Final report

1. Project details

Project title	IEA Wind Task Digitalisering
File no.	64019-0531
Name of the funding scheme	EUDP
Project managing company / institution	Danmarks Tekniske Universitet (DTU)
CVR number (central business register)	DK30060946
Project partners	Danmarks Tekniske Universitet, Aalborg Universitet, Det Norske Veritas
Submission date	23 April 2024

2. Summary

Summary in English:

Denmark has strong leadership and long traditions in the wind energy industry. Nowadays, the wind industry is facing a transformation caused by the uptake of digital technologies. Digitalization is seen as an enabler for significant cost reductions across the wind energy industry. This project enabled Danish participation in the IEA Wind Task 43 on Digitalization which tackled several important topics within the digitalization space.

Concrete results from IEA Task 43 included:

- A study on the challenges that prevent successful digitalization carried out through surveys, interviews and expert group discussions. The main outcome is a scientific publication outlining the "Grand Challenges in the Digitalization of Wind Energy". The three major challenges defined are: 1) Data: Creating reusable data frameworks; 2) Culture: Connecting people and data to foster innovation, and 3) Coopetition: Enabling collaboration and competition between organisations. Further work on solving these challenges is seen as a key focus point of future extensions of IEA Wind Task 43.
- A number of solutions for facilitation of data exchange and sharing. This includes work on data schemas for, among others, wind resource assessment, as well as metadata collection and analysis to facilitate the creation of wind energy data taxonomies.
- Proposed solutions for reduction of Operation & Maintenance costs through implementation of the concept of risk-based inspection and maintenance. A concrete example of maintenance of leading edge-erosion related damage on wind turbine blades has been developed.

As a result of the EUDP support, the Danish participants have received increased exposure to the latest findings from international research efforts, have established new collaborations, and have actively contributed to the progress in the digitalization agenda that was achieved by IEA Wind Task 43.

Opsummering på dansk:

Danmark har stærkt lederskab og lange traditioner inden for vindenergiindustrien. I dag står vindindustrien over for en forandring forårsaget af fremkomsten af digitale teknologier. Digitalisering betragtes som en mulighed for betydelige reduktioner i omkostningerne i vindenergisektoren. Dette projekt muliggjorde dansk deltagelse i IEA Wind Task 43 om Digitalisering, som undersøgte flere vigtige emner inden for digitaliseringsområdet.

Konkrete resultater fra IEA Task 43 inkluderede:

- En undersøgelse af de udfordringer, der forhindrer vellykket digitalisering, udført gennem rundspøgsler, interviews og diskussioner i ekspertgrupper. Hovedresultatet er en videnskabelig publikation, der præsenterer "Grand Challenges in the Digitalization of Wind Energy". De tre mest væsentlige udfordringer, der er defineret, er: 1) Data: Oprettelse af genanvendelige data-modeller og løsninger for deling af data; 2) Kultur: sammenspil af mennesker og data for at fremme innovation, og 3) Samarbejde: Muliggør samarbejde og konkurrence mellem organisationer. Yderligere arbejde med at løse disse udfordringer ses som et centralt fokuspunkt for fremtidige udgivelser af IEA Wind Task 43.
- En række løsninger til at fremme dataudveksling og deling. Dette omfatter arbejde med dataskemaer til blandt andet vurdering af vindressourcer, samt metadata-indsamling og analyse for at muliggøre oprettelsen af datataksonomier for vindenergi.

- Demonstration af muligheden for reduktion af drift & vedligeholdelsesomkostninger gennem implementering af konceptet risikobaseret inspektion og vedligeholdelse. Et konkret eksempel på vedligeholdelse af forkanterosion relaterede skader på vindmøllevinger er blevet udviklet.

Som følge af EUDP-støtten har de danske deltagere udvidet deres viden om de seneste resultater fra internationale forskningsindsatser, har etableret nye samarbejdspartnerskaber og har aktivt bidraget til fremskridtene i digitaliseringsdagsordenen, som blev opnået af IEA Wind Task 43.

3. Project objectives

The overall objective of IEA Wind Task 43 on digitalization of wind energy was to coordinate research and development activities, from data and analytics to connectivity, across the global wind industry and to recommend best practices and maximize realization of benefits from digitalization while minimizing duplicate effort. The project convened an international expert body with the following goals:

- Define what is meant by wind energy digitalization
- Describe the current state of digitalization capability and practice within the wind energy sector
- Identify and prioritize value-add opportunities enabled by further digitalization
- Learn from and build upon similar work in other sectors to develop recommended digitalization practices for the wind energy sector

IEA Wind Task 43 intended to address the broad theme of the digitalization of wind energy. The scope of the task aimed to include digitalization topics across the following dimensions:

- Lifecycle stages from turbine design, wind farm design and operation through to mid-life repowering and end-of-life.
- Value-chain components including equipment suppliers, service providers, owners, asset operators, grid operators, as well centralized, aggregated and peer-to-peer energy market participants.
- Interaction between and across lifecycle and value-chain players including the exchange of standard-ized and/or anonymized data, digitalization-related tools, and best practices for privacy and security around these exchanges.

The scope, as outlined, enables broad collaborations among all stakeholders of the global wind industry. As recognized both within the energy sector and outside, collaboration is key for success in the digital age. Task 43 aimed at building consensus among academic and applied research entities, equipment manufacturers, owner/operators, utilities, and solution and service providers within the wind energy sector. The intention was to harmonize that body around what digitalization means, how to enable it, and how to derive increased value through digitalization for themselves and their customers.

The primary objective of the EUDP project was to enable the Danish participation in the IEA Wind Task on Digitalization. The expected benefits of the participation were that it will facilitate the exposure of the Danish wind sector to the latest research findings and will increase the possibilities for capturing new opportunities enabled by digitalization. The Danish participants could contribute to the workshops and publications which provide an excellent dissemination channel, to confirm the Danish wind sector as leading in the digitalization-related topics such as Big Data, Data Science, Artificial Intelligence, and Internet of Things.

4. Project implementation

The initial IEA Task 43 objectives were derived from the outcome of the IEA Wind Topical Expert Meeting (TEM) #91 held in Dublin in the end of 2018, as well as on the results from an online survey on the opportunities and challenges with respect to digitalization. The opportunities identified by survey respondents as having highest value potential were included in the work plan. This resulted in six work packages: three technical work packages and three cross cutting ones. Figure 1 depicts the structure of the planned work packages as well as the idea of the collaboration of technical and cross cutting working groups.
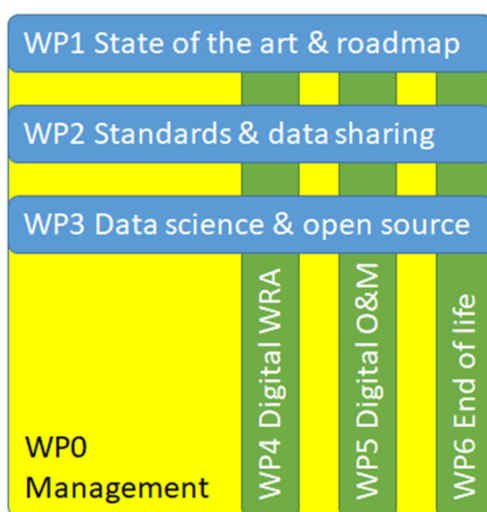

Figure 1. Structure of the task and its work packages.

At the launch of the new IEA task, participation from the following countries was confirmed (specific organizations are given in brackets):

-        USA (NREL, NRG Systems, Sentient Science, EPRI)
-        UK (EDF Renewables, Renewable Energy Systems (RES), DNV GL)
-        Belgium (University Brussels)
-        Germany (Fraunhofer IEE)
-        Ireland (ServusNet informatics)
-        Denmark (DTU Wind Energy, DNV GL Denmark, Aarhus University (AU))

The intended outcomes of the project were distributed as deliverables within the individual work packages. A complete list of the intended deliverables is provided in Table 1.

The official kick-off of IEA Task 43 took place as a 2-day physical meeting in Boulder, Colorado, USA, in November 2019. The meeting assembled working groups and initiated parallel discussions in all work packages according to the original structure.

The nature of the IEA task as an international collaboration activity means that the level and type of commitments of different participants are inhomogeneous, and the outcomes will typically depend on the actions of participants from multiple organizations and countries. As a result, the scope of IEA Task 43 has evolved significantly over its duration, and the final outcomes do not overlap completely with the original intentions. This is also obvious from Table 1, where the estimated degree of completion is indicated for each of the original deliverables. A more detailed overview of the concrete activities and their evolution for each work package are detailed in Table 2.

Table 1 Overview of intended deliverables at project start and their estimated level of completion at the end of the EUDP project term.

No.	Month Due	Status	Description
D 0.1	diverse	achieved	Regular virtual meetings
D 0.2	diverse	achieved	Regular reports incl. this document
D 0.3	3	achieved	Communication Plan
D 1.1	24	in progress	Draft paper "Data Maturity Roadmap"
D 1.2	30	achieved	Paper "Grand challenges of Digitalization", pre-print available
D 1.3	33	in progress	as part of roadmap paper (D 1.1)
D 2.1, D 2.2	34	in progress	Draft technical report "Data Standards Gap Analysis"
D 3.1	3	achieved	One page document describing goals and drafting timeline
D 3.2	26	pending	*Big data analytics and digital twins recommendations*
D 3.3	26	pending	*IoT and Open data framework*
D 3.4	33	pending	*Automated and data-driven decision making*
D 4.1, D 4.2	8 19	achieved	Data model published in github, applied by first movers, under further development in collaboration with users
D 4.3	35	pending	*Open source WRA framework*
D 4.4	32	pending	*Recommended practice document*
D 5.1	6	achieved	Definitions from IEA Wind Task 33 reliability data was found to be sufficient
D 5.2	19	in progress	Technical report on "Risk based maintenance" has been started
D 5.3	35	pending	*Overview of disruptive opportunities*

D 6.1,	11		
D 6.2,	19	pending	Work package has been stopped
D 6.3	35		

Work package 0: Management

The main management body of IEA Task 43 is the Organizing Committee (OrgCom) that supports the Operating Agents and coordinates the various activities within the Task. One Danish stakeholder (DTU) has been represented in the OrgCom during the entire project period, while another member from AU stepped in in the last 6 months.

The activities in WP0 were carried out largely as intended, with regular (bi-weekly) coordination meetings and organizing larger collaborative workshops between once and twice each year. Due to the covid-19 pandemic, not all workshops were held in-person. Out of six major plenary workshops, two were held in person and four – as online events:

- November 2019: kick-off meeting (in-person)
- May 2020: 1st Digital week
- May 2021: 2nd Digital week
- November 2021: Virtual internal meeting on common themes
- February 2022: Virtual internal follow-up meeting on common themes
- June 2022: General meeting in Brussels (in-person)

The Organizing Committee setup has been helpful to distribute the workload and ensure better coordination and outreach. It is therefore considered as a successful approach to IEA Wind Task management.

An additional means of coordination, the Task 43 Industrial Advisory Board (IAB), was set up shortly before the conclusion of the EUDP project. It seeks to increase the industrial relevance of the IEA Wind Task 43 activities. Two out of the current nine members of the IAB are based in Denmark, and one of them (Peter Enevoldsen, AU) is also a stakeholder in the EUDP project. All Danish stakeholders have taken part in at least two of the workshops listed above.

Work package 1: State-of-the-art and roadmap

A major activity in this work package was a series of surveys and interviews that led to the formulation of three "Grand Challenges" towards digitalization of wind energy. Regular meetings in the WP were used to coordinate the interview/surveying process and later to develop the draft of a paper. An additional activity included the "data maturity roadmap" which is expected to result in another journal publication.

All Danish stakeholders took part in the WP1 activities, either as interviewers or as respondents to interviews and surveys. In addition, two of the Danish stakeholders (DTU and AU) are represented as co-authors in the main "Grand Challenges" paper.

Work package 2: Data standards and sharing

WP2 was primarily focused on identifying barriers to data sharing and working out possible solutions. This includes the activity of "data standards gap analysis" as means of mapping the state of existing standards. Additional activities included preparation of reference lists with available open-source data and tools. From the Danish participants, DTU and AU were continuously involved in WP2 activities.

Work package 3: Data Science and Open Source

WP3 began with the following activities:

- A scientific paper club, with the main purpose of knowledge sharing and learning from peers. Several key papers from the data science domain have been discussed. This activity was most active in 2020.
- Scoping of a data science hackathon challenge. Potential topics, procedure and evaluation criteria for the hackathon challenges have been defined. Continuing the activities requires the commitment of industrial partners to provide datasets, and allocating resources to organize and deliver the event.
- A first draft of the best practices document for wind energy data science. The intention of the best practices document was to include learnings from the use cases defined in other WPs, such as the risk-based O&M discussed in WP5.

The progress on the best practices document was hindered due to lack of participation. The efforts were therefore relocated to other activities working on examples of the problems that the best practices document should summarize. This includes e.g. the risk-based decision modelling addressed in WP5. As a result, at the time of the project conclusion there were no ongoing activities directly under WP3.

Work package 4: Digital Wind Resource Assessment

The main focus of WP4 was in developing a "Wind Resource Assessment data model" which prescribes the metadata format that is to be used when describing the configuration of wind resource measurement devices. The goal is to enable more efficient sharing of information between different stakeholders. Danish stakeholders did not participate in a significant way in this work package.
Work package 5: Digital Operations & Maintenance
WP5 started initially on two activities: 1) asset valuation and 2) O&M cost reduction. The latter activity evolved into the application of a specific methodology, risk-based O&M, for the concrete use case of wind turbine blade maintenance. This activity has significant presence from Danish stakeholders from DTU, as well as from Aalborg University (external to the EUDP project). Other potential use cases and scopes that have been explored in the Work Package include digital twins and data-driven vibration analysis. At the end of the current project period, the major remaining activity is the risk-based O&M use case as it has been prioritized by the WP participants.
Work package 6: End-of-life
After the initiation of this work package, it has become apparent that: 1) There is a significant overlap in the scope with WP5, especially on the problem of asset valuation which is common for both work packages; 2) There can also be a resource clash as the same people active in WP6 would be the relevant contributors to WP5. 3) Some or similar problems are also being considered in IEA Wind TCP Task 42 on lifetime assessment. As a result, it was decided to close down WP6 and combine all efforts in WP5 instead.

Due to the fluctuations in the activity level in the different work packages and subgroups as well as the tendency to siloing, after 2 years of project duration it was decided to highlight the activities where significant progress is being made and redirect focus to these concrete activities and re-invite potential contributors. Hence each of the ongoing activities was defined as a "collaborative action" where each collaborative action should have its dedicated workgroup and agenda. The following collaborative actions were introduced:

1) Metadata schemas (WP3, WP5)
2) Internal variable vocabulary (WP2)
3) Set of use cases benefitting from digitalization (WP5)
4) Value related data standards gap analysis (WP2)
5) Aligning WRA data with FAIR (WP2, WP4)
6) Digitalization maturity model (WP1, WP2, WP3, WP5)
7) Value of data (WP2, WP5)
8) Open source data catalog (WP3)
9) Categories and timeline of IEA Task 43 roadmap (WP1, WP5)
10) Data engineering & transformation (WP3)

The introduction of the collaborative actions is not intended as a change in project scope, rather a change in the meeting & discussions format. The overall goals of the Task have not been changed.

In order to ensure a stronger link between the IEA Task 43 findings and their potential implementation in industry, the Task introduced a new body – an Industrial Advisory Board (IAB). The IAB consists of 9 digital experts from various industries represented in the wind energy value chain (including IT/software providers). The IAB convened for the first time in November 2022, with a current schedule of holding quarterly meetings between the IAB and the Task 43 Organizing Committee.

5. Project results

5.1 Overview of major results

Digitalization Grand Challenges paper
This paper is one of the most prominent outcomes of the project as it summarizes a large part of the Task activities and develops concrete recommendations for improving the digitalization of wind energy. It provides value to the entire scientific community and the industry by outlining concrete points of attention. An important learning was that the aim of increasing digitalization is associated with not only technological challenges but there are also cultural and humanistic aspects to it. The three concrete challenges identified are:

1) Data: Creating reusable data frameworks;
2) Culture: Connecting people and data to foster innovation, and
3) Coopetition: Enabling collaboration and competition between organizations.

Danish stakeholders (both DTU and AU) are among the co-authors of the Grand Challenges paper.

Data modelling and standardization efforts
A number of dissemination and coordination efforts within the data management and standardization scope have led to an improved public understanding of the need for data standardization and the potential solutions. This includes activities such as building the wind energy data glossary and the metadata challenge (see links in Section 5.2 under dissemination).

Data maturity roadmap: A "data maturity roadmap" has been initiated which aims to align the industry on what data policies and technologies will be needed for a mature wind industry.

WRA (wind resource assessment) data model: it represents a specific demonstration of how data can be shared effectively in a standardized way that facilitates collaboration. A number of organizations have already adopted the WRA data model.

Risk-based O&M model
The risk-based inspection & maintenance use case demonstrates how data and digital tools can be used to provide quantitative basis for taking operating decisions. A concrete example for maintenance of blade leading edge erosion damages has been developed and further efforts towards maturing the concept are ongoing. This activity was strongly supported by the Danish EUDP project participants as well as other Danish stakeholders.

5.2 Dissemination

IEA Task 43 has used a number of different dissemination channels in order to broaden the outreach of the results and to establish collaborations. The WindEurope events have emerged as one of the preferred dissemination forums, due to the profile of the attendees with a significant number of potential end users. In addition to papers and conference materials, a number of other digital objects (datasets, glossaries, catalogues) has also been made publicly available. The complete overview of the currently known dissemination results from the overall IEA Task 43 are listed below.

Publications

- Grand Challenges in the Digitalization of Wind Energy paper (in review, Wind Energy Science journal)

- AWEA Wind Resource and Project Energy Yield Conference 2019: Poster
- WindEurope Resource and Operational Assessment Conference 2020: Poster
- ASME wind digital solutions summit 2021: Oral presentation
- WindEurope Technology Workshop 2021: Separate own Task 43 session, one oral presentation, five Posters
- Poster at WindEurope Annual Event 2022
- WindEurope Technology Workshop 4/2022: Two oral presentations
- Presentation, paper and poster at WindEurope Annual Event 2023 planned

Further Dissemination
IEA Wind Task 43 Websites: https://iea-wind.org/task43/ , https://www.ieawindtask43.org/home
Zenodo: https://zenodo.org/communities/iea_wind_task_43/?page=1&size=20
IEA Wind Task 43 Github: https://github.com/IEA-Task-43
List of open data resources: https://www.ieawindtask43.org/proceedings-work-products/open-data-resources
Glossary: https://iea-task-43.gitbook.io/iea-task-43-glossary/
IEA Wind Task Metadata Challenge: https://www.wedowind.ch/task-43-space
Launch of Metadata Challenge Webinar Series: https://www.wedowind.ch/digitalisation

Task 43 was represented at an IEA Workshop as side event of the Wind Power Denmark summit, Nov 2nd 2022.

5.3 Degree of fulfilment of the primary objectives

The overall objective of IEA Wind Task 43 on digitalization of wind energy was to "*Coordinate research and development activities, from data and analytics to connectivity, across the global wind industry and to recommend best practices and maximize realization of benefits from digitalization while minimizing duplicate effort*". This broad overall objective can be achieved by multiple means and the presented outcomes of IEA Task 43 certainly qualify. Hence we consider the overarching project objective as fulfilled.

The concrete Task goals are considered either completely or partially fulfilled, with a brief elaboration below:

- *Define what is meant by wind energy digitalization*: partially fulfilled. A concrete definition of digitalization has not been produced, however multiple related concepts have been defined such as the Grand Challenges in digitalization.
- *Describe the current state of digitalization capability and practice within the wind energy sector*: fully achieved (e.g. with presenting the digitalization challenges and the digitalization maturity model)
- *Identify and prioritize value-add opportunities enabled by further digitalization*: fully achieved. Concrete value-add opportunities have been identified and examples have been demonstrated in several areas such as the data models (with the resource assessment example in WP4) and risk-based O&M (WP5). In addition, ongoing activities are aiming at identifying and prioritizing further use cases with high added value.
- *Learn from and build upon similar work in other sectors to develop recommended digitalization practices for the wind energy sector*: partially fulfilled. The major part of the work has come from within the wind energy sector. There has also been substantial involvement of stakeholders from the IT industry, however only minimal involvement from other sectors.

5.4 Additional details of the Danish participation

In the earlier chapters of this report, most activities are described in the context of the overall IEA Wind Task 43 collaboration. This section provides several additional clarifications of the role of the Danish participants.

The three Danish organizations supported by EUDP (DTU, AU, DNV) have all contributed to various activities within the Task. The contributions of the respective organizations is largely proportional to the amount of allocated EUDP support and the corresponding effort that has been enabled through this support. Some key contributions include:

- Keynote talks were held at three of the Task 43 plenary workshops, by Julia Kirch Kirkegaard (DTU), Henrik Madsen (DTU), Peter Enevoldsen (AU)
- The Task organizing committee had one Danish member (Nikolay Dimitrov, DTU), through the entire task duration, and an additional one has joined in the last six months (Peter Enevoldsen, AU)
- All participants (DTU, AU, DNV) did contribute to the work towards the Grand Challenges paper. This included survey design and analysis, carrying out interviews, being interviewed, and analysing the results.
- An IEA dissemination workshop was organized as a side event to the Wind Power Denmark summit. The workshop included presentations of the primary results as listed in Section 5.1. Since the workshop was co-organized with other IEA tasks, many of the participants were involved in these tasks. This outlined some concrete opportunities for collaboration between the tasks, i.e. between the task on blade leading edge erosion and the group within Task 43 working on risk-based blade maintenance.
- Danish participants have actively contributed to a large fraction of the IEA Wind Task 43 dissemination efforts. This includes co-authorship of the major journal paper on "Grand Challenges in the Digitalization of Wind Energy" as well as co-authorship of two conference oral presentations and three WindEurope posters. A second journal paper draft (on a data maturity roadmap) with a participant from DTU as co-author is under preparation.
- The Industrial Advisory Board (first convened in November 2022) was envisioned and assembled primarily with the efforts of Peter Enevoldsen (AU).

6. Utilisation of project results

Table 2 provides an overview of how the outcomes of IEA Wind Task 43 can be utilized by various stakeholders. Since many stakeholder groups are also represented as task participants, they simultaneously contribute to the results and make use of them.

Table 2 Overview of project result exploitation possibilities for different stakeholder types.

Stakeholder group	Role as contributors	Takeaways as end users
Academics and research institutes (wind energy)	Analysis methods, computational tools, expertise, coordination	Dissemination of research, influencing industrial and research agenda, forging collaborations, insights into practical challenges, solutions for data sharing to facilitate collaboration.
Operators and OEMs	Practical experience, technical expertise, sharing data and use cases	New digital solutions for cost reduction, forging collaborations, solutions for data sharing to facilitate collaboration

Digital solution providers (i.e. asset management)	Practical experience, technical expertise, coordination	Solutions for data sharing to facilitate business collaboration, insights into common challenges (social and technical)
Software developers (full stack, cloud, IoT)	Data and software structuring / management approaches, cyber security support	Insights into practical challenges of the wind industry as customer for software solutions
Certification bodies	Inputs on requirements on e.g. data quality, uncertainty	Potential adoption of recommendations / guidelines on data models and digitalization roadmaps. Insights into maturity levels and potential sources of uncertainty.
Energy Policymakers	Inputs on challenges in the energy transition and energy system development	Insights into the role and significance of data and digitalization in the future development of the wind energy sector. Insights into maturity levels and where further support is needed. Potential adoption of recommendations / guidelines on data models and digitalization roadmaps.

7. Project conclusion and perspective

The IEA Wind TCP Task 43 on digitalization took place between December 2019 and December 2022. The primary outcomes of the Task include:

- A study on the challenges that prevent successful digitalization carried out through surveys, interviews and expert group discussions. The main outcome is a scientific publication outlining the "Grand Challenges in the Digitalization of Wind Energy". The three major challenges defined are: 1) Data: Creating reusable data frameworks; 2) Culture: Connecting people and data to foster innovation, and 3) Coopetition: Enabling collaboration and competition between organisations.
- A number of solutions for facilitation of data exchange and sharing. This includes work on data schemas for, among others, wind resource assessment, as well as metadata collection and analysis to facilitate the creation of wind energy data taxonomies.
- Proposed solutions for reduction of Operation & Maintenance costs through implementation of the concept of risk-based inspection and maintenance. A concrete example of maintenance of leading edge-erosion related damage on wind turbine blades has been developed.

In addition, a few general learnings from the task activities can be summarized:

- Digitalization is too broad to be considered (or addressed) in its entirety by a single activity. Therefore, a useful practice is to consider digitalization as a means to an end – i.e., as a set of tools to achieve certain goals, and work on concrete use cases. This was demonstrated by the success of several concrete use case-related activities in the task.
- The challenges in adopting digitalization are far from being only technical. There is a strong humanistic and social component such as e.g. resistance to change and engrained culture.

These learnings and the related three "Grand Challenges" identified in the paper with the same name provide a clear direction for potential further work where the challenges can be addressed. A future continuation of IEA Wind Task 43 will be structured around the three Grand Challenges and will utilize the use case approach to demonstrate concrete digital solutions.

The current EUDP project enabled the Danish participation in the IEA Wind Task 43 on Digitalization. As a result of the EUDP support, the Danish participants have received increased exposure to the latest findings from international research efforts, have established new collaborations, and have actively contributed to the progress in the digitalization agenda that was achieved by IEA Wind Task 43.

8. Appendices

8.1 Links to annual reports

https://www.eudp.dk/projekter/iea-wind-task-digitalisering

8.2 Other relevant links

Grand Challenges Paper:
https://wes.copernicus.org/preprints/wes-2022-29/wes-2022-29.pdf

IEA Wind Task 43 Websites: https://iea-wind.org/task43/ , https://www.ieawindtask43.org/home
Zenodo: https://zenodo.org/communities/iea_wind_task_43/?page=1&size=20
IEA Wind Task 43 Github: https://github.com/IEA-Task-43
List of open data resources: https://www.ieawindtask43.org/proceedings-work-products/open-data-resources
Glossary: https://iea-task-43.gitbook.io/iea-task-43-glossary/
IEA Wind Task Metadata Challenge: https://www.wedowind.ch/task-43-space
Launch of Metadata Challenge Webinar Series: https://www.wedowind.ch/digitalisation