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A use-case-driven approach for demonstrating the added value of digitalisation in wind energy

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A use-case-driven approach for demonstrating the added value of digitalisation in wind energy

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Abstract. Digitalisation is one of the key drivers for reducing the costs and risks of wind energy. When considering whether to embark on a digitalisation initiative, two key questions arise. The first is what business or operational opportunities might feasibly be addressed and the second is which of the many potential aspects of digitalisation are relevant to those opportunities. In this work, we show how these questions can be answered with a use-case-driven approach, based around a survey aiming to collect and collate the main "pain points" (or everyday challenges) of people in the wind energy sector. Although the relatively low number of participants of the survey (46) means that the results should only be used indicatively, it is still possible to make some general recommendations for priorities for digitalisation efforts in the wind energy sector. Firstly, digitalisation efforts should focus both on supporting people carrying out cross-lifecycle tasks, in particular sharing data, managing data, undertaking general data analyses and accessing data. Tools to do this should deal with varying data formats and naming conventions, make metadata more accessible, define data and metadata standards, make more data publicly available and improve the quality of data. Secondly, efforts should also focus on supporting people in the wind farm operational phase, in particular with failure detection, fault diagnosis, failure rate modelling and predictive maintenance. Solutions to do this should focus on accessible and validated tools for fault detection, cloud or other data pipeline solutions for SCADA data and tools for exhaustive data documentation. Finally, digitalisation efforts should focus on better communicating and helping people become aware of existing solutions and tools, as well as on helping people to exert a stronger influence on possible solutions.

1. Introduction

Digitalisation, defined as "the organisational and industry-wide use of data and digital technologies to improve efficiency, create insights, and develop products and services" [1] is one of the key drivers for reducing costs and risks of wind energy due to the opportunities it offers [2]. These opportunities include new processes and business models resulting from large amounts of data becoming available at different phases of the wind energy project life cycle, and include digital twins, predictive maintenance, drones and decision support systems. These can all contribute to reducing maintenance costs, increasing energy production and increasing efficiency.

However, a number of challenges stand in the way of a successful exploitation of these opportunities. The three "Grand Challenges" of wind energy digitalisation have recently been defined in [1] as: (1) Creating findable, accessible, interoperable and reusable (FAIR) data frameworks [3]; (2) Connecting people and data to foster innovation; (3) Enabling collaboration and competition between organisations. IEA Wind Task 43 [4] aims to solve these challenges by developing solutions and recommendations for the adoption of digital technologies such as data standards, machine learning and Artifical Intelligence (AI), data analytics and visualisation, open-source tools and Internet of Things (IoT) instrumentation.

When considering whether to embark on a digitalisation initiative, two key questions arise. The first is what business or operational opportunities might feasibly be addressed and the second is which of the many potential aspects of digitalisation are relevant to those opportunities. It is not possible to prescribe an approach to every potential scenario, but a set of well-defined value-adding use cases, key inhibitors (or "pain points") and potential solutions to those inhibitors can provide a starting point upon which to build a business case. It is with this purpose in mind that IEA Wind Task 43 set out to research and map representative use cases, pain points and typical solutions. In addition to exploring these relationships, teams within IEA Wind Task 43 are also exploring specific use cases in further detail to identify the tangible benefits, data requirements and relevant analytics or modelling methods [5].

In this paper, we therefore present a use-case-driven approach for demonstrating the added value of digitalisation in wind energy, developed within IEA Wind Task 43. We define a "digitalisation use case" as "an activity that an organisation or consortium carries out - and the steps as part of this - in order to generate value/save costs/make decisions, to which digital solutions can be applied to improve it.". As well as demonstrating the value of digitalisation to the industry, this approach has the potential to compare reference methodologies, quantify the range of data types required for certain tasks, highlight implementation challenges and frame opportunities around key decisions. In Section 2 we introduce the approach, in Section 3 we present the results, in Section 4 a discussion of the resulting recommended priorities for digitalisation efforts for the wind energy sector as well as an evaluation of the approach. In Section 5 we draw the conclusions.

2. Approach

This work was carried out using a simplified version of the approach applied for identifying the "Grand Challenges in the digitalisation of wind energy" [1], shown in Figure 1. The approach was simplified and applied as follows:

(a) Exploit databases: we defined an initial list of "use cases" by carrying out a literature review and collecting inputs from IEA Wind Task 43 participants via brainstorming sessions. We focused on defining value-creating processes that we think are important in the wind energy sector today.

(b) Analysis: we analysed which existing digital solutions (from and beyond IEA Wind Task 43) could be used to add value to the processes from (a). The results showed that more information was required in order to prioritise which of the processes provide the most value and which have the highest potential to be improved by digital solutions. This was achieved in part (c).

(c) Enrichment: Instead of carrying out individual interviews, we opted for a survey in order to get a larger range of inputs from the sector. The aim of the survey was to collect and collate the main "pain points" of people in the wind energy sector, where "pain point" was defined as "anything that poses you with challenges, difficulties, problems, or even emotional pain", i.e. something that really frustrates people and gets in the way of reaching their goals or carrying out their tasks.

(d) Use cases: The results of the initial table and the survey from parts (a)-(c) were used to define a set of priorities for digitalisation efforts for the wind energy sector.

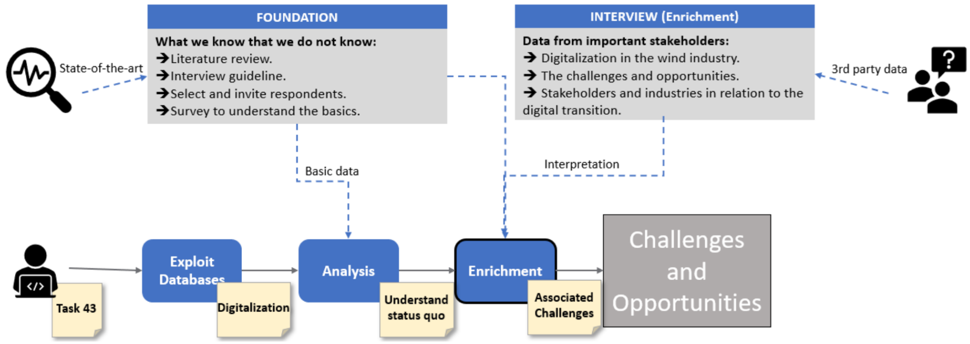

Figure 1. The data collection, processing and analysis approach applied for identifying the Grand Challenges in the digitalisation of wind energy [1].

3. Results

In this section, the results of the four steps of the approach described in Section 2 above are presented.

3.1. Exploit databases

An excerpt from the table resulting from the first step "(a) Exploit databases" is shown in Table 1. The full table can be accessed in [6], and contains a total of 33 use cases. The first three columns of the table summarise the potential challenges people in the wind energy sector are facing for different wind energy project lifecycle phases, and what the related "use case" is according to the definition from Section 1. The fourth column is discussed below. We divided the use cases into the following wind project lifecycle phases:

A. Wind turbine design
B. Wind farm planning
C. Wind farm operation
D. Project selling / buying
E. End of life
F. General

The "general" category was defined for activities that cannot be assigned to a particular lifecycle phase, such as recruiting, project acquisition and data sharing.

3.2. Analysis

An excerpt of the results of the phase "(b) Analysis" is shown in the right-hand column of Table 1. For each "use case", we assess which digital solutions (from and beyond IEA Wind Task 43) could be used to add value. The possible digital solutions were established by first creating a list of the activities and outputs of IEA Wind Task 43 and then combining this with the knowledge and experience of the IEA Wind Task 43 participants in other areas such as Digital Twins and Decision Support Systems.

Table 1. Excerpt from initial list of use cases [6].

Lifecycle phase	Challenges people in the wind energy industry are facing	What's the "use case"? (the task that someone is doing)	How could digital solutions contribute to solving this?
A. Wind turbine design	Improving aerodynamic design tools (engineering models) for +10MW wind turbines	Designing +10 MW wind turbines	IoT monitoring systems, recommendations for data sharing
B. Wind farm planning	Efficiently comparing different scenarios and choosing the best project layout	Holistic wind farm layout planning	Digital WRA tools
C. Wind farm operation	Choice of predictive models with optimal balance of complexity and scalability for specific decisions	Model choice - operation	Decision Support Systems
D. Project selling / buying	Evaluating asset performance, maintenance and financial data to determine potential insurance risk	Asset risk assessment	Decision Support Systems
E. End of life	Deciding what to do at the end of life	Design standards	Digital logistics tools
F. General	Finding customers and project partners	Project acquisition	Digital matchmaking tools or data marketplaces

3.3. Enrichment

3.3.1. Survey The results of parts (a) and (b) showed that there are a large number of tasks and processes with a high potential to be improved through digitalisation, even though it was recognised that the list was not yet complete. However, it was not possible for a small group of IEA Wind Task 43 participants to fully understand and prioritise the most important "use cases" in the entire industry, and therefore a survey was designed and shared with people working in the wind energy sector across the entire value chain. The main question asked in the survey was "Describe a "pain point" in your everyday work and the related task (which can be either carried out by you or your team)". The survey allowed each participant to enter up to three "pain points". As well as this, for the "pain points" that were described, the survey asked "Do you have any ideas for how digital tools might be used to reduce or relieve the pain?" The results are described in the next four sections: first the general results, followed by more details of the two most important lifecycle phases, and then finally an analysis of the ideas for "pain relief".

3.3.2. General results A total of 46 people took part in the survey, with a total of 55 pain points being described. As shown in Figure 2, of these 46 people, five self-identified as only data scientists, 18 as only domain scientists, none as only data stewards (as defined in [7]), 12 as domain scientists and data scientists, and five as domain scientists and data scientists and data stewards. As shown in Figure 3, of these 46 people, five are involved only in wind farm planning, seven only in wind farm operation, two only in wind turbine design, eight in multiple lifecycle phases and 24 in R&D (21 of which work in multiple lifecycle phases). Due to the relatively small number of participants compared to the size of the entire sector (approximately 1.4 million people [8]), the results need to be treated with care and should be used indicitavely rather than quantitatively.

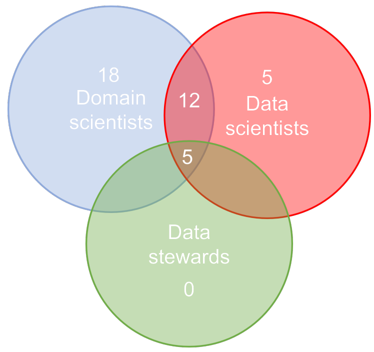

Figure 2. Summary of type of survey participants (domain scientists, data scientists and data stewards).

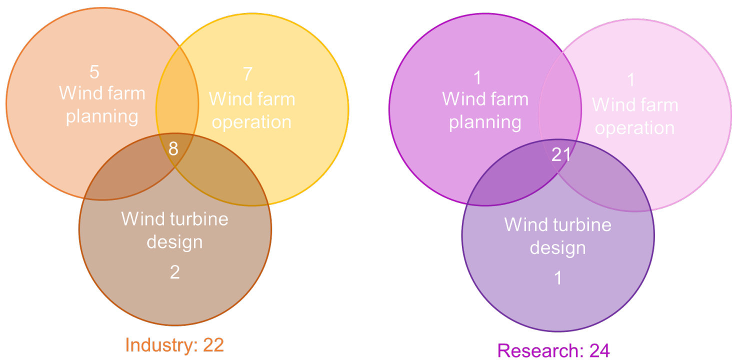

Figure 3. Summary of type of survey participants (industry and academia).

In order to analyse the large amount of data obtained, the pain points and use cases were mapped to each other in a manual process. During this process, additional use cases were created for activities that the respondents referred to but were not yet included in the existing table from phase "(a) Enrichment". This extended the list from 33 to 50 use cases, as can be seen in [6]. Some additional use cases that came up include choosing the best wake model for a given application, predictive design and operation, project acquisition and managing data. The full list of use cases that came up in the survey is given in Appendix A. The full list of pain points is given in Appendix B.

The total number of pain points for each use case is summarised in Figure 4. This highlights which use cases were associated with pain points most frequently, with the pain points grouped into the relevant lifecycle phase. Table 2 summarises the number of pain points per lifecycle phase, showing that most of the pain points were associated with the operational phase and with general tasks. These numbers need to be interpreted with care, because the total number of respondents was certainly not representative of the entire sector. However, there was no strong bias of participants towards the wind farm operational phase, and therefore it is possible to conclude that the wind farm operational phase seems to be associated with a particularly large number of pain points. The domination of the general pain points could be a result of the large number of respondents carrying out tasks across all lifecycle phases (nearly all of the academic respondents and approximately one third of the industry respondents). The completely missing (or almost completely missing) lifecycle phases "wind turbine design", "project selling / buying" and "end of life" indicate the lack of respondents dedicated to these phases. Future surveys should ensure a better distribution across all phases. Due to these results, the wind farm operation and the general use cases are examined in more detail below. Further analysis of all the results is underway but is beyond the scope of this paper.

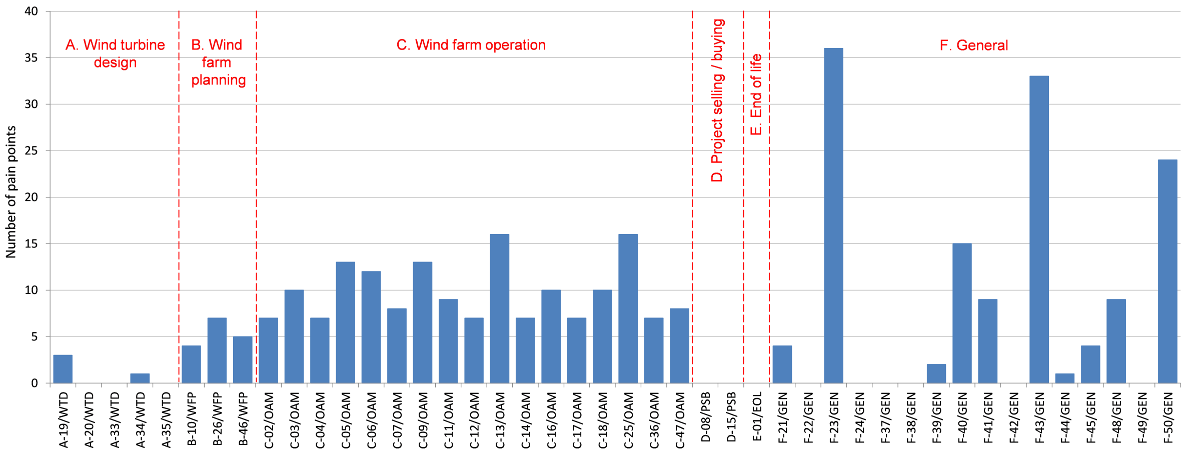

Figure 4. Mapping of pain points to use cases.

Table 2. Number of pain points per lifecycle phase

Lifecycle phase	Number of pain points
Wind turbine design	2
Wind farm planning	16
Wind farm operation	167
Project selling / buying	0
End of life	0
General	139

3.3.3. General use cases Within this category, the four use cases with the most number of pain points associated with them are "F-23/GEN: Sharing data" with 37 pain points, "F-43/GEN:

Managing data" with 33 pain points, "F-50/GEN: General data analysis" with 24 pain points and "F-40/GEN: Accessing data" with 17 pain points. This indicates that these four use cases should be the main focus of future digitalisation efforts. For these four use cases, the specific pain points and their frequencies are summarised in Figure 5.

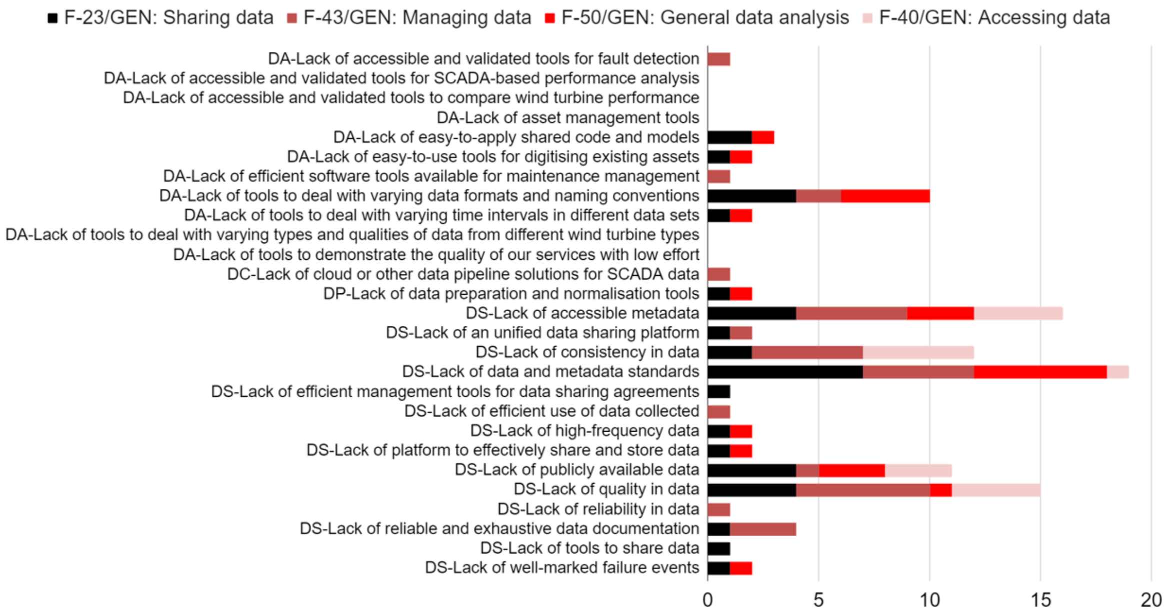

Figure 5. Mapping of pain points to use cases for the top four "general" use cases.

This shows that the dominating pain points in this category are the lack of tools to deal with varying data formats and naming conventions, a lack of accessible metadata, a lack of data and metadata standards, a lack of publicly available data and a lack of quality in data. These topics broadly agree with previous surveys carried out in IEA Wind Task 43 [1], and at the same time indicate that solutions for these problems should focus on the general use cases "F-23/GEN: Sharing data", "F-43/GEN: Managing data", "F-50/GEN: General data analysis" and "F-40/GEN: Accessing data".

3.3.4. Wind farm operation use cases The four use cases with the most number of pain points associated with them are "C-25/OAM: Failure detection" with 16 pain points, "C-13/OAM: Fault diagnosis" with 16 pain points, "C-09/OAM: Failure rate modelling" with 13 pain points and "C-05/OAM: predictive maintenance" with 13 pain points. This indicates that these four use cases should be the main focus of future digitalisation efforts. For these four use cases, the specific pain points and their frequencies are summarised in Figure 6.

This shows firstly that the top four use cases were mapped to the same pain points. This probably happened because the four use cases are very similar (they are all related to failure detection), and the inputs of the respondents were not detailed enough for differences between these four cases to be made in the analysis. To avoid this in the future, the survey needs to more clearly differentiate between exactly what is meant by a use case (an activity that someone is carrying out to bring value) and a pain point (anything that poses you with challenges, difficulties, problems, or even emotional pain).

As well as this, it can be seen that the dominating pain points in this category are a lack of accessible and validated tools for fault detection, a lack of cloud or other data pipeline solutions

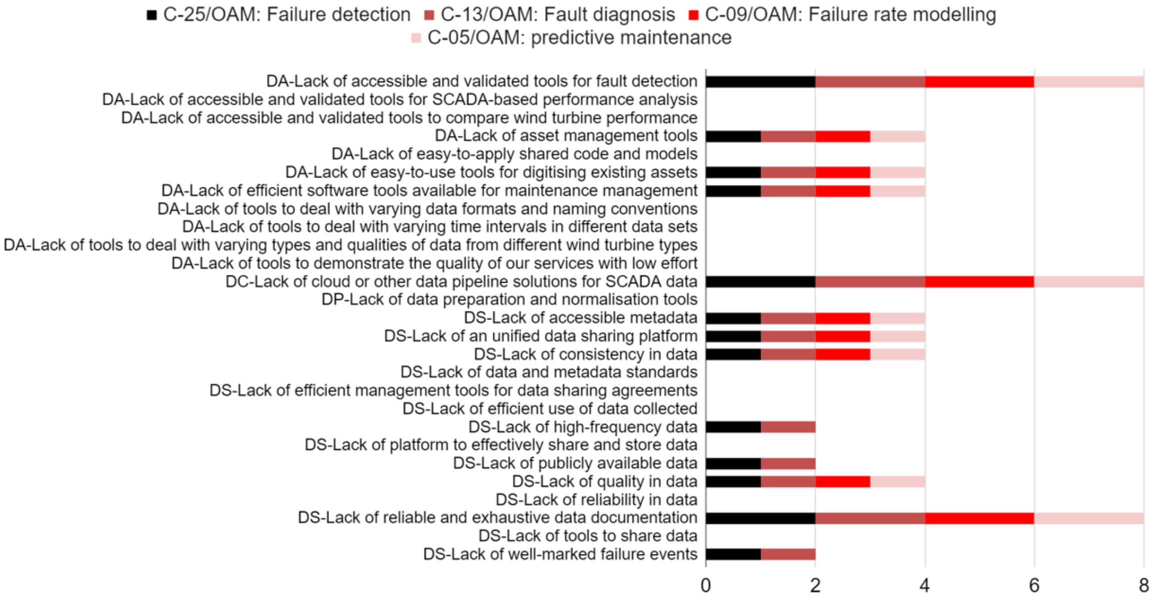

Figure 6. Mapping of pain points to use cases for the top four "operation" use cases.

for SCADA data and a lack of reliable and exhaustive data documentation. This is interesting, because it highlights particular needs of wind farm operators. These three topics should be focused on by future efforts to advance digitalisation in wind energy.

3.3.5. Possible "pain relievers" With multiple pain points per respondent, and multiple solutions per pain point, there were a total of 63 responses to the question "Do you have any ideas for how digital tools might be used to reduce or relieve the pain?". These were categorised according to the type of solution suggested, and the resulting profile is shown in Figure 7. It is interesting that the most common response is "None" (occurring 19 times), showing that many respondents did not have any ideas for solutions to relieve their pain points. This indicates that a priority for the future is to better communicate and help people become aware of existing solutions and tools.

Other frequent responses include suggestions related to data standards (10 occurrences), enhancing metadata (10 occurrences) and data sharing tools (6 occurrences). This corresponds well with the main pain points discussed in the previous two sections, many of which were related to data formats, metadata and data sharing. In the category "data standards", the suggestions included "Standardisation of data streams and data models, extending to information about the source of the data and expected inaccuracies or behaviour", "Further standardisation", "Getting OEMs and owner/operators to follow standards and best practices", "Data standardisation or automated data formatting tools", "Standard data formats", "Standardisation of data collection and reporting". In the category "enhancing metadata", the suggestions included "Knowledge base describing datasets", "Comprehensive metadata and schemas", "Standardised data and metadata", "Enhanced data and metadata", "Better metadata", "Data schema identifying data sources", "Enhanced metadata". In the category "data sharing tools", the suggestions including "Data sharing platform", "Accessible repositories for energy market data", "Tools to analyse energy market data", "Data exchange tools", "Data sharing framework". These responses indicate a high need for data standards, enhanced metadata and data sharing tools, but a low level of detail regarding which topics should be prioritised and, more importantly, how - and by whom - these data standards should be developed and enforced. In total, there are 44 suggested solutions, corresponding to 70% of the responses, indicating that while respondents have some ideas to alleviate pain points, they are not in a position to influence the solutions. Addressing this problem should be one of the priorities of future digitalisation efforts.

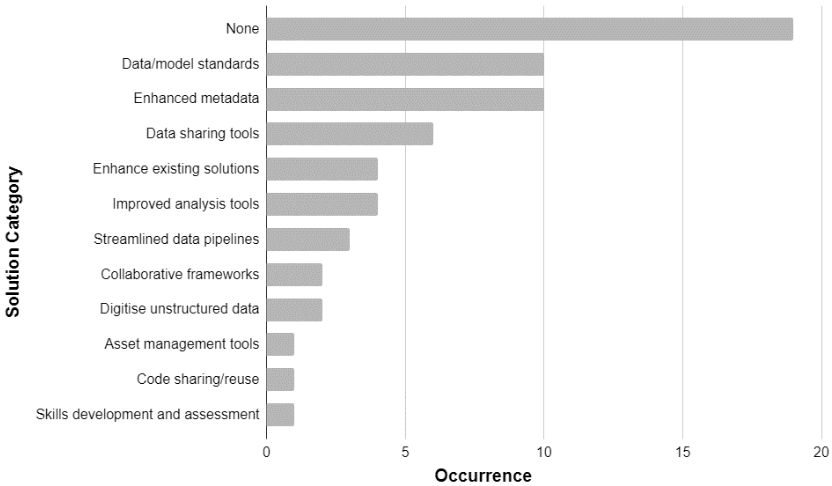

Figure 7. Categorisation of solutions suggested in the survey.

4. Discussion
In this section, the recommended priorities for future digitalisation efforts that could be defined in this work are introduced, followed by an evaluation of the use-case-driven approach.

4.1. Recommended priorities
The results of this work have allowed some priorities for digitalisation efforts for the wind energy sector to be recommended, as summarised below.

Firstly, digitalisation efforts should focus both on supporting people in the wind energy sector carrying out cross-lifecycle tasks, in particular sharing data, managing data, undertaking general data analyses and accessing data. Tools to do this should focus on dealing with varying data formats and naming conventions, making metadata more accessible, defining data and metadata standards, making more data publicly available and improving the quality of data.

Secondly, digitalisation efforts should also focus on supporting people in the wind farm operational phase, in particular carrying out failure detection, fault diagnosis, failure rate modelling and predictive maintenance. Solutions to do this should focus on accessible and validated tools for fault detection, cloud or other data pipeline solutions for SCADA data and tools for exhaustive data documentation.

Thirdly, digitalisation efforts should focus on better communicating and helping people become aware of existing solutions and tools, as well as on helping people to exert a stronger influence on possible solutions. This could be realised through strengthening the dissemination and education activities of IEA Wind Task 43.

Further analysis is beyond the scope of this paper. However, the survey will be used in the future to develop further recommendations for the other lifecycle phases. Additional surveys will be carried out by focusing the questions for people from specific lifecycle phases. These surveys will more clearly differentiate between exactly what is meant by a use case and a pain point, in order to allow for a more detailed description of use cases for each pain point.

4.2. Evaluation of use-case-driven approach
The use-case-driven approach developed in this work has proven to be valuable in a number of different ways. The main value is related to the survey, which has allowed "use cases" to be mapped with "pain points" effectively, thereby making a prioritisation of future digitalisation efforts possible. The survey also allowed the state of knowledge of the respondents to be assessed, and recommendations for improving this in the future to be defined. As well as this, the approach of dividing the responses into different lifecycle phases was useful, and could be applied in future analyses on the topic of digitalisation. However, the study was limited by the fairly low number of survey participants, and the results should be treated with care. Further work to obtain more inputs is underway as part of IEA Wind Task 43.

5. Conclusions
In this work, we presented a use-case-driven approach for demonstrating the added value of digitalisation in wind energy, developed within IEA Wind Task 43. The approach involved firstly defining an initial list of use cases by carrying out a literature review and collecting inputs from IEA Wind Task 43 participants via brainstorming sessions, and then analysing which existing digital solutions could be used to add value to these use cases. The results showed that more information was required in order to prioritise which of the use cases provide the most value and which have the highest potential to be improved by digital solutions. This was achieved by implementing a survey aiming to collect and collate the main "pain points" of people in the wind energy sector, where "pain point" was defined as "anything that poses you with challenges, difficulties, problems, or even emotional pain", i.e. something that really frustrates people and gets in the way of reaching their goals or carrying out their tasks. The results were used to define a set of priorities for digitalisation efforts for the wind energy sector. The main value brought to the sector through this approach was the survey design, which has allowed "use cases" to be mapped with "pain points" effectively, thereby making a prioritisation of future digitalisation efforts possible. The survey also allowed the state of knowledge of the respondents to be assessed, and recommendations for improving this in the future to be defined. The survey will be used in the future to develop further recommendations for the other lifecycle phases. Additional surveys will be carried out by focusing the questions for people from specific lifecycle phases.

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Appendix A. Inventory of Use Cases

Lifecycle Stage	Unique ID	Use Case
Wind turbine design	A-19/WTD	Benchmarking simulation tools
	A-20/WTD	Root Cause Analysis
	A-33/WTD	Design tools
	A-34/WTD	Designing large wind turbines
	A-35/WTD	Designing for site-specific conditions
Wind farm planning	B-10/WFP	Design for reliability
	B-26/WFP	Wind resource assessment
	B-46/WFP	Wake modelling
Wind farm operation	C-02/OAM	Energy Market Participation
	C-03/OAM	AEP Assessment
	C-04/OAM	Turbine Parameter Optimisation
	C-05/OAM	Predictive Maintenance (of gear boxes)
	C-06/OAM	Risk-Based maintenance
	C-07/OAM	Evaluate Potential Turbine Performance Enhancements
	C-09/OAM	Failure Rate Modelling
	C-11/OAM	Curtailment management
	C-12/OAM	Digital Twin(s)
	C-13/OAM	Fault Diagnosis
	C-14/OAM	Performance Assessment with External Parties
	C-16/OAM	Performance Benchmarking
	C-17/OAM	Availability Benchmarking
	C-18/OAM	Detecting under-performance
	C-25/OAM	Failure detection
	C-36/OAM	Predictive design and operation
	C-47/OAM	Reliability based forecasting
Project selling/buying	D-08/PSB	Asset Risk Assessment
	D-15/PSB	Asset Valuation
End of life	E-01/EOL	End-of-life decision
General	F-21/GEN	Project acquisition
	F-22/GEN	Recruiting
	F-23/GEN	Sharing data
	F-24/GEN	Finding metadata
	F-37/GEN	Increasing the diversity of the workforce
	F-38/GEN	Making sure the workforce has the right skills needed today
	F-39/GEN	Making sure research gets transferred to the industry effectively
	F-40/GEN	Accessing data
	F-41/GEN	Validating models
	F-42/GEN	Accessing published methods
	F-43/GEN	Managing data
	F-44/GEN	Code and Model Sharing/Reuse
	F-45/GEN	General admin tasks
	F-48/GEN	Homogenization and digitalisation of data from existing assets
	F-49/GEN	Standard data formats, data streams and models
	F-50/GEN	General data analysis

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Appendix B. Pain Points by Category

Category	Pain Point
Data Analysis	Lack of accessible and validated tools for fault detection Lack of accessible and validated tools for SCADA-based performance analysis Lack of accessible and validated tools to compare wind turbine performance Lack of asset management tools Lack of easy-to-apply shared code and models Lack of easy-to-use tools for digitising existing assets Lack of efficient software tools available for maintenance management Lack of tools to deal with varying data formats and naming conventions Lack of tools to deal with varying time intervals in different data sets Lack of tools to deal with varying types and qualities of data from different wind turbine types Lack of tools to demonstrate the quality of our services with low effort
Data Collection	Lack of cloud or other data pipeline solutions for SCADA data
Data Preparation	Lack of data preparation and normalisation tools
Data Sharing	Lack of accessible metadata Lack of an unified data sharing platform Lack of consistency in data Lack of data and metadata standards Lack of efficient management tools for data sharing agreements Lack of efficient use of data collected (?) Lack of high-frequency data Lack of platform to effectively share and store data Lack of publicly available data Lack of quality in data Lack of reliability in data Lack of reliable and exhaustive data documentation Lack of tools to share data Lack of well-marked failure events
Mindset	Lack of willingness to share data
Resources	Lack of easy-to-use recruiting tools Lack of efficient paperwork management Lack of good funding opportunities Lack of good people Lack of prioritisation of technical work and more emphasis on general administration Lack of time to write proposals