A04 - Spatial Analysis for Wind Technology Development

Modeling & Analysis – Modeling & Analysis
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August 2, 2021
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 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

Environmental

National scale assessments

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.

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

**Left image:** data/methods used since circa 2012

**Right image:** data/methods developed 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.
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.
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.
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.
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.

**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