IEA Wind Task 51 Workshop: **Data and Forecasting Challenges for the Transition to an Increasingly Weather-driven Electric System**

All times are Eastern Time (ET)

Tuesday, October 29, 2024 | Zimmerli Art Museum, Rutgers University	
1:00 pm – 1:30 pm	Overview of IEA Wind Task 51 Structure and Activities John Zack, Meso Inc.
1:30 pm – 3:00 pm	Panel Discussion: Meteorological Datasets for Grid System Planning Facilitator: John Zack, Meso Inc. • **Julia Gottschall** (Fraunhofer IWES): Overview of IEA Wind TEM #111 meeting at DTU (Renalyses for wind energy) and follow-up activities • **Caroline Draxl** (EPRI): Overview of NREL workshop *Bridging the gap between atmospheric sciences and grid integration* and follow-up activities • **Justin Sharp** (EPRI): Overview of current datasets and challenges, future steps • **Victoria Rojo** (ISO-NE): User perspectives Short presentations will be followed by a guided discussion with all workshop participants.
3:00 pm – 3:30 pm	Networking Break
3:30 pm – 4:50 pm	Open Space Discussions Facilitator: John Zack, Meso Inc. • **Current and Future State-of-the-Art** • **Matching applications and evaluation** • **Standards for Energy Data Collection, Assessment, and Access** • **Topics for Extreme Power System Event workshop in spring 2025**
4:50 pm – 5:00 pm	Wrap up & Adjourn Ideas for the next phase of IEA Wind Task 51

IEA Wind Task 51 Workshop:
Data and Forecasting Challenges for the Transition to an Increasingly Weather-driven Electric System
Rutgers University
New Brunswick, NJ, USA
29th October 2024

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

John Zack
MESO, Inc.
Troy, NY

Task Leaders: C. Möhrlen, G. Giebel, H. Frank, C. Draxl,
J. Browell, G. Kariniotakis, R. Bessa, D. Lenaghan

What is the IEA (International Energy Agency)?

- International organization with 30 members countries and 8 associates within the Organization for Economic Cooperation and Development (OECD)
- Promotes global dialogue on energy, providing authoritative analysis through a wide range of publications
- For more information: www.iea.org
- **One activity: convenes panels of experts to address specific topics via its "Technology Collaboration Programmes (TCPs)"**

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.

Image source: dpa

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)**

iea Energy Technology Network

See iea.org!

IEA Wind TCP Research Tasks

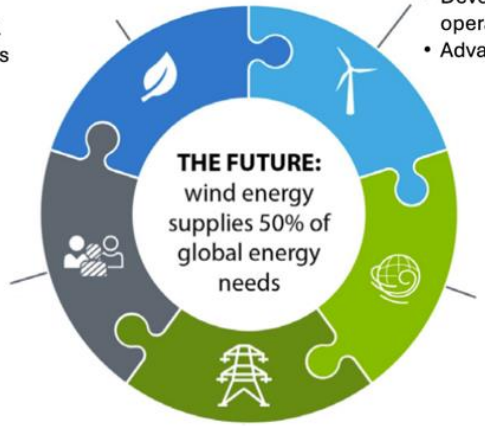
Technology Collaboration Programmes

Environmental Co-Design
- Avoiding, minimising, compensating for environmental impacts
- Incorporating environmental costs, benefits into decisions
- Addressing both immediate concerns, future impacts

Tasks 42, 45, 59 & 60

Social Science
- Acknowledging the transformational nature of development
- Creating just processes
- Valuating benefits, effects, burdens

Tasks 39, 53 & 62



The Turbine
- Incorporating holistic design
- Developing intelligent controls, operation, maintenance
- Advancing industrialisation

Tasks 44, 49, 52, 54 & 57

The Atmosphere
- Increasing atmospheric observations
- Expanding, validating universal predictive capability
- Integration, adopting improved models

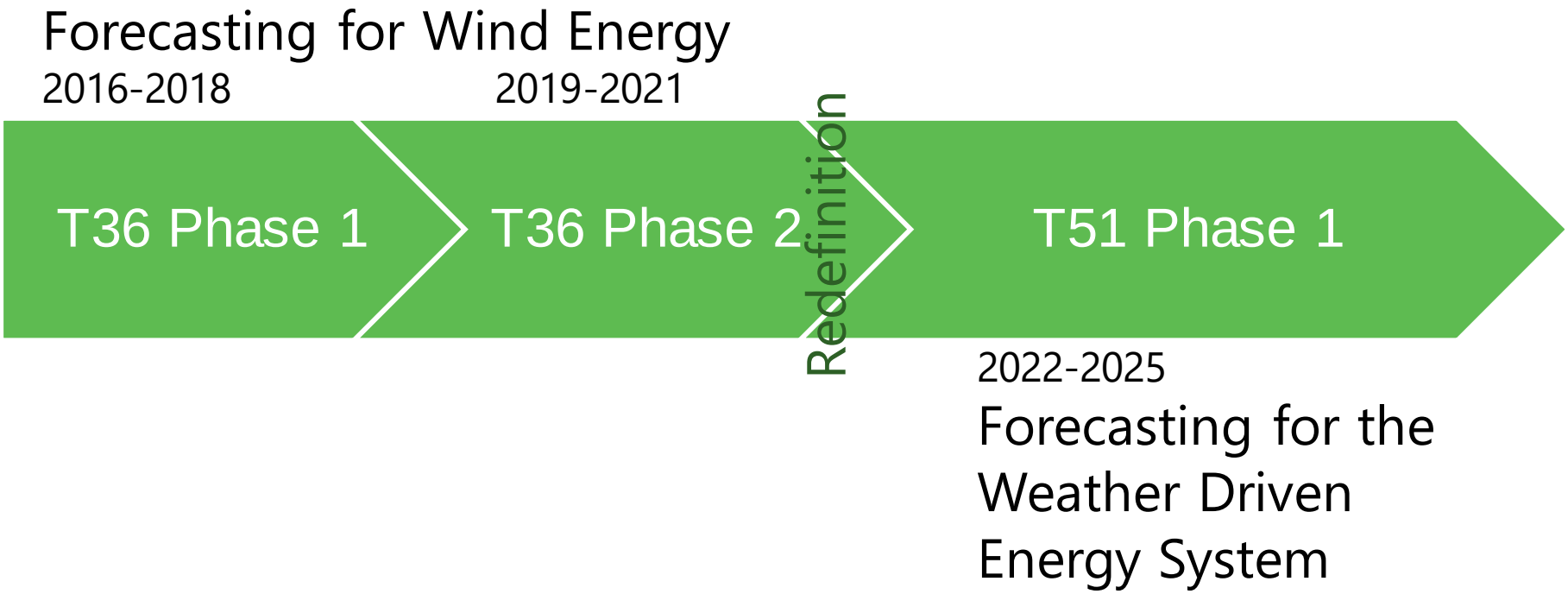
Tasks 43, 46, 47, 48, 49, 51, 56

The Plant and Grid
- Improving modelling
- Optimising plant design for multiple objectives
- Readying wind plants for grid support

Tasks 25, 41, 50, 55, 58 & 61

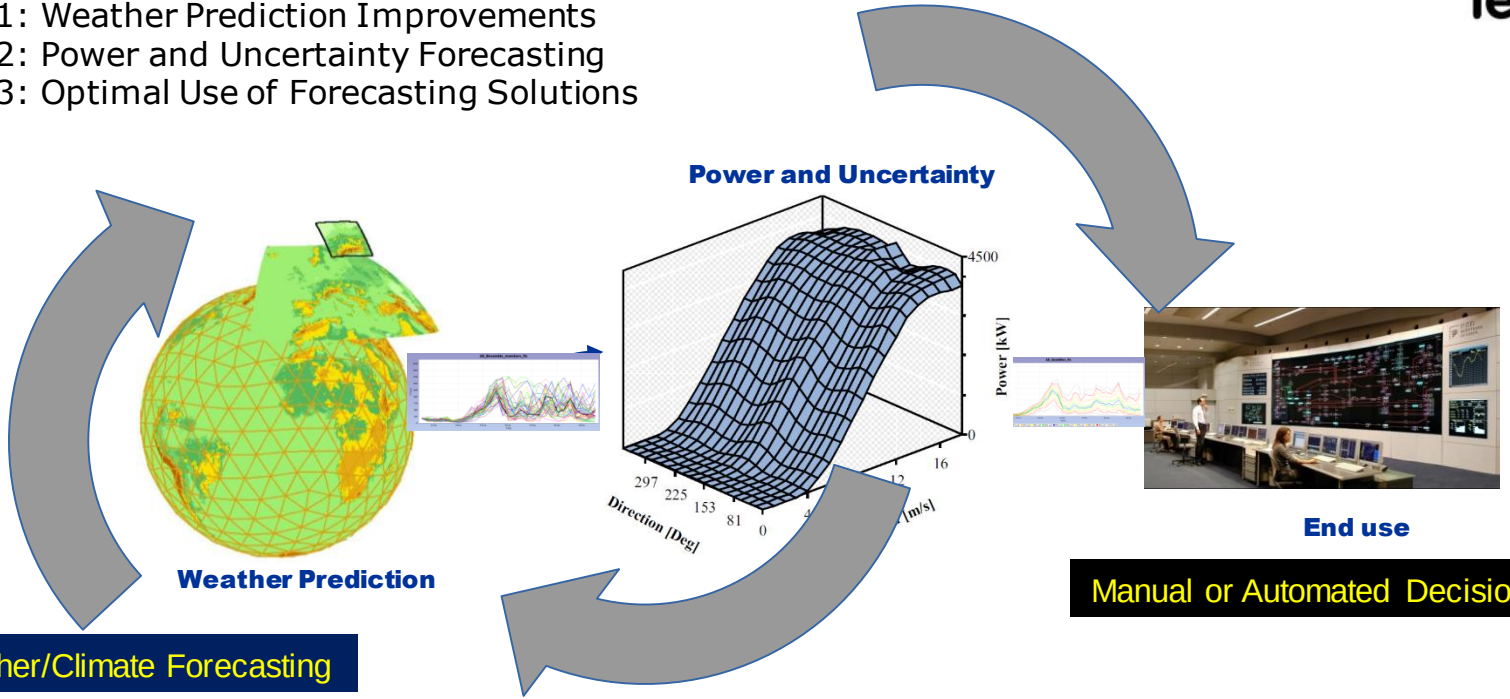
Evolution of Task 51

Task website: https://iea-wind.org/task51



IEA Wind Task 51 Work Distribution

Task Work is divided into 3 work packages:
WP1: Weather Prediction Improvements
WP2: Power and Uncertainty Forecasting
WP3: Optimal Use of Forecasting Solutions



Australian Government
Bureau of Meteorology

IEA Wind Task 51 Work Distribution: 11 Work Streams (WS)

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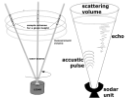
	Work Streams:	WP1 Weather	WP2 Power	WP3 Applications
1	Atmospheric physics and modelling (WP1)	★		
2	Airborne Wind Energy Systems (WP1)	★		
3	Seasonal forecasting (WP1)	★		
4	State of the Art for energy system forecasting (WP2)		★	
5	Minute scale forecasting (WP2)		★	
6	Data science and artificial intelligence (WP3)			★
7	Extreme power system events (WP3)			★
8	Uncertainty / probabilistic forecasting (WP3) & for underserved areas			★
9	Decision making under uncertainty (WP3)			★
10	Privacy, data markets and sharing (WP3)			★
11	Value of forecasting (WP3)			★



Modelling & data assimilation

Workshops

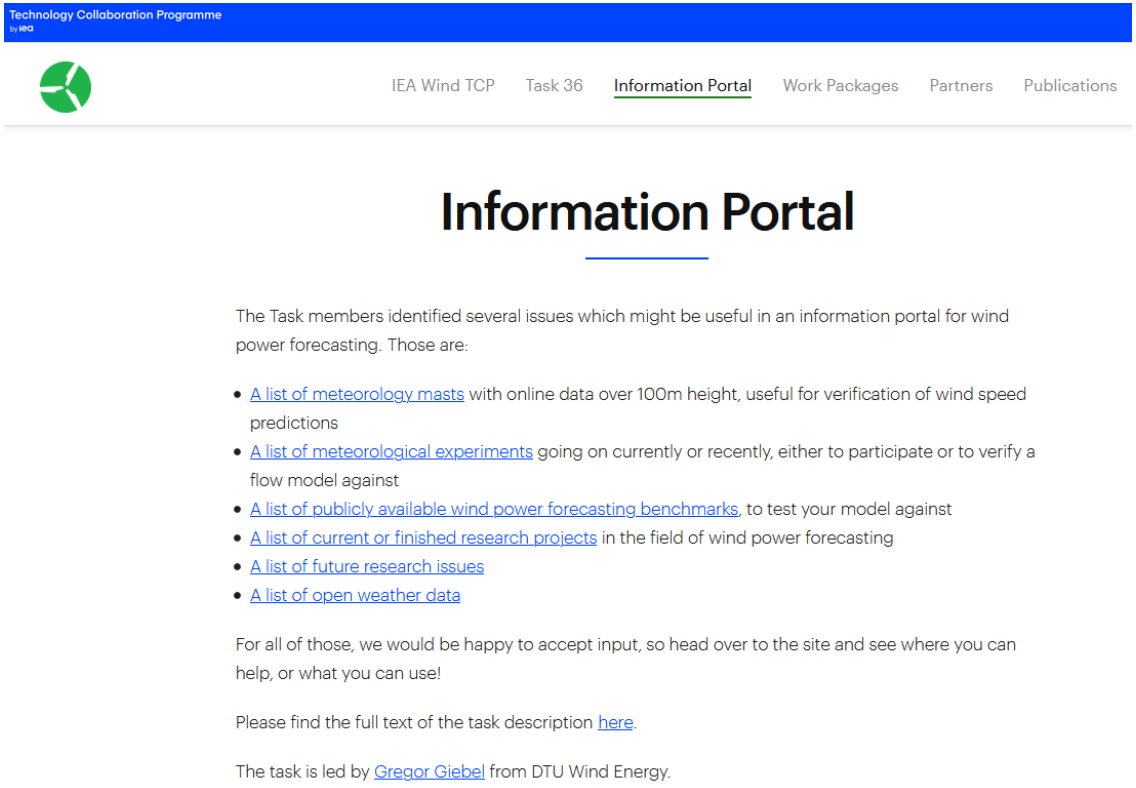
Verification Platform

Publications

WS1: Atmospheric Physics and Modeling: Information Portal

- Designed to be a useful resource for people in forecasting, especially providing links to publically available data for model development.

- Can be accessed at: https://iea-wind.org/task-51/t51-information-portal/



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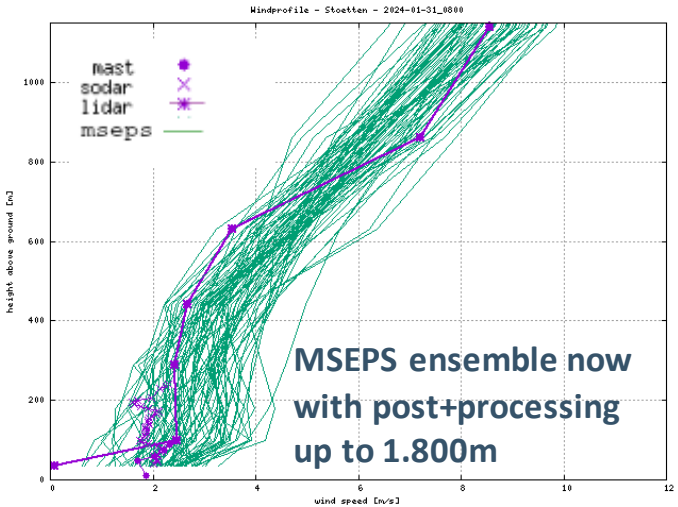
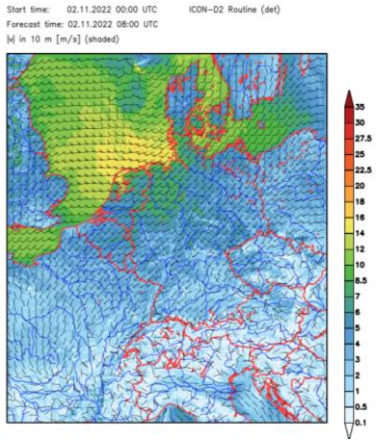
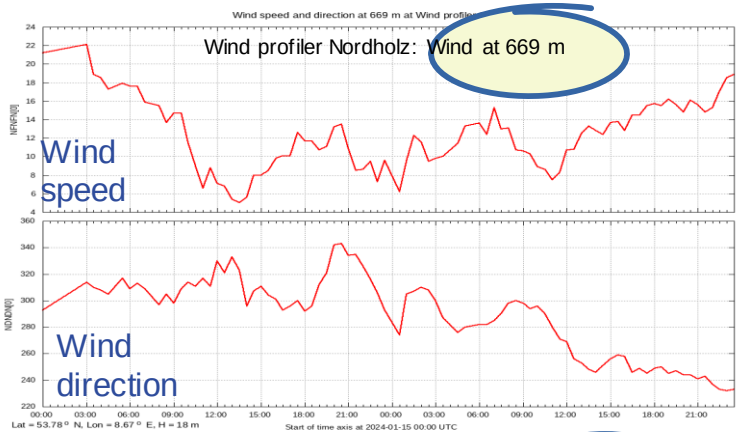
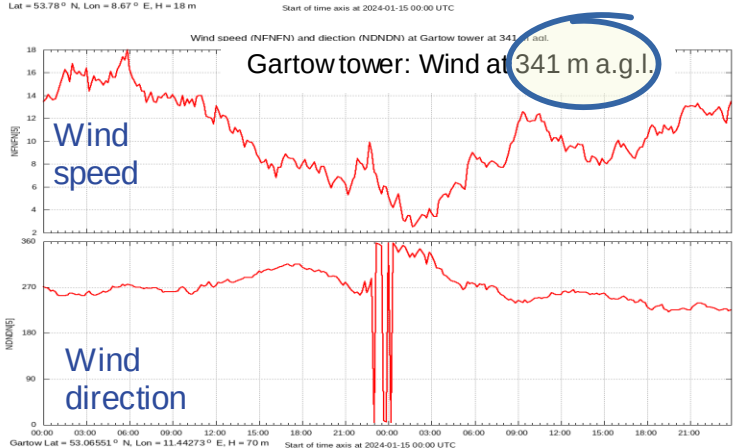
WS 1&2: Development of Forecasts for Airborne Wind Power





ICON-DE model now in 15min resolution every hour





WS3: S2S Forecasting for Energy Systems

- Held S2S Workshop at University Reading in May 2023

- Preparing review paper for submission in 2025

Workshop Agenda

Session	Title
Keynote	History, Current Status and Challenges of S2S Forecasting
1	Forecasting Techniques
2	Forecast Evaluation
3	Public Forecast Providers and Products
4	Commercial Forecast Providers and Products
5	Forecast User Experiences
6	Open-space Discussion
7	Research Issues and Projects: Current and Envisioned

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S2S Forecasting Workshop: Key Points

- **Objectives/Focus**
  - Predictions typically focus on anomalies vs “climatology”
  - Usually expressed as a probability of an anomaly
- **Current Techniques**
  - Ensemble of long-term (weeks to months ahead) NWP runs with postprocessing statistics
  - Statistical teleconnections to atmospheric circulation indices (e.g. ENSO) and “slow-changing” ocean (e.g. SST anomalies)/earth’s surface (e.g. snow cover) variables
- **Evaluation**
  - Anomaly prediction has considerable skill vs climatology from 3 weeks to multi-seasons ahead
  - **Skill is strongly episodic** – i.e. when strong signals are detected (e.g. ENSO)
- **Products**
  - Forecasts of temperature and precipitation are most widely available – especially from public sources
  - **Wind & solar forecasts have much more limited availability** – mostly private sources

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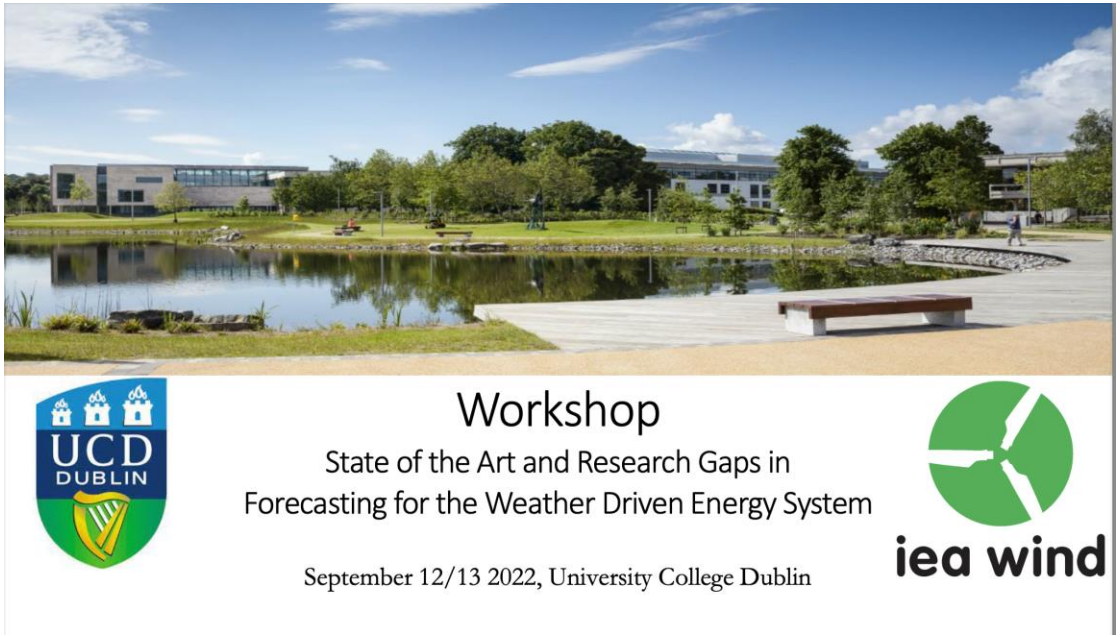
WS 4: State-of-the-Art for Energy System Forecasting

- Held Workshop in Dublin, Ireland in September 2022
- Refinement of the **Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions**



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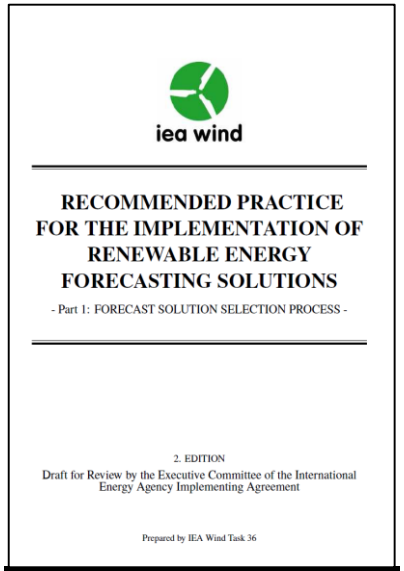
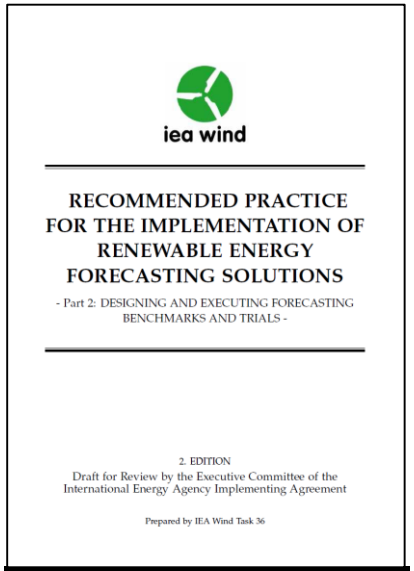
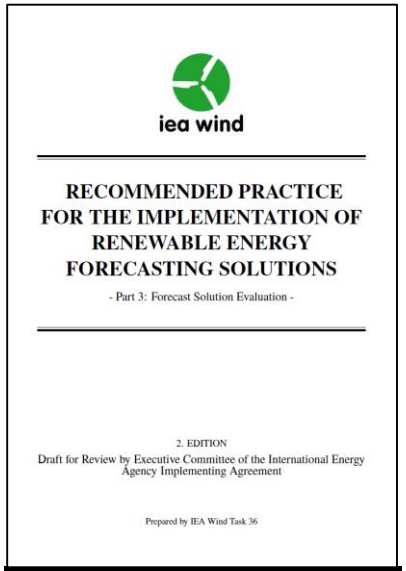
Version 2 of the Recommended Practice for the Implementation of Renewable Energy Forecasting Solution



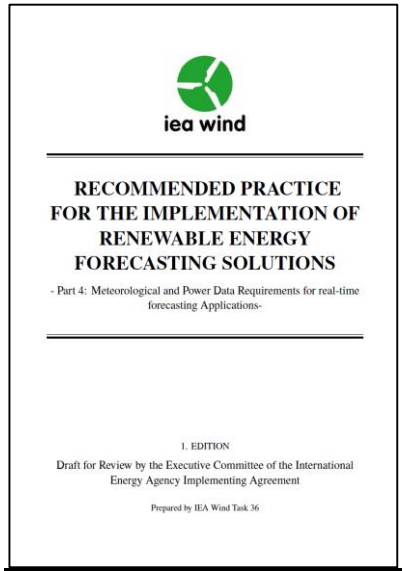
Part 1: Selection of an Optimal Forecast Solution



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

Now as OpenAccess book!

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

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Elsevier OpenAccess Book

ORDER or DOWNLOAD NOW!

ISBN: 978-0-443-18681-3
PUB DATE: November 2022
DISCOUNT: Non-serials
FORMAT: Paperback

Editors: Corinna Möhrlen, John W. Zack, and Gregor Giebel

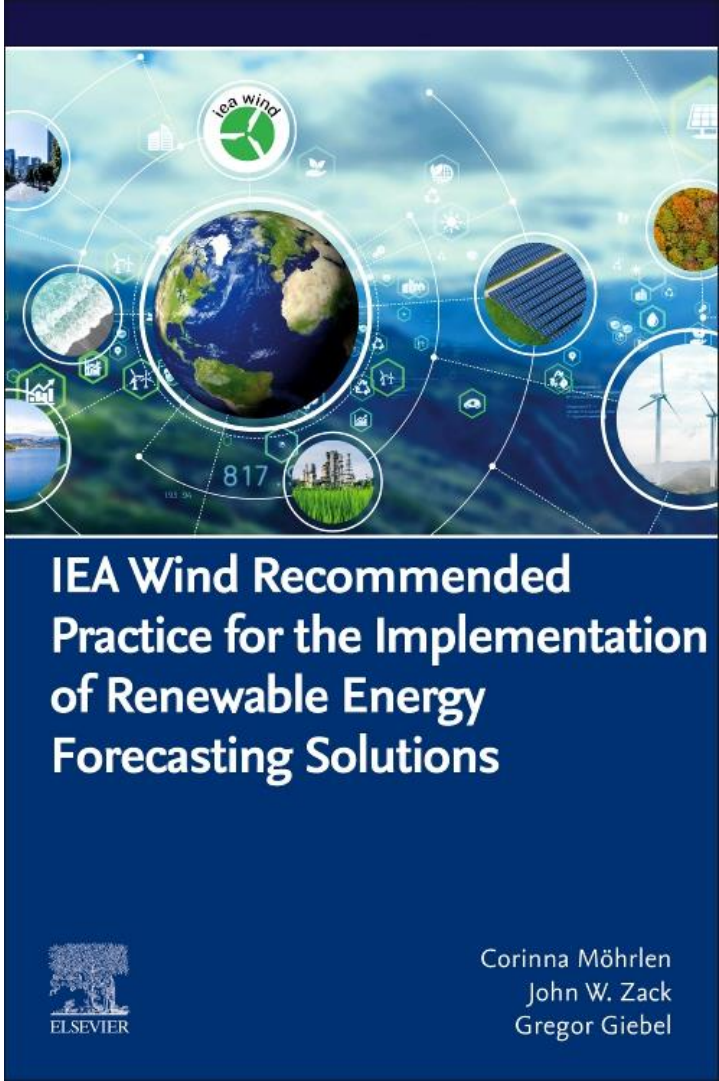
https://www.elsevier.com/books/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions/mohrlen/978-0-443-18681-3

Online OpenAccess:

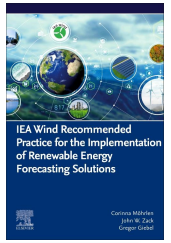
https://www.sciencedirect.com/book/9780443186813/iea-wind-recommended-practice-for-the-implementation-of-renewable-energy-forecasting-solutions

IEA Wind Task 51 Information

iea-wind.org → Task 51 → Publications → Recommended Practice



Validation & Verification



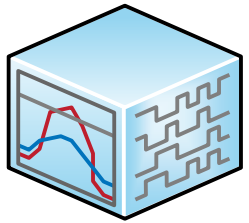
Examples developed within the IEA Wind Task 36 and Task 51:

WE-validate

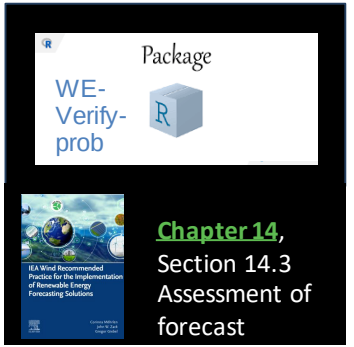
Available on GitHub: https://github.com/joejoeyjoseph/i-validate/

Use Case: Demo Jupyter Notebook (U.S. Mountain Wave case):
https://nbviewer.jupyter.org/github/joejoeyjoseph/i-validate/blob/main/notebooks/demo_notebook.ipynb

Existing metrics: RMSE, cRMSE, mean bias, mean absolute error
Existing plots: time series, histogram, scatter plot



WE-validate-prob – R-package for probabilistic verification
Existing metrics: CRPS, Brier Score, ROC curve, Histograms, Reliability Diagram, Contingency table
Existing plots: time series, histograms, ROC curve, CRPS



See also our workshops & conference page:
https://iea-wind.org/task51/task51-publications/task51-workshops-and-special-sessions/

WS5: Minute-scale Forecasting: April 2024 Workshop

Forecasts of wind and clouds are important inputs for the control and value of renewable power plants. The forecasts on a time resolution of minutes or seconds are typically data driven, looking at upstream plants, all-sky images of clouds or direct measurements of wind by lidars. Therefore, to facilitate the dissemination of information about minute scale forecasting products, skill, applications, issues, and best practices to members of the electric energy community, we invite you to a Minute Scale Forecasting workshop with the goal of gathering information about methods used to produce the forecasts, the current state-of-the-art skill and uncertainty in forecasting for variables on high temporal resolution, current and planned research activities intended to improve the current level of skill, types of public and private sector operational forecasting products, the range of minute scale applications in the energy community and the quantified or perceived value obtained from those applications, the sensitivity of user's application performance to variations in forecast skill, and the unmet minute-scale forecasting-related needs or desires of the energy user community.

The workshop takes place as the collaboration of the International Energy Agency's (IEA) Wind Task 51, entitled "Forecasting for the Weather Driven Energy System", IEA Wind Task 52 Lidars, IEA Wind Task 50 Hybrid Power Plants, IEA Wind Task 44 Wind Farm Flow Control and IEA Photovoltaic Power Systems Programme (PVPS) Task 16 Solar Resource.

The venue is Risø, Denmark, on the campus of the Technical University of Denmark (https://www.dtu.dk/om-dtu/kontakt-og-besoeg/find-vej/dtu_risoe_campus).

- Venue: Risø, Denmark.
- Attendance: 70+ in-person, 20 online.
- Collaboration of multiple IEA tasks:
  - IEA Wind Task 51 "Forecasting for the Weather-driven Energy System"
  - IEA Wind Task 52 Lidars
  - IEA Wind Task 50 Hybrid Power Plants
  - IEA Wind Task 44 Wind Farm Flow Control
  - IEA PVPS Task 16 Solar Resource.

See talks at iea-wind.org/task51 →Workstreams → Minute Scale Forecasting
& videos at our YouTube Chanel "IEAWind Forecasting"

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Task 51 Minute-Scale Forecasting Workshop

Two aspects of Minute-scale

1) **Forecasts for the minutes-ahead (i.e. 0-1 hour look-ahead time)**

Applications use data-driven or hybrid algorithms such as:

Data-driven algorithms: Machine Learning, dynamic graph ML, neural networks (e.g. GNN), feature engineering, generator models, graph convolutional long-short-term memory models etc.

Hybrid algorithms: can include heterogenous data sources from satellite or NWP images improve predictions, use cloud-scale dependent auto-regressive advection or deep learning radiative transfer emulators, Kalman filters

2) Longer term (hours or longer) forecasting in **time-scales of minutes**

e.g. high-time resolution NWP, Interpolation algorithms using AI methods

Observational Data Sources:

- WIND: scanning LIDARs, sonic anemometers, sodars
- SOLAR: ASI (all sky imaging, fish-eye cameras pointed at the sky) and satellite observations

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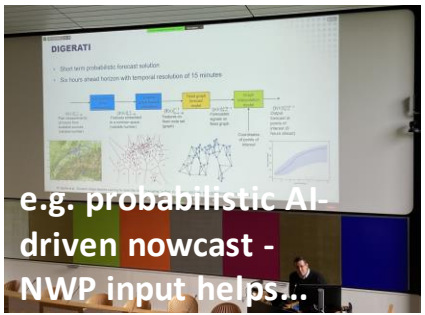
IEA Minute-Scale Forecasting Workshop

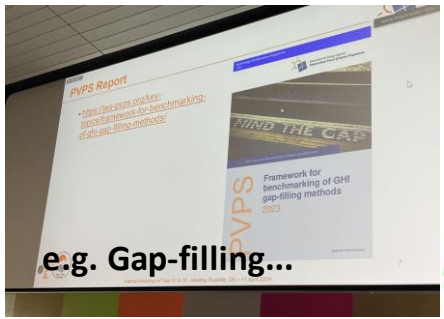
- ***Key points from Research & Development presentations:***
  - Feature engineering methods need "engineering" in the sense of knowing the atmosphere and its development to be useful
  - High-resolution NWP with high-time resolution of the order 5-10 min are enabling NWP models to be used for minute-scale forecasting
  - AI weather forecasting system 3D-CNN is mapping relationship between global analysis and local measurements and aims to replace the modelling process of NWP with local measurements
  - The need for remote sensing is driving the development of instruments to solve current short-comings

e.g. improved scanning heads



e.g. probabilistic AI-driven nowcast - NWP input helps...

e.g. AI-driven data assimilation in power space



e.g. Gap-filling...

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WS 6 (Data Science and AI): January 2024 Webinar

Webinar now available in our YouTube channel IEAWindForecasting
https://youtu.be/t6H7diavQdg

- Webinar in **Deep Learning for Weather-Based Power Prediction** was held in January 2024 to help address stakeholders' concerns about the impacts of incorporating AI and Machine Learning into weather and power prediction models,
- Webinar brought together the **Energy Meteorology and Machine Learning/ Deep Learning (ML/DL) communities** to showcase the latest advancements in ML/DL for weather prediction.

Some Lessons Learned from the webinar:

Positive developments:

⇧ The models show considerable skill
⇧ The models suggest a new approach to meteorological questions
⇧ Fast hypothesis testing and scope narrowing for simulations with physics models
⇧ The models develop fast due to large resources put into new features
⇧ Huge ensembles (>1000 members) are on the horizon
⇧ There is work underway to start the AI models from measurements alone

Challenges to be solved:

⇩ Quality control of input data is not yet handled - outliers, missing or corrupt data
⇩ High complexity and variety of data to train models is a challenge
⇩ Feature engineering needs features – without physics this will be difficult
⇩ Data-driven models require new look at data sharing, which has been an ongoing challenge

WS 7 (Extreme Power System Events): Workshops & Collaboration

IEA Wind Task 51 Workshop on
Extreme Power System Events
Boulder CO , April 2025

- What should be addressed in this workshop?
  - Topic in the OpenSpace Discussion in the 2nd half of today's workshop

IEA Wind Task 51 Austria Workshop at the NH Danube City Hotel in Vienna on November 6, 2024

GeoSphere Austria, Austro Control Digital Services GmbH and WEB Windenergie AG are organizing the IEA Task 51 Austria Workshop on...

https://iea-wind.org/2024/07/31/iea-wind-task-51-austria-workshop-in-vienna-on-6th-nov-2024/

Collaboration

<u>Collaboration with Subtask</u>: *On-demand digital twin extremes forecasting system for renewables - The Destination Earth Extremes digital twin*

https://destine.ecmwf.int/news/meteo-france-led-international-partnership-wins-bid-to-develop-destination-earths-on-demand-extremes-digital-twin/

WS 8 & 9: Uncertainty Propagation through the Modeling Chain with Real Data

PHASE I
2022-2023

tool 1

tool 2

WE-prob tool

tool 3

Uncertainty Quantification with test data sets according to 2022 UQ publication*

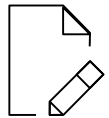
PHASE II
2024

Online Verification Platform

Discussion & testing of verification platform

PHASE III
2025

Publication



Discussion & writing of publication with most suitable test cases

* Uncovering wind power forecasting uncertainty sources and their propagation through the whole modelling chain
https://www.sciencedirect.com/science/article/pii/S1364032122004221

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WS 8 & 9: Review of Uncertainty Propagation

Work Program Part I

- **Qualitative description** of the origins and propagation of uncertainty through the forecasting chain

→ **Published in *Renewable and Sustainable Energy Reviews* in 2022**

Work Program Part II (2023-2025)

- **Quantification** of the origins and propagation of uncertainty through the forecasting chain

Uncovering wind power forecasting uncertainty origins and development through the whole modelling chain★,★★

Jie Yan[a], Corinna Möhrlen[b], Tuhfe Göçmen[c], Mark Kelly[c], Arne Wessel[d] and Gregor Giebel[c,*]

[a]North China Electric Power University, State Key Lab of Alternate Electrical Power System with Renewable Energy Sources, Beijing, P.R. China
[b]WEPROG, Dreijervaenget 8, 5610 Assens, Denmark
[c]Technical University of Denmark, Department of Wind Energy, Frederiksborgvej 399, 4000 Roskilde, Denmark
[d]Fraunhofer Institute for Energy Economics and Energy System Technology IEE, Kassel, Germany

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Keywords:
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forecast uncertainty
modelling chain

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, endogenetic 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 standardise 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 forecasters 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.

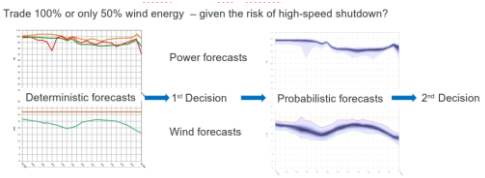
It is impossible to achieve perfect predictions of wind power at any given time or location, due to chaotic atmospheric motions having temporal and spatial scales that typically span more than six orders of magnitude [17, 18, 19]. Along with the complex wind field, wind turbine performance creates nonlinear 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 Mörlen, Tuhfe Göçmen, Mark Kelly and Gregor Giebel were funded by the Danish EUDP project "IEA Wind Task 36 Phase II Danish Consortium", Grant Number 64018-0515.
*Corresponding Author: Gregor Giebel
grgi@dtu.dk (G. Giebel)
www.dtu.dk (G. Giebel)
ORCID(s): 0000-0002-9412-0999{0000-0002-9412-0999} (J. Yan); 0000-0002-8842-1533{0000-0002-8842-1533} (C. Möhrlen); 0000-0002-4453-8756{0000-0002-4453-8756} (G. Giebel)

WS9: Decision-making under Uncertainty

"Probabilistic Forecasting Games & Experiments" initiative

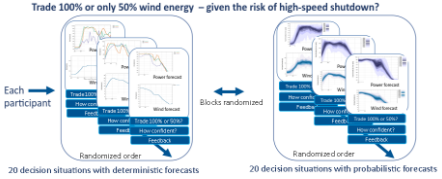
1. Experiment (2020)



Game: 12 cases
Decision structure: 12 deterministic forecasts followed by a probabilistic forecast
After each decision, possible change of decision based on new information

2. Experiment (2021-2024*)

Game: 40 cases



Decision structure: 20 deterministic cases + decision confidence request
20 probabilistic cases + decision confidence request

Table and Collection of Forecasting Games:
https://iea-wind.org/task51/task51-work-streams/ws-decision-making-under-uncertainty/

* still open...: https://meteorology.mpib.dev/wind-power-decisions/about.html

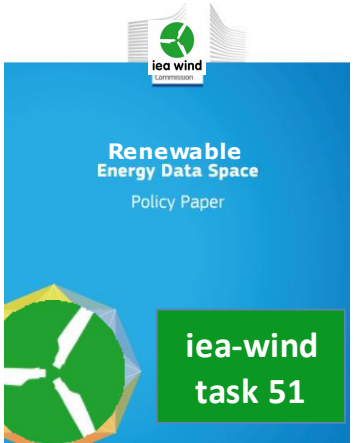
WS 10: Data Sharing

Workplan

A recently policy paper for the European Commission about the transformation of the energy system covering digitilisation and data sharing addressed general energy sector issues – but only superficially addressed RES topics.

Status: Development of a position paper about data sharing for the renewable energy sector has been started

A group of contributors are covering different aspects of RES: resource assessment/site location, forecasting, trading, O&M, etc.



* https://op.europa.eu/en/publication-detail/-/publication/21b0260e-a2d5-11ee-b164-01aa75ed71a1/language-en/format-PDF/source-300344208

WS11: Value of Forecasting

Status is monitored by looking and discussing the use of wind power forecasts

+++ now in collaboration with Task 50 Hybrid Power Plants +++

User Cases presented at Meetings + Reports

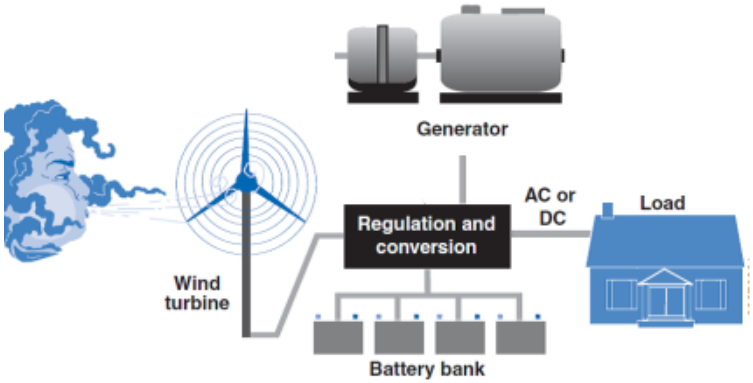
See iea-wind.org/task51 → Publications → Workshops & Special Sessions

Dimitrios Eleftheriou, Ea Energianalyse: *use of wind power forecasts in scheduling a hybrid energy asset consisting of wind turbines, electrolyser and hydrogen storage*

Honglin Wen, Shanghai Jiao Tong University: *Value-oriented Renewable Energy Forecasting for Coordinated Energy Dispatch Problems at Two Stages*

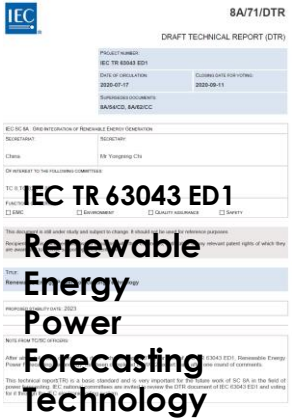
Antonio Couto, LNEG, Portugal: *Addressing the challenges of wind power plants hybridised with solar power: A generation forecast perspective. (see also publication)*

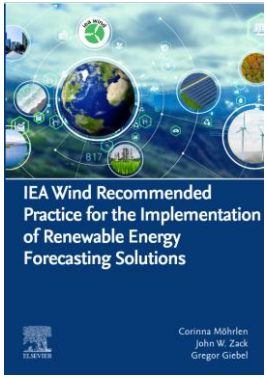
Rujie Zhu, Technical University of Denmark: *Value of forecasting for hybrid Energy Management*



Developing Project: Collaboration and Liaison with IEC Scientific Committee 8A on *Grid Integration of Renewable Energy Generation*

Common work: IEC Technical Report TR63043 - Renewable Energy Power Forecasting Technology





- Technical Report was released in 2020 by IEC Sub-Committee 8A Grid Integration of Renewable Energy Generation, Working Group 2 Renewable Energy Power Prediction
  https://webstore.iec.ch/publication/26529 - Link to IEC SC8A_WG2

- New Work Item for the development of a **IEC Standard for Renewable Energy Forecasting** in Oct. 2023

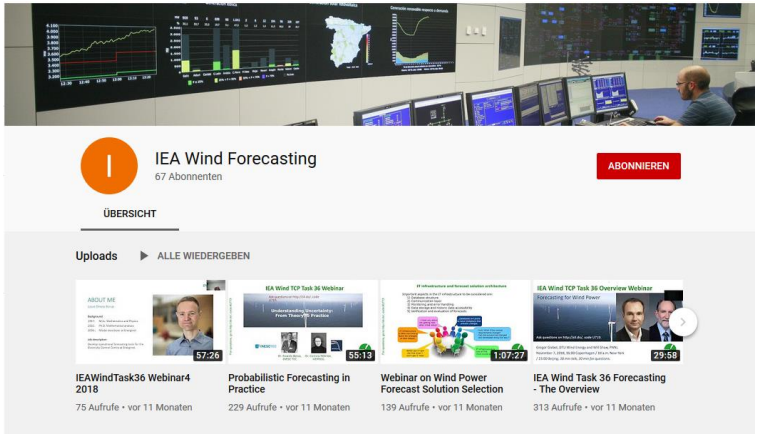
Task 51 Web Presence

Website

https://iea-wind.org/task51

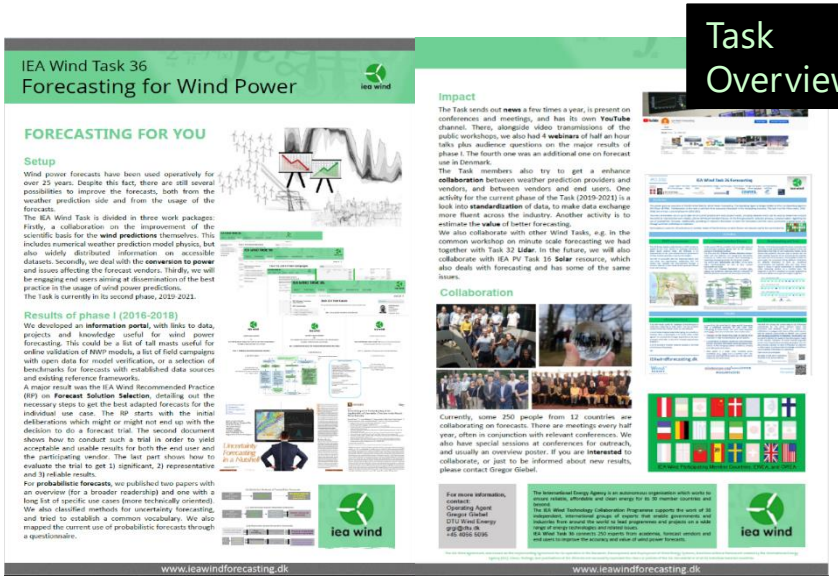
YouTube Channel

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

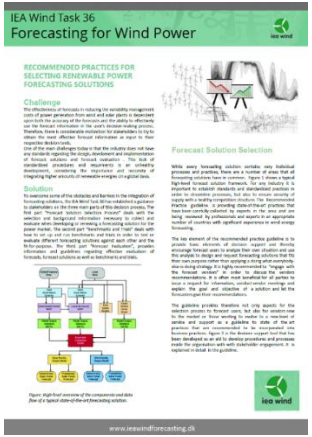


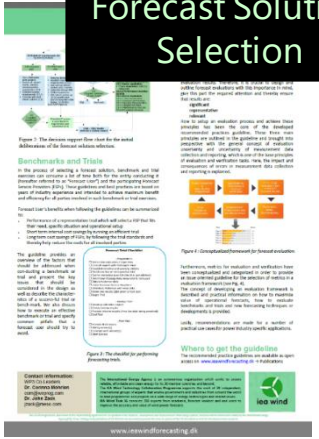
Handouts

- 2-page handouts: quick overview of major results
- 3 currently available; can be obtained from: https://iea-wind.org/task51/task51-publications/task51-posters-and-handouts/

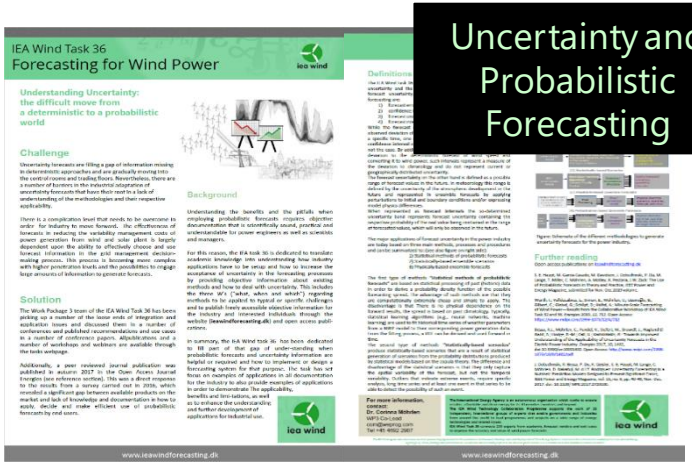


Task Overview





Forecast Solution Selection



Uncertainty and Probabilistic Forecasting

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Task 51 - "Forecasting for the weather-driven Energy System"

Summary

- Framework conditions changed since first phase of Task 36: **RES is no longer addition to system, but IS the system**; sector coupling to transport, heat, X…
- Has new challenges for **new forecast horizons** (seasonal forecasting…)
- Needs strong **collaboration with related TCPs** (**solar**, hydro, hydrogen, …) and related Tasks (Integration, Lidar, Farm Flow Control, Hybrids, …), standardisation (IEC), data markets, data control & quality assessment (WMO)
- **Uncertainty**, probabilistic Forecasting & data-driven **AI** modelling is in focus
- **Workshops & Webinars** State of the art, Seasonal Forecasting (2023), Minute Scale Forecasting (2024) and Extreme Power System Events (2025) Webinar on AI in meteorology & energy

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Task 51 – *"Forecasting for the weather-driven Energy System"*

iea-wind.org/task51

Get in touch with us…

Task Managers and Workpackage Leads :

Gregor Giebel	Caroline Draxl	Corinna Möhrlen	John Zack
Roskilde, Denmark	Golden (CO), USA	Böblingen, Germany	Troy(NY), USA
grgi@dtu.dk	caroline.draxl@epri.com	com@weprog.com	john@meso.com