plants in the United States, particularly in offshore zones and the U.S. Southeast.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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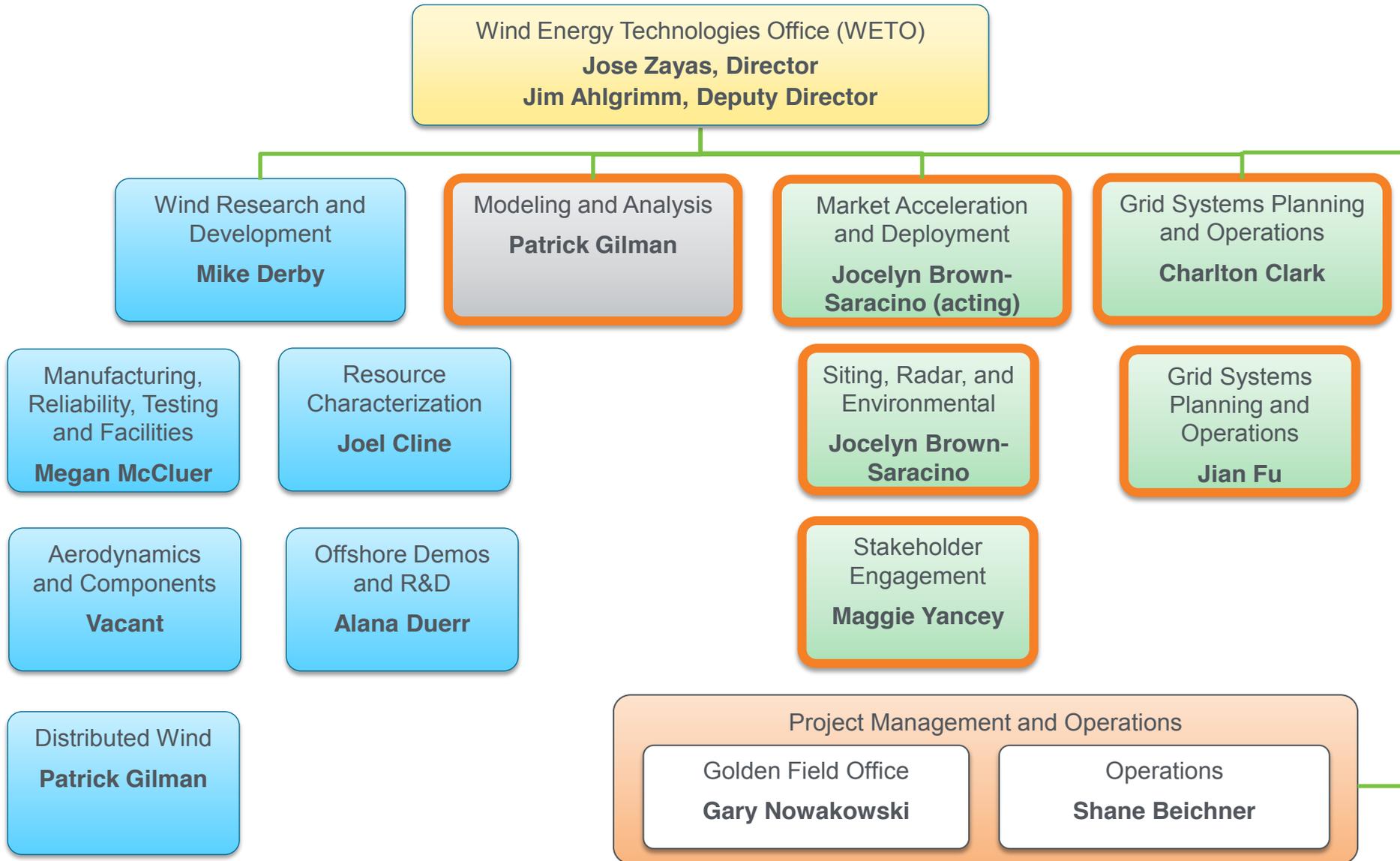
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- **Facilitating coexistence between wind energy and wildlife**
- **Offshore wind environments**
- **Information synthesis and dissemination**
- **Successful coexistence with radar systems**
- **Wind energy workforce and education development**
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Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and tech transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement
- Standards and certification
- **Communicating the costs and benefits of wind energy**

Who We Are: Wind Market Acceleration and Deployment Team

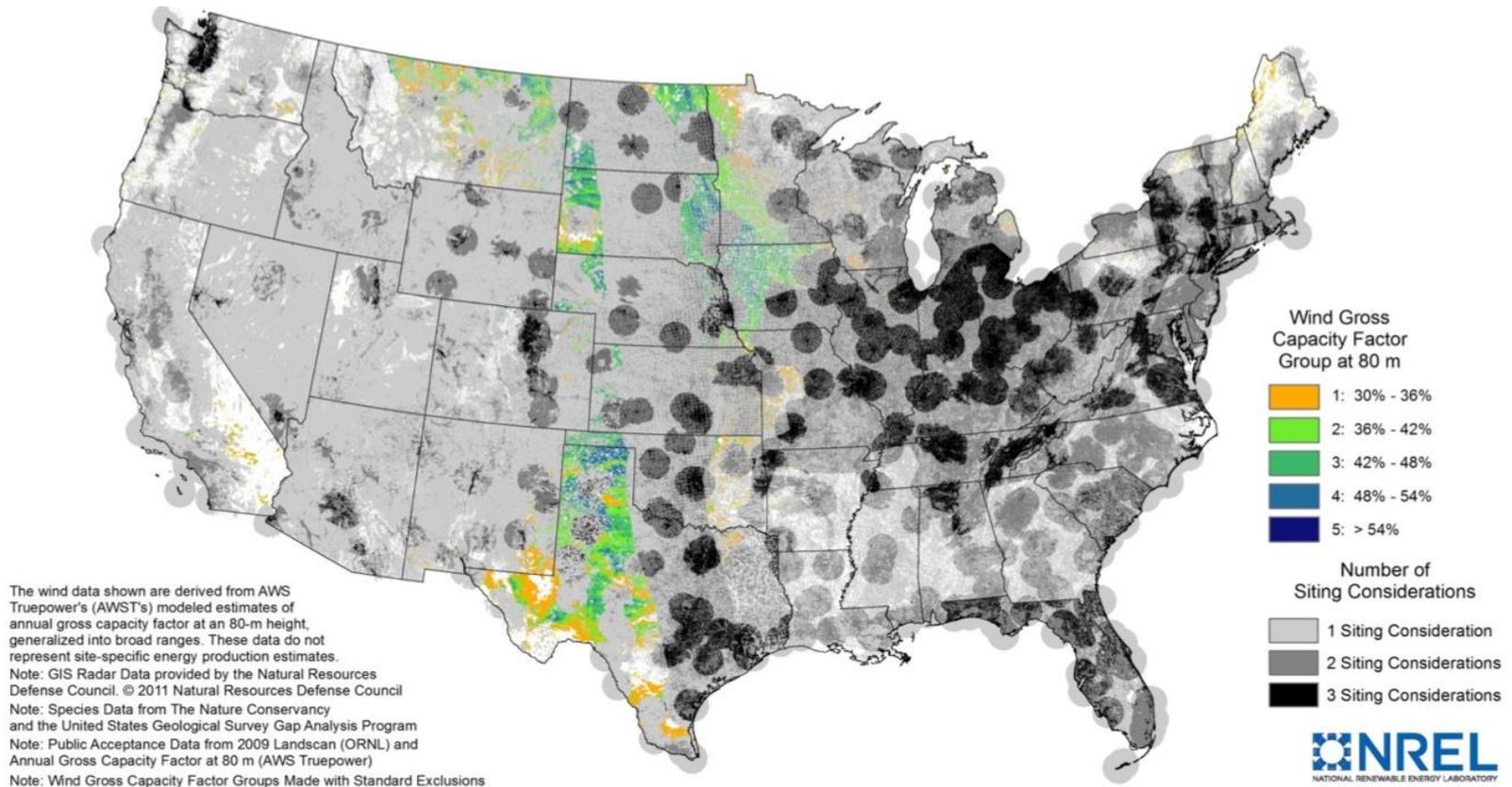


The Wind MA&D Team leverages unique DOE capabilities to:

- Convene diverse stakeholders in a national dialogue
- Disseminate impartial, state-of-the-art data
- Leverage expertise from the national laboratories
- Carry out visionary R&D beyond the scope of industry
- Engage and promote small, innovative stakeholders and companies

Why Address Market Barriers?

- Siting and environmental constraints on wind development have the **potential to reduce wind deployment by over 4,940 gigawatts**, or approximately 80%.
- **Siting and developing projects is getting harder.**



NREL Unpublished Analysis for DOE

LCOE and deployment goals will not be met unless market barriers impacting wind development are addressed. Tools to address wildlife, stakeholder, grid, and radar barriers will increase certainty for regulators, decrease risk for developers, and reduce LCOE, leading to more deployment.

Program Goal:

Reduce market barriers to preserve or expand access to quality wind resources. Better understanding of impacts and mitigation solutions will increase the certainty of development outcomes and ultimately lead to more deployment.

Modeling & Analysis

Deep insight to enable informed decision making

- *Market trends*
- *Wind energy futures*
- *R&D and Policy decision support*

Grid Integration

Enable high levels of wind penetration

- *Essential Reliability Services*
- *Market design*
- *Technology Integration*
- *Technology Deployment*

Stakeholder Engagement, Education & Outreach

Catalyze public acceptance and develop skilled workforce

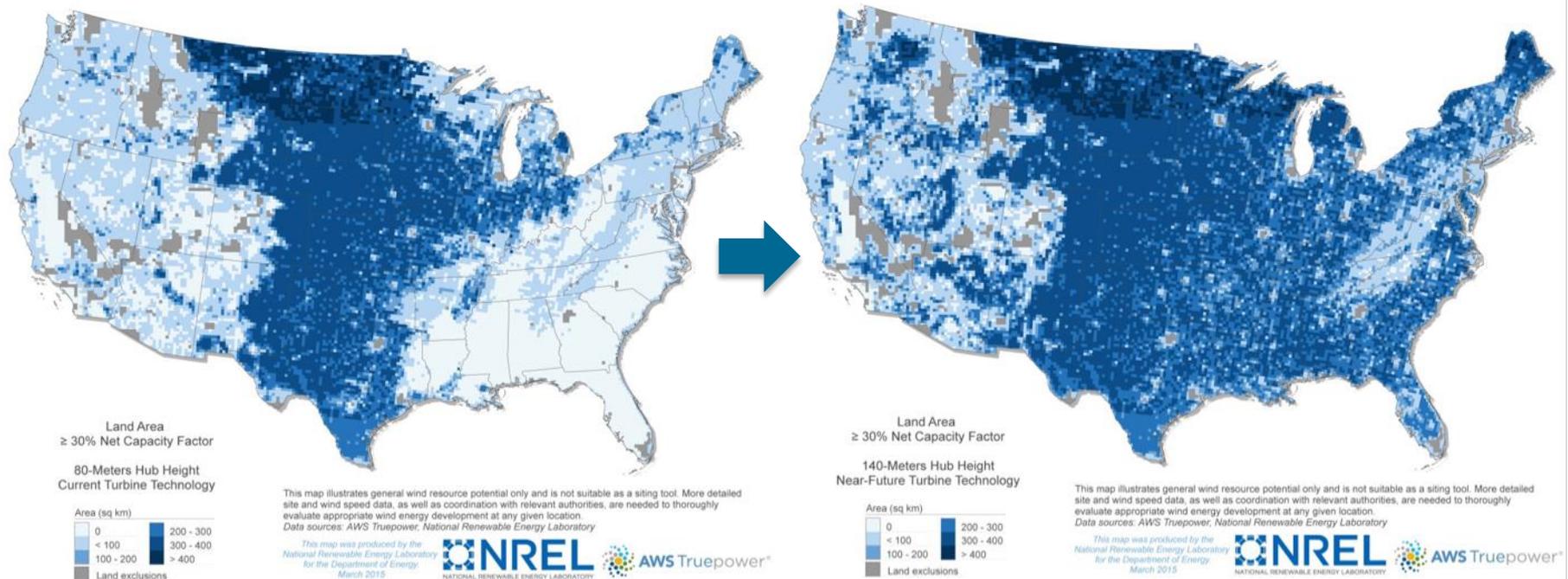
- *WINDEXchange*
- *Collegiate Wind Competition*
- *Regional Resource Centers*
- *Wind for Schools*

Siting & Environmental Research

Developing solutions to siting challenges

- *Radar interference mitigation*
- *Land-based and offshore wind environmental research*

Motivation: Deep insight on wind energy technology, market trends and potential futures to enable informed decision making



Example: R&D enabling cost-effective “tall wind” technologies (150 W/m^2 specific power rotors at 140m hub height) would increase land area with $\geq 30\%$ net capacity factor by 67% and open substantial development opportunities in all 50 states. Zayas et al. (2015), *Enabling Wind Power Nationwide*

Motivation: Enable high levels of wind penetration onto the electrical grid

Provide essential reliability services

Being good stewards of the grid

Efficient market design

Rules that work for everyone as variable generation increases

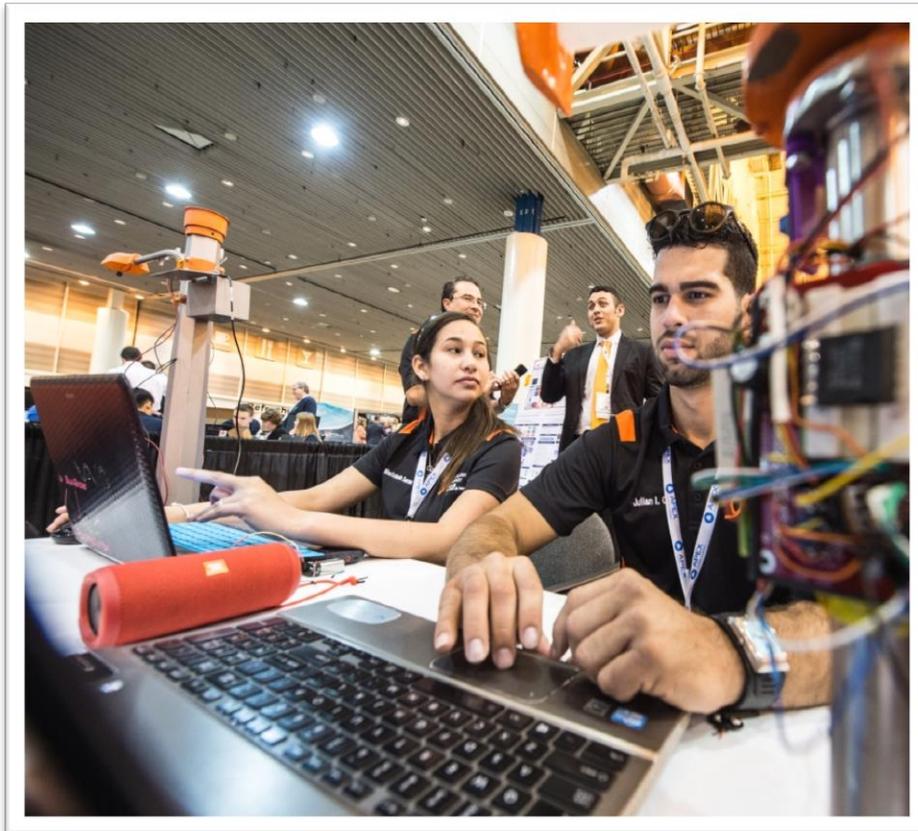
Integration with other technologies

Working across EERE

Technology deployment

Assuring adoption

Motivation: Enable well-informed decisions about wind energy deployment and ensure the availability of a robust workforce



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

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ACTIVITIES

What is happening in my area?
Selected state:

STAY UPDATED

Sign up for our e-newsletter
Enter Email:

NEWS

Public Public News: Wind Power Means Job Opportunities
October 28, 2014

DTEA Launches SMART Wind Consortium
May 13, 2014

U.S. Department of Energy Wind Program Announces Key Milestone of Funding for 2016 Collegiate Wind Competition
October 30, 2014

FEATURED PROJECTS

COLLEGIATE WIND COMPETITION
U.S. DEPARTMENT OF ENERGY
Now accepting proposals for the 2016 Collegiate Wind Competition

WIND RESOURCE MAPS

Installed Wind Capacity Maps
Maps that show installed wind capacity by state and its progression since 1999.

Land-based and Offshore Wind Resource Maps
Wind maps for utility-, community-, and residential-scale wind development.

Wind for Homeowners, Farmers, and Businesses
A Small Wind Guidebook is available for each state, along with a detailed 50-m height state wind resource map.

EVENTS

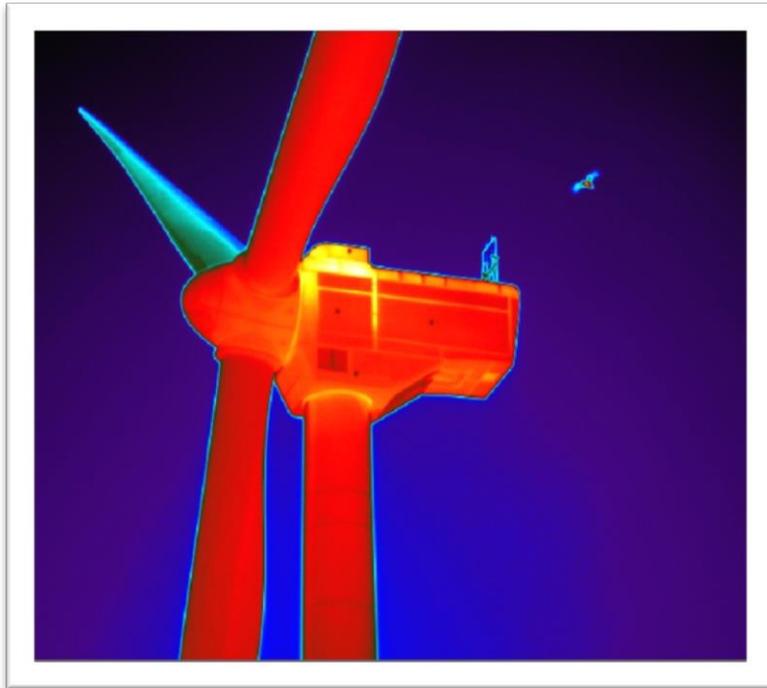
WINDExchange Webinar: Economic Impacts of Offshore Wind Market, Manufacturing, and Jobs
November 19, 2014

WINDExchange Offshore Wind Webinar: Transmission Planning and Interconnection for Offshore Wind
December 02, 2014

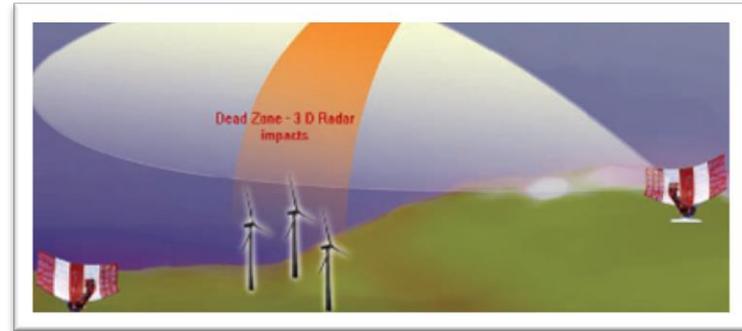
WINDExchange Webinar: Small and Distributed Wind Turbine Update
December 17, 2014

Motivation: Facilitate and disseminate research to understand and mitigate wind/wildlife impacts and wind/radar interference

Better understand and model risk

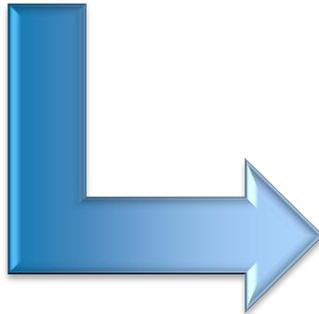


Develop mitigation solutions



Budget Summary

Total Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$14M	\$13M	\$15M	\$42M



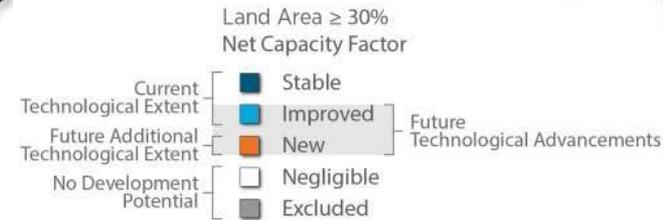
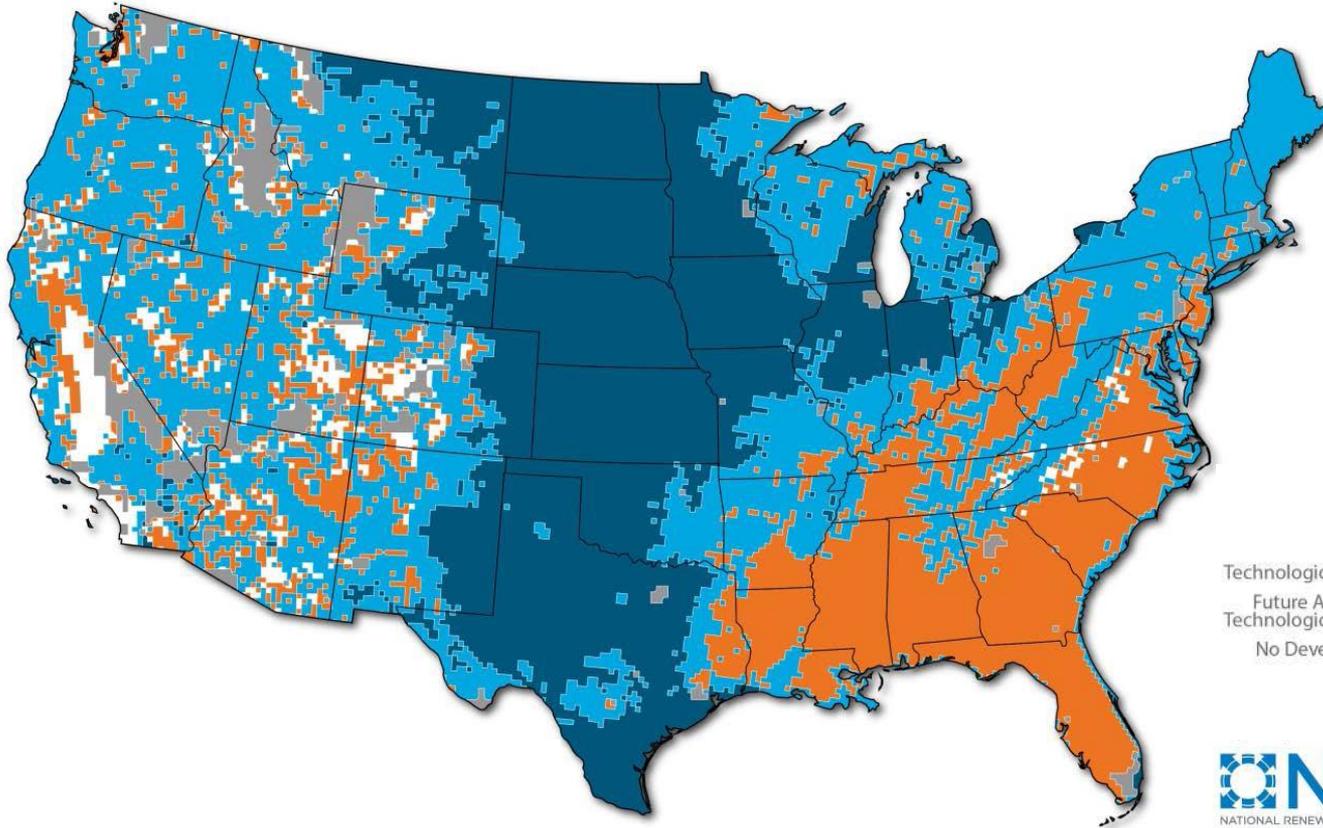
Peer Reviewed Budget*			
FY2014	FY2015	FY2016**	Total FY2014-FY2016
\$11M	\$9M	\$5M	\$25M
78%	70%	35%	60%

*Note: Totals include Modeling and Analysis funding, however these projects are exempt from peer review per EERE policy

** Reduction in FY16 primarily due to grid funds being sent to the Grid Modernization Lab Consortium and the issuance of a new environmental Funding Opportunity Announcement, which are not under review

- We are a **strong team** of experienced, motivated subject matter experts.
 - We **leverage unique capabilities** to execute our program.
 - Our projects are aligned to provide **maximum impact** to the industry.
-

Welcome and thank you to the Review Panel



Modeling and Analysis Program Overview

Patrick Gilman

Program Manager
Modeling and Analysis

February 14, 2017

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- **GOAL:** Reduce the unsubsidized market levelized cost of energy (LCOE) for utility-scale land-based wind energy systems from a reference wind cost of \$0.074/kWh in 2012 to \$0.057/kWh by 2020 and \$0.042/kWh by 2030.
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- **GOAL:** Expand the geographic development potential of wind power plants in the United States, particularly in offshore zones and the U.S. Southeast.

Enable Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- Reduce capital and O&M costs and optimization plant performance
- **Reduce technical and financial risk and improve permitting processes**
- Improve resource forecasting, reduce integration costs, increase value of ancillary services
- Develop technology that leverages lower speed wind resources

Enhancing U.S. Energy Security and Independence

- Facilitate coexistence between wind energy and wildlife
- Collect environmental impact data and support testing of monitoring and mitigation technologies
- **Information synthesis and dissemination**
- Manufacturing and installation cost reductions for Distributed Wind systems

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Demonstrate offshore wind advanced technology projects
- Reduce, mitigate and eliminate market barriers through improved siting
- Improve grid planning and operation
- Develop and demonstrate larger wind turbines

Enable Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

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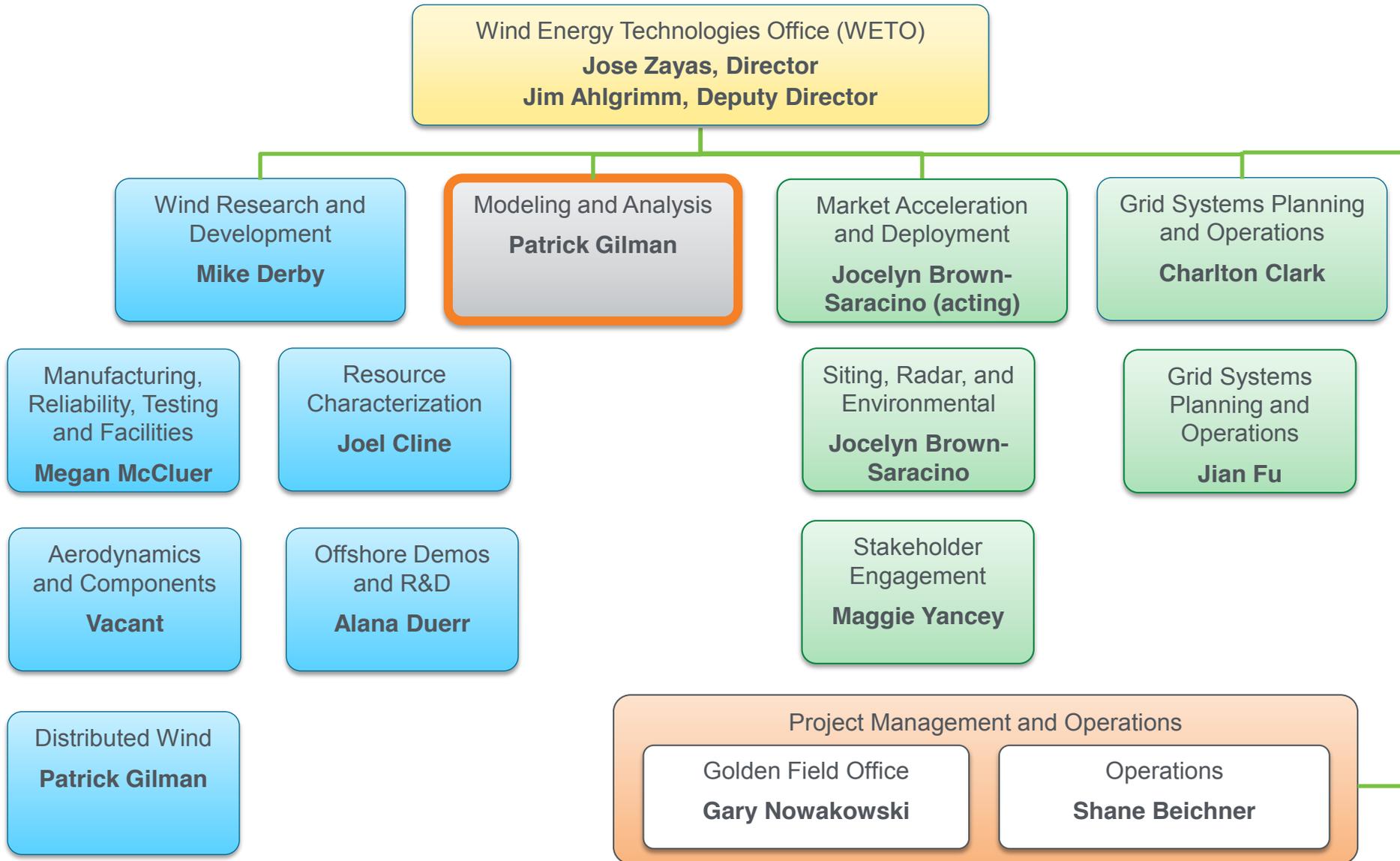
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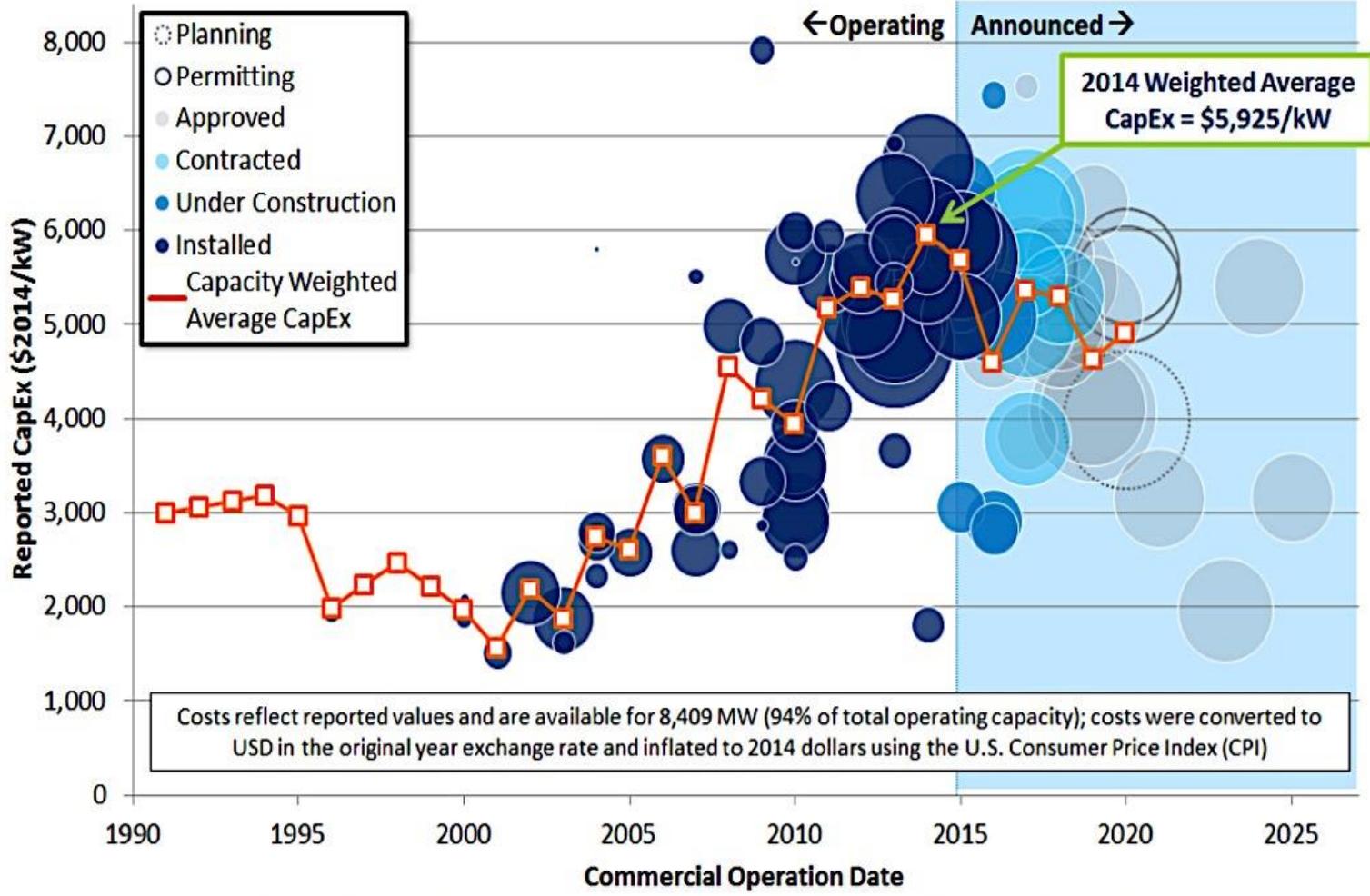
Wind Energy Technologies Office Structure



Strategic Focus Areas

Challenges, Goals, & Approach

Strategic Area	Challenges	Goals	Approaches
Market Reporting and Analysis	Little consistent access to unbiased, publicly-accessible data to understand current wind market and technology conditions.	Provide intelligence on market trends and empirical foundation for wider technology and economic analysis.	<ul style="list-style-type: none"> • Sector-specific market reports and databases • Annual LCOE review.
Wind Energy Futures Analysis	Long-term R&D investment payoff times lie beyond our ability to forecast using current market information.	Continuously improve capability and conduct analysis to provide deep insight into potential wind energy future scenarios.	<ul style="list-style-type: none"> • Capacity expansion modeling (ReEDS) • Production cost modeling • Scenario cost/benefit analysis • Model comparison and improvement.
R&D Investment and Policy Decision Support	Sound government decisions require rigorous analysis of investment and policy options.	Serve as trusted source of analysis to DOE, federal and state government leaders on wind energy.	<ul style="list-style-type: none"> • Proactive support to DOE analysis efforts • Flexibility to support emergent needs.

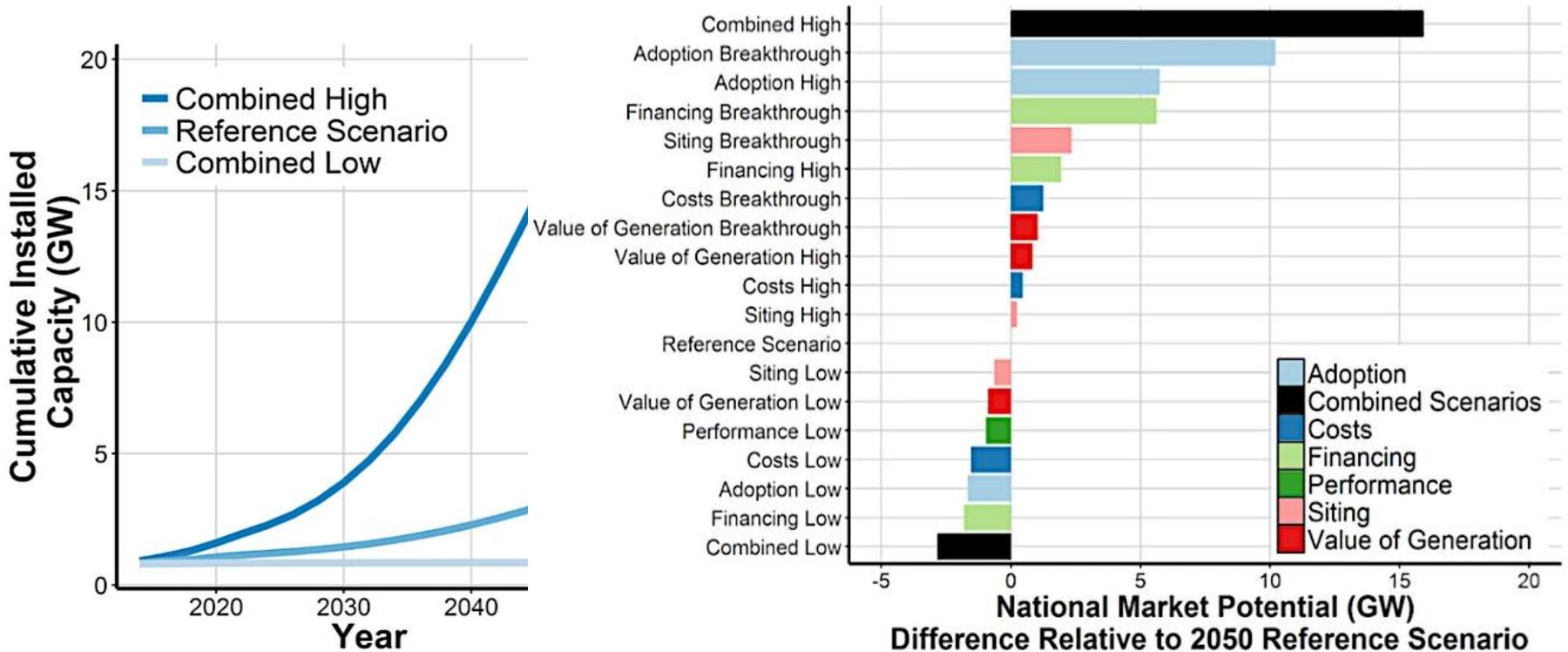


- Deep market insight to public and decision makers on:
 - Installation, Cost, Performance, Manufacturing, Export/Import, Finance and Policy Trends
- Targeted analysis of key questions
- Benchmarking: Aggregation and anonymized analysis of proprietary data for benefit of all.

Example: Global offshore wind costs turn the corner after years of cost increases driven by lack of competition and site complexity. Smith et al. (2015), *2014-2015 Offshore Wind Market Report*

Detailed scenario analysis of policy alternatives, technology improvement opportunities and deployment drivers across technology sectors

- Capacity expansion and technology diffusion modeling, production cost modeling, cost and benefit analysis, expert elicitation

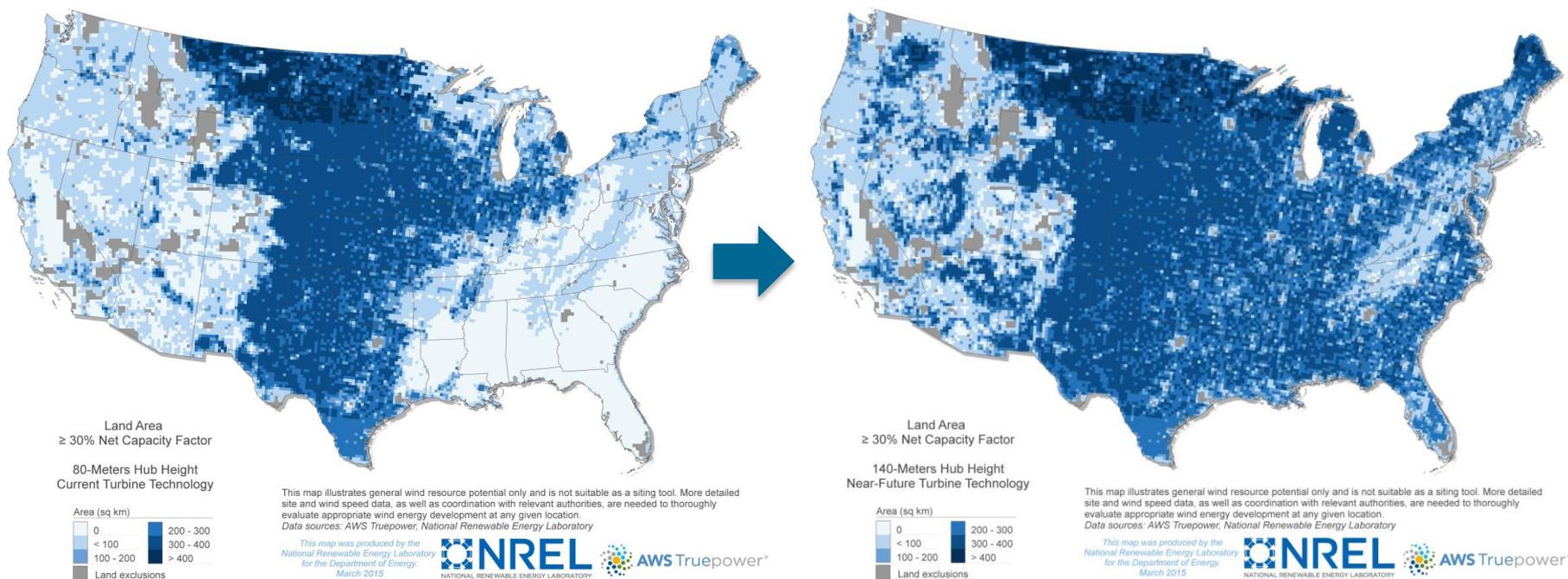


Example: dWind modeling shows that distributed wind can play a substantial role, but cost reduction, improvements in financing and siting, and increased adoption rate are all necessary to accelerate market growth.

Lantz et al (2016), *Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects*

R&D Investment and Policy Decision Support

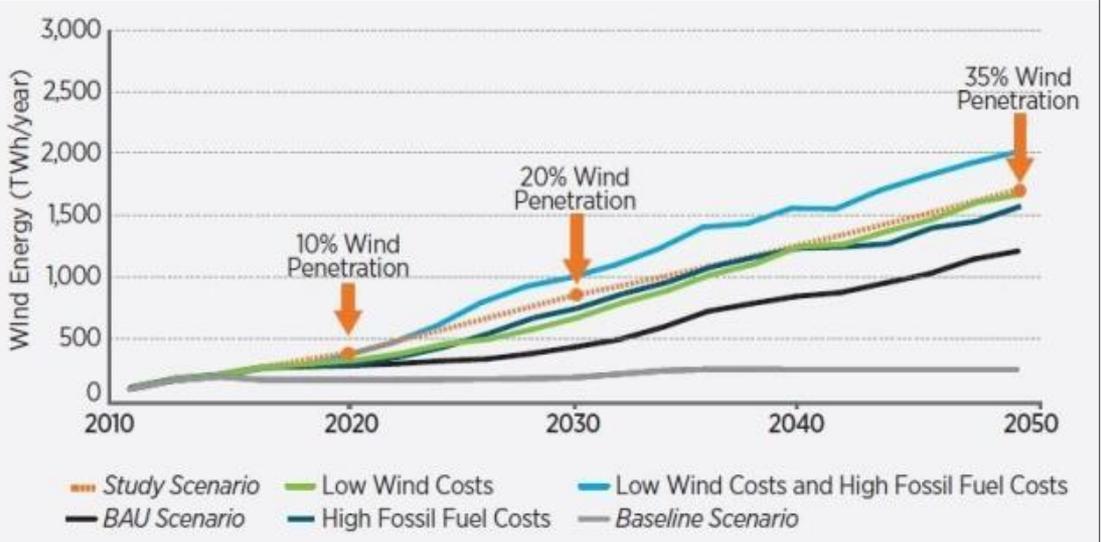
- Wind technology and market expertise to inform White House, DOE (Office of Energy Policy and Systems Analysis, Energy Information Administration [EIA]) and EERE corporate analysis
- Detailed systems engineering modeling and technology improvement opportunity analysis
- Metrics and goal development and tracking.



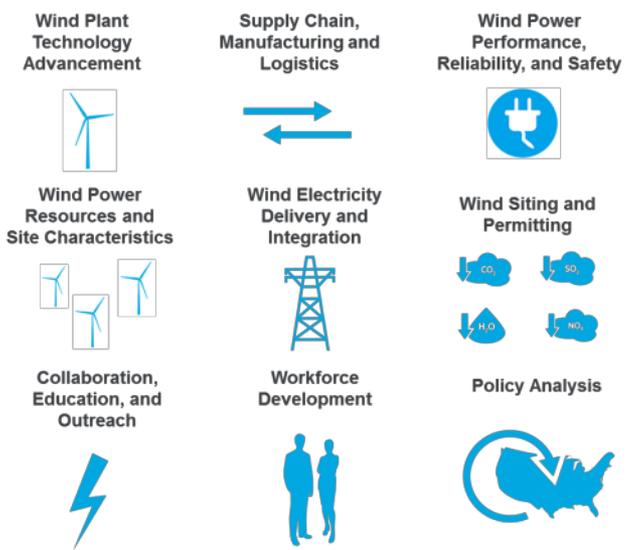
Example: R&D enabling cost-effective “tall wind” technologies (150 W/m^2 specific power rotors at 140m hub height) would increase land area with $\geq 30\%$ net capacity factor by 67% and open substantial development opportunities in all 50 states. Zayas et al. (2015), *Enabling Wind Power Nationwide*

Wind Vision—20% by 2030 and 35% by 2050 future feasible and beneficial

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



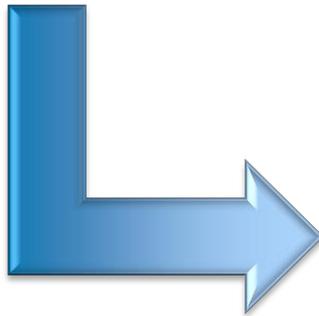
- *Wind Vision* concludes that 10 % wind by 2020, 20% wind by 2030, and 35% wind by 2050 is technically feasible, generates long-term savings, and brings substantial economic and environmental benefits.
- *Wind Vision* shows expansion of wind development to all 50 states.
- The *Wind Vision* roadmap (below) informs ongoing DOE technology research and development initiatives.



Costs*	Benefits* <i>*Cumulative 2014-2050</i>		
\$149 Billion [3%] savings	GHG: 14% less GHG; \$400 Billion savings	108 Billion savings; 22,000 lives saved	260 Billion gallons [23%] less consumption

Budget Summary

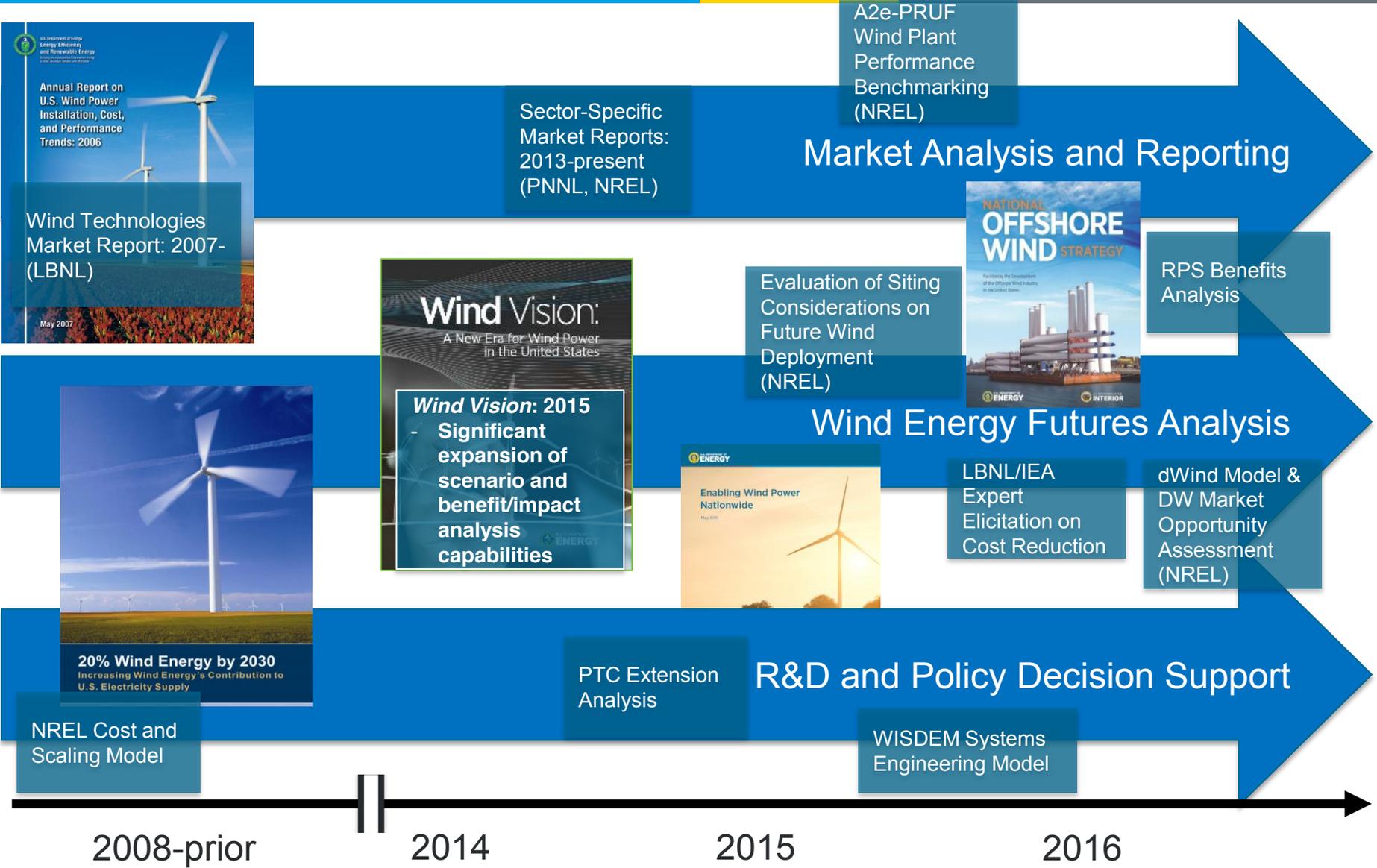
Total Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$3.3M	\$3.0M	\$3.3M	\$9.6M



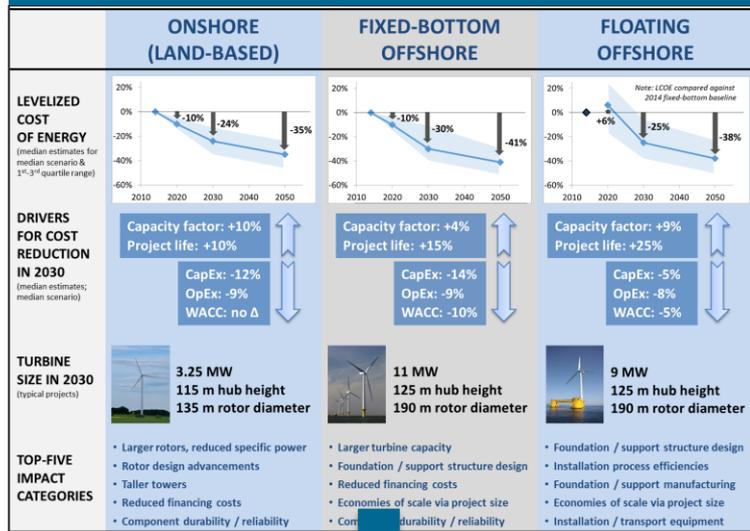
Peer Reviewed Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$0.60M	\$0.75M	\$0.60M	\$2.0M
18%	25%	18%	20%

Note: Small peer review budget reflects EERE exemption of modeling and analysis activities from peer review requirements.

Evolution of Modeling and Analysis Portfolio: Greater Coverage, Expanded Capabilities



IEA Wind Task 26 Expert Survey of Future Wind Costs



Online attention



Altmetric score (what's this?)

- Tweeted by 86
- Blogged by 13
- Mentioned in 3 Google+ posts
- Picked up by 35 news outlets
- 23 readers on Mendeley

This Altmetric score means that the article is:

- in the 99th percentile (ranked 1,299th) of the 233,958 tracked articles of a similar age in all journals
- in the 93rd percentile (ranked 3rd) of the 43 tracked articles of a similar age in *Nature Energy*



Expert elicitation survey on future wind energy costs

Ryan Wiser, Karen Jenni, Joachim Seel, Erin Baker, Maureen Hand, Eric Lantz & Aaron Smith

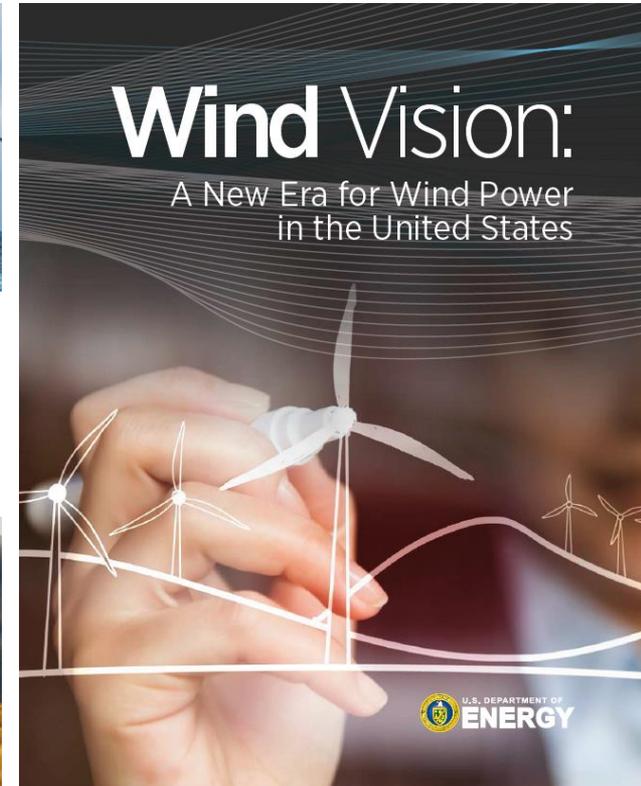
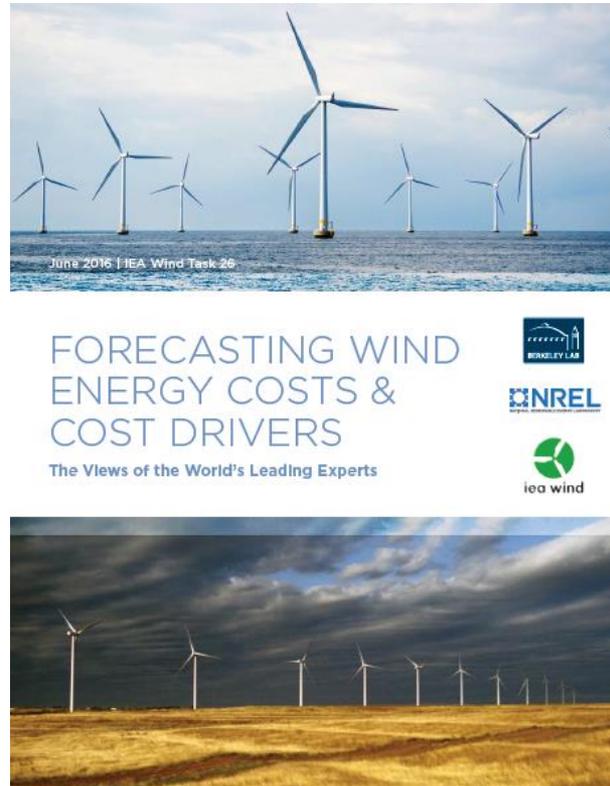


Key Projects/Activities and Accomplishments (FY14–16)

(RED = INCLUDED IN PEER REVIEW)

Key Project	Key Accomplishments	Key Collaborators
Wind Vision	<ul style="list-style-type: none"> • <i>High-penetration wind future feasible, major benefits, low cost</i> • <i>Benefit analysis capabilities</i> • <i>Future scenario analysis capabilities</i> 	<ul style="list-style-type: none"> • <i>NREL, LBNL</i> • <i>Senior Peer Review Group</i> • <i>A Cast of Hundreds</i>
Wind Technology Characterization and Techno-economic Modeling	<ul style="list-style-type: none"> • <i>Cost of Energy Review</i> • <i>Enabling Wind Nationwide</i> 	<ul style="list-style-type: none"> • <i>NREL (Eric Lantz, PI)</i>
Policy Impact and Wind Technology Market Reports	<ul style="list-style-type: none"> • <i>Wind Technologies Market Report</i> • <i>Environmental Benefits (10:40, Tuesday)</i> 	<ul style="list-style-type: none"> • <i>LBNL (Ryan Wiser, PI)</i>
Crosscutting (Modeling and Analysis engagement in other Wind office programs)	<ul style="list-style-type: none"> • <i>DW Modeling and Market Assessment (NREL)</i> • <i>Distributed Wind Market Report (PNNL)</i> • <i>Offshore Wind Market Report (NREL)</i> • <i>Nat'l. Offshore Wind Strategy (NREL)</i> • <i>A2E/PRUF Plant Performance Benchmark (NREL)</i> • <i>Public Acceptance Baseline Analysis (LBNL)</i> 	<ul style="list-style-type: none"> • <i>NREL (Eric Lantz, Walt Musial, Jason Fields)</i> • <i>PNNL (Alice Orrell)</i> • <i>LBNL (Ben Hoen)</i>

Note: There were over 60 publications supported by WETO Modeling and Analysis (M&A) during FY14-16, not including significant in-kind support on numerous publications sponsored by other offices.



Cost of Energy, Policy Impact Analysis, and Market Report

Ryan H. Wiser

Lawrence Berkeley National Laboratory
(LBNL)

rhwiser@lbl.gov; 510 486 5474

February 2017

Analysis and Modeling

- LBNL provides data, analysis & technical assistance to DOE and other key stakeholders to inform DOE R&D activities, and to provide stakeholders with unbiased data on and objective analysis of the potential benefits, costs, and barriers to wind power

The Challenge

- Rapid wind industry growth, market volatility, and policy debates all complicate the creation of a clear understanding of wind's benefits, costs, and barriers at both the local and national levels

Partners

- Wind Technologies Market Report (National Renewable Energy Laboratory [NREL], Exeter); International Energy Agency (IEA) Wind (Task members, NREL, UMass, Insight, Global Wind Energy Council, BVG, DTU, 163 experts; Property Values (Mass Clean Energy Center, Univ. of CT); Other (GLWN, NREL)

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

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- Communicating the costs and benefits of wind energy

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- World-class test and user facilities
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The Impact:

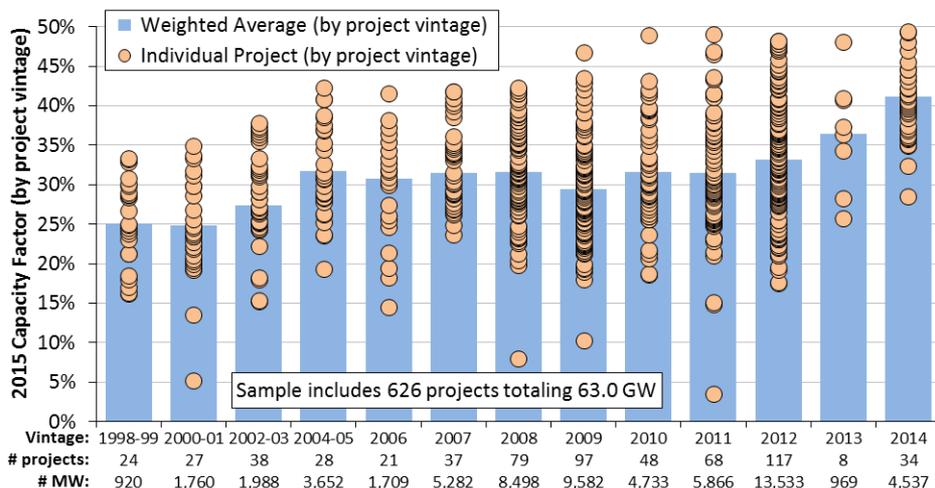
- **Wind Technologies Market Report:** Help stakeholders stay current by publishing an annual report that provides a detailed overview of wind energy developments
- **Wind Energy Costs and Benefits:** Inform decision making by evaluating the costs, benefits, and impacts of wind energy
- **Wind Policies and Finance:** Inform decisions related to federal and state policy deployment drivers and related implications for finance
- **Public Acceptance of Wind Power:** Conduct objective analysis to inform stakeholders in the wind project siting and permitting process
- **Technical Assistance:** Provide state and federal decision-makers, as well as wind and utility stakeholders, assistance on a variety of matters relating to the DOE Wind Office mission

- The **variety of analyses performed** under this overarching “project” leads to diverse methods, including various forms of **statistical, economic, financial, and engineering analysis.**
- In all cases, work is designed to **build on existing literature** to give stakeholders greater **confidence in the results.**
- As much as possible, analyses are **grounded in actual data from operating wind energy projects** and in experience with wind energy deployment efforts.
- Where appropriate, **experts** from other labs, industry, and academia are **used as both advisors and subcontractors.**
- A key goal is to **stay nimble** in order to be **responsive to emerging issues** and stakeholder needs in a timely manner.
- The key objective is to ensure that work is **used and useful.**

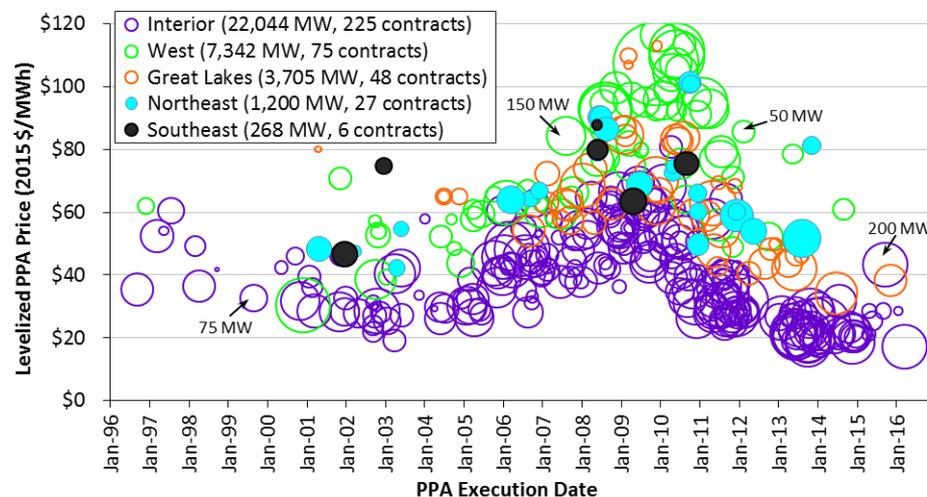
Accomplishments and Progress: Wind Technologies Market Report

- Goal: publish annual ‘flagship’ DOE report that presents data on key trends in the U.S. wind market, building on other available data collection efforts
- Covers installation, industry, technology, performance, cost, price, and policy/market trends, as well as future outlook → most important contribution is synthesis of wind project price, cost, and performance trends
- A “go to” guide for stakeholders; helps DOE benchmark its activities; provides input to other analyses (Wind Vision, IRP, AEO, IRENA, NREL)

Dramatic rise in capacity factors



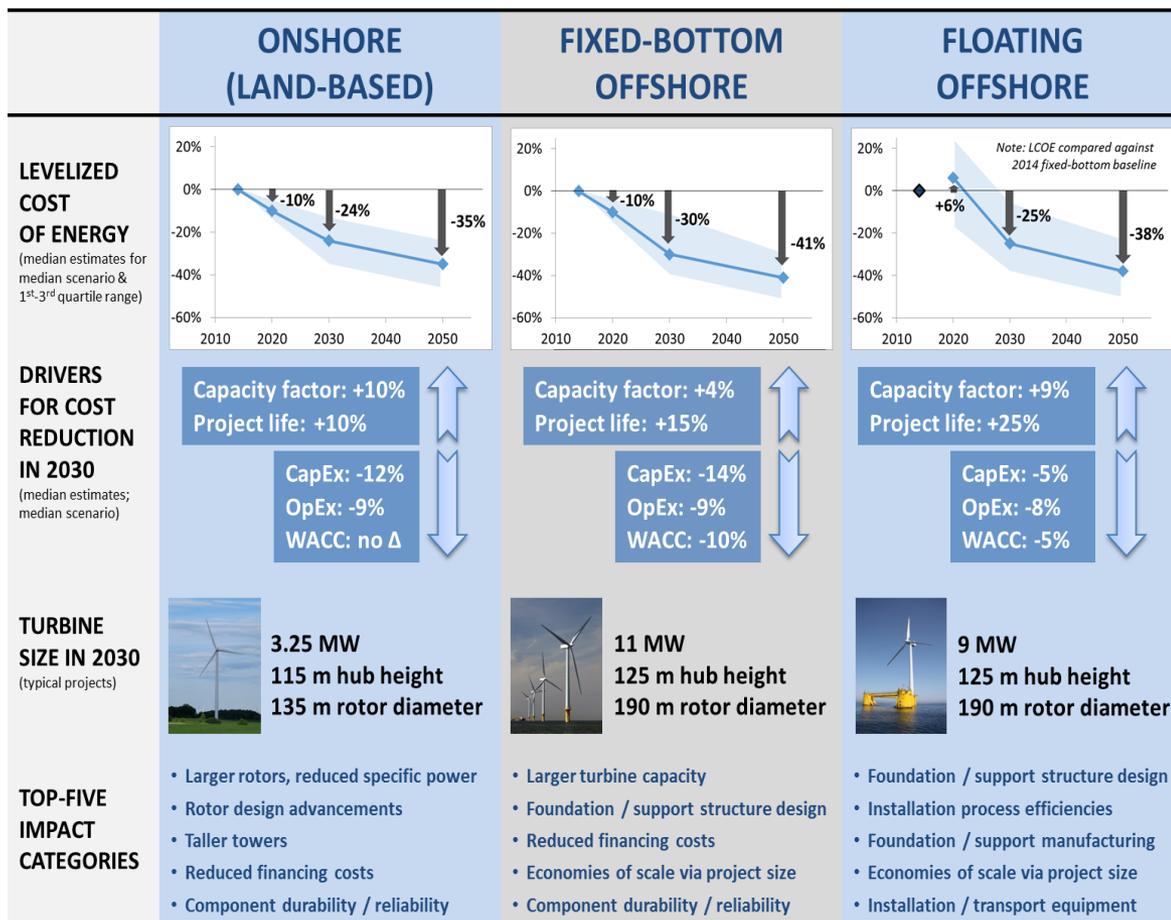
Rock-bottom PPA prices



Latest report: <https://emp.lbl.gov/publications/2015-wind-technologies-market-report>

Accomplishments and Progress: IEA Wind Task 26 Expert Survey

- Goal: Conduct largest expert elicitation survey (163 respondents) on an energy technology to gain insight on possible magnitude and drivers of future land-based and offshore wind energy cost reductions
- Inform policy and planning, R&D, and industry investment and strategy development while also improving treatment of wind in energy-sector models



LBNL report: <https://emp.lbl.gov/iea-wind-expert-survey>

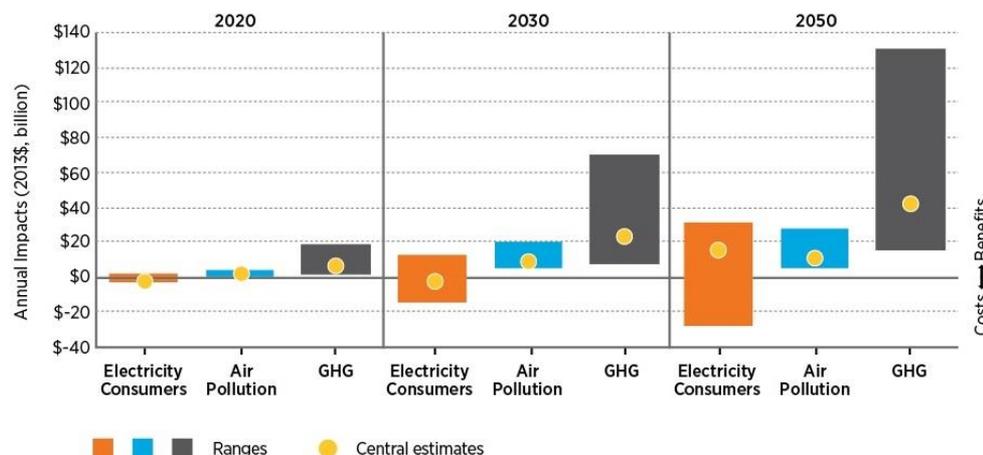
Nature Energy article: <http://rdcu.be/khRk>

Three short articles / blogs: <https://emp.lbl.gov/news>

WindEurope conference paper and related award

Accomplishments and Progress: *DOE Wind Vision Analysis & Report*

- Goal: contribute to DOE report that sought to inform decision makers and the public of wind power's costs and benefits, and to mobilize the industry around common actions to support a robust wind power future
- Berkeley Lab role was extensive:
 - Summarize current status of wind deployment, cost, and policy drivers
 - Roadmap actions in areas of cost, benefit, and policy analysis
 - Core team member in creation of analysis framework
 - Lead for benefits and impacts assessment
 - Subsequent publication of three peer-reviewed journal articles



Note: Results represent the present value of incremental costs or benefits (impacts) of the *Study Scenario* relative to the *Baseline Scenario*. Central estimates are based on *Central Study Scenario* modeling assumptions. The electricity consumer costs range reflects incremental expenditures (including capital, fuel, and O&M for transmission and generation of all technologies modeled) across a series of sensitivity scenarios. Air pollution and GHG estimates are based on the *Central Study Scenario* only, with ranges derived from the methods applied and detailed in the full report.

DOE report: <http://energy.gov/eere/wind/wind-vision>

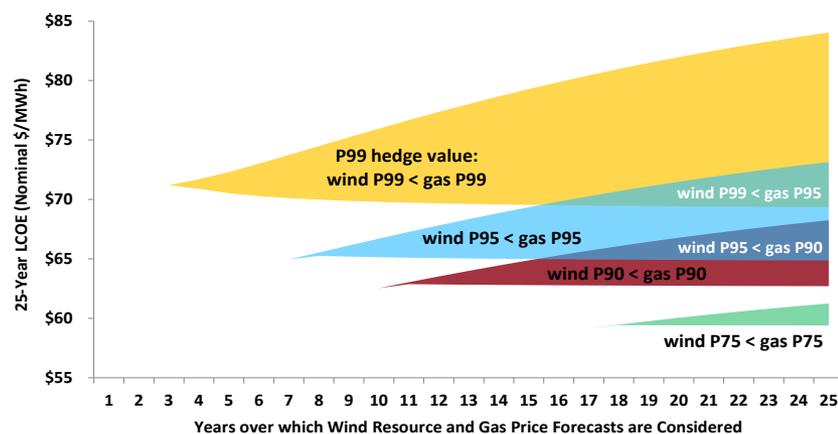
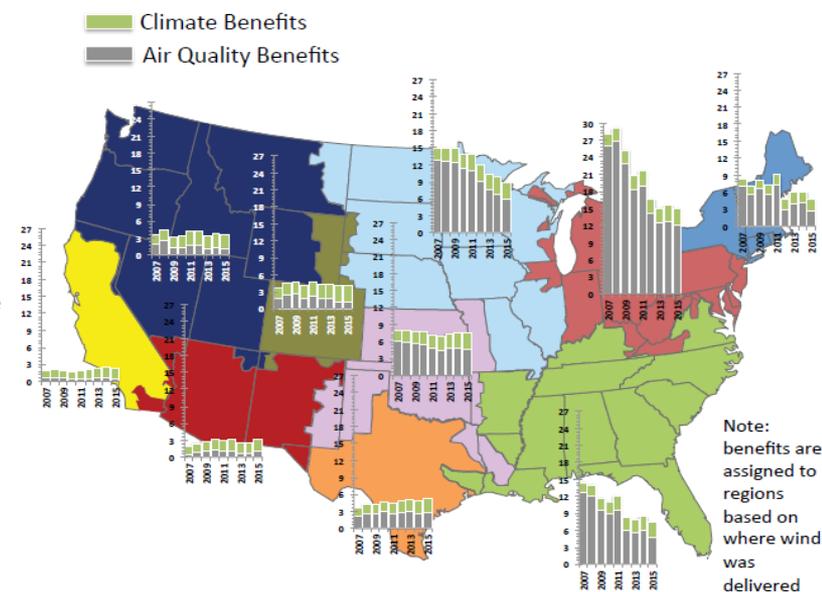
Electricity Journal: <http://www.sciencedirect.com/science/article/pii/S1040619015001992>

Applied Energy: [doi:10.1016/j.apenergy.2016.07.023](https://doi.org/10.1016/j.apenergy.2016.07.023)

Applied Energy: [doi:10.1016/j.energy.2016.07.068](https://doi.org/10.1016/j.energy.2016.07.068)

Accomplishments and Progress: *Additional Benefit / Impact Analysis*

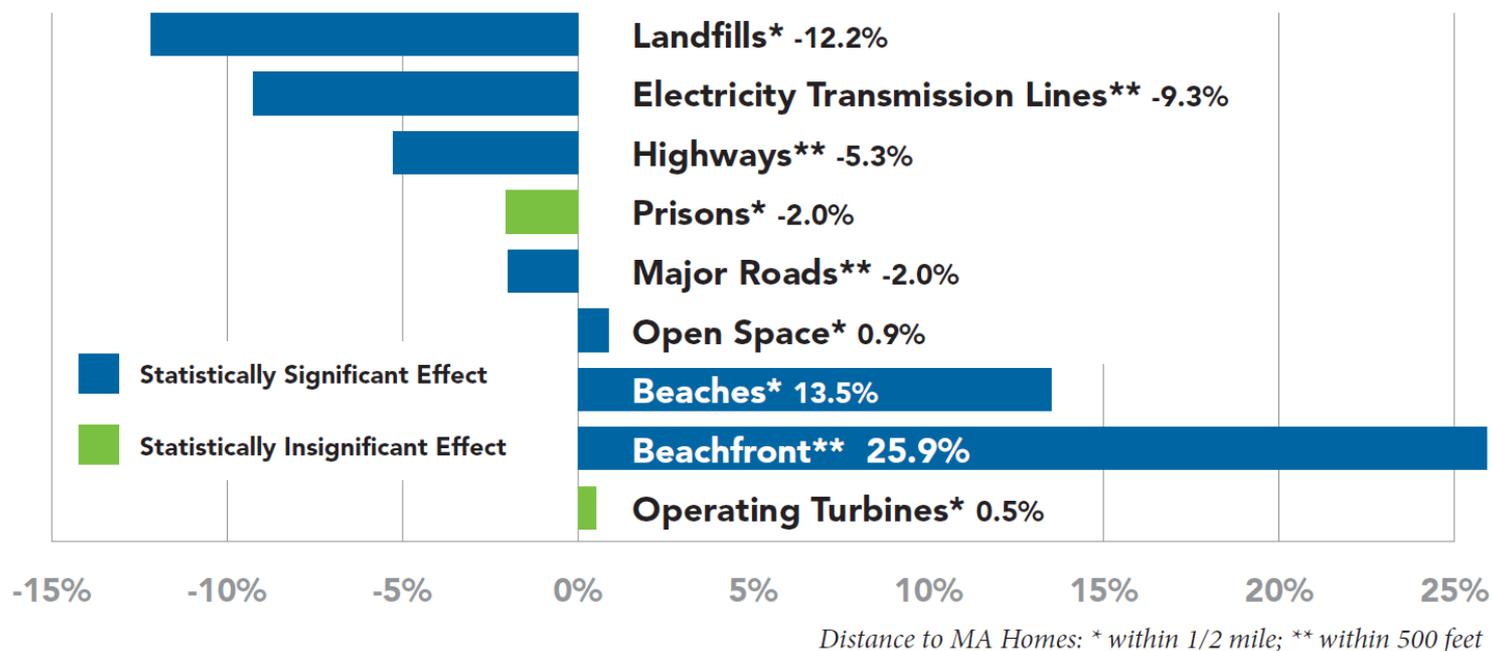
- Goal: Berkeley Lab leads analyses to better understand and communicate the benefits and impacts of wind
- **Historical Health & Environmental Benefits:** Evaluate how wind health and environmental benefits have evolved from 2007–2015 both in absolute terms as well as on a dollar-benefit per kWh basis. Additionally, analyze how benefits differ regionally.
- **Hedge Benefits of Wind Energy:** Analysis of the fuel price hedge value of wind, applying new approach that focuses on P99 levelized cost of energy curves of wind and gas-fired generation over time



LBNL report on hedge benefits: end-of-2016
Article on health & enviro benefits: forthcoming

Accomplishments and Progress: *Property Value Impacts*

- Goal: Increase understanding of community concerns about wind, providing objective analysis of potential impacts; assess affect of wind on property values (and sales volume) of nearby homes
- Based on Mass. sample, no statistical evidence that property values of homes located in proximity to turbines have been systematically affected



LBNL report: <https://emp.lbl.gov/publications/relationship-between-wind-turbines>

Journal article: <http://link.springer.com/article/10.1007%2Fs11146-014-9477-9>

- **IEA Wind Task 26 country comparison:** participate in Task 26; compare technology, cost, and performance data across IEA Wind Task 26 countries
<https://emp.lbl.gov/publications/iea-wind-task-26-wind-technology-cost>
- **Turbine price drivers:** analyzed drivers behind increase in turbine prices from early 2000s to 2009, and then subsequent drop in prices; included in NREL COE review
- **Mitigating the drop in value of wind with increasing penetration:** estimated the benefit of mitigation strategies to stem the decline in wind's value with penetration
<http://www.sciencedirect.com/science/article/pii/S0306261915002986>
- **Cost and benefits of tax equity:** quantified both the costs and benefits of tax equity; published a lab report and integrated the results into ReEDS model
<https://emp.lbl.gov/publications/analysis-costs-benefits-and-0>
- **Transmission and wind energy:** comparison of 'distant' vs. 'local' wind in the upper Midwest
<http://www.sciencedirect.com/science/article/pii/S0301421516302944>
- **Domestic content of wind equipment:** worked with GLWN to understand historical trends in the domestic content of wind equipment installed in the U.S.; findings integrated into DOE Wind Technologies Market Report
- **Technical assistance:** provided extensive technical assistance to numerous parties, including federal and state policymakers, the DOE, and a variety of wind and utility stakeholders; *examples: DOE Revolution Now, EIA AEO assumptions*

Project Plan & Schedule

Project Milestones	FY14	Percent Complete	Date Complete
Q1 Project Milestone Description: Present impact analysis methods and framework in PowerPoint form to Senior Peer Review Group on November 5, 2013		100%	11/5/13
Q2 Project Milestone Description: Complete draft of Chapter 3 report sections led by "Market, Data and Analysis" Task Force by March 31, 2014		100%	01/15/13
Q3 Project Milestone Description: Complete full draft of report content related to "Market, Data and Analysis" Task Force responsibilities, including portions of Chapter 3 and Chapter 4, by June 30, 2014		100%	06/30/14
Q4 Project Milestone Description: Task force leaders collect and collate comments on 7/18 draft from their task force member		100%	09/30/14

Project Milestones	FY15	Percent Complete	Date Complete
Q1 Project Milestone Description (Progress Measure): Wind Vision final analysis and document revisions complete.		100%	12/31/14
Q2 Project Milestone Description (Progress Measure): IEA Task 26 expert survey drafted and finalized.		100%	3/27/15
Q3 Project Milestone Description (Progress Measure): Complete external review draft of "2014 Wind Technologies Market Report."		100%	6/23/15
Q4 Project Milestone Description (SMART and Go/No-Go): By 9/30/2015, LBNL will publish the final version of the "2014 Wind Technologies Market Report."		100%	8/10/2015

Project Milestones	FY16	Percent Complete	Date Complete
GO/NO-GO Milestone: By 9/30/2016, LBNL will publish the final version of the "2015 Wind Technologies Market Report."			
Q1 Project Milestone Description (Progress Measure): Disseminate IEA Task 26 online survey to domestic and international experts.		100%	10/15/2015
Q2 Project Milestone Description (Progress Measure): Collect IEA Task 26 survey responses and present analysis and initial results in PowerPoint form.		100%	3/30/2016
Q3 Project Milestone Description (Progress Measure): Complete external review draft of "2015 Wind Technologies Market Report."		100%	6/22/2016
Q4 Project Milestone Description (SMART and Go/No-Go): By 9/30/2016, LBNL will publish the final version of the "2015 Wind Technologies Market Report."		100%	8/17/2016
Q4 Project Milestone Description (Progress Measure): By 9/30/2016, LBNL will deliver a PowerPoint slide deck summarizing wind's historical environmental benefits from 2007-2015, and will also deliver to NREL a writeup (to be inserted into the "cost of energy" report) that summarizes results from the updated wind turbine price drivers analysis.		100%	10/06/2016

- Milestones reflect Annual Operating Plans
- Additional projects and deliverables described earlier
- All milestones met with minimal delay; all Go/No-Go decision points achieved

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$600k	\$0	\$750k	\$0	\$694k	\$0

- Budget available matches well with total expenditure
 - Funding ~\$2.0 million, expenditure ~\$1.9 million; 5% funding remains
- Several projects described in previous slides were co-funded by other DOE offices, or leveraged by other resources
 - Hedge benefits of wind: co-funded by DOE SunShot Initiative
 - Historical health and environ. benefits: co-funded by DOE Sustainability Performance Office and SunShot
 - IEA Wind Task 26 expert survey: in-kind assistance from many others
 - Property value impacts: co-funded/led by Mass CEC, Univ. of CT
 - Cost of tax equity, ReEDS tax equity: co-funded by DOE SunShot
 - Strategies for mitigating value decline: co-funded by DOE Office of Electricity and SunShot

Partners, Subcontractors, and Collaborators:

- NREL (Wind Technologies Market Report, IEA Cost of Wind, NREL COE review, etc.)
- Exeter Associates and Ventyx (subcontractors on Wind Technologies Market Report)
- MA Clean Energy Center, Univ. of CT (collaborators on MA wind property values work)
- GLWN (subcontractor on domestic content work)
- Univ. of MA, Insight Decisions, NREL, IEA Task 26, GWEC, BVG, DTU, 163 wind experts (IEA Wind survey)

Communications and Technology Transfer:

13 reports, seven journal articles, one conference paper; we have also presented our research at a wide array of national and local venues (64 presentations total):

Wind Technologies Market Report: WindExchange (4), Wells Fargo, EPA, RPS Summit (2), Four Corners Wind Resource Center, NY Interagency Working Group, Clean Energy States Alliance, Chinese Delegation, IEA Wind (3), Southern Wind Energy Association

IEA Wind Task 26: AWEA WINDPOWER, EPRC, DOE, Governors' Wind and Solar Coalition, IEA Wind (5), public webinar, LBNL, Wells Fargo, DWIA

Wind Vision & Benefits/Impacts Work: EPA, NARUC, WindExchange (2), MAP, Wind Vision Task Forces (5), KAPSARC, Georgia PSC, ARPA-E, INFORMS, The Seminar Group, NPCC, Oregon Citizens Utility Board

Property Values: AWEA, ARES, AAG, WINDEXchange, IRWA, Mass Governor's Office, IEA

Other: Aspen Pathways to Climate Solutions, AWEA WINDPOWER (2), AWEA Wind Finance, DOE Lab Summit, DOE Wind Executive Summit, DOE Wind, AWEA, EIA, IEA Wind

Press uptake: leading example is expert survey--27 original news articles, 15 blogs, 5 radio or podcast interviews, 29 reprints or slightly revised press releases, ~5000 downloads

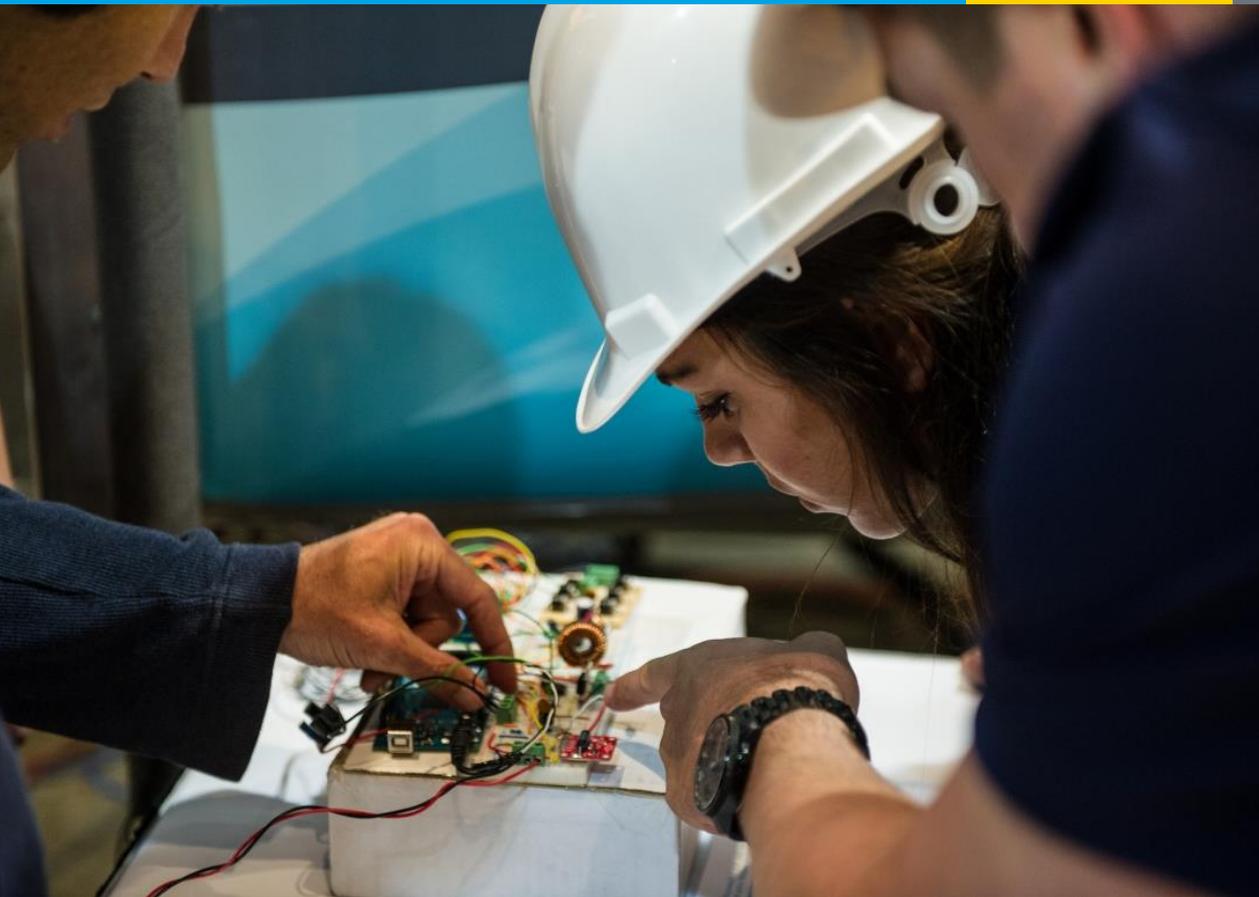
Extensive technical assistance to wide diversity of stakeholders

FY17/Current Research:

- **Wind Technologies Market Report:** Publication Aug. 2017*
- **Historical Health & Environ. Benefits:** Article submission Dec. 2016*
- **Hedge Benefits of Wind Energy:** Publication by year-end 2016
- **Wind Turbine Price Drivers:** Publication by year-end 2016
- **Offshore Wind Value Analysis:** Summary of core results Sept. 2017*
- **IEA Task 26:** Update U.S. data; continue dissemination survey results

* Signifies an activity that represents a FY17 AOP milestone

Planned Future Research: Future research likely to be centered around core areas that have defined recent effort: Wind Technologies Market report, understanding and projecting cost and performance trends, assessment of wind energy benefits and impacts, nimble policy- and market- relevant analysis, and technical assistance



Stakeholder Engagement, Education, and Outreach

Jocelyn Brown-Saracino
Acting Market Acceleration and
Deployment Program Manager

February 14, 2017

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- **GOAL:** Reduce the unsubsidized market levelized cost of energy (LCOE) for utility-scale land-based wind energy systems from a reference wind cost of \$0.074/kWh in 2012 to \$0.057/kWh by 2020 and \$0.042/kWh by 2030.
- **GOAL:** Reduce the unsubsidized market LCOE for offshore fixed-bottom wind energy systems from a reference of \$0.18/kWh in 2015 to \$0.15/kWh by 2020 and \$0.096/kWh by 2030.

Enhancing U.S. Energy Security and Independence

- **GOAL:** Accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality.

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- **GOAL:** Expand the geographic development potential of wind power plants in the United States, particularly in offshore zones and the U.S. Southeast.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

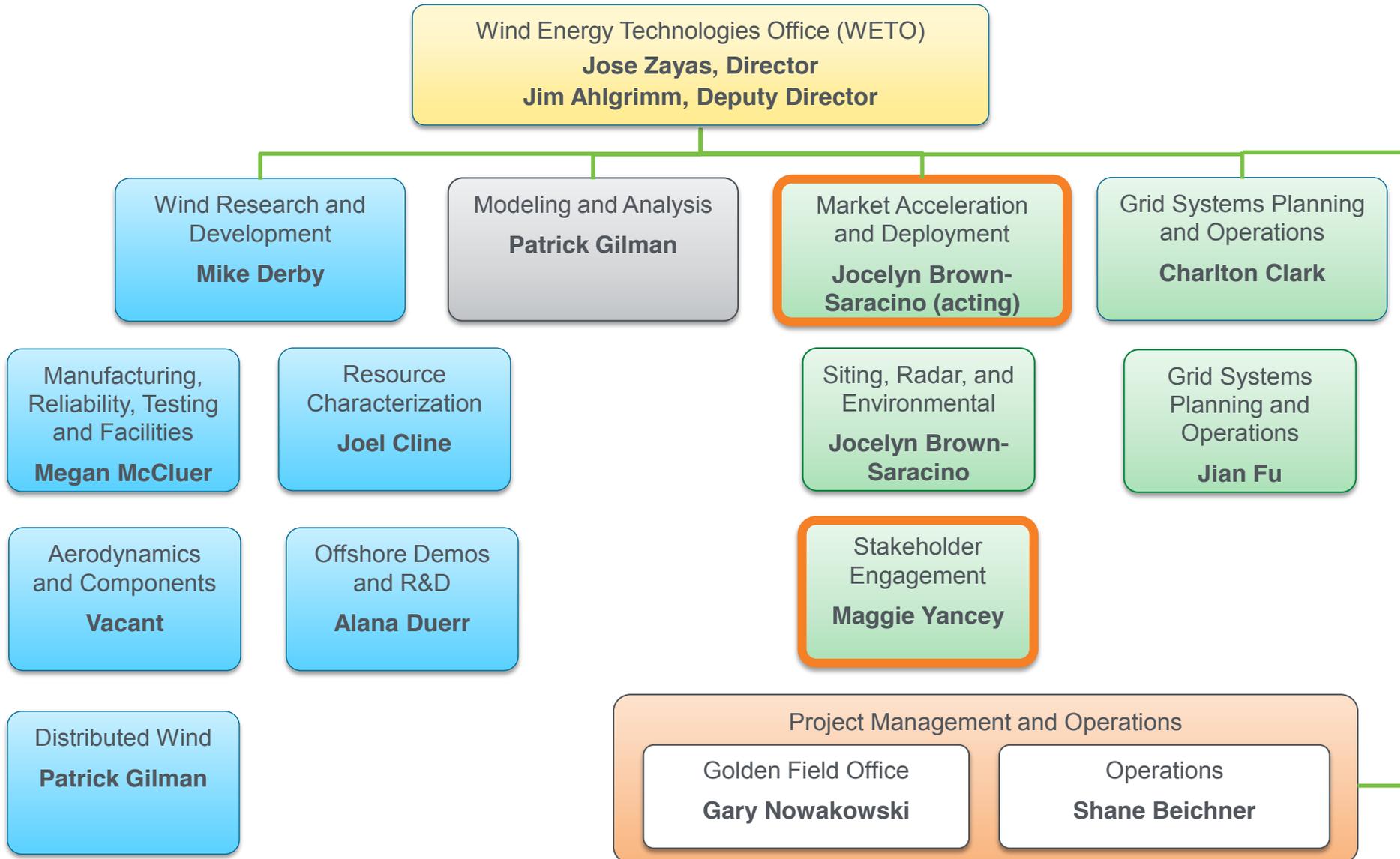
- Wind plant optimization
- Resource assessment and characterization
- Reliability improvements
- **Enabling access to better resources through tall wind**
- Distributed wind R&D
- NextGen component innovations

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- **Communicating the costs and benefits of wind energy**



- **Act as a convener of diverse stakeholders** in a national-scale dialogue about wind energy and to promote workforce development
 - *Only agency whose primary mission is addressing the deployment of wind energy technologies*
- **Disseminate trusted, impartial, unbiased, state-of-the-art data**
- **Engage the network of national laboratories** to carry out research and analysis that is beyond the scope of any one company.

Strategic Focus Areas

Challenges, goals, and approach

Strategic Area	Challenges	Goals	Approach
Stakeholder Engagement	There is a need for neutral information regarding wind energy to enable informed siting and development decision making.	Enable well-informed decisions about the appropriate deployment of wind energy Inform the policy and permitting processes and improve public discourse.	<ul style="list-style-type: none">• Disseminate accurate and state-of-the-art information• Conduct analyses to better understand socioeconomic impacts of wind• Develop regional networks for engagement on wind energy development issues.
Education and Workforce Development	There is a need for a robust, educated wind workforce to meet rapidly growing demand.	Skilled scientists and engineers who can develop the next generation of wind power technologies A highly qualified workforce that is equipped to join a growing field.	<ul style="list-style-type: none">• Provide public, highly visible hands-on learning opportunities for future scientists, engineers, and technicians• Engage institutions in efforts to establish lasting programs• Utilize a multi-generational teaching and mentoring approach to foster near-term and long-term workforce potential.

WINDEXchange: WETO's hub of stakeholder engagement and outreach activities

Purpose: help communities weigh the benefits and costs of wind energy, understand the deployment process, and make wind development decisions supported by science- and fact-based information.

WINDEXchange Engagement & Web Resources

- Wind resource, potential, and installed capacity maps
- Wind ordinances library, webinars, podcasts, and fact sheets, e-newsletter
- Siting and project information
- Educational materials and outreach
- Guidebooks and technical briefs
- Meetings, workshops, and WINDEXchange Summit
- Active outreach on WWPTO products (i.e. market reports).

JEDI tools and economic analysis

- Analysis of impact of wind on jobs and the economy.

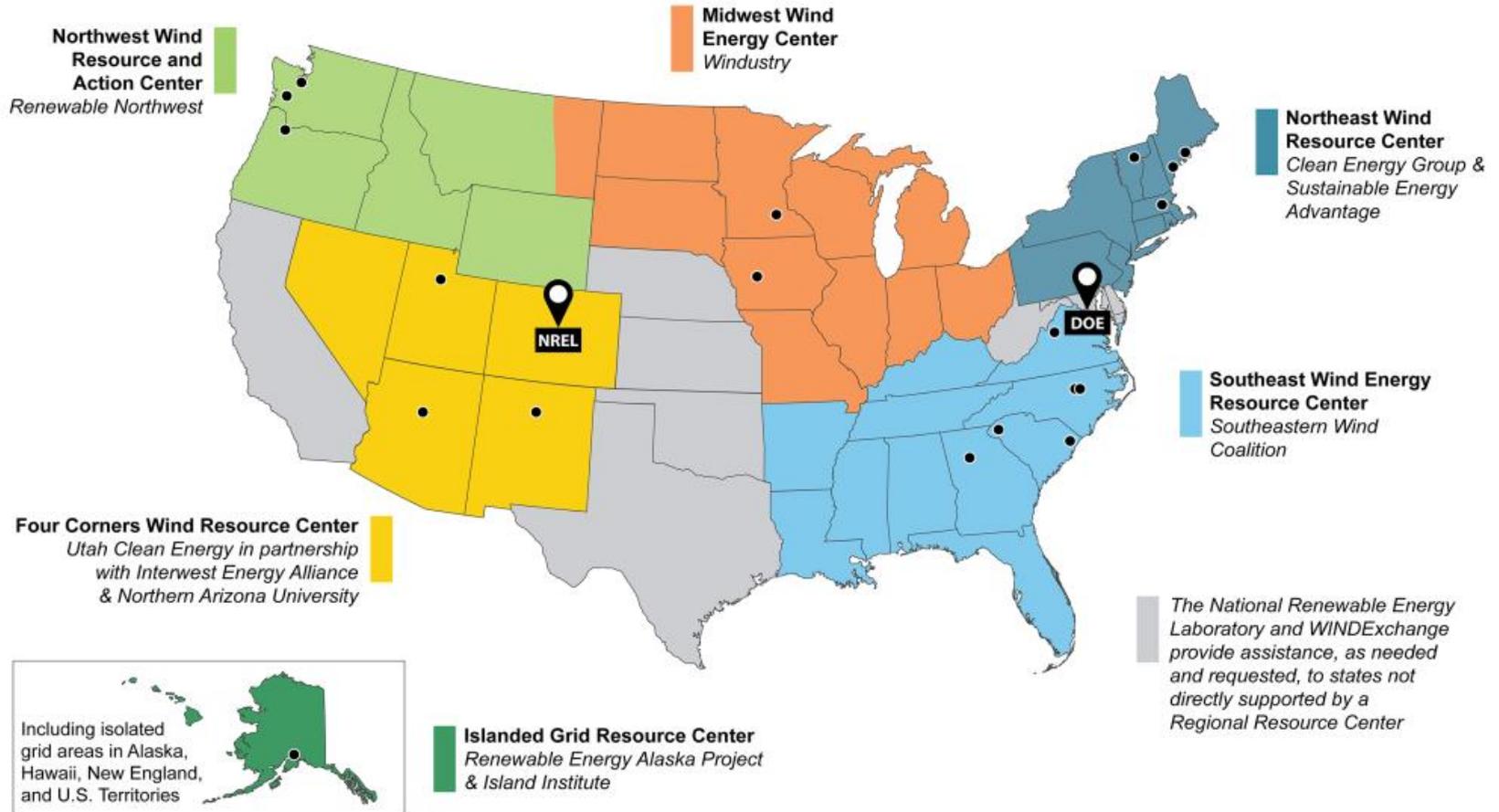
Regional Resource Centers (RRCs)

- Directly engage within states on regional wind deployment issues
- Lead or enable local initiatives, strategic programs, projects, and/or campaigns to address deployment-related considerations and support the goal of substantial market transformation
- Provide technical expertise and tools, ensuring informed decision making
- Conduct regional outreach on key challenges by hosting meetings, trainings, and other direct outreach.



Public Acceptance Baseline Analysis: First-ever nationwide quantitative assessment of the drivers of public acceptance and opposition to wind projects, largest-ever survey of wind farm neighbors (plus: national wind turbine mapping project).

WINDEXchange and Regional Resource Centers



WindExchange

Key Project/Activity	Key Accomplishments	Key Collaborators
<p>WINDEXchange</p>	<p>Implemented the first round of six RRCs</p>	<p>DOE, NREL, RRCs</p>
	<p>Published State of the Regions Reports</p>	<p>NREL, DOE, RRCs</p>
	<p>Documented engagement with more than 97,000 key stakeholders (e.g. utilities, government)</p>	<p>NREL, RRCs</p>
<p>Public Acceptance Baseline Analysis</p>	<p>Largest-ever survey of residents living within five miles of wind turbines (1,700+ respondents); private-public partnership to develop national turbine map</p>	<p>Baseline: LBNL, U. of Delaware, Portland St. University, Martin Luther University, NREL Turbine Map: USGS, AWEA</p>

DOE helps develop the future U.S. wind workforce through education initiatives:

Wind for Schools

- **Introduces wind energy education** and careers to teachers and K-12 and post-secondary students, supporting the industry's need for a skilled and qualified workforce
- **Equips college students** with hands-on wind energy applications and education to provide the growing U.S. wind industry with a competitive workforce.

Collegiate Wind Competition (CWC)

- **Introduces students to the primary disciplines within the wind energy industry**, including engineering, project management, business, and stakeholder engagement
- **Prepares students from multiple disciplines to enter the wind energy workforce** by providing real-world technology and business plan development experience.

Wind For Schools (WfS) and Collegiate Wind Competition (CWC)

Key Project/Activity	Key Accomplishments	Key Collaborators
Wind for Schools (wfS)	<p>Restarted WfS, Enabling 12 Wind Application Centers (WACs) to reengage</p> <p>Installed 180 turbines in K-12 schools to date</p>	<p>12 universities, 135 K-12 schools, Distributed Wind Energy Association (DWEA), KidWind, National Energy Education Development Project</p>
WINDEXchange	<p>Launched Wind Career Map on DOE website</p>	<p>NREL</p>
Collegiate Wind Competition	<p>Successfully planned and managed the inaugural and second competition at AWEA Wind Power Conference and an interim technical challenge</p> <p>On track to host second interim challenge in April 2017</p>	<p>NREL, American Wind Energy Association, Wind Energy Foundation, KidWind, selected collegiate teams</p>

Workshops and Conferences

DOE and awardees planned and led numerous stakeholder engagement, outreach and education leadership activities.

Significant outreach events include:

- Hosted WINDEXchange Summit (2014 and 2015)
- Supported North American Wind Energy Academy Summit (2015)
- Hosted DOE Workforce and Education Summit (2016)
- Regional workshops hosted by RRCs in Oregon, North Carolina, South Carolina, Virginia, Maine, and Alaska, as well as participation in many AWEA regional conferences
- Bi-weekly e-newsletter with more than 13,300 subscribers

Stakeholder Engagement

Public Acceptance Baseline Analysis (11:20am)

Ben Hoen

WindExchange and Regional Resource Centers (11:45am)

Ian Baring-Gould

Education and Workforce Development

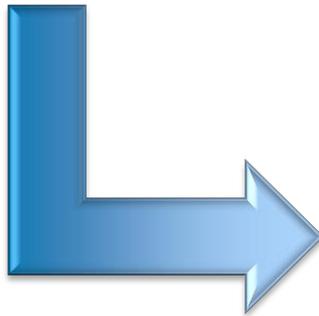
Collegiate Wind Competition (CWC) (1:35pm)

Suzanne Tegen

Wind for Schools (2:00pm)

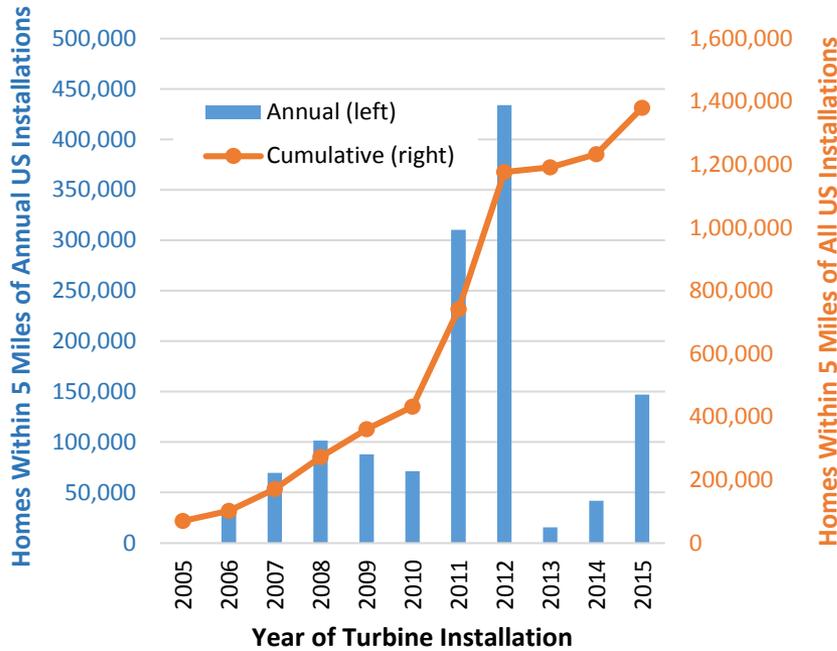
Mark Jacobson

Total Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$2.4M	\$3.0M	\$3.1M	\$8.5M

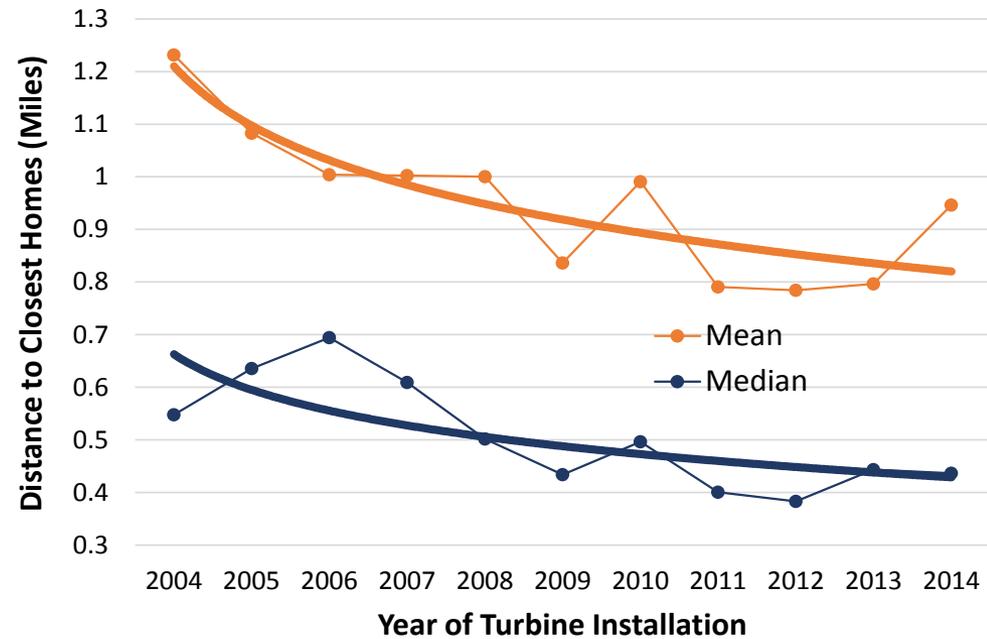


<i>Peer Reviewed</i> Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$2.4M	\$3.0M	\$3.1M	\$8.5M
100%	100%	100%	100%

Number of Homes Within 5 Miles of Industrial Scale US Wind Turbines



Mean and Median Distance to Nearest Home By Installation Year



Source: LBNL Baseline Public Acceptance Data; Note: Turbines > 364 ft & 1.5 MW

Source: LBNL Baseline Public Acceptance Data; Note: Turbines > 364 ft & 1.5 MW

Public Acceptance Baseline Analysis (FY15 & FY16)

Ben Hoen

Lawrence Berkeley National Laboratory
bhoen@lbl.gov; 845-758-1896

February, 2017

Public Acceptance Baseline Analysis

- Levels of and correlates to support, opposition, and annoyance of individuals living near U.S. wind turbines
- Characterization and mapping of U.S. wind turbines
- Continuing technical assistance on residential property value impacts of turbines.

The Challenge

- Turbines getting closer to people
- There is no nationwide assessment of attitudes towards or annoyance from those turbines
- Nor is there understanding of their drivers
- There is no high-quality regularly-updated source of locations and characteristics of U.S. turbines.

Partners

- **Baseline Public Acceptance Survey and Analysis:** University of Delaware, Portland State University, Martin Luther University (Germany), National Renewable Energy Laboratory (NREL)
- **U.S. Utility-Scale Wind Turbine Characterization and Mapping:** United States Geological Survey (USGS) and American Wind Energy Association (AWEA)

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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- Resource assessment and characterization
- Reliability improvements
- **Enabling access to better resources through tall wind**
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Enabling Wind Nationwide

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Communicating the costs and benefits of wind energy

Enhancing U.S. Energy Security and Independence

- Information synthesis and dissemination
- Successful coexistence with radar systems

The Impact: Baseline Public Acceptance Survey and Analysis

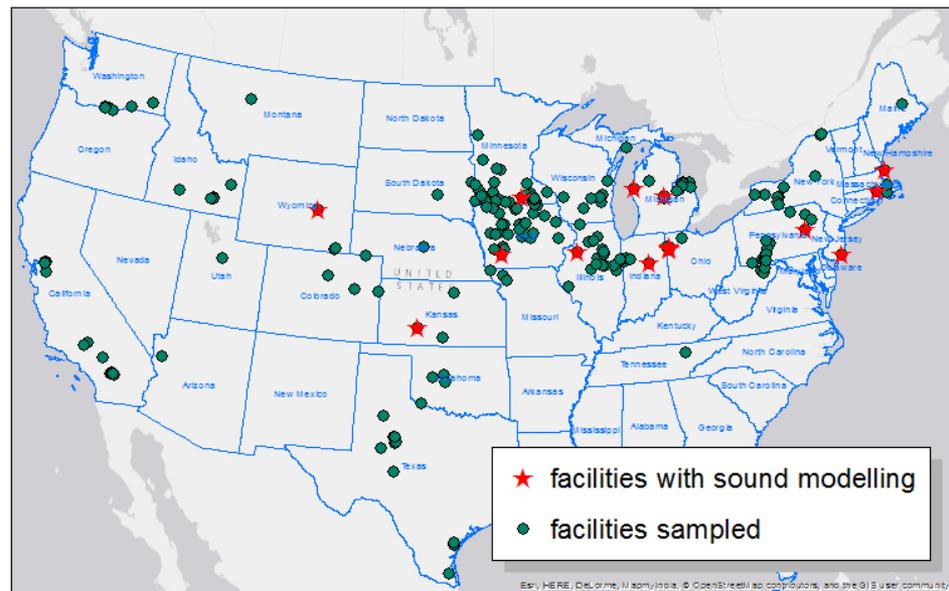
- Deliver to industry, community stakeholders, and other researchers unbiased measurements on the social cost and benefits of wind energy
- Examine what drives higher or lower levels to provide results stakeholders can act on going forward
- Inform where research dollars should be spent to reduce related deployment barriers.

The Impact: U.S. Utility-Scale Wind Turbine Characterization and Mapping

- Provide a regularly updated comprehensive dataset of existing, pending and proposed turbine locations
- Characterize fleet in terms of height, rotor diameter, installation year
- Release data to federal agencies (including National Oceanic and Atmospheric Administration, USGS, Department of Defense), other researchers and the public.

- Largest-ever representative sample of neighbors ($n=1,743$)
- All homes within five miles of U.S. turbines, most within one mile
- Detailed info on support, opposition, and annoyance, and factors affecting those perceptions.

Surveyed US Facilities ($n=254$)



Relevance and Impact

- Directly address growing proximity of wind facilities to homes
- Provide stakeholders unbiased information about existing facilities to allow greater confidence in the likely effects of proposed facilities
- Address common claims made about wind facilities
- Use state-of-the-art statistics to examine correlates to improve wind development outcomes in the future.

Technical Approach: US Utility Scale Wind Turbine Characterization and Mapping

- Collaboration: industry (AWEA), lab (LBNL), and federal agency (USGS)
- Merge publically available and privately held data
- Existing, pending and proposed turbines and turbine characteristic information
- Share with federal agencies, public, and researchers.

Relevance & Impact

- "U.S. Government" lacks single-source wind turbine database for impact assessments
- Growing problem with increasing deployment
- DOE (via LBNL) has skills, relationships, and reach to provide data
- Will save federal time and dollars
- Allows North American Aerospace Defense Command (NORAD) and others to do accurate assessments (they currently fear the worst)

Example Turbine



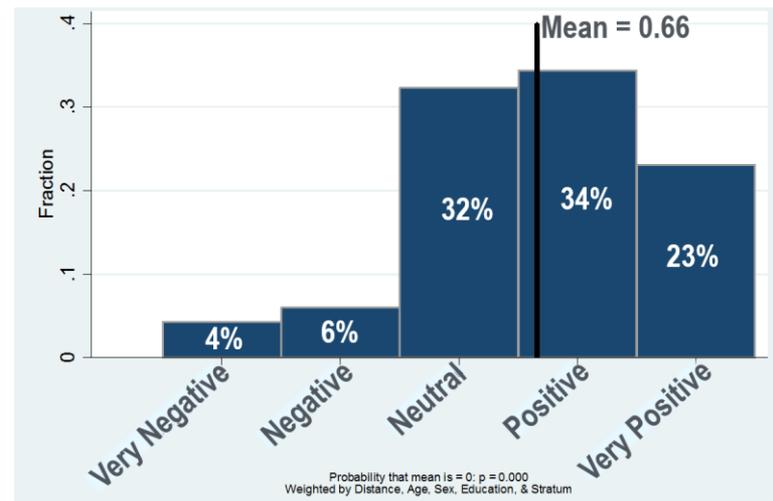
Baseline Public Acceptance Survey and Analysis

- Conducted extensive literature and stakeholder review to ensure results are broadly applicable and fill gaps (FY15)
- Developed multi-modal (phone, mail and web) survey instruments to ensure a representative sample is surveyed (FY 15-16)
- Conducted survey during aggressive presidential election achieving an impressive 22% response rate (FY16)
- Prepared summary results for DOE and advisors to meet Go/No-Go milestone (FY16).

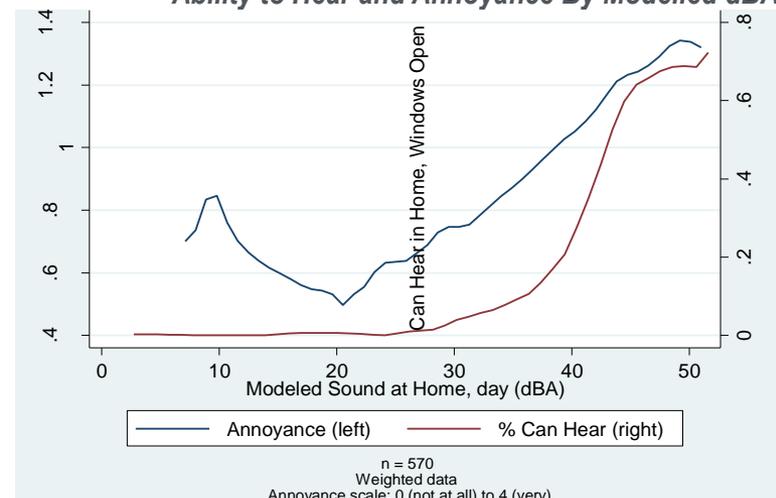
Initial Findings

- Drivers for support and annoyance include: proximity to turbines, move-in-date, belief in climate change, facility size, and view of turbines
- Compensation not panacea for all individuals
- Modelled sound highly predictive of annoyance
- Demographics (except age) not predictive of support or opposition.

Distribution Of Attitudes Across Full Sample

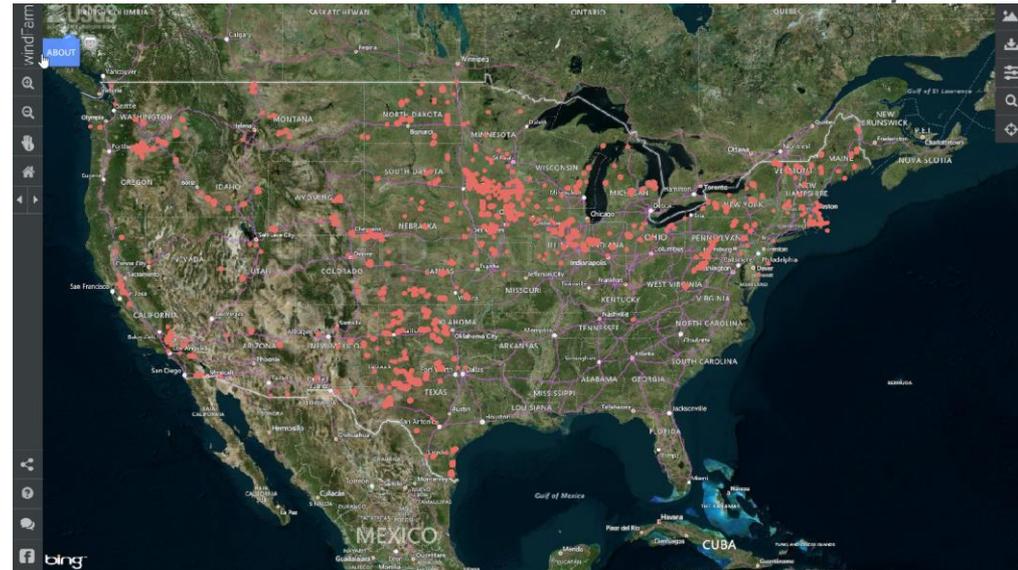


Ability to Hear and Annoyance By Modelled dBA



U.S. Utility-Scale Wind Turbine Characterization and Mapping

- Successfully developed collaboration Statement of Work with USGS, AWEA, and LBNL
- Developed process flow and determinations on protected data
- Negotiated and nearly completed three-party public-private Cooperative Research and Development Agreement
- Piloted automated Federal Aviation Administration (FAA) data scraping, cleaning and storage process



Other Public Acceptance Work

- Continued to provide technical assistance around property value impacts near turbines
- Served as advisor/participant to two international public acceptance of wind efforts (International Energy Agency Task 28, Denmark Wind 2050)

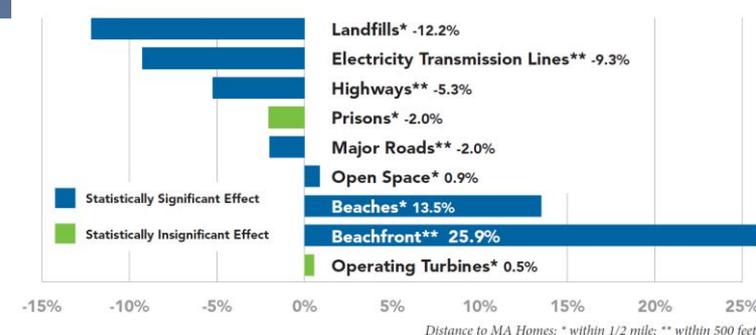
Technical University of Denmark

WIND2050



iea wind

Comparison of Home Price Effects in Massachusetts



- **Three-year Project (FY15 - 17)**
- **All Milestones and deliverables met on and before required dates**
- **Go/No-Go decision criteria achieved**

FY15 Project Milestones (First Year of Project)

	Percent Complete	Date Complete
Q1 Project Milestone Description (Progress Measure): Complete subcontract arrangements with key methodological team members	100%	10/24/2014
Q2 Project Milestone Description (Progress Measure): Create an advisory committee, the composition of which will be agreed to by DOE, and complete a public acceptance literature review in PowerPoint form to be presented to DOE and the advisory committee	100%	03/19/2015
Q3 Project Milestone Description (Progress Measure): With the help of the advisory committee and project team members, prepare a final draft of research questions	100%	06/15/2015
Q4 Project Milestone Description (SMART and Go/No-Go): By 09/30/2015, LBNL will prepare a final draft version of the survey instrument for review by the DOE and the advisory committee.	100%	10/12/2015

FY16 Project Milestones

	Percent Complete	Date Complete
Q1 Project Milestone Description (Progress Measure): Complete subcontract arrangements with data collection provider	100%	1/10/16
Q2 Project Milestone Description (Progress Measure): Program survey into data collection software	100%	3/10/16
Q3 Project Milestone Description (Progress Measure): Collect data from respondents	100%	6/30/16
Q4 Project Milestone Description (SMART and Go/No-Go): By 09/1/2016, LBNL will prepare a draft summary of the survey findings	100%	8/16/16
GO/NO-GO Milestone: By 09/1/2016, LBNL will prepare a draft summary of the survey findings	100%	8/16/16

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
n/a	n/a	\$275k	\$0	\$450k	\$0

- Budget authority matches well with total expenditure
 - Spending Variance: **FY15 -3% (under budget)**; **FY16 -13%**
- 72% of total project budget has been expended to date
- No additional funding sources used for this project
- It is expected that the final *Baseline Public Acceptance* and *U.S. Utility-Scale Wind Turbine* datasets will be released publically and, therefore, be used by many researchers in years to come at **no additional cost to DOE.**

Partners, Subcontractors, and Collaborators:

- **Baseline Public Acceptance Survey and Analysis:** University of Delaware; Portland State University Survey Research Lab; Martin Luther University (Germany); RSG Inc.; NREL; Melissa Data; CoreLogic; MSG Data
- **U.S. Utility-Scale Wind Turbine Characterization and Mapping:** AWEA; USGS; ABB/Ventyx; Massachusetts Institute of Technology Lincoln Labs; Wind Turbine Radar Interference Mitigation Working Group; FAA

Communications and Technology Transfer:

- Neither project has completed; dissemination not been conducted; plans include:

Baseline Public Acceptance Survey and Analysis:

- Advisory committee involving Regional Wind Resource Center representatives and industry will assist with outreach
- Submissions to WINDPOWER and AWEA siting conferences have occurred
- Past wind property values work received wide ranging press and dissemination and over 20,000 downloads over multiple projects/years – similar uptake is expected with Baseline Public Acceptance Work
- Multiple papers and reports are expected to be prepared

US Utility Scale Wind Turbine Characterization and Mapping:

- DOE, AWEA, USGS, and others will participate in outreach and dissemination

FY17/Current Research:

- **Baseline Public Acceptance Survey and Analysis:** Complete multiple research efforts led by various team members; papers and reports released in FY17; submit articles for publication; and, develop plans for dataset release
- **U.S. Utility-Scale Wind Turbine Characterization and Mapping:** *Pending CRADA execution:* Draft dataset due Q2 FY17; present draft dataset to WTRIM and other federal partners for feedback; and, expected public release of dataset by end of FY

Planned Future Research:

- Future research will focus on measuring and characterizing public acceptance and community issues such as:
 - Estimating community/county level tax and school benefits especially for rural areas; and,
 - Examining ways that improve siting/permitting outcomes.
- Wind mapping dataset quarterly updates will be sought as goal



WINDEXchange and Regional Wind Resource Centers

Stakeholder Engagement and Outreach

Ian Baring-Gould

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February 2017

WINDEXchange and Regional [Wind] Resource Centers (RRCs): The central support and outreach efforts (WINDEXchange) and main direct outreach efforts (RRCs) of DOE's stakeholder engagement and outreach efforts. Disseminating credible and unbiased information about wind energy, which can be used by decision makers to consider future deployments of wind energy.

The Challenge: Although wind has broad conceptual support, some significant information gaps and misconceptions remain, which can add unnecessary delay and costs to projects or even stop the development of seemingly viable projects. The challenges will increase as wind expands into new areas across the nation.

Partners: All efforts are completed in close partnership with many organizations, including non-governmental organizations, academia, and national laboratories (Lawrence Berkeley National Laboratory [LBNL] most specifically).

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- **Communicating the costs and benefits of wind energy**



- Primary focus



- Secondary focus

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- NextGen component innovations

The Impact

- Enabled access to better information resources around tall wind, focused on active engagement with developing markets in the southeast and southwest United States
- Developed and published national potential maps for future wind technologies on tall towers that highlight the potential development opportunities of tall wind
- Funded direct outreach on information products that demonstrate expanded tall wind potential, including presentations at domestic and international meetings and conferences

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- **Communicating the costs and benefits of wind energy**

The Impact

- Content development, synthesis, and outreach on major impacts of wind energy made available through the WINDEXchange website, webinars, fact sheets, and other outreach materials
- Continued development and updates of the Jobs and Economic Development Impact (JEDI) tool
- Support of IEA Task 28, Social Acceptance of Wind Energy Projects
- Support of landmark LBNL study on the impacts of wind energy development

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The Impact

Stakeholder engagement and outreach impact: a broad range of programmatic strategies from across the portfolio, reaching more than 1.2 million documented stakeholders, including 12,600 key stakeholders actively engaged

- Active synthesis and dissemination of unbiased and science-based information through six regional organizations, one of the most visited EERE websites, and a listserv of more than 13,300 participants
- Direct support for educational programs and projects, including North American Wind Energy Academy and university programs, to engage in local wind informational outreach efforts.

- Support active information portals while developing educational products, market analyses, and tools to provide unbiased information, allowing stakeholders to make educated decisions
- Develop and implement collaborative partnerships engaging state and local agencies, universities, non-profits, industry, and others
- Leverage existing regional and state resources to address defined wind power issues and misconceptions
- Use a metrics-based program plan to focus work in problem areas where other support does not exist to retire the concern—then move on
- Use new and innovative communication tools to lower engagement costs while expanding outreach
- Engage across the wind technology spectrum
- Develop, synthesize, and articulate new information on wind energy impacts and benefits
- Collaborate in appropriate International Energy Agency efforts.



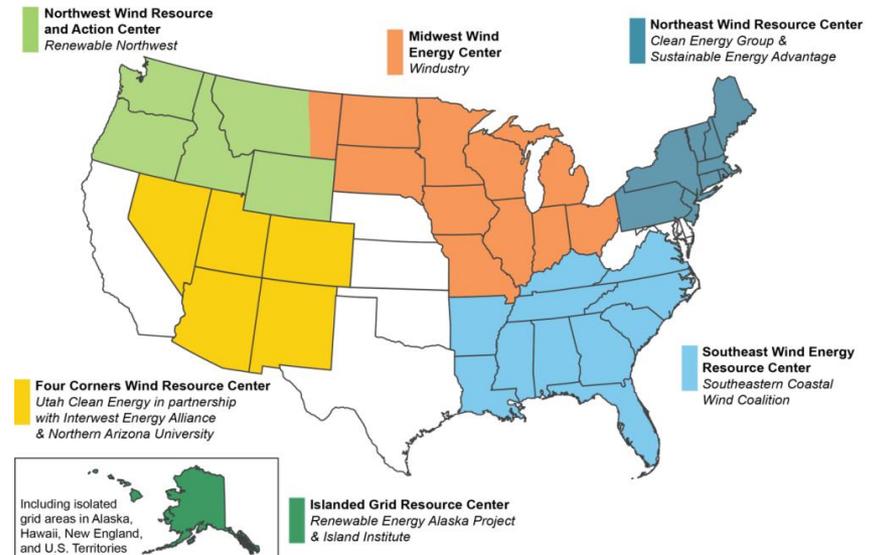
*Engaging with stakeholders,
WINDEXchange All-States Summit*

Unique Aspects: Regional Resource Centers (RRCs)

- Provide direct engagement on regional wind deployment challenges
- Provide technical expertise and tools, ensuring informed decision making
- Conduct regional outreach on key challenges through hosting meetings, trainings, and other direct outreach
- Form working groups on issues relevant to that region and tailor messaging specific to states within that region
- Collaborate across regions to maximize impacts.

RRCs Prioritize Activities to Those Promising the Largest Impact

- Maximize local implementation of national outreach priorities
- Provide science-based information to regulators and decision makers
- Educate communities about the impact of wind development
- Provide guidance on issues and regional priorities, which help inform national priorities.

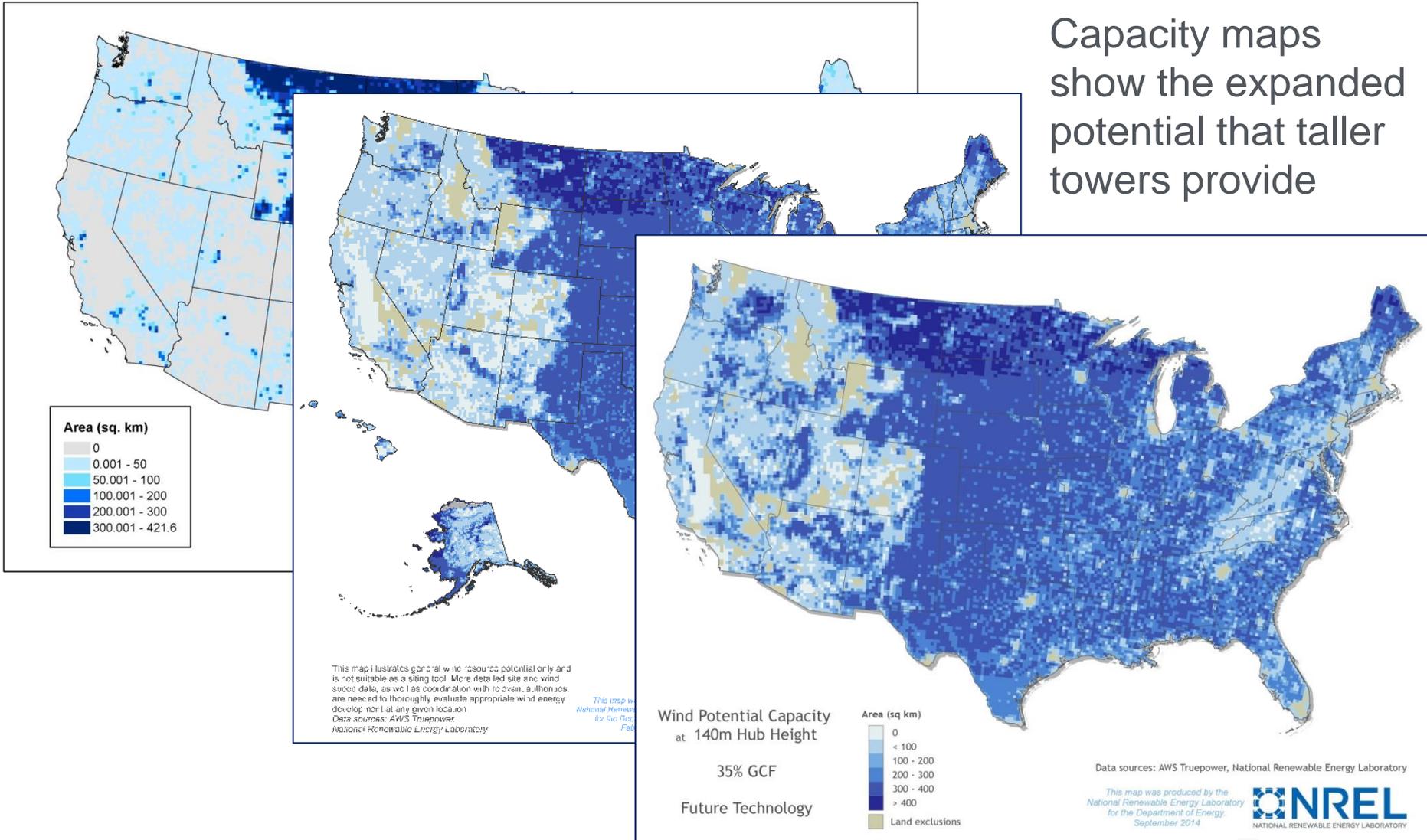


- Implemented the first round of six RRCs, focused on specific challenges and stakeholders
- Implemented advanced impact-based metric tracking process
- Completed upgrade of the WINDEXchange website structure and content
- Published a new annual, high-value state of the regions report, providing detailed information on state-by-state wind markets
- Developed a high-value information portal with a growing number of wiki-based community-supported deployment best-practice documents
- Developed a referenced myth-busters series of side shows, building on the Wind Vision project
- Conducted first regional Offshore Wind Jobs and Economic Impact studies.



Impact-based metric tracking allows better targeting of key stakeholders (identified by each RRC and includes utilities, county-level decision makers, etc.) and then the documentation of movement from being engaged around the appropriate application of wind energy to acceptance of wind as a viable energy option.

Capacity maps show the expanded potential that taller towers provide



Project Plan and Schedule



- Project length: Initiated in FY14 and built on previous program stakeholder engagement efforts. Current RRC efforts expected through March 2018.
- All milestones have been completed on time and within budget.
- Go/No-Go decision points completed in FY15 and FY16. Merit review expected in FY17.

Budget History

FY2014		FY2015		FY2016	
DOE	Cost Share	DOE	Cost Share	DOE	Cost Share
\$1,286k	\$229k	\$ 2,500k	\$455k	\$1,302k	\$553k

- Significant reductions in FY16 funding required the de-scoping of WINDEXchange and RRC engagement efforts and a reduction of NREL-based technical support. Plans and RRC contracts were adjusted accordingly.
- 92.7% of budget expended.
- RRCs are required to cover an increasing amount of the expense of outreach efforts, as indicated by the increases in program cost share.

Partners, Subcontractors, and Collaborators:

RRCs, academia, other regional wind-focused organizations, and federal agencies. WINDEXchange also works directly with other national organizations addressing wind deployment issues, including American Wind Energy Association, Distributed Wind Energy Association, National Wind Coordinating Committee, American Wind Wildlife Institute, and Utility Variable-Generation Integration

Communications and Technology Transfer:

Majority of work focuses on communications and stakeholder engagement outreach.

- WINDEXchange: <http://wind.energy.gov/WindExchange.gov> (~500,000 visits per year)
- Wiki-based deployment guides: <http://en.openei.org/wiki/Gateway:Wind>
- 2015 and 2016 State of the Region reports (530+ downloads)
- New national and state advanced wind technology capacity maps
- Bi-weekly e-newsletter with more than 13,300 subscribers
- Four myth-buster slide shows on wind deployment challenges
- Full suite of JEDI models available (< 42,000 page views in 2015)
- Documented more than 50,000 meaningful engagements with key stakeholders

FY17/Current Research:

- Conduct outreach through the WINDEXchange and newsletter
- Revamp outdated website database structure to expand functionality
- Extend RRCs for a 4th year to complete engagement projects
- Release 2016 and draft 2017 State of the Regions report
- Conduct detailed study of economic impacts of Colorado wind development.

Planned Future Research:

- High-impact outreach focused on high-level challenges and benefits (local economic development, manufacturing, and job creation) of distributed, utility, and offshore wind development
- Initiate new RRC efforts to address additional deployment-focused challenges (e.g., wildlife, offshore deployment, taller towers, grid integration, high costs in some areas)
- Expand research and national engagement, focusing on key challenges identified through Berkeley Lab (LBNL) study (e.g., visual, sound).



Collegiate Wind Competition

Elise DeGeorge

National Renewable Energy Laboratory

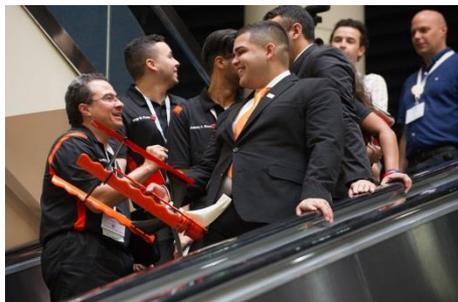
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February 2017

Collegiate Wind Competition — Project Overview

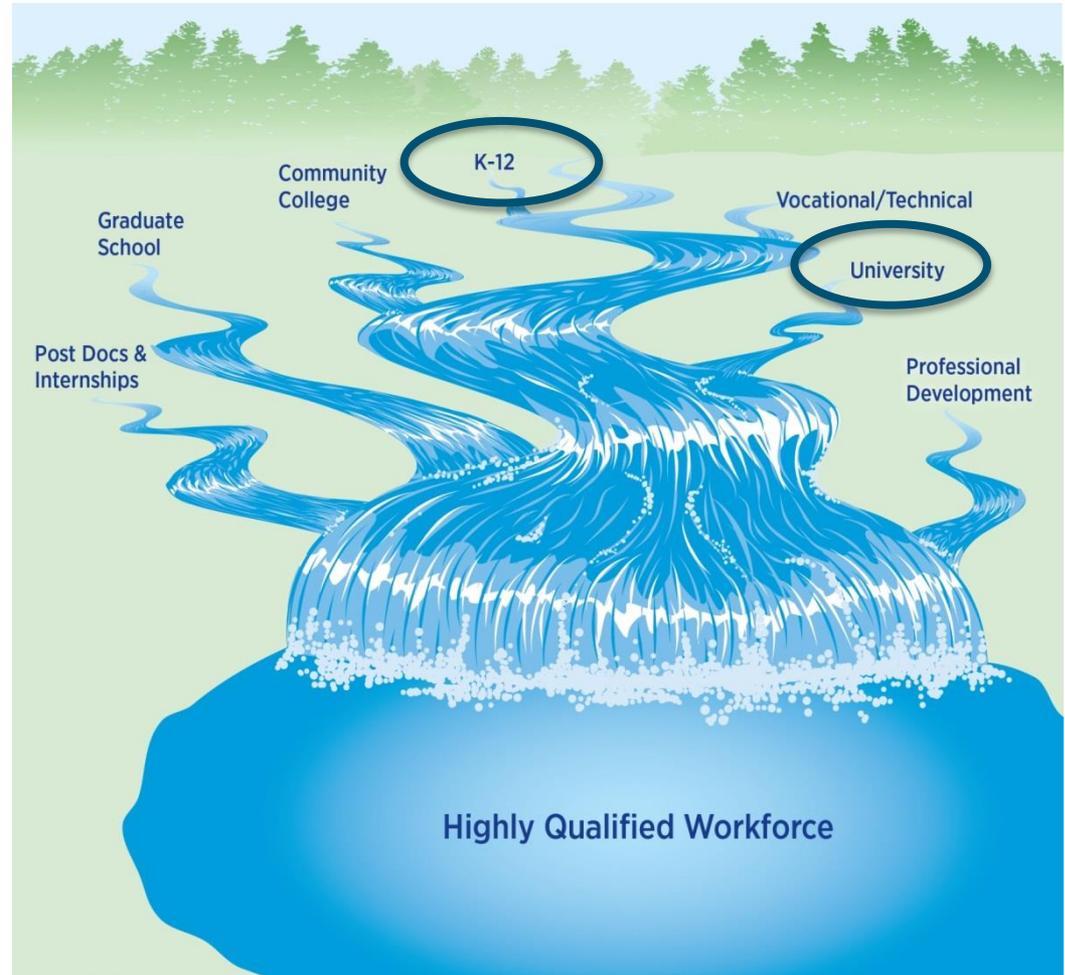
- The Collegiate Wind Competition (CWC) is a **workforce development–focused collegiate competition** designed to introduce students to the primary disciplines within the wind energy industry, including engineering, project management, business, and stakeholder engagement.
- The CWC has and continues to **inspire** and **prepare** students from multiple disciplines to enter the wind energy workforce by providing real-world technology and business plan development experience.
- The CWC benefits from **rich partnerships** with the American Wind Energy Association (AWEA) (advisory/industry alignment); Wind Energy Foundation (WEF) (event planning); the Collegiate teams; KidWind (advisory/K-12 alignment); and the industry sponsors, speakers, and judges.



The DOE's *Wind Vision* report estimates a need for ~300,000 new wind energy positions by 2050, many of which will require professional training.

The CWC addresses the challenge of ensuring a highly qualified workforce as documented in the National Skills Assessment of the U.S. Wind Industry (Leventhal and Tegen, 2012), which identified that employers preferred candidates with traditional engineering and business skills with hands-on wind energy experience.

The CWC increases responsible wind energy deployment by engaging universities and building collegiate wind programs to meet the training needs of an expanding wind industry.



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Impact

- Develops more engaged educational institutions in wind energy
- Increases exposure to wind energy coursework and tools through increased availability of programs, certificates, classes, and wind-education materials
- Increases opportunities for interactions with the wind industry
- Provides students with hands-on experience in wind energy technology, challenges, and tools
- Promotes experience-based diversity and collaboration across competition aspects
- Expands the diversity of the wind energy workforce

Collegiate Wind Competition Approach — Historic Timeline

A series of overlapping activities leads to successful and impactful annual competitions.

	FY13	FY14			FY15				FY16				
	Q1 through Q4	Q1 - Oct to Dec	Q2 - Jan-Mar	Q3 - Apr-Jun	Q4 - Jul-Sept	Q1 - Oct to Dec	Q2 - Jan-Mar	Q3 - Apr-Jun	Q4 - Jul-Sept	Q1 - Oct to Dec	Q2 - Jan-Mar	Q3 - Apr-Jun	Q4 - Jul-Sept
Inaugural CWC14 Competition at AWEA WINDPOWER in Las Vegas	Conducted Solicitation, selected teams, developed rules and requirements, Partner with AWEA/WEF, held kickoff meeting	Logistics; Collect Prelim Docs from Teams (Dec 31)	Focus on Logistics (speakers, judges, sessions, events, etc.)	Receive Deliverables; Host CWC14 at WINDPOWER (May)	Compile Feedback								
CWC15 Engineering Contest					Invite Teams to Return for CWC15	Logistics; Complete Rules and Reqts	Focus on Logistics (speakers, judges, sessions, events, etc.)	Receive Deliverables; Host CWC15 Engineering Contest at NWTC	Compile Feedback				
CWC16 at AWEA WINDPOWER in New Orleans					Develop Solicitation and Theme	Conduct Solicitation	Select teams	Release Updated R&R Document	Hold Kickoff Meeting followed by bimonthly calls	Logistics; Collect Prelim Docs from Teams (Dec 31)	Focus on Logistics (speakers, judges, sessions, events, etc.)	Receive Deliverables; Host CWC at WINDPOWER (May)	Compile Feedback

Collegiate Wind Competition Approach — Annual Activities

Inaugural 2014 Competition	2015 Engineering Contest	2016 Competition
<p>10 universities, more than 150 students.</p>	<p>10 universities from 2014 invited to re-compete.</p>	<p>12 universities; 7 returning teams, more than 175 students.</p>
<p>Location: AWEA WINDPOWER in Las Vegas.</p>	<p>Location: National Wind Technology Center in Colorado.</p>	<p>Location: AWEA WINDPOWER in New Orleans.</p>
<p>Elements:</p> <ul style="list-style-type: none"> • Turbine Testing • Technical Design • Business Plan • Market Issues 	<p>Elements:</p> <ul style="list-style-type: none"> • Turbine Testing • Technical Design • Bonus: Siting Challenge (New) 	<p>Elements:</p> <ul style="list-style-type: none"> • Turbine Testing • Technical Design • Business Plan • Deployment (New) • People's Choice (New) • Bonus: Visually Appealing Load (New)



Through its activities, the CWC remains true to its objective to attract the next generation of wind energy professionals by providing exposure to experts and educational opportunities and informing students of the issues and challenges facing the wind industry today.

Collegiate Wind Competition Approach —Tunnels

- Designed and constructed two portable wind tunnels to test each team's wind turbine at the Competition.
- Tunnel specifications include:
 - 19-ft long with 4-foot by 4-foot test chambers designed to test wind turbines with rotors that are less than 17.7 inches (45 cm) in diameter
 - Turbines are subjected to wind speeds that range from 5 to 13 m/s and are tested for durability, safety, cut-in, power curve, and control
 - Wind tunnel specifications are available at wind.energy.gov/windcompetition/.

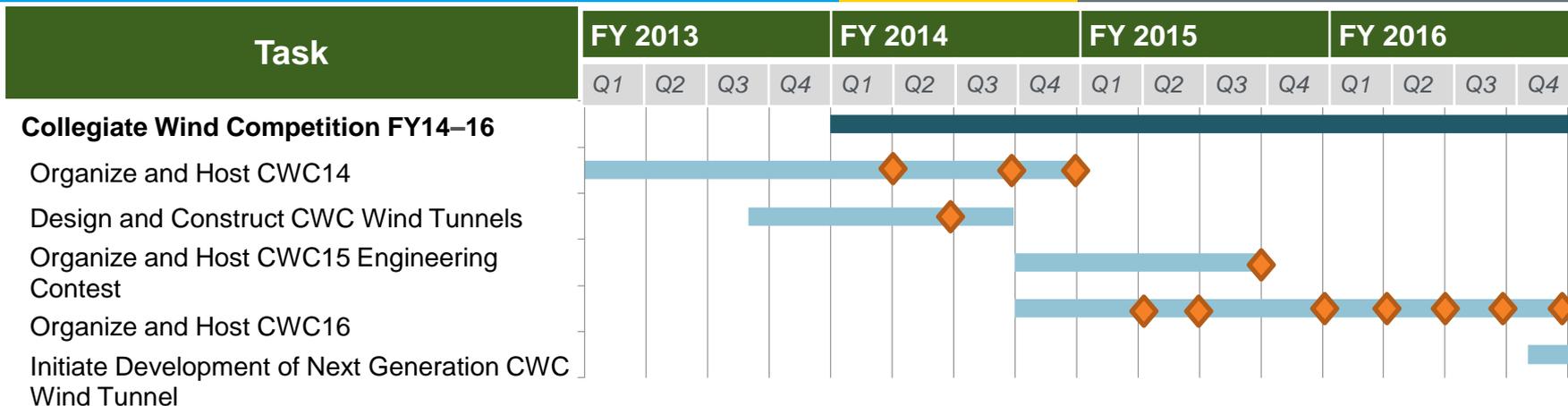


- Held three multi-faceted, educational competitive events: two at AWEA WINDPOWER and one at the National Wind Technology Center
- Facilitated industry and educational alignment through integration of industry throughout the CWC process (sponsors, judges, speakers)
- Developed a sustainable alumni community through the ~300 students (15 unique schools) that have participated in the CWC
- Co-located event with the National KidWind Challenge (which hosted 230 students amongst 50 teams), to enhance the generational impact of the CWC
- Co-developed train-the-trainer classes with KidWind (which touched 30 educators).

“ . . . I learned so much and can talk to people in the industry now, which I never imagined I would be able to do at the beginning of the year.”

—Student who competed in the Collegiate Wind Competition 2016

Project Plan and Schedule



- Each year, milestones were based upon the release of the RFP (or modifying existing contracts in the interim years), along with development of rules and requirements, hosting of each years' competition, and development of a lessons learned report to ensure continual improvement.
- Go/No-Gos have been centered around assessing impact before committing resources towards subsequent competitions. Evidence has continued to support continuation of the CWC.
- All milestones were completed on time.

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-Share	DOE	Cost-Share	DOE	Cost-Share
\$1,235k	\$296k	\$205k	\$0	\$960k	\$290k

- Expenditures to date = 90%; no variances.
- Other cost-share funding sources include:
 - Sponsorships from AWEA, Siemens, Vestas, Blattner Energy, GE, Akin Gump, and many voluntary industry speakers
 - Teams leveraged DOE seed funding to support their own involvement (included in-kind and external funding sources payable to individual teams).

Partners, Subcontractors, and Collaborators

AWEA, WEF, KidWind, all selected collegiate teams (15 total, sponsors for 2014 and 2016 events)

Communications and Technology Transfer

- Social media reach*: 1.5M
- Social media impressions: 10.9M
- Unique pageviews for related articles: 2,624
- Active website, blogs, informational webinars, Google group discussions, and more

* Social media includes Twitter, Instagram and Facebook

A successful outcome is a growing wind industry workforce that is competitive in the global marketplace and that closely mirrors the wind industry, incorporating multiple engineering disciplines, business, marketing, and communications into strong diverse teams.

FY17/Current Research

- Competitively select teams to participate in CWC in May 2018 at AWEA Windpower in Chicago
- Host 2017 Technical Challenge in Colorado
- Revise CWC rules and requirements
- Develop a new wind tunnel to ensure continual challenge (e.g., greater speeds, turbulent or off-axial flow)
- Broaden reach and understand impact of the CWC
- FY17 Go/No-Go: Decide whether to convert the CWC to encompass two competitions across two fiscal years to accommodate university's request for program continuity.

Planned Future Research

- Develop plans for CWC growth in the United States, and consider international involvement



Wind For Schools (WfS)

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February 2017

Primary Goal: In order to address the workforce needs identified in DOE's *Wind Vision* report, the Wind for Schools (WfS) Project provides wind energy educational programming (*with a focus on hands-on learning*) to K-12 and post-secondary students in order to introduce wind to more of our nation's youth and stimulate interest in pursuing wind careers.

Project Objectives:

- Inspire and collaborate with teachers and students in energy education—specifically wind
- Engage American communities in wind energy, detailing how it offers an economically beneficial future for rural America
- Equip college students with hands-on wind energy applications and education to provide the growing U.S. wind industry with a highly qualified and competitive workforce
- Through Wind Application Centers (WACs), develop state-based centers of excellence for wind energy information to better inform communities and decision makers
- Provide empirical data on the U.S. wind workforce.



Photo Gallery, NREL 14872

WfS introduces wind energy learning and careers to K–12 and post secondary students, supporting the industry’s need for a skilled and qualified wind workforce.



Education and Workforce Challenges

- The U.S. wind workforce must be highly qualified to compete in a global energy market. Today, some companies are hiring from Europe because their graduates have wind energy experience.
- DOE's *Wind Vision* and NREL research have shown the U.S. wind industry needs more education and training programs on wind energy from kindergarten through graduate school.
- Students and educational institutions are often not introduced to wind energy career options.
- The wind energy workforce lacks diversity. Currently, the industry is made up of approximately 20% women, with very little data on minorities or veterans.
- Many U.S. communities are not informed about wind energy benefits.



Photo by Warren Gretz, NREL 07696

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▲ **Key Metric**

Impact

- 147 school turbines installed (since 2005) ▲
- 300 teachers/year trained on wind energy curricula ▲
- 30 wind energy courses/workshops presented to ~1,600 students (2016)
- 105 college students assisting K–12 students (2016)
- 3 new educational tools developed to stimulate STEAM (science, technology, engineering, art, and math)
- ~90 community outreach activities by WACs/year (1,800 informed community members)
- Created and disseminated reports, webinars, and blog posts, summarizing the wind workforce educational/training needs ▲
- Collaborated with AWEA and universities to gather data and provide workforce statistics and analysis to partners and the public
- Updated *Wind Vision* roadmap; Wind Career Map; standards-based, downloadable education tools for teachers; and posters and webinars for information outreach in FY14–16
- Aligned end goals with *Wind Vision*: Highly educated wind workforce and highly informed communities about wind energy.

Overall approach to this work has been twofold:

- 1. Developed wind application centers** (initiated at state universities) to support hands-on wind-focused education at the K–12 and post-secondary levels
- 2. Collected and disseminated workforce statistics, analyses, and trends** to educate stakeholders.



Wind turbine at Sanborn Central School in Forestburg,
South Dakota. PIX # 16032
Photo credit: East River Electric Power Cooperative

Specific approaches to achieve goals:

- Funded WAC activities and initiated plan for additional states
- *Unique: Supported “hands-on” learning via turbine installs and new educational curricula, tools, and materials (KidWind)*
 - Challenge: How to stimulate the average student mind about science
 - Solution: Study and analyze wind energy data from their school’s turbine
- Initiated development of a long-term funding strategy for WfS
 - Challenge: Reliable funding and funding growth
 - Solution: Developing a strategic sustainability plan
- Launched Wind Career Map on DOE website and researched career info. (linked info. to students)
- Interviewed and collaborated with industry to identify training needs (used to inform future programs)
- Collaborated with minorities and other groups to learn and disseminate information on diversity

By approaching young minds early and providing hands on learning opportunities on wind energy concepts, benefits, and industry challenges, the WfS project is inspiring more students to consider wind as a career.

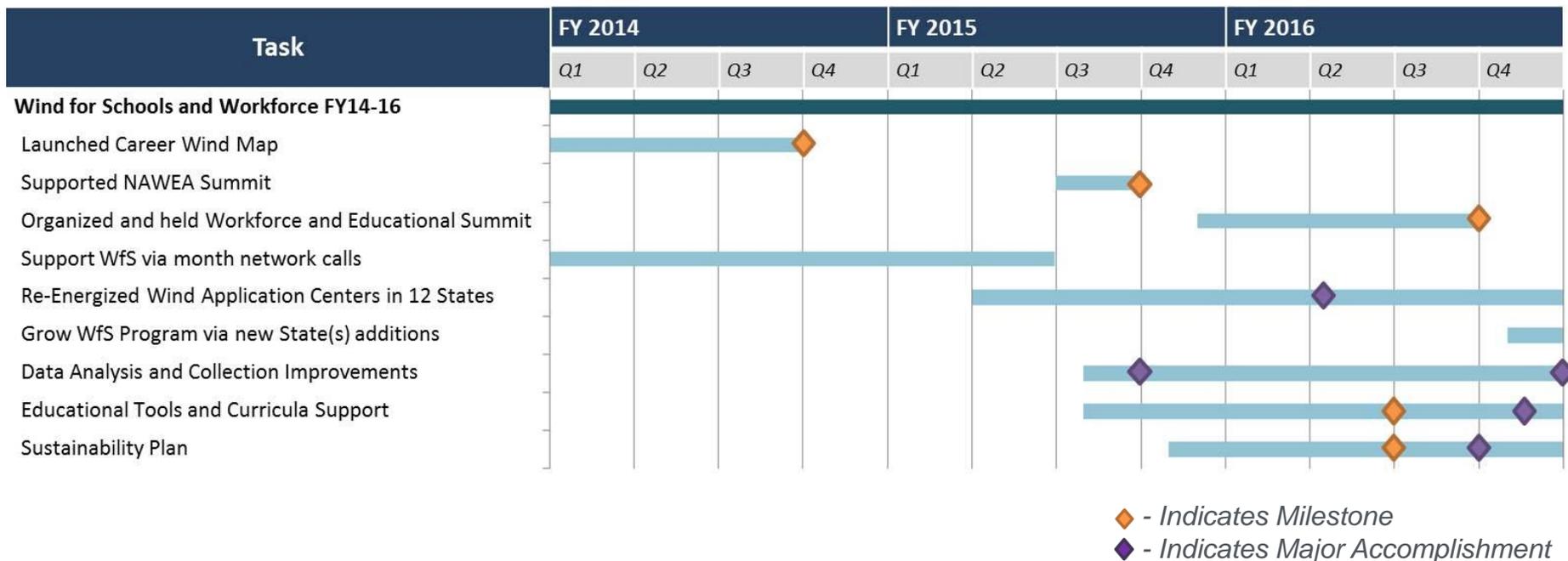
Accomplishments and Progress

Accomplishments to Date	Significance
<p>Re-Energized the WfS Program, Enabling 12 University WACs to Reengage</p>	<ul style="list-style-type: none"> • Creating new champions/leaders in K–12 schools • Introducing wind energy lessons/careers to 135 schools
<p>WfS Long-Term Funding Plan Development (M):</p> <ul style="list-style-type: none"> • Completed contracting after competitive RFP • Received draft Organization Plan 	<ul style="list-style-type: none"> • Finding funding outside DOE could satisfy future needs, adding program stability and growth potential
<p>DOE <i>Wind Vision Roadmap</i> Prioritization and Collaboration</p>	<ul style="list-style-type: none"> • Working with DOE, the educational community, and industry on the <i>Wind Vision's</i> workforce sections and the <i>Wind Vision</i> roadmap to assess progress and prioritize roadmap efforts; collaborating closely with other DOE wind projects such as Collegiate Wind Competition and WINDEXchange
<p>Hosted DOE Workforce & Education Summit (M):</p> <ul style="list-style-type: none"> • Actively engaged 70+ members of industry and education organizations 	<ul style="list-style-type: none"> • Allowed discussion of challenges and solutions, which will be used in future program design • Promoted new WfS funding and received feedback for future activities and prioritization of needs
<p>Wind Energy Educational Tool Development (M):</p> <ul style="list-style-type: none"> • Excel data comparison/graphing tool • GIS-based turbine-siting tool 	<ul style="list-style-type: none"> • Addresses need for wind energy educational tools. <ol style="list-style-type: none"> 1) Introduces students to a GIS tool used in industry 2) Fills a gap in educational “wind turbine siting” learning

(M) = work-supported milestone

Accomplishments to Date	Significance
<p>Developed WfS Website/Portal on OpenEI:</p> <ul style="list-style-type: none"> • Consolidated database • Data collection reliability and troubleshooting codes implemented • 2,000+ page views 	<ul style="list-style-type: none"> • Provides one-stop shop for school turbine data, curricula, and other educational resources • Provides teachers and students reliable tool to access their turbine data (and all 147 turbines) and graph data to better understand wind energy concepts and turbine performance
<p>Supported Educational Training & Curricula (M):</p> <ul style="list-style-type: none"> • KidWind Academy Scholarships • Supported curricula development by teachers 	<ul style="list-style-type: none"> • Trained teachers how to teach wind energy, provided materials for their classrooms, encouraged them to hold similar workshops at other schools • Supported partners, such as NEED and KidWind, in their annual effort to develop fresh wind energy curricula and connect to state and federal standards
<p>Supported North American Wind Energy Academy Summit</p> <ul style="list-style-type: none"> • ~120 people attended the bi-annual summit where graduate students and others presented and discussed cutting-edge wind energy research results 	<ul style="list-style-type: none"> • Support the only low-cost venue for U.S. graduate students and professors to come together and share insights on current wind energy problems and solutions—feedback was very positive
<p>Metrics Development – initiated</p>	<ul style="list-style-type: none"> • Initiated discussion with WACs about metrics tracking • Piloted key categories
<p>Wind Career Map Launched on DOE Website (M):</p> <ul style="list-style-type: none"> • Modeled after Solar Career Map 	<ul style="list-style-type: none"> • Display jobs and career paths in one place—over 5,600 views.

Project Plan and Schedule



Project origination date: Pilot in 2005; 2006–2012; 2014–2016

Project completion date: WAC support ramping down through 2019 (as Diversified Funding Plan ramps up); forecast some lower level of continued support of educational initiatives—guided by industry feedback

Slipped milestones (2): Completed pre-decision summary of the WfS project funding in FY16 Q2 (instead of FY16 Q1); RFP and selection process was delayed to ensure quality respondents; Wind Career Map delayed by one quarter due to lengthy approval processes.

Go/No-Go decision: The implementation of the Diversified Funding Plan will be decided in FY17 Q2.

Budget History					
FY2014		FY2015		FY2016	
DOE	Cost Share	DOE	Cost Share	DOE	Cost Share
\$0	\$0	\$500.5k	\$0	\$970k	\$0

Budget Notes:

- 73% of the funds have been spent (funding arrived late in 2015)
- The project was suspended by OMB in 2013 and 2014

Project Management/Planning Activities:

- Monthly WAC update/feedback conference calls that:
 - A. Maintained network collaboration
 - B. Prioritized and improved activities to fund
- Quickly ramped up WfS project planning with new funding
- Implemented significant project scope change (2015), seeking WAC and industry feedback
- Bi-weekly team meetings to measure progress

Partners, Subcontractors, and Collaborators

Partners/subcontractors: 12 universities (135 K–12 schools), Distributed Wind Energy Association, KidWind, National Energy Education Development Project (NEED), AWS Truepower, BW Research.

Collaborators: American Wind Energy Association; North American Wind Energy Academy (NAWEA); hiring managers at wind energy companies; other NREL initiatives such as WINDEXchange and Collegiate Wind Competition.

Communications and Technology Transfer

Overall wind workforce: Five workshop/conference presentations; AWEA conference poster; two webinars; highly interactive DOE Wind Energy Workforce and Education Summit with 70+ attendees from industry and educational organizations; Wind Career Map (6,562 unique page views); NAWEA bi-annual meeting with 120 graduate students, professors, and others.

WfS: 147 turbine installs (since 2005) has been a significant transference of wind technology activities (thousands of students/year); a new WfS brochure (2016); DOE quarterly newsletter features (2016); DOE blogs (2016); 2,088 page views on OpenEI WfS website.

A successful outcome is a growing supply of graduates with strong skills who can compete in the global marketplace—meeting the wind industry’s needs, which require diverse teams that incorporate multiple engineering disciplines—environmental, business, marketing, and communications.

FY17/Current Research

- Select and fund the addition of two new states into the WfS family
- Manage the existing 12 WAC educational activities and turbine data communications
- Complete development of diversified funding plan; if approved, implement plan
- Update workforce information by interviewing 300+ wind energy companies
- Collaborate with KidWind and NEED to continue showing teachers how to educate on wind energy and improve and develop new curricula
- Complete development, beta test, and disseminate educational tools—web-based, data analysis, and new siting tools

Planned Future Research

- Expand more educational activities in more states, creating additional WACs
- Support/promote opportunities for WAC's to assist schools with their turbine installations (*via support in turbine selection criteria, siting and community funding strategies*)
- Develop additional curricula adhered to standards
- Increase promotion of “Affiliate WfS Project” (WfS project participation without DOE funding)
- Continued support and coordination between WACs and DWEA during the implementation of the WfS' long term funding plan



NREL Photo Gallery, 26081

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- **GOAL:** Reduce the unsubsidized market levelized cost of energy (LCOE) for utility-scale land-based wind energy systems from a reference wind cost of \$0.074/kWh in 2012 to \$0.057/kWh by 2020 and \$0.042/kWh by 2030.
- **GOAL:** Reduce the unsubsidized market LCOE for offshore fixed-bottom wind energy systems from a reference of \$0.18/kWh in 2015 to \$0.15/kWh by 2020 and \$0.096/kWh by 2030.

Enhancing U.S. Energy Security and Independence

- **GOAL:** Accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality.

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- **GOAL:** Expand the geographic development potential of wind power plants in the United States, particularly in offshore zones and the U.S. Southeast.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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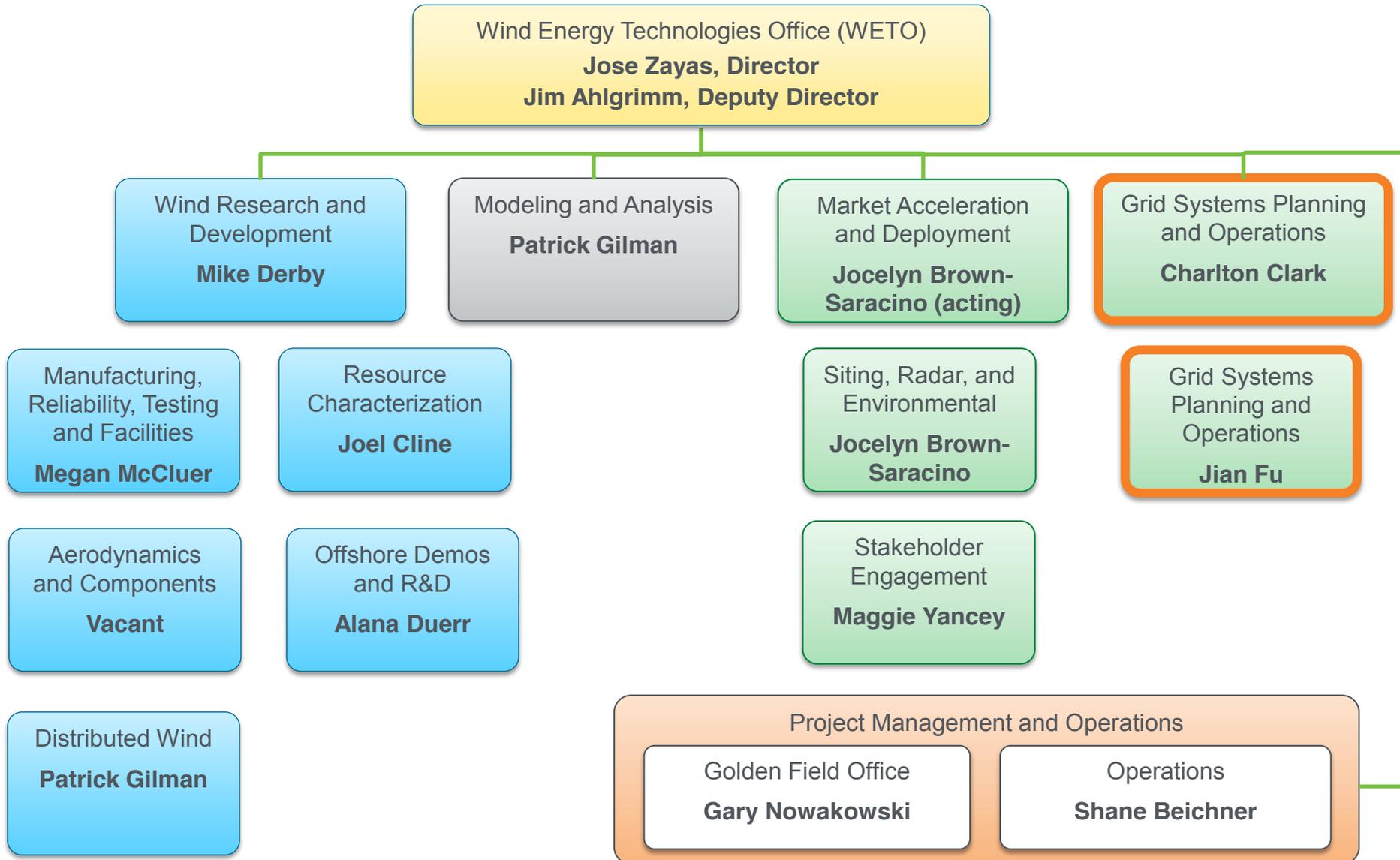
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Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

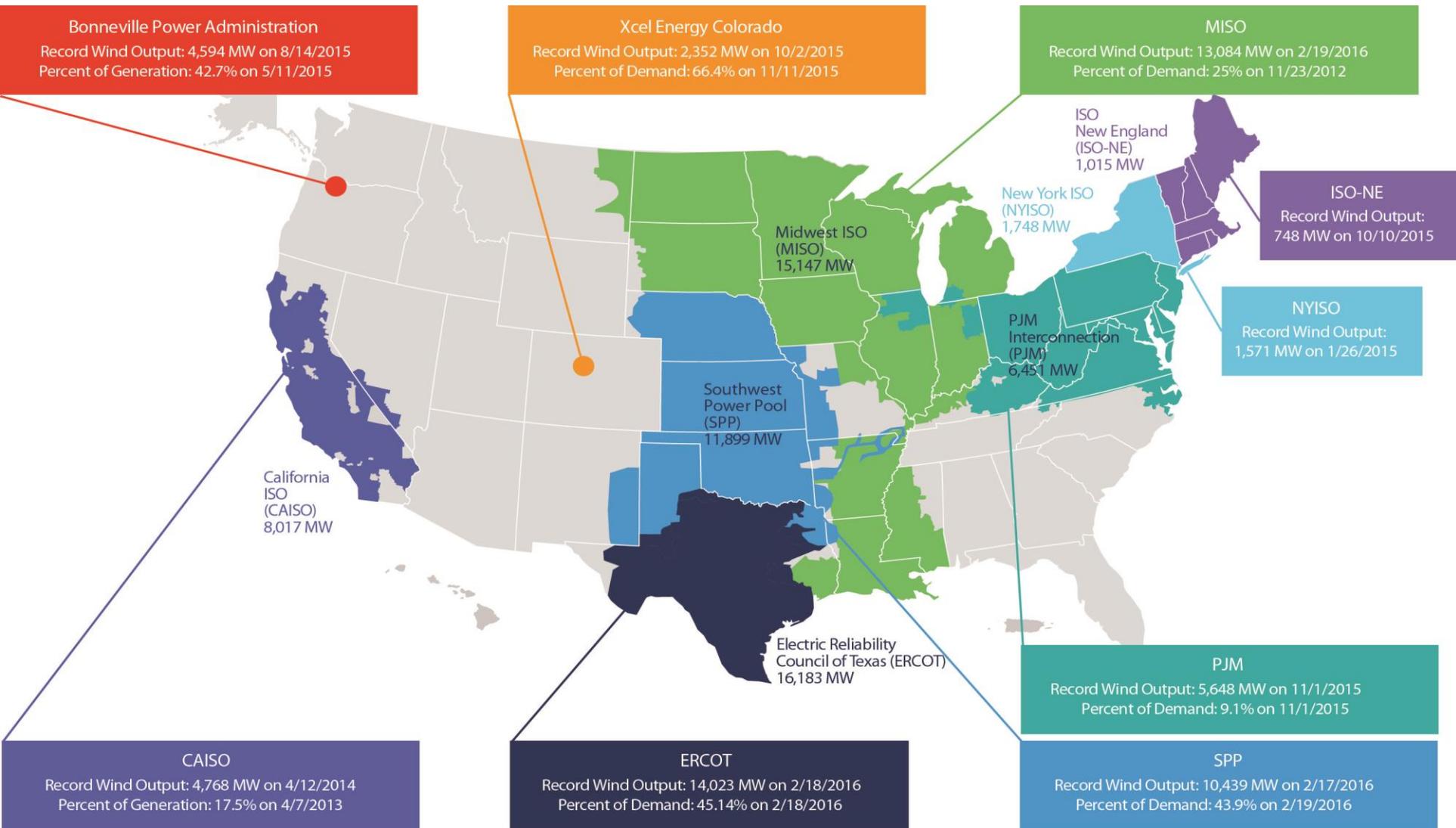
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- **World-class test and user facilities**
- Advanced technology demonstration projects
- **Technical engagement initiatives**
- **Standards and certification**
- Communicating the costs and benefits of wind energy

Wind Energy Technologies Office Structure



Grid Integration Motivation

High Wind Penetrations are HERE!!!



<http://www.aweablog.org/wp-content/uploads/2016/02/Regional-Wind-Records-2.22.2016.jpg>

Grid Integration Motivation

Wind penetration levels discussed in past studies are becoming a reality

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Bonneville Power Administration
Record Wind Output: 4,594 MW on 8/14/2015
Percent of Generation: 42.7% on 5/11/2015

Xcel Energy Colorado
Record Wind Output: 2,352 MW on 10/2/2015
Percent of Demand: 66.4% on 11/11/2015

MISO
Record Wind Output: 13,084 MW on 2/19/2016
Percent of Demand: 25% on 11/23/2012

Provide essential reliability services

Being good stewards of the grid

Efficient market design

Rules that work for everyone as variable generation increases

Integration with other technologies

Working across EERE

Technology deployment

Assuring adoption

CAISO
8,017 MW

CAISO
Record Wind Output: 4,768 MW on 4/12/2014
Percent of Generation: 17.5% on 4/7/2013

ERCOT
Record Wind Output: 14,023 MW on 2/18/2016
Percent of Demand: 45.14% on 2/18/2016

PJM
Record Wind Output: 5,648 MW on 11/1/2015
Percent of Demand: 9.1% on 11/1/2015

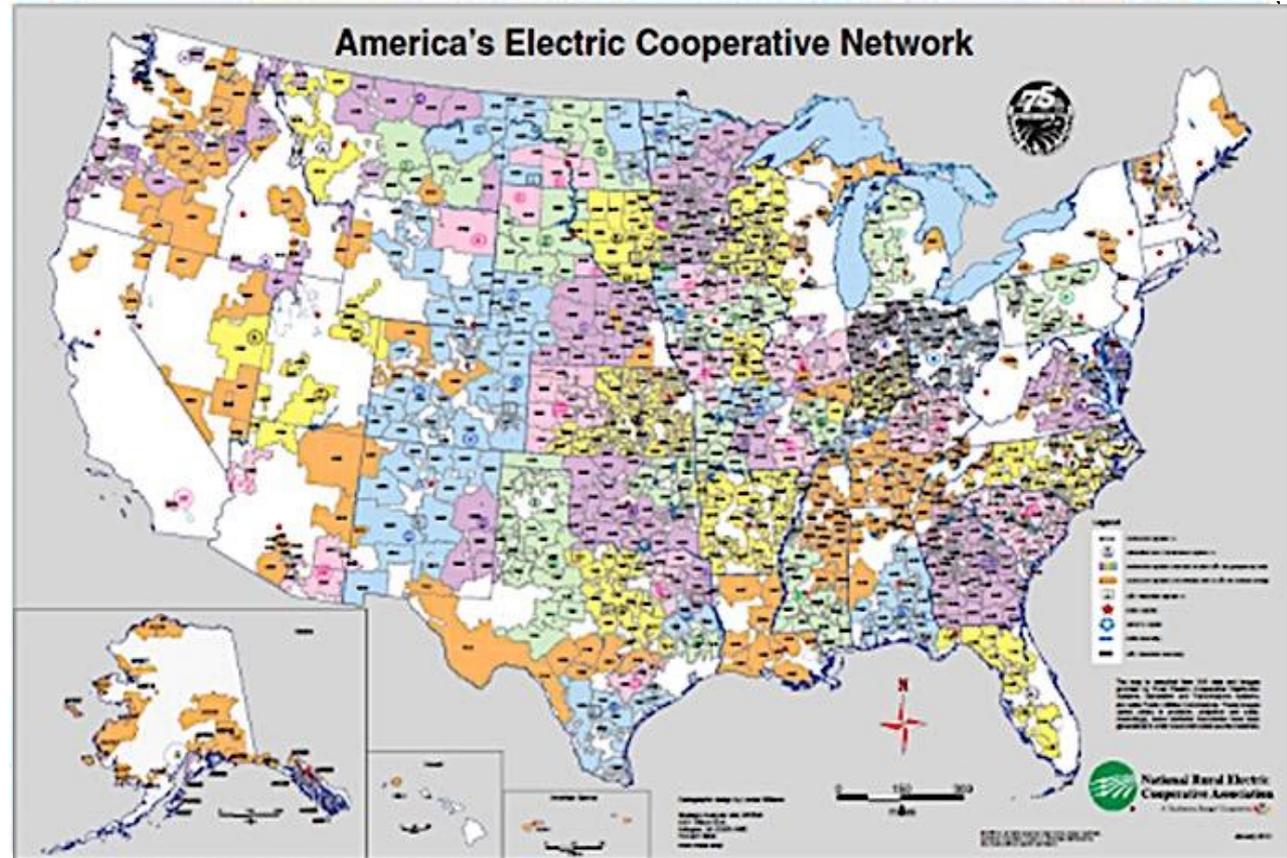
SPP
Record Wind Output: 10,439 MW on 2/17/2016
Percent of Demand: 43.9% on 2/19/2016

ISO-NE
Record Wind Output:
748 MW on 10/10/2015

NYISO
Record Wind Output:
1,571 MW on 1/28/2015

A Complex Set of Stakeholders

- Three interconnections
- Seven RTOs/ISOs
- Eight NERC regions
- 50 Public Utility Commissions
- 150 investor-owned utilities
- 2,000 municipal utilities
- 900 cooperatives (members of National Rural Electric Cooperative Association)



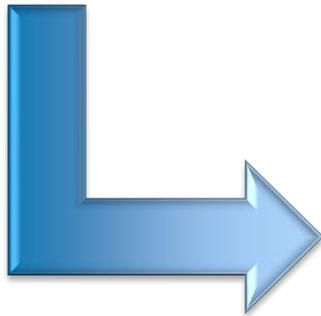
Strategic Focus Areas

Challenges, Goals, & Approach

Strategic Area	Challenges	Goals	Approach
Providing Essential Reliability Services	<p>Providing services such as voltage regulation and frequency support are necessary to system reliability. The way in which these capabilities are provided can vary from location to location.</p>	<p>Work to continually refine and improve the delivery of these services.</p>	<ul style="list-style-type: none"> • Wind integration studies • Testing of new control systems for voltage and frequency management.
Market Design	<p>Adding larger amounts of low marginal cost energy into electricity markets tends to impact overall market revenues. Wind is not always compensated for some of the services it provides.</p>	<p>Ensure market rules that provide reasonable compensation for services provided and ensure adequate revenue to all market participants .</p>	<ul style="list-style-type: none"> • Impact analysis for market rules and designs • Work with Federal Energy Regulatory Commission (FERC) and other stakeholders to improve market rules.
Integration with other technologies	<p>Working to integration wind with other Energy Efficiency and Renewable Energy technologies will be key to maximizing their potential.</p>	<p>Ensure seamless integration of wind energy with other EERE technologies.</p>	<ul style="list-style-type: none"> • Test grid services capabilities • Evaluate flexibility options presented by other technologies.
Technology Deployment	<p>Best practices, new operational paradigms, and new technologies provide no benefit if left on the lab bench or bookshelf .</p>	<p>Support information sharing and adoption of technologies as they come to maturity.</p>	<ul style="list-style-type: none"> • Convene industry stakeholder workshops • Support technology adoption.

Budget Summary

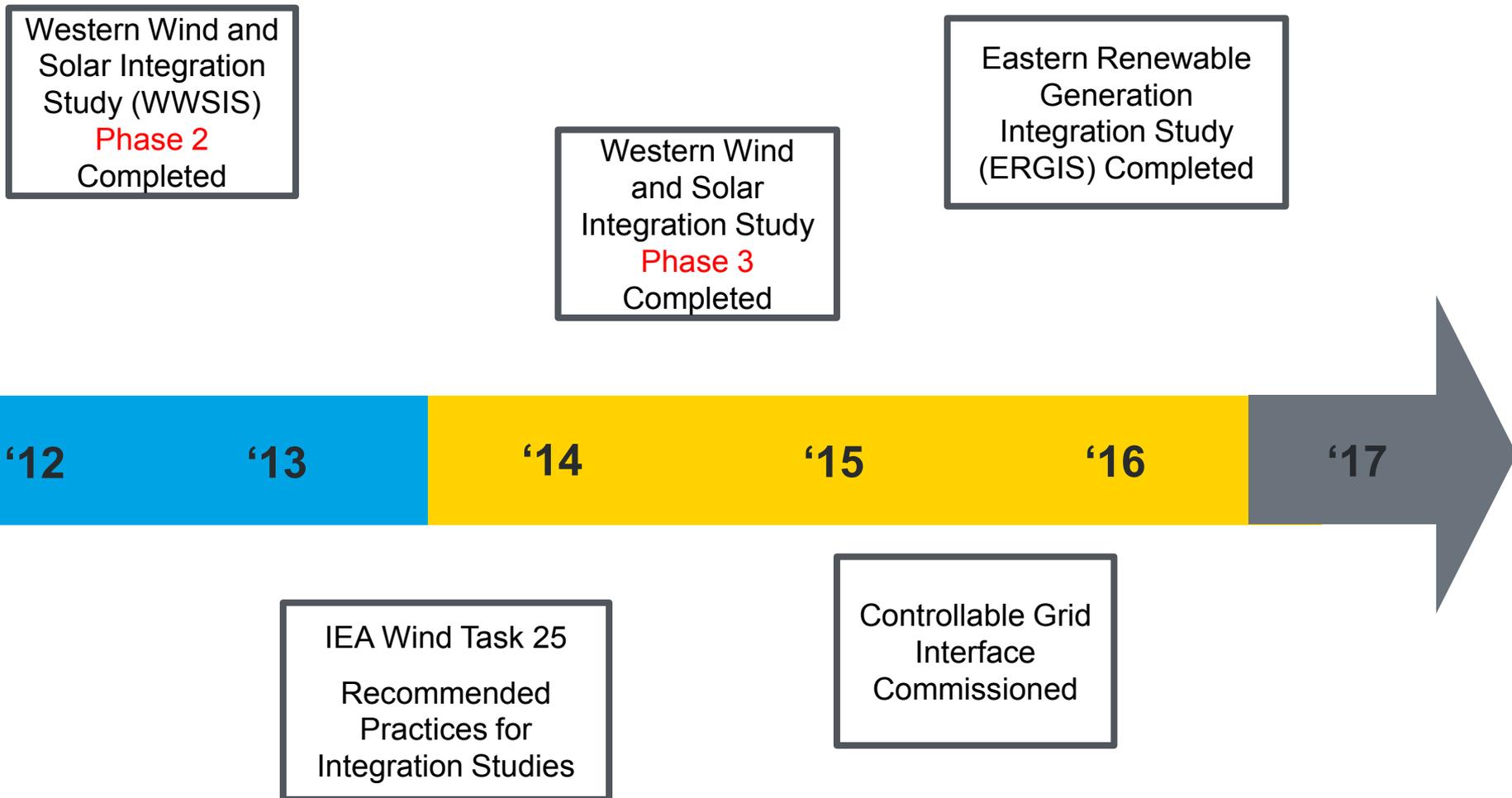
Total Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$2.3M	\$3.5M	\$3.5M	\$9.3M



Peer Reviewed Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$2.3M	\$2.0M	\$0.2M	\$4.5M
100%	57%	6%	48%

* Small funding in FY16 primarily due to grid funds being sent to the Grid Modernization Lab Consortium, which is controlled external to WETO and not under review

Key projects over time

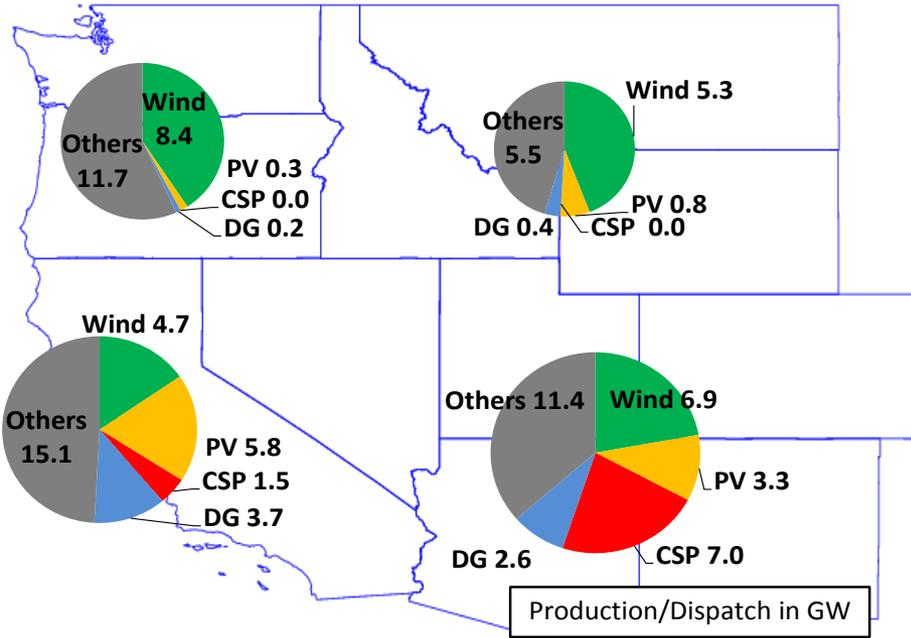


Grid Systems Planning and Operation

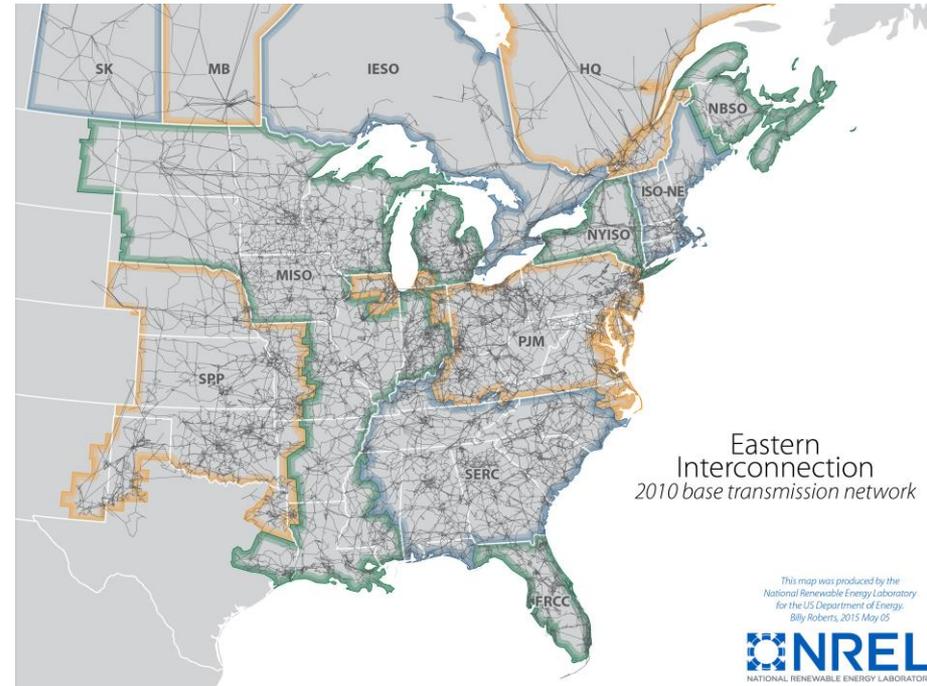
Wind Integration Studies (ERGIS and WWSIS 3) <i>(2:40pm)</i>	Aaron Bloom
Wind Generator Modeling <i>(3:20pm)</i>	Ben Karlson
Stochastic Tool Evaluation <i>(3:40pm)</i>	Audun Botterud
Distributed Wind Integration <i>(4:20pm)</i>	Bri-Mathias Hodge
Grid Integration Support, UVIG, IEEE, NERC, IEA Task 25 <i>(4:40pm)</i>	Dave Corbus
Concurrent Cooling <i>(5:00pm)</i>	Jake Gentle
Connecting NWTTC to the Energy Systems Integration Facility (ESIF) <i>(9:10am, Wed)</i>	Dave Corbus
Analysis Using PMU Data and Dynamic analysis <i>(9:35am, Wed)</i>	Edward Muljadi
Active Power Controls <i>(10:00am, Wed)</i>	Yingchen Zhang

Activities and Accomplishments (FY14–16)

Strategic Area	Accomplishments	Collaborators
Providing essential reliability services	<ul style="list-style-type: none"> Completed the largest U.S.-based RE integration study (Eastern Renewable Generation Integration Study, ERGIS) Reduced the solve time for large scale integration studies from months to days Further supported the development of active power controls capabilities. 	<ul style="list-style-type: none"> NREL and several other study collaborators
Market design	<ul style="list-style-type: none"> Investigated the impact of high RE penetration on electricity markets Proposed possible mitigation measure to address market failures Worked with FERC to better understand the impact of self scheduling on market operations. 	<ul style="list-style-type: none"> NREL/ANL
Integration with other technologies	<ul style="list-style-type: none"> Developed new ways to evaluate and utilize Phasor Measurement Unit (PMU) information Testing of grid services capabilities for load technologies Created high-speed data connections between National Wind Technology Center and ESIF as well as with INL. 	<ul style="list-style-type: none"> NREL NREL NREL/INL
Technology deployment	<ul style="list-style-type: none"> Supported over 12 Utility Variable-Generation Integration Group (UVIG) workshops Develop new generic dynamics models which include frequency support capability Installed dynamic line rating system 	<ul style="list-style-type: none"> NREL NREL/SNL INL



Western Wind and Solar Integration Study Phase 3



Eastern Renewable Generation Integration Study

Grid System Planning for Wind Integration Studies: ERGIS and WWSIS

Aaron Bloom

National Renewable Energy Laboratory

Aaron.Bloom@nrel.gov, 720 402 2065

Projects:

- Western Wind and Solar Integration Study Phase 3 (WWSIS-3)
- Eastern Renewable Generation Integration Study (ERGIS)

The Challenge: Identify and evaluate the challenges to wind grid integration by creating state-of-the-art tools to analyze power system operations at an unprecedented scale.

Partners: GE Energy Consulting and a technical review committee (TRC) (more than 60 active participants)

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

- Facilitating coexistence between wind energy and wildlife
- Offshore wind environments
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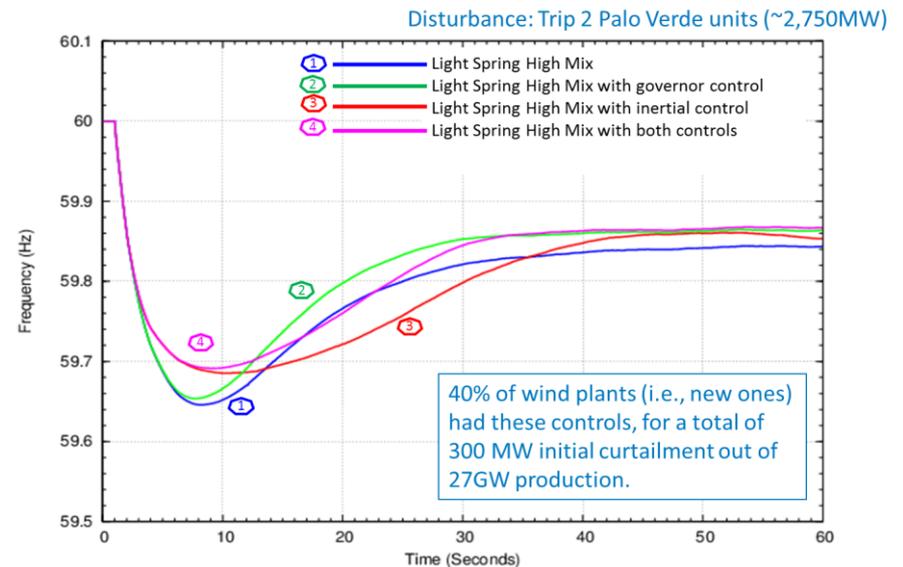
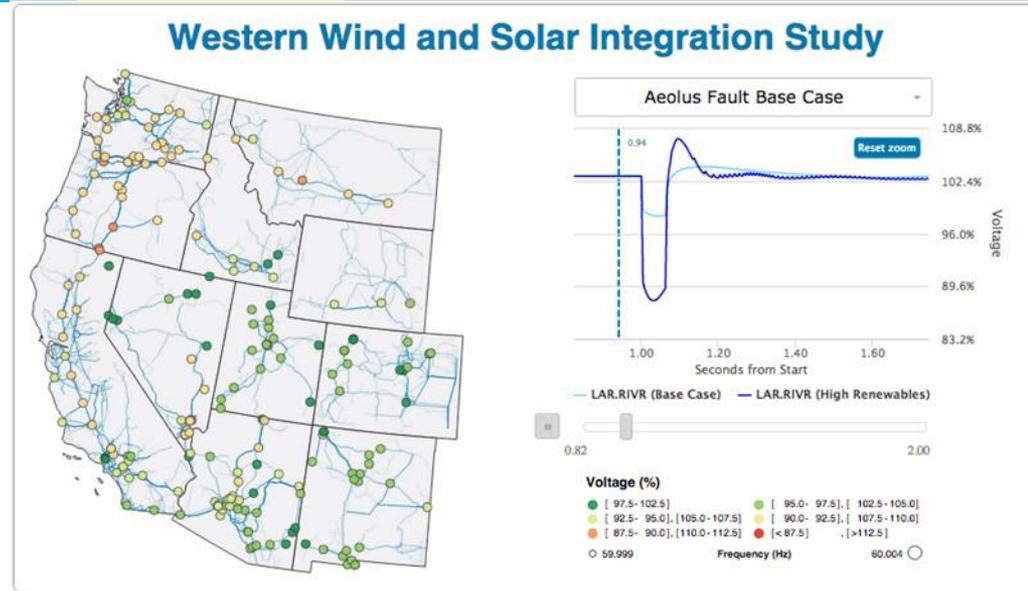
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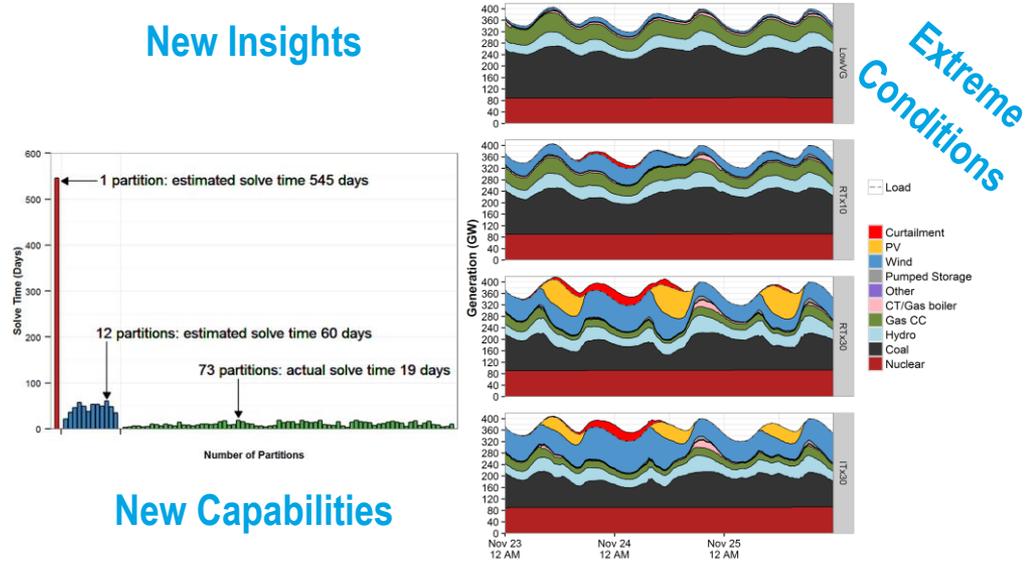
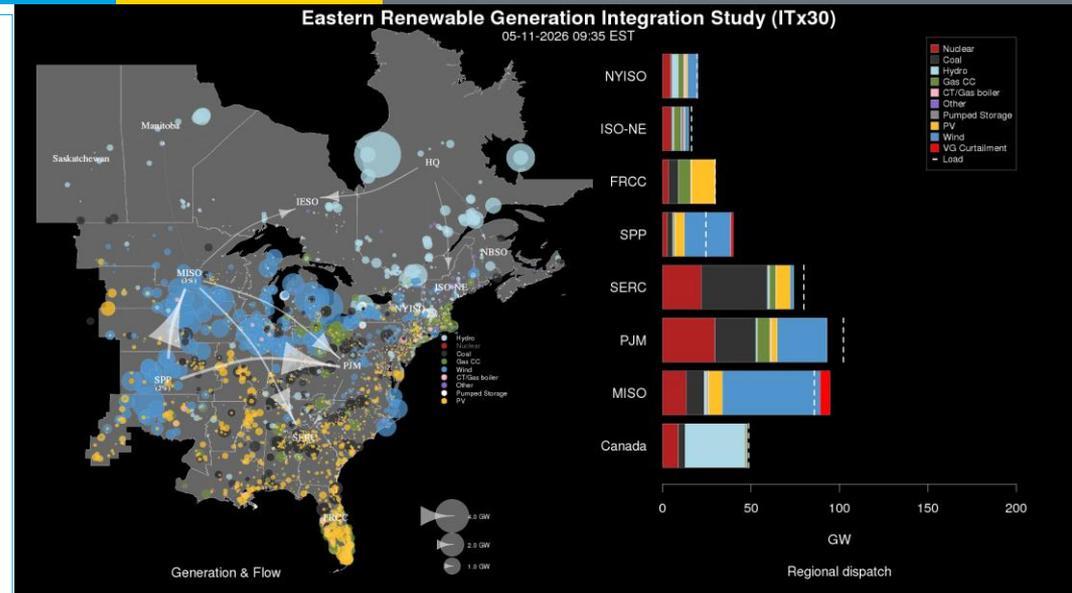
The Impact

- The first detailed transient stability and frequency response analysis of wind in high-penetration futures under emergency conditions such as contingencies (WWSIS-3)
- The most detailed integration study of the largest power system in the world provided critical insights into what we could expect in futures with more than 25% wind (ERGIS)
- The first integration study to release the model, data, and code to the public while respecting security needs (ERGIS)
- Collectively, this body of work shows that 25% wind is a technical possibility under a wide range of conditions and across multiple economic and reliability metrics
- New products:
 - <http://www.nrel.gov/grid/wwsis.html>
 - <http://www.nrel.gov/grid/ergis.html>

- Builds on WWSIS-1 and 2
- Applies a traditional modeling tool (PSLF) to a new series of questions:
 - Transient stability under high wind and solar
 - Frequency response under high wind and solar
- Test the deployment of new wind power plant controls to handle traditional reliability emergencies:
 - Two Palo Verde Units
- Key issue: Given that you can balance the net load, can you manage emergencies?
→ Yes, we can!



- First-of-its-kind analysis that explored the relationships between wind and solar at an unprecedented fidelity and resolution:
 - MIP
 - 5,600 generators
 - 5-minute dispatch
- Key issue: If you got to a high wind and solar future, could you balance the net load?
 - Yes, we can!



- **WWSIS-3: *Project Complete***
 - The Western Interconnection can withstand the crucial first minute after grid disturbances with high penetrations of wind and solar
 - Local stability, voltage, and thermal problems can be addressed with traditional transmission system reinforcements (e.g., transformers, shunt capacitors, local lines)
 - Nontraditional frequency-responsive controls on wind, utility-scale solar photovoltaic, concentrating solar power plants, and energy storage are effective at improving system performance.
- **ERGIS: *Project Complete***
 - Development and deployment of new tools to accelerate the adoption of wind, ERGIS model/data are public, parallelization code is being deployed to industry, and new visualization capabilities are public
 - Wind and solar can be balanced at a 5-minute level under a variety of conditions
 - New insights into system stress and the ability to manage uncertainty.

Project Plan & Schedule

	Milestone Description	Percent Complete	Due Date	Date Complete
FY14	Q1 Project Milestone Description: WWSIS-3—Give a presentation to the TRC on an analysis of the Western Interconnection frequency response for the light spring 2022 case to determine the impacts of high wind penetrations on grid reliability and ensure expert review of analysis by December 31, 2013. Frequency response is of concern to utilities because wind and solar do not generally provide that function, and they will be displacing synchronous machines that frequently do. This step is critical to ensuring that the project is on track with frequency response before the heavy summer case is run and before stability is examined in detail.	100%	12/31/2016	10/10/2013
FY14	Q2 Project Milestone Description: ERGIS—Present initial modeling results for the study scenarios to the TRC by February 14, 2014. This step is critical to building a stakeholder-vetted database that can be relied upon to produce reliable results for the 2025 analyses.	100%	2/14/2014	2/5/2014
FY14	Q3 Project Milestone Description: WWSIS-3—Prepare a memorandum on preliminary frequency response and transient stability results for review by DOE and the TRC to ensure expert vetting and review of results by June 30, 2014. The results are relevant because utilities are concerned that displacing conventional generation will hurt reliability and stability, and no one has examined high wind/solar penetrations on the Western Interconnection before. This step is important because it provides the review of results and the input to mitigation option analysis before that step can be done.	100%	6/30/2014	6/26/2014
FY14	Q4 Project Milestone Description: ERGIS—Work with the mitigation options working group to define additional model runs to test the impact of mitigation options on system operations. Present modeling results from these runs to the TRC by August 30, 2014. This step allows NREL to identify and test mitigation options that are important to industry and regulators.	100%	9/30/2014	8/12/2014
FY15	Task 2.8.0.401.2 WWSIS-3 Q1: A final report and executive summary will be submitted for publishing, incorporating TRC and DOE review and feedback on the draft final report, to disseminate study findings on the impact of high wind and solar penetration on frequency response and transient stability in the Western Interconnection by December 31, 2014.	100%	12/31/2014	12/16/2014
FY15	Task 2.8.0.401.1 ERGIS Q2: A detailed PowerPoint presentation will be made at an in-person TRC meeting to debut final modeling results. This presentation will include the results of all simulations and mitigation options and sensitivity analyses. Input on the presentation will be solicited from the TRC and incorporated into the final report by March 31, 2015.	100%	3/31/2015	4/10/2015
FY15	Task 2.8.0.401.1 ERGIS Q3 (SMART): A final report and executive summary will be submitted for publishing, incorporating TRC and DOE review and feedback on the draft final report, to disseminate study findings on the impact of high wind and solar penetration on system operations by June 30, 2015.	100%	6/30/2015	Submitted and retracted 10/1/15
FY16	Task 2.8.0.401.1 ERGIS Q3 (SMART): A final report and executive summary will be submitted for publishing, incorporating TRC and DOE review and feedback on the draft final report, to disseminate study findings on the impact of high wind and solar penetration on system operations by June 30, 2015.	100%	6/30/2015	8/30/2016
FY16	Successfully submit final reports for both WWSIS-3 and ERGIS in FY15, and engage headquarters to identify emerging integration questions.	100%	9/30/2015	5/31/2016
FY16	In alignment with the Grid Modernization Lab Call, submitting an annual operating plan modification extending the current FY15 Q4 milestone—"Task 2.8.0.401.2 WWSIS-3 Q4: Engage stakeholders with a webinar or presentation to explain overall project objectives, results, and implications for high wind and solar penetration. Develop presentation with animation of study results."—into Q1 of FY16, and make any associated cost adjustments.	100%	12/31/2015	12/17/2015

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$724.571k		\$361.356k		\$480.571k	

- The U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy’s SunShot Systems Integration program provided \$300k in FY14 and \$275k in FY15.
- The U.S. Office of Electricity Delivery and Energy Reliability, National Electricity Delivery Division, provided \$500k in FY14 and \$25k in FY16.

Partners, Subcontractors, and Collaborators:

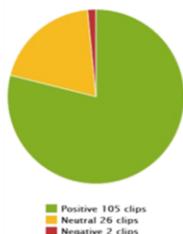
Subcontractors: GE Energy Consulting, RePPAE

Partners: Quarterly TRC meetings with more than 30 participants in every meeting for both projects

Communications and Technology Transfer:



133 Media Mentions (through 9/13/16)



#16 Reddit front page
#1 in r/Science.

High-caliber Coverage: Vox, Greentech Media, Forbes, Utility Dive, Clean Technica, Energy.gov

2,245 Downloads



5,100 User Sessions
(8/15/16 – 9/30/16)



Reach: 12,330
Reactions: 158
Shares: 47



Reach: 15,769
Reactions: 167
Shares: 46

60%-170% better

Performance of ERGIS Facebook and Twitter posts compared to NREL average for that time period.



Redefining what's possible
with clean energy

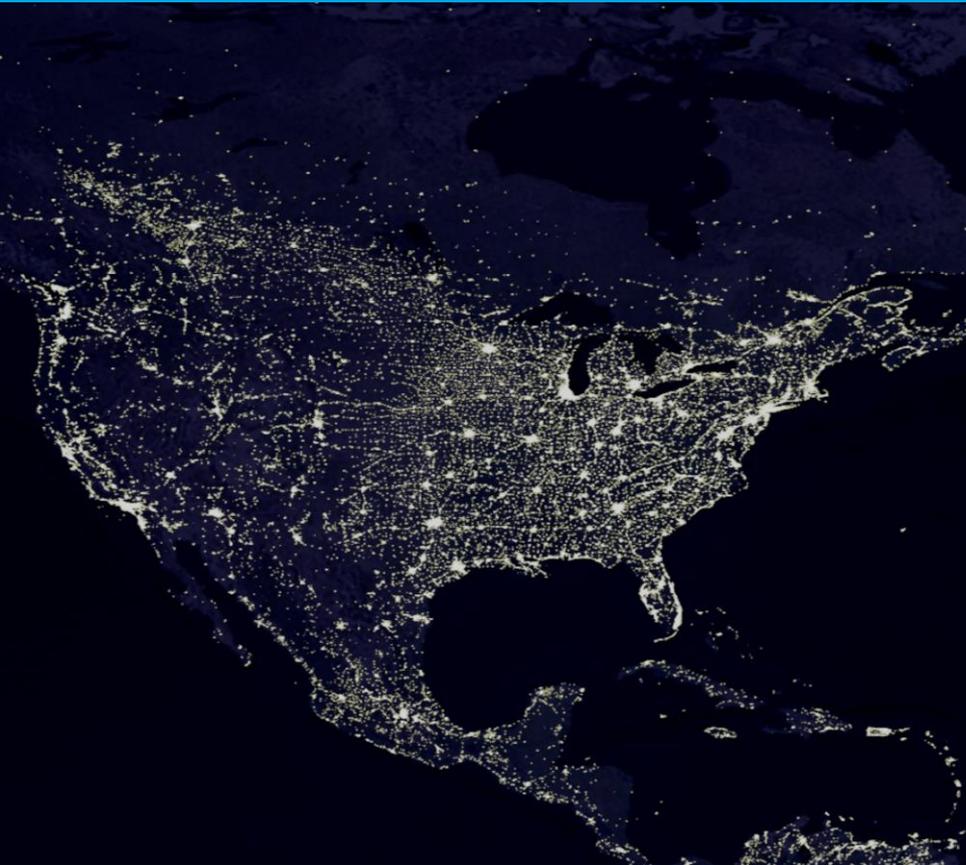


3,099 Views for Highlights

5,480 Views for Simulations

FY17/Current Research: Projects are complete, transitioning to new work in the North American Renewable Integration Study

Planned Future Research: Coordinated power system planning and operations across North America



003 / 45 / 7844

Wind Generator Modeling

Grid System Planning for Wind

Benjamin Karlson / Eduard Muljadi

Sandia National Laboratories / NREL
bkarlso@sandia.gov 505.377.3774

Wind Generator Modeling:

With wind generation dominating interconnection queues the need for generic, standard, validated, and publicly available models that allow transmission planners to study the impact to the grid is a high priority.

The Challenge:

These generic, standard models have not been readily available to the regional reliability organizations and grid operators who are responsible for maintaining the grid.

Partners:

- Industry: Western Electricity Coordinating Council (WECC), IEEE, International Electrotechnical Commission (IEC), Utility Variable-Generation Integration Group (UVIG), the Electric Power Research Institute (EPRI), Bonneville Power Administration, Public Service Company of New Mexico (PNM), GE, Siemens, PowerWorld
- National Labs: Sandia, National Renewable Energy Laboratory (NREL), Pacific Northwest National Laboratory (PNNL), Idaho National Laboratory (INL)
- Universities: Univ. of Denver, Univ. of Colorado, Univ. of Texas, Technical Univ. of Catalonia, Spain, Univ. of Castilla LaMancha, Spain, Chonbuk National Univ., Korea

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The Impact

- With fully validated, generic, standard, non-proprietary models available to system planners and operators wind power projects and be more accurately studied providing a higher confidence level of their impact to the existing and planned power grid.
- These model must be updated regularly as new features and technologies are added to wind turbines that will be beneficial to grid operations.

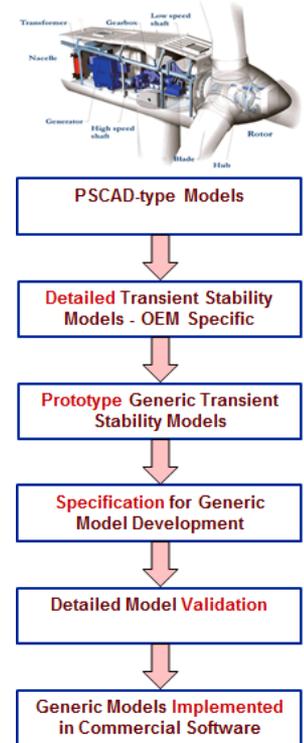
Key Issues:

- Historically, most wind turbine generator (WTG) models are proprietary user-defined models developed by manufacturers
 - Prevents the exchange of data and the validation of models
- Generic, standard, publicly available models should:
 - Allow for easy exchange of model data
 - Facilitate comparisons of system dynamic performance between different simulation programs
 - Allow for implementation of WTG models in different simulation programs
 - Provide a mechanism for parameter tuning.

Technical Approach:

Coordination and participation in industry efforts is paramount

- The WECC Renewable Energy Modeling Task Force (REMTF)
 - Sandia was the chair and NREL is a member of the REMTF leading the efforts for continued improvements of WTG models.
- The NERC Integration of Variable Generation Task Force (IVGTF)
 - Sandia and NREL contributed to the NERC IVGTF guidelines.
- The International Electrotechnical Commission TC 88 WG27
 - Sandia was the U.S. delegate to the IEC TC88 WG27.



Western Electricity Coordinating Council

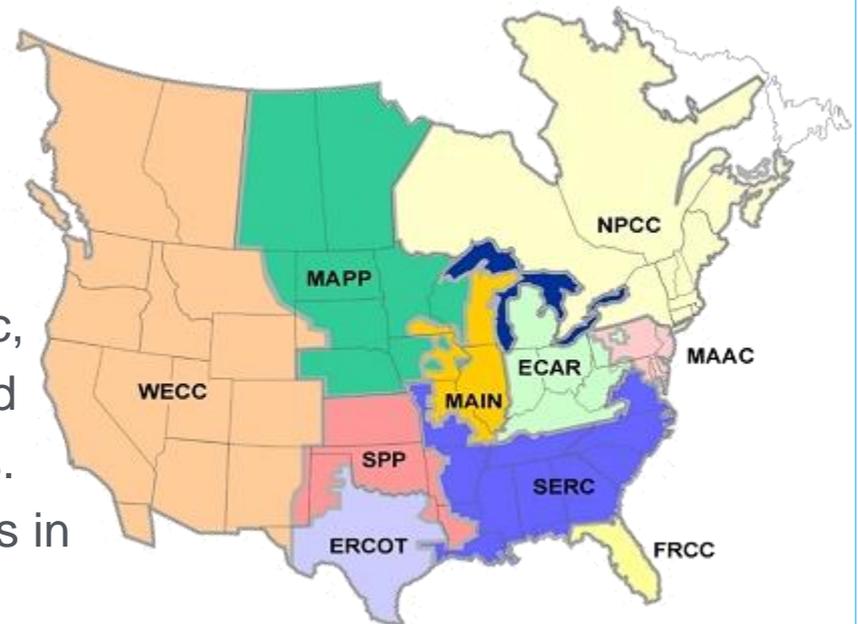
“promotes Bulk Electric System reliability in the Western Connection.”

Renewable Energy Modeling Task Force

“The REMTF leads the effort to develop generic, non-proprietary models for planning studies.

Responsibilities include:

1. Development of specifications for generic, non-proprietary models for solar and wind generation for use in bulk system studies.
2. Coordination of implementation of models in commercial simulation software.
3. Development of model application and validation guidelines, and
4. Coordination with stakeholders.”

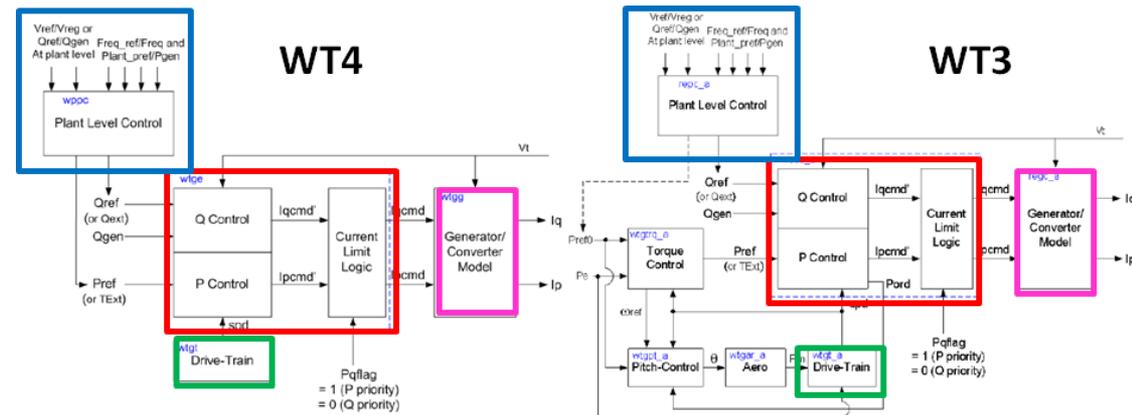


Source: WECC, www.wecc.biz

- Second-generation WTG models have been developed
 - Models have been updated with improved capability (inertial response, governor control, reactive compensation).
- Models are available in power system simulation software
 - PSS®E
 - PSLF™
 - PowerWorld
- Model guideline published

Modular structure for wind and PV models
- Easier to implement and maintain models

Module	Use
REPC_A	Wind/PV plant controller
REE_A, REE_B	Wind /PV electrical controls
REGC_A	Generator/Converter model
WTGT_A	Drive Train
WTGAR_A	Aerodynamic Model
WTGPT_A	Pitch Control Model
WTGTQ_A	Torque Control Model
lhvrt	Voltage/current Protection Model



Block diagram of type 3 and type 4 WTG models

WTG models have been improved and implemented in power system simulation software

Project Plan & Schedule

Summary					Legend							
WBS Number or Agreement Number					Work completed							
Project Number					Active Task							
Agreement Number					Milestones & Deliverables (Original Plan)							
					Milestones & Deliverables (Actual)							
Task / Event	FY2014				FY2015				FY2016			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Sandia National Laboratories												
Project Name: Wind Generation Modeling												
Q1 Proof of concept report reviewing the existing structure for plant controller		◆										
Q2 Report to DOE on prototype implementation to test models			◆									
Q3 Finalize WT4 model improvements as recommended by WECC REMTF				◆								
Q4 Finalize WT3 model improvements with active power control					◆							
Q1 Host and participate in the Fall WECC Modeling and Validation WG						◆						
Q2 Develop and deliver wind energy data to PNM for the frequency reliability st							◆					
Q3 Deliver status report on the WTG models and validation progress								◆				
Q4 Develop and deliver a draft model validation guideline to WECC REMTF									◆	◆		
National Renewable Energy Laboratoy												
Q1 Develop control algorithms to provide oscillation damping and reactive pow		◆										
Q2 Document in letter report the wind plant oscillation damping control algorith			◆									
Q3 Develop algorithms for offshore wind plants to provide inertial response				◆								
Q4 Complete technical report on oscillation damping control by wind plants					◆							
Q1 Develop equivalent model to represent WPPs under harmonic current comp						◆						
Q2 Validate WPP models for harmonics components w/ typical data set							◆					
Q3 Complete technical report on dynamic model validation for WPP applications								◆				
Q4 Conduct survey of power system planners to guide the future direction of mo									◆			

Sandia Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$250k		\$200k		\$0	

NREL Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$178k		\$243k		\$0	



Communications and Technology Transfer:

This work has been presented at numerous conferences and workshops including, but not limited to:

- WECC Modeling Webinars and Workshops
- IEEE Power & Energy Society General Meetings
- UVIG Technical Conferences

Communications and Technology Transfer (Downloadable website: www.wecc.biz/PCC/Pages/REMTF.aspx; www.nrel.gov/publications/):

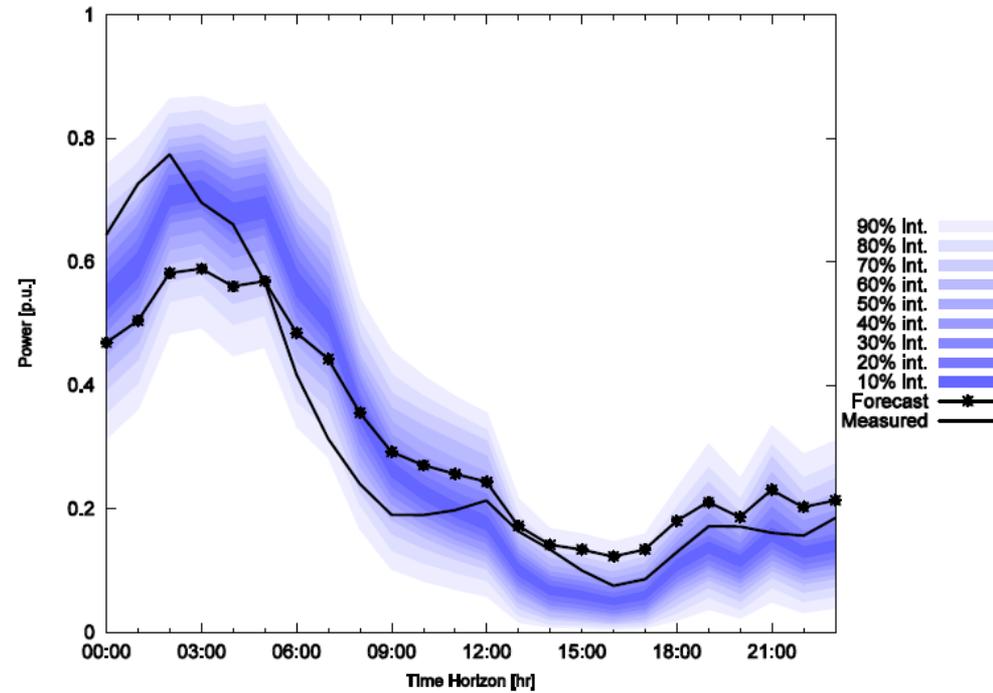
- Dynamic Modeling of Wind Generator and Wind Plant: (five journal papers and four conference papers)
- Dynamic Modeling on Power Oscillation Damping: (four journal papers and four conference papers)
- Dynamic Modeling on Frequency Response: (three journal papers and four conference papers)
- Dynamic Modeling on Voltage/Reactive Power Controls: (four journal papers and nine conference papers)
- Dynamic Modeling of Wind for Short-Circuit Transmission Studies: (one journal paper)
- Support and develop WECC Renewable Energy Modeling Task Force - to get input among the power system planners to guide the future direction of the dynamic model development activities for wind turbine generation
 - Including co-authoring of numerous WECC Reports and Modeling Guidelines

FY17/Current Research:

NA

Planned Future Research:

- Model validation against a range of system events remains a high priority. Challenges remain in obtaining good data.
- Future revisions of the models are inevitable as new features are added and grid codes are adopted.



Stochastic Tool Evaluation

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February 2017

Stochastic Tool Evaluation: Argonne National Laboratories (ANL) analyzed the potential use of *stochastic methods* for improved power systems operations with increasing shares of wind power.

The Challenge: Addressing the *variability and uncertainty in wind power* is a key challenge for power system operators. The project looked at the potential use of stochastic methods towards this end, evaluating the advantages and disadvantages of different operational strategies.

Partners: None

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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- **Advancing grid integration**

The Impact

- Stochastic methods can reduce grid integration costs and enable a larger penetration of wind power.
- Our project facilitates the adoption of stochastic methods by (1) providing an improved understanding of the potential benefits of introducing these methods in power system operations, (2) synthesizing the current state-of-the-art in terms of algorithms and tools.
- ANL provides a comprehensive summary of relevant stochastic methods applied to power systems and conducted numerical experiments with different operational strategies.
- ANL also developed novel mathematical formulations for power system operation under wind power uncertainty.

Reviewed 180 papers on stochastic methods applied to power systems operations

Categorized and summarized relevant approaches

Deterministic programming w/reserves

Stochastic programming

Chance-constrained programming

Robust programming

Interval programming

Fuzzy programming

Identified advantages and disadvantages as well as industry applications and interest



Technical Approach

Evaluation of Stochastic Operational Methods

Generated probabilistic wind power forecasts: scenarios and intervals

Kernel density estimation (Bessa et al. 2012), considering spatio-temporal correlations

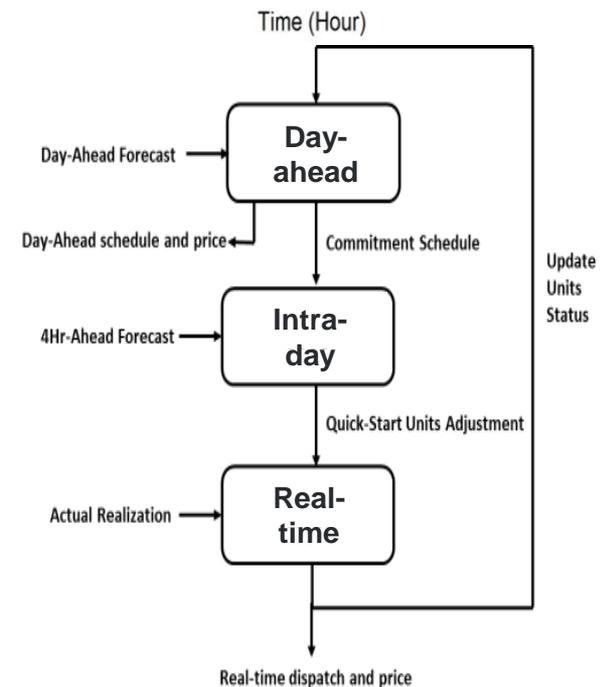
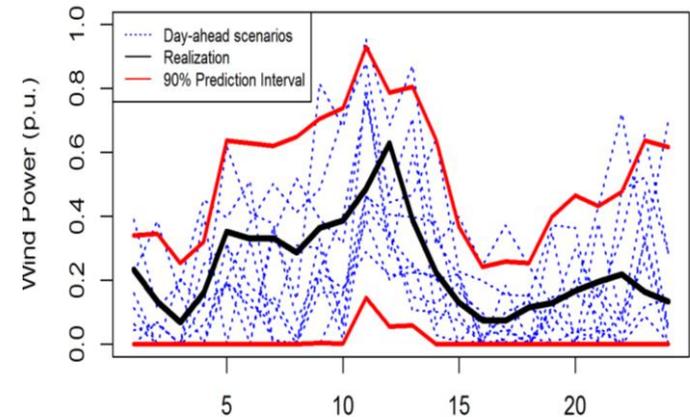
Computationally efficient unit commitment (UC) and economic dispatch (ED) formulations

Deterministic, stochastic, interval programming

Developed simulator with different stages of system operation

Explored novel alternative methods

Fuzzy programming, chance-constrained goal programming, optimal uncertainty intervals



Extensive literature on probabilistic reserve setting, but current rules largely based on heuristics

Recent surge in research on stochastic methods with renewable energy; mainly stochastic programming

Main focus on cost savings and reliability impacts, less focus on pricing/market implications

No standard frameworks or metrics for comparing different operational approaches

Industry adoption of stochastic methods still limited

Study	Stochastic UC Cost Savings
Gröwe et. al. (1995)	1.6%
Takriti et. al. (1996, 2000)	0.4-4.0%
Tuohy et. al. (2008)	0.6%
Wang et. al. (2008)	1.3%
Pappala et. al. (2009)	2.8-3.8%
Ruiz et. al. (2009, 2010)	0.8-1.8%
Constantinescu et. al. (2011)	1.0%
Wang et al. (2011)	2.9 %
Zhou et al. (2013)	1.7 %
Papavasilliou and Oren (2013a,b)	1.9-5.4%

Zhou et al., ANL/ESD-16/14, 2016.

Accomplishments and Progress

State of the Art in Stochastic Methods for Operations

TABLE 1 Summary of Current and Proposed Scheduling Approaches with Renewable Energy

Optimization Method	Objective Function	Uncertainty Representation	Operating Reserves	Pros/Cons
Deterministic programming w/dynamic reserves	Min Cost	Only through reserve constraints	Dynamic reserve constraints	<ul style="list-style-type: none"> + Small departure from current practice + Well-defined prices for energy and reserves + Reserve requirements reflect forecast uncertainty - Uncertainty not explicitly represented
Stochastic programming	Min Expected Cost	Scenarios/ scenario trees	Implicit*	<ul style="list-style-type: none"> + Rational decision strategy + Minimizes expected cost + Explicit uncertainty representation - Computational burden - Adequate scenario generation - Complex energy prices, no explicit reserve prices
Interval programming	Min Cost for Baseline	Continuous interval set without assumptions on probability	Implicit*	<ul style="list-style-type: none"> + Explicit uncertainty representation + Can provide cost intervals + Fast computation - Uncertainty not reflected in objective function - Hard to derive adequate uncertainty set - No explicit reserve prices

Zhou et al., ANL/ESD-16/14, 2016.

Testing of operational strategies on IEEE 118 bus system with 21% wind power over four months simulation period

- Deterministic UC (DUC)
 - Perfect forecast, point forecast, dynamic reserves (DR)
- Interval UC (IUC): 10% quantile lower bound
- Stochastic UC (SUC): 10 forecast scenarios
 - Extensive form or decomposition (Benders or Linear-Shift-Factor)

UC Model	Summer (July-August)			Fall (September-October)		
	DA Cost (\$M)	RT Cost (\$M)	RT Load Shedding (MW)	DA Cost (\$M)	RT Cost (\$M)	RT Load Shedding (MW)
DUC-perfect	1.517	1.517	0	1.023	1.023	0
DUC-point	1.589	1.523	0	1.074	1.050	3.43
DUC-DR	1.637	1.523	0	1.146	1.043	0.52
IUC	1.623	1.524	0	1.131	1.046	0
SUC	1.565	1.521	0	1.078	1.034	0

Accomplishments and Progress

Evaluation of Stochastic Operational Methods

Average Comp. Time Per Day	Day-ahead (s)	Intra-day (s)	Real-time (s)
DUC-Perfect Forecast	11	4.3	0.54
DUC-Point Forecast	10	4.6	0.89
DUC-Dynamic Reserve	22	5.9	1.01
IUC	11	4.3	0.46
SUC (Extensive Form)	248*	62	1.19
SUC (Linear Shift Factor)	266	48	0.87
SUC (Benders)	171	14	0.89

*Solution not found for some days.

Stochastic UC gives lowest expected cost, but at high computational expense

- Decomposition enables the solution of larger stochastic UC cases reliably

Interval UC gives high reliability with fast computational speed

Some load curtailment occurring with deterministic strategies

Pricing of energy and reserve challenging with stochastic and interval UC

Deterministic UC w/dynamic reserves easier to implement in current markets

Hard to make realistic comparison between different operational strategies

- Project initiated 11/2014 and completed 06/2016
- Milestones met on time
- Continued work on related topics through June 2016, while waiting for FY16 GMLC/wind funding for new projects

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
		\$500K			

Project spending as planned.

Project completed in FY16.

Partners, Subcontractors, and Collaborators:

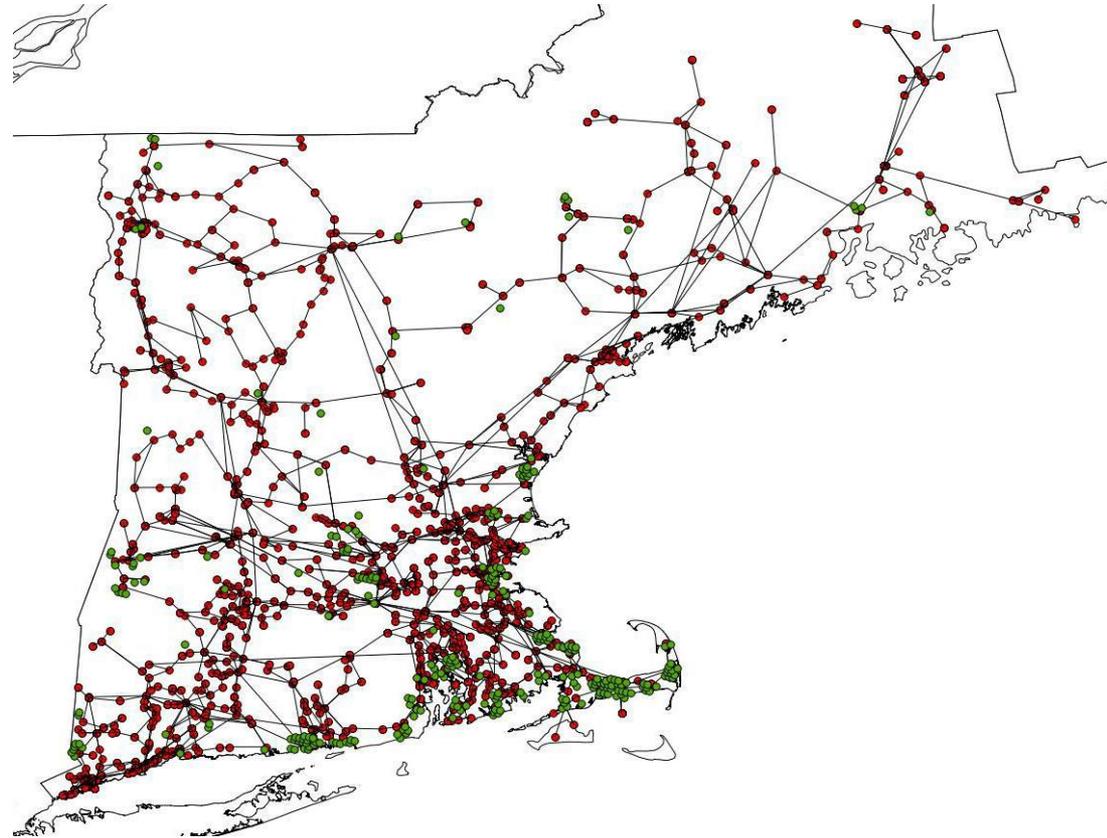
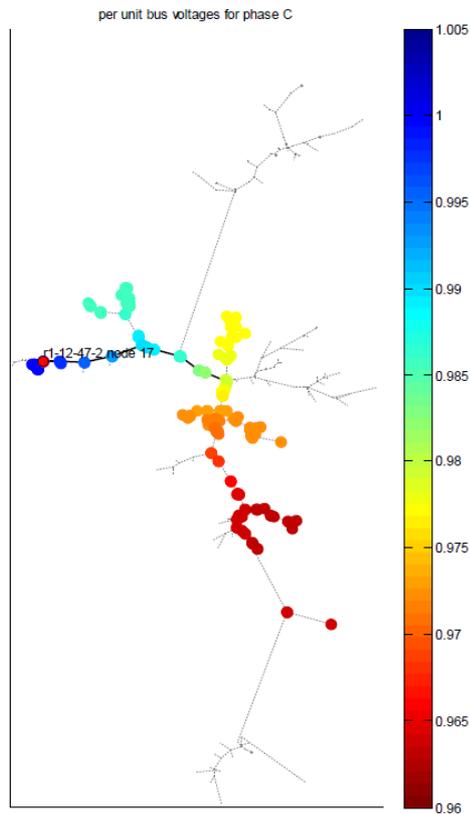
Argonne project. ANL collaborates with several universities in this area of research (e.g. University of Chicago, University of Washington, Tsinghua University).

Communications and Technology Transfer:

- Utility Variable-Generation Integration Group forecasting workshop (Feb. 2015)
- Federal Energy Regulatory Commission technical meeting (Jun. 2015)
- INFORMS meeting (Nov. 2015, Nov. 2016)
- IEEE Energy Conference (Apr. 2016)
- IEEE Power and Energy Society General Meeting (Jul. 2016)
- Two technical reports, three journal papers, three conference papers
- 1,200+ citations for wind power papers (since 2010)
- Fully documented stochastic/interval UC algorithms (computationally efficient)

FY17/Current Research: Project completed.

Planned Future Research: Current NREL/ANL project
“Market and Reliability Opportunities for Wind on the Bulk
Power System”



Distributed Wind Integration

Bri-Mathias Hodge, Ph.D.

NREL ESIF PSEC PSDS

Bri.Mathias.Hodge@nrel.gov 720 409 6673

February 2017

Distributed Wind Integration

The Challenge: To examine the possible operational challenges associated with large additions of distributed wind generation.

- Distribution network impacts
 - Voltage transient and dynamic limitation factors for interconnection of large-scale wind generation at typical distribution feeders.
 - Distribution-level protection, islanding operation of large distributed generation, and protection coordination.
- Transmission network impacts
 - Impact of a large number of distributed wind generators on bulk power system operations.
 - Distributed generation response (e.g., low-voltage ride through) and system stability support.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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- **Distributed wind R&D**
- NextGen component innovations

The Impact

- Better understanding of the operational and reliability impacts of distributed wind on both distribution and transmission networks.

Enabling Wind Nationwide

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The Impact

- Analysis of distributed wind impacts on voltage stability, power system operations, and electricity prices.

Distribution feeder-level voltage issues that can arise when adding utility-scale wind turbines to the distribution system (four PNNL taxonomy feeders were examined with wind turbines at different distances from the substation)

This study also investigated the reaction from the distributed generation to a single transmission disturbance and the impact on system stability.

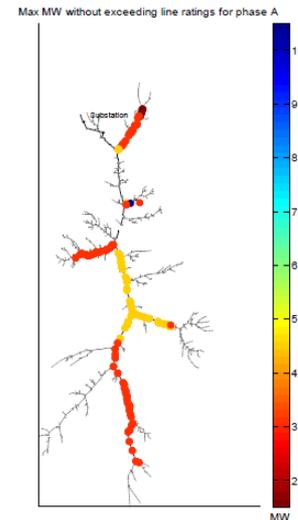


Figure 112.
Maximum wind power at a bus that does not exceed line ratings for Phase A

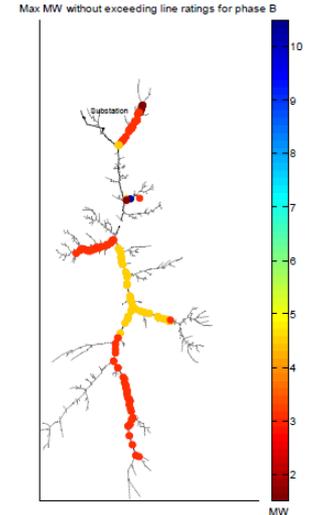
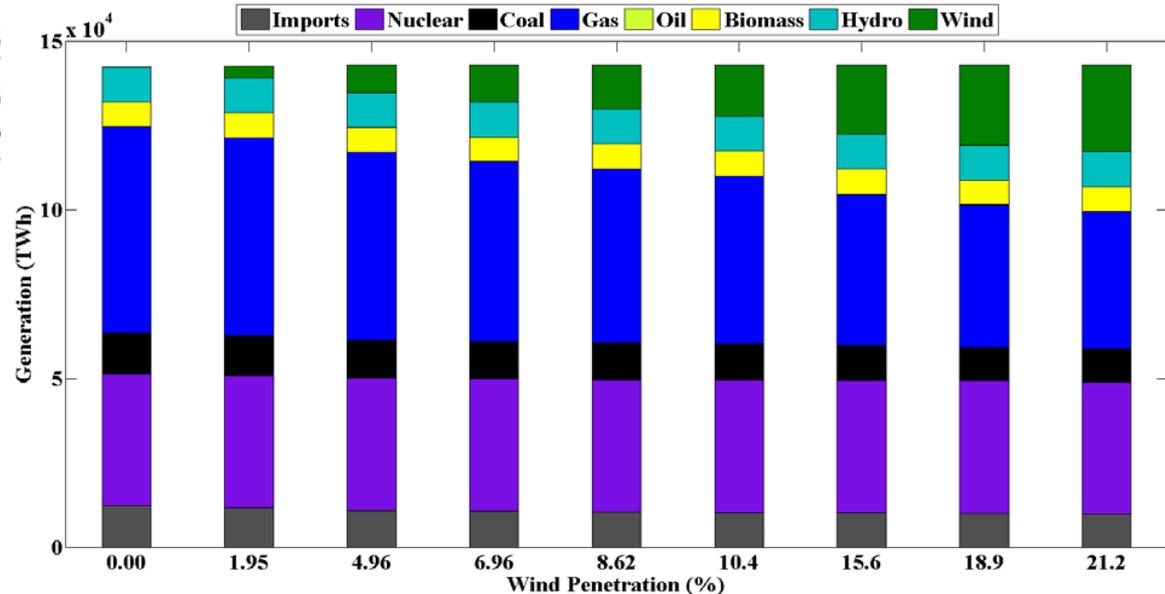
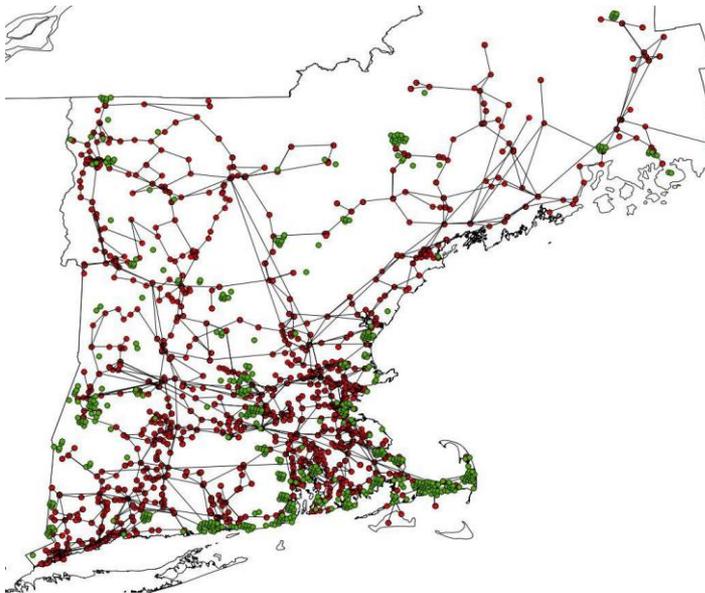


Figure 113.
Maximum wind power at a bus that does not exceed line ratings for Phase B

Assessment of the potential for adding distributed wind to the current power system with minimal or no upgrades to the distribution or transmission electricity systems

Analysis of the impacts of integrating large amounts of utility-scale distributed wind power on bulk system operations with a case study on the ISO-New England power system



NREL Technical Reports

- *Voltage Impacts of Utility-Scale Distributed Wind*
- *Impact of Utility-Scale Distributed Wind on Transmission-Level System Operations*

Conference Papers

- Impact of Distribution-Connected Large-Scale Wind Turbines on Transmission System Stability During Large Disturbances
- The Impact of Distributed Wind on Bulk Power System Operations in ISO-NE
- Investigating the Impact of Wind Turbines on Distribution System Stability

Journal Article

- “The Impact of Wind on Electricity Prices (*Renewable Energy*)

Project was completed during FY13 & FY14.

Budget History	
FY2014	
DOE	Cost-Share
\$149.952k	\$0

Complete budget spent by end of Q1 FY15

Partners, Subcontractors, and Collaborators

Not Applicable.

Communications and Technology Transfer

- 6 Publications
- Automatic conversion software developed to convert from GridLab-D to OpenDSS format.
- Conference Presentations
 - IEEE Power & Energy Society General Meeting (Washington, D.C., 2014)
 - 13th International Workshop on Large-Scale Integration of Wind Power into Power Systems (Berlin, 2014)
 - IEEE Innovative Smart Grid Technologies Conference (Minneapolis, 2016)

FY17/Current Research

Not Applicable

Planned Future Research

Not Applicable



Grid System Planning for Wind: Grid
Integration Support, UVIG, IEEE, NERC,
FERC, IEA Task 25

David Corbus

National Renewable Energy Laboratory

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Grid System Planning for Wind: Grid Integration Support, UVIG, IEEE, NERC, FERC, IEA Task 25

The Challenge: Key stakeholders in power system planning and operations need access to best practices for integrating wind energy that are built on actual experience and analysis/modeling

Partners: Utility Variable Integration Group (UVIG), North American Electric Reliability Corporation (NERC), International Energy Agency (IEA) Task 25, Federal Energy Regulatory Commission (FERC), Institute of Electrical and Electronics Engineers (IEEE)

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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Enabling Wind Nationwide The Impact

Enhancing U.S. Energy Security and Independence

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- Advancing grid integration

- Enabled high wind penetrations (e.g., hourly Colorado balancing area wind often reaches greater than 70% wind) with knowledge and information from National Renewable Energy Laboratory (NREL) grid integration analysis
- Encouraged use of best practices in analysis and rules that incorporate latest research findings and industry experience in wind grid integration through participation in technical committees
- Influenced treatment of wind in utility studies and tariffs through analysis and engagement with key stakeholders
- Greater education for key decision-makers through regulatory outreach; actions shown to be favorable by NREL analysis have been adopted by key stakeholders
- Increased legislative action to address wind grid integration was achieved through enhanced education of policymakers
- Increased sharing of best practices across utilities and system operators via UVIG meetings.

- Approach—addresses three main groups:
 - Regulatory and legislative
 - Technical committees such as International Energy Agency (IEA) Task 25, IEEE, North American Electric Reliability Corporation (NERC), Federal Energy Regulatory Commission (FERC), Western Electricity Coordinating Council (WECC), and Technical Review Committees for integration studies
 - Wind energy/utility forums such as Utility Variable-Generation Integration Group (UVIG)
- Provide unique access to credible information and applied research to facilitate wind energy integration
 - Ensure that state-of-the art results, methods, and data in wind integration reach critical decision-makers
 - Synthesize key results from National Renewable Energy Laboratory (NREL) grid integration work and work of others
 - Disseminate information, results, data, and tools to key stakeholders
- External review
 - Integration Support Review Committee meets annually to provide input and feedback to this project.

- Key technical approaches include:
 - Determining impacts of high levels of wind energy on power system planning, operations, and reliability
 - Encouraging electricity market design and operation with high levels of variable generation
 - Managing uncertainty in variable generation plant output
 - Determining Interconnection requirements for wind plants
 - Evaluating ancillary services from wind plants
 - Evaluating the role of transmission in high-wind penetration scenarios
 - Engaging and educating power industry stakeholders.

- Regulatory and Legislative Engagement
 - FERC briefings including presentation on the Eastern Renewable Generation Integration Study
 - National Association of Regulatory Utility Commissioners (NARUC) meeting presentation and National Conference of State Legislatures (NCSL) webinars
- Wind/Utility Forums
 - Presentations of key wind integration findings at UVIG fall and spring technical meetings, forecasting workshop, and short course
- EIM has been adopted by PacifiCorp, CAISO, and NV Energy; earlier modeling and dissemination of results through engagement showed benefits of the Energy Imbalance Market (EIM)
- Technical Committees and Task Forces apply latest wind integration findings
 - Webinar for WECC Variable Generation Subcommittee on methods for calculating flexibility reserves
 - WECC Variable Generation Subcommittee, Operating Committee, Market Committee
 - IEA Task 25 – Design and Operation of Power Systems with Large Amounts of Wind Energy
 - IEEE Loss of Load Expectation Working Group

- NERC requested NREL support for the new Essential Reliability Services Task Force.
 - NREL prepared draft document to serve as a starting point for the full Task Force white paper
- NREL helped to assess planning models and how they can help analyze the impact of high penetrations of wind on flexibility requirements in California through participation in a white paper with California utilities (investor-owned utilities [IOUs]).
- NREL influenced utility tariffs; for example, Xcel Energy requested input from NREL on its proposed integration tariff.
- NREL's participation in the Minnesota integration study has enabled best practices estimation and will influence whether a higher renewable portfolio standard is possible.
- NREL worked with PacifiCorp who recently reduced integration cost estimates from \$9.70/megawatt-hour (MWh) to \$1.90/MWh.

Project Plan & Schedule

	Milestone Description	Percent Complete	Due Date	Date Complete
FY14	Q1 Project Milestone Description: Organize UVIG's 2013 Fall Technical Workshop and participate in the UVIG DG user group meetings. At these events, staff will present on emerging issues in variable generation integration. This task will be completed by November 1, 2013.	100%	11/1/13	10/29/13
FY14	Q2 Project Milestone Description: In collaboration with the WECC Operating Reserve Task Force, NREL will develop a summary document on regulation reserve requirement methods from WECC member utilities and other balancing areas throughout the United States. This work will be completed by March 31, 2014.	100%	3/31/14	3/31/14
FY14	Q3 Project Milestone Description: NREL will host a meeting of the IEA Task 25 in the United States. This work will be completed by June 30, 2014.	100%	6/30/14	4/10/14
FY14	Q4 Project Milestone Description: NREL will travel to and participate in at least three meetings or trainings for regulators and policymakers, such as the NCSL Legislative Horizons Institute or NARUC meetings, to engage stakeholders on critical issues in grid integration. This task will be completed by September 30, 2014.	100%	9/30/14	8/30/14
FY 15	2.8.0.402.1 Stakeholder, Q1 Description: Participate in the organization of UVIG's 2014 Fall Technical Workshop and present on emerging issues in variable generation integration by November 30, 2014.	100%	11/30/14	11/30/14
FY 15	2.8.0.402.1 Stakeholder, Q2 Description: Participate in drafting reports for IEA Task 25 work and attend and present as needed at IEA Task 25 meetings by April 30, 2015.	100%	4/30/15	4/14/15
FY 15	2.8.0.402.1 (SMART) Stakeholder, Q3 Description: Participate in the organization of UVIG's 2015 Spring Technical Workshop and present on emerging issues in variable generation integration by May 31, 2015.	100%	5/31/15	4/24/15

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$477.711k	0	\$650k	0	0	0

- UVIG Subcontract \$300k per year

◆ Partners and subcontractors include:

- ◆ UVIG, NERC, IEA Task 25, FERC, WECC, IEEE Wind/Solar Power Coordinating, NCSL, NARUC, Western Interstate Energy Board, Canadian Wind Energy Association

◆ Collaborators include:

- ◆ Every independent system operator (ISO) in North America (this includes outreach through UVIG); IOUs including PG&E, SCE, SDG&E, Hawaiian Electric Company, APS, Duke, Southern Co, Xcel Energy, TEP, MidAmerican, NextEra, OG&E, PNM, DTE, ITC Transmission, Oncor; Public Power including BPA, NPPD, LADWP, Platte River, SMUD, WAPA, Lincoln Electric; rural coops including Basin Electric, Tri State G&T, GRE, Golden Spread, AVEC, Iowa Lakes; corporate including ABB, First Solar, SunEdison, GE, Vestas, Siemens, Iberdrola, S&C Electric.

Communications and Technology Transfer:

Task Force Report. 2014. Collaborative Review of Planning Models. Conducted for the California Public Utilities Commission. Available at <http://www.energy.ca.gov/2014publications/CEC-100-2014-001/CEC-100-2014-001-F.pdf>

North American Electric Reliability Corporation. 2014. Integrating Variable Generation Task Force 1.6: Probabilistic Methods. Task Force Lead: Michael Milligan and Mark O'Malley. Available at http://www.nerc.com/comm/PC/Integration%20of%20Variable%20Generation%20Task%20Force%2011/VGTF%20Task%201-6_09182014.pdf

Technical Advisory Committee member for the “Pan-Canadian Wind Integration Study,” prepared for the Canadian Wind Energy Association by GE Energy Consulting. Study released July 2016. Available at <http://canwea.ca/wind-energy/wind-integration-study/>.

Ahlstrom, M., C. Smith, R. J. Piwko, D. Lew, A. Bloom, T. Mai, Kara Clark; Michael Milligan. Relevant Studies for NERC's Analysis of EPA's Clean Power Plan 111(d) Compliance, Utility Variable Generation Integration Group; GE Energy 2015. NREL/TP-5D00-63979. <http://www.nrel.gov/docs/fy15osti/63979.pdf>.

Söder, L., M. Milligan, A. Orths, C. Pelling, D. Flynn, V. Silva, M. Lopez-Botet Zulueta, B. O'Neill, J. Kiviluoma. “Comparison of integration studies of 30-40 percent energy share from variable renewable sources,” submitted to journal Renewable & Sustainable Energy Reviews, May 2016.

Communications and Technology Transfer:

Milligan, M., B. Frew, E. Ibanez, J. Kiviluoma, H. Holttinen, L. Söder. Capacity Value Assessments for Wind Power: An IEA Task 25 Collaboration. Wiley Wires. 2016.

Ahlstrom, M., E. Ela, J. Riesz, J. O'Sullivan, B. Hobbs, M. O'Malley, M. Milligan, P. Sotkiewics, J. Caldwell. Evolution of the Market: Designing a Market for High Levels of Variable Generation. IEEE Power and Energy Society, Power and Energy Magazine. Nov/Dec 2015.

M. Milligan presented to PUC Commissioners and staff at the EIM meetings in Boise, Idaho. The PUC EIM Chair said, "your ability to break down the essential components of each (of the EIM) analyses and offer valuable comparisons and contrasts . . . was of particular value to the PUC EIM Group and its stakeholders."

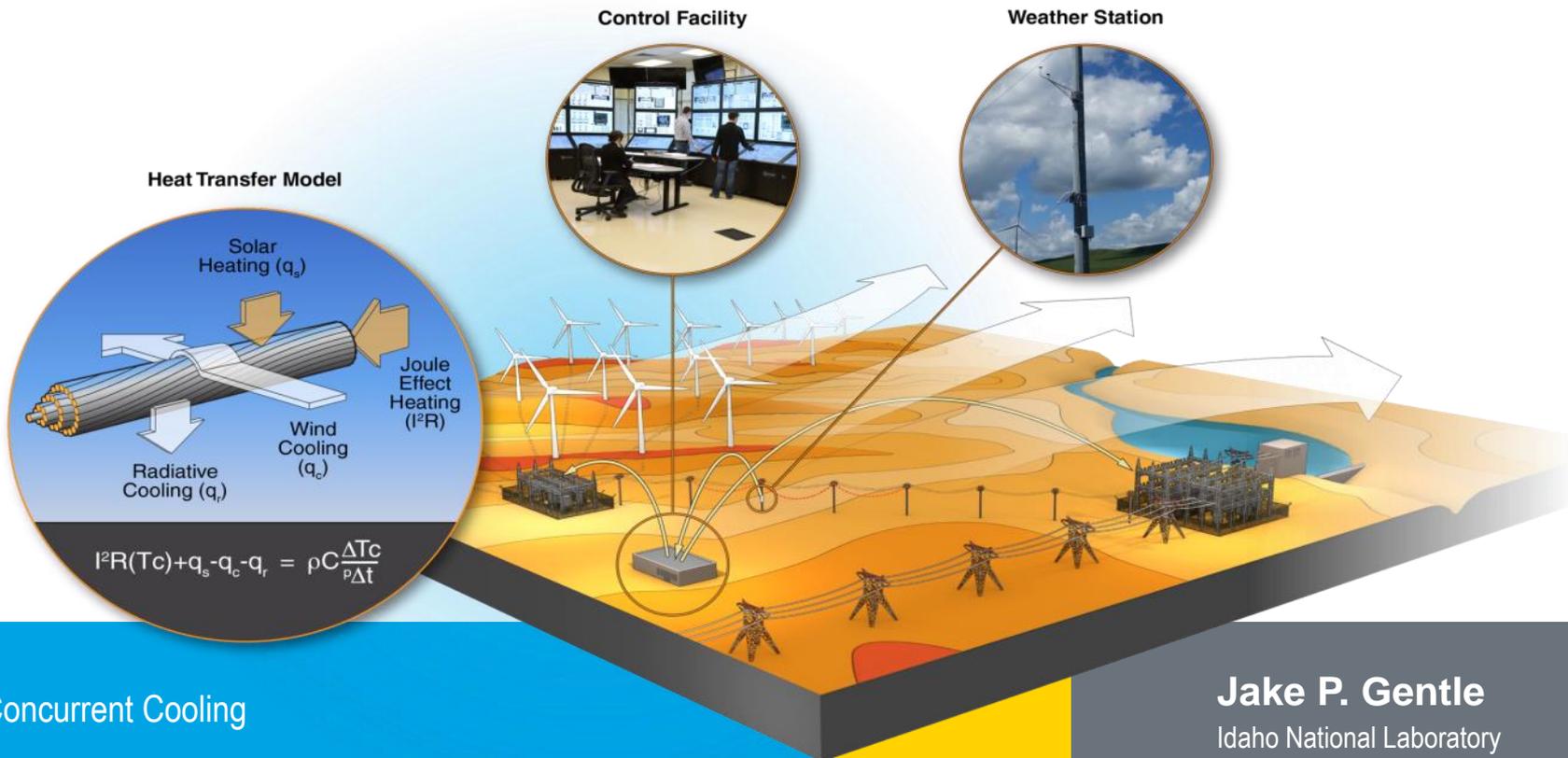
NERC IVGTF was "unprecedented opening of the door" to start resolving integration issues. "Being at the table is critical to influence the long-term direction and thinking..." "What NREL has been doing in the West is just right...NREL has been "essential to the process" of the EIM development."

L. Bird delivered a presentation to a webinar co-hosted by NREL and NCSL on methods of managing integration challenges. There were about 50 participants with about 25 representing state legislators or staff. Participant feedback included: "great webinar, congratulations."

FY17/Current Research: This work has transitioned to a new Grid Modernization Lab Consortium project.

Planned Future Research: This work has transitioned to a new Grid Modernization Lab Consortium project.

A “Cool” Way to Increase the Utilization of Existing Transmission and Distribution Infrastructure and the Optimization of New Infrastructure Developments



Concurrent Cooling

Jake P. Gentle

Idaho National Laboratory

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February, 2017



Jake P. Gentle
Principal Investigator



Tim McJunkin
Electrical
Engineer



Katya Le Blanc
Human Factors
Psychologist



Dr. Alex Abbaud
Computational
Fluid Dynamics



Jacob Lehmer
Software
Development



Dr. Wei Zhang
Human Factors
User Interface

Operational and Strategic Implementation of Dynamic Line Rating for Optimized Wind Energy Generation Integration

“A “Cool” Way to (1) Increase the Utilization of Existing Transmission and Distribution Infrastructure - DLR, and (2) the Optimization of New Infrastructure Developments – P&R Toolkit”

Affordable and effective implementation of real-time weather and forecast based dynamic line rating of overhead transmission lines by mitigating transmission congestion and optimizing the use of electricity infrastructure for the integration of wind energy to enhance the nation’s energy portfolio.

The Challenge:

Provide science based methodologies and solutions that are readily adopted and usable by a conservative, regulated industry

Requirements:

Provide industry with a low cost, robust solution set, and enabling human operators to make informed decisions and take appropriate actions without being overwhelmed with data

Concurrent Cooling Portfolio

- FY14
 - DLR
- FY15
 - DLR
 - P&R
- FY16*
 - DLR
 - P&R
 - HF*

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

Enabling Wind Nationwide

Enhancing U.S. Energy Security and Independence

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

The Impact

- Increasing the capacity of existing power lines enables an improved approach at mitigating transmission congestion and optimizing the use of existing electric infrastructure for the integration of wind energy.
- To-date, this R&D has shown an enhanced transmission capacity on existing transmission lines of more than 30% above their static rating.
 - For Wind Plant Tie-Lines, this R&D has shown that the transfer capability could be increased by more than 100% above static with “concurrent cooling” - DLR.
- Industry feedback supports P&R Toolkit ability to provide a useful feature set for wind developers to optimize conductor and infrastructure sizing and placement, to reduce high capital expenditures for new wind plants.

Putting it into "Perspective"



DYNAMIC LINE RATING

WindSim AS – Tonsberg, Norway

- Computational fluid dynamics (CFD) software collaborator and development partner

Idaho Power Company – Boise, ID

- Test area (~500 line miles)
- 50+ Weather Stations

AltaLink, LLC – Alberta, Canada

- Test area (~4 line miles)
- 4 Weather Stations

Genscape (Promethean Devices) – Boston, MA

- Field validation subcontract (three months)

Idaho State University – Pocatello, ID

- Collaborator: BS/MS/PhD Interns, Faculty R&D

Boise State University – Boise, ID

- Graphical processing units CFD research (GIN3D)

Durham University – Durham, UK

- Collaborator and methodology validation/comparison

Montana Tech – Butte, MT

- Collaborator: BS/MS Interns, Faculty R&D

University of Idaho – Moscow, ID

- Collaborator: BS/MS/PhD Interns, Faculty R&D

Alberta Electric System Operator – Alberta, Canada

Bonneville Power Administration – Portland, OR

Southwest Power Pool – Little Rock, AR

Oklahoma Gas and Electric – Oklahoma City, OK

North American Electric Reliability Corporation – Atlanta, GA

Western Electricity Coordinating Council – Salt Lake City, UT

Underground Systems, Inc – USA, Germany

Nexans, The Valley Group – USA

Southwire Company – Carrollton, GA

Lindsey Manufacturing – Azusa, CA

National Oceanic and Atmospheric Administration – Boulder, CO

StormGeo – Houston, TX

Vaisala, Inc – Seattle, WA

TechFlow – San Diego, CA

OSIsoft – San Leandro, CA

Stantec – Portland, OR

Power Engineers – Hailey, ID

Interactions w/ Industry & Academia – 15+ Non-Disclosure Agreements, **1** SPP Agreement Executed, **1** CRADA Project Executed, **1** CRADA Project Initiated, nearly **\$1M** invested by industry/academia partners over a 3-year period.

Partners and Collaborators



Institute for Electrical and Electronic Engineers (IEEE)

- Subcommittee 15.11: Overhead Lines Subcommittee
- Task Force - Line Ratings (Risk & Prediction)
- Working Group on Transmission and Distribution Overhead Conductors and Accessories—15.11.02/06
- Working Group on Construction of Overhead Lines—15.11.03
- Working Group on Management of Existing Overhead Transmission Lines—15.11.09
- Working Group on Wind and Solar Plant Collector System Design

Presented and updated on report contributions in Memphis, TN and Boston, MA

 **IEEE** IEEE Transmission & Distribution Committee
IEEE Power & Energy Society

International Council on Large Electric Systems (CIGRE)

- Full & Corresponding Member: US Representative
 - Jake P. Gentle (INL)
 - Mark Lancaster (Southwire Company)
- Working Group - Corresponding Member: A3.36—Application and Benchmark of Multi-Physics Simulations and Engineering Tools for Temperature Rise
- Working Group - Full Member: B2.59—Forecasting Dynamic Line Ratings

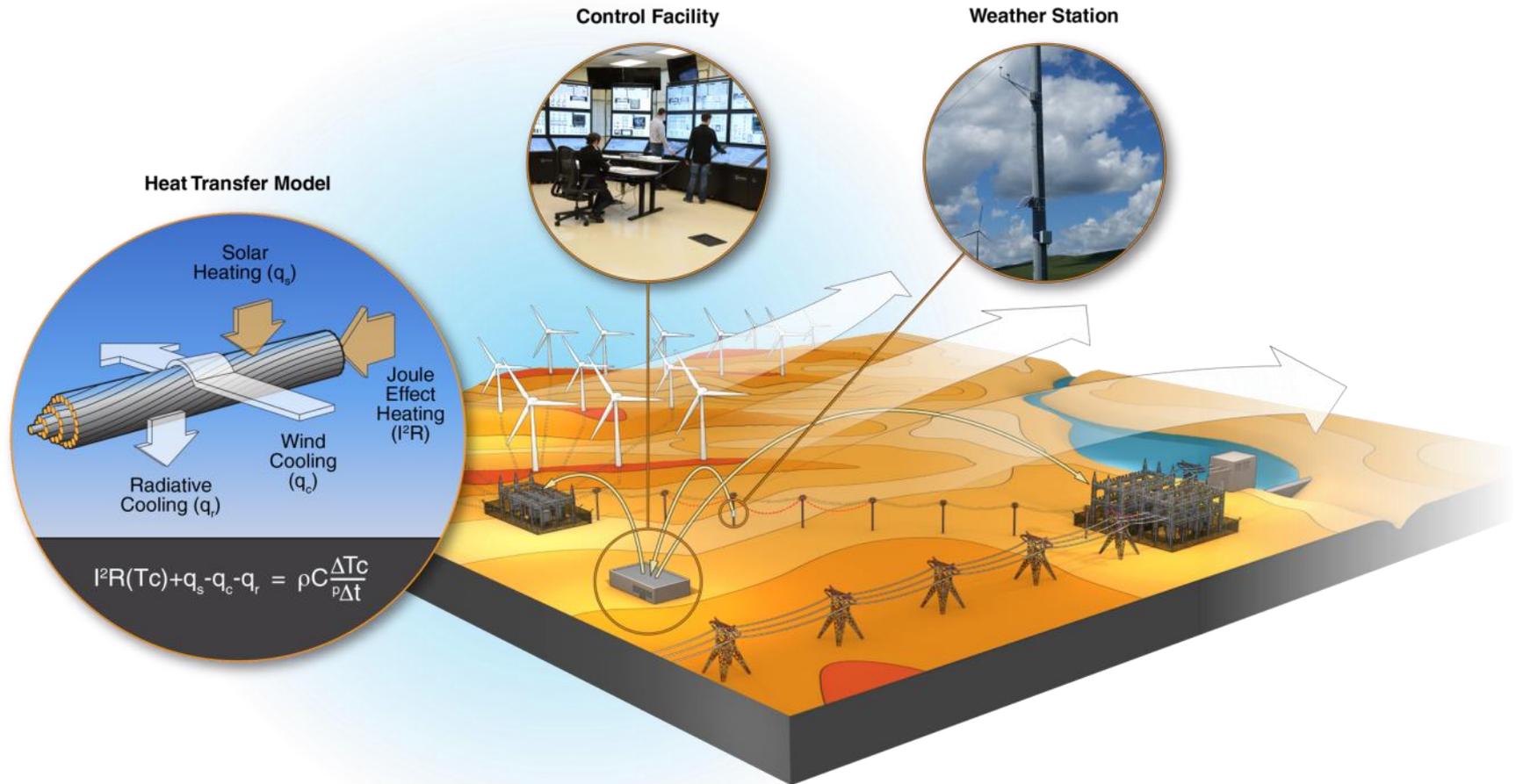
Presented and updated on WG Report in Montreal, Canada and Paris, France



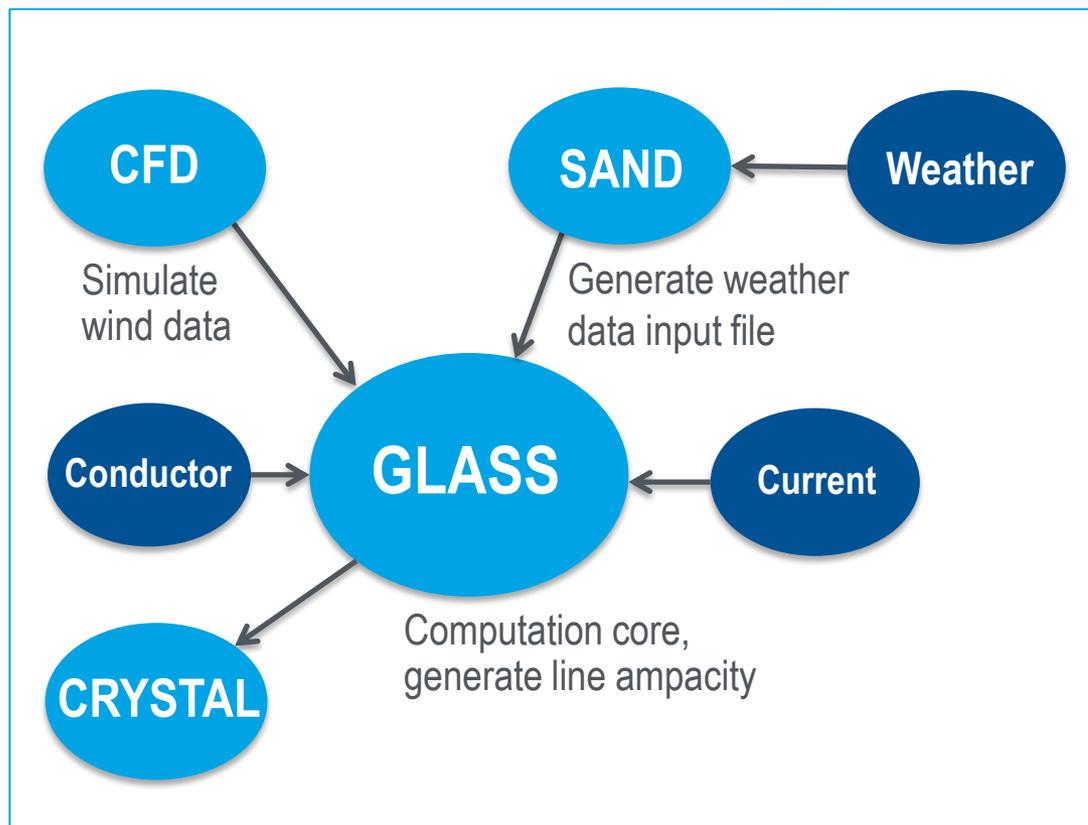
SC B2
Overhead Lines



A “Cool” Way to Increase the Utilization of Existing Transmission and Distribution Infrastructure and the Optimization of New Infrastructure Developments



Use computational fluid dynamics and real-time weather data to deploy an industry standard line rating methodology to open up marked increases in power carrying capacity of existing overhead lines and seamlessly implement it into the control room.



Implementing the technology into control center:
Human Factors Approach

Flowgate Time to Max Temp			
1 Line 1	39:39:31	13 Line 13	39:39:31
2 Line 2	46:20:02	14 Line 14	46:20:02
3 Line 3	34:33:31	15 Line 15	34:33:31
4 Line 4	49:39:31	16 Line 16	49:39:31
5 Line 5	48:39:53	17 Line 17	48:39:53
6 Line 6	01:21:01	18 Line 18	31:21:01
7 Line 7	39:39:31	19 Line 19	39:39:31
8 Line 8	46:20:02	20 Line 20	46:20:02
9 Line 9	44:33:31	21 Line 21	34:33:31
10 Line 10	49:39:31	22 Line 22	49:39:31
11 Line 11	48:39:53	23 Line 23	48:39:53
12 Line 12	31:21:01	24 Line 24	31:21:01

Key Software

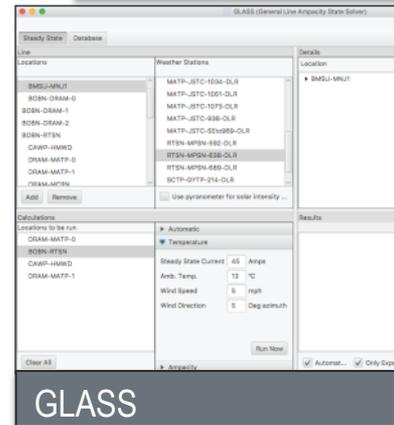
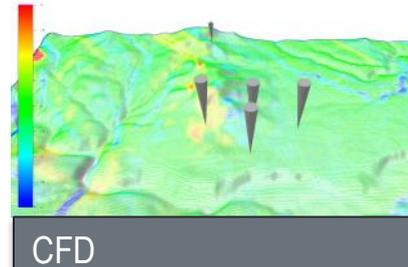
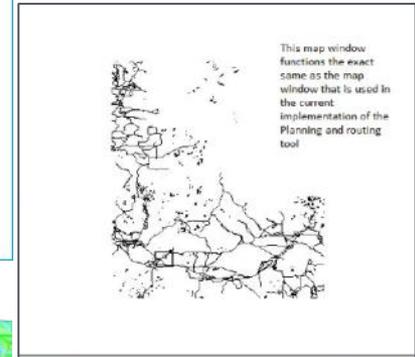
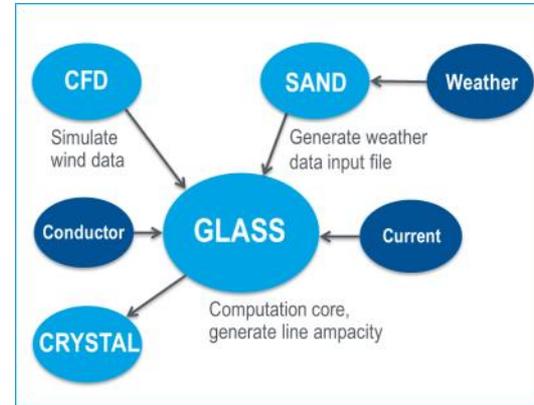
GLASS: General Line Ampacity State Solver. Computational engine to consume historical, real time, and forecasted weather and line current data to produce maximum current a line can carry

SAND: Organize historical weather data and drive GLASS computation

CRYSTAL: Organize Forecast (predicted) weather data and drive GLASS computation

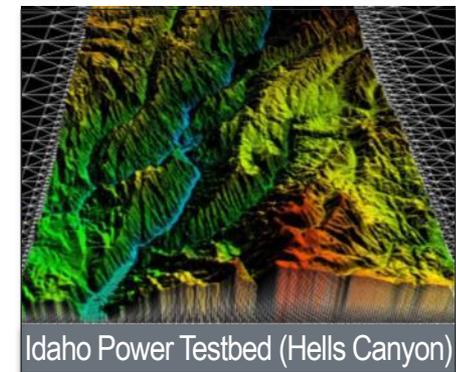
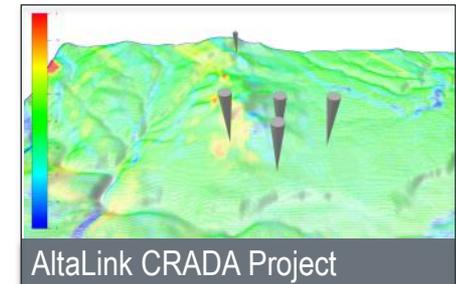
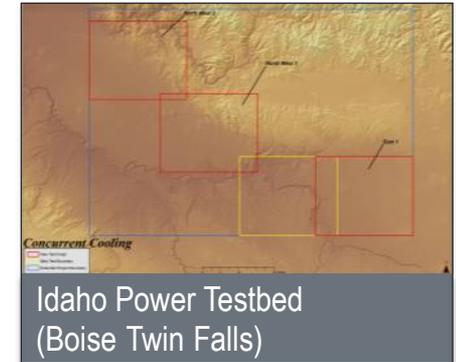
WindSim: Simulate wind data, map and create look up tables for highly complex terrain

Planning and Routing Tool: An easy to use application to utilize DLR data to find the least cost power line path through a variety of terrain



Test Areas

- 2014**
- Field campaign of CFD simulation model verification using mobile met tower trailer to validate CFD Look-up Tables
 - PowerLine module initiated to handle every span, and automatically compute line azimuth at each model point.
- 2015**
- Full Idaho Power (Boise-Twin Falls) Testbed simulated individually and prepped for use in the development of the WindSim “Wind Atlas” method.
 - 2,600 mi², 450 line miles, four model areas
 - Extended “Wind Atlas” methodology to Idaho Power Hells Canyon
 - 741 mi², 30 line miles, 30-meter resolution, extreme complex terrain
- 2016**
- CFD simulations of (Boise-Twin Falls) Testbed completed, and lookup tables for piecewise sections.
 - 2,600 mi², 450 line miles, four model areas
 - AltaLink area mapped out, wind simulations completed, and lookup tables created
 - 85 mi², four line miles, one model area
 - Refined Hells Canyon area mapped out, wind simulations completed and lookup tables created in 10 meter resolution.
 - 741 mi², 30 line miles, two model areas



Milestone	2014				2015				2016				2017-18
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Current/Future Emphasis
Beta GLASS eval at Idaho Power	100												
Power Line Module with WindSim		100											
Cost of Weather Station Eval			100										
Feasibility of DLR in P&R				100									
GLASS-GEN test suite developed					100								
Test Wind Lookup Tables													
Analyze IPCo Boise Bench Data							100						
True Dynamic Concept						100							
TDLR Development													
Weather Station Recovery/Resilience							75	100					
Eval previous P&R toolsets						100							
P&R Tool Development							65	100					
P&R Python Beta Webinar								100					
GMLC Proposals								100					
Idaho Power Funds in project													
Alta Link Funds in CRADA											100		
GMLC Funding Delay Milestones Delayed									0	0			
GLASS update with IEEE stds											100		
DLR publication dissemination													
Wind Atlas CFD wide area tested												100	
P&R Road Map											100		
P&R Java Prototype												100	
P&R Demonstration Webinare												100	
P&R Industry alignment Stantec													
Human Factors for DLR Launch											100		
Human Factors Control Room												100	
Forecasting Implementation													

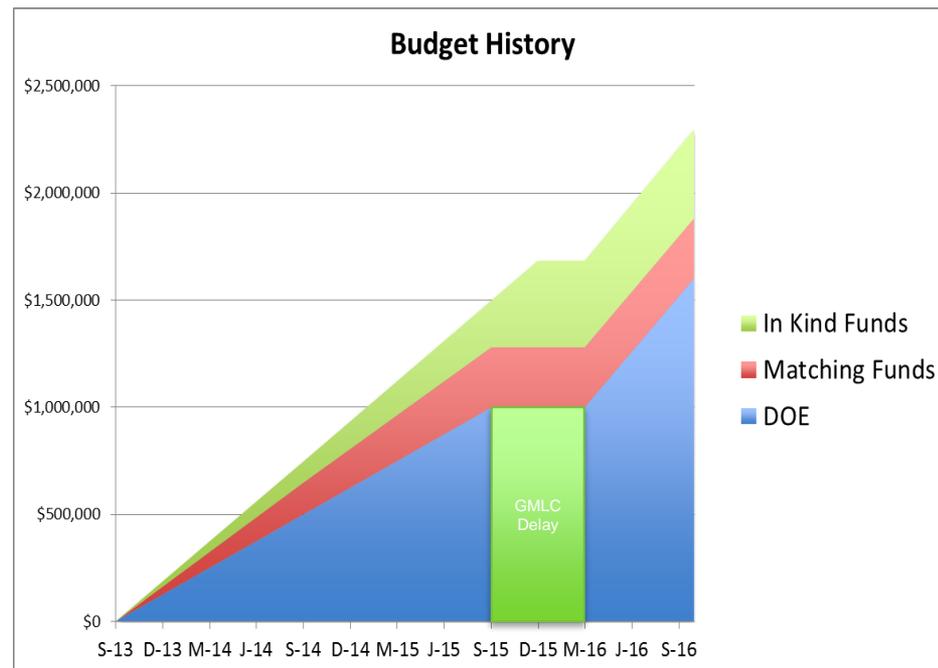
Ground work prior to funding/formal initiation
 Active task
 100 75 65 Milestones (complete, minor slip, significant slip)

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$500k	\$246k*	\$500k	\$251k**	\$600k	\$200k

Industry In-Kind, WFO (FY14), and CRADA (FY15)

- AltaLink: (labor, equipment, software integration and testing)
 - FY14 - \$0k;
 - FY15 - \$158k (\$130k Funds In**);
 - FY16 - \$8k
- Idaho Power: (labor, equipment, software integration and testing)
 - FY14 - \$201k (\$151k Funds In*);
 - FY15 - \$53k;
 - FY16 - \$150k
- WindSim: (labor, software, simulation support).
 - FY14 - \$45k;
 - FY15 - \$40k;
 - FY16 - \$27k
- Oklahoma Gas and Electric: (control center observations and Flowgate R&D support)
 - FY14 - \$0k;
 - FY15 - \$0k;
 - FY16 - \$15k



Partners, Subcontractors, and Collaborators:

Partners and Collaborators

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

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- Test area (~500 line miles)
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WECC – Salt Lake City, UT

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5 | Wind Energy Technologies Office

eere.energy.gov



IEEE Transmission & Distribution Committee
IEEE Power & Energy Society



SC B2
Overhead Lines



Partners and Collaborators

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



GENSCAPE

LINSEY



windsim



VAISALA

University of Idaho



StormGeo

OG+E

WECC



MontanaTech



6 | Wind Energy Technologies Office

eere.energy.gov

Communications and Technology Transfer:

Impact and Dissemination

2014 [22]

- **Three peer-reviewed journals and periodicals:**
 - IEEE Transactions on Power Delivery
 - Proceedings of American Society of Mechanical Engineers 2014
 - 2014 IEEE Power and Energy Society General Meeting
 - *Best Conference Papers on Markets, Economics, and Planning*
- **Six peer-reviewed conference papers and posters**
- **Four transmission and distribution publications**
- **Nine invited presentations**

2015 [21]

- **Three peer-reviewed journals and periodicals**
- **Four peer-reviewed conference papers and posters**
- **Three transmission and distribution publications**
- **15 Invited Presentations**
- **One Copyright Submission (GLASS Rev1)**



FY17 - FY19 Research:

- FY16 DOE (EERE-OE) Grid Modernization Lab Consortium (GMLC)
 - Part of \$220MM Grid Modernization Initiative (GMI)
 - Merit Review Process
 - Awarded 3 year project, started late in Q3 of FY16, ends Q2 of FY19
- Development of the "True" Dynamic Line Rating module within GLASS
- Development of the industry (Stantec) informed cost/risk attributes for the Planning and Routing Toolkit
- Develop Human Factors requirements/metrics for DLR decision making tools to be used in the control center
- Design and engineering of a module in GLASS to enable the inclusion of direct measurement sensor data (temp, sag, tension, etc.)
- Develop and demonstrate a Human Factors informed prototype of control center visualizations in INL's Human Systems Simulation Laboratory
- Support Standards Association (IEEE and CIGRE) efforts in partnership with industry
- Interface with NERC and FERC to share science based results to support industry and regulatory acceptance.

Go/No-Go Decisions

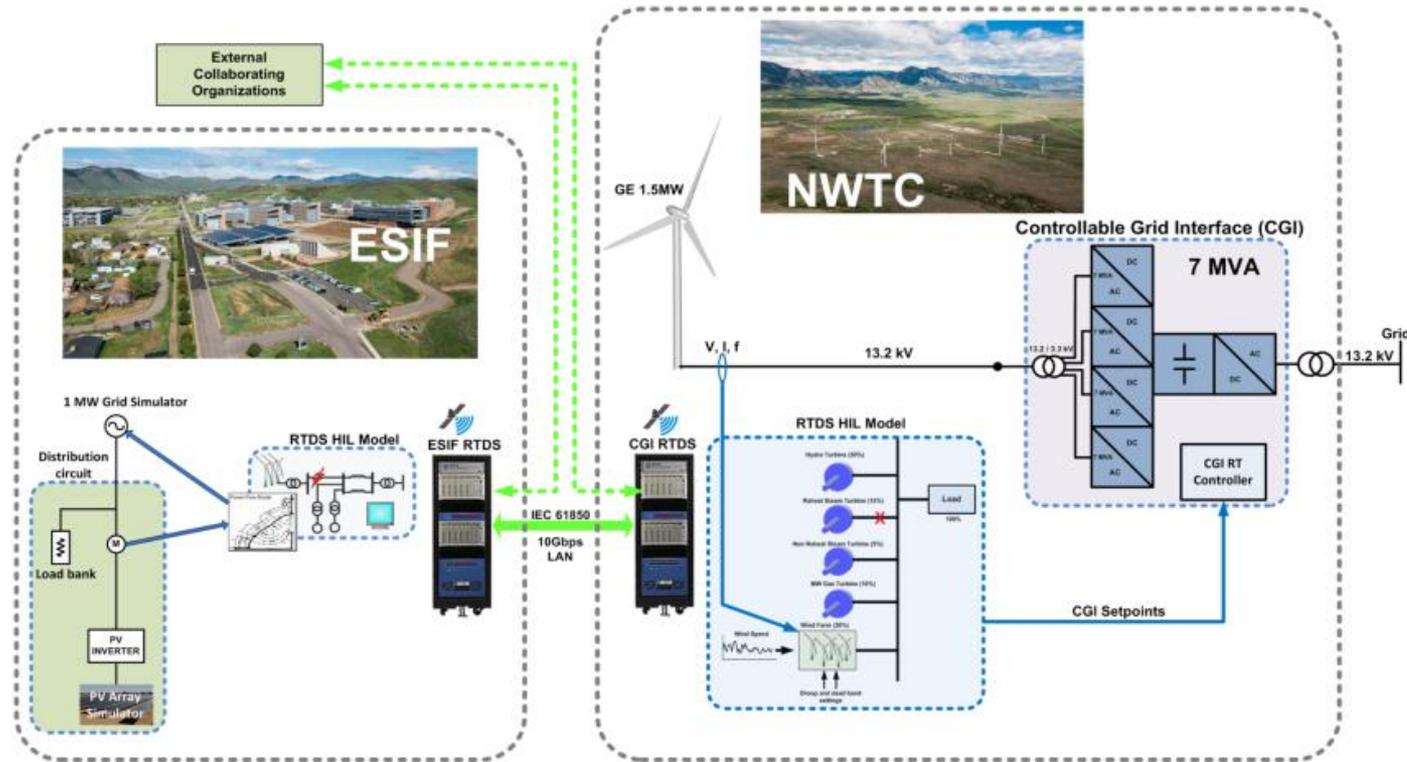
Name	Description	Criteria	Date
FY17 Q4 Operations Integration	FY17 Q4 Operations Integration	Automatic delivery of DLR data into Utility Operations through PI Historian, SCADA, or EMS.	9/30/2017



Idaho National Laboratory

WIND INTEGRATION R&D
Concurrent Cooling, Dynamic Line Rating

Jake P. Gentle — jake.gentle@inl.gov



Hardware-in-the-Loop Connection of the Energy Systems Integration Facility (ESIF) to the National Wind Technology Center (NWTC)

**Grid System Planning for Wind: ESIF
(Connecting the National Wind Test
Center at NREL to the Energy
Systems Integration Facility)**

David Corbus

National Renewable Energy Laboratory

David.Corbus@nrel.gov 303.384.6966

February 2017

Projects:

- Connecting the National Wind Technology Center (NWTC) at the National Renewable Energy Laboratory (NREL) to the Energy Systems Integration Facility (ESIF)
- The Challenge: Demonstrate integrated communications and testing capabilities for two existing NREL capabilities—ESIF and the NWTC/controllable grid interface (CGI)—into a combined multimegawatt-scale test bed for grid integration controls and operations validation at both transmission and distribution levels
- Partners: GE; Idaho National Laboratory; Clemson University

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

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- Facilitating coexistence between wind energy and wildlife
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- Wind energy workforce and education development
- **Advancing grid integration**

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- **World-class test and user facilities**
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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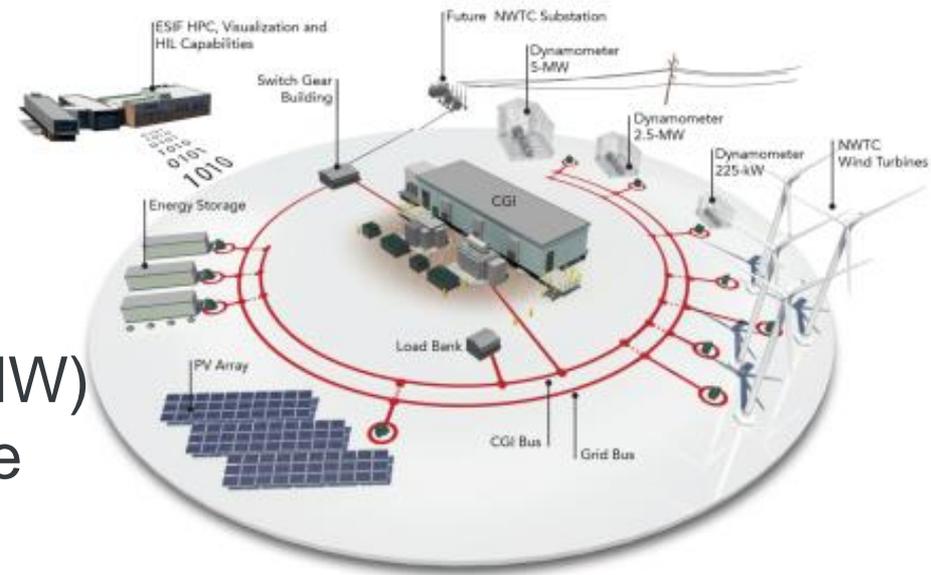
Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- World-class test and user facilities

The Impact

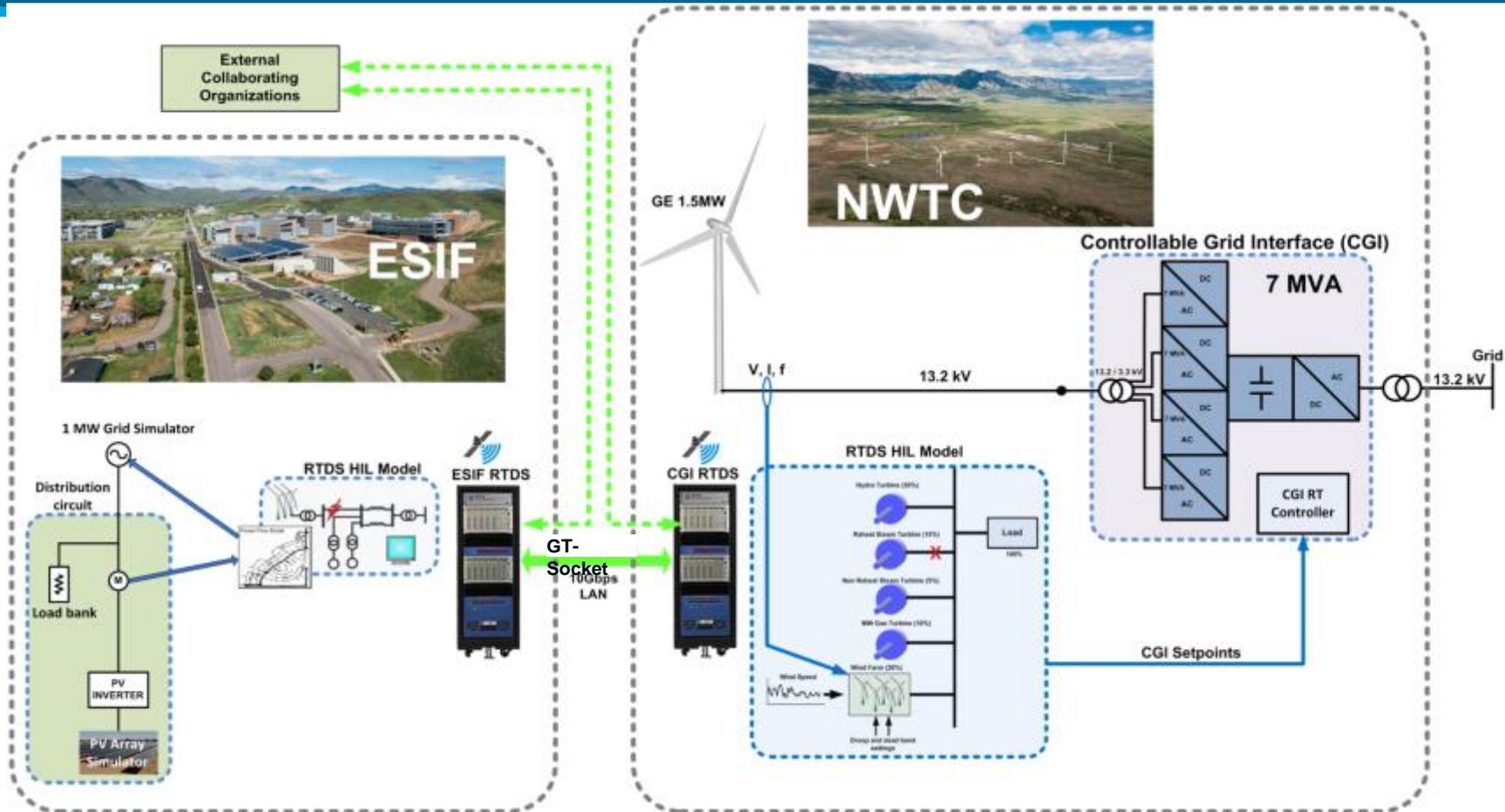
- Test bed supports validation of models for advanced control of renewable energy systems connecting both distribution- and transmission-level elements
- Plant-level controls demonstrated the ability to provide wind systems with conventional generator control attributes including frequency droop, active power control, dynamic volt/VAR control, voltage droop, and ramp rate control
- Combined multi-megawatt-scale test bed for grid integration testing and demonstration of renewable technologies
- Capability to conduct complex integrated power hardware-in-the-loop (PHIL) experiments involving transmission- and distribution-level renewables.

- Integrate the two existing NREL testing capabilities—the ESIF and NWTC/CGI—into a combined multi-megawatt-scale test bed for grid integration testing and demonstration of renewable technologies, energy storage, and demand response at both transmission and distribution levels
- Establishing real-time communication between the ESIF and NWTC/CGI for combined experiments
- Upgrade GE 1.5-megawatt (MW) wind turbine controls to enable “wind farm of one” capability.



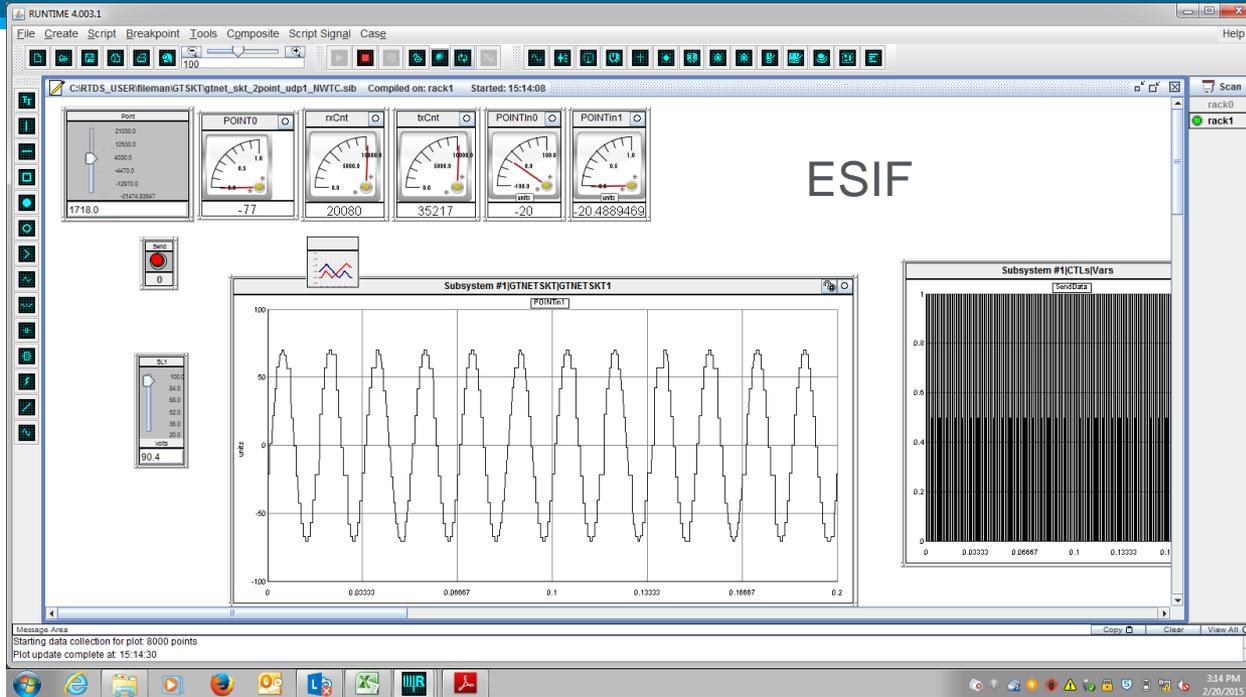
NWTC grid integration facility with connection to the ESIF

Technical Approach–NWTC/ESIF Real-Time Interconnection



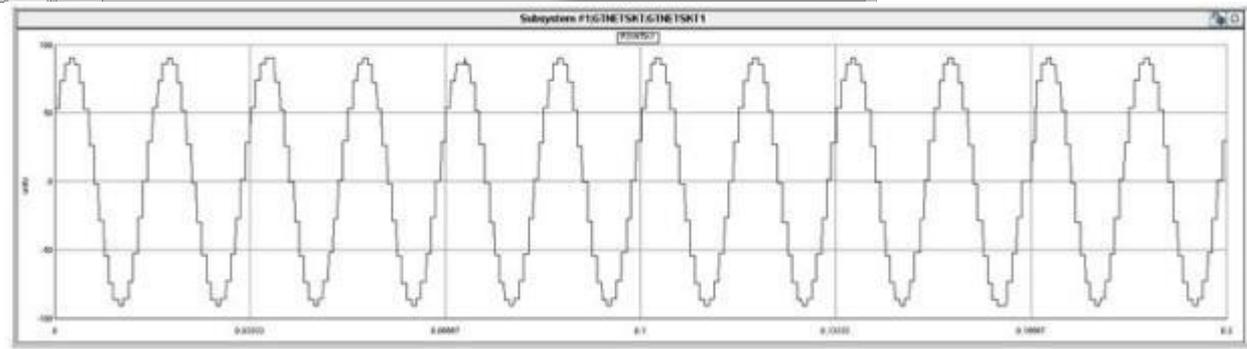
- CGI real time digital simulator (RTDS) purchased in October 2014
- Real-time link between RTDS-to-RTDS models established and tested in FY15 including connection of NWTC to ESIF and NWTC to Idaho National Laboratory's RTDS

Technical Approach—ESIF-NWTC Sine Waveform Exchange Test (02/20/2015)



ESIF

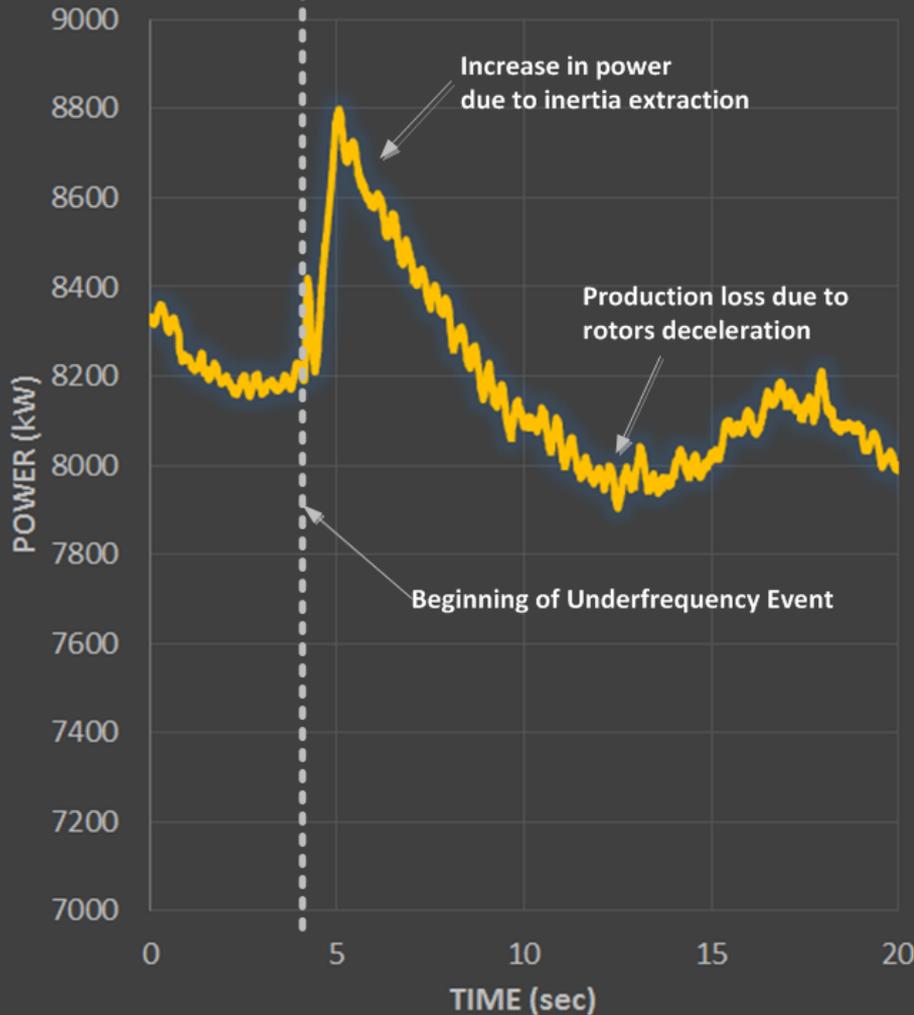
NWTC



- Real-time data exchange at 1,200 hertz demonstrated

Technical Approach—Aggregate Inertial Response Seven 1.5-MW Wind Turbines

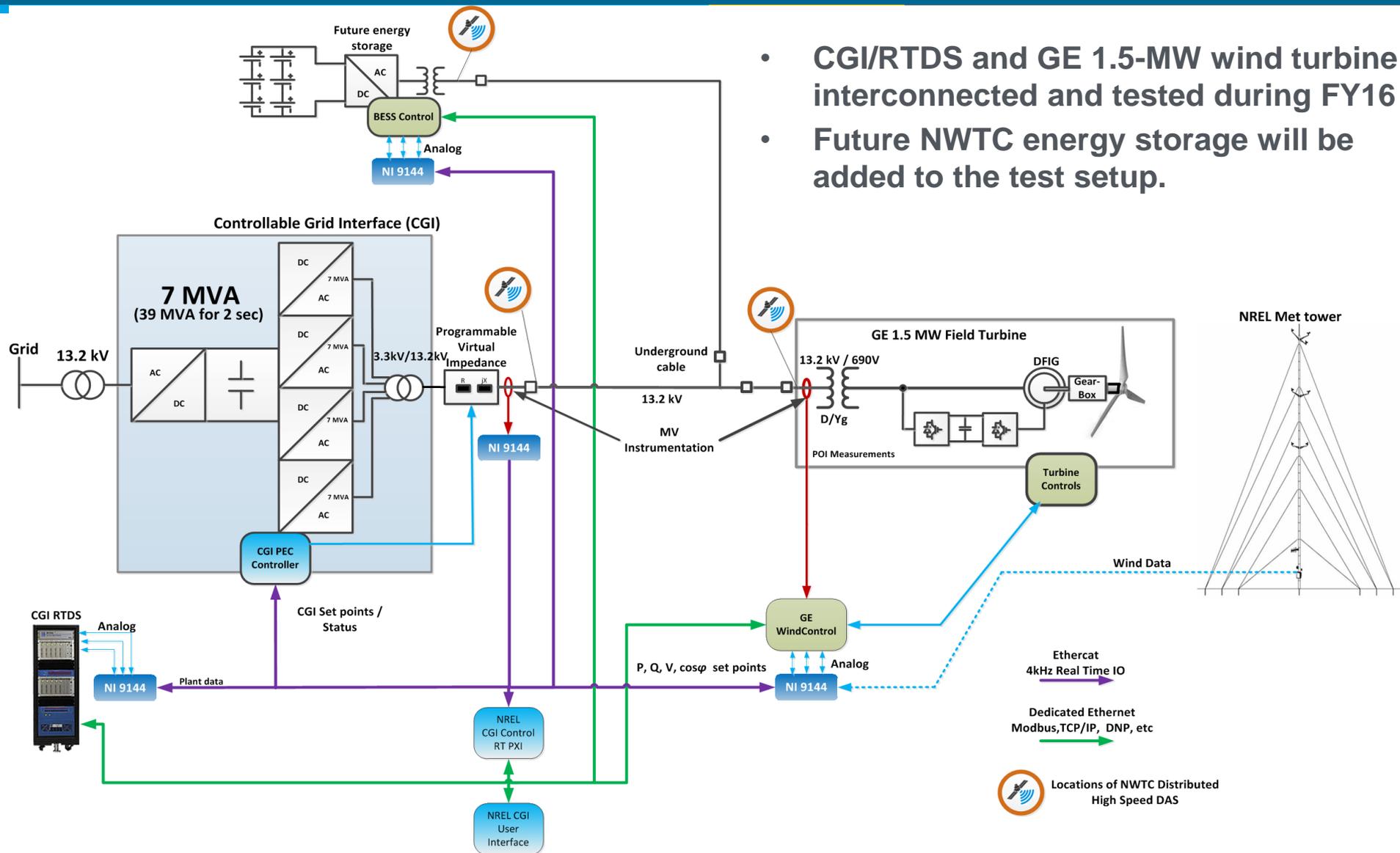
Aggregate inertial response of 7 turbines



- Aggregate inertial response of seven turbines (virtual power plant simulated with just a single wind turbine)
- Single turbine exposed to exact same frequency event at seven different initial conditions
- Replicates wind speed diversity in larger wind power plant
- Example of possible future test scenario: repeat this same test 1,000 times and get aggregate inertial response of 1.5 gigawatts (GW) of wind capacity.

Technical Approach–NWTC PHIL Setup for Wind Power Testing

- CGI/RTDS and GE 1.5-MW wind turbine interconnected and tested during FY16
- Future NWTC energy storage will be added to the test setup.



- RTDS-to-RTDS link between NWTC and ESIF established and tested
 - Capability to conduct complex integrated PHIL experiments involving transmission- and distribution-level renewables
- GE WindControl installed and commissioned
 - Enabled “wind farm of one” capability
- Number of tests involving CGI, GE 1.5-MW wind turbine, and RTDS conducted with ESIF, Idaho National Laboratory, and Clemson University
 - Inertia test
 - Active power control test

	Milestone Description	Percent Complete	Due Date	Date Complete
FY 15	Grid System Planning for Wind: ESIF, Q2 (SMART). Set up RTDS systems at both NWTC and ESIF to perform real-time bidirectional communication and data exchange with each other by March 31, 2015.	100%	3/31/15	3/31/15
FY 16	Task 2.8.0.404.1 Grid System Planning for Wind: ESIF, Q2. Complete upgrades and commission the "grid-friendly controls package" for GE 1.5-MW wind turbine at NWTC by March 31, 2016. Work includes receipt under CRADA from GE of suite of wind turbine grid-friendly controls including (1) WindCONTROL (voltage and active power control system), (2) WindINERTIA (wind turbine inertial control package), (3) WindFREE Reactive Power (reactive power control capability with no wind), (4) WindRIDE-THRU (control that provides uninterrupted turbine operation through grid disturbances).	100%	3/31/16	2/18/16
FY 16	In alignment with the Grid Modernization Lab Call, submitting an AOP mod extending the current FY15 Q3 milestone "Task 2.8.0.404.1 Grid System Planning for Wind: ESIF, Q3. Receive and install GE hardware for GE 1.5 turbine upgrade by December 30, 2015, into Q1 of FY16, and make any associated cost plan adjustments.	100%	3/31/16	2/19/16

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$500k		\$40k	\$150k		

- \$40k reallocated funds in FY15
- GE provided \$100K cost share in the form of provision of the turbine-level controls for the DOE 1.5-MW wind turbine.

Partners, Subcontractors, and Collaborators: Subcontractors: GE, Idaho National Laboratory, Clemson University
Partners: Technical Review Committee Meetings with over 30 participants in every meeting for both projects

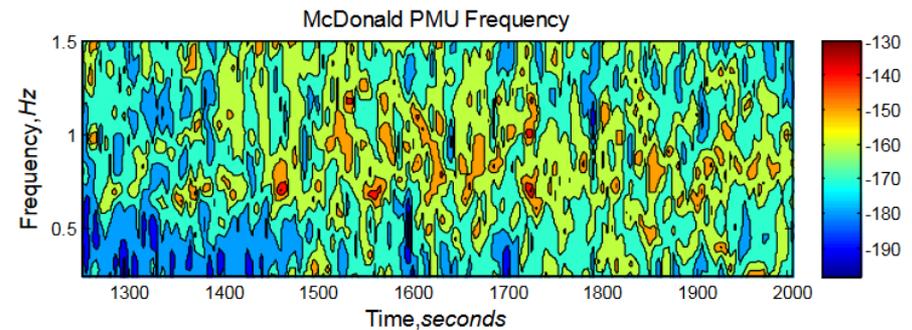
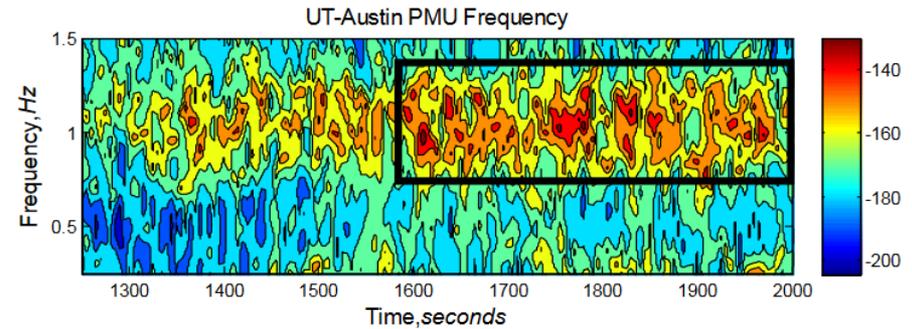
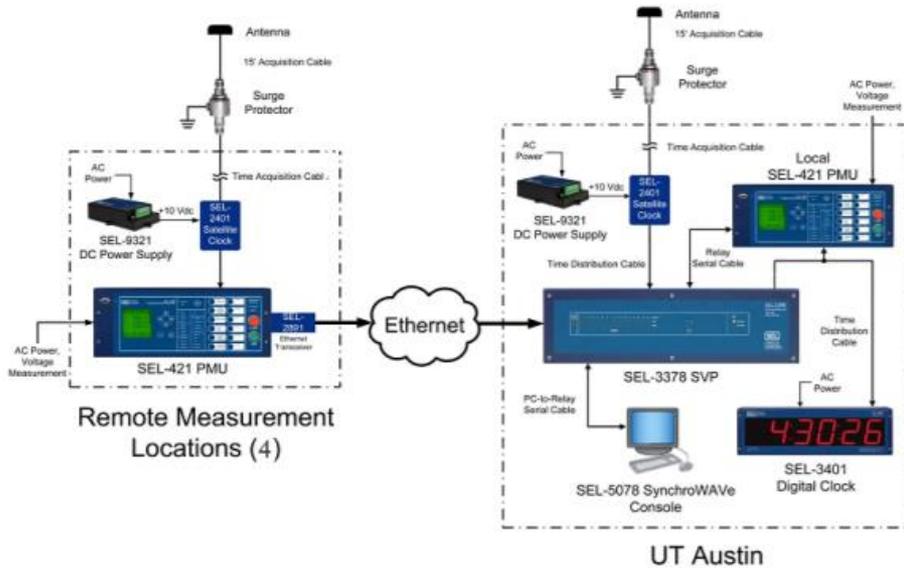
Communications and Technology Transfer:

Papers for this project are listed below. In addition several presentations at conferences were also delivered.

- Wu, Z., X. Wang, W. Gao, M. Kang, M. Hwang, Y. Kang, V. Gevorgian, and E. Muljadi. 2016. "[Frequency Support of PMSG-WTG Based on Improved Inertial Control: Preprint](#)." Paper presented at the 2016 IEEE Power and Energy Society General Meeting, Boston, Massachusetts, July 17–21. NREL/CP-5D00-65916.
- Muljadi, Eduard, Vahan Gevorgian, and Andy Hoke. "Short-Term Forecasting of Inertial Response from a Wind Power Plant." Paper to be presented at the Energy Conversion Congress and Exposition (ECCE), Milwaukee, Wisconsin, September 18–22. NREL/CP-5D00-66395.
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- Vahan Gevorgian, Robb Wallen, and Scott Lambert, Ryan Schkoda, Curtiss Fox, Ramtin Hadidi, "Hardware-in-the-Loop Testing of Utility-Scale Wind Turbine Generators", NREL technical Report, January 2016
- P. Koralewicz, V. Gevorgian, W. van der Merve, "Advanced Grid Simulator for Multi-Megawatt Power Converter Testing and Certification", ECCE 2016 conference paper

FY17/Current Research: Projects are complete, new projects will build off capabilities developed under this project

Planned Future Research: Grid Modernization Lab Consortium (GMLC) project on active power controls for wind; project demonstrating and validating NWTTC grid as dispatchable power plant; short-term energy storage for wind; technical partnerships (non-DOE-funded work) projects with Siemens/Gamesa and First Solar; and currently pursuing work with several other wind, solar, and energy storage companies



Grid System Operations for Wind: Analysis using PMU data and dynamic analysis

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February 2017

Analysis using PMU data and dynamic analysis: The massive deployment of synchrophasor phasor measurement units (PMUs) enables us to confidently plan and operate modern power system under high penetration wind power scenario.

The Challenge: There is a need to filter raw data, identify, and discriminate various event from the PMU signals for wind plant and power system controls. In addition there is a need to really understand this new areas in terms of data mining, time delay and latency in data acquisition.

Partners: Oklahoma Gas and Electric Company (OG&E), Western Area Power Administration (WAPA), Bonneville Power Administration (BPA), Western Electricity Coordinating Council (WECC), Sandia, Univ. of Denver, Univ. of Colorado, Univ. of Texas, Technical Univ. of Catalonia, Spain

Advancing Grid Integration

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

Enabling Wind Nationwide

Enhancing U.S. Energy Security and Independence

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

The Impact – Advancing Grid Integration

- This project benefited utility and wind industries by development of various methods to utilize PMU data to detect and characterize disturbance events, to analyze power system condition (system oscillations, damping, frequency), to estimate of on-line power system inertia, to estimate the short circuit impedance, to track the stability margin, to implement active power damping, and to validate dynamic models of wind turbines and wind plant.
- The computer programs and user guide are available for public domain from NREL's publications portal.
- The findings (methods, algorithms, concepts) were published as conference papers, technical journals, and NREL reports.

- Develop tools to screen, analyze, and visualize the PMU data to identify and discriminate disturbances or abnormal events to evaluate the possible responses from wind plant
- Develop methods to utilize PMU data to improve and optimize power system analysis for planning and operation on high wind penetration systems
- Coordinate with partners to get access to the data, and collaborate to find applications in wind generation
- Disseminate the results of the efforts via technical publications and seminars.

Table 5. Inertial Estimation Results

Bus	H Input	H Calc	% Error
1	2.13	1.9314	9.3
2	2.41	2.5095	4.1
3	2.417	2.5195	4.2
4	2.38	2.4027	0.95

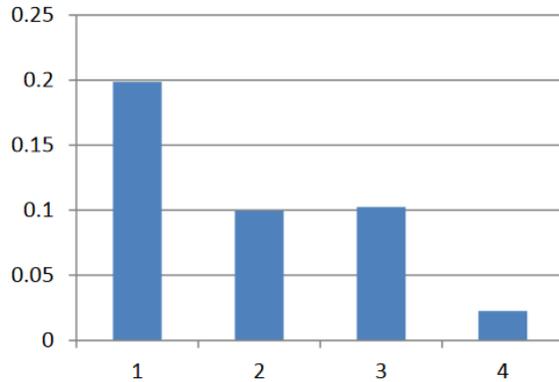
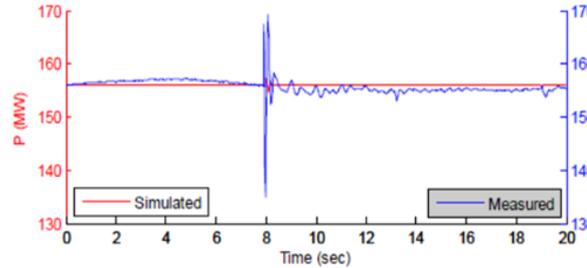
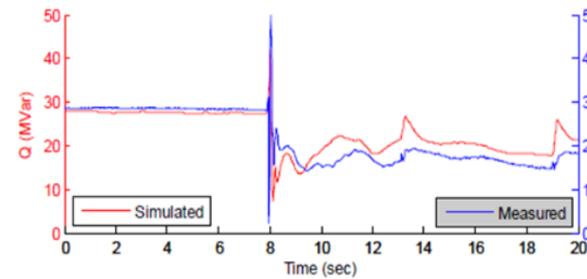


Figure 50. Frequency responses from PMUs at four buses

**Examples of Inertia Estimation
(data supplied by OG&E)**



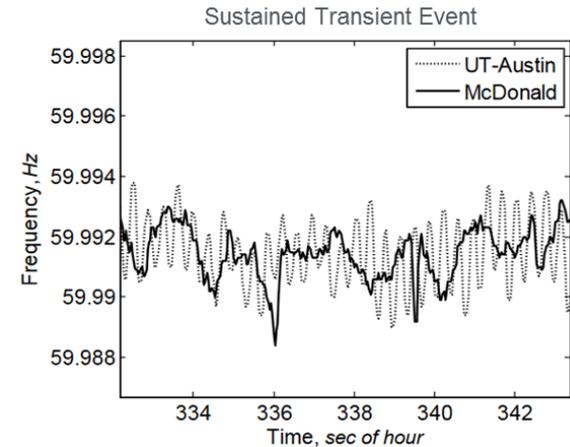
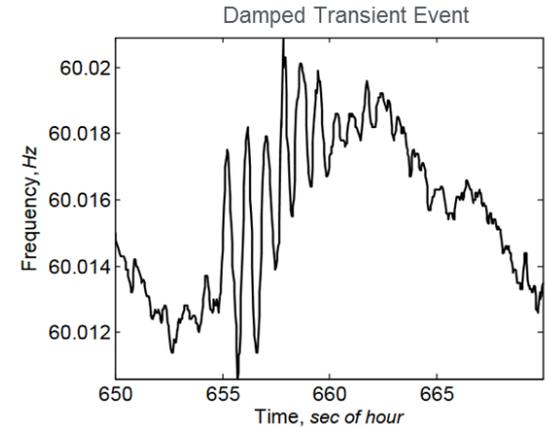
(a) Real power



(b) Reactive power

Fig. 4. Real and reactive power comparison of the WPP validated for Case 1

**Examples of Dynamic
Model Validation
(data supplied by BPA)**



**Examples of Frequency
Oscillation (Detection
and Characterization)**

- Completed three NREL reports: 1) Algorithms for Screening PMU data, 2) Synchrophasor Applications for Wind Power Generation, 3) A User Guide for PMU Data Event Detections
- Published the following technical reports/papers/journals:
 - Two papers on Wind Turbine and Wind Power Plant Dynamic Model Validations
 - Five papers on Wind Plant and Power Stability Related Issues
 - Four papers on Power System Damping Capabilities of Wind Power Plants
- Graduate four PhDs + one Postdoc from different universities

- Project original initiation date – October 1, 2013
- Project planned completion date – September 30, 2014
- Project actual completion date – December 30, 2014
- All milestones were met

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$ 196K	0	\$69K	0	N/A	N/A

- The project was started in FY2014 with carry-over to FY2015
- The funding expired in Q1-FY2015

Partners, Subcontractors, and Collaborators:

- Oklahoma Gas and Electric Company, WAPA, BPA, WECC
- National Laboratory: Sandia
- Universities:
 - University of Denver
 - University of Colorado
 - University of Texas
 - Technical University of Catalonia, Spain

Communications and Technology Transfer:

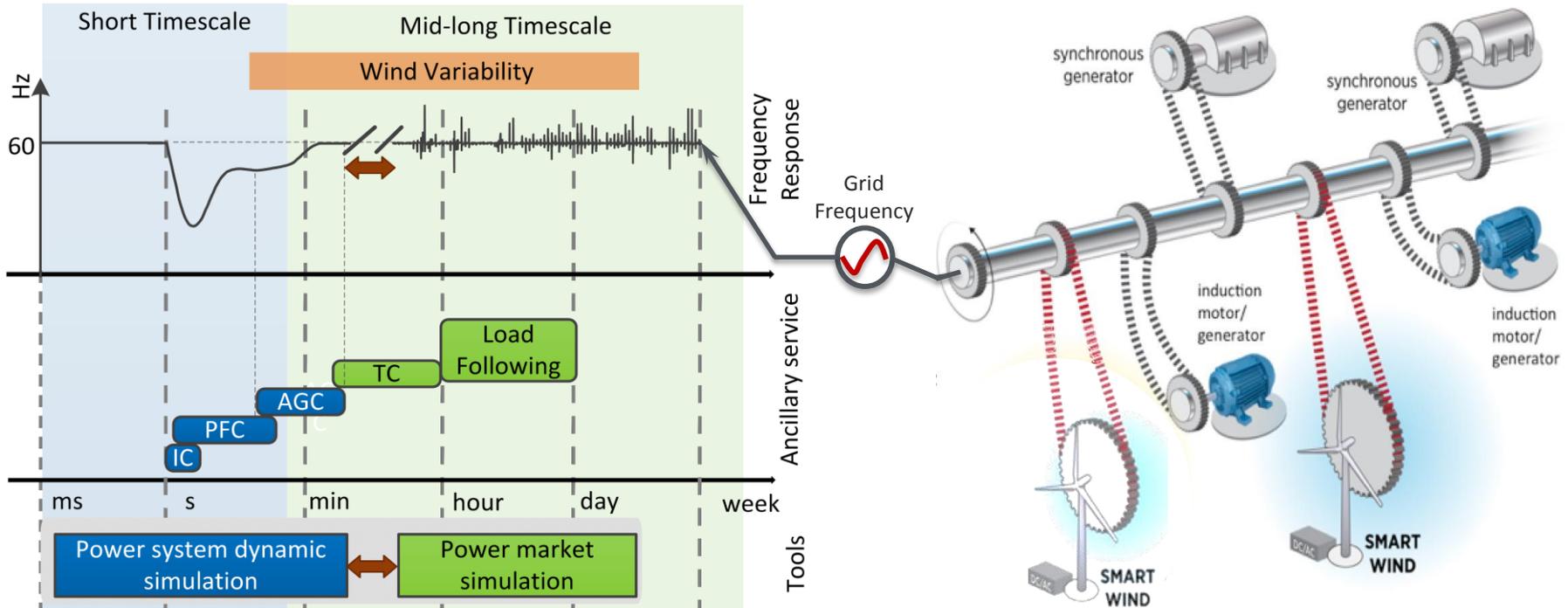
- Three NREL reports on computer modules, user guide, and applications of PMUs
- Six conference papers
- Five journal papers
- Downloadable website: www.nrel.gov/publications/

FY17/Current Research:

- The project ended in FY2014 with carry over to Q1-FY2015

If funding were available, NREL can extend the work in:

- Development of synchrophasor-based control for wind turbine and wind plant controls in partnership with the wind industry
- Full and subscale testing of wind turbine and wind plant control concepts based on synchrophasor technologies
- Utilization of NREL National Wind Technology Center—controllable grid interface and turbines at NREL to perform various control development and testing with hardware in the loop implemented in real time digital simulators



IC: Inertial Control; PFC: Primary frequency control ; TC: tertiary control.

Active Power Control (APC) from Wind Power

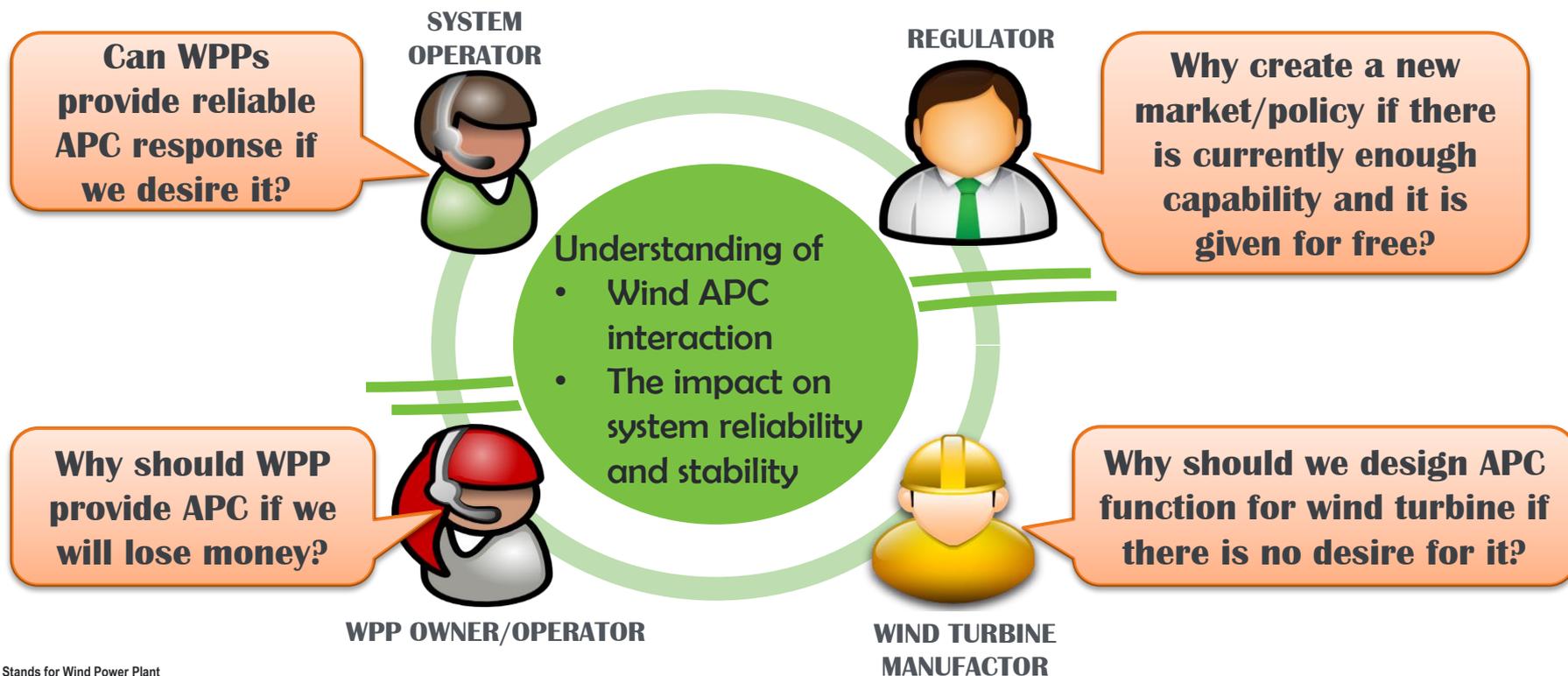
YC Zhang

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February 2017

Challenge:

- The frequency response of the North American power grid is declining
- Gaps exist in designing and evaluating wind active power control's (APC's) impact on system reliability and stability
- Ancillary service markets to incentivize the frequency response services are not mature



Enabling Wind Nationwide

Enhancing U.S. Energy Security and Independence

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

The Impact

APC research shows:

- Wind can support the power system rather than impair it
- Wind generators can provide active power controls economically
- Wind-providing frequency response has negligible structural impact on the wind turbine
- New capability of simulating the interaction between primary and secondary reserve can provide means to evaluate wind APC revenue sufficiency and reliability impact

REGULATOR



- NERC BAL-003-1 2014 Frequency response and frequency bias settings
- FERC Order 819 2015 Permit the sale of primary frequency response

SYSTEM OPERATOR

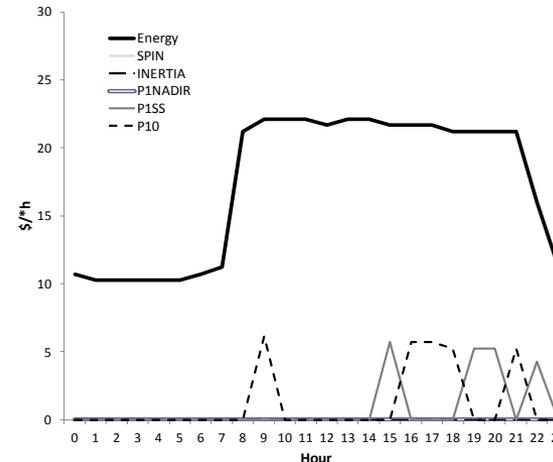
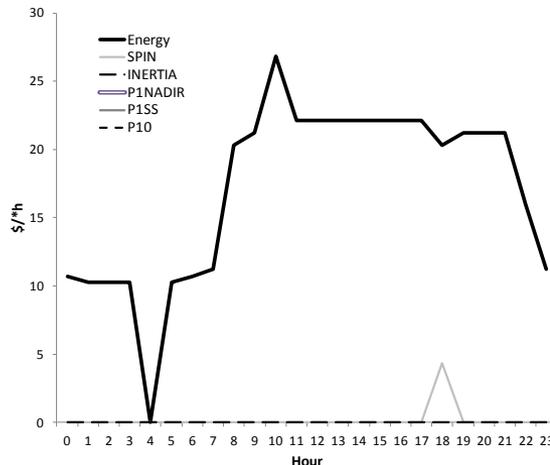


- Electric Reliability Council of Texas (ERCOT)-2013 Fast frequency response market-ancillary services in ERCOT
- PJM-2012 Frequency regulation market-offered higher payments for fast-responding assets in FERC
- CAISO-2016 Frequency response market initiative

APC project's capability leveraged by other projects

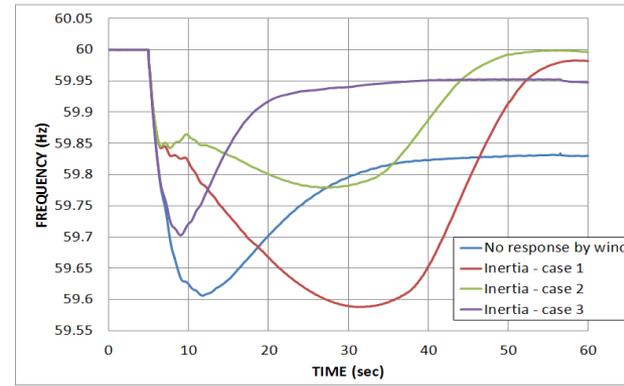
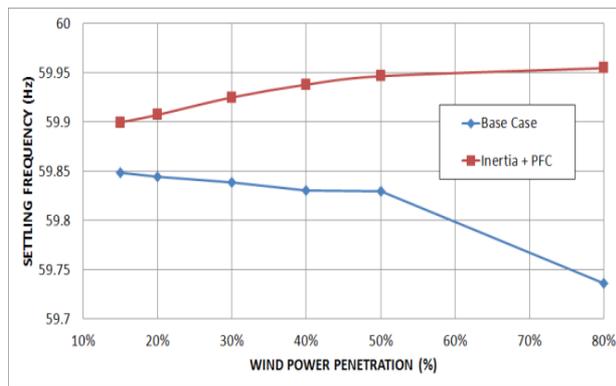
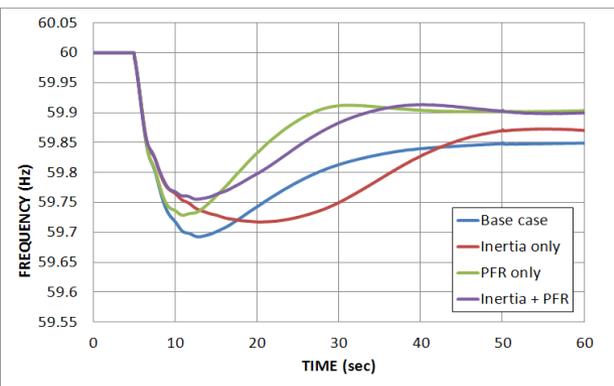
- DONG Energy-NREL Cooperative Research and Development Agreement: Utilization of real-scale renewable energy test facility for validation of generic wind turbine and wind power plant controller models
- Grid Modernization Laboratory Consortium: Understanding the role of short-term energy storage and large motor loads for active power controls by wind power

- Approaches toward incentivizing primary frequency control (PFC)
 - Primary frequency response market will spur the growth of resources that are willing to provide it
 - Regulation market shown to have benefits if wind were allowed to provide it
 - Lower production cost
 - Additional revenues for WPP
 - Increased wear-and-tear incentives on thermal plants for providing these responses
- Key Message
 - When providing APC, the properly designed market can positively impact WPP revenue streams without adversely impact the cost borne by consumers.



Prices for system without PFC requirement (left) and system with PFC requirements (right)

- The impact of wind providing synthetic inertia and primary frequency response on system stability
 - Wind synthetic inertia control improves rate of change of system frequency and does not require headroom
 - Wind primary frequency response increases the system frequency nadir and settling frequency
 - Combine synthetic inertia and primary response for superior performance
 - Better utilizing wind turbines operating under good wind condition will overcome the synthetic inertia “payback” issue
- **Key Message:** Wind APC can improve system frequency response and stabilize the grid.

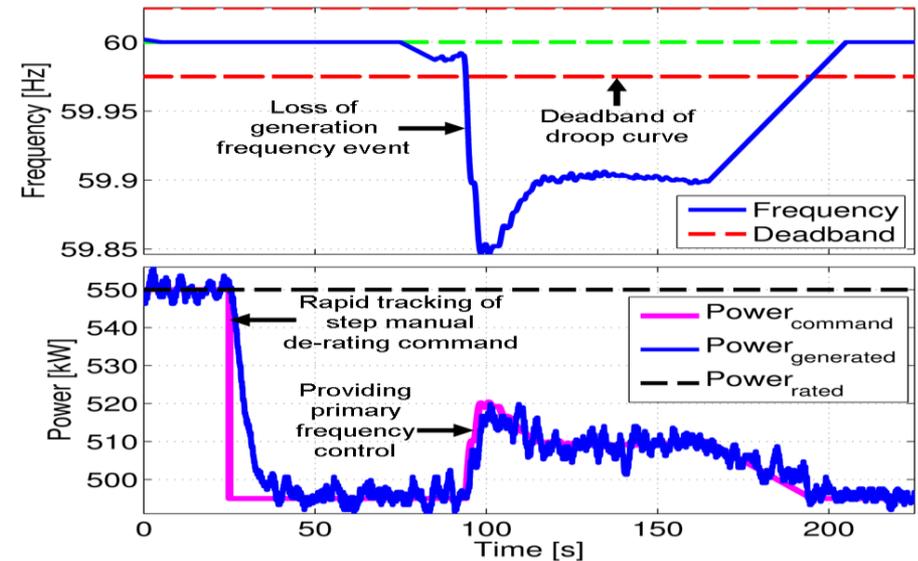


WECC frequency response with/without wind APC

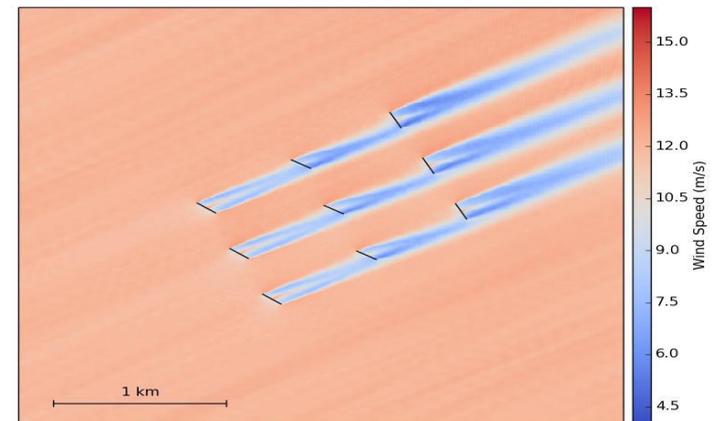
WECC frequency nadir with/without wind APC

WECC frequency response with wind providing synthetic inertia

- First-of-its-kind analysis that explored the relationships between wind at an unprecedented fidelity and resolution
 - Response time of frequency control from the wind power plant can be very fast
 - No additional structural load is added to the wind turbine
 - Careful design of WPP control can provide the frequency response even in wake wind flow conditions
- Key Message
 - Wind generators can track APC command very quickly even under waked conditions without imposing additional loading on structure



Wind APC follows command signal closely



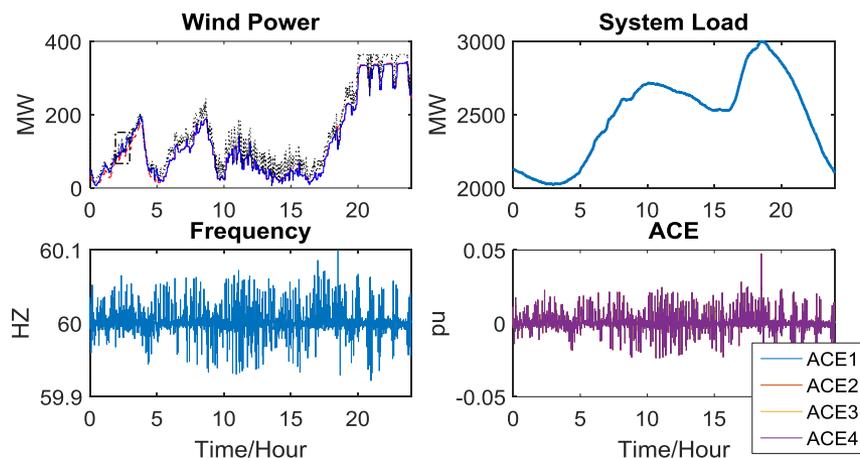
Wind plant provides APC under wake effect

- **Develop Multi-Area Frequency Response Integration Tool (MAFRIT)**

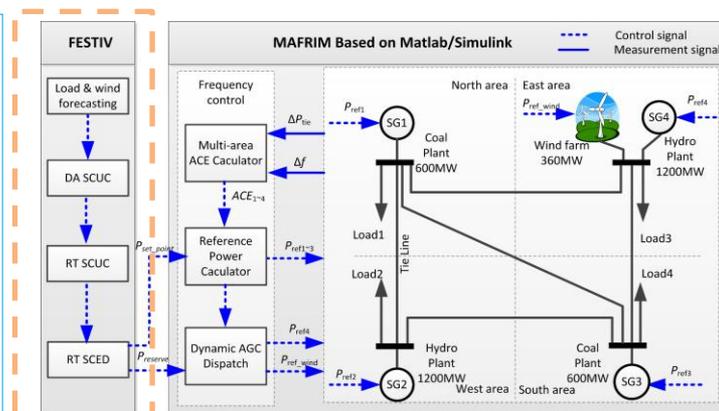
- Represent frequency dynamics **from seconds to days**
- Response to 4-s multi-area AGC signal
- Consider the variability of wind and load.

- **Key Message**

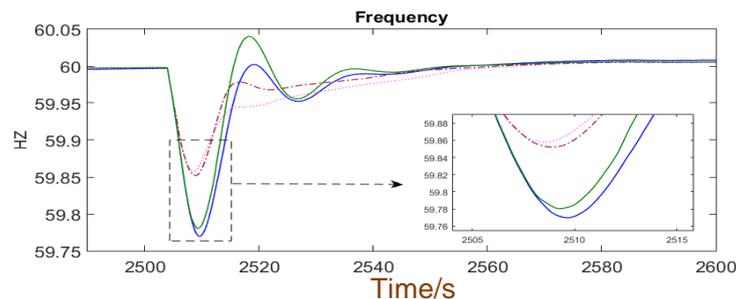
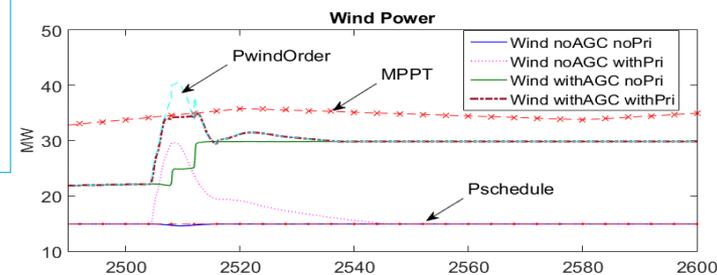
- The newly developed tool can reveal the interaction between the primary and secondary reserves, thus providing understanding of system response and market performance that cannot be achieved through conventional wisdom.



24-hour simulation of MAFRIT



MAFRIT concept



Interaction between the PFC and SFC

- APC Project Complete
 - Careful design of the ancillary services markets will result in increased revenue when wind plants provide these services
 - Careful design of control systems will result in responses that are in many ways superior to those of conventional thermal generation with negligible impacts to the turbine loading
 - Careful consideration of these responses will improve power system reliability
 - Full-time spectrum impact of renewable resources on power system reliability can be understood using the extended frequency response study tool to inform better market and reliability operation.

Project Plan and Schedule

	Milestone Description	Percent Complete	Date Due	Date Complete
FY 14	Q1 Project Milestone Description: Complete paper and presentation of dynamic modeling of wind plants providing APC to the 12th International Wind Integration Workshop or IEEE Power and Energy Society General Meeting.	100%	12/31/2013	10/10/2013
FY 14	Q2 Project Milestone Description: Submit final paper on control design of wind plants, combining grid impacts and structural loading impacts when various control strategies are performed; the paper will be submitted as an NREL report and journal article.	100%	3/31/2014	2/5/2014
FY 14	Q3 Project Milestone Description: Develop concept that describes interactions between market designs and proper active power control response.	100%	6/30/2014	6/26/2014
FY 14	Q4 Project Milestone Description: Completed four-area system for use in the multi-area frequency response tool and preliminary benchmarking of primary frequency response with PSLF.	100%	9/30/2014	8/12/2014
FY 15	Q1 Project Milestone Description: Complete a four-area system for use in the multi-area frequency response tool for primary and secondary frequency response integration tool.	100%	12/31/2014	12/31/2014
FY 15	Q2 Project Milestone Description: Develop a concept on improved plant level control utilizing existing research on wind plant wake optimization; deliver a short memo describing the concept.	100%	3/31/2015	3/31/2015
FY 15	Go/No-Go: If the tool is not completed by this date, it may show the development is not possible with budget and time constraints, and the funding should focus on other aspects.	100%	3/31/2015	7/31/2015
FY 15	Q3 Project Milestone Description: (SMART) Complete a technical report describing the simulation study results of primary and secondary reserve interactions in a high wind penetration system using the multi-area frequency response integration tool.	100%	6/30/2015	6/30/2015
FY 16	In alignment with the Grid Modernization Lab Call, submitting an AOP mod extending the current FY15 Q4 milestone "Task 2.9.0.402.1 Active Power Control from Wind Power, Q4 Complete a journal or conference paper on providing active power control services accounting for wind plant wake interactions by 9/30/2015" into Q1 FY16 and make any associated cost plan adjustments.	100%	12/31/2015	12/31/2015

Budget History

FY2014		FY2015		FY2016	
DOE	Cost Share	DOE	Cost Share	DOE	Cost Share
\$355k		\$503k		\$0	

- Electric Power Research Institute provided internal funding for their researchers to collaborate on this project.

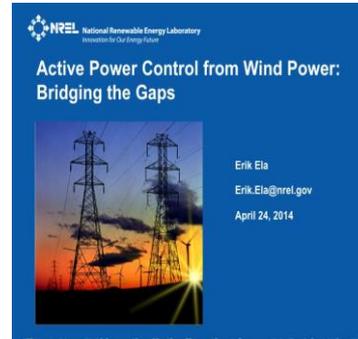
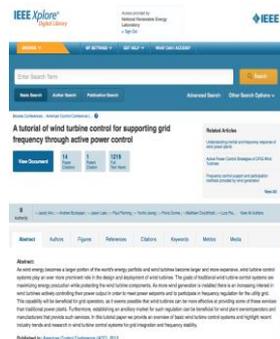
Partners, Subcontractors, and Collaborators

Subcontractors: University of Colorado-Boulder

Partners: EPRI

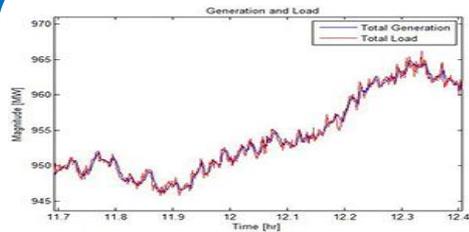
Communications and Technology Transfer

Two technical reports, five journal publications, 11 conference papers, two on-site workshops, three web workshops, cited by multiple media (e.g., utility dive, governors' wind energy coalition, wind power monthly)

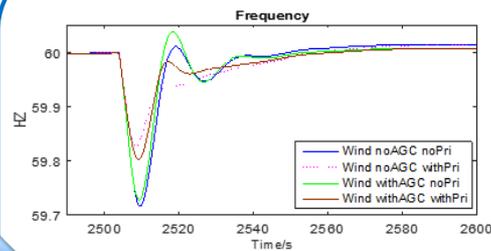


FY17/Current Research: Project was completed in FY16

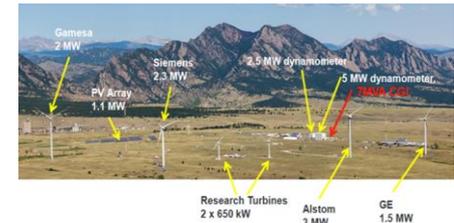
Planned Future Research: Integrated platform



Advanced optimization techniques that can handle the nonlinearity of fast wind controls scheduling



Closed-loop interaction of market-scheduling and extended dynamic simulation platform



Cluster-level control bundling two or more plants to provide services



Environmental and Siting Research Portfolio

Jocelyn Brown-Saracino
Acting Market Acceleration and
Deployment Program Manager
February 15, 2017

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- **GOAL:** Reduce the unsubsidized market levelized cost of energy (LCOE) for utility-scale land-based wind energy systems from a reference wind cost of \$0.074/kWh in 2012 to \$0.057/kWh by 2020 and \$0.042/kWh by 2030.
- **GOAL:** Reduce the unsubsidized market LCOE for offshore fixed-bottom wind energy systems from a reference of \$0.18/kWh in 2015 to \$0.15/kWh by 2020 and \$0.096/kWh by 2030.

Enhancing U.S. Energy Security and Independence

- **GOAL:** Accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality.

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- **GOAL:** Expand the geographic development potential of wind power plants in the United States, particularly in offshore zones and the U.S. Southeast.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- Reduce capital and O&M costs and optimization plant performance
- Reduce technical and financial risk and improve permitting processes
- Improve resource forecasting, reduce integration costs, increase value of ancillary services
- Develop technology that leverages lower speed wind resources

Enhancing U.S. Energy Security and Independence

- Facilitate coexistence between wind energy and wildlife
- Collect environmental impact data and support testing of monitoring and mitigation technologies
- Information synthesis and dissemination
- Manufacturing and installation cost reductions for Distributed Wind systems

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Demonstrate offshore wind advanced technology projects
- Reduce, mitigate and eliminate market barriers through improved siting
- Improve grid planning and operation
- Develop and demonstrate larger wind turbines

Enabling Wind Nationwide

Enabling U.S. Industry Growth and U.S. Competitiveness

- Reduce capital and O&M costs and optimization plant performance
- **Reduce technical and financial risk and improve permitting processes**
- Improve resource forecasting, reduce integration costs, increase value of ancillary services
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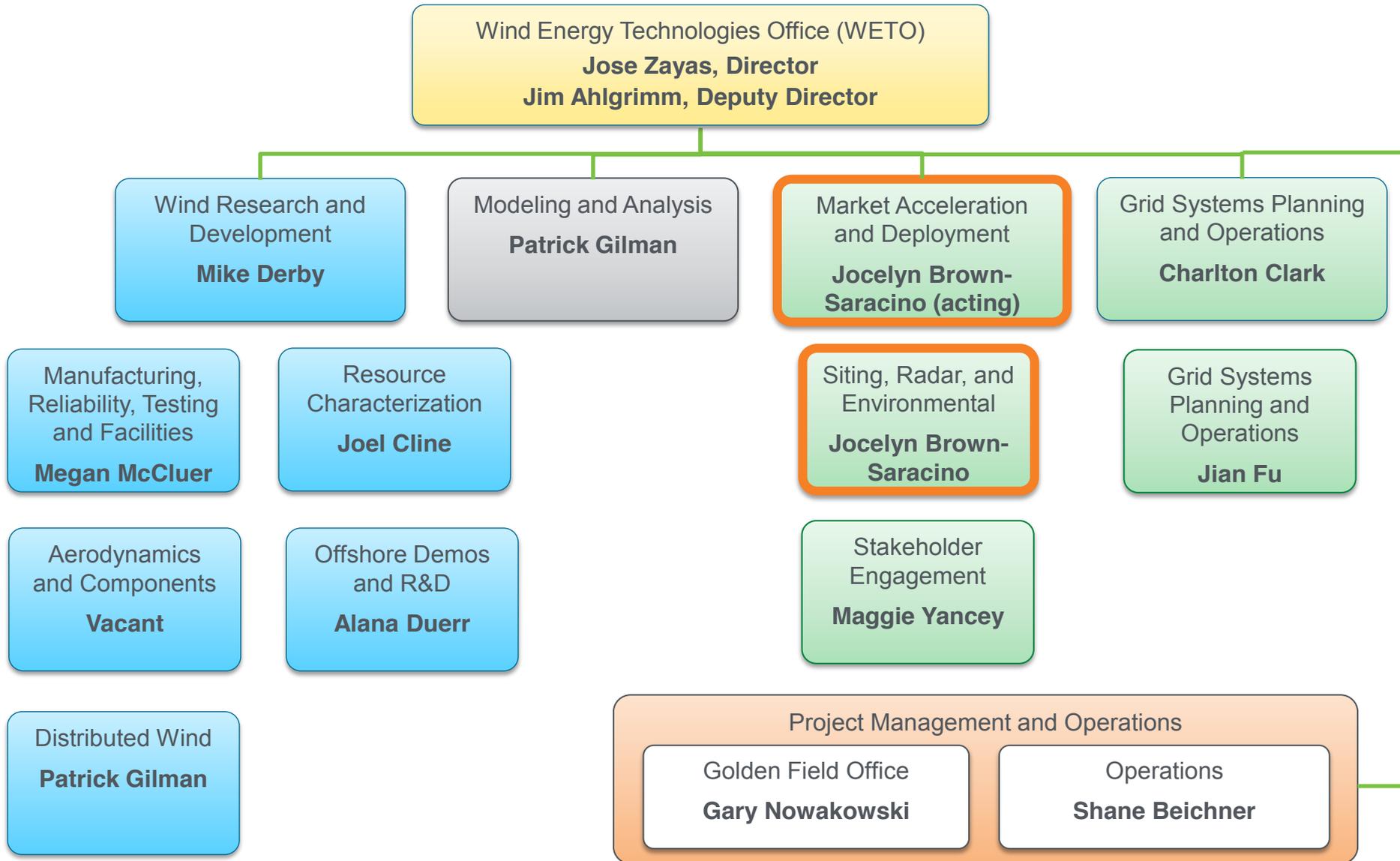
Enhancing U.S. Energy Security and Independence

- **Facilitate coexistence between wind energy and wildlife**
- **Collect environmental impact data and support testing of monitoring and mitigation technologies**
- **Information synthesis and dissemination**
- Manufacturing and installation cost reductions for Distributed Wind systems

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Demonstrate offshore wind advanced technology projects
- **Reduce, mitigate and eliminate market barriers through improved siting**
- Improve grid planning and operation
- Develop and demonstrate larger wind turbines

Wind Energy Technologies Office Structure



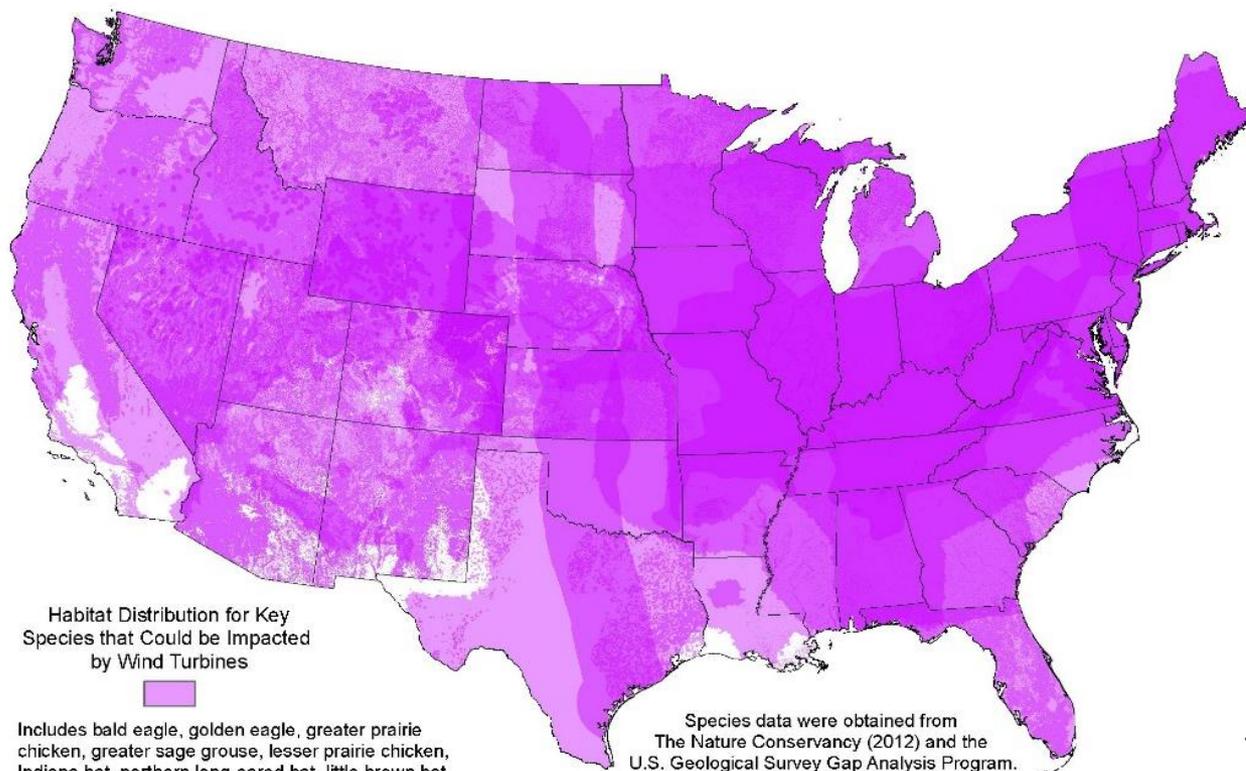
- **Catalyze credible research** through leveraged investment to fill gaps in understanding of critical environmental and siting issues and develop mitigation measures
- As the only agency whose primary mission is addressing the deployment of wind energy technologies, **Act as a convener of diverse stakeholders**, including federal agencies, in a national-scale dialogue, around wind environmental and siting issues
- **Disseminate trusted, impartial, unbiased, state-of-the-art data**
- **Engage the network of national laboratories** to carry out research and analysis that is beyond the scope of any one company
- **Develop technologies for monitoring and mitigation** of wind environmental and siting challenges.

Strategic Focus Areas

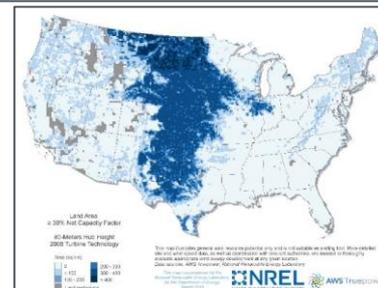
Challenges, goals, and approach

Strategic Area	Challenges	Goals	Approaches
Wind Turbine Radar Interference Mitigation (WTRIM)	<p>Impacts on missions difficult to systematically evaluate</p> <p>Legacy radar systems can't handle wind turbine clutter</p> <p>Future radar systems in development, have decade-plus lead times.</p>	<p>Improve ability to evaluate impacts</p> <p>Mitigate wind farm impacts on existing radars</p> <p>Next-gen radars resilient to wind farms.</p>	<p>Federal coordination to:</p> <ul style="list-style-type: none"> • Improve modeling and simulation tools • Software upgrades to legacy radars, gap-fill radars, radar fusion • Participate in next-gen radar spec development.
Land-Based Wind Wildlife Impacts	<p>Lack of refined understanding of risk drivers for some key species</p> <p>Need for proven impact minimization tools and technologies</p> <p>Need for expanded and validated compensatory mitigation options.</p>	<p>Improve understanding of risk drivers to inform minimization solutions</p> <p>Develop and validate effective and affordable impact minimization technologies</p> <p>Validate promising compensatory mitigation options.</p>	<ul style="list-style-type: none"> • Support for research collaboratives to support empirical research, synthesize research results, establish research gaps • Create a Technology Readiness Level pipeline to support both technology development and validation • Provide funding to validate compensatory mitigation options.
Offshore Wind Wildlife Impacts	<p>Lack of environmental impact data for offshore wind in United States</p> <p>Offshore environmental precludes many established land-based monitoring practices.</p>	<p>Retire risk for future projects</p> <p>Develop and validate a suite of monitoring and mitigation technologies.</p>	<ul style="list-style-type: none"> • Leverage international research • Support research at first generation projects, synthesize results • Support technology development and validation.

Mitigate Environmental Barriers: Making the Case



80M, 2008 Tech



Addressing the barriers to wind deployment is critical to meeting the *Wind Vision* target of 35% wind by 2050. Tools to better understand and mitigate wind impacts on wildlife will increase certainty for regulators, decrease risk for developers, and lower LCOE, leading to more deployment.

Consider:

Up to **73% of developable wind (4,500 gigawatts [GW])**, based on *Wind Vision's* “business as usual” scenario, is **constrained by various environmental factors**. Individually:

- Golden Eagles constrain up to 4,454 GW (28%)
- Northern Long Eared Bats constrain up with 4,855 GW (21%)
- Whooping Crane constrain up to 4,919 GW (20%)
- Greater & Lesser Prairie Chicken constrain up to 5,194 GW (16%).

Objective: Facilitate and disseminate research to understand and mitigate the impacts of wind energy on wildlife.

Data Collection and Experimentation

Conduct research to better understand species' exposure and the factors that drive risk in order to inform siting and mitigation solutions

Monitoring and Mitigation

Advance technologies or measures to reduce fatalities at wind energy facilities in an affordable manner

Information Synthesis and Sharing

Coordinate information synthesis and dissemination through collaboratives and information to reduce redundancy, make sense of disparate studies, and catalyze solution development.

Wind Turbine Radar Interference Mitigation: Making the Case

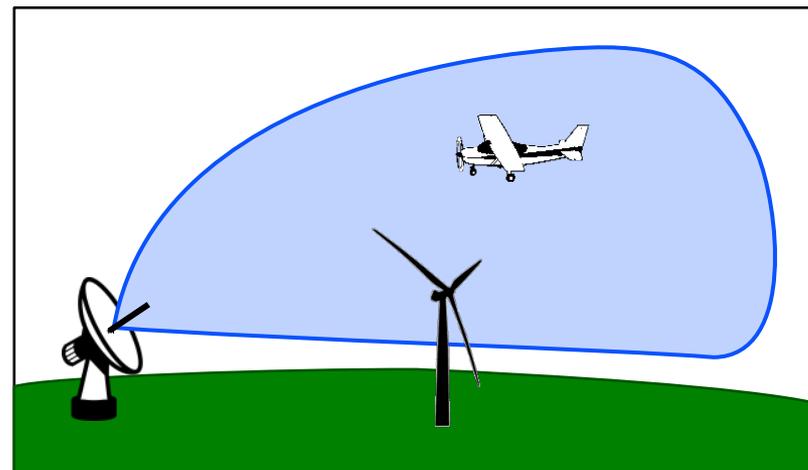
Turbine interference impacts air traffic control, national security and weather radars:

- Reduced ability to detect targets
- Increased false alarms
- Reduced tracking effectiveness.

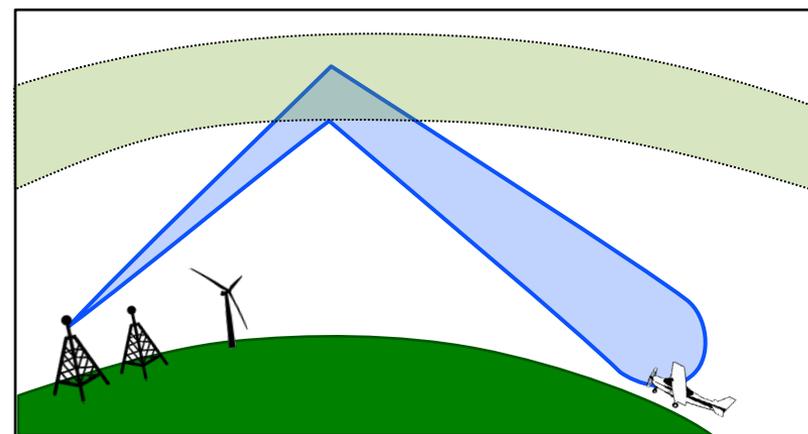
Impacts wind development:

- FAA evaluates all structures over 200', consults with other agencies
- Significantly increases cost and risk associated with siting in radar line of sight
- Cumulative impact concerns have restricted development in several wind resource areas.

Air Surveillance Radar

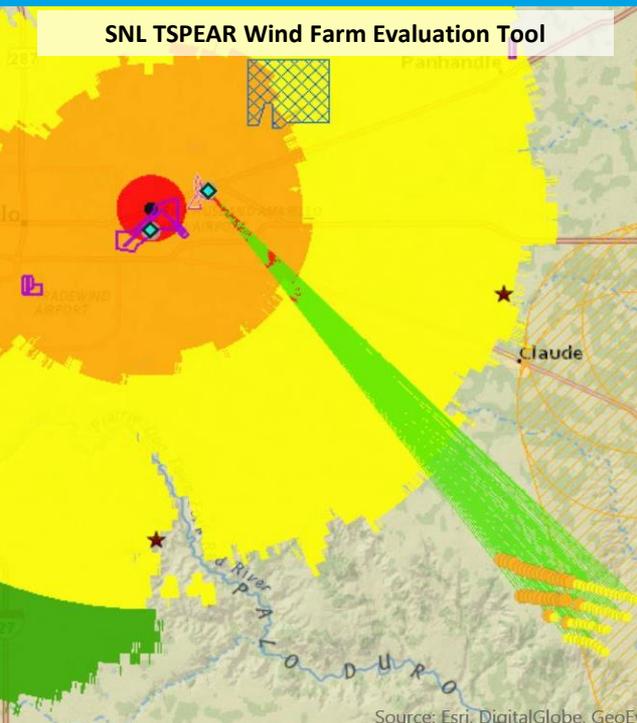


Over-the-Horizon Radar

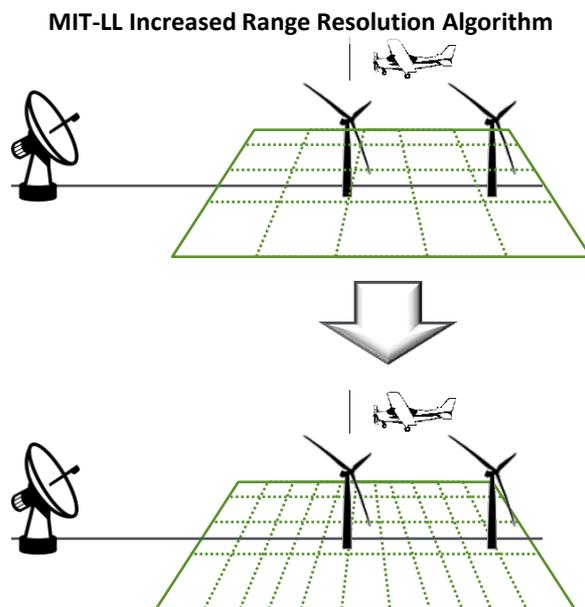


Wind Turbine Radar Interference Mitigation Program

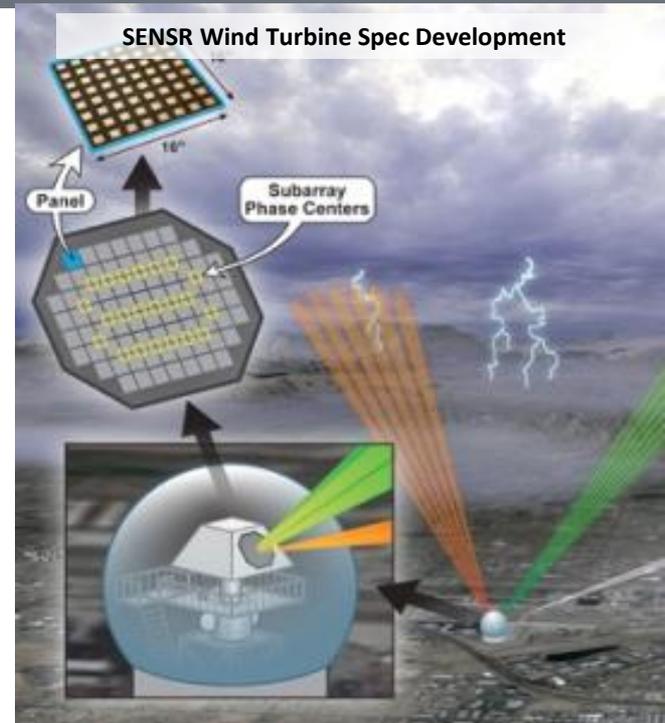
Focus: Strong Federal Strategy and Collaboration



Improve capacity to evaluate the impacts of wind energy on sensitive radars



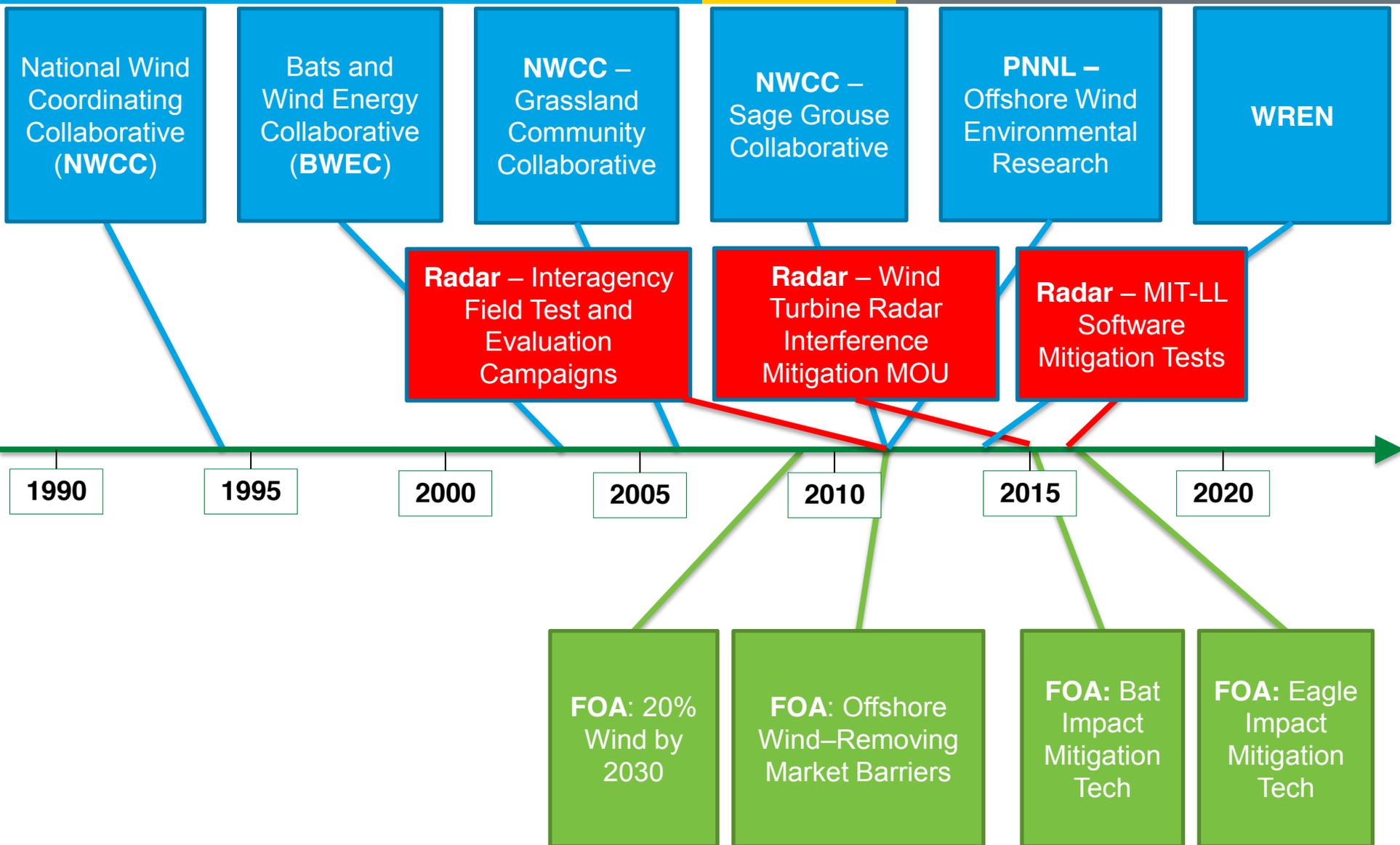
Develop and deploy mitigation measures to increase resilience of existing radars to wind turbines



Encourage the development of next-generation radars resistant to wind turbine interference

2015 Memorandum of Understanding (MOU) establishes working group to collectively develop and deploy mitigation approaches, allows significant leverage of DOE funds
Key partners: DOD Siting Clearinghouse, FAA, NOAA, BOEM, DHS.

Mitigate Environmental and Siting Barriers - Research Timeline



Wind Turbine Radar Interference Mitigation

SNL Wind-Turbine RCS Mitigation (10:55am)

Ben Karlson

MIT Lincoln Labs Radar Mitigation R&D (11:20am)

Jason Biddle

Land Based Wind Environmental Research

Wind Environmental Collaborative Research and Support (11:45am)

Karin Sinclair

Texturizing Wind Turbine Towers to Reduce Bat Mortality (1:35pm)

Victoria Bennett

Biomimetic Ultrasonic Whistle for Use as a Bat Deterrent on Wind Turbines (2:00pm)

Paul Sievert
(Raphael Tisch)

Rotor-Mounted Bat Impact Mitigation (2:25pm)

Myron Miller

Ultrasonic Bat Deterrent Technology (2:50pm)

Michael Booth

Evaluating the Effectiveness of Ultrasonic Acoustic Deterrents in Reducing Bat Fatalities at Wind Energy Facilities (Wednesday, 3:15pm)

Cris Hein

Offshore Wind Environmental Research

OSW Environmental Data Aggregation, Analysis and Dissemination (4:00pm)

Andrea Copping

Stereo-Optic High Definition Imaging: A New Technology to Understand Bird and Bat Avoidance of Wind Turbines (4:20pm)

Evan Adams

Avian Remote Sensing (4:40pm)

Shari Matzner

Key Projects/Activities & Accomplishments (FY14-16)

Key Project/Activity	Key Accomplishments	Key Collaborators
<p>Land-based Wind Research</p>	<ul style="list-style-type: none"> • <i>Five awards issued to projects developing bat impact minimization technologies</i> • <i>Six awards issued to further research, development, and validation of eagle impact minimization technologies</i> • <i>Renewed and increased funding of research collaboratives including NWCC Collaborative, Bats and Wind Energy Cooperative, and WREN (Working Together to Resolve Wind Energy Wildlife Impacts).</i> 	<p><i>National Renewable Energy Laboratory, Bat Conservation International, American Wind Energy Institute, and many others</i></p>
<p>Offshore Wind Research</p>	<ul style="list-style-type: none"> • <i>Completed largest survey to date of marine mammals, sea birds, and sea turtles in the mid-Atlantic</i> • <i>Completed largest study of bat activity offshore to date</i> • <i>Completed initial development of collision detection system.</i> 	<p><i>Pacific Northwest National Laboratory, Biodiversity Research Institute, Stantec, Oregon State University and many others</i></p>
<p>Information Sharing, Synthesis, Dissemination</p>	<ul style="list-style-type: none"> • <i>Expanded Tethys to cover land-based wind, creating WREN Hub</i> • <i>Renewed funding of collaborative work to support ongoing information sharing portals.</i> 	<p><i>Pacific Northwest National Laboratory, National Renewable Energy Laboratory, Bat Conservation International, American Wind Energy Institute, and many others</i></p>

Key Projects/Activities & Accomplishments (FY14-16)

Key Project/Activity	Key Accomplishments	Key Collaborators
Wind Turbine Radar Interference Mitigation (WTRIM)	<ul style="list-style-type: none">• <i>MOU establishing interagency WTRIM working group, 2015</i>• <i>Developed and field tested two wind turbine interference mitigation software upgrades now in consideration for operational deployment</i>• <i>Released public-facing wind turbine radar interference impact evaluation tool.</i>	<i>DOD, FAA, NOAA; SNL, MIT-Lincoln Labs</i>

Workshops and Conferences

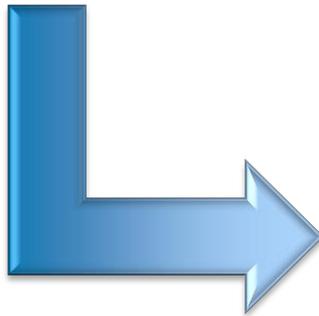
DOE and awardees planned and led numerous environmental and siting outreach, engagement and leadership activities. DOE staff are leaders in this area and gave many technical and programmatic strategy talks over this period.

Significant outreach events include:

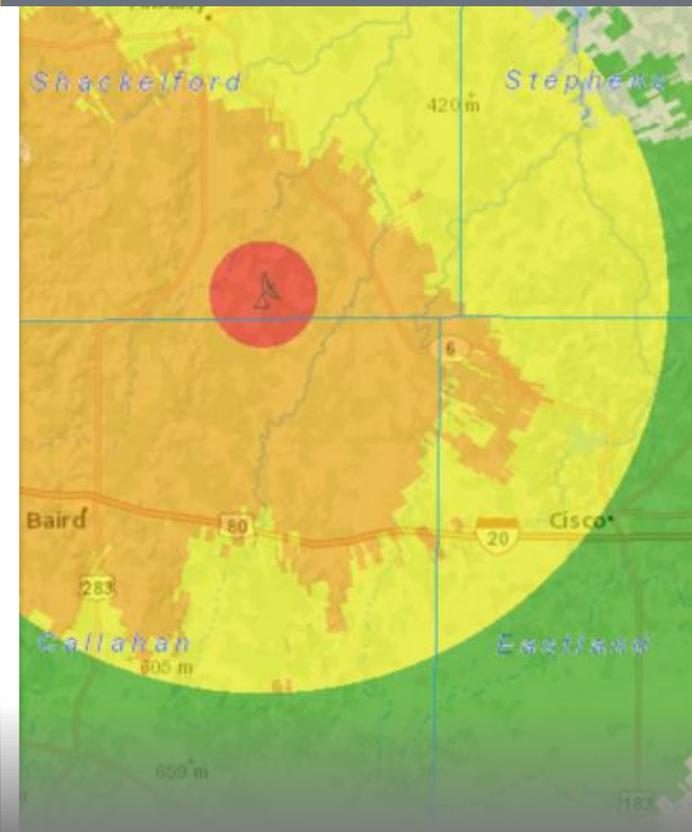
- Workshop on eagle impact minimization technologies (2015)
- Published three Requests for Information on potential funding opportunities seeking input on structure and focus
- Workshop on adaptive management at the CWW Conference in Berlin (2015)
- Public Environmental Strategy Input Meeting (2016)
- Held BWEC bi-annual science meeting
- Held two NWCC bi-annual research conferences
- Numerous webinars on radar interference mitigation, offshore wind and land-based wind environmental research
- Weekly Tethys blasts on recent research efforts added to Tethys
- Periodic Tethys Stories
- Special session on radar mitigation at 2015 AWEA Siting Conference
- AWEA WINDPOWER Government listening sessions on radar and airspace issues (2015–2016).

Budget summary

Total Budget			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$5.6M	\$3.4M	\$4.7M	\$13.8M



<i>Peer Reviewed Budget</i>			
FY2014	FY2015	FY2016	Total FY2014-FY2016
\$5.4M	\$3.4M	\$1.2M	\$10.0M
96%	98%	25%	72%



Wind Turbine RCS Mitigation

Benjamin Karlson

Sandia National Laboratories

bkarlso@sandia.gov 505.377.3774

February 2017

Problem Statement:

Wind turbines have grown in size and number. When these machines are installed within the line-of-sight of a radar system, they **can cause significant interference**, detrimentally **impacting radar** performance.

This project from the Sandia (SNL) perspective is divided into three efforts:

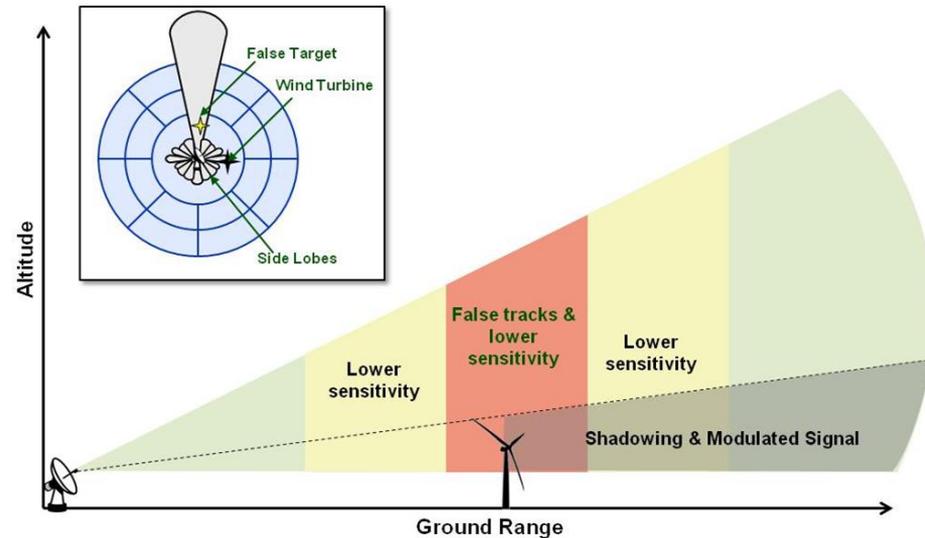
1. Facilitation of the Wind Turbine-Radar Interference Mitigation (WTRIM) Working Group
2. Wind Turbine-Radar Interference Mitigation Field Test Support
3. Modeling and Assessment: Tools for Siting, Planning, and Encroachment Analysis for Renewables (TSPEAR)

- Decreased Sensitivity (P_D)
- False Targets (P_{FA})
- Corrupted Track Quality



Concern for:

- Flight Safety
- Homeland Air Security



- Tip speeds over 225 mph
- Blades more than 50 m long
- 30 – 40 dBsm
- Wind farms with 100s of turbines

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
- World-class test and user facilities
- Advanced technology demonstration projects
- Technical engagement initiatives
- Standards and certification
- Communicating the costs and benefits of wind energy

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The Impact

- Improve the capacity of government agencies and the wind industry to site and evaluate the impacts of wind energy projects on sensitive radar systems
- Enhance modeling and simulation tools that aid in the siting and evaluation of future wind facilities
- Leads to lower costs, improve tool accuracy, cut assessment timelines, reduce financial and mission risk, and accelerate wind energy deployment

■ *Improving Interagency Coordination & Planning*

Capturing all key existing wind turbine radar interference work (e.g. Private Industry, National Government & International WTRIM Activities) Pilot Mitigation Project (PMP) Initiative

■ *Medium to Long-Term Research & Development (R&D) to enable wind-radar coexistence*

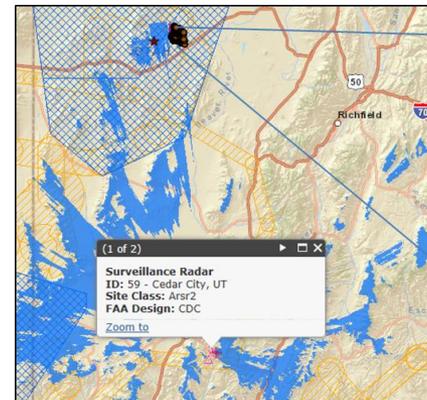
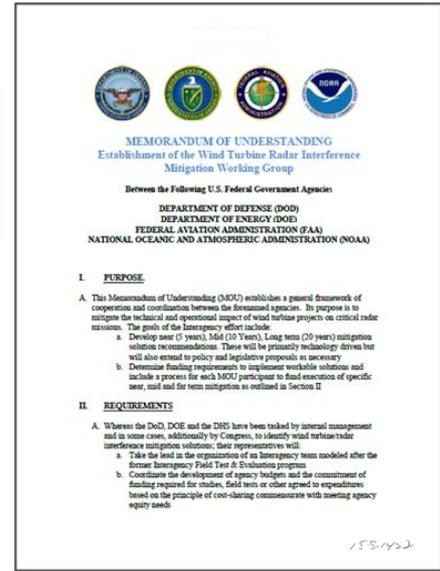
Wind Turbine Blade Lightning Protection System

■ *Rapidly Deploying Near-Term Mitigation Solutions*

Pilot Mitigation Project (PMP) Initiative

■ *Enhancing Modeling & Simulation Capabilities*

Tool for Siting, Planning, and Encroachment Analysis for Renewables
TSPEAR



Radar Viewshed – Long Range UT Site

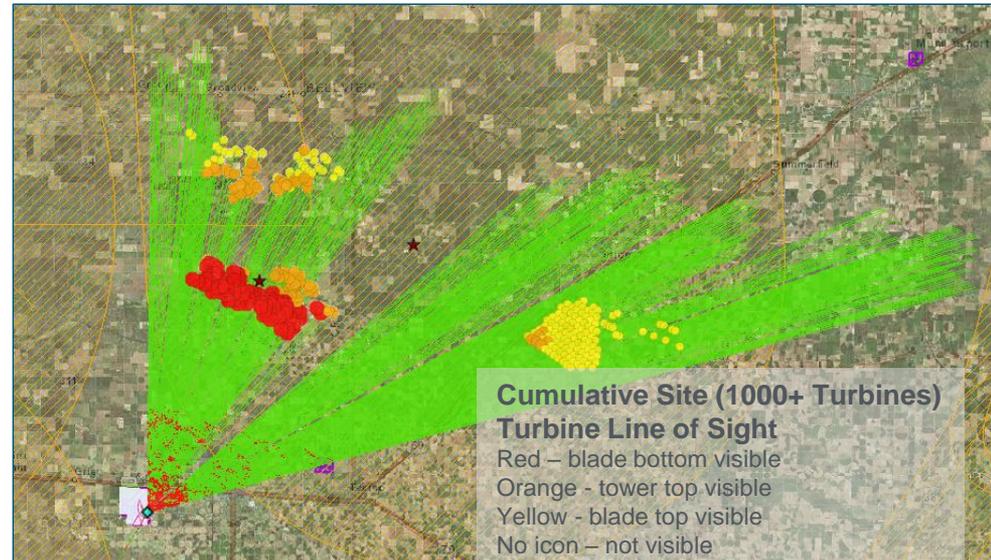
Capabilities

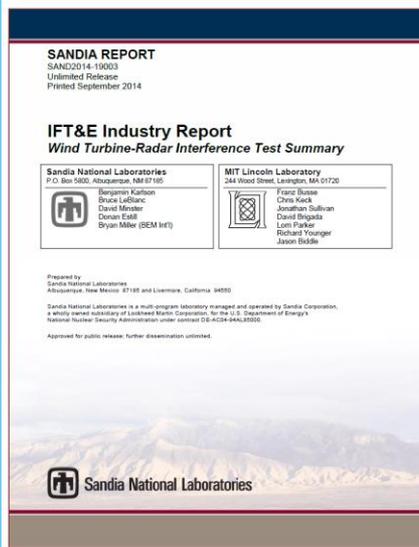
The TSPEAR analysis offers a wide range of input and output options for more detailed radar assessments. Integrated geographic data includes: base map data, base imagery data, elevation data, NOAA radars and their wind development constraint overlays, airfields, USGS Wind Turbine Database (Jul 2013), and military sites.

- **Radar Models Included:**

- CARSR
- ARSR-4
- ARS-9
- ASR-11
- NOAA NEXRAD

- **TSPEAR Inputs:** The basic inputs to the model, aircraft position/LOS, Turbine Properties (physical dimensions, geographic location and elevation), and Radar Properties, offer potential for modification and/or access as variables, to an analyst.
- **TSPEAR Outputs:** The radar model in TSPEAR has the ability to output a wide variety of analytical data. The public wind developer system reduces and generalizes the output so that the technical details of the analysis don't overwhelm their particular interests. Model output for developers includes:
 - Radar-turbine line-of-sight,
 - Radar view-sheds,
 - Probability of detection (Pd) degradation percentages at the turbine locations for three different RCS types and seven altitudes,
 - Shadowing impacts of wind turbine towers at three distances behind the turbines



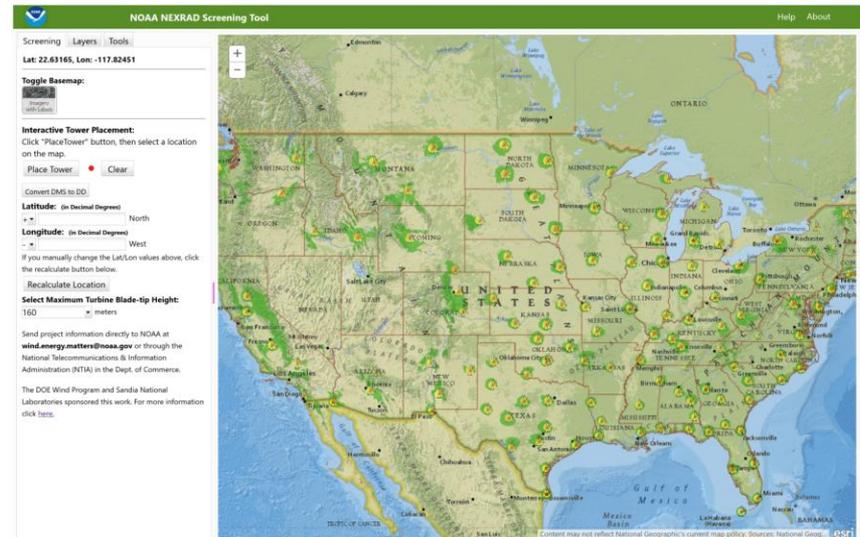


Published the *IFT&E Industry Report*; compiled and distilled three Official Use Only (OUO) Interagency Field Test and Evaluation (IFT&E) test reports and data for industry

Obtained wind turbine telemetry for the WTRIM Test 3 evaluating TANC and IRR enhancements consumption

Enhanced TSPEAR's modeling and simulation capabilities

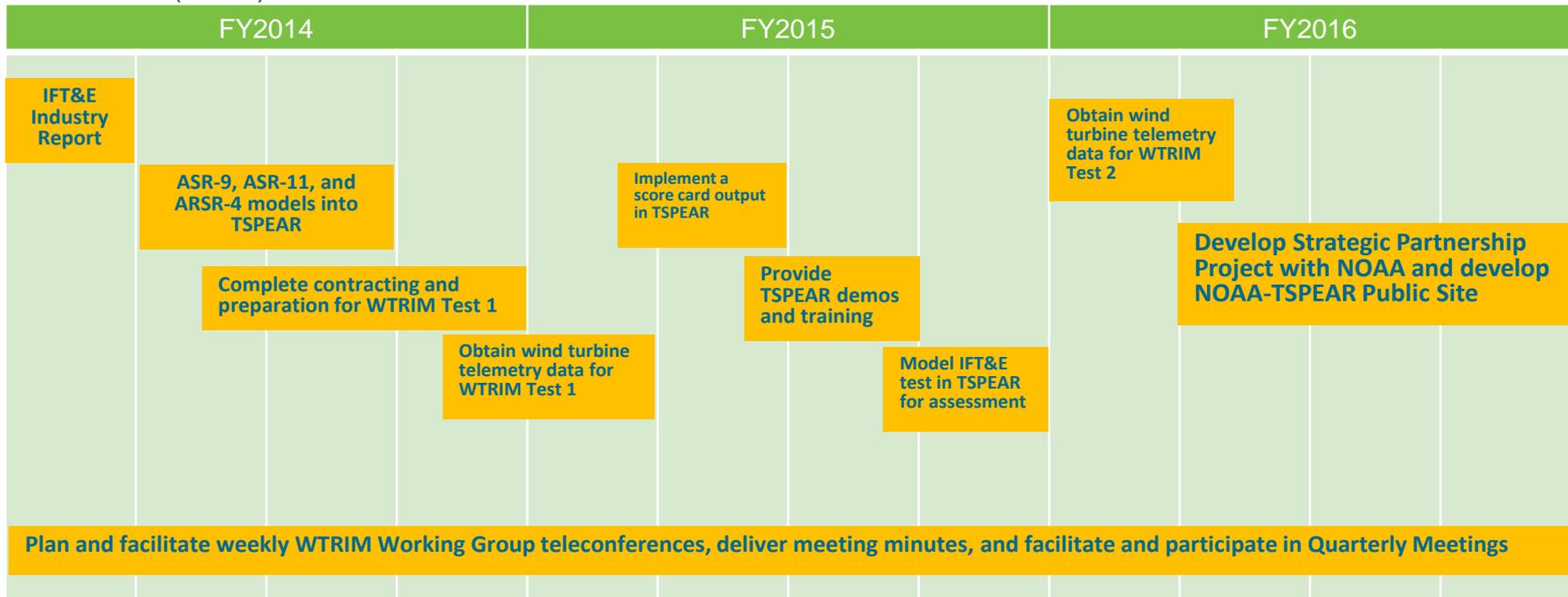
Facilitated and led weekly WTRIM Working Group teleconferences and Quarterly Meetings that aligns government agencies on current and planned activities.



Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$750k*		\$500k*		\$300k*	\$100k

- Cost share is provided by multiple organizations including the Department of Defense (DOD) and NOAA



Partners, Subcontractors, and Collaborators:

- Partnership between Sandia National Laboratories and Massachusetts Institute of Technology Lincoln Laboratory
 - Subcontractors: BEM International and Peak Spatial
- Government partnership between DOE, DOD, FAA, and NOAA – DHS and Bureau of Ocean Energy Management as observers
- Wind industry providing data

Communications and Technology Transfer:

- IFT&E Industry Report
- DOE's Federal Interagency Wind Turbine Radar Interference Mitigation Strategy
- Conducted TSPEAR demonstrations and training for Department of Defense [DoD] (SCH, USAF)
- AWEA "Industry Listening Sessions" at WindPower 2014, 2015, and 2016
- DoD-sponsored Technical Interchange Meetings (TIMs) & Domain Awareness Symposium
- Multiple Webinars

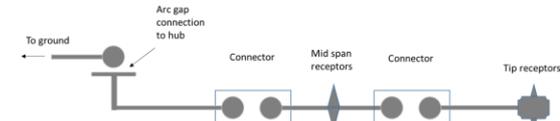


FY17/Current Research:

- Integration of NOAA weather radars into TSPEAR
 - Publicly available site up and running
 - <http://energy.sandia.gov/energy/renewable-energy/wind-power/wind-turbine-siting-and-barrier-mitigation/>
 - Click on [ACCESS THE NOAA TSPEAR SITE](#)
- Lightning and Wind Turbine Blades
 - \$30K per blade per repair
 - Nearly \$98M per year for US wind
 - Down-conducting lightning cable accounts for biggest RCS of a blade

Planned Future Research:

- Support Pilot Mitigation Projects
 - Infill radar integration
- TSPEAR Model Validation
- Offshore mitigation



Proposed SNL solution: a combination of segmented down conduction by electrical isolation and increased efficiency of the receptors.



Photos Courtesy of BEM Int'l, LLC



Wind Turbine – Radar Interference Mitigation R&D

Jason Biddle

MIT Lincoln Laboratory

JBIDDLE@LL.MIT.EDU (781) 981 5473

14 Feb 2017

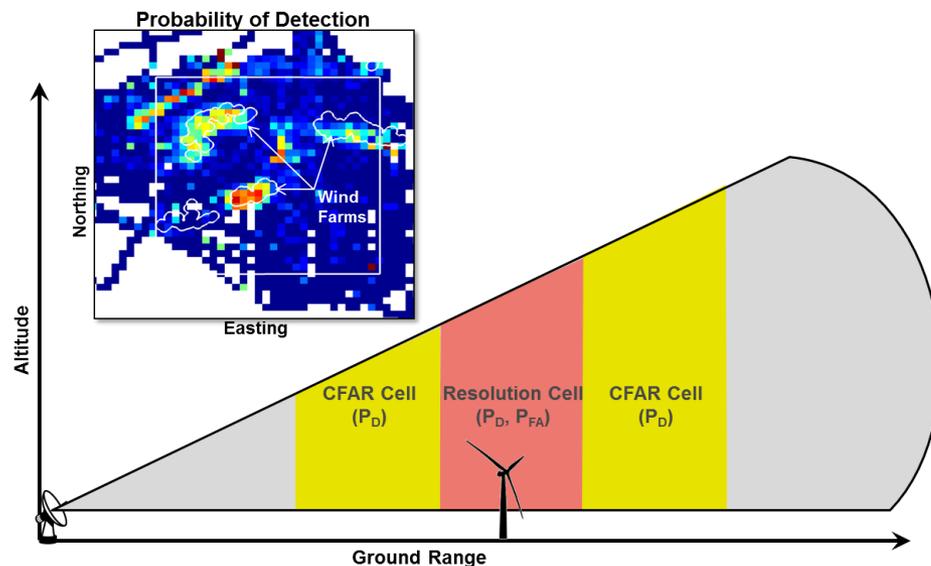
Wind Turbine – Radar Interference Mitigation R&D

Wind turbines impact radars:

- Decrease sensitivity
- Increase false alarms
- Corrupt track quality

Concern for:

- Flight safety (FAA)
- Homeland security (DHS)
- Homeland defense (DOD)
- Weather forecasting (NOAA)



The Challenge:

- Improve the capacity of government and industry to evaluate the impacts of existing and planned wind energy installations on sensitive radar systems.
- Develop and facilitate the deployment of mitigation solutions to increase the resilience of existing radar systems to wind turbines.
- Encourage the development of next-generation radar systems to be resistant to wind turbine interference.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

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- Commercialization of innovations and technology transfer
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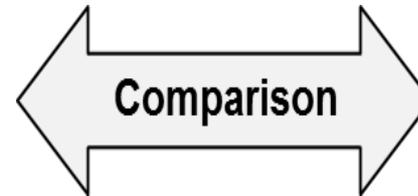
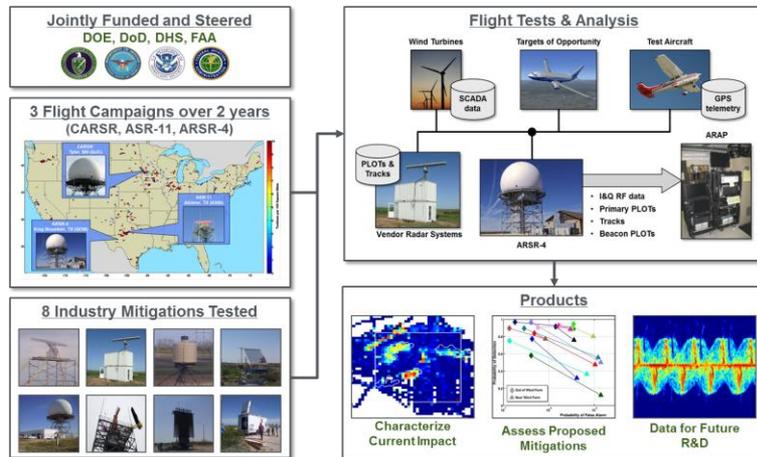
The Impact

- Increased success and reduced cost in siting projects with respect to critical radar systems
- Improved review process and criteria for evaluation by radar agencies in cases where wind could have potential mission impacts
- Reduced mission impacts to critical radar systems and coexistence between wind development and radar systems even in cases where unmitigated impacts would have been unacceptable
- Over the long term, reduced or eliminated mission impacts and need for site-specific mitigation for wind turbine radar interference for most classes of radar, enabling responsible deployment.

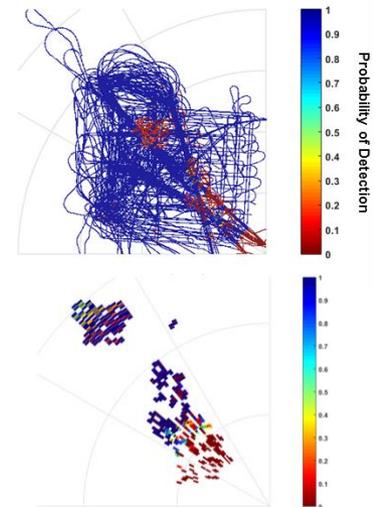
Improve modeling and simulation tools to aid in the siting and evaluation of planned wind facilities and assessment of potential mitigation measures

Interagency Field Test and Evaluation (IFT&E) Program [1]

2011 – 2013



Model Predictions

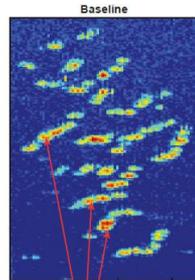
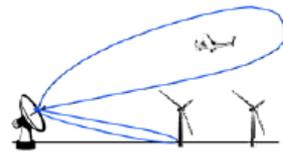
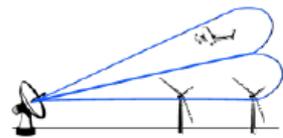


Assess radar model wind turbine impact predictions using real-world data collected during the Interagency Field Test & Evaluation (IFT&E) Program

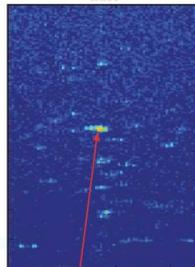
[1] <http://energy.gov/eere/wind/downloads/interagency-field-test-evaluation-wind-turbine-radar-interference-mitigation>

Develop hardware and software upgrades to make existing radars more resilient to the impacts of wind turbines

Multi-Beam Elevation Nulling

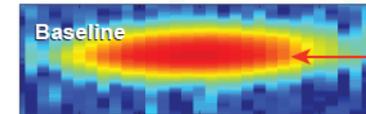
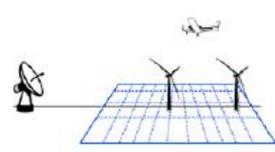
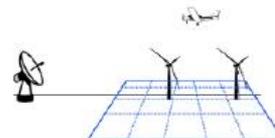


Many Wind Turbines Obscure Aircraft

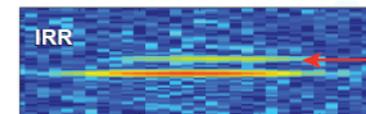


High-Flying Aircraft Clearly Visible

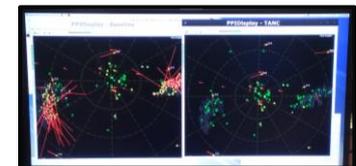
Improve Range Resolution



Large Reflection Hides Aircraft



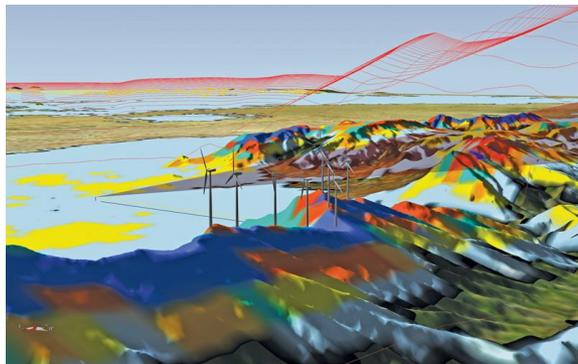
Aircraft Detectable Behind Turbine with High Resolution



Test mitigation concepts on raw data from the IFT&E Program, then prototype upgrade and evaluate performance at radar sites with real-time testbed

- Evaluated Turbine Adaptive Nulling Concept (TANC) and Improved Range Resolution (IRR) mitigations with flight tests at air traffic control radars in Michigan (Oct 2015) and Texas (Jan 2016)
- Completed assessments of ROEMS and TSPEAR wind turbine – radar interference impact models (Feb 2016)

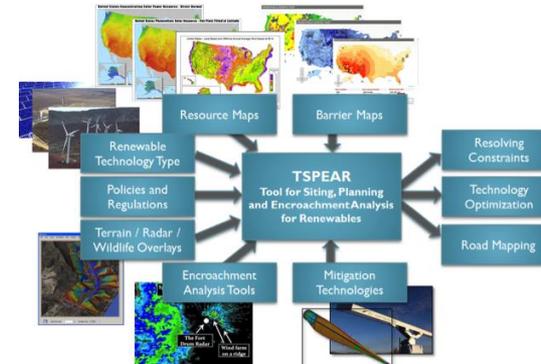
Radar Obstruction Evaluation Model / Simulator (ROEMS) [2]



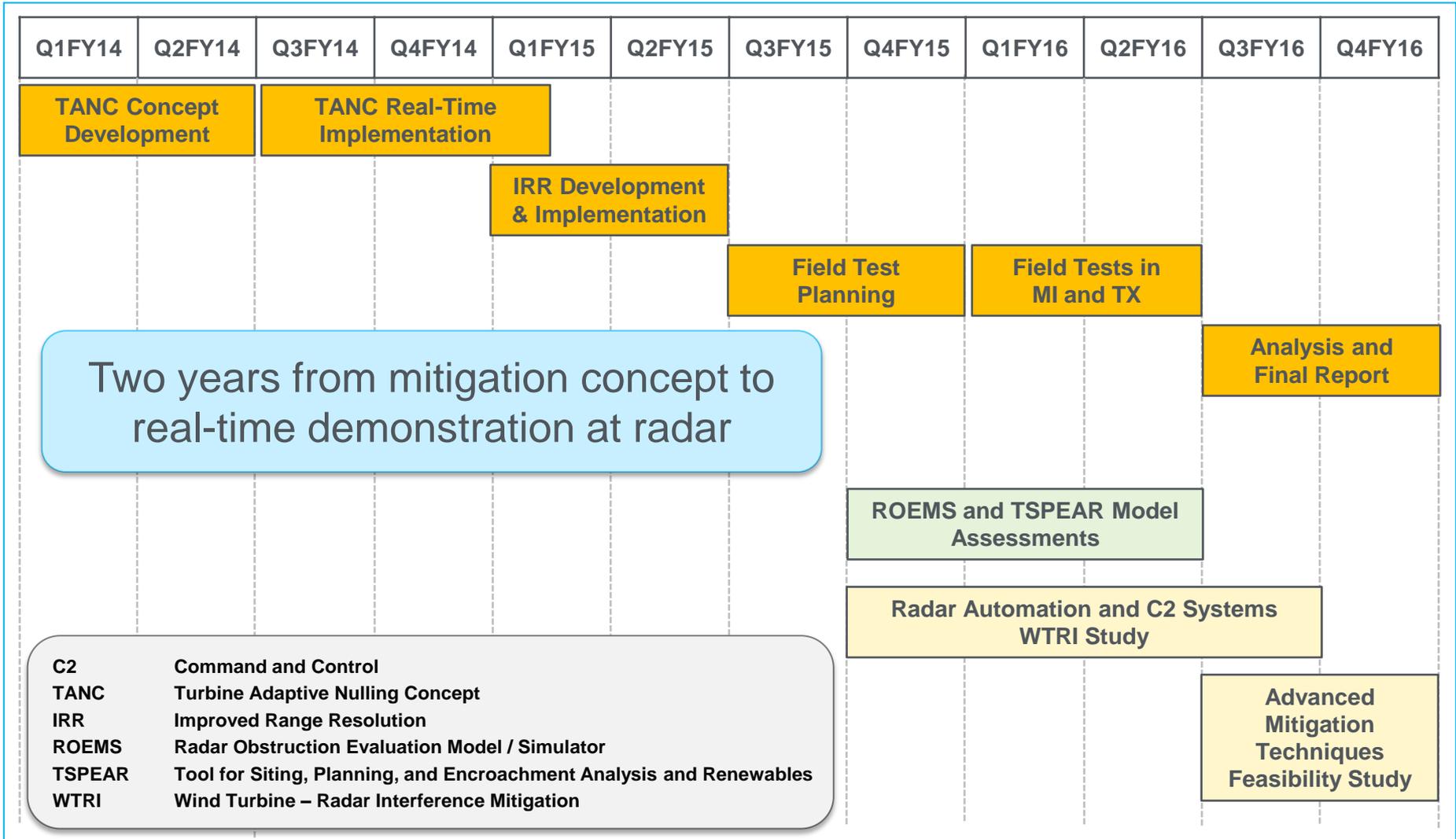
[2] <http://blogs.agi.com/agi/wp-content/uploads/2013/04/modeling-and-simulating-wind-turbine-effects-on-radar-systems-4.jpg>

[3] http://energy.sandia.gov/wp-content/gallery/uploads/Turbine_radar3_SAND_20140951P.png

Tool for Siting, Planning, and Encroachment Analysis and Renewables (TSPEAR) [3]



Project Plan & Schedule

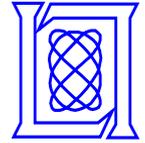


Budget History [\$K]					
FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
390k	1,110k	310k	1,340k	385k	1,260k

- Cost share is provided by multiple organizations from the Department of Defense (DoD)
- Spending from DOE share below projections in FY2015-16
 - Due to higher than expected DoD cost-share contributions and internal staffing constraints
 - Carrying over \$650K of DOE funds into FY2017

Partners, Subcontractors, and Collaborators:

- Partnership between Sandia National Laboratory and MIT Lincoln Laboratory
 - Subcontractors: BEM International
- Oversight from Government partnership between DOE, Department of Defense, Federal Aviation Administration, and National Oceanic and Atmospheric Administration
 - Wind Turbine Radar Interference Mitigation (WTRIM) Working Group (WG)



Communications and Technology Transfer:

- American Wind Energy Association Wind Project Siting Seminar (10 Mar 2015), Austin, TX
- National Renewable Energy Laboratory Webinar Overcoming Wind Siting Challenges II: Radar (15 Apr 2015)
- International Energy Agency Topic Experts Meeting (TEM) #83: Mitigation of Wind Turbine Impacts on Radar (6-7 Oct 2015), Wachtberg, Germany

FY17/Current Research:

- Investigating unique impacts of offshore wind on coastal radars and other federal missions
- Studying feasibility of advanced signal-processing techniques for existing National Airspace System radars
- Drafting mitigation requirements for next-generation radar systems
- Supporting infill radar evaluation and integration

Planned Future Research:





Golden Eagle at NWTC. Photo by John De La Rosa-Dennis Schroeder, NREL 35801

Environmental Collaborative
Research and Support

Karin Sinclair

National Renewable Energy Laboratory (NREL)

Karin.sinclair@nrel.gov

303.384.6946

February 2017

Environmental Collaborative Research and Support: Concerns for wildlife impacts from domestic and international wind energy projects can—and do—create a barrier to deployment of wind energy projects. In order to enable wider deployment of wind energy in the U.S., activities are conducted within multistakeholder collaborative efforts focused on solutions to address wind-wildlife impact issues. These include research and development as well as outreach and engagement efforts.

Challenge: Impacts to wildlife from wind energy results in regulatory barriers to deployment, especially in geographic areas where sensitive species occur. Limited scientific research results for a wide range of species and ecosystems makes it difficult to provide information to decision makers that can be used to facilitate lower-cost and more expeditious wind-project deployment.

Partners:

- American Wind Wildlife Institute (National Wind Coordinating Collaborative, NWCC) <https://www.nationalwind.org/>
- National Wind Coordinating Collaborative (Sage Grouse Collaborative, SGC) <https://www.nationalwind.org/research/collaboratives/sage-grouse/>
- Bat Conservation International (Bats and Wind Energy Cooperative, BWEC) <http://www.batsandwind.org/>
- Association of Fish and Wildlife Agencies http://www.fishwildlife.org/index.php?section=wind_energy&activator=32
- International Energy Agency (IEA) Wind Task 34 http://www.ieawind.org/task_34.html
- Pacific Northwest National Laboratory (Task 34/WREN) <https://tethys.pnnl.gov/about-wren>

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The intended impact for the wind industry of this project's work is to

- decrease impacts to wildlife from wind energy
- improve understanding of the relative impact of wind energy
- identify methodologies to assess potential impacts and risks, and
- shortened timelines to complete environmental requirements and lower environmental compliance costs for project deployment.

The project's endpoint is the enhanced ability for the wind industry to deploy projects across a range of landscapes, including offshore, with reduced risk and impacts on wildlife.

Outreach efforts are critical to reaching target audiences with accurate information.

Unique aspect: Use of collaboratives to engage federal regulatory agencies, wind industry, and other wind stakeholders to work on wind-wildlife impact issues and disseminate information

Technical approach or methods

- Engage stakeholders to leverage research funds and expand knowledge base
- Develop and disseminate unbiased, scientifically rigorous research results to facilitate expanded deployment of wind energy, including in areas where species or habitat challenges exist
- Provide technical expertise on wildlife research activities and to key national and international collaborators
- Engage the international community
- Facilitate access to wind wildlife data and literature (Wind Wildlife Impacts Literature Database (NREL) and Working Together to Resolve Environmental Effects of Wind Energy (WREN) Hub (Pacific Northwest National Laboratory)).

Key issues being addressed

- Concerns for impacts to a number of species (bats, golden eagles, greater sage grouse)
- Reducing risk to bats
- Reducing risk to golden eagles
- Developing mitigation strategies
- Outreach and engagement
- Information dissemination
- Improving coordination of international community on land and offshore wind/wildlife issues.



Sage Grouse sitting in grassland. Photo by LuRay Parker, NREL 17429



Golden Eagle at NWTCC. Photo by Dennis Schroeder NREL 35741

Golden Eagle (Nova). Photo by Lee Jay Fingersh, NREL 35724



Technical accomplishments

Domestic

Field research. BWEC (pre- and post-construction studies; impact reduction research (operational minimization, deterrent research); behavioral studies (bat migration, thermal video monitoring). NWCC (sage grouse collaborative).

Information exchange. BWEC (science meeting and publication of proceedings; presentations; publications; training workshops; development of state guidelines). NWCC (research meeting and publication of proceedings; outreach and engagement (fact sheets, webinars). Association of Fish & Wildlife Agencies (AFWA) (training workshops). NREL (framework for testing; eagle workshop).

International

IEA Wind Task 34/WREN: expansion of country participation (from two countries to nine countries); expansion of WREN Hub (part of *Tethys*) to include land based wind research; development of white paper on adaptive management and four other white papers; outreach and engagement (presentations, webinars, workshop)

Project original initiation date and planned completion date

- NWCC: 1994 – 2020
- BWEC: 2003 – 2020
- AFWA: 2015 – 2020
- IEA Wind Task 34: FY12 – FY16 (1st term); FY17 – FY20 (2nd term)

Slipped milestones and schedule

All milestones were completed; two required time extensions to complete.

- **FY14:** Detailed planning schedule and preliminary draft agenda for BWEC Science Meeting shall be submitted to DOE by June 30, 2014. Delayed to September 2, 2014. Science meeting was planned for January 2015. Developing agenda and securing speakers was not completed in the June timeframe by the meeting organizers. Disconnect on timing needs.
- **FY15:** DOE staff, in consultation with NREL project leads, will determine by September 30, 2015, whether the *Framework for Testing the Effectiveness of Fatality-Reduction Strategies at Wind Energy Projects* document should be published. Completed February 9, 2016; report delayed due to multiple review cycles that took longer than anticipated.
- **FY15:** Publication of *Framework for Testing the Effectiveness of Fatality-Reduction Strategies at Wind Energy Projects*. Scheduled for publication January 2015; published March 2016. Document was developed with input from a range of stakeholders (mostly volunteers). *Framework* is heavily focused on statistics; lots of effort to get it right and get agreement from key contributors.

Go/No-Go decision points

FY14: N/A

FY15: Should the *Framework* document be published? Go

FY16: Should the U.S. continue to participate in IEA Wind Task 34? Go

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$782K BA	\$277K	\$170K BA	\$129K	\$350K BA	\$362K

- Cost-share is from American Wind Wildlife Institute (AWWI) to support NWCC facilitation
- 93% of current project budget has been expended

Partners, Subcontractors, and Collaborators:

- American Wind Wildlife Institute
- Bat Conservation International
- University of Missouri
- Association of Fish and Wildlife Agencies
- IEA Wind Task 34 (WREN)
- Pacific Northwest National Laboratory
- PWT Communications

Communications and Technology Transfer: National Wind Coordinating Collaborative, Bats and Wind Energy Cooperative, Conference of Wind and Wildlife Impacts, AWEA Siting Conference, IEA Wind, Sustainable Energy Authority of Ireland, WREN webinar series, WREN Hub web site <https://tethys.pnnl.gov/about-wren>

Identify reports and publications

- *Wind Energy Industry Eagle Detection and Deterrents: Research Gaps and Solutions Workshop Summary Report* <http://www.nrel.gov/docs/fy16osti/65735.pdf>
- *Framework for Testing the Effectiveness of Fatality-Reduction Strategies at Wind Energy Projects* <http://www.nrel.gov/docs/fy16osti/65624.pdf>
- Numerous BWEC reports (see 4-page report for list)
- Final technical reports from two research teams in the sage grouse collaborative.

FY17/Current Research:

Land based Collaborative (LBC) (with AWWI, BCI, AFWA): coordinated effort across all collaboratives, with input from Expert Panel to prioritize efforts, identify efficiencies, and eliminate duplicative efforts. Focused on reducing risk to wildlife at domestic land based wind and providing science-based input to environmental regulatory issues.

Milestones/Deliverables:

Q1: 4-year work plan for LBC

Q2: Sage Grouse field research (pending commitments from others)

Q3: Field study investigating the behavior of bats near wind turbines, using thermal video camera and bat migration using miniaturized GPS tags

Q4: White paper on the status of operational minimization strategies to reduce bat fatalities at wind turbines

IEA Wind Task 34 (moved to a separate project): focus is on white papers, WREN Hub, synthesis, and outreach and engagement activities. Milestones/Deliverables:

Q1: Factsheet on adaptive management white paper

Q2: One-page synthesis; specific topic to be determined

Q3: Present status report to IEA Wind ExCo

Q4: Manuscript submitted to peer review journal (*Considerations for upscaling individual effects of wind energy development towards population-level impacts on wildlife*)

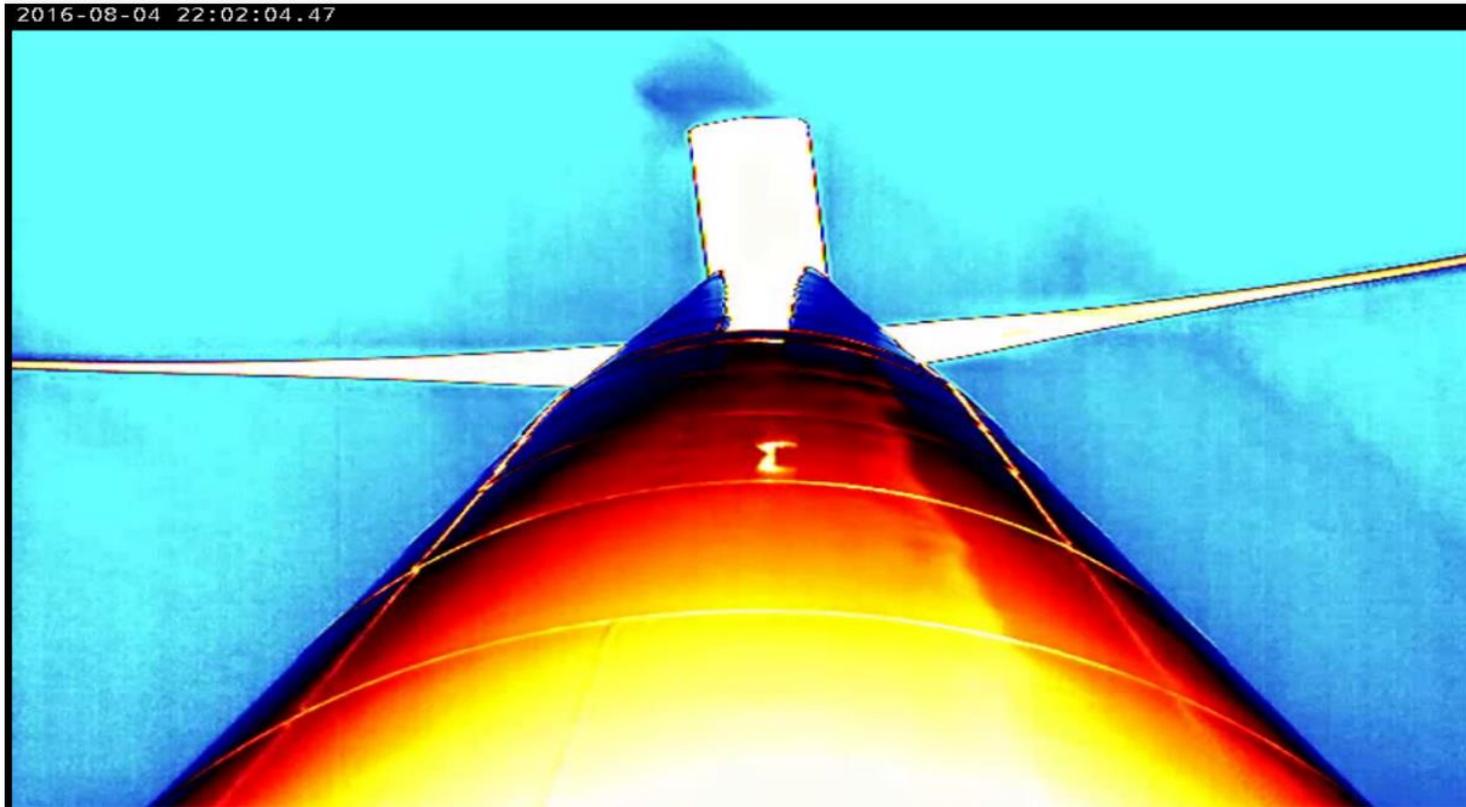
Future efforts include science-based research that lead to reduced risk for wildlife (especially bats and golden eagles) and increased deployment of wind energy. Efforts must align with DOE Environmental Research Strategy (under development). Research results will be publicly available and disseminated through the outreach efforts as part of this project.

Potential expansion activities within LBC, prioritized with input from Expert Panel, may include

- Eagle collaborative, to pull together stakeholders and focus efforts
- Resume grassland community collaborative
- Emerging issues, to focus on bird and bat species at high risk
- Expand webinar series, with particular focus on informing state and federal agencies
- International workshops, with particular focus on information exchange

Potential expansion activities within WREN

- Expanded development of outreach materials, with particular focus on syntheses documents and information dissemination
- Expansion of webinar series, with particular focus on current research results, tools and models, and emerging topics



Texturizing Wind Turbine Towers to Reduce Bat Mortality

Amanda Hale

Texas Christian University
a.hale@tcu.edu 817 257 6182
November 22, 2016

Texturizing Wind Turbine Towers to Reduce Bat Mortality

The Challenge:

- Large numbers of bats are being killed at wind turbines worldwide
- Limited understanding of why bats are coming into close contact with wind turbines
- Need to develop technologies that reduce bat mortality, especially technologies that do not incur losses in power production.

Partners:

- Texas Christian University: study design, flight room testing, and bat behavior field studies
- NextEra Energy Resources: wind farm operation, texture coating development, and tower application.

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

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

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

- Commercialization of innovations and technology transfer
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The Impact

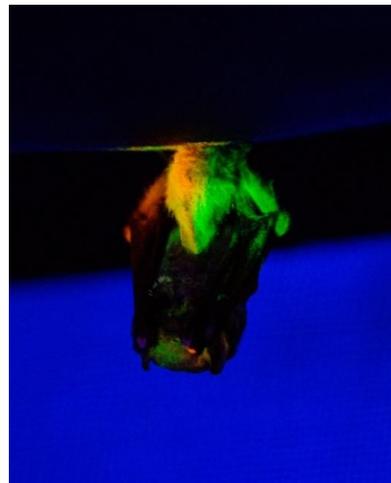
- Based on the water attraction hypothesis, this project is developing a turbine tower coating that bats show little or no interest in approaching.
- The prediction is that a texture coating will contribute to a reduction in bat mortality by decreasing the amount of time bats spend investigating the tower surface within and near the rotor swept zone.
- Texture coating will have no impact on power generation.
 - Durable, one-time application to the non-moving parts of monopole turbine towers
- The target market includes existing wind farms, turbine manufacturers, and wind farm developers.
- Commercialization efforts will focus on 1) geographic areas with high risk for bat mortality, and 2) areas with threatened and endangered bat species.

- The project hypothesis is that echolocating bats perceive wind turbine tower surfaces to be one or more resources, such as water, and that this may contribute to bat-wind turbine fatalities.
- Bat mortality at wind turbines is a significant challenge for wind farm operations and development.
- There is a pressing need for technological solutions that do not reduce power generation.



Budget Period (BP)1: Tasks 1 and 2

- Texture coating development
- Behavioral experiments with wild-caught bats in a flight facility – part I



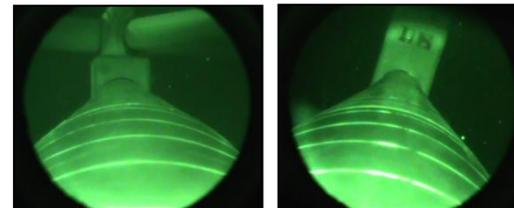
BP2: Tasks 3 and 4 (2016)

- Behavioral experiments with wild-caught bats in a flight facility – part II
- Feasibility study at smooth turbine towers



BP2: Tasks 5, 6, and 7 (2017)

- Coating application to turbine towers
- Bat activity surveys at smooth and texture-treated turbines
- Final analysis and report writing



Tasks 1, 2, and 3:

- Successfully completed two rounds of experiments with wild-caught bats
 - Bat activity differed between the smooth and texture-treated surfaces
 - Bats made contact with smooth vertical surfaces in the flight facility
- Developed a commercially ready texture coating and application plan for turbine towers.

Task 4:

- Observed free-flying bats interacting with and contacting smooth tower surfaces

Project milestones and deliverables:

- Completed on time
- Scope of Work for BP2 was modified during the Go/No-Go decision phase
 - Added a second round of flight facility testing (Task 3)
 - Added the feasibility study (Task 4)
 - Modified the field study to observe bat activity and behavior at an operational wind facility (Task 6)
 - Extended the project length by one year

Project Plan & Schedule

Award Date: July 1, 2015 Notification of Award: July 21, 2015 with pre-award costs approved by the DOE Go Decision: August 10, 2016		Budget Period 1			Budget Period 2						
		Q1 Jul- Sept 2015	Q2 Oct- Dec 2015	Q3 Jan- Mar 2016	Q4 Apr- Jun 2016	Q5 Jul- Sept 2016	Q6 Oct- Dec 2016	Q7 Jan- Mar 2017	Q8 Apr- Jun 2017	Q9 Jul- Sept 2017	Q10 Oct- Dec 2017
Task 1	Testing Behavioral Response of Bats to Textures in Flight Room										
1.1	Make Textured Surfaces for Flight Facility										
1.2	Behavioral Study in Flight Facility										
Task 2	Texture Coating Development, Field Study Design, and Application Plan										
2.1	Texture Coating Development										
2.2	Field Study Design										
	G1 Go/No-Go Decision Point										
2.3	Texture Coating Application Plan										
Task 3	Testing Behavioral Response of Bats to Textures in Flight Room – Part II										
	Milestone 3.1 (5/12/16)										
	Milestone 3.2 (Due Dec. 16 – 1 mo. extension)										
Task 4	Feasibility Study at Control Turbines at Wolf Ridge										
	Milestone 4.1 (5/26/16)										
	Milestone 4.2 (10/28/16)										
Task 5	Application of Coating to Turbines at Wolf Ridge										
	Milestone 5 (Due Apr. 17))										
Task 6	Bat Activity Surveys at Control and Texture-treated Turbines at Wolf Ridge										
	Milestone 6.1 (11/22/16)										
	Milestone 6.2 (Due Oct. 17)										
Task 7	Data Analysis and Final Reporting										
	Milestone 7 (Due Dec. 17)										

Budget History					
FY2015		FY2016		FY2017	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$36.105k	\$30.525k	\$93.131k	\$69.927k	\$119.842k	\$137.430k

- The funds for the field test (FY2016) in the original planned budget were insufficient to cover the coating application in the field test.
- During the Go/No-Go decision phase, the budget was revised for FY2016 and added FY2017 to accommodate two additional tasks and the modified field test.
- NextEra provided \$82,922 in additional cost-share (cash) for the project.
- The total cost-share for the budget is now 48.8%.
- 36.0% of the project budget has been expended to date.

Partners, Subcontractors, and Collaborators:

- Texas Christian University (study design, flight facility testing, behavioral studies, effectiveness evaluation)
- NextEra Energy Resources (wind farm operation, texture coating development, tower coating application)
 - Duromar (texture coating development)
 - Aeolus Energy Group (coating application)

Communications and Technology Transfer:

- The project description and rationale has been shared in a wind-wildlife webinar and in presentations to university classes and interested community groups. As this project is a work in progress, no final reports or publications have been completed.

FY17/Current Research:

The project plans are to complete the following tasks in FY17:

- Apply the texture coating to turbine towers at an operational wind facility (Task 5)
- Estimate levels of bat activity at smooth and texture-treated tower surfaces (Task 6)
- Evaluate the effectiveness of the texture coating at reducing bat activity and contacts with the tower surface by bats (Task 7)

Planned Future Research:

If the texture coating is demonstrated to reduce bat activity and the number of contacts with turbine tower surfaces, we will continue to work with our research partners to determine if a larger-scale field test is necessary while simultaneously working on commercialization efforts.



A Biomimetic Ultrasonic Whistle for Use as a Bat Deterrent on Wind Turbines

Paul R. Sievert

University of Massachusetts Amherst
psievert@eco.umass.edu / 413 545 4888
February 14 16, 2017

A Biomimetic Ultrasonic Whistle For Use As A Bat Deterrent On Wind Turbines

The Challenge: Design a series of ultrasonic pulse generators, or whistles, to be affixed to a wind turbine blade, which produce ultrasound through mechanical means, and thus deter bats from approaching

Partners: 1) UMass Department of Mechanical and Industrial Engineering – whistle design, 2) Texas A&M University – testing whistles as bat deterrents

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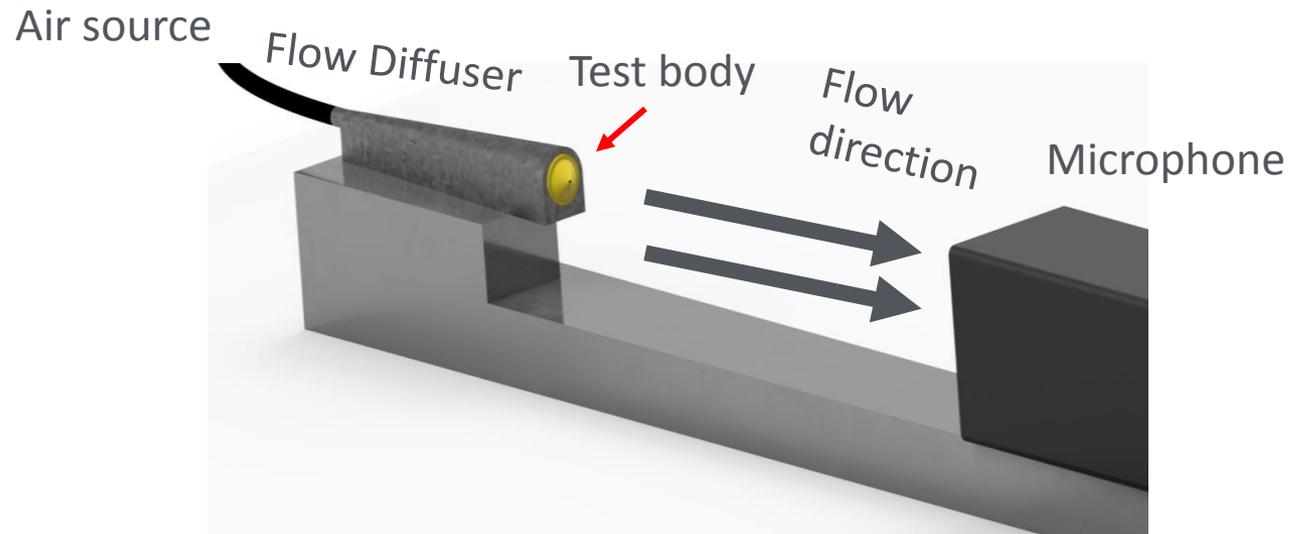
- **Facilitating coexistence between wind energy and wildlife**
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The Impact

- This project will develop ultrasonic whistles that can be attached to wind turbine blades and operate passively.
- The ultrasonic pulse generators will mimic bat echolocation pulses and deter bats, thus allowing wind turbines to operate continuously, even during periods of bat activity.
- The endpoint of the study will be a series of prototype whistles that 1) successfully produce expected ultrasound regimes in the wind tunnel, and 2) generate an avoidance response from at-risk bat species.

- This project will use a biomimetic modelling approach to develop ultrasonic pulse generators (whistles) that are based on the structure of the greater horseshoe bat larynx and the concave-eared torrent frog larynx.
- Whistles will be designed in the Fluid Structure Interactions Laboratory and tested in the wind tunnel facilities at the University of Massachusetts Amherst.
- The effectiveness of the ultrasound deterrent will be tested on three bat species by Dr. Michael Smotherman at Texas A&M University.
- Whistle placement on turbine blades will be guided by Dr. Matthew Lackner of the UMass Wind Energy Center.

Experimental Setup for Testing Ultrasonic Whistle



-Experimental tests of whistles were conducted at air pressures of 5 to 30 psi, which is greater than air pressures experienced on operational turbine blades. A concentrator, or funnel, will be placed in front of the whistles on the turbine blades in order to increase the psi to the level needed for whistle function.

- Developed a prototype whistle that produced ultrasound frequencies of 40, 60, 80 and 120 kHz. Tested a flexible output on the whistle and observed frequency jumps (modulation) as seen in a bat larynx.
- Y-Maze experiments were ineffective because bats adapted to the ultrasonic noise and then ignored it; therefore, this experiment was replaced with a Turning Assay.
- Perch Selection and Turning Assay experiments both showed that ultrasounds were an effective deterrent for Mexican free-tailed bats.

- Project initiated September 1, 2015; expected completion date September 1, 2017.
- Go/No-Go decision point originally scheduled for October 2016 has been postponed until February 2017, since ultrasound deterrent tests have only been completed on one of three bat species proposed.
- Remaining milestones and deliverables have been accomplished.

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
NA	NA	NA	NA	\$74.414k	\$62.5k

- There have been no major variances from the planned budget.
- A subcontract is currently being established to support the ultrasound deterrent testing of bats at Texas A&M University.
- 29.8% of the project budget has been expended.
- \$62,500 in matching funds have been provided by the Massachusetts Clean Energy Center.

UMass Collaborators include Dr. Elizabeth Dumont, Dr. Yahya Modarres-Sadeghi, Dr. Matthew Lackner, Dr. Banafsheh Seyed-Aghazadeh, Daniel Carlson, and Zara Dowling. Texas A&M Collaborator is Dr. Michael Smotherman.

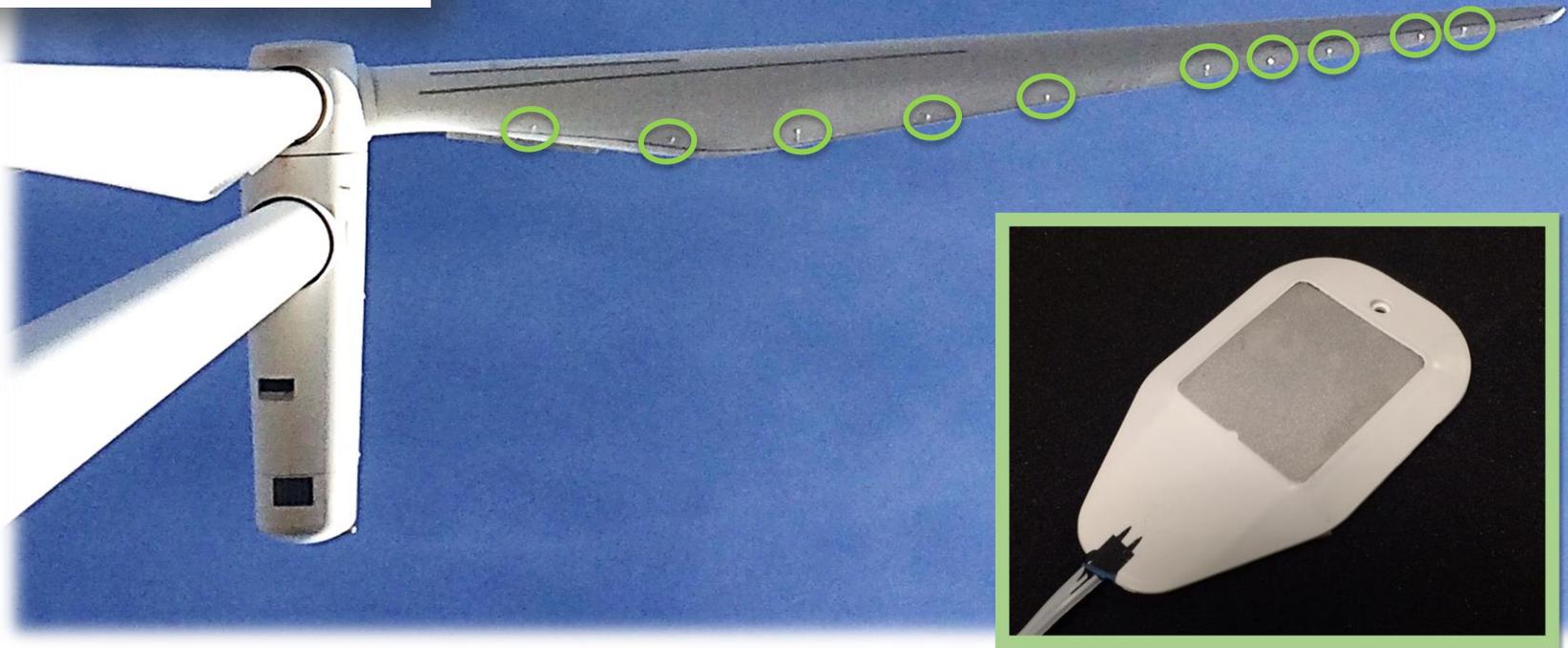
Presentations/Interviews: American Physical Society – Division of Fluid Dynamics, Northeast Bat Working Group, UMass IGERT (*Integrative Graduate Education and Research Traineeship*) Offshore Wind Energy Group, U.S. Forest Service Northeast Research Station - Science Dialog, New England Public Radio, Christian Science Monitor, local high school classes

FY17/Current Research:

- Develop a series of prototype whistles that operate over a range of frequencies, test the whistles on bats in a laboratory, and test their functionality on a wind turbine

Planned Future Research:

- Test ultrasonic whistles on turbine blades of functioning wind farm to document changes in mortality rates for migratory bat species



Rotor-Mounted Bat Impact Mitigation System

Myron Miller

Frontier Wind
mmiller@frontierwind.com
February 2017

Rotor-Mounted Bat Impact Mitigation System:



It is estimated that 600,000 to 888,000 bats are killed in the United States annually. The current solution to reduce bat fatalities is to curtail wind turbines during bat activity. This drives up cost, creates inefficiency, and limits wind power deployment.

Under this program, Frontier Wind is developing a system to deter bats from flying/foraging near the blades of wind energy turbines. Frontier Wind is currently conducting a study of the effectiveness of a bat impact deterrence system that utilizes ultrasound transmitters mounted on a wind turbine rotor. FY 2015–2016 included system development, fabrication, installation, and preliminary fatality monitoring. FY 2017 will include further system improvement and a fatality study during the bat migration season .

The attenuation of ultrasonic frequencies is the primary challenge to envelop the entire rotor with ultrasonic transmissions. Today's average rotor covers more than 11,000 sq. meters. Additional challenges are the development of reliable components exposed to harsh environments and mounting components to a highly flexible wind turbine blade that rotates continuously.

A key aspect of the product development is to design a system capable of being retrofitted to existing turbines to provide for significantly faster deployment.

Partners:



Pacific Southwest Research Station



Bruce Walker, Ph.D.

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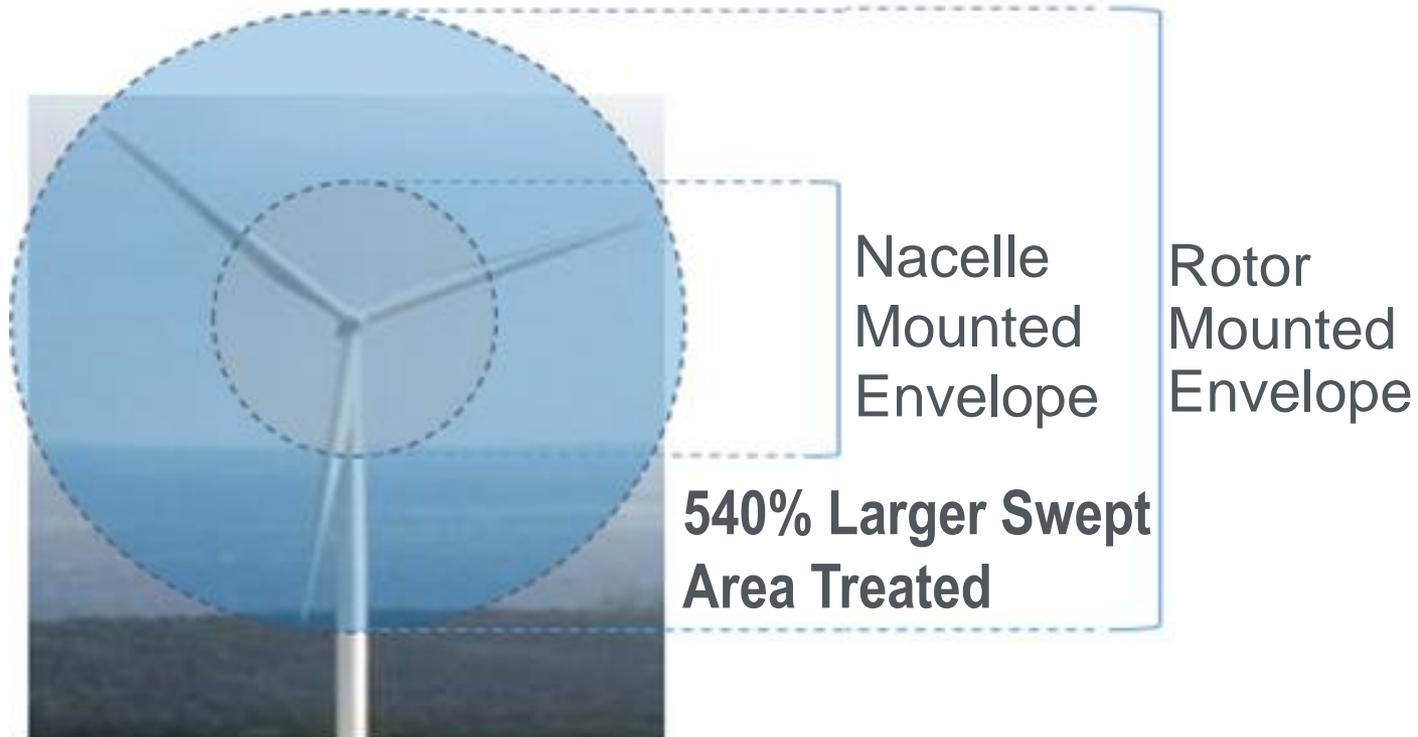
The Impact

- Reduced bat fatalities
- Wind power cost is a function of productivity and capacity factor; curtailment of turbines results in lower capacity factors, utilization, and efficiency; and higher energy costs
- A successful rotor-mounted bat deterrent system can open up areas that were previously not economical because of curtailment requirements and wildlife interaction

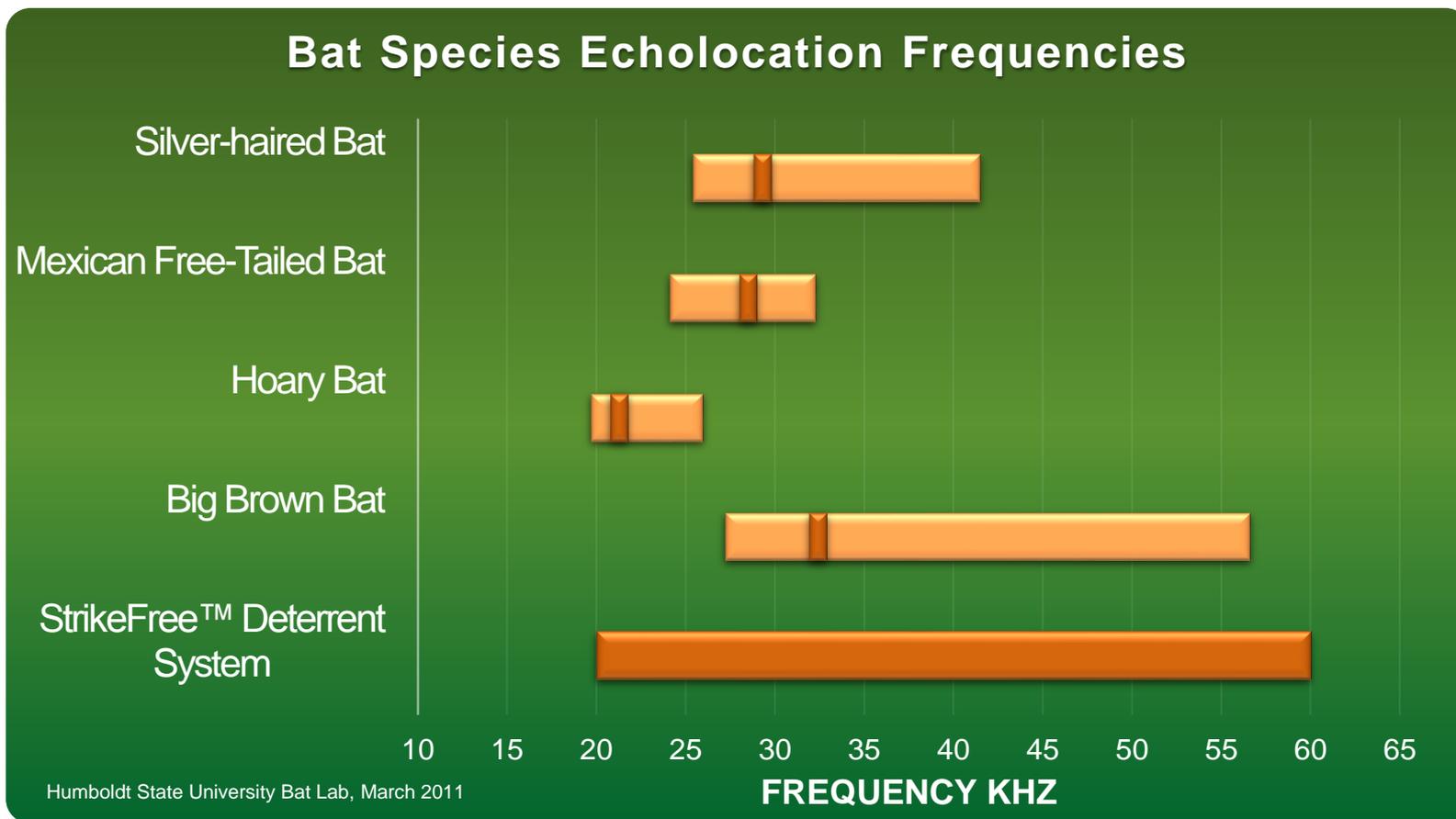


- Invent, design, and fabricate an ultrasonic bat deterrent that acoustically treats the entire wind turbine rotor

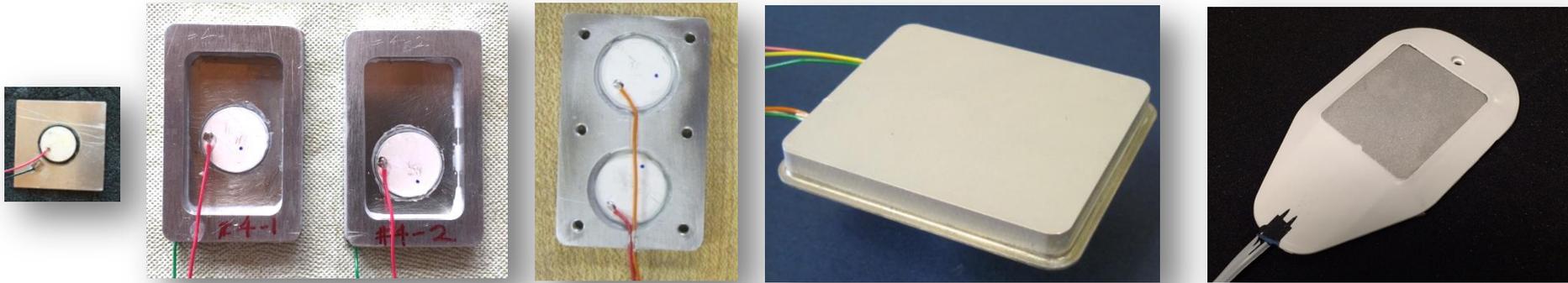
This unique approach ensonifies the **entire wind turbine rotor** with ultrasonic noise versus treating the nacelle alone.



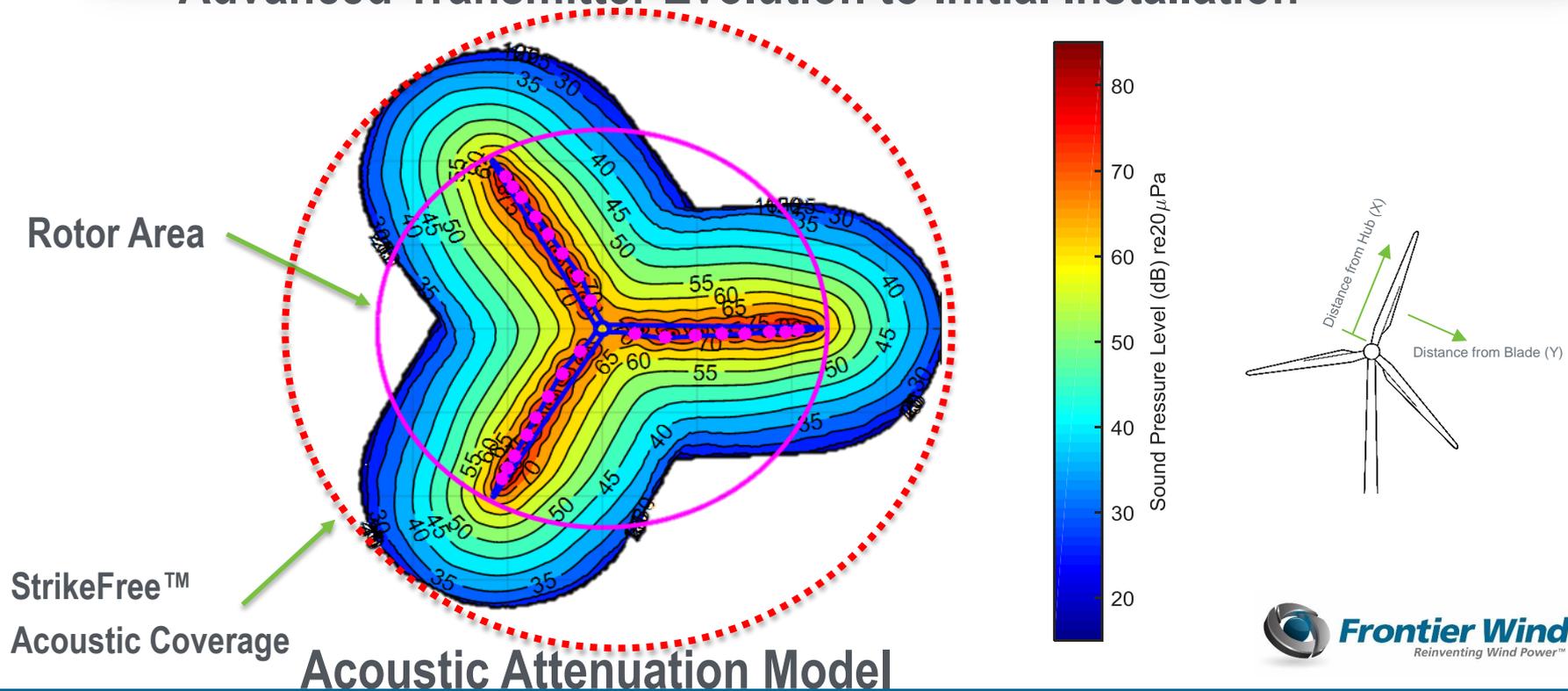
- Install the system in a field of wind turbines
- Demonstrate the effectiveness



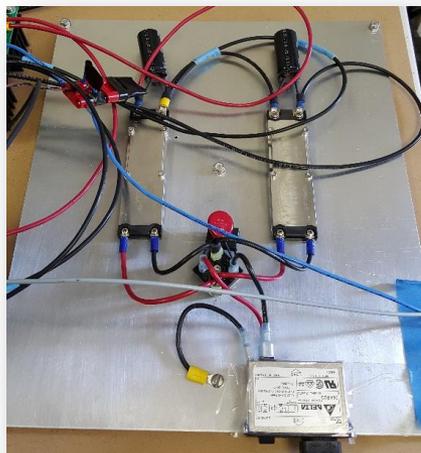
Accomplishments and Progress Transmitter & Acoustic Attenuation



Advanced Transmitter Evolution to Initial Installation



Accomplishments and Progress Controller Development



Advanced Controller Evolution to Initial Installation

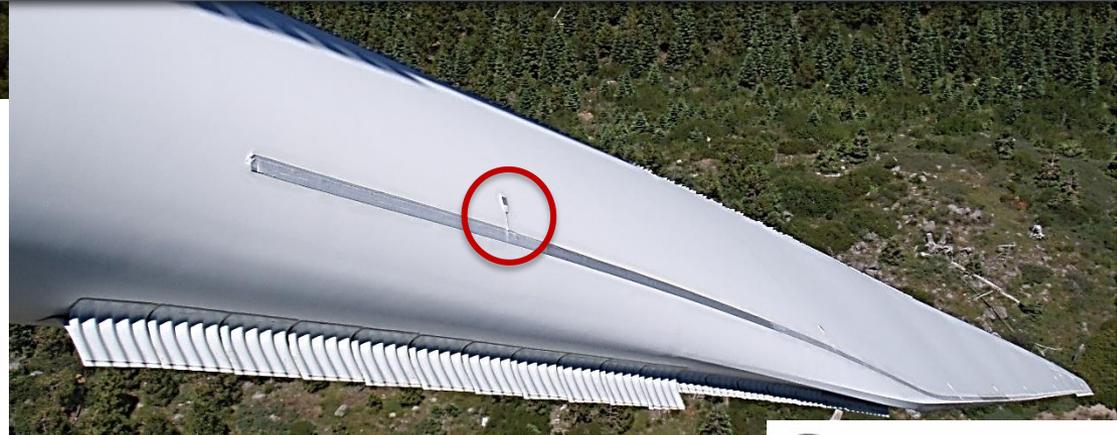
Hatchet Ridge Wind Farm Installation



Facility	Hatchet Ridge Wind Farm
Owner	Pattern Energy
Location	West of Burney, CA
Generating Capacity	101.2 MW
Number of Units	44
Commercial Online Date	2010
Manufacturer	Siemens

Siemens 2.3 MW Wind Turbine Specs

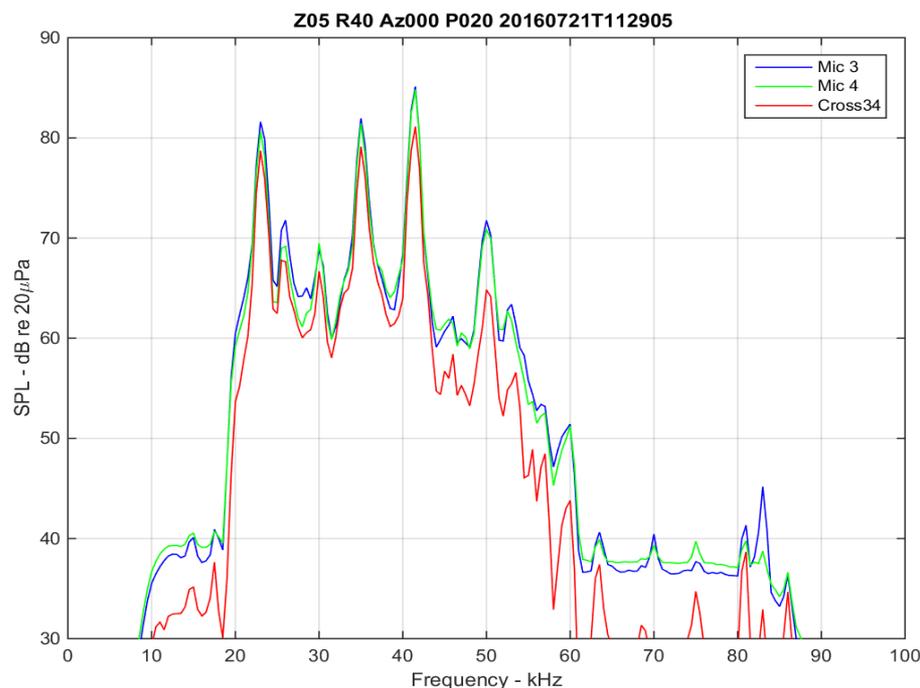
Rotor Diameter: 93m
Tower Height: 80m
Cut-in: 4 m/s
Cut-out: 25 m/s





Microphone Array

Field Measurements Exceed Targets



The field measured spectra show that at the primary peaks in the actuator design, levels exceed requirements.

Tasks Complete

TASK 1: Site characterization and System Specification

TASK 2: System Design and Lab Testing

TASK 3: Assemble and Install System

Tasks In-Progress

*TASK 4: Perform System Field Tests Perform System Field Test, Bat Activity Study
Adjust system configurations to respond to on-site conditions.*

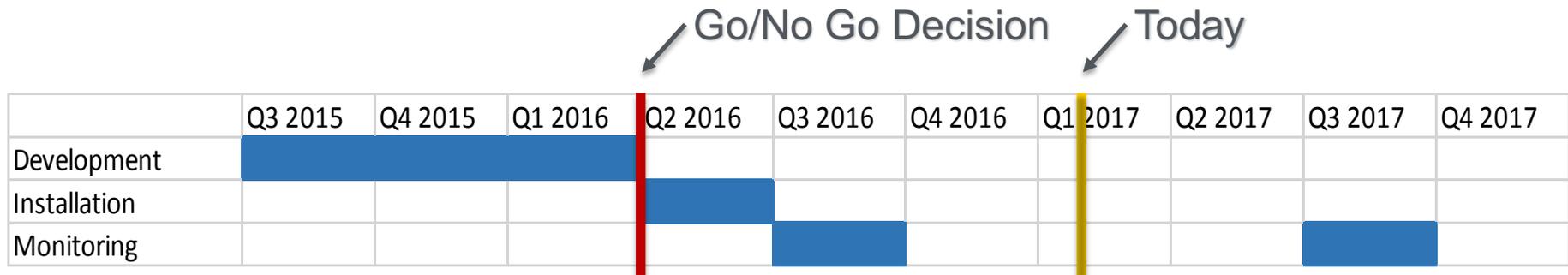
System input power monitoring

Future Tasks

Further reconfiguration / re-installation

2017 bat migration fatality study

TASK 5: Evaluation of Benefits



Budget History			
FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share
\$17.8K	\$10.4K	\$246.8K	\$78.6K

- Additional funding provided by
 - California Energy Commission (CEC)
 - Frontier Wind



Partners, Subcontractors, and Collaborators:

Taber Allison, Ph.D. – American Wind Wildlife Institute Director of Research and Evaluation

Rene Braud - Director of Environmental Compliance and Policy – Pattern Energy

Jocelyn Brown-Saracino – Environmental Research Manager - U.S. Department of Energy

C.P. van Dam, Ph.D. – Warren and Leta Giedt Professor and Department Chair, UC Davis

Wallace Erickson - Chief Executive Officer and Board of Directors – Western Ecosystems Technology (WEST) Inc.

Jeff Gruver - Consulting Ecologist/Senior Bat Biologist – WEST Inc.

Bronwyn Hogan – US Fish and Wildlife Service

Manuela Huso - Research Statistician – U.S. Geological Survey Forest and Rangeland Ecosystem Science Center

Scott Osborn, Ph.D. – California Department of Fish and Wildlife

David Stoms, Ph.D. – California Energy Commission – CEC Grant Manager

Bruce Walker, Ph. D. – Walker Consulting – Principal Acoustics Consultant

Ted Weller – Ecologist - Pacific Southwest Research Station – U.S. Department of Agriculture Forest Service

Communications and Technology Transfer:

- Dec 2, 2015, National Wind Coordinating Committee Webinar: Bat Detection and Deterrence Technologies
- Nov 29, 2016 Wind Wildlife Research Meeting XI – Poster Presentation
[Rotor-mounted Bat Impact Deterrence System](#) – Myron Miller, Frontier Wind

FY17/Current Research:

The planned fatality study includes the 2017 bat migration season to provide statistically significant data to demonstrate effectiveness of the bat deterrent system

Demonstrate the effectiveness of the installed system in lieu of wind turbine curtailments that reduce energy production

Planned Future Research:

Commercial Product Development
European Engagement



Ultrasonic Bat Deterrent Technology

Kevin Kinzie

General Electric Company

Kevin.Kinzie@ge.com 864 254 3959

February 2017

Ultrasonic Bat Deterrent Technology:

Advance the understanding of how bats respond to ultrasonic sound in a laboratory environment, on the ground in a natural setting, and in the vicinity of turbines. Use this information to 1) refine the device (amplitude and/or frequency of the acoustic signal) and/or 2) refine the deployment strategy (more devices, strategic placement). Research will culminate in a 2016 study of a turbine-mounted deterrent system at the California Ridge project that incorporates the design and deployment insights learned from the behavioral studies. Moreover, the proposed research will make significant strides toward improving our understanding of how bats respond to ultrasonic sound and how bats behave around wind turbines, which collectively may stimulate other technological advances to reduce bat-wind turbine mortality.

The Challenge:

The challenges to understand and mitigate the impact of wind energy on bats is especially difficult given the size of the wind turbines, the environments in which they operate, the difficulties of studying a nocturnal flying organism, and the seasonal nature of peak bat activity during fall migration. It has proven difficult to create a highly effective ultrasonic sound field around a turbine that produces avoidance equally impressive as that observed on the ground.

Partners:

- **Texas Christian University** – Subawardee – Technical research
- **California Ridge Wind Energy LLC**– Consultant – Wind Farm Operator
- **Shoener Environmental** – Consultant – Field Team and Data Management
- **Skalski Statistical Services** – Consultant – Statistics and Data Analysis

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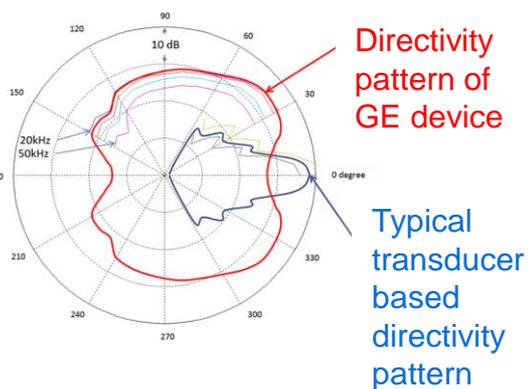
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The Impact

- Targeted effectiveness of the deterrent is a 50% or greater reduction in estimated bat mortality.
- Proposed research will make significant strides toward improving our understanding of how bats respond to ultrasonic sound and how bats behave around wind turbines, which collectively may stimulate other technological advances to reduce bat-wind turbine mortality.
- Conducting behavioral studies in controlled (i.e. flight room) and in small-scale (e.g. foraging area) environments that will enhance the information gathered during field testing is of paramount importance to the eventual commercial viability of the deterrent device.

- 1) Develop causal bat behavioral characteristics to understand:
 - How bats respond to various ultrasonic stimuli
 - Deterrent effectiveness on different species and in different bat environments (i.e. foraging, near turbines)
 - How bats interact with operating wind turbines with and without the deterrent operating using video imaging and 3D flight mapping
- 2) Redesign of existing GE deterrent system based on new behavioral learnings and test the efficacy in a operating wind farm



Flight Room Behavioral Testing to Document Response to Ultrasonic Signals



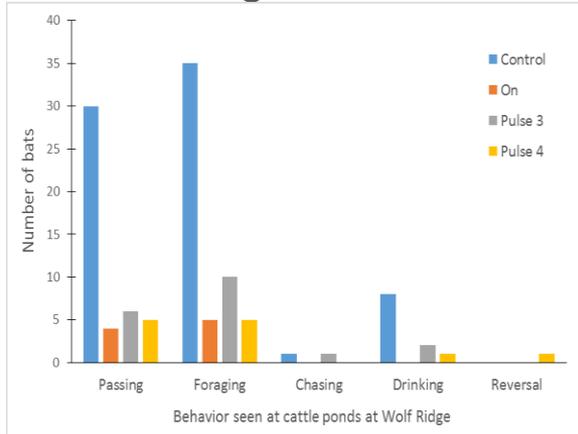
Ground-Based Deterrent Testing to Identify Deterrent Characteristics

3D Flight Mapping of Bat Motion Around Turbine



Field Testing of Redesigned Deterrent Installed in Operating Wind Farm

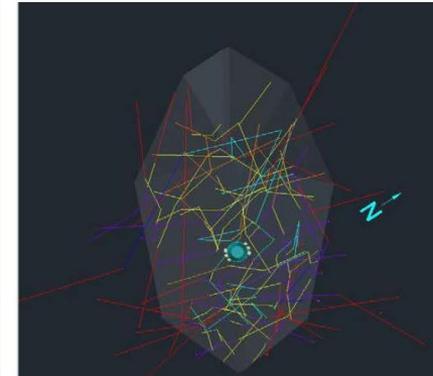
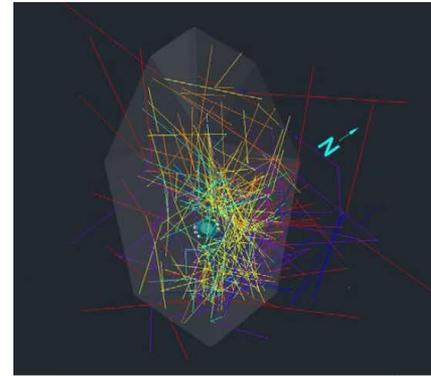
Ground Testing of Pulsed Deterrent



2015 Flight Path Mapping Around Turbine

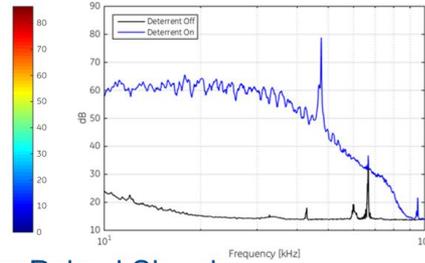
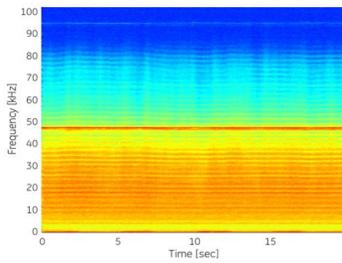
Silent Control

Deterrent

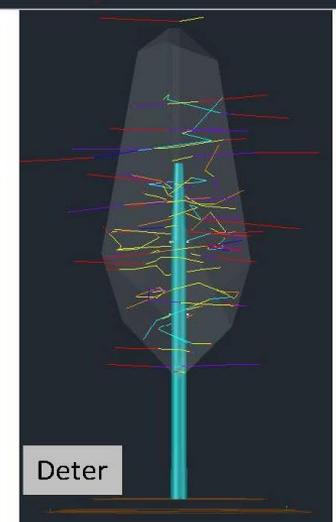
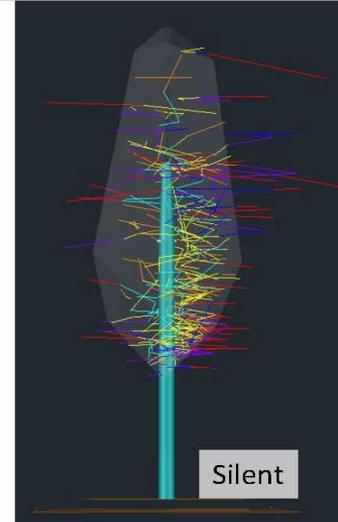
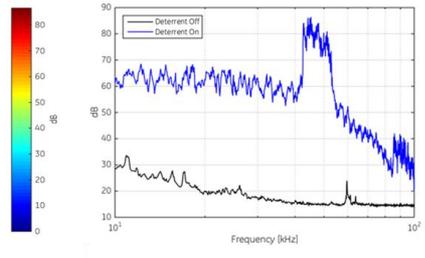
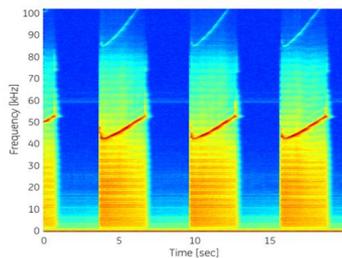


Redesigned Pulsed Deterrent Signal

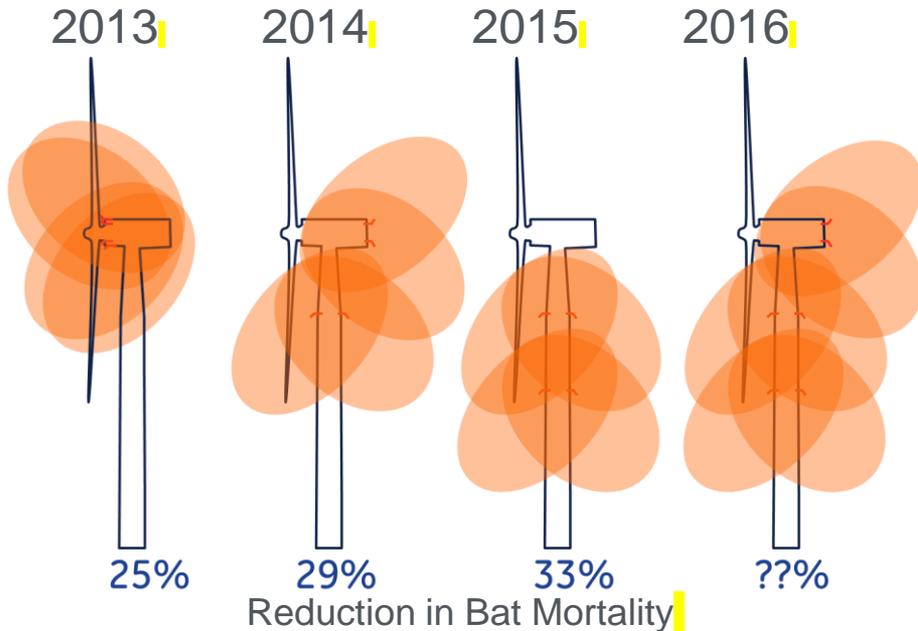
Continuous Signal



Pulsed Signal



Development of Deterrent Configurations at California Ridge



- Study at California Ridge (234 GE 1.6-100 turbines)
- 3-year study (2013-2015) independent of DOE program
- 1-year study (2016) included in DOE program
- Study design:
 - 20 turbines outfitted with deterrents in 2013-2015; 12 turbines outfitted in 2016
 - Six night treatment blocks; control and treatment switched after three nights; treatment and control groups randomized every six days; combination of manual and dog searchers (over 90% searcher efficiency)

Key Findings to Date

- Results from 2013-2015 indicate approximately 30% reduction of bat mortality; each year with different installed deterrent locations (continuous operation deterrent mode). Mortality reduction jumps to 56% if E. Red bats are excluded from data.
- Pulsed deterrent operation mode in 2016 experienced unexpected bursts of water vapor as byproduct of compression in field environment
- Field testing modified for 2nd half of testing season in attempt to isolate effects of pulsing and water emission
- Preliminary results from 2016 indicate a degradation in deterrent effectiveness. Data analysis focused on understanding if degradation is result of technological or biological effects.

Project Plan & Schedule

Project Quarters ->		Budget Period 1			Budget Period 2			
		Q1	Q2	Q3	Q4	Q5	Q6	Q7
Calendar Quarters ->		2015		2016	2016			2017
		Q3	Q4	Q1	Q2	Q3	Q4	Q1
BUDGET PERIOD 1								
Task 1	Flight Room Testing							
1.1	Acoustic Signal Development							
1.2	Behavior Test in Bat Test Facility							
Task 2	Ground Testing							
2.1	Wolf Ridge Turbine and Cattle Pond - paired study							
2.2	Myotis Effectiveness Evaluation							
Task 3	Deterrent Integration Design during BP1							
3.1	Determine Deterrent Location							
3.2	Design Pulsing System							
3.3	Initiate Design Modified Integrated Deterrent System							
Task 4	Turbine Field Study during BP1							
4.1	Thermal Imaging and 3D Flight Mapping during BP1							
Task 7	Program Management and Reporting							
	<i>Deliverable: Award Continuation/Technical Report</i>							
	Go/No Go for 2016 Testing							
BUDGET PERIOD 2								
Task 5	Deterrent Integration Design during BP2							
5.1	Complete Design of Modified Integrated Deterrent System							
Task 6	Turbine Field Study during BP2							
6.1	Thermal Imaging and 3D Flight Mapping during BP2							
6.2	Deterrent Field Test during BP2							

Started 2015 ground testing later than planned due to delayed National Environmental Policy Act approvals

- Requested no-cost extension of BP1 to allow for additional ground testing due to late start
- Added two weeks additional field testing at Cal Ridge to address issues with deterrents

“Go” decision approval in June 2016 based on results of 2015/16 lab and ground testing

Budget History (\$s Invoiced through 9/30/16)

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
0	0	\$59K	\$64K	\$430K	\$529K

BUDGET CHANGES:

	<u>Total</u>	<u>DOE</u>	<u>Recipient</u>	<u>Notes</u>
• Original Plan	\$1,307K	\$625K	\$682K	
• Revised at Go Decision Point	\$1,396K	\$625K	\$771K	\$89K increase - added Spring 2016 Ground Testing (to make up for delayed program start in 2015)
• Projected Completion	\$1,529K	\$625K	\$904K	\$39K overruns due to installation issues \$94K additional hardware, engineering, and field testing to address field issues

Increased costs covered by recipients

Partners, Subcontractors, and Collaborators:

- **General Electric Company** – Prime Recipient
- **Texas Christian University** – Subawardee – Technical research
- **California Ridge Wind Energy LLC** – Wind Farm Operator – Consultant
- **Shoener Environmental** – Consultant – Field Team and Data Management
- **Skalski Statistical Services** – Consultant – Statistics and Data Analysis

Communications and Technology Transfer

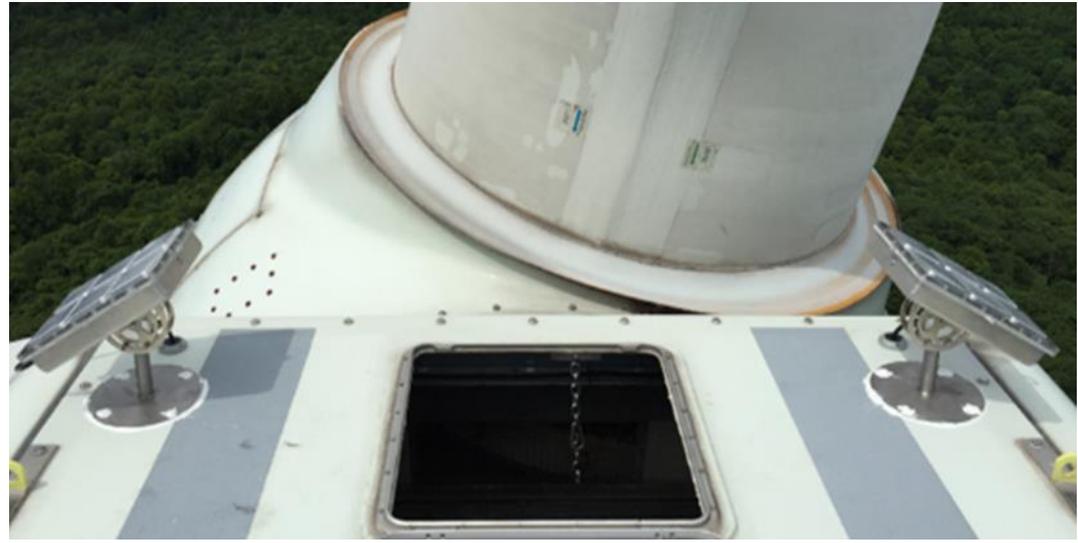
None to-date

FY17/Current Research:

- Analyze Cal Ridge field testing data (carcass and video) to assess effectiveness of pulsing and constant deterrent signals

Planned Future Research:

None



Evaluating the Effectiveness of Ultrasonic Acoustic Deterrents in Reducing Bat Fatalities at Wind Energy Facilities

Cris Hein

Bat Conservation International
chein@batcon.org; 706 621 1975

February 2017

Evaluating the Effectiveness of Ultrasonic Acoustic Deterrents in Reducing Bat Fatalities at Wind Energy Facilities

The Challenge: Developing a technology that provides a cost-effective means of reducing impact of wind turbines on bats

Avangrid Renewables—Wind energy industry partner
Renewable NRG Systems—Technology manufacturer
U.S. Geological Survey—Study design and analysis

Enabling Wind Nationwide

Enabling U.S. Industry Growth and Enabling U.S. Competitiveness

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

Enhancing U.S. Energy Security and Independence

- **Facilitating coexistence between wind energy and wildlife**
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- Successful coexistence with radar systems
- Wind energy workforce and education development
- Advancing grid integration

Strengthening Domestic Manufacturing and Providing Local Economic Value in all 50 States

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- World-class test and user facilities
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- Communicating the costs and benefits of wind energy

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The Impact

- Greater power production by industry in regions where endangered bat species occur or in areas where operational minimization is not feasible (i.e., low wind regions)
- Wildlife impact reduction strategy that optimizes power generation
- A commercially ready, cost-effective ultrasonic acoustic deterrent less expensive than operational minimization (i.e., feathering blades and raising cut-in speeds)

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The Impact

- Fewer fatalities at wind turbines equipped with ultrasonic acoustic deterrents
- Reduces overall fatalities of bats, reduces risk of take of a threatened or endangered species and increases perception of wind energy being a 'green' energy
- A commercially ready, cost-effective ultrasonic acoustic deterrent will be less expensive to the wind industry and result in greater implementation

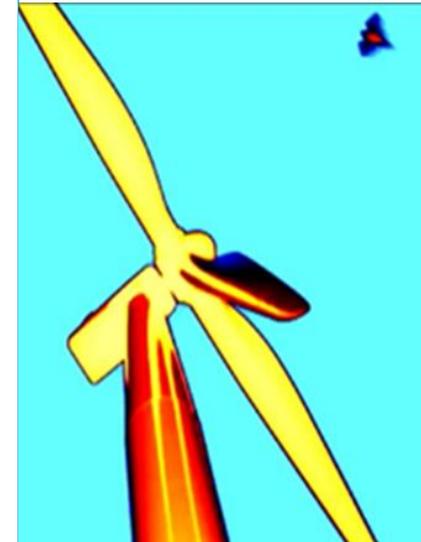
Use thermal video cameras to understand how bats are interacting with deterrents and fatality monitoring to quantify the effectiveness of ultrasonic acoustic deterrents in reducing bat fatalities at wind turbines

Phase 1: Functionality Study

- 1) determine the placement and orientation of deterrents
- 2) conduct initial test of their performance
- 3) compare bat behavior at treatment and control turbines using thermal video cameras.

Phase 2: Comparative Study

- 1) compare deterrents to operational minimization



Testing the weatherization, communication and performance of the deterrents (i.e., were there any operational failures) during Phase 1

Analyzing the thermal video data to compare bat activity levels and behavior at control and treatment turbines (i.e., deterrent-equipped turbines)

This initial field test is critical to remedy any issues prior to conducting the fatality monitoring study (Phase 2) to limit confounding factors and ensure a successful test of the ultrasonic acoustic deterrent.

Improved the performance and weatherization of the deterrent - stronger signal output, and resolved water entry (i.e., passed IP67 reliability tests) and overheating of the previous design

Improved the infrastructure of mounting design-less hardware, greater stability and easier to install

Improved communications-can remotely monitor performance of deterrents, receive status updates, and send commands and firmware updates

Successfully installed deterrents on wind turbines

Successfully completed initial test of the deterrents

- 1 September 2015–30 June 2018
- Milestones 1–3 completed as scheduled
- Milestone 4: Minor delay in completion: greater than anticipated bat observations recorded during thermal video monitoring (previous data suggested approximately 20 bat observations/night, project recorded nearly 100 bat observations/night)
- Go/No-Go decision point:
 - January 2017; Upon completion of Milestone 4
 - Submit Award Continuation/Technical Report
 - Submit Biological Study Plan for peer review

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$0	\$0	\$7.065k	\$147.237k	\$72.146k	\$348.428k

- No significant variance in planned budget and no modifications to project occurred
- As of the end of Q3 2016, approximately 13% of project budget has been spent. Anticipated to spend 17% of budget by Go/No-Go decision point.

Partners, Subcontractors, and Collaborators:

Avangrid Renewables (Vendor)-industry partner providing technical and financial support, and hosting the study at one of their wind energy facilities

Renewable NRG Systems (Subrecipient)-technology manufacturer

U.S. Geological Survey (Subrecipient)-providing statistical expertise and assistance on thermal video analysis

Communications and Technology Transfer:

Only one introductory presentation of this project, given in 2015 during a joint U.S. Department of Energy and National Wind Coordinating Collaborative webinar

FY17/Current Research: Finalize design and placement (Milestone 5.1). Manufacture and install deterrents (Milestone 6.1). Conduct comparative study (Milestone 6.1). Analyze data (Milestone 7.1). Submit final report for peer review and publication in a scientific journal (Milestone 8.1).

Planned Future Research: Direct comparison of deterrents to operational minimization (i.e., feather blades up to 5.0 m/s), and test potential synergistic effect of both strategies

Use a randomized block design to compare four treatments at 16 turbines (four turbines/treatment). We will randomly assign each treatment to four turbines on a nightly basis and monitor fatalities over a 112-night period.



OSW Environmental Data Aggregation, Analysis, and Dissemination

Andrea Coppington

Pacific Northwest National Laboratory (PNNL)

andrea.coppington@pnnl.gov 206.528.3049

February 2017

This Project: Develops technologies and other means of identifying, analyzing, and proposing solutions for potential environmental effects of wind energy development. These environmental effects are slowing and complicating permitting of offshore and land-based wind farms in the United States and abroad.

The Challenge: Offshore wind (OSW) is new to the United States and, while we are learning fast, there are still many gaps in our knowledge of potential effects. Wind and wildlife interactions continue to complicate siting and permitting of land-based wind energy development.

Who Benefits: Determining risks to wildlife from wind farms, and sharing that information broadly, can assist regulators and developers to reduce monitoring and mitigation requirements, and decrease time and cost to deployment.

Partners and their Role:

- U.S. federal agencies (DOE, Bureau of Ocean Energy Management [BOEM], U.S. Fish and Wildlife Service [USFWS], National Oceanic and Atmospheric Administration [NOAA])—planning and oversight of Working Together to Resolve Environmental Effects of Wind Energy (WREN)
- WREN countries (10)—all planning and implementation of WREN
- DOE—planning and oversight of environmental data task

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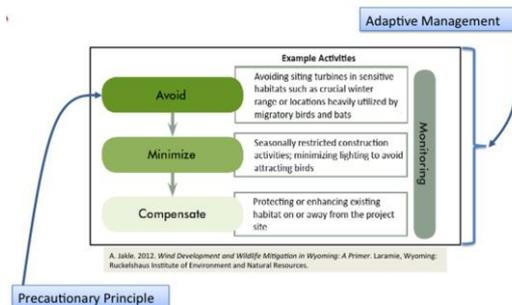
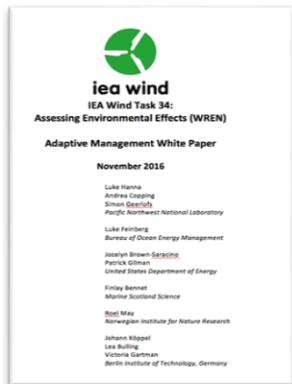
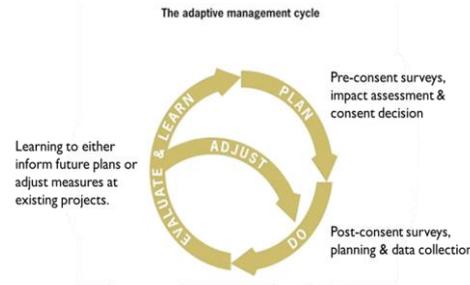
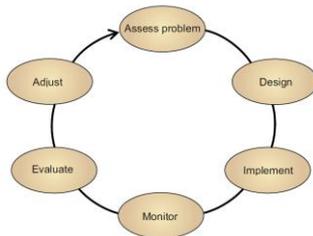
- Facilitating coexistence between wind energy and wildlife
- Offshore wind environments
- Information synthesis and dissemination

Target: Develop technologies and other means to identify, analyze, and propose solutions for potential environmental effects of wind energy development, and distribute the information broadly

Impact: Solutions to potential environmental problems will facilitate faster and more efficient permitting and monitoring of wind energy

Endpoint: Regulators and other wind energy practitioners will better understand risks of wind energy and encourage more efficient siting, permitting, and monitoring

- WREN - Outreach and engagement activities
- WREN - white paper on Adaptive Management:
 - Multiple authors, led by PNNL
 - Understanding use of AM for wind energy permitting in US and abroad

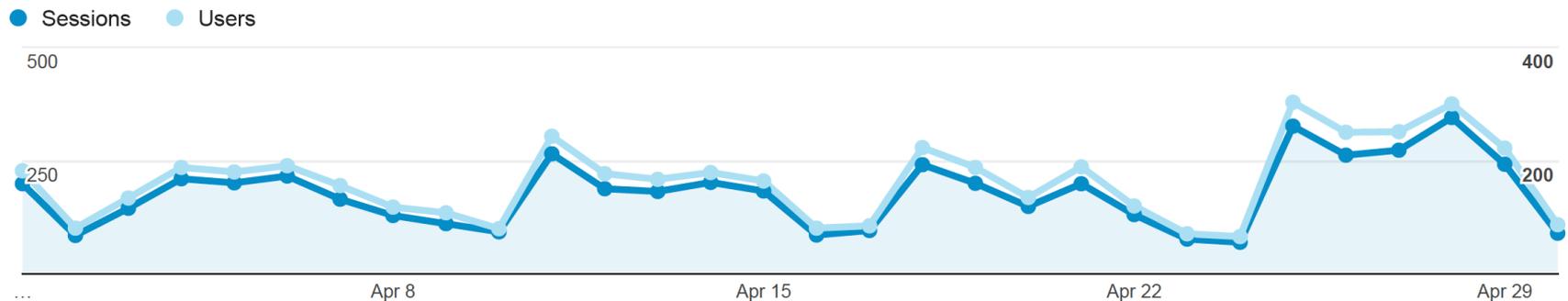


Environmental data analysis of first generation offshore wind farms in United States:

- Examine questions to be answered, data collection methods, analytical solutions
- Explore appropriate repository for OSW environmental data

Tethys Stats from FY14 – FY16:

- Content has grown from 946 to 3,275 documents (x 3.5)
- 400,000 pageviews from 110,000 visitors
- Accessed from 196 countries
- Hosted 12 webinars
- 63 Tethys Blasts to ~1,400 people
- Enhanced cyber security
- Faster load times
- Modern web design
- 12,000 pages on site
- Peak daily access = 324 (4/2015)
- Peak page view = 1415 (4/2015)
- 500 registered users
- 221 followers on Twitter, 138 on Facebook
- Multiple Google Analytics tracked



Major accomplishments include:

- **Tethys**—Adding wind content, providing additional outreach functions for wind energy community (webinars, *Tethys Blast*, etc.)
- **WREN**—Standing up WREN Hub, webinars, outreach plan
 - Adaptive Management (AM) white paper:
 - Need for better AM tools and understanding
 - Scale mismatch monitoring migratory birds and bats at wind farm, versus ecosystem level
- **Environmental data analysis:**
 - Pre- and post-construction data analyzed to establish potential for meta-analyses or information syntheses to further understanding of impacts of U.S. offshore wind farms



WREN Nations:

France	Sweden
Ireland	Switzerland
Netherlands	United Kingdom
Norway	United States
Spain	

Significant Dates and Schedule	Explanation
Project Initiation Date	October 2009
Project Completion Date	September 2017
Slipped milestones/schedule	All significant milestones delivered on schedule; overall schedule on track with plan

Go/No Decisions

Year	FY14	FY15	FY16
Go/No-Go decision point	None	None	Decision whether to request 2nd phase of WREN
Outcome	-	-	Decision to go forward. Request for Phase 2 granted by International Energy Agency (IEA) Wind.

	Budget History					
	FY2014		FY2015		FY2016	
	DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
Total, four tasks	*\$500K	\$0	\$498K	\$0	\$346K	\$0
Without Tech Assessment task	*\$340K	\$0	\$343K	\$0	\$238K	\$0

* Includes \$50K to move *Tethys* to new Drupal platform

- No significant variances from planned budget
- Project budget expended at end of FY16 (except mandatory 25% carryover to FY17)

Partners, Subcontractors, and Collaborators:

Project Partners	Role in Project
NREL	Planning and implementation of WREN. NREL is the Operating Agent
DOE Water Power Program and federal partners (BOEM and NOAA)	Planning and oversight of WREN
WREN country partners: France, Ireland, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and United States.	Planning and implementation of all aspects of WREN

Communications and Technology Transfer:

Publication or Presentation	Impact and Distribution
Three peer-reviewed papers, one book chapter	
Four quarterly webinars per year Environmental topics from international speakers	Live attendance per webinar = 55-138 per webinar Online views = 653-2,808 per webinar
Adaptive management white paper and associated outreach	Prepared for IEA Wind Committee, distributed through WREN Hub and IEA Wind, presented as WREN webinar
Report on environmental data analysis of initial US offshore wind farms, presentation to federal partners	Prepared for DOE
Presentation on WREN Hub (poster)	National Wind Coordinating Committee (NWCC) 2014, >80 attendees
Presentation on Adaptive Management	NWCC 2016, >100 attendees

FY17/Current Research and Planned Future Research:

- Increase in wind content, upgrades to functionality, and maintenance of Tethys continues, with emphasis on speed increases
- Phase 2 of WREN continues through 2020 with increased emphasis on:
 - New white papers
 - Risk-based management
 - Individual effects to population impacts
 - Cumulative impacts
 - Developing *Short Science Summaries* to address key wind and wildlife issues
 - Increased outreach to wind community in United States and abroad.



Stereo-Optic High Definition Imaging: A
New Technology to Understand Bird and
Bat Avoidance of Wind Turbines

Evan Adams, PhD

Biodiversity Research Institute (BRI)
evan.adams@briloon.org; 207 839 7600
February 14, 2017

Stereo-Optic High Definition Imaging: A New Technology to Understand Bird and Bat Avoidance of Wind Turbines

The Challenge: Monitoring and modeling collision mortality of birds and bats in the terrestrial and offshore environment

Partners:

- Software development: UMaine School of Computing and Information Science & New Media at the University of Maine
- Camera system configuration: HiDef Aerial Surveying
- Wind farm operator: SunEdison

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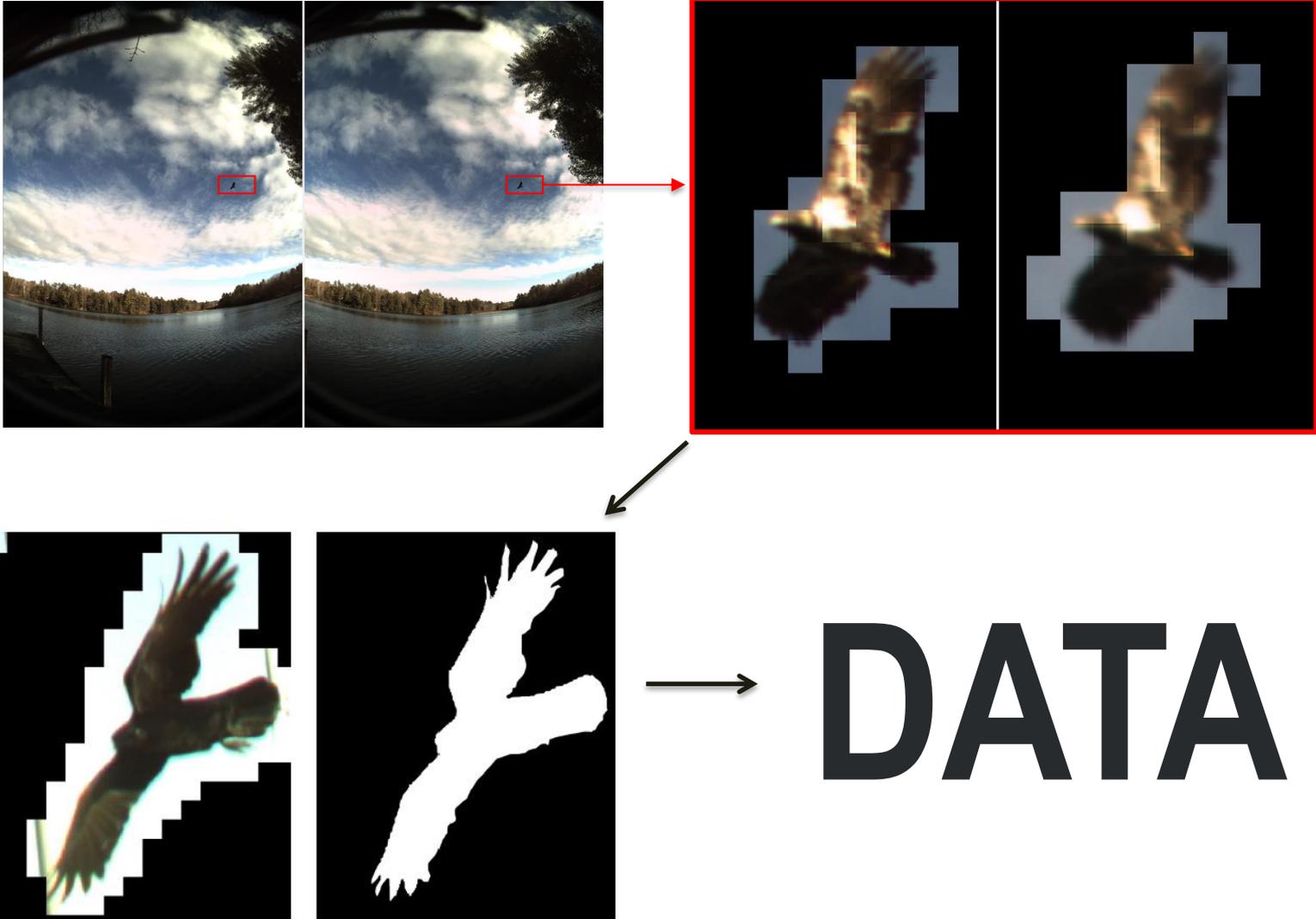
The Impact

- Target: Reduce permitting and mitigation uncertainty
- Impact on industry: Advance a visual monitoring system that can record avian avoidance behavior and interactions with terrestrial and offshore wind turbines
- Final product: A stereo-optic camera system at Technology Readiness Level 5 designed to detect and track birds in three-dimensions around wind turbines



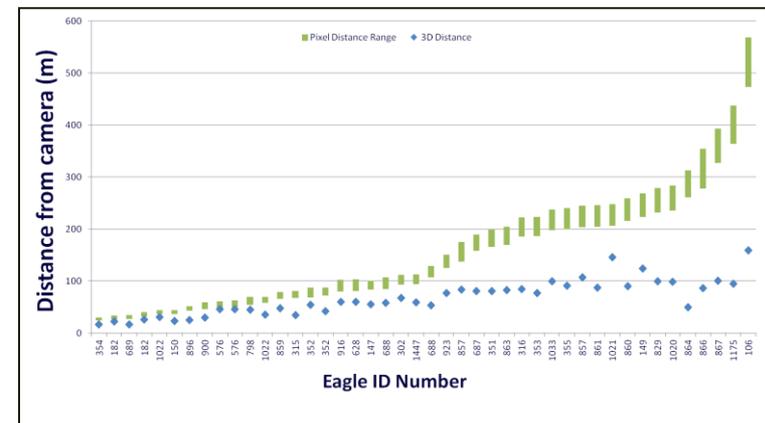
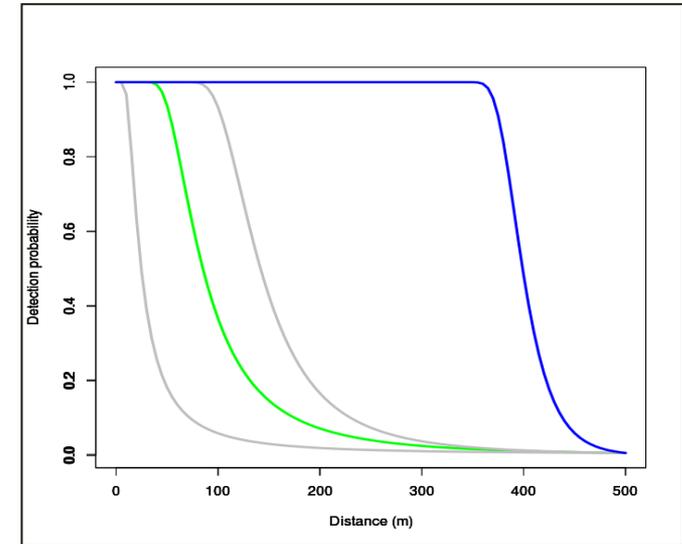
- Position estimation
- Range of detection and identification
- Effectiveness of shape filtering





Accomplishments and Progress

- Detection distance of a 30cm object
 - Day/Night: 200m/30m
 - Eagles IDed up to 352 m
- Field testing
 - 16,173 video segments over a period of 79 days
 - 2,508 video segments analyzed, 1,140 objects detected
 - 51 Bald Eagles observed, 2,033 images
- New bird event viewer developed
- Refined fish-eye lens flattening methods
- Developed method to measure distance using pixel size
- Developed shape recognition algorithms
- Refined 3D algorithm
- Used distance sampling methods to determine strip width
- Develop SOP



- Project duration (Start and End Date): 12/15/14-12/14/16
- Slipped milestones and schedule: Six month no-cost extension
- Go/No-Go decision points: Testing the performance of the camera system in both day and night
 - Daytime system performed well
 - Based upon controlled nighttime field trials, nIR with fish-eye lens did not detect sized bats further than 60m with most detections <30m
 - Resources dedicated to future nIR work were re-directed towards the development of a video post-processing viewer and obtaining baseline nIR images of bats at varying distances

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
NA	NA	\$892.368k	\$880k	\$217.707k	\$20k

- Budget variance: None
- 100%
- Other funding sources: None

Partners, Subcontractors, and Collaborators:

- University of Maine Orono School of Computing and Information Science (Chris Dorr, Reinhard Moratz)
- New Media at the University of Maine (Mike Scott)
- HiDef Aerial Surveying Limited (Mark Robinson, Steve Burns)
- SunEdison (Dave Cowan)

Communications and Technology Transfer:

Website: <http://www.briloon.org/renewable/imaging>

Presentations:

- Conference on Spatial Information Theory XII, Presentation (UMaine)
- American Wind Energy Association Offshore, Poster (BRI)
- National Wind Coordinating Committee, Presentation (BRI)

Report: Final report to DOE currently being finalized

FY17/Current Research:

None. Project complete.

Planned Future Research:

None. Project complete.



Avian Remote Sensing

Shari Matzner, Ph.D.

Pacific Northwest National Laboratory
shari.matzner@pnnl.gov 360 681 4577

February 2017

Avian Remote Sensing: Uncertainty about the effects of offshore wind turbines on birds and bats is slowing U.S. offshore wind energy development. This project develops technology for monitoring offshore locations to better understand risks to birds and bats.

The Challenge: Offshore locations are difficult to monitor. Very little data exist on avian behavior around turbines and on long-term population effects.

Collaborators: National Northwest Marine Renewable Energy Center (NNMREC) – joint data collection, shared lessons learned

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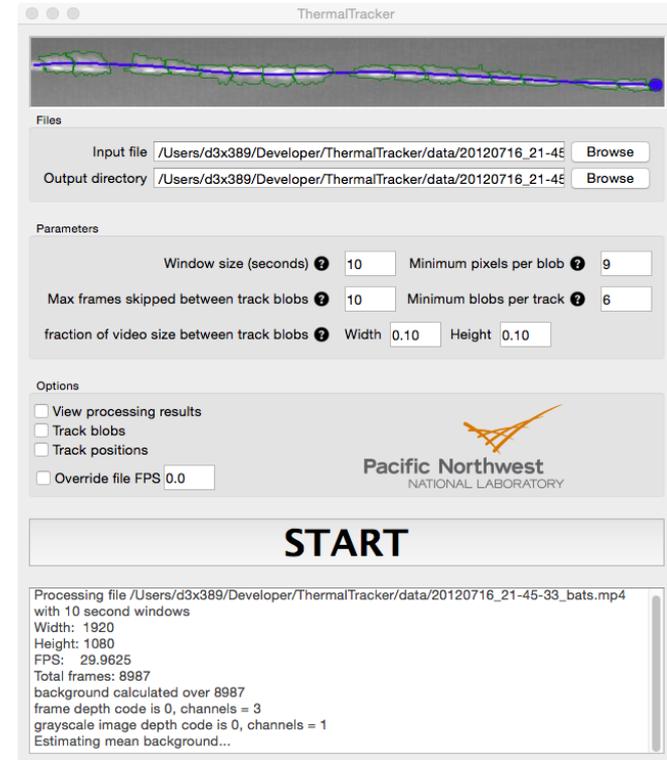
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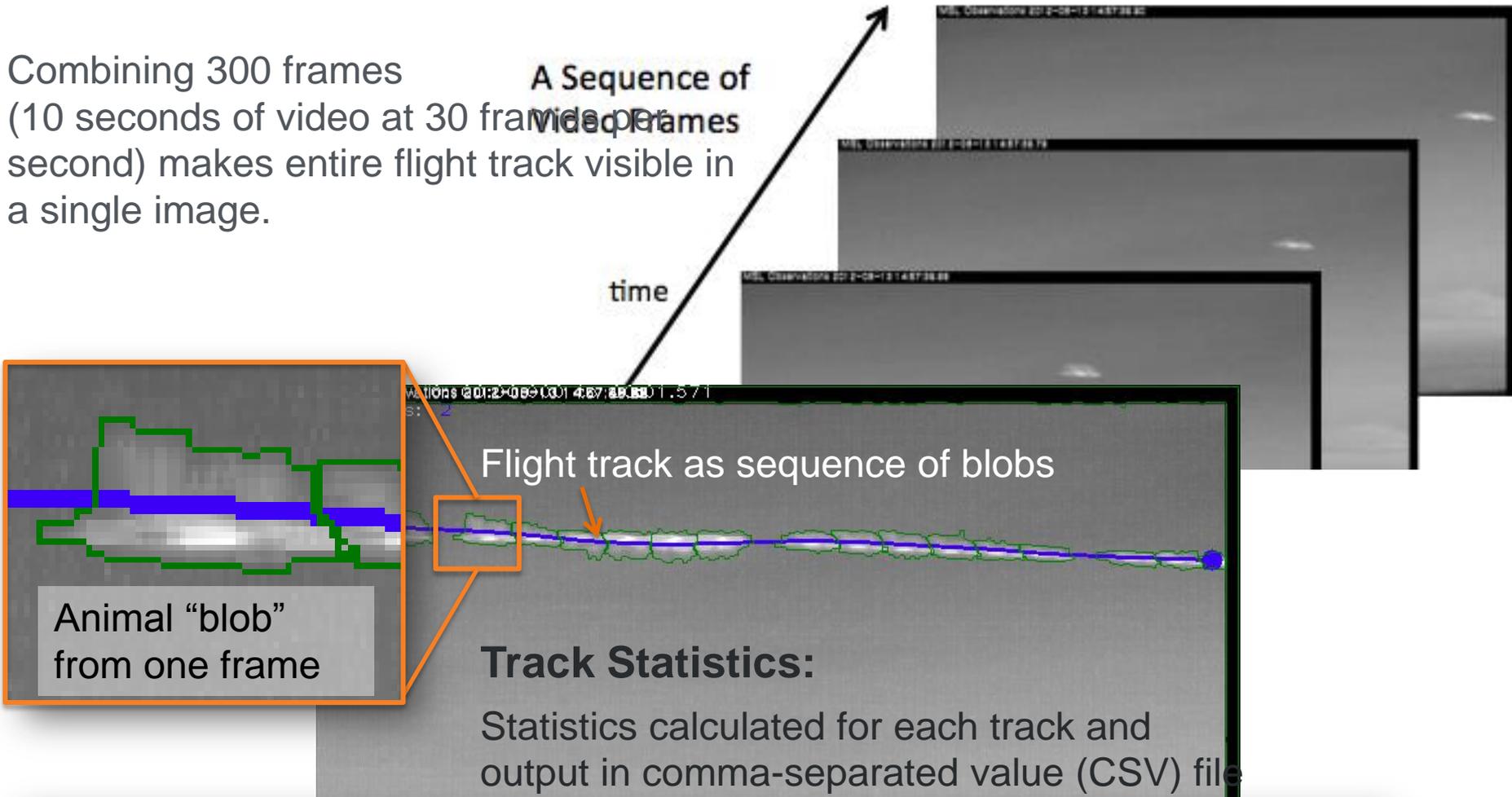
The Impact

- **Target:** Practical, cost-effective technology for collecting data to quantify risks to bird and bat populations
- **Impact:** The technology will accelerate permitting timelines for turbine deployment by simplifying baseline data collection and post-installation monitoring
- **Endpoint:** Regulators and wind energy developers will better understand risks to wildlife and will make siting and permitting decisions that minimize the potential effects of wind resource utilization

- **Thermal video** was selected to enable recording bird and bat activity both night and day, and in low visibility conditions.
- **Automated processing** delivers quantified passage rates and features for species classification, and reduces data volume and analysis costs.
- **Video peak store** is a unique approach that exploits animal temperature contrast with background temperature to capture flight tracks.



Combining 300 frames (10 seconds of video at 30 frames per second) makes entire flight track visible in a single image.



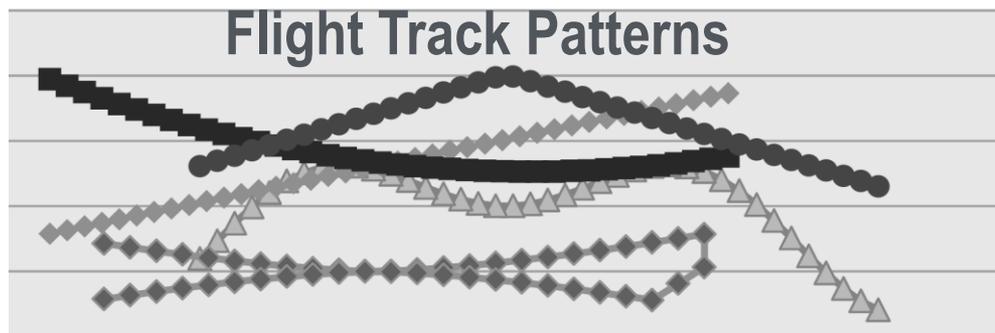
ID	Start		x	y	top/bottom	left/right	End		x	y	top/bottom	left/right
	video time	frame					video time	frame				
2	00:00.3	9	11.4	112	top	left	00:01.0	29	683	136	top	right

Detection performance:

Number of Test Videos	Total Flight Tracks	Detection Rate	False Positives	Over counted*
6	184	81%	6	25

*One track counted as two.

Demonstrated 82% correct classification of species in test data using flight tracks.



Data volume reduced to 18% of raw video size.

426 Mb
of test video



75 Mb
of images
0.063 Mb
of text



- The project originated in as a Lab Directed Research and Development (LDRD) project in FY12.
- The project became part of the Wind Annual Operating Program (AOP) in FY13.
- The project was completed in FY16.

	FY2014	FY2015	FY2016
Quarter One	Software design completed.	Benchmark tests using video dataset.	Graphical user interface added to improve usability.
Quarter Two	Video data collection and annotated for development.	Publication on algorithms and performance.	Report on study of wing beat frequency for classification of species.
Quarter Three	Initial version of software completed and tested.	Added software functionality, fixed issues.	No milestone due to reduced budget.
Quarter Four	Publication on taxonomic classification using flight tracks.	Developed model for wingbeat frequency and compiled allometry data.	Software publicly released as open source.

Budget History

FY2014		FY2015		FY2016	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
\$160k		\$155k		\$108k	

- The budget was reduced in FY16 due to overall Wind Program reductions.
 - Classification algorithm development was postponed.
- 100% of the project budget has been expended to date.
- There were no other funding sources for this project.

Partners, Subcontractors, and Collaborators:

- Northwest National Marine Renewable Energy Center
 - joint data collection
 - advisory meeting
 - shared knowledge
- Software provided on request to two university research projects and one private consultant for early testing.

Communications and Technology Transfer:

- Three presentations at 2014 National Wind Coordinating Committee American Wind Wildlife Institute Research Meeting
- Two publications in *Ecological Informatics* 2015
- Open-source code available at github.com/pnnl/thermaltracker
- HiDef is new industry commercialization partner in FY17.

FY17/Current Research:

- Follow-on project selected by merit review kicked off in FY17
- Transition from offline tool to real-time detection and integration with stereo-optic camera system
- Commercialization is planned through industry partnership (contract pending).

Planned Future Research:

- Field studies to characterize performance under different conditions
- Develop stereo-vision algorithms for thermal video
 - 3D tracks to study avoidance behaviors
 - Locate animals in the rotor-swept zone
- Improve classification using size and wing beat frequency.