Performance Risk, Uncertainty & Finance
Project ID # T-11

Jason Fields

NREL
FY17-FY18 Wind Office Project Organization

“Enabling Wind Energy Options Nationwide”

Technology Development
- Atmosphere to Electrons
- Offshore Wind
- Distributed Wind
- Testing Infrastructure
- Standards Support and International Engagement
- Advanced Components, Reliability, and Manufacturing

Market Acceleration & Deployment
- Stakeholder Engagement, Workforce Development, and Human Use Considerations
- Environmental Research
- Grid Integration
- Regulatory and Siting

Analysis and Modeling (cross-cutting)
Project Overview

T11: Performance Risk, Uncertainty & Finance

Project Summary
PRUF identifies and reduces risk and uncertainty factors that impact long-term operation and profitability of wind power plants. Improving the predictability and reliability of wind power generation and operations increases investor confidence and boosts returns for wind plant owners, both of which are critical for robust and organic industry growth.

Project Objective & Impact

- **Market Impacts**
  - Improved project selection & business outcomes
  - Increase investor confidence

- **Unleash innovations**
  - Improve data access
  - Validate new methods that can be deployed quickly

- **LCOE Impacts (quick impact; 1-3 year uptake)**
  - Up to 5% LCOE reduction from risk reduction

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<th>Project Attributes</th>
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<tr>
<td><strong>Project Principal Investigator(s)</strong></td>
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<tr>
<td>Jason Fields</td>
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<td><strong>DOE Lead</strong></td>
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<td>Patrick Gilman</td>
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<td><strong>Project Partners/Subs</strong></td>
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<td>John Meissner – Canvas Innovations</td>
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<td><strong>Project Duration</strong></td>
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<td>2015-Present</td>
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Technical Merit and Relevance

- **Prediction bias**
  - model errors
- **Predicted losses**
  - availability, wakes, electrical, turbine performance, environmental effects, curtailment.

**Probabilty Density**

**Actual Energy Production**

- P95
- P90
- P84

**Uncertainty**

- $\sigma$
- $2\sigma$

- *site measurements, horizontal and vertical extrapolation, annual wind variability, turbine performance, plant losses*

**Gross Energy Estimate**

**Uncertainty**

- $\sigma$
- (34.1%)

- *site measurements, horizontal and vertical extrapolation, annual wind variability, turbine performance*

Clifton, 2016
Technical Merit and Relevance

WP3-Benchmark

What’s My Wind Farm Going To Produce?

WP3 compares pre-construction energy production estimates with the actual operational data to find ways to improve them.

Reduce the Cost of Capital
- Reduced risk premiums
- Improved project selection

Reduce LCOE
- Increased prediction accuracy
- Improve project selection
Approach and Methodology

Changing the game, breaking down the walls that limit collaboration
Unprecedented Data Sharing & Collaboration among Wind Plant Owners, Resource Assessment Consultants, and Manufacturers
Approach and Methodology

Benchmarking:
• P50, P90, P95
• Loss & Uncertainty Assumptions

Responsibilities:
• Owners: Share Data
• Consultants: Energy Estimates
• NREL: Operational Assessment

The Virtuous Cycle

Prediction Benchmarking

Prediction Improvement

Improvement:
• Methods

Responsibilities:
• Consultants: Method Improvements
• NREL: Data Aggregation & Reporting

Continuous improvement opportunity by advancing models with expanding operational source data
Approach and Methodology

Major Activities

**Historical Validation Study**
- Large scale study of Energy Yield Assessment accuracy

**Benchmark at Scale**
- Pilot project: trial run to fix the bugs
- Phase 1: Disbursement and validation of first 10 projects
Accomplishments and Progress-HVS

Historical Validation Study (HVS):
Investigate underperformance in wind plant annual energy production using public/private data sources

- Compares pre-construction energy estimates from industry partners to actual energy production data
  - 62 projects
  - Financed Energy Yield Estimates
  - Public Data: Energy Information Administration (EIA)
- First independent, consultant agnostic analysis of its kind
HVS - Industry Performance Gap

- Mean bias: -5.5%
- Uncertainty: 1.3%

- Correction methods:
  - Extreme events
  - Long term period

- First independent, market agnostic analysis of its kind
HVS – Evidence of Improvement

Mean: -9.9%

Mean: -5.5%
WP3Benchmark Work Activities

Pilot Project.
• 150 MW Project (TX)

Phase 1: (First 10 projects)
• Pre-Con Data released: 10 of 10
• Operational Data: 9 of 10 projects processed
• Consultant Responses: 40 of 100
Normalized AEP vs Net
P50 vs OA Percent Difference
Uncertainty
New Tools for Research and Industry

OpenOA
What is OpenOA?

- Built largely to support WP3 Benchmarking study
- Extensive feedback from industry during code development
- v1.0 released September 2018 (https://github.com/NREL/OpenOA)
- Built in Python
- GitFlow, unit and integration tests, Sphinx documentation, examples
OpenOA
The Future of OpenOA

- Supported and developed by a large user community
- NREL houses codebase and manages its development
Communication, Coordination, and Commercialization

• Presentations and posters
  – AWEA, TORQUE, IEA, AMS, AGU

• Publications
  – Understanding Biases in Pre-Construction Estimates. M. Lunacek et al
  – Uncertainty Quantification in the Analysis of Operational Wind Plant Data A. Craig, M. Optis, J. Fields, P. Moriarty

• Software Development
  – OpenOA (https://github.com/NREL/OpenOA)
Conclusions

HVS
Industry is improving but bias exists

Benchmark:
Changing the game on collaboration

New Tools: OpenOA
Upcoming Project Activities

- Phase 1 completion
- OpenOA development and dissemination
- Wind Energy Digitalization
Upcoming Project Activities

- Phase 1 completion
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<tr>
<td>AEP analysis</td>
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