U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

NREL Transforming ENERGY

T24 – Modeling and Validation for Offshore Wind

Technology RD&T and Resource Characterization – Atmosphere to Electrons (A2e)

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FY21 Peer Review - Project Overview

Project Summary:
Enable the advancement of innovative offshore wind technologies to commercial maturity by validating offshore wind modeling tools with high-quality datasets under a variety of conditions. Validation will assess the accuracy of the modeling tools, provide a better understanding of their uncertainties, identify needed areas of improvement, and increase their acceptance within industry and wind research communities.

Key project partners: IEA Wind Task 30 participants, which include offshore wind design tool developers, turbine/support structure designers, research institutions, test laboratories, and certifiers.

Project Start Year: FY 2016
Expected Completion Year: FY 2023
Total expected duration: 8 years

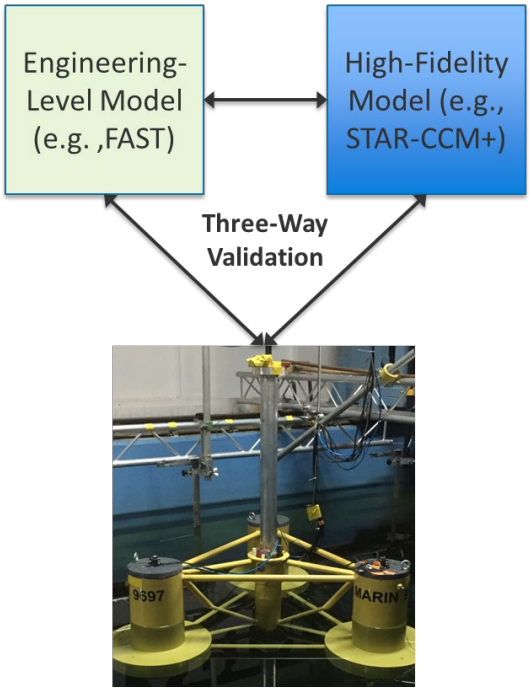
FY19 - FY20 Budget: $2,094,388

Key Project Personnel: PI: Amy Robertson, Jason Jonkman, Roger Bergua, Lu Wang, Yi-Hsiang Yu

Key DOE Personnel: Alana Duerr, Nathan McKenzie

Project Objective(s) 2019-2020:
- Lead OC6 project, with new focus on 3-way validation between engineering and high-fidelity modeling tools and measurements for phenomena critical to load prediction in offshore wind systems: nonlinear hydrodynamics for floating wind systems and soil/pile interaction for fixed-bottom.
- Create new soil/structure interaction module in OpenFAST (SoilDyn)
- Develop high-fidelity modeling competency for offshore wind systems

Overall Project Objectives (life of project):
- Verify and validate offshore wind modeling tools against measurement data to assess accuracy in design and innovation.
- Develop datasets needed to address specific validation objectives identified as critical to the accurate use of offshore wind modeling tools.
- Improve physics of offshore wind modeling tools to address outcomes of validation campaigns and technology innovations.
- Develop best practices for modeling, testing, and validation

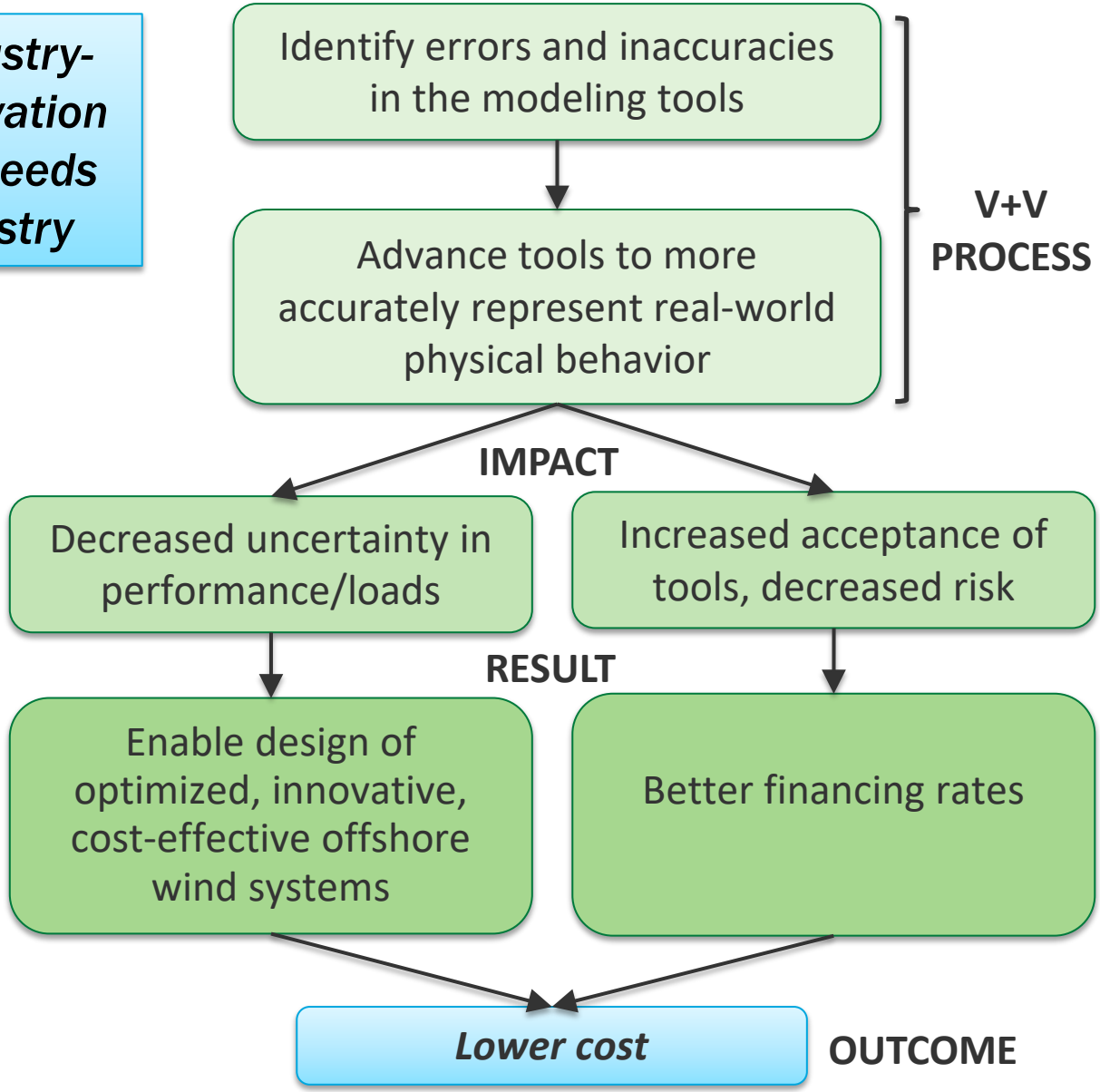


Impact of Verification and Validation (V+V)

Validated tools enable industry-wide rapid technology innovation to address cost-reduction needs for the offshore wind industry

V+V work in this project builds off and informs other projects:

- **V+V and UQ of Wind Plant Models:** V+V approach for windfarms
- **Multi Physics Model Validation & UQ:** V+V of large rotors and windfarms
- **This Project:** Adaption of V+V methods from T22+T23 for offshore wind systems, and application to phenomenon critical to offshore technology
- **HFM:** This project informs needs for development of new HFM capabilities for offshore wind

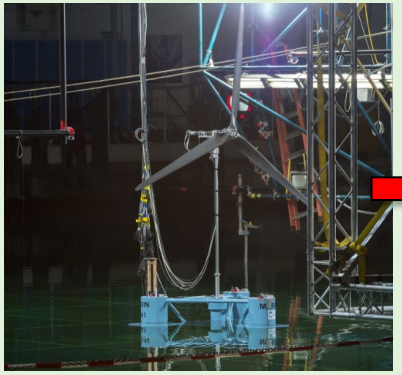


Project Impact

This project supports NREL's leadership of OC6, which is performed collaboratively with end-users across the industry, developing project objectives, supplying guidance and results, and implementing into their engineering practices.

- *Example of impact:* Modeling tools under-predict motion/loads of floating offshore wind (FOW) semi by 20%, OC6 seeks to eliminate this uncertainty.
  - Significant impact on ability to optimize (stream-line or make smaller) support structure and mooring system
  - Stream-lining needed to reach large-sized designs that challenge limit on physical capabilities
- Validation projects created in OC6 to better understand issue (nonlinear hydrodynamics)

OC5 Phase II



Full FOW system

Tested: MARIN, 2013

Impact: Underestimation of global loads – 20%

OC6 Phase Ia

FOW support structure

Tested: MARIN, 2017

Impact: Confirmed 20% underprediction, assessed uncertainty

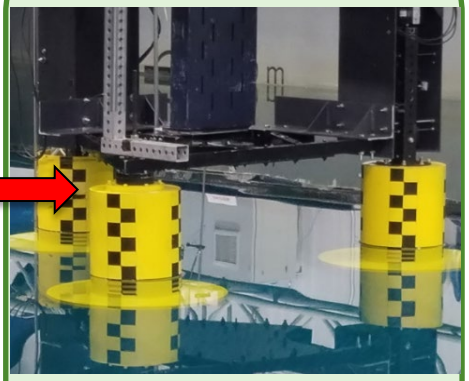
OC6 Phase Ia

FOW substructure

Tested: MARIN, 2018

Impact: Identified hydro components contributing to underestimation

OC6 Phase Ib

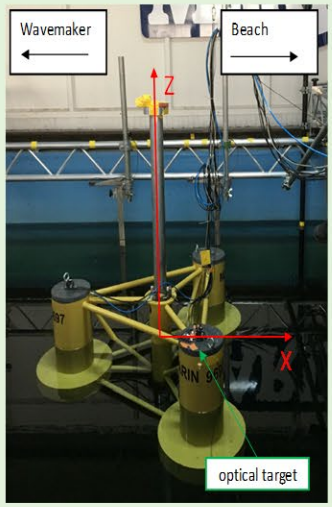


FOW subst. components

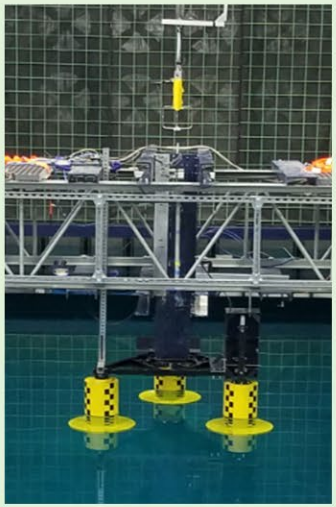
Tested: UMaine,TBD

Impact: Broke apart hydro comp. further and data for high-fidelity validation

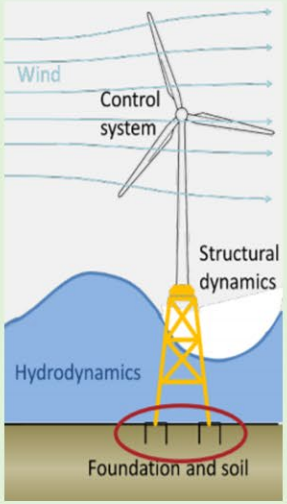
Project Performance - OC6 Schedule



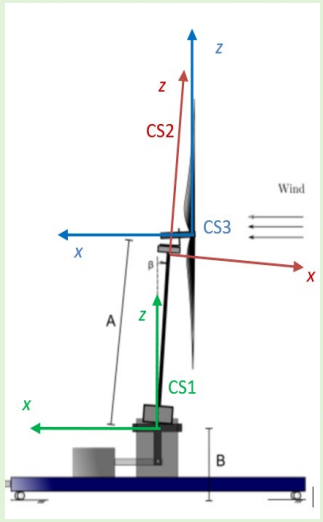
Phase Ia:
Nonlinear Hydrodynamics
Jan 2019 – March 2020
(OWN TESTING)



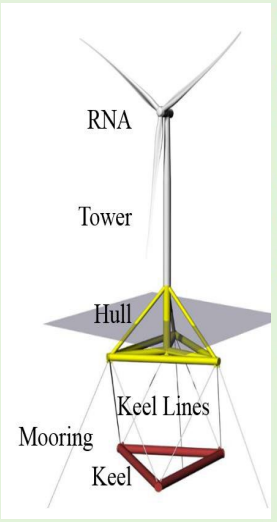
Phase Ib:
Nonlinear Hydrodynamics2
Jan 2019 – May 2021
(OWN TESTING)



Phase II:
Soil/Structure Interaction
March 2020 – March 2021
(REDWIN)



Phase III:
Aerodynamics under Motion
March 2021 – March 2022
(LIFES50+)



Phase IV:
Hydrodynamic Challenges
March 2022 – June 2023
(STIESDAL)

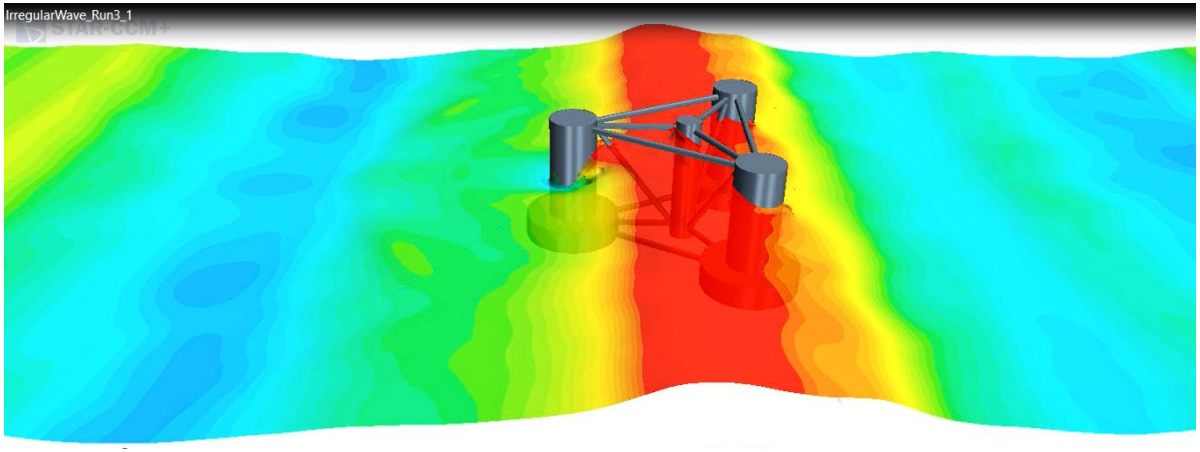
- Red = Work completed in FY19-FY20
- Blue = Initiated in FY20 – to be completed in FY21
- Black = Future work

- All project milestones completed on time and on budget, with the exception of one related to OC6 Phase Ib.
- **OC6 Phase Ib delayed**– new validation campaign focused on better understanding nonlinear hydrodynamic loads and enabling CFD validation
  - Planned to be completed end of FY19 – now mid FY21
  - Original testing facility was not producing data of quality needed for validation
  - Made decision to change test venues, which incurred delays – and then more delays due to COVID (laboratory shut down)

Project Performance – OC6 Phase Ia Completion

OC6 Phase I Objective:

Improve load and motion predictions in semisubmersible offshore wind systems at their pitch and surge natural frequencies



Computational Fluid Dynamics (CFD) simulation of floating wind semisubmersible substructure

Outcomes:

- OC6 Phase Ia - Identified hydrodynamic component with largest underestimation in engineering models, but not how to address
- Performed complete uncertainty assessment of validation campaigns to understand role in underprediction -> **uncertainty approach for others to follow**
- Initiated three-way validation with higher-fidelity models -> **developed offshore wind CFD competency** (expertise in how to accurately use CFD for offshore wind analysis)
- OC6 Phase Ib – new validation campaign planned to dissect hydrodynamic loads and validate CFD models
  - Focus: component interactions, bichromatic waves, distributed measurements, pitched condition, wave uncertainty
  - **Once CFD validation complete, will use knowledge to address underestimation in engineering models**

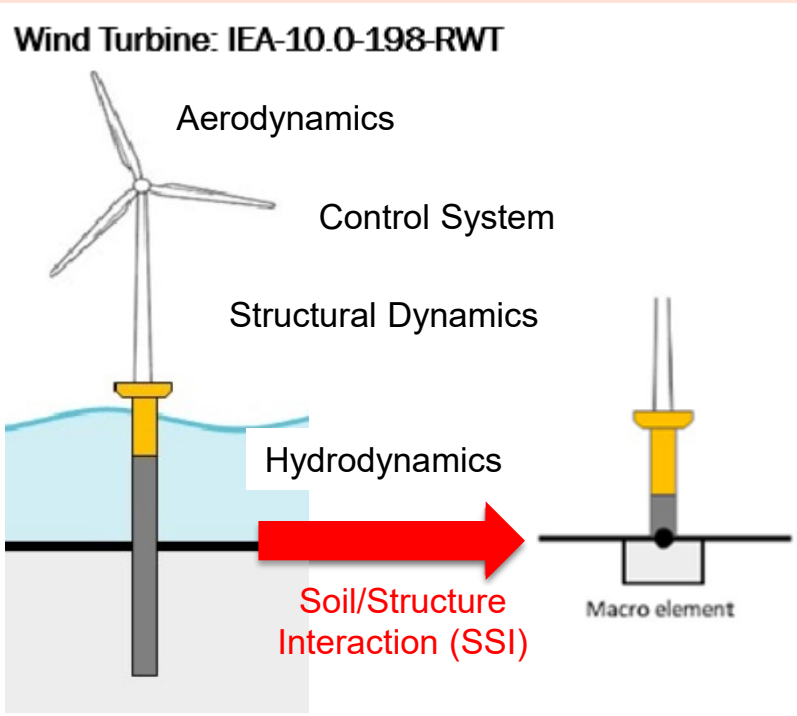
Project Performance – New SoilDyn Module

OC6 Phase II Objective:

Improve accuracy of soil/structure interaction models in engineering-level offshore wind tools, which directly affects the dynamic response of fixed-bottom offshore wind systems

Outcomes:

- SoilDyn = Created new soil/structure interaction module in OpenFAST
  - Includes a higher-fidelity modeling capability developed in REDWIN project
- REDWIN model being coupled to a variety of offshore wind modeling tools in OC6 Phase II – verification is on-going



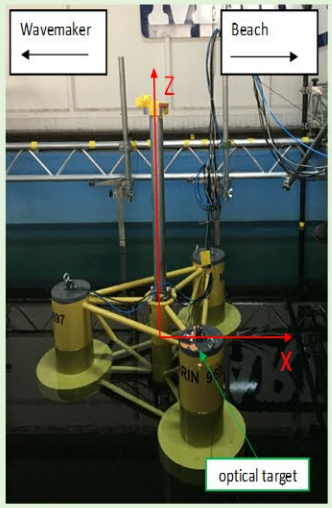
REDWIN Macro-element approach:

- Response of pile and surrounding soil is condensed to a force-displacement relation at seabed
- Includes hysteretic damping and plasticity
- Coupled to wind modeling tools through DLL

R&D program | REDWIN - reduce wind energy cost

REDucing cost in offshore WINd by integrated structural and geotechnical design is a R&D Project supported by The Norwegian Research Council ENERGIX program.

Project Performance – Upcoming Activities



Phase Ia:
Nonlinear Hydrodynamics
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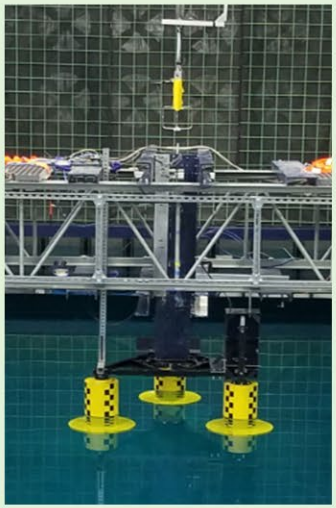

Phase Ib:
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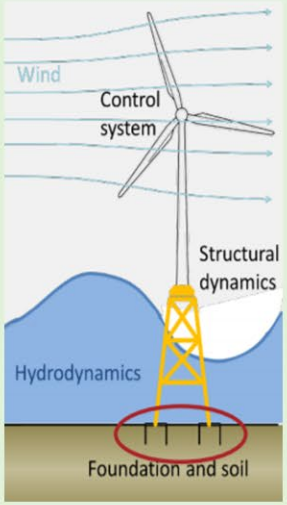

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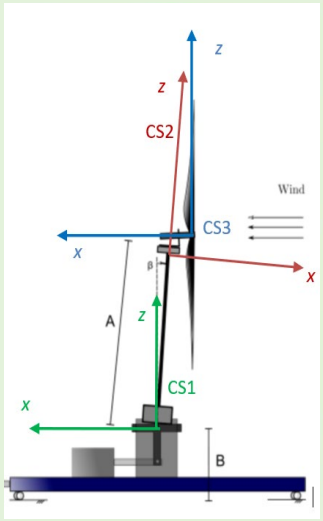

Phase III:
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March 2021 – March 2022
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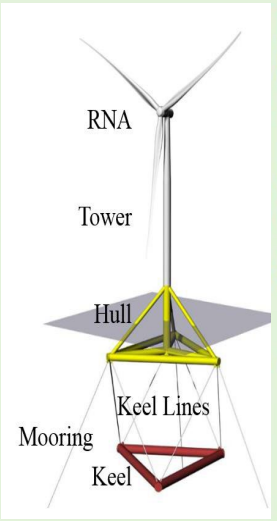


Phase IV:
Hydrodynamic Challenges
March 2022 – June 2023
(STIESDAL)

- **OC6 Phase Ib:** Complete campaign, validate CFD tools, modify engineering tools based on findings
- **OC6 Phase II:** Complete verification of coupling of REDWIN soil/structure interaction model in SoilDyn and other industry tools
- **OC6 Phase III:** Initiate and complete
- **OC6 Phase IV:** Initiate and complete
- **OC7:** Gauge interest and hold planning workshop

Continue successful leadership of OC6, and develop plans for OC7

Stakeholder Engagement & Information Sharing

OC6 is performed collaboratively with end-users across the offshore wind industry, developing project objectives, supplying guidance and results, and implementing into their engineering practices

246 Attendees	97 Organizations	17 Countries	$3.6M In-kind labor per year

Key Participants *(OW = Offshore Wind):*

- *OW turbine designers:* Siemens Gamesa, LM Wind Power
- *OW platform designers*: Principle Power, IFP Energies nouvelles, SBM, Saitec Offshore
- *Project developers:* EDF renewables, Shanghai Electric Group
- *Certifiers*: ABS Consulting, DNV, Bureau Veritas, ClassNK, China General Cert.
- *Software developers:* Siemens PLM, Danish Tech. Univ., DNV (repeat), NREL, Orcina, Simis
- *Testing laboratories:* MARIN, Marintek
- *Research institutions:* CENER, TNO, Politecnico di Milano, SINTEF Ocean, Tecnalia, Sandia National Labs, Norwegian Geotechnical Institute

Stakeholder Engagement & Information Sharing

Broader dissemination:

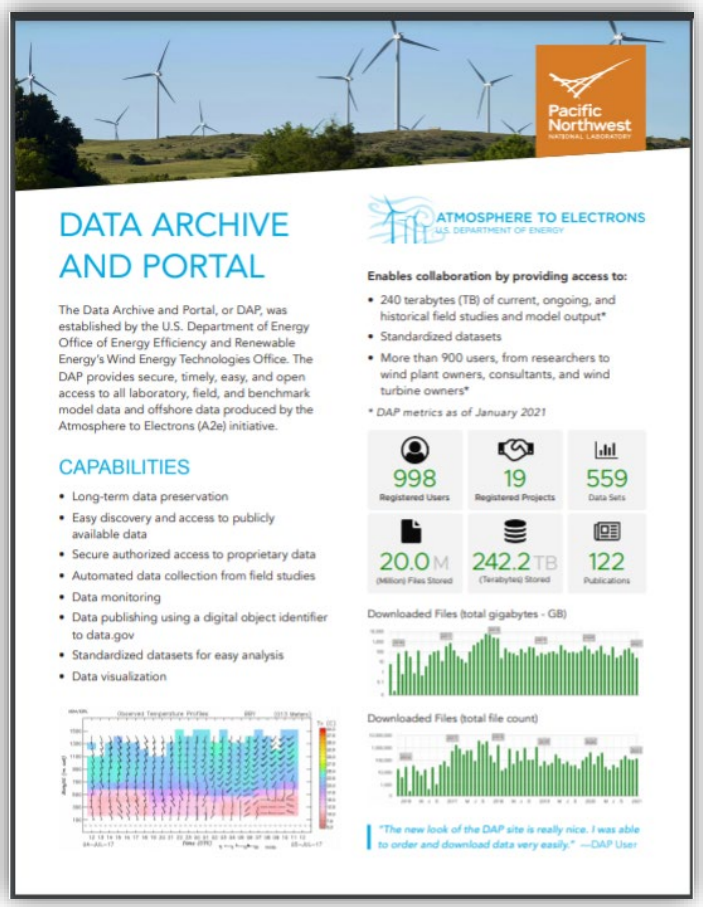
- **Project report at end of each phase (conference or journal article, and IEA report)**
  - 8 journal articles/conference papers in FY19/FY20
  - 1000 citations to OC4 and OC5 papers
- **All data, models, and reports shared with public via DOE's Data Archive and Portal**

  OC5 Project: https://a2e.energy.gov/projects/oc5

  OC6 Project: https://a2e.energy.gov/projects/oc6

Advisory role in EU-funded projects (leverage additional research work):

- LIFES50+
- DNV GL JIP
- COREWIND
- WindMoor
- MooringSense



Stakeholder engagement is achieved primarily through direct participation in the project