INTERNATIONAL ENERGY AGENCY

Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

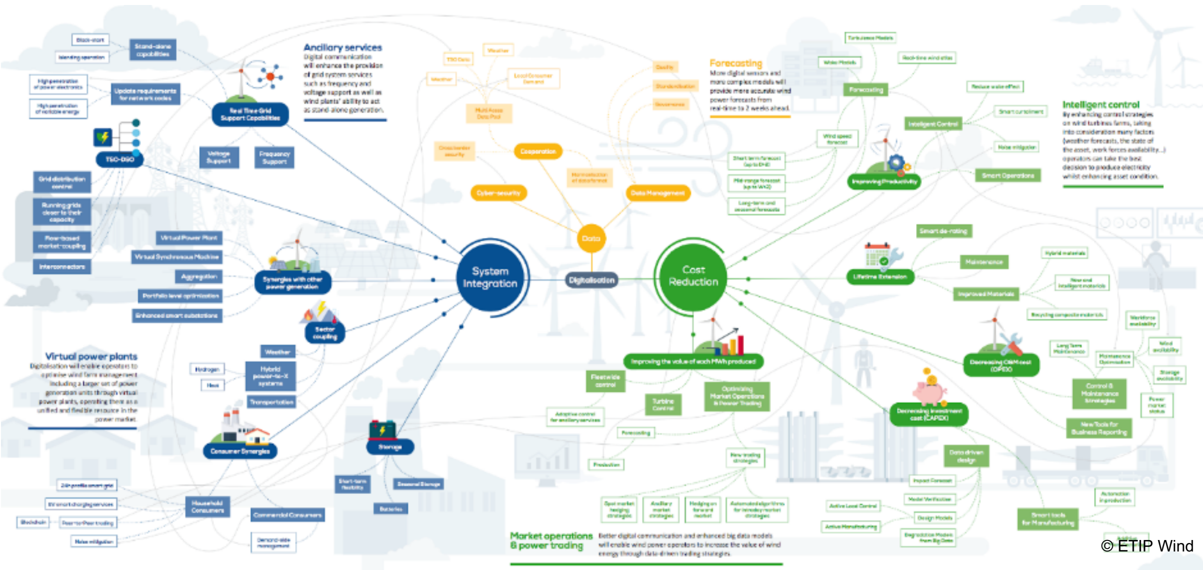
Topical Expert Meeting #92 on

Wind Energy and Digitalization

IEA Wind Task 11- Topical expert meeting

October 4-5, 2018

Sustainable Energy Authority of Ireland, Dublin, Ireland



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V1	**Organizing committee first draft**
V2	**Comments from reviewers incorporated (Final)**

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Executive Summary of Topical Expert Meeting 92

Introduction

The wind energy sector is data intensive in character due to large commercial fleets of decentrally distributed turbines, dynamically changing ambient conditions, continuous interaction with the grid, and a real-time processing of data from all systems. Throughout turbine design, planning and construction, operation and maintenance and decommissioning, increasing volumes of diverse data are accumulated for a variety of purposes.

This evolving complexity demands highly scalable data infrastructure, efficient interoperability across sector participants and innovative analytical methods to ensure continued competitiveness. It is timely, therefore, to take a strategic review of the “digitalization” of wind energy.

The objective of the International Energy Agency (IEA) topical expert meeting (TEM) 92 was to provide an overview of the current trends in the digitalization of wind energy and the challenges and opportunities that accompany those trends. Participants explored the potential need for collaboration and international guidelines and discussed the priorities for the formation of a new IEA task.

Meeting Overview

On October 4th and 5th, 46 experts from 11 countries participated in the two day meeting, which facilitated 18 presentations interspersed with Q&A, group discussions and structured brainstorming sessions. In general, presentations ranged from the strategic implications of digitalization to specific implementations and practices already deployed.

The first day was dedicated to exploring what digitalization means to the different players in the wind energy sector and to present and discuss the current challenges. The following definition was put forward as a working definition for digitalization: **Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business**[1]

Several presentations underlined the importance of high quality datasets as a critical basis for all applications and highlighted a variety of challenges and barriers from data acquisition via wind farm modelling to data analytics.

On the second day, the participants discussed opportunities to mitigate the barriers and to exploit the advantages of digitalization. A perceived lack of standards and the complicated implementation of standards into existing processes hinder the beneficial application of modern data analytic techniques. Thus, some presentations referenced existing standards and recommendations for data acquisition and presented first results from approaches for performance assessment and reliability analyses using operator’s databases.

[1] **https://www.gartner.com/it-glossary/digitalization/**

In breakout sessions, three groups worked on a prioritization of challenges to overcome by weighing impact versus effort to achieve. All participants then discussed the output from those breakout sessions and identified and ranked five main fields to be tackled by a research task within IEA Wind TCP.

The overall assessment from the group was that, while islands of digitalization already exist in the sector, significant benefit can be derived by developing a framework around which to focus and collaborate. Consequently, a core team volunteered to collaboratively prepare a work proposal for an IEA Wind TCP research task.

Main Results

The IEA TEM 92 covered many of the important topics for wind energy digitalization including helping to define the space in terms of enabling digital technologies and key applications. Figure 1[2] below from ETIPWind shows the diversity of potential wind energy applications which are enabled by, or can benefit from, the new wave of digital technologies.

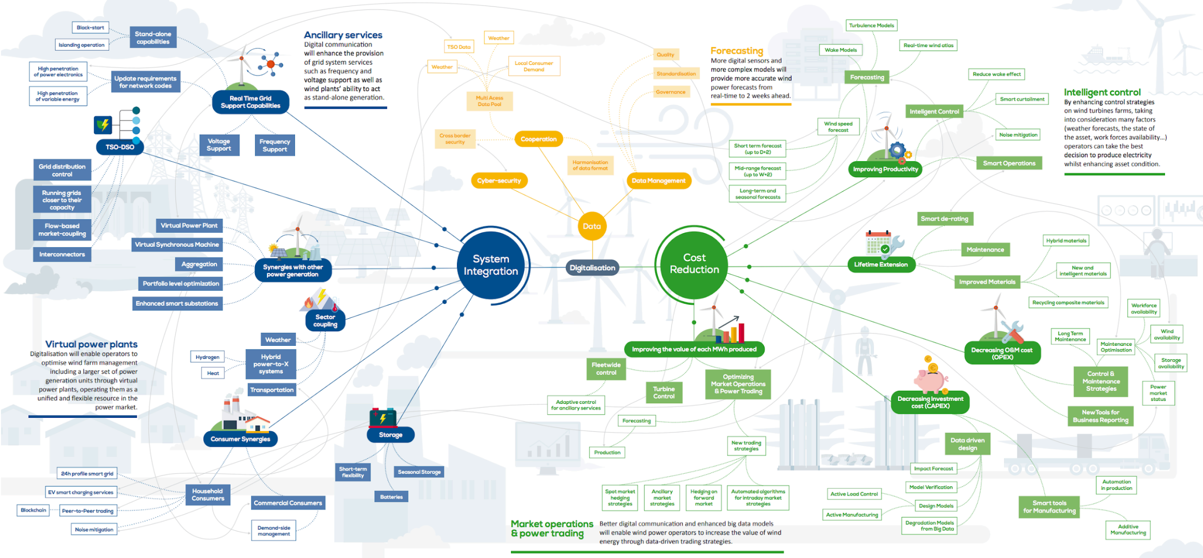


Figure 1 ETIPWind wind energy digitalization application map

At the highest level, wind energy digitalization means that a variety of new digital technologies will disrupt current methods at every point in the wind energy life cycle. These technologies include:

- Ubiquitous digital communications
- Cheap, fast computing
- Internet of Things (IOT) connected sensors
- Data Science tools
    - Distributed computing and analysis (Big data methods)
    - Machine learning (ML)/ Artificial Intelligence (AI)
    - Computer Vision
    - Natural Language Processing
- Open Source codes
- Edge Computing
- Blockchain & Distributed Ledger
- Universal Data Standards & Taxonomies
- Widely available and discoverable Data Sharing
- Centralized vs. decentralized Data Storage

[2] https://etipwind.eu/wp-content/uploads/When-Wind-Goes-Digital.pdf

These technologies and more will ripple through the current wind energy design, development and operations processes to create a new, more efficient, more productive and more customer-centric wind energy industry.

The following themes surfaced consistently throughout the two-day meeting:

- Digitalization is widely believed to yield significant advancement opportunities for the wind energy sector, though it is still largely unquantified.
- Wind Energy Digitalization is hindered by the lack of adoption of standards and best practices.
- Strategic thought and guidance is needed for organizations on best path forward to materialize digitalization gains.
- Collaborative research and development on wind energy digitalization would be highly valuable for both individual businesses and the industry as a whole

Key outcomes of TEM 92:

- **Meeting presentations are available here[3] on the IEA Wind platform.**
- **Proposal to form a new collaborative IEA task with a focus on the following areas:**
    - White paper/Journal Article on Wind Energy Digitalization Opportunity
    - Wind Energy Digitalization roadmap
    - Focused topical area research including
        i. Gap analysis and adoption of data standards
        ii. Digital Operations & Maintenance (O&M)
        iii. Digital Wind Resource Assessment (WRA)

[3] https://community.ieawind.org/communities/community-home/librarydocuments?communitykey=16eedd24-90fb-43ea-b291-546d0bc537aa&tab=librarydocuments

Summary of Presentations

Wind Energy Digitalization: Overview

The first set of presentations which opened the TEM, set the aim of the upcoming two days and introduced the topic of digitalization in wind energy. It was stated that society needs to make use of all benefits of digitalization to mitigate the consequences of climate change. The upcoming transition of the energy systems from centrally controlled to decentralized systems provides an enormous potential for improvements regarding technologies like cloud computing, networking, sensors and software and for approaches like blockchain, data platforms and artificial intelligence techniques. Moreover, presenters made the case that the ability to share data and analytical models is a critical enabler of enhanced stakeholder collaboration.

IEA Wind TCP supports research in the energy sector to foster cost reduction of wind energy, improve the market value, promote social acceptance and exploitation, and to initiate collaborative research. Digitalization has been identified as a major upcoming topic and IEA Wind is ready to support a new research task if the experts appraise it essential. IEA Wind task 11 is dedicated to support the international research community in identifying new important scientific fields, start research tasks and to support them in summarizing results in reports or recommended practices.

Invited experts reported about the different fields and benefits from digitalization, which will affect technical aspects and help modify many organizational processes. For all these improvements, aligning of data requirements and merging of data streams will lead to a digital convergence. Consequently, data acquisition will be simplified, concatenation of data will be possible, new applications will emerge and will provide new services in a variety of fields.

Wind Plant Operations

Wind farm operators may improve their insight into the performance of their wind turbine fleets through accessing statistical performance data for particular models. It has been challenging for operators to access such data to carry out wind farm operational assessments (OA’s) despite international benchmarking projects. Open Data initiatives have been adopted in other industries to address software development challenges and NREL is pioneering this for wind turbine operational data through their OpenOA platform. OpenOA may serve to demonstrate industry’s appetite for an open-source codebase to maintain and disseminate best practices for wind plant OA’s.

The combination of predictive analytics, materials science, and data science can inform operational actions and business decisions across the wind project value chain. The challenges in implementing predictive analytics primarily may be that up to 80% of the effort is spent in cleaning heterogeneous raw data to use within predictive models. These challenges may partially be addressed through better adherence to existing standards for data taxonomy. However, a significant part of the problem lies within the so-called “small data”, including work orders and any form of textual information.

IEC standard 61400-25 defines communication between wind power plant components and SCADA systems and complements IEC standards for interfacing systems such as IEC 61850 on substation automation. Full adherence to the standards brings many benefits, including data standardization, interoperability, cybersecurity and reduced development timescales.

Data analytics may not only inform power plant operational decisions but also provide wind turbine condition data critical to making decisions on life extension, repowering and decommissioning. Distributed ledger or "blockchain" has revolutionized certain financial transactions and has the potential to be applied to standardized energy market transactions.

Data Standards and Best Practices

Wind turbines are produced in large volumes and operated in fleets. Thus statistical analyses of large data sets and the application of artificial intelligence methods promise highly valuable insights.

However, analysts are often presented with poor quality data in terms of the level of detail, data gaps and consistency of data structures and formats. One approach to obtain well-structured data sets is to follow the IEA Wind Recommended Practices (RP) #17 from task 33 "Reliability Data". The RP suggests making use of existing standards and guidelines and recommends certain ones for different purposes. But since some guidelines stem from different applications and industries, they overlap in some parts, give contradictory suggestions and leave several gaps in other fields.

The presentation included an approach to set up a data model for the life cycle of a wind turbine fleet, making use of the recommended practices. Unfortunately, besides the problem of overlaps and gaps between the guidelines, it also proved difficult to populate the model with operational data. On one hand, few owners/operators have structured data available and on the other hand, owners/operators tend to withhold their data as they could be commercially sensitive.

One way to overcome the lack of data for promising analyses is to publish only metadata and to forward real data only under certain preconditions. This idea was developed, following the European Commission's request for storing data gathered through publicly funded mechanisms in a manner that makes them **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable (FAIR). One proposal presented a set of formal metadata according to the Dublin Core Metadata Initiative (DCMI) and additionally suggested a handful of keywords roughly identifying the data content.

Data Science Case Studies

There are many challenges when applying data science solutions to business and operational applications in the wind sector. A consistent message from this session was that many of these challenges can be overcome by "closing the loop" and collaborating with stakeholders throughout the analytics lifecycle; from data acquisition through to implementation of resulting insights.

The effort to discover actionable insights begins by working with end users to understand their needs and often requires an iterative approach to refine datasets, analysis methods and conclusions to ensure these needs are fully addressed. A number of detailed closed loop models were presented which described a collaborative process and highlighted the individual elements involved.

Deploying data science solutions involves managing a large quantity and variety of data types, even to produce high-level performance indicators, and the ingestion of data from multiple sources. This complexity drives the need to consistently apply standards and formats. Presenters described implementations of data management platforms designed to address this and to enable the automation and scalability of their data science workflows. These platforms also serve as data sharing frameworks, either within an organization or across the industry as a whole.

A broad selection of data science case studies was presented, covering topics including data processing, availability improvement and performance enhancement. The case studies demonstrated a range of analytics and machine learning techniques with diverse application areas including:

- Real-time assessment of sensor data integrity.
- Classification of asset health using SCADA data.
- Prediction of trends in condition monitoring time-series data.
- Detection of anomalous patterns in both turbine time-series and turbine state data.
- Discovery of recurrent sequences in turbine state data.
- Analytics approaches to failure investigation.

Additional lessons learned from the case studies included the importance of ensuring access to both machine data and textual information, as well as the necessity of combining analytics expertise with domain knowledge in areas such as component failure modes.

Summary of Brainstorming Sessions

The brainstorming sessions collated and prioritized digitalization ideas arising from presentations and discussions throughout the day and from the professional experience of attendees. Three highly engaged groups generated and classified over 70 ideas according to implementation effort and industry impact.

The output from each breakout group was presented to and discussed by all attendees. Further affinitization post-meeting grouped the individual ideas into the following seven categories, which were ranked based on the level effort and impact for each category (see **APPENDIX D - Brainstorming Session Material**)

- Application Areas (O&M, Wind Farm Control, Wind Farm Development)
- Best Practices & Tools
- Data Access & Sharing (Sharing Mechanisms, Data Types, Datasets, Tools)
- Data Analytics, ML, AI (Modelling, Simulation, Digital Twin, Edge Computing)
- Data Platforms
- Data Standards & Harmonization (Data, Interoperability, Adoption, Operations)
- Energy Markets & Commercial Operations

The findings from the session will inform follow-up actions, including the scoping of a possible IEA task on digitalization.

Full details of both raw and consolidated brainstorming results are provided in **APPENDIX D - Brainstorming Session Material**.

Conclusions & Next Steps

The IEA TEM 92 group identified the following key activities and next steps as part of the 2 day meeting.

Key Activities
A number of key activities emerged from the discussions and brainstorming sessions.

- Define the scope of what is meant by digitalization.
- Identify the potential value and opportunities around the adoption of digital technologies in wind
- Define clear objectives of the effort under consideration.
- Conduct a state of the art analysis to capture the state of the industry and areas to prioritize.
- Consider all aspects of digitalization from data infrastructure and formats to end-user value.
- Consider all stages of the wind sector lifecycle and all steps in the value chain(s).
- Learn from and build upon similar work in other sectors.

Next Steps

The group generally agreed that an IEA Task focused on Wind Energy Digitalization was a timely and valuable contribution to the wind energy industry. Furthermore, many of the participants and countries were interested in direct participation in a future task on wind energy digitalization. A group debrief distilled the potential activities of a future task into three main areas:

- White paper/Journal Article on Wind Energy Digitalization
    - A white paper defining digitalization as it applies to wind energy and the value contribution of specific sub areas such as digital operations and maintenance (O&M).
- Wind Energy Digitalization roadmap
    - Develop a 5-10 year roadmap that would identify critical next steps for the industry stakeholders to realize the value contribution as described in the wind energy digitalization white paper
- Focused topical areas
    - Operation & Maintenance
    - Wind resources and site assessment
    - Standards for relevant data sets, formats, and taxonomies
    - Data sharing and preconditions like ownership, confidentiality, utilization
    - Digitalization for future electricity systems and markets

APPENDIX A - TEM 92 Introductory Note

John Mc Cann – Sustainable Energy Authority of Ireland (SEAI)
Jason Fields – National Renewable Energy Laboratory (NREL)
Des Farren – ServusNet Informatics Ltd.
Berthold Hahn – Fraunhofer IEE

Background

The wind energy sector is data intensive in character due to a number of factors:

- larger commercial fleets of highly instrumented turbines
- dynamic interaction with the grid, energy markets and storage technology requires processing of real-time data from all these systems
- site-specific conditions and analysis to support planning and operation

Throughout the lifecycle of a wind farm, increasing volumes of diverse data are accumulated for a variety of purposes, including:

Turbine Design and Certification	Planning and Construction
● Aerodynamic, Structural, Mechanical, Electrical ● Control system, firmware, software ● Design verification and reliability testing ● Mid-life upgrades ● Regulatory approval/certification	● Wind resource, noise, flicker and wildlife ● Environmental, geotechnical planning and permitting ● Design, validation, manufacturing, investment analysis and construction ● Community surveys and communications
Site Operations and Maintenance	**Commercial Operations**
● Meteorological (Atmospheric/Sea) Data ● Turbine measurements and alarms ● Preventative and predictive maintenance ● Inspection procedures and results ● Component reliability, spares inventory ● Work order data ● Environmental monitoring ● Decommissioning	● Asset management and investment return ● Project sale, re-powering, insurance ● Energy market, production/ price forecasting optimization ● Grid code compliance and services ● Integration with other renewable generation, storage and fuel production e.g. hydrogen

This evolving complexity demands highly scalable data infrastructure, efficient interoperability across sector participants and innovative analytical methods to ensure continued competitiveness. It is timely, therefore, to take a strategic review of the "digitalization" of wind energy.

Holistic Approach

As the fundamental purpose of collecting these wide-ranging datasets is to add value to a wind farm project in all stages of its lifecycle, it is useful to introduce the concept of the "wind energy project data value chain". This might be the first step towards a holistic approach to data, identifying:

- The value attached to each category of data.
- Current data management and analysis best practice
- The key investment, planning and operational decisions supported by each category.
- Forward looking R&D priorities to maximize wind plant value and minimize cost

Such a strategic approach would facilitate the development of integrated solutions supporting the full data lifecycle of a wind energy project, yielding significant cost and efficiency benefits for the industry.

This TEM, therefore, proposes to explore the development of an overarching data framework, with data quality standards, data management and analytics best practices, in order to maximize data value and minimize wind energy LCOE.

Objectives

This topical expert meeting will seek to provide an overview of the current trends in the digitalization of wind energy and the data challenges and opportunities that may emerge with this. Participants will explore the potential needs of collaboration and international guidelines and prepare a first outline of a new task. Particular topics that may be dealt with are:

- State of the industry
    - Trends in digitalization and types and size of resulting datasets
    - Initiatives on data standardization and quality
    - Components of the data stack e.g. acquisition, cleansing, warehousing, processing and presentation
    - Data security, ownership and rights
    - Identify Open data initiatives, sharing of research datasets
    - Identify data end-users, key decisions requiring significant supporting analysis and corresponding relevant datasets.
- Research and Development
    - Bulk and streaming analytics
    - Edge Computing
    - Predictive Analytics including machine learning
    - Data Summarization and mapping (e.g. clustering)
    - Hybrid data driven and physical modeling techniques

Tentative Program

1. Introductions
2. Overview of Wind Energy Digitalization
    a. Concept
    b. Stakeholders
    c. Challenges and Opportunities
3. Review of current projects, practices and stakeholders
    a. Data Taxonomy & Storage
    b. Data Transmission & Access
    c. Data Science Case Studies
4. Identification of key priorities
    a. Key Challenges
    b. Key Opportunities
5. Scope of work for IEA Task

Intended Particiation

- Wind Turbine OEMs
- Wind Energy Consultancies
- Wind Energy Owner/Operators
    - Utilities
    - IPP's
    - 3rd party operators
- Wind Energy Investors
    - Debt and Equity investors
    - Project Sponsors

- Service providers
- Research Institutions and Funding Organizations
    - NREL
    - DTU
    - Sustainable Energy Authority of Ireland
    - …
- Grid and Transmission Authorities
    - FERC
    - …

Expected Outcomes

There are two primary expected outcomes from the IEA Topical Expert Meeting

- Report outlining the state of the industry for wind energy digitalization including:
    - Definition of the wind energy digitalization and the opportunity
    - Current trends and applications for wind energy digitalization
    - Next steps
- Scoping of proposed IEA Task for submission to IEA Executive Committee including major tasks and subtasks

APPENDIX B - Meeting Agenda

Note: The presentations given during the meeting can be found here on the IEA Wind platform

On the evening of October 3rd, all TEM 92 participants were invited to an event of the Irish Wind Energy Research Network organized by the SEAI starting at 5.30 pm and taking place at the Gresham Hotel, O'Connell St. Dublin.

Day 1: October 4th

Time Block	Duration	Topic	Presenter / lead	Format
8:30a-9:00a	30 mins	Breakfast and Registration		
9:00a-9:30a	30 mins	Welcome, Goals, and Introductions		
	10 mins	Welcome and goals -State of industry report -Scoping of IEA Task	Jason Fields, NREL	PPT
	10 mins	IEA Wind TCP introduction: general and task 11 introduction	Ignacio Marti, Nadine Mounir, IEA Wind TCP	PPT
	10 mins	Introduction of Experts	All	Go-around
9:30a-10:20a	50 mins	Wind Energy Digitalization: Overview		
	20 mins	What does digitalization actually mean and how can it improve efficiency and create value?	Michael Wilkinson, DNV-GL	PPT
	30 mins	Q&A/discussion with the group	Plenum	Discussion/ Brainstorming
10:20a-10:35a	15 mins	Networking & Refreshment BREAK		
10:35a-11:35a	60 mins	Brainstorming session 1		
	45 mins	Have we captured the correct outline of the space? Do we have the correct definition of Digitalization? - Key Applications - Challenges & Opportunities - Value of Information/Action Breakout Groups division: - Turbine Design & Certification - Planning Development & Construction -Wind Plant Operations	Breakout groups	Discussion/ Brainstorming
	15 mins	Plenum Discussion of key points	Plenum	Discussion/ Brainstorming
11:35a-12:20p	45 mins	Turbine Design and Certification & Planning, Development and Construction		
	10 mins	Pre-construction data gathering	Aengus Connolly, Wood – Digital Solutions	PPT

	10 mins	Research and innovation challenges on the way to wind energy digitalization	Nikolay Dimitrov, DTU	PPT
	10 mins	Development and validation of wind farm models within the data science paradigm	Javier Sans Rodrigo, CENER	PPT
	15 mins	Discussion of key points	Plenum	Discussion
12:20p-1:30p	70 mins	LUNCH		
1:30p-2:30p	60 mins	Wind Plant Operations		
	10 mins	OpenOA: open operational assessment framework for SCADA data	Mike Optis, NREL	PPT
	10 mins	Challenges and Opportunities for operational data	Vijayant Kumar, Sentient Science	PPT
	10 mins	Data Analytics for wind plants end of life	Paul Leahy, UCC	PPT
	10 mins	IEC 61400-25 Wind Power Plant Communication under the aspects of cyber risks and compliance to security standards	Bertram Lange, Bachmann electronics	PPT
	10 mins	Blockchain: the biggest digital disruption for the energy sector	Piyush Verma, IERC	PPT
	10 mins	Discussion of key points	Plenum	Discussion
2:30p-3:30p	60 mins	Brainstorming session 2		
	60 mins	Potential Solutions to Challenges identified in Session 1: - solutions - next steps - effort vs. reward ranking	Breakout Groups (see session 1)	Discussion/ brainstorming
3:30p-3:45p	15 mins	Networking & Refreshment BREAK		
3:45p-5:00p	75 mins	Day One Wrap up		
	20 mins	Breakout group results presentation	Plenum	Discussion
	50 mins	(1) Review of Day One topics and presentations-state of industry discussion (2) Summary of key challenges identified (3) Day Two Agenda Review & Modification	NREL / Various	Discussion

Day 2: October 5th

Time Block	Duration	Topic	Lead	Presenter / lead	Format
8:30a-9:00a	30 mins	Breakfast and Registration			
9:00a-9:20a	20 mins	Welcome, Goals, and Introductions			
	5 mins	Welcome and goals for Day 2			Discussion
	15 mins	Review of Day One			Go-around

9:20a-10:20a	60 mins	Data Standards & Best Practices		
	20 mins	Standards and taxonomies for collecting reliability relevant data from O&M	Berthold Hahn, Fraunhofer	PPT
	10 mins	Taxonomy and metadata to manage the wind energy digital transformation	Anna Maria Sempreviva, DTU	PPT
	10 mins	The challenges and solutions of converting industry standards to usable business solutions	Anders Hvashøj, ZEVIT	PPT
	20 mins	Discussion of key points	Plenum	Discussion/ Brainstorming
10:20a-10:35a	15 mins	Networking & Refreshment BREAK		
10:35-11:35a	60 mins	Brainstorming session 3		
	40 mins	What are the barriers for existing standards to be used by industry? What gaps exist? What capabilities do we unlock if standards are used more broadly?	Breakout Groups	Discussion
	20 mins	Plenum Discussion of key points	Plenum	Discussion/ Brainstorming
11:35a-12:35p	60 mins	Data Science Case Studies (Part 1?)		
	10 mins	Hybrid digital twins as prognosis enablers	Diego Galar, Tecnalia	PPT
	10 mins	Using data to improve wind performance	Chitra Sivaraman, PNNL	PPT
	10 mins	Lessons learnt from the application of data management and analytics techniques in offshore wind farms	Alexios Koltsidopoulos, EDF	PPT
	10 mins	Operations Analytics - Approaches and Challenges	Des Farren, Servusnet	PPT
	20 mins	Discussion of key points	Plenum	Discussion
12:35-1:35p	60 mins	LUNCH		
1:35p-2:35p	60 mins	Brainstorming Session 4		
	60 mins	Next Steps and Value of Action - key opportunities for collaboration - value of making improvements in standards, workflows, etc. - discussion on work packages for a potential new IEA Wind Task	Breakout Groups	20 mins
2:35p-3:35p	60 mins	Moving Forward: Timeline and Management		
	20 mins	State of industry report discussion & timeline	NREL	PPT/ Discussion
	20 mins	New work proposal discussion & timeline	SEAI / Various	PPT/ Discussion
	20 mins	Action Items and wrap-up	Fraunhofer	PPT/ Discussion

3:35p-3:50p	**15 mins**	**BREAK**		
3:50p-4:30p	**40 mins**	**Day Two Wrap up**		
	40 mins	**(1) Review of Day one & two topics and presentations** **(2) Review of Action Items and Next Steps**	**SEAI / Various**	**Working Group**

APPENDIX C - Meeting Participants

The meeting was attended by 46 participants from 11 countries. Following is the list of participants and their affiliations.

Name	Country	Company/Organization
Aengus Connolly	United Kingdom	Wood - Digital Solutions
Aidan Cronin	Denmark	Siemens Gamesa
Alexios Koltsidopoulos	United Kingdom	EDF Energy
Amândio Ferreira	Portugal	INEGI
Amir Nejad	Norway	Norwegian University of Science & Technology
Anders Hvashøj	Denmark	ZEVIT
Andreas Nuber	Germany	Wölfel
Anna Maria Sempreviva	Denmark	DTU
Berthold Hahn	Germany	Fraunhofer IEE
Bertram Lange	Germany	bachmann electronics
Chitra Sivaraman	United States	PNNL
Corinne Dubois	France	Meteolien
Daniel Averbuch	France	IFPEN
Des Farren	Ireland	ServusNet Informatics Ltd.
Diego Galar	Spain	Tecnalia
Geert-Jan Bluemink	Finland	VTT
Gerald Curtin	United States	Sentient Science
Gibson Kersting	United States	E.ON
Guiju Song	United States	GE Renewable Energy
Hendrik Heißelmann	Germany	ForWind - Center for Wind Energy Research / University Oldenburg
Ignacio Marti	Denmark	DTU Wind, IEA Wind TCP Chair
Ivan Moya	Spain	CENER

Name	Country	Company/Organization
Jan Helsen	Belgium	Vrije Universiteit Brussel
Jan-Frederik Uhlenkamp	Germany	BIBA - Institut für Produktion & Logistik / University Bremen
Jason Fields	United States	NREL
Javier Sanz Rodrigo	Spain	CENER
Jean-Thomas Meyer	Denmark	Orsted
John LaFleche	United States	GE Renewable Energy
John McCann	Ireland	SEAI, IEA Wind TCP Vice-Chair
Juan Ollo	Spain	CENER
Markus Taumberger	Finland	VTT
Michael D. Purdue	United States	NRG Systems
Michael Wilkinson	United Kingdom	DNV GL - Energy
Mike Optis	United States	NREL
Kevin Leahy	Ireland	University College Cork
Nadine Mounir	Switzerland	IEA Wind TCP
Nikolay Krasimirov	Denmark	DTU Wind
Paul Leahy	Ireland	University College Cork
Peter Gregg	United States	GE Renewable Energy
Piyush Verma	Ireland	International Energy Research Center
Ricardo Simon Carbajo	Ireland	UCD
Shane Holden	Ireland	Bord Na Mona
Shawn Sheng	United States	NREL
Steven H. Clark	United States	NRG Systems
Thomas Nemila	United States	Uptake
Vijayant Kumar	United States	Sentient Science

APPENDIX D - Brainstorming Session Material

Combined Group Brainstorming Outputs

	Effort (Low/Medium/High)		
Impact (High, Med, Low)	• Define analytical model types and sharing standards • Data marketplace for trading data • Standardized data - format structure and taxonomies. Event, alarm logs, SCADA reliability	• Workflow effort in labor • Metadata standards • More open source / validation • Definition of needed data • Reduce wind resource uncertainty/ reduce risk • Enable turbine data • Data sharing (getting it into the hands of those who'll use it.). Open-source for data pre-processing, taxonomy metadata standard, digital workflow for fast results. Easier access to hi-freq. SCADA. • Interoperability of tools and databases. • O&M – digitalization/AI for O&M, access for owners/operators to more granular service records, digitalize service records. • Wind farm control – optimize life consumption, energy prices and design life. Dynamic wake control.	• Policy to share data • Digital twins component/ turbine/farm/system • Plant optimization model refinement validation • Operational product/process data standards implemented • Quality worldwide met. database • Legacy equipment controls • Integration of diverse data sets • Reduce development costs/time • Close loop of predictions with actual data NEW/LEGACY • Improve control integration • Adoption of standards incl. IEC61400-25 • Edge computing/AI/analysis for fast turnaround. • Using blockchain to bypass utility. • Benchmarking of tools as enabler for benchmarking of assets.

	• Standard use case based contracts for data sharing • Proof of concept cases • Trust in new tools and methods grown from shared trust in underlying standards and reference implemented • One platform (standardized) enabling integration of different data system • Reduce failure rates & system failures • Improve availability • Enable predictive maintenance • Increased sensors / improved forecasting • Life assessment and extension.	• Universal tag/sensor mapping adoption by OEM's • Discovery from data • Public participation in profit • Ability to orchestrate workflows across best-of-breed tools from multiple vendors • Enhanced interoperability across industry • Enable data/energy market place • Life cycle management (DFx) – feedback analysis to turbine designers, design of reliability. • New standards for evaluation/testing protocols, Power curve modelling, operational performance assessment.	• Scalability • Maintenance documentation using new media • Flag failures to learn • Use gamers to test • Improve power performance • Reduced price cannibalization • Increase / improve demand response • Build visibility to align perspectives • Windfarm intercommunication to support short-term forecasting. • Digital twin for performance, efficiency, virtual sensors. Inspection techniques as input to twin models.
	• IEC (and others) Free of charge		• Partnering between SME's through connection

Post-Meeting Consolidation of Brainstorming Inputs

Consolidated brainstorming outputs, below, reflect ideas grouped under sub-headings or themes. Where a group included different Impact/Effort ratings, the highest value was assigned to the sub-group.

Mapping Impact/Effort to Priority/rank

Ranking	Low Effort	Medium Effort	High Effort
High Impact	9	8	7
Medium Impact	6	5	4
Low Impact	3	2	1

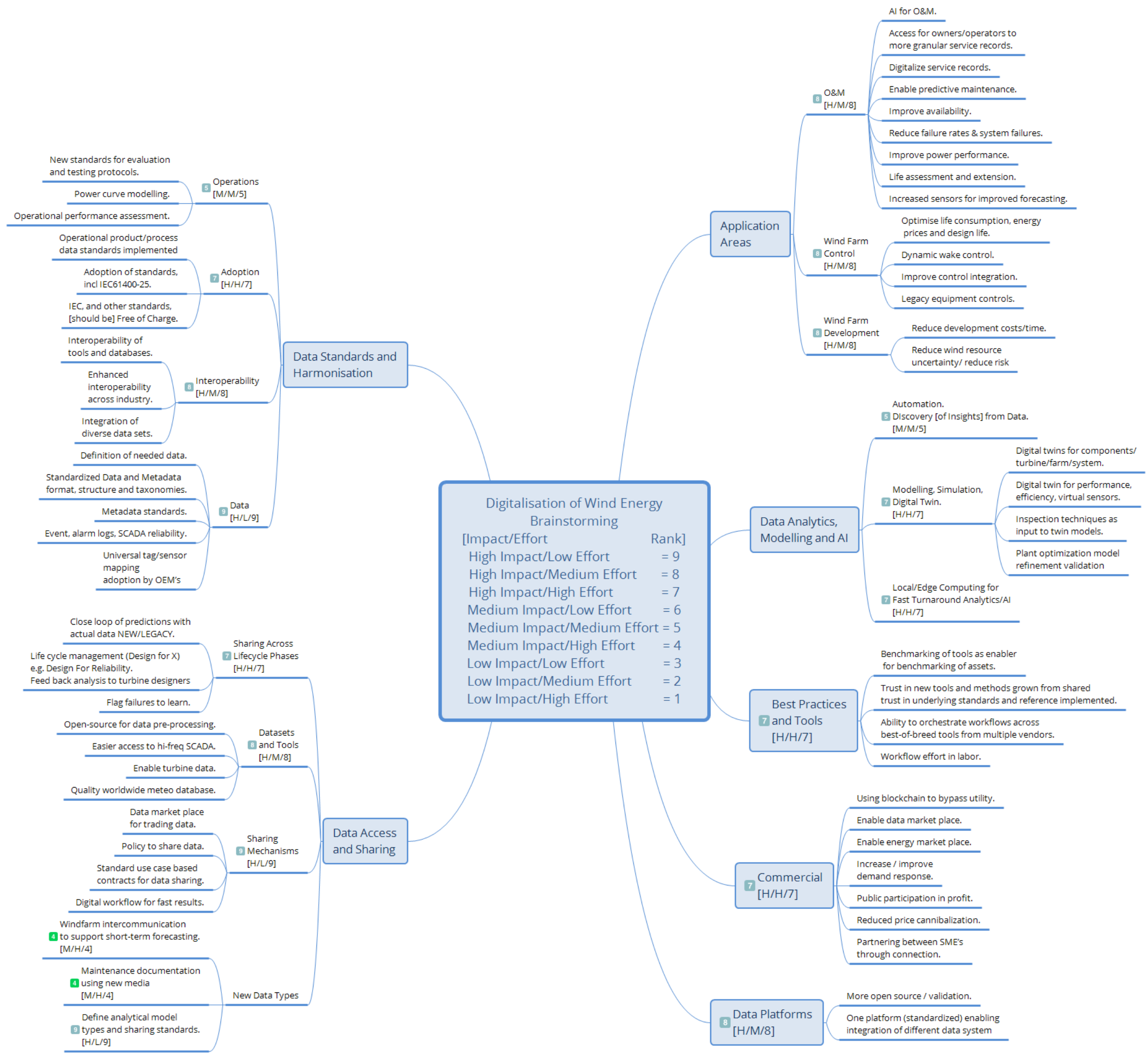
Consolidated Brainstorming Outputs (Tabular)

Category	Subcategory	Idea	Impact	Effort	Rank
Application Area	O&M	O&M – digitalization/AI for O&M. Access for owners/operators to more granular service records. Digitalize service records. Enable predictive maintenance. Improve availability. Reduce failure rates & system failures. Improve power performance. Life assessment and extension. Increased sensors for improved forecasting.	H	M	8
Application Area	Wind Farm Control	Wind farm control – optimize life consumption, energy prices and design life. Dynamic wake control. Improve control integration. Legacy equipment controls.	H	M	8
Application Area	Development	Reduce development costs/time. Reduce wind resource uncertainty/ reduce risk	H	M	8
Best Practices & Tools (Both Data/Technical and Operational Workflows)		Benchmarking of tools as enabler for benchmarking of assets. Trust in new tools and methods grown from shared trust in underlying standards and reference implemented. Ability to orchestrate workflows across best-of-breed tools from multiple vendors. Workflow effort in labor.	H	H	7
Commercial		Using blockchain to bypass utility. Enable data market place. Enable energy market place. Increase / improve demand response. Public participation in profit. Reduced price cannibalization. Partnering between SME's through connection.	H	H	7
Data Access & Sharing (Between lifecycle stages and among users)	Sharing Mechanisms	Data market place for trading data. Policy to share data. Standard use case based contracts for data sharing. Digital workflow for fast results.	H	L	9

Data Access & Sharing (Between lifecycle stages and among users)	Datasets and Tools	Open-source for data pre-processing. Easier access to hi-freq. SCADA. Enable turbine data. Quality worldwide met. database.	H	M	8
Data Access & Sharing (Between lifecycle stages and among users)	Sharing Across Lifecycle Stages	Close loop of predictions with actual data NEW/LEGACY. Life cycle management (Design for X) – feed back analysis to turbine designers, e.g. Design For Reliability. Flag failures to learn.	H	H	7
Data Access & Sharing (Between lifecycle stages and among users)	New Data Types	Maintenance documentation using new media	M	H	4
Data Access & Sharing (Between lifecycle stages and among users)	New Data Types	Windfarm intercommunication to support short-term forecasting.	M	H	4
Data Access & Sharing (Between lifecycle stages and among users)	New Data Types	Define analytical model types and sharing standards	H	L	9
Data Analytics, Modelling, ML, AI (Decision Support)	Modelling, Simulation, Digital Twin	Digital twins for components/turbine/farm/system. Digital twin for performance, efficiency, virtual sensors. Inspection techniques as input to twin models. Plant optimization model refinement validation	H	H	7
Data Analytics, Modelling, ML, AI (Decision Support)		Edge computing/AI/analysis for fast turnaround.	H	H	7
Data Analytics, Modelling, ML, AI (Decision Support)		Discovery from data	M	M	5
Data Platforms (Proprietary and Open Source curation, reporting, analytics)		More open source / validation. One platform (standardized) enabling integration of different data system	H	M	8
Data Standards & Harmonization (Adoption of existing and creation of new)	Data	Definition of needed data. Standardized data - format structure and taxonomies. Metadata standards. Event, alarm logs, SCADA reliability. Universal tag/sensor mapping adoption by OEM's	H	L	9
Data Standards & Harmonization (Adoption of existing and creation of new)	Interoperability	Interoperability of tools and databases. Enhanced interoperability across industry. Integration of diverse data sets.	H	M	8
Data Standards & Harmonization (Adoption of existing and creation of new)	Adoption	Operational product/process data standards implemented Adoption of standards incl IEC61400-25. IEC, and other standards, [should be] Free of Charge.	H	H	7

Data Standards & Harmonization (Adoption of existing and creation of new)	Operations	New standards for evaluation/testing protocols. Power curve modelling. Operational performance assessment.	M	M	5

Consolidated Brainstorming Outputs (Map)



APPENDIX E - IEA Agreement

International Energy Agency Agreement Implement Agreement for Co-operation in the

Research, Development and Deployment of Wind

Turbine Systems (IEA Wind)

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977 and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 26 contracting parties from 22 countries, the European Commission, and Wind Europe, participate in IEA Wind. Austria, Belgium, Canada, Denmark, the European Commission, EWEA, France, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Republic of China, Republic of Korea, Mexico, Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Two Subtasks

The task includes two subtasks.

The objective of the first subtask is to develop recommended practices (RP). Recent developed RPs were on "Wind Farm Data Collection and Reliability Assessment for O&M Optimization (Task 33)" (RP#17) and "Floating Lidar Systems (Task 32 in coordination with the Offshore Wind Accelerator initiative)" (RP#18).

The objective of the second subtask is to conduct topical expert meetings in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, Topical Expert Meetings are arranged four times a year.

Documentation

Since these activities were initiated in 1978, more than 80 volumes of proceedings have been published. In the series of Recommended Practices 19 documents were published and six of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task.

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COUNTRIES PRESENTLY PARTICIPATING IN THE TASK 11	
COUNTRY	**INSTITUTION**
Denmark	Danish Technical University (DTU) - Riso National Laboratory
Finland	Technical Research Centre of Finland - VTT Energy
Germany	Federal Ministry for Economic Affairs and Energy (BMWi)
Ireland	Sustainable Energy Ireland - SEI
Italy	Ricerca sul sistema energetico, (RSE S.p.A.)
Japan	New Energy and Industrial Technology Development Organization (NEDO)
Mexico	Instituto de Investigaciones Electricas - IEE

Netherlands	Rijksdient voor Ondernemend Nederland (RVO)
Norway	The Norwegian Water Resources and Energy Directorate - NVE
Republic of China	Chinese Wind Energy Association (CWEA)
Spain	Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas CIEMAT
Sweden	Energimyndigheten - Swedish Energy Agency
Switzerland	Swiss Federal Office of Energy - SFOE
United Kingdom	CATAPULT Offshore Renewable Energy
United States	The U.S Department of Energy -DOE