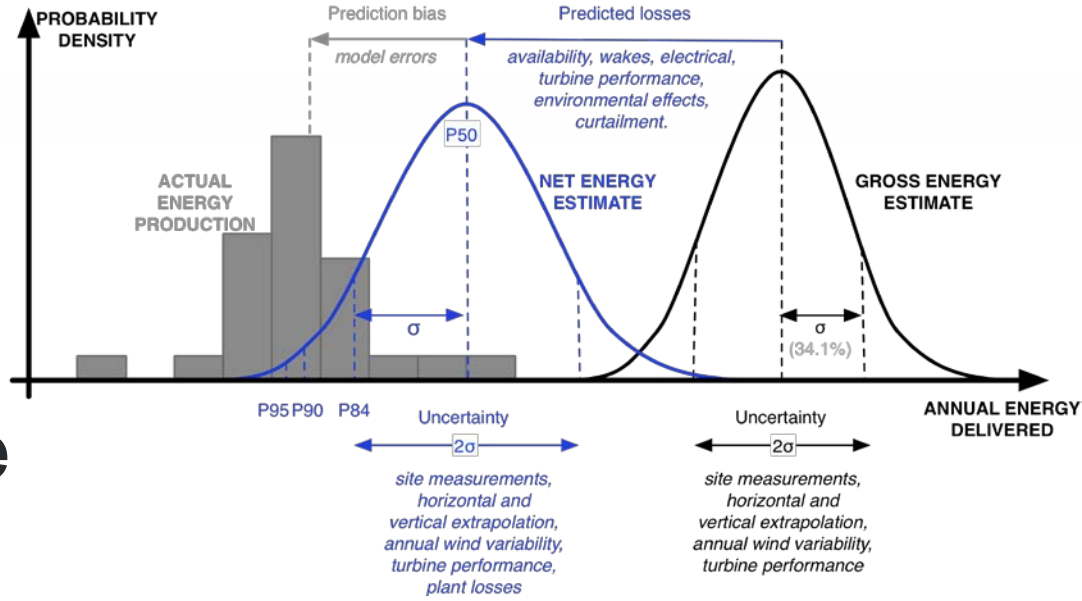
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY



Performance Risk, Uncertainty & Finance

Project ID # T-11

Jason Fields

NREL

FY17-FY18 Wind Office Project Organization

"Enabling Wind Energy Options Nationwide"

Technology Development	Market Acceleration & Deployment
Atmosphere to Electrons	Stakeholder Engagement, Workforce Development, and Human Use Considerations
Offshore Wind	Environmental Research
Distributed Wind	Grid Integration
Testing Infrastructure	Regulatory and Siting
Standards Support and International Engagement	
Advanced Components, Reliability, and Manufacturing	

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.

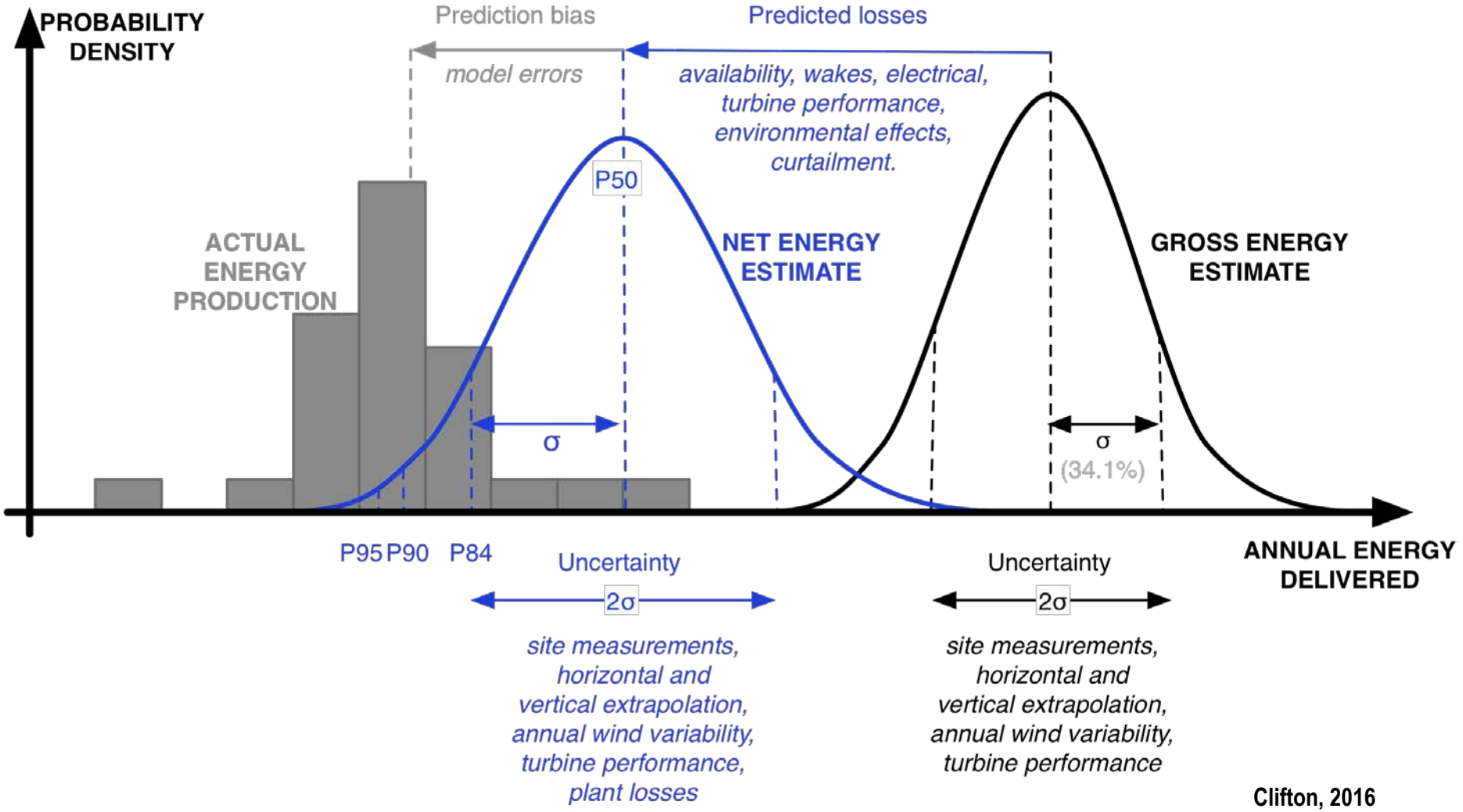
Project Objective & Impact

- **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

Project Attributes

Project Principal Investigator(s)
Jason Fields
DOE Lead
Patrick Gilman
Project Partners/Subs
John Meissner – Canvas Innovations
Project Duration
2015-Present

Technical Merit and Relevance



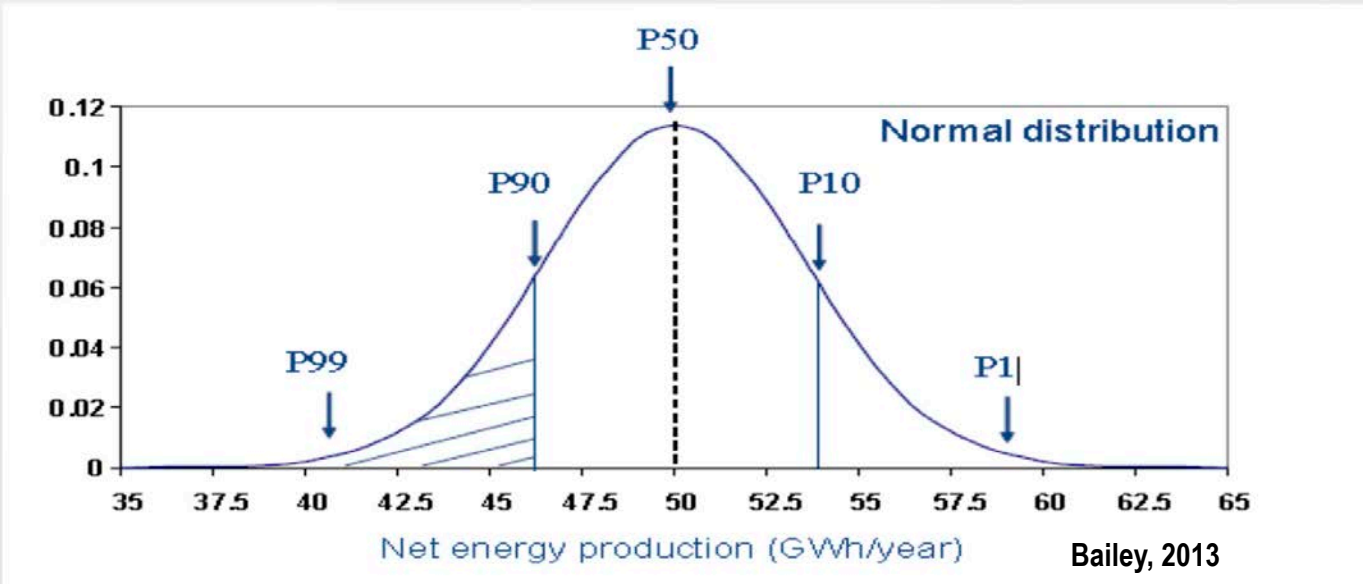
Clifton, 2016

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.



Bailey, 2013

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

Research Integration & Collaboration

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

Approach and Methodology

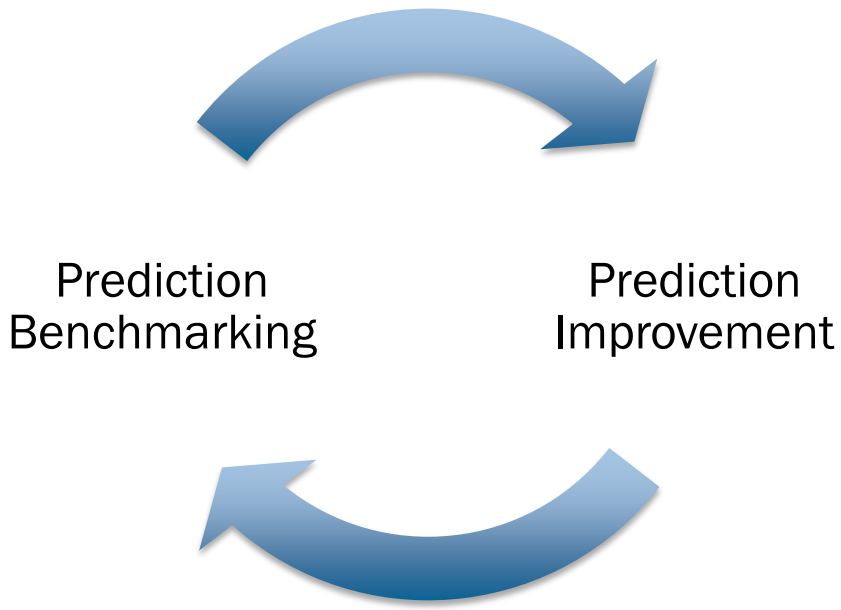
Benchmarking:

- P50,P90, P95
- Loss & Uncertainty Assumptions

Responsibilities:

- Owners: Share Data
- Consultants: Energy Estimates
- NREL: Operational Assessment

The Virtuous Cycle



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

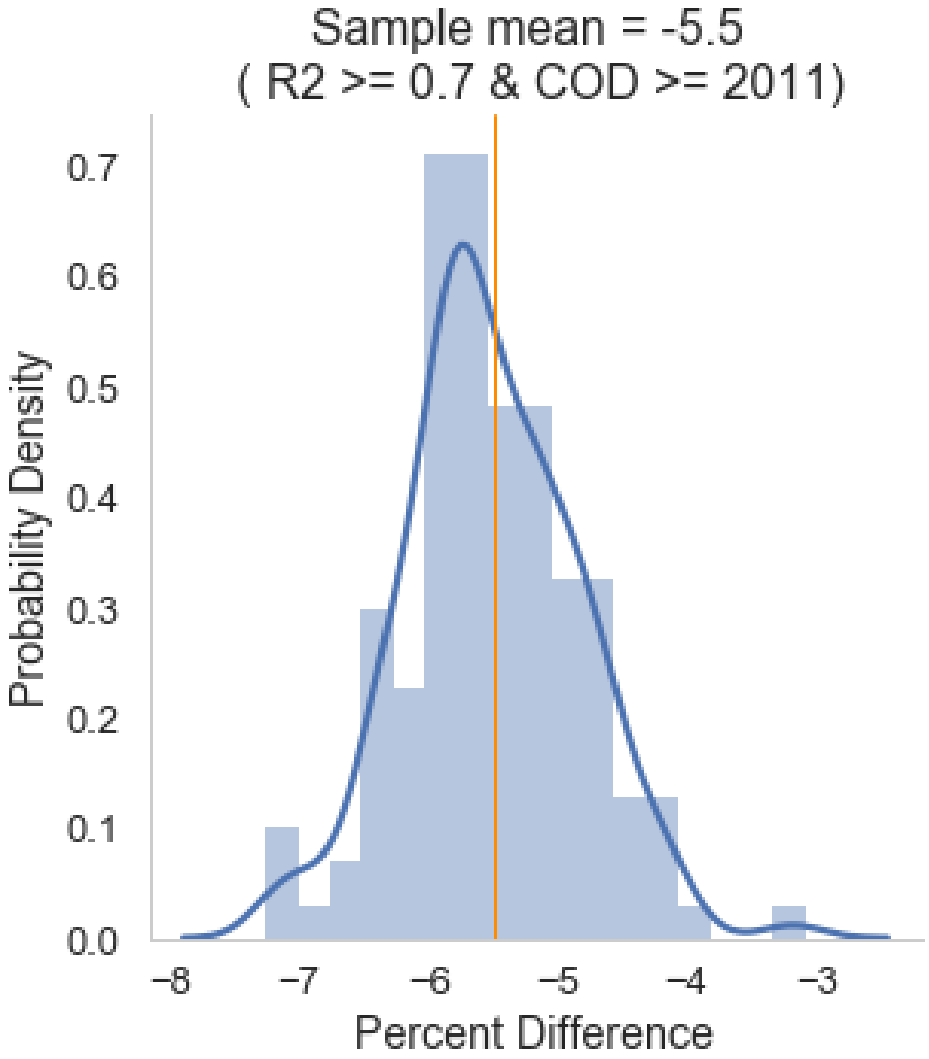
Accomplishments and Progress-HVS

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

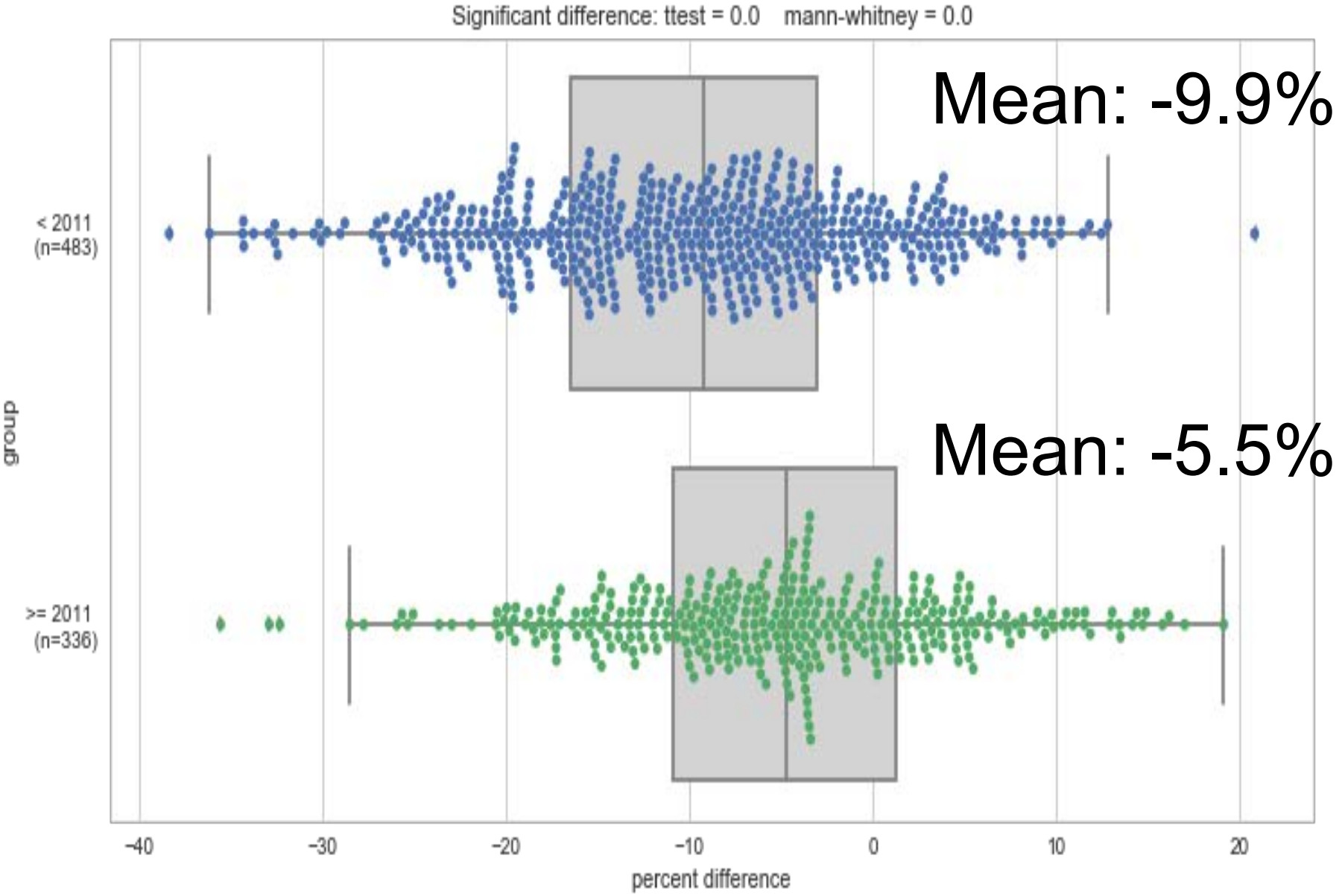


- Mean bias: -5.5%
- *Uncertainty: 1.3%*

- *Correction methods:*
  - *Extreme events*
  - *Long term period*

- *First independent, market agnostic analysis of its kind*

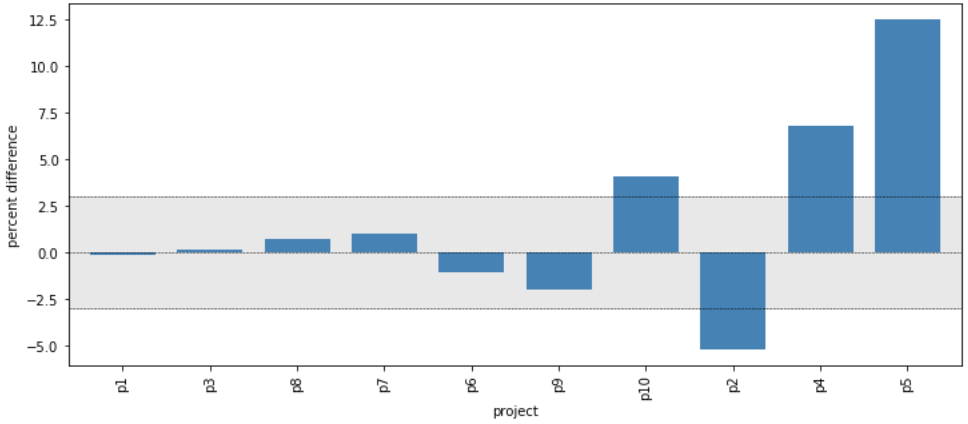
HVS – Evidence of Improvement



WP3Benchmark Work Activities

Pilot Project.

- 150 MW Project (TX)

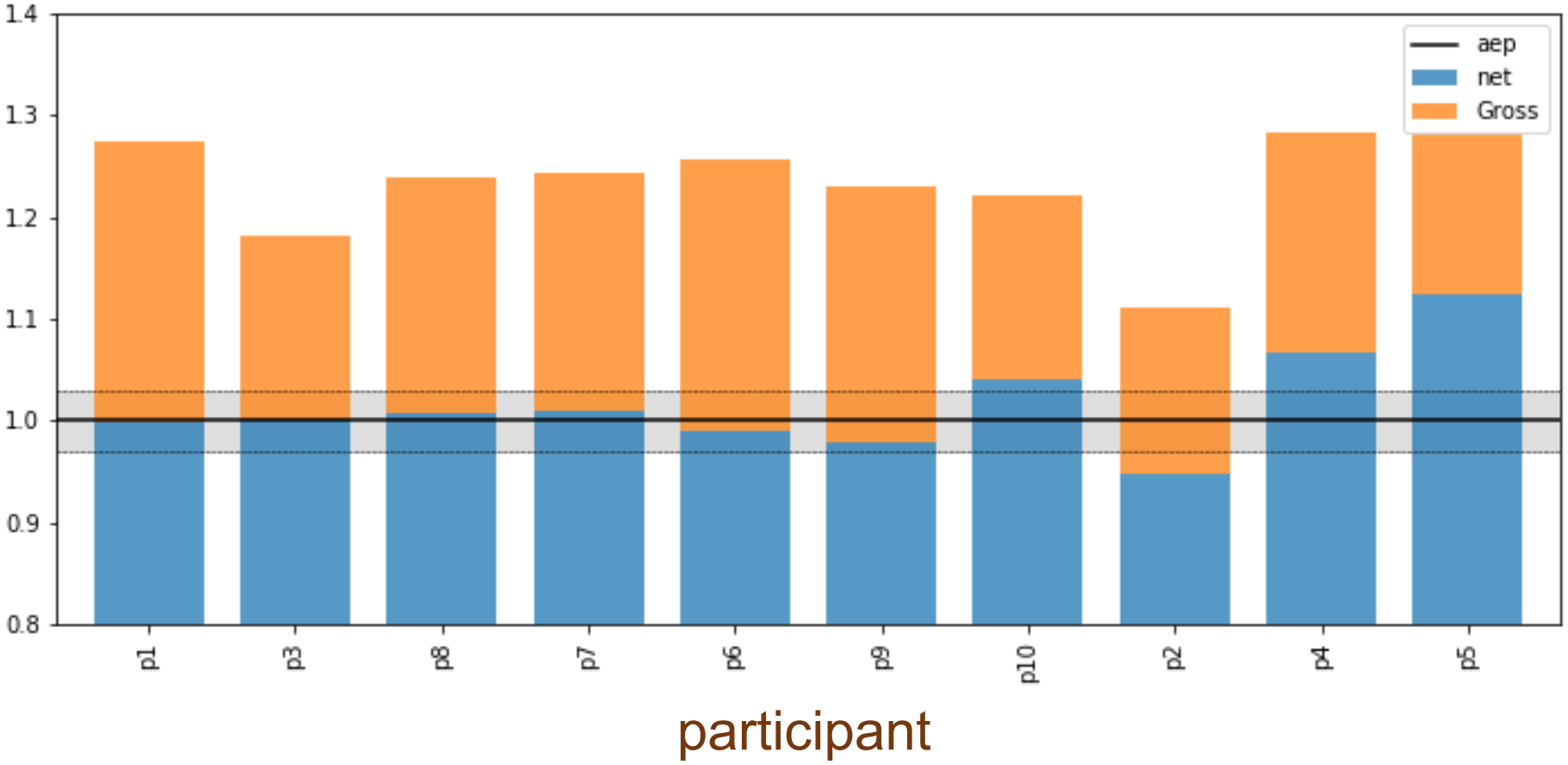


Phase 1: (First 10 projects)

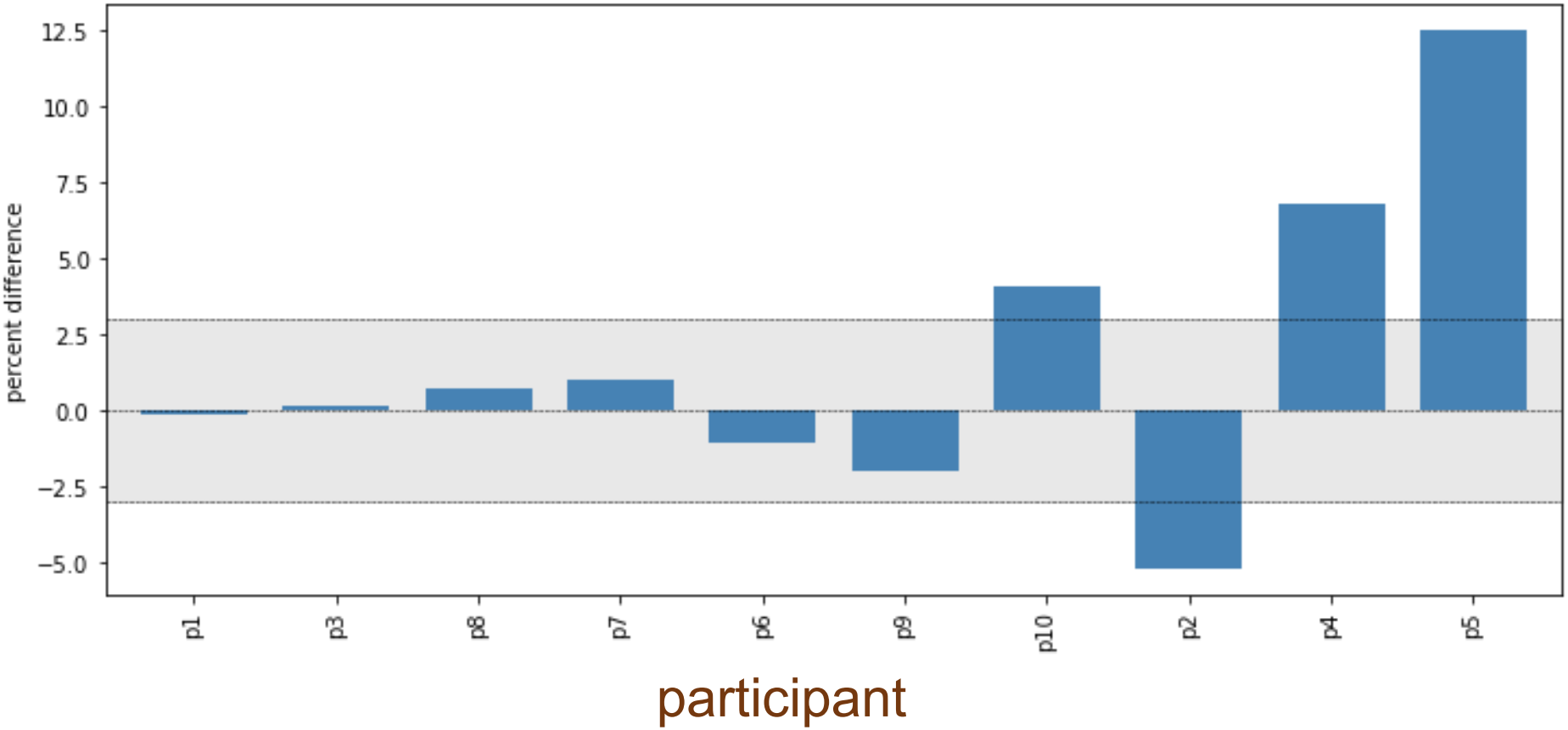
- Pre-Con Data released: 10 of 10
- Operational Data:

  9 of 10 projects processed
- Consultant Responses: 40 of 100

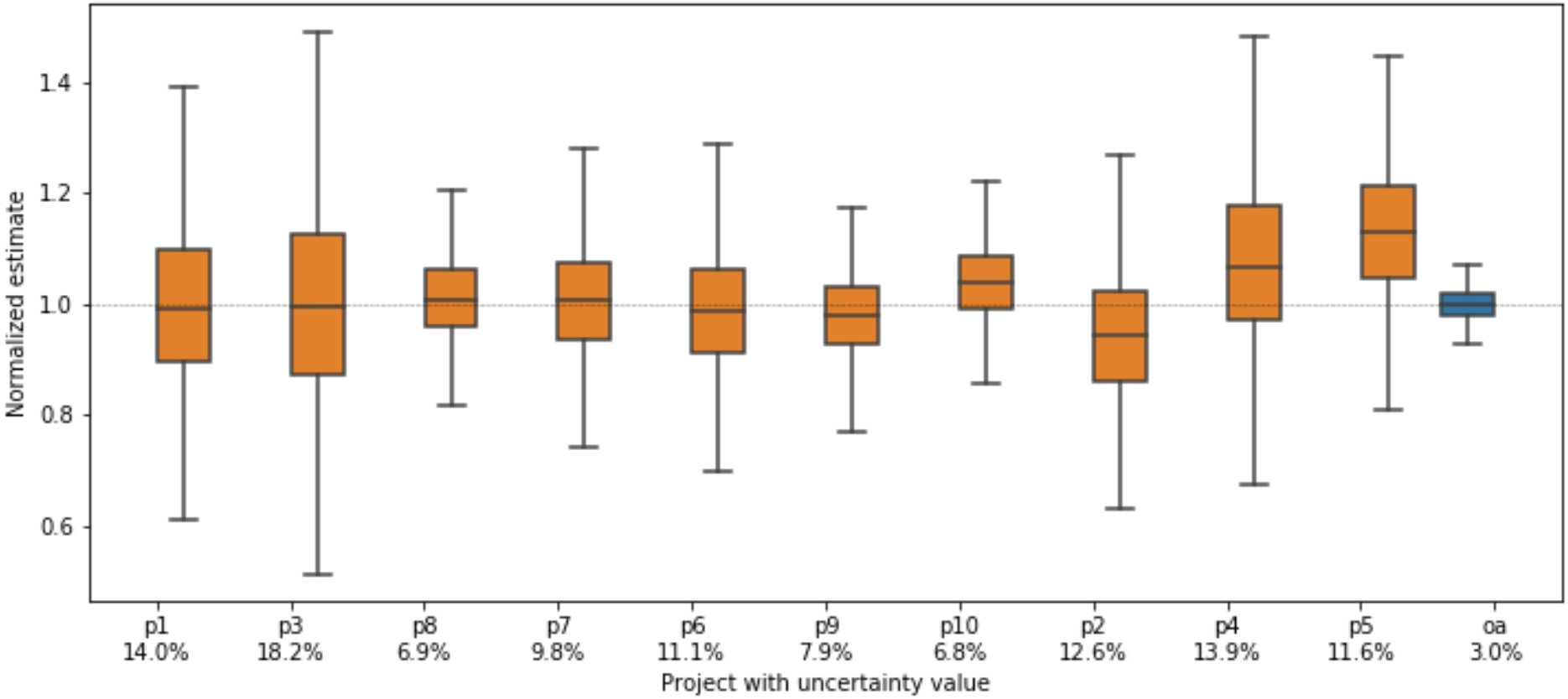
Normalized AEP vs Net



P50 vs OA Percent Difference



Uncertainty

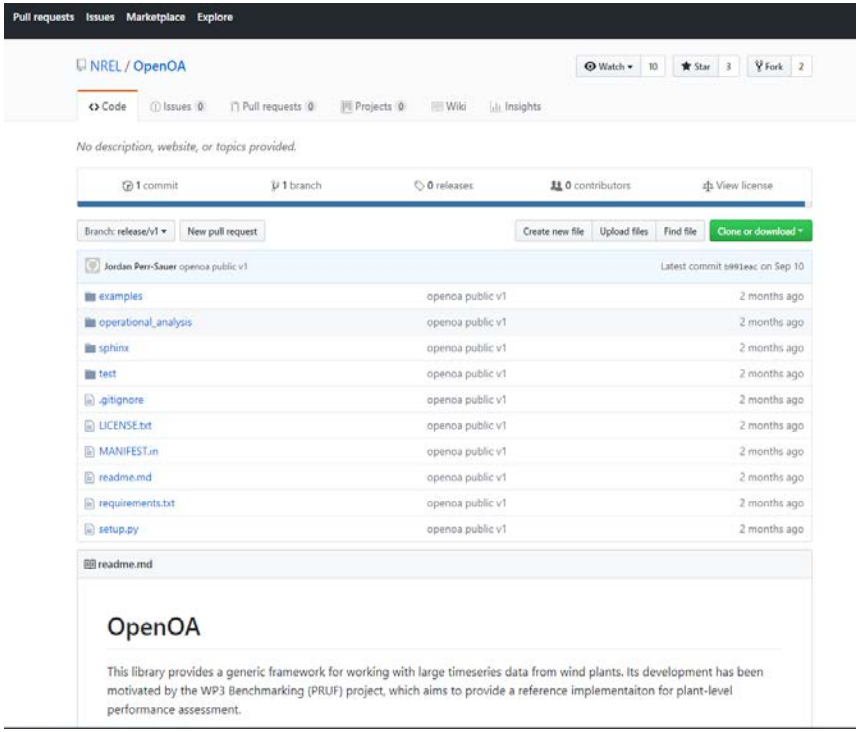


New Tools for Research and Industry

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



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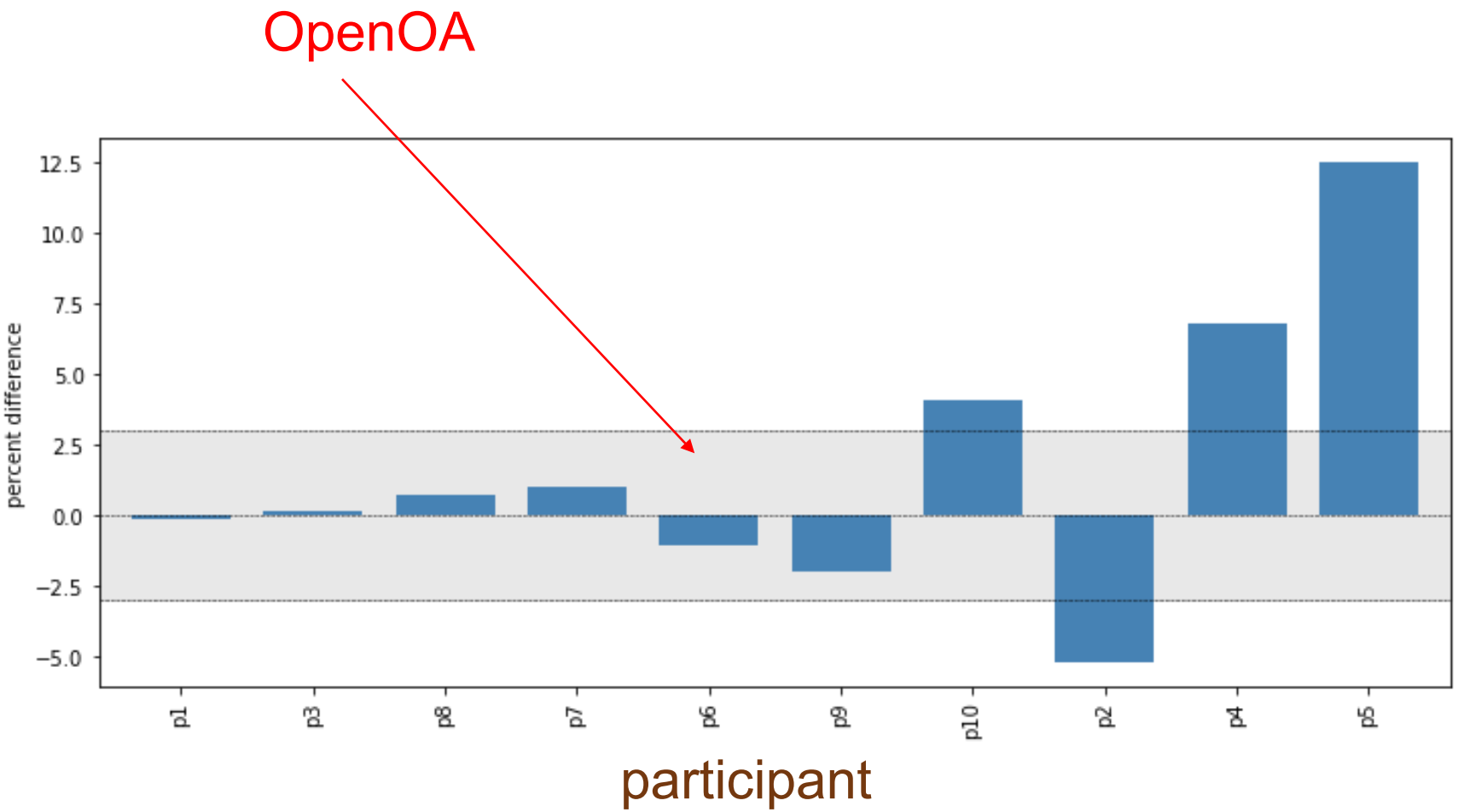
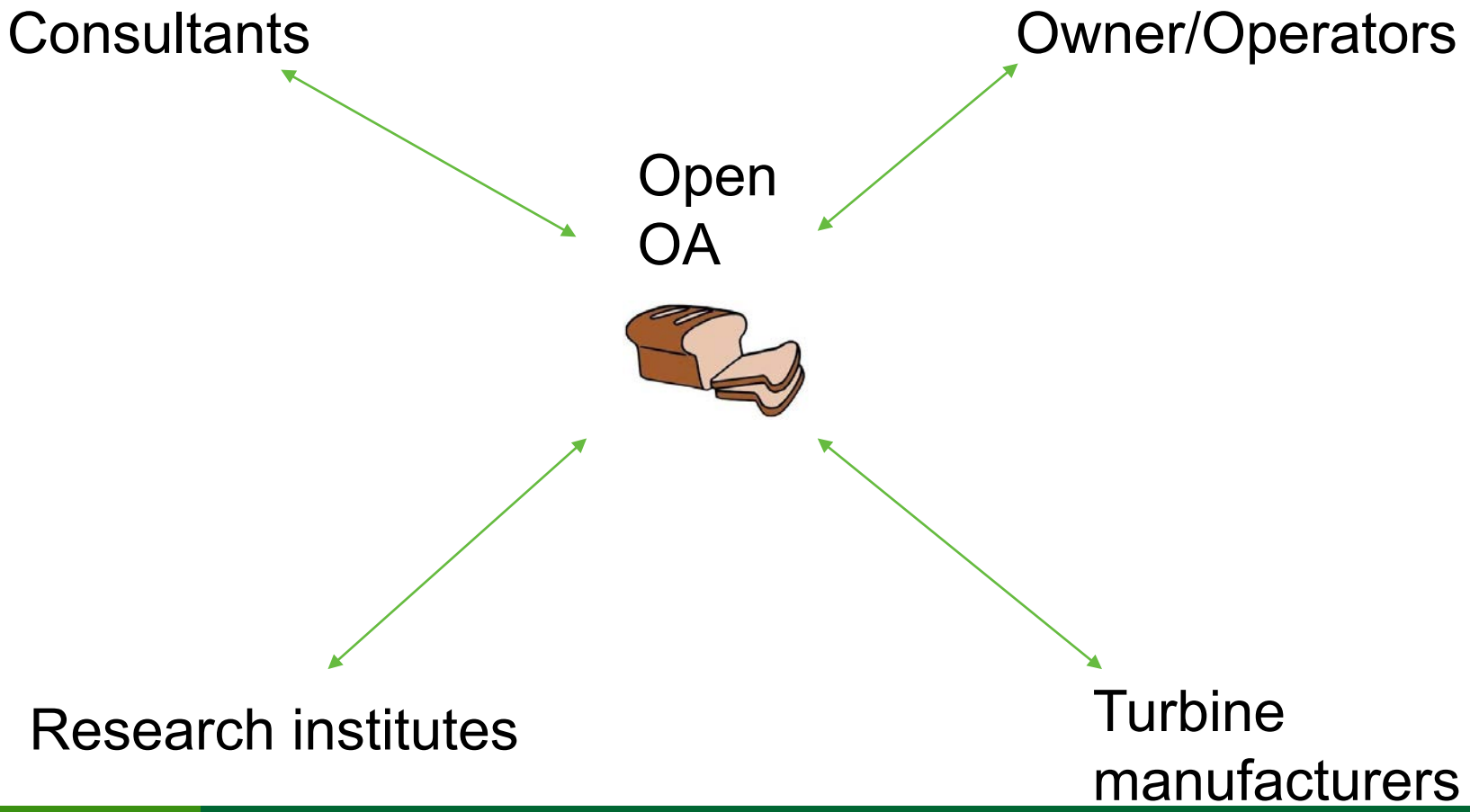


The Future of OpenOA

- Supported and developed by a large user community
- NREL houses codebase and manages its development

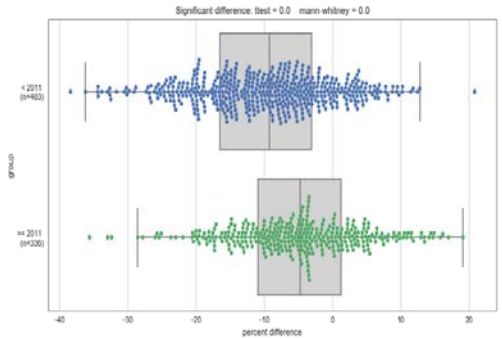


Communication, Coordination, and Commercialization

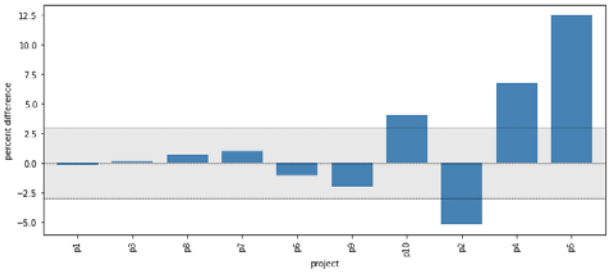
- **Presentations and posters**
  - AWEA, TORQUE, IEA, AMS, AGU
- **Publications**
  - Wind Plant Preconstruction Energy Estimates: Current Practice and Opportunities. A.Clifton, A. Smith, M.J. Fields
  - Wind Energy Finance in the United States: Current Practice and Opportunities. P Schwabe, D Feldman, J. Fields, and E. Settle
  - 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



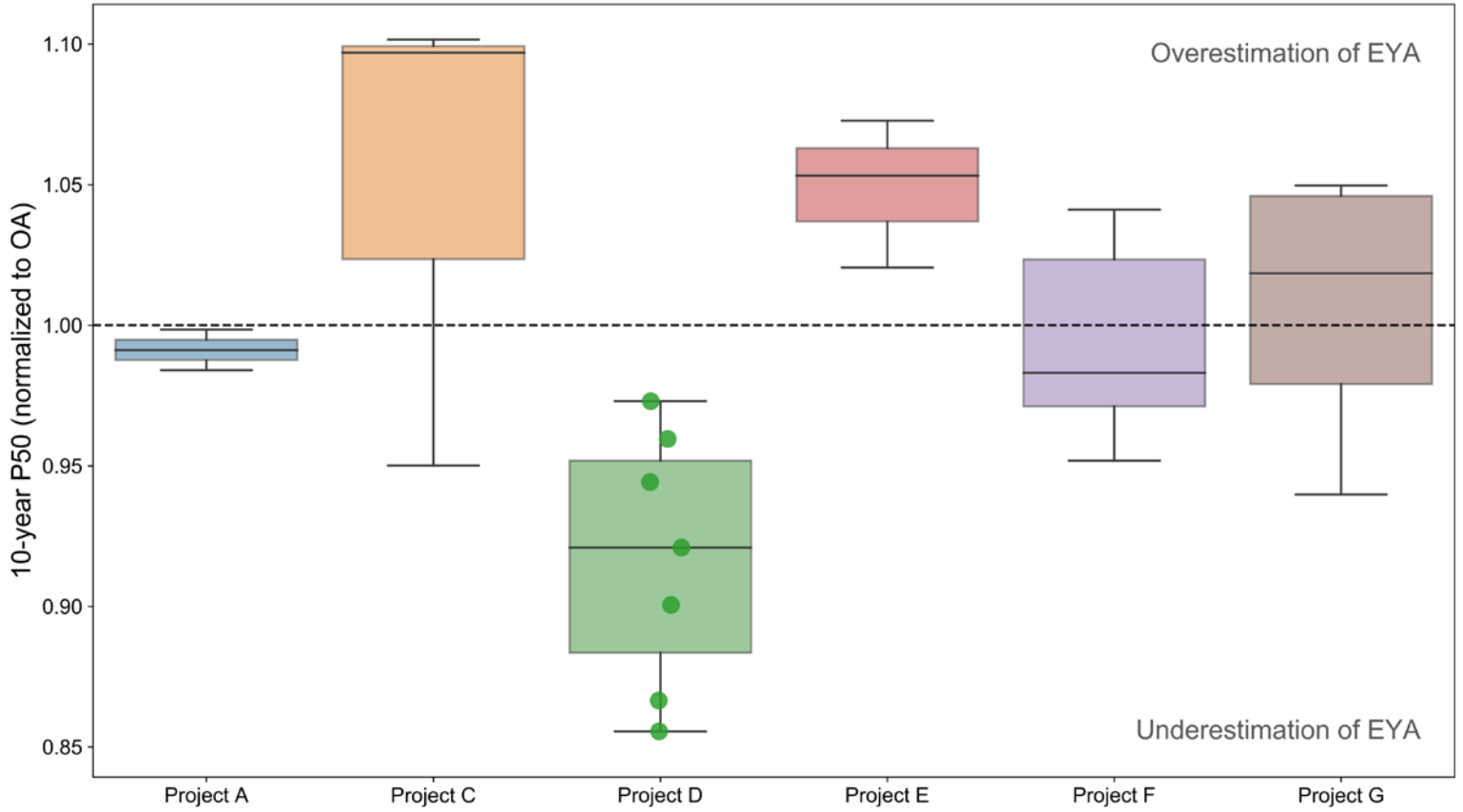
Benchmark:
Changing the game on collaboration



New Tools: OpenOA

Upcoming Project Activities

- **Phase 1 completion**
- OpenOA development and dissemination
- Wind Energy Digitalization



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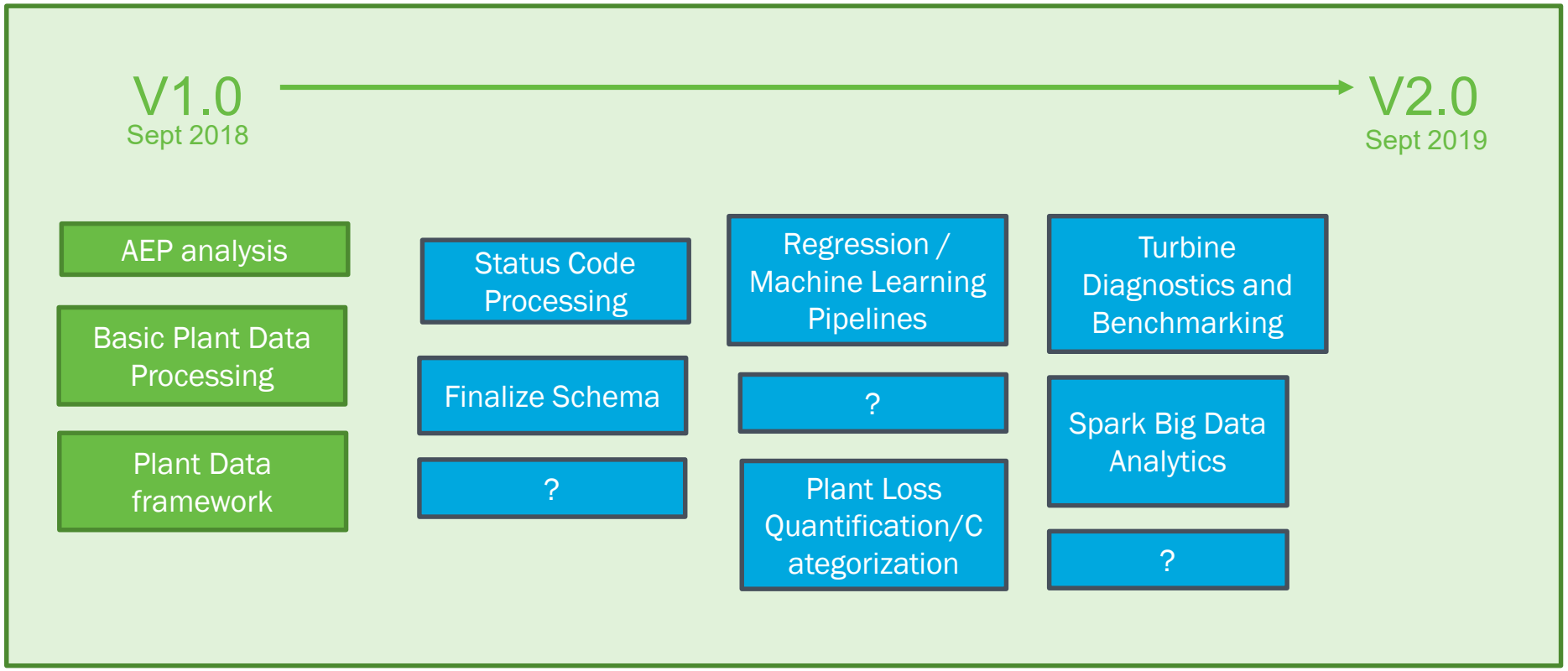

Upcoming Project Activities

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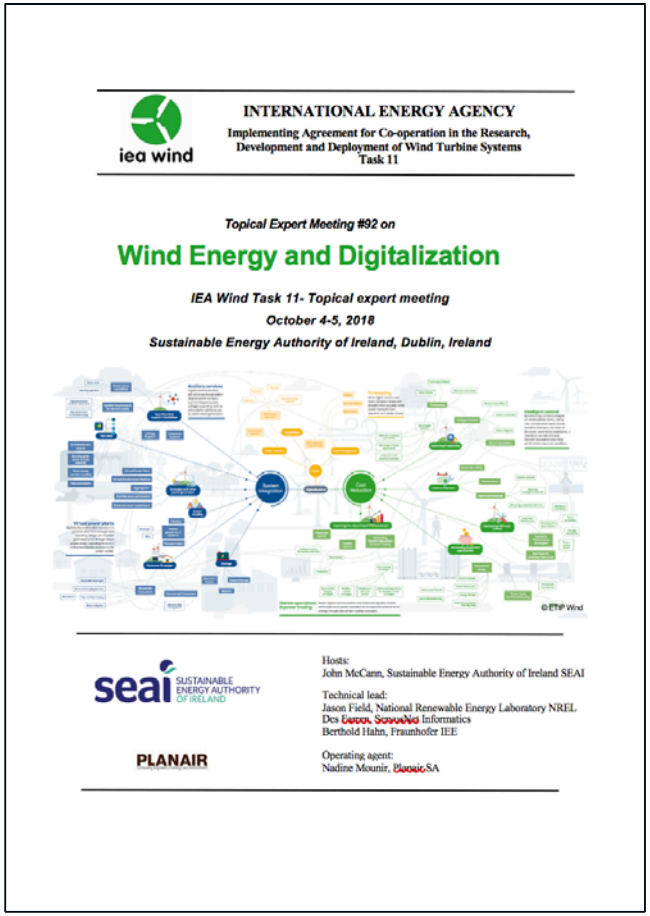

iea wind

INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems

Task 11

Topical Expert Meeting #92 on

Wind Energy and Digitalization

IEA Wind Task 11- Topical expert meeting

October 4-5, 2018

Sustainable Energy Authority of Ireland, Dublin, Ireland

©ETIP Wind

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PLANAIR

Hosts:
John McCann, Sustainable Energy Authority of Ireland SEAI

Technical lead:
Jason Field, National Renewable Energy Laboratory NREL
Des Farren, ServusNet Informatics
Berthold Hahn, Fraunhofer IEE

Operating agent:
Nadine Mounir, Planair SA