GRAPHIC: JOSHUA BAUER, NATIONAL RENEWABLE ENERGY LABORATORY

TASK 37 REPORT 2020

Systems Engineering

Significant technological innovation has resulted in larger turbines and wind plants with lower costs of energy. However, the increasing importance of wind energy's role within the electricity sector also imposes more requirements on the performance, reliability, and cost of the technology.

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To meet these requirements, industry has sought to improve the performance, reliability, and cost of turbine and plant design. However, trade-offs among competing goals require a more integrated approach (see Figure on complex wind systems). An integrated approach is needed to fully assess how a change or an uncertainty in a design parameter affects the myriad objectives in system performance and cost. Integrated systems research, design, and development (RD&D), which can be applied to both tools and methods, can improve system performance and reduce the levelized cost of energy. Nevertheless, developing such an approach poses significant challenges, both within and across organizations.

The purpose of IEA Wind TCP Task 37 is to apply a holistic, systems-engineering approach across the entire wind energy system and to improve the practice and application of systems engineering to wind energy RD&D. The Task comprises three interrelated and complementary work packages (WP):

- WP 1: Guidelines for a common framework for integrated RD&D at different fidelity levels
- WP 2: Reference wind energy systems (both turbines and plants)
- WP 3: Benchmarking multidisciplinary design, analysis, and optimization (MDAO) activities at different system levels (both turbines and plants)
- WP 4: Expert workshops on advanced MDAO topics

Progress and achievements

In 2020, Task 37 continued with its four work packages in its second 3-year phase.

In WP 1, the Task extended the wind turbine ontology, or common parameterization, to include the floating substructure and mooring system. Additional work is ongoing to also parameterize the drivetrain and its many architecture variations. 2020 also saw significant progress in developing the plant ontology to support layout optimization, with aa first release to come in n2021. All of the ontology implementation is based on json schema in the WindIO project.

For WP 2, the Task officially released both fixed-bottom and floating variants of the new offshore 15-MW reference wind turbine, developed through a collaboration between NREL, DTU Wind Energy and the University of Maine [1,2]. The design was implemented in the ontology and aeroelastic models in HAWC2 and OpenFAST are also available. Work then shifted to ongoing maintenance, including responding to community questions and requests. On the plant side, a series of offshore reference wind farms for a range of depths, layout types, and turbine sizes is under development. Task 37 also plans to coordinate on floating wind farm design with the new floating arrays Task 48.

TABLE 1. COUNTRIES PARTICIPATING IN TASK

Table 1. Task 37 Participants in 2020		
	Country/Sponsor	**Institution(s)**
1	The United States of America	National Renewable Energy Laboratory (NREL) Sandia National Laboratories (SNL) Brigham Young University (BYU) Siemens Gamesa Renewable Energy (SGRE) Envision Energy GE Global Research University of Massachusetts Amherst
2	Denmark	DTU Wind Energy (DTU) LM Wind Power Vestas Wind Systems
3	Norway	SINTEF Energy Research CMR (NORCOWE)
4	Germany	TU München (TUM) Fraunhofer IWES Nordex
5	The Netherlands	TU Delft
6	Spain	CENER
7	The United Kingdom	DNV GL BVG Associates
8	China	Goldwind

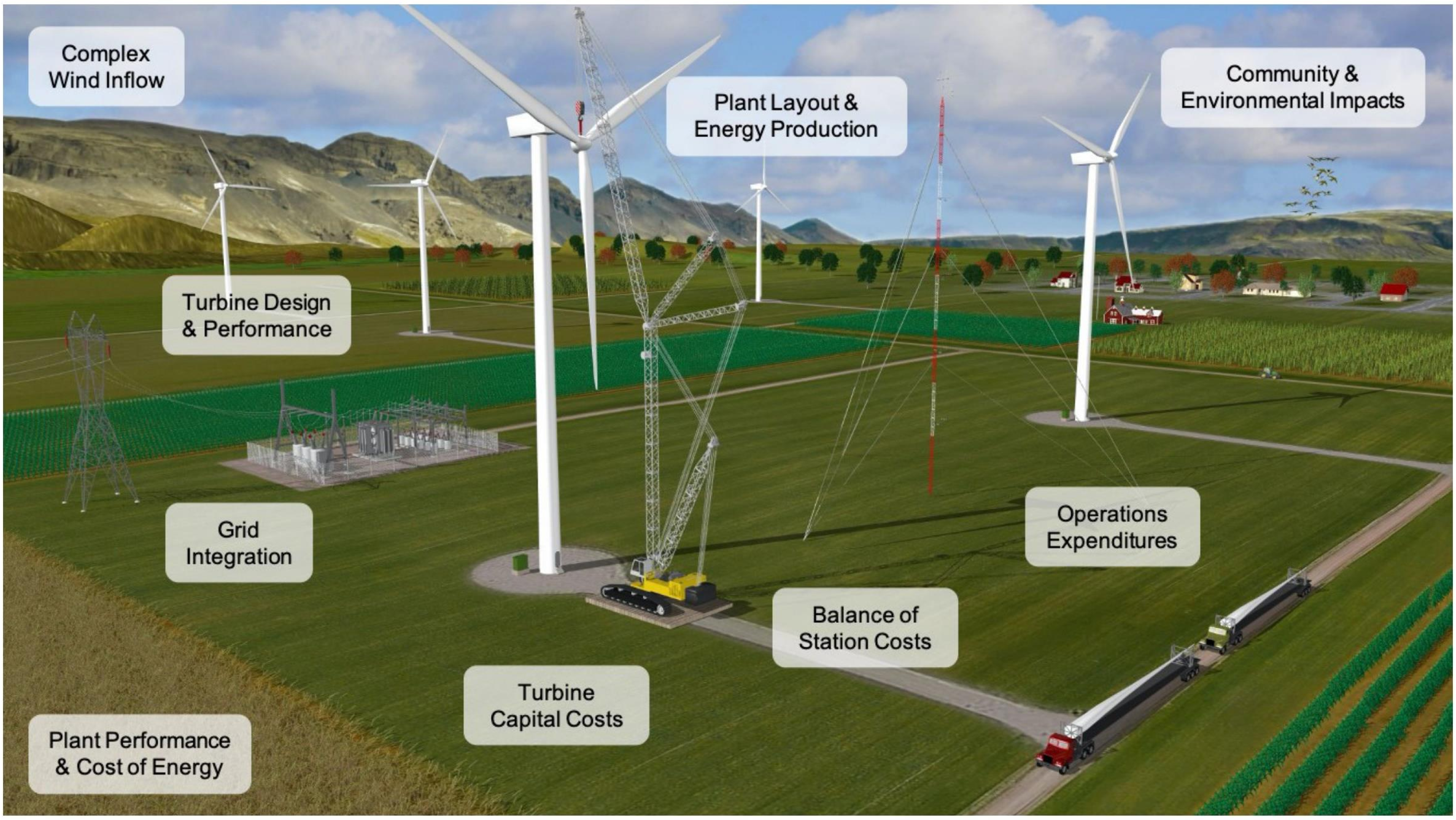

FIGURE 1: EXAMPLE OF A WIND PLANT: A COMPLEX AND HIGHLY INTERCONNECTED SYSTEM (GRAPHIC: ALFRED HICKS, NATIONAL RENEWABLE ENERGY LABORATORY)

For WP 3, on benchmarking MDAO activities, the Task facilitated a detailed comparison of optimization methods on an array layout optimization with real-world constraints (concave boundaries and multiple discontinuous regions). A journal paper describing the lessons learned is in draft and will be completed later in 2021. On the turbine side, the Task formulated a new aerodynamic optimization case study based on the prior lessons learned [3]. For both plant and turbine case studies, the use of the WindIO ontologies has been extremely helpful for sharing inputs, methods, and results easily.

In WP 4, the IEA Wind Task 25/26/37 Workshop on Reference Energy Systems was held in November 2020 in conjunction with the Wind Integration Workshop. There were 38 attendees split relatively evenly across the three Tasks. A writeup of the proceedings will be completed in 2021.

In 2020, the Task persevered despite the COVID disruptions to the normal work habits and rhythms of all participants. The annual meeting was held online across two separate days in September. The online format succeeded in engaging a larger number of participants (60) across a broader swath of geography and industry.

Highlight

Reference wind turbines (RWTs)—open-access designs of a complete wind turbine system, with supporting models for simulation and design—serve multiple roles within the wind community. First, they serve as open benchmarks that are defined with publicly available design parameters to be used as baselines for studies that explore new technologies or design methodologies. Second, as an open design, reference wind turbines enable collaboration between industry and external researchers. Finally, reference wind turbines offer an entry point and educational platform for newcomers to wind energy to understand fundamental design elements and system trade-offs.

Offshore wind turbines eclipsed the prior slate of reference turbines in terms of size and utility. Therefore, in 2020, we released the IEA Wind 15-MW reference wind turbine, which features both fixed-bottom and floating substructure variants. The IEA Wind 15-MW's configuration goes beyond the 10- to 12-MW turbines already in commercial development, but can still serve as a baseline for future designs. This open-source model, available on GitHub, can accommodate multiple turbine modeling tools and provide industry, researchers, and academics a starting point for designing next-generation offshore wind technology.

FIGURE 2: THE IEA WIND 15-MW REFERENCE WIND TURBINE (GRAPHIC: JOSHUA BAUER, NATIONAL RENEWABLE ENERGY LABORATORY)

An overview of the design is presented in the accompanying graphic. The effort was a tight collaboration between the National Renewable Energy Laboratory (sponsored by the U.S. Department of Energy), Technical University of Denmark (DTU) (European Union's H2020 programme), and the University of Maine. Several companies provided feedback on the design of individual subsystems

Outcomes and significance

There have been several requests from the research community and consortiums to use the reference wind turbines developed under WP 2. The new IEA Wind 15 MW reference turbine in particular has received a large amount of positive press and reception from the international community as demonstrated here, here, and here. Currently there are 92 'stars', 54 forks, and 35 unique daily visitors on the GitHub page.

Task 37 participants and others are using the series of IEA Wind Task 37 reference turbines for follow-on studies ranging from novel approaches to load mitigation in wind turbine blades, new materials for wind turbine blade design, tall-tower applications for land-based technologies, code to code load comparison, floating wind support structure design, and more.

In WP1, the ongoing work to extend the ontology to floating substructures and drivetrains has engaged a new community of users. Similarly, the joint Task 25/26/37 workshop exposed other leading researchers to systems-oriented thinking and approaches to the problem.

Next steps

In 2021, focus will be on continuing Phase II work including:

- WP 1: Completion of plant ontology and technical publication on turbine/plant ontologies.
- WP 2: Publication of reference wind farm series for offshore wind and ongoing updates to reference turbines ('maintenance').
- WP 3: New rotor aero, structural, and aero-structural optimization case study and overall case study roadmap development.
- WP 4: Low-wind wind turbine workshop (CENER to host)

References

[1] Gaertner, Evan, Jennifer Rinker, Latha Sethuraman, Frederik Zahle, Benjamin Anderson, Garrett Barter, Nikhar Abbas, Fanzhong Meng, Pietro Bortolotti, Witold Skrzypinski, George Scott, Roland Feil, Henrik Bredmose, Katherine Dykes, Matt Shields, Christopher Allen, and Anthony Viselli. 2020. Definition of the IEA 15-Megawatt Offshore Reference Wind Turbine (Technical Report). Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75698. https://www.nrel.gov/docs/fy20osti/75698.pdf.

[2] Allen, Christopher, Anthony Viselli, Habib Dagher, Andrew Goupee, Evan Gaertner, Nikhar Abbas, Matthew Hall, and Garrett Barter. Definition of the UMaine VolturnUS-S Reference Platform Developed for the IEA Wind 15-Megawatt Offshore Reference Wind Turbine (Technical Report). Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-76773. https://www.nrel.gov/docs/fy20osti/76773.pdf.

[3] Michael K. McWilliam, Frederik Zahle, Katherine Dykes, Pietro Bortolotti, Andrew Ning, Evan Gaertner, Terence Macquart, Karl Merz and Ainara I. Ruiz. "IEA Wind Energy Task 37 - System Engineering - Aerodynamic Optimization Case Study," AIAA 2021-1412. AIAA Scitech 2021 Forum. January 2021. https://arc.aiaa.org/doi/abs/10.2514/6.2021-1412

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