U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

A04 - Spatial Analysis for Wind Technology Development

Modeling & Analysis – Modeling & Analysis
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National Renewable Energy Laboratory (NREL)

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NREL Transforming ENERGY

FY21 Peer Review - Project Overview

Project Summary:
This project informs WETO of possible challenges to wind deployment as well as increased opportunities driven by WETO turbine innovation research and cost targets.

1. Identification of key siting issues and innovation pathways through broad stakeholder engagement, regulatory reviews, and assessment of empirical deployment patterns
2. Spatially resolved modeling of local siting conditions, economics, and turbine performance
3. Evaluation of the sensitivity of the national wind supply curve to social, ecological, physical, regulatory and techno-economic drivers

Key project collaborators include: Lawrence Berkeley National Laboratory, United States Geologic Survey, and the American Wind and Wildlife Institute.

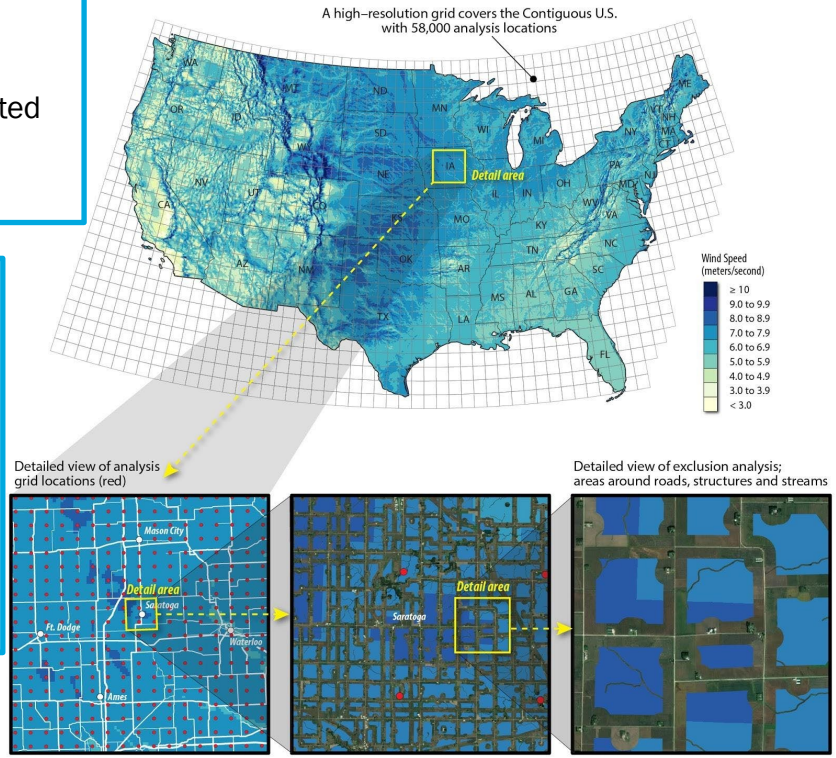
Project Start Year: [FY19]
Expected Completion Year: FY [Y]
Total expected duration: [Z] years
FY19 - FY20 Budget: $2,275,534

Key Project Personnel: Anthony Lopez (PI), Dylan Harrison-Atlas, Travis Williams, Owen Roberts, Galen Maclaurin, Trieu Mai, Grant Buster, and Michael Rossol

Key DOE Personnel: (Patrick Gilman)

Project Objective(s) 2019-2020 and beyond:

- How do social, ecological and wind resource considerations as well as other technical constraints (e.g., radar, bat curtailment, setbacks) impact wind energy potential?
- How sensitive and dynamic is wind energy potential, performance?
- To what extent can ecological and social impacts of wind energy be better managed through design and innovation?

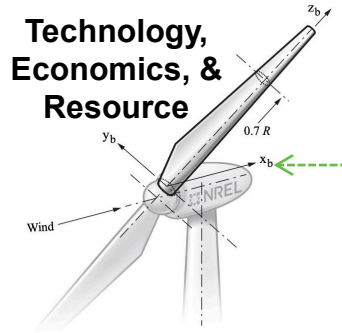


Project Impact

Plant and turbine level spatial modeling of constraints and technology interaction

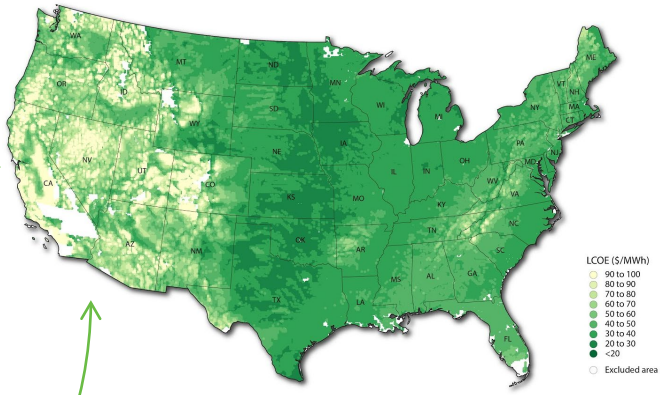
Social

Technology, Economics, & Resource



Regulatory

National scale assessments



Environmental

Feedback to evaluate interactions between constraints and technology

Uses and Impact

Informs WETO R&D impacts to availability and cost of wind

Provides best-in-class wind characterizations for internal/external energy models

Provides policy and decision makers clear understanding of wind potential

Enhances understanding of the magnitude of siting challenges for wind deployment

Contextualize and quantify the broader challenges facing wind technology as it is increasingly relied on at higher penetrations in the electricity sector, through higher and mixed fidelity modeling at a national scale

Program Performance – Scope, Schedule, Execution

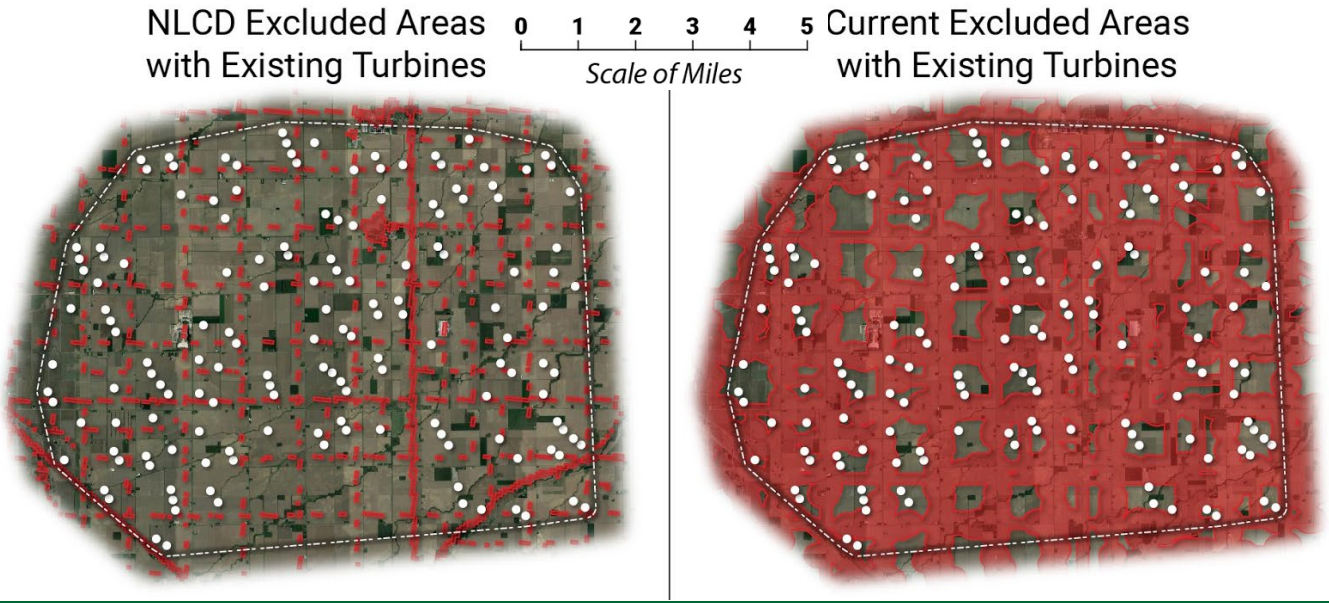
All milestones have been met or are on track to be met. Budgets are on track.

FY19	FY20	FY21	Beyond
• Formalization and open-source of the Renewable Energy Potential model (reV) • Curtailment strategies to mitigate bat fatalities • Land-use requirements of wind power plants • Formalized coupling with WIND Toolkit, capacity expansion, and production cost efforts	• Hyper-local spatial fidelity of siting constraints • Land-based wind supply curves • Surrogate model for instantaneous evaluation of control strategies • Deep coupling with ReEDS model	• Offshore supply curve scenarios • Spatial optimization of discreate turbine placements • Transmission routing • National shadow flicker assessment • Interactive visualization platform for exploring reV scenarios	• Model interoperability/co-optimization - energy models and bat demographic models • Turbine scaling interactions with siting constraints • Site dependent wind technology supply curves • Noise deployment constraints • Bottom-up cost modeling in reView • AWE, Wind/PV Hybrids

State-of-the-art spatial methodologies enable evaluation of critical constrain and accurate representation of wind technology and potential

Left image: data/methods used since circa 2012

Right image: data/methods develope and implemented in FY20



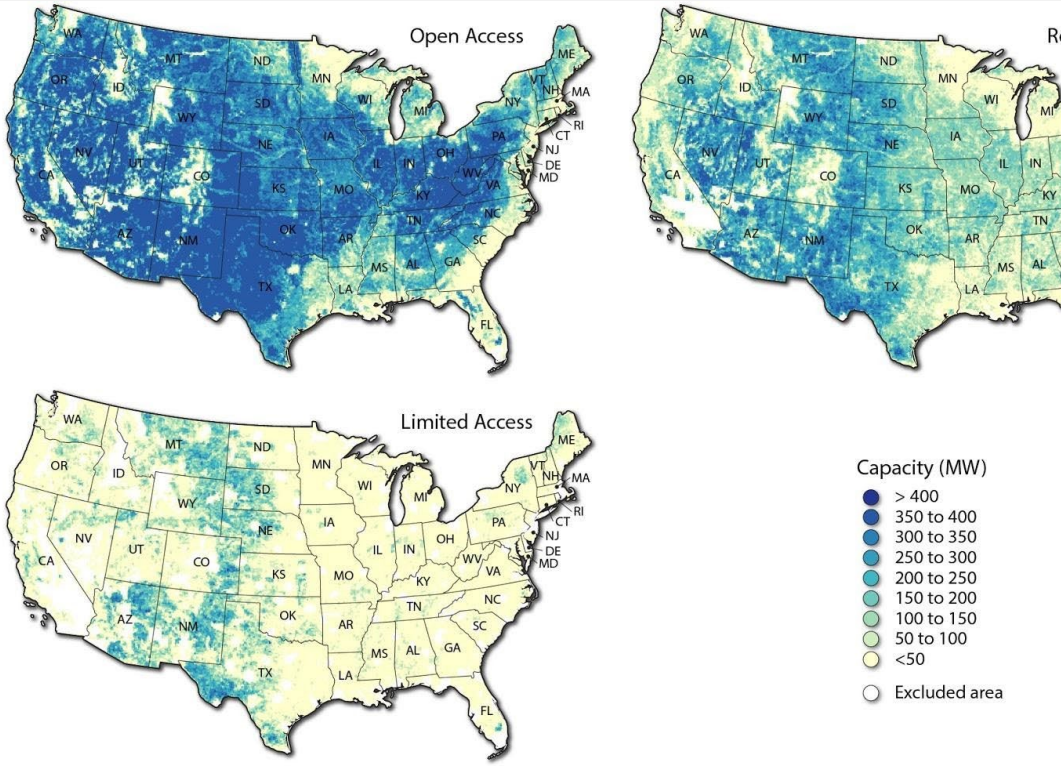
Project Performance, Accomplishments and Impacts:
Supply Curve Modeling

Objective: Develop state-of-the-art spatial methods to capture interactions between siting, wind technology, grid infrastructure, society, and the environment.

Tools: Renewable Energy Potential Model (reV) and reV Exchange (reVX) – both open-source models were developed with WETO funds are used throughout EERE and external users.

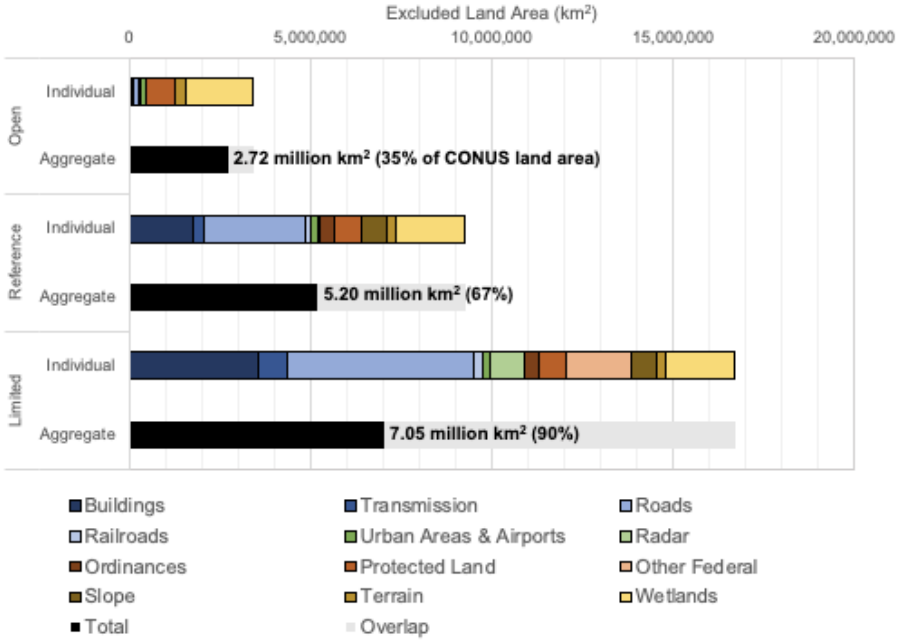
Impact: Supply curve results serve basis of capacity expansion and production cost modeling with internal and external stakeholders.

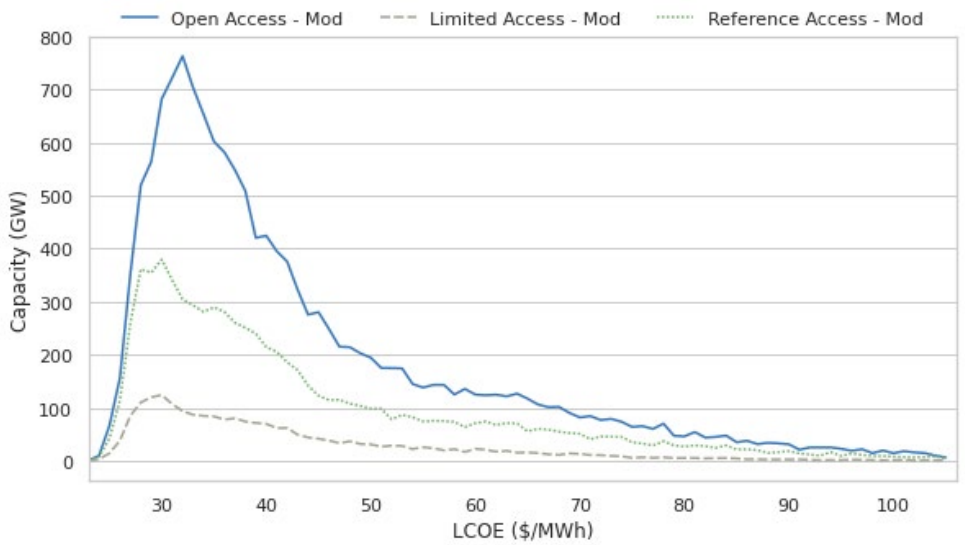
Scenario exploration of plausible siting challenges reveal impacts to geographic distribution of opportunities for wind deployment



Project Performance, Accomplishments and Impacts:
Supply Curve Modeling

Spatially refined accounting reveals magnitude of potential siting challenges





"**Individual**" bars show magnitude of land area consumed by different siting exclusions

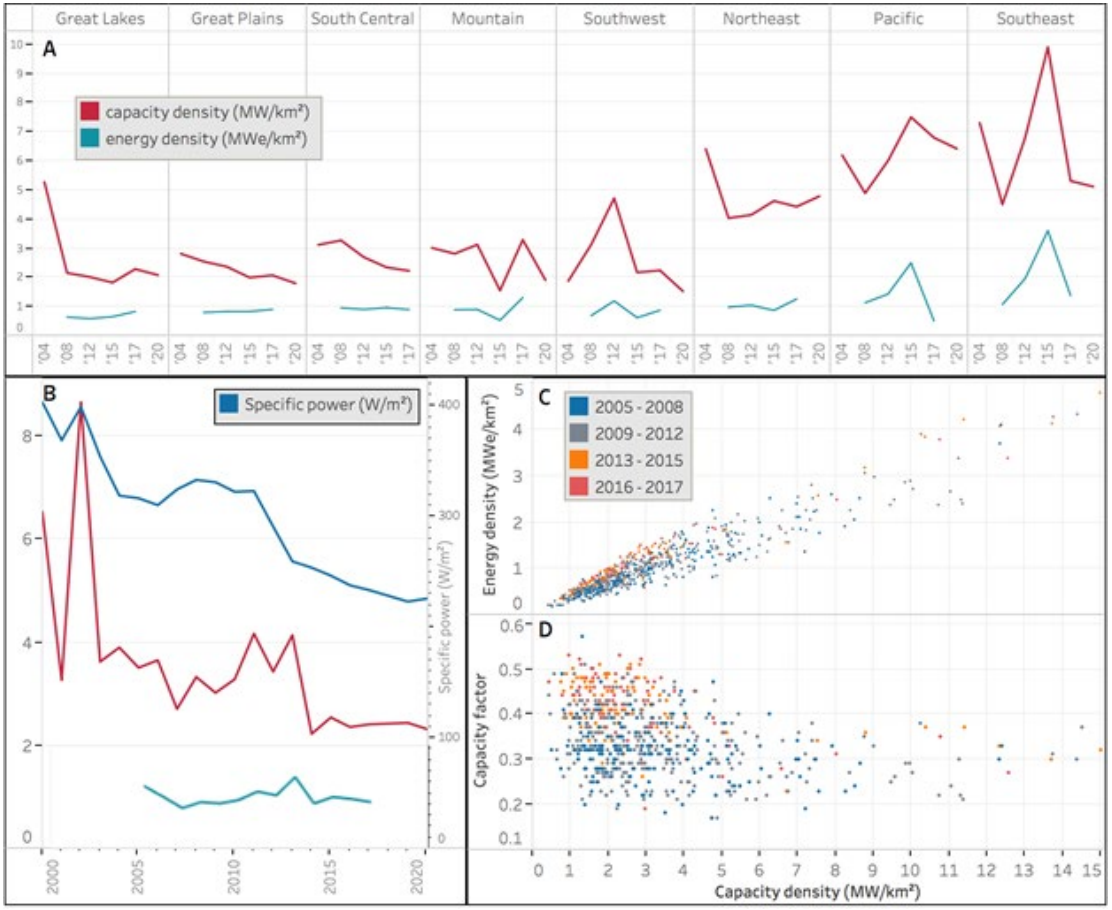
"**Aggregate**" bars demonstrate the spatial overlap of siting exclusions

The quantity, quality, and cost of wind is explored on a scenario basis to understand implications of plausible siting exclusions e.g., failure to unlock federal lands, saturation of radar viewsheds, and more

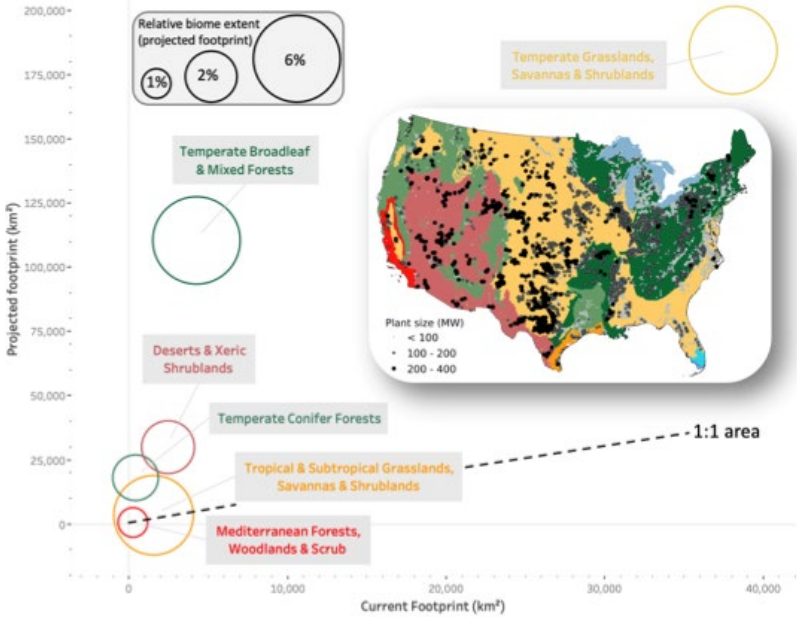
Project Performance, Accomplishments and Impacts:
Land-use requirements, interactions with wildlife

Objective: Quantify and integrate insights into forward-looking models to capture evolving land-use requirements from wind power plants and their possible intersection with wildlife species. Investigate the cost impact of wildlife mitigation strategies to reveal national implications.

Wind power deployment across time and space reveal changing land-use requirements and critical interactions with social and ecological systems

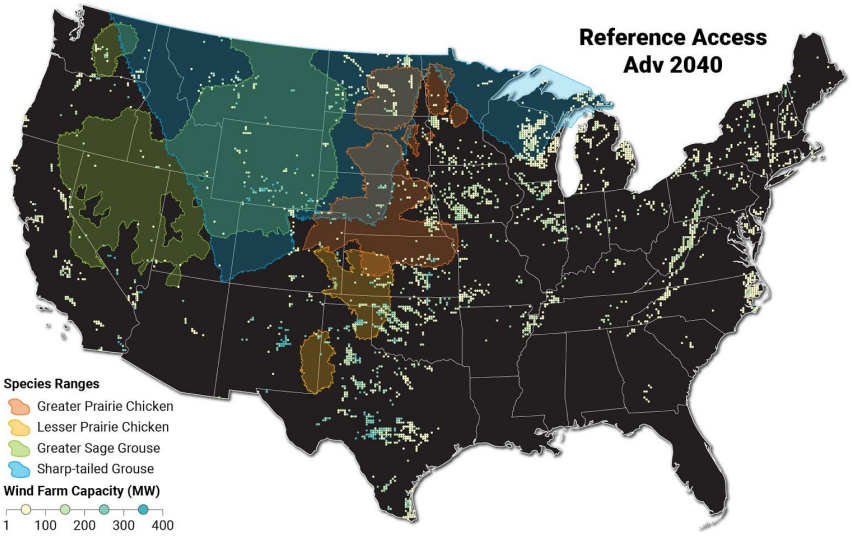


Projecting anticipated future land requirements and impacts to biomes

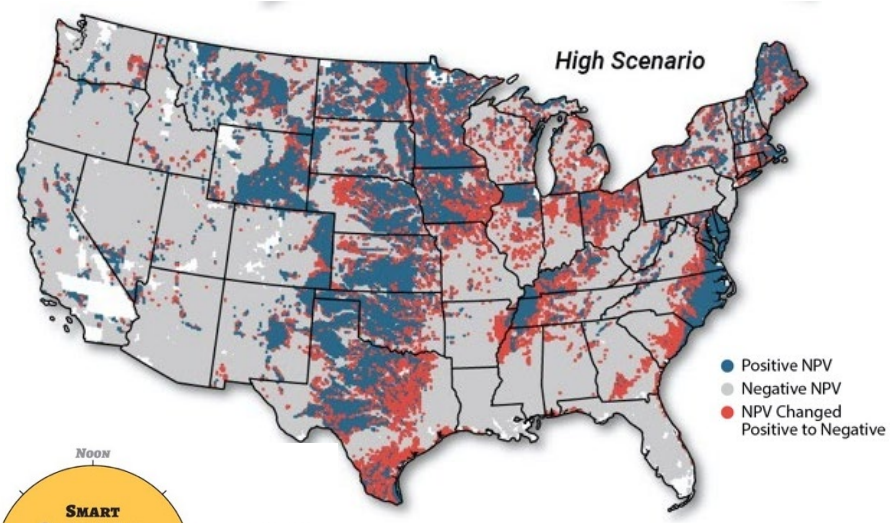


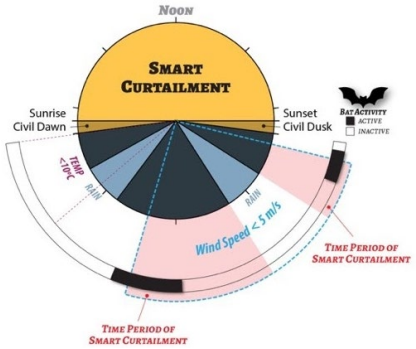
Project Performance, Accomplishments and Impacts:
Land-use requirements, interactions with wildlife

Exploring the intersection of wind resource with different species of concern illuminates needs for future research into best-management practices and mitigation measures



Quantifying a range of financial impacts to wind power plants from different mitigation strategies informs stakeholders of broader implications

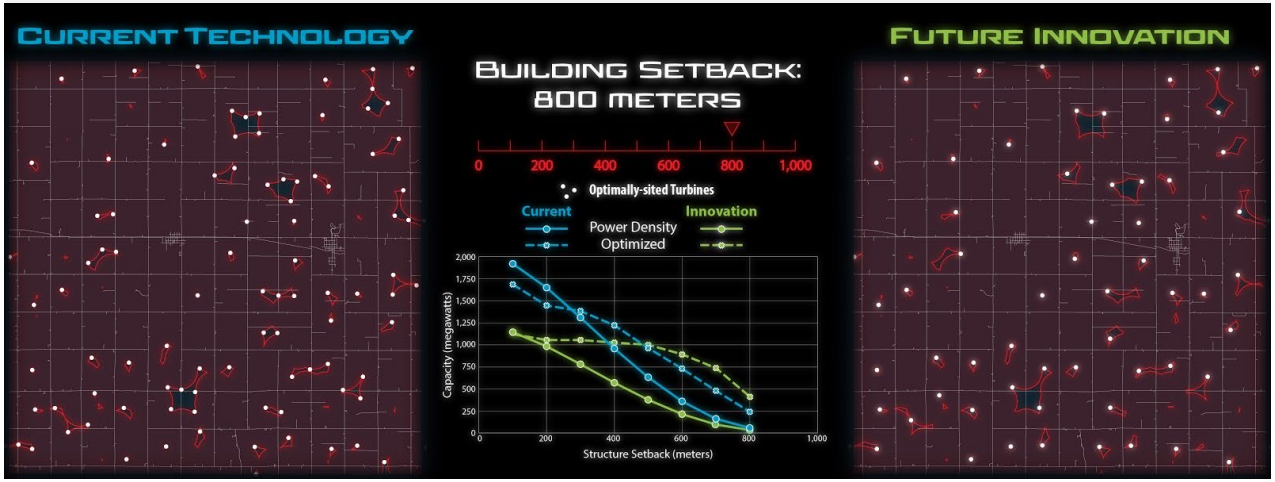




Project Performance, Accomplishments and Impacts:
Machine Learning, Artificial Intelligence, and Optimization

Objective: Establish novel research capabilities using machine learning, artificial intelligence, and spatial optimization to overcome conventional computation limits.

Turbine siting optimization reveals effects of siting constraints and opportunities for turbine scale



Streamlined surrogate models built on higher fidelity wake models enable near instantaneous evaluation of control strategies and AEP gains for a variety of plant layout and turbine designs across the United States

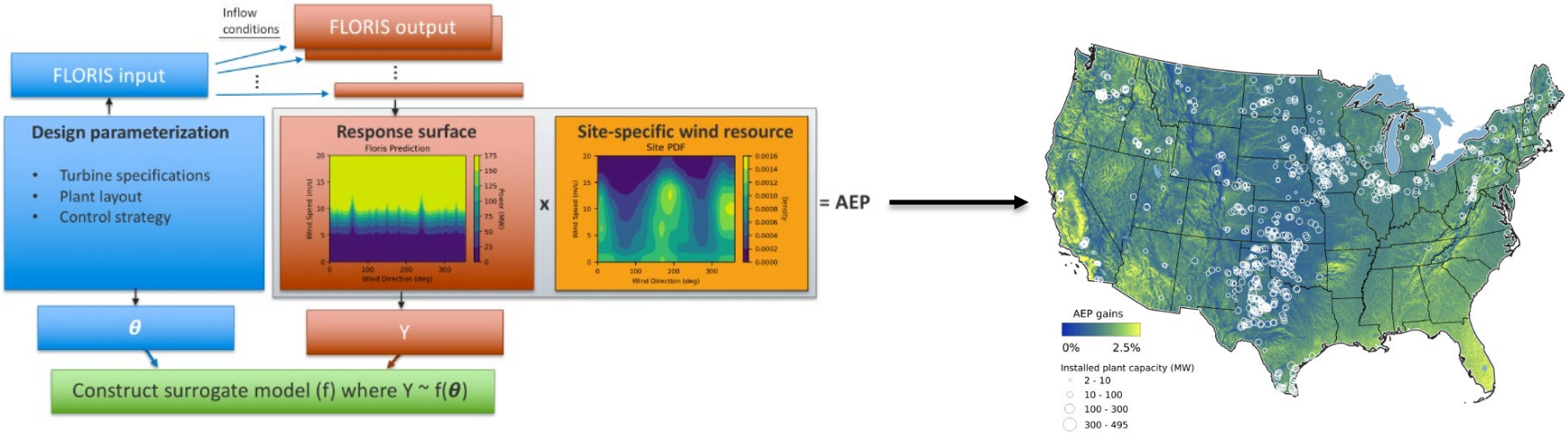


FIGURE 1 Overview of surrogate modeling process for AEP estimation

Publications, Stakeholder Engagement, Information Sharing

The Spatial Analysis project has deep collaborations across a diverse stakeholder group, providing data, methods, models, reports, scientific journals, and technical assistance. State-of-the-art wind characterizations performed by Spatial Analysis are proliferated throughout multiple agencies ensuring appropriate representation of key wind properties. Land managers, utilities, energy modelers, decision makers, and policy makers rely upon Spatial Analysis to provide comprehensive quantification of wind deployment constraints and opportunities.

2 Technical Reports

7 Journal Publications (4 in review)

13 Presentations & Engagements

>280 Model Clones, 14 Forks

7 Visualizations

Wind Data Sharing
- Internal NREL Modelers/Analysts
- United States Fish and Wildlife
- Environmental Protection Agency
- Energy Information Agency
- Evolved Energy

Collaboration, Proposal Development
- American Wind and Wildlife Association
- United States Geologic Survey
- United States Department of Agriculture

Technical Assistance and Report Writing
- Duke Energy
- Southern Company
- Bureau of Land Management
- US-AID (over a dozen countries supported)
- State Department

Knowledge Sharing
- Wind Industry
- The Nature Conservancy
- International Energy Agency
- Lawrence Berkeley National Laboratory
- National Wind Coordinating Collaborative
- United States Geological Survey

Project Performance - Upcoming Activities

Ongoing FY21 activities and project vision

Driving increased spatial fidelity in national-scale assessments to capture hyper-local drivers of wind deployment

- **Offshore wind scenarios:** Development of offshore wind siting regimes
- **Shadow flicker:** National evaluation of shadow flicker impacts to wind supply curve
- **Transmission modeling:** updated regional, land type, and voltage-based costs, spatial routing algorithms to determine optimal right-of-ways
- **Spatial optimization:** Enhanced spatial optimization methods for evaluating turbine scale opportunities in siting constrained environments.
- **Machine learning:** Surrogate methods for predicting power generation of wind farms for innovative control strategies.
- **Collaboration**: Joint research with U.S. Geological Survey and U.S. Fish and Wildlife. Integrating and increasing spatial dimensions throughout Modeling and Analysis.
- **Website:** Disseminate supply curve data, publications, interactive mapping visualization

Supply Curve Website stats since Oct. 2020
- 2,676 visits
- 273 data downloads

Wind Science Leadership stats
- 648 visits
- 163 webinar attendees
- 164 views to date

reV website stats since 2019
- 6,684 visits