Workshop

State of the Art and Research Gaps in Forecasting for the Weather Driven Energy System

September 12/13 2022, University College Dublin

http://www.iea-wind.org/task51/

Agenda Mon 12 Sept, morning

09:00 *Gregor Giebel, DTU*: Welcome and introduction from the Operating Agent
09:30 *Conor Kavanagh, Eirgrid*: Forecasting Challenges in Ireland
10:00 *Eamonn Lannoye, EPRI*: Integrating forecasting into power system operations and planning – current gaps and research needs

11:00 Coffee break

11:20 *Malte Rieck, Meteorologist, Vattenfall Trading*: How are wind forecasts used operationally? A tour of marketing wind energy
11:50 *Edward McGarrigle, Galánta Energy*: On forecasting for trading
12:20 *Kathryn Fowler, Centrica Energy Trading*: Changing forecast requirements in a trading environment

12:50 Lunch break

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Agenda Mon 12 Sept, afternoon

12:50 Lunch break
13:40 *Caroline Draxl, co-Operating Agent, NREL:* The WFIP projects 1-3, and Forecasting for Airborne systems
14:00 *Irene Schicker, ZAMG:* Subseasonal forecasting
14:20 *Frédéric Vitart, ECMWF:* Season to Season (S2S) forecasts and their relevance for energy *(virtual)*
14:40 *Remco Verzijlbergh, Whiffle:* Very high resolution forecasting using LES on GPUs

15:50 Coffee break

16:10 Session on Extreme event definition and forecasting
16:10 *David Lenaghan, UK National Grid ESO*: An introduction to extreme events in future energy systems
16:40 OpenSpace discussion (30min) round of 3 topics: weather extremes, wind/solar power extremes, extreme events in the power grid.
17:20 Discussion in plenum

18:00 Close
Optional: Self-paid dinner at Farmer Brown's in Clonskeagh (walk from here, 68 Clonskeagh Road)

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Agenda Tue 13 Sept, morning

09:00 *Bradley Eck, IBM:* AI and cloud computing developments towards integrating renewables
09:25 *Ricardo Bessa, INESC TEC:* Smart4RES collaborative analytics for renewable energy forecasting: federated learning and data
09:45 *Paul Cuffe, UCD:* Prediction markets as forecasting and hedging instruments within the renewable electricity sector
10:10 Discussion speakers & audience (20 min)

10:40 Coffee break / Group picture

11:10 Open Space session: minute and hour scale forecasting, intraday and day-ahead forecasting, and week-ahead to season-ahead forecasting

12:30 Lunch break

Agenda Tue 13 Sept, afternoon

12:30 Lunch break

Kristian Horvath (DHMZ/WMO): The Energy study group
13:50 *David Lenaghan:* The Journey from deterministic to probabilistic – an introduction
13:35 *George Kariniotakis, Mines Paris:* How do the applications influence the forecasting tech evolution?
13:50 *Juan Sopena, Solute:* People just want numbers - How to fairly compare and interpret forecasts with a benchmarking framework for performance evaluation
Justin Rutherford:
14:05 ~~*Allison Campbell, PNNL:* Reconstructing forecast errors and how these can be compressed into something useful for power systems *(virtual)*~~
14:20 *Corinna Möhrlen, WEPROG:* Introduction to the probabilistic gaming concept, the games purpose and setup to demonstrate a real-time environment and how to integrate probabilistic forecasts into decision making processes (automatically as well as with human intervention) *(30min).*
14:45 Playing the IEA Wind/WEXICOM Forecast Game *(30min).*

15:00 Coffee break
Results from the game
15:30 Panel discussion and Q&A

Agenda Wed 14 Sept, morning

09:00 Work Stream status+plans, 8 min per Work Stream

11:00 Coffee Break

11:30 Next steps: next meeting, next workshop, SOTA paper, AOB

13:00 Close / Lunch

IEA Wind Task 51 “Forecasting for the Weather Driven Energy System”

Gregor Giebel, DTU Wind and Energy Systems

H. Frank, C. Draxl, J. Zack, J. Browell, C. Möhrlen, G. Kariniotakis, R. Bessa, D. Lenaghan

25 May 2022

Photography encouraged

International Energy Agency History

The IEA was founded in 1974 to help countries co-ordinate a collective response to major disruptions in the supply of oil.

Image source: dpa

Specific Technology Collaboration Programs (in renewable energy):

Bioenergy TCP
Concentrated Solar Power (SolarPACES TCP)
Geothermal TCP
Hydrogen TCP
Hydropower TCP
Ocean Energy Systems (OES TCP)
Photovoltaic Power Systems (PVPS TCP)
Solar Heating and Cooling (SHC TCP)
Wind Energy Systems (Wind TCP)

See iea.org!

iea Energy Technology Network

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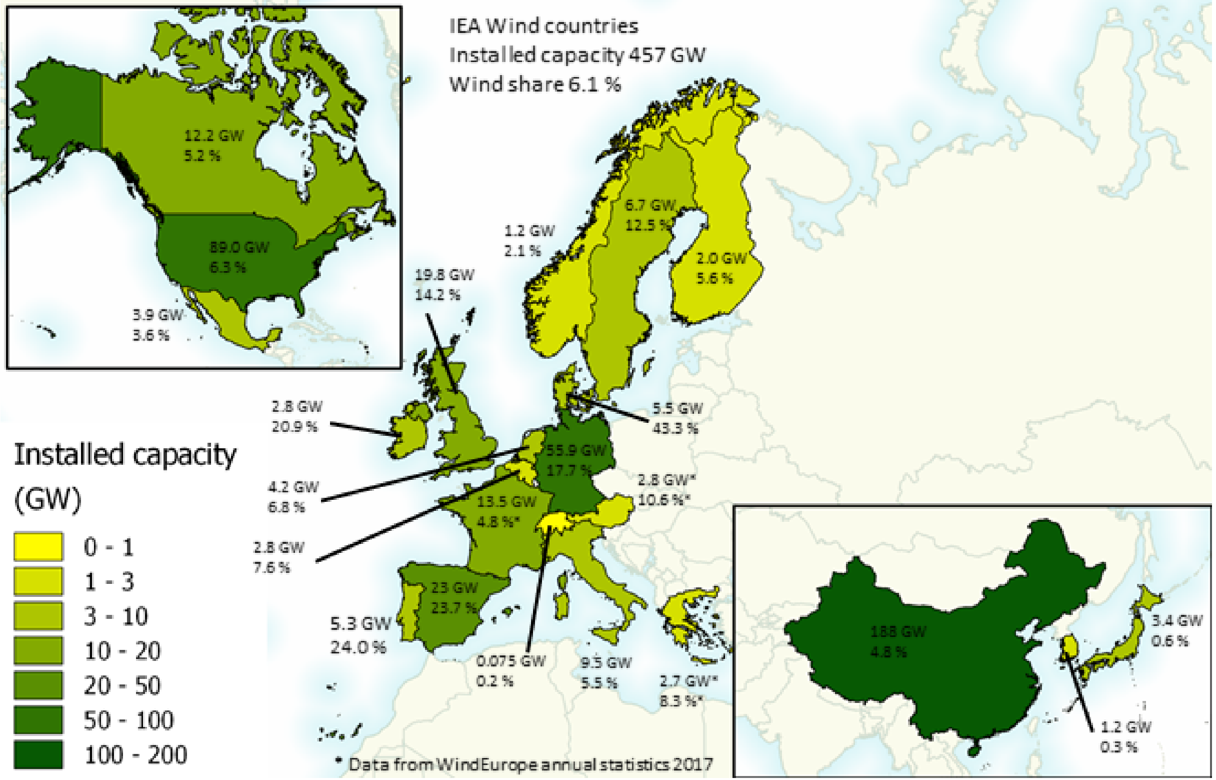
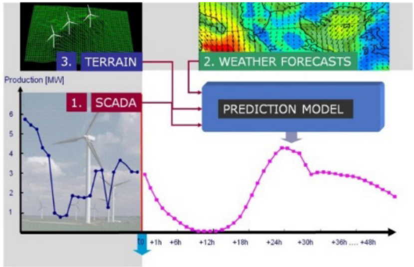


Task 51 members:

AT, CN, DE, DK, ES, FI, FR, IE, PT, SE, UK, US

Deterministic approaches

Hybrid approaches



Next generation of tools

Focus on extremes

Diversify predicted information

Spatio-temp

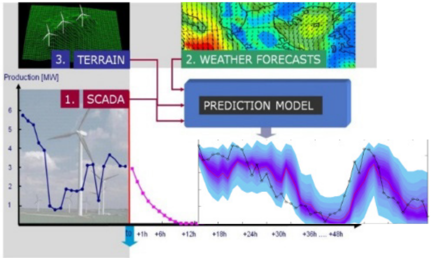
Ramp forecasting

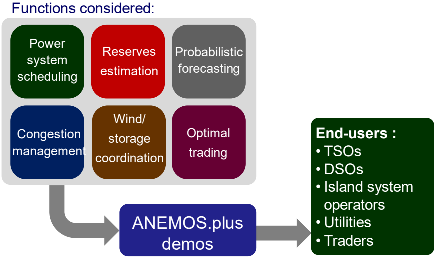
Cut-off forecasting

Alarming, risk indices

Link to meteorology etc

1990 — 2002 Anemos — 2008 SafeWind ANEMOS./plus — 2016 iea wind





Probabilistic approaches

1st Benchmarking

Towards standardisation

Combined forecasts (multi model/NWPs)

Link forecasts to the application

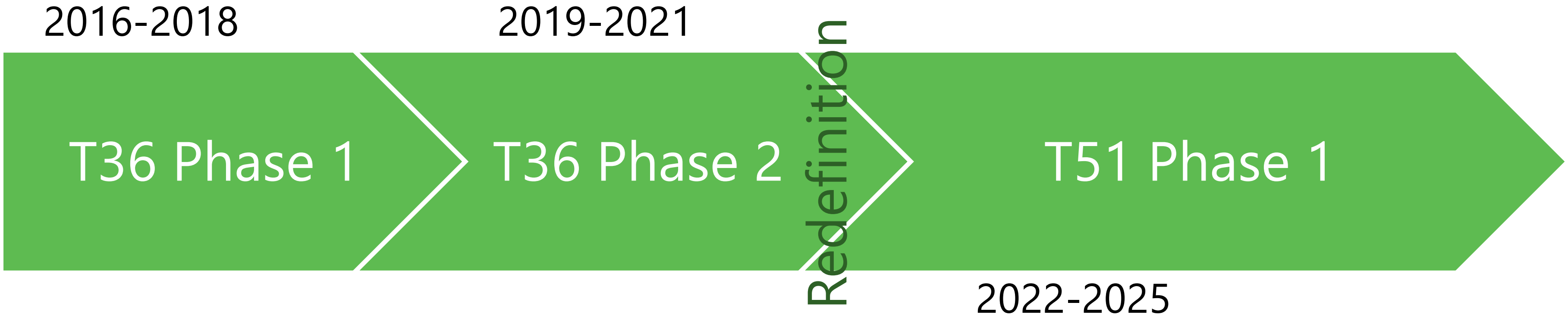
Power system management/trading

Stochastic optimisation

Demonstration

For a relatively complete list of forecasting projects, see the Information Portal on iea-wind.org/task51 !

Forecasting for Wind Energy



Forecasting for the Weather Driven Energy System

Task Objectives & Expected Results

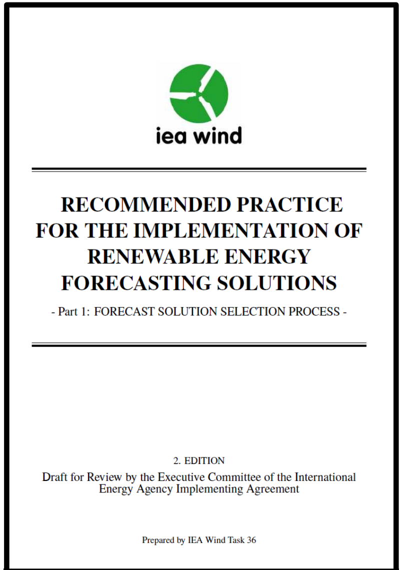
Task Objective is to encourage improvements in:
1) weather prediction
2) power conversion
3) use of forecasts

Task Organisation is to encourage international collaboration between:
- → Research organisations and projects
- → Meteorologists
- → Forecast providers
- → End-users and stakeholders

Task Work is divided into 3 work packages:
WP1: Weather Prediction Improvements
WP2: Power and Uncertainty Forecasting
WP3: Optimal Use of Forecasting Solutions

Current Term: 2022-2025

IEA Best Practice Recommendations for the Selection of a Wind Forecasting Solution v2: Set of 4 Documents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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

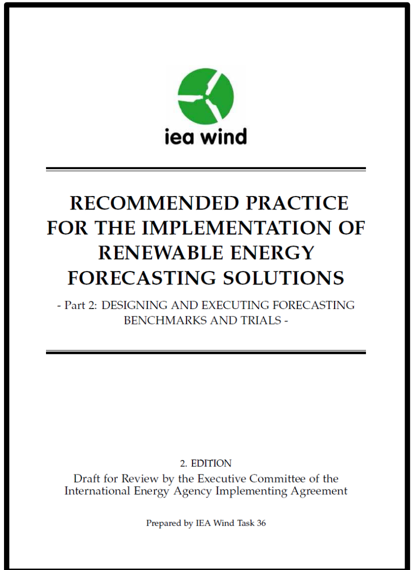
- Part 1: FORECAST SOLUTION SELECTION PROCESS -

2. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 1: Selection of an Optimal Forecast Solution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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

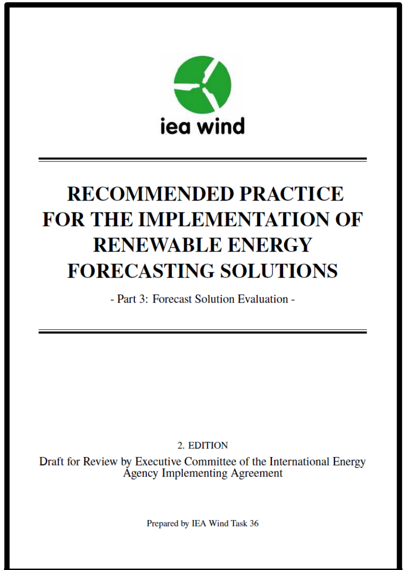
- Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS -

2. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 2: Design and Execution of Benchmarks and Trials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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

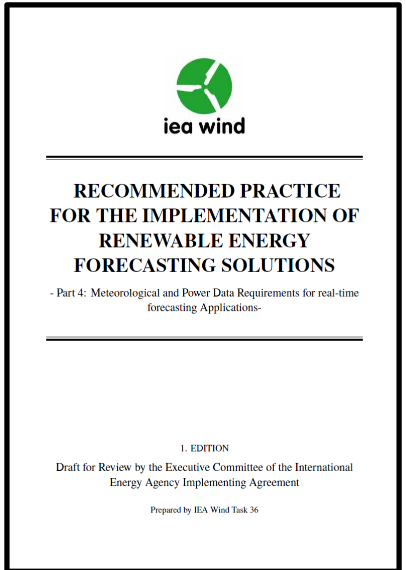
- Part 3: Forecast Solution Evaluation -

2. EDITION

Draft for Review by Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 3: Evaluation of Forecasts and Forecast Solutions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RECOMMENDED PRACTICE FOR THE IMPLEMENTATION OF RENEWABLE ENERGY FORECASTING SOLUTIONS

- Part 4: Meteorological and Power Data Requirements for real-time forecasting Applications-

1. EDITION

Draft for Review by the Executive Committee of the International Energy Agency Implementing Agreement

Prepared by IEA Wind Task 36

Part 4: Data Requirements for Real-time Applications

Finalising now - also as book!

Introduction: https://www.youtube.com/watch?v=XVO37hLE03M

Elsevier Open Book

PREORDER NOW!

ISBN: 978-0-443-18681-3

PUB DATE: November 2022

LIST PRICE: $150.00

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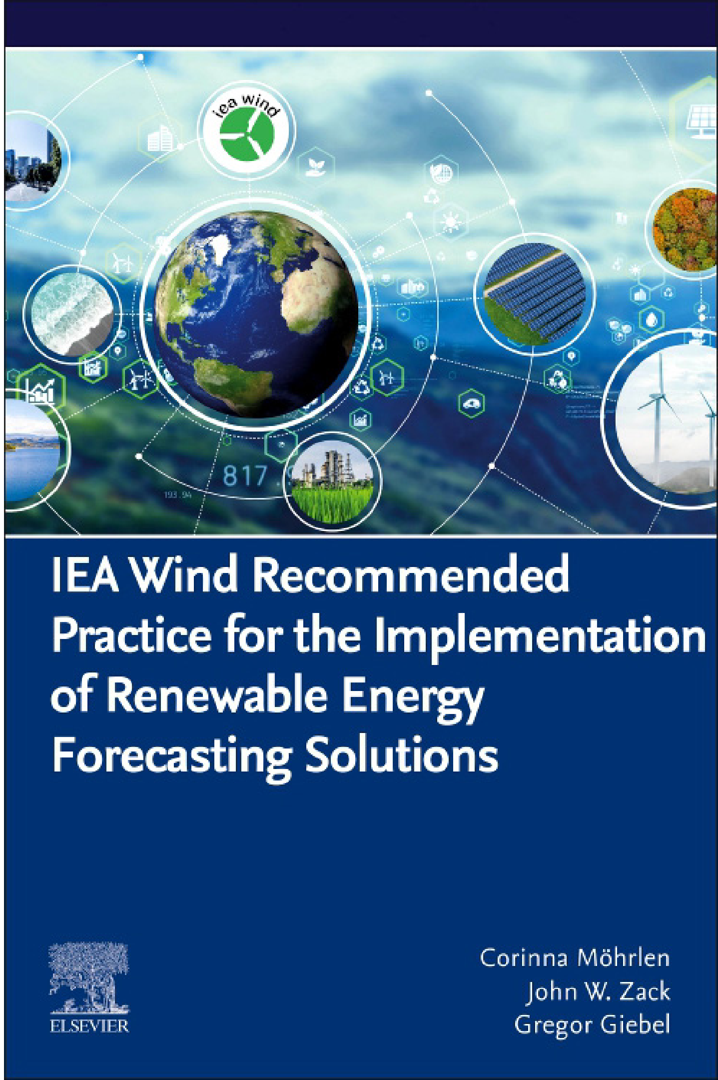
FORMAT: Paperback

Editors: Corinna Möhrlen, John W. Zack, and Gregor Giebel

https://www.elsevier.com/books/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions/mohrlen/978-0-443-18681-3



Review of uncertainty propagation

- Conceptual paper on the origins and propagation of uncertainty through the forecasting chain (D2.2)
- Wind and solar power
- Renewable and Sustainable Energy Reviews 2022

- Next paper should use data and quantify the contributions

Uncovering wind power forecasting uncertainty origins and development through the whole modelling chain⋆,⋆⋆

Jie Yan[a], Corinna Möhrlen[b], Tuhfe Göçmen[c], Mark Kelly[c], Arne Wessel[d] and Gregor Giebel[c,*]

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ARTICLE INFO

Keywords:
wind power
forecast uncertainty
modelling chain

ABSTRACT

Wind power forecasting has been supporting operational decision-making for power system and electricity markets since 30 years. Efforts of improving the accuracy and/or certainty of wind power forecasts, either deterministic or probabilistic, are continuously exerted by academics and industries. Forecast errors and associated uncertainties, which propagate through the whole forecasting chain, from weather provider to the end user, cannot be eliminated completely due to many reasons; for instance, endogenetic randomness of weather systems and varying wind turbine performance. Therefore, understanding the sources of uncertainty and how these uncertainties propagate throughout the modelling chain is significant to implement more rational and targeted uncertainty mitigation strategies and standardise the uncertainty validation. This paper presents a thorough review of the uncertainty propagation through the modelling chain, from the planning phase of the wind farm and the forecasting system through the operational phase and market phase. Moreover, the definition of the uncertainty sources throughout these phases build the guiding line of uncertainty mitigation throughout this review. In the end, a discussion on uncertainty validation is provided along with some examples. Highlights of this paper include: 1) forecasting uncertainty exists and propagates everywhere throughout the entire modelling chain and from planning phase to market phase; 2) the mitigation efforts should be exerted in every modelling step; 3) standardised uncertainty validation practice and global data samples are required for forecasters to improve model performance and for forecast users to select and evaluate the model's output.

1. Introduction

High penetration of wind power has been recognised globally as one of the most important features of current and future sustainable power systems. The natural randomness and variability of the wind itself can aggravate negative impacts of wind power on power system operation and market trading, which strengthens the significance of forecasting technology. Wind power forecasting (WPF) started more than three decades ago [16], with the first operational forecasting tools arriving at system operation level some 10 years later at the Danish transmission system operator ELSAM [10]. Since then, researchers have been making continuous efforts to improve the forecasting accuracy and reliability.

It is impossible to achieve perfect predictions of wind power at any given time or location, due to chaotic atmospheric motions having temporal and spatial scales that typically span more than six orders of magnitude [17, 18, 19]. Along with the complex wind field, wind turbine performance creates nonlinear and time-varying uncertainties in wind power forecasting. To improve the value of forecasts and their usage, we practically consider three questions: why, when and to what extent the forecasting uncertainty will happen [20]. Accordingly, this further guides the mitigation of forecasting uncertainty. There is plenty of literature in this area, and can be clarified into following three categories.

* 'This paper was coordinated under the auspices of IEA Wind Task 36 'Forecasting for Wind Energy'. Corinna Mörlen, Tuhfe Göçmen, Mark Kelly and Gregor Giebel were funded by the Danish EUDP project "IEA Wind Task 36 Phase II Danish Consortium", Grant Number 64018-0515.
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Yan et al.: *Preprint submitted to Elsevier* Page 1 of 42

Broader paper on uncertainty forecasting

Prediction Models Designed to Prevent Significant Errors

By Jan Dobschinski, Ricardo Bessa, Pengwei Du, Kenneth Geisler, Sue Ellen Haupt, Matthias Lange, Corinna Möhrlen, Dora Nakafuji, and Miguel de la Torre Rodriguez

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Uncertainty Forecasting in a Nutshell

DOI: *10.1109/MPE.2017.2729100*

Digital Object Identifier 10.1109/MPE.2017.2729100
Date of publication: 18 October 2017

IT IS IN THE NATURE OF CHAOTIC ATMOspheric processes that weather forecasts will never be perfectly accurate. This natural fact poses challenges not only for private life, public safety, and traffic but also for electrical power systems with high shares of weather-dependent wind and solar power production.

To facilitate a secure and economic grid and market integration of renewable energy sources (RES), grid operators and electricity traders must know how much power RES within their systems will produce over the next hours and days. This is why RES forecast models have grown over the past decade to become indispensable tools for many stakeholders in the energy economy. Driven by increased grid stability requirements and market forces, forecast systems have become tailored to the end user's application and already perform reliably over long periods. Apart from a residually moderate forecast error, there are single extreme-error events that greatly affect grid operators.

Nevertheless, there are also forecast systems that provide additional information about the expected forecast uncertainty and estimations of both moderate and extreme errors in addition to the "best" single forecast. Such uncertainty forecasts warn the grid operator to prepare to take special actions to ensure grid stability.

The State of the Art in Forecast Generation

Today, some forecast systems have been developed specifically to predict the power production of single wind and solar units, differently sized portfolios, local transformer stations and subgrids, distribution and transmission grids, and entire countries. Nearly all forecast systems have one thing in common: they rely on numerical weather predictions (NWPs) to calculate the expected RES power production. The way to transform weather predictions into power forecasts depends crucially on the end user's application and the available plant configuration and measurement data. If historical measurements are available, forecast model developers often use statistical and machine-learning techniques to automatically find a relation between historical weather forecasts and simultaneously observed power measurements. If no historical measurement data are available, e.g., for new installations of RES units, the transformation of weather to power is often accomplished by physically based models that consider the unit's parameters to map the internal physical processes.

1540-7977/17©2017IEEE

Use of probabilistic forecasting

Open Access journal paper

48 pages on the use of uncertainty forecasts in the power industry

Definition – Methods – Communication of Uncertainty – End User Cases – Pitfalls - Recommendations

Source: http://www.mdpi.com/1996-1073/10/9/1402/

energies

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Review

Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry

Ricardo J. Bessa [1,*], Corinna Möhrlen [2], Vanessa Fundel [3], Malte Siefert [4], Jethro Browell [5], Sebastian Haglund El Gaidi [6], Bri-Mathias Hodge [7], Umit Cali [8] and George Kariniotakis [9]

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Academic Editor: David Wood
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Abstract: Around the world wind energy is starting to become a major energy provider in electricity markets, as well as participating in ancillary services markets to help maintain grid stability. The reliability of system operations and smooth integration of wind energy into electricity markets has been strongly supported by years of improvement in weather and wind power forecasting systems. Deterministic forecasts are still predominant in utility practice although truly optimal decisions and risk hedging are only possible with the adoption of uncertainty forecasts. One of the main barriers for the industrial adoption of uncertainty forecasts is the lack of understanding of its information content (e.g., its physical and statistical modeling) and standardization of uncertainty forecast products, which frequently leads to mistrust towards uncertainty forecasts and their applicability in practice. This paper aims at improving this understanding by establishing a common terminology and reviewing the methods to determine, estimate, and communicate the uncertainty in weather and wind power forecasts. This conceptual analysis of the state of the art highlights that: (i) end-users should start to look at the forecast's properties in order to map different uncertainty representations to specific wind energy-related user requirements; (ii) a multidisciplinary team is required to foster the integration of stochastic methods in the industry sector. A set of recommendations for standardization and improved training of operators are provided along with examples of best practices.

Minute scale forecasting

- How to use Lidars, Radars or SCADA for very short term forecasts
- 30 sec – 15 min.
- Workshop with Task 32 Lidars at Risø 12/13 June 2018.
- Slides available from workshop website.
- Complete workshop on YouTube.
- Summary paper in Energies journal.

Minute scale forecasting

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Article

Minute-Scale Forecasting of Wind Power—Results from the Collaborative Workshop of IEA Wind Task 32 and 36

Ines Würth [1,*], Laura Valldecabres [2], Elliot Simon [3], Corinna Möhrlen [4], Bahri Uzunoğlu [5,6], Ciaran Gilbert [7], Gregor Giebel [3], David Schlipf [8] and Anton Kaifel [9]

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Received: 14 December 2018; Accepted: 14 February 2019; Published: 21 February 2019

check for updates

Abstract: The demand for minute-scale forecasts of wind power is continuously increasing with the growing penetration of renewable energy into the power grid, as grid operators need to ensure grid stability in the presence of variable power generation. For this reason, IEA Wind Tasks 32 and 36 together organized a workshop on "Very Short-Term Forecasting of Wind Power" in 2018 to discuss different approaches for the implementation of minute-scale forecasts into the power industry. IEA Wind is an international platform for the research community and industry. Task 32 tries to identify and mitigate barriers to the use of lidars in wind energy applications, while IEA Wind Task 36 focuses on improving the value of wind energy forecasts to the wind energy industry. The workshop identified three applications that need minute-scale forecasts: (1) wind turbine and wind farm control, (2) power grid balancing, (3) energy trading and ancillary services. The forecasting horizons for these applications range from around 1 s for turbine control to 60 min for energy market and grid control applications. The methods that can be applied to generate minute-scale forecasts rely on upstream data from remote sensing devices such as scanning lidars or radars, or are based on point measurements from met masts, turbines or profiling remote sensing devices. Upstream data needs to be propagated with advection models and point measurements can either be used in statistical time series models or assimilated into physical models. All methods have advantages but also shortcomings. The workshop's main conclusions were that there is a need for further investigations into the minute-scale forecasting methods for different use cases, and a cross-disciplinary exchange of different method experts should be established. Additionally, more efforts should be directed towards enhancing quality and reliability of the input measurement data.

Keywords: wind energy; minute-scale forecasting; forecasting horizon; Doppler lidar; Doppler radar; numerical weather prediction models

WP3 End-user Workshop in Glasgow

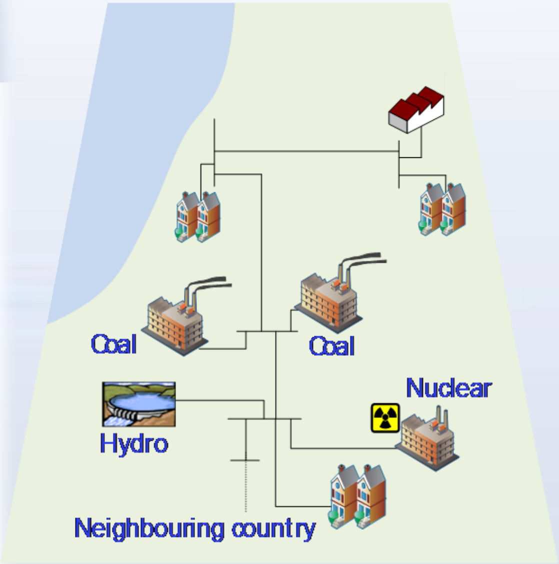
“Maximising Value from State-of-the-art Wind Power Forecasting Solutions”

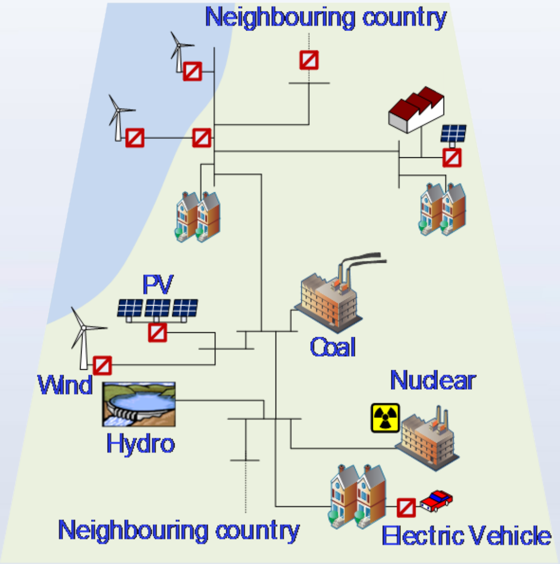
hosted by Jethro Browell at Strathclyde University, Glasgow, 21 Jan 2020

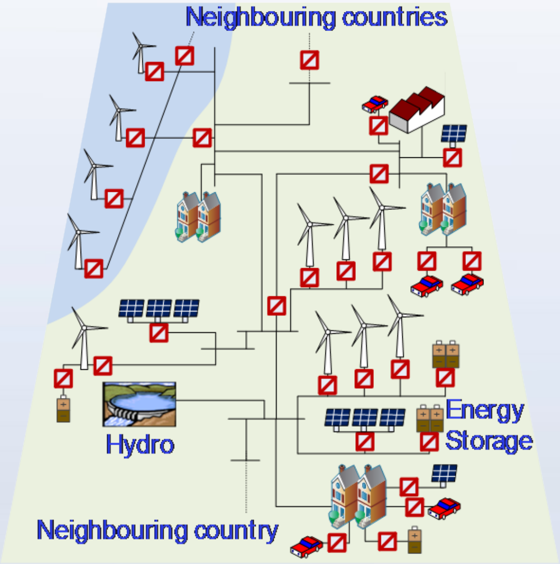
- Talks by academia and industry (e.g. UK National Grid, WindPoint, UStrathclyde)
- Open Space discussion on RP, data and forecast value
- Game on value of probabilistic forecasts: https://mpib.eu.qualtrics.com/jfe/form/SV_d5aAY95q2mGI8El
- Streamed on YouTube: https://www.youtube.com/watch?v=1NOIr7jIuXI

From Wind Integration to Energy Systems

(almost) no RES	Some RES	100% RES
Past	**Present**	**Future**







Forecasting needs: little

All RES seperately

All RES with correct correlations and longer time scales

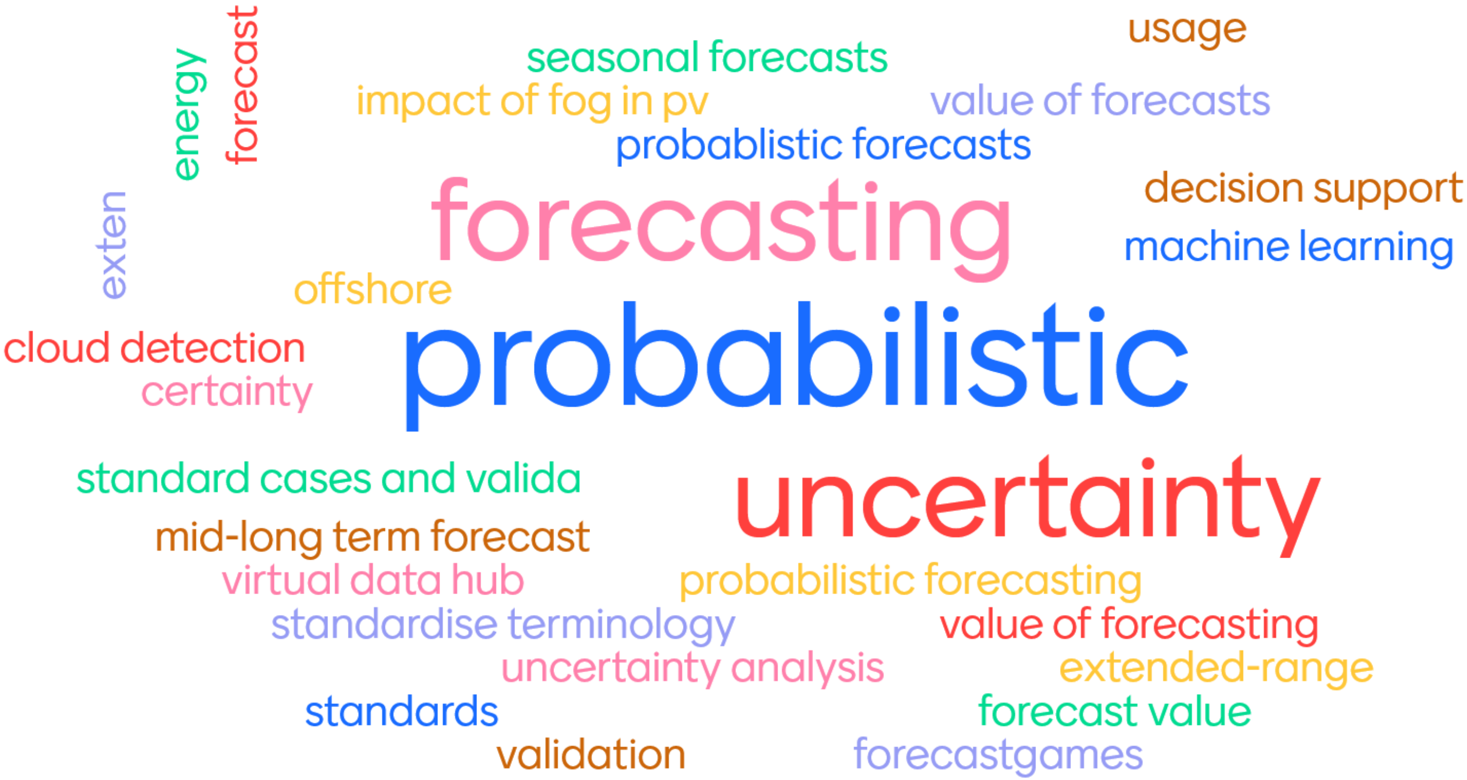
Slide design: Ömer Göksu and Nicos Cutululis

Next: Forecasting for the Weather Driven Energy System

Preparations for the next phase of forecasting collaboration are ongoing. A recent Task meeting yielded this word cloud.

Strong collaboration with other TCPs.

To start 2022.



Work Streams:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Atmospheric physics and modelling (WP1)	★			List of experiments and data	D1.1, Ongoing	WMO, PVPS T16
Airborne Wind Energy Systems (WP1)	★			Presentations on workshops	Part of D2.1	Task 48 Airborne Wind Energy
Seasonal forecasting (WP1)	★			Workshop / Paper	D1.6 / M19	Hydro TCP, Hydrogen TCP, Biomass TCP
State of the Art for energy system forecasting (WP2)		★		Workshop / Paper RecPract on Forecast Solution Selection v3	D2.1 / M7, M12 M2.1 / M36	PVPS Task 16, Hydro TCP, Hydrogen TCP, …
Forecasting for underserved areas (WP2)		★		Public dataset	D2.4 / M24	WMO
Minute scale forecasting (WP2)		★		Workshop / Paper	D2.5 / M31, M36	Wind Tasks 32 Lidar, 44 Farm Flow Control and 50 Hybrids
Uncertainty / probabilistic forecasting (WP3)			★	Uncertainty propagation paper with data RecPract v3	D 2.6 / M42 M48	PVPS T16
Decision making under uncertainty (WP3)			★	Training course Games	M12 M18	
Extreme power system events (WP3)			★	Workshop	D3.6 / M42	Task 25, ESIG, IEA ISGAN, PVPS T16, G-PST
Data science and artificial intelligence (WP3)			★	Report	D2.3 / M30	
Privacy, data markets and sharing (WP3)			★	Workshop / Paper Data format standard	D3.5 / M15	ESIG IEEE WG Energy Forecasting
Value of forecasting (WP3)			★	Paper	D 3.4 / M33	
Forecasting in the design phase (WP3)			★			Task 50 (hybrids), PV T16, hydrogen TCP

WS State of the Art and Research Gaps

WS:	WP1 Weather	**WP2 Power**	WP3 Applications	**Deliverable**	**#, Due**	**Collaboration**
State of the Art for energy system forecasting (WP2)				Workshop / Paper RecPract on Forecast Solution Selection v3	D2.1 / M7, M12 M2.1 / M36	PVPS Task 16, Hydro TCP, Hydrogen TCP, …

In year 1, the new Task will organise a **workshop** on the state of the art and future research issues in energy forecasting, inviting other TCPs (PVPS Task 16 already has voiced interest). The workshop is modelled after the first workshop in Task 36, which established a baseline and research agenda. The established state-of-the art will be carried forward in the recommended practice guideline for forecasting solution selection and its dissemination to the industry at workshops, webinars, conferences, white papers and a book publications. Every WP contributes to this activity.

D 2.1: **Workshop** and paper on **state-of-the-art and future research issues** in the forecasting of weather-dependent energy system variables (M7=Summer 2022, M12=Dec 2022) -> **September in Dublin!**

M 2.1: Version 3 of IEA Recommended Practice on Forecast Solution Selection (M36=Dec 2024)

Work stream Atmospheric Physics

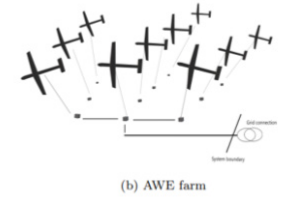
WS:	**WP1 Weather**	WP2 Power	WP3 Applications	**Deliverable**	**#, Due**	**Collaboration**
Atmospheric physics and modelling (WP1)				List of experiments and data	D1.1, Ongoing	WMO, PVPS T16

Knowing the atmosphere and its developments is the basis for forecasting for all horizons beyond a few hours. Especially with the new emphasis on seasonal forecasting and forecasts for storage management, the weather forecasts are in focus. This work stream spans mostly WP1, where the larger meteorological centres are at home, but crosses over into WP2, where the derived application variables need knowledge of the meteorology.

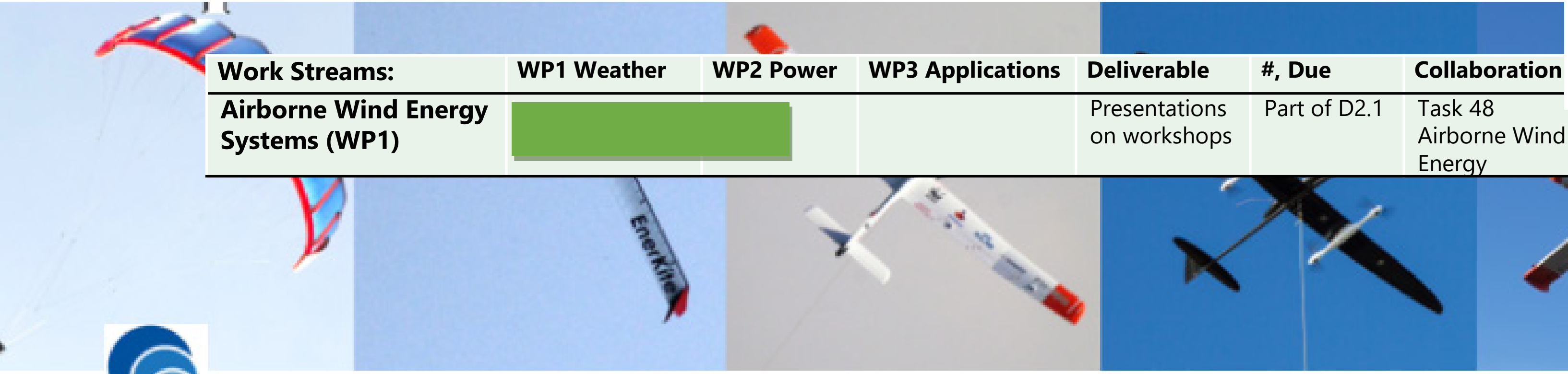
D 1.1: Online summary of major field studies supportive of wind forecast improvement; list of available data (ongoing)

Image source: NOAA

Work stream Airborne Wind Energy



Work Streams:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Airborne Wind Energy Systems (WP1)				Presentations on workshops	Part of D2.1	Task 48 Airborne Wind Energy



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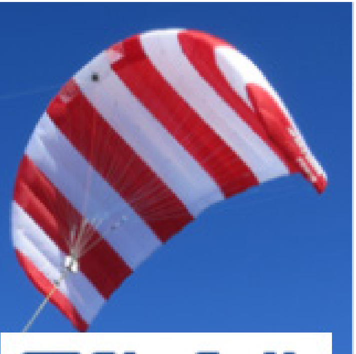
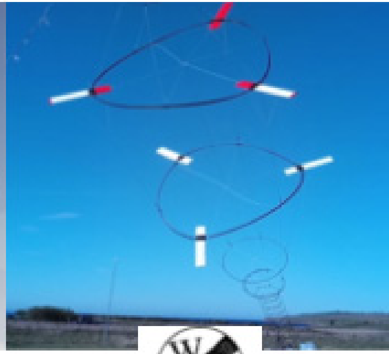


- Novel topic, winds in 300-600m height
- Mapping state of the art on workshop
- Collaboration with Task 48

Image source: Task 48 presentation on IEA Wind ExCo 88, Nov 2021



SkySails POWER

SKYPULL

RWTH AACHEN UNIVERSITY

KITE//KRAFT

Windswept & Interesting

WS Seasonal Forecasting

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Seasonal forecasting (WP1)				Workshop / Paper	D1.5 / M19	Hydro TCP, Hydrogen TCP, Biomass TCP

Seasonal forecasts are growing in importance for the power grid planning, especially, where hydropower, storage and other technologies are involved. This topic is also interlinked to the uncertainty forecasting work stream and will focus on the communication between weather and energy community. Seasonal forecasts are a subset of weather forecasting, and are therefore managed by WP1. WP3 will interlink these communities and serve as a platform to establish new applications for the use of seasonal forecasting in the energy community and the transformation into a carbon free energy system.

D 1.5: Convene workshop and develop paper on seasonal forecasting, emphasizing hydro and storage (M19)

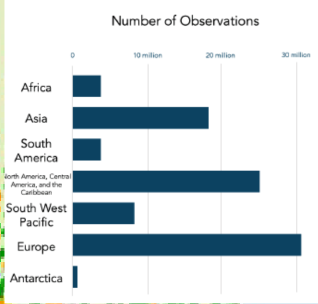
Data source SEAS5 ensemble mean from C3S ECMWF | Reference 1993-2016 | Run

Background image: Vortex FdC

Wind Speed Anomaly @ 100m - [%]

WS Forecasting for underserved areas

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Forecasting for underserved areas (WP2)				Public dataset	D2.4 / M24	WMO

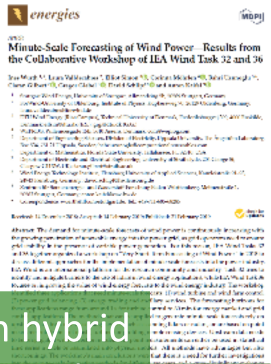


Forecasting in the established markets like Europe, North America or China has both a long tradition, and a well-established infrastructure. But in sync with the wind industry opening up new markets for the technology, the grid operators and/or market participants need good solutions to deal with the novel influx of power. However, both data availability and possibly market or grid code structures might be quite different in those places. The quality of the forecast needs to be provided by the vendors, which is why this WS is run by WP2. The recommended practices for the implementation of renewable energy forecasting solutions will also serve the under-served markets as valuable guidelines. An adaptation considering the limitations of under-served or emerging countries will be one focus area in collaboration with WP1.

D 2.4: Inventory and web interface of data and tools for forecasting applications in underserved areas. (M24)

Graphics source: WMO 2021: The value of Surface-Based Meteorological Observation Data: Costs and benefits of the Global Basic Observing Network. Image source: WMO

WS Minute scale forecasting


energies
Minute-Scale Forecasting of Wind Power—Results from the Collaborative Workshop of IEA Wind Task 32 and 36

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Minute scale forecasting (WP2)				Workshop / Paper	D2.5 / M31, M36	Wind Tasks 32 Lidar, 44 Farm Flow Control and 50 Hybrids, PVPS T16

On the power plant level, forecasts some minutes ahead can be used for battery control in hybrid power plants, in wind farm flow control (it takes minutes for the wind field to pass through a larger wind farm), and sometimes also in market structures like the Australian market, which operates on a 5-min schedule. Advances in minute-scale forecasting have been investigated in phase 2 and will be further developed and communicated to the industry. Since minute scale forecasting mainly uses data driven tools (statistical or machine learning), the WS is administered by WP2, but has connections to WP1 for knowing the wind flow through a farm, and to WP3 with regards to usage of the forecasts. We plan to have a workshop together with the IEA Wind Tasks on Lidar and on Hybrid Power Plants, and possibly others.

D 2.5: Workshop and paper on minute-scale forecasting for hybrid power plants or wind farm control, in conjunction with Task 32 on Lidars, Task 44 on Farm Flow Control and Task 50 on Hybrid Power Plants (M31=Summer 2024, M36)

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WS Uncertainty / Probabilistic FC / Decision making

WS:	WP1 Weather	WP2 Power	**WP3 Applications**	**Deliverable**	**#, Due**	**Collaboration**
Uncertainty / probabilistic forecasting / decision making under uncertainty (WP3)				Uncertainty propagation paper with data Games RecPract v3 Training course	D 2.6 / M42 M18 M48 M12	PVPS T16

Uncertainty is inherent in the forecasting of weather driven power generation. The preparation of calibrated uncertainty measures is done by the WP2 stakeholders. In WP3, the integration of forecast uncertainty into power grid management, wind power bidding strategies, and storage operation, will be analysed considering the role of humans (and their perception of uncertainty and risk), costs and benefits of end-users. Since this is the research topic needing more attention, WP3 is responsible for this WS. Analysis of critical bottlenecks in forecasting accuracy, as well as validation and value determination, are topics that will be dealt with in interdisciplinary groups and collaborations with associated partners and other WPs. Additionally, a qualitative overview paper of the propagation of uncertainty through the modelling chain was submitted in mid-2021. A natural extension of the work is to use the techniques on real data, to calculate the results and to publish it as a new paper.

D 2.6: Paper on uncertainty propagation in the modelling chain, using quantitative data (M42)

M 2.1: Version 3 of IEA Recom. Practice on Forecast Solution Selection (M36)

WS Extreme Power System Events

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Extreme power system events (WP3)				Workshop	D3.6 / M42	Task 25, ESIG, IEA ISGAN, PVPS T16, G-PST

Weather extremes are a threat to the power system, not only due to destruction of hardware, but also due to inadequate unit commitment, grid planning and available generation units. The challenges are broad and reach into the power markets, where extreme prices can be caused by extreme weather events. Knowledge and exchange of information on how to forecast extremes and mitigate effects from such extremes are topics that need attention in the next phase. While there is a strong weather dependency in this WS, the work will be structured according to the needs of the end users, and therefore administered by WP3.

D 3.6: Convene **workshop** on extreme power system events (M42, summer 2025)

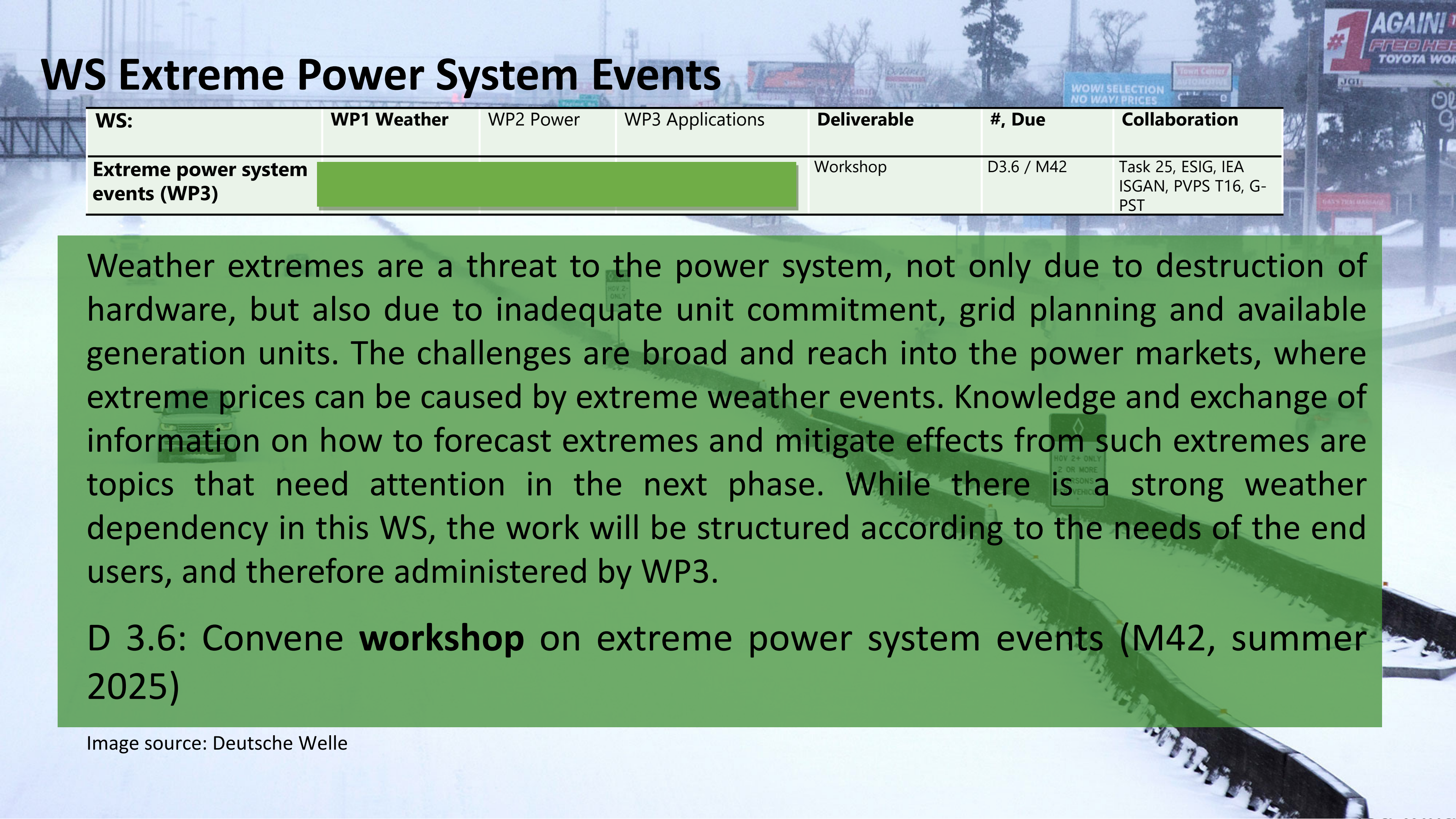

Image source: Deutsche Welle

WS Data Science and Artificial Intelligence

WS:	WP1 Weather	WP2 Power	**WP3 Applications**	**Deliverable**	**#, Due**	**Collaboration**
Data science and artificial intelligence (WP3)				Report or paper	D2.3 / M30	

Data-driven decision-making under risk and uncertainty is being augmented with advances in data science (e.g., deep learning with heterogeneous data sources) and artificial intelligence (e.g., reinforcement learning for optimization) techniques. WP3 will administer the WS and will collect success cases of application in the forecasting and decision-making domain of wind power forecasting, and study different paradigms for integrating uncertainty, data science and AI, such as: human-in-the-loop decision making, digital twins for decision support, interactive machine learning, etc. Finally, trust and security of data-driven methods will be a topic of analysis, in particularly considering industry requirements for integrating new technologies in their business processes. For meteorologists, the numerical weather prediction models change faster than the climate. How can the local adaption or some kind of AI adapt to this without running a new and old model in parallel for a long time? To shorten this parallel time would free up some effort to be used somewhere else.

D 2.3: Report and conference papers on techniques to optimize the use of data science/AI tools for the forecasting of energy-application variables (M30)

WS Privacy, Data Markets and Sharing

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Privacy, data markets and sharing (WP3)				Workshop / Paper Data format standard	D3.5 / M15	ESIG, IEEE WG Energy Forecasting

The transformation of the energy system towards a carbon free generation, and the EU strategy for Common European data spaces that will ensure that more data becomes available for use in the economy and society, requires new policies for data sharing (monetary and non-monetary incentives) and privacy, but also developments of regulatory frameworks and data market designs. This will cover different use cases, such as forecasting and operation & maintenance of wind power plants, where data sharing across the energy value chain can bring benefits for multiple stakeholders (e.g., improved predictability, reduced O&M costs, improvement of turbine component reliability, etc.). The Task also develops its own API, to become a common open-source framework, standardised across vendors, and looks into other data transfer issues.

D 3.5: Summary of use cases, such as forecasting and operation & maintenance of wind power plants to show benefits of data sharing across the energy value chain (M15)

WS Value of Forecasting

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Value of forecasting (WP3)				Paper	D 3.4 / M33	

Without value for the end users, there wouldn't be a market for forecasts. The incremental value of increase accuracy is though much harder to assess. The value proposition is though quite country and market specific. Therefore, we will analyse different market structures w.r.t. to the regulatory framework, the amount of renewable power in the system (i.e. whether it is a price taker or price maker), the possibilities for gaming and the implications of gaming for the system.

D.3.4: Documentation and communication of the assessment of the value of probabilistic forecasts in selected markets, bidding strategies (M24)

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WS Forecasting in the Design Phase

WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Forecasting in the design phase (WP3)						Task 50 (hybrids), PV T16, hydrogen TCP

An assessment of the expected forecasting accuracy for a given site was already investigated for a single case in Europe. However, since then it has been quiet.

- Case in Denmark analyzed during SafeWind project

The new Task will analyse the tradeoffs between normal siting of the turbines, and the forecast capability type.

Summary Forecasting for the Weather Driven Energy System

- Relaunch of Task 36
- Framework conditions changed since first phase of Task 36: RES is not small addition to system, but IS the system; sector coupling to transport, heat, X…
- Has new challenges for new forecast horizons (seasonal forecasting…)
- Needs strong **collaboration with related TCPs** (solar, hydro, hydrogen, …) and related Tasks (Integration, Lidar, Farm Flow Control, Hybrids, …)
- Data markets coming into focus

- 4 public workshops: State of the art, Seasonal Forecasting (2023), Minute Scale Forecasting (2024) and Extreme Power System Events (2025).

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www.IEA-Wind.org/task-51 or www.IEAWindForecasting.dk

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