



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

John Zack, MESO, Inc.

G. Giebel, H. Frank, C. Draxl, J. Browell, C. Möhrle, G. Kariniotakis, R. Bessa, D. Lenaghan

14 October 2022



International Energy Agency History

The IEA was founded in 1974 to help countries co-ordinate a collective response to major disruptions in the supply of oil.



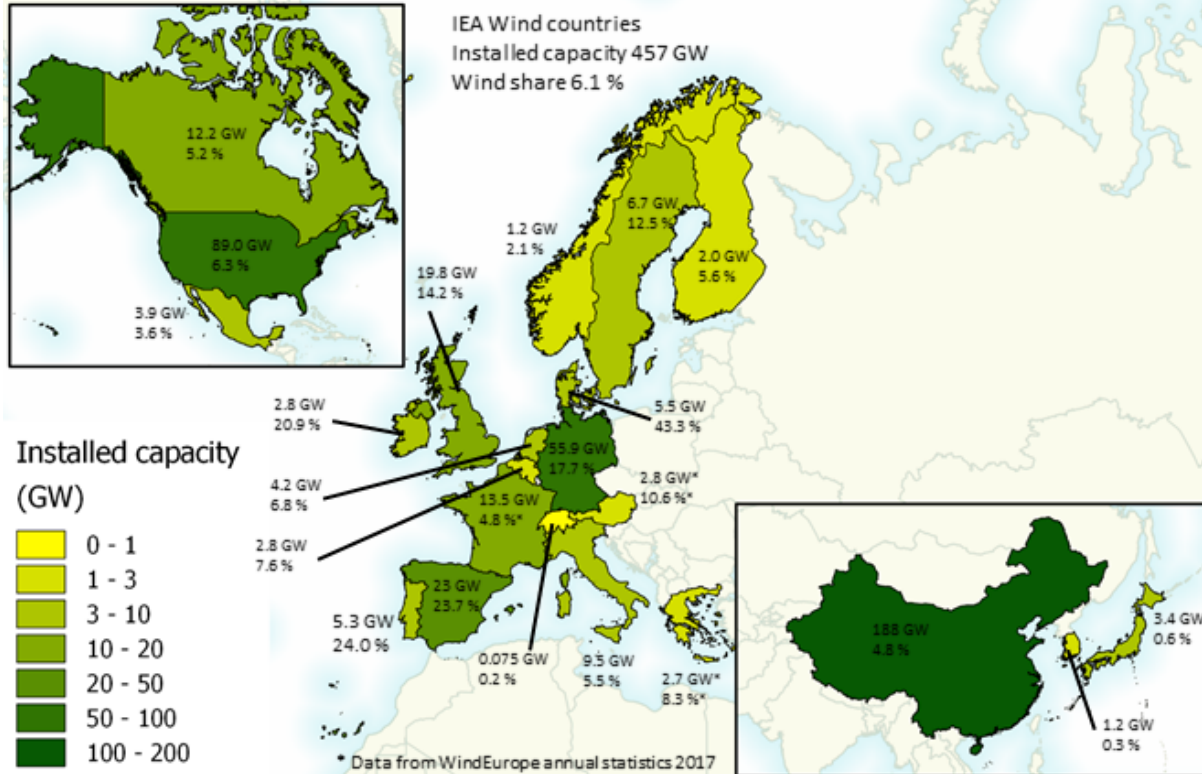
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- *Specific Technology Collaboration Programs (in renewable energy):*
- Bioenergy TCP
- Concentrated Solar Power (SolarPACES TCP)
- Geothermal TCP
- Hydrogen TCP
- Hydropower TCP
- Ocean Energy Systems (OES TCP)
- Photovoltaic Power Systems (PVPS TCP)
- Solar Heating and Cooling (SHC TCP)
- Wind Energy Systems (Wind TCP)

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iea wind



- Task 51 Members:
 - AT, CN, DE, DK, ES, FI, FR, IE, PT, UK, US



iea wind

- Task 11 Base Technology Exchange
- Task 19 Wind Energy in Cold Climates
- Task 29 Mexnext III: Analysis of Wind Tunnel Measurements and Improvements of Aerodynamic Models
- Task 30 Offshore Code Comparison Collaboration, Continued, with Correlation (OC5)
- Task 39 Quiet Wind Turbine Technology
- Task 40 Downwind Turbines
- Task 41 Distributed Energy
- Task 42 Wind Turbine Lifetime Extension
- **Task 51 Forecasting for the Weather-driven Energy System**
 - See iea-wind.org!
- Task 31 WAKEBENCH: Benchmarking Wind Farm Flow Models
- Task 32 LIDAR: Wind Lidar Systems for Wind Energy Deployment
- Task 36 Forecasting for Wind Energy
- Task 25 Design and Operation of Power Systems with Large Amounts of Wind Power
- Task 27 Small Wind Turbines in High Turbulence Sites
- Task 37 Wind Energy Systems Engineering
- Task 26 Cost of Wind Energy
- Task 28 Social Acceptance of Wind Energy Project
- Task 34 Working Together to Resolve the Environmental Effects of Wind Energy (WREN)

Forecasting for Wind Energy

2016-2018

2019-2021

T36 Phase 1

T36 Phase
2

Redefinition

T51 Phase 1

2022-2025

Forecasting for the
Weather Driven
Energy System

Highlights of IEA Wind Task 36 (2016-2021)

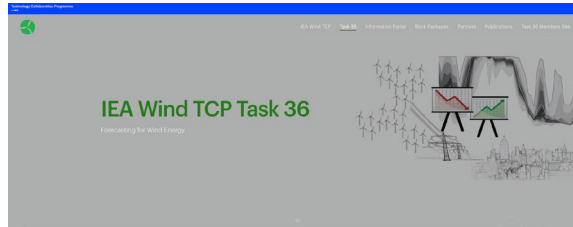


iea wind

Task 36 Web Presence

Website

www.iaa-wind.org/task36



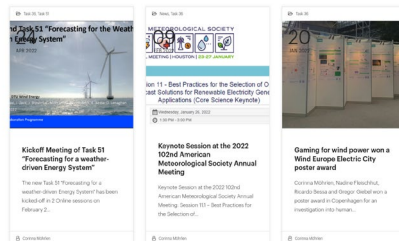
About Task 36

Improving the value of wind energy forecasts to the wind industry

Wind power forecasts have been used operationally for over 20 years. Despite this fact, there are still several possibilities to improve the forecasts, both from the weather prediction side and from the usage of the forecasts. The new International Energy Agency (IEA) Task on Forecasting for Wind Energy tries to engage international collaboration, among national weather centers with an interest and/or large projects on wind forecast improvements (NCA, DWD, ...), operational forecasters, and forecast users.

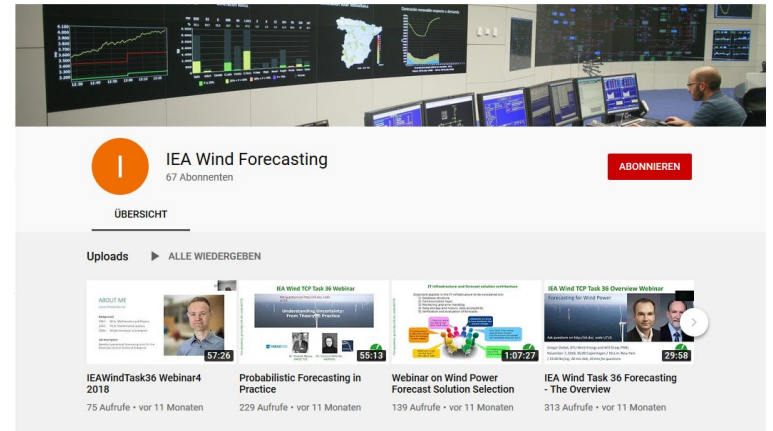
The Task is divided into three work packages. Firstly, a collaboration on the improvement of the scientific basis for the wind prediction themselves. This includes numerical weather prediction model physics, but also widely distributed information on accessible datasets. Secondly, we will be aiming at an international on-parallel on EA Benchmarking Practice on benchmarking and comparing wind power forecasts, including probabilistic forecasts. This WP will also organize benchmarks. In cooperation with the EA Task Workbench. Thirdly, we will be engaging end-users aiming at the dissemination of the best practices in the usage of wind power prediction.

News



 YouTube Channel

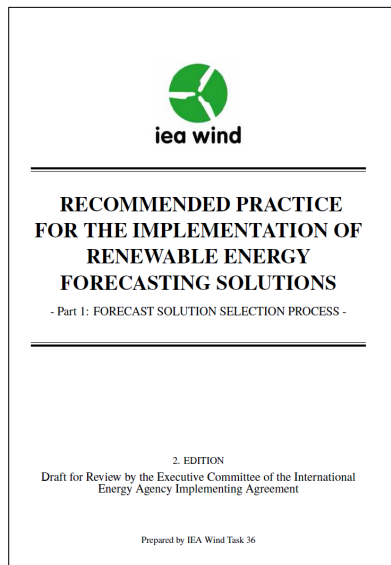
<https://www.youtube.com/c/IEAWindForecasting>



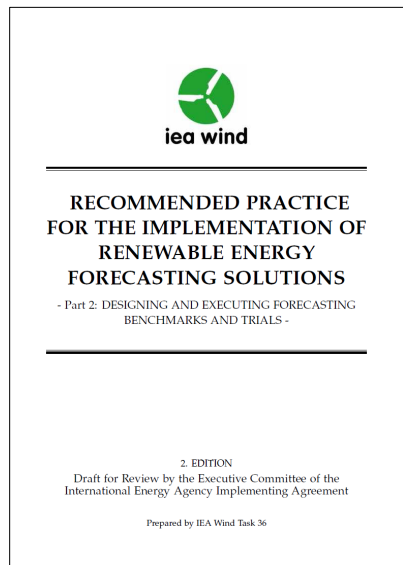
Task 36 (2016-2021) Key Accomplishments

1. List of wind forecasting validation datasets
2. Recommended Practices for Forecast Solution Selection: Versions 1 and 2
3. Several publications that address origin, use and value of forecasting uncertainty information
4. Publications that document 2 games/experiments that illustrate & analyze the value of probabilistic forecast information in human operational decision-making
5. Community workshops
 - Forecasting state-of-the-art workshop
 - Minute-scale forecasting workshop
 - Task 36 end-user workshop

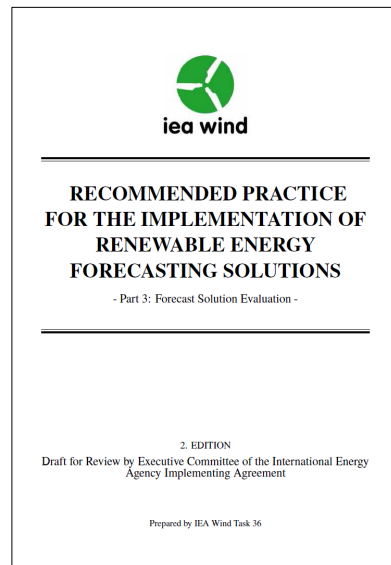
IEA Best Practice Recommendations for the Selection of a Wind Forecasting Solution Version 2: Set of 4 Documents



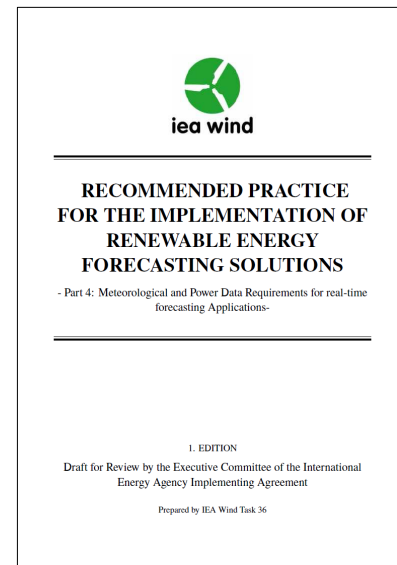
Part 1: Selection of an Optimal Forecast Solution



Part 2: Design and Execution of Benchmarks and Trials



Part 3: Evaluation of Forecasts and Forecast Solutions



Part 4: Data Requirements for Real-time Applications

Finalising now - also as book!

Introduction: <https://www.youtube.com/watch?v=XVO37hLE03M>

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IEA Wind Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions



Corinna Möhrle
John W. Zack
Gregor Giebel

Broad Overview of Uncertainty Forecasting

Prediction Models
Designed to
Prevent Significant
Errors

By Jan Dobschinski,
Ricardo Bessa, Pengwei Du,
Kenneth Geisler,
Sue Ellen Haupt,
Matthias Lange,
Corinna Möhrlen,
Dora Nakafuji, and
Miguel de la Torre Rodriguez

Uncertainty Forecasting in a Nutshell

Digital Object Identifier 10.1109/MPE.2017.2729100
Date of publication: 18 October 2017

IT IS IN THE NATURE OF CHAOTIC ATMOSPHERIC processes that weather forecasts will never be perfectly accurate. This natural fact poses challenges not only for private life, public safety, and traffic but also for electrical power systems with high shares of weather-dependent wind and solar power production.

To facilitate a secure and economic grid and market integration of renewable energy sources (RES), grid operators and electricity traders must know how much power RES within their systems will produce over the next hours and days. This is why RES forecast models have grown over the past decade to become indispensable tools for many stakeholders in the energy economy. Driven by increased grid stability requirements and market forces, forecast systems have become tailored to the end user's application and already perform reliably over long periods. Apart from a residually moderate forecast error, there are single extreme events that greatly affect grid operators.

Nevertheless, there are also forecast systems that provide additional information about the expected forecast uncertainty and estimations of both moderate and extreme errors in addition to the "best" single forecast. Such uncertainty forecasts warn the grid operator to prepare to take special actions to ensure grid stability.

The State of the Art in Forecast Generation

Today, some forecast systems have been developed specifically to predict the power production of single wind and solar units, differently sized portfolios, local transformer stations and subgrids, distribution and transmission grids, and entire countries. Nearly all forecast systems have one thing in common: they rely on numerical weather predictions (NWP) to calculate the expected RES power production. The way to transform weather predictions into power forecasts depends crucially on the end user's application and the available plant configuration and measurement data. If historical measurements are available, forecast model developers often use statistical and machine-learning techniques to automatically find a relation between historical weather forecasts and simultaneously observed power measurements. If no historical measurement data are available, e.g., for new installations of RES units, the transformation of weather to power is often accomplished by physically based models that consider the unit's parameters to map the internal physical processes.

Use of Probabilistic Forecasting

- Open Access journal paper
- 48 pages on the use of uncertainty forecasts in the power industry
- Scope:
 - Definition
 - Methods
 - Communication of Uncertainty
 - End-user Cases
 - Pitfalls
 - Recommendations
- Source: <http://www.mdpi.com/1996-1073/10/9/1402/>



Review

Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry

Ricardo J. Bessa ^{1,*}, Corinna Möhrlein ², Vanessa Fundel ³, Malte Siefert ⁴, Jethro Browell ⁵, Sebastian Haglund El Gaidi ⁶, Bri-Mathias Hodge ⁷, Umit Cali ⁸ and George Kariniotakis ⁹

¹ INESC Technology and Science (INESC TEC), 4200-465 Porto, Portugal

² WEPROG, 5610 Assens, Denmark; com@weprog.com

³ Deutscher Wetterdienst, 63067 Offenbach, Germany; vanessa.fundel@dwd.de

⁴ Fraunhofer Institute for Wind Energy and Energy System Technology (IWES), 34119 Kassel, Germany; malte.siefert@iwes.fraunhofer.de

⁵ University of Strathclyde, Department of Electronic and Electrical Engineering, Glasgow G1 1XQ, UK; jethro.browell@strath.ac.uk

⁶ Royal Institute of Technology, Department of Mechanics, SE-100 44 Stockholm, Sweden; sheg@kth.se

⁷ National Renewable Energy Laboratory, Golden, CO 80401, USA; bri-mathias.hodge@nrel.gov

⁸ University of North Carolina Charlotte, Dept. of Engineering Technology and Construction Management, Charlotte, NC 28223, USA; ucali@uncc.edu

⁹ MINES ParisTech, PSL Research University, Centre for Processes, Renewable Energies and Energy Systems (PERSEE), 06904 Sophia Antipolis Cedex, France; georges.kariniotakis@mines-paristech.fr

* Correspondence: ricardo.j.bessa@inesctec.pt; Tel: +351-22209-4216

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Abstract: Around the world wind energy is starting to become a major energy provider in electricity markets, as well as participating in ancillary services markets to help maintain grid stability. The reliability of system operations and smooth integration of wind energy into electricity markets has been strongly supported by years of improvement in weather and wind power forecasting systems. Deterministic forecasts are still predominant in utility practice although truly optimal decisions and risk hedging are only possible with the adoption of uncertainty forecasts. One of the main barriers for the industrial adoption of uncertainty forecasts is the lack of understanding of its information content (e.g., its physical and statistical modeling) and standardization of uncertainty forecast products, which frequently leads to mistrust towards uncertainty forecasts and their applicability in practice. This paper aims at improving this understanding by establishing a common terminology and reviewing the methods to determine, estimate, and communicate the uncertainty in weather and wind power forecasts. This conceptual analysis of the state of the art highlights that: (i) end-users should start to look at the forecast's properties in order to map different uncertainty representations to specific wind energy-related user requirements; (ii) a multidisciplinary team is required to foster the integration of stochastic methods in the industry sector. A set of recommendations for standardization and improved training of operators are provided along with examples of best practices.

Evaluation of Probabilistic Forecasts

- Review Paper by Blicher Bjerregård et al
 - Includes case studies
- “Our overall recommendation for evaluation of a multivariate probabilistic forecast is thus to apply VarS [**Variogram score**] to the full, multivariate forecast, while simultaneously evaluating its marginal densities by either univariate CRPS [Continuous ranked probability score] or LogS [Logarithmic score/log score], depending on whether the shapes of the tails are considered important (LogS) or not (CRPS). ”

Mathias Blicher Bjerregård, Jan Kloppenborg Møller, Henrik Madsen: *An introduction to multivariate probabilistic forecast evaluation*. Energy and AI 4 (2021) 100058. <https://doi.org/10.1016/j.egyai.2021.100058>

Energy and AI 4 (2021) 100058

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Review

An introduction to multivariate probabilistic forecast evaluation

Mathias Blicher Bjerregård*, Jan Kloppenborg Møller, Henrik Madsen

Technical University of Denmark, Department of Applied Mathematics and Computer, Denmark

HIGHLIGHTS

- An introduction to multivariate probabilistic forecast evaluation.
- A demonstration of how the probabilistic forecasting evaluation methods can be implemented for univariate as well as multivariate problems.
- A demonstration of how the probabilistic forecasting evaluation methods can be applied, exemplified in three case studies, with an emphasis on the evaluation on wind power forecasts.
- A summary table that highlights the advantages and drawbacks of the methods discussed.

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Wind power forecast

Ensemble forecast

Time series analysis

ABSTRACT

Probabilistic forecasting is becoming increasingly important for a wide range of applications, especially for energy systems such as forecasting wind power production. A need for proper evaluation of probabilistic forecasts follows naturally with this, because evaluation is the key to improving the forecasts. Although plenty of excellent reviews and research papers on probabilistic forecast evaluation already exist, we find that there is a need for an introduction with some practical application. In particular, many forecast scenarios in energy systems are inherently multivariate, and while univariate evaluation methods are well understood and documented, only limited and scattered work has been done on their multivariate counterparts. This paper therefore contains a review of a selected set of probabilistic forecast evaluation methods, primarily scoring rules, as well as practical sections that explain how these methods can be calculated and estimated. In three case studies featuring simple autoregressive models, stochastic differential equations and real wind power data, we implement, apply and discuss the logarithmic score, the continuous ranked probability score and the variogram score for forecasting problems of varying dimension. Finally, the advantages and disadvantages of the three scoring rules are highlighted, and this provides a significant step towards deciding on an evaluation method for a given multivariate forecast scenario including forecast scenarios relevant for energy systems.

1. Introduction

Forecast evaluation refers to the assessment of the quality of a forecast or to the selection between several competing forecasts. Traditionally, forecasters have used point forecasts [1] such as the conditional expectation for prediction of real processes. If the process is Gaussian, the uncertainty of the prediction is completely characterized by a simple symmetrical confidence interval. However, since real processes are often far from Gaussian, in order to capture all information of a process of interest, it is generally necessary to consider the entire forecast distribution. The evaluation of this is called probabilistic forecast evaluation [2].

A reliable forecast of future events is of crucial importance in, but not limited to, the design and operation of energy systems. A classic application is in the wind power sector, where the associated revenue is very dependent on reliable wind power forecasts [3]. In particular, one unexpected extreme event under which an entire wind farm is forced to shut down temporarily, can easily negate several months of revenue.

This is a powerful example of why not only the expectation, but also the uncertainty of the forecasted wind power must be taken into account to minimize such a risk, ideally by forecasting the full probability distribution [4]. In order to obtain accurate probabilistic forecasts, it is necessary to have a good forecasting model, and in order to obtain the best forecasting model, it is necessary to be able to evaluate the forecasts in a meaningful way. Therefore, probabilistic forecast evaluation is clearly very important in energy systems. Besides energy systems, other examples of relevant applications include weather and climate prediction [5], economic and financial risk management [6] and epidemiological forecasting [7]. A shift from point forecasts towards probabilistic forecasts is becoming increasingly important in all of these areas [8].

Forecasting of energy systems may concern univariate or multivariate forecasts. A forecast is multivariate when it consists of multiple variables, which may refer to multiple time-steps, multiple sites or multiple parameters. Plenty of good research about probabilistic forecast evaluation has been published in the univariate case [8]. However, most practical forecast applications consider a sequence of future time points

* Corresponding author.
E-mail address: mab@tau.dtu.dk (M.B. Bjerregård).

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2666-5468/© 2021 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Overview of Uncertainty Propagation in the Forecasting Chain

- Conceptual paper on the origins and propagation of uncertainty through the forecasting chain
- Applicable to wind and solar power
- Published in *Renewable and Sustainable Energy Reviews 2022*
- Recommendation: Next paper should use data and quantify the contributions

Uncovering wind power forecasting uncertainty origins and development through the whole modelling chain^{*,**}

Jie Yan^a, Corinna Möhren^b, Tuhe Güçmen^c, Mark Kelly^d, Arne Wessel^d and Gregor Giebel^{e,*}

^aNorth China Electric Power University, State Key Lab of Alternate Electrical Power System with Renewable Energy Sources, Beijing, P.R. China

^bWEPROG, Dreijersvænget 8, 5610 Assens, Denmark

^cTechnical University of Denmark, Department of Wind Energy, Frederiksborgvej 399, 4000 Roskilde, Denmark

^dFraunhofer Institute for Energy Economics and Energy System Technology IEE, Kassel, Germany

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Keywords:
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ABSTRACT

Wind power forecasting has been supporting operational decision-making for power system and electricity markets since 30 years. Efforts of improving the accuracy and/or certainty of wind power forecasts, either deterministic or probabilistic, are continuously exerted by academics and industries. Forecast errors and associated uncertainties, which propagate through the whole forecasting chain, from weather provider to the end user, cannot be eliminated completely due to many reasons; for instance, endogenous randomness of weather systems and varying wind turbine performance. Therefore, understanding the sources of uncertainty and how these uncertainties propagate throughout the modelling chain is significant to implement more rational and targeted uncertainty mitigation strategies and standardize the uncertainty validation. This paper presents a thorough review of the uncertainty propagation through the modelling chain, from the planning phase of the wind farm and the forecasting system through the operational phase and market phase. Moreover, the definition of the uncertainty sources throughout these phases build the guiding line of uncertainty mitigation throughout this review. In the end, a discussion on uncertainty validation is provided along with some examples. Highlights of this paper include: 1) forecasting uncertainty exists and propagates everywhere throughout the entire modelling chain and from planning phase to market phase; 2) the mitigation efforts should be exerted in every modelling step; 3) standardised uncertainty validation practice and global data samples are required for forecasts to improve model performance and for forecast users to select and evaluate the model's output.

1. Introduction

High penetration of wind power has been recognised globally as one of the most important features of current and future sustainable power systems. The natural randomness and variability of the wind itself can aggravate negative impacts of wind power on power system operation and market trading, which strengthens the significance of forecasting technology. Wind power forecasting (WPF) started more than three decades ago [16], with the first operational forecasting tools arriving at system operation level some 10 years later at the Danish transmission system operator ELSAM [10]. Since then, researchers have been making continuous efforts to improve the forecasting accuracy and reliability.

It is impossible to achieve perfect predictions of wind power at any given time or location, due to chaotic atmospheric motions having temporal and spatial scales that typically span more than six orders of magnitude [17, 18, 19]. Along with the complex wind field, wind turbine performance creates nonlinear and time-varying uncertainties in wind power forecasting. To improve the value of forecasts and their usage, we practically consider three questions: why, when and to what extent the forecasting uncertainty will happen [20]. Accordingly, this further guides the mitigation of forecasting uncertainty. There is plenty of literature in this area, and can be clarified into following three categories.

* This paper was coordinated under the auspices of IEA Wind Task 36 'Forecasting for Wind Energy', Corinna Möhren, Tuhe Güçmen, Mark Kelly and Gregor Giebel were funded by the Danish EUFP project 'IEA Wind Task 36 Phase II Danish Consortium', Grant Number 64018-0515.

^eCorresponding Author: Gregor Giebel

✉ grg1@dtu.dk (G. Giebel)

www.dtu.dk (G. Giebel)

ORCID(i): 0000-0002-9412-0909(0000-0002-9412-0999) (J. Yan); 0000-0002-8842-1533(0000-0002-8842-1533) (C. Möhren); 0000-0002-4453-8756(0000-0002-4453-8756) (G. Giebel)

How do Humans Decide under Wind Power Forecast Uncertainty

• Paper & Poster by Corinna Möhrlein et al.

• "In the first part of IEA Wind Task 36 initiative, a forecast game was designed as a demonstration of a typical decision-making task in the power industry. The game had been played by 120 participants. We will discuss the results of our first experience with the experiment and introduce some new features of the second generation of experiments as a continuation of the initiative."

• Möhrlein, C., Giebel, G., Bessa, R.J., and Fleischhut, N. How do Humans decide under Wind Power Forecast Uncertainty — an IEA Wind Task 36 Probabilistic Forecast Games and Experiments initiative, Journal of Physics: Conference Series, Volume 2151, WindEurope Electric City 2021 23/11/2021 – 25/11/2021 Copenhagen, Denmark, DOI: [10.1088/1742-6596/2151/1/012014](https://doi.org/10.1088/1742-6596/2151/1/012014)



Award-winning Poster at Wind Europe Electricity 2021

PO.008

How do Humans decide under Wind Power Forecast Uncertainty?

Corinna Möhrlein¹, Ricardo J. Bessa², Gregor Giebel², Nadine Fleischhut¹
¹VERROC, Denmark ²INSTITEC, Portugal ³DTU Wind, Denmark
⁴Max-Planck Institute for Human Development, Germany

Abstract

As penetration levels of renewable energy sources increase and climate changes produce more and more extreme weather conditions, the uncertainty of weather and power production forecasts can no longer be ignored for grid operation. However, large parts of the industry still have difficulties adopting probabilistic forecasts into their operation.

We work with decision experiments to empirically investigate the potential benefits of probabilistic forecasts for human decision making and to enable stakeholders to understand and explore their value and use, in the first experiment, 120 participants decided whether to trade 100% or 20% of the energy of an offshore wind park facing the possibility of a high-speed shutdown. Decisions were based on deterministic and probabilistic forecasts and scored based on a cost function reflecting the high risk of a missed event. Overall, the majority of the participants benefited from probabilistic forecasts, participants made more correct decisions and took less risk when this was appropriate. Almost all preferred a type of probabilistic forecast for their decisions.

The results encouraged us to develop the second experiment, as we could demonstrate that decision-making can benefit from probabilistic forecasts—and that probabilistic forecasts were also perceived as more useful.

Objectives

By developing a series of games and experiments, our aim is to also provide training tools that simulate decision scenarios with feedback and thus allowing people to learn from an own experience of using probabilistic forecasts.

The experiments are an initiative of IEA Wind Task 36 in collaboration with the Max-Planck Institute of Human Development and part of a larger research effort at the Hans-Ertel Center for Weather Research in order to understand and support human decision making under uncertainty.

Methods

Decision Tools for Experiments.

- 3 independent deterministic forecasts showing the wind power & wind speed
- probabilistic forecast showing wind power & wind speed (inclusive uncertainty bands from 75 Ensemble Member of a multi-scheme Ensemble (MSE-EP))

1. Experiment (2020)

GAME: Decisions were to be made in 12 cases

- participants made decisions based on deterministic and can correct their decision after being presented with probabilistic forecasts
- whether to trade a high-speed cost of 4000 € defines the forecast time
- whether to trade 50% or 100% generating power of an offshore wind park

2. Experiment (2021)

GAME: Decisions were to be made in 2 times 20 cases

- participants make decisions based on deterministic or probabilistic forecasts
- require 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-act

Cost function for the experiments:

Training	HSB	No HSB
100%	-5,000	5,000
50%	0	2,000

High-speed Shutdown (probability 50%)

Experiment Setup

1. Experiment with sequential Decision-Making

Participants made a decision on the basis of 3 deterministic forecasts and were able to correct for the decision after seeing the probabilistic ensemble forecasts with uncertainty bands.

2. Experiment with shared Decision-Making

Participants made 20 decisions first on the basis of 3 independent deterministic forecasts and thereafter 20 on the basis of probabilistic ensemble forecasts with uncertainty bands built from 75 ensemble members (MSE-EP).

Results & First Conclusions

Summary of the main results from 1. Experiment

- Participants higher decision rates with probabilistic forecasts
- Less risky decisions were taken when this was appropriate

Analysis of the results also showed that:

- participants changed their mind in 14% of the cases
- 91% of participants changed their mind at least once
- no one wanted to trade decisions with deterministic forecasts alone

Conclusions from the 1. experiment: ONE-SIZE DOES NOT FIT ALL

- Basic information: Probabilistic information can improve decisions, if the information that needs to be made are relevant/ necessary
- Decision support: Define decision strategies based on probabilistic information by
 - providing cases for interpretation (e.g. highlight critical thresholds)
 - adding information in perspective (e.g. comparison, typical distributions)
 - allowing users to develop decision strategies based on own experience
 - providing simple and robust heuristics/decision strategies for users

References

IEA Wind Task 36 homepage: <https://www.windenergy-iaea.org/en/activities/wind-task-36>

Journal of Physics: Conference Series, Volume 2151, WindEurope Electric City 2021 23/11/2021 – 25/11/2021 Copenhagen, Denmark

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PAPER • OPEN ACCESS

How do Humans decide under Wind Power Forecast Uncertainty — an IEA Wind Task 36 Probabilistic Forecast Games and Experiments initiative

Corinna Möhrlein¹, Gregor Giebel², Ricardo J. Bessa³ and Nadine Fleischhut⁴

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Journal of Physics: Conference Series, Volume 2151, WindEurope Electric City 2021 23/11/2021 – 25/11/2021 Copenhagen, Denmark

Citation Corinna Möhrlein et al 2022 J. Phys.: Conf. Ser. 2151 012014

Article PDF

References

Article information

Abstract

The need to take into account and explicitly model forecast uncertainty is today at the heart of many scientific and applied enterprises. For instance, the ever-increasing accuracy of weather forecasts has been driven by the development of ensemble forecasts, where a large number of forecasts are generated either by generating forecasts from different models or by repeatedly perturbing the initial conditions of a single forecast model. Importantly, this approach provides robust estimates of forecast uncertainty, which supports human judgement and decision-making. Although weather forecasts and their uncertainty are also crucial for the weather-to-power conversion for RES forecasting in system operation, power trading and balancing, the industry has been reluctant to adopt ensemble methods and other new technologies that can help manage highly variable and uncertain power feed-ins, especially under extreme weather conditions.

In order to support the energy industry in the adaptation of uncertainty forecasts into their business practices, the IEA Wind Task 36 has started an initiative in collaboration with the Max Planck Institute for Human Development and Hans-Ertel Center for Weather Research to investigate the existing barriers in the industry to the adoption of such forecasts into decision processes. In the first part of the initiative, a forecast game was designed as a demonstration of a typical decision-making task in the power industry. The game was introduced in an IEA Wind Task 36 workshop and thereafter released to the public. When closed, it had been played by 120 participants. We will discuss the results of our first experience with the experiment and introduce some new features of the second generation of experiments as a continuation of the initiative. We will also discuss specific questions that emerged when we started and after analysing the experiments. Lastly we will discuss the trends we found and how we will fit these into the overall objective of the initiative which is to provide training tools to demonstrate the use and benefit of uncertainty forecasts by simulating decision scenarios with feedback and allowing people to learn from experience, rather than reading articles, how to use such forecasts.

A Decision-making Experiment under Wind Power Forecast Uncertainty

- Paper by Corinna Möhrle et al
- “In the framework of an IEA Wind Task 36 workshop, the experiment aimed to investigate existing psychological barriers in the industry to adopt probabilistic forecasts and to better understand human decision processes”.
- “The focus was on a decision-making process dealing with extremes that can cause high cost...”
- Möhrle, C., Bessa, R. J., & Fleischhut, N.(2022). A decision-making experiment under wind power forecast uncertainty. *Meteorological Applications*, 29(3), e2077. <https://doi.org/10.1002/met.2077>

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RESEARCH ARTICLE

Meteorological Applications
Science and Technology for Weather and Climate

A decision-making experiment under wind power forecast uncertainty

Corinna Möhrle¹ | Ricardo J. Bessa² | Nadine Fleischhut³

¹Department of Research and Development, WEPROG ApS, Assens, Denmark

²INESC Technology and Science (INESC TEC), Porto, Portugal

³Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

Correspondence

Nadine Fleischhut, Center for Adaptive Rationality, Max Planck Institute for Human Development, 14195 Berlin, Germany.
Email: nfleischhut@gmail.com

Present address

Nadine Fleischhut, Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany

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Abstract

As the penetration levels of renewable energy sources increase and climatic changes produce more and more extreme weather conditions, the uncertainty of weather and power production forecasts can no longer be ignored for grid operation and electricity market bidding. In order to support the energy industry in the integration of uncertainty forecasts into their business practices, this work describes an experiment conducted with 105 participants from the energy industry. In the framework of an IEA Wind Task 36 workshop, the experiment aimed to investigate existing psychological barriers in the industry to adopt probabilistic forecasts and to better understand human decision processes. We designed and ran a ‘decision game’ to demonstrate the potential benefits of uncertainty forecasts in a realistic—although simplified—problem, where an energy trader had to decide whether to trade 100% or 50% of the energy of an offshore wind park on a given day based on deterministic and probabilistic uncertainty day-ahead forecasts. The focus thus was on a decision-making process dealing with extremes that can cause high costs in the form of security issues in the electric grid for system operators, or high monetary losses for traders, who have bid a power production into the market that failed to be produced due to high-speed shutdown of the wind turbines. This paper presents the obtained results, extracts behavioural conclusions and identifies how to overcome psychological barriers to the adoption of uncertainty forecasts in the energy industry.

KEYWORDS

ensemble forecasting, experiment, forecast value, *human decision-making*, uncertainty, wind power

Minute-scale Forecasting Workshop

- Workshop with Task 32 Lidars at Risø 12/13 June 2018.
- How to use Lidars, Radars or SCADA for very short-term forecasts
- Target: 30 sec – 15 min look-ahead.
- Slides available from workshop website.
- Complete workshop on YouTube.
- Summary paper in Energies journal.



Article

Minute-Scale Forecasting of Wind Power—Results from the Collaborative Workshop of IEA Wind Task 32 and 36

Ines Würth ^{1,†}, Laura Valdecabres ², Elliot Simon ^{3,†}, Corinna Möhrlen ^{4,†}, Bahri Uzunoglu ^{5,†}, Ciaran Gilbert ^{7,†}, Gregor Giebel ^{3,†}, David Schlipf ^{6,†} and Anton Kaifel ^{9,†}

- ¹ Stuttgart Wind Energy, University of Stuttgart, Allmandring 5b, 70569 Stuttgart, Germany
 - ² ForWind-University of Oldenburg, Institute of Physics, K pkerweg 70, 26129 Oldenburg, Germany; laura.valdecabres@forwind.de
 - ³ DTU Wind Energy (Risø Campus), Technical University of Denmark, Frederiksborgvej 399, 4000 Roskilde, Denmark; elsim@dtu.dk (E.S.); greg@dtu.dk (G.G.)
 - ⁴ WEPK&C, Willemoesgade 15B, 5610 Assens, Denmark; com@weprog.com
 - ⁵ Department of Engineering Sciences, Division of Electricity, Uppsala University, The  ngstr m Laboratory, Box 534, 751 21 Uppsala, Sweden; bahriuzunoglu@computationalrenewables.com
 - ⁶ Department of Mathematics, Florida State University, Tallahassee, FL 32310, USA
 - ⁷ Department of Electronic and Electrical Engineering, University of Strathclyde, 204 George St, Glasgow G11XW, UK; ciaran.gilbert@strath.ac.uk
 - ⁸ Wind Energy Technology Institute, Flensburg University of Applied Sciences, Karleistra e 91–93, 24943 Flensburg, Germany; david.schlipf@hs-flensburg.de
 - ⁹ Zentrum f r Sonnenenergie- und Wasserstoff-Forschung Baden-W rttemberg, Meitnerstra e 1, 70563 Stuttgart, Germany; anton.kaifel@zsw-bw.de
- * Correspondence: wuerth@ifb.uni-stuttgart.de; Tel: +49-711-685-68285

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Abstract: The demand for minute-scale forecasts of wind power is continuously increasing with the growing penetration of renewable energy into the power grid, as grid operators need to ensure grid stability in the presence of variable power generation. For this reason, IEA Wind Tasks 32 and 36 together organized a workshop on “Very Short-Term Forecasting of Wind Power” in 2018 to discuss different approaches for the implementation of minute-scale forecasts into the power industry. IEA Wind is an international platform for the research community and industry. Task 32 tries to identify and mitigate barriers to the use of lidars in wind energy applications, while IEA Wind Task 36 focuses on improving the value of wind energy forecasts to the wind energy industry. The workshop identified three applications that need minute-scale forecasts: (1) wind turbine and wind farm control, (2) power grid balancing, (3) energy trading and ancillary services. The forecasting horizons for these applications range from around 1 s for turbine control to 60 min for energy market and grid control applications. The methods that can be applied to generate minute-scale forecasts rely on upstream data from remote sensing devices such as scanning lidars or radars, or are based on point measurements from met masts, turbines or profiling remote sensing devices. Upstream data needs to be propagated with advection models and point measurements can either be used in statistical time series models or assimilated into physical models. All methods have advantages but also shortcomings. The workshop’s main conclusions were that there is a need for further investigations into the minute-scale forecasting methods for different use cases, and a cross-disciplinary exchange of different method experts should be established. Additionally, more efforts should be directed towards enhancing quality and reliability of the input measurement data.

Keywords: wind energy; minute-scale forecasting; forecasting horizon; Doppler lidar; Doppler radar; numerical weather prediction models



WP3 End-user Workshop in Glasgow

“Maximising Value from State-of-the-art Wind Power Forecasting Solutions”

hosted by Jethro Browell at Strathclyde University, Glasgow, 21 Jan 2020

- Talks by academia and industry (e.g. UK National Grid, WindPoint, UStrathclyde)
- Open Space discussion on RP, data and forecast value
- First Game introduced on value of probabilistic forecasts
(see <https://iea-wind.org/task51/task51-work-streams/ws-decision-making-under-uncertainty/>)
- Streamed on YouTube: <https://www.youtube.com/watch?v=1NOlr7jluXI>




Handouts

- 2-page handouts: quick overview of major results
- 3 currently available; can be obtained from:

<http://www.ieawindforecasting.dk/publications/posters-og-handouts>

IEA Wind Task 36
Forecasting for Wind Power



FORECASTING FOR YOU

Setup

Wind power forecasts have been used operationally for over 25 years. Despite this fact, there are still several possibilities to improve the forecasts, both from the vendor's position and from the usage of the forecasts.

The IEA Wind Task is divided in three work packages: Firstly, a collaboration on the improvement of the scientific basis for the wind predictions themselves. This includes numerical weather prediction model physics, but also widely distributed information on accessible datasets. Secondly, we deal with the conversion to power and losses affecting the forecast vendors. Thirdly, we will be engaging end users aiming at dissemination of the best practice in the usage of wind power predictions. The Task is currently in its second phase, 2019-2023.

Results of phase I (2016-2018)

We developed an **informative portal**, with links to data, projects and knowledge useful for wind power forecasting. This could be a list of full assets useful for online validation of NWP models, a list of field campaigns with open data for model verification, a selection of benchmarks for forecasts with established data sources and existing reference frameworks.

A major result was the IEA Wind Recommended Practice (RP) on **Forecast Solution Selection**, detailing on the necessary steps to get the best adapted forecasts for the individual use case. The RP starts with the initial deliberation which might or might not end up with the decision to do a forecast trial. The second document shows how to conduct such a trial in order to yield accurate and usable results for both the end user and the participating vendor. The last part shows how to evaluate the trial to get 1) representative and 2) reliable results.

For **probabilistic forecasts**, we published two papers with an overview (for a broader reader) and one with a long list of specific use cases from technically oriented. We also classified methods for uncertainty forecasting, and tried to establish a common vocabulary. We also mapped the current use of probabilistic forecasts through a questionnaire.

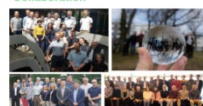


Impact

The Task sends out news a few times a year, is present on conferences and meetings, and has its own YouTube channel. There, alongside video transmissions of the public webinars, we also had 1 webinars of full on-hour talks plus audience questions on the major results of phase I. The fourth one was an additional one on forecast use in Denmark. The Task members also try to get an enhance collaboration between weather prediction providers and vendors, and between vendors and end users. One activity for the current phase of the Task (2019-2023) is a look into standardization of data, to make data exchange more fluid across the industry. Another activity is to estimate the value of better forecasting.

We also collaborate with other Wind Tasks, e.g. in the common workshop on minute scale forecasting we had together with Task 32 Usher. In the future, we will also collaborate with IEA PV Task 15 Solar resource, which also deals with forecasting and has some of the same issues.

Collaboration



Currently, some 250 people from 12 countries are collaborating on forecasts. There are meetings every half year, often in conjunction with relevant conferences. We also have special sessions at conferences for our members. The last one was in November 2019, where we had a number of speakers and presentations. We also had a number of workshops and webinars available through the task website.

The International Energy Agency is an international organization which works to improve the world's energy efficiency, promote sustainable development and reduce poverty. The IEA Wind Technology Collaboration Programme supports the work of 30 international organizations from 40 countries that study energy technologies and energy systems in order to improve the accuracy and value of international forecasts.

Task 36 Overview



IEA Wind Task 36 Forecasting for Wind Power

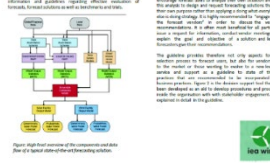
RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Challenge
The objective of this practice is to provide a methodology to help the end user and the forecast vendor to select the best forecast solution for their specific use case. The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs.

Solution
The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs.

Forecast Solution Selection
The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs.

Benefits
The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs. The methodology is based on a set of criteria that are relevant to the end user's specific needs.



Forecast Solution Selection


Figure 1 The process suggests how to use the best solution of the forecast solution selection process. The process is based on a set of criteria that are relevant to the end user's specific needs. The process is based on a set of criteria that are relevant to the end user's specific needs. The process is based on a set of criteria that are relevant to the end user's specific needs.

Benchmarks and Trials
The process is based on a set of criteria that are relevant to the end user's specific needs. The process is based on a set of criteria that are relevant to the end user's specific needs. The process is based on a set of criteria that are relevant to the end user's specific needs.

Figure 2 The results of the forecast solution selection process. The results are based on a set of criteria that are relevant to the end user's specific needs. The results are based on a set of criteria that are relevant to the end user's specific needs. The results are based on a set of criteria that are relevant to the end user's specific needs.

Figure 3 The results of the forecast solution selection process. The results are based on a set of criteria that are relevant to the end user's specific needs. The results are based on a set of criteria that are relevant to the end user's specific needs. The results are based on a set of criteria that are relevant to the end user's specific needs.

Where to get the guideline
The guideline is available on the IEA Wind Task 36 website. The guideline is available on the IEA Wind Task 36 website. The guideline is available on the IEA Wind Task 36 website.



IEA Wind Task 36 Forecasting for Wind Power

Understanding Uncertainty: from a deterministic to a probabilistic world

Challenge
The challenge is to understand the uncertainty in the forecast solution selection process. The challenge is to understand the uncertainty in the forecast solution selection process. The challenge is to understand the uncertainty in the forecast solution selection process.

Solution
The solution is to use a probabilistic approach to forecast solution selection. The solution is to use a probabilistic approach to forecast solution selection. The solution is to use a probabilistic approach to forecast solution selection.

Background
The background is the need for a probabilistic approach to forecast solution selection. The background is the need for a probabilistic approach to forecast solution selection. The background is the need for a probabilistic approach to forecast solution selection.



Uncertainty and Probabilistic Forecasting

Definition
The definition of uncertainty and probabilistic forecasting is based on a set of criteria that are relevant to the end user's specific needs. The definition of uncertainty and probabilistic forecasting is based on a set of criteria that are relevant to the end user's specific needs. The definition of uncertainty and probabilistic forecasting is based on a set of criteria that are relevant to the end user's specific needs.

Further reading
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References
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A photograph of an offshore wind farm in the ocean. The sun is shining brightly from the top center, creating a lens flare effect. Several white wind turbines are visible, with the largest one in the foreground on the right. The water is blue with whitecaps, and the sky is a clear, bright blue with some light clouds.

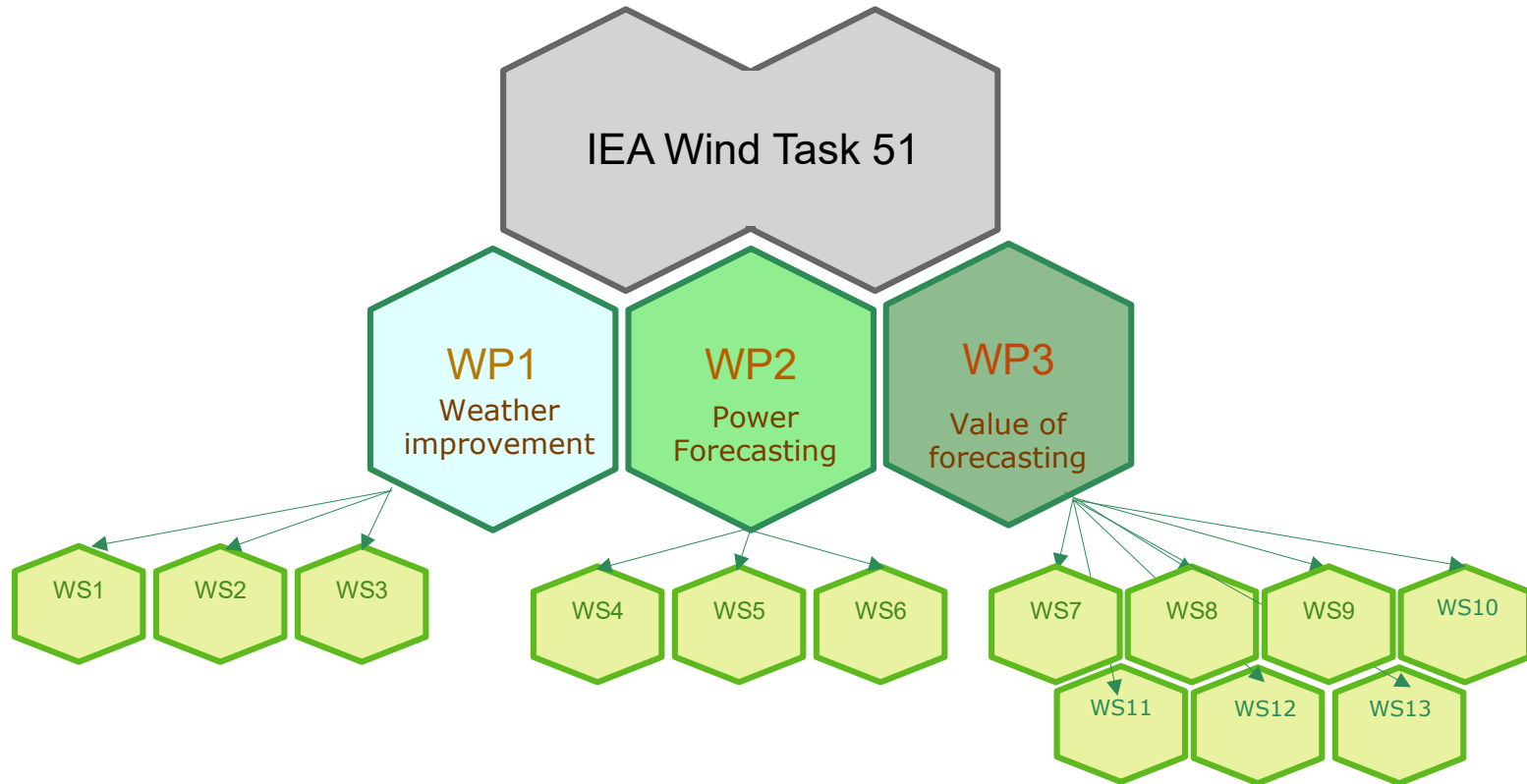
IEA Wind Task 51: Forecasting for the Weather Driven Energy System















Overview of Task 51:

Forecasting for the Weather Driven Energy System

- "Relaunch" of Task 36
- Framework conditions have changed since first phase of Task 36: RES is not small addition to system, but IS the system; sector coupling is critical
- New challenges for new forecast horizons (e.g. seasonal forecasting...)
- Needs strong **collaboration with related TCPs** (solar, hydro, hydrogen...) and related Tasks (Integration, Lidar, Farm Flow Control, Hybrids, ...)
- Data markets coming into focus
- 4 public workshops: State of the Art (2022), Seasonal Forecasting (2023), Minute-scale Forecasting (2024) and Extreme Power System Events (2025).

Overall Structure of Task 51



Work Streams:	WP1 Weather	WP2 Power	WP3 Applications	Deliverable	#, Due	Collaboration
Atmospheric physics and modelling (WP1)				List of experiments and data	D1.1, Ongoing	WMO, PVPS T16
Airborne Wind Energy Systems (WP1)				Presentations on workshops	Part of D2.1	Task 48 Airborne Wind Energy
Seasonal forecasting (WP1)				Workshop / Paper	D1.6 / M19	Hydro TCP, Hydrogen TCP, Biomass TCP
state of the Art for energy system forecasting (WP2)				Workshop / Paper	D2.1 / M7, M12	PVPS Task 16, Hydro TCP, Hydrogen TCP, ...
				RecPract on Forecast Solution Selection v3	M2.1 / M36	
Forecasting for underserved areas (WP2)				Public dataset	D2.4 / M24	WMO
Minute scale forecasting (WP2)				Workshop / Paper	D2.5 / M31, M36	Wind Tasks 32 Lidar, 44 Farm Flow Control and 50 Hybrids
Uncertainty / probabilistic forecasting (WP3)				Uncertainty propagation paper with data	D 2.6 / M42	PVPS T16
				RecPract v3	M48	
Decision making under uncertainty (WP3)				Training course Games	M12 M18	
Extreme power system events (WP3)				Workshop	D3.6 / M42	Task 25, ESIG, IEA ISGAN, PVPS T16, G-PST
Data science and artificial intelligence (WP3)				Report	D2.3 / M30	
						
Privacy, data markets and sharing (WP3)				Workshop / Paper Data format standard	D3.5 / M15	ESIG IEEE WG Energy Forecasting



Workshop

State of the Art and Research Gaps in
Forecasting for the Weather Driven Energy System

September 12/13 2022, University College Dublin

<http://www.iea-wind.org/task51/>



iea wind

State of the Art and Research Gaps Workshop, Dublin 2022

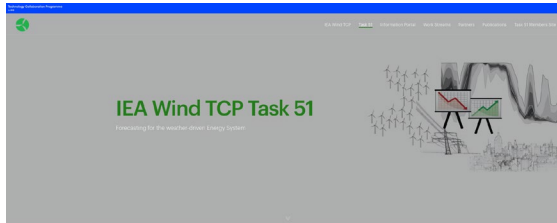
- Personal and online some 60 participants
- Slides and video on <https://iea-wind.org/task51/task51-work-streams/ws-state-of-the-art-for-energy-system-forecasting/>
- Journal paper being worked on



Task 51 Web Presence

Website

www.iaea-wind.org/task51



About Task 51

Forecasting for the Weather-Driven Energy System – Improving the value of renewable energy forecasts to the wind industry

The Task 51, under the IEA Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Energy (Wind) (RDWED), focuses on improving the value of renewable energy forecasts.

There are many existing users of wind power forecasting and power. The first area in the continuing effort to improve the representation of physical processes in weather forecast models through high-quality performance evaluations and tailored parameterizations. The second part is the harmonization of the meteorological and data for the understanding of the uncertainties throughout the modeling chain and the incorporation of model data into power forecasting algorithms. A third is representation, communication, and use of these power data by industry in forms that readily support decision-making in their operations and marketing markets.

The Task will focus on facilitating communication and collaborations among international research groups engaged in the improvement of the accuracy and availability of forecast models and their utility for the stakeholders in the wind industry in the power sector and in the energy system.

The Task has the following specific objectives:

- To establish an action plan for sharing knowledge among the participants, related IEA Wind Task and other related TCP through workshops, dissemination and communication measures;
- To establish and communicate standards and frameworks for the operation and evaluation of forecast model performance;
- To identify gaps to increased accuracy and ability of forecast information to the task stakeholders;
- To advance the knowledge in the underlying atmospheric physics in the operational models concerning the underlying atmospheric quantities to energy system operation variables, in the modeling of the uncertainty and in the operation and dissemination;
- To identify most promising areas for more research to improve the quality and utility of forecasts;
- To provide guidelines for the implementation of optimal forecasting solutions.

News



YouTube Channel

<https://www.youtube.com/c/IEAWindForecasting>



IEA Wind Forecasting
67 Abonnenten

ABONNIEREN

ÜBERSICHT

Uploads **ALLE WIEDERGEBEN**



IEAWindTask36 Webinar4
2018
75 Aufrufe · vor 11 Monaten

Probabilistic Forecasting in
Practice
229 Aufrufe · vor 11 Monaten

Webinar on Wind Power
Forecast Solution Selection
139 Aufrufe · vor 11 Monaten

IEA Wind Task 36 Forecasting
- The Overview
313 Aufrufe · vor 11 Monaten

Follow us at:

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www.IEAWindForecasting.dk



Get in touch with the operating agents of the task:

Gregor Giebel

grgi@dtu.dk

Caroline Draxl

caroline.draxl@nrel.gov

The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.