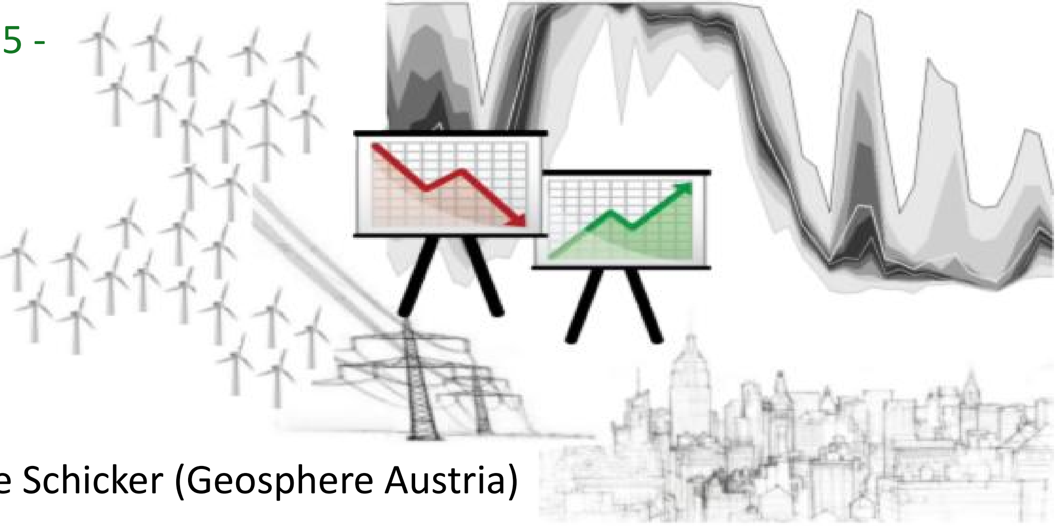
iea wind **Task 51 "Forecasting for the Weather-driven Energy System"**

Wind Energy & Science Conference

Session RS#07.4 – Advances in Wind Power Forecasting

Nantes, France – 26th June 2025 -

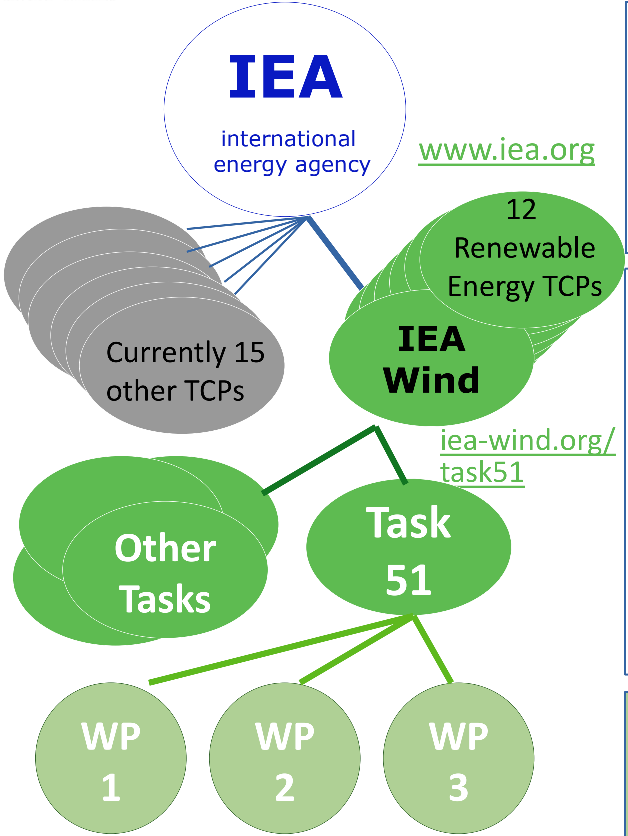


Extreme Power System Events within IEA Wind Task 51 Forecasting for the weather-driven Energy System

Corinna Möhrlen (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 <u>30 members countries</u> 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:

- <u>*One out of 25 Tasks of IEA Wind*</u>: https://iea-wind.org/
- Task 51 Phase 1: 2022-2025 (previous Task 36: 2016-2021)
- <u>Operating Agent</u>: Gregor Giebel (DTU), T-Manag.: C. Draxl (EPRI), C.Möhrlen (WEPROG)
- <u>12 Member countries</u>: AT, CN, DE, DK, ES, FI, FR, IE, PT, SE, UK, US
- <u>Objective</u>: **facilitate int. collaboration on renewable energy forecasts**
- <u>Participants</u>: (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

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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

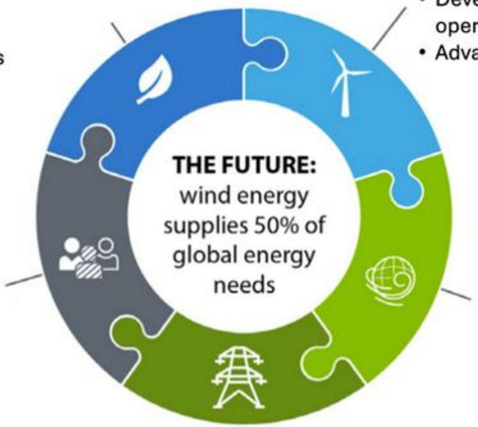
Currently 25 active TASKS

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

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

Tasks 44, 49, 52, 54 & 57



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

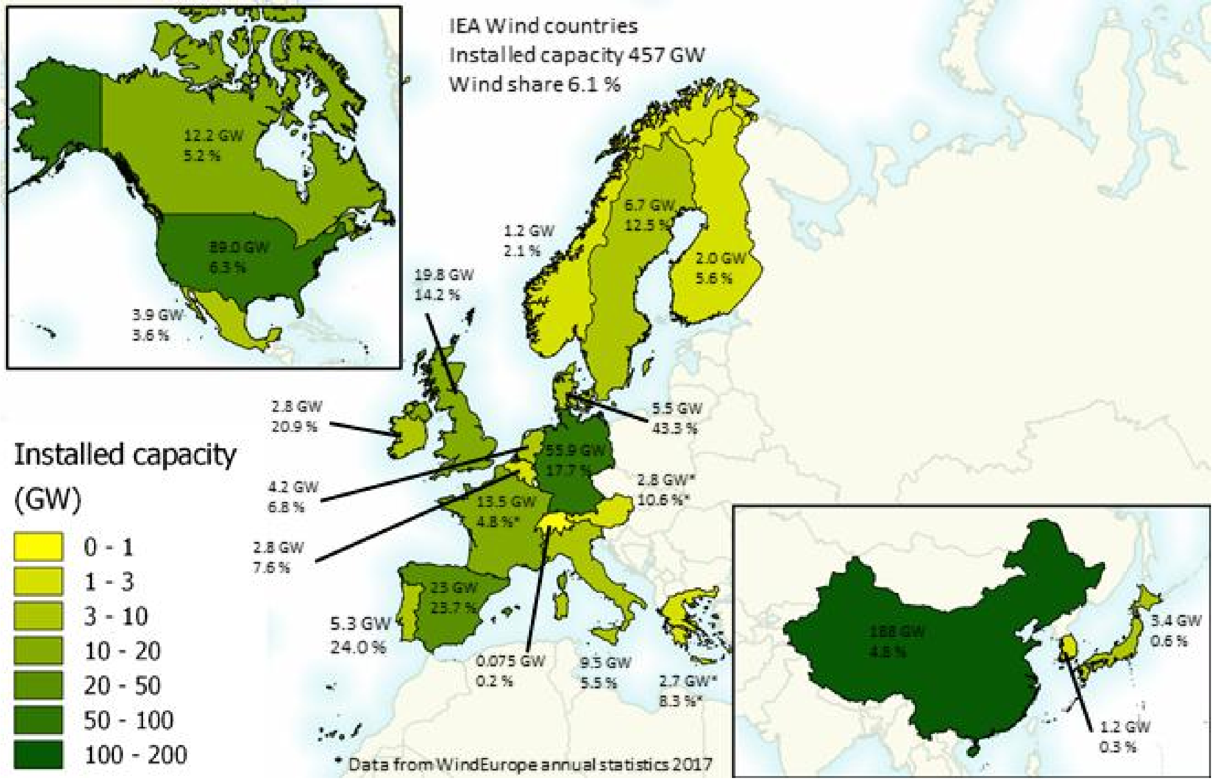
Tasks 28, 39, 53

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

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

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

The Plant and Grid
- Improving modelling
- Optimising plant design for multiple objectives
- Readying wind plants for grid support



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

Forecasting for Wind Energy

2016-2018

T36 Phase 1

2019-2021

T36 Phase 2

Redefinition

T51 Phase 1+2

2022-2029

Forecasting for the weather-driven Energy System

IEA Wind Task 51 Work - distributed over 11 work streams

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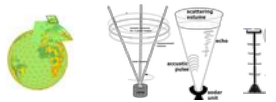
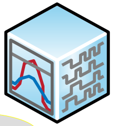
Work Streams:	WP1 Weather	WP2 Power	WP3 Applications	Collaborations
Atmospheric physics and modelling (WP1)				WMO, PVPS T16
Airborne Wind Energy Systems (WP1)				IEA Task 48 Airborne Wind Energy
Seasonal forecasting (WP1)				Hydro TCP, Hydrogen TCP, Biomass TCP
State of the Art for energy system forecasting (WP2)				PVPS Task 16, Hydro TCP, Hydrogen TCP, IEC SC8A WG2, …
Minute scale forecasting (WP2)				Wind Tasks 52 Lidar, Task 44 Farm Flow Control and 50 Hybrids
Data science and artificial intelligence (WP3)				PVPS Task 16
Extreme power system events (WP3)				Task 25, ESIG, IEA ISGAN, PVPS T16, G-PST, DESTINE
Uncertainty / probabilistic forecasting (WP3) & for underserved areas				ESIG, IEEE WG Energy Forecasting, PVPS Task 16, IEC SC8AWG2
Decision making under uncertainty (WP3)				EMS, WEMC, WEXICOM
Privacy, data markets and sharing (WP3)				PVPS Task 16, Wind Tasks 52 Lidar, DestinE, IEC SC8AWG2
Value of forecasting (WP3)				PVPS Task 16



Modelling & data assimilation

workshops

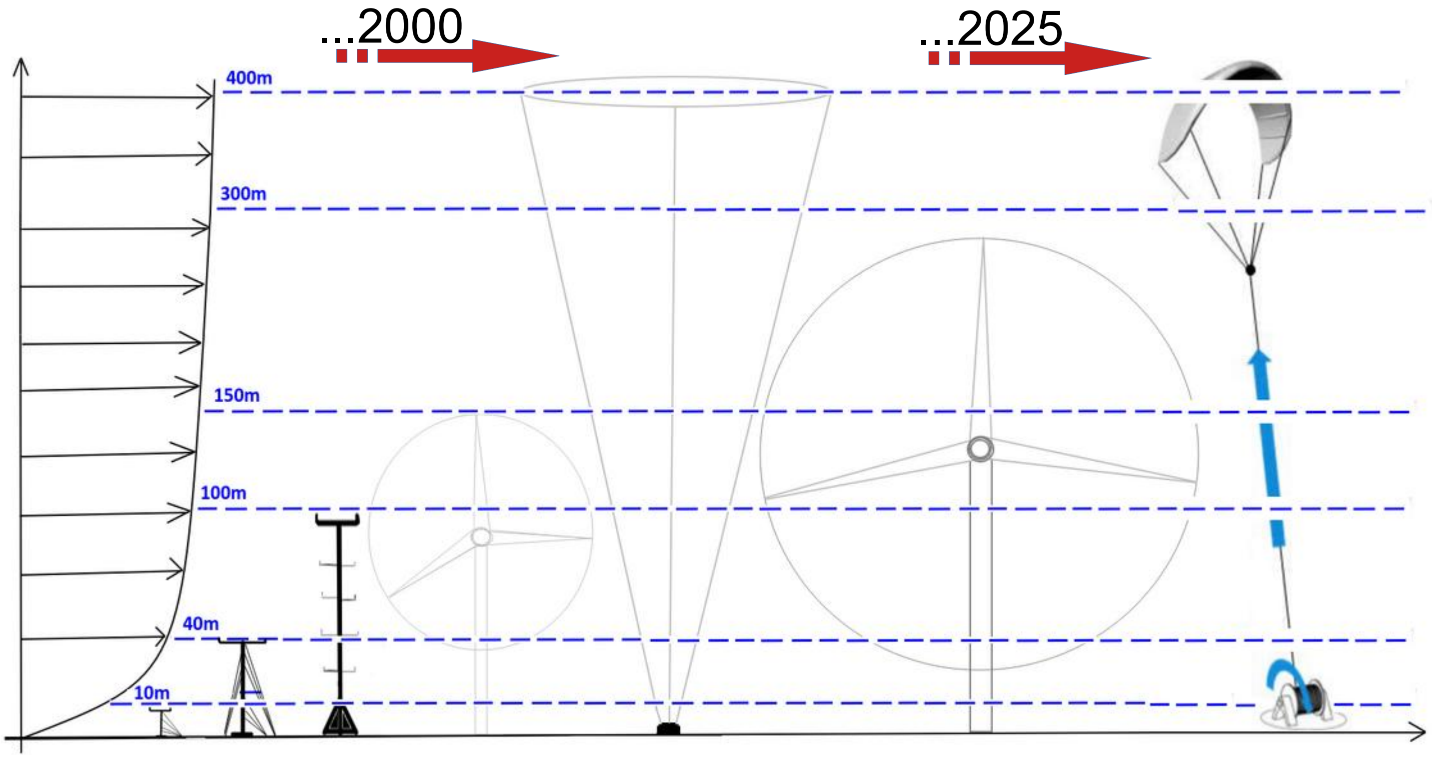


Verification Platform

Publications

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

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



Slide design: Corinna Möhrlen

IEA's take on the VRE integration development:

Introduction to iea's VRE integration phases

iea

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

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.

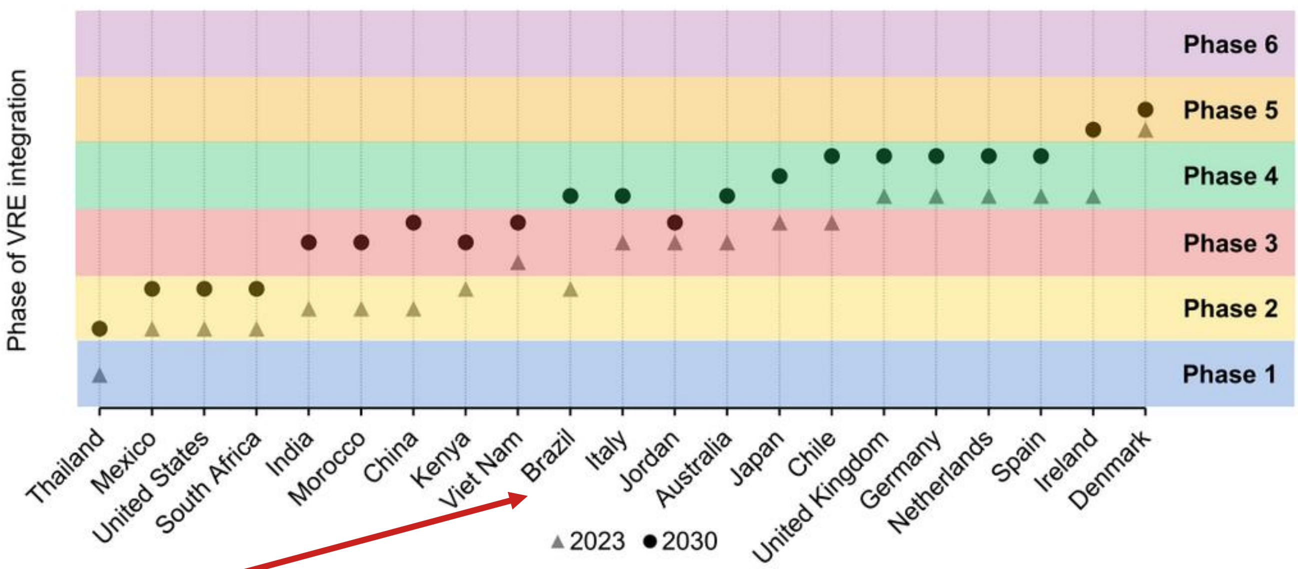
NOTE: Phases are not to be understood as decarbon-isation measures, but as **integration challenge** !!!

IEA's take on the VRE integration development:

Introduction to iea's VRE integration phases

30

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

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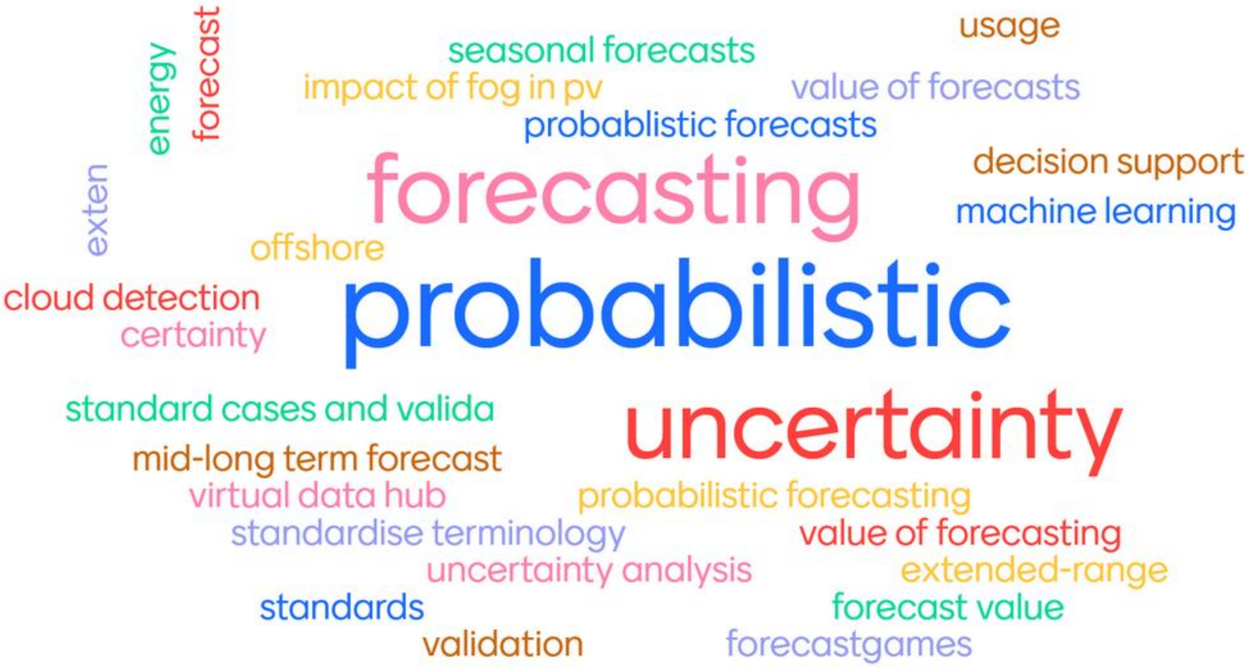
Task 51: Forecasting for the Weather-Driven Energy System

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

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

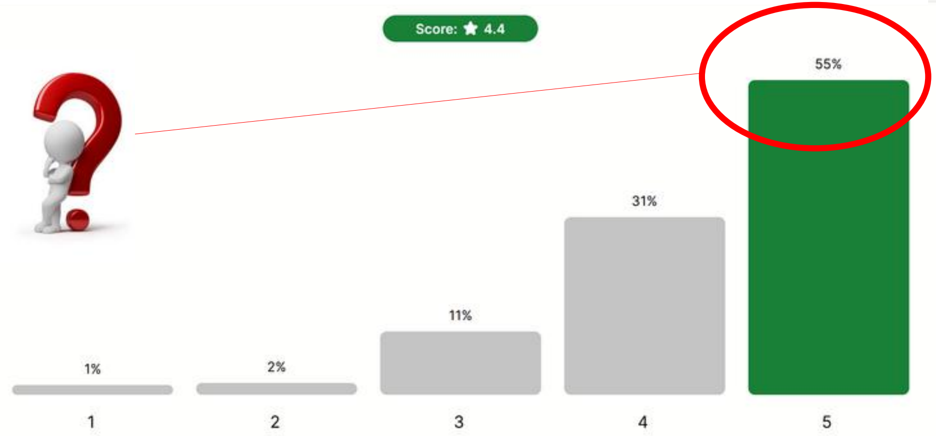


Where are the gaps ... ?

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)



Example 1: Meaning of a “holistitc” view:

Uncertainty Propagation throughout the entire model chain

The publication served to

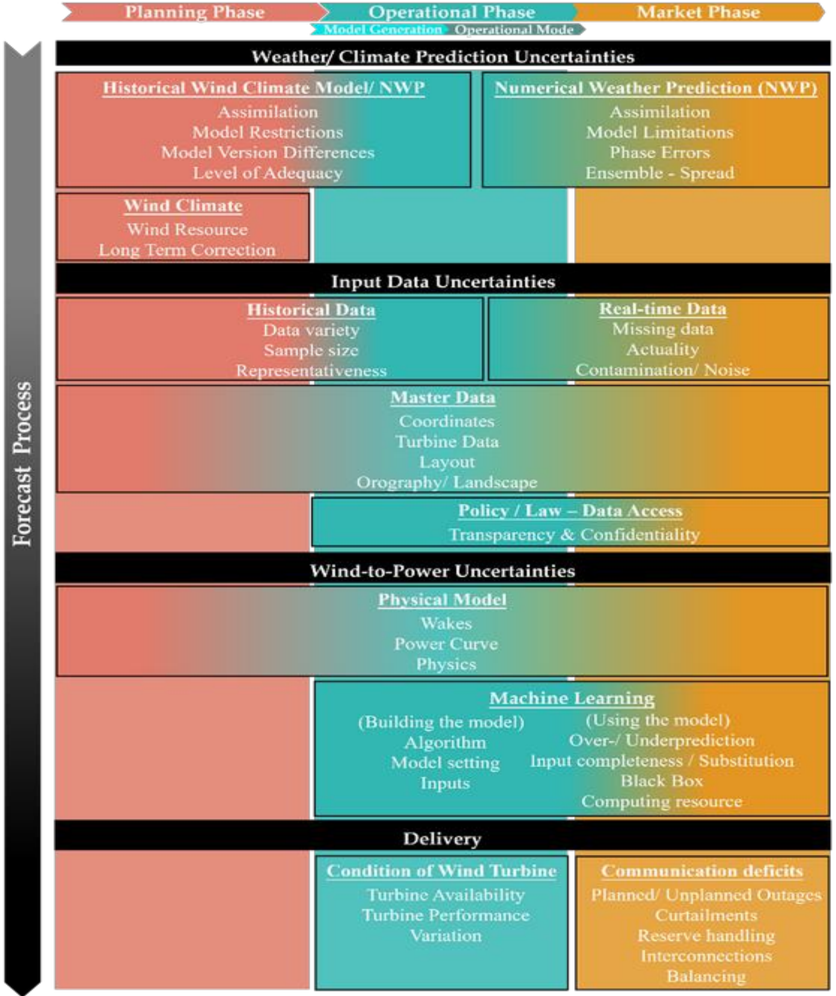
1) Define
2) describe
3) review

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

OpenAccess Download:
https://www.sciencedirect.com/science/article/pii/S1364032122004221



Workstream Uncertainty :

Uncertainty Propagation throughout the model chain with real data

PHASE I
2022-2023

tool 1

tool 2

R-verify tool

tool 3

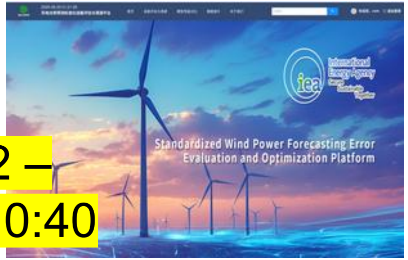
Uncertainty Quantification with test data sets according to 2022 UQ publication*

TALK by Jie Yan
Mini Symposium MS#01.12 – 27.06.2025 Room E 8:50-10:40

PHASE II
2024-2025

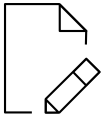
Online Verification Platform

Discussion & testing of verification platform



PHASE III
2025...

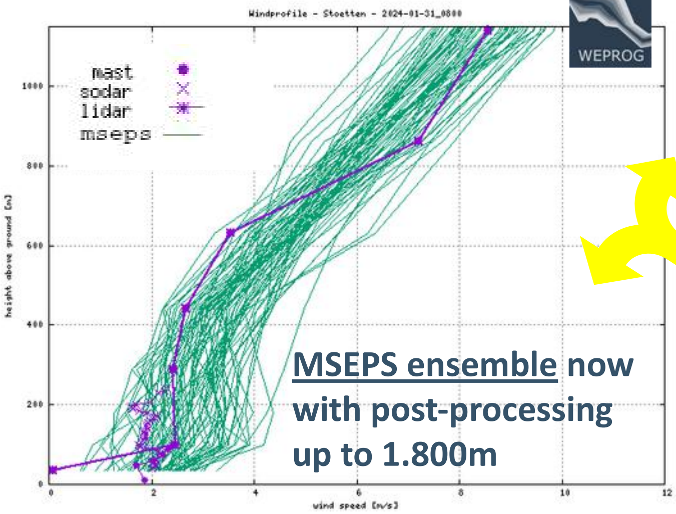
Publication



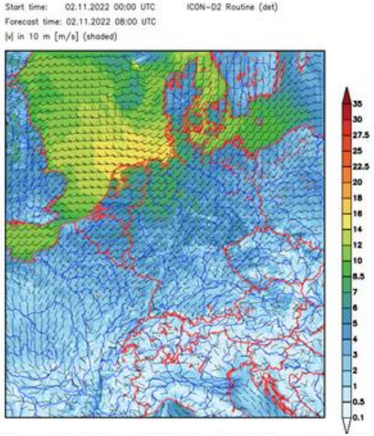
Discussion & writing of publication with most suitable test cases

* 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

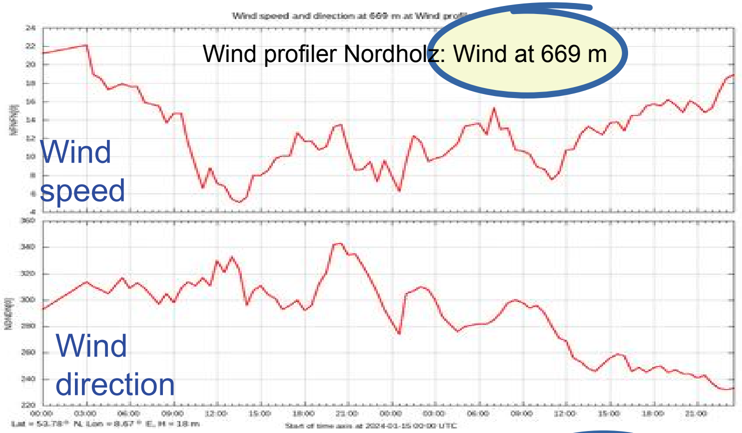


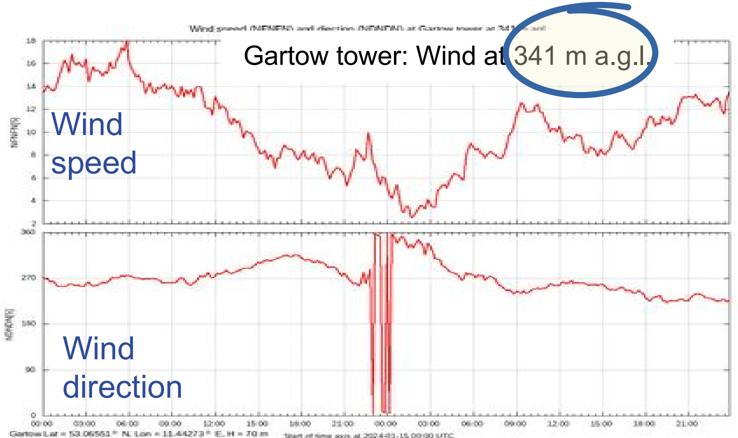
MSEPS ensemble now with post-processing up to 1.800m



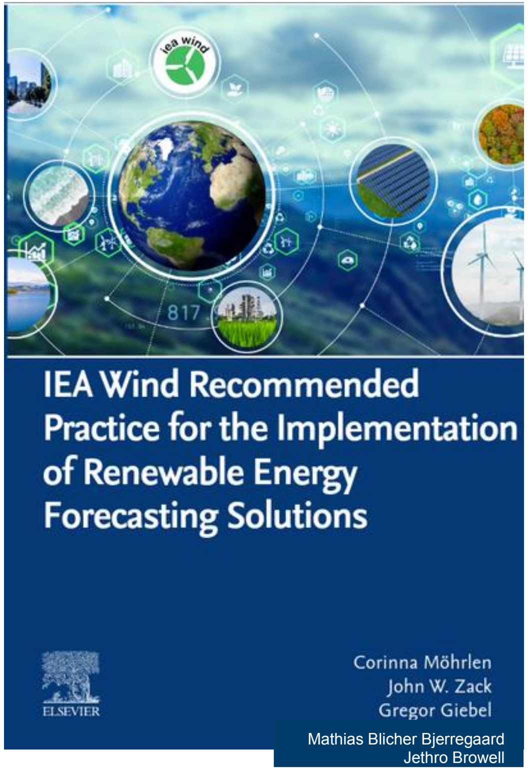
ICON-DE model now in 15min resolution every hour

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





IEA Wind Recommended Practice Example Evaluation Software package: *evalprob4cast*



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

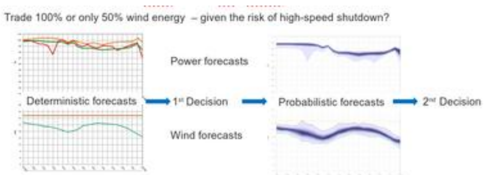
See also our workshops & conference page
for workshop presentations
https://iea-wind.org/task51/task51-publications/task51-workshops-and-special-sessions/

Decision-making under Uncertainty

Max-Planck-Institut für Bildungsforschung
Max Planck Institute for Human Development

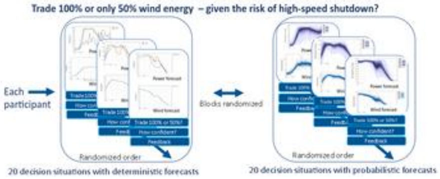
"Probabilistic Forecasting Games & Experiments" initiative

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.dev/wind-power-decisions/about.html

WS Extreme Power System Events

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 dicipines?

Collaboration across diciplines

- Multi-diciplinary task requires multi-diciplinary 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 ov wind causes damage across Ireland

Flights cancelled and diverted in Dublin Airport due to 'severe and des reporting fallen trees

Expand

Waves crash over the pier at Fenit, Co Kerry on Sunday as Storm Isha lashes the southwest. Photograph: Domnick 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

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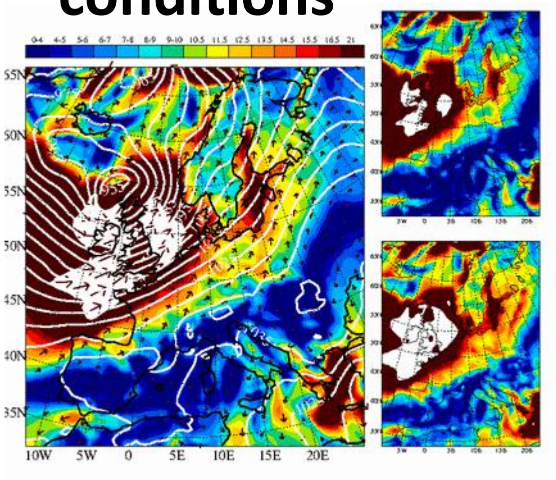
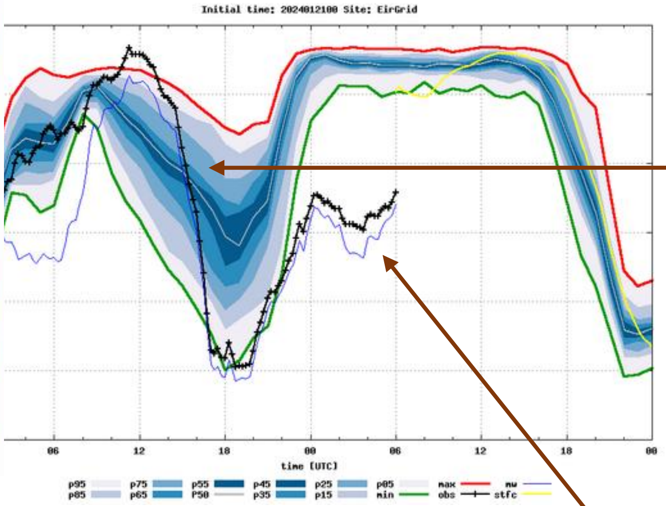
WS Extreme Power System Events caused by extreme weather conditions





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

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

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

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/

ENGAGE

Focus on interaction with stakeholders and users

to tackle possible **current and future** vulnerable hot spots of renewable infrastructure under adverse weather.

DEVELOP

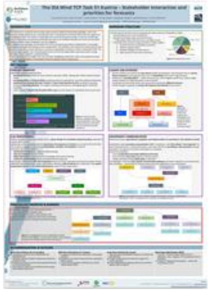
Develop physics-informed machine learning algorithms

to detect adverse weather for renewable infrastructure in weather forecasts and climate scenarios.

RISK AWARNESS

Estimate and quantify the effect of adverse weather

for renewable infrastructure of events, changes in intensity, shift of (current/future) location of hot spots.



EGU-group

EnergyProtect

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

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., Möhrlen, C., **EGU General Assembly 2025**, Vienna, Austria, 27 Apr–2 May 2025

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

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 -

GeoSphere Austria

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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/m²), 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/m²), 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
Thunder-storms	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 -

GeoSphere Austria

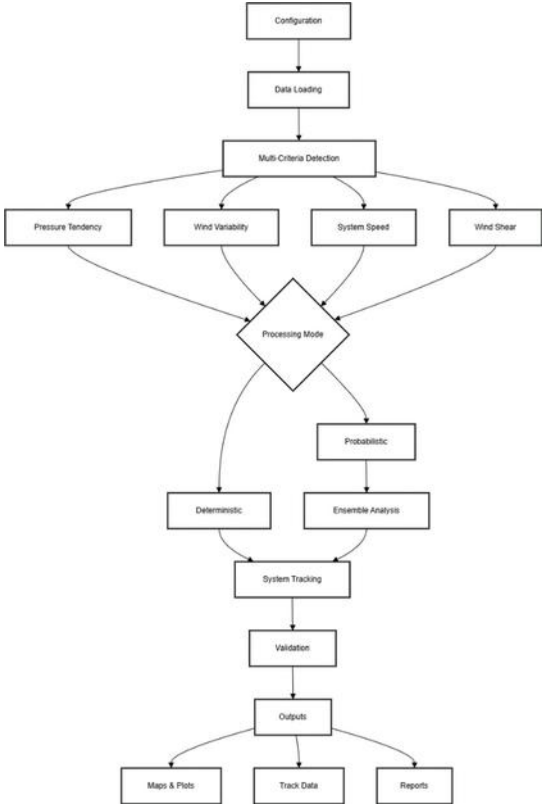
Physics-informed pattern detection of adverse weather events and model mixing

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



WS Extreme Power System – *Severity Indices* -

GeoSphere Austria

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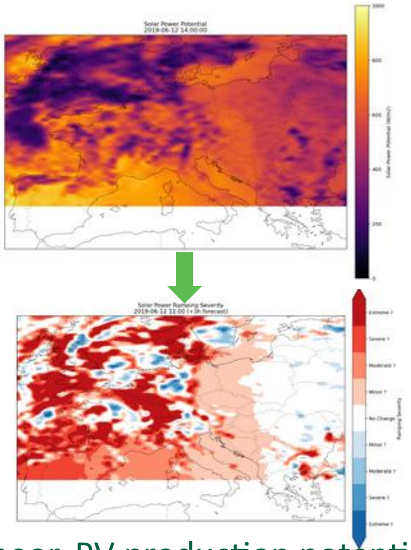
Looking ahead and evaluating conditions … before it becomes critical !!!

Theor. Solar power potential



+ theor. PV production potential

+

Thunderstorm severity index

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

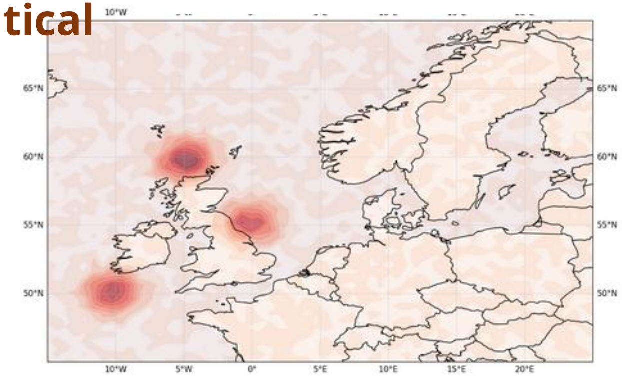
Dealing with Extreme Power System Events – *Storm Tracking* -

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	∂p/∂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	$\lvert u_{850} - u_{10} \rvert$	> 10 m/s	Vertical wind structure indicates system strength	850 hPa - Surface
Geostrophic Wind	$\sqrt{(u^2_m + v^2_m)}$ at 500 hPa	> 20 m/s	Upper-level flow pattern strength	500 hPa level
Thermal Wind	$\lvert u_{850} - u_{10} \rvert$ 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

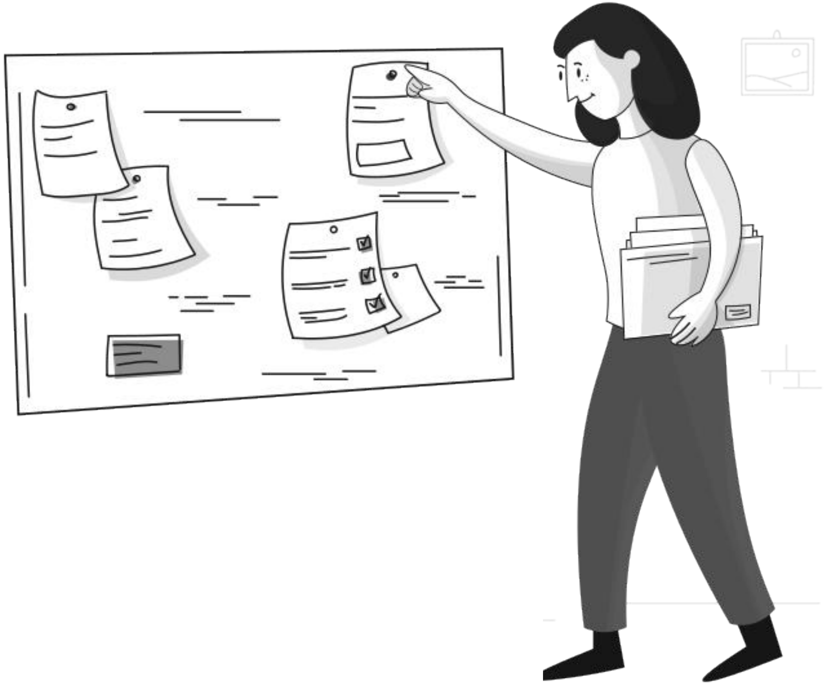
Renewable Energy Meteorology:

- **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*

Safe 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

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NEWS

iea-wind.org/task51

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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, automatisation

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

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"*

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iea-wind.org/task51

Get in touch with us...

See following dissemination slides ...

Operating Agent & Task Managers:

presenting

Gregor Giebel	Caroline Draxl	Corinna Möhrlen
Roskilde, Denmark	Golden (CO), USA	Assens, Denmark
grgi@dtu.dk	caroline.draxl@epri.com	com@weprog.com

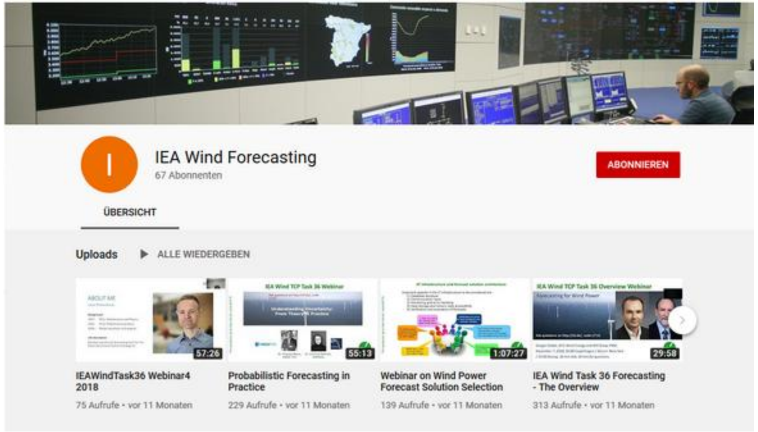
Task 51 Web Presence

Website

https://iea-wind.org/task51

YouTube Channel

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



Webinar Weather-AI

IEAWindForecasting https://youtu.be/t6H7diavQdg

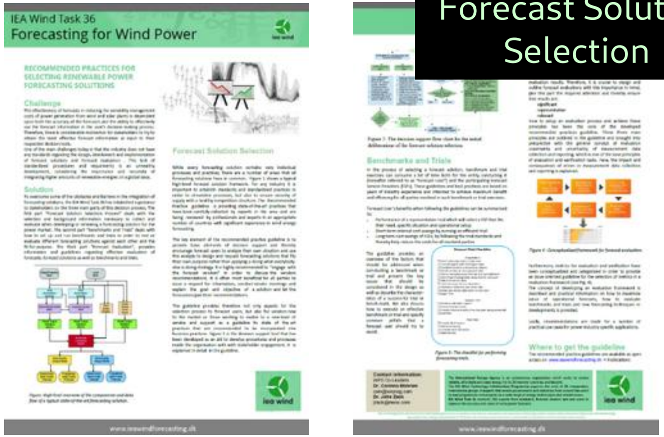
Handouts

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

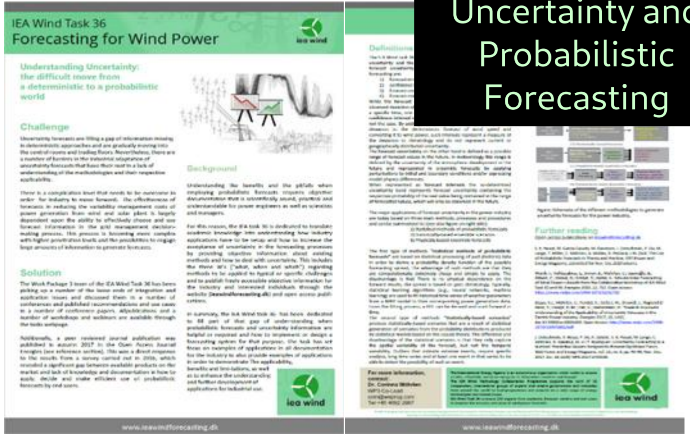
  https://iea-wind.org/task51/task51-publications/task51-posters-and-handouts/

Task Overview

Forecast Solution Selection



Uncertainty and Probabilistic Forecasting



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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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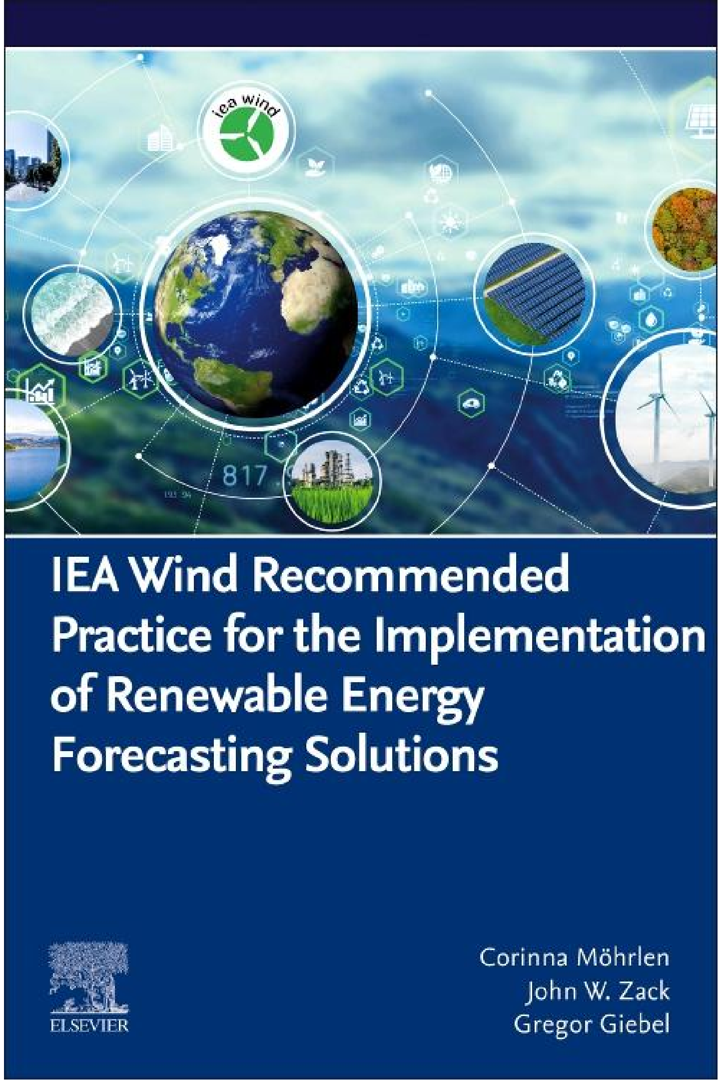
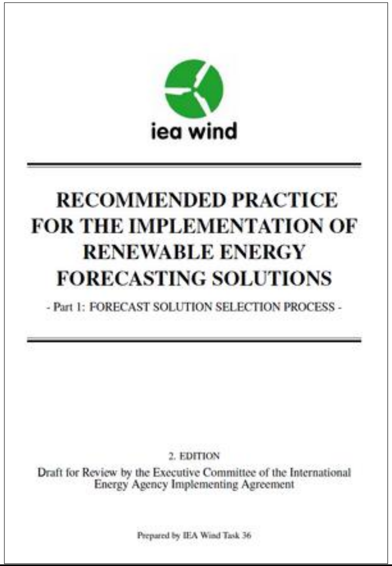
IEA Wind Task 51 Information

iea-wind.org → Task 51 → Publications → Recommended Practice



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

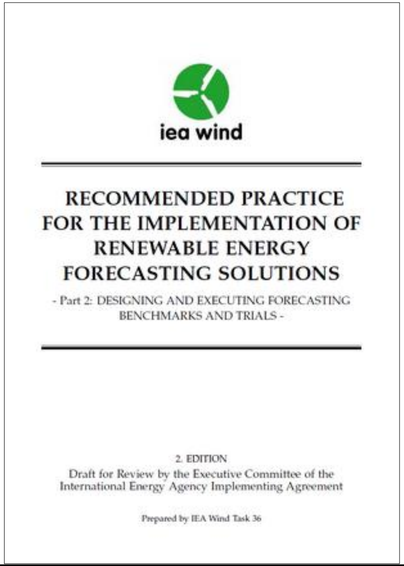
- Part 1: FORECAST SOLUTION SELECTION PROCESS -

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

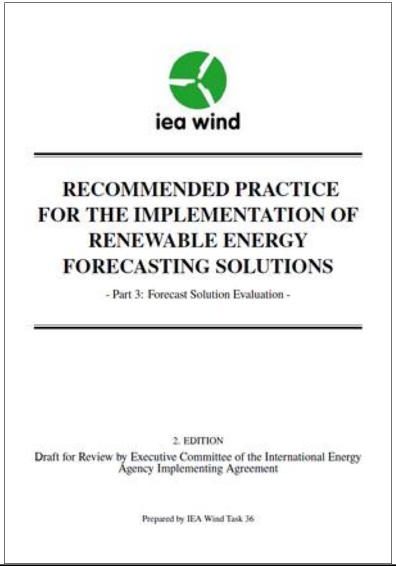
- Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS -

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

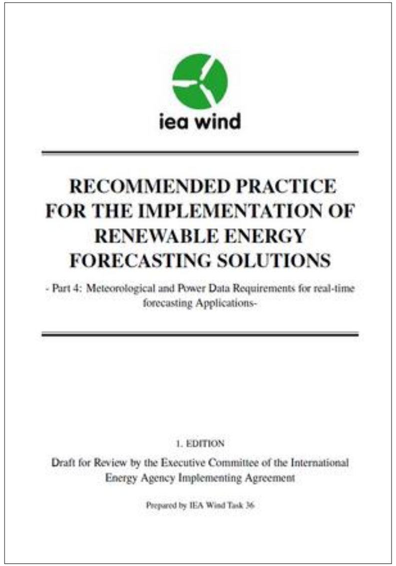
- Part 3: Forecast Solution Evaluation -

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

Now as OpenAccess book!

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

Validation & Verification code examples

ACADEMIC PRESS

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

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

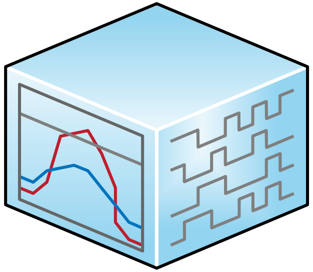
Chapter 14, Section 14.3 Assessment of forecast

WE-validate

Software package **for W**ind **E**nergy **Validat**ion
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/

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/

Technology Collaboration Programme
by iea

IEA Wind TCP | Task 36 | Information Portal | Work Packages | Partners | Publications

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.

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Workstream *Decision-making under Uncertainty*

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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 MPI for Human Development have released a forecast game at the European Meteorological Society Annual Conference 2021. 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. 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.	Forecast Game (choose "Play the Game" at top menu) Forecast Game Results Links to additional material: WIW2022: Key Note Presentation EMS 2022: Presentation AMS 2022: Presentation Electric-City 2021: Paper & award winning Poster EMS 2021: Presentation IEA Task 36 Webinar Youtube & Presentation
Wind Power Trading decisions for an Offshore Wind Park	IEA Wind Task 36 and MPI for Human Development have released a forecast game at the IEA Wind Task 36 Glasgow workshop in Jan 2020. 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 Northsea in a number of situations based on deterministic and probabilistic power and wind forecasts.	Forecast Game (offline version to come soon) Forecast Game Results Forecast game introduction presentation: IEA Wind Task 36 YouTube channel at time: 3:03:00 Presentation Download Publications: MetApplications 2022 J.of Phys. Conf Series 2021
Call for Water Game	In the game the player is managing a water supply reservoir! Purpose of the Game is to train with forecast information and improve decision-making. The player is newly appointed water manager for a reservoir that serves water uses for a town and is responsible to secure sufficient water for the town at a specific time. The game is played in two rounds of 5 years each.	Forecast Game License conditions Creative Commons CC-BY-NC-ND 4.0
HEPEX Forecast Game "Pathways to running a flood forecasting centre: an adventure game"	The game simulates the responsibilities of a water management centre in charge of protecting a city against floods. The game is investigting 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.	Forecast Game A blog post on the game was published in the Imprex project website Reference: Arnal et al. (EGU 2017 abstract)
Feuerwache (only available in German)	The game's aim is to well users understand and are able to make use of the uncertainty of weather forecasts The task of the game is to decide on 16 days, whether or not to request more firefighters for the next 21 hours to handle additional missions in predicted storm events.	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 (original version), German Reference: Crochemore 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. **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.**	**Download: Peak Box Game** **Reference: Zappa et al., 2013** **HEPEX blog post**

Table and collection of forecasting Games:
iea-wind.org/taks 51
→ Workstreams → Decision Making under Uncertainty

https://iea-wind.org/task51/task51-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 Ministery 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

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