International Energy Agency (IEA)
Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems (IEA Wind TCP)

Annex 41 – Task Extension Proposal (2023 – 2026)
Enabling Wind to Contribute to a Distributed Energy Future

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1. Scope

The purpose of extending International Energy Agency (IEA) Wind Technical Collaboration Programme (TCP) Task 41 is to build on previous efforts and continue to coordinate international collaboration and research on wind as a distributed energy resource (i.e., distributed wind) to enable wind to contribute to a distributed energy future. Task 41 Phase II will be a four-year effort (January 2023 through December 2026). The U.S. Department of Energy (DOE) will continue to fund the equivalent of the Operating Agent costs, meaning that Task members will not need to pay participation fees to cover Operating Agent costs. The ability of DOE to cover Operating Argent costs is dependent on approved funding and may change over the course of the four-year project. Task members will build on efforts from other international projects, share knowledge on relevant national research efforts, and develop new integration and deployment strategies for distributed wind. In this extension, there will be a diverse representation of task members leading work packages.

Wind technology considered within this Task includes all sizes of wind turbines deployed in distributed applications and connected at a distribution voltage (nominally 70 kV) or below. These installations can be behind-the-meter, front-of-the-meter, or in an isolated hybrid power system. In the context of Task 41 Phase II, distributed wind is inclusive of all scales of wind turbine technologies and is agnostic to business model, although in some instances, such as technology standards, more specific industry segmentation is included.

The Task work packages (WPs) are organized around the following four dominant themes (as shown in Figure 1):

- Inform Standards

  This theme includes coordinating international research to inform standards, particularly for the ongoing update of International Electrotechnical Commission (IEC) 61400-2, and technical specifications and innovations. The research to inform standards will support the development of the fourth and subsequent revisions of the IEC 61400-2 standard. Efforts will focus specifically on updating the handling of turbulence and design class (WP1A), and improving design loads, methods, and tools (WP1B). Additional work includes developing technical specifications for distributed wind in cold climates and addressing recyclability and sustainability (WP5).

- Grid and System Integration

  This theme includes research on integration with both distribution grids and isolated hybrid systems (WP3). The theme will focus on distributed-scale hybrid power plants particularly in behind-the-meter applications and isolated hybrid power systems. In relation to IEA Wind TCP, Task 50, Hybrid Power Plants, this effort will focus on smaller energy systems and based on close partnering, will ensure that no duplication of effort will occur while sharing of relevant results across the two Tasks (41 and 50).

- Social Science

  Educating stakeholders about distributed wind can be an expansive task compared to educating stakeholders about wind farms. Consumers, decision makers, and local government officials who grant permissions typically need to be educated about the possibilities of distributed wind. Given this vast population requiring education and the varying viewpoints that drive decision making, limited social science research has been undertaken to understand and document specific outcomes that would help distributed wind meet market deployment opportunities. Under this theme, WP6 will explore the human dimensions of distributed wind through valuation exercises and stakeholder engagement activities as methods to facilitate social acceptance of distributed wind.

- Information Dissemination

  This theme includes the collaboration, outreach, and primarily the dissemination of the products produced by Task 41. These activities at the task level are covered in WP4 and each work package has additional dissemination plans.

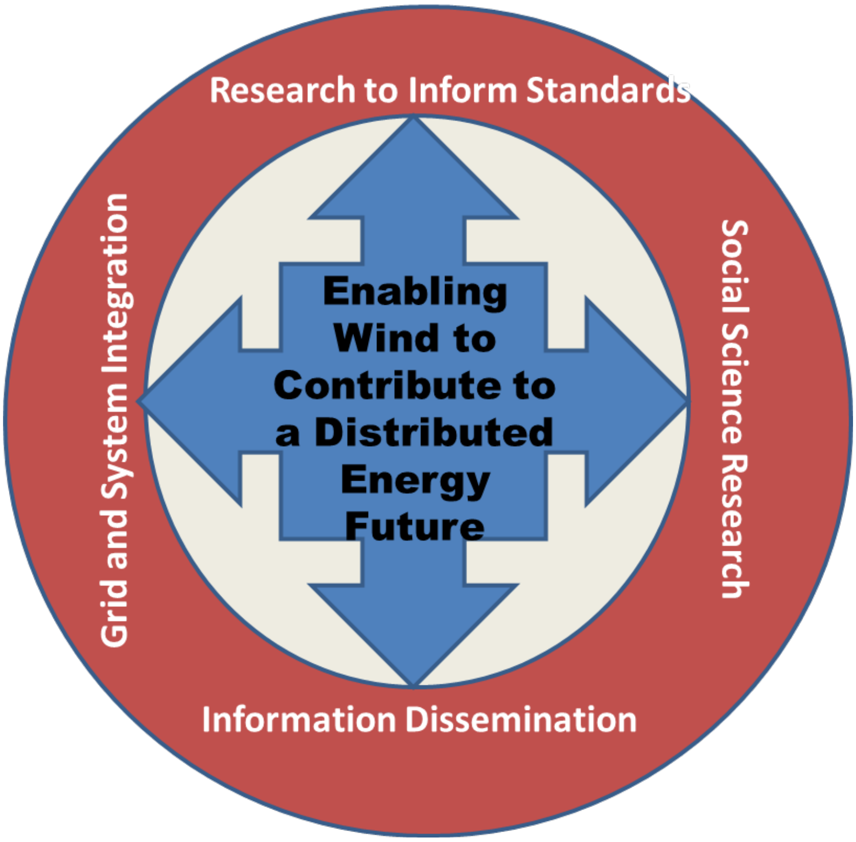

Figure 1. IEA Task 41 Research Themes

2. Introduction

World markets are seeking renewable technology solutions to meet their distributed energy needs. Europe and the United States specifically call for greatly expanded use of renewable energy, with distributed generation proving a near-term means to expand local generation. Distributed wind energy can allow energy consumers and providers to expand local generation beyond that provided by solar or solar and storage.

The distributed wind market has expansive potential across the globe. There have been active markets in Italy and the United Kingdom when incentive policies made distributed wind life cycle costs competitive with consumer electricity rates. In addition, countries with limited transmission infrastructure will quickly reach integration limits for large central station power, including renewable energy, indicating an expanding need for more distributed solutions. China, for example, is experiencing severe curtailment of wind power (as well as solar power) due to the limitation of power transmission while countries across Africa and southeast Asia have limited transmission networks to support the deployment of large-scale wind applications, leading to more smaller scale deployments of distributed technologies.

Market potential projections in the United States show that the economic potential of distributed wind through 2035 can exceed 1,400 GW[1], many times the outlined potential for offshore wind energy, which has been identified at less than 50 GW over the same time period. The majority of this installed capacity is expected to come from large-scale wind turbine technology installed in distributed applications, primarily in grid-connected, behind-the-meter applications. Additionally, IEA research identifies that approximately 34% of unserved populations across the globe will be supplied by smaller scale, isolated hybrid power system solutions which could include distributed wind, an estimated $113 billion-dollar market through 2030.[2] However, the integration needs to optimize grid and hybrid power connections, deployment methodology, and social acceptance strategies are far from optimized for this emerging sector. For the distributed wind market to thrive, the additional research proposed for Task 41 Phase II is required.

[1] https://www.nrel.gov/docs/fy22osti/82519.pdf

[2] http://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_EnergyAccessOutlook.pdf

3. Objectives and Expected Results

The Task 41 work plan focuses on addressing topics for which international collaboration can have a significant impact with an emphasis on expanding access to general information, improving consumer understanding, confidence, and engagement, pursuing ways to continue technology cost reductions, and continuing to articulate the benefits of integrating distributed wind into energy markets and systems. Although some of the challenges that distributed wind faces may require country-specific solutions, Task 41 provides an international platform to address the four primary research themes of standards and technical specifications, integration, social science, and information dissemination.

Anticipate outcomes and results from Task 41 Phase II include the following:

- Technical reports, journal articles, and other products that highlight key research findings under the auspices of the Task or through member or partnering organizations that advance the state-of-the-art, help lower costs and deployment barriers, and expand the deployment of wind as a distributed energy resource.
- Research results and findings that can inform the fourth revision of the IEC 61400-2 standard. Some of the Task 41 experts are also involved with IEC standard making, allowing for multiple paths of communication about the research results.
- Established participation in conferences focused on small and medium wind turbines. By partnering with the European Wind Energy Academy Small Wind Turbine Committee and defined wind-focused technical conferences such as Torque and NAWEA\WindTech, Task 41 will ensure that other venues will be available to continue international collaboration after Phase II is completed.
- Expanded collaboration and engagement in the wider distributed energy research fields, including other IEA Wind TCP tasks and IEA PVPS tasks, to enable broad-based uptake and internalization on the findings to a potentially wider audience.

4. Approach and Methodologies

The following sections provide detail on the proposed work packages.

4.1 Work Package 1: Characterization, Testing, and Loads Assessment of Small Wind Turbines

This work package focuses on obtaining a better understanding of the loads that are experienced by smaller distributed wind turbines, with a specific focus of supporting the appropriate refinement of the IEC 46100-2 standard, which is currently underway as of the end of 2022. To fairly consider this topic, one must look at the atmospheric conditions that drive loading at the small scales experienced by distributed wind turbines and then the models that are used to estimate the loading based on a specific turbine design. For this reason, this work package is being implemented with three focus areas: data mining, classification and pattern recognition, and characterization of the local environment with respect to turbulence.

4.1.1 Work Package 1A: Turbulence Research

WP1A Lead: Dr. Mark Runacres, Vrije Universiteit Brussel, Belgium

WP1A Participants:

- Mark Kelly, Technical University of Denmark, Denmark
- Narasimalu Srikanth, Energy Research Institute at Nanyang Technological University, Singapore (observer)
- Luisa Pagnini, University of Genoa, Italy
- Alexander Hirschl, University of Applied Sciences FM Technikum Wien, Austria
- Trudy Forsyth, Wind Advisors Team, United States
- Dominic Bolduc, Nergica, Canada
- Beatriz Ramos, CIEMAT, Spain
- Jia Yan, Key Laboratory of Wind Energy and Solar Energy Technology, Ministry of Education (Inner Mongolia University of Technology), China

4.1.1.1 Introduction

Atmospheric turbulence is characterised by variations in wind speed and direction at timescales less than roughly 10 minutes. It is generated by atmospheric dynamics such as buoyancy, and by the flow's interaction with obstacles, including other wind turbines. As it mostly concerns small turbines that are placed close to where the generated electricity is needed (e.g., near buildings), distributed wind energy is especially affected by obstacles. While turbulence affects the energy production and fatigue of all wind turbines, it is of particular concern for distributed wind energy. This work package aims to better characterise and model turbulence with the goal of improving the reliability, application, and energy yield of distributed wind energy.

4.1.1.2 Objectives

- **Characterisation of turbulence**: The normal turbulence model of the IEC 61400 standard characterises turbulence through the standard deviation of the streamwise velocity component of the flow or the corresponding turbulence intensity. Although this is certainly the most important measure of turbulence, it does not fully characterise the turbulent flow field, particularly in the distributed wind environment and other measures may be necessary to give a more complete picture for distributed wind. The turbulence length scale has importance[3] for both production and loads.[4] For wind turbines with passive yaw, that are common in distributed wind energy, the variability of the wind direction is expected to be important too, pointing to the need to account for the perpendicular velocity

[3] https://www.sciencedirect.com/science/article/pii/S0167610520301458?via%3Dihub
[4] https://wes.copernicus.org/articles/3/767/2018/

component.[5] We therefore propose a fuller characterisation of turbulence by combining different measures. Further, turbulence in distributed wind environments is highly dependent on the shape and distance of obstacles from turbines, as well as the atmospheric inflow; various simplified parameterisations exist, though they tend to be anecdotal, and the problem has yet to be systematically treated or treatments harmonised into a wind standard. **We therefore propose a practicable characterisation of turbulence by establishing metrics that address obstacle effects, appropriately cast to be combined with relevant flow metrics.**

- **Modelling and prediction of turbulence:** Towards turbulence measurements, very few wind energy projects will have multidimensional wind data available at the turbine site. For the small-scale projects that are typical for distributed wind, there will generally be no wind speed measurements at all. **It is therefore important to be able to estimate turbulence measures from site conditions. This is a second major goal of the work plan extension.**

4.1.1.3 Summary of Concurrent National Work

The following efforts are being undertaken within national level programmes:

– In Denmark, working with the EU Hiperwind project and other internal and external projects, DTU Wind Energy is investigating and developing statistical representations for terrain-affected turbulence, generalized terrain descriptions to drive such, and three-dimensional load-driving flow accelerations in the atmospheric boundary layer.

– In Belgium, the Vrije Universiteit Brussel has a number of projects on wind speed measurements and modelling. This includes a classification effort that is relevant to the present proposal. A current measurement campaign involves 3D sonic anemometry at 1 Hz. Measurements up to 32 Hz will be performed over the next 3 years.

– In Austria, the University of Applied Sciences FH Technikum Wien runs the Lichtenegg Energy Research Park where high turbulences in combination with high wind speeds appear. A recent master’s thesis investigates wind turbulences in the research park based on 1 minute average values and compares the results with the normal turbulence model of IEC 61400-1. In addition, the university investigates time-dependencies of turbulences.

– In Canada, Nergica owns and operates 4 met masts: two multi-level 126-m masts and one 20-m mast at its Rivière-au-Renard site and one 15-m mast in Murdochville. Both of these sites are considered complex terrain. Those met mast are equipped with heated and unheated anemometers and wind vanes. Some historical data also include vertical wind speed and 3D wind speed. Nergica also owns a Windcube 200S 3D scanning LIDAR in Rivière-au-Renard. Those infrastructures are available for the data mining and classification phase of this work package.

– In Italy, the University of Genoa has recently performed extensive wind speed measurements and turbulence characterisation in the main ports of the Northern Tirrenian Sea, and linked this with turbine performance and fatigue life assessment under synoptic winds and thunderstorms.

– In Spain, CIEMAT has worked on the characterisation of small wind turbines but has also carried out different studies of the wind flow behaviour around obstacles by studying the wind behaviour and its turbulence with LIDAR and sonic anemometers. In addition, CIEMAT has conducted a terrain evaluation with cup anemometer and LIDAR and studies of wind flow on the roof of a building with sonic anemometer (two heights) comparing the vertical wind speed of these sonic anemometers with a LIDAR on the ground.

4.1.1.4 Approach and Methodologies

Coordinated by the work package lead, the following four efforts will be implemented.

- **WP1A-1 Data Mining:** A data mining effort will be undertaken by the WP team. We shall start from the catalogue of metadata that was assembled during Task 41 Phase 1 and extend this with published

[5] https://www.sciencedirect.com/science/article/pii/S1352231099002873

open-source data.[6] It is expected that, in some cases, a considerable data cleaning and wrangling effort will be necessary. The members of the WP team also have access to additional datasets, some of them proprietary, that may be used for the characterisation of turbulence. If needed, tailored measurements will be performed. The Danish, Belgian, Italian, and Austrian partners have access to the necessary measurement set-ups.

- **WP1A-2 Classification and Pattern Recognition:** Depending on the size of the datasets, some automation of feature selection through machine learning may be necessary. The Belgian partner will undertake the data classification effort, in collaboration with the task team. The gathered data and the classification will be used to try and derive turbulence scaling laws that, ideally, allow to predict turbulence from site conditions. In parallel, drawing from and continuing their recent advances in statistical parameterisation of turbulence and terrain effects, the Danish partner will develop simplified, universal site-based metrics and reduced three-dimensional turbulent flow measures, which are appropriately combinable. We anticipate that the availability of detailed descriptions of measurement sites will be a major challenge and risk for this work package.
- **WP1A-3 Characterising the Local Environment with Respect to Turbulence:** Based on the turbulence classes and patterns obtained in WP1A-2, rules of thumb will be identified that relate the level and type of turbulence to site conditions.
- **WP1A-4 Dissemination:** To enhance the visibility and usefulness of the project results, the WP team is committed to engaging with tool developers to explore how to integrate these research results into tools (e.g., mywindturbine.com, the API for the DOE Tools Assessing Performance project).

4.1.1.5 Key Partnering Organisations Outside of Task 41 Participants

- Small wind technical committee of the European Academy of Wind Energy (EAWE)
- Maintenance team for IEC 61400-2 standard (MT2)
- DOE Tools Assessing Performance project

4.1.1.6 Expected Results or Outcomes

There are three main groups of recipients of the proposed project's outcomes:

- Scientific and academic community
- Industry, developers, and end users
- Standards committees

The overall expected results and outcomes are as follows:

- Very close collaboration with the Task 41 WP1B on aeroelastic loads modelling. WP1A is mainly about characterising turbulence. The effects of turbulence on performance and fatigue will be investigated in WP1B.
- Scientific journals publications and presentations at international conferences (e.g., Torque 2024 and 2026).
- Rules of thumb regarding the expected degree and type of turbulence for different site conditions, aimed at industry, developers, and end users.
- Input to standards committees, in the form of technical recommendations.
- A thorough characterisation of turbulence, including the built environment, has relevance beyond wind energy. Urban drone flight and pollutant dispersions are good examples. We will attempt to liaise with researchers active in those fields to share with them the results of WP1A.

4.1.1.7 Milestones and Deliverables

- WP1A-1: Data mining

[6] For an extensive summary, see https://doi.org/10.1002/we.2766.

- M1A-1: Full datasets have been obtained, where possible (June 2023)
- D1A-1: A catalogue of validated turbulence data to be used in the project has been established (December 2023)

- WP1A-2: Classification and pattern recognition
  - M1A-2: Data from the data mining have been catalogued according to their salient turbulence features (December 2024)
  - M1A-3: simplified, universal site-based metrics and reduced three-dimensional turbulent flow measures have been established (December 2024)
- WP1A-3: Characterising the local environment with respect to turbulence
  - M1A-4: Rules of thumb relating the level and type of turbulence to site conditions have been identified (December 2025)
- WP1A-4: Dissemination
  - D1A-2: First results of the turbulence classification presentation at Torque 2024 (May 2024)
  - D1A-3: Submit journal publication on the classification and reduced-order statistical characterisation of turbulence; Q1 journals will be selected (e.g., *Journal of Wind Engineering and Industrial Aerodynamics*) (January 2025)
  - D1A-4: Presentation summarising the major project results at Torque 2026 (May 2026)
  - D1A-5: Submit journal publication on the predictability and prediction of turbulence in the context of distributed wind energy (June 2026)
  - D1A-6: Publish technical report with recommendations for standards on the task website and disseminated through the networks of the project contributors (September 2026)

4.1.2 Work Package 1B: Loads Assessment and Modelling

WP1B Leads: Dr. Francesco Castellani, University of Perugia, Italy; David Wood, University of Calgary, Canada

WP1B Participants:

- Mark Kelly, Technical University of Denmark, Denmark
- Tonny Brink, Nordic Folkecenter for Renewable Energy, Denmark
- Nikolaos Stefanatos, Centre for Renewable Energy Sources and Saving, Greece
- Trudy Forsyth, Wind Advisors Team, United States
- Brent Summerville, NREL, United States
- Rafael Carniceros, CIEMAT, Spain

4.1.2.1 Introduction

Loads calculations on small wind turbines can be a very complex task due to the poor support from industry standards, which are much more developed for large-scale turbines. New simplified approaches are needed to better address the optimal design solutions, but this job is very challenging due to the wide scale range of the machines as well as the great number of different technological solutions. A weakness of horizontal-axis small wind turbine modelling is the inability to address unsteady aerodynamics, which affect the yaw behavior, gyroscopic loads, and the ability of models to capture these effects. In addition, unsteady aerodynamics is still an important topic to be addressed in the design of vertical-axis small devices and correctly evaluate the blade loads. Starting from these premises, the present work package is aimed at contributing to the development of the most effective design approach through the correct estimation of the operating loads.

4.1.2.2 Objectives

The objective of this work package is to move beyond general considerations about the impact of turbulence on small devices, which have peculiar characteristics as the wide operation range (up to hundreds of revolutions per minute) and often have fixed blade pitch and passive yaw control. Furthermore, the exploitation of small wind turbines as distributed energy conversion devices often takes place in urban environments, where the turbulence profile can be complex due to the presence of buildings and obstacles. Based on this, the work package will develop more advanced methods to characterize small wind turbine loads occurring during normal operation. Current aeroelastic models do not capture tail fin impacts and gyroscopic loads, which are believed to be very relevant for the dynamic behavior of small wind turbines. In particular, the expected output is to correlate numerical modelling with empirical data from wind tunnel and field testing.

4.1.2.3 Summary of Concurrent National Work

The following efforts are being undertaken within national level programmes:

- In Canada, faculty from the University of Calgary are working to refine and update the Simplified Loads Methodologies currently incorporated into national standards for small wind turbines. These updated simplified models are expected to be incorporated into revisions of IEC 61400-2. Modelling of tail fin yaw behaviour and associated gyroscopic loads is underway.
- In the United States, NREL, in partnership with other non-IEA Wind TCP members (Egypt, Australia) are working to improve the OpenFAST tool to better capture characteristics of small wind turbines. This includes the re-introduction of tail modelling for yaw control, as an example. At the NREL Flatirons campus, three distributed wind turbine models will be installed, which meet three of the four most common horizontal-axis wind turbine topologies. This will provide important data for turbine model validation for a variety of parameters, including turbine yaw behavior and gyroscopic loads.
- In Italy, staff from the University of Perugia are running developed-scale wind turbine models within a wind tunnel, collecting data on yaw behavior and gyroscopic loading of turbine systems. A series of experiments on tail fin yaw behaviour has been completed and will be extended in the near future.
- In Spain, technical staff from CIEMAT are installing two small wind turbines, covering the final primary distributed wind turbine topology.
- In Denmark, the researchers at the Technical University of Denmark, Wind and Energy Systems department are working to identify what is the impact of advanced electrical control, which enhances wind turbines' capabilities to support the grid, on wind turbines' mechanical loads.

4.1.2.4 Approach and Methodologies

WP team members will work collaboratively to better understand and then implement strategies to improve the assessment of potential atmospheric loading on wind turbines. The team will use interorganisational collaboration to improve current modelling approaches, and then validate these approaches with wind tunnel and operational turbine data. Results of the work will be published in an effort to broaden industry use and build academic engagement.

4.1.2.5 Key Partnering Organisations outside of Task 41 Participants

As part of the implementation of this work, work package leaders will work with members of Task 42 (Wind Turbine Lifetime Extension) to investigate their approaches and copy any methodologies that are appropriate for small wind turbines.

4.1.2.6 Expected Results or Outcomes

The project team plans to perform task outreach through peer-reviewed journal articles, papers or sessions at specific wind-focused conferences (i.e., Torque, WESC, NAWEA\WindTech), and virtual seminars on the empirical and modelling results to be shared with academia and industry. Expected outcomes of this work include the following:

- Fundamental loads research to inform future IEC 61400-2 standards making.
- Open-source research code for load calculations for small wind turbine topology configurations.
- Virtual seminars on the empirical and modelling results to be shared with academia and industry.

4.1.2.7 Milestones and Deliverables

- M1B-1: Define simplified approaches to small wind turbine loads and lifetime estimates
  - Analyze and define approaches for different archetypes (HAWT, VAWT, Multi-Blade) (October 2023)
  - Summary of the Previous work and standards (May 2024)
  - Final definition and role of simplified approaches (Dec 2025)
- M1B-2: Characterize the most effective approach in relation to the technology, topology, size and environment
  - Simplified load approaches (October 2024)
  - Aeroelastic modeling (May 2025)
  - Data-Driven surrogate models (AI) (October 2026)
- D1B-1: Best practice guideline for wind energy system design and verification (February 2024 draft, October 2024 draft, February 2026 final)
- D1B-2A: Presentation at WESC2023 (May 2023)
- D1B-2B: Presentation at Torque2024 (May 2024)
- D1B-3: Journal publication (December 2025)

4.2 Work Package 2: Data Sharing Catalogue

This work was completed as part of Task 41 Phase I.

4.3 Work Package 3: Expand Learning and Support of the Integration of Distributed Wind into Evolving Electricity Systems

In a continuation of efforts from Phase I, the WP3 team will continue international collaboration with a focus on Hybrid Power System incorporating wind energy.

WP3 Lead: Ian Baring-Gould, National Renewable Energy Laboratory, United States

WP3 Participants:

- Tonny Brink, Nordic Folkecenter, Denmark
- Anca D. Hansen, Kaushik Das, Technical University of Denmark, Denmark
- Ignacio Cruz, CIEMAT, Spain
- Narasimalu Srikanth, Energy Research Institute at Nanyang Technological University, Singapore (observer)
- Caitlyn Clark, National Renewable Energy Laboratory, United States
- David Wood, University of Calgary, Canada
- Dominic Bolduc, Nergica, Canada
- Seokwoo Kim, Korea Institute of Energy Research, Republic of Korea
- Nikolaos Stefanatos, Centre for Renewable Energy Sources and Saving (CRES), Greece
- Eftichia Tzen, Centre for Renewable Energy Sources and Saving (CRES), Greece
- Raymond Byrne, Dundalk Institute of Technology, Ireland

4.3.1 Introduction

While some examples exist of integrating distributed wind at higher outputs with other distributed energy resources (DERs) in microgrids, controls protocols, data requirements and integration have not been standardized, increasing the cost of each system. Additionally, expanding insight into markets with increased costs (isolated microgrids) or additional non-monetary benefits (resiliency, reliability, grid support, and diversification) will allow the expanded consideration of distributed wind technologies, especially in higher renewable contribution energy systems that are being more widely considered.

The custom system engineering and testing is a barrier to the expansion and contribution of distributed wind in this market sector. Similar issues exist with the expanded deployment of DERs into the distribution network, with increasing expectations and requirements around the controllability and security of DER technology, which the distributed wind industry is becoming more cognizant of, but still requires expanded research.

Over the last four years there has been expanded interest in the development of hybrid power plants, the hybridization of large-scale renewable sources with storage and improved integrated control to support constrained transmission systems. This focus continues to highlight the need for continued research on distributed voltage hybrid power plants that can provide local loads in front-of-the-meter, behind-the-meter, or in fully isolated energy systems. Considerations of energy valuation, the provision of grid support services, and energy system resiliency are already being considered at the distribution level, the learning of which can easily be applied to larger-scale energy systems.

4.3.2 Objectives

This project will support collaboration around the research, development, demonstration, and testing of distributed wind technologies with a focus on new and developing distributed generation markets, building on work completed by member research organizations over the last four years. Efforts will also be undertaken to collaborate closely with Task 50 (Hybrid Power Plants), focusing on smaller scale, distributed hybrid power plants. In place of focusing on the integration of wind into the wider energy system, this task will focus on wind energy deployed at a distribution voltage as part of integrated power plants. Expanded articulation of recent innovations and the need to rapidly expand renewable energy development to meet a larger percentage of specific, local loads will help to ensure that distributed wind is deployed in collaboration with other generation technologies.

This project will focus on supporting the inclusion of wind energy in distribution level hybrid power plants and isolated and remote energy systems, ranging from small (10s of kW) to larger (10s of MW) microgrid systems with focuses on:

- Information dissemination and education around wind as a valuable part of distributed energy systems
- Integration of wind with different types of storage (short- and long-term storage technologies, including green hydrogen/fuel cells), transportation, applications (water desalination), and dispatchable loads/smart meters.
- Interconnection of weak grids (combining isolated power systems with weak interconnections)

4.3.3 Summary of Concurrent National Work

The following efforts are being undertaken within national level programmes:

- In Denmark, the Nordic Folkecenter’s Greenland project is focused on integration and education around O&M for smaller systems, building on existing marine/boat maintenance and cold climate research and experience. In addition, Technical University of Denmark has a facility to conduct research on hybrid systems including microgrids and isolated systems with an emphasis on wind power support in active distribution systems.
- In Singapore, research is focused on lower cost technology, typhoon resistance, lower cost deployability, smart grid integration, and designing for tropical conditions. Many current applications for distributed scale wind energy development are for isolated energy systems.
- In Spain, small scale development Very niche markets right now, focused on telecommunications and integration questions, demonstration/research projects (wind turbines, flow batteries, complex PV array), Canary Islands
- In the United States, multiple work projects are underway looking at the controls, operation design of turbines in isolated areas and multi-technology/distributed energy systems. Work efforts include

developing and proof testing operational control strategies in hardware in the loop settings, developing an improved understanding of the valuation of distributed energy technology in behind and front of the meter hybrid system deployments, and direct technical support to hybrid power system applications. Hardware in the loop research facilities at Sandia National Laboratory, Idaho National Laboratory, and at the National Renewable Energy Laboratory will allow expanded high-fidelity research into distributed wind driven, high renewable contribution power systems.

- In Korea, research is focused on grid-connected microgrids and isolated grids. Key areas of concern focus on turbine reliability and maintenance in isolated applications, a key historical concern for the use of distributed wind technology.
- In Canada, Nergica conducts research in remote, arctic climates and developing countries while being actively engaged in national level programs to expand wind deployment in First Nation communities.
- In Greece, distributed wind and high renewable energy system (RES) contributions on an isolated grid are to be studied in the research-demonstration project "Green Island-Agios Efstratios." The project includes the design and implementation of a hybrid system, embedding mature RES technologies, Energy Storage and Energy-Saving, and electro mobility to the very small autonomous power system of the island of Agios Efstratios in the North Aegean Sea, aiming at a RES contribution level of 85%. The project is in an advanced pre-construction stage and is expected to start operation by the end of 2023.

4.3.4 Approach and Methodologies

Building on work being conducted by member countries, this WP will work to expand the international knowledge relating to wind as a key part of isolated and distributed-scale energy systems. Research being conducted within member nations will be communicated, looking for areas where results may have more global applicability. In these cases, task members will consider the development of collaborative journal articles.

With Task 50 focused on larger-scale hybrid power plants, Task 41 will engage with Task 50 participants and other stakeholders to better understand the applicability of similar system designs at distribution scale. The task will also further define the development space for distribution-scale hybrid power plants, considering design and valuation of high renewable contribution energy systems incorporating wind.

Although focused at large-scale hybrid power plants, Task 50 has developed a large list of potential stakeholders, many of which may be interested at distribution-scale development. In support of these stakeholders, Task 41 members will coordinate with Task 50 participants and co-operating agents to allow continued dialogue, understanding what synergies there may be relating to research development across the full range of hybrid power plant sizes.

Although there seems to be strong interest in cross technology (and thus cross TCP) development, most near term projects will be done at the distributed scale, allowing a strong need to build understanding of larger hybrid power plant development at a distribution scale. In this context task members have discussed holding workshops at the OA level with other TCPs (Hydrogen, PV, Energy storage, etc.) to identify way to share information and best practice, joint publications, and potentially joint research.

Lastly, to bring in research interest from non-wind TCP nations, the WP team will include the University Research Collaborative established in Phase I, which in previous years has had an outsized interest in research around hybrid power systems.

4.3.5 Key Partnering Organisations outside of Task 41 Participants

As part of the implementation of this work, work package leaders will work with members of Task 50 to ensure harmonization of work for distribution grid-level integration efforts and minimize any potential duplication of effort. This will include coordinating on the development of terminology to describe hybrid power plants, documenting design, control, and market approaches between the different technology scales, and understanding modelling approaches that may be applicable for both development groups. The two tasks have several collaborating members including cross collaboration in task leadership and could result in several joint project meetings over the four-year span of the two efforts.

4.3.6 Expected Results or Outcomes

The WP team plans to perform task outreach through peer-reviewed journal articles, papers or sessions at specific wind-focused conferences (i.e., Torque, WESC, NAWEA\WindTech, Nordic Folkecenter small wind conference). Expected outcomes of this work include the following:

- Improved understanding of distributed wind integration into isolated energy systems.
- Improved articulation of the valuation of distributed wind-based energy systems within the energy network specific to individual energy categories or load types.
- Improved understanding of effective control and communications of wind as an integrated part of distributed scale hybrid energy systems.

4.3.7 Milestones and Deliverables

- M3-1 Support for hybrid power system terminology. Provide technical support and input to IEA Wind TCP Task 50 efforts under Work Package 1, Define Taxonomy for Hybrid Power Plants, relating to distributed scale hybrid power plants. (March 2023)
- M3-2: Finalize journal publication research topic, scope and core authors relating to the role of distributed wind as part of a high renewable energy driven future power system for Deliverable 3-3 (November 2023)
- D3-1: Industry Best Practice guide for high wind contribution, isolated hybrid Power Systems. Building from lessons learned from remote power system implementation, the design guide developed in the first phase of this work and case studies conducted in the United States, Canada, Greenland, and Korea, produce a Best Practice guide for isolated hybrid power systems (July 2024)
- D3-2: Journal article summarizing international perspective on distributed wind as part of the future energy system (July 2025)
- D3-3: Key Performance Indices for isolated power systems. Working in collaboration with IEA PVPS Task 14 (Solar PV in the 100% RES Power System) and Task 18 (Off-Grid and Edge-of-Grid PV Systems), build on existing literature to articulate and publicize Key Performance Indices for isolated power systems with a specific focus on performance, power quality, and project finance (July 2026)

4.4 Work Package 4: Outreach & Collaboration

In a continuation of efforts under Phase I, the project team will expand efforts to engage with other tasks in the Wind TCP, other TCP's with similar interests, and other international bodies relating to the potential of distributed wind technologies.

<u>WP4 Leads</u>: Alice Orrell, Pacific Northwest National Laboratory and Ian Baring-Gould, National Renewable Energy Laboratory, United States

<u>WP4 Participants</u>:

- Dominic Bolduc, Nergica, Canada
- Tonny Brink, Nordic Folkecenter for Renewable Energy, Denmark
- Nikolaos Stefanatos, Centre for Renewable Energy Sources and Saving, Greece
- David Wood, University of Calgary, Canada
- Ruth Baranowski, National Renewable Energy Laboratory, United States
- Kaushik Das, Tom Cronin, David Rudolph, Technical University of Denmark, Denmark

4.4.1 Introduction

The goal of Task 41 is to expand international collaboration, disseminate information, and promote expanded engagement in the wider distributed energy research fields and deployment markets to lower the costs and deployment barriers for wind as a distributed energy resource. While each work package has its own publications and will include work package-specific collaboration, outreach, and dissemination efforts, this work package addresses general outreach and collaboration for the overall task. This work package identifies collaboration opportunities with other select IEA Wind TCP tasks, the IEA Photovoltaic Power Systems Programme (PVPS), and relevant outside agencies.

4.4.2 Objective

The key objective of this task is to expand the understanding of the appropriate role of distributed wind energy within the framework of wind energy, renewable energy, and clean energy transitions. This effort will also work to ensure the incorporation of distributed wind as a technology solution within other materials, efforts, and research related to distributed generation.

4.4.3 Approach and Methodologies

This task will be implemented through two specific efforts, the first set focused on direct engagement with identified high priority projects or organizations while the second will focus on more general outreach and communication.

4.4.4 Key Partnering Organisations outside of Task 41 Participants

Other Tasks within the IEA Wind TCP are doing work that could directly support the expanded use of wind technology as a distributed energy resource, but are not actively considering distributed wind in their research. Having Task 41 members engaged with these other tasks will allow them to keep Task 41 informed of their research and potential collaboration opportunities. These Wind TCP Tasks that are of interest to Task 41 include the following:

- Task 25 (Design and Operation of Energy Systems with Large Amounts of Variable Generation)
  - Engagement with Task 25 will be at the task level via Kaushik Das.
- Task 28 (Social Acceptance of Wind Energy Projects)
  - Engagement with Task 28 will be coordinated through Work Package 6 (Human Dimensions of Distributed Wind).
- Task 45 (Recycling wind turbine blades)
  - Engagement with Task 45 will be coordinated through Work Package 5.
- Task 50 (Hybrid Power Plants)
  - Engagement with Task 50 will be coordinated through Work Package 3 (Integration) with several identified collaboration opportunities and others being identified over the course of the project timeline. Team members Kaushik Das and Ian Baring-Gould will support this collaboration.
- Task 52 (Large-Scale Deployment of Wind Lidar)
  - Engagement with Task 52 will be at the task level and include considering the development of assessment decision trees relating to the appropriate use and scope of lidar deployment for distributed wind applications.
- Task 54 (Cold Climate Wind Power)
  - Engagement with Task 54 will be both at the task level and coordinated through Work Package 5 and Work Package 6 (Human Dimensions) and siting considerations for distributed wind deployment in cold climates with the specific focus on identifying appropriate turbine technology.

Tasks within the IEA PVPS are pursuing research objectives that could more broadly benefit distributed energy. The two most relevant solar PV Tasks are Task 14 (Solar PV in the 100% RES Power System) and Task 18 (Off-Grid and Edge-of-Grid PV Systems).

The objective of IEA PVPS Task 14 (Solar PV in the 100% RES Power System) is to reduce the technical barriers to achieving high contribution levels of distributed renewable generation on electric power systems. As wind energy is also a variable renewable energy source, this research could be applicable to distributed wind. Although wind amounts in distribution systems are not typically at the same high contribution levels as solar PV, there is value in Task 41 following and understanding the work of Task 14 and how it could apply to distributed wind. If Task 41 can identify a member to be a liaison with Task 14, that member will reach out to PVPS Task 14 to initiate dialogue and, as appropriate, attend Task 14 meeting(s) and report back findings that could inform Task 41 research.

The objective of IEA PVPS Task 18 (Off-grid and Edge-grid PV Systems) is to find the technical issues and barriers which affect the planning, financing, design, construction and operations and maintenance of off-grid and edge-of-grid systems, especially those which are common across nations, markets and system scale, and offer solutions, tools, guidelines and technical reports for free dissemination for those who might find benefit from them. Bethel Tarekegne with Pacific Northwest National Laboratory will engage with PVPS Task 18 to initiate dialogue and, as appropriate, attend Task 18 meeting(s) and report back findings that could inform Task 41 research.

Task member, Ignacio Cruz with CIEMAT, will also pursue potential collaborative relationships with storage or smart grid IEA tasks.

4.4.5 Expected Results or Outcomes

Task 41 members will participate in specific, targeted conferences and collaborate to create outreach materials. Task members agree that a priority of our participation and outreach is to spread the message that distributed wind is not a niche market and can provide specific benefits.

Materials will be disseminated through IEA Wind TCP channels (e.g., Task webpage, LinkedIn) and through collaboration with organisations that work to promote the use of renewable energy in distributed applications and may be open to the expanded inclusion of wind energy, such as International Renewable Energy Agency (IRENA).

After the completion of this work plan extension, Task 41 would like there to be other venues, such as conferences, to continue cross industry collaboration on distributed wind. This has also been identified as a need by the Small Wind Committee of the European Wind Energy Academy, which will be working to develop research focused communication forums. As such, conference participation is a focus of this subtask.

4.4.6 Milestones and Deliverables

- M4-1: Participate in Nordic Folkecenter International Conference on Small and Medium Wind Energy (September 2023)
- M4-2: Participate in NAWEA/WindTech Conference (October 2023)
- M4-3: Identify journal publication research topic and define scope for Deliverable 4-1 (December 2023)
- M4-4: Participate in Torque Conference (May 2024, Florence, Italy)
- M4-5: Participate in Nordic Folkecenter International Conference on Small and Medium Wind Energy (September 2024)
- M4-6: Participate in Nordic Folkecenter International Conference on Small and Medium Wind Energy (September 2025)
- M4-7: Participate in Torque Conference (May 2026)
- M4-8: Participate in Nordic Folkecenter International Conference on Small and Medium Wind Energy (September 2026)
- D4-1: Distributed Wind Fact Sheet (May 2023, lead: Ruth Baranowski)

Task members will create a two-page fact sheet about distributed wind that will be translated into the different languages of the member countries for distribution in those countries and include a designated area to fill with country-specific market information. Additional fact sheets on more specific topics (e.g., valuation, recycling, cold climates) may also be pursued.

- D4-2: Video Presentation (expected completion: January 2024, lead: Ruth Baranowski)

  Task members will participate in the development of a short video that highlights the work of Task 41. The video session will be co-located with the Task 41 in-person meeting anticipated for October 2023. The video will then be hosted on the Task 41 website and highlighted through social media.

- D4-3: Capstone publication by all interested task members (December 2025, lead: TBD)

  Task members will collaborate to publish a journal article on a key research topic for Task 41. The publication research topic could discuss the international opportunities as a follow up to the challenges identified in the *Current status and grand challenges for small wind turbine technology* publication or expand the challenges to include all distributed wind, not just small wind.

4.5 WP5: Innovation and Technical Specifications

WP5 Leads: Ignacio Cruz, CIEMAT, Spain; David Wood, University of Calgary, Canada; Dominic Bolduc, Nergica, Canada

WP5 Participants:

- Ian Baring-Gould, National Renewable Energy Laboratory, United States
- Trudy Forsyth, Wind Advisors Team, United States
- Tonny Brink, Nordic Folkecenter, Denmark
- Seokwoo Kim, Korea Institute of Energy Research, Republic of Korea

4.5.1 Introduction

This work package will review the technical specifications required for distributed wind turbines to meet the needs of the cold climate market needs (small wind turbines are often needed in cold and dark locations), and an examination of sustainability and end-of-life recyclability options for smaller wind turbines.

4.5.2 Objective

The objective of this work package is to explore innovative research topics that have yet to be considered with respect to distributed wind.

4.5.3 Summary of Concurrent National Work

- In Canada, Nergica is developing a preliminary cold climate specification as part of Task 54. And the University of Calgary has sustainability projects with Brazil and Ethiopia universities that could also be part of the University Research Collaborative that was established during Phase I.
- In the United States, a new research activity on recyclability of small wind turbines is being investigated under the leadership of Oak Ridge National Laboratories.
- In Denmark, the Nordic Folkecenter's research in Greenland is relevant to this work package.
- In Austria, the University of Applied Sciences FH Technikum Wien may have an alternative materials project funded in 2023.

4.5.4 Approach and Methodologies

Building on national projects , Task 41 will pursue the two topics and disseminate resultant products to Task 41 members for editing, modification suggestions, or country-specific variability. Written feedback and comments will be gathered considered, and where applicable incorporated into Task 41 final deliverables.

- **WP5-1 Cold climate specification**: Under the guidance from Dominic Bolduc and his experience developing projects using small wind turbines in the northern latitudes of Canada, a draft cold climate specification will be developed and shared with other Task 41 and Task 54 members. Feedback will be collected, and the cold weather specification will be documented in final form.
- **WP5-2 Recyclability & Sustainability**: Assess the recyclability and associated costs of the selected recycling pathways to enable recyclability in distributed wind as the market and manufacturing scale-up. Multiple components at various scales will be assessed as the recycling pathway will most likely be dependent on scale and component.

4.5.5 Key Partnering Organisations outside of Task 41 Participants

- Oak Ridge National Laboratory, United States
- Task 45 (Recycling wind turbine blades)

4.5.6 Expected Results or Outcomes

The products from this WP will provide guidance to end users, manufacturers, and installer/developers and provide forward thinking on critical issues for the distributed wind industry.

4.5.7 Milestones and Deliverables

- WP5-1: Cold climate specification
  - M5-1: Virtual meeting with Task 54 (Cold climate wind power) to discuss technical specifications for wind turbines installed in cold climates (March 2023), possibly co-located with Winterwind conference and leading to the development of deliverable D5-1.
  - D5-1: Guidelines for IEC “S” class for remote deployments. Building on existing requirements for wind turbines in arctic climates developed by IEA Task 19 and recent work undertaken in Canada and the US, this document will provide initial guidance on technical requirements for distributed scale wind turbines that will be deployed in isolated locations. (as a technical report or journal publication) (March 2024)
- WP5-2: Recyclability & Sustainability
  - M5-2: University Research Collaboration Symposium on small wind turbine recyclability and sustainability (May 2024), possibly co-located with Torque 2024
  - D5-2: Preliminary assessment that maps how distributed wind technologies can be designed for recyclability and sustainability (August 2025)

4.6 Work Package 6: Human Dimensions of Distributed Wind

WP6 Leads: Dominic Bolduc, Nergica, Canada; Alex Hirschl, University of Applied Sciences FH Technikum Wien, Austria

WP6 Participants:

- Tom Cronin, David Rudolph, Technical University of Denmark, Denmark
- Imen Romdhane, Nergica, Canada
- Bethel Tarekegne, Sarah Barrows, and Danielle Preziuso, Pacific Northwest National Laboratory, United States
- Suzanne MacDonald, National Renewable Energy Laboratory, United States
- Tonny Brink, Nordic Folkecenter, Denmark

4.6.1 Introduction

While wind as a distributed energy resource can provide a variety of benefits to society, these benefits are not always well documented or quantified. This work package will explore the human dimensions of distributed wind through valuation exercises and stakeholder engagement activities as methods to facilitate social acceptance of distributed wind. Social acceptance can be influenced by project characteristics, distribution of benefits and burdens, and the level of public participation in project planning, implementation, and operation of energy systems. Low or no social acceptance could result in project delay, opposition, cost escalation, and failure of distributed wind projects. Alternatively, increased social acceptance can help increase distributed wind deployment.

4.6.2 Objective

This project will coordinate international experience on distributed wind social science, building on work being undertaken in several national programmes. Task members engaged in these activities may collaborate with Task 28 (Social Science of Wind Energy Acceptance) members. In addition, this work package will investigate the human-environment interactions of distributed wind (i.e., the interactions associated with people residing in close proximity to wind turbines).

4.6.3 Approach and Methodologies

The project will be implemented through the following specific activities:

- **WP6-1 Valuation Exercises**: Sometimes the energy delivered from a distributed wind project is seen as the only benefit of the project. And when a developer is negotiating a power purchase agreement with a utility, the community is most often not part of the negotiations. But for a community to accept a distributed wind project, it must be able to recognize the benefits that the project is providing it, and these benefits could go beyond energy delivery or price.

  Nergica, a task member from Canada, is helping northern First Nation communities in Nunavik evaluate adding wind to their isolated village grid systems. Nergica will apply Pacific Northwest National Laboratory's distributed wind valuation framework to one of these isolated grids to demonstrate the value of including wind, for both the community in terms of what they value, and to the developer and utility. Task members will collaborate with Nergica to identify value stream calculation methods, model distribution systems, and make potential adaptations to the framework that may be needed to make it more applicable to remote Canadian villages. Nergica has identified Tarquti Energy and Hydro-Quebec as potential collaborator for the valuation exercise.

- **WP6-2 Stakeholder Engagement**: The University of Applied Sciences FH Technikum Wien's SmallWind4Cities project will develop a simplified assessment to site small wind in urban areas. It will also install four small wind turbines with one rotating through 5 to 10 different urban areas and then survey the immediate community about their perceptions of the small wind turbine. The survey covers the visual perception, acoustic perception as well as personal requirements for small wind turbines e.g., expected yield, costs, durability, etc. Community perceptions may vary based on distance, demographics (e.g., age, gender, etc.), and participation. Understanding these factors and their influence on social acceptance will help distributed wind developers and policymakers address potential community resistance. Additionally, the approval procedure of the ten small wind turbine installations will be monitored to evaluate a possible simplification.

- **WP6-3 Human-Environment Interaction Research**: Many distributed wind projects are constructed in remote areas that are affected by atmospheric icing, but icing mitigation solutions are not often designed or suited for small-scale deployments. In these locations, icing issues and impacts can be the same as they are in larger-scale applications, but in many cases the owner or operator of the distributed wind project does not have the resources required to deal with icing problems as is possible for larger projects. And many technical solutions from megawatt-scale turbines do not scale downward very effectively. In locations where atmospheric icing is not prevalent, icing concerns may still arise for a distributed wind project given its relative proximity to infrastructure and populations.

Regardless of this, developers of distributed wind projects still need support for siting and operations on how to minimize risks caused by icing. In 2022, Task 41 collaborated with Task 54 to publish *A Framework for Characterizing the Ice Fall and Ice Throw from Small Wind Turbines*. Under Task 41 Phase II, Task 41 and Task 54 members will collaborate to disseminate the report and receive feedback from stakeholders who have or could apply the framework to their projects.

4.6.4 Key Partnering Organisations outside of Task 41 Participants

- SmallWind4Cities project partners: Bluepower, Tulln, and Grossschoenau.

4.6.5 Expected Results or Outcomes

The desired outcome of this work package is an improved understanding of how valuation exercises and stakeholder engagement activities can facilitate social acceptance of distributed wind.

4.6.6 Milestones and Deliverables

- WP6-1: Valuation exercises
  - M6-1: Meetings with first nation communities and Tarquti Energy (May 2023)
  - M6-2: Workshops with task member, Tarquti Energy and Hydro-Quebec (November 2023)
  - M6-3: Propose a joint meeting with Task 28 to share results (October 2024)
  - D6-1: Reports on valuation results (February 2024)
  - D6-2: Adjustments to the valuation framework for application outside of the United States (September 2024)
- WP6-2: Stakeholder engagement
  - M6-4: Workshop: Discussion of simplified Site assessment methodology (September 2023)
  - M6-5: Workshop: Discussing of challenges during approval procedures and simplification potential. (December 2023)
  - M6-6: Workshop: Evaluation and comparison of prejudice against small wind turbines (May 2024)
  - M6-7: Compare and contrast Austrian and Nunavik stakeholder values and feedback as appropriate (May 2024)
  - D6-3: Validation of simplified assessment methodology (June 2023)
  - D6-4: Joint paper(s) on lessons learned/best practices on how to include communities to achieve public acceptance (i.e., procedural justice), how to improve approval processes, and/or a comparison of approval process (i.e., for rural or urban or tribal communities and across countries) (April 2024)
- WP6-3: Human-Environment Interaction
  - D6-5: Summary of dissemination results and feedback (December 2023)

5. Time Schedule with Key Dates

To maintain continuity of the Task 41's work and participation, we propose to initiate the Task on 1 January 2023, and to continue, in principle, for a period of four years, through 31 December 2026. At the conclusion of this four-year period, task participants will discuss the value of implementing a new work package to allow continued international collaboration.

The proposed schedule for the activities and deliverables described in Section 4 of this document are shown in Figure 1. Details include planned meetings, OA administrative deliverables and deliverables and activities associated with each of the specific work packages.

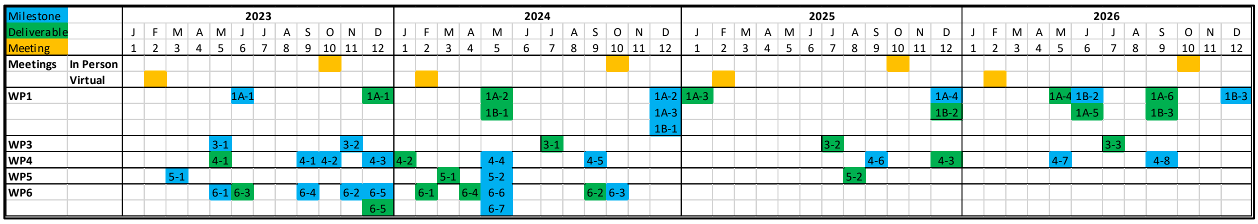

Figure 2. Task 41 Proposed Work Plan Chronogram

6. Reports, Deliverables, and Dissemination of Results

Reports and other deliverables will be accessible through the Task 41 website and any other Participant web-based dissemination mechanism at the discretion of the Participant. Efforts will also be made to incorporate Wind TCP LinkedIn and other social media platforms in the dissemination and outreach. In addition, all participants are encouraged to seek opportunities to disseminate results through conferences, webinars, social media or other means. Specific conferences, collaborations, and outreach activities are detailed in each of the work package plans.

To actively engage with the academic community, with a specific interest of engaging with academic institutions from nations outside of IEA Wind TCP, this Task will continue the development of the Distributed Wind University Research Collaboration, where faculty and graduate students are encouraged to work in collaboration with Task members to solve pressing, distributed wind-focused research questions. The Research Collaboration will lead to the hosting of one or two graduate student forums per year, in partnership with the European Wind Energy Academy, Small Wind Committee. Task 41 members will provide recommendations for interesting and industry relevant research topics, but specific research topics will be chosen by the students and their faculty advisers. Task members will seek out opportunities to fund specific research projects and publish a compendium of annual research. The Research Collaboration will be run under the authority of the Operating Agents of Task 41.

We expect that the project results will be valuable to wind turbine manufacturers, domestic and international project developers and end users. To engage more actively with the wind industry, over the course of this project timeline national participants will be encouraged to reach out directly to industry members who do not frequent technical conferences. Project participants will also look for non-technical conferences where direct industry engagement may be more likely.

Due to close cross pollination of IEA Task 41 members and the current IEC 61400-2 review team, Task 41 members should have good access to the standards development process. As needed, documents with technical recommendations will be prepared for standards committees, including final technical recommendations that came out of Task 27. The revision for IEC 61400-2 is expected to run concurrently to the project period of Task 41 Phase II.

Table 1. Planned Deliverables and Schedule

Number	Deliverable	Contributors	Expected Completion Date
D1A-1	A catalogue of validated turbulence data	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	December 2023
D1A-2	Presentation at Torque 2024	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	May 2024
D1A-3	Journal publication on the classification and reduced-order statistical characterization of turbulence	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	January 2025
D1A-4	Presentation at Torque 2026	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	May 2026
D1A-5	Journal publication on the predictability and prediction of turbulence in the context of distributed wind energy	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	June 2026
D1A-6	Technical report with recommendations for standards	Belgium, Denmark, Italy, Austria, United States, Canada, Spain, China	September 2026

D1B-1	Best practice guideline for wind energy system design and verification	Italy, Canada, Denmark, Greece, United States, Spain	February 2026
D1B-2A	Presentation at WESC 2023	Italy, Canada, Denmark, Greece, United States, Spain	May 2023
D1B-2B	Presentation at Torque 2024	Italy, Canada, Denmark, Greece, United States, Spain	May 2024
D1B-3	Journal publication	Italy, Canada, Denmark, Greece, United States, Spain	December 2025
D3-1	Industry Best Practice guide for high wind contribution, isolated hybrid Power Systems	United States, Denmark, Spain, Canada, Republic of Korea	July 2024
D3-2	Journal article summarizing international perspective on distributed wind as part of the future energy system	United States, Denmark, Spain, Canada	July 2025
D3-3	Key Performance Indices for isolated power systems	United States, Canada	July 2026
D4-1	Distributed Wind Fact Sheet	All	May 2023
D4-2	Video Presentation	All	January 2024
D4-3	Capstone publication	All	December 2025
D5-1	Cold climate specification	Canada, United States, Denmark, Republic of Korea	March 2024
D5-2	Preliminary recyclability and sustainability assessment	Canada, United States, Denmark, Republic of Korea	August 2025
D6-1	Reports on valuation results	Canada, Austria, Denmark, United States	February 2024
D6-2	Adjustments to the valuation framework for application outside of the United States	Canada, Austria, Denmark, United States	September 2024
D6-3	Validation of simplified assessment methodology	Canada, Austria, Denmark, United States	June 2023
D6-4	Joint paper(s) on lessons learned/best practices	Canada, Austria, Denmark, United States	April 2024
D6-5	Summary of dissemination results and feedback	Canada, Austria, Denmark, United States	December 2023

7. Methods of Review and Evaluation of the Work Progress

The Operating Agent will consult and monitor each project participant on the progress made in relation to the plan through regular virtual meetings and in-person meetings. Initially, more frequent communication will occur to assure that the full work plan document is completed and up to date with descriptions of each party's contribution. Based on input from these regular consultations, a status report which summarizes the progress of each work package will be developed and submitted to the IEA Wind Executive Committee annually. Changes to the work plan will be managed on an as needed basis pending potential changes in participating personnel or availability.

8. Obligations and Responsibilities

This Task requires collaboration among all Participants as well as contributing technical work that is conducted independently. The general obligations of the OA and the Participants are described below. Although considered minimal since most specific results will be the result of identified national research efforts, the data and products developed through this Task will be available equally to all participants. Data and products of this Task will not be available externally until completion of the Task or by agreement of the Participants. New entrants will be encouraged throughout the Task.

8.1 Operating Agent

In addition to the responsibilities enumerated in Article 4 of the IEA Wind Agreement the Operating Agent shall:

- Act as the single point of contact for the Task with the IEA.
- Work to coordinate WP efforts through direct dialogue with WP leads
- Prepare a detailed Task Work Plan in cooperation with the WP leads and other Participants. The work plan will be reviewed annual and updated as appropriate. The final work plan will be submitted for approval by the Executive Committee with status and updates summarized annually.
- Be responsible for organizing meetings with representatives designated by Participants, including:
  - Semi-annual technical exchange meetings per year to report on each WP effort with specific focused discussions on specific WP efforts as needed
  - Semi-annual web meeting with WP leads.
- Maintain a website of documents and summary of activities.
- Conduct a review of IEA Wind TCP tasks to identify ones with specific DW overlap.
- Conduct a review of general IEA efforts to identify ones with specific DW overlap.
- Develop a DW engagement strategy that will include the identification of Participants or WP leads to attend specific meetings hosted by others or the co-hosting on Task meetings with other IEA efforts as appropriate.
- Be responsible for the performance of the Task and report annually to the IEA Wind TCP Executive Committee (ExCo) on the progress and the results of the work performed under the work plan.
- Provide to the ExCo, within six months after completion of all work defined in the Work Plan, a final report summarizing the findings of the Task for its approval and transmittal to the Agency.

The responsibilities of the Operating Agent relate to the cooperation in the WP0 and WP5. The Operating Agent shall not be liable for the national efforts of the Participants even if the national efforts are in relation to specific efforts identified within a WP.

8.2 Participants

In addition to any obligations listed in the IEA Wind Agreement, the following obligations and responsibilities will be adhered to by the Participants of the Task:

- Each Participant shall bear its own cost for the scientific work, including travel expenses.
- The host country/sponsor shall bear the costs of workshops and meetings of experts.
- In the event that the U.S. DOE is unable to support the costs of the Operating Agency, the total costs of the Operating Agent shall be borne jointly and in equal shares by the Participants.

- Each Participant shall transfer to the Operating Agent its annual share of the costs in accordance with a time schedule to be determined by the Participants, acting under the direction of the Executive Committee.
- Each Participant will identify which WP in which they will participate and is expected to participate in at least one WP.
- Each Participant shall submit presentation materials and reports presented at the Task meetings to the Operating Agent for posting on the Task website, the format of which shall be agreed upon by the Participants.
- Each Participant will participate in editing and review of Task articles, presentations, technical documents, and the final report with expanded focus of documents that are produced by WP they are supporting.

In addition to the activities described in the Work Packages in Section 4, each participating country/sponsor is conducting related work. The planned effort from each participating country/sponsor will be estimated and documented in Table 2 at the Task kick-off meeting. The column "Task Effort" indicates the effort taken specifically for this Task while the column "Related Effort" indicates the effort for related work that will partly support this task. The Task is expected to officially begin effort (on at the start of the project and will conclude four years after.

Table 2. Planned Effort (FTE months) from Each Participant

Country	Participating Organization	Work Package	National Effort	Related Effort	Total Effort
Austria	University of Applied Sciences FM Technikum Wien	1,4,6	TBD	TBD	TBD
Canada	Nergica	1,3,4,5,6	TBD	TBD	TBD
	University of Calgary	1,3,4,5	TBD	TBD	TBD
China	Inner Mongolia University of Technology	1	TBD	TBD	TBD
Denmark	Technical University of Denmark, DTU Wind and Energy Systems	1,3,4,6	TBD	TBD	TBD
	Nordic Folkecenter	1,3,4,5,6	TBD	TBD	TBD
Greece	Centre for Renewable Energy Sources and Saving	1,3,4	TBD	TBD	TBD
India	National Institute of Wind Energy	TBD	TBD	TBD	TBD
Ireland	Dundalk Institute of Technology	3	TBD	TBD	TBD
Italy	University of Perugia	1,4	TBD	TBD	TBD
	University of Genoa	1,4	TBD	TBD	TBD
Korea	Korea Institute of Energy Research	3,4,5	TBD	TBD	TBD
Spain	CIEMAT	1,3,4,5	TBD	TBD	TBD
Singapore	Energy Research Institute at Nanyang Technological University	1,3,4	TBD	TBD	TBD
United States	National Renewable Energy Laboratory	1,3,4,5,6	TBD	TBD	TBD
	Pacific Northwest National Laboratory	4,6	TBD	TBD	TBD
	Wind Advisors Team	1,3,4,5	TBD	TBD	TBD

9. Funding

Alice Orrell from Pacific Northwest National Laboratory (PNNL) and Ian Baring-Gould from National Renewable Energy Laboratory (NREL) will continue as the co-Operating Agents for IEA Wind Task 41 (Enabling Wind to Contribute to a Distributed Energy Future).

While the operating agent's costs for NREL and PNNL are paid by the DOE, to increase participation from other task members, the work plan extension will ask participating countries to commit a minimum of 20 hours per month of labor. The Operating Agent position requires project management, organizing and facilitating virtual and in-person task meetings, reporting progress to both IEA Wind TCP Executive Committee and U.S. DOE Wind Energy Technology Office (WETO) leadership, leading outreach and collaboration efforts, and recruiting more countries to increase and diversify task membership.

WETO and the United States receive extensive benefits from this IEA engagement with partner research organizations across Europe and Asia. Collaboration with international partners on key issues such as international standards, integration of distributed wind in hybrid power systems, and the expansion of university-related research on distributed wind energy act as force multipliers for ongoing WETO-funded research in these areas.

The funding principles are summarized as follows:

- Each Participant shall bear their own costs for carrying out the scientific work, including reporting and travel expenses.
- The host shall bear the costs of workshops and meetings convened in conjunction with this Task.
- Each participating country's intended resource allocations for the projected four years will be determined at the Task kick-off meeting (see Table 2 above).

10. Budget Plan

The estimated total OA costs for coordination, management and reporting is shown in Table 3.

Table 3. Projected Estimated Expense Items of the Operating Agent

Expense Item	Description	Estimated Cost (USD per Year)	Estimated Cost (USD Total)
Management & Technical Support	Organize meetings, produce progress reports, etc.	75,000	300,000
Task Travel	A total of 4 expected person trips per year	20,000	80,000
Communications, Outreach, and Miscellaneous	Website, outreach materials, product development	30,000	120,000
Total		75,000	300,000

11. Management of Task

The OA is responsible for overall Task management and reporting. The management structure will be designed to conduct the work packages as described in Section 4 of this document according to the planned work scope and budget. The OA will coordinate with the participants to 1) define the scope and estimated labor for each Participant's contribution for inclusion in the work plan, 2) establish a communication method and procedure for collaboration to conduct the work, 3) monitor progress through semi-annual reporting, and 4) conduct plenary meetings at approximately 6-month intervals at which progress is evaluated by all participants. Each Participant will support the Task according to the list of planned and agreed country/sponsor participant contributions within the defined work scope.

The OA will arrange all task member meetings twice a year in coordination with the meeting host. As part of each meeting, Participants will be expected to give a presentation on the most recent national/sponsor activities that support the work of Task 41 and other topical items within the work scope. Meeting notes will be distributed to all participants after each of the plenary meetings.

In order to facilitate the required collaboration, web-based meetings will be conducted as needed throughout the project duration, ideally quarterly.

Email will be used as the primary method of communication between meetings using a master mailing list that will be used for organizing meetings, distributing information, and as a platform for discussions. The OA will keep the mailing list up to date.

The Task 41 website will be maintained and updated throughout the project duration for data archive, transfer, and dissemination of information to the Participants and to the public.

The annual Task status reports that are prepared for the ExCo will also be distributed to the participants. All of this information will be available on the IEA Wind members-only website.

12. Organization

The Operating Agent Task will be performed in collaboration between the National Renewable Energy Laboratory and Pacific Northwest National Laboratory.

13. Information and Intellectual Property

1. **Executive Committee's Powers**. The publication, distribution, handling, protection and ownership of information and intellectual property arising from activities conducted under this Annex, and rules and procedures related thereto shall be determined by the Executive Committee, acting by unanimity, in conformity with the Agreement.
2. **Right to Publish.** Subject only to copyright restrictions, the Annex Participants shall have the right to publish all information provided to or arising from this Task except proprietary information.
3. **Proprietary Information.** The Operating Agent and the Annex Participants shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect proprietary information provided to or arising from the Task. For the purposes of this Annex, proprietary information shall mean information of a confidential nature, such as trade secrets and know-how (for example computer programmes, design procedures and techniques, chemical composition of materials, or manufacturing methods, processes, or treatments) which is appropriately marked, provided such information:
   a. Is not generally known or publicly available from other sources.
   b. Has not previously been made available by the owner to others without obligation concerning its confidentiality; and
   c. Is not already in the possession of the recipient Participant without obligation concerning its confidentiality.

   It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent for arising proprietary information, to identify the information as such and to ensure that it is appropriately marked.
4. **Use of Confidential Information.** If a Participant has access to confidential information which would be useful to the Operating Agent in conducting studies, assessments, analyses, or evaluations, such information may be communicated to the Operating Agent but shall not become part of reports or other documentation, nor be communicated to the other Participants except as may be agreed between the Operating Agent and the Participant which supplies such information.
5. **Acquisition of Information for the Task.** Each Participant shall inform the other Participants and the Operating Agent of the existence of information that can be of value for the Task, but which is not freely available, and the Participant shall endeavor to make the information available to the Task under reasonable conditions.
6. **Reports on Work Performed under the Task.** Each Participant and the Operating Agent shall provide reports on all work performed under the Task and the results thereof, including studies, assessments, analyses, evaluations and other documentation, but excluding proprietary information, to the other Participants. Reports summarizing the work performed and the results thereof shall be prepared by the Operating Agent and forwarded to the Executive Committee.
7. **Arising Inventions.** Inventions made or conceived in the course of or under the Task (arising inventions) shall be identified promptly and reported to the Operating Agent. Information regarding inventions on which patent protection is to be obtained shall not be published or publicly disclosed by the Operating Agent or the Participants until a patent application has been filed in any of the countries of the Participants, provided, however, that this restriction on publication or disclosure shall not extend beyond six months from the date of reporting the invention. It shall be the responsibility of the Operating Agent to appropriately mark Task reports that disclose inventions that have not been appropriately protected by the filing of a patent application.
8. **Licensing of Arising Patents.** Each Participant shall have the sole right to license its government and nationals of its country designated by it to use patents and patent applications arising from the Task in its country, and the Participants shall notify the other Participants of the terms of such licenses. Royalties obtained by such licensing shall be the property of the Participant.

9. **Copyright.** The Operating Agent may take appropriate measures necessary to protect copyrightable material generated under the Task. Copyrights obtained shall be held for the benefit of the Annex Participants, provided however, that the Annex Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise directed by the Executive Committee, acting by unanimity.
10. **Inventors and Authors.** Each Annex Participant will, without prejudice to any rights of inventors or authors under its national laws, take necessary steps to provide the co-operation from its inventors and authors required to carry out the provisions of this paragraph. Each Annex Participant will assume the responsibility to pay awards or compensation required to be paid to its employees according to the law of its country.

14. List of Potential Participants

The individuals listed below have expressed interest in participating in Task 41 Phase II.

Nation	Expert Participants	Email
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