

Behavioural decision-making Experiments in weather-driven Energy Systems

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DISPLAY MATERIAL





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

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

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



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







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

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

Research Team:

emerged as another.

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



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

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

> WP2 Image Credit: Jürgen Rossbach (MPIB)

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.



WEXICOM Project – WP2 -

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

AR Max Planck Institute for Human Development

How to communicate probabilistic impact forecasts?



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**"



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





Dealing with Extremes....



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



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

Randomly selected

deterministic forecasts <u>do not</u> provide a realistic uncertainty!

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

Dealing with Extremes....

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

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



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



Wind Power 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.



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

Percentiles

in Forecast

graphs

Cost Function Table				
Trading	HSSD*	No HSSD*		
100%	-5.000	5.000		
50%	0	2.500		



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?





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 Institute 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?



20 decision situations with deterministic forecasts

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



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

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



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





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 <u>cues for interpretation</u> or directly <u>provide impacts</u> 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



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.

Link for the 2nd experiment **Open to Play!** <u>https://arc-vlab.mpib-berlin.mpg.de/wind-power/</u> <u>experiment/</u>

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

THANK YOU for your attention...

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/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: <u>https://www.youtube.com/channel/UCsP1rLoutSXP0ECZKicczXg</u>

Contact WP Leads: Dr. Corinna Möhrlen, WEPROG <u>com@weprog.com</u>

Follow us:



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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