IEA Wind Task 36 & WEXICOM "Probabilistic Forecasting Games and Experiments" initiative:
How do Humans decide under Wind Power Forecast Uncertainty?

Electric City Conference 2021 – *Forecasting* -
WindEurope's annual on- and offshore wind energy event
25th Nov. 2021, 11.45-12.30 Copenhagen

'It is better to be roughly right than precisely wrong.'
— John Maynard Keynes (attributed)

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The study is a cooperation of the IEA Task 36 WP3 and project WEXICOM at the Max Planck Institute for Human Development.

...the overarching goal is to demonstrate the value of using probabilistic forecasts in the Renewable Energy Sector

→ **What we develop:** unified and inter-disciplinary approaches

→ **How we work: merge of separate fields and competencies**
Energy-Meteorology
Statistical Mathematics
Behavioural & Cognitive Science

→ **What we use: behavioural decision experiments**
* simulate real-time problems ("gamification") for specific user groups
* formulate strategies for applications & research
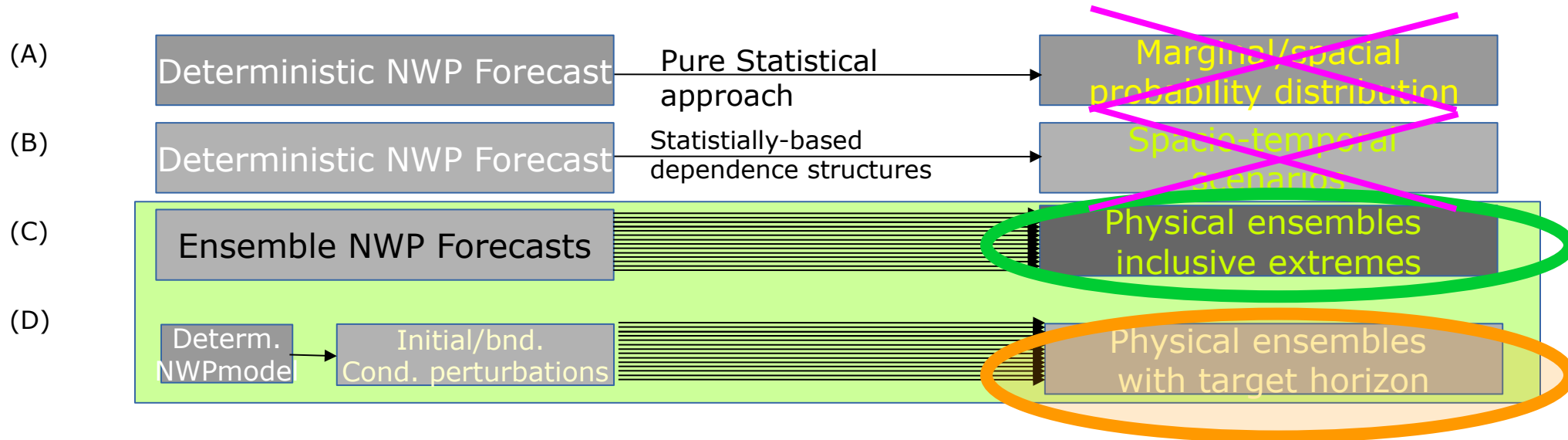* design experiments to study communication and knowledge gaps

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 21-27m/s**, mostly known as the *cut-off wind threshold of 25 m/s*.
Note that wind turbines use both wind gusts and the mean wind to determine, whether or not they turn into high-speed shutdown (HSSD).

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

Know, which methodology works for your target problem !

(A) Deterministic NWP Forecast → Pure Statistical approach → Marginal/spacial probability distribution

(B) Deterministic NWP Forecast → Statistially-based dependence structures → Spacio-temporal scenarios

(C) Ensemble NWP Forecasts → Physical ensembles inclusive extremes

(D) Determ. NWPmodel → Initial/bnd. Cond. perturbations → Physical ensembles with target horizon

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

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.

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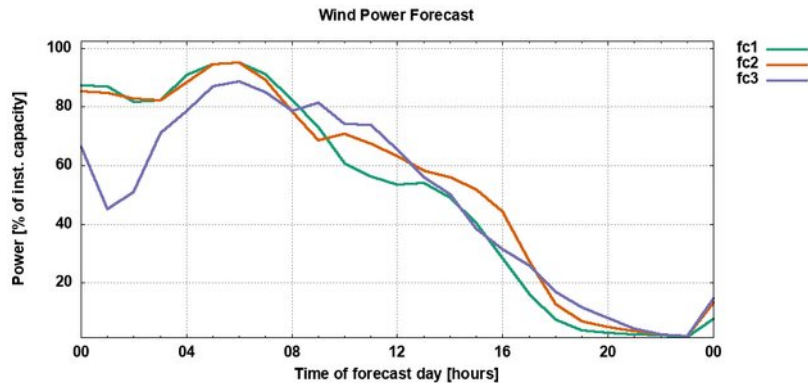
3 independent deterministic wind power forecasts in the unit [% of installed capacity] based on 3 different NWP (numerical weather prediction) models

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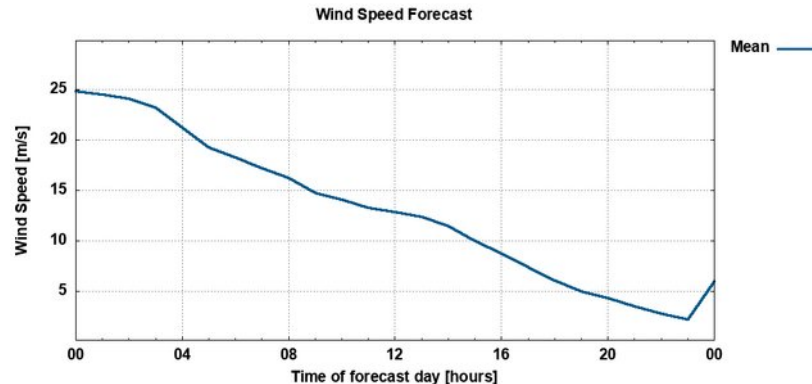
1 wind speed forecast in the unit [m/s], which is a mean forecast from 75 ensemble members and smoother than a typical deterministic forecast.

Forecast Game: decision-making in extreme events

Wind Power Forecast

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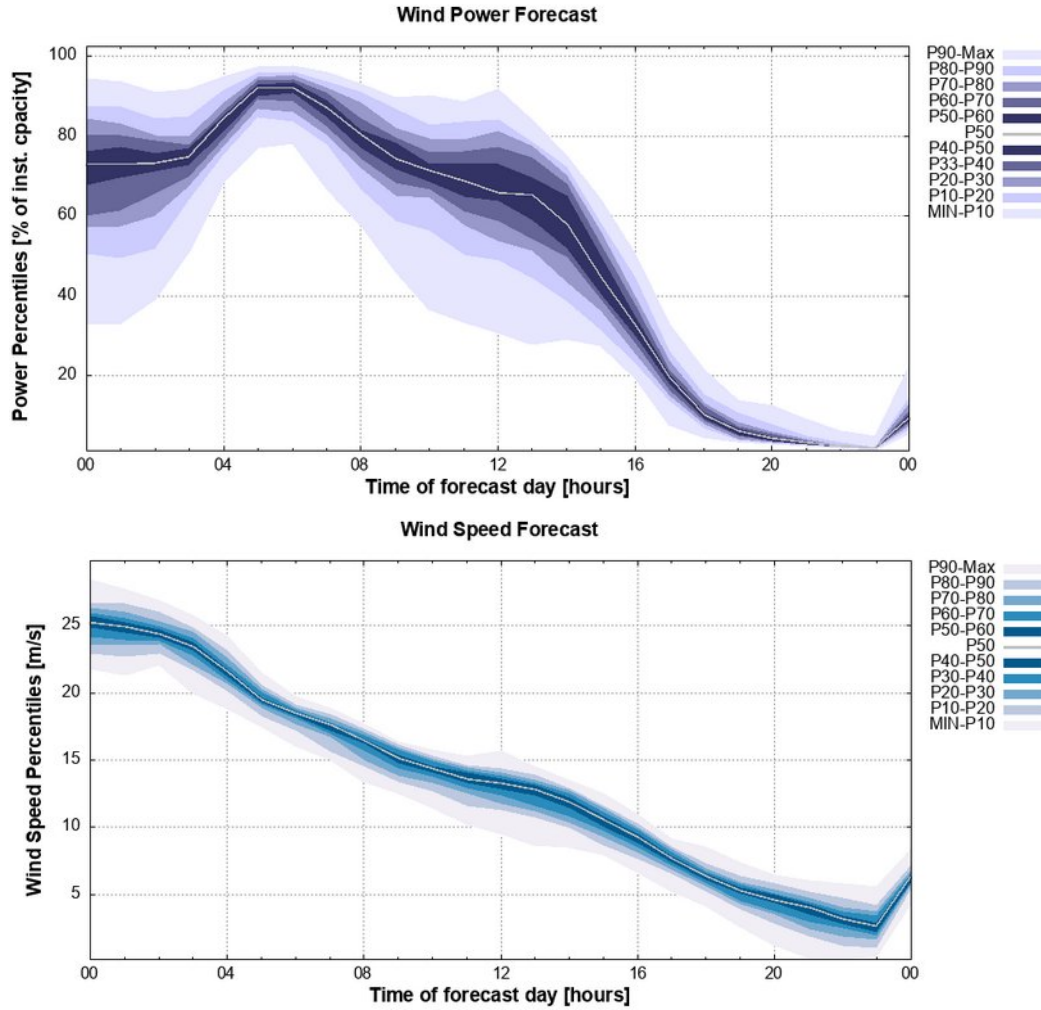
9 wind power percentiles (P10..P90) and a mean (white line) in the unit [% of installed capacity] generated from 75 NWP forecasts of a multi-scheme ensemble prediction system (MSEPS).

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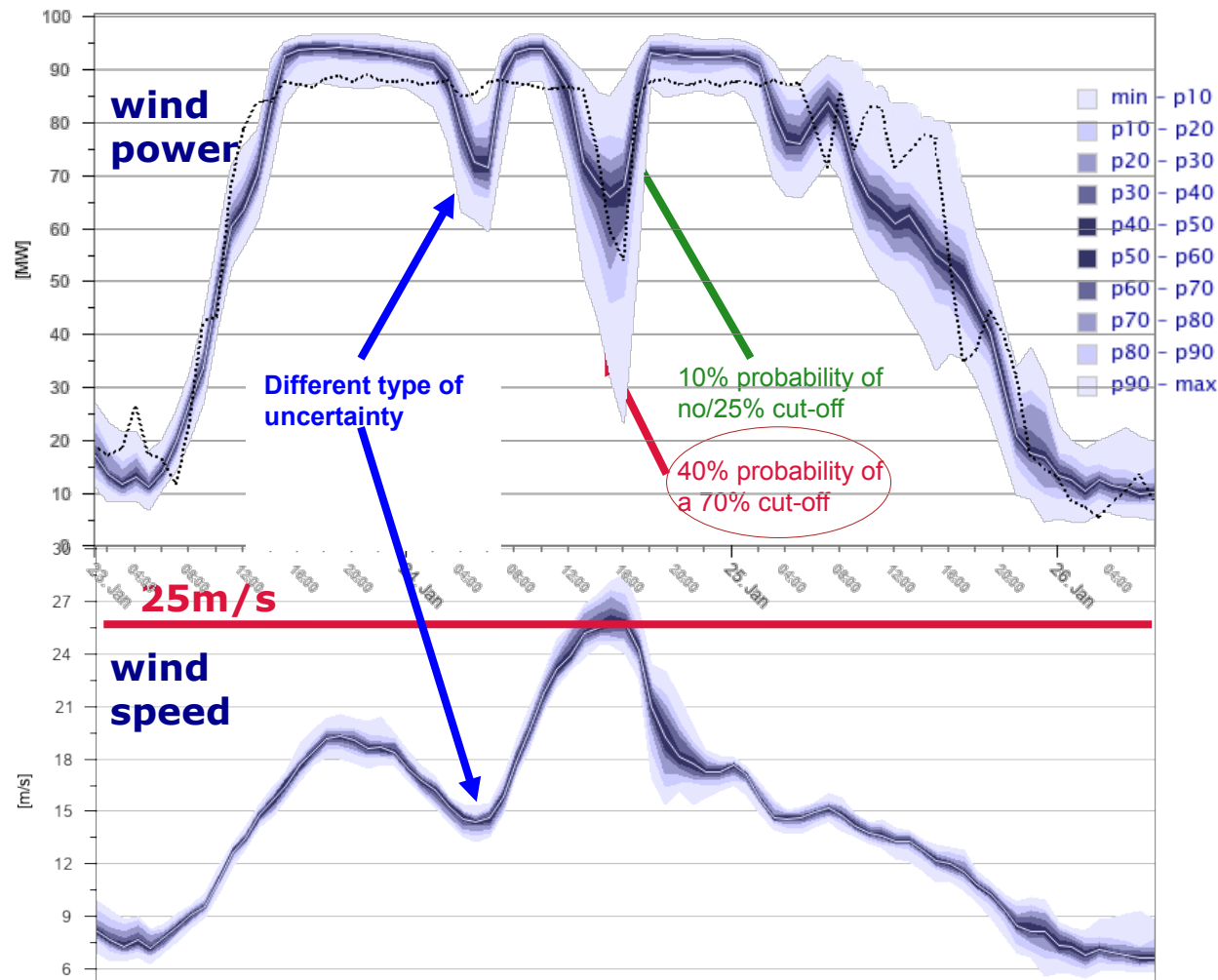
Definition: A percentile indicates the value below which a given percentage of forecasts from the 75 available forecasts falls. E.g., the 20th percentile is the value below which 20% of forecasts are found.

Which cues ("predictors") do people use and why?

Simple heuristic decision tree?
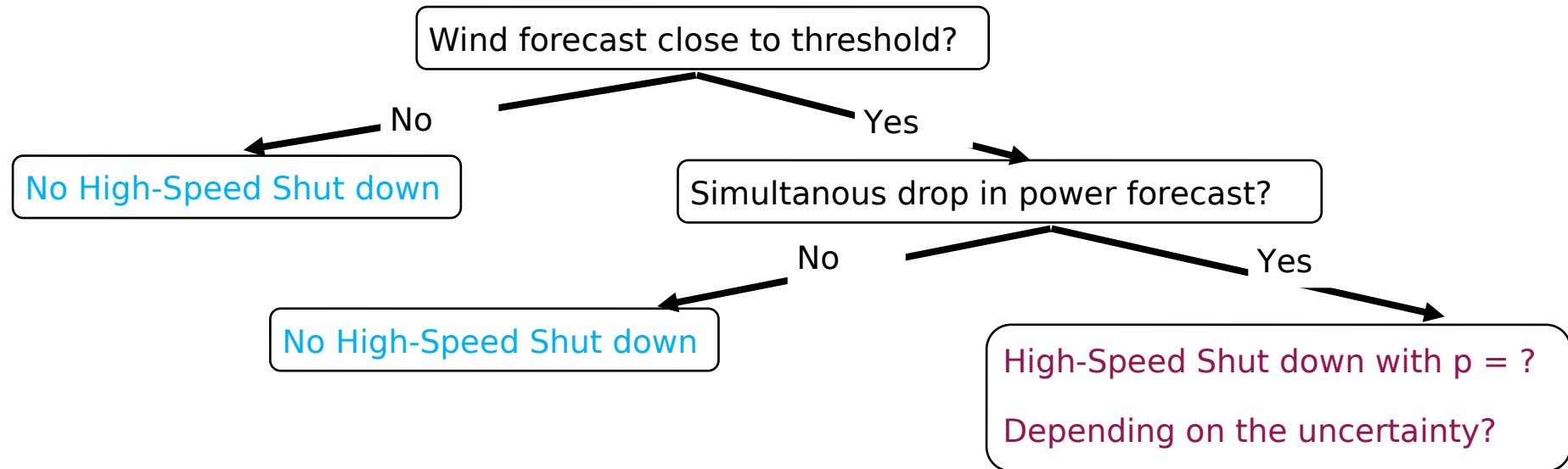
When dealing with Extremes....

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

wind power

wind speed

25m/s

Different type of uncertainty

10% probability of no/25% cut-off

40% probability of a 70% cut-off

**Decision Clues...
Remember:**
Each uncertainty band contains 10% of the 75 forecasts, i.e.
P10 = 10%
P20 = 20%
...
P90 = 90%
of forecasts below that value!

Cost Function Table

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

Cost Function Graph
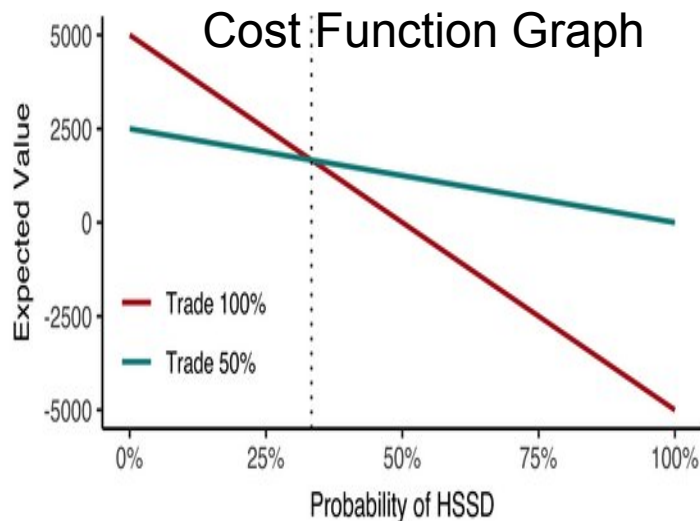
Percentiles in Forecast graphs

☐	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

Could participants read this out ?
Deterministic forecasts: no information

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

2nd Experiment Design (2021)
Value of probabilistic power forecasts

Wind Power Trading: What is the value of probabilistic forecasts for decision making?

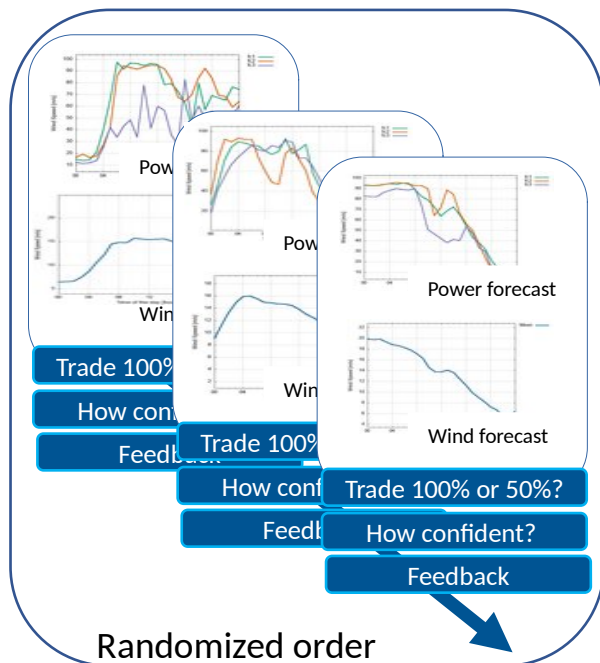How well can you use probabilistic or determinstic forecasts for simple trading decisions?

Find out by participating in a short decision experiment (ca. 20-30 minutes).

The study is a cooperation of the IEA Task 36 WP3 and project WEXICOM at the Max Planck Institute for Human Development.

Start

See also Poster PO008

Link for the 2nd experiment

Open to Play!

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

...check out our **poster PO008** for the link or our webpage iea-wind.org/task36 → workpackage 3 → Forecast Games

2nd Experiment Design (2021)

Wind Power Trading:
What is the value of probabilistic forecasts for decision making?

How well can you use probabilistic or determinstic forecasts for simple trading decisions?

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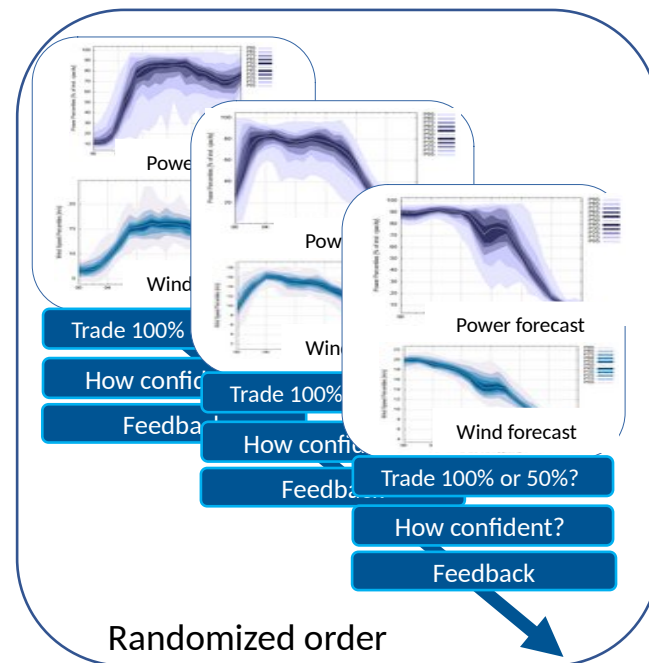Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

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

Each participant → Blocks randomized

Power forecast
Wind forecast
Trade 100% or 50%?
How confident?
Feedback

Randomized order

Randomized order

20 decision situations with deterministic forecasts

20 decision situations with probabilistic forecasts

To reflect the costs of large and small errors we have defined a simplified cost function for the period, where high-speed shutdown (HSSD) can take place.

Definitions:
- the wind farm is 100MW and the spot market price is 50 Eur/Mwh.
- balance costs are equivalent to spot market prices
- The cost function will only consider your choice for the hours, where the actual generation is full load or no generation
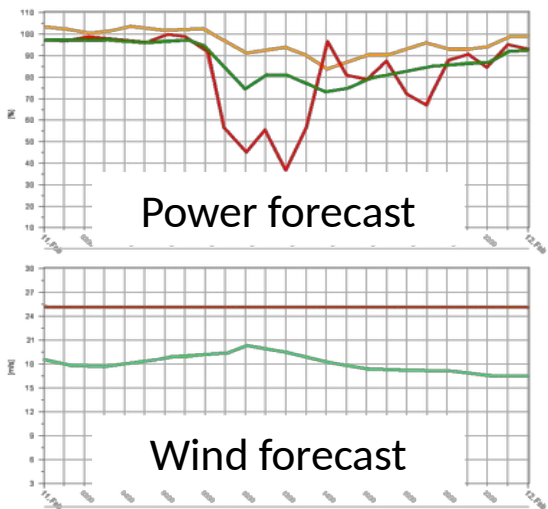
Trading	HSSD*	No HSSD*
100%	-5.000	5.000
50%	0	2.500

* High-Speed Shutdown == cut-off winds

Note that trading **100% is a risky choice** that can both increase your income and loss.
The more conservative **50% trading strategy eliminates the risk of a loss**, because **balance costs are equal to spot market prices** and **you can curtail the wind farm to avoid balance costs.**

Any questions ?
... if not ...

Join at www.kahoot.it
or with the Kahoot! app

THANK YOU

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

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Hans-Ertel Center for Weather Research
Nadine Fleischhut <fleischhut@mpib-berlin.mpg.de>

Link for the 2nd experiment
Open to Play!

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

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für Wetterforschung

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