IEA Wind Task 36 & WEXICOM "Probabilistic Forecasting Games and Experiments" initiative:

How do Humans decide under Wind Power Forecast Uncertainty?

- IEA Wind Task 36 WEBINAR Series 2021 -

15th December 2021

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Dr. Nadine Fleischhut, MPI-B

Dr. Ricardo Bessa, INESC TEC

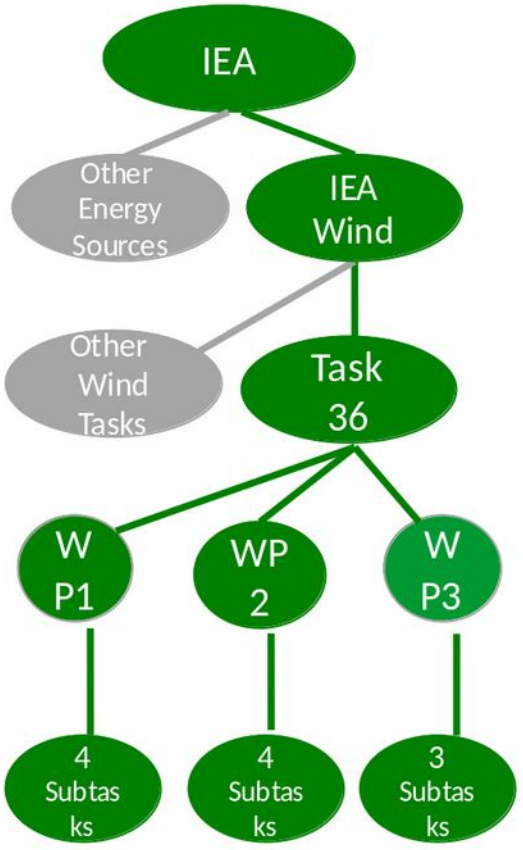
Dr. Gregor Giebel, DTU

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

'It is better to be roughly right than precisely wrong.'

— John Maynard Keynes (attributed)

IEA Task 36 - Forecasting for Wind Energy



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 36: Forecasting for Wind Energy: (www.iea-wind.org/task-36)

- One of 17 Tasks of IEA Wind: https://community.ieawind.org/home
- Phase 1: 2016-2018; Phase 2: 2019-2021
- 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 36 Scope: Three "Work Packages"

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

Task homepage: http://www.ieawindforecasting.dk/

Task 36 : Work Package Scope

- WP 1: **Global Coordination in Forecast Model Improvement**
  - 1.1 Compile list of available wind data sets suitable for model evaluation
  - 1.2 Annually document field measurement programs & availability of data
  - 1.3 Verify and validate NWP improvements with common data sets
  - 1.4 Work with the NWP centers to include energy forecast metrics in evaluation of model upgrades
- WP 2: **Benchmarking, Predictability and Model Uncertainty**
  - 2.1 Update the IEA Recommended Practice on Forecast Solution Selection
  - 2.2 Uncover uncertainty origins & development through the whole modelling chain
  - 2.3 Set-up and disseminate benchmark test cases and data sets
  - 2.4 Collaborate with IEC on standardisation for forecast vendor-user interaction
- **WP 3: Optimal Use of Forecasting Solutions**
  - 3.1 Collection and dissemination of benchmark cases for wind power forecasts
  - **3.2 Review and best practice on how to measure/quantify the value of probabilistic forecasts**
  - 3.3 Develop data requirements for real-time forecasting models for use in grid codes

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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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Forecast Games and Experiments Initiative

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WEPROG

Research Questions

How are probabilistic forecasts used & when do they benefit decisions?

- Decision outcomes: Do users make better decisions and in which forecast situations?
- Risk preferences: Do they decide more risk averse or risk seeking?
- Decision strategies: What cues ("predictors") do they use and how?
- Representation format: Do we need to make the move to impact forecasts ?

Do probabilistic forecasts allow better learning from feedback?

- How confident are users in their decisions?
- How well can they learn to calibrate their confidence? (Knowing when you don't know)
- How do users react to failure?

Do probabilistic forecast allow better adaptation to new environments?

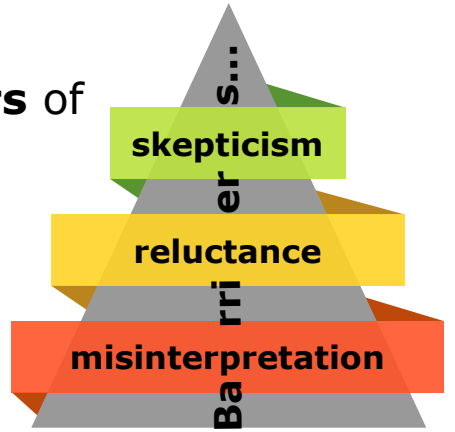
- Train in one environment and test behavior in new environment

Goals and Objectives of the Initiative

With our approach, we aim to test the most known and observed **barriers** of making use of uncertainty/probabilistic/risk forecasts:

``skepticism, reluctance, misinterpretation''

And, develop solutions to overcome these personal barriers



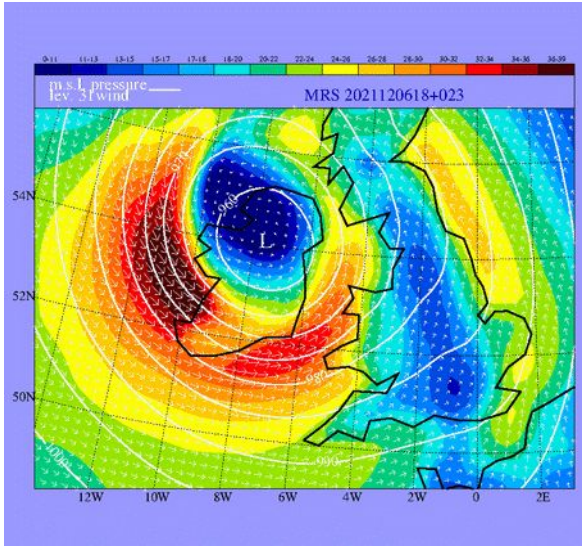
Tools and design structures that we integrate in our experiment make use of:

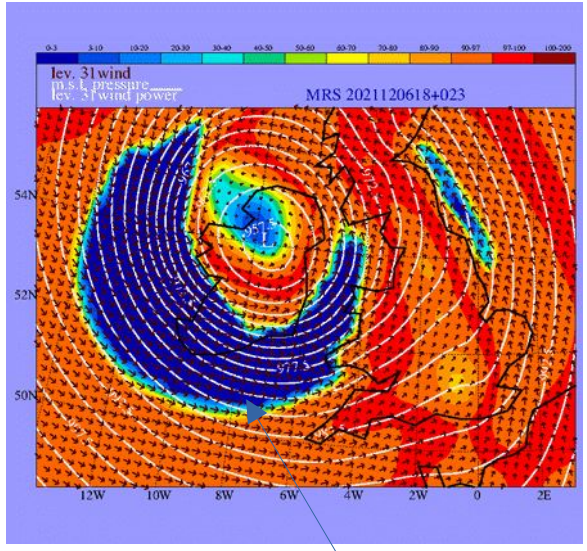
i. use of "**decision from experience**" principle rather than "**decision from description**"

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

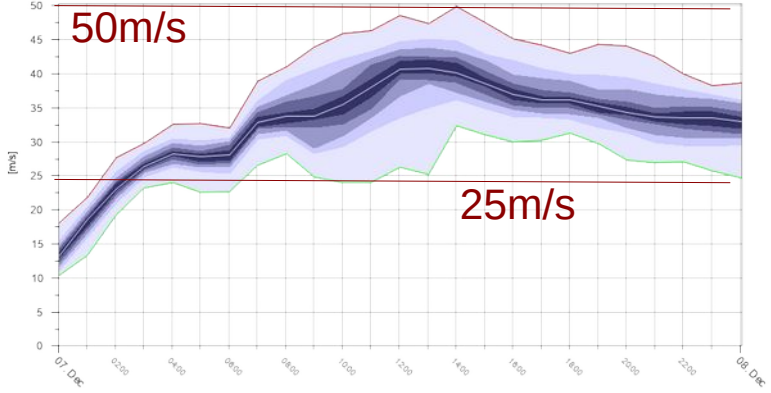
iii. Use of **Gamification**: a game illustrates an action without the seriousness and responsibility that comes from real applications and "**a more relaxed atmosphere**"

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



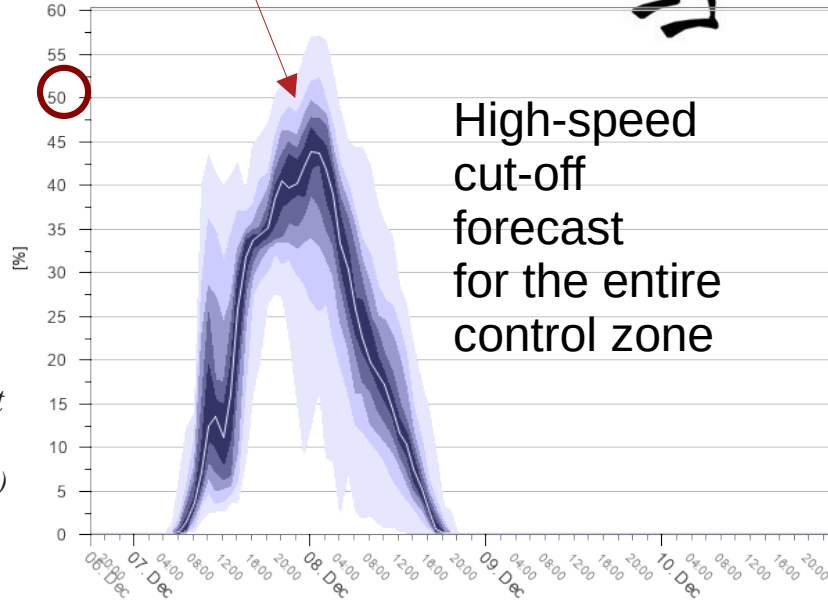


Cut-off area



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

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

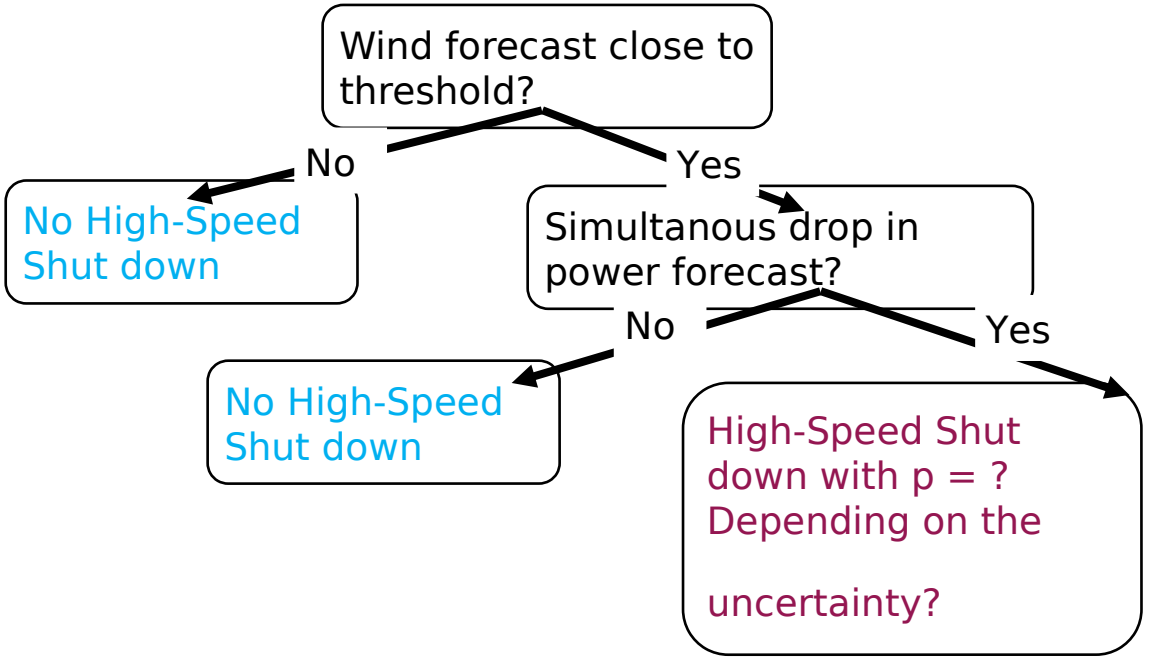


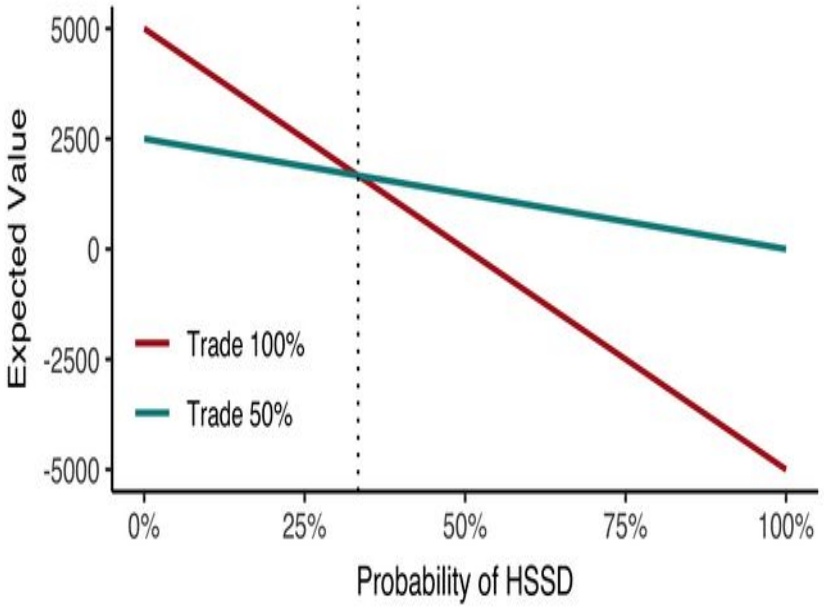
High-speed cut-off forecast for the entire control zone

Heuristic Decision strategies

Which cues ("predictors") are important in the decision process ?

Simple heuristic decision tree? ....or... (more complex) cost-loss functions ?





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"Probabilistic Forecasting Games & Experiments" initiative:

Decision-making in extreme events

1. Experiment (2020)

Game: Decisions were to be made

- whether or not a high-speed cut-off takes place within the forecast time in 12 cases
- whether to trade 50% or 100% of the generating power of an offshore wind park

Decision Tools:

- 3 deterministic forecasts showing the wind power & wind speed
- probabilistic forecast showing wind power and wind speed inclusive uncertainty bands

2. Experiment (2021)

Game:

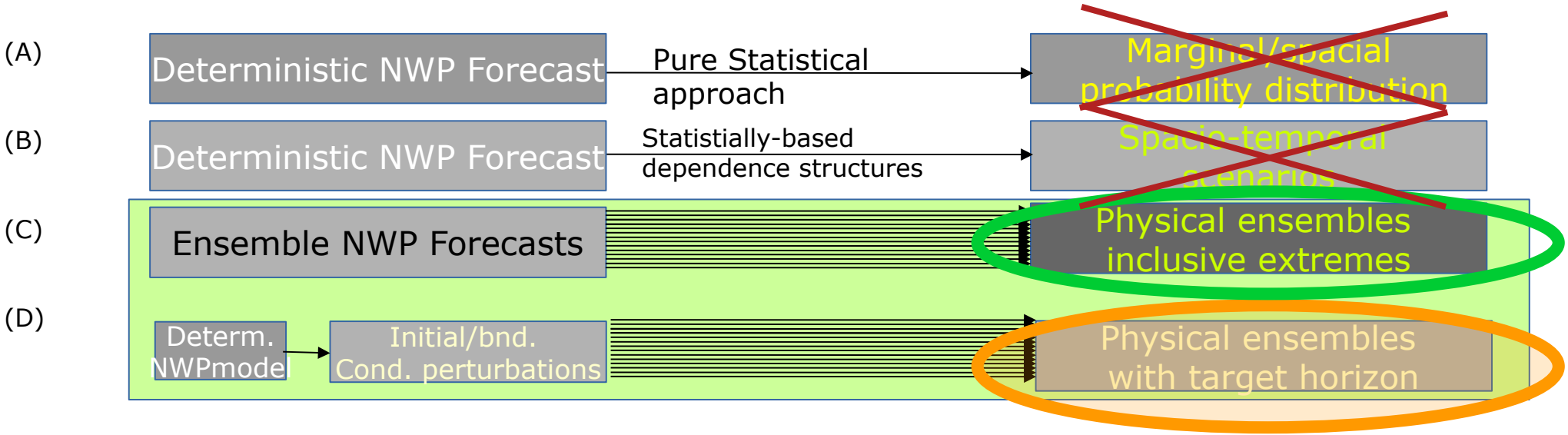
- 2 x times 20 cases (20 deterministic and 20 probabilistic cases)
- the participants make decisions based on either deterministic or probabilistic forecasts
- request on participant's confidence level regarding their decision
- real-time environment, e.g. participants may be surprised by forecasts that fail to warn or over-predict

Decision Tools:

Same as in 2020

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 - also those that have not been there in the last 5 years...**

(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

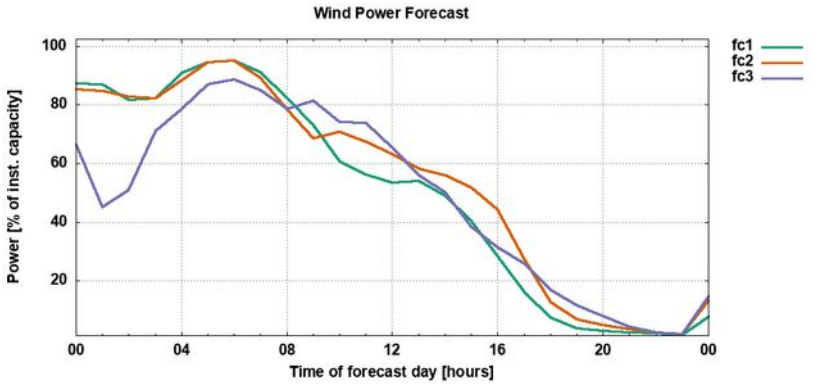
(D): target horizons need calibration for the time component

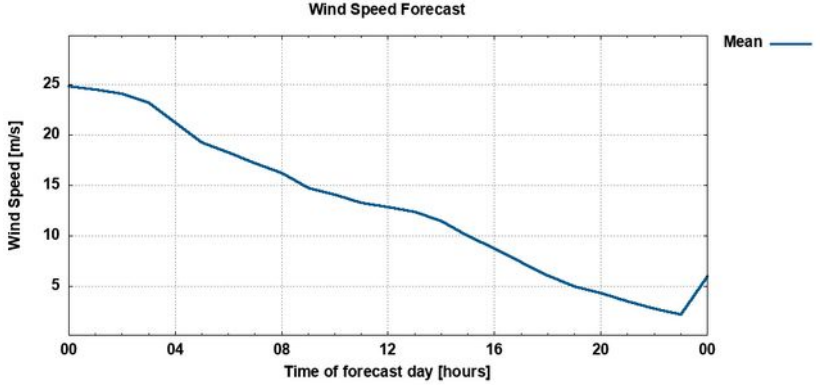
See e.g. Bessa et al. 2017, Haupt et al. 2019

Forecast Game: 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.

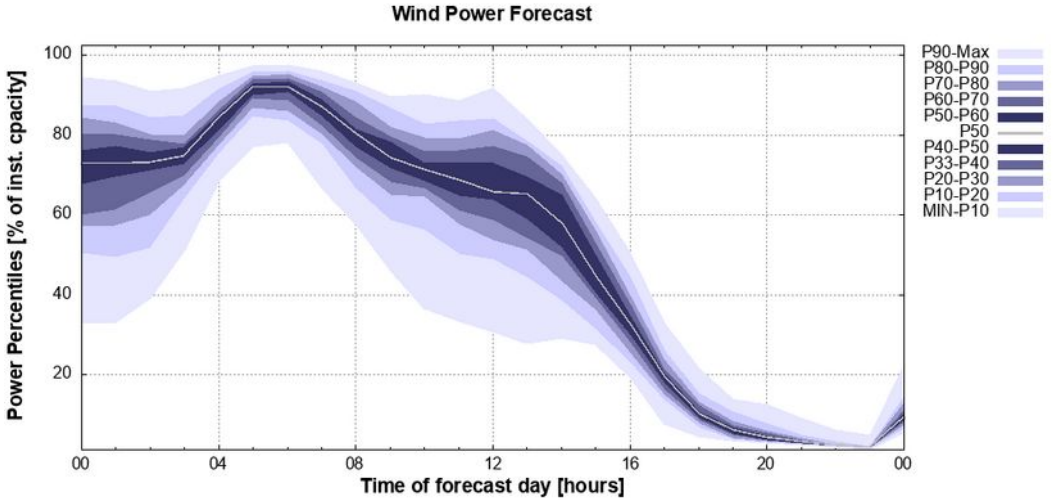


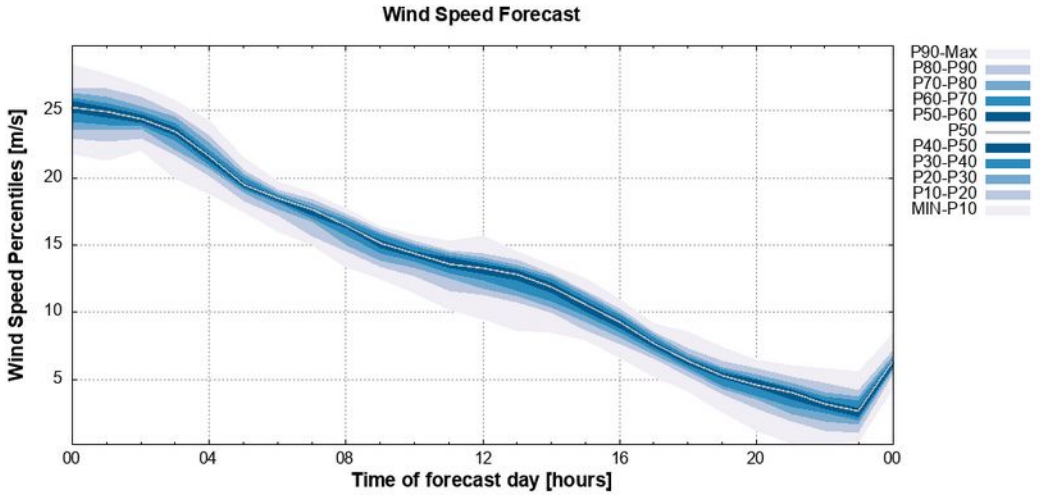


3 independent deterministic wind power forecasts in the unit [% of installed capacity] based on 3 different NWP (numerical weather prediction) models

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).

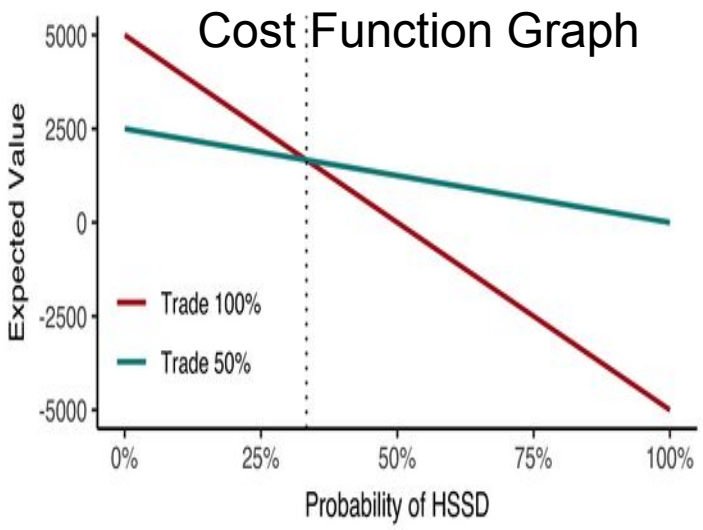
Note: The percentiles here are physically based uncertainty bands and provide an overview of the uncertainty of the forecast.

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

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

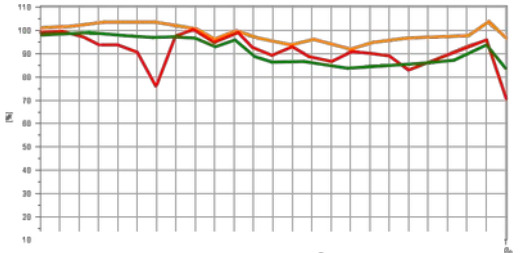
1st Experiment Design (2020)

Value of probabilistic power forecasts

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

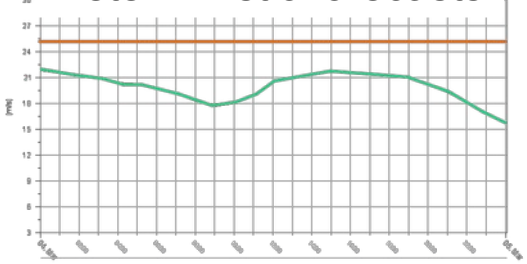
Design & Analysis: Dr. Nadine Fleischhut*, Dr. Corinna Möhrlen** & Dr. Ricardo Bessa (INESCTEC)
Host of Experiment: *Max-Planck Insititute for Human Development, Hans-Ertl Center of Weather Reseach, Germany
Ensemble Forecasts: **MSEPS 75 Member EPS of WEPROG

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



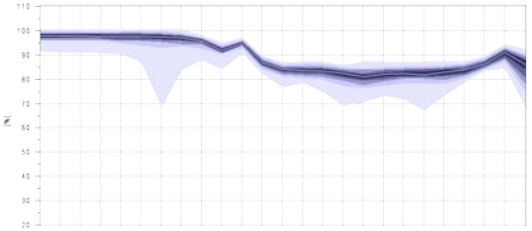
Deterministic forecasts → 1st Decision

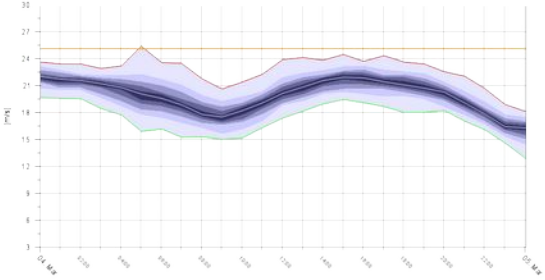
Power forecasts



Wind forecasts

1st Decision → Probabilistic forecasts → 2nd Decision





Cost function

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

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

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Max Planck Institute for Human Development
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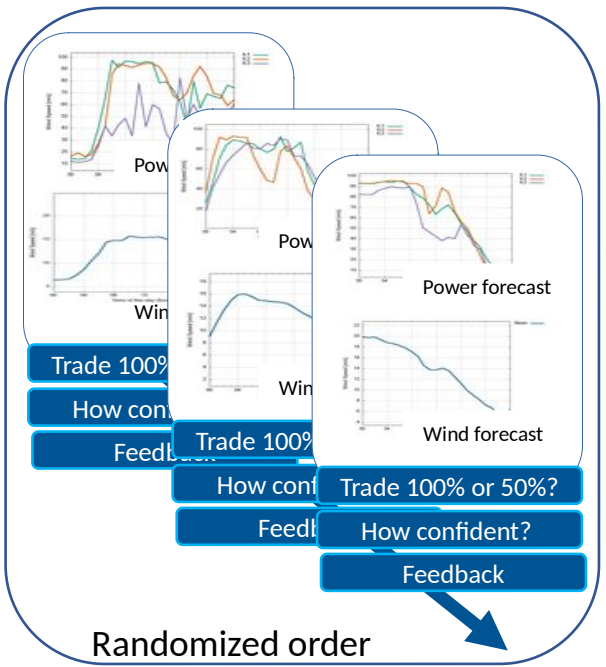
How do professionals decide based on probabilistic wind & power forecasts?

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

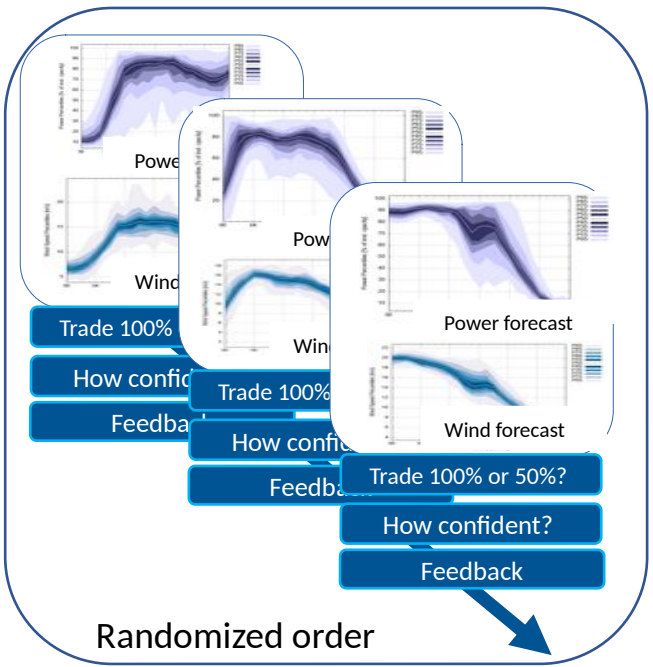
Trade 100% or only 50% wind energy – given the risk of high-speed shutdown?

Each participant →



20 decision situations with deterministic forecasts

Blocks randomized

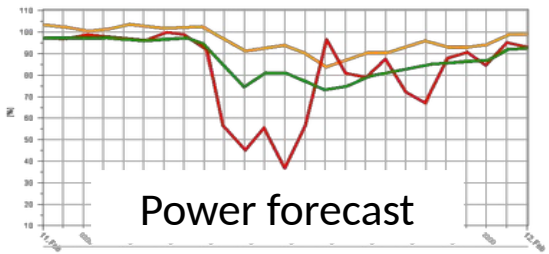


20 decision situations with probabilistic forecasts

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.

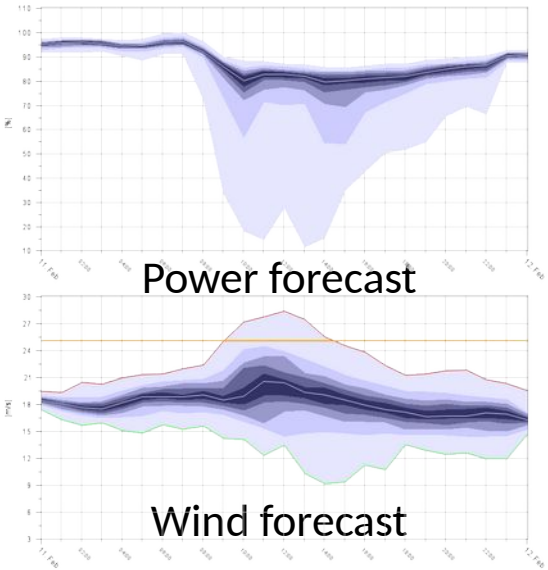
You chose to trade 100%.
You current balance therefore is: -5000

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

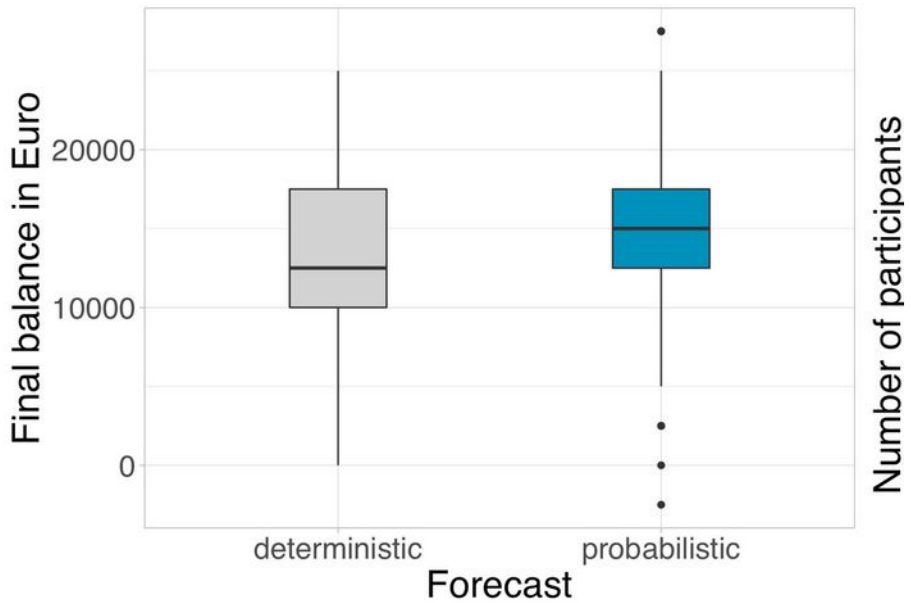
Feedback

Forecast Game No. 1 and No.2 preliminary results

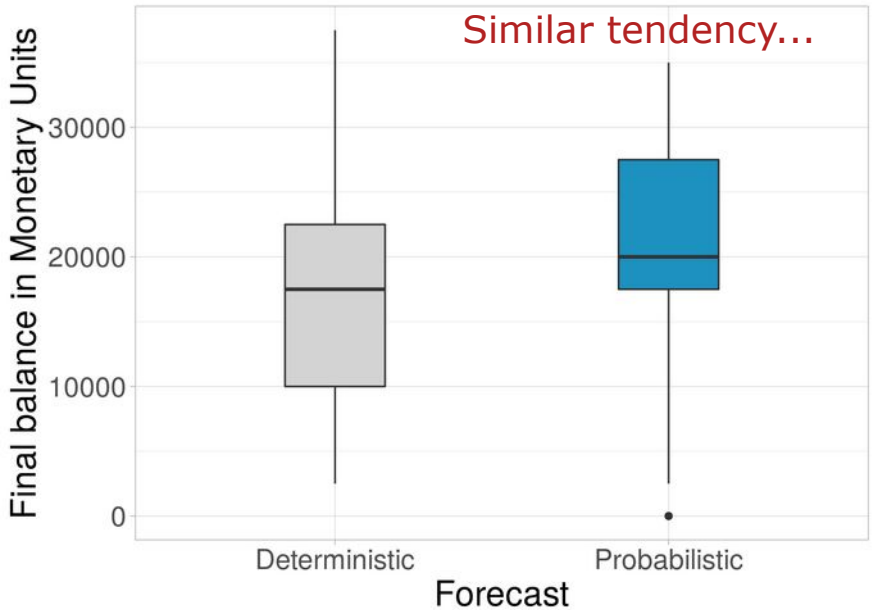
ANALYSIS – final balance -

Distribution and histogram of participants' final balance based on deterministic vs. probabilistic forecasts

Experiment 1 (120 participants)



Experiment 2 (50 participants)



Forecast Game No. 1 and No.2 preliminary results

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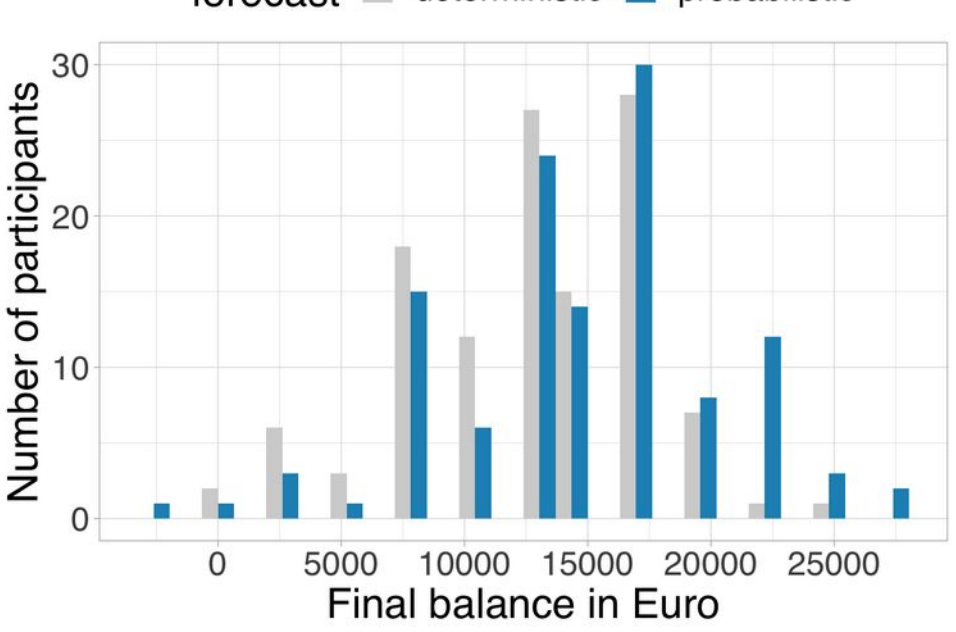
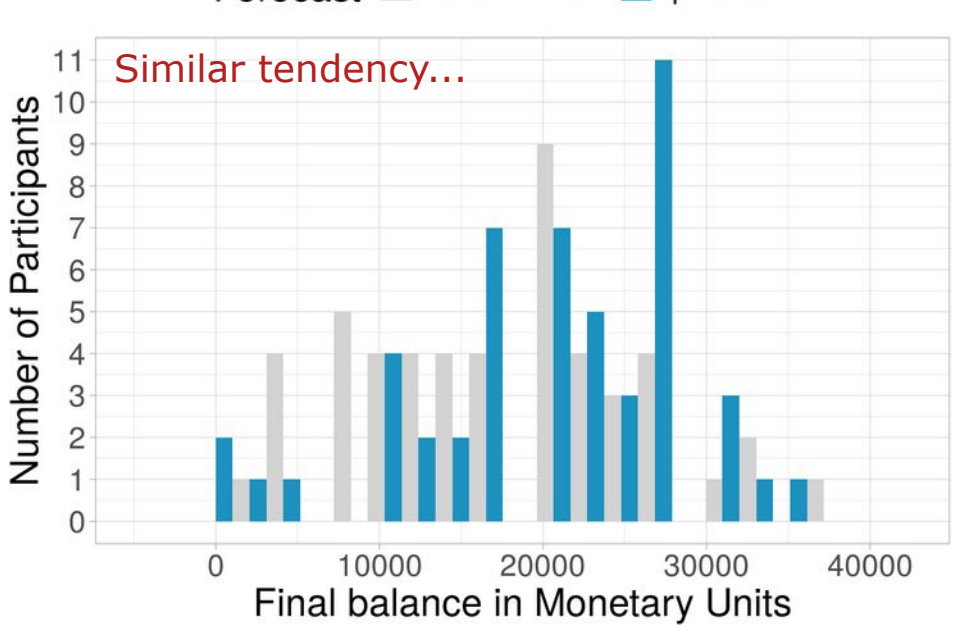


Experiment 2 (50 participants)

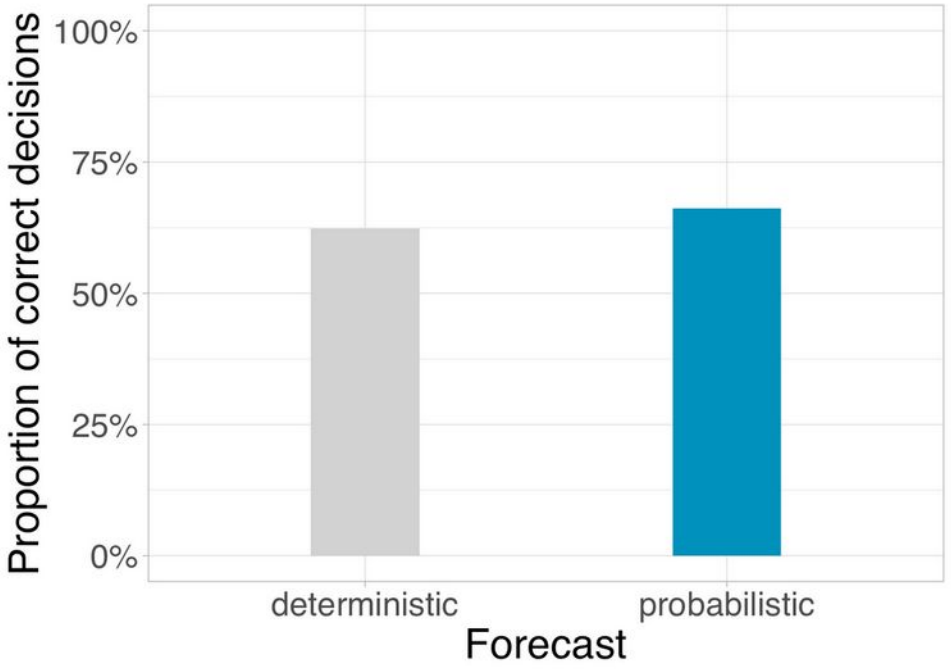


Forecast Game No. 1 and No.2 preliminary results

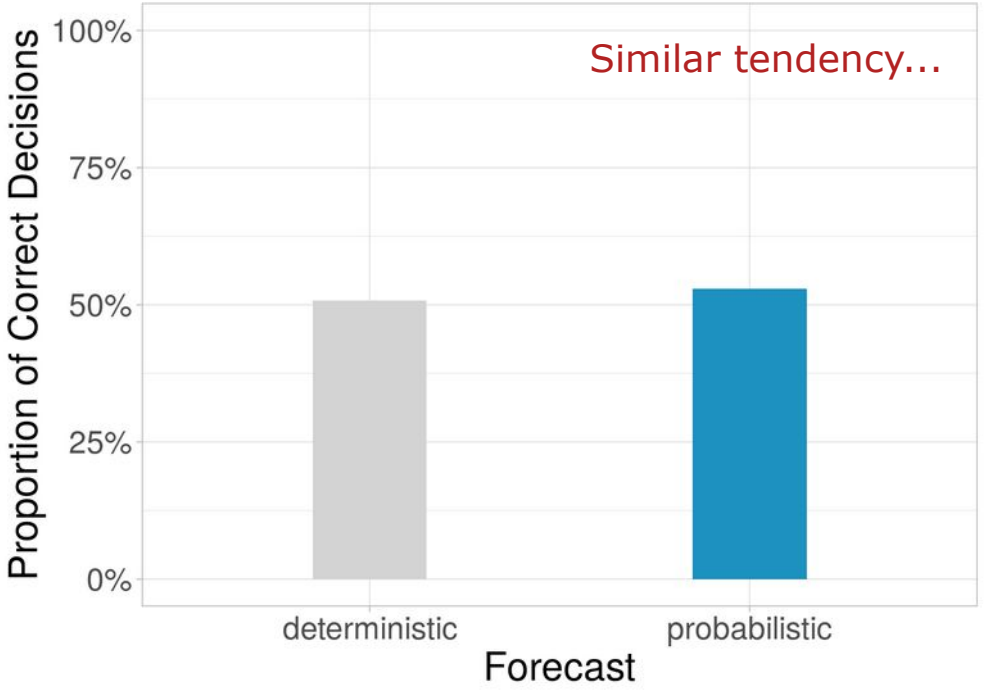
ANALYSIS – correct decisions -

Proportion of correct decisions based on deterministic vs. probabilistic forecasts

Experiment 1 (120 participants)

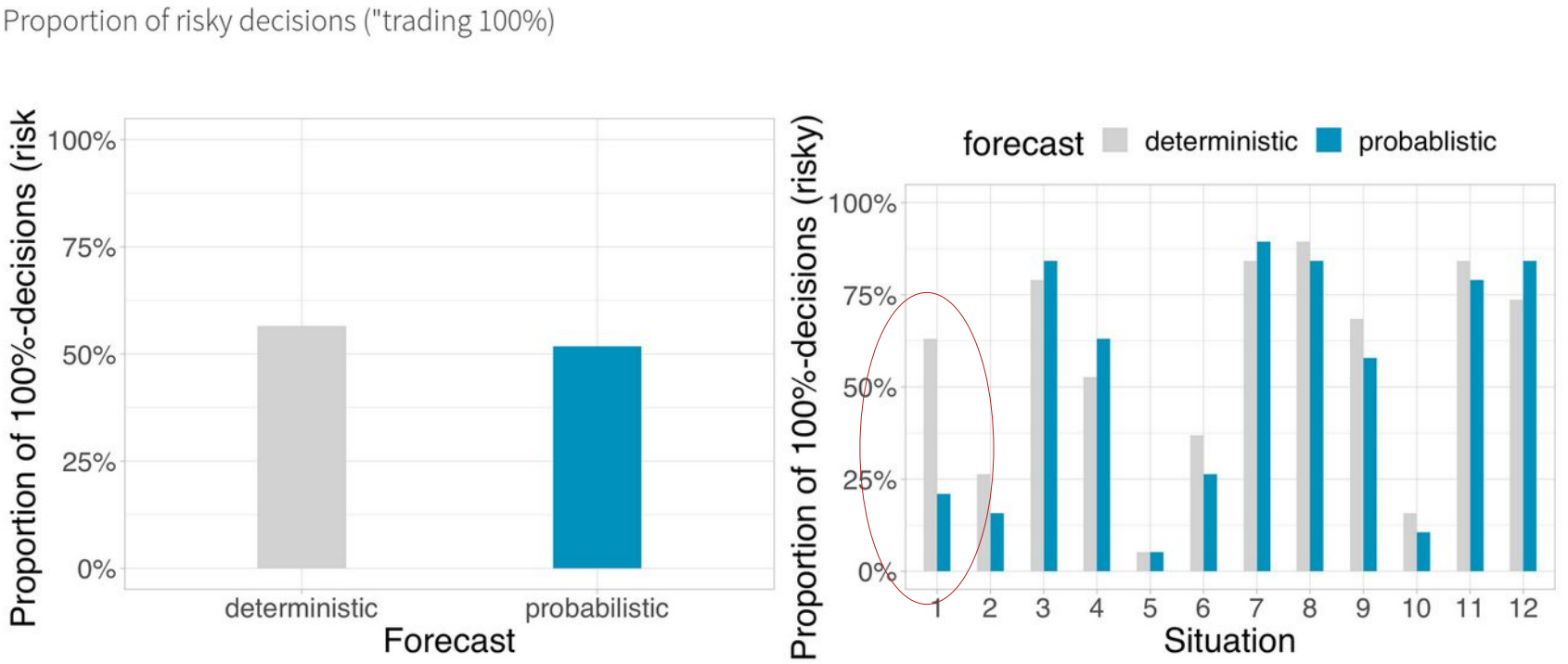


Experiment 2 (50 participants)



Forecast Game No. 1

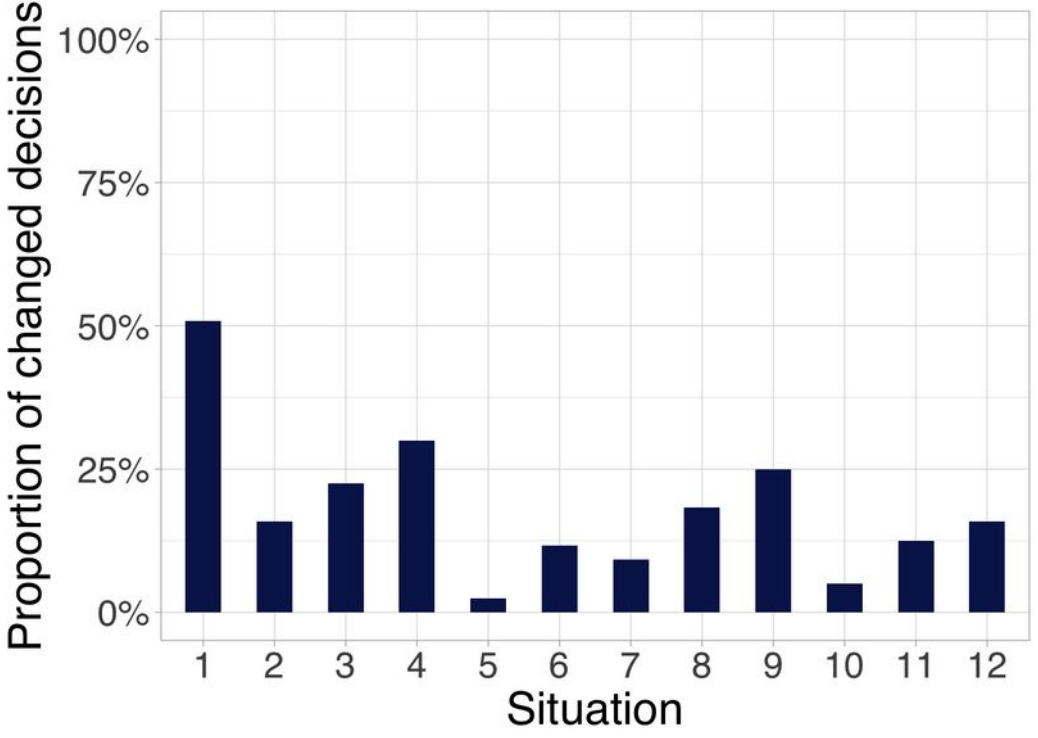
ANALYSIS – risky decisions -



Forecast Game: Offshore wind power decision making in extreme events

ANALYSIS – changed decisions -

Proportion of changed decisions based on the probabilistic forecast



Across all decisions, **participants changed** their **mind in 18 % of the situations**.

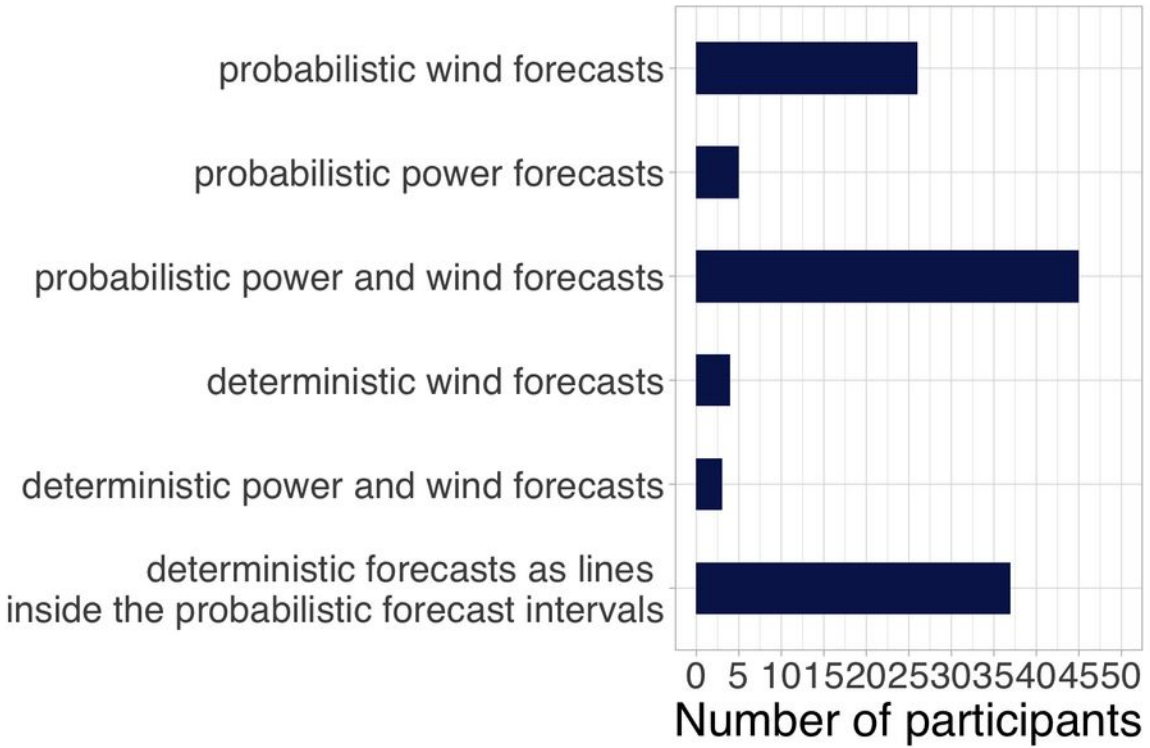
On an individual level, **91 % of the participants changed their mind at least once** based on the probabilistic forecast.

Forecast Game: Offshore wind power decision making in extreme events

task 36

ANALYSIS of Questions – preferred information -

Histogram of participants' preferred information



No one preferred to make decisions based on deterministic power forecast alone.

Summary and Take-away

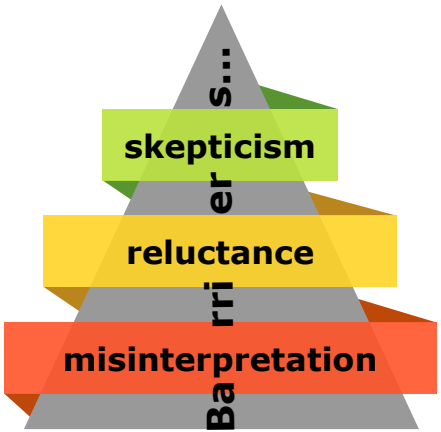
Probabilistic forecasts can benefit decision making…
Can we break down the barriers ?
Do we need to go from „description" to „impact" ?

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 (2021)
Value of probabilistic power forecasts

Link for the 2nd experiment

Open to Play!

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

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THANK YOU

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Publications: https://iea-wind.org/task-36/task-36-publications

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

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

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Link for the 2nd experiment

Open to Play!

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

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