A short introduction to IEA Wind Task 36

Forecasting for Wind Power

Gregor Giebel, DTU Wind Energy

ESIG Forecasting Workshop, St. Paul, US

June 21, 2018

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Short-Term Prediction Overview

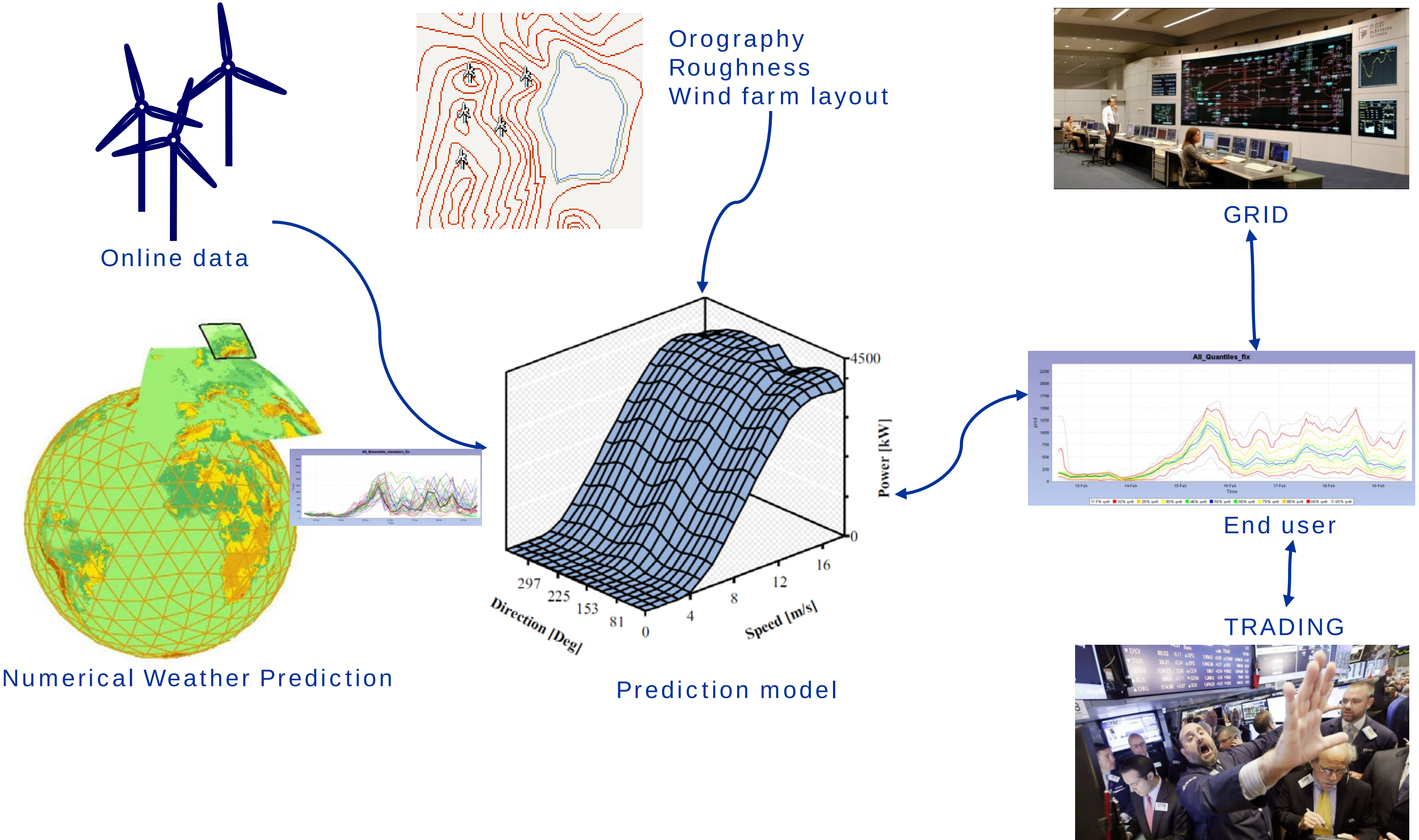
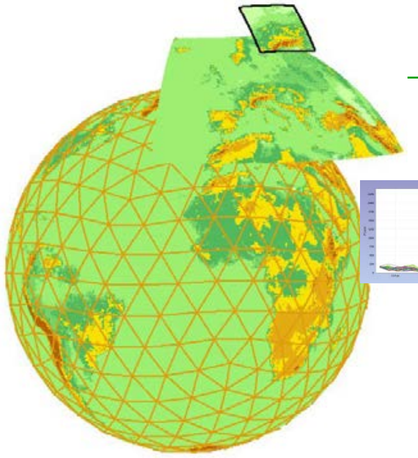
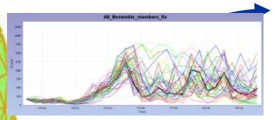
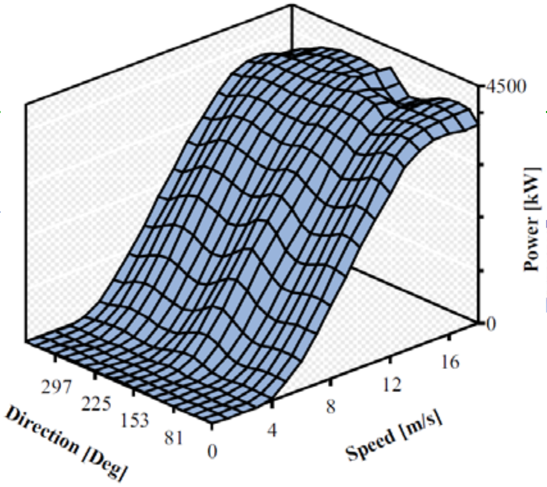


Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC’97, Pittsburgh Post-Gazette, Red Electrica de España.





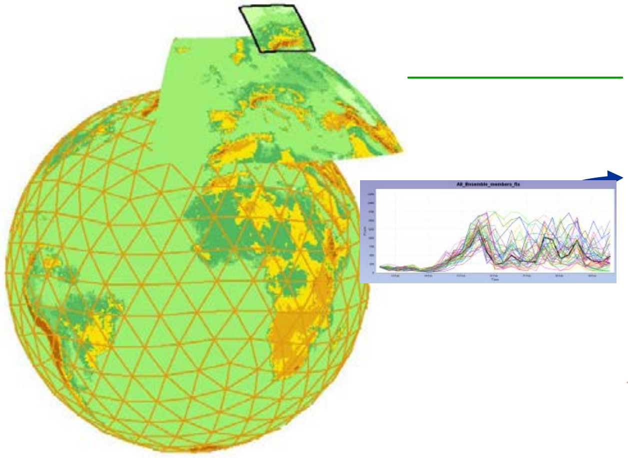
Numerical Weather Prediction



Prediction model

End user

Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC'97, Red Electrica de España.



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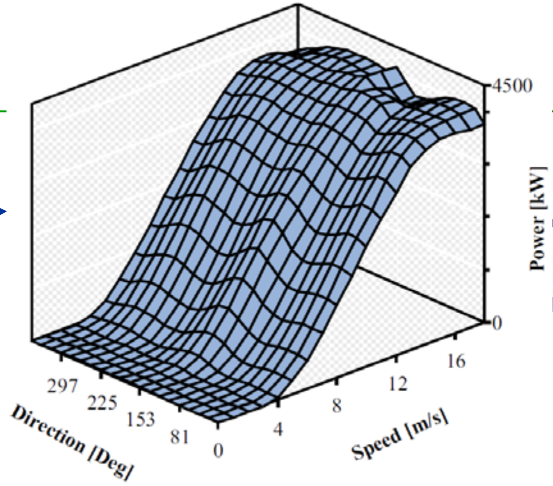


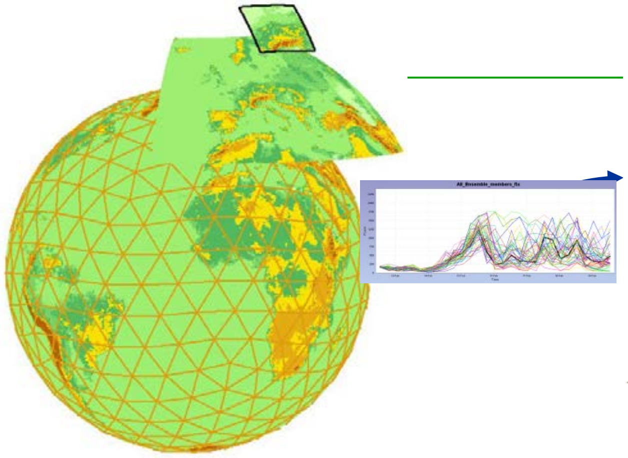
Prediction model

End user

WP1:

Coordination
Datasets
Benchmarks

Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC'97, Red Electrica de España.



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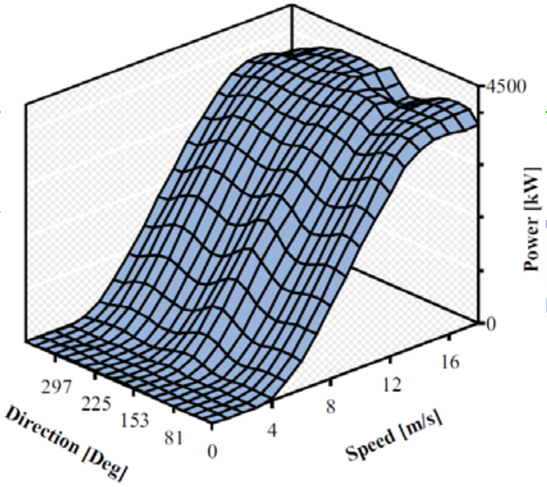

Prediction model

End user

WP2:

Vendor selection process
Standard evaluation protocol
Benchmarks

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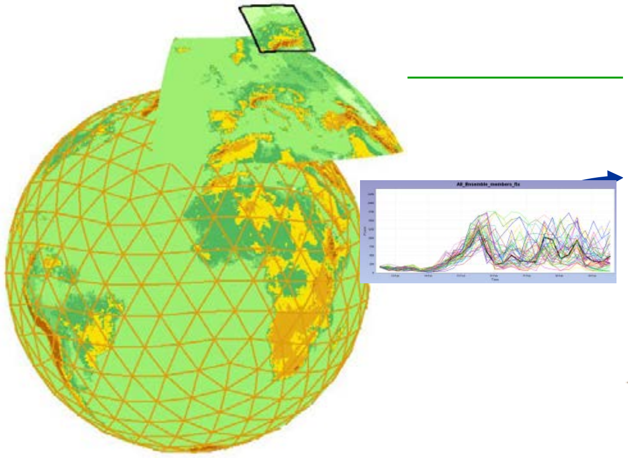

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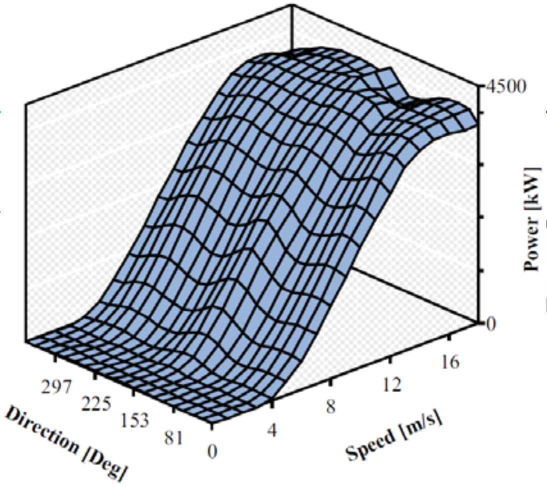

Prediction model

End user

WP3:

Decision support
Best Practice in Use
Communication

Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC’97, Red Electrica de España.

Timeline

- First phase 2016-2018.
- Phase II content currently under discussion.
- To run from 2019-2021.

Minute scale forecasting

- How to use Lidars, Radars or SCADA for very short term forecasts
- 30 sec – 15 min.
- Workshop at Risø last week.
- Slides available from workshop website
- Complete workshop on YouTube.

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Minute scale forecasting

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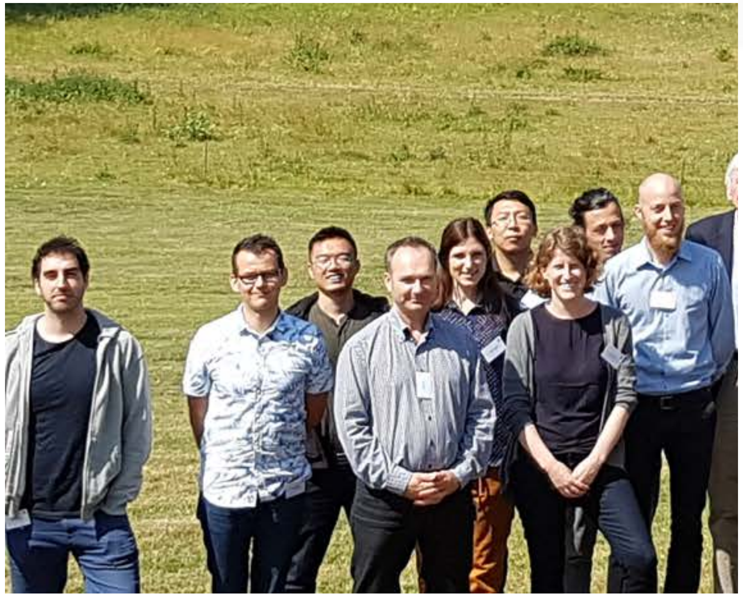

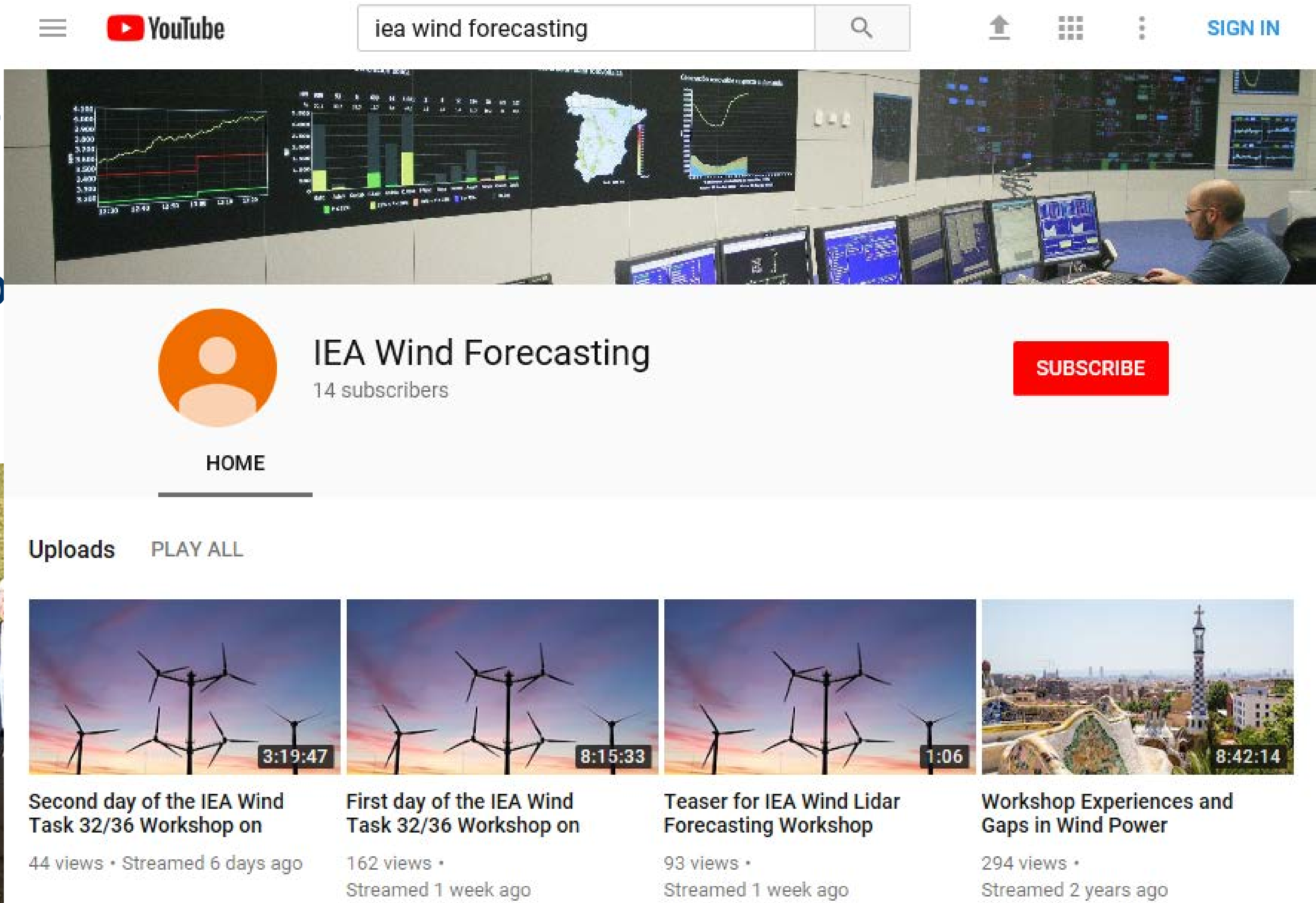

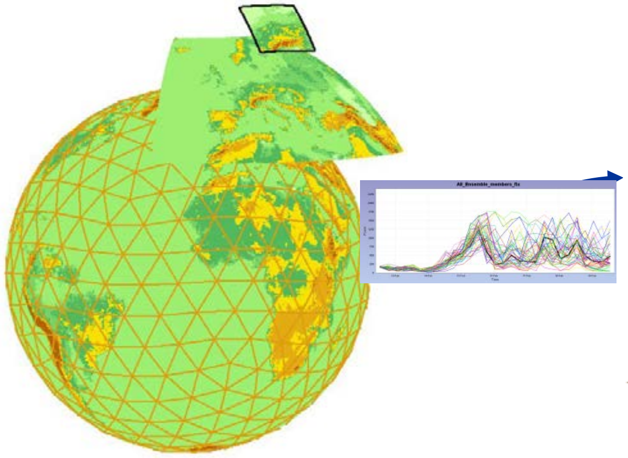

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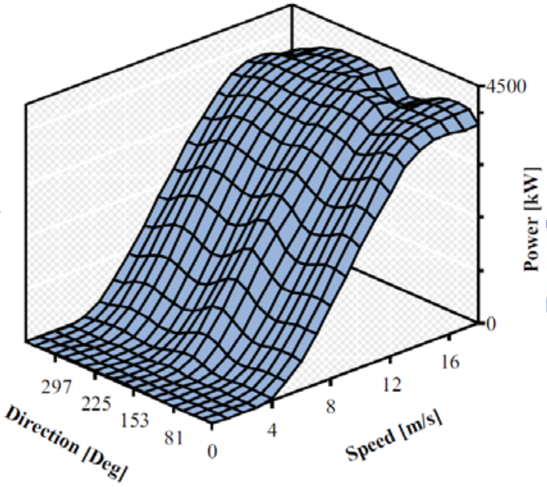

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WP1:

Coordination
Datasets
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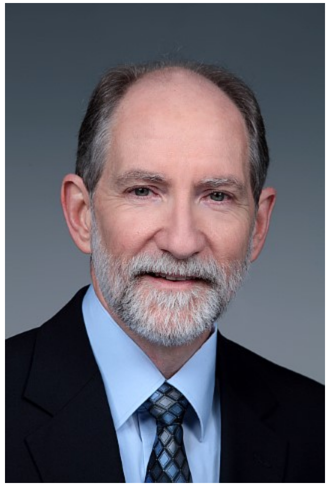
WP1 Meteorology

Lead:

- Helmut Frank, DWD
- Will Shaw, PNNL



Mission:

To coordinate NWP development for wind speed & power forecasting

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Task 1.1 Available Data Sets

Compile list of available data sets, especially from tall towers.

- **Aim:** NWP models need data to compare to, in turbine relevant heights -> 50-200 m.
- **Task** compiles list of data sets, especially masts.
- **Partners**: DWD, ForWind, ZSW, Danish partners, PNNL.

Lead

Helmut Frank
DWD, Deutscher Wetterdienst

Please find a list of meteorological masts over 100m and their accessibility below. If you know of more information, which could be used for wind verification, please send a mail to Helmut Frank, DWD.

SITE NAME	COORDINATES	ALTITUDE ABOVE MSL	TOWER HEIGHT	URL	CONTACT	DATA POLICY	DATA FORMAT	OBS. PERIOD	OTHER
Cabauw, NL	4.926° E, 51.97° N	-0.7 m	200 m	www.cesar-observatory.nl/index.php	henk.klein.baltink@knmi.nl	Cesar data policy	netCDF	2000-04-01 to previous month	
IJmuiden, NL	52.848° E, 3.436° N	0 m	92 m	www.meteomastijmuiden.nl/en/measurement-campaign/	verhoef@ecn.nl			since 2012	offshore North Sea
Risø, DK	12.088° E, 55.694° N	0 m	125 m	rodeo.dtu.dk/rodeo/ProjectOverview.aspx?&Project=5&Rnd=975820	Allan Vesth	Ask nicely		1995-11-20 -	Data measured since 1958; some months break in 2008.
Østerild, DK	12.088° E, 55.694° N	0 m	250 m	rodeo.dtu.dk/rodeo/ProjectOverview.aspx?&Project=179&Rnd=975820	Yoram Eisenberg	Ask nicely		2015-01-28 -	Two 250m masts in 4.3 km distance, both instrumented.

Risø, DK	12.088° E, 55.694° N	0 m	125 m	rodeo.dtu.dk/rodeo/ProjectOverview.aspx?&Project=5&Rnd=975820	Allan Vesth	Ask nicely		1995-11-20 -	Data measured since 1958; some months break in 2008.
Østerild, DK	12.088° E	0 m	250 m	rodeo.dtu.dk/rodeo	Yoram Eisenberg	Ask nicely		2015-01-28	Two 250m

Task 1.2 List of Field Campaigns

Creation of annual reports documenting and announcing field measurement programs and availability of data.

- **Aim:** to find new data useable for further NWP development, and to coordinate new measurement campaigns (e.g. New European Wind Atlas, WFIP2).
- **Partners:** DWD, PNNL, DTU

April 12, 2017

Helmut Frank (DWD), Will Smith (PNNL), Joel Cline (DoE)

Field measurement programs in 2016

Introduction

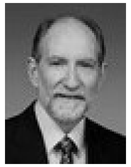
In IEA Wind Task 36 no experiments are made to compare Numerical Weather Prediction (NWP) models with observations. However, there are work packages trying to foster this comparison. Therefore, we compile a list of experiments which are particularly relevant for wind energy forecasting. We try to give a short description of the experiments and some information on the data.

Major Field experiments in 2016

Lead

Helmut Frank
DWD, Deutscher Wetterdienst

Co-lead



Will Shaw
Pacific North-West National Laboratory

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Major Field experiments in 2016

Wind Forecast Improvement Project 2 (WFIP 2) in Complex Flow

WFIP 2 (http://www.esrl.noaa.gov/gsd/renewable/wfip2.html) aims to improve NOAA's short-term weather forecast models and increase understanding of physical processes such as stability, turbulence, and low-level jet that affect wind energy generation in regions of complex terrain, such as coastlines, mountains, and canyons. The experiment takes place in the Columbia River

mountains, and canyons. The experiment takes place in the Columbia River
Gorge area in the northwestern USA. The terrain includes mountains, canyons, and coastlines, and experiences a variety of complex flow including frontal passages, strong cross-barrier flow, mountain waves, topographic wakes, convective outflow, and marine pushes.

The field campaign started in fall 2015 and lasts 15 to 18 month running through the whole year 2016. Measurement instruments include Lidar, Sodar, wind profiler, surface meteorological stations, microbarographs, microwave radiometers. Partners are Vaisala, ESRL, PNNL, University of Colorado, NOAA, ARL, NREL. Measurements are taken by Vaisala, Project data are archived at the PNNL Data Archive and Portal (DAP) https://a2e.pnnl.gov/data/ Access to a lot of data is free after registration at https://a2e.energy.gov/.

Experiments in the New European Wind Atlas (NEWA)

The New European Wind Atlas (NWEA, http://www.neweuropeanwindatlas.eu/) will create a freely accessible wind atlas for Europe. To validate the models used for this project it includes several atmospheric flow experiments. An overview of the experiments is given by Mann et al (2017). The experiments employ Doppler Lidar systems to supplement or replace meteorological masts. At the latest by the end of the New European Wind Atlas project all data will become freely available for the scientific community.

The coastal experiment RUNE (Floors et al, 2016) took place from November 2015 to February 2016 at the Danish west coast to measure offshore flow by wind lidar systems. It was followed by an experiment to investigate flow over heterogeneous roughness with horizontally scanning wind lidars. This experiment took place at the DTU test station for wind turbines at Østerild (http://rodeo.dtu.dk/rodeo/ProjectOverview.aspx?&Project=179&Rnd=975820) in northern Jutland, Denmark.

In another experiment, a ship-lidar system developed by Fraunhofer IWES, i.e. a Doppler lidar device installed on a vessel and supplemented by a motion

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In another experiment, a ship-lidar system developed by Fraunhofer IWES, i.e. a Doppler lidar device installed on a vessel and supplemented by a motion
monitoring and correction unit, is deployed to measure the wind along a regular ferry route between northern Germany and the Baltic countries across the Baltic Sea. A two-month test campaign took place in summer 2016 with measurements from the ferry between Bremerhaven and the island of Helgoland in the German North Sea.

Flow over forested rolling hills is investigated by the experiment in Hornamossen in south-central Sweden from April to July 2016. The site includes a variety of heterogeneities in topography, land cover and forest height. Measurement are taken at a 180 m mast, several SODAR and two lidar
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systems.

Another experiment to measure flow over a forested hill is the NEWA Kassel Experiment from August to December 2016 in central Germany. The experiment is centered around a 200 m tall tower on the Rödeser Berg. This tower is equipped with sonic and cup anemometers at several heights. In addition up to 11 long-range WindScanners, 8 wind profilers, and another 140 m mast measure the mean flow and turbulence. A predecessor was the Kassel 2016 Experiment (Pauscher et al, 2016).

Field experiments in 2017

WFIP 2 continues into 2017.

In February 2017 the main campaign of the ship-lidar experiment of Fraunhofer IWES within **NEWA** started on the route between Kiel, Germany, and Klaipeda, Lithuania.

The big **NEWA** experiment will be the campaign in **Perdigão**, in central Portugal from January to June 2017. Several US universities and research institutes will join several European groups for this experiment. Serra do Perdigão is formed by two parallel ridges with Southeast-Northwest orientation, separated by circa 1.5 km, 4 km long and 500-550 m tall at their summit. A preparation for the large Perdigão experiment took place in May-June 2015 (see Mann et al., 2016).

References

J. Mann, N. Angelou, J. Arnqvist, D. Callies, E. Cantero, R. Chávez Arroyo, M. Courtney, J. Cuxart, E. Dellwik, J. Gottschall, S. Ivanell, P. Kühn, G. Lea, J. C. Matos, C. M. Veiga Rodrigues, J. M. L. M. Palma, L. Pauscher, A. Peña, J. Sanz Rodrigo, S. Söderberg and N. Vasiljevic. Complex terrain experiments in the New European Wind Atlas, *Phil. Trans. R. Soc. A*, **2017**, 375. DOI:10.1098/rsta.2016.0101 (http://rsta.royalsocietypublishing.org/content/375/2091/20160101)

Mann J, Palma JMLM, Matos JC, Angelou N, Courtney M, Lea G, et al.. Experimental investigation of flow over a double ridge with several Doppler lidar systems; **2016**. Available at http://ams.confex.com/ams/96Annual/webprogram/Paper284781.html. 96th American Meteorological Society Annual Meeting.

Floors, R.; Peña, A.; Lea, G.; Vasiljević, N.; Simon, E.; Courtney, M. The RUNE Experiment—A Database of Remote-Sensing Observations of

Wind power prediction project list

This list shows a large number of (mostly publically funded) research projects in short-term forecasting of wind power. The list is incomplete, as the emphasis was a) on current projects, and b) on projects collected from the Task participants. Even so, the list contains research projects from the last two decades worth 46 M€, with 32 M€ public funding, though not all of this can be attributed to forecasting (e.g. the IRP Wind or RAVE projects).

If you have additions or comments, please send them to the operating agent, Gregor Giebel (grgi /at/ dtu.dk).

Country	**Project acronym**	**Full title**	**Sponsor**	**Total / Funded budget**	**Start - end date**	**Participants** (IEA Task 36 members in bold)
DE	gridcast	Increasing supply reliability by using flexible weather and power forecast models based on stochastic and physical hybrid methods	German Federal Ministry of Economic Affairs and Energy (BMWi)	6 M€ / 5.5 M€	Apr 2017 – Mar 2021	**Fraunhofer IWES**, **German Weather Service**, Amprion, TenneT, 50Hertz, TransnetBW, Innogy, Netze BW, EnBW, **Enercon**
EU	InteGrid	Demonstration of INTElligent	European Commission	14.5 M€ / 11.3 M€	1 Jan 2017 - 30 Jun 2020	EDP Distribuição (Coordinator),

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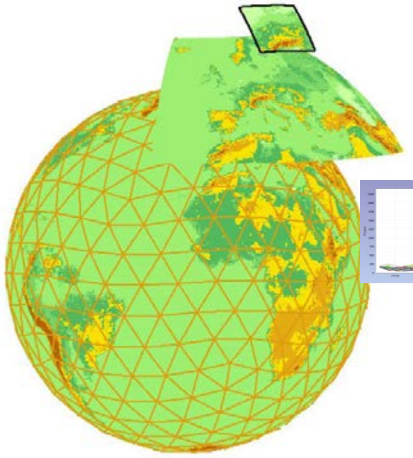
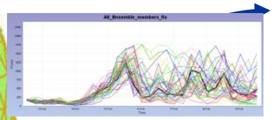
EU	InteGrid	Demonstration of INTELligent grid technologies for renewables INTEgration and INTEractive consumer participation enabling INTEroperable market solutions and INTErconnected stakeholders	European Commission (Horizon 2020)	14.5 M€ / 11.3 M€	1 Jan 2017 - 30 Jun 2020	EDP Distribuição (Coordinator), **INESC TEC**, EDP CNET, Águas de Portugal, Elektro Ljubljana, Ellevio, KTH, CyberGrid, AIT, GE, **DNV GL**, SAP, SIM, Univ. Comillas.
DK	OffshoreWake	Large scale offshore wake impact on the Danish power system	ForskEL (administered by EUDP)	6.879 MDKK / 6.063 MDKK	1 May 2017 - 30 Apr 2020	**DTU Wind Energy**, **Vattenfall**
NO	NowWind	Nowcasting for wind energy production - an integrated modelling approach	The Research Council of Norway (ENERGIX)	12 MNOK / 6.3 MNOK (1.3 / 0.7 M€)	2016 - 2019	**MET Norway**, **Windsim AS**, **Vestas Wind Systems AS**, TrønderEnergi AS, **Kjeller Vindteknikk AS**
FR	FOREWER	Modélisation, prévision et évaluation des risques pour la production d'énergie éolienne	Agence Nationale de la Recherche (French)	2160 k€ / 481 k€	1 Oct 2014 - 31 Mar 2019	Université Paris 7, **ENGIE Green**, Ecole Polytechnique, EDF, RTE, CNRS
FR	meteo*swift	Development of a short-term wind power forecasting tool based on adaptive multi-agent systems and ensemble weather forecasts	FEDER EU funding & Occitania French region	~1 M€ / ~500 k€	Mar 2016 - Mar 2018	**meteo*swift**, National Weather Research Center (part of Météo-France), Toulouse Computer Science Research Institute
DK	[link]	IEA Wind Task 36 Forecasting Danish Consortium	EUDP (nationally Danish)	2.72 MDKK / 1.83 MDKK	Jan 2016 - Dec 2018	**DTU Wind Energy**, **DTU Elektro**, **DTU Compute**, **DMI**, **ENFOR**, **DNV GL**, **WEPROG**, **Vestas**, **Energinet.dk**
US		IEA Task on Development & Use of [illegible]	Department of Energy USA	$22,732	Sep 2016 - Sep 2017	**NREL**
US	WFIP 2 (alternate link)	Second Wind Forecast Improvement Project	U.S. Department of Energy	$17M USD / $17M USD	1 Oct 2015 - 30 Sep 2018	**Vaisala**, **NOAA/ESRL**, **NOAA/ARL**, **NOAA/NWS**, Argonne National Laboratory, Lawrence Livermore National Laboratory, **NREL**, **PNNL**
EU	EoCoE	Energy oriented Centre of Excellence	EU Horizon2020	~5.5 M€ / ~1.4 M€	Oct 2015 – Sep 2018	21 teams in 8 countries, lead by Maison de la Simulation, including **Fraunhofer IWES**
EU	IRP Wind	Integrated EU R&D efforts on wind energy	EU 7th Framework Programme (Project ID: 609795)	~ 10 M€ / ~10 M€	Mar 2014 – Feb 2018	24 European teams (participants of the European Energy Research Alliance (EERA) Joint Programme on Wind Energy) lead by **DTU Wind Energy**
DE	PriME	Innovative probabilistic methods for energy system technology	German Federal Ministry of Education and Research (BMBF)	~1 M€ / ~1 M€	Jan 2015 – Dec 2017	University Kassel, **FH IWES**, EnerginetDK, Netze BW
FR/DK	HD-RESforecast	High-dimensional dynamical models for improving renewable energy forecasting at distributed locations	EDF	116 k€ / 65 k€	Nov 2015 -	**DTU Elektro**, EDF
DE	VORKAST	Optimisation of design and operational management for hybrid power plants and energy storage technologies by means of wind and PV power nowcasting (Optimierung der Auslegung und Betriebsführung	Federal Ministry for Economics and Technology	1 M€ / 1 M€	1 Sep 2014 – 31 Oct 2017	ZSW - Center for Solar Energy and Hydrogen Research Baden-Württemberg (Project lead) SWE – Stuttgart Wind Energy @ Institute of Aircraft Design, University of Stuttgart
DE	SMART GRID SOLAR		Bavarian ministry for economy, EU infrastructure fund "Investments for the future"	10 M€ / 6.3 M€	2012 - 2018	Bavarian Center for Applied Energy Research (ZAE), 3 Fraunhofer institutes, 9 other partners and **WEPROG**
PT	P1	Renewable Energy Dispatch Tools	China Electric Power Research Institute (CEPRI); State Grid Corporation of China (SGCC)	2 M€ / -	1 Jul 2013 - 31 Dec 2016	R&D NESTER (PT), **REN** (PT), **CEPRI** (CN)
DK	X-WiWa	Extreme winds and waves for offshore turbines	ForskEL (PSO)	5.96 MDKK / 5.4 MDKK	1 Jun 2013 - 2017	**DTU Wind Energy**, DHI, **Uni Research**, Bergen University
DE	EWeLiNE	Erstellung innovativer Wetter- und Leistungsprognosemodelle für die Netzintegration wetterabhängiger Energieträger	Bundesministerium für Wirtschaft und Energie	7.06 M€ / 6.5 M€	Dec 2012 - Feb 2017	**Fraunhofer IWES**, **DWD**, Amprion, TenneT, 50Hertz
DE	PerduS	Photovoltaikertragsreduktion durch Saharastaub	BMWi (Bundesministerium für Wirtschaft und Energie)	962 k€ / 962 k€	Nov 2012 - Feb 2017	**Deutscher Wetterdienst**, KIT, meteocontrol
EU	SafeWind	Multi-scale data assimilation, advanced wind modeling and forecasting with emphasis to extreme weather situations for a integration	EU 7th Framework Programme (FP7-ENERGY, Project ID: 213740)	5.6 M€ / 3.98 M€	1 Sep 2008 - 31 Aug 2012	**Armines**, **DTU**, **Risø**, **Uni Oldenburg**, **ENFOR**, **Overspeed**, **CENER**, **Energinet.dk** and 13 other partners
DK	DEWEPS	Development and Evaluation of a new wind profile theory with an Ensemble Prediction System	Danish PSO Fund	480 k€ / 180 k€	1 Apr 2009 - 31 Dec 2011	**WEPROG**
EU	ANEMOS.plus	Advanced Tools for the Management of Electricity Grids with Large-Scale Wind Generation	EU 6th Framework Programme (Project ID: 38692)	5.7 M€ / 2.6 M€	1 Jan 2008 - 30 Jun 2011	**Armines**, **DTU**, **Risø**, **ENFOR**, **Overspeed**, **CENER**, **INESC**, and 14 other partners
DE	RAVE	Research at Alpha Ventus - Grid Integration of offshore wind farms	BMU, German ministry for the Environment	5 M€ (60-80% funded)	2008 - 2011	**Fraunhofer IWES**, **Forwind - University Oldenburg**, **Deutscher Wetterdienst**, **WEPROG**
DK	HREnsembleHR	High-resolution Ensemble for Horns Reef	Danish PSO Fund (Contract No. 2006-1-6387)	700 k€ / 400 k€	1 Apr 2006 - 31 Dec 2009	**WEPROG**, **DTU IMM**, **DTU Risø**, **Fraunhofer IWES**, **DONG Energy**, **Vattenfall**
EU	POWWOW	Prediction of Waves, Wakes and Offshore Wind	EU 6th Framework Programme (Project ID 19898)	1.05 M€ / 1.05 M€	1 Oct 2005 - 30 Mar 2009	**Risø**, **DTU**, **Armines**, **CENER**, **Uni Oldenburg**, **Fraunhofer IWES**, and 8 other partners including UFPE (BR)
EU	ANEMOS	Development of a next generation wind resource forecasting system for the large-scale integration of onshore and offshore wind farms	EU 5th Framework Programme (Project ID: ENK5-CT-2002-00665)	4.3 M€ / 2.5 M€	1 Oct 2002 - 30 Sep 2006	**Armines**, **DTU**, **Uni Oldenburg**, **CENER**, **IASA**, and 16 others from TSOs to meteorologists





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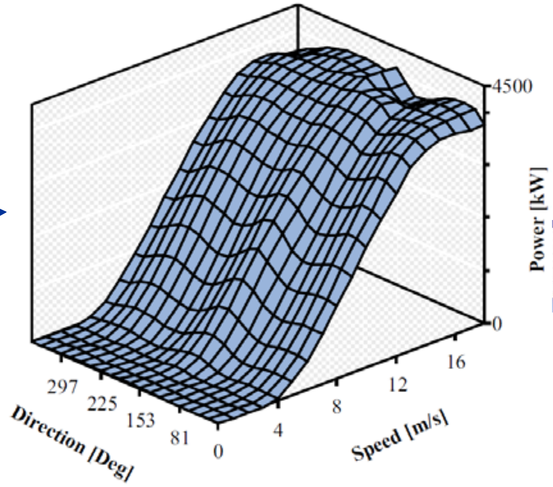

Prediction model

End user

WP2:

Vendor solution selection
Standard evaluation protocol
Benchmarks

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WP2 Benchmarks

Lead:

Pierre Pinson, DTU Elektro

~~Jakob Messner, DTU Elektro~~

Bri-Mathias Hodge, NREL

Caroline Draxl, NREL




Task 2.4 Test Cases

Set-up and dissemination of benchmark test cases and data sets.

- **Aim:** Set-up and dissemination of benchmarks.
- **Partners:** DTU Elektro, DTU Wind Energy, EDF, INESC TEC, Smartwatt, Prewind, PNNL.

NAME	TYPE OF DATA	AREA	PERIOD	TEMPORAL RESOLUTION
RE-Europe	Simulated aggregated generation and +1 to +91 hour forecasts for 1494 European regions based on ECMWF and COSMO analysis and ECMWF forecast data	Europe	2012-2014	1 hour
NREL WIND Toolkit	Simulated generation and 1	US	2007-2013	5 min

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Task 2.4 Test Cases

Set-up and dissemination of benchmark test cases and data sets.

-

Aim: Set-up and dissemination of benchmarks.

- **Partners:** DTU Elektro, DTU Wind Energy, EDF, INESC TEC, Smartwatt, Prewind, PNNL.

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RE-Europe	Simulated aggregated generation and +1 to +91 hour forecasts for 1494 European regions based on ECMWF and COSMO analysis and ECMWF forecast data	Europe	2012-2014	1 hour
NREL WIND Toolkit	Simulated generation and 1, 4, 6, and 24-hour wind and power forecasts for	US	2007-2013	5 min
NREL Western and Eastern Wind Integration data sets	Simulated generation for 1326 (Eastern) + 32043 (Western) US sites based on MASS and WRF. For Eastern data set also 4 hour, 6 hour and day ahead forecasts	US	2004-2006	10 min
GEFCom 2012	Observed generation and +1 to +48 hour ECMWF wind forecasts for 7 wind farms	unknown	2009-2012	1 hour
GEFCom 2014	Observed generation and +1 to +48 hour ECMWF wind forecasts for 7 wind farms	unknown	2009-2012	1 hour
AEMO	Generation data from various Australian wind farms	Australia	2005-	5 min

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Additional information:

RE-Europe:
Full data set can be downloaded as zip-file. Generation signals and forecasts and meta data on location and aggregation are stored in csv-files. Additional to wind power data the data set includes solar generation and power load data. More information can be found on https://zenodo.org/record/35177#.WqmNAzclFmB. Data policy: Creative Commons Attribution-NonCommercial 4.0.

NREL WIND Toolkit:

to Analysis & Downloads, choose either Wind Resource Data Download (Point) or Wind Resource Data Download (Box) and select points on the map for which you want data. A configuration window will pop up where you have to supply your contact data and can select the data sources. After your query has been processed you will get an email with a download link. Forecast data can only be accessed through a special request.

NREL Western and Eastern Wind Integration data sets:
see NREL WIND Toolkit

GEFCom 2012:
The full data set can be downloaded as supplementary data of the paper http://www.sciencedirect.com/science/article/pii/S0169207013000745. Wind power measurements are found in windpowermeasurements.csv and forecasts for the different wind farms are stored in separate files windforecasts_wf*.csv. Further information can also be found on https://www.kaggle.com/c/GEF2012-wind-forecasting.

GEFCom 2014:
The full data set can be downloaded as zip file from https://www.dropbox.com/s/pqenrr2mcvl0hk9/GEFCom2014.zip?dl=0. Wind power data can be found in GEFCom2014-W_V2.zip Task 15/. Task 1 - Task 14 are just subsets of Task 15. More information can be found on http://www.drhongtao.com/gefcom/2014 or http://blog.drhongtao.com/2016/07/datasets-for-energy-forecasting.html and the links there.

AEMO:
The Australian Energy Market Operator (AEMO) provides generation data from a number of generation units. Wind power data can be found on https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Market-Management-System-MMS/Generation-and-Load in both, the Actual Generation and Non-Scheduled Generation data sets. Information on wind farm location and capacity can e.g., be found on https://benjaminjweise.carto.com/tables/aemo_wind_plants/public. An already prepared data set for 2012-2013 is available at https://pure.strath.ac.uk/portal/en/datasets/australian-electricity-market-operator-aemo-5-minute-wind-power-data(9e1d9b96-baa7-4f05-93bd-99c5ae50b141).html. Data policy: https://www.aemo.com.au/Privacy_and_Legal_Notices/Copyright_Permissions_Notice

Status: Wed May 10 11:24:11 2017, Jakob W. Messner, DTU.

Updated by Gregor Giebel on 10 May 2017

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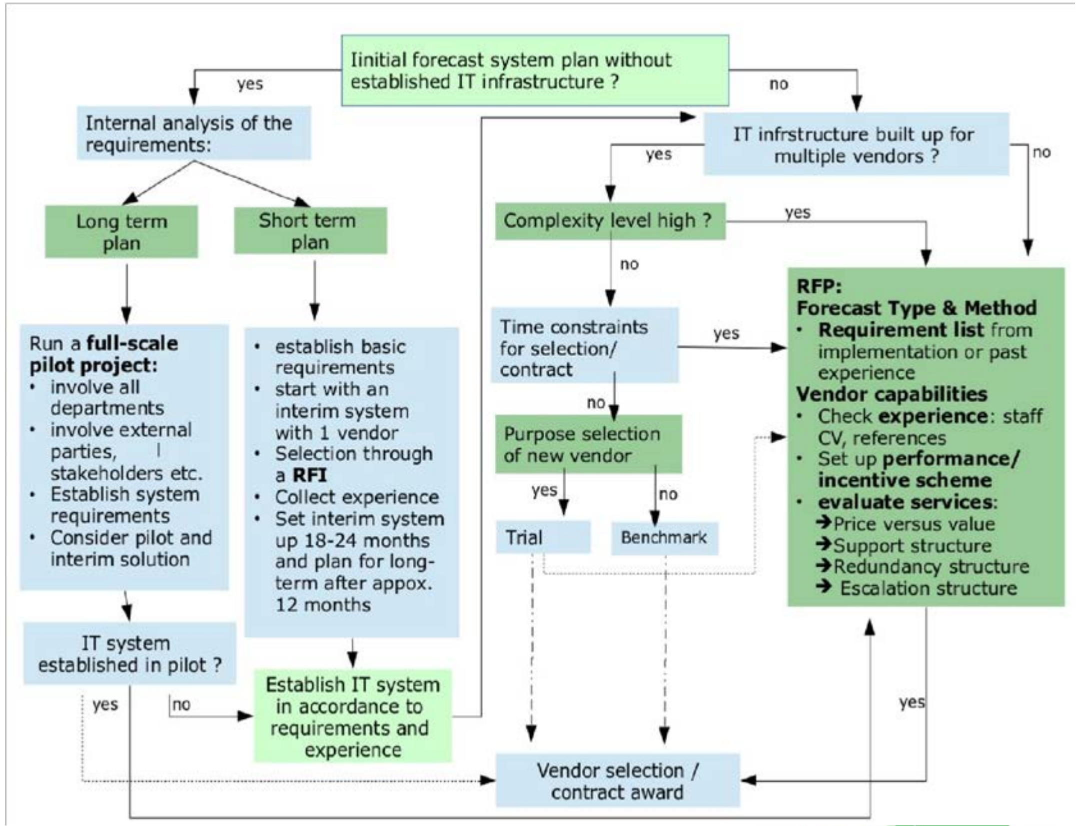
IEA Task 36 WP2.1

FORECAST SOLUTION SELECTION AND TRIAL/BENCHMARK EXECUTION

- **Purpose:**
  - Develop a global industry reference document to assist companies, governments, academics on how to select a forecast provider and conduct a benchmark or trial
  - Document best practices to yield a forecast that will provide the most value to the end-user
  - Ultimately, reduce renewable energy integration costs

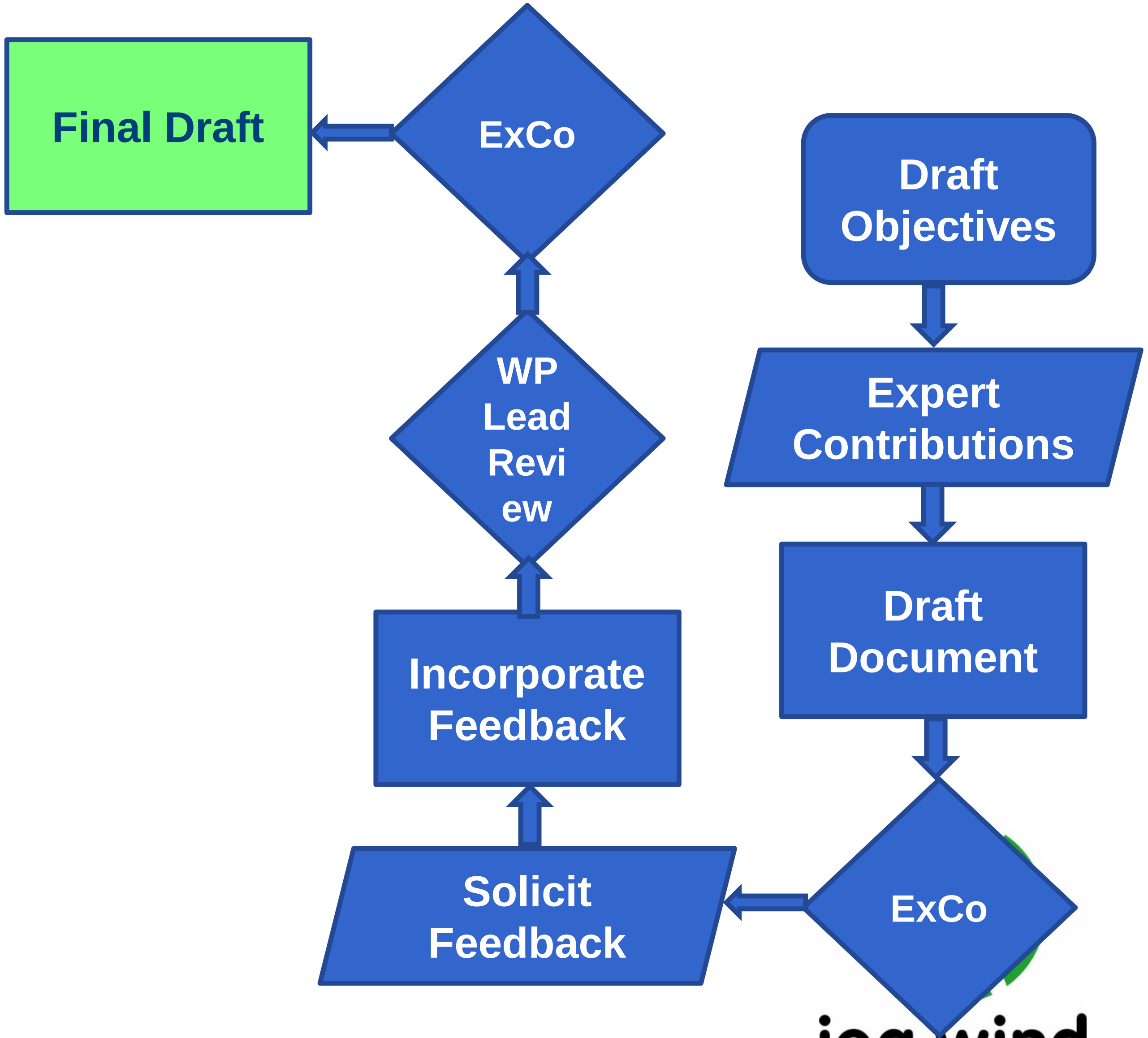


DECISION SUPPORT TOOL

IEA Task 36 WP2.1

FORECAST SOLUTION SELECTION AND TRIAL/BENCHMARK EXECUTION

- **June 2018 Status:**
  - First draft developed with input from experts in the field
  - WP2.1 Lead presented and received feedback from IEA ExCo in May 2018
  - Further input being solicited



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IEA Task 36 WP2.1

FORECAST SOLUTION SELECTION AND TRIAL/BENCHMARK E

- **Content Examples:**
  - Decision Support Tool to find best path for appropriate solution
  - Summary trial/benchmark checklist for all end-users
  - Appendices with
    - meta-, historical-, and real time-data details to make communication more efficient
    - Forecast file format sample
    - Questions to ask in RFI/RFP
  - Detailed steps during the three main phases of a trial: preparation, during, and post-trial

Forecast Trial Checklist

--Preparation--

- ☐ Determine outcomes / objectives
- ☐ Consult expert with trial experience
- ☐ Establish timeline and winning criteria
- ☐ Decide on live or retrospective trial
- ☐ Gather metadata (use IEA checklist spreadsheet)
- ☐ Determine if adequately resourced to carry out
- ☐ Obtain historical data
- ☐ Invite Forecast Service Providers
- ☐ Distribute historical and meta-data
- ☐ Allow two weeks Q&A prior to trail start
- ☐ Begin Trial

--During Trial--

- ☐ Develop validation report
- ☐ Check interim results
- ☐ Provide interim results (if no live data being provided)
- ☐ End Trial

--Post Trial--

- ☐ Provide final results
- ☐ Notify winner(s)
- ☐ Contract with winner(s)
- ☐ Start Service

	A	B	C
1	Wind Power Forecast Trial Checklist		
2			
3	Purpose: To efficiently set up site-specific wind power forecast, this checklist should be filled out as best as it could with available informaiton. This will expedite forecast configuration and save back and forth communication time. Please note the comments in the corner of the cells.		
4			
5	QUESTIONS		ANSWERS
6	**Metadata Checklist:**		
7	Name(s) of sites as needed in datafile:		*Acme Wind Farm*
8	Latitude and longitude coordinates of sites? Attaching or copying the turbine as-built locations to another worksheet will be sufficient here.		*42.3523, -121.3282*
9	Nameplate capacity of each site:		*62.5 MW*
10	Will a web tool be needed?		*Yes*
11	Turbine make/model/rating:		*GE:GE2.5-100*
12	Number of turbines:		*25*
13	Hub height of turbines?		*95 meters*
14	Please provide a suitable plant power curve		*attached*
15			
16	**Value of forecast questions:**		
17	Which variables will be forecasted and validated?		*Power (MW)*
18	Which forecast horizon(s) are being verified?		*24-48 hours*
19	Which metrics are being used to gage performance?		*RMSE*
20	If head-to-head trial competition, what are the criteria for determining winning forecast provider?		*Lowest RMSE and price*

WIND | Sample Forecast File

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Recommended Practice on Forecast Solution Selection

EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Part 1: FORECAST SOLUTION SELECTION PROCESS

1. EDITION 2018

Submitted to the Executive Committee of the International Energy Agency Implementing Agreement on ...

Prepared as part of the IEA Task 36, WP 2.1.

Edited by: Corinna Möhrlen, Gregor Giebel, Jakob Messner, Jeff Lerner, Craig Collier

EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR SELECTING RENEWABLE POWER FORECASTING SOLUTIONS

Part 2: DESIGNING AND EXECUTING FORECASTING BENCHMARKS AND TRIALS

1. EDITION 2018

Submitted to the Executive Committee of the International Energy Agency Implementing Agreement on 1st May 2018

Prepared as part of the IEA Task 36, WP 2.1.

Edited by: Jeff Lerner, Corinna Möhrlen, Gregor Giebel, Jakob Messner, Jethro Browell

EXPERT GROUP REPORT

ON

RECOMMENDED PRACTICES FOR THE IMPLEMENTATION OF WIND POWER FORECASTING SOLUTIONS

Part 3: Forecast Solution Evaluation

1. EDITION 2018

Submitted to the Executive Committee of the International Energy Agency Implementing Agreement on 1st May 2018

Prepared as part of the IEA Task 36, WP 2.1.

Edited by: Corinna Möhrlen, Gregor Giebel, John Zack, Craig Collier, Aidan Tuohy, Justin Sharp

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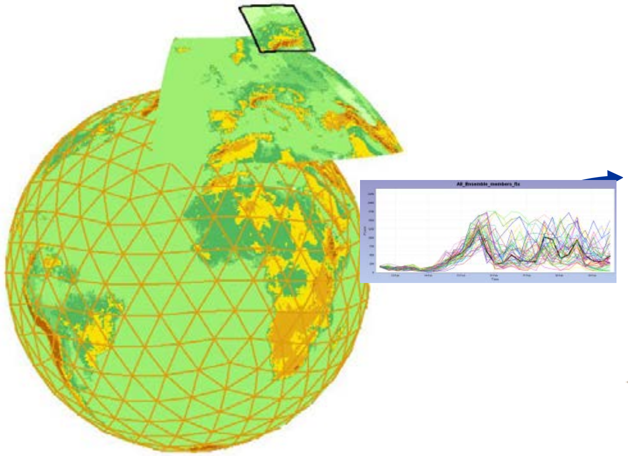
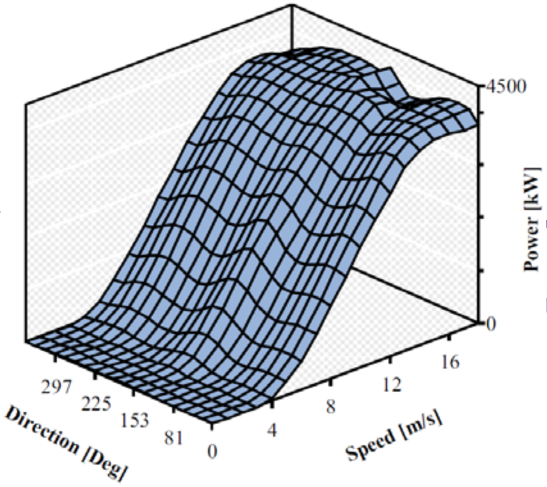


Numerical Weather Prediction



Prediction model

End user

WP3:

Decision support
Scenarios
Best Practice in Use
Communication

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Image sources: DWD, WAsP, Joensen/Nielsen/Madsen EWEC'97, Red Electrica de España.

WP3 Advanced Usage

Lead:
George Kariniotakis, Mines ParisTech
Corinna Möhrlen, WEPROG

15th Int. Workshop on Large-Scale Integration of Wind Power into Power Systems, Vienna, Nov. 2016

Use of Forecast Uncertainties in the Power Sector: State-of-the–Art of Business Practices

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***Abstract*—The work we present is an investigation on the state-of-the-art use of forecast uncertainties in the business practices of actors in the power systems sector that is part of the "IEA Wind Task 36: Wind Power Forecasting". The purpose of this task is to get an overview of the current use and application of probabilistic forecasts by actors in the power industry and investigate how they estimate and deal with uncertainties. The authors with expertise in probabilistic forecasting have been gathering information from the industry in order to identify the areas, where progress is needed and where it is difficult to achieve further progress. For this purpose, interview questions were compiled for different branches in the power industry and interviews carried out all around the world in the first six months of 2016. At this stage, we present and discuss results from this first round of interviews and draw preliminary conclusions outlining gaps in current forecasting methodologies and their use in the industry. At the end we provide some recommendations for next steps and further development with the objective to formulate guidelines for the use of uncertainty forecasts in the power market at a later stage.**

I. Introduction

The relevance of forecast uncertainties for wind power and other renewable energies grows as the penetration of these sources in the energy mix increases. Once a certain level of penetration is reached, ignoring the reliability of forecasts not only becomes expensive in terms of reserve roughly goes with wind speed to the power of three, and small errors and uncertainties are thus amplified and have an even higher impact compared to wind speed uncertainties. Weather development associated with fronts moving over large areas where wind is increasing rapidly over a short time are the most critical situations for a balance responsible party or a transmission system operator (TSO): it is under these circumstances that a deterministic forecast may be strongly incorrect and suppress steep ramping that can cause system security issues as well as large imbalances. Translated in the market, it means that there can be a sudden lack of power during a down-ramping event or too little flexible power that can be down-regulated fast and efficiently, which then results in curtailment. As long as the penetration level of wind is below 20% of generation, such uncertainty can usually be dealt with with a reasonable amount of reserves. As penetration increases, or in the case of island grids or badly interconnected grids, reserves and ancillary services grow above a desirable level.

In order to get an understanding of the current state of use of uncertainty forecasts and to find the gaps in the understanding of uncertainties and the associated forecasting tools and methods, we have been carrying out a study with a combination of questionnaires and interviews, which will

Use of probabilistic forecasting

Open Access journal paper

48 pages on the use of uncertainty forecasts in the power industry

Definition – Methods – Communication of Uncertainty – End User Cases – Pitfalls - Recommendations

Source: http://www.mdpi.com/1996-1073/10/9/1402/

energies MDPI

Review

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

Ricardo J. Bessa [1,*], Corinna Möhrlen [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]

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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

Academic Editor: David Wood
Received: 18 August 2017; Accepted: 8 September 2017; Published: 14 September 2017

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.

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Broader paper on 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

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Uncertainty Forecasting in a Nutshell

DOI: *10.1109/MPE.2017.2729100*

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-error 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 (NWPs) 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.

D3.3

Webinars to inform users about outcomes of tasks 3.3 – 3.6

Watch this space!

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Data Science for Environmental Modelling and Renewables

- A Massive Open Online Course -

PRESENTATION SLIDES

ESIG Forecasting Workshop

Session 8

Jethro Browell

(presented by Corinna Möhrlen)

June 2018

St. Paul, MN, USA

supported by

Data Science for Environmental Modelling and Renewables

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Hosted on: Future Learn

Course Outline

Week 1: Introduction

Week 2: R Bootcamp

Week 3: Patterns in temporal data

Week 4: Patterns in spatial, spatio-temporal and network data

Week 5: Open data, Citizen Science and Twitter

Week 6: Wind and Solar Power Forecasting

Go-Live in September 2018

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Go-Live in September 2018

Week 6: Wind and Solar Power Forecasting

By the end of the week participants will be able to:

- Explain the principles of numerical weather prediction and make informed use of such data
- Produce basic deterministic and probabilistic wind and solar power forecasts
- Explain and apply the principles of forecast evaluation

Video Content

30-60 Minutes of video comprising a short lecture and interviews with forecast users.

Content Pages

1. Overview of the model chain: NWP → Physical/Statistical Model → Use and Evaluation
2. Numerical Weather Prediction: Basic Principles
3. Tools and methods in R
4. Deterministic Wind Power Forecasting
5. ***Principles of Deterministic Forecast Evaluation***
6. Deterministic Solar Power Forecasting
7. Introduction to Probabilistic Forecasting
8. Producing Probabilistic Forecasts
9. Principles of Probabilistic Forecast Evaluation
10. ***Best Practice for Users of Commercial Forecasts***

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Website: www.ieawindforecasting.dk

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Discussion

Recommended Practice on Forecast Solution Selection

1. Forecast Value

1A. For end users: **how do you value forecasts**, and do you consider costs vs. benefits of forecasting when making decisions on forecast solution selection?

1B. How is the value of forecasting and value assessment evolving as wind and solar penetrations continue to get even higher?

- Have people in very high penetration areas noticed that there is a **change** in emphasis away **from traditional metrics to other measures** of forecast value?

1C. What examples are there of regions where the **incentives to improve forecasts** are there such that end users are willing to pay more for targeted or improved performance? In other words, are there examples where the risks are put on the appropriate entity such that there is quantified incentive to improve forecasts?

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2. Forecast Solution Selection

2A. **Which information** do end-users/consultants feel they are **missing** when they start looking for forecasting solutions?

2B. How important is the **relationship between end-user and forecaster** in the changing environments? How much are end-users engaging with forecasters to find new solutions?

2C. What is the experience with **met measurements** and their value in forecasting solutions?

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3. Assessing Forecast Performance

3A. What are the most challenging points in the **verification** of forecasts from end-users and forecaster's perspective:

Would a public verification platform and/or **public code** be welcomed (e.g. IEA wind forecast benchmark) ?

What are the challenges when **interpreting statistical metrics with business values**?

3B. What are the most challenging points in the **evaluation of forecasts** methodologies - from end-users and forecaster's perspective:

How much interest do forecast users have in understanding forecast methodologies and their relative performance?

Would specific test cases that forecasters supply their results to be sufficient as a test of methodologies?

How should theoretical information be accessible (public reports, peer reviewed journals, technical documentation, standard, guideline) ?

4. Best Practices and Standards

4A. What kind of **documentation format** (standard, guideline/recommended practice/technical report form, fact sheets (short), etc...) do end-users/consultants wish to have in order to have objective guidance for:

- pre-selection or qualification of forecasting solutions
- evaluation and verification of forecast performance
- design and execution of trials and benchmarks

4B. What is most needed in terms of **standardization** from an end-user's perspective and a forecaster's perspective?

4C. Other than metrics and data, are there other areas that could be suitable for standardization?

*4D. How do we get the **word out** to the industry at large about the existence of the IEA documentation?*

4E. *How do we insure the greatest likelihood of **industry adoption** of the best practices documentation? e.g., Conferences, Publications, Social Media? Others?*

Discussion points

1. Forecast Value

2. Forecast Solution Selection

3. Assessing Forecast Performance

4. Best Practices and Standards

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Future topics

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Wind power forecasting: IEA Wind Task 36 & future research issues
G Giebel[1], J Cline[2], H Frank[3], W Shaw[4], P Pinson[5], B-M Hodge[6], G Kariniotakis[7], J Madsen[8] and C Möhrlen[9]
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The Science of Making Torque from Wind (TORQUE 2016) IOP Publishing
Journal of Physics: Conference Series 753 (2016) 032042 doi:10.1088/1742-6596/753/3/032042

Wind power forecasting: IEA Wind Task 36 & future research issues

G Giebel[1], J Cline[2], H Frank[3], W Shaw[4], P Pinson[5], B-M Hodge[6], G Kariniotakis[7], J Madsen[8] and C Möhrlen[9]

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E-mail: grgi@dtu.dk

Abstract. This paper presents the new International Energy Agency Wind Task 36 on Forecasting, and invites to collaborate within the group. Wind power forecasts have been used operatively 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 organise international collaboration, among national meteorological centres with an interest and/or large projects on wind forecast improvements (NOAA, DWD, MetOffice, met.no, DMI, …), operational forecaster and forecast users.

Collected Issues

Nowcast (especially for difficult situations, thunderstorms, small lows, …)
Sub 1 hour temporal resolution
Meteorology below 1km spatial resolution
Stability issues, especially with daily pattern / (Nightly) Low level jets
Icing
Farm-Farm interaction / quality of direction forecast
Short-term ensembles
Ramps and other extremes
Spatio-temporal forecasting
Rapid Update Models (hourly, with hourly data assimilation)
Use of probabilistic forecasts and quality of the extreme quantiles
Do DSOs need different forecasts than TSOs?
Penalties for bad performance? Incentives for improved perf.?
Seasonal forecasting? What's the business case?
Data assimilation (with non-linear Kalman filters, 4D Var, …)

Red: Important research, but (to be) done elsewhere
Green: We work on at least some aspects

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5. Anticipated Changes in the Need/Value of Forecast Information

5A. Which direction do end-users and forecasters expect for the next few years in terms of **forecast time intervals** (1min, 5min, 10/15min, hourly, ...short-term, ultra-short-term) and long-term (7 days, 10days, 2 weeks) - and what do they expect is required to get there.

5B. How do we line up **incentives to improve forecasts** with the right end users, and how can they evaluate different solutions from a cost/benefit perspective?

5C. How can the renewable energy forecasting community emphasize and **work closer with the international modeling centers** to include energy forecast metrics in NWP model upgrades?

6. Measurement Data: Value and Access

6A. What is the experience at end-users regarding **meteorological measurement requirements in the grid code** - is it important for the future with higher penetration levels or only in high-wind speed regions ? (End-user and forecaster that have experience)

6B. Data sharing models to create historical resource data across renewable plant build-out areas. That is, creating an open-source **wind / irradiance database for benchmarking** and/or new wind forecast setup.

6C. Related to above two topics: should there be an IEA Task 36 effort to setup a growing **met tower data history** for wind forecasting improvements (R&D, industry, and NWP modeling center usage)?

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7. User Education

7A. To what degree should forecast user education be focused on **practical issues** such as forecasting solution selection, value of different data inputs, relative performance of methods, evaluation protocols, etc.?

7B. How do we better **educate end users** on what is possible from forecasts? Rather than just giving them an end result, how do we ensure they know the range of information (i.e. solutions) available to them?

Future topics for phase II

5. Anticipated Changes in the Need/Value of Forecast Information

6. Measurement Data: Value and Access

7. User Education

Task meeting Friday

Tentative agenda:

08:30 Introduction (Gregor Giebel)

09:00 WP1 (Helmut Frank)

10:00 WP2, hereunder the Best Practice on the Forecast Solution Selection Process.

11:30 WP3 (Corinna Möhrlen)

12:30 Lunch

13:30 IEC 63043 TR (Feng Shuanglei)

14:30 New topics for second round (Gregor and WP leads)

16:45 AOB

17:00 Close of meeting

Regular Task meeting Friday, here in the hotel.

Streaming will be available.

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Thank You!!

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