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

Giebel, Gregor

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Task 51

Forecasting for the Weather Driven Energy System

Gregor Giebel, DTU Wind

Workshop Seasonal Forecasting

17-18 May 2023

Agenda

Wednesday 17 May

12:00 Welcome and introduction from the Operating Agent (*Gregor Giebel)*
12:15 Keynote (*David Brayshaw, Univ Reading*)
13:15 *Networking Break*
13:45 S2S Forecasting techniques in China (*Jie Yan, NCEPU*)
14:00 Postprocessing subseasonal ensembles (*Irene Schicker, Geosphere Austria*)
14:15 Challenges in S2S post-processing (*Petrina Papazek, Geosphere Austria*)
14:30 Power Plant Database (*Allison Campbell, PNNL*)
14:45 The value of S2S post-processing (*Paula Gonzalez, Met Office)*
15:15 *Networking break*
15:30 S2S in the solar community (*Jan Remund, IEA PVPS Task 16 OA*)
15:45 Seasonal value of hydropower storage (*Natalie Voisin, PNNL, IEA Hydro*)
16:00 Weather regimes' influence over the CONUS (*Ye Liu, PNNL*)
16:15 NOAA S2S Forecasting Overview (*Dave Turner, NOAA*)
16:30 Seasonal Forecasting at DWD (*Kristina Fröhlich, DWD*)

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Agenda

Thursday 18 May, morning

08:30 Seasonal products and user interaction at DWD (*Helmut Frank, DWD*)
08:50 Long-range predictions from Copernicus (*Anca Brookshaw, ECMWF*)
09:10 Climate service research at Barcelona Supercomputing Centre (*Albert Soret, BSC*)
09:30 MetOffice products, and Wind droughts in the North Sea (*Nicky Stringer and Gillian Kay, Met Office*)
10:15 *Networking break*
10:45 Benefits of using calibrated S2S forecasts (*Jan Dutton, Prescient Weather*)
11:05 Vortex S2S Products and Services (*Albert Bosch i Mas, Vortex FDC*)
11:25 Enercast S2S Products and Services (*Huan Zhang, Enercast*)
11:45 Co-production of Seasonal Forecasts for Energy (*Alberto Troccoli, Inside Climate Service and WEMC*)
12:20 *Lunch*

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Agenda

Thursday, 18 May 2023, afternoon

13:30 Use of S2S Forecasts at National Grid ESO (*David Lenaghan, National Grid ESO*)
14:00 S2S Applications in Energy Trading (*Kim Bentzen, Danske Commodities*)

14:45 *Networking Break*

15:15 Open Space Session
16:45 Wrap-up and plans for next steps

17:00 Close

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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

CC BY

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

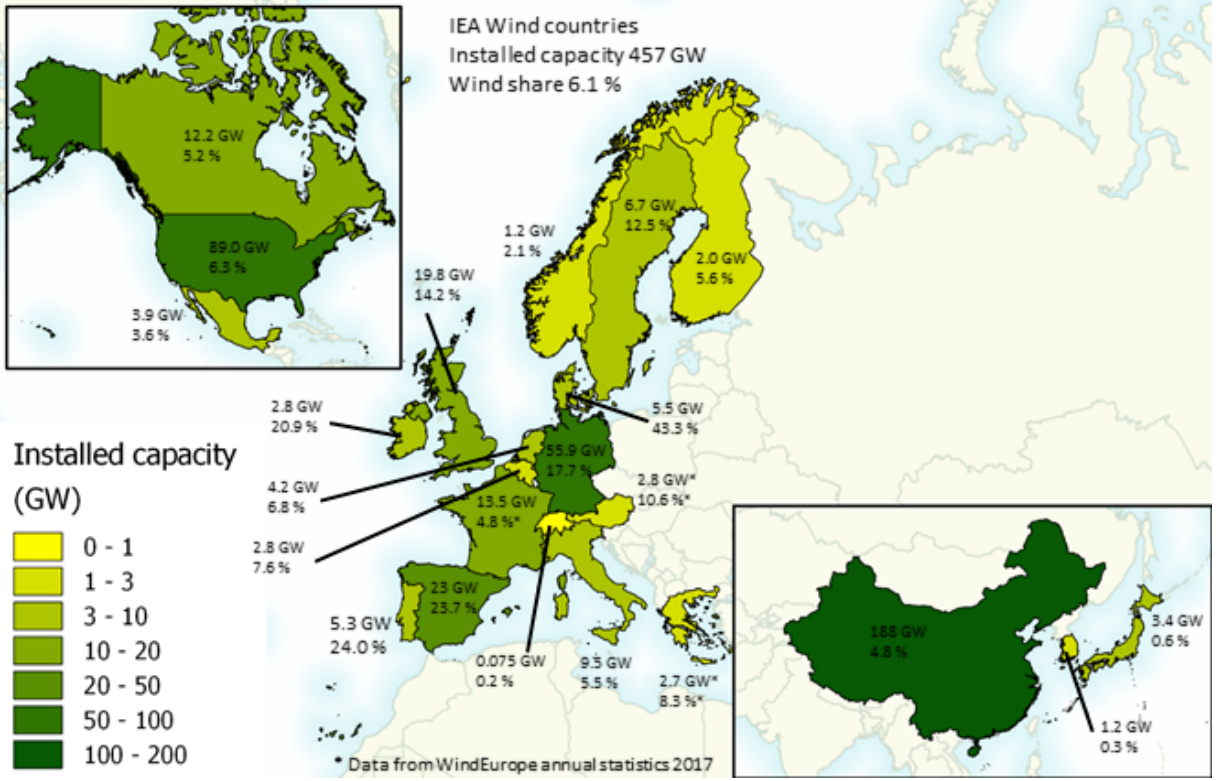
Specific Technology Collaboration Programs (in renewable energy):

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

iea wind



Task 51 members:

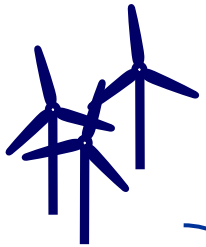
AT, CN, DE, DK, ES, FI, FR, IE, PT, SE, UK, US

iea wind

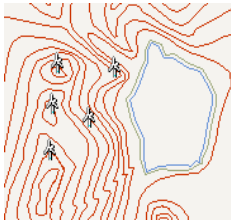
Task 11 Base Technology Exchange
Task 19 Wind Energy in Cold Climates
Task 29 Mexnext III: Analysis of Wind Tunnel Measurements and Improvements of Aerodynamic Models
Task 30 Offshore Code Comparison Collaboration, Continued, with Correlation (OC5)
Task 39 Quiet Wind Turbine Technology
Task 40 Downwind Turbines
Task 41 Distributed Energy
Task 42 Wind Turbine Lifetime Extension

See iea-wind.org!

Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models
Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment
Task 36 Forecasting for Wind Energy
Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power
Task 27 Small Wind Turbines in High Turbulence Sites
Task 37 Wind Energy Systems Engineering
Task 26 Cost of Wind Energy
Task 28 Social Acceptance of Wind Energy Project
Task 34 Working Together to Resolve the Environmental Effects of Wind Energy (WREN)

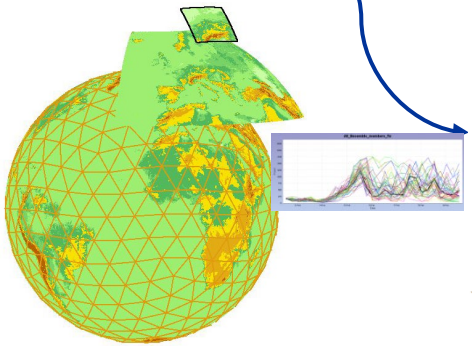


Online data

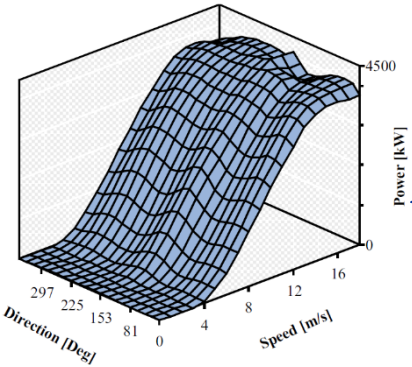


Sometimes:
Orography
Roughness
Wind farm layout

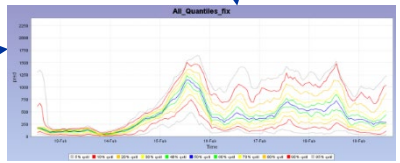
GRID



Numerical Weather Prediction



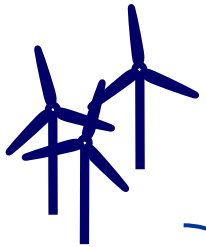
Prediction model



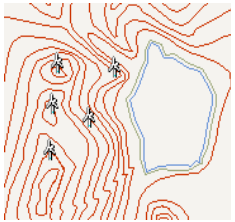
End user

TRADING

Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC'97, Pittsburgh Post-Gazette, Red Electrica de España.



Online data



Sometimes:
Orography
Roughness
Wind farm layout

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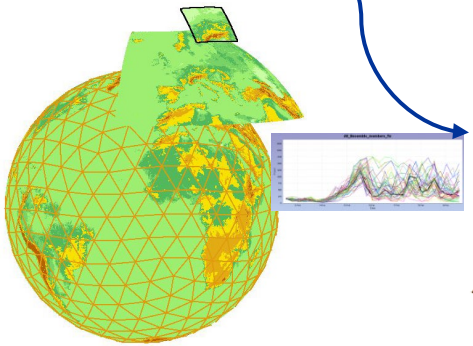
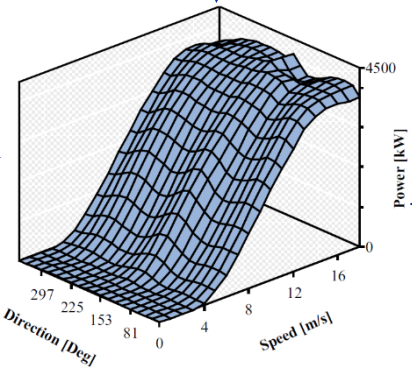
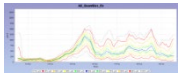


Numerical Weather Prediction



Prediction model



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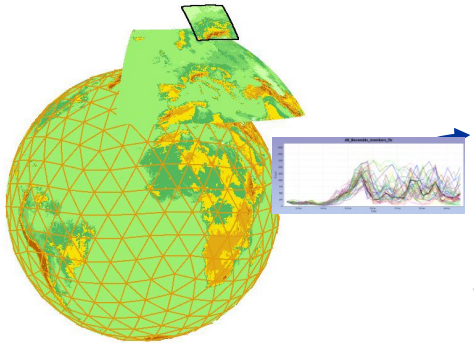
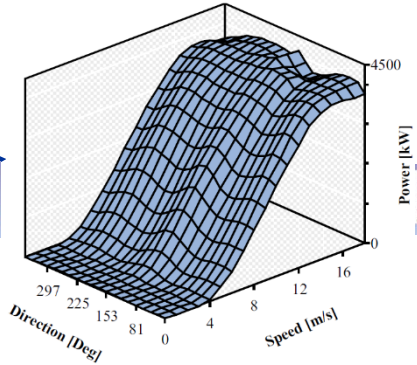


Numerical Weather Prediction

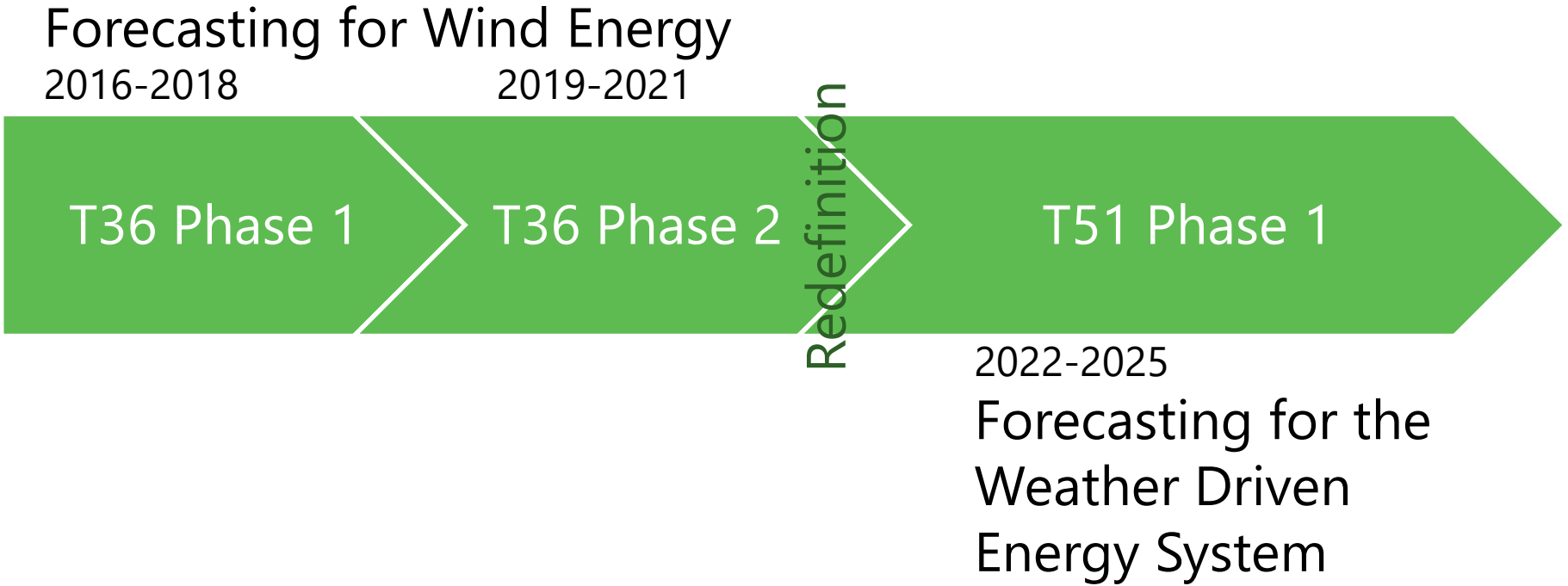


Prediction model

End user

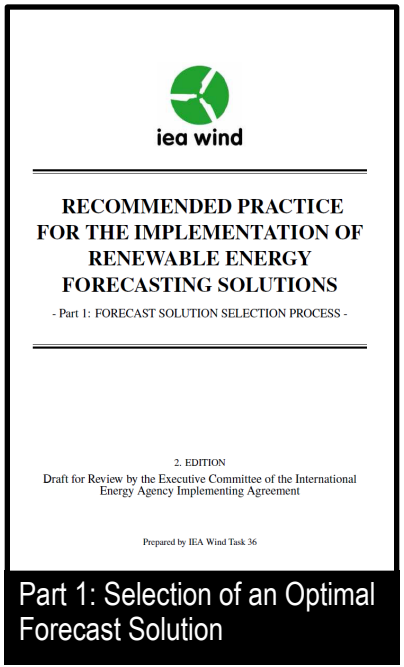
Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC'97, Red Electrica de España.

Forecasting for Wind Energy

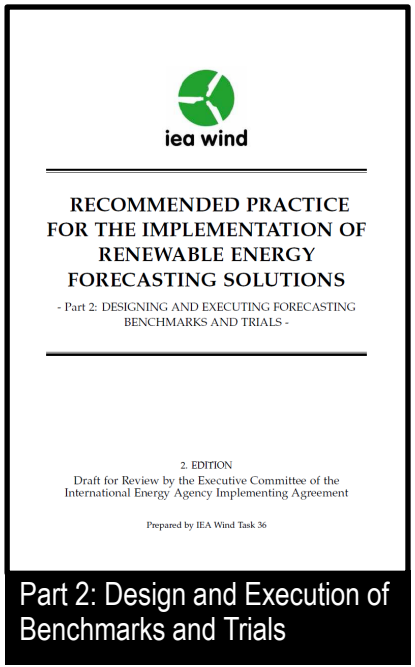


Work Streams:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Atmospheric physics and modelling (WP1)				List of experiments and data	D1.1, Ongoing	WMO, PVPS T16
Airborne Wind Energy Systems (WP1)				Presentations on workshops	Part of D2.1	Task 48 Airborne Wind Energy
Seasonal forecasting (WP1)				**Workshop** / Paper	D1.6 / M19 = **Summer 2023**	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= Sept '22, Dublin 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 = Summer 2024	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 = Summer 2025	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

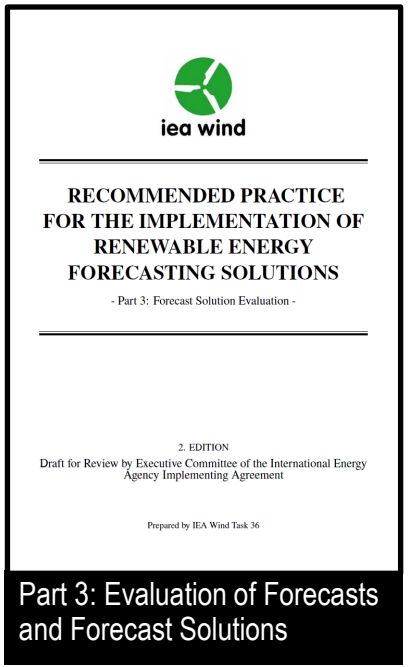
IEA Best Practice Recommendations for the Selection of a Wind Forecasting Solution v2: Set of 4 Documents



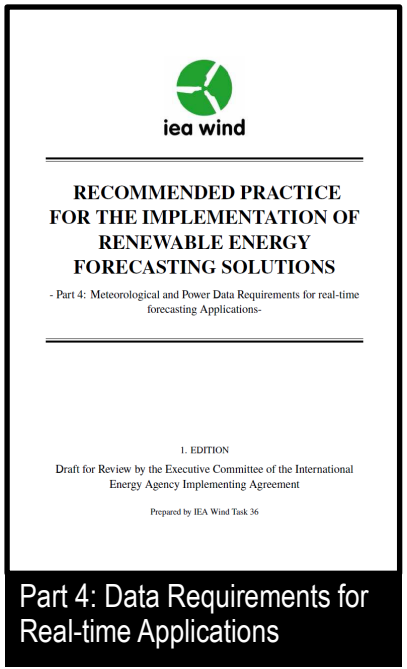
Part 1: Selection of an Optimal Forecast Solution



Part 2: Design and Execution of Benchmarks and Trials



Part 3: Evaluation of Forecasts and Forecast Solutions



Part 4: Data Requirements for Real-time Applications

Also as book!

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

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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

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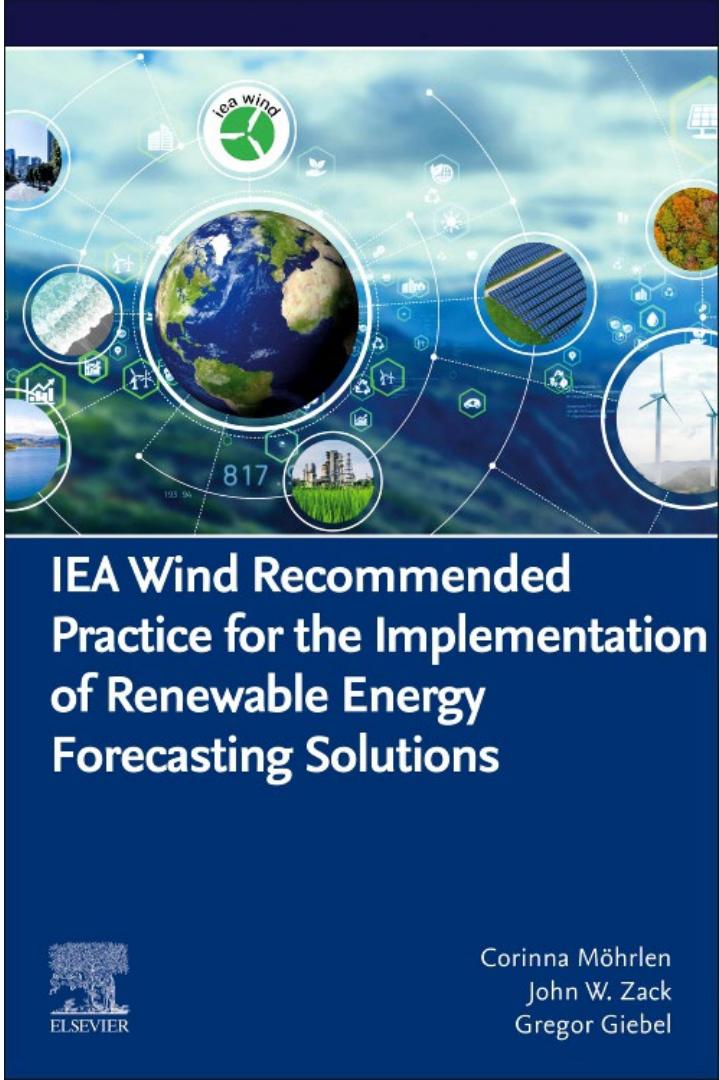
IEA Wind Task 51 Information
iea-wind.org → Task 51 → Publications → Recommended Practice



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
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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)

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/

State of the Art and Research Gaps Workshop, Dublin 2022

- Personal and online some 60 participants
- Slides and video on https://iea-wind.org/task51/task51-work-streams/ws-state-of-the-art-for-energy-system-forecasting/
- Journal paper being worked on

Stakeholders in the electric energy system have expressed a growing interest in sub-seasonal to seasonal (S2S) forecasting information in their applications. Therefore, to facilitate the dissemination of information about S2S forecasting products, skill, applications, issues, and best practices to members of the electric energy community, the team of the International Energy Agency's (IEA) Wind Task 51 (https://iea-wind.org/task51/), entitled "Forecasting for the Weather Driven Energy System", would like to invite you to a S2S forecasting workshop with the goal of gathering information about methods used to produce S2S forecasts, the current state-of-the-art skill in S2S forecasting for variables relevant for energy system applications, current and planned research activities intended to improve the current level of skill, types of public and private sector operational S2S forecasting products, the range of S2S applications in the energy community and the quantified or perceived value obtained from those applications, the sensitivity of user's application performance to variations in forecast skill, and the unmet S2S-forecasting-related needs or desires of the energy user community.

MAY 17–19, 2023 | University of Reading, UK
All times are British Summer Time (UTC+1)

DRAFT AGENDA

Registration: https://www.conferencemanager.dk/s2s/

Work stream Atmospheric Physics

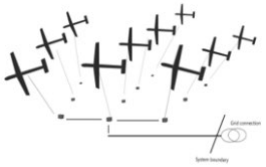
WS:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Atmospheric physics and modelling (WP1)				List of experiments and data	D1.1, Ongoing	WMO, PVPS T16

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

- 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

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

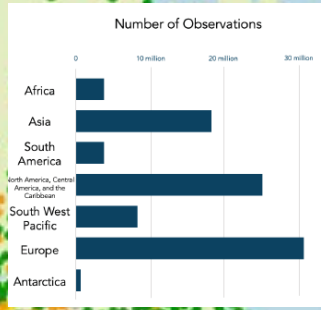
Seasonal forecasts are growing in importance for the power grid planning, especially, where hydropower, storage and other technologies are involved. This topic is also interlinked to the uncertainty forecasting work stream and will focus on the communication between weather and energy community. Seasonal 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)

Background image: Vortex FdC

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



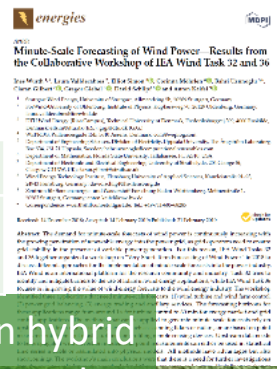
Forecasting in the established markets like Europe, North America or China has both a long tradition, and a well-established infrastructure. But in sync with the wind industry opening up new markets for the technology, the grid operators and/or market participants need good solutions to deal with the 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

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


energies

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

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)

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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)

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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.

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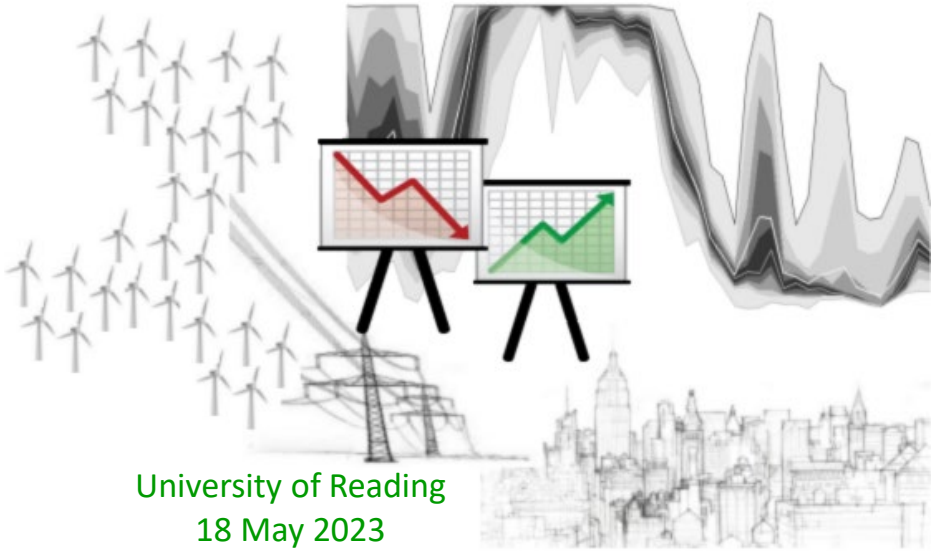
IEA Wind Task 51
"Forecasting for the Weather-driven Energy System" S2S Forecasting Workshop

Open Space Discussion

Energy Applications of S2S Forecasts



University of Reading
18 May 2023

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Open Space Workshop: How We Run It…

Principle	Meaning
Whoever comes is the right people	CHANGE group whenever you think you have said what you wanted or you are no longer interested in the discussion
Law of two feet	You can contribute on any discussion, use this opportunity!
When it's over, it's over	We stop after 60 minutes…use the time to tell about your ideas!
Whenever it starts it starts	Whenever you come to a discussion it is OK to engage and participate
Whatever happens is the only thing that could have happened	No matter who and what is discussed regarding the topic, it's good. Leave if you no longer like the discussion!

Introduction to the Open Space Topics

Topic #	Title Example Questions
1	**Evaluation and Performance** - Which performance metrics are most relevant to providers, users, researchers? - Are there important issues in how performance is measured? - How can current state-of-the-art S2S forecast performance be characterized?
2	**Services and Products** - What types of S2S products(e.g. parameters, time scales etc.) are most widely used/requested? - How can S2S forecast information be most effectively communicated to users? - What are the barriers to the use of existing and/or new S2S forecast products
3	**Applications (Use Cases)** - What is the range of current applications and which have benefited the most? - How has the value to the user been measured? How could it be better assessed? - What are potential new applications?
4	**Research Priorities** - What research should be done to increase the value to energy applications? - What are the most promising pathways to improved forecast performance?

IEA Task 51 Open Space Workshop on
Energy Applications of S2S Forecasts

Topic	Location
Evaluation and Performance	Left Front
Services and Products	Right Front
Applications (Use Cases)	Left Rear
Research Priorities	Right Rear

Time	Activity
15:15 - 15:30	This Introduction
15:30 – 16:15	OpenSpace discussions in **4 groups** - participants rotate freely among the groups
16:15 – 16:45	Group leaders provide summary of each group to the full group; full group discussion

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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The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.