Report 2022
Task 37

Photo: Angelica Reyn / Pexels.

Systems Engineering

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- **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 Optimisation (MDAO) activities at different system levels (both turbines and plants)
- **WP 4:** Expert workshops on advanced MDAO topics

Table 1. Countries Participating in Task 37

	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 and Energy Systems (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

Key results from 2022 included:

- The publication of a technical report on system modelling frameworks/ontologies for wind turbines and plants, and progress on the development of reference wind energy systems (turbines and plants) [1]. The report is now publicly available https://doi.org/10.2172/1868328.
- The completion of the wind farm ontology implemented in windIO and available at https://github.com/IEAWindTask37/windIO.
- Verification between the aero-servoelastic models OpenFAST and HAWC2 of the IEA15 reference wind turbine [2,3].
- Survey released discussing the initial design for the next reference offshore wind turbine, the IEA 22.
- Publication of a journal article comparing different algorithms for wind farm design optimisation [4].

Introduction

Over the last few decades, wind energy has evolved into an international industry involving major players in its manufacturing, construction, and utility sectors. Significant progress in technological innovation has resulted in larger turbines and wind plants while lowering the cost of wind generated energy. However, the increasing importance of the role of wind energy within the electricity sector also generates greater requirements for the performance, reliability, and cost of the technology.

To meet these expectations, the industry has sought to improve the performance, reliability, and cost of turbine and plant design. However, trade-offs among these competing goals require a more integrated approach (as shown in Figure 1). This strategy is necessary to fully assess the impact of a new design parameter on a myriad of objectives in system performance and cost. The application of integrated systems research, design, and development (RD&D), which can be applied to both tools and methods, makes it possible to improve system performance, and reduce the levelised cost of energy. Despite its potential, developing such an approach poses significant challenges, both within organisations and across the industry.

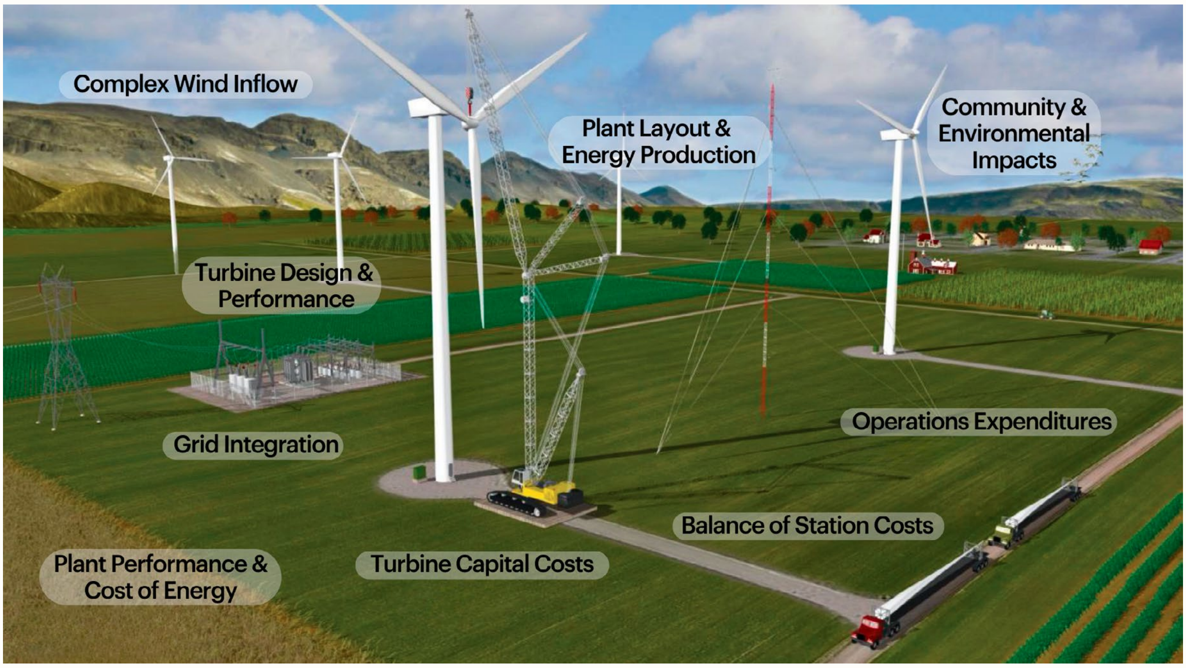

Figure 1: An example of a wind plant: A complex and highly interconnected system.
(Graphic: Alfred Hicks, National Renewable Energy Laboratory)

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Progress and Achievements

In 2022, Task 37 continued with its four work packages, entering the third of its three-year phase, which will conclude in the summer of 2023. The progress and achievements of each work package in 2022 are detailed in the following subsections below. As the Task comes to an end, the participants are finalising ongoing activities and ensuring proper documentation. In addition to this, a new IEA task centred on a new reference wind turbine is being discussed.

Work package 1: Guidelines for a common framework for integrated RD&D at different fidelity levels

During 2022, significant progress was made in WP1 with the development of the plant ontology which supports the rigorous and complete definition of any arbitrary wind farm. The turbine and plant ontologies are implemented in YAML format, which is a user- and computer-friendly data serialisation language. Both ontologies are supported by JSON schemas, which provide metadata that specify how the YAML files should be structured. All of the ontology implementations are publicly available at https://github.com/IEAWindTask37/windIO, whereas documentation is available at https://windio.readthedocs.io/en/latest/.
An additional accomplishment in 2022 was the publication of the technical report which discusses the turbine and plant ontology [1]. The report is now publicly available at https://doi.org/10.2172/1868328.

Work package 2: Reference wind energy systems (both turbines and plants)

Concerning the accomplishments of WP2, researchers at NREL and DTU released v1.1 of the 15MW offshore reference wind turbine. The release addressed many of the community requests and shortcomings from the original version [2,3]. The release

is available at https://github.com/IEAWindTask37/IEA-15-240-RWT/tags. Release v1.1 was supported by a thorough verification between the OpenFAST model and the HAWC2 model describing the turbine above the water line.
Additionally, 2022 marked the initial design phase of the next offshore reference wind turbine. DTU presented a conceptual design at 21.55MW of nameplate power, which became the subject of a survey submitted to industry, academia, and lab experts to gather feedback. The survey returned generally positive feedback, which provided the basis for improvements to the design. These design modifications will be implemented in 2023. Progress can be monitored at https://github.com/IEAWindTask37/IEA-22-280-RWT.

Work package 3: Benchmarking Multidisciplinary Design, Analysis, and Optimization (MDAO) activities at different system levels (both turbines and plants)

WP3, which is dedicated to benchmarking MDAO activities, facilitated a detailed comparison of optimisation methods. This involved an array layout optimisation with real-world constraints (concave boundaries and multiple discontinuous regions). A journal paper describing the key takeawys was submitted in 2022 at Wind Energy Science titled "A Comparison of Eight Optimization Methods Applied to a Wind Farm Layout Optimization Problem" [4]. The preprint can be found at https://doi.org/10.5194/wes-2022-90. The authors are currently working on responding to referee comments.

Work package 4: Expert workshops on advanced MDAO topics

2022 marked the return of the Wind Energy Systems Engineering workshop. The 6th edition returned to the U.S. after two editions in Europe (Copenhagen, Denmark in 2016 and Pamplona, Spain in 2018) and was held in Boulder, CO, between the 31st of August and 2nd of September. The workshop was organized by NREL, with the help of DTU. Approximately 90 people attended in-person two days of technical talks and networking events. The third day featured an optional tour of the Vestas blade factory, located in Windsor, CO, or of the National Wind Technology Centre of NREL. On the 30th of August, approximately 50 participants attended the annual meeting of Task 37.

Highlight(s)

The first notable highlight is the initial activities of designing a new offshore reference wind turbine. After the successful efforts behind the design of the popular reference wind turbines at 3.4MW, 10MW, and 15MW, participants in the IEA Wind Task 37 will now leverage their expertise to design a futuristic 22MW offshore wind turbine. The design will be equipped with both fixed-bottom and floating offshore substructures. An initial design point provided by DTU leveraged a previous project with the Norwegian owner and operator Equinor. The initial design was the subject of a survey released by the Task and answered by 71 participants. The breakdown of participants between the sectors industry, academia, government, and labs is provided in Figure 2. The survey yielded exceptionally positive feedback, confirming the design as a suitable starting point. In 2023, NREL

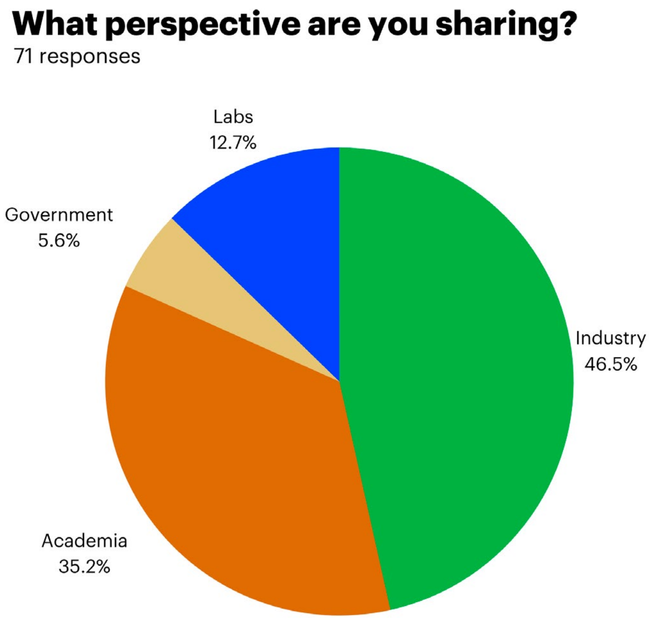

Figure 2: Pie chart depicting the breakdown of sectors belonging to the participants of the survey reviewing the new IEA 22MW offshore wind turbine.

and DTU will lead the design effort, actively encouraging input from all participants of Task 37. The design is expected to be finalised in the second half of 2023.

A second notable highlight is the publication of the paper titled "A Comparison of Eight Optimization Methods Applied to a Wind Farm Layout Optimization Problem" in the journal of Wind Energy Science [4]. Figure 3 depicts the optimal layouts of wind farms, generated using eight different optimisation methods. The comparison has attracted a lot of interest by informing Task participants about the strengths and weaknesses of their wind farm design frameworks. As of the 3rd of February 2023, the article has collected 769 views, signifying its popularity.

Outcomes and Significance

Hundreds, if not thousands of research and industry practitioners use the reference wind turbines daily. The flux of questions and requests on the GitHub repositories is constant. So too are the complaints when something goes inadvertently out of sync. In addition, the windIO repository has also gain popularity, as well as famous aeroelastic tools like HAWC2 and Bladed, which now utilise the ontology to generate wind turbine models. The interest in the Task and in systems engineering appears to be continuous as more than 90 people attended the

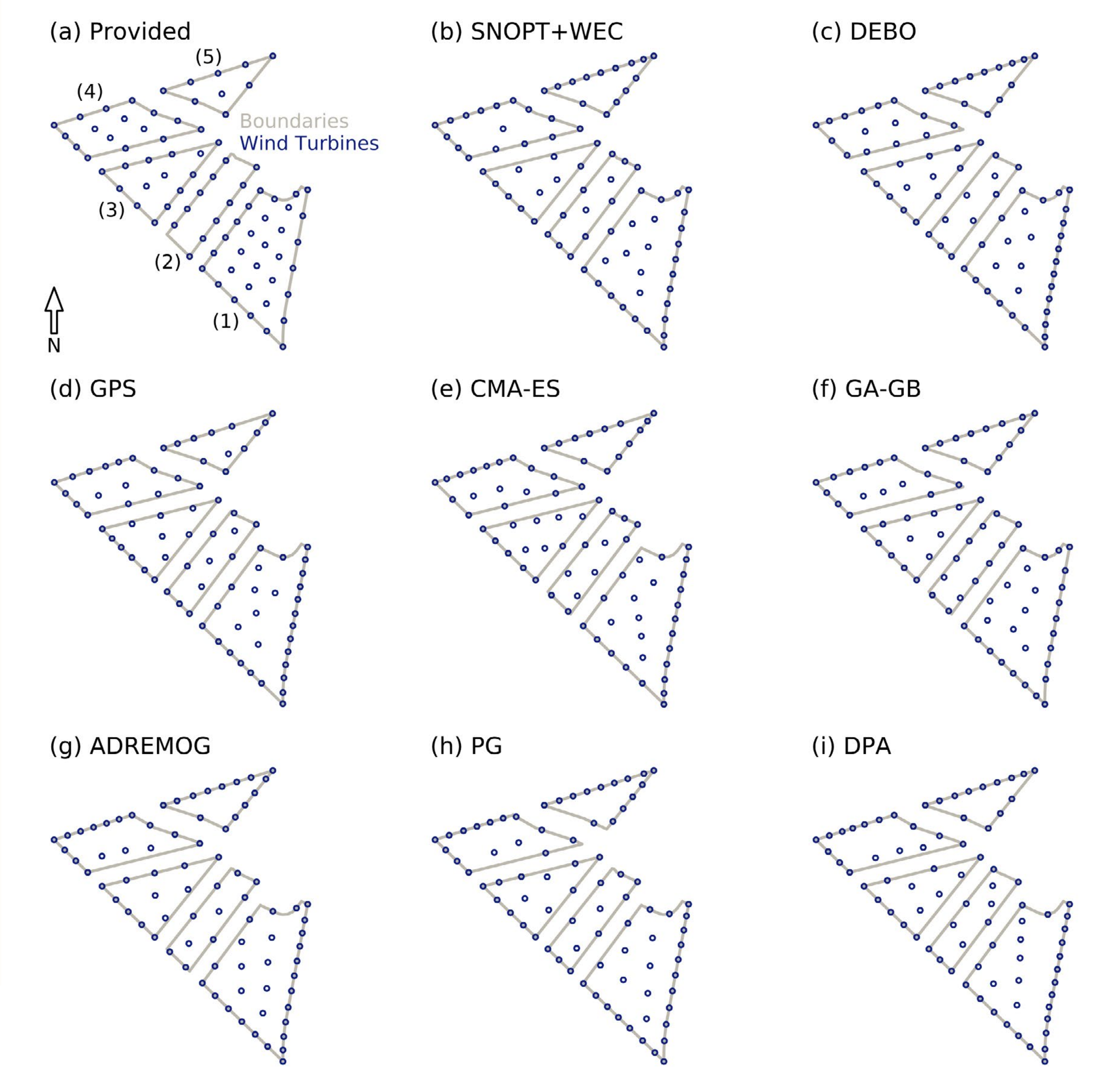

Figure 3: Optimal layout found for each wind farm optimisation algorithm described by Thomas et al., 2022. Labels in (a) also apply to (b) to (i) [4].

systems engineering workshop. The annual meeting of Task 37 furthermore hosted 50 attendants, who engaged in a lively discussion about the successes and challenges of each work package.

Next Steps

The focus for 2023 lies in wrapping up Phase II and scoping out a new Task, presumably focused on the reference wind turbines. The remaining activities in the four work packages are:

- **WP 1:** Maintenance of the windIO repository and minor improvements to ontology YAML files.
- **WP 2:** Maintenance of GitHub repositories of the reference wind turbines and design of the new 22MW offshore reference wind turbine.
- **WP 3**: Final publication of the journal paper concerning wind farm optimisation [4].
- **WP 4:** Publish notes from past workshop.

References

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[3] 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.

[4] Thomas, J. J., Baker, N. F., Malisani, P., Quaeghebeur, E., Perez-Moreno, S. S., Jasa, J., Bay, C., Tilli, F., Bieniek, D., Robinson, N., Stanley, A. P. J., Holt, W., and Ning, A. (in review 2022) *A Comparison of Eight Optimization Methods Applied to a Wind Farm Layout Optimization Problem, Wind Energ. Sci. Discuss. [preprint],* DOI: 10.5194/wes-2022-90.

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