

Final report

Project details

Project title	EUDP 2019-II IEA Wind Task 41 Contribution to distributed wind in future energy systems
File no.	64019-0518
Name of the funding scheme	EUDP
Project managing company / institution	DTU Wind and energy systems
CVR number (central business register)	30060946
Project partners	None
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1. Summary

The overall objective of this project was to identify and explore studies of particular Danish interest of Distributed Wind (DW) for cost effective technology development and integration into an continuously evolving energy system. This was done by collaborating and contributing to the IEA Wind TPC Task 41 international activities on DW turbine technology development and assessment in a series of dedicated work packages (WPs). IEA Wind TPC Task 41 is an international network centered on international collaboration and coordination in the field of DW. The purpose of Task 41 is to accelerate the development and deployment of DW technology as one of the leading generation sources in global renewable markets, the facilitation of easier and faster DW integration into electrical grids, increasing thus the competitiveness of wind and accelerating the replacement of fossils fuels. The IEA collaboration is enforced partly by exchange of information, sharing of results, and conducting analyses and explorative studies in the form of reports and publications and partly by implementing a strong cross IEA Wind TPC Tasks collaboration effort. The results were disseminated through regular meetings, workshops, conferences, and journal papers. All results can be found on <https://iea-wind.org/task41/>.

Den overordnede målsætning med dette projekt var at identificere og analysere undersøgelser med særlig dansk interesse mht. distribueret vind (DW) for omkostningseffektiv teknologiudvikling og integration i el-system, som kontinuerligt udvikles. Dette blev gjort ved at samarbejde og bidrage til IEA Wind TPC Task 41 internationale aktiviteter omkring udvikling og evaluering af DW-teknologi gennem en række fokuserede ar-

bejdspakker (WP'er). IEA Wind TPC Task 41 er et internationalt netværk centreret omkring internationalt samarbejde og koordinering af indsatsen inden for DW-området. Formålet er at fremskynde udviklingen og anvendelsen af DW-teknologier og dermed give DW mulighed for at blive en integreret og dominerende del af de fremtidige vedvarende markeder. De udviklede processer og procedurer er med til at understøtte en omkostningseffektiv udvikling af DW-teknologier, som derved øger vindens konkurrenceevne og accelererer udfasningen af fossile brændsler. IEA-samarbejdet har sin styrke i at udveksle information, dele resultater og gennemføre analyser og undersøgelser i form af rapporter og publikationer. Hertil kommer implementering af en stærk tværgående IEA Wind TPC Tasks arbejdsindsats. Alle resultater kan findes på <https://iea-wind.org/task41/>.

Project objectives

IEA Wind Task 41 on Distributed Wind in future energy systems is a group of researchers from eleven member countries and associations within the International Energy Agency Wind Technology Collaboration Program (IEA Wind TCP).

Task 41 is an interdisciplinary and international research, knowledge creation and exchange platform dedicated to **advancing wind technology as a cost-effective and reliable distributed energy resource**. It has as primer objective to coordinate international distributed wind energy research, facilitate collaboration on priority research topics, and increase the visibility of wind technology as a distributed energy resource.

This EUDP supported project was created to be able to participate actively in the international network of IEA Wind TPC Task 41. This **project's primary aim** was to gather the latest and most relevant Danish research in this area and through the Task 41 network, disseminate this through regular meetings, seminars, workshops, conferences, both at the international and national level, through IEA Wind TPC Task 41 network and annual Danish players and stakeholders' workshops, respectively. By identifying and exploring studies of DW cost effective technology development and integration into evolving global markets, which were of particular interest of Danish stakeholders (i.e., wind turbine manufacturers), this project focused on increasing the Danish influence and participation in IEA collaborations, both bringing the long experience of Danish actors into play and to learn from others around the world.

The secondary aim was in parallel, to harvest the corresponding best research findings from the international network to keep Danish research at the forefront in the DW field and thus to consolidate the Danish knowledge and experience within DW area. This project has strengthened the collaboration both with national and international wind players, thus increasing the competitiveness of wind and accelerating the replacement of fossil-based fuels.

2. Project implementation

How did the project evolve?

Did the project develop as foreseen and according to milestones agreed upon?

Did the project experience problems not expected?

The project was implemented closely the structure of IEA Wind TPC Task 41 planned work-packages, namely being organized into five work-packages (WPs):

- **WP0:** Management, coordination, and dissemination

One important task of WP0 was to organize three Danish annual workshops, where the results have been presented to the Danish wind energy industry and research community.

- **WP1:** DW technology design standards for small and mid-sized wind turbines
One important task of WP1 was to support collaboration and research leading to the update of standards specific to small and mid-sized wind turbines.
- **WP2:** Data information catalog for DW research
One important task of WP2 was to develop a searchable catalog for all digital objects for DW technologies to map data availability.
- **WP3:** Integration of DW into evolving electricity systems
One important task of WP3 was to support the integration of DW into the expanding distributed generation markets, with a focus on the mini-grid/off-grid markets and distributed generation markets.
- **WP4:** Outreach and expand collaboration of ongoing R&D DW activities.
One important task of WP4 was to identify and develop of a Danish stakeholder's network within DW area of interest.

The project evolved mostly as planned. The Corona pandemic forced to move some of the meetings online, hence reducing the physical networking opportunities (coffee breaks, lunches/dinners, etc) and travels, and increasing the time needed to prepare for the meetings (as experience with fully digital meetings was scarce, but the overall objective of knowledge and experience sharing was achieved).

The project implemented all the milestones and achieved all the objectives and tasks. Task 41 had 2 physical meetings (Feb 2019 in Poland, Oct 2022 in Austria) and 5 virtual meetings (Fall 2020, Nov 2020, Feb 2021, April 2021, Jul 2022). Pictures from two meetings (one virtual and one physical) are provided.



Fall 2020 Virtual Meeting
October 20-22, 2020

Task 41 members held three 2-hour meetings on October 20, 21, and 22, 2020 to discuss distributed wind research collaboration opportunities with a focus on grid integration, hybrid systems, downscaling and innovation, and specific country research activities. Task members from the Taiwan Institute of Economic Research, Inner Mongolia University of Technology, Technical University of Denmark, and the National Renewable Energy Laboratory presented their current research activities. Participants shared great dialog and ideas. Task 41 plans to meet again virtually in February 2021.



Joint Tasks 41 (Distributed Wind), 52 (Large-Scale Wind LIDAR), and 54 (Cold Climate Wind Power) Meeting
October 18-20, 2022
Vienna, Austria

October 18: Joint conference with the Austrian Wind Energy Association

October 19: Individual/Joint Task meetings

October 20: Individual/Joint Task meetings and student symposium

[Download the agenda](#) and [access the detailed agenda](#) with individual session info.

[Contact Trudy Forsyth](#) with questions about the University Research Collaborative Student Symposium 2022 at the meeting.

Three annual Danish stakeholders' workshops have been held during the project. Homepage of the project is: [Danish IEA Task 41 EUDP funded project | IEA Wind TCP \(iea-wind.org\)](https://www.iaa-wind.org/)

3. Project results

The aims of the EUDP project were fulfilled well. The project has gathered the latest and most relevant Danish research in DW area and disseminated the results through regular meetings, seminars, workshops, conferences, both at the international and national level, through IEA Wind TPC Task 41 network and annual Danish players and stakeholders' workshops, respectively. The project has initiated the basis for eventually new Danish standards aligned to international efforts, specifications of DW data sharing catalog and support the integration of DW through exchange of information and conducting explorative studies in the form of reports, data sets collections and publications.

The project has continuously disseminated the achieved results both at international and national level through participation in IEA Wind TPC Task 41, Danish workshops, and conferences. The project has also provided recommendations and guidelines to IEA deliverables that can be used by both Danish industry, researchers, and society at large.

The EUDP project has strengthened the collaboration with international wind players by providing relevant research and contributions to the recommendations on potential standards changes applicable to distributed wind turbines, the distributed wind metadata (information about data) catalog for task members, the development of new advanced controls for distributed wind, and the collaboration with outside university researchers.

In the recommendations report on potential standards changes applicable to distributed wind turbines, written by researchers from DTU Wind and NREL, it is anticipated that these recommendations will be considered by standards experts working on the fourth revision of IEC 61400-2.

Data is the main component of a problem-solving cycle, whether it is scientific, social, technological, or innovative in nature. Researchers around the world are conducting research and creating data sets relevant to distributed wind; however, researchers often do not know about others' research and data sets. DTU Wind researchers have contributed to the Task 41 goal of creating and documenting a catalog of distributed wind metadata (information about data) for task members. The elaborated metadata catalog shows researchers what is available but, at the same time, mitigates potential data sensitivity and intellectual property concerns. In the specific case of Task 41's data catalog, when a task participant needs specific data, they can consult the catalog, identify data sets, and then approach the data owner about conditions for use. This report covers

the requirements for data sharing, storage, and security protocols for the metadata catalog created and the specification of a potential data sharing portal.

Furthermore Task 41 supports research into the integration of distributed wind in evolving electricity systems. Through investments in distributed renewable energy technologies, energy storage, and electric vehicle charging, future distribution networks are likely to resemble an active network with multiple weather-dependent assets. These assets, when coupled with active control and connected at different voltage levels, can create changes in power flow that affect voltage profile, power losses, and reactive power flow. As more wind capacity is added to distribution systems, isolated grids, grid-connected microgrids, and hybrid power plants and systems, the need for distributed wind turbines to provide additional grid services and support grid stability becomes more important.

DTU Wind has also been active in identifying and developing advanced controls needed to enable distributed wind to provide grid services and to determine what other design requirements may be needed specifically for high renewable-contribution isolated power systems. With advanced controls, DW can provide additional benefits beyond electricity, such as enhancing grid reliability and resilience. Researchers at DTU Wind developed a multi-voltage level distribution network model to study the performance, operation, and control of future weather-dependent distribution networks in terms of grid requirements and specifications and flexibility requirements. Such research helps promote active participation of distribution networks in the provision of flexibility services through controllable power electronics based distributed generation such as wind.

An overview of the notable network and dissemination results and events during the project is given in the following.

5.1 Networking events (presentations, workshops and meetings)

Presentations in conferences, workshops and IEA Task 41 meetings:

- Towards updating the standards for small wind turbines via IEA Wind Task 41, 6th International Conference on Small & Medium Wind Energy sept, 2021.
- WRA in the “small wind” regime, feb 2021
- Can renewable energy sources support future active distribution networks? Guest Talk in Bachelor's course titled: Power System Elements for Smart Grids and Renewable Energy Systems Integration at University of Kiel (Christian-Albrechts-Universität zu Kiel), July 2022
- DTU 7k Bus Active Distribution Network: Overview and Features at Conference & School 3 JUMP2 Excel ,Malta, Feb 2022
- Modelling and control of wind turbines for fast frequency support, Viena, oct 2022
- Effects of Weather-dependent Uncertainty in Distribution Grids with Large Share of Wind Power Plants at Panel Session Supporting Power Grid Operation Through Large Wind Farms Innovative Smart Grid Technologies Conference– Middle East, March 2023

Three Danish stakeholders' workshops have been held during EUDP project:

- Workshop 1 - organized by DTU Wind together with Nordic FolkeCenter on 30.04.2020 within the 3rd International Conference on Small and medium Wind Energy- targeted to initiate good and expanded discussions of relevance for the Danish players and stakeholders and thus influence the research and development in the field of DW on a national level,

- Workshop 2 - organized by DTU Wind and hold on 23 March 2021- targeted to generate, define, and discuss potential new collaboration ideas/projects of particular Danish interest in various relevant distributed wind (DW) topics, for example, DW standards, DW integration, support of DW in MV-LV networks, and DW open data.
- Workshop 3 - organized by DTU Wind and hold on 20 January 2023 - further discuss how research can support and strengthen the Danish industry to deploy more wind power and renewable energy at distribution grid to meet the Danish vision of green transition.

Besides conferences and workshops, DTU Wind researchers have actively participated in all work packages discussions with presentations, elaborated discussions, and contributions in the regular virtual international IEA Task 41 meetings on different topics such as:

- Data Catalog Specification IEA Task 41 document
- Identification of the data contributors and users needed shared resources, data availability on key topics, recommended practices for data collection, reporting, accessing.
- Decision on the best platform for assigning metadata to digital objects (i.e. data, analysis tools and computer programs)
- Research priorities Domestic and International Standards for Distributed Wind technology
- Revision of IEA Wind TCP task 41 Outreach & Collaboration Plan
- Review on the research needs to improve IEC 61400-2 and other relevant IEC standards
- Assessment of current standards and improvement recommendations
- Presentation of WRA in the “small wind” regime in IEA Task 41 meeting; Wind Resource Assessment and Obstacle Modelling
- Discuss and design recommendations on potential standards changes for distributed wind: driving re-search via IEA Task 41
- Expand taxonomies required to suit specific needs of DW and adoption for data sharing.
- Design the guideline for best practices for compiling DW distributed object catalogues, data management plan template for Danish actors.
- Integrate the new terms of the taxonomy in the Community Taxonomy curated by DTU Wind at the addresses <https://github.com/wind-energy/taxonomy-topics>
- Workshop arranged between DTU Wind Energy & NREL and participations in discussion on how to enhance the research collaboration between DTU Wind research and NREL Miracle research
- Identify and implement a distribution system model with large share of distributed generation for integration studies.
- Review of mini-grid modelling tools and approaches
- Design guide for high renewable penetration isolated systems
- Present and discuss IEA Task41 activities with Dansk Energy for potential future collaborations
- University research collaboration on distributed wind technologies within IEA Task 41
- Revision of IEA Wind TCP task 41 Outreach & Collaboration Plan
- Participation in collaboration discussions concerning Airborne Wind as part of IEA Task 28 Social Science of Acceptance of Wind Energy

- Collaboration discussions & meetings for ongoing R&D activities across different IEA Tasks (19, 32, 43)
- Recommendations report on potential standards changes applicable to distributed wind turbines has been completed in March 2021. Download from <https://iea-wind.org/wp-content/uploads/2021/12/IEA-Task-41-Report-with-recommendations-on-potential-standards-changes-for-DW.pdf>. This report was not captured in our previous annual progress report and therefore it is mentioned here. It is anticipated that these recommendations will be considered by standards experts working on the fourth revision of IEC 61400-2.
- Distributed wind data catalog development guide and instruction manual. <https://usercontent.one/wp/iea-wind.org/wp-content/uploads/2021/02/Task-41-Deliverable-D11.pdf>

Such metadata catalog shows researchers what is available but, at the same time, mitigates potential data sensitivity and intellectual property concerns. In the specific case of Task 41's data catalog, when a task participant needs specific data, they can consult the catalog, identify data sets, and then approach the data owner about conditions for use.

5.2 Deliverables

Ten deliverable reports have been written during the EUDP project. All deliverable can be found on the project homepage [Danish IEA Task 41 EUDP funded project | IEA Wind TCP \(iea-wind.org\)](#).

D1.1

Recommendations on potential standards changes for distributed wind: driving research via IEA Task 41.

D1.2

Justification for changes to standards regarding distributed wind.

D2.1

Report on the adopted metadata and taxonomies specific for DW and metadata catalogue for data sharing.

D2.2

Guidelines for best practices for compiling DW distributed object catalogues.

D2.3

EUDP IEA Task 41 – suggested improvements for time series simulation tools when working with DW.

D3.1

Control strategies of wind turbines in future distribution systems.

D3.2

Contribution to the D14 deliverable report of IEA Task 41 - Review of mini-grid modelling tools and approaches.

D3.3

Contribution to the D16 deliverable report of IEA Task 41 – Design guide for high-renewable contribution isolated power systems.

D3.4

State of the industry report for isolated mini-grid power systems.

D4.1

Distributed wind relevant aspects for Danish stakeholders.

5.3 Publications

Several conferences, journal publications, contributions to different IEA Task 41 reports have been written during the EUDP project. DTU researchers have also contributed. All publications can be found on the project homepage [Danish IEA Task 41 EUDP funded project | IEA Wind TCP \(iea-wind.org\)](https://www.iaa.dtu.dk/en/iea-task-41-eudp-funded-project).

- Baviskar A, Das K, Koivisto M, Hansen AD. Multi-Voltage Level Active Distribution Network with Large Share of Weather-Dependent Generation. IEEE Transactions on Power Systems. 2021 Mar 1;37(6):4874-84.
- Baviskar A, Das K, Hansen A.D., Loss minimization in distribution network using wind power plant reactive power support. IET conference proceedings, 2021.
- Baviskar A, Das K, Hansen A.D., Minimize distribution network losses using wind power, CIRED 2021 Conference 2021.
- Baviskar A, Hansen A.D, Das K, Douglass P., Open-Source Active Distribution Grid Model with a large share of RES- features, and studies}, 9th International Conference on Power Systems}, 2021
- Baviskar A, Hansen A.D, Das K, Reactive power support from converter connected renewable generation in an active distribution network, 13th International Symposium on Power Electronics for Distributed Generation Systems, 2022
- Reactive power potential of converter-connected renewables using conex power flow optimization, Baviskar A., Hansen A.D., Das K., Nazir F., journal paper in IJEPES, accepted in April 2022,
- Opportunities of battery energy storage in stand-alone and co-located hybrid power plant in distribution grid, 22nd Wind & Solar power integration Workshop, Copenhagen, 2023
- Distributed Wind Data Catalog Development Guide and Instruction Manual, June 2021
- IEA-Task-41-Report-with-recommendations-on-potential-standards-changes-for-DW, March 2021.

4. Utilisation of project results

As the project was mainly network and dissemination activities, the project results are in the form of knowledge, experience sharing and dissemination at various conferences and seminars, without any technology or product development. The results benefit the participants by enlarging their own expertise and by comparing/benchmarking methods and approaches.

The emphasis is thus on knowledge sharing and contribution to the recommendations and guidelines to IEA deliverables that can be used by both Danish industry, researchers, and society at large. In this respect, the EUDP project has strongly contributed and initiated the basis for eventually new Danish standards aligned to international efforts, specifications of DW data sharing catalog and support the integration of DW into evolving Danish electrical system through exchange of information, sharing of results and conducting analyses and explorative studies in the form of reports, data sets collections and publications.

The scientific articles and the dissemination of work progress at all major and minor workshops and conferences brings scientists, developers, and end-users together to discuss challenges and form initiatives to overcome barriers, which enables steady progress alongside new technical developments and policies that need adaptation. Without an international collaboration many of these tasks would not be able to be solved in an efficient and sustainable way.

The results of the project have strengthened the collaboration both with national and international wind players, thus increasing the competitiveness of wind and accelerating the replacement of fossil-based fuels.

5. Project conclusion and perspective

The aim of the EUDP project was fulfilled well. For the task, the Danish partners were responsible for or contributed to most results, influenced the work, and pushed boundaries by initiating the basis for eventually new Danish standards aligned to international efforts, defining specifications of distributed data sharing catalog and supporting the integration of distributed wind through exchange of information and conducting explorative studies in the form of reports, data sets collections and publications.

The project has managed to succeed in exchanging information and disseminating Danish research results within the distributed wind field, although travel to conferences and meetings were stopped in 2020 due to the corona virus situation, and some of the associated work delayed/postponed. There have been significant advantages in forming an international collaboration network designed to share information as well as to compare methodologies and analyze case study results. Through international collaboration, this work has moved forward to increase thus furthermore the competitiveness of wind and accelerating the replacement of fossil-based fuels.

All these have resulted in a unanimous decision to continue the collaboration for IEA Task 41 Phase II, addressing distributed wind hybrid power systems research and the valuation of those hybrids, especially at the MW scale but below that of hybrid power plants that is being proposed as a separate topic area.

6. Appendices

Link to Danish IEA Task 41 website: [Danish IEA Task 41 EUDP funded project | IEA Wind TCP \(iea-wind.org\)](#).

Link to IEA Wind Task 41 website: <https://iea-wind.org/task41/>