

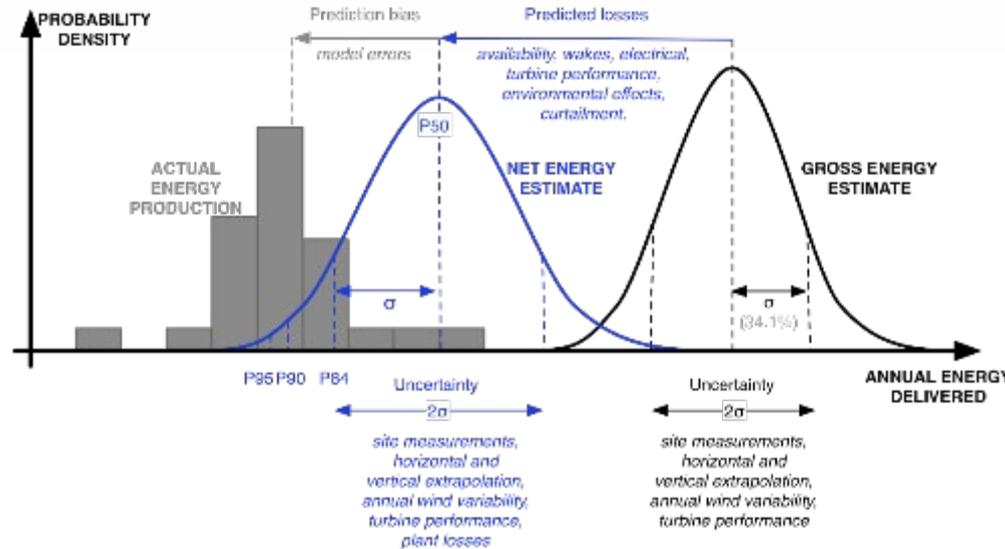
A07 – PRUF – Wind Plant Performance Benchmarking

Modeling & Analysis – Modeling & Analysis

Jason Fields

National Renewable Energy Laboratory (NREL)

August 2, 2021



FY21 Peer Review - Project Overview

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.

- EDPR, RES, EDF-RE, Avagrid, Pattern, E-ON/RWE, Enel, Siemens Gamesa RE, Vestas, Nordex/Acciona, GE, UL, DNV-GL, ArcVera, Natural Power, Mott Macdonald, K2, Luminate, WSP, Wood, EMD, EAPC

Project Start Year: [2015]
Expected Completion Year: FY [24]
Total expected duration: [9] years

FY19 - FY20 Budget: \$2,377,232

Key Project Personnel: Jason Fields (PI), Eric Simley, Jordan Perr-Sauer

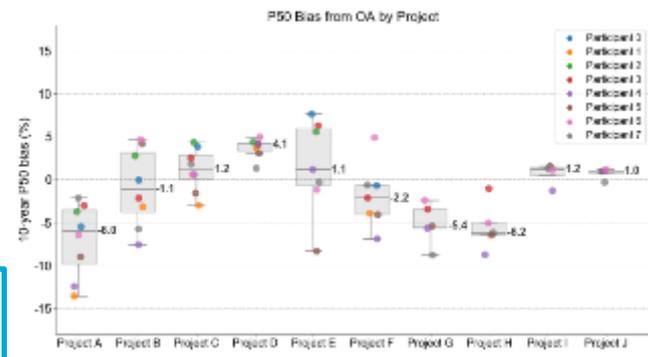
Key DOE Personnel: Patrick Gilman

Overall Project Objectives (life of project):

- 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

Project Objective(s) 2019-2020:

- Execute WP3 Benchmark Phase 1
- Publish OpenOA as an open source project
- Explore Wind Energy Digitalization as an innovation opportunity



Project Impact

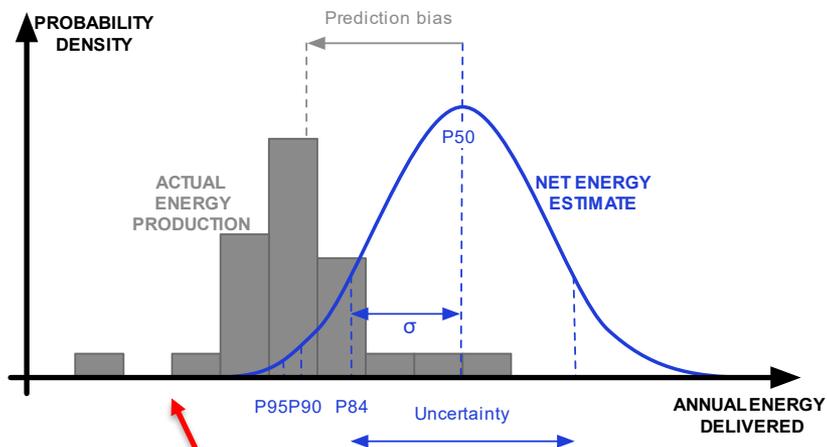
What's My Wind Farm Going To Produce?

Why it matters

- Drives profits and investment
- Drives LCOE & Finance Cost
- A2e/Industry alignment

Current State

- Performance bias exists
- Poor sub models



Data is a huge challenge for validation

PRUF Major Activities-Scope

WP3 Benchmark

- Phase 1: 10 projects

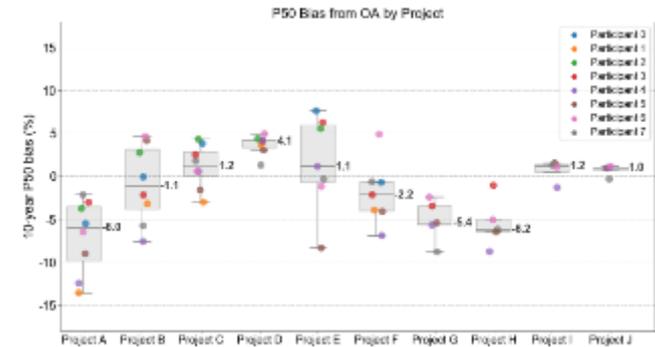
OpenOA

- Open source operational assessment project

Wind Energy Digitalization

- New data frontiers

Met all milestones on time (except 1)



Wind Plant Performance Prediction

WP3 is industry collaboration.

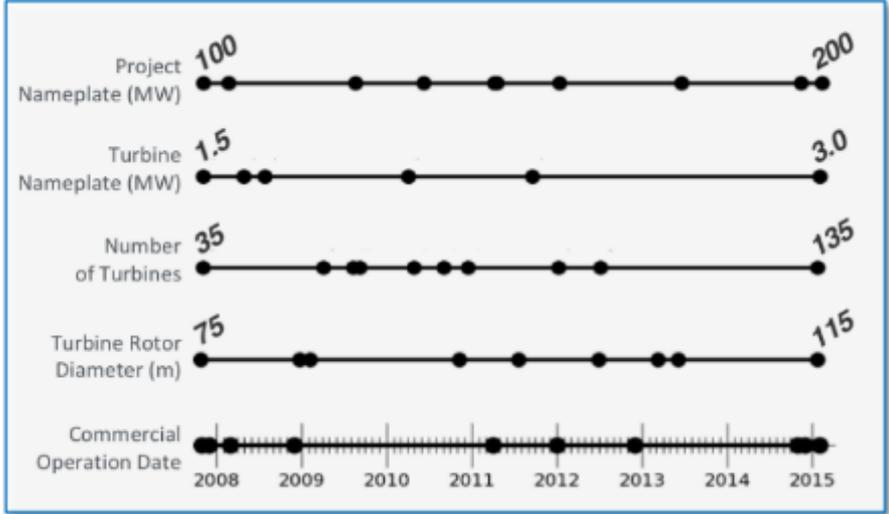
- Compare **pre-construction estimates to operational data**
- 100+ projects, representing **~25GW** of installed capacity
- **First of its kind collaboration** between gov't, owner/operators, consultants, independent engineers, and OEMs
- **GOAL: Improve methods for conducting pre-construction energy assessments** using data from operating projects

WP3 Stakeholder Engagement

Unprecedented Data Sharing & Collaboration among Wind Plant Owners, Resource Assessment Consultants, and Manufacturers



WP3 Results-Phase 1 participation



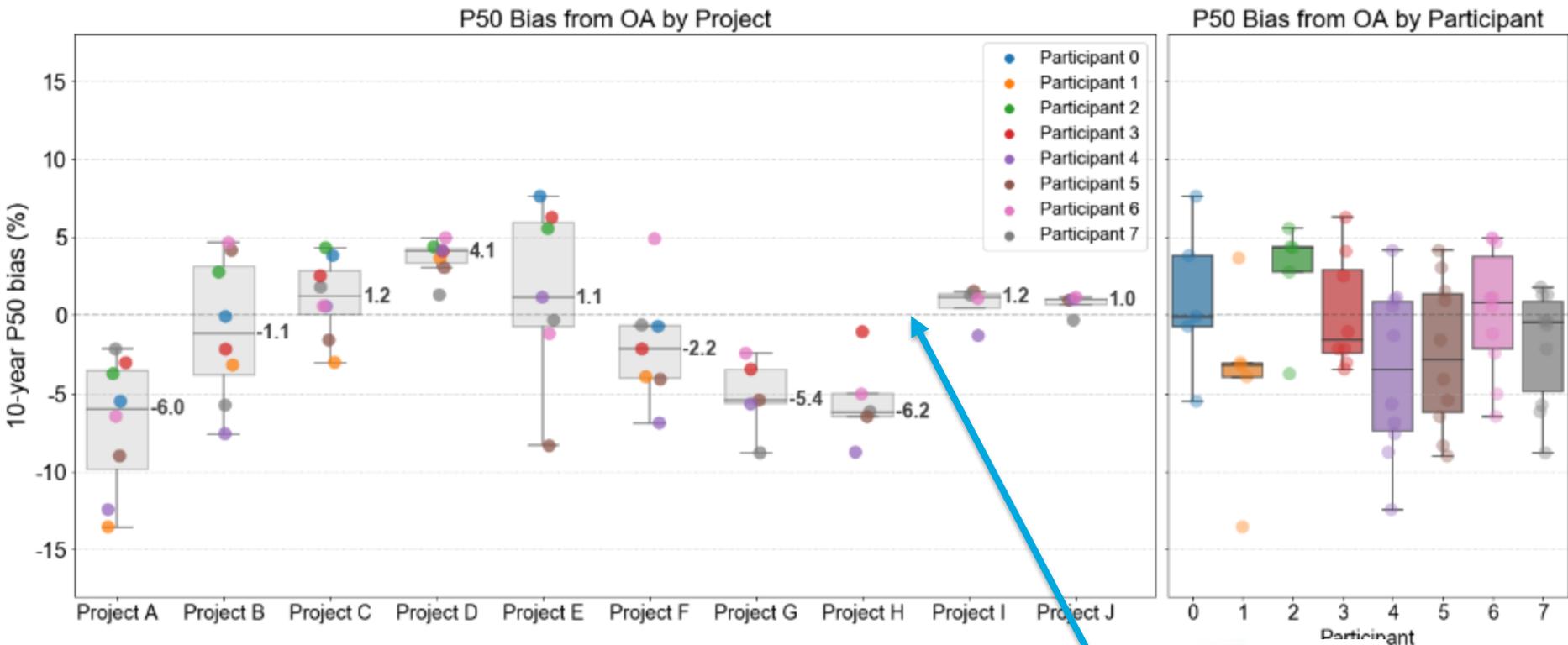
In kind contributions:
~\$2,000,000

Participant	Project										TOTAL
	A	B	C	D	E	F	G	H	I	J	
0	✓	✓	✓	✓	✗	✓	✗	✗	✗	✗	5
1	✓	✓	✓	✓	✓	✗	✗	✗	✗	✗	5
2	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	8
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
TOTAL	8	8	8	8	7	7	6	6	5	5	68

*85% completion for 10 projects/8 consultants

WP3 Results-P50

P50 Net Energy Estimate



WP3 Benchmark Data Challenges

Data Type	Number of plants
Metered Energy Data	
- Monthly	1
- Hourly or better	9
Availability and Curtailment Losses	
- Monthly	3
- Hourly or better	7
- Single availability metric	7
- Detailed breakdown of avail.	3
Losses	
- Turbine level	3
- Plant level	7
Status Codes / Event logs	
- No data provided	2
- High level categories provided	2
- Detailed (i.e. raw) data provided	6

80% of the effort is just wrangling disparate or bad or unstandardized data

Example 1:
No upgrade information

Example 2:
Operations started in 2011 but no information before 2015

Industry interviews

“Basic data management and reporting takes all of our time” - Wind Plant Operator

“We have no time or ability to engage third parties with 4 month trials” -Wind Plant Operator



NREL PIX 04178

Researcher interviews

We spend 20-80% of our time cleaning data and working with data providers to figure out the quirks in each new dataset.

- Researcher(s)



Our findings can be completely different depending upon how we process the data

- Researcher(s)

What is OpenOA ?

- **Python package** built largely to support **Wind Plant Performance Prediction (WP3) Benchmarking project**
- Extensive input from industry during code development
- Released publicly in 2018 (v1.0)
 - v2.0 released October 2020
- Implemented using **modern software development practices** to promote community engagement
 - Code hosted on GitHub:
<https://github.com/NREL/OpenOA/>
 - Community contributions managed using pull requests
 - Unit and integration tests
 - Documented using Sphinx

NREL / OpenOA

Watch 25 Star 69 Fork 31

Code Issues 9 Pull requests 2 Actions Projects 2 Wiki

v2.1 Go to file Code

Commit	Message	Time Ago
folder	Hotfix: Incorrect version of pypi publisher...	2 months ago
folder	Open OA Final Logos OenOA logos	11 months ago
folder	examples Merge branch 'develop' into new_LT_corre...	3 months ago
folder	operational_analysis bumping version number, appending to c...	2 months ago
folder	paper removed 20-year label from long term cor...	2 months ago
folder	sphinx Enhancement/add binder (#110)	4 months ago
folder	test Merge branch 'develop' into new_LT_corre...	3 months ago
file	.coveragerc created coveragerc file	10 months ago

About

This library provides a framework for working with large timeseries data from wind plants, such as SCADA. Its development has been motivated by the WP3 Benchmarking (PRUF) project, which aims to provide a reference implementation for plant-level performance assessment.

Readme

BSD-3-Clause License

Digital Technology

what is it? why now?

compute



Large and
small
Distributed
Cloud
Edge

connectivity



Internet
Mobile
5G

sensors & data

000111

100110

111011

Proliferation of data
Decreasing cost
of sensors
IoT

software

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AI/Machine learning
Blockchain
Big data
Open Source

Source: DNV-GL

IEA Wind Task 43



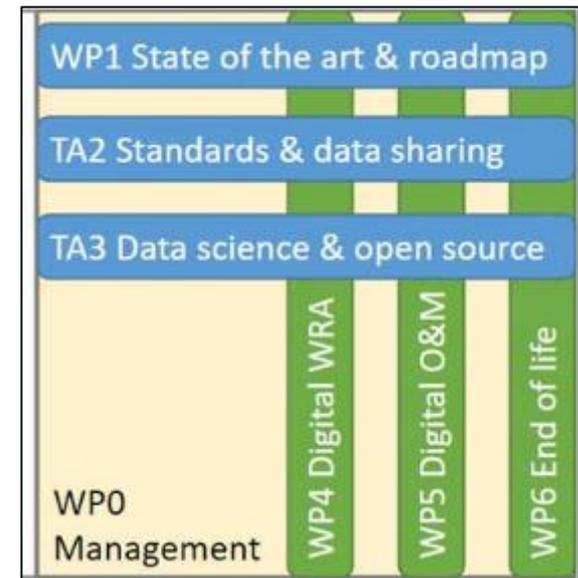
WP1-3: Cross cutting

WP4-6: Application areas

Deliverables:

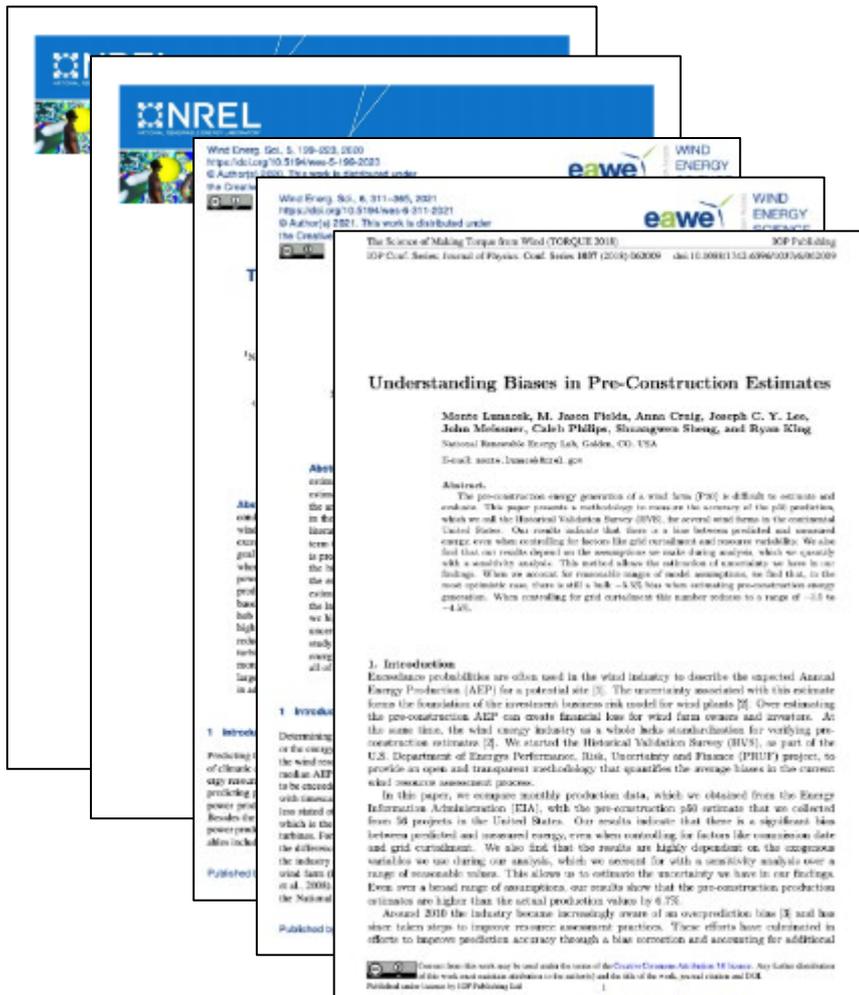
- Data Standards, Best Practices, and open source tools

Leading the Digitalization grand challenges



Participants: DNV-GL, EDF R&D, EDF Energy, NREL, NRG Systems, Fraunhofer IEE, DTU, RES, Sentient Science, GI-Engineering, OWI-lab/VUB, GE, Siemens-Gamesa

PRUF Accomplishments & Outreach



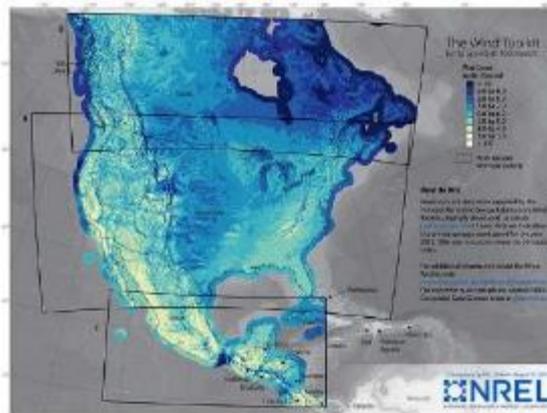
- Technical Reports
- Peer reviewed Publications
- Open Source Software
- Conferences
- Podcast
- IEA Task



PRUF Accomplishments-Research Support

DOE Research Support

- Wind Toolkit Validation
- ML Downscaling Validation
- OpenOA



Wind Farm Simulation and Layout Optimization in Complex Terrain

Jeffrey Adams, Brian King, Garrett Drake
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Abstract. Wind farm layout optimization is a complex task due to the large number of variables and the high cost of wind energy. This paper presents a novel approach to wind farm layout optimization in complex terrain. The approach involves the use of machine learning to predict the power output of a wind farm layout in a given terrain. The approach is based on a deep neural network that takes as input the terrain data and the layout data. The approach is able to predict the power output of a wind farm layout in a given terrain with a high degree of accuracy. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain.

1. Introduction

Wind energy is a renewable source of energy that is becoming increasingly important in the global energy mix. Wind farms are a key component of wind energy production. The layout of a wind farm is a critical factor in determining its power output. The layout of a wind farm is a complex task due to the large number of variables and the high cost of wind energy. This paper presents a novel approach to wind farm layout optimization in complex terrain. The approach involves the use of machine learning to predict the power output of a wind farm layout in a given terrain. The approach is based on a deep neural network that takes as input the terrain data and the layout data. The approach is able to predict the power output of a wind farm layout in a given terrain with a high degree of accuracy. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain. The approach is able to handle complex terrain and is able to optimize the layout of a wind farm in a given terrain.

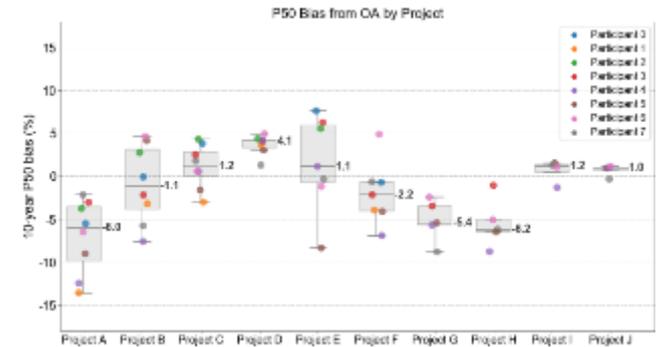
External Research Support



Summary

WP3 Benchmark

- Phase 1: 10 projects



OpenOA

- Open source operational assessment project



Wind Energy Digitalization

- New data frontiers



Thank you

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www.nrel.gov/wind