



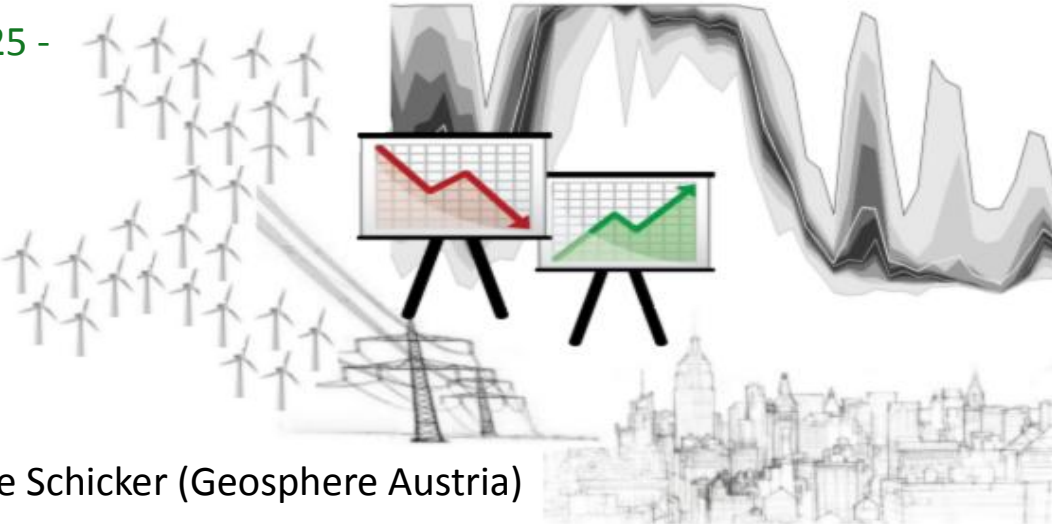
iea wind Task 51 "Forecasting for the Weather-driven Energy System"

Wind Energy & Science Conference

Session RS#07.4 – Advances in Wind Power Forecasting

Nantes, France – 26th June 2025 -

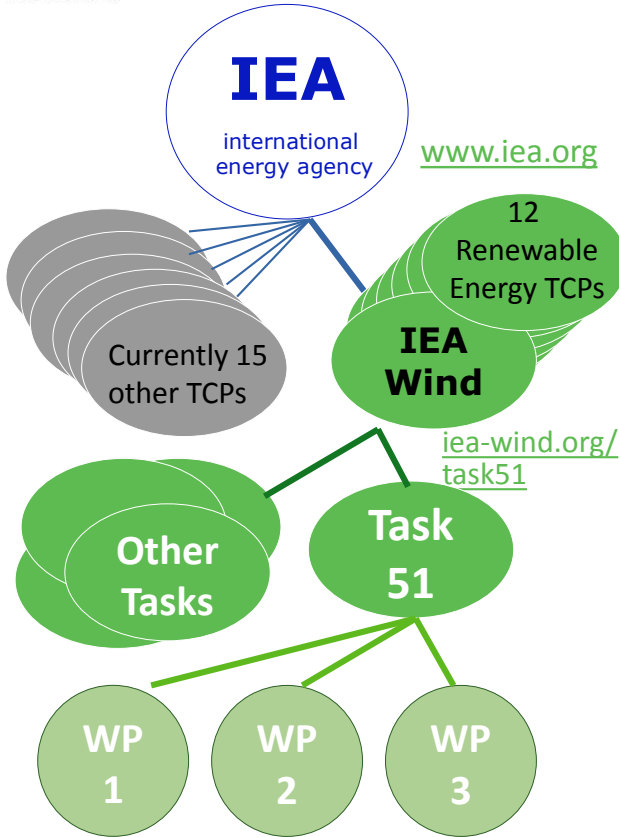
Extreme Power System Events within IEA Wind Task 51 Forecasting for the weather-driven Energy System



Corinna Möhrle (WEPROG) and Irene Schicker (Geosphere Austria)

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

Task 51: Forecasting for the weather-driven Energy System



International Energy Agency (IEA) was established in 1973 after 1st oil crisis

- International organization within OECD with 30 members countries and 8 associates
- Promotes global dialogue on energy & authoritative analysis via so far 80 TCP*s
- Convenes expert panels to address energy related topics of urgency or importance

* Technology Collaboration Program

Task 51: Forecasting for the weather-driven Energy System:

- One out of 25 Tasks of IEA Wind: <https://iea-wind.org/>
- Task 51 Phase 1: 2022-2025 (previous Task 36: 2016-2021)
- Operating Agent: Gregor Giebel (DTU), T-Manag.: C. Draxl (EPRI), C.Möhrle (WEPROG)
- 12 Member countries: AT, CN, DE, DK, ES, FI, FR, IE, PT, SE, UK, US
- Objective: **facilitate int. collaboration on renewable energy forecasts**
- Participants: (1) research organization and projects, (2) forecast providers, (3) policy-makers and (4) end-users & stakeholders

Task 51 Scope: 3 “Work Packages” distributed over 13 “Workstreams”

- WP1: Global Coordination in Forecast Model Improvement
- WP2: Benchmarking, Predictability and Model Uncertainty
- WP3: Optimal Use of Forecasting Solutions

Task 51 homepage: <https://iea-wind.org/task51>



iea wind

Founded in 1977, the International Energy Agency **Wind Technology Collaboration Programme** is an international co-operation that **shares information and research** to advance wind energy research, development and deployment in **member countries**. The consortium operates under the auspices of the International Energy Agency (IEA).

IEA Wind TCP Research Tasks

Technology Collaboration Programmes

**Currently 25
active TASKS**

Environmental Co-Design

- Avoiding, minimising, compensating for environmental impacts
- Incorporating environmental costs, benefits into decisions
- Addressing both immediate concerns, future impacts

Tasks 32, 42, 45

Social Science

- Acknowledging the transformational nature of development
- Creating just processes
- Valuating benefits, effects, burdens

Tasks 28, 39, 53

The Turbine

- Incorporating holistic design
- Developing intelligent controls, operation, maintenance
- Advancing industrialisation

Tasks 44, 49, **52** 54 & 57

The Atmosphere

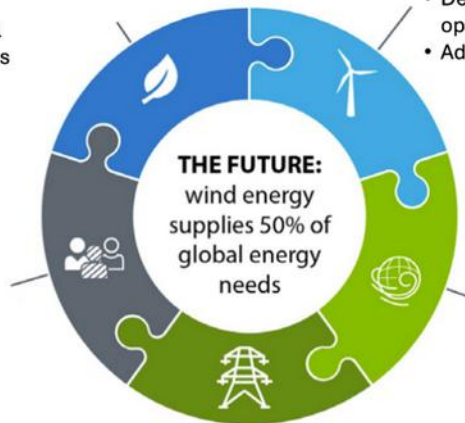
- Increasing atmospheric observations
- Expanding, validating universal predictive capability
- Integration, adopting improved models

Tasks 43, 46, 47, **48** 49, **51**, 56

The Plant and Grid

- Improving modelling
- Optimising plant design for multiple objectives
- Ready wind plants for grid support

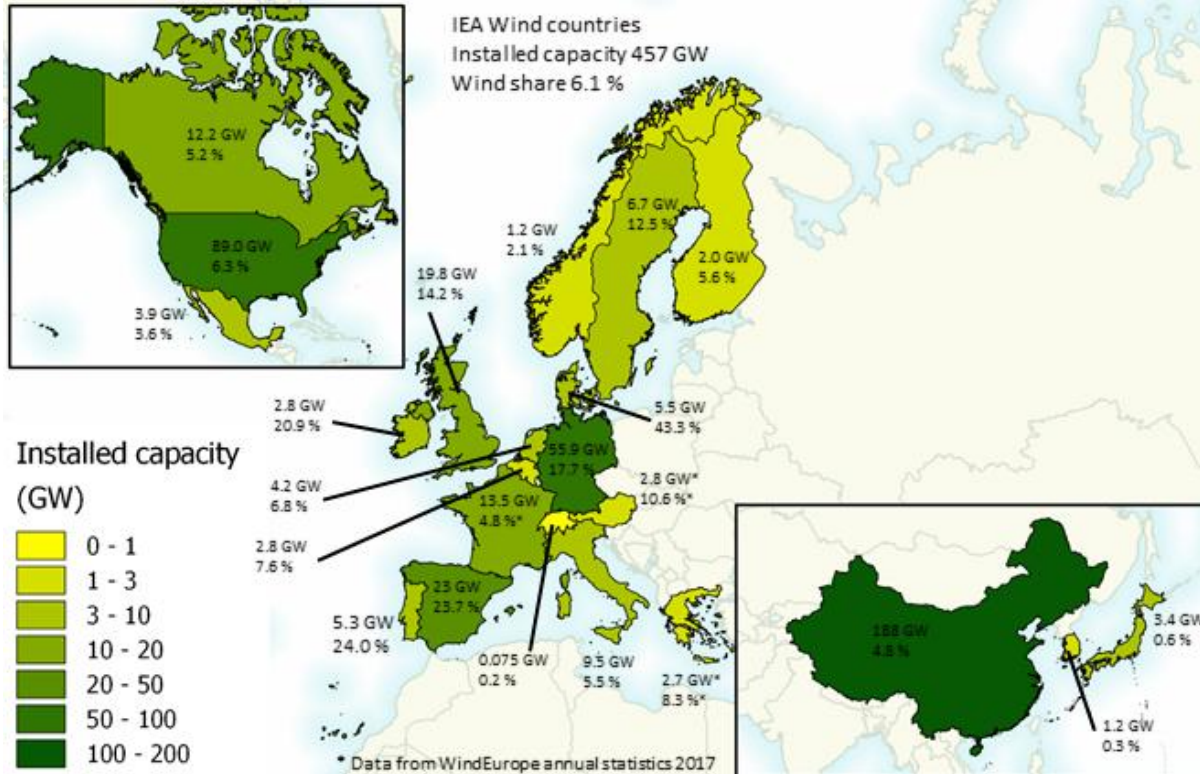
Tasks **25**, 41, **50**, 55, 58 & 61





iea wind

task 51: forecasting for the weather-driven energy system



- Task 51 members (12)
- AT, CN, DE, DK, ES, FI, FR, IE, PT, SE, UK, US



Forecasting for Wind Energy

2016-2018

2019-2021

T36 Phase 1

T36 Phase 2

Redefinition

T51 Phase 1+2

2022-2029

**Forecasting for the
weather-driven
Energy System**



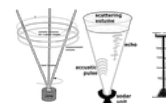
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IEA Wind Task 51 Work - distributed over 11 work streams

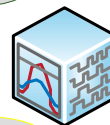
Work Streams:	WP1 Weather	WP2 Power	WP3 Applications
Atmospheric physics and modelling (WP1)	★		
Airborne Wind Energy Systems (WP1)	★		
Seasonal forecasting (WP1)	★		
State of the Art for energy system forecasting (WP2)		★	
Minute scale forecasting (WP2)		★	
Data science and artificial intelligence (WP3)			★
Extreme power system events (WP3)			★
Uncertainty / probabilistic forecasting (WP3) & for underserved areas			★
Decision making under uncertainty (WP3)			★
Privacy, data markets and sharing (WP3)			★
Value of forecasting (WP3)			★



Modelling & data assimilation



workshops



Verification Platform

Publications

Collaborations

WMO, PVPS T16

IEA Task 48 Airborne Wind Energy

Hydro TCP, Hydrogen TCP, Biomass TCP

PVPS Task 16, Hydro TCP, Hydrogen TCP, IEC SC8A WG2, ...

Wind Tasks 52 Lidar, Task 44 Farm Flow Control and 50 Hybrids

PVPS Task 16

Task 25, ESIG, IEA ISGAN, PVPS T16, G-PST, DESTINE

ESIG, IEEE WG Energy Forecasting, PVPS Task 16, IEC SC8AWG2

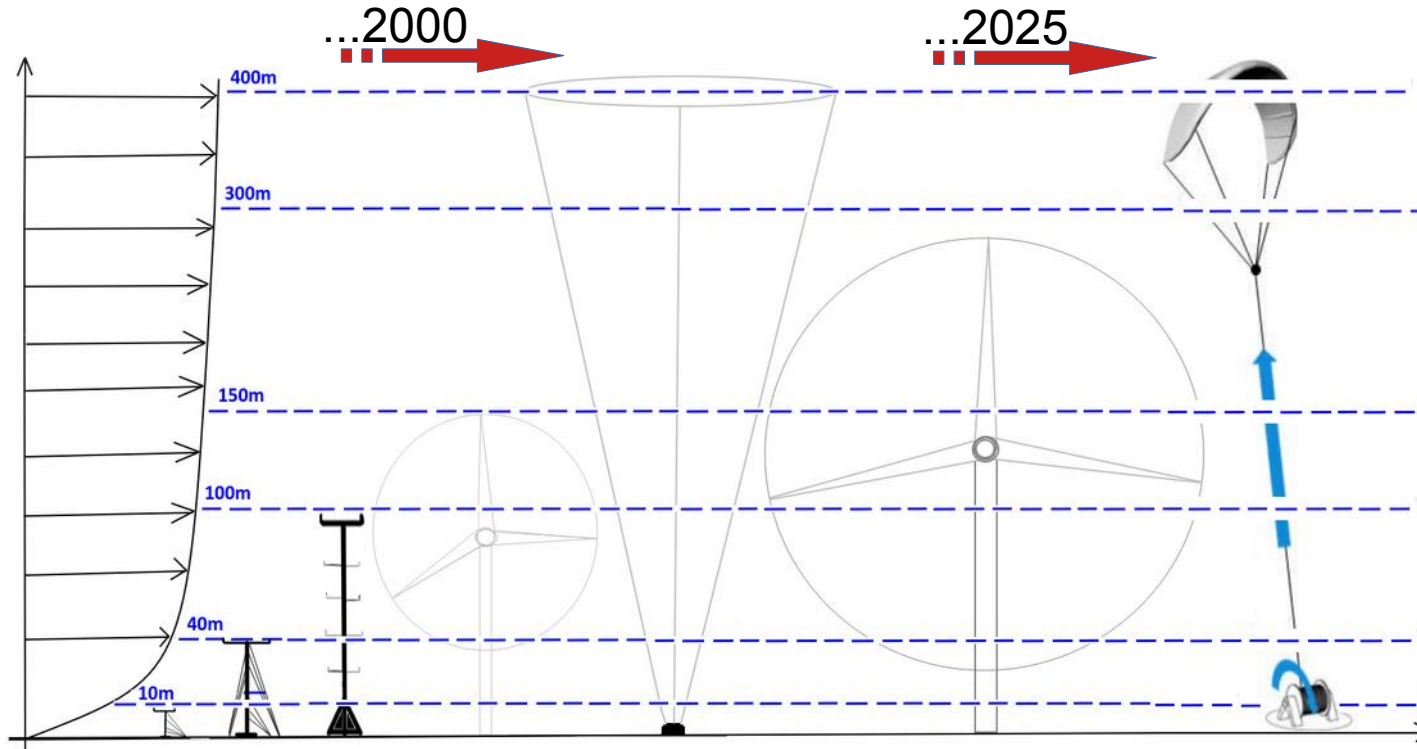
EMS, WEMC, WEXICOM

PVPS Task 16, Wind Tasks 52 Lidar, DestinE, IEC SC8AWG2

PVPS Task 16

From groups of single wind turbines to large-scale Wind Energy Systems

Penetration level: From 0.5% wind >50% wind in electric grids



IEA's take on the VRE integration development:

Introduction to iea's VRE integration phases

Phases of VRE integration framework

Low phases

Phase 1: VRE has no significant impact at the system level

Phase 2: VRE has a minor to moderate impact on the system

Phase 3: VRE determines the operation pattern of the power system

High phases

Phase 4: VRE meets almost all demand at times

Phase 5: Significant volumes of surplus VRE across the year

Phase 6: Secure electricity supply almost exclusively from VRE

VRE = variable renewable energy

The framework allows policy makers to identify VRE integration measures that need to be prioritised at each phase to ensure its timely implementation.

NOTE: Phases are not to be understood as decarbonisation measures, but as **integration challenge !!!**

Full presentation available here:

[Integrating Solar and Wind - Global experience and emerging challenges - launch webinar - Event - IEA](https://www.iea.org/events/integrating-solar-and-wind-global-experience-and-emerging-challenges-launch-webinar)

<https://www.iea.org/events/integrating-solar-and-wind-global-experience-and-emerging-challenges-launch-webinar>

IEA's take on the VRE integration development:

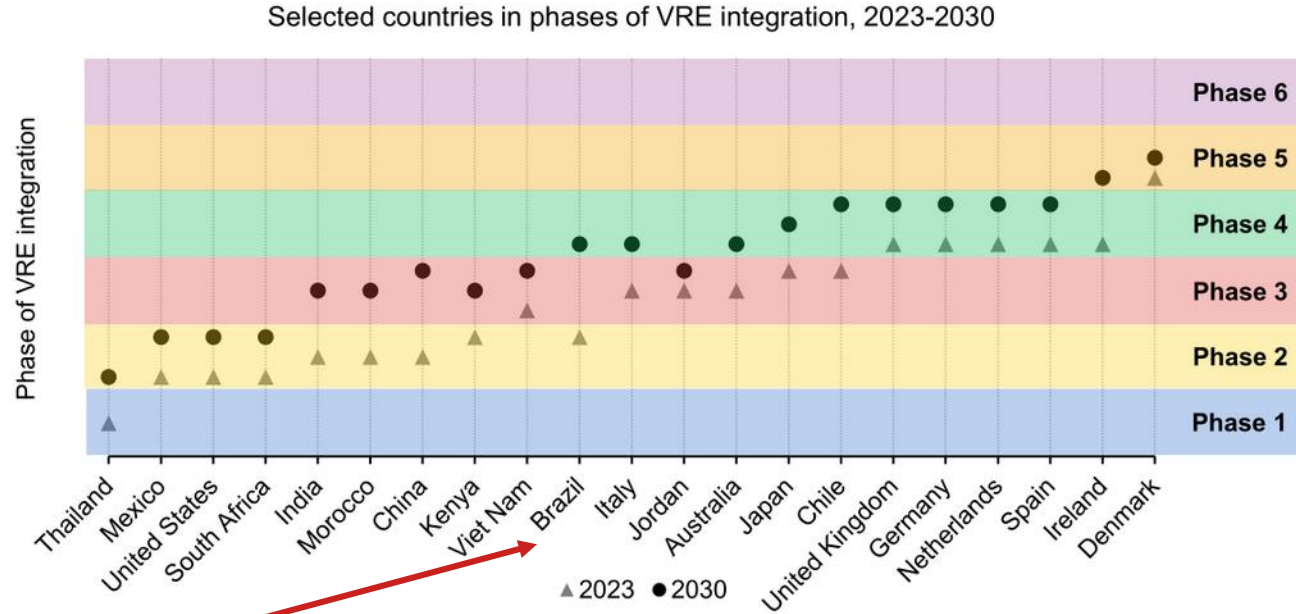
Introduction to iea's VRE integration phases

30

iea

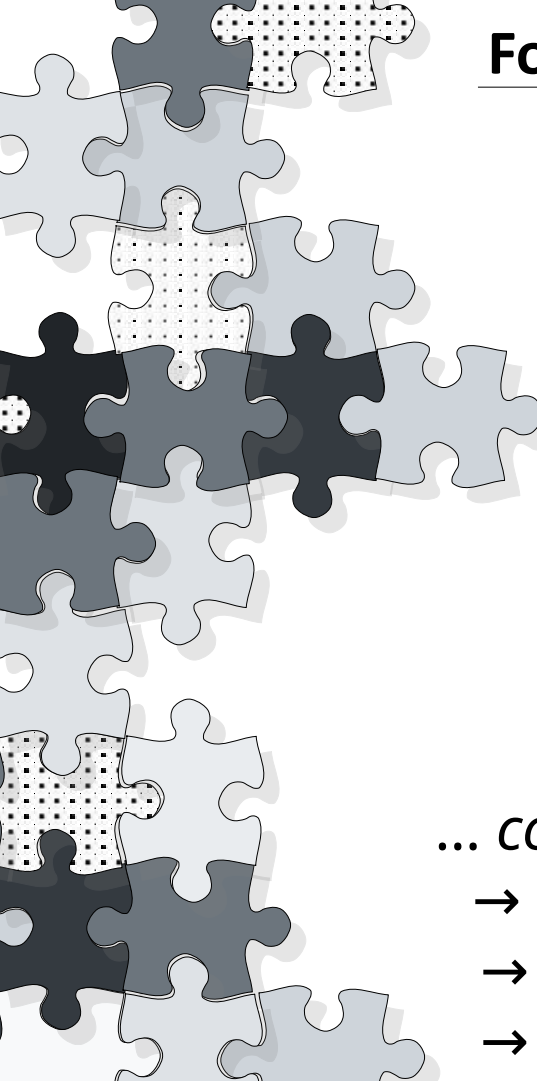
Legend

- 2030
- ▲ 2023



NOTE: Some countries are in low phases due to hydro power prevalence – not necessarily because they are not far enough in the decarbonisation!!

Some countries are currently classified at high phases with high wind penetration, but more systems will be at high phases by 2030, driven by solar PV penetration.



Forecasting for the weather-driven Energy System

“

..to succeed with the energy transition, we need to **close the gap** between research and industry applications...

”

... *complex systems* require

→ *Structured* solutions

→ *Cooperation* on all levels

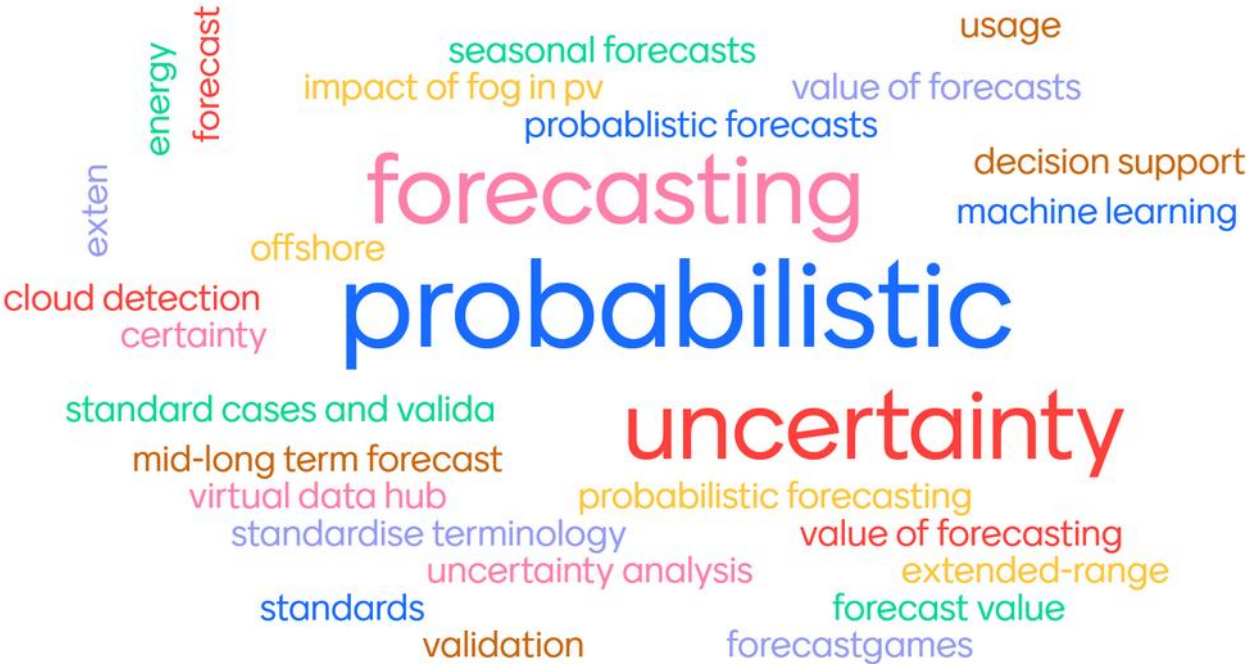
→ a *holistic view* for the solution development



Task 51: Forecasting for the Weather-Driven Energy System

What are the most important topics to cover in the next phase of the task ?

Poll result
at a task
meeting in
2021 when
preparing for
the next
phase of the
task yielded
this word
cloud ...





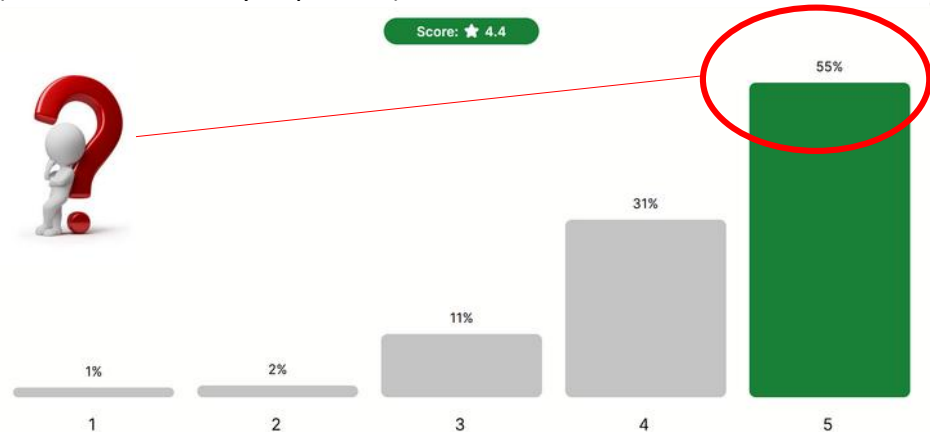
iea wind

Where are the gaps ... ?

Questions posed to 120 participants in an IEA Wind Task 51 workshop in Vienna in 2024

How do you deal with uncertainty in weather forecasts at the moment?

AI makes forecasting easier and faster. If you (would) get high-resolution forecasts from AI – how important is **uncertainty** and transparency ?
(1=not at all, 5=very important)



iea wind



iea wind

Example 1: Meaning of a “holistic” view:

Uncertainty Propagation throughout the entire model chain

The publication served to

- 1) Define
- 2) describe
- 3) review

throughout the chain of forecast modelling:

- **Uncertainty sources**
- **Uncertainty mitigation** approaches
- **Uncertainty validation** approaches

for each type of uncertainty source from

planning phase → operation phase → market phase

Forecast Process



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

Jin-Yan Chen, Gert-Thomas Mehlert, Toshihiro Gotoh, Yoon-Kyung Kim, Yoon-Min Kim and Gert-Thomas Mehlert

Renewable Energy, 150 (2018) 100–110

ARTICLE INFO:

Keywords:

Forecasting

Uncertainty

Model chain

Wind power

Forecasting

Uncertainty

Model chain

Wind power

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Forecasting

Uncertainty

Model chain

Wind power

OpenAccess Download:

<https://www.sciencedirect.com/science/article/pii/S136403212004221>

Workstream Uncertainty :

Uncertainty Propagation throughout the model chain with real data

PHASE I

2022-2023

tool
1

tool
2

R-
verify
tool

tool
3

Uncertainty
Quantification
with test data
sets
according to
2022 UQ
publication*

TALK by Jie Yan

Mini Symposium MS#01.12 –
27.06.2025 Room E 8:50-10:40

PHASE II

2024-2025

Online
Verification
Platform



Discussion & testing of
verification platform



PHASE III

2025...

Publication

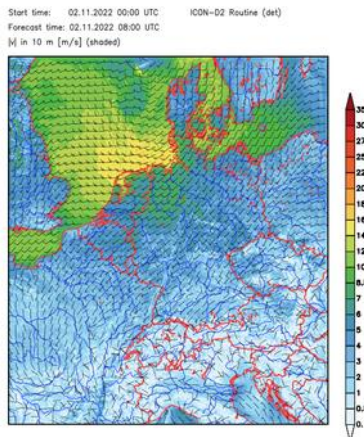
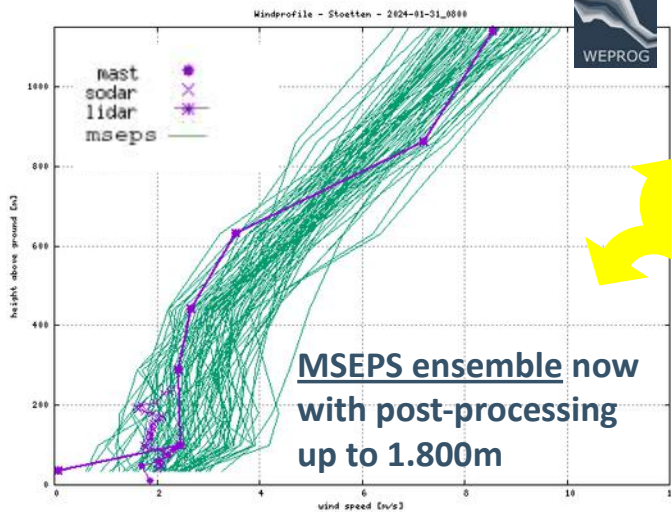


Discussion & writing of
publication with most
suitable test cases

* Uncovering wind power forecasting uncertainty sources and their propagation through the whole modelling chain

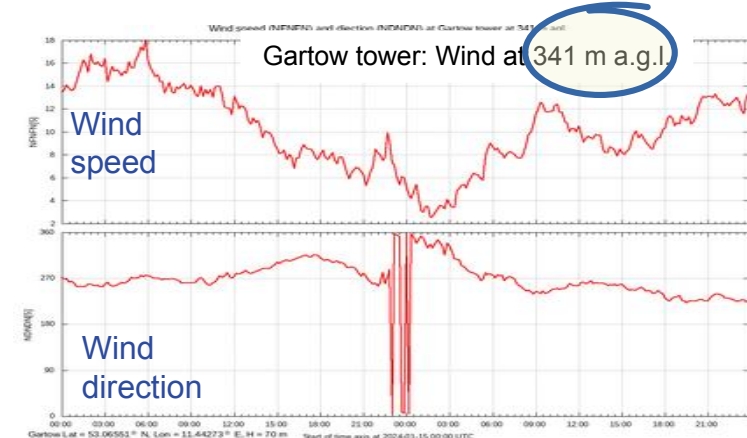
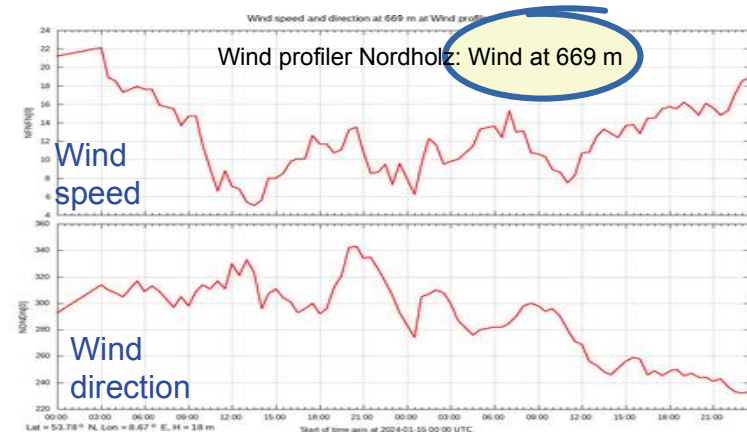
<https://www.sciencedirect.com/science/article/pii/S1364032122004221>

Workstream Atmospheric Modelling and Physics & first simulations for airborne wind



ICON-DE model now
in 15min resolution
every hour

Private and public
weather forecast
services prepare for
phase 4-6



IEA Wind Recommended Practice Example Evaluation

Software package: *evalprob4cast*



IEA Wind Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions



Corinna Möhrlein
John W. Zack
Gregor Giebel

Mathias Blicher Bjerregaard
Jethro Browell

Hands-on Examples and IEA-WT51 Verification R-package

Online OpenAccess:

<https://www.sciencedirect.com/book/9780443186813/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions>



Chapter 14, Section 14.3

Assessment of forecast performance

Available on
GitHub:
<https://github.com/jbrowell/evalprob4cast>
Publication:
<https://doi.org/10.48550/arXiv.2504.03544>

See also our workshops & conference page for workshop presentations

<https://iea-wind.org/task51/task51-publications/task51-workshops-and-special-sessions/>

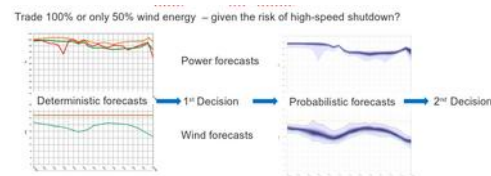


“Probabilistic Forecasting Games & Experiments” initiative

1. Experiment (2020)

Game: 12 cases

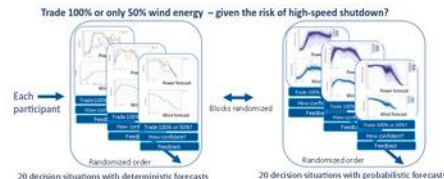
Decision structure: 12 deterministic Forecasts followed by a probabilistic forecast
After each decision, possible change of decision based on new information



2. Experiment (2021-2024*)

Game: 40 cases

Decision structure: 20 deterministic cases + decision confidence request
20 probabilistic cases + decision confidence request



* still open...: <https://meteorology.mpib.de/wind-power-decisions/about.html>

Resilience of the power system has many faces

- impact changes with penetration levels > 30% of Renewables
- Can forecasts mitigate impact?

Definition of Extremes are dependent on impact

- How can we cooperate on critical conditions ?
- What time-scales do we need for mitigation strategies across disciplines?

Collaboration across disciplines

- Multi-disciplinary task requires multi-disciplinary task force groups
 - Meteorologists
 - Energy Meteorologists
 - Grid operators and Power Engineers
 - Traders and Markets
- Policy Makers
- Governments

WS Extreme Power System Events

THE IRISH TIMES

Storm Isha Live

Storm Isha: Second storm, Jocelyn, to hit on Tuesday as thousands remain without power and water

Some 93,000 properties still without electricity as Met Éireann issues further Orange warnings for Donegal, Mayo and Galway

Ireland

Storm Isha: Thousands without power and over 100 deaths as wind causes damage across Ireland

Flights cancelled and diverted in Dublin Airport due to 'severe and dangerous' weather, with reports of fallen trees

Expand



Waves crash over the pier at Fenit, Co Kerry on Sunday as Storm Isha lashes the southwest. Photograph: Dornnack Walsh/Eye Focus

What is an extreme event ?

Ireland and UK experienced two storms in a row:

Isha on Jan, 21st 2024 and
Jocelyn on Jan, 22nd 2024

THE IRISH TIMES

14:31



Main points:

- Follow live coverage of the [clean-up after Storm Isha in Monday with our live coverage.](#)
- Over 170,000 homes and businesses are without power on Sunday evening
- A status red weather warning for wind is in effect in Co Donegal
- An orange weather warning is in effect for all of Ireland
- Earlier red wind warnings issued for counties Mayo and Galway have since expired
- Dublin Airport says Storm Isha is having an impact on flights
- Local authorities and fire and rescue services across the country are responding to reports of fallen trees



iea wind

WS Extreme Power System Events caused by extreme weather conditions

What is an extreme event ?

Ireland and UK experienced 2 storms within 3 days in **January 2024**

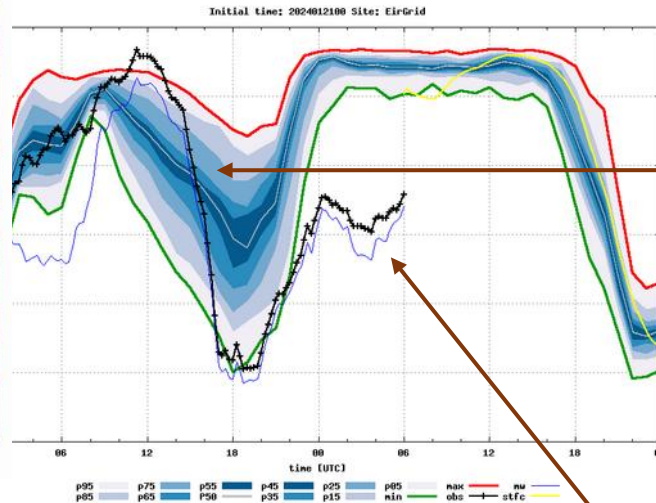
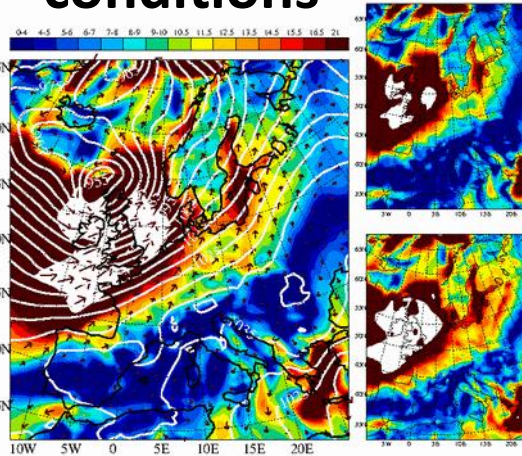
The Irish grid operator had to deal with an **almost 50% cut-off from wind** on Jan, 21st 2024 with storm Isha!

Possible causes for electricity outages:

- Damages in the grid infrastructure
- Fallen trees
- Missing reserves, even though forecasted well!!!

Issues following:

- Re-establishment of the power lines and infrastructure
- Restoration of grid due to non-regulated re-powering of wind/solar units
- Missing inertia
- Missing Fault-ride-through capabilities



Storm Isha: Second storm, Jocelyn, to hit on Tuesday as thousands remain without power and water

Some 93,000 properties still without electricity as Met Éireann issues further Orange warnings for Donegal, Mayo and Galway

Mon Jan 22 2024 - 10:40



Crews from ESB Networks replace fallen electricity poles in a field near Galway Airport after they were damaged during Storm Isha. Photograph: Neil Carson/RTÉ News

Ireland
Storm Isha: Thousands without power and over 150 flights cancelled as wind causes damage across Ireland

Flights cancelled and diverted in Dublin Airport due to 'severe and destructive gusts', with several counties reporting fallen trees

Sun Jan 21 2024 - 22:22



Waves crash over the pier at Fenit, Co Kerry on Sunday as Storm Isha lashes the southwest. Photograph: Dermot Walsh/Eye Focus

Extreme Power System Events – Blackouts -

April 28, 2025 Iberia blackout



Government report concludes: the incident had a multifactorial origin, with three key elements standing out:

- 1) insufficient voltage control capacity
- 2) oscillations creating difficulties to stabilise voltage
- 3) 'apparently improper' disconnections of generation plants

→ **temporal cascade of events** that progressively unbalanced the system and culminated in the peninsular electricity **grid** being **shut down due to overvoltage**

Large power failure...
from wind?

What was missing?

Older wind farms **lack**

- inertia
- fault-ride-through capabilities

... grid resilience must now be treated as an economic imperative ...



Redeia, the spanish grid operator has **disputed the findings**, according to Reuters reportage, saying its own investigation had discovered **anomalies in the disconnection of power plants** on April 28 even though voltage in the system was within legal limits, as well as an anomalous growth in demand from the transport network.

WS Status: Extreme Power System Events

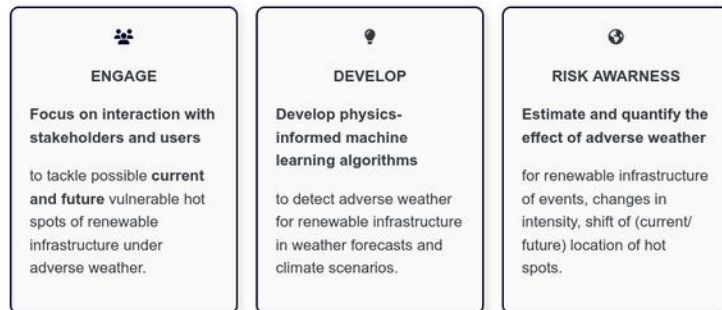
Collaboration



IEA Wind Task 51 Austria
Workshop at the NH Danube
City Hotel in Vienna on
November 6, 2024

GeoSphere Austria, Austro Control Digital
Services GmbH and WEB Windenergie AG
are organizing the IEA Task 51 Austria
Workshop on...

<https://iea-wind.org/2024/07/31/iea-wind-task-51-austria-workshop-in-vienna-on-6th-nov-2024/>
<https://ieatask51-austria.gitlab.geosphere.at/web/workshops/>



EGU 2025

The IEA Wind TCP Task 51 Austria – Stakeholder interaction and priorities for forecasts, Tilg, A.-M., Schicker, I., Strauss, L., Mader, F., Niederl, A., Messner, J., Möhrle, C., **EGU General Assembly 2025**, Vienna, Austria, 27 Apr–2 May 2025

<https://doi.org/10.5194/egusphere-egu25-15415>



EGU-group

EnergyProtect

A research project connecting **adverse weather and climate** with AI and renewables



Collaboration with Subtask:
On-demand digital twin extremes forecasting system for renewables - The Destination Earth Extremes digital twin

<https://destine.ecmwf.int/news/meteo-france-led-international-partnership-wins-bid-to-develop-destination-earths-on-demand-extremes-digital-twin/>

Extreme Power System Events - Definitions -



Event Type	Key Parameters	Severity Levels	Infrastructure Impacts	Impacts on Power Production and Grid Stability
Wind Speed Ramping	Change in wind speed over three time steps (m/s)	Minor: 3–5 m/s Moderate: 5–7 m/s Severe: 7–10 m/s Extreme: ≥ 10 m/s	- Turbine cut-in/cut-out at 3–20 m/s - Risk of turbine damage above 25 m/s, structural failure possible at 60 m/s	- Rapid fluctuations destabilize grid balance - Requires quick ramping of backup generation or curtailment - May reduce wind farm efficiency during extreme changes
High Wind Events	Sustained wind speeds > 20 m/s, gusts > 25 m/s	- Turbines shut down for protection above 25 m/s - Risk of blade, tower, or substructure damage at > 40 m/s	Mechanical failures, maintenance delays during storms	- Power output ceases when turbines shut down - Extreme high winds stress grid balancing during power ramping - Regional outages possible due to grid overload
Dunkelflauten (Dark Doldrums)	Low solar irradiance (<150 W/m ²), low wind speed (<3 m/s)	Combined capacity factor < 0.06 over 48 hours	Grid stress, increased energy demand for heating	- Sharp drops in renewable generation - Requires heavy reliance on fossil fuel or stored energy - Grid stability threatened by prolonged low generation
Hellsturm (Sunny/Windy Overproduction)	High solar irradiance (>800 W/m ²), high wind speeds (>20 m/s)	Renewable generation > 90th percentile, demand < 10th percentile	Significant curtailment, grid balancing challenges	- Excess power leads to curtailment and revenue loss - Overproduction stresses grid, requiring storage or export options
Heatwaves	Temperatures > 35°C	Persistent events lasting >3 days	Overheating of power components, reduced cooling system efficiency	- Solar production peaks but efficiency drops above 30°C - Increased electricity demand for cooling - Stress on transmission systems due to high demand

Extreme Power System Event – Definitions -



Event Type	Key Parameters	Severity Levels	Infrastructure Impacts	Impacts on Power Production and Grid Stability
Cold Spells	Temperatures < -10°C	- Persistent low temperatures, often coinciding with low wind speeds	Increased energy demand, icing on turbines	- Significant reliance on backup generation - Increased heating demand amplifies grid stress - Reduced wind energy efficiency due to icing
Snow/Ice Events	Snowfall, ice accumulation	- Wet snow weight > 240 kg/m² can damage PV modules	Turbine shutdown, reduced PV efficiency due to shading	- Solar generation curtailed due to snow cover - Icing of transmission lines increases failure risks - Wind farm production halts due to icing
Thunderstorms	Lightning, hail, wind gusts	- Hail diameter > 3 cm damages PV - Severe impacts with hail > 5 cm	Hail cracks PV modules, rapid power fluctuations	- Power surges can damage grid components - Curtailment required during gusty conditions - Localized blackouts possible
Flooding	River discharge > 98th percentile (duration >30 min)	- Tailwater rise reduces hydropower generation capacity	Sediment load increases turbine wear	- Reduced hydropower output due to high tailwater - Infrastructure failures disrupt regional power supply - Risk of electrical faults in flood zones
Wind Droughts	Wind speeds < 2 m/s	- Prolonged events (>7 days) with <2 m/s	Reduced wind energy production, grid stability risks	- Prolonged low wind generation strains grid reliability - Requires heavy reliance on other renewable or non-renewable resources - Load shedding may occur

Dealing with Extreme Power System Events – Heuristics -

Physics-informed pattern detection of adverse weather events and model mixing

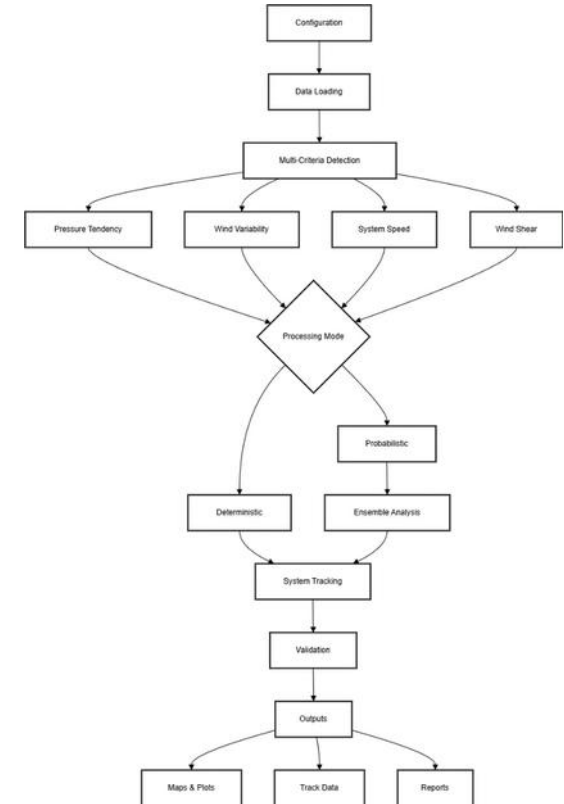


Fast running low pressure systems – Challenge of rapid wind changes

- Critical for renewable energy
- Grid stability risks
- Economic impact

Solution: *Heuristic tree of actions*

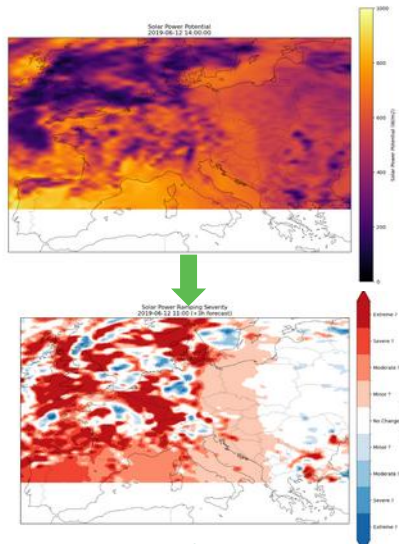
- Automated detection using multiple meteorological criteria
- Manual adjustment possibilities
- Probabilistic uncertainty quantification
- High-resolution spatial analysis
- Low resolutions „grid size“ independant
- Real-time processing capability



Looking ahead and evaluating conditions ... before it becomes critical !!!



Theor. Solar power potential



+ theor. PV production potential

Thunderstorm severity index

```
def severe_thunderstorm_index(indices):  
    # Normalize each index to a 0-1 scale  
    normalized_indices = {  
        'CAPE': np.clip(indices['CAPE'] / 4000, 0, 1),  
        'K_Index': np.clip(indices['K_Index'] - 20, 0, 20),  
        'Total_Totals': np.clip(indices['Total_Totals'] -  
        44, 0, 1),  
        'Showalter': np.clip(indices['Showalter'] /  
        6, 0, 1),  
        'SNEAT': np.clip(indices['SNEAT'] - 3, 0, 1),  
        'Deep_Sea': np.clip(indices['Deep_Sea'] / 30,  
        0, 1),  
        'SRH': np.clip(indices['SRH'] / 10, 0, 1),  
        'ENI': np.clip(indices['ENI'] / 10, 0, 1),  
        'SCP': np.clip(indices['SCP'] / 10, 0, 1)  
    }  
    # Combine normalized indices into a single index  
    weights = {  
        'CAPE': 0.2,  
        'K_Index': 0.1,  
        'Total_Totals': 0.1,  
        'Showalter': 0.1,  
        'SNEAT': 0.1,  
        'Deep_Sea': 0.1,  
        'SRH': 0.1,  
        'ENI': 0.1, 'SCP': 0.1  
    }  
    severe_index = sum(normalized_indices[k] * weights[k]  
        for k in normalized_indices)  
    return severe_index
```

At present
experimental
--> needs
threshold
adjustment.

SSI Index Value	Instability Condition
>0	Stability
-3 and 0	Mid level instability
-6 and -4	High level instability
<-6	Ultra high level instability

Dealing with Extreme Power System Events – Storm Tracking -

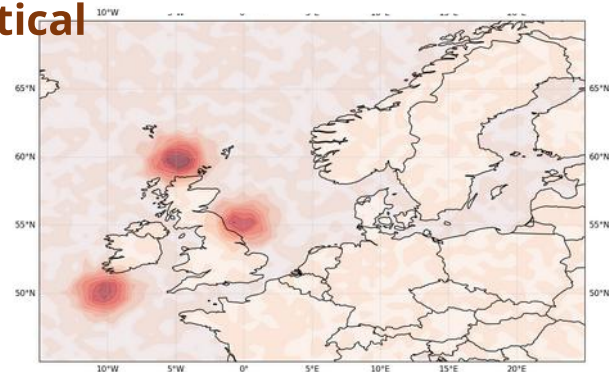
Physics-informed pattern detection of adverse weather events and model mixing ... before it becomes critical



Method

- Multi-criteria ensemble approach for fast-system detection
- Spatial-temporal neighborhoods to reduce verification double penalty
- Energy-sector specific validation against wind farm observations

Criterion	Meteorological Variable	Threshold	Physical Meaning	Data Level
Pressure Tendency	$\partial p / \partial t$ (pressure change rate)	> 1.5-2.0 hPa/h	Rapid pressure drops indicate system passage	Surface (MSL)
Wind Variability	σ (wind speed) temporal std	> 1.2-1.5 m/s	High wind fluctuations during system passage	10m level
System Speed	Propagation velocity	> 12-15 m/s	Fast-moving systems of interest	Derived from pressure field
Wind Shear	$ u_{850} - u_{10} $	> 10 m/s	Vertical wind structure indicates system strength	850 hPa - Surface
Geostrophic Wind	$\sqrt{(u_m^2 + v_m^2)}$ at 500 hPa	> 20 m/s	Upper-level flow pattern strength	500 hPa level
Thermal Wind	$ u_{850} - u_{10} $ magnitude	> 15 m/s	Temperature gradient indicator	850 hPa - Surface



Storm Tracking & Detection:

- **Hodges (1994):** "A general method for tracking analysis" - Established fundamental tracking algorithms
- **Neu et al. (2013):** *IMILAST intercomparison* - Standardized detection criteria and validation metrics

Renewable Energy Meteorology:

- **Brayshaw et al. (2011):** "Impact of large scale atmospheric circulation patterns on wind power" - Linked synoptic patterns to energy generation
- **Cannon et al. (2015):** "Using reanalysis data to quantify extreme wind power statistics" - Statistical approaches for energy applications

Upcoming Workshop on *Forecasting for Extremes in the Power System*

Save the date: 30.th Sep -1. Oct 2025 at DWD in Offenbach, near Frankfurt, DE

Workshop topics

Topic 1: Defining Extremes

Topic 2: Tools to mitigate Extremes
in the power system

Topic 3: AI and Cybersecurity in
Extreme situations

Topic 4: Uncertainty of Extremes and
Decision-making in extremes



IEA Wind Task 51 Workshop
Forecasting Extremes in the Power System



DWD, Offenbach/Frankfurt, Germany
30th September - 1st October 2025

NEWS

iea-wind.org/task51



<https://iea-wind.org/2025/02/14/iea-wind-task-51-workshop-on-extremes-in-the-power-system/>

Agenda topics:

- **Definition and associated differences of extremes in meteorology and the power system**
 - extremes in weather with relation to the power system
 - extremes in the power system and their weather dependency
 - combinations of non-extremes that additively form an extreme (e.g. Dunkelflaute)
- **Forecasting tools to mitigate Extremes in the power system**
 - Forecasting tools availability for different time horizons (near-real-time, day ahead, long-term/seasonal forecasting...)
 - Forecast types specific designed for extreme detection
 - Difference between a general forecast and an extreme forecast software tool
- **AI and Cybersecurity in Extreme situations**
 - Risks with AI algorithms related to Extremes in the power system
 - Benefits of AI tools in or when approaching Extremes
- **Uncertainty of Extremes**
 - Decision-Making in Extremes – human factor, automatisisation

Want to present your
ideas/work on
extremes ?
Send an abstract to
com@weprog.com



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Collaboration Needs & Research

Definition is key:

Which tools are necessary to tackle uncertainties & Extremes in systems with high penetration of renewable energy?



Impact when moving from 20% to 50+% RES in power grids in a changing climate

Extremes Definitions
weather conditions & power system

HOWTO deal with ...

visibility & operability
DSO <-> TSO

Data quality requirements
to tackle challenges in power system



Task 51 – “Forecasting for the weather-driven Energy System”

iea-wind.org/task51

Get in touch with us...

See following
dissemination
slides ...

Operating Agent & Task Managers:

presenting

Gregor Giebel

Caroline Draxl

Corinna Möhrle

Roskilde, Denmark

Golden (CO), USA

Assens, Denmark

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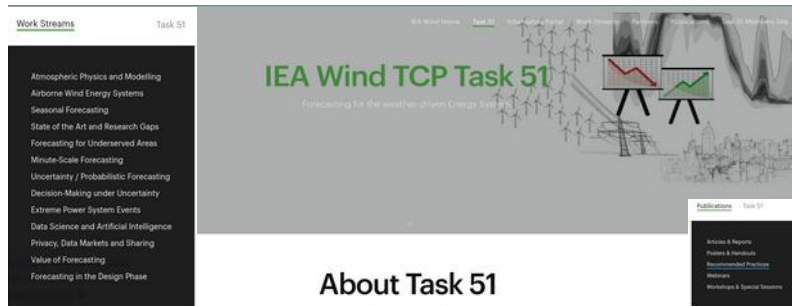
com@weprog.com

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.

Task 51 Web Presence

Website

<https://iea-wind.org/task51>



Forecasting for the Weather Driven Energy System – Improving the value of renewable energy forecasts to the wind industry

The Task 51, under the IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind) focuses on improving the value of renewable energy forecasts.

There are three distinct areas of challenge in forecasting wind power. The first area is in the continuing effort to improve the representation of physical processes in weather forecast models through both new high performance initializations and tailored parameterizations. The second area is the heterogeneity of the forecasters and end users, the full understanding of the uncertainties throughout the modelling chain and the incorporation of novel data into power forecasting algorithms. A third area is representation, communication, and use of these uncertainties to industry in forms that readily support decision-making in plant operations and electricity markets.

This Task will focus on facilitating communication and collaborations among international research groups engaged in the improvement of the accuracy and applicability of forecast models and their utility for the stakeholders in the wind industry, in the power sector and in the energy system.

This Task has the following specific objectives:

- To establish an active, open forum for sharing knowledge among the participants, related IEA Wind Tasks and other related TCPs through workshops, dissemination and communication measures
- To establish and communicate standards and frameworks for the operation and evaluation of forecast model performance
- To identify paths to increased application and utility of forecast information to the task stakeholders
- To advance the knowledge in the underlying atmospheric physics, in the mathematical models converting the transforming atmospheric quantities to energy system application variables, in the modelling of the uncertainty and in the applications and decision-making
- To identify most promising areas for new research to improve the quality and utility of forecasts
- To provide guidelines for the implementation of optimal forecasting solutions



YouTube Channel

<https://www.youtube.com/c/IEAWindForecasting>



IEA Wind Forecasting
67 Abonnenten

ABONNIEREN

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Uploads ▶ ALLE WIEDERGEBEN



IEAWindTask36 Webinar4
2018
75 Aufrufe • vor 11 Monaten



Probabilistic Forecasting in
Practice
229 Aufrufe • vor 11 Monaten



Webinar on Wind Power
Forecast Solution Selection
139 Aufrufe • vor 11 Monaten



IEA Wind Task 36 Forecasting
- The Overview
313 Aufrufe • vor 11 Monaten



Webinar
Weather-AI



IEAWindForecasting <https://youtu.be/t6H7diavQdg>

Handouts

- 2-page handouts: quick overview of major results
- 3 currently available; can be obtained from:

<https://iea-wind.org/task51/task51-publications/task51-posters-and-handouts/>

IEA Wind Task 36
Forecasting for Wind Power

FORECASTING FOR YOU

Setup

Wind power forecasts have been used operationally for over 25 years. Despite this fact, there are still several possibilities to improve the forecasts, both from the weather prediction side and from the usage of the forecast.

The IEA Wind Task is divided in three work packages. Firstly, a collaboration on the improvement of the scientific basis for the **wind predictions** themselves. This includes numerical weather prediction model physics, but also widely distributed information on accessible datasets. Secondly, we deal with the **conversion to power** and losses affecting the forecast renders. Thirdly, we will be engaging real users aiming at dissemination of the best practice in the usage of wind power predictions. The Task is currently in its second phase, 2022-2023.

Results of phase I (2016-2018)

We developed an **information portal**, with links to data, projects and knowledge useful for wind power forecasting. This could be a list of full maps useful for online validation of NWP models, a list of field campaigns with open data for model verification, or a selection of benchmarks for forecasts with established data sources and existing reference frameworks.

A major result was the **IEA Wind Recommended Practice (RP)** on **Forecast Solution Selection**, detailing our recommendations to get the best related forecasts for the individual use case. The RP starts with the initial definition which might or might not end up with the decision to do a forecast first, the second document shows how to conduct such a trial in order to yield acceptable and usable results for both the end user and the participating vendor. The trial part shows how to evaluate the trial to get 2) significant, 2) representative and 3) reliable results.

For **probabilistic forecasts**, we published two papers with an overview (for a broader reader) and one with a long list of specific use cases (more technically oriented). We also classified methods for uncertainty forecasting and tried to establish a common vocabulary. We also mapped the current use of probabilistic forecasts through a questionnaire.

Impact

The Task sends out **news** a few times a year, is present on conferences and meetings, and has its own **YouTube** channel. There, alongside video transmissions of the public workshops, we also had a **webinars** of half an hour talks plus audience questions on the major results of phase I. The fourth one was an additional one on forecast use in Germany.

The Task members also try to get an **enhanced collaboration** between weather prediction providers and vendors, and between vendors and end users. One activity for the current phase of the Task (2020-2023) is a book into **standardization** of data, to make data exchange more fluid across the industry. Another activity is to evaluate the **value** of better forecasting.

We also collaborate with other Wind Tasks, e.g. to the common workshop on minute scale forecasting we had together with Task 12 later. In the future, we will also collaborate with IEA PV Task 13 Solar resources, which also deal with forecasting and has some of the same themes.

Collaboration

Currently, some 250 people from 12 countries are collaborating on forecasts. There are meetings every half year, often in conjunction with relevant conferences. We also have special sessions at conferences for outreach, and usually an overview poster. If you are interested to collaborate, or just to be informed about new results, please contact Giorgio Gobbi.

For more information, contact:
Giorgio Gobbi
Senior Technical Officer
IEA Wind Task 36
g.gobbi@iea-wind.org

The International Energy Agency is an intergovernmental organization that works to promote energy security, economic development, and environmental protection. It is the world's largest international organization of its kind, with 38 member countries and 12 associate members. The IEA's mission is to ensure the reliable, affordable, and sustainable energy supply for its member countries and to promote energy efficiency and clean energy technologies. The IEA also provides technical assistance and policy advice to developing countries. The IEA's work is supported by a secretariat in Paris, France, and a network of regional offices and experts around the world.

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Task Overview

Challenge

Understanding the benefits and the pitfalls when employing probabilistic forecasts requires deeper understanding than is currently found, practice, and infrastructure for power engineers as well as scientists and researchers.

There is a complex level that needs to be mastered in order to be able to make use of probabilistic forecasts. The challenge of forecasts is reducing the available management tools of power generation from time and scale. This is a large challenge for the power industry, which is currently facing a number of challenges. The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

Solution

The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

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IEA Wind Task 36
Forecasting for Wind Power

RECOMMENDED PRACTICES FOR SELECTING PROBABLE POWER FORECASTING SOLUTIONS

Challenge

For operators of wind farms, selecting the right forecasting solution is a complex task. It involves understanding the different types of forecasting solutions available, their strengths and weaknesses, and how they can be used to optimize the performance of the wind farm. The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

Solution

The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

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IEA Wind Task 36
Forecasting for Wind Power

Understanding Uncertainty: the difference from a deterministic to a probabilistic world

Challenge

Understanding the benefits and the pitfalls when employing probabilistic forecasts requires deeper understanding than is currently found, practice, and infrastructure for power engineers as well as scientists and researchers.

There is a complex level that needs to be mastered in order to be able to make use of probabilistic forecasts. The challenge of forecasts is reducing the available management tools of power generation from time and scale. This is a large challenge for the power industry, which is currently facing a number of challenges. The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

Solution

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Forecast Solution Selection

Challenge

Understanding the benefits and the pitfalls when employing probabilistic forecasts requires deeper understanding than is currently found, practice, and infrastructure for power engineers as well as scientists and researchers.

There is a complex level that needs to be mastered in order to be able to make use of probabilistic forecasts. The challenge of forecasts is reducing the available management tools of power generation from time and scale. This is a large challenge for the power industry, which is currently facing a number of challenges. The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

Solution

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Uncertainty and Probabilistic Forecasting

Challenge

Understanding the benefits and the pitfalls when employing probabilistic forecasts requires deeper understanding than is currently found, practice, and infrastructure for power engineers as well as scientists and researchers.

There is a complex level that needs to be mastered in order to be able to make use of probabilistic forecasts. The challenge of forecasts is reducing the available management tools of power generation from time and scale. This is a large challenge for the power industry, which is currently facing a number of challenges. The IEA Wind Task 36 is a collaborative effort to address these challenges and to develop a common framework for the use of probabilistic forecasts. The task is currently in its second phase, 2022-2023.

Solution

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IEA Wind Task 51 Information

iea-wind.org → Task 51 → Publications → [Recommended Practice](#)

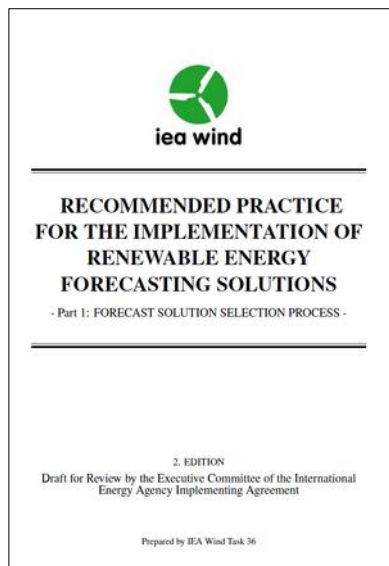


IEA Wind Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions

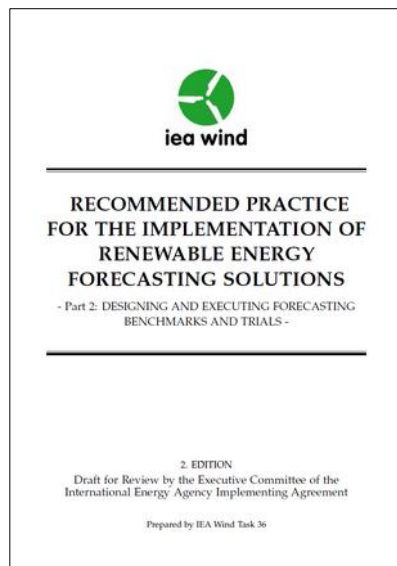


Corinna Möhrle
John W. Zack
Gregor Giebel

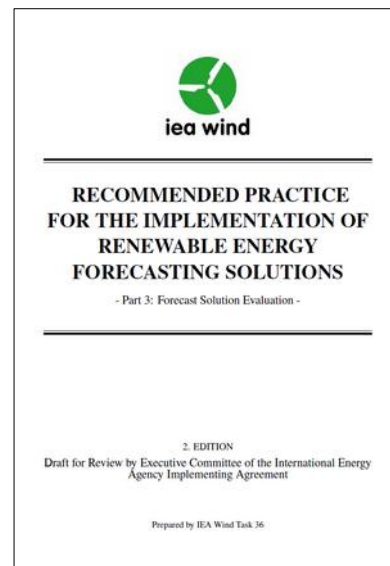
IEA Best Practice Recommendations for the Selection of a Wind Forecasting Solution v2: Set of 4 Documents



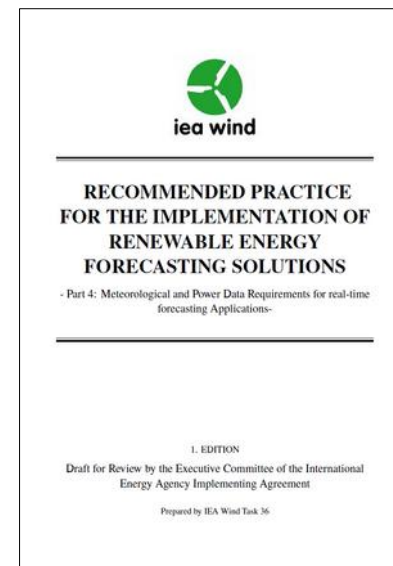
Part 1: Selection of an Optimal
Forecast Solution



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

Now as OpenAccess book!

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



Validation & Verification code examples

Examples developed within the IEA Wind Task 36 and Task 51:

See: <https://iea-wind.org/task51/task51-publications/task51-recommended-practices/>

evalprob4cast

An R-package for evaluation of ensembles as probabilistic forecasts or event forecasts

Available on GitHub: <https://github.com/jbrowell/evalprob4cast>

Publication: <https://doi.org/10.48550/arXiv.2504.03544>

Existing metrics: CRPS, Brier Score, ROC curve, Histograms, Reliability Diagram, Contingency table

Graphics: time series, histograms, ROC curve, CRPS

WE-validate

Software package **for Wind Energy Validation**

Available on GitHub: <https://github.com/joejoeyjoseph/WE-Validate>

Publication: <https://www.sciencedirect.com/science/article/pii/S0960148122014707>

Use Case: Demo Jupyter Notebook (U.S. Mountain Wave case):

https://nbviewer.jupyter.org/github/joejoeyjoseph/i-validate/blob/main/notebooks/demo_notebook.ipynb

Existing metrics: RMSE, cRMSE, mean bias, mean absolute error

Existing plots: time series, histogram, scatter plot

See also our workshops & conference page:

<https://iea-wind.org/task51/task51-publications/task51-workshops-and-special-sessions/>



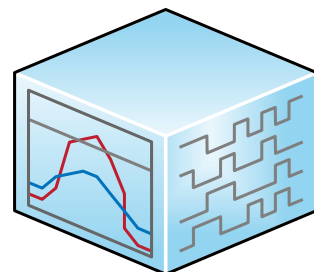
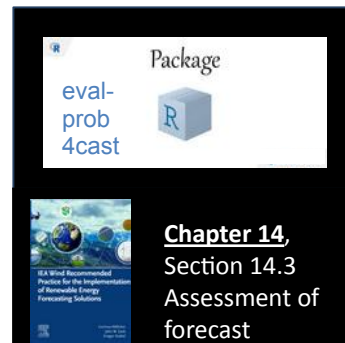
IEA Wind Recommended Practice for the
Implementation of Renewable Energy
Forecasting Solutions

Wind Energy Engineering

2023, Pages 321-322



Appendix G - Validation and verification code examples





Information Portal

The Task 51 Information Portal aims to be a useful resource for people in forecasting, especially providing links to publically available data for model development.

<https://iea-wind.org/task-51/t51-information-portal/>

The Task members identified several issues which might be useful in an information portal for wind power forecasting. Those are:

- [A list of meteorology masts](#) with online data over 100m height, useful for verification of wind speed predictions
- [A list of meteorological experiments](#) going on currently or recently, either to participate or to verify a flow model against
- [A list of publicly available wind power forecasting benchmarks](#), to test your model against
- [A list of current or finished research projects](#) in the field of wind power forecasting
- [A list of future research issues](#)
- [A list of open weather data](#)

For all of those, we would be happy to accept input, so head over to the site and see where you can help, or what you can use!

Please find the full text of the task description [here](#).

The task is led by [Gregor Giebel](#) from DTU Wind Energy.

Decision making under uncertainty

Forecasting Games		
Forecast Game	Short Description	Link
Wind Power Trading decisions for a Wind Park in complex Terrain	IEA Wind Task 36/51 and MP for Human Development have released a forecast game at the European Meteorological Society Annual Conference 2021.	Forecast Game (choose "Play the Game" at top menu)
	The game investigates how ensemble forecasts showing forecast uncertainty can improve our ability to make informed decisions, also when the weather conditions are complex or extreme.	Forecast Game Results Links to additional material WW2022: Key Note Presentations EMS 2022: Presentation
	In the experimental game, the player is asked to make trading decisions for a wind farm in complex terrain in a number of situations based on deterministic and probabilistic power and wind forecasts.	AMS 2022: Presentation Electric-City 2021: Page & award winning Poster EMS 2021: Presentation
	IEA Task 36 Webinar	YouTube & Presentation
Wind Power Trading decisions for an Offshore Wind Park	Forecast Game (offline version to come soon)	Forecast Game Results
	IEA Wind Task 36 and MP for Human Development have released a forecast game at the IEA Wind Task 36 Glasgow workshop in Jan 2020.	Forecast game introduction presentation: IEA Wind Task 36 YouTube channel at time 3:03:00 Presentation Download
	The game investigates how useful different forecasts are for wind power trading decisions in a simplified way in the game, the player is asked to make trading decisions for an offshore wind farm in the North Sea in a number of situations based on deterministic and probabilistic power and wind forecasts.	Publications: Methodologicals 2022 1st Phys. Conf Series 2021
Call for Water Game	In the game the player is managing a water supply reservoir!	Forecast Game
	Purpose of the Game is to train with forecast information and improve decision-making.	License conditions: Creative Commons CC BY-NC-ND 4.0

Call for Water Game	In the game the player is managing a water supply reservoir!	Forecast Game
	Purpose of the Game is to train with forecast information and improve decision-making.	License conditions: Creative Commons CC BY-NC-ND 4.0
	The player is newly appointed water manager for a reservoir that serves water users for a town and is responsible to secure sufficient water for the town at a specific time.	
HEPEX Forecast Game "Pathways to running a flood forecasting centre: an adventure game"	The game is played in two rounds of 5 years each.	Forecast Game A blog post on the game was published in the latest review website
	The game simulates the responsibilities of a water management centre in charge of protecting a city against floods.	
Feuerwehr (only available in German)	The game is investigating what kind of information is needed and how many days in advance the forecast information is good enough to make a decision that could save lives and money.	Reference: Arnal et al. (EGU 2017 abstract)
	The game's aim is to well users understand and are able to make use of the uncertainty of weather forecasts	Forecast Game

Offline Games

HEPEX Forecast Games		
Water Management Game	The game experiment focuses on risk-based decision-making in water management using probabilistic forecasts of inflows to a reservoir	Download: English , French , German Reference: Coughenour et al. 2015 HEPEX blog post
Peak Box Game	The "Peak Box" game supports interpretation and verification of operational ensemble peak flow forecasts, proposed by Zappa and colleagues, and encourages discussions of the use of ensemble predictions in operational hydrology.	Download: Peak Box Game Reference: Zappa et al. 2013 HEPEX blog post
	The Peak-Box defines the "best estimate" of a flood event's timing and magnitude by framing the discharge peaks of all members of an ensemble forecast and taking their median in timing and magnitude.	

Table and collection of forecasting Games:

iea-wind.org/taks 51

→ Workstreams → Decision Making under Uncertainty

<https://iea-wind.org/task51/tasks51-work-streams/ws-decision-making-under-uncertainty/>

Research projects

<https://iea-wind.org/task-51/project-list/>

Here are some ongoing and finished projects towards short-term prediction of wind power throughout the last two decades. In total, the public (and partly private) spending on this list exceeds 150 million euro.

Country	Project acronym	Full title	Sponsor	Total / Funded budget	Start – end date	Participants incl. those from IEA Task 36/51
DE	WindStore	Optimized system integration of offshore wind energy through intelligent linking of various forecast concepts and forward-looking management of distributed cascade storage systems.	BMWK (German Federal Ministry for Economics and Climate Protection)	1.76 M€ / 1.47 M€	Jan 2024 – Dec 2026	Fraunhofer IEE, DLR, 4Cast, SETrade, WEPROG, EnBW, Stadtwerke Hassfurt und Wunsiedel
BE	BeFORECAST	Wake-effect included offshore wind power forecasting for smooth operation of the Belgian electricity grid based on advanced data handling and sensor technology, including airborne systems.	Energy Transition Funds of the Federal Public Service Economy of the Belgian Federal Government	3.25 M€ / 2.74 M€	Nov 23 – Oct 25	von Karman Institute for Fluid Dynamics, Vrije Universiteit Brussel, KU Leuven, 3E, SABCA, Royal Meteorological Institute of Belgium
UK		Multi-variate forecasting for wind power integration in electricity markets	Shell/ETP Scotland	90k€/120k€	Oct 22 – Mar26	University of Glasgow, Jethro Browell