



Annual Report 2024

Task 50

Photo: HPP research facility at DTU Risø campus. (Photo credit: DTU)

Hybrid Power Plants

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Task 50 aims to accelerate the development and deployment of hybrid power plants (HPPs) by addressing key technical, regulatory, and market challenges.

The task focuses on defining hybrid plant concepts, identifying adoption barriers, creating strategic roadmaps, and supporting the design of reference

HPPs that integrate wind, solar, storage, and other technologies. These goals are advanced through five collaborative work packages covering definitions, design, controls, grid integration, and outreach.

In 2024, the task made significant progress. A refined definition and taxonomy for HPPs was established

and shared in a published memorandum. Control strategies and optimization techniques were benchmarked, highlighting performance tradeoffs in different configurations.

Development of an open-source simulation model began, focused on market and grid service integration. Monthly coordination meetings are driving this

effort toward a complete model and report by year-end. Additionally, collaboration with Task 55 began to create a shared hybrid system ontology, aligning language and data models across tasks.

Task 50 has engaged a growing community of stakeholders, including turbine manufacturers, software developers, utilities, research institutions, and government agencies. Industry participation is reflected in both technical contributions and attendance at regular workshops and symposia.

In 2024, the task also strengthened ties with IEA Wind Tasks 41 and 55 to ensure alignment and knowledge sharing across related initiatives.

Task 50 continues to position hybrid power plants as a cornerstone of a flexible, reliable energy system.

Introduction

Hybrid Power Plants (HPPs) combine energy technologies such as wind, solar, and storage to provide more traditional energy system services, increase the

deployment and utilization of renewable energy, and ensure profitability for developers, owners, and operators.

IEA Wind Task 50’s purpose is to coordinate international research and development in the field of hybrid wind power plants (see Table 1 for current participants). This effort includes gathering ongoing research results as well as state-of-the-art in industrial practices, creating an overview of best practices on hybrid power plant design, operation and regulation, and exploring how uncertainties affect the performance and potential for adoption of hybrid power plants.

The expected results are guidance for the industry, lawmakers, regulators and researchers on the current modeling efforts, control/optimization approaches, requirements, test and standards, impediments to adoption, future directions and expected benefits of hybrid power plants. Specifically, the aim is to support the strategic initiatives of the IEA Wind TCP by:

Maximizing the value of wind energy in systems and markets by increasing the capacity of hybrid power plants and the

ability to play a role in grid services.

Accelerating the development and deployment of hybrid power plants in various markets across the globe through availability of data, advanced models and tools, and test methods.

Determining the viability of other end-use products powered by wind-based hybrid power plants including electricity, hydrogen, desalination, carbon capture, and other renewable-based alternative fuels.

Fostering collaborative research and the exchange of best practices and data by developing benchmarks and best practices for realistic hybrid power plants and ensuring easy access to the most up-to-date knowledge, algorithms, and ideas for hybrid power plants.

Progress and Achievements

WP1 - Collection of research results, state-of-the-art and expert consensus. The WP1 taxonomy effort has been completed, culminating in definition version 2.1 of the hybrid power plant definition, “a hybrid power plant is a combination

| COUNTRY/SPONSOR | INSTITUTIONS |
|-----------------|--|
| Belgium | Engie |
| Canada | Wind Energy Institute of Canada, Natural Resources Canada, Nergica |
| Denmark | Denmark Technical University (DTU), South Denmark University, Vattenfall, Vestas, Aalborg University, Orsted, WEPROG, Floating Power Plant A/S, ConWX, Aarhus University |
| Germany | Technical University of Munich, ZSW, ENERCON, Reutlingen University |
| Ireland | Sustainable Energy Authority of Ireland (SEAI), University College Dublin |
| Netherlands | Delft University of Technology |
| Norway | Institute for Energy Technology |
| United States | U.S. Department of Energy Wind Energy Technologies Office, National Renewable Energy Laboratory (NREL), Electric Power Research Institute (EPRI), Wind Advisors Team, Lawrence Berkeley National Laboratory (LBNL), Sandia National Laboratory (SNL), HOMER Energy, GE Renewable Energy, Shell |

Table 1. Countries Participating in Task 50

of independent electricity generation and storage technologies connected at a single point to provide coordinated electrical power services.”

Over the entire duration of WP1, efforts have included 12 different draft iterations on shaping the definition and taxonomy of hybrid power plants; establishing clear boundaries between hybrid power plants, virtual power plants, and co-located facilities; the organization of a sub-definition list of qualifying phrases to accommodate the varying capabilities provided through hybrid power plants;

a decision tree matrix to guide interpreters through the sub-definition term list (Figure 1); and graphics to visually represent some of the more common hybrid power plant configurations.

Furthermore, these efforts have helped establish boundaries between hybrid power plants, multi-commodity HPPs, hybrid energy systems, hybrid power systems, and microgrids.

Lastly, the team is currently working to deliver detailed outputs through a final report and is exploring journal

publication pathways for the final outputs of the work package.

WP2 - Reference designs for hybrid power plants. The concept of a reference design for hybrid power plants has been clearly defined, and expectations for the associated work package deliverable have been established.

Additionally, development is underway on a reference design featuring a wind farm, solar PV, and battery energy storage system (BESS) for a representative site in Denmark.

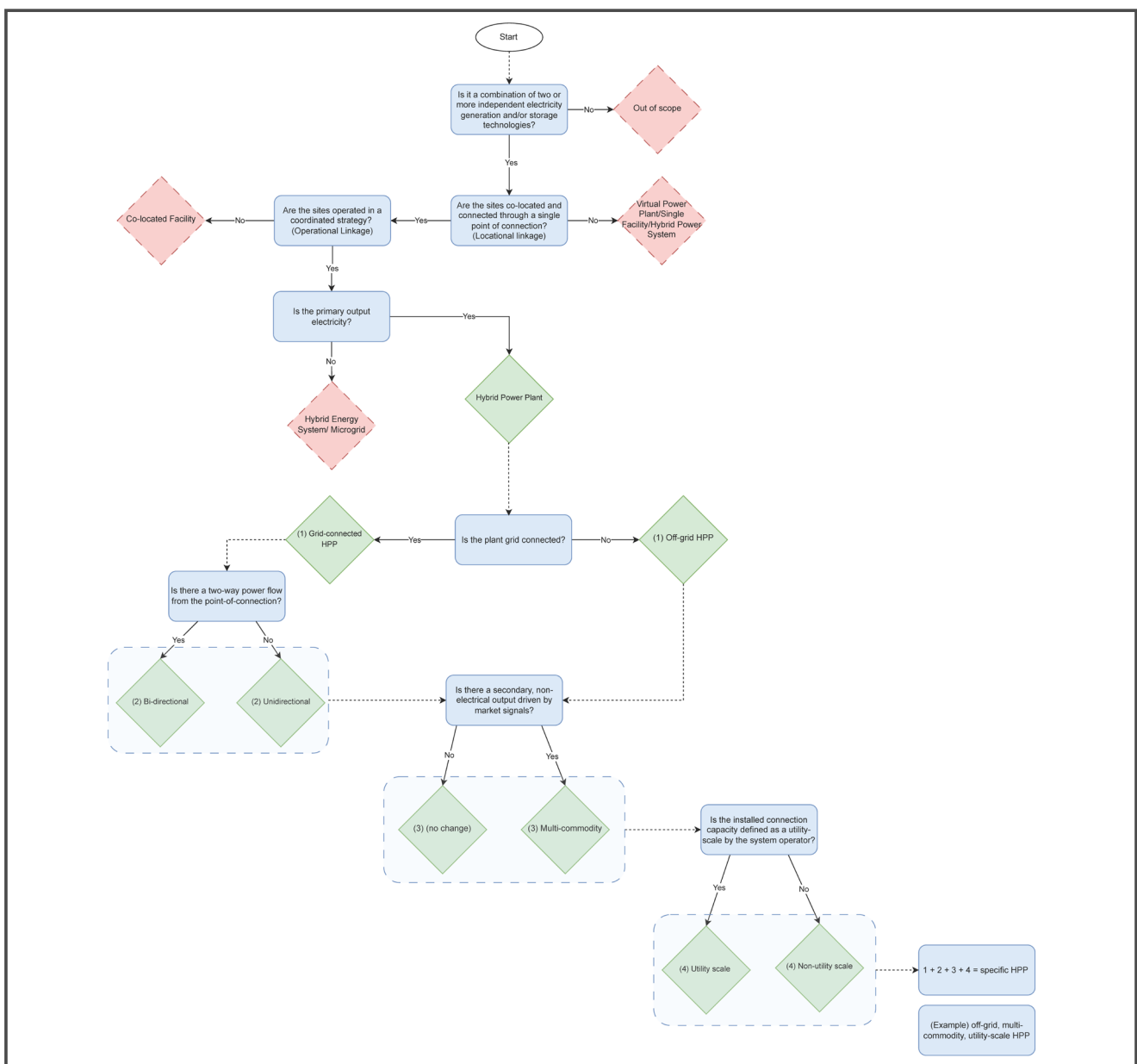


Figure 1. A decision tree for determining the type of hybrid energy system being used, created by Work Package 1. (Source: : IEA Wind TCP Task 50 Work Package 1.)

WP3 - Overview of design and operation technology/algorithms. Benchmarking activities between 2 open-source software, H2Integrate (formerly HOPP) github.com/NREL/H2Integrate and HyDesign gitlab.windenergy.dtu.dk/TOPFARM/hydesign, have progressed, with updated comparative results presented to WP3 participants in October 2024. To enhance technical exchange and broaden the scope of knowledge dissemination beyond the core benchmarking tools, targeted scientific presentations have been incorporated into WP3 monthly meetings. Recent contributions include Erik Stensrud Marstein (IFE) and Sayak Mukherjee (PNNL).

WP4 - Electrical design, control, market, and grid service provision from hybrid power plants. Task 50 WP4 working group has been focusing on developing a generic hybrid power plant control architecture, contributing to a report on the generic control architecture. The report details the development of hybrid power plants along with the control requirements with a brief overview of the grid code requirements on the HPPs. Furthermore, fundamental services that should be provided by the HPP have been identified and elaborated on in the report.

The report further outlines the electrical infrastructure in an HPP focusing on the connection points, transformers, and measurement points. A theoretical

framework of the control architecture and the communication infrastructure for an HPP is also detailed. The working group in Task 50 WP4 is now driving towards developing the described control architecture model. The model along with its simulation results will be delivered in the completed report by the end of this year.

Highlights

The WP1 taxonomy effort has been successfully completed, resulting in the release of version 2.1 of the hybrid power plant definition. This definition serves as a critical foundation for understanding and standardizing HPP concepts. The team is now exploring publication options, which will document the research and conclusions drawn throughout this work package.

The Task 50 leads will host two mini-symposia at the 2025 Wind Energy Science Conference (WESC), occurring June 24-27, 2025. The first mini-symposium will focus on presentations from each of the work packages, highlighting recent work. The second mini-symposium is a gathering of academic and industry researchers presenting their recent advancements in the design and operation of HPPs.

A successful annual task meeting was held at the Hybrid Power Plants and

Systems Workshop on May 13th, 2024 (Figure 2). Participants from all work packages came together to discuss progress and plan research activities, coordinating across efforts and institutions.

Outcomes and Significance

The work packages have collectively advanced the development and deployment of hybrid power plants (HPPs), delivering practical tools, frameworks, and knowledge for participants and stakeholders. In WP1, the finalization of the hybrid power plant taxonomy (v2.1) provides a shared definition and structure that supports clearer communication, coordination, and alignment across research and industry.

WP3 has made progress benchmarking the H2Integrate (NREL) and HyDesign (DTU) tools, with 6 sites identified and results accepted for presentation at WESC 2025. These efforts foster tool transparency, build user confidence, and promote knowledge sharing beyond the tools themselves.

WP4 developed a generic control architecture for hybrid plants, detailing grid service needs, control strategies, and infrastructure considerations. This work is critical for supporting grid integration, reliability, and regulatory compliance.

Together, these efforts enable faster and



Figure 2. IEA Wind Task 50 on Hybrid Power Plants annual general meeting, May, 2024. (Photo credit: Christopher Bay.)

more informed development of hybrid projects. Industry and regulators are already leveraging these results, while society benefits through increased deployment of flexible, low-carbon energy systems that support climate goals and energy resilience.

Next Steps

Task 50 has many promising initiatives underway. A hybrid power plant design combining wind, solar, and battery storage is taking shape for a Danish site within WP2, marking a key step toward showcasing integrated renewable solutions. Benchmarking of open-source and privately developed simulation tools will continue.

Development of the simulation model is steadily advancing through monthly strategy sessions, keeping us on track for a comprehensive year-end report. Meanwhile, an exciting collaboration with Task 55 is laying the groundwork for a shared hybrid system ontology,

aimed at unifying concepts across the field.

We will hold a joint meeting with IEA Wind Task 61 – Variable Renewable Energy for Hydrogen on June 24, 2025, at WESC, where we will solicit feedback on a variety of activities and plan collaboration. We will also seek industry-specific feedback focused on practical issues and upscaling via a virtual workshop planned for September 2025.

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