U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Analysis and Modeling

2019 Wind Program Peer Review

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April 30 – May 2, 2019

Wind Energy Technologies Office

Overview

Wind Office Vision

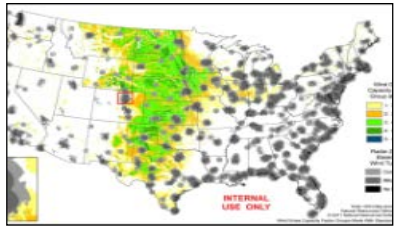
Clean, low cost wind energy as an option nationwide

Wind Office Scope

The Wind Energy Technologies Office aims to accelerate widespread U.S. deployment of clean, affordable, reliable, and domestic wind power to promote national security, economic growth, and environmental quality. Office RDD&D activities are applicable to **utility-scale land** and **offshore wind** markets, as well as **distributed** turbines—typically interconnected on the distribution grid at or near the point of end-use.

Wind Office Programmatic Priorities

- **Reduce the cost of wind energy technology**—targeting near-zero costs with no cost fuel —and increase wind value to the economy in all sectors – land-based, offshore, and distributed; contributing to lower, stable electricity rates, with increased domestic manufacturing, and increased domestic investment
- **Improve wind energy grid integration and increase grid resilience and reliability**; with diverse locations providing value to address extreme weather events and cyber-attacks
- **Reduce market barriers and associated costs** to increase options for responsible deployment in markets where wind is cost competitive; with improvements for local communities through lower pollution and minimized impacts to wildlife and the environment



Wind Office Goals

Enabling Wind Options Nationwide

FY 2017–18 LCOE Targets

- The Office exceeded its Government Performance Reporting Act (GPRA) levelized cost of energy (LCOE) end of year targets for both land-based and offshore wind in Both FY 2017 and FY 2018.

FY 17-18 GPRA Targets

Land-Based Wind: Reduce the unsubsidized market LCOE for utility-scale land wind energy systems from a reference wind cost of $.074/kWh in 2012 to $.057/kWh by 2020 and $.042/kWh by 2030.

Offshore Wind: Reduce the unsubsidized market LCOE for offshore fixed-bottom wind energy systems from a reference of $.18/kWh in 2015 to $.15/kWh by 2020 and $.096/kWh by 2030.

Future Goals

- **LCOE targets:** The office works to achieve breakthroughs in reducing the LCOE for land-based wind by 50% from today's LCOE, to $.023/kWh without subsidies by 2030, and achieving a 50% reduction in offshore wind and distributed wind by 2030 from a 2015 benchmark.

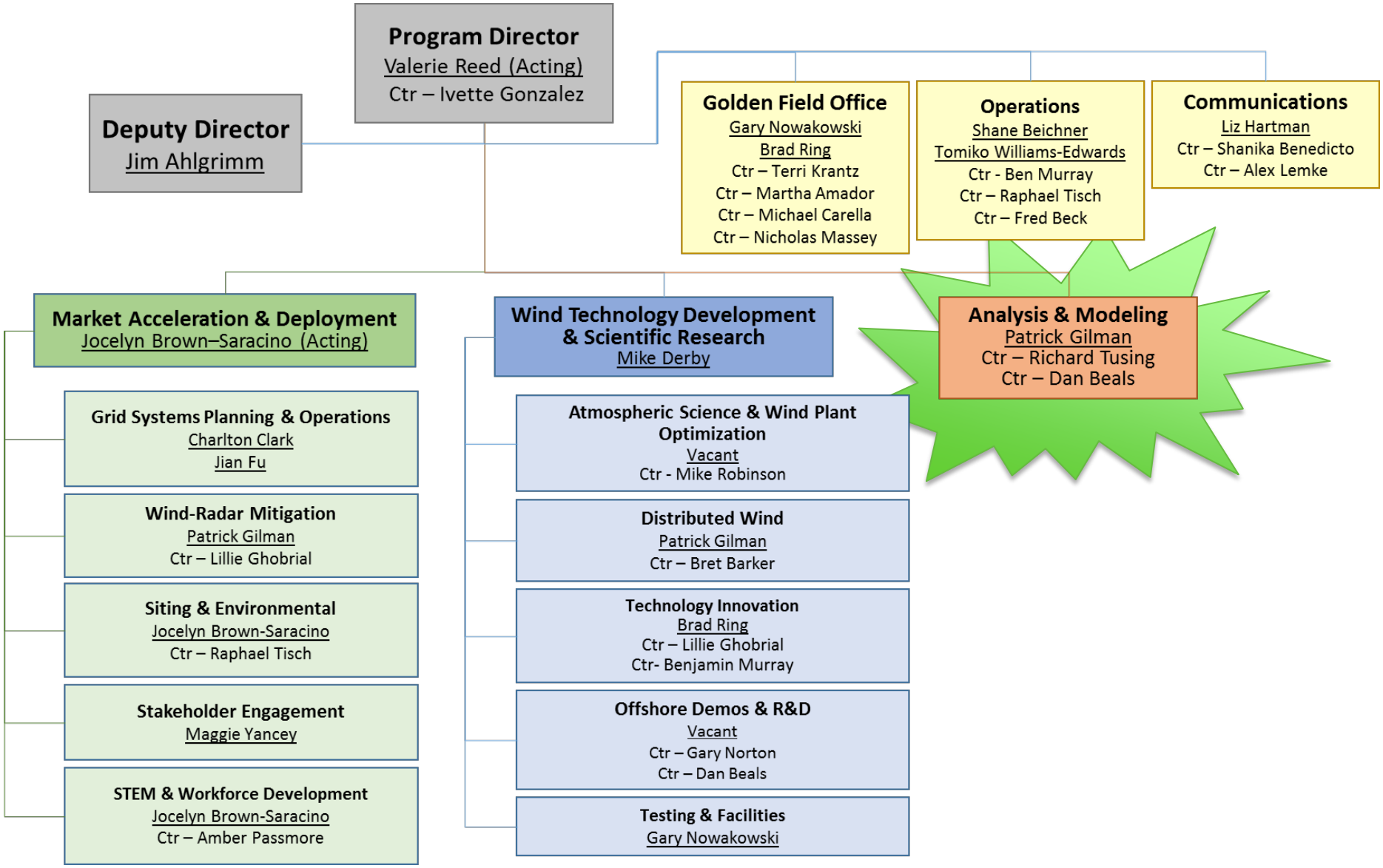
- **Additional non-LCOE targets are under development by the office**

Wind Office Strategic Priorities

Clean, low-cost wind energy options nationwide

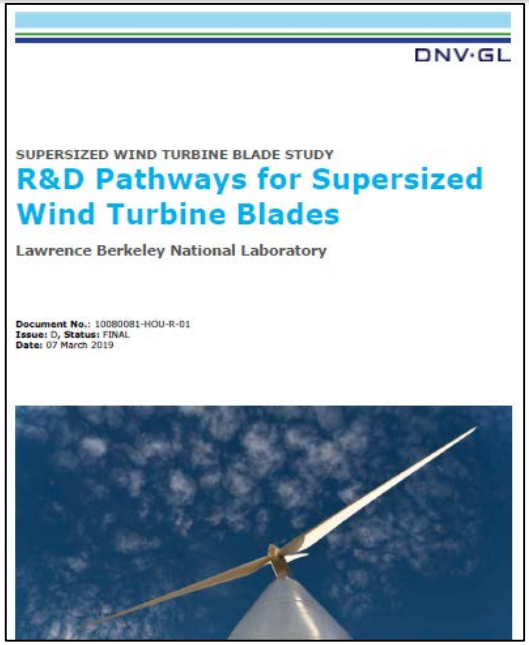
	Land-Based Wind	Offshore Wind	Distributed Wind
Technology Development & Scientific Research	Atmospheric Science & Wind Plant Systems Engineering	Atmospheric Science & Wind Plant Systems Engineering	Atmospheric Science
	Standards and Certification	Standards and Certification	Standards and Certification
	Technology Innovation	Technology Innovation	Technology Innovation
	World Class Testing Facilities	World Class Testing Facilities	
	Tech to Market Commercialization	Tech to Market Commercialization	
	Integrated Systems Design	Integrated Systems Design	
		Offshore Specific R&D	
		Advanced Technology Demo Projects	
Market Acceleration & Deployment	Advanced Grid Integration	Advanced Grid Integration	Advanced Grid Integration
	Workforce and Education Development	Workforce and Education Development	Workforce and Education Development
	Stakeholder Engagement	Stakeholder Engagement	Stakeholder Engagement
	Environmental Research	Environmental Research	
	Siting & Wind Radar Mitigation	Siting & Wind Radar Mitigation	
Analysis & Modeling	Evaluate and Prioritize R&D	Evaluate and Prioritize R&D	Evaluate and Prioritize R&D
	Model Development and Maintenance	Model Development and Maintenance	Model Development and Maintenance
	Techno-economic Analysis	Techno-economic Analysis	Techno-economic Analysis
	Electricity Sector Modeling	Electricity Sector Modeling	Electricity Sector Modeling

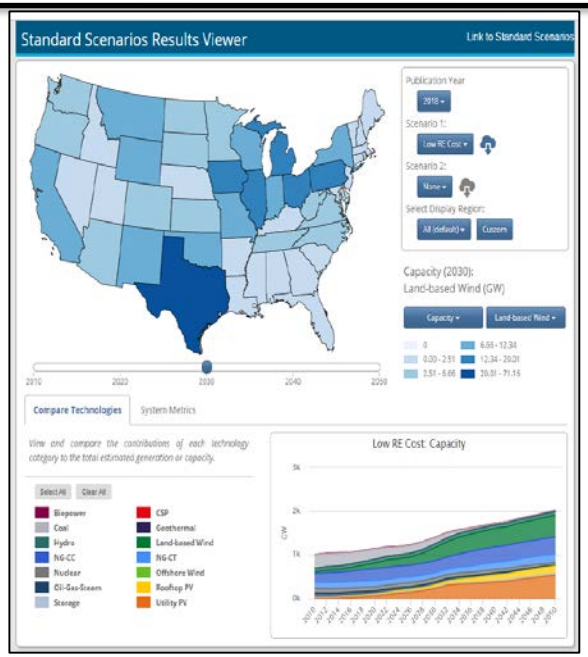
Wind Energy Technologies Office Structure



Analysis and modeling: why and how?

Goals: Ensure WETO 1) sets robust goals and tracks progress against them, 2) makes decisions based on a robust analytical foundation to maximize taxpayer return on investment; and 3) provide deep insight on wind's role in the electricity sector of today and in potential future scenarios.





Market data collection, analysis, and reporting

- Establish technology baselines and industry benchmarks
- Set goals, track progress, evaluate return on investment
- Retrospective cost/benefits analysis

R&D investment analysis and evaluation

- Techno-economic analysis
- Electricity sector modeling
- Model development, validation, and maintenance

Strategic wind energy futures analysis

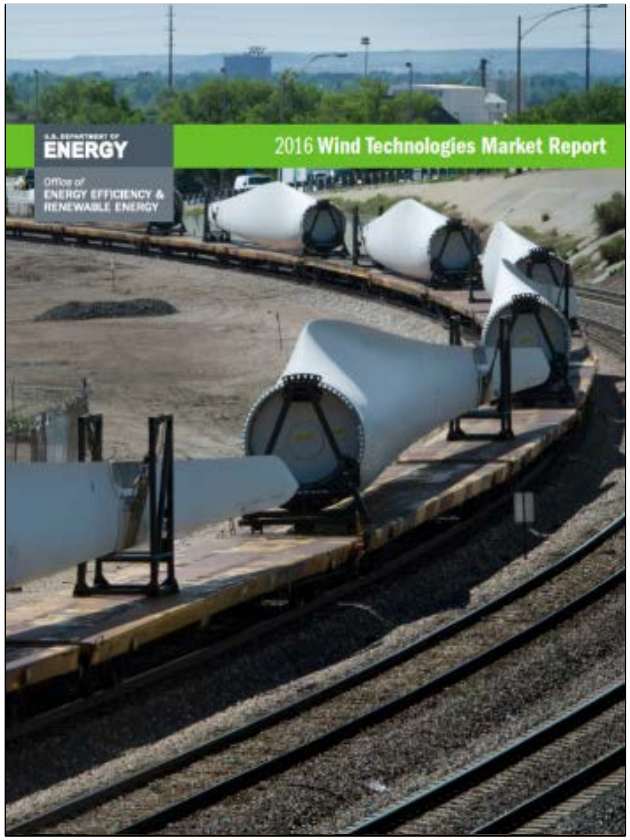
- Electricity sector scenario modeling
- Scenario analysis of wind costs, value to the grid and other benefits
- "Beyond LCOE"
- Model development, "validation", and maintenance
- Deep collaboration across DOE/gov't

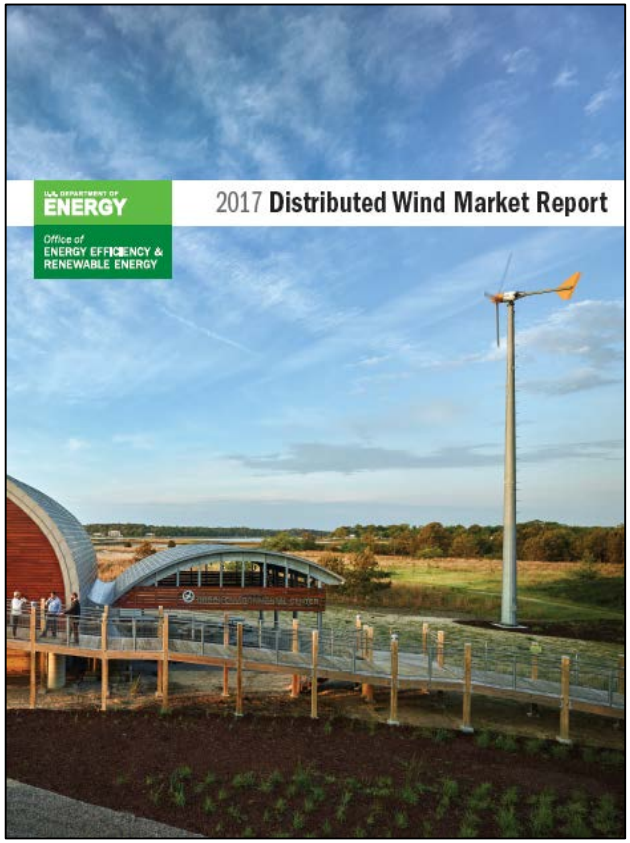
Built on constantly improving, world-class analytical and modeling capabilities

A few examples :

- Cost and performance modeling (SAM)
- Grid planning/Capacity expansion modeling (ReEDS, RPM)
- Agent based technology diffusion (dGen/dWind)
- Multidisciplinary Design and Optimization/systems engineering (WISDEM)
- Grid operation modeling (PLEXOS, REFlex)
- Spatial/economic modeling (reV, ORCA)

Market data collection, analysis, and reporting





Wind Technologies Market Report, Offshore Wind Market Report, Distributed Wind Market Report and associated data establish cost and technology trends, help us set baselines, targets and measure progress against them

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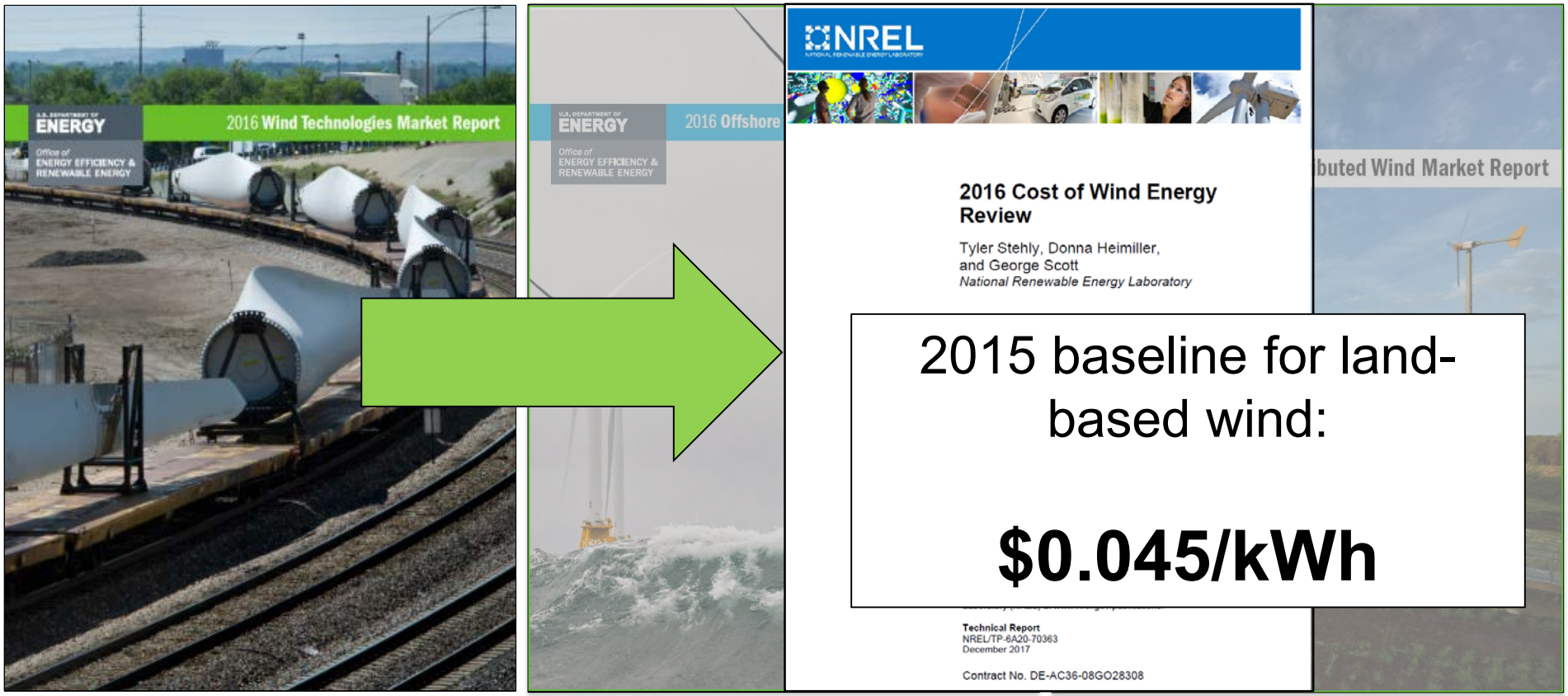

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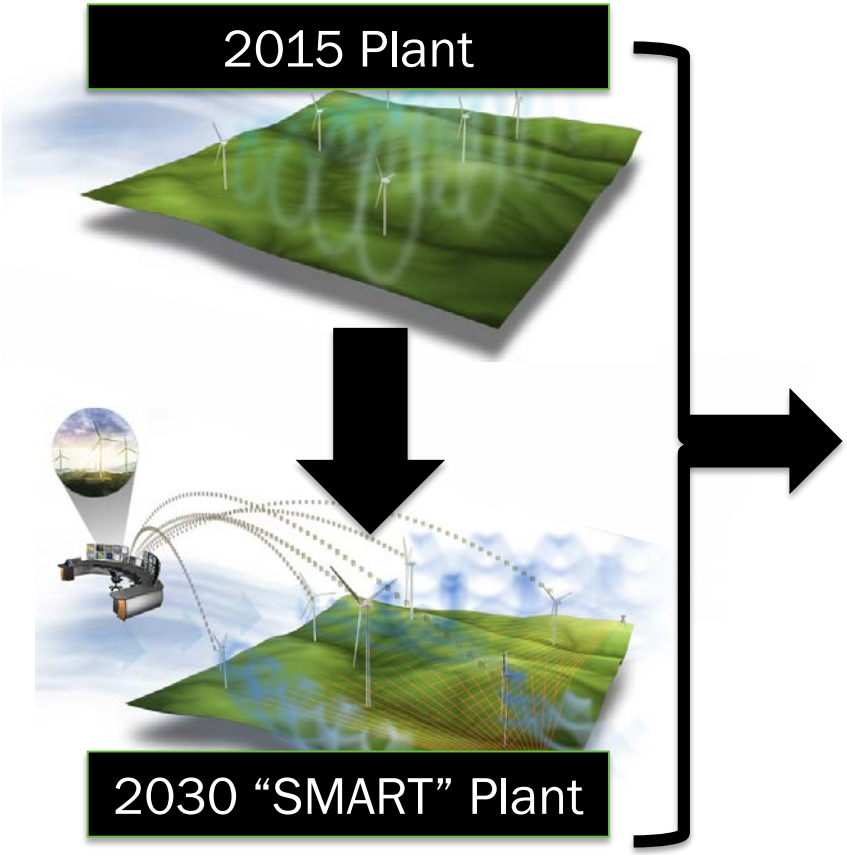
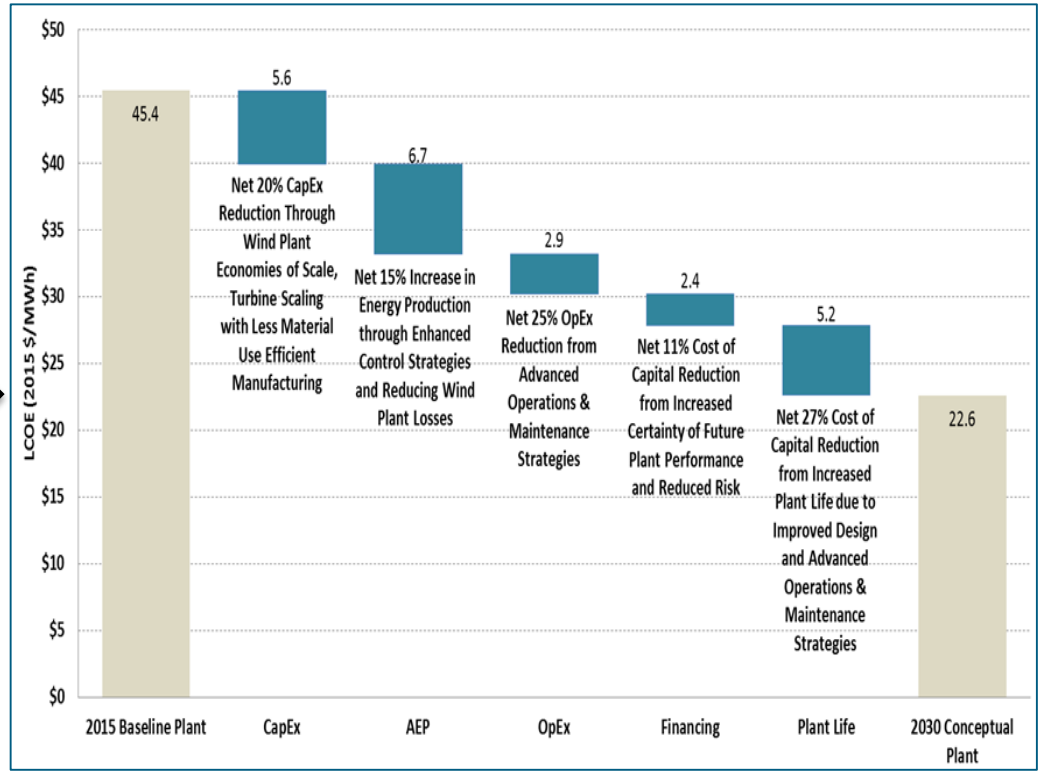
R&D investment analysis

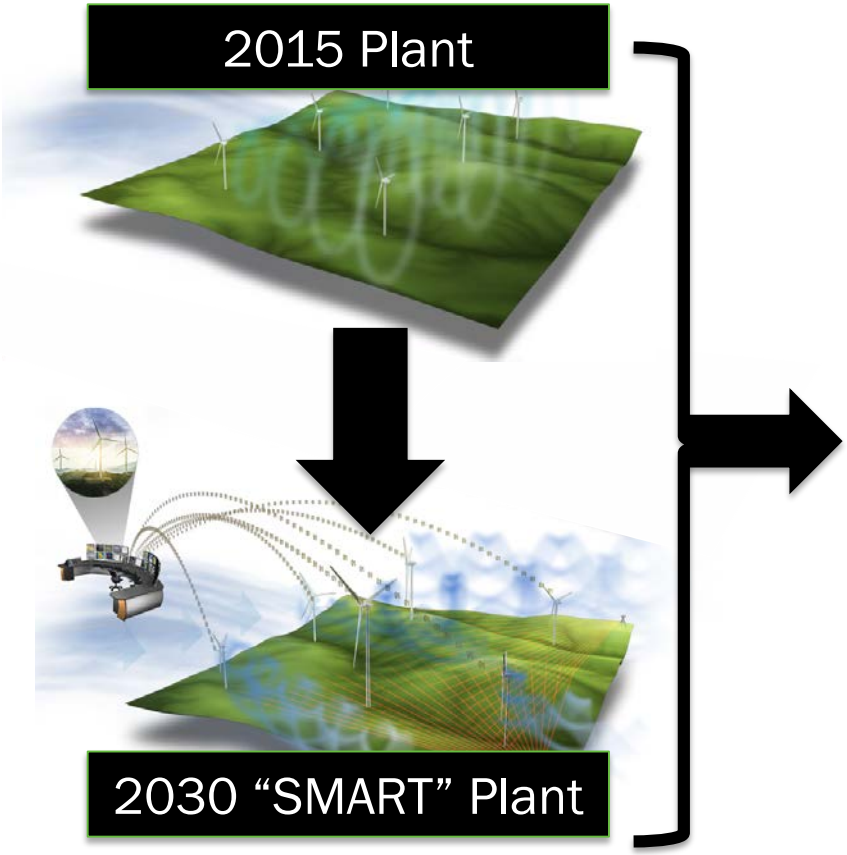


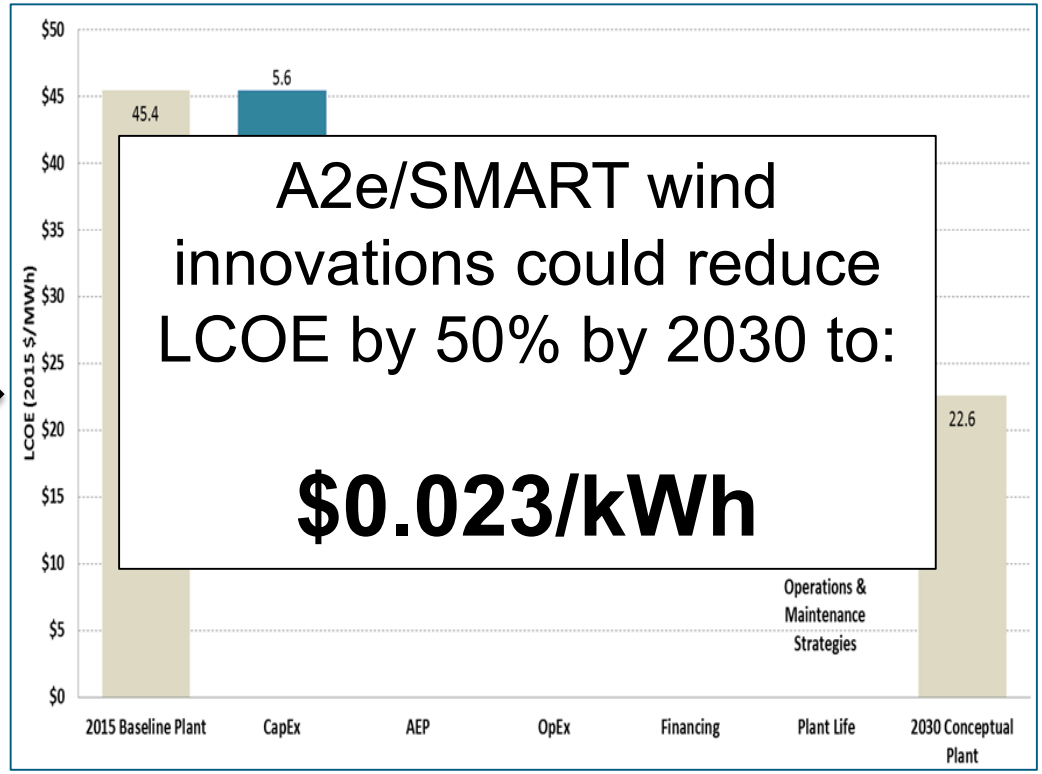


Dykes et al. 2017. "Enabling the Smart Wind Plant of the Future through Science-Based Innovation"

A2e SMART Wind Plant study – Looked at the LCOE impacts of multiple innovations—plant level control and optimization, larger, lighter turbines, increased reliability and longevity, etc--that could be enabled by a full understanding of the physics of how wind plants interact with the complex flow of wind into and through them.

R&D investment analysis





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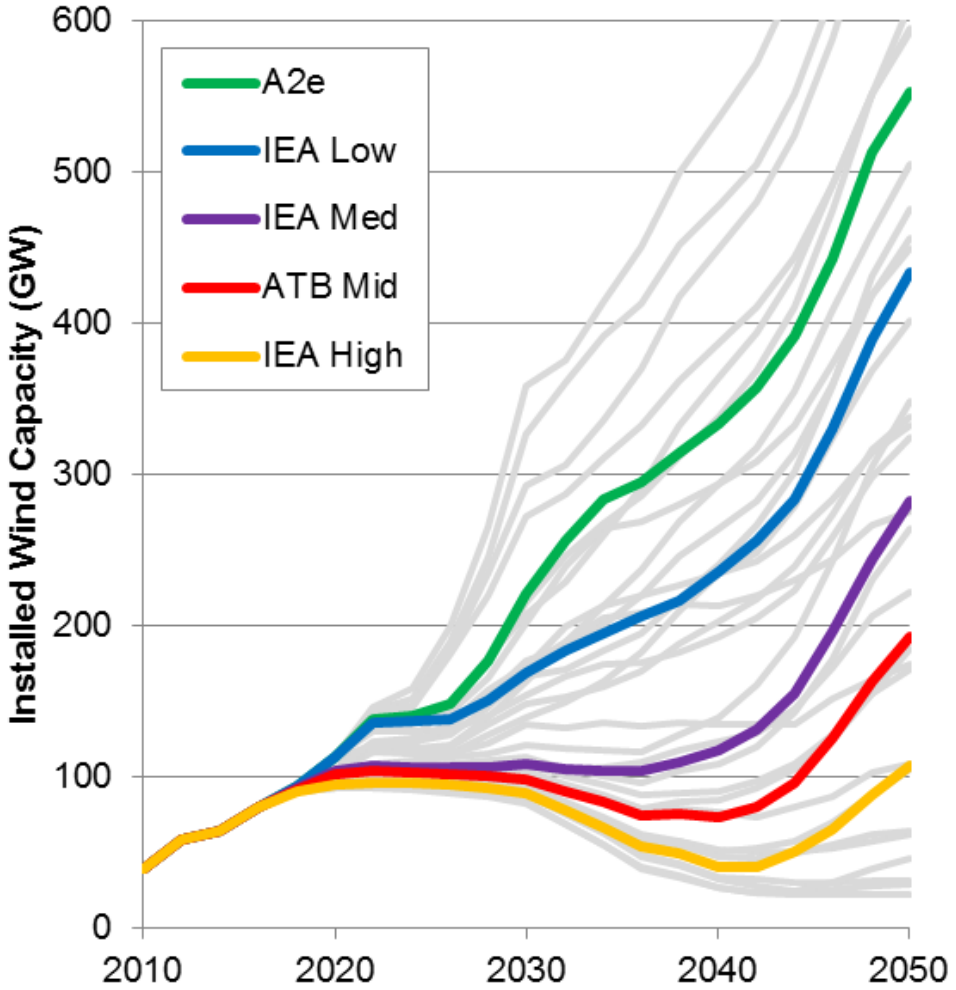
Strategic Wind Energy Futures Analysis

Mai et al. 2017. "The Value of Wind Technology Innovation: Implications for the U.S. Power System, Wind Industry, Electricity Consumers, and Environment."



	IEA Med (Absolute value)	IEA High (% of IEA Median)	ATB Mid (% of IEA Median)	IEA Low (% of IEA Median)	A2e (% of IEA Median)
WIND INSTALLED CAPACITY 2050 (GW)	282	-62%	-32%	+53%	+96%
WIND GENERATION 2050 (TWh)	1,238	-66%	-29%	+50%	+76%
SYSTEM COSTS 2017–2050 (BILLION $)	3,250	+2.8%	+1.1%	-3.1%	-4.6%
SO_2 EMISSIONS 2050 (THOUSAND TONS)	651	+5.0%	+3.8%	-19%	-30%
NO_x EMISSIONS 2050 (THOUSAND TONS)	887	+12%	+6.4%	-18%	-28%
CO_2 EMISSIONS 2050 (MMT)	1,527	+15%	+6.9%	-16%	-26%
WATER CONSUMPTION 2050 (BILLION GALLONS)	878	+14%	+6.2%	-16%	-25%
WATER WITHDRAWALS 2050 (BILLION GALLONS)	7,716	+7.5%	+4.4%	-15%	-32%
AVERAGE WIND JOBS 2017–2050 (THOUSAND FTEs)	170	-51%	-21%	+38%	+50%

System costs use a 3% real discount rate. Air emissions are from direct combustion only. Water use includes operational water use only. Wind-related jobs are averaged over all years and reflect the average of the "higher" and "lower" domestic content assumptions. FTE = full time equivalent units; SO_2 = sulfur dioxide; NO_x = nitrogen oxides; CO_2 = carbon dioxide

The Value of Wind Technology Innovation - Understand the implications of different wind innovation pathways on the electricity sector in different potential future scenarios, in terms of wind deployment, costs, value to the grid, and other variables.

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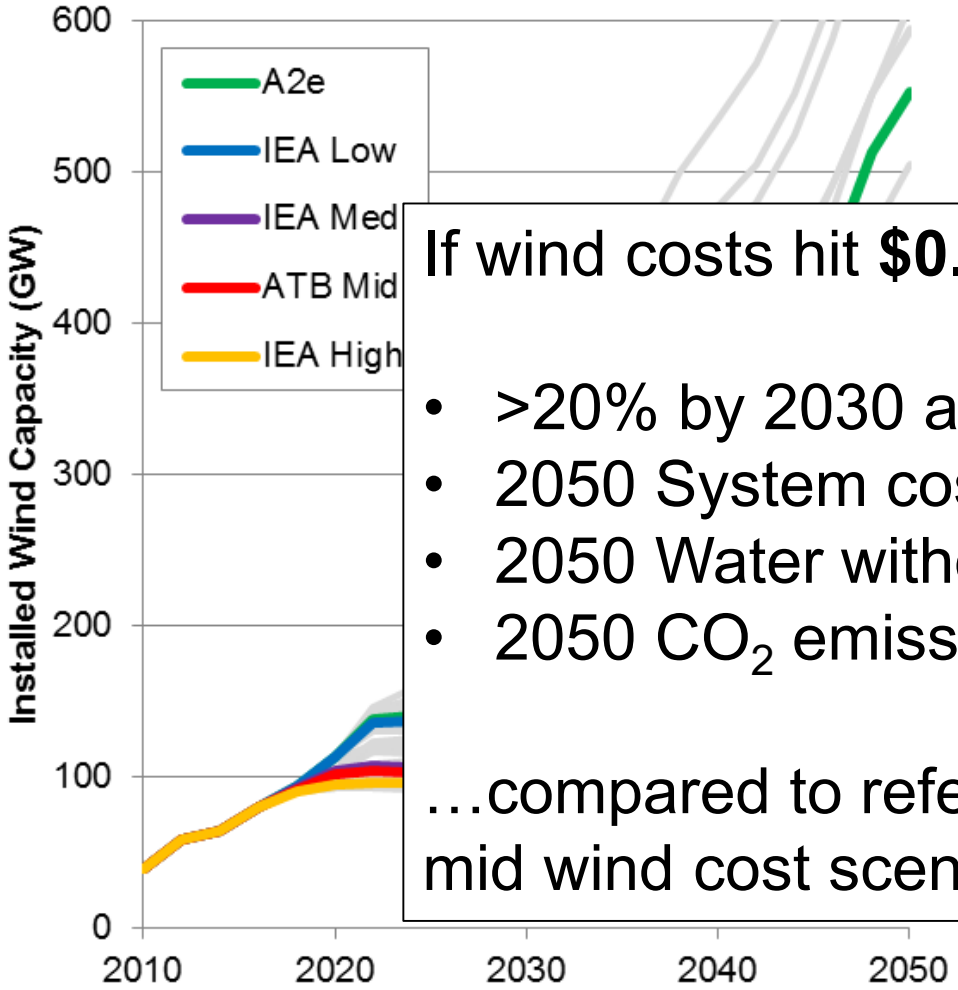
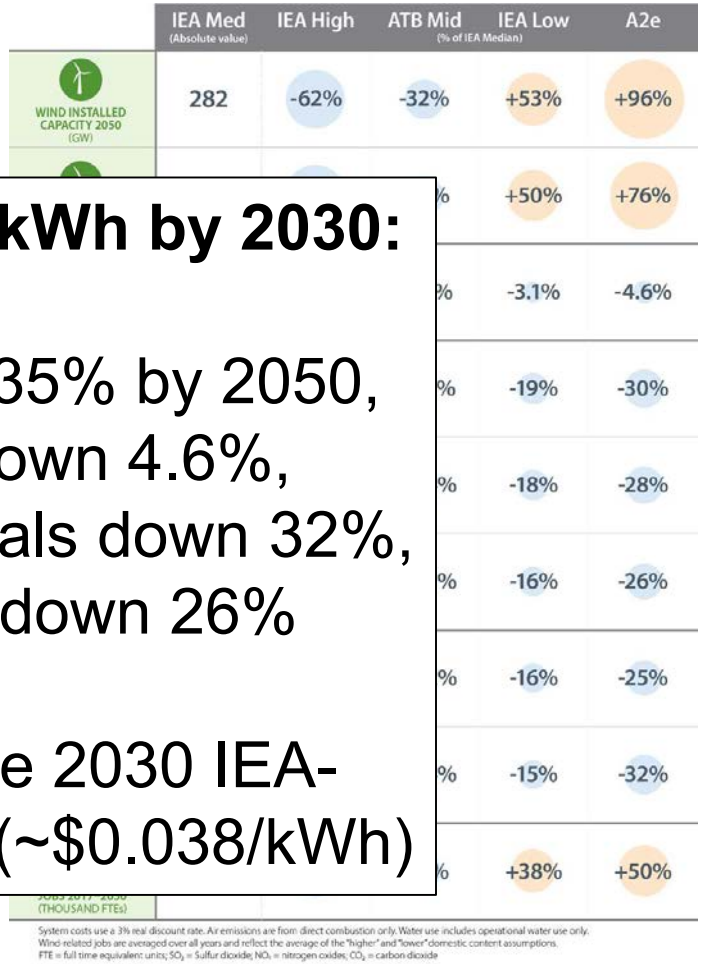




If wind costs hit **$0.023/kWh by 2030:**

- >20% by 2030 and >35% by 2050,
- 2050 System costs down 4.6%,
- 2050 Water withdrawals down 32%,
- 2050 CO_2 emissions down 26%

…compared to reference 2030 IEA-mid wind cost scenario (~$0.038/kWh)

The Value of Wind Technology Innovation - Understand the implications of different wind innovation pathways on the electricity sector in different potential future scenarios, in terms of wind deployment, costs, value to the grid, and other variables.

Communications and Impact, FY2017-2018

50+

Total Publications

~$150K per publication

(DOE/lab reports, journal articles, conference papers/posters, and published presentations)

Presentations

100+

Press Hits

200+

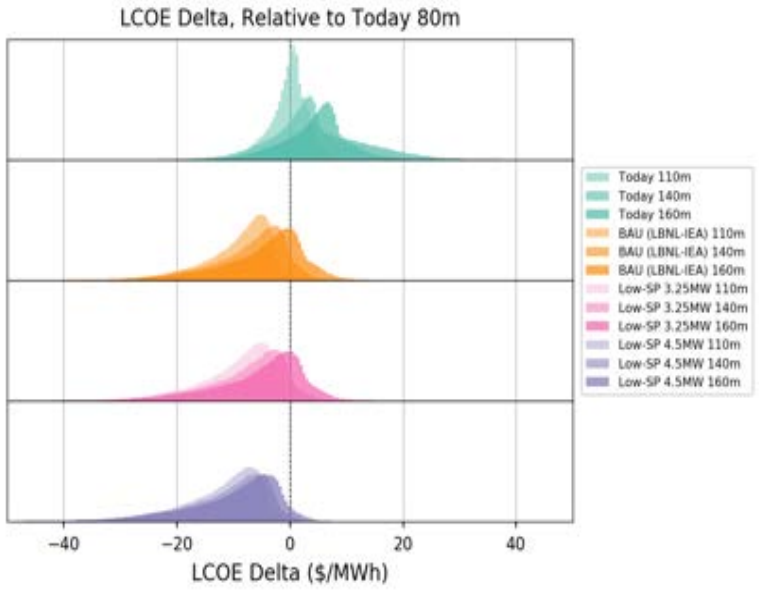
NREL 2017 Publication of the Year:

Dykes et al. 2017. "Enabling the Smart Wind Plant of the Future through Science-Based Innovation"

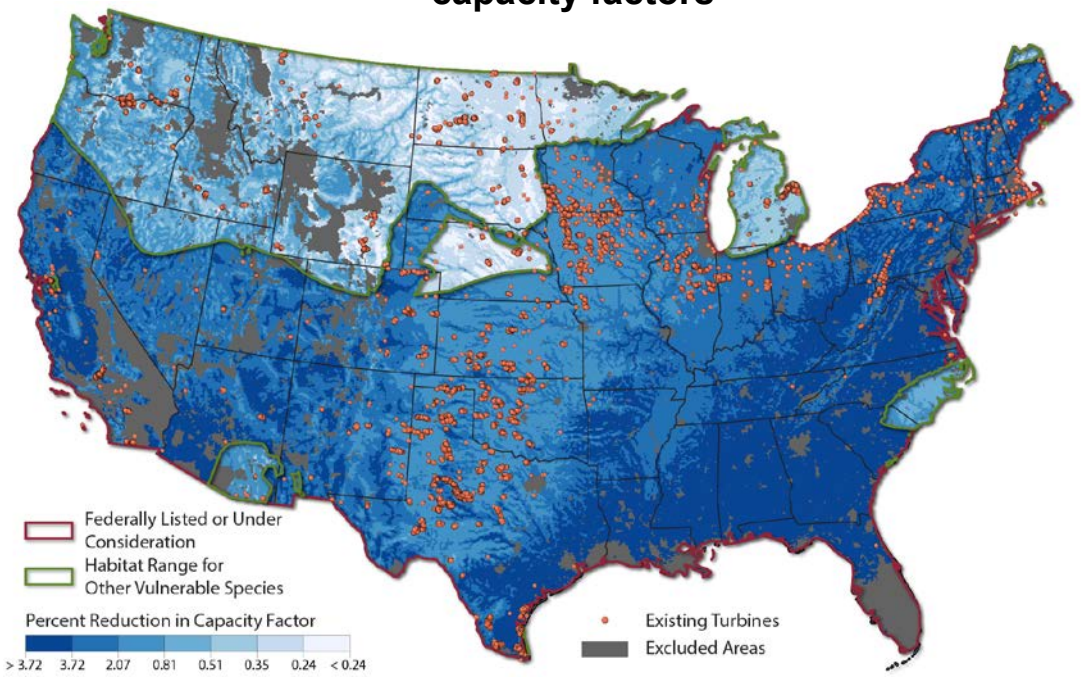
Where next? (1) A Wind Plant for Every Place

Goal: Optimize wind plants (both land-based and offshore) at every resource pixel, considering terrain, logistics, siting and permitting challenges across an array of technology pathways, and understand sensitivity to changes in these variables, to inform R&D

National LCOE differences by hub height for four conceptual turbines



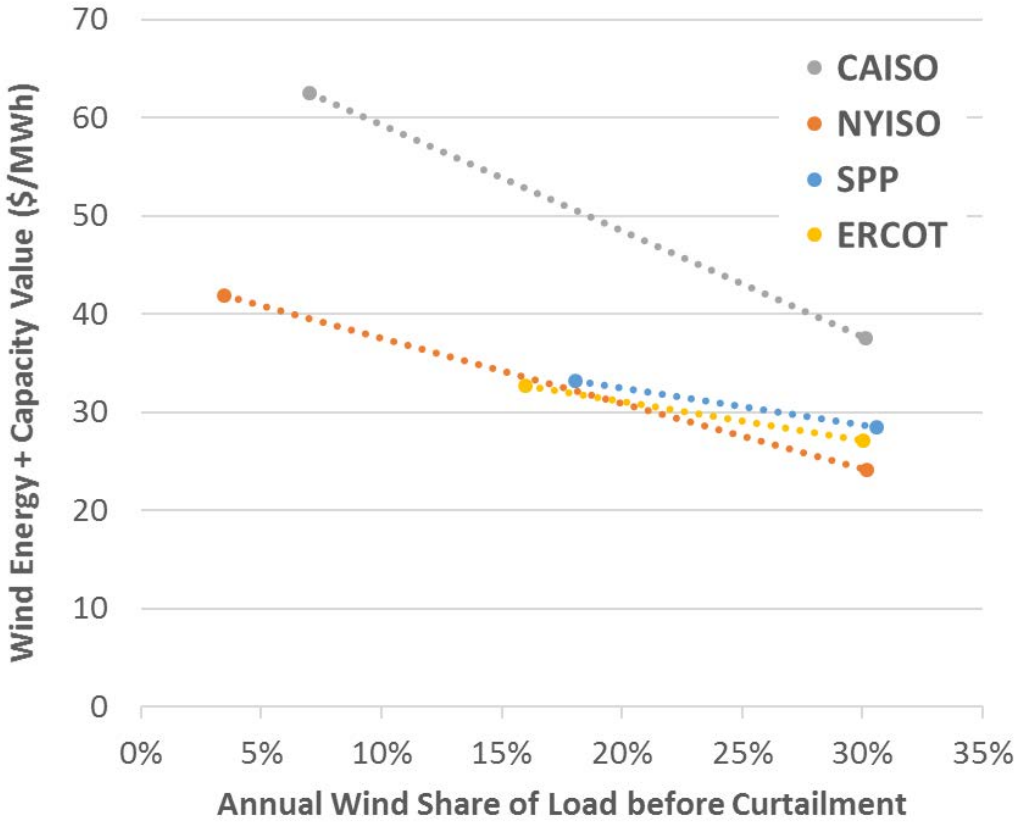
Impact of bat curtailment requirements on capacity factors



Where next? (2)
From 'rock-bottom prices' to 'best value product'

Goal: Understand how to measure the impact of technology changes not just on LCOE but on value to the future grid, and how to optimize wind through R&D to maximize that value, particularly in high VRE scenarios.

Future Energy and Capacity Value for Wind (four 2030 scenarios, four regions)



Wind value declines by **14-42% in High Wind scenarios** (30% wind, 10%+ solar)…how can we mitigate this?

Wiser, Ryan. "The Future of Wind Energy Will Be Impacted By Its Value in Wholesale Electricity Markets" WINDPOWER 2019.