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

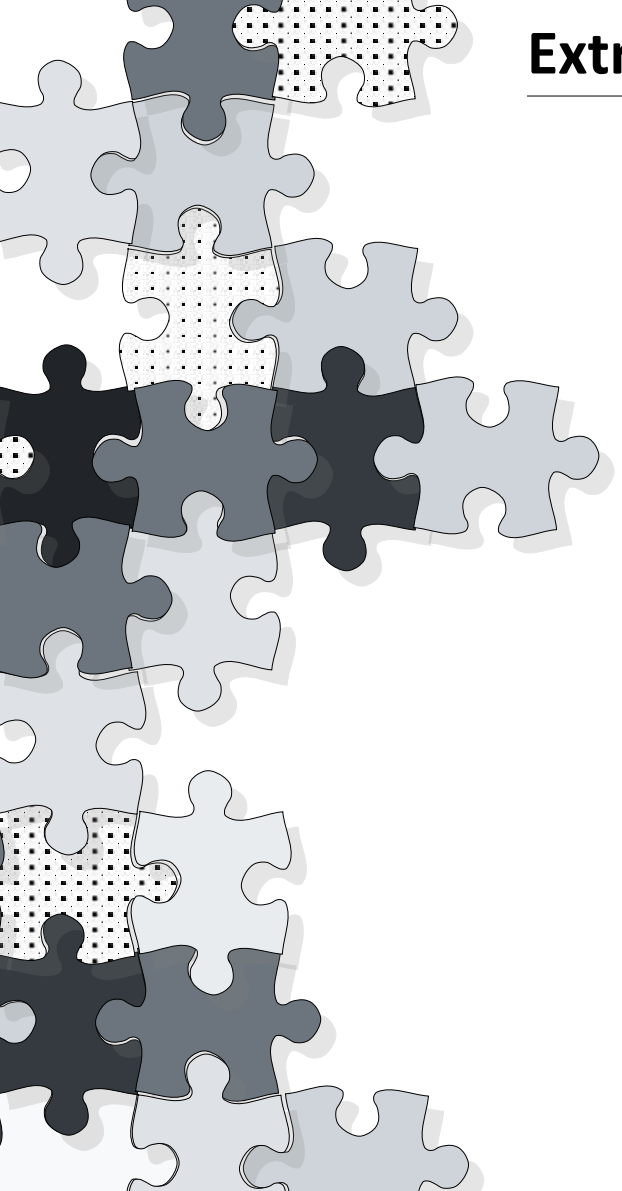
November Webinar Series 4

Review from 5 workshops on Extremes in the Power System

Irene Schicker
Corinna Möhrlen

26. November 2025

Extreme Power System Events

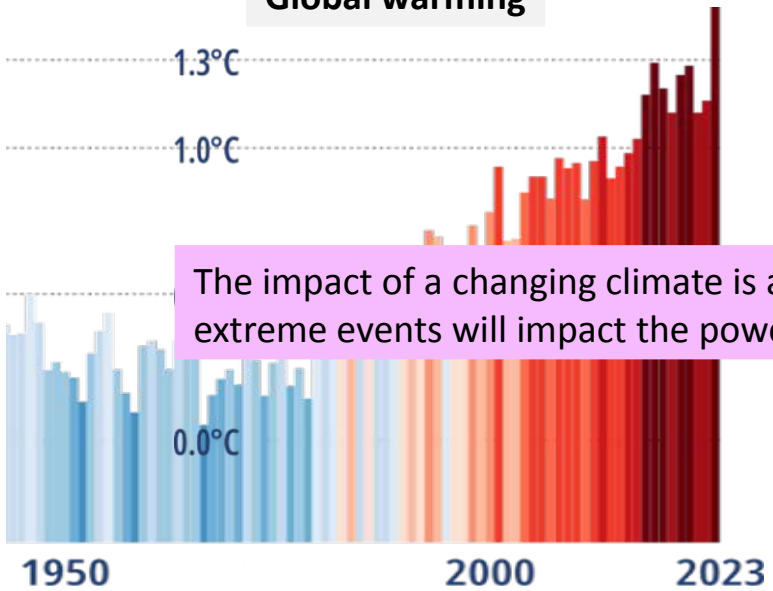


> “Knowledge is NOT power.
> Knowledge is only POTENTIAL power.
> WISE Action & PREPAREDNESS is what is needed in extreme events...”

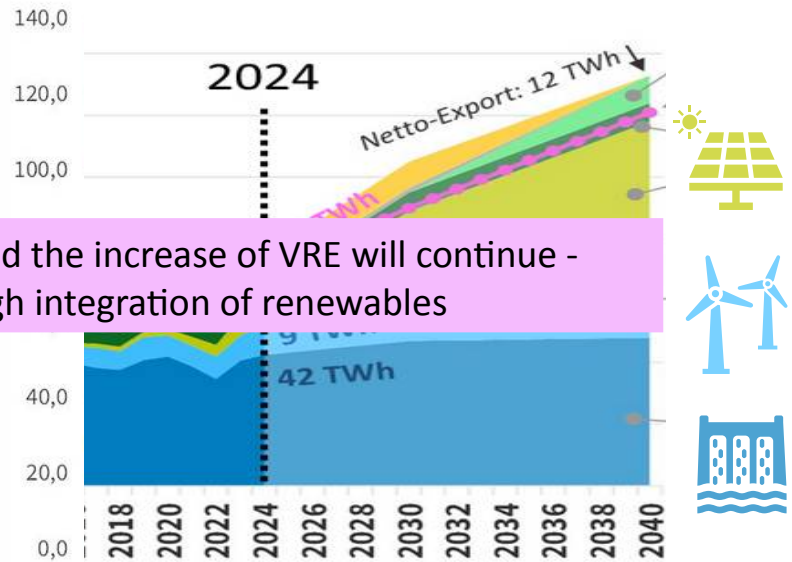
iea wind

VRE share increase and will continue to increase

Global warming



Increase of share of var. renewables

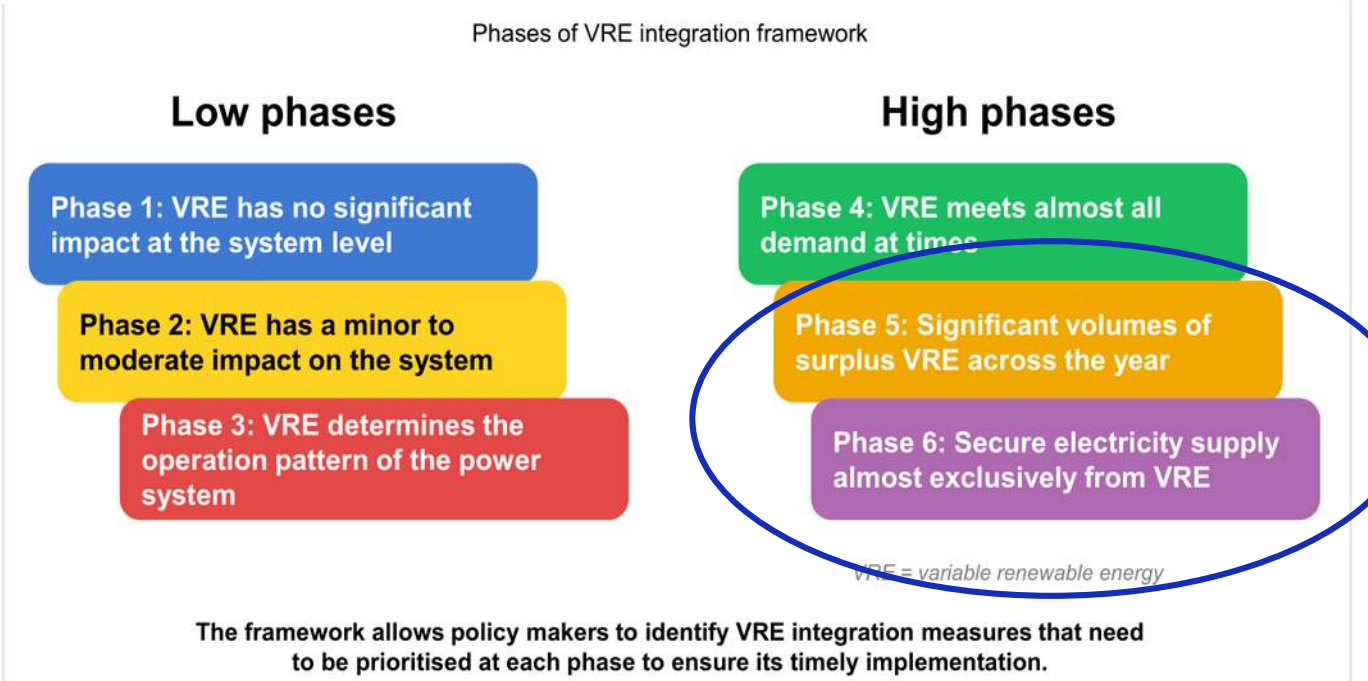


The impact of a changing climate is already visible – and the increase of VRE will continue - extreme events will impact the power systems with high integration of renewables

iea wind

When do extreme events impact a power system?

IEA Infographic: Six phases of Variable Renewables Integration



IEA Infographic: Six phases of Variable Renewables Integration

https://www.iea.org/reports/integrating-solar-and-wind/infographic-six-phases-of-variable-renewables-integration

iea wind

When do extreme events impact a power system?

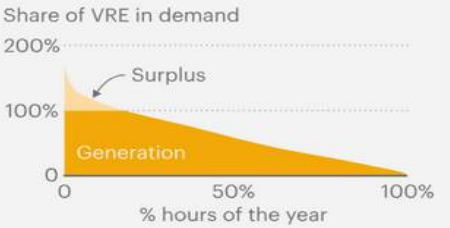
Phase 5

Significant volumes of surplus VRE across the year

Rising shares of VRE mean that without additional measures VRE availability will exceed demand during many hours and be in **overall surplus for periods of a day or more**. Achieving such shares under decarbonisation goals in an **economic and secure manner** requires increased measures to support VRE utilisation, such as large deployment of demand response, energy storage and grids, and more extensive solutions to ensure stability at low levels of conventional supply.

Percentage of hours covered by VRE

VRE generation can be higher than 100% of the local demand: surplus energy must be managed



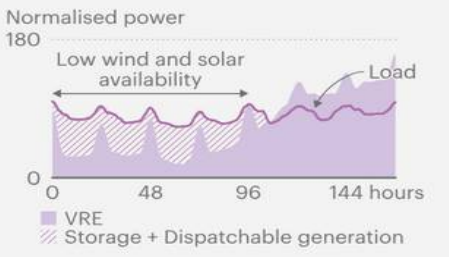
Phase 6

Secure electricity supply almost exclusively from VRE

Phase 6 applies to regions looking to meet extremely high shares of annual electricity demand with VRE. The main challenges in this phase include **operating a system largely dependent on converter-connected resources and meeting demand during extended periods of low wind and sun availability**. Addressing flexibility needs can involve long-duration energy storage or extensive electricity trade with other regions.

Electricity generation and load profiles

Prolonged periods of low VRE availability need to be compensated for by storage and dispatchable generation



IEA Infographic: Six phases of Variable Renewables Integration

https://www.iea.org/reports/integrating-solar-and-wind/infographic-six-phases-of-variable-renewables-integration

iea wind

When do extreme events impact a power system?

Is it true that more and more extreme events happen… ?

Outages Shed Light On unreliability & vulnerability of the power systems

- ➔February **2021**: **Texas, US** with loss of power for more than 4.5 million homes
- ➔December **2024**(Storm Darragh): **Ireland & UK**- hundreds of thousands without power
- ➔January **2025**(Storm Éowyn): **Ireland & UK** - Caused "unprecedented damage" to the network, with over a million customers losing supply
- ➔April **2025**: **Spain & Portugal** Blackout : The most significant event in this region was a massive, cross-border blackout affected tens of millions of people in Spain, Portugal, France for up to a full day.

NOTE

5 storms in Western Europe from 2021-2025
→ almost every year…

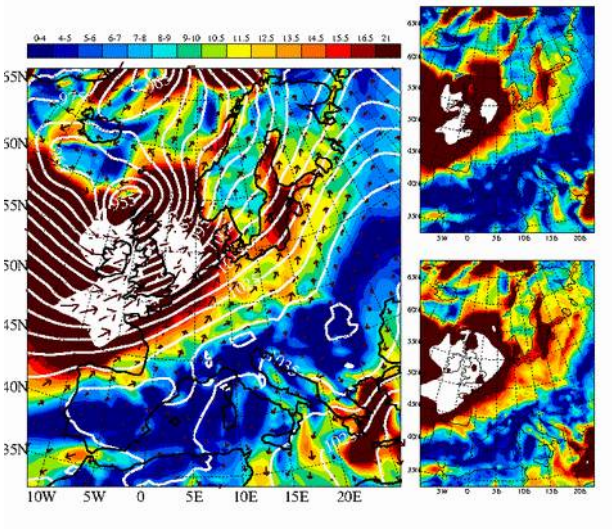
5 storms happened also in Western Europe from 1980-2000
The Great October Storm of 1987
Burns' Day Storm in January 1990
The December 1998 Storms
October 2000 Storm

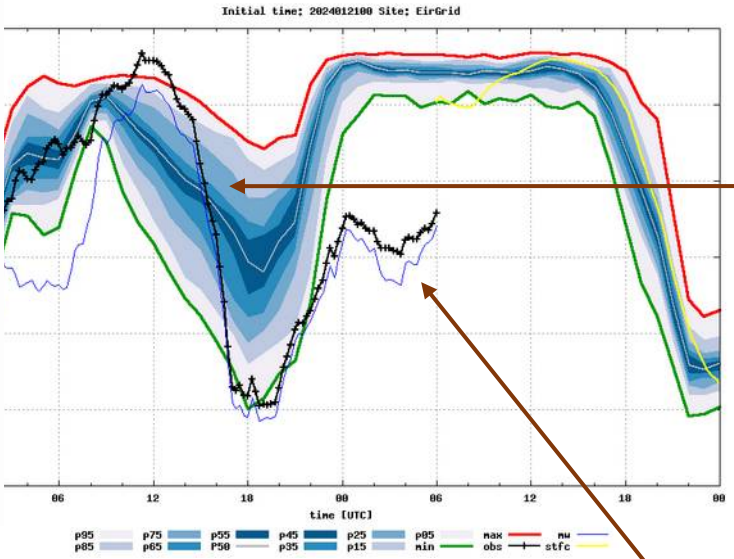
Reliability

Resilience

What does that mean for forecasting in the future with 80% … 100% renewables on the grid ?

WS Extreme Power System Events





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.
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:

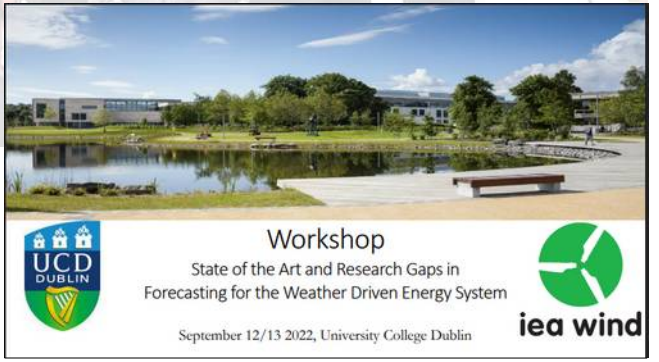
- Re-establishment of the power lines and infrastructure
- Restoration of the grid due to non-regulated re-powering of wind and solar units

WEPROG

Results from Workshops on Extremes in the Power System 2022-2025

2022

NAWEA/ Wind Tech 2024
Rutgers University- New Brunswick



2025

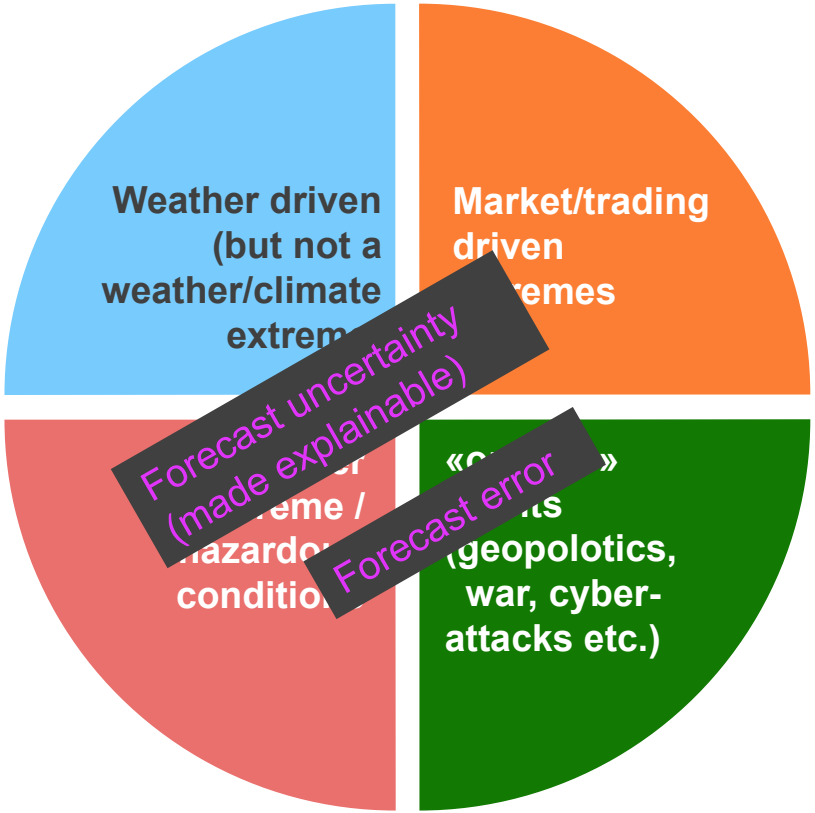
2024

2025

YouTube

Recordings are available here:
https://www.youtube.com/@IEAWindForecasting

Key Question in the Workshops: How can we define extreme power events in a system with high share of renewables?



Weather driven events survey

Defining Extreme Weather: Existing Standards and Definitions

Adverse Weather Type	Effects on Infrastructure	Examples of Impacted Components	Threshold/Design Value	Standard/Reference
Extreme Wind/Gust	Turbines are designed to withstand winds up to this limit; above this, failure is tolerated.	Wind Turbines	≈ 60 m/s (Survival Wind Speed)	IEC 614001, ÖNORM EN 61400
Icing Conditions	Ensures aerodynamic performance; antiicing systems are recommended.	Wind Turbines	Temperature < 0°C with defined water content	IEC 614003, ÖNORM EN 61400
Excessive Wind Loads/Gusts	Can damage structures and affect system stability.	Power Masts / Grid Infrastructure	Typically designed for up to ≈ 50 m s (site and designdependent)	EN 50160, IEC 61850, Local Grid Codes
Temperature Range	Ensures module performance and durability under extreme ambient temperatures.	Photovoltaic (PV) Systems	Operational: –40°C to +85°C	IEC 61215, ÖNORM EN 61215
Humidity/Damp Heat	Tests simulate longterm exposure to humid conditions.	Photovoltaic (PV) Systems	85% RH at 85°C for 1000 hours (damp heat test conditions)	IEC 61215, IEC 61730, ÖNORM EN 61730
Flooding/High Precipitation	Thresholds for precipitation which are used in the electrical infrastructure.	Hydro Infrastructure	Defined thresholds for precipitation which may lead to Flooding for critical infrastructures.	EN 12975, EN 12976, Local Hydraulic Guidelines
Lightning	Adequate lightning protection minimizes equipment damage.	Grid / PV Systems	Design based on risk assessment (e.g., systems rated for >10 kA pea current)	IEC 62305, Local Lightning Protection Guidelines

Power infrastructure

Defining Extremes in the Power System

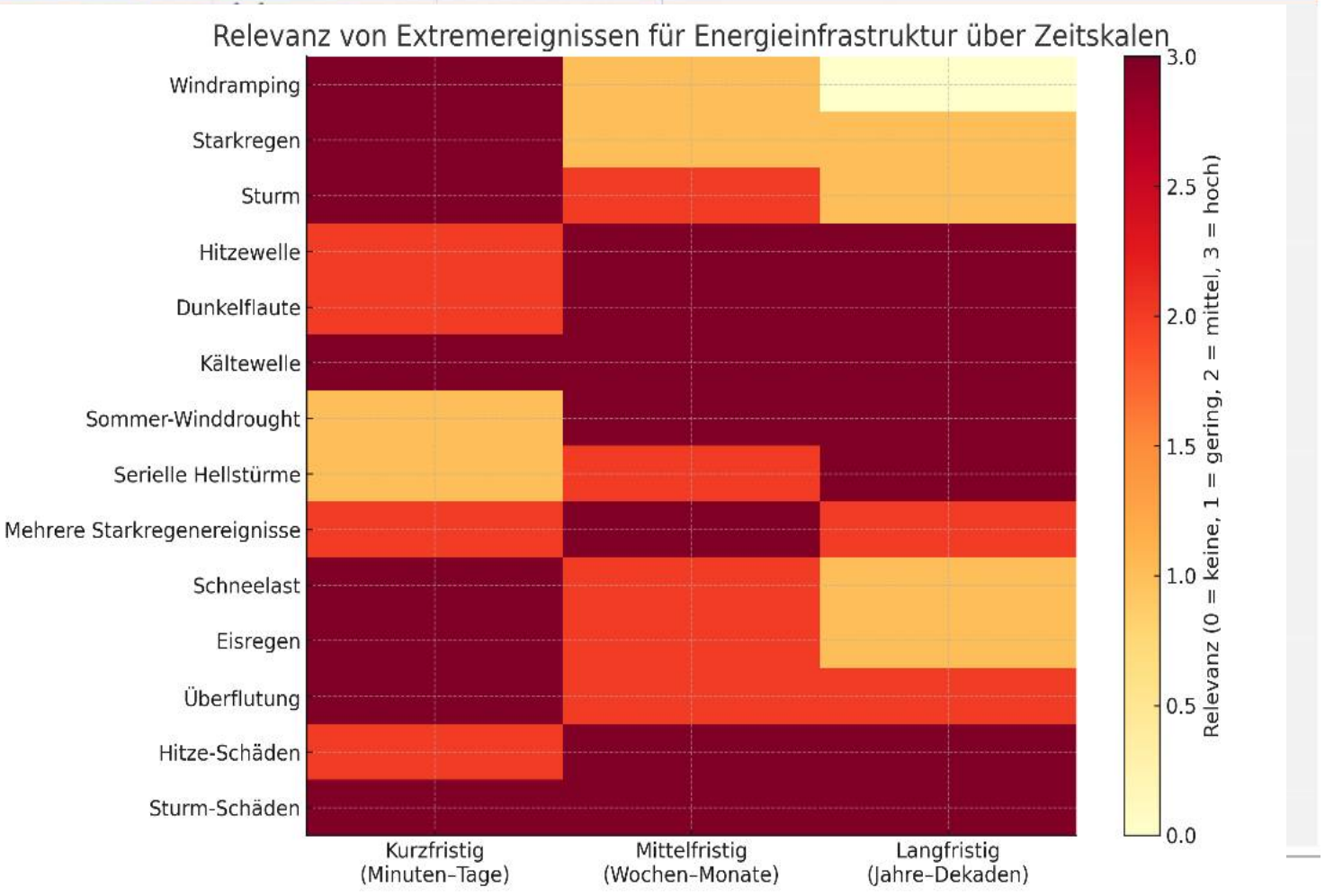
Adverse Weather Type	Causal Weather Patterns	Related Parameters	Notes on Compound/Consecutive Events	Detection/Forecasting Methods
Winter Peak Demand ("Dunkelflauten")	High pressure system over Germany/Central Europe (European Blocking), Scandinavian Blocking, Greenland Blocking	Low temperatures, Low wind speeds, Low solar irradiance	Can persist for multiple days (median duration 3.2 days, max 8 days)	Weather regime forecasts, especially for longerlived regimes
Wind Power Ramping	Low pressure systems moving across UK	Rapid changes in wind speed	Most frequent in autumn/winter	Highresolution NWP models (e.g. Met Office UKV1.5) for shortterm forecasts
Summer Wind Drought	High pressure system over UK/Europe	Very low wind speeds, High temperatures	Can last up to 32 days, may coincide with heatwaves	Weather regime forecasts, especially European Blocking
Extreme Solar Variability	Mixed sky conditions	Rapid changes in solar irradiance	Can occur frequently on short timescales (seconds to minutes)	Shortterm solar irradiance forecasts, satellite imagery
Flooding	Positive NAO phase, Low pressure systems	Heavy rainfall	More frequent in summer during NAO+ phases	Weather regime forecasts, hydrological models
Windstorms	Strong low pressure systems, typically in winter	High wind speeds	Frequency linked to NAO phase, can occur in clusters	Weather regime forecasts, storm track predictions
Cold Spells	Blocking high pressure, Negative NAO phase, Greenland Blocking	Very low temperatures	Can persist for extended periods, may coincide with low wind speeds	Weather regime forecasts, especially for Greenland Blocking
Heatwaves	Blocking high pressure in summer	Extreme high temperatures	Can last multiple days/weeks, often coincides with low wind speeds	Weather regime forecasts, especially for European Blocking
Thunderstorms	Unstable atmosphere, typically in summer	Lightning, heavy rainfall, strong winds, gustiness, squal lines, hail	Can occur in clusters or organized systems or single cells	Shortterm convectionpermitting models
Snow/Ice Events	Cold air masses, winter precipitation	Snow accumulation, icy conditions, snow fall, temperature and season (e.g. late April snow), wind, very low extreme temperatures, "wetness of snow"	Can persist for days, may coincide with low temperatures and wind speeds	Weather regime forecasts, precipitation type forecasts
Saharan dust, pollen events, air pollution				
Hellsturm				
Fast running low	At the southwest edge of a strong low pressure system a small, but fastrunning new system develops. It develops close to a cold front or occlusion.	High wind speeds	The fast running low develops much faster as the main low pressure system. Thus, it shows up very late in the forecast.	Some ensemble members show the development. High resolution NWP and rapid update rate
Dunkelflauten (Dark Doldrums)	European Blocking (22%), Scandinavian Blocking (15%), Greenland Blocking (14%)	Low wind speeds, low solar irradiance, often cold temperatures	Median duration 3.2 days, max 8 days. Occur mainly in autumn/winter.	Combined capacity factor threshold of 0.06 averaged over 48 hours
Compound High Energy Shortfall	NAO negative, Scandinavian Blocking	Low wind speeds, low solar irradiance, low temperatures	Doubled risk during NAO, 50% increased risk during Scand. Blocking	Weather regime forecasts, especially for longerlived regimes
WindDroughtPeakDemand	High pressure systems over UK/Europe	Low wind speeds, extreme temperatures (low in winter, high in summer)	Can persist for multiple days. More common in winter.	WindDroughtPeakDemand Index (WDI) exceeding 90th percentile, 7day accumulation
Surplus Generation	High pressure systems in summer	High wind speeds, high solar irradiance, moderate temperatures	Most common in summer. Can stress grid management.	SurplusGeneration Index (SGI) exceeding 90th percentile, 7day accumulation
"Hellsturm" (Sunny/Windy Overproduction)	High pressure systems with strong wind patterns	High wind speeds, high solar irradiance, low demand (often weekends)	Most frequent MaySeptember, especially on Sundays. Can lead to significant curtailment.	Identify days with renewable generation above 90th percentile and demand below 10th percentile. Analyze wind/solar ratio and time patterns.
Fastrunning Low Pressure Systems	Develops at southwest edge of strong low pressure system, near cold front or occlusion	High wind speeds	Develops much faster than main low pressure system. Can cause rapid fluctuations in wind power output.	Highresolution NWP models with rapid update rates. Monitor ensemble forecasts for potential development.

Power production

„Hellsturm“ + „long“ weekend + runoff (snowmelt) + not a lot of consumption or
Dunkelflaute + increased demand (heating + EV charging) + holiday or
Cyberattack + icy conditions with cut-off + windy + high demand

Extreme Events: time scales and impact

Extreme Event Type	Minutes–Hours(Nowcasting)	0–72 Hours – 2 weeks (High-res NWP)	2–5 Weeks(S2S)	2–4 Months(Seasonal)	Years–Decades(Climate)
Storms (wind storms, gust fronts)					
Heatwaves					
Cold spells					
Floods / Heavy rainfall					
Icing / Freezing rain					
Fog / Stratus (high impact, not "extreme" meteorologically)					
Dust, haze, aerosols (PV impact)					
Dunkelflaute *(low wind + low solar)*					
Wind drought / summer wind lull					
Hellsturm *(too much wind + PV)*					
Extreme ramps (wind/PV)					
Extreme forecast errors *(winter stratus, secondary depressions)*					
Hydropower extremes (flood, drought)					



Extreme Events: time scales and impact

Extreme Event Type	Minutes–Hours(Nowcasting)	0–72 Hours – 2 weeks (High-res NWP)	2–5 Weeks(S2S)	2–4 Months(Seasonal)	Years–Decades(Climate)
Storms (wind storms, gust fronts)	✔gust detection, radar, rapid-update ensembles	✔✔best skill from convection-permitting NWP	✔?linked to synoptic regimes	–	✔?climate trends in storm tracks
Heatwaves	–	✔NWP temperature anomalies	✔✔blocking regimes detectable	✔✔seasonal outlook skill (NAO/jet)	✔✔clear trends under climate change
Cold spells	–	✔cold-air outbreaks in NWP	✔stratosphere–troposphere coupling	✔?weak/moderate predictability	✔✔shifts in winter extremes
Floods / Heavy rainfall	✔✔nowcasting, radar-based prediction	✔✔convection-permitting models	–	–	✔?climate-induced intensity changes
Icing / Freezing rain	✔local conditions detectable	✔✔vertical temperature structure resolved	–	–	✔?climate shifts in freezing levels
Fog / Stratus (high impact, not "extreme" meteorologically)	✔✔nowcasting strongest	✔?NWP often struggles	–	–	–
Dust, haze, aerosols (PV impact)	✔?satellite-based	✔NWP–aerosol coupling	✔?aerosol climatology	✔?ENSO/monsoon links	✔climate aerosol trends
Dunkelflaute *(low wind + low solar)*	–	✔?short-term predictability	✔✔regime-dependent wind patterns	✔✔seasonal wind/solar anomalies	✔✔climate trends in winter wind regimes
Wind drought / summer wind lull	–	✔?low skill short term	✔✔pressure pattern persistence	✔✔seasonal jet shifts	✔✔long-term climatology
Hellsturm *(too much wind + PV)*	✔?short-term spikes	✔✔NWP ramps	✔?linked to synoptic regimes	–	✔?trends in jet & cloud climatology
Extreme ramps (wind/PV)	✔✔nowcasting and rapid-update ensembles	✔✔resolution-dependent	–	–	–
Extreme forecast errors *(winter stratus, secondary depressions)*	✔?detected through ensemble spread	✔physics limitations visible	✔?low reliability	–	–
Hydropower extremes (flood, drought)	–	✔NWP rainfall	✔✔S2S hydrological drivers	✔✔seasonal inflow	✔✔climate-driven shifts

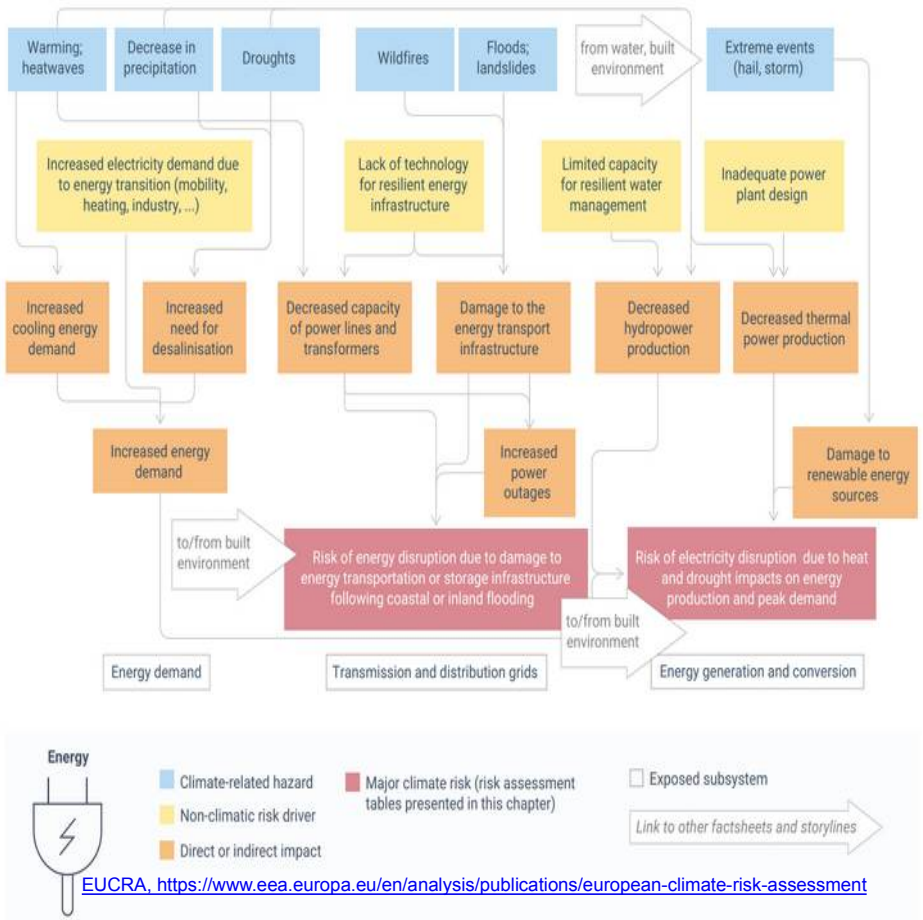
Predictability skills & Decision Support are required across all time scales

Event Type	Nowcasting	NWP 0–72h/ 2 weeks	S2S	Seasonal	Climate	Predictability (Generalized)
Storms	✔	✔✔	✔?	–	✔?	Medium — Good short-range skill, poor medium-range regime locking
Heatwaves	–	✔	✔✔	✔✔	✔✔	High — Strong persistence & blocking predictability
Dunkelflaute	–	✔?	✔✔	✔✔	✔✔	Medium–High — Dominated by regimes & pressure patterns
Wind drought	–	✔?	✔✔	✔✔	✔✔	Medium–High — Persistence & jet/pressure anomalies predictable
Extreme ramps	✔✔	✔✔	–	–	–	Low — Driven by microscale & rapid dynamics
Cold spells	–	✔	✔	✔?	✔✔	Medium — Linked to SSW events but still uncertain
Heavy rainfall / floods	✔✔	✔✔	–	–	✔?	Low–Medium — Convection predictable only <72h
Icing / freezing rain	✔	✔✔	–	–	✔?	Medium — Strong vertical profile dependency
Fog / stratus	✔✔	✔?	–	–	–	Very Low — One of the least predictable phenomena
Hellsturm (oversupply)	✔?	✔✔	✔?	–	✔?	Medium — NWP OK, but cloud/wind uncertainty high
Extreme forecast errors	✔?	✔	✔?	–	–	Very Low — By definition tied to model failure modes
Hydropower extremes	–	✔	✔✔	✔✔	✔✔	Medium–High — Driven by large-scale moisture/temperature patterns
Heat damages	–	✔?	✔✔	✔✔	✔✔	Medium–High — Same drivers as heatwaves
Storm damages	✔	✔✔	✔?	–	✔?	Medium — Short-range reliable, long-term only trends

iea wind

Predictability skills & Decision Support are required across all time scales

Event Type	Predictability (Generalized)
Storms	Medium — Good short-range skill, poor medium-range regime locking
Heatwaves	High — Strong persistence & blocking predictability
Dunkelflaute	Medium–High — Dominated by regimes & pressure patterns
Wind drought	Medium–High — Persistence & jet/pressure anomalies predictable
Extreme ramps	Low — Driven by microscale & rapid dynamics
Cold spells	Medium — Linked to SSW events but still uncertain
Heavy rainfall / floods	Low–Medium — Convection predictable only <72h
Icing / freezing rain	Medium — Strong vertical profile dependency
Fog / stratus	Very Low — One of the least predictable phenomena
Hellsturm (oversupply)	Medium — NWP OK, but cloud/wind uncertainty high
Extreme forecast errors	Very Low — By definition tied to model failure modes
Hydropower extremes	Medium–High — Driven by large-scale moisture/temperature patterns
Heat damages	Medium–High — Same drivers as heatwaves
Storm damages	Medium — Short-range reliable, long-term only trends



EUCRA, https://www.eea.europa.eu/en/analysis/publications/european-climate-risk-assessment

iea wind

Extreme events in the power system are multi-dimensional:

Meteorologically/Climatology Perspective

1. Intensity (Magnitude)

How strong is the meteorological driver or power-system impact?

2. Duration

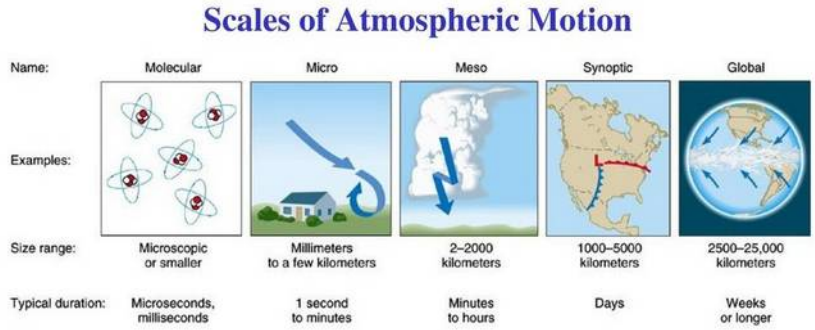
Short bursts vs. multi-day or multi-week persistence.

3. Frequency (Return Period)

Extremity defined via percentiles or recurrence (e.g., 1-in-30 year).

5. Seasonality

Events occurring in shoulder seasons during maintenance windows.



https://opengeology.in/wind-at-different-scales/

Non-meteorological/climatological Aspects

4. Regionality

Local → national → cross-border impacts.

6. Compound Hazards

Simultaneous extremes (heat + low wind + high demand).

7. Consequence-driven Extremes

Events small in meteorology but extreme for the system (e.g., Dunkelflaute, ramps, market prices).

From Knowledge to Action

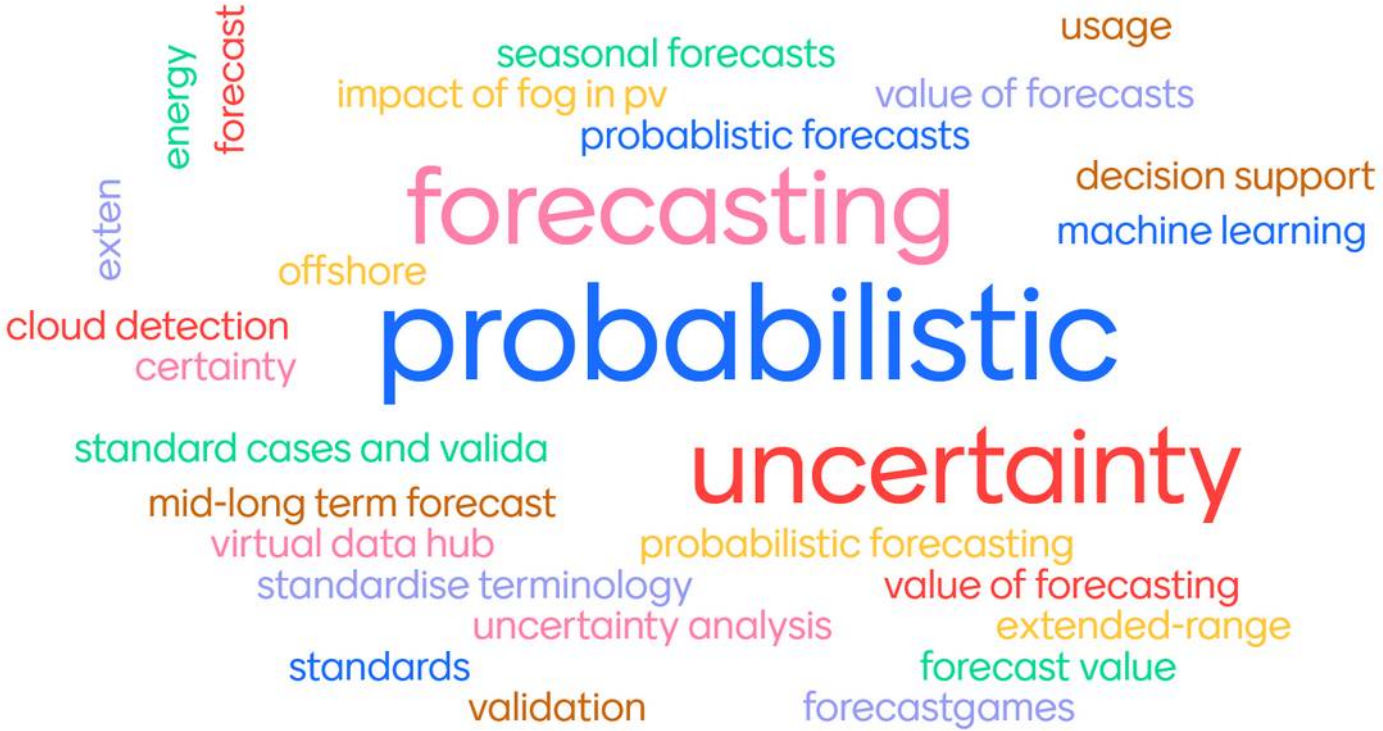
So, let’s have a look at the topics
that participants are concerned about …

… and how they deal with them today...

Where are the gaps ... ?

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 ?

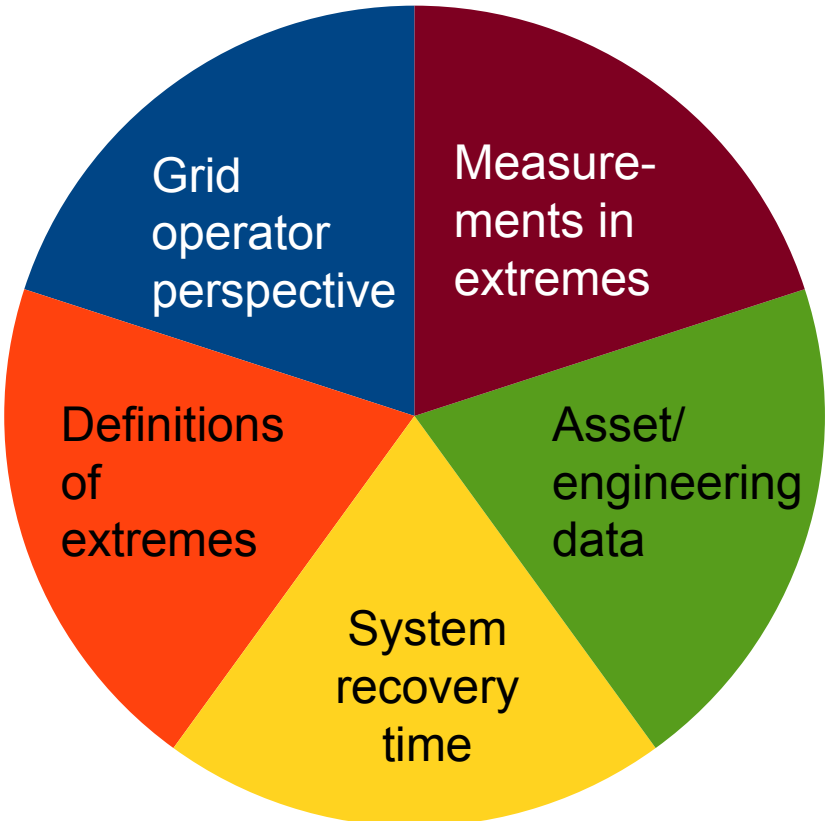


Results from the NAWEA Conference Side Event 2024

IEA Wind Task 51 (Forecasting for the Weather-driven Energy System) will host a 4-hour workshop that focuses on the current state-of-the-art, issues and potential solutions to meet the meteorological data and forecasting needs of an increasingly weather-driven electric system. The workshop will open with an overview presentation of the IEA Wind Task 51 objectives, scope, recent activities and plans for the next year and beyond. This will be followed by a panel discussion of meteorological datasets (e.g. "reanalysis" datasets) for grid system planning, which will be a follow-up to workshops on this topic that were held earlier this year at DTU in Denmark and at the National Renewable Energy Laboratory in Colorado. Leaders in the organization of those meetings will serve as panelists. The second half of the event will feature an open-space facilitated discussion among all meeting participants in four fluid topic-focused sub-groups to develop an overview of the community's perspective on the key issues and possible solutions in each topic area. The topics will include: (1) current and future state-of-the-art in historical datasets and forecasts including the impact of machine learning (ML) and artificial intelligence (AI), (2) defining the scope of applications and the datasets attributes that are important to each, (3) how to effectively evaluate the relative quality of datasets, which is very likely application-dependent and (4) formulation of potential dataset standards for quality, content, format, and access.

All times are Eastern Time (ET)

Tuesday, October 29, 2024 | Zimmerli Art Museum, Rutgers University	
1:00 pm – 1:30 pm	Overview of IEA Wind Task 51 Structure and Activities John Zack, Meso Inc.
1:30 pm – 3:00 pm	Panel Discussion: Meteorological Datasets for Grid System Planning Facilitator: John Zack, Meso Inc. • **Julia Gottschall** (Fraunhofer IWES): Overview of IEA Wind TEM #111 meeting at DTU (Renalyses for wind energy) and follow-up activities • **Caroline Draxl** (EPRI): Overview of NREL workshop *Bridging the gap between atmospheric sciences and grid integration* and follow-up activities • **Justin Sharp** (EPRI): Overview of current datasets and challenges, future steps • **Victoria Rojo** (ISO-NE): User perspectives Short presentations will be followed by a guided discussion with all workshop participants.
3:00 pm – 3:30 pm	Networking Break
3:30 pm – 4:50 pm	Open Space Discussions Facilitator: John Zack, Meso Inc. • **Current and Future State-of-the-Art** • **Matching applications and evaluation** • **Standards for Energy Data Collection, Assessment, and Access** • **Topics for Extreme Power System Event workshop in spring 2025**
4:50 pm – 5:00 pm	Wrap up & Adjourn Ideas for the next phase of IEA Wind Task 51

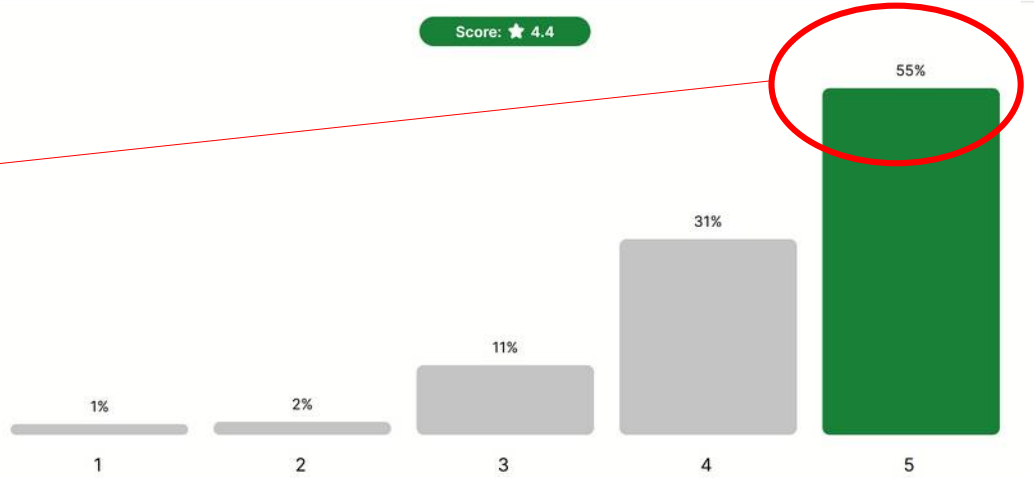


Where are the gaps ... ?

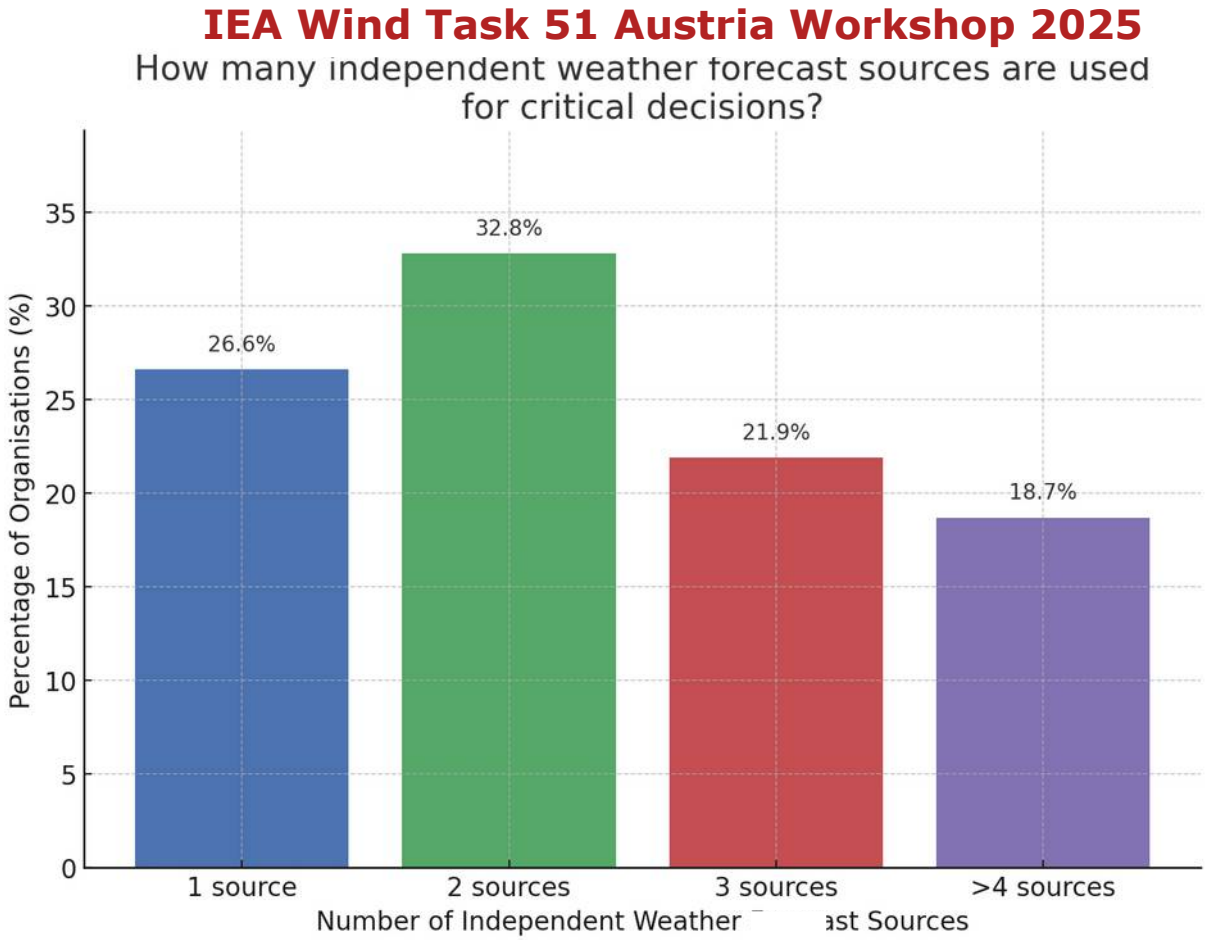
Questions posed to 120 participants in an **IEA Wind Task 51 workshop in Vienna in 2024**

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)



Where are the gaps ... ?



Where are the gaps ? … Decision-making under Uncertainty

"Probabilistic Forecasting Games & Experiments" initiative:

Results from ***2nd Experiment Evaluation*** that are worth looking into…

Participant scores

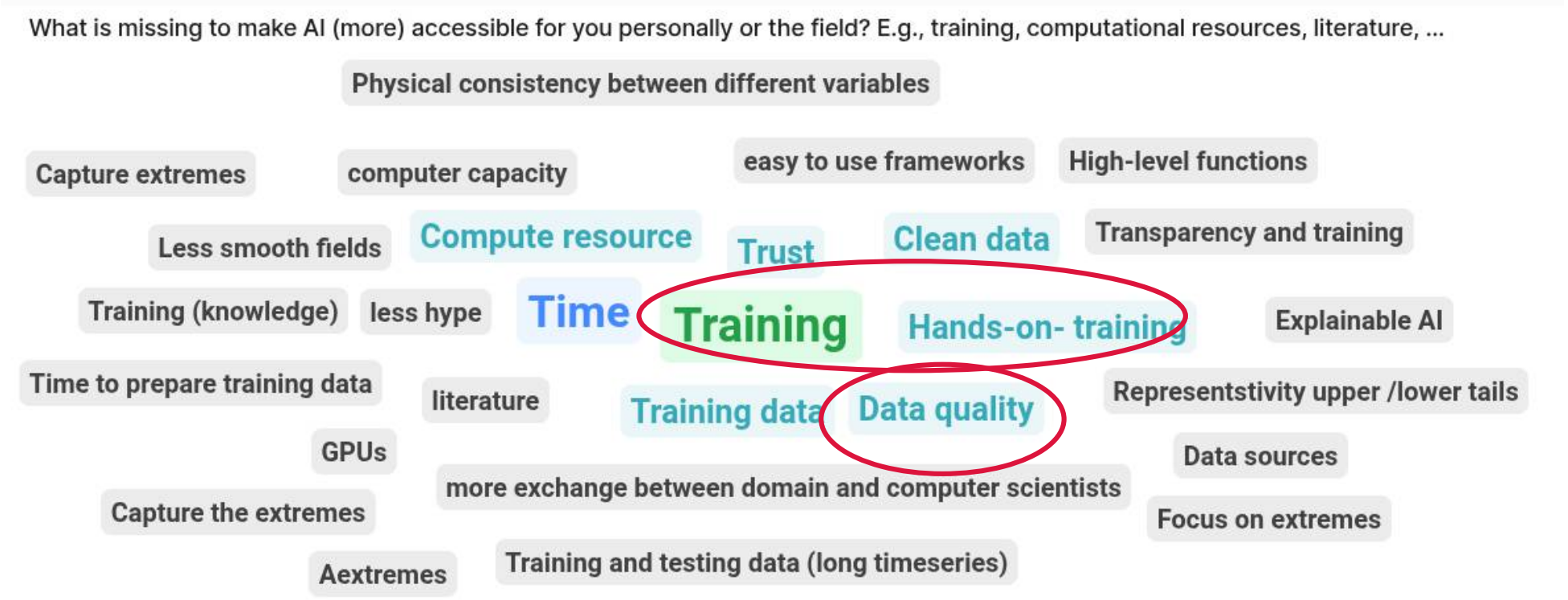
- ~80% of participants did not reach a score > "all-safe"
- ~42% reached a score > "chance level" < "all-safe"
- ~17% reach exactly "all safe" - only 1% played safe!
- ~40% had a score < "chance level"

Strategy	Payoff
Risky	0
All Safe	27.000
Chance level	13.750
Gods eye	55.000

Take away from the experiment:
Teaching, use-cases and industry recommendations are necessary for the industry to deal with weather uncertainty impacting the energy transition!

IEA Wind Task 51 Extremes Workshop 2025 results …

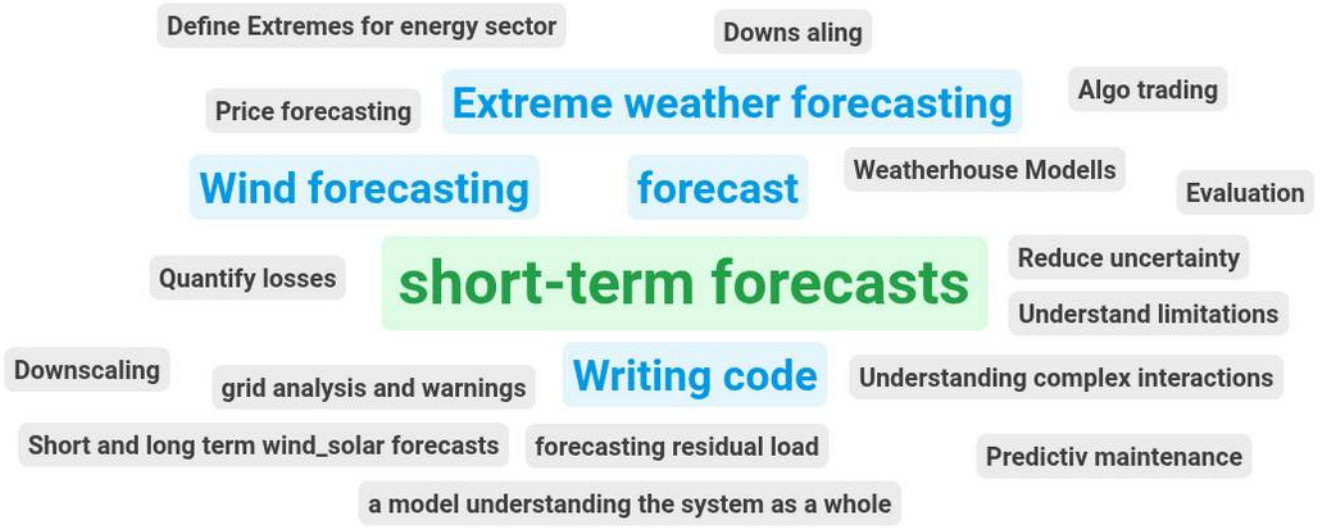
AI/data driven tools for the field (RES, Extreme Events, Power grid Management) … Question: What is missing to make AI more accessible ?



Where are the gaps ... ?

Question posed to 60 participants in an ***IEA Wind Task 51 Workshop Forecasting for Extremes in the Power System*** at the German Weather Service in October 2025 ...

What is the most important application for you (related to power system extremes) that you would like AI to help with?



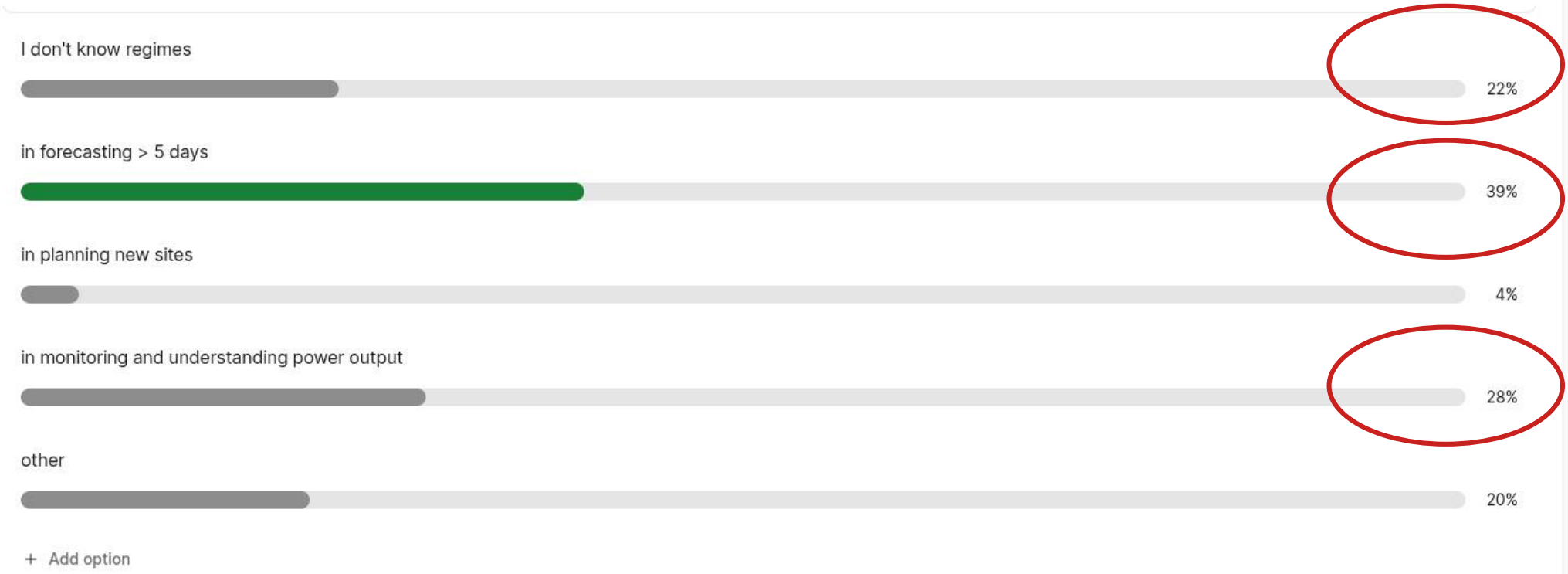
Where are the gaps ... ?

Question posed to 60 participants in an ***IEA Wind Task 51 Workshop Forecasting for Extremes in the Power System*** at the German Weather Service in October 2025 ...

What comes to your mind, when you think about forecast uncertainty in energy markets?

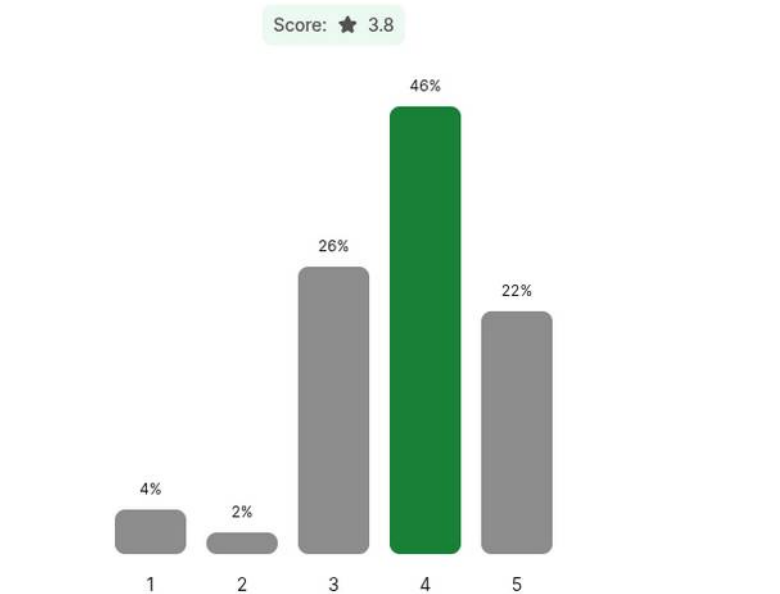
IEA Wind Task 51 Extremes Workshop 2025 results …

Weather regimes – can provide early warnings …
Question: are weather regimes known and in which context?

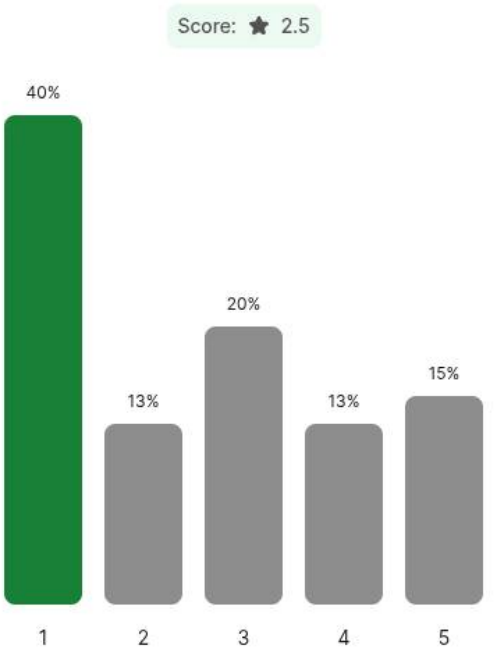


IEA Wind Task 51 Extremes Workshop 2025 results …

AI/data driven tools for the field (RES, Extreme Events, Power grid Management) …
Question: (left) rank the potential // rank the use (right)

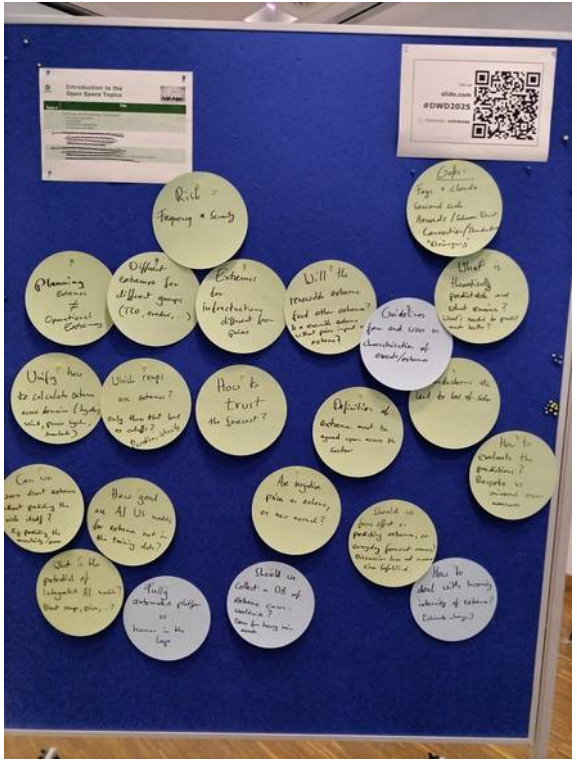


How high do you rank the potential of AI/data-driven tools for the field (renewable energy/extreme events/power grid management)?
-> 0 (no relevance) to 5 (should be primary focus)



How many AI/data-driven techniques do you use right now in production?
-> 0 (none) to 5 (all core processes/products are AI)

Topic 1: Defining and Predicting "Extremes"



Characteristics of extremes

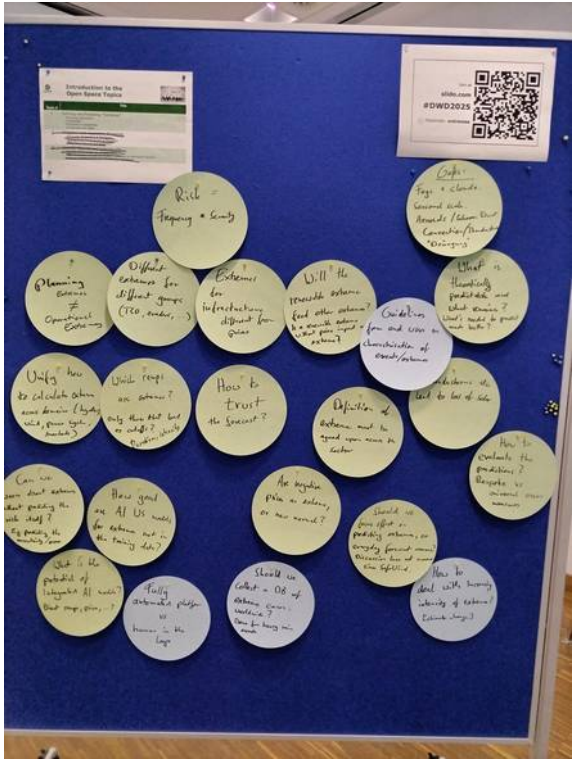
Predictability & evaluation

Definition

System resilience & risk management

Impact & Causes of extremes

Topic 1: Defining and Predicting "Extremes"



1. Definition and Characterization of Extremes

- Subjectivity and Lack of Consensus is state-of-the-art
- Need for harmonisation sector-wide definitions and guidelines

2. Prediction, Forecasting, and Evaluation

- Forecasting Limitations and Uncertainty required
- Trust and universal evaluation of forecasts

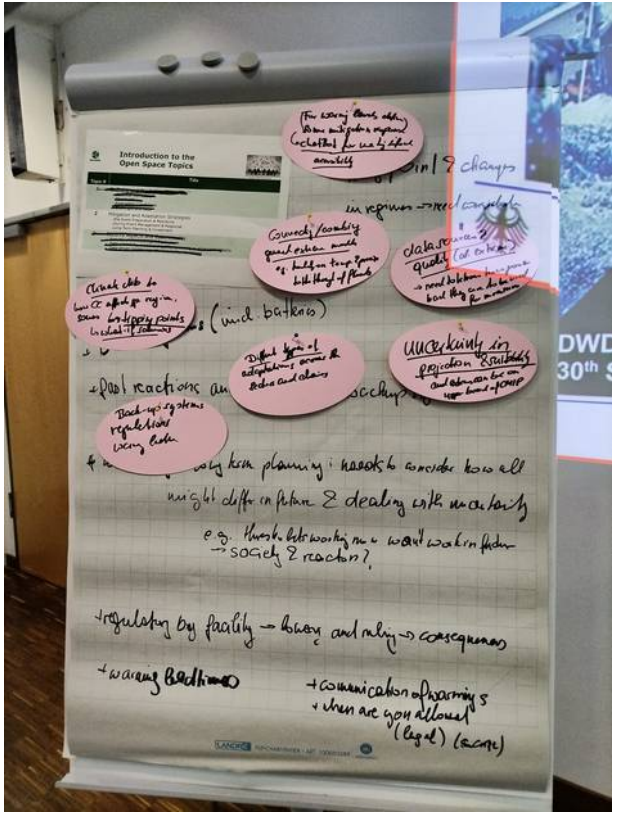
3. System Resilience, Risk Management and Planning

- Risk-Informed Strategies require risk assessment framework
- Data and Automation to enhance resilience

4. Impacts & Causes of Extremes in Renewable Systems

- Renewable-Specific triggers of new types of extreme events
- System Interdependencies of extremes in power systems with high shares of renewables

Topic 2: Mitigation and Adaptation Strategies



Warning Systems & Communication

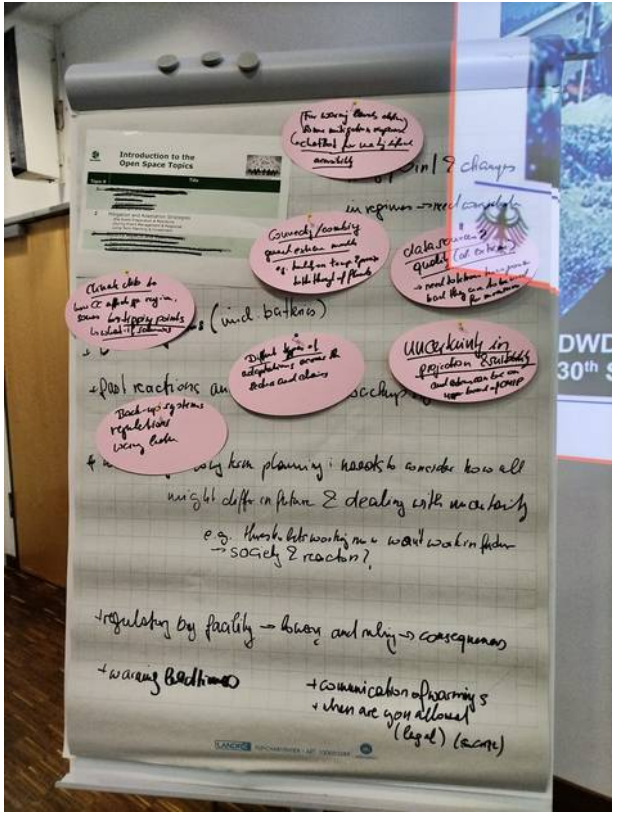
Operational Strategies & infrastructure adaptation

Mitigation
Adaptation

Risk management & Regulatory Framework

Data & Data sharing

Topic 2: Mitigation and Adaptation Strategies



1. Risk Management, Planning, and Regulatory Frameworks

- Proactive, Future-Oriented Planning to use forward-looking projections
- Regulatory and Legal Integration of frameworks that enforce long-term adaptations

2. Operational Strategies and Infrastructure Adaptation

- Enhancing Physical Resilience with specific infrastructure adaptations,
- Rapid-Response Backup systems fast response mechanisms to maintain service during an event.

3. Warning Systems and Communication

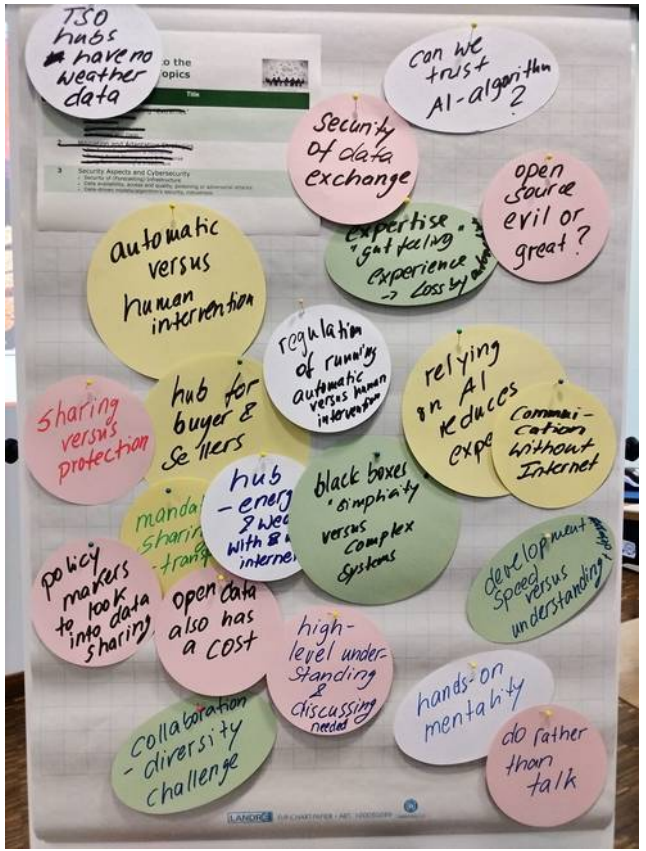
- Effective and Trustworthy Communication with warnings
- Coordinated, Knowledge-Based, legally sound protocols on when to issue warnings

4. Data, Information, and Usability

- Understanding the quality, limitations and uncertainty inherent in data sources
- Improving complex data accessibility and education for various users

IEA Wind Task 51 Workshop Forecasting for Extremes in the Power System 2025

Topic 3: Security Aspects and Cybersecurity



1. Automation, AI, and Human Expertise

- Balancing AI Efficiency with Human Expertise preventing the erosion of invaluable human expertise, experience, and "gut feeling" over time.
- Trust and Regulation that define the boundaries and interplay during extreme events.

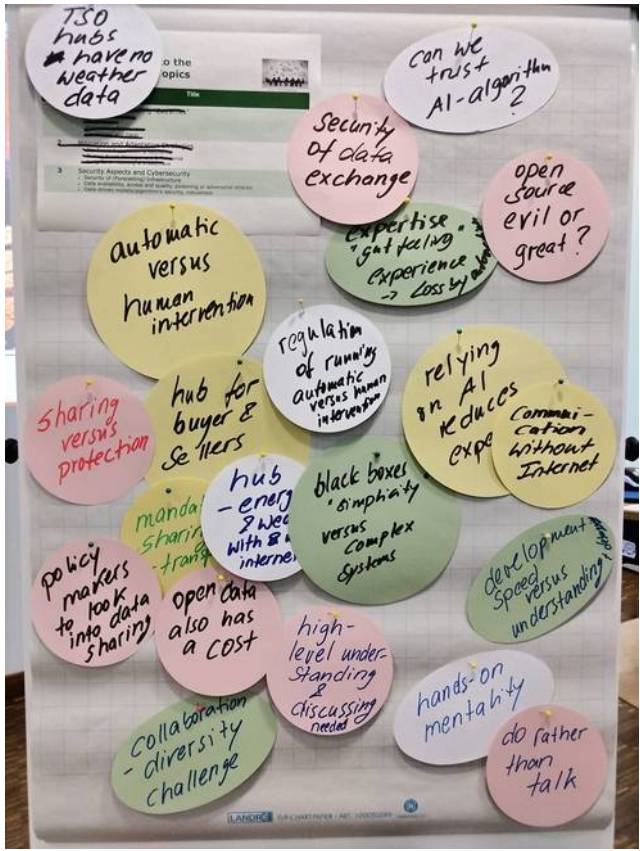
2. Data Sharing, Open Source, and Open Data

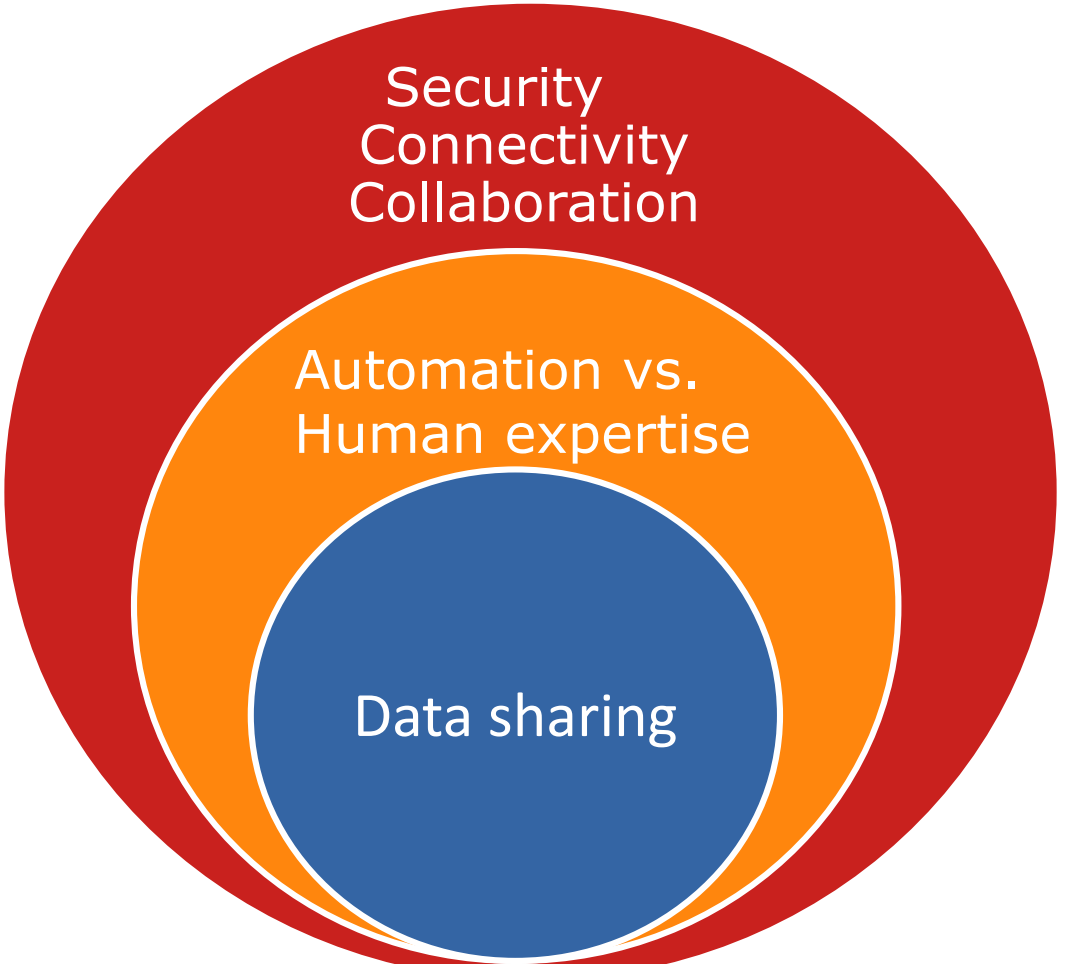
- Mandatory Sharing vs. Cost and Security and intellectual property concerns.
- Policy and Infrastructure Requirements of resilient infrastructure that can facilitate data exchange even in compromised situations (e.g., without the internet).

3. Security, Connectivity, and Collaboration Challenges

- Resilient Communication Systems ensuring secure data exchange and ability to function without the internet during a major incident
- High-Level Security Strategy collaboration across diverse groups presents challenges

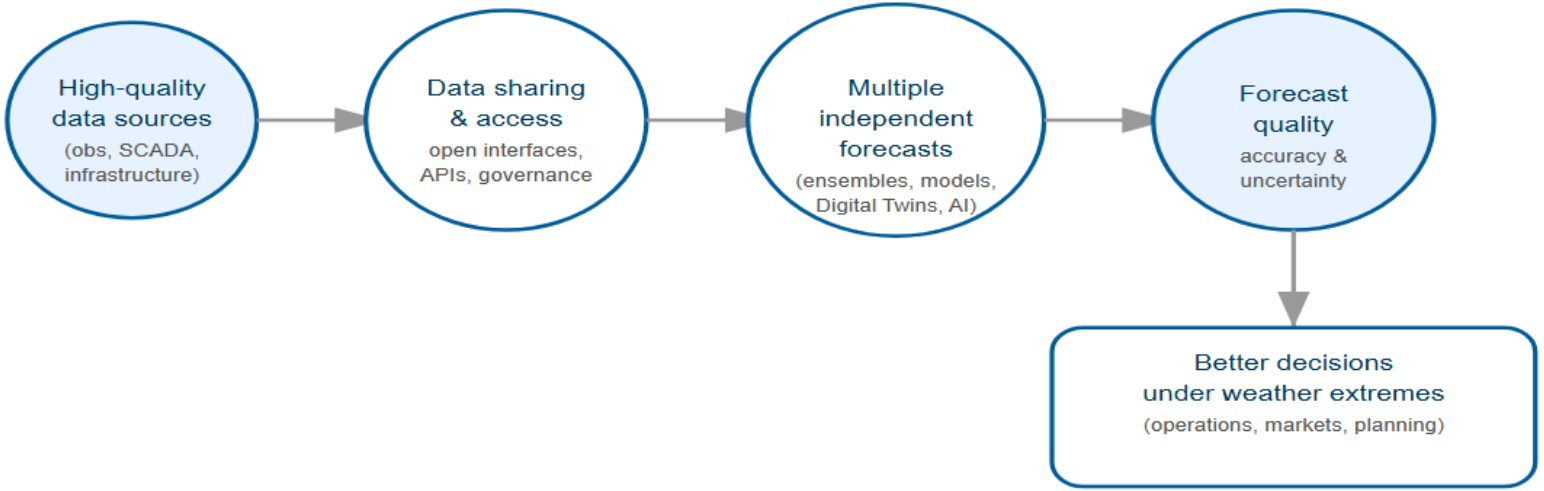
Topic 3: Security Aspects and Cybersecurity





Austrian stakeholders stake in 2025 on …

Forecast quality needs data – and data sharing

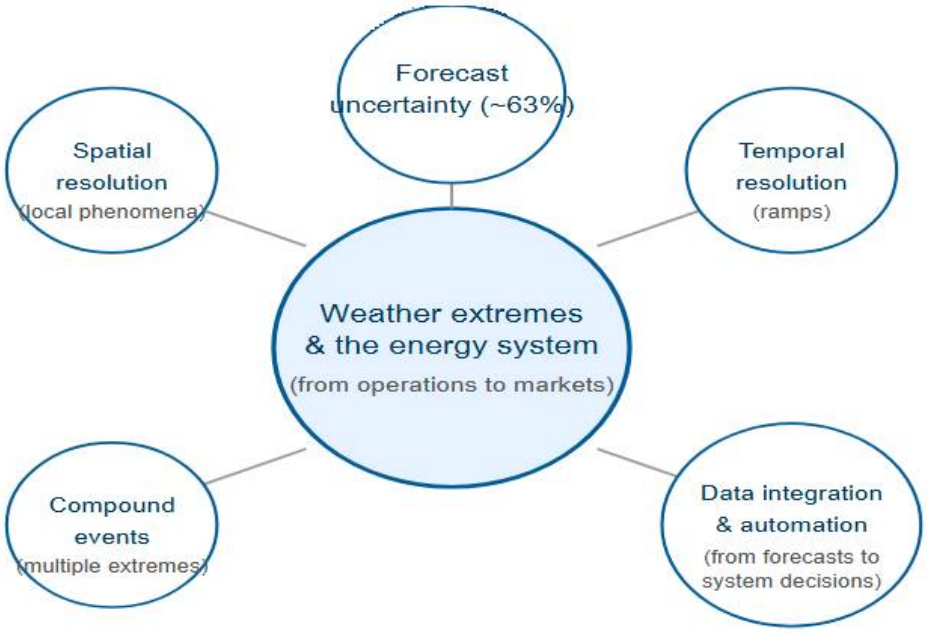


Forecast quality is co-produced: it depends on good data, sharing and access – for both the energy sector and meteorological services.

Austrian stakeholders stake on Top challenges during weather extremes in 2025

iea wind

Top challenges during weather extremes



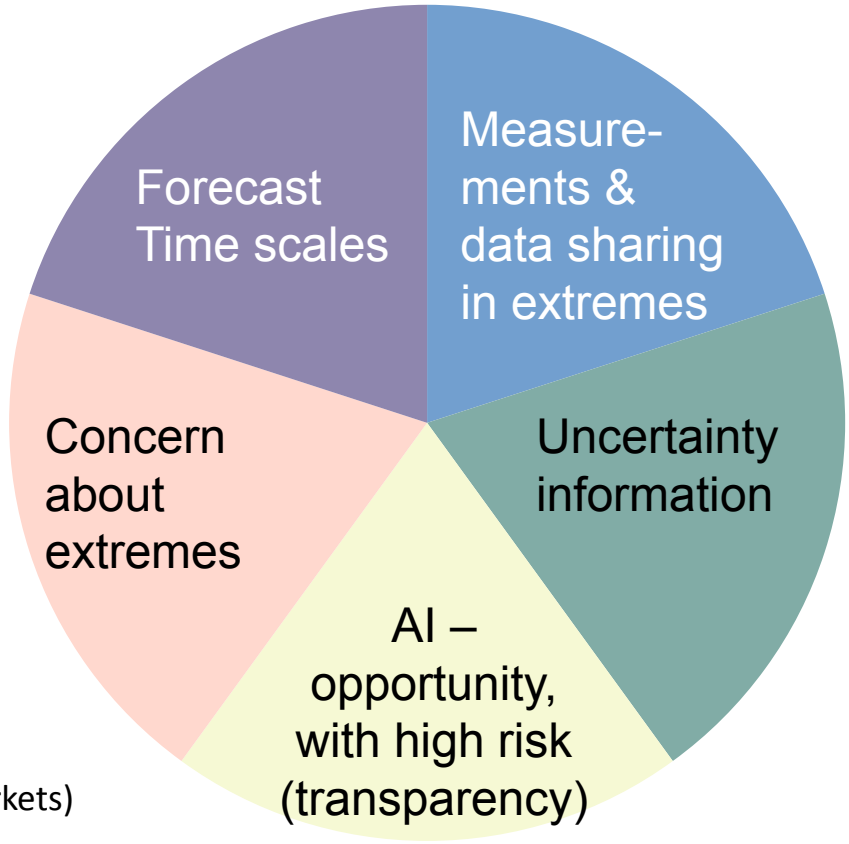
Live poll results from the 2nd IEA Task 51 Austria Workshop (Vienna, 2025)

Austrian stakeholders stake summary from 2025 IEA Wind Task 51 Austria Workshop

iea wind

Learnings – Stakeholder and TSO/User Feedback

1. **Forecast horizons & operational needs**
   – Day-ahead remains mission-critical (56%)
   – Nowcasting & intraday strongly increasing in importance
   – Sub-seasonal emerging for storage & maintenance planning
2. **Extreme events are the top concern (85%)**
   – Storms, heat, floods, icing, Dunkelflaute
   – Increasing compound/cascade effects under climate change
   – Strong need for event classification & trigger mechanisms
3. **AI = Opportunity, but only with transparency**
   – Explainability scored 4.35/5
   – Concerns around governance, cybersecurity, bias
   – Clear benchmarks, standards, and training required
4. **Uncertainty = central, but poorly implemented**
   – Users rely on “gut feeling” in absence of good visuals
   – Large gap between research and application
5. **Data access = main bottleneck**
   – Need for harmonised Austrian data spaces (weather + grid + markets)
   – Cross-border flows require EU-level interfaces



Across all our workshops (2022 → 2025), clear consensus emerged...

1. Definitions must be harmonised
– Thresholds, typology, event catalogues
– Cross-sector alignment
(met, TSO, market, RES operators)

2. Extremes are often *compound*, not single hazards
– Low-wind + low-solar + high-demand
– Extreme ramps
– Infrastructure sensitivity (icing, floods, heat)

3. Predictability remains limited in high-impact regimes
– Blocking patterns, fog/stratus, thunderstorms, dust events
– Ensemble divergence is a warning signal

4. AI opens opportunities but also systemic risks
– Forecast harmonization risk
– OOD (out-of-distribution) events under climate change
– Black-box concerns → need for explainable methods

5. We need a structured mitigation framework
– Operational, regulatory, infrastructural
– Warning chains
– System resilience & restoration plans

Towards Phase II – What do we need to build

Phase II Priorities (2026–2029): Extreme Events Subtask

1. **Extreme Event Handbook & Taxonomy & Standards:** Unified definitions, severity scales, event templates

2. **Global Case Study Library:** Icing, Dunkelflaute, multi-day heat, storms, ramp failures, cyber + weather combinations

3. **Multi-scale forecasting pipeline:** Nowcasting → NWP → S2S → seasonal → climate; Focus on blocking regimes, persistent lows, compound drivers

4. **Impact-based Forecasting (Weather → Power → Market):** Towards impact-based forecasting; Co-design with TSOs and energy market participants

5. **AI Governance for Critical Infrastructure:** Explainability, multi-provider strategies, resilience to harmonization risk

Summary & Take-aways for Phase 2

Task list for phase 2

1. Extreme Event Taxonomy Handbook & Standard(s)
2. Multi-scale forecasting
3. Impact-based Forecasting
4. Data sharing & AI Governance
5. Global Case Study Library

Meteorological Society
WMO
EMS, AMS,
EGU, ...

Power Sector
TSOs
ENTSO-E,
CIGRE,
IEEE, ...

Collaboration

Renewable Energy Sector
Stakeholders
(Traders,
Developpers
Operators..)

Standardisation Authorities
IEC, IEEE, IEA

THANK YOU FOR YOUR ATTENTION

IEA Wind Task 51: Forecasting for the Weather Driven Energy System

Follow us:

Project webpage: http://iea-wind.org/task51

Publications: https://iea-wind.org/task51/task51-publications

LinedIn: https://www.linkedin.com/groups/12709289/

Youtube chanel: https://www.youtube.com/@IEAWindForecasting

Contact us...

Dr. Corinna Möhrlen
Task Manager
WP3 Leader
WEPROG, DE & DK
com@weprog.com

Dr. Irene Schicker
AT-Lead
WP2 Co-lead
Geosphere, Austria
Irene.schicker@geosphere.at

WEPROG

GeoSphere Austria

Questions

Q&A slido.com

#IEA51Webinar