Behavioural decision-making Experiments in weather-driven Energy Systems

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DISPLAY MATERIAL

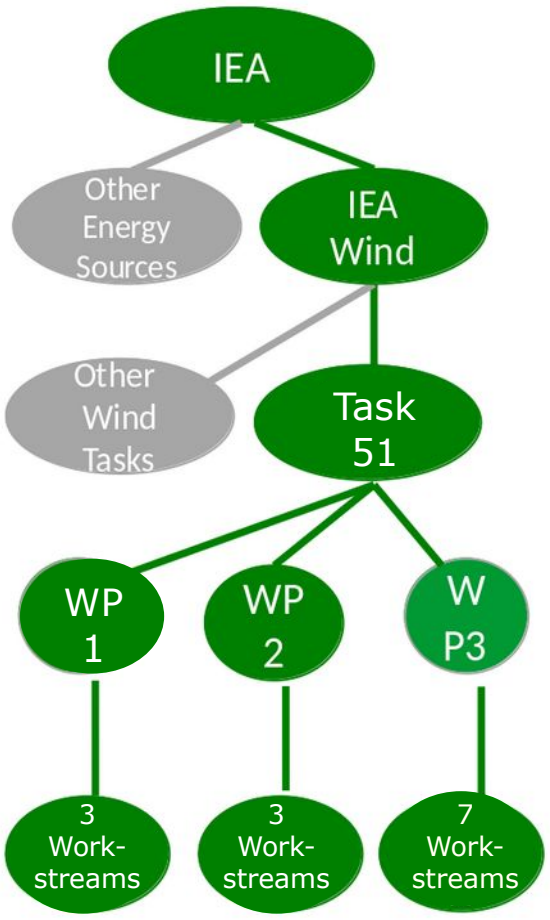
IEA Wind Task 36 "Probabilistic Forecasting Games and Experiments" initiative

EMS Annual Meeting 2022: Session ES2.3 "Dealing with Uncertainties" – 5th September 2021 –

Corinna Möhrlen, WEPROG
Nadine Fleischhut, MPI
Gregor Giebel, DTU

Uncertainty is a very good thing: it's the beginning of an investigation, and the investigation should never end. — *Tim Crouch*

IEA Task 51 - Forecasting for the Weather-Driven Energy System



What is the IEA (International Energy Agency)? (www.iea.org)

- International organization within OECD with 30 members countries and 8 associates
- Promotes global dialogue on energy, providing authoritative analysis through a wide range of publications
- **One activity: convenes panels of experts to address specific topics/issues**

Task 51: Forecasting for the Weather-Driven Energy System:

- One of 17 Tasks of IEA Wind: https://community.ieawind.org/home
- Phase 1: 2022-2025
- Operating Agent: Gregor Giebel of DTU Wind Energy
- Objective: facilitate international collaboration to **improve wind 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" divided into 13 "Work Streams"

- WP1: Global Coordination in Forecast Model Improvement
- WP2: Benchmarking, Predictability and Model Uncertainty
- **WP3: Optimal Use of Forecasting Solutions – WS8: Decision Making**

Task homepage: https://www.iea-wind.org/task51

Hans-Ertel-Zentrum
für Wetterforschung

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

WEXICOM Project – WP2 -

https://www.geo.fu-berlin.de/en/met/wexicom/

ARC Center for Adaptive Rationality
Max Planck Institute
for Human Development

How to communicate probabilistic impact forecasts?

WP2: Effectively communicating probabilistic impact forecasts for severe weather conditions using cognitive and behavioural science

Research Team:

- Dr. Nadine Fleischhut
- Prof. Dr. Ralph Hertwig
- Dr. Stefan M. Herzog

Despite good forecasts and warnings, people may misperceive weather risks and fail to respond appropriately. Their understanding of forecast uncertainty has long been a major concern (Joslyn and Savelli, 2010, Spiegelhalter et al., 2011); more recently, understanding weather risks and impacts has emerged as another.

WP2
Image Credit: Jürgen Rossbach (MPIB)

One currently advocated solution for helping people understand weather risk is to move from weather forecasts to impact forecasts; essentially, translating how the weather will be into what the weather will do (WMO, 2015). While the approach sounds promising, it remains unclear whether impact forecasts would in fact be beneficial for behaviour.

The main goal of this work package is to develop representations for communicating impact forecasts and to test their effect on risk perception, expectations, and behaviour. Using a crowdsourcing approach, we will develop and test ways to translate impact model forecasts into a meaningful risk representation for the public. Another part of the workpackage will investigate the potential benefits of impact forecasts for emergency manager.

Our results will shed light on the extent to which communicating impact forecasts can live up to its promise and improve our understanding of how to communicate impact forecasts to professional users and the public.

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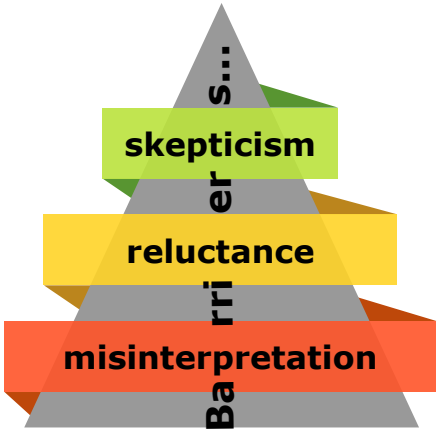
Goals and Objectives of the Initiative

Our aim is:

* test the **most known** and **observed barriers** of making use of uncertainty/ probabilistic/risk forecasts:

– skepticism – reluctance – misinterpretation –

* **develop solutions to overcome** these personal barriers



Tools and design structures integrated in our experiments make use of:

i. Use of "**decision from experience"** principle rather than "**decision from description**"

ii. Use of "**learning with feedback"** principle rather than "**theoretical learning"**

iii. Use of **Gamification**: a game illustrates an action without the seriousness and responsibility that comes from real applications and "**a more relaxed atmosphere**"

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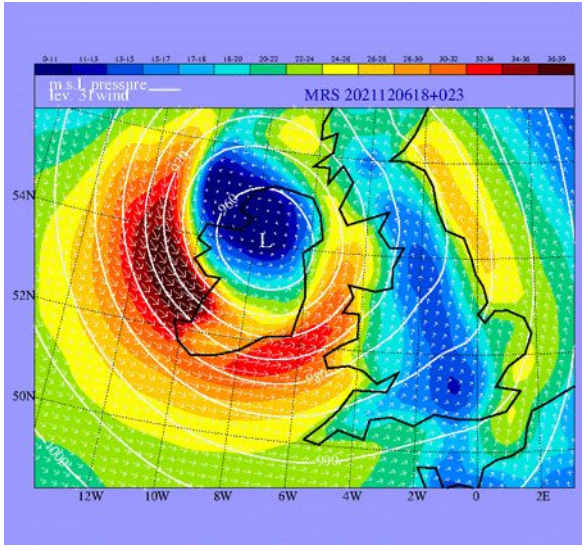
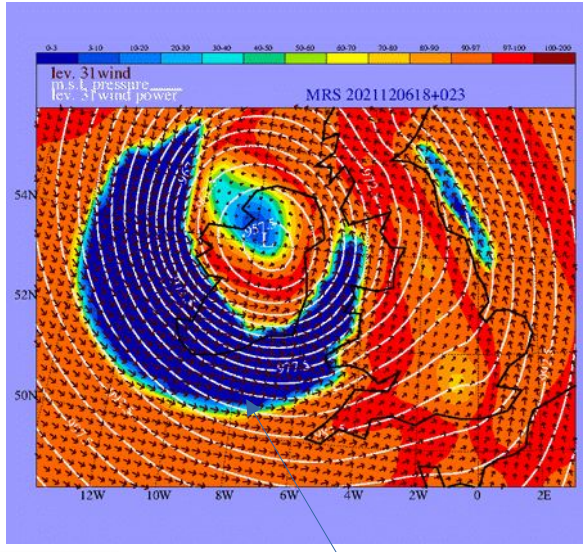
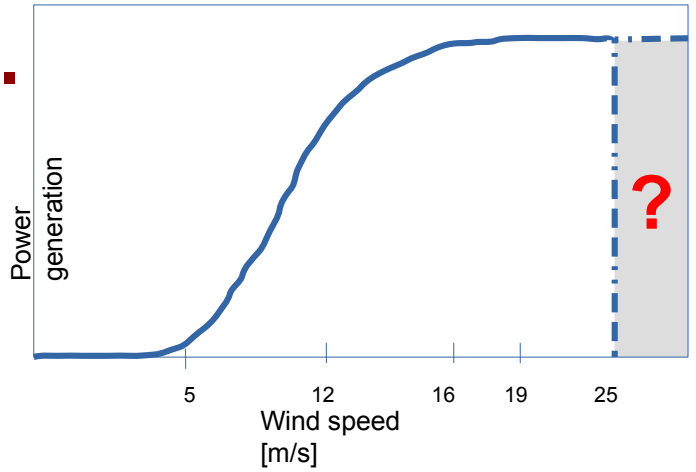
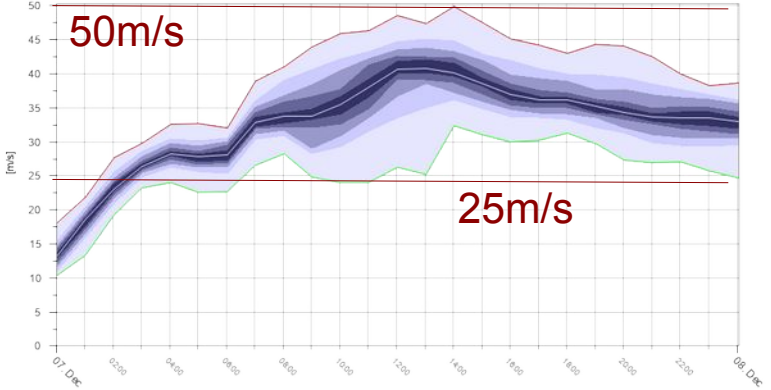
Dealing with Extremes....
...from forecast to impact...



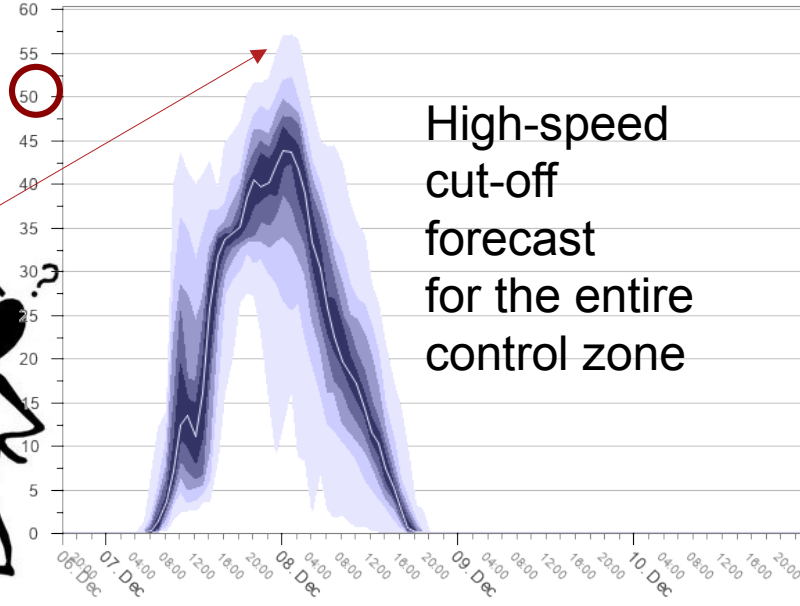






Cut-off area

...if over 50% of capacity can drip, how do I have to handle this.. ?

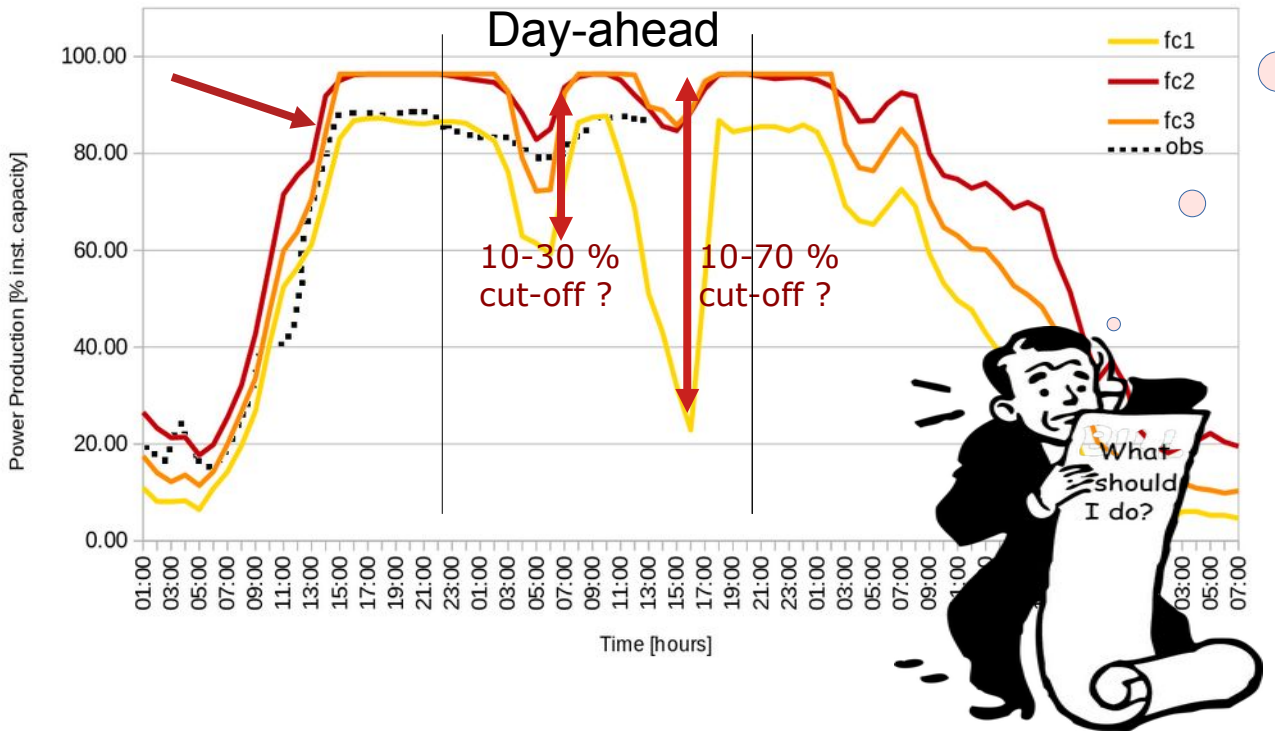


High-speed cut-off forecast for the entire control zone

Dealing with Extremes….

..if the power last night didn't cut off, it will probably also not do so now…

Scene: Decision to be made for Day-ahead: Wind Power Forecast



- **Randomly selected** deterministic forecasts do not provide a realistic uncertainty!

Deterministic forecasts can deviate a lot for unknown reasons* or provide confidence, where there is no reason for confidence…!

* especially at the steep part of the power curve

Dealing with Extremes....

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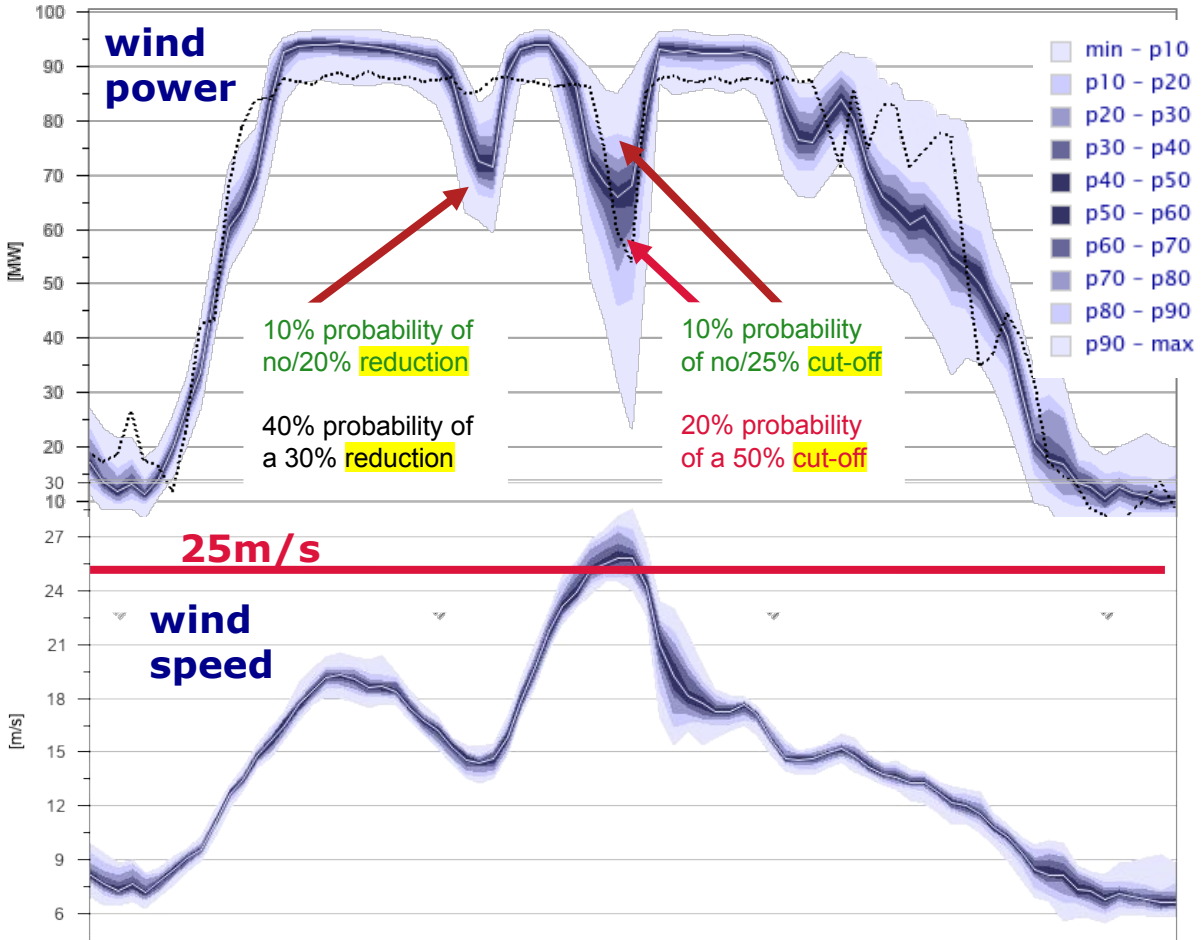
Scene: Decision to be made for Intra-day:
Wind Power + Wind Speed Forecast **+ Uncertainty**



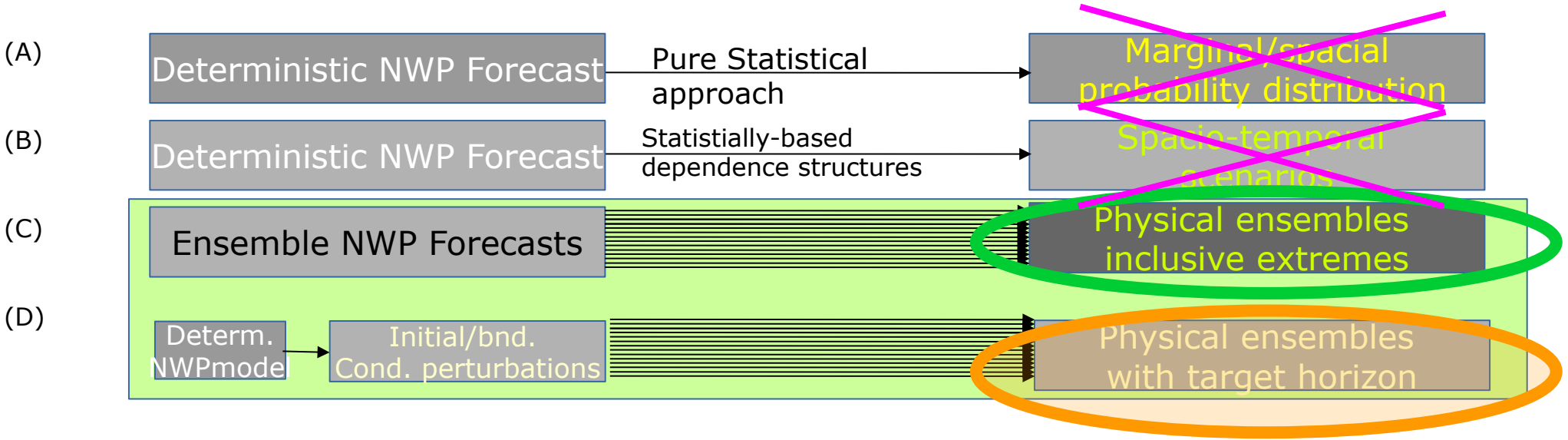
Considerations:

uninformed decision:
Decision on basis of 1-3 deterministic power forecasts
Deterministic forecasts can deviate a lot or provide confidence, where there is no reason for confidence...!

informed decision:
decision on the basis of at least *wind and power* forecasts + uncertainty → provides probability for worst case scenarios

High Speed Shut Down
– also a question of methodology ? -

Know, which methodology works for your target problem !



For high-speed shutdown forecasts you need **to capture extremes**:
(A) + (B): statistical methods can only capture and predict, what has been there in the past
(A): Captures only climatology and cannot be aggregated over larger areas
(D): target horizons need calibration for the time component

See e.g. Bessa et al. 2017, Haupt et al. 2019

Forecast Game Design: decision-making in extreme events

3 Postulates:

1) Success in the trading is highly dependent on the costs of the balancing power needed due to forecast errors
2) 5% of the cases, where there are large forecast errors are responsible for 95% of the costs in a month or a year.
3) Reducing these costs is more important than improving the general forecast by 1-2%.

Definition of a "high-speed shutdown" (HSSD) or "cut-off wind" event :

A high-speed shutdown event occurs typically in the **wind range above 20-27m/s**, mostly known as the *cut-off wind threshold of 25 m/s*.

Note: wind turbines use both wind gusts and the mean wind to determine, whether or not they turn into high-speed shutdown (HSSD).

Game experiments for decision making in extreme events*:

Experiment 1 (2020): Offshore wind park

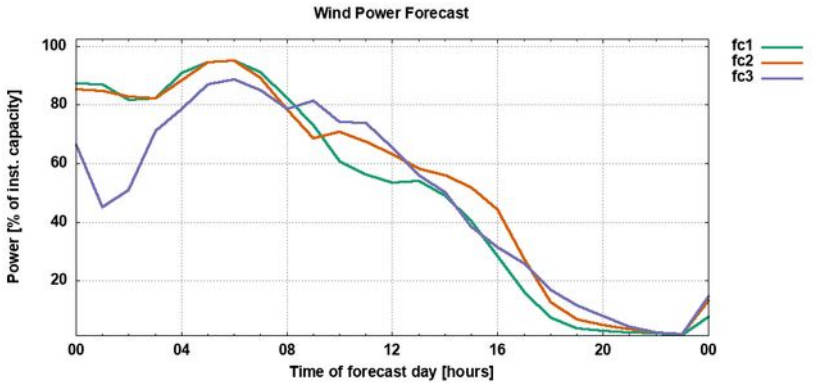
Experiment 2 (2021/2022): Wind park in complex terrain

* https://iea-wind.org/task-36/work-packages/work-package-3-optimal-use-of-forecasting-solutions/probabilistic-forecast-games/

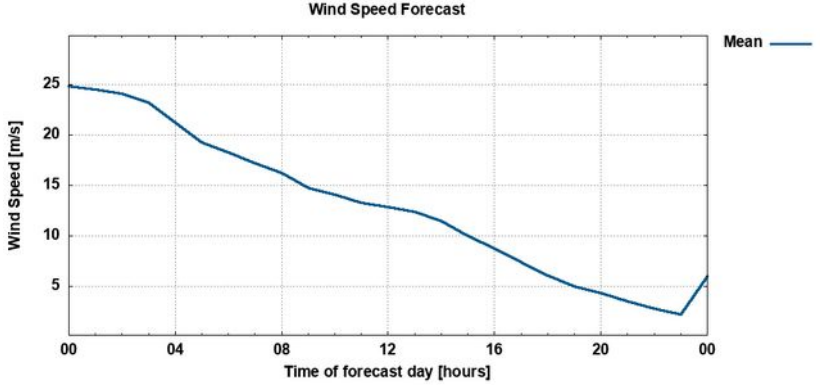
Forecast Game: decision-making in extreme events

Type of forecasts used in the game

In the games we use deterministic and probabilistic forecasts for the **day-ahead horizon**. All forecasts are generated with input of NWP (numerical weather prediction) forecasts from the 00UTC cycle the day before.

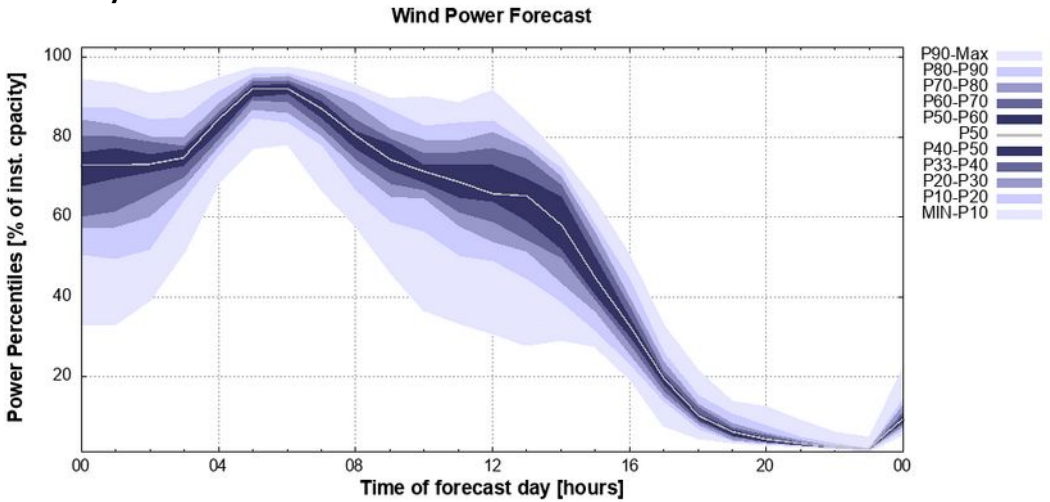


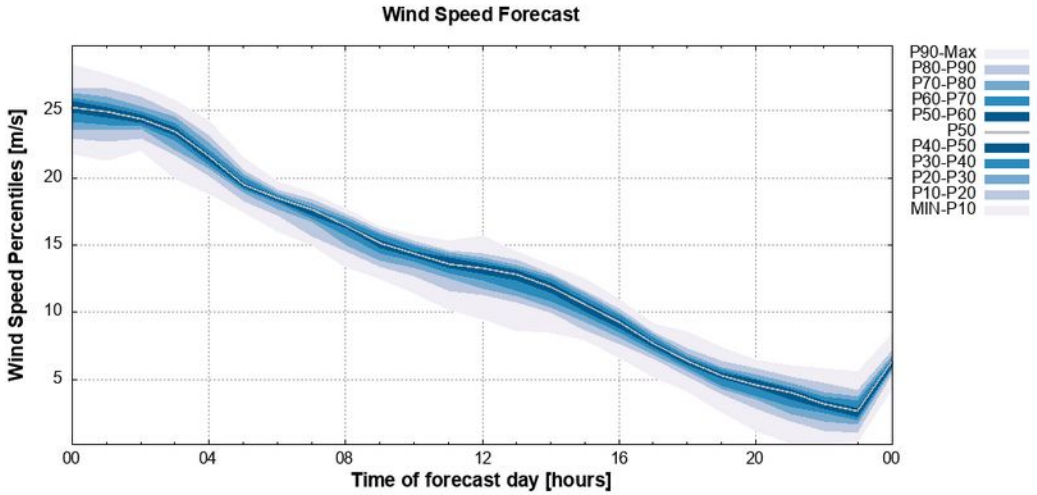
3 independent deterministic wind power forecasts in the unit [% of installed capacity] based on 3 different NWP (numerical weather prediction) models



1 wind speed forecast in the unit [m/s], which is a mean forecast from 75 ensemble members and smoother than a typical deterministic forecast.

Forecast Game: decision-making in extreme events





9 wind power percentiles (P10..P90) and a mean (white line) in the unit [% of installed capacity] generated from 75 NWP forecasts of a multi-scheme ensemble prediction system (MSEPS).

9 wind speed percentiles P10..P90 and a median (white line) in the unit [% of installed capacity] generated from 75 NWP forecasts of a multi-scheme ensemble prediction system (MSEPS).

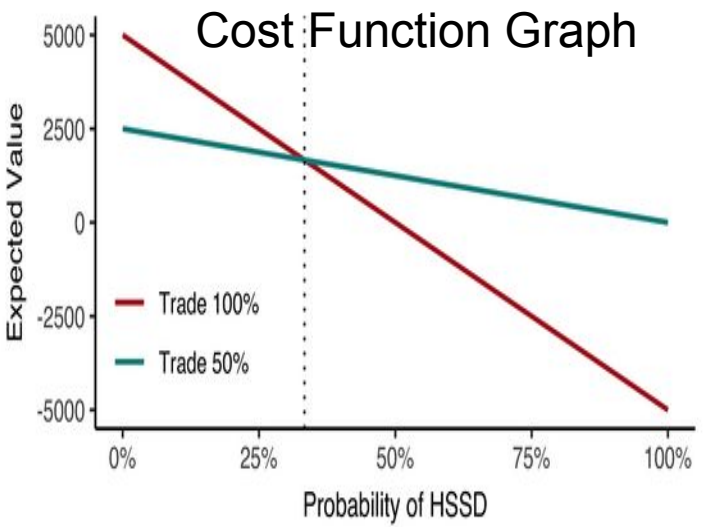
Note: The percentiles here are physically based uncertainty bands and provide an overview of the uncertainty of the forecast.

Definition: A percentile indicates the value below which a given percentage of forecasts from the 75 available forecasts falls. E.g., the 20th percentile is the value below which 20% of forecasts are found.

Aspects on Cost Functions from 1st Experiment: "Offshore wind power trading in extreme events"

Cost Function Table

Trading	HSSD*	No HSSD*
100%	-5.000	5.000
50%	0	2.500



Percentiles in Forecast graphs

- min – p10
- p10 – p20
- p20 – p30
- p30 – p40
- p40 – p50
- p50 – p60
- p60 – p70
- p70 – p80
- p80 – p90
- p90 – max

Some interesting aspects of the cost function:

- if the probability of a HSSD exceeds 33% trading 50% will give higher payoff

- if the probability of a HSSD < 33% trading 100% will give higher payoff

<u>Can/Could participants read this out ?</u>
Deterministic forecasts: no information

Probabilistic forecasts:
→ percentiles provided information about the probability in wind and power !

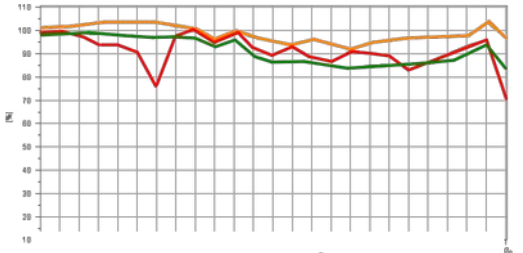
1st Experiment Design (2020)

Value of probabilistic power forecasts

How do professionals decide based on probabilistic wind & power forecasts?

Design & Analysis: Dr. Nadine Fleischhut*, Dr. Corinna Möhrlen** & Dr. Ricardo Bessa (INESCTEC)
Host of Experiment: *Max-Planck Insititute for Human Development, Hans-Ertl Center of Weather Reseach, Germany
Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

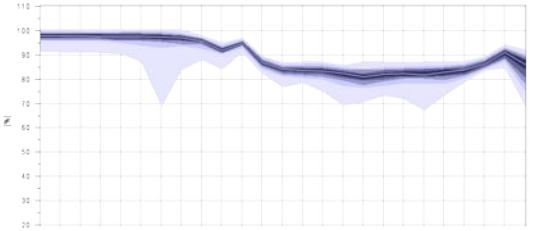
Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

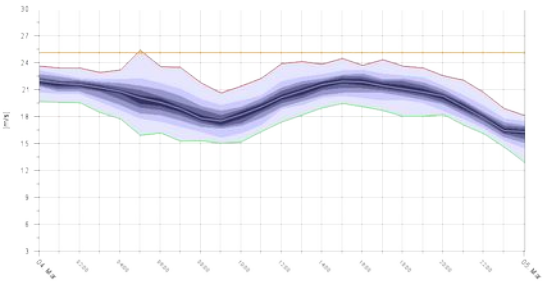


Deterministic forecasts → 1st Decision

Power forecasts

Wind forecasts





Probabilistic forecasts → 2nd Decision

Cost function

	HSSD	No HSSD
Trading 100%	-5000	5000
Trading 50%	0	2500

2nd Experiment Design (2021/22)

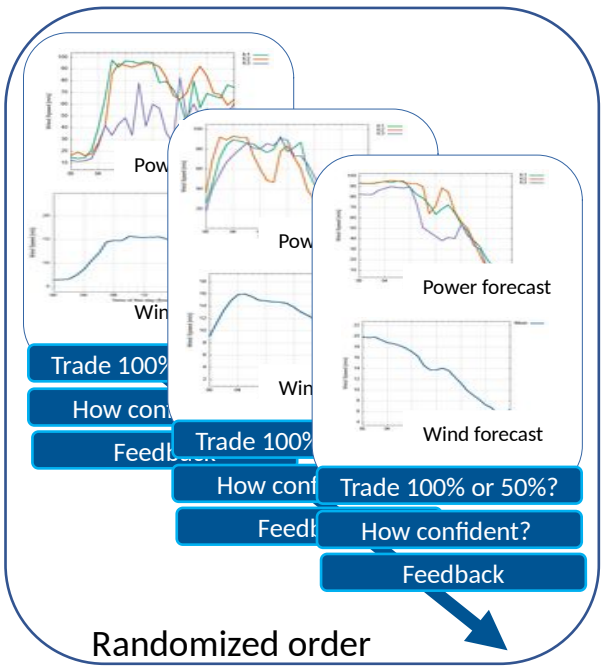
Value of probabilistic power forecasts

How do professionals decide based on probabilistic wind & power forecasts?

Design & Analysis: Dr. Nadine Fleischhut*, Dr. Corinna Möhrlen**
Host of Experiment: *Max-Planck Insititute for Human Development, Hans-Ertel Center for Weather Research, Germany
Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

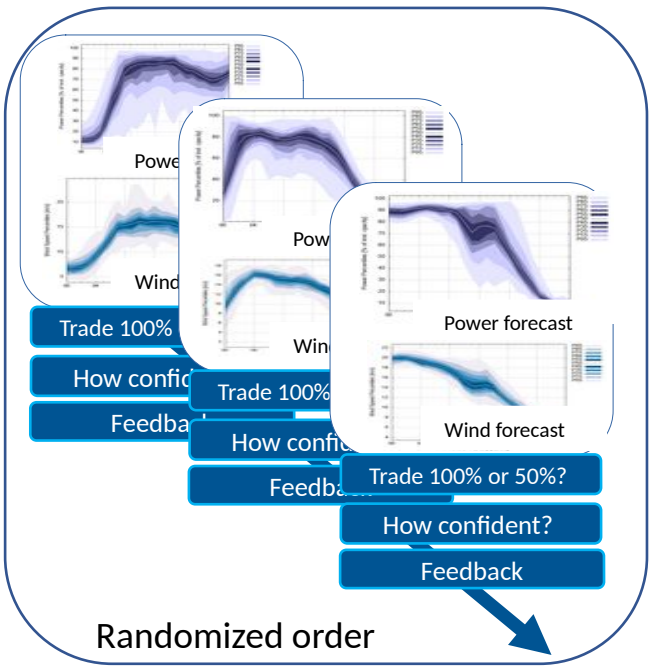
Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

Each participant →



20 decision situations with deterministic forecasts

Blocks randomized ↔

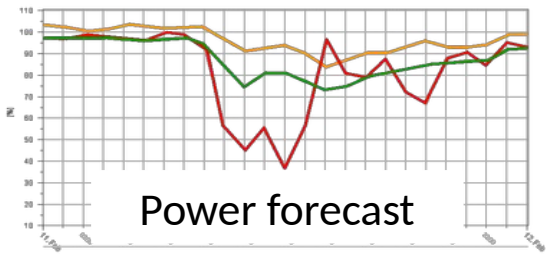


20 decision situations with probabilistic forecasts

How do professionals decide based on probabilistic wind/power forecasts?

Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

	HSSD	No HSSD
Trading 100%	-5000	5000
Trading 50%	0	2500



Trade 100% | Trade 50%

How confident are you ?
50% | 60% | 70% | 80% | 90% | 100%

High-speed shutdown occurred.

If you trade 100%, you loose 5000 EUR
If you trade 50%, you neither loose or gain anything.

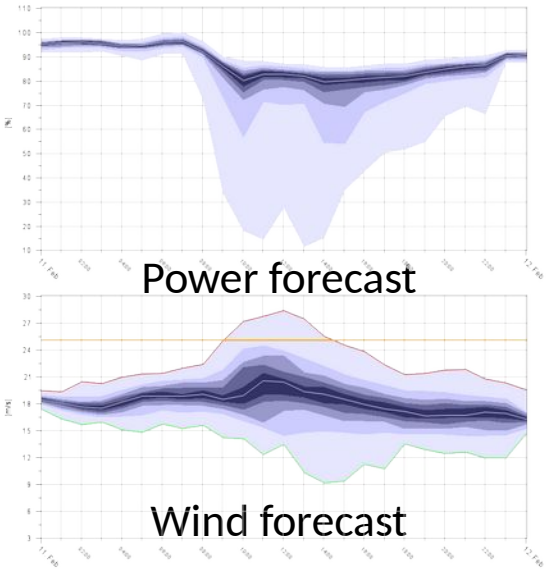
You chose to trade 100%.
You current balance therefore is: -5000

Feedback

How do professionals decide based on probabilistic wind/power forecasts?

Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

	HSSD	No HSSD
Trading 100%	-5000	5000
Trading 50%	0	2500



Trade 100% | Trade 50%

How confident are you ?
50% | 60% | 70% | 80% | 90% | 100%

High-speed shutdown occurred.

If you traded 100%, you loose 5000 EUR
If you traded 50%, you neither loose or gain anything.

You chose to trade 50%.
You current balance therefore is: 0

Feedback

Summary and Take-away

Probabilistic forecasts can benefit decision making…
Can we break down the barriers ?
Do we need to go from „description" to „impact" ?

Tailor information: Probabilistic information can improve decisions

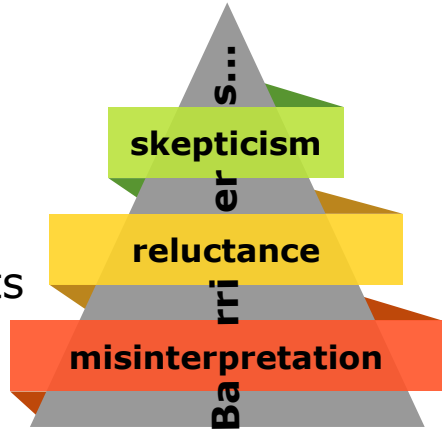
- Define the decisions that have to be made precisely

Risk communication: Improve risk perception via transparent representations

- Evidence-based design and evaluation of different representations
- From pure **forecast description** to **impact from forecast**

Decision support: **Define how to decide** based on probabilistic information

- Allow users to learn by feedback instead of by description
- Provide cues for interpretation or directly provide impacts from forecasts
- Put information in perspective (e.g. possible impact from the forecast)
- Provide simple and robust heuristics /decision strategies & the impact



2nd Experiment Design (2022)
Value of probabilistic power forecasts

Link for the 2nd experiment

Open to Play!

https://arc-vlab.mpib-berlin.mpg.de/wind-power/experiment/

Follow us on: iea-wind.org
→ Task 36 → Workpackage 3 → Forecast Games
or
Task 51 → Workstream
Decision making under uncertainty

THANK YOU for your attention…

Follow us:

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

Task-page: https://iea-wind.org/task51/task51-work-streams/ws-decision-making-under-uncertainty/ or
https://iea-wind.org/task36/task36-work-packages/wp3-optimal-use-of-forecasting-solution/wp3-4-probabilistic-forecast-games/

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

YouTube Channel: https://www.youtube.com/channel/UCsP1rLoutSXP0ECZKicczXg

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Contact Operating Agent:
Dr. Gregor Giebel, DTU Wind
grgi@dtu.dk

Link for the 2nd experiment

Version **… still Open to Play!**

https://arc-vlab.mpib-berlin.mpg.de/wind-power/experiment/

Contact Behavioural & Cognitive Scientist:
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Hans-Ertel Center for Weather Research
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