Task 36 Forecasting for Wind Power

Gregor Giebel,
DTU Wind Energy

28 October 2017

Wind Integration Workshop
Berlin, Germany

Energy Technology Network

iea wind

Website: www.ieawindforecasting.dk

Contact

IEA WIND TASK 36

ABOUT | PARTNERS | TOPICS | MEMBER SITE | IEA WIND

iea wind

RELATED PROJECTS

- IEA Wind
- IEA Wind Task 25 - Large-sc...
- IEA Wind Task 31 Wakebench
- EWeLiNE
- WFIP2
- New European Wind Atlas

Source: Red Electrica de España

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 weather centres with an interest and/or large projects on wind forecast improvements (NOAA, DWD, ...), operational forecaster and forecast users.

The 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 will be aiming at an international pre-standard (an IEA Recommended Practice) on benchmarking

NEWS

All

03 June 2016
Questionnaire on State of the art...

18 May 2016
10 June 2016: IEA Wind Task 36...

18 May 2016
9 June 2016 Workshop in Barcelona

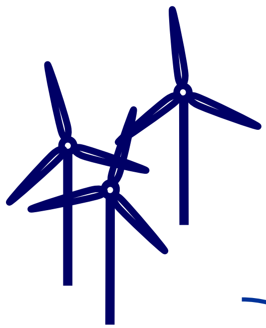
18 May 2016
8 June 2016 Potentially sub-task...

g/task_25.html

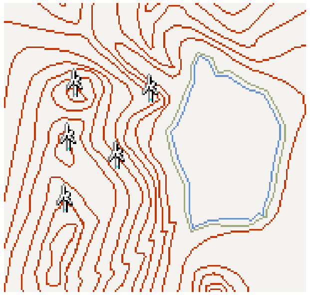
iea Energy Technology Network

iea wind

Short-Term Prediction Overview

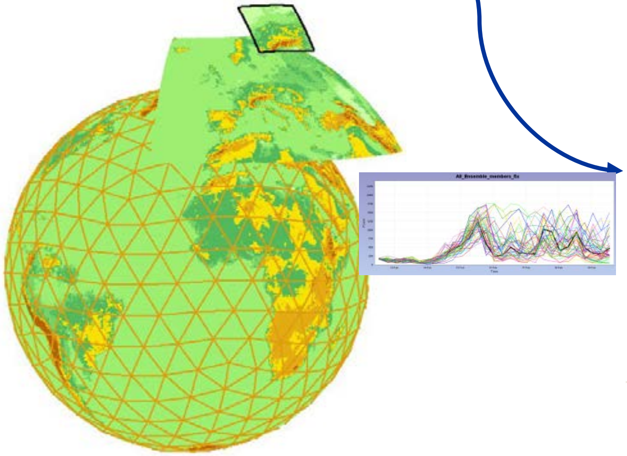


Online data

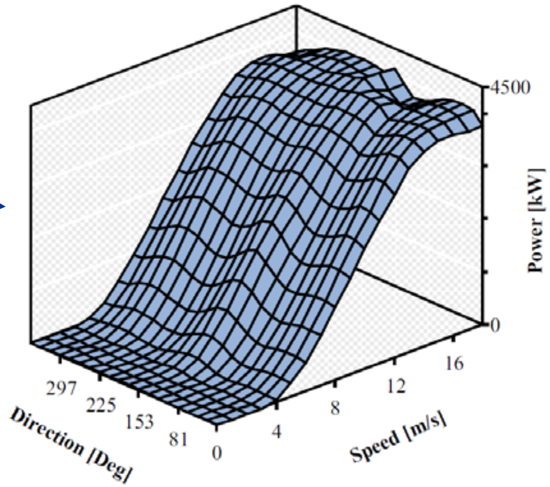


Orography
Roughness
Wind farm layout

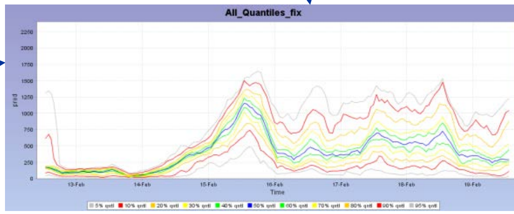
GRID



Numerical Weather Prediction



Prediction model

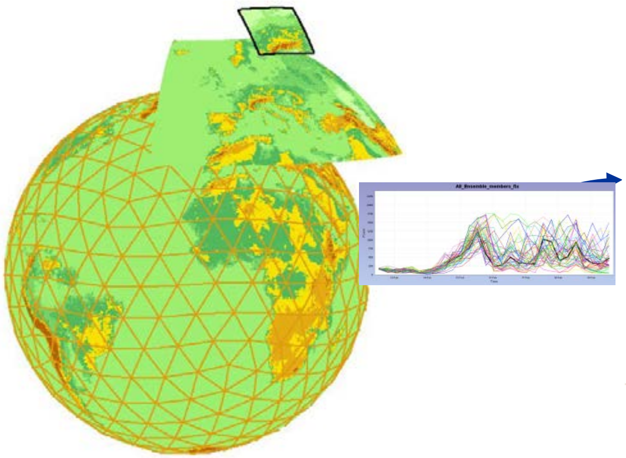


End user

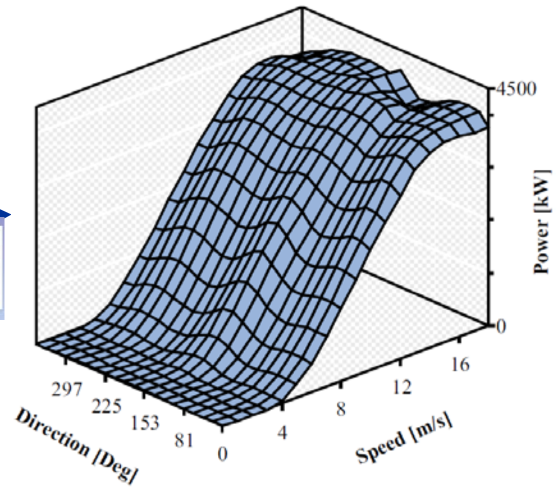
TRADING

Energy Technology Network

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



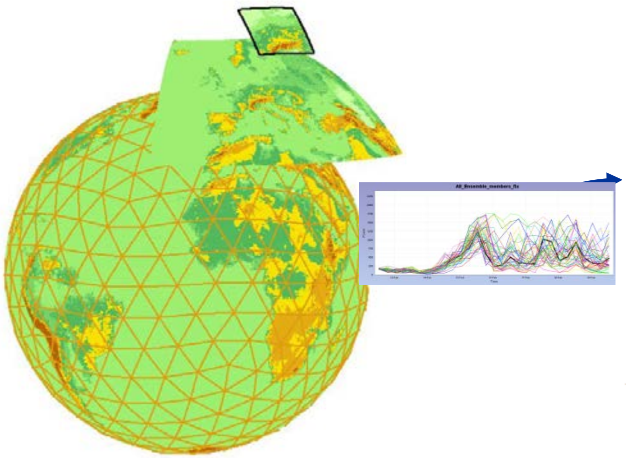
Numerical Weather Prediction



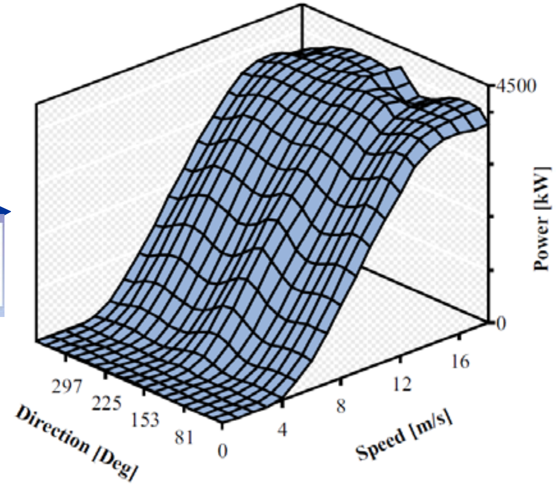
Prediction model

End user

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



Numerical Weather Prediction

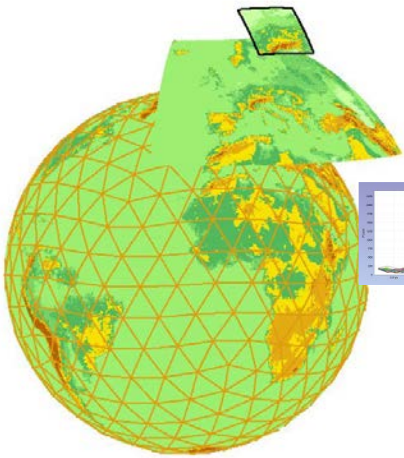


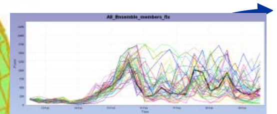
Prediction model

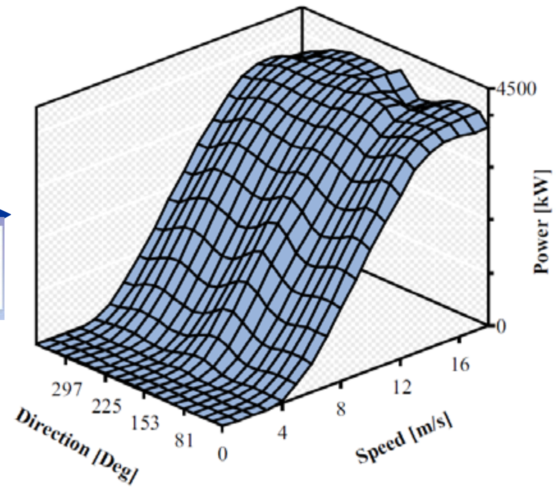
End user

WP1: Coordination Datasets Benchmarks

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







Numerical Weather Prediction

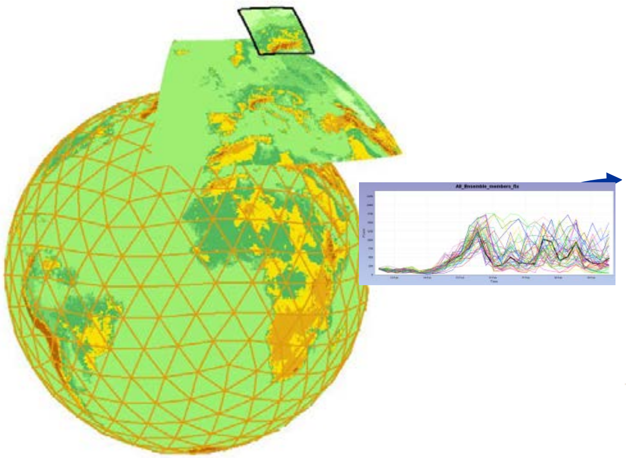
Prediction model

End user

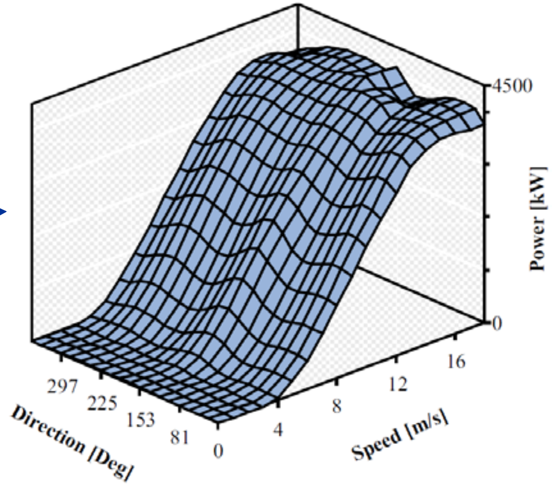
WP2:

Benchmark Best Practice
Standard evaluation protocol
Benchmarks

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



Numerical Weather Prediction



Prediction model

End user

WP3:

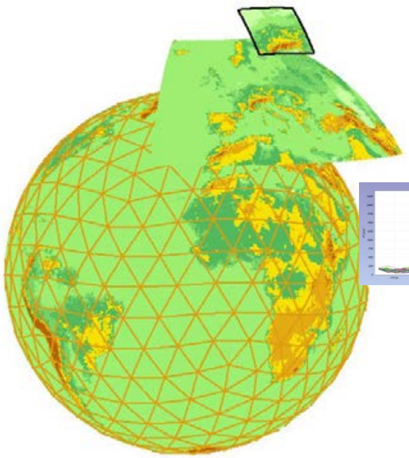
Scenarios
Best Practice in Use
Communication

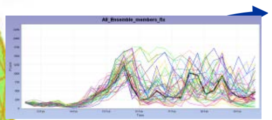
Decision support

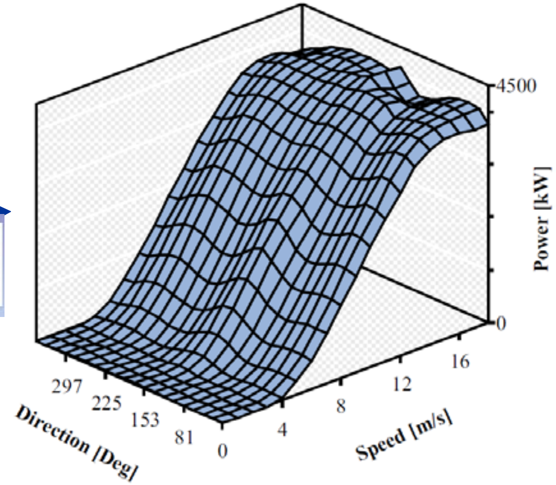
Energy Technology Network

iea wind

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







End user

Numerical Weather Prediction

Prediction model

WP1:

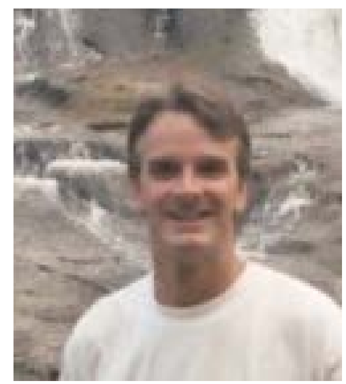
Coordination
Datasets
Benchmarks

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

WP1 Meteorology

Lead:

- Helmut Frank, DWD
- Joel Cline, DoE
- Will Shaw, PNNL



iea Energy Technology Network

iea wind

WP1 Meteorology

- Task 1.1: Compile list of **available data sets**, especially from tall towers.
- Task 1.2: Creation of annual reports documenting and announcing **field measurement programs** and availability of data.
- Task 1.3: Verify and Validate the improvements through a **common data set** to test model results upon and discuss at IEA Task meetings

Wind observation need beyond 100m

iea Energy Technology Network

iea wind

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

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

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

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)

Lead

Helmut Frank
DWD, Deutscher Wetterdienst

Co-lead

Will Shaw
Pacific North-West National Laboratory

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

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

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 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 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 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).

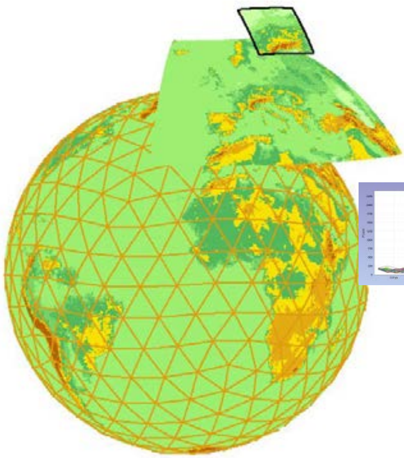
References

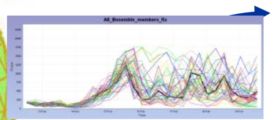
J. Mann, N. Angelou, J. Arnqvist, D. Callies, E. Cantero, R. Chávez Arroyo, M. Courtney, J. Cuxart, E. Dellwik, J. Gottschall, S. Ivanell, P. Kühn, G. Lea, J. C. Matos, C. M. Veiga Rodrigues, J. M. L. M. Palma, L. Pauscher, A. Peña, J. Sanz Rodrigo, S. Söderberg and N. Vasiljevic. Complex terrain experiments 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)

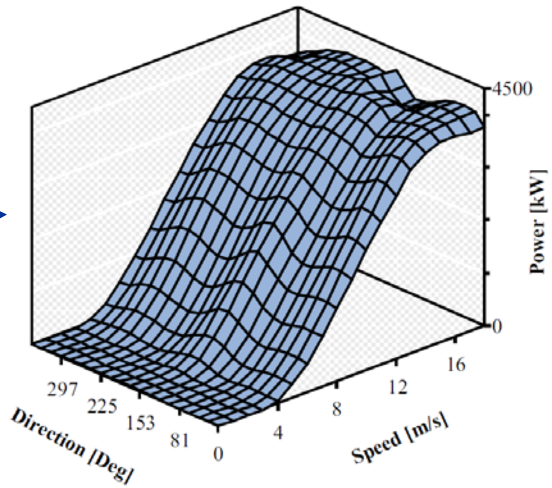
Mann J, Palma JMLM, Matos JC, Angelou N, Courtney M, Lea G, et al.. Experimental investigation of flow over a double ridge with several Doppler lidar systems; **2016**. Available at http://ams.confex.com/ams/96Annual/webprogram/Paper284781.html. 96th American Meteorological Society Annual Meeting.

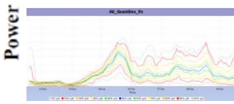
Floors, R.; Peña, A.; Lea, G.; Vasiljević, N.; Simon, E.; Courtney, M. The RUNE Experiment—A Database of Remote-Sensing Observations of

iea wind









End user

Numerical Weather Prediction

Prediction model

WP2:

Benchmark Best Practice
Standard evaluation protocol
Benchmarks

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

WP2 Benchmarks

Lead:

Pierre Pinson, DTU Elektro

Jakob Messner, DTU Elektro

Bri-Mathias Hodge, NREL

Caroline Draxl, NREL

D2.1

IEA Recommended Practice on Wind Power Forecast Evaluation, for both deterministic and probabilistic forecasts

- Central document for us: preparation started
- Good list of cases of ”how not to do it”
- Pros and cons of live vs retroactive trials
- Error measures
- Writing team established.

Task 2.4 – Lead DTU Elektro

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

E.g. Global Forecast Competition on Kaggle, ANEMOS comparison

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	Simulated	US	2007-2013	5 min

Contact

Jakob Messner
Postdoc
DTU Electrical Engineering
+45 45 25 35 06

Lead

Pierre Pinson
Professor
DTU Electrical Engineering
+45 45 25 35 41

WP1 Weather Prediction Improvements
WP2 Benchmarks
› Task 2.1 Best Practice
› Task 2.2 Evaluation Protocol
› Task 2.3 Uncertainty
› Task 2.4 Test Cases
WP3 End Use

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, 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

Contact

Jakob Messner
Postdoc
DTU Electrical Engineering
+45 45 25 35 06

Lead

Pierre Pinson
Professor
DTU Electrical Engineering
+45 45 25 35 41

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

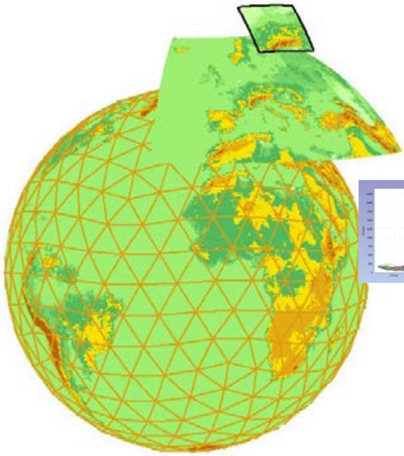
GEFCom 2012:
The full data set can be downloaded as supplementary data of the paper http://www.sciencedirect.com/science/article/pii/S0169207013000745. Wind power measurements are found in windpowermeasurements.csv and forecasts for the different wind farms are stored in separate files windforecasts_wf*.csv.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

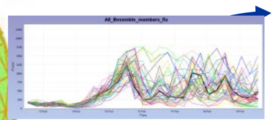
GEFCom 2014:
The full data set can be downloaded as zip file from https://www.dropbox.com/s/pqenrr2mcvl0hk9/GEFCom2014.zip?dl=0. Wind power data can be found in GEFCom2014-W_V2.zip Task 15/. Task 1 - Task 14 are just subsets of Task 15. More information can be found on http://www.drhongtao.com/gefcom/2014 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

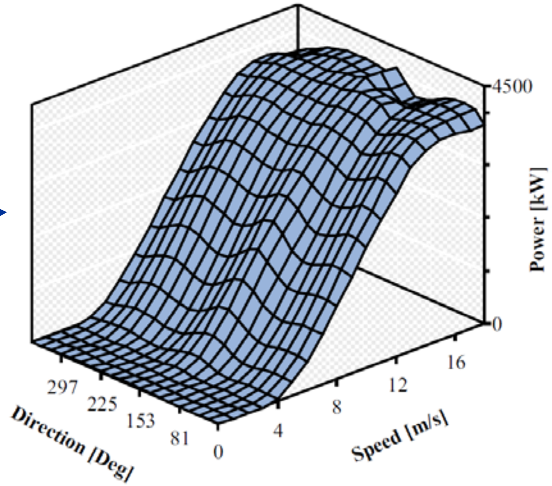
Status: Wed May 10 11:24:11 2017, Jakob W. Messner, DTU.

Updated by Gregor Giebel on 10 May 2017

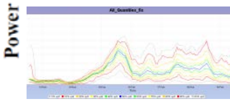




Numerical Weather Prediction



Prediction model



End user

WP3:

Scenarios
Best Practice in Use
Communication

Decision support

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

WP3 Advanced Usage

Lead:

George Kariniotakis, Mines ParisTech

Corinna Möhrlen, WEPROG

Wanted: End-user co-lead

Task 3.1: Use of Forecast Uncertainties in the Power Sector: State-of-the Art of Business Practice

Purpose:

- Get an overview of the current use and application of probabilistic forecasts in the power industry sector;
- Investigate how participants estimate and deal with uncertainties.

Phase 1: Collection of Information

Phase 2: Analysis of Results

Phase 3: Communication and Dissemination

Work-in-progress over 3 years

How we setup the interviews

Questions were separated into 2 categories:

General character to identify:

→ the type of business

→ the size of the organisation

→ the span of the business processes

→ the possible existing barriers

Forecasting & uncertainty to identify:

→ the forecasting products used today

→ the knowledge & awareness of probabilistic products

→ the challenges that hinder the implementation of new products

Get a broad overview of state-of-the-art use of forecasting and uncertainty in the power market

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

C. Möhrlen*, R. J. Bessa†, M. Barthod‡, G. Goretti§ and M. Siefert¶
*WEPROG ApS, Assens, Denmark, Email: com@weprog.com
†INESC TEC, Porto, Portugal, Email: ricardo.j.bessa@inesctec.pt
‡meteo*swift, Toulouse, France, Email: morgane.barthod@meteoswift.com
§Dublin Institute of Technology, Ireland, Email: gianni.goretti@mydit.ie
¶Fraunhofer IWES, Kassel, Germany, Email: malte.siefert@iwes.fraunhofer.de

***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

Task 3.5 – Lead: INESC TEC

Communication of wind and wind power forecasts to end-users. Review, recommendations/best practice. Is it necessary to standardise wind power forecasting products?

Energy Technology Network

iea wind

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]

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

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.

D3.3

Webinars to inform users about outcomes of tasks 3.3 – 3.6

Technical Results

Mainly: published 5 lists, useful for peers

- Tall masts for NWP verification, and how to access their data
- Field experiments in wind power meteorology
- Openly available benchmarks for power forecasts
- Research projects in the field
- Future research issues

iea Energy Technology Network

iea wind

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),

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 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**

Country	Project acronym	Full title	Sponsor	Total / Funded budget	Start - end date	Participants
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	Photovoltaikertragsre[illegible]on	BMWi	962 k€ / 962 k€	Nov 2012 - Feb	**Deutscher**

Country	Project acronym	Full title	Sponsor	Total / Funded budget	Start - end date	Participants
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, U **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, 50Her

Country	Project acronym	Full title	Sponsor	Total / Funded budget	Start - end date	Participants
DE	PerduS	Photovoltaikertragsre[illegible]on 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 [illegible]	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 [illegible]
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 UFP (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

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]

[1] DTU Wind Energy, Risø, Frederiksborgvej 399, 4000 Roskilde, Denmark
[2] Department of Energy, Wind and Water Power Program, 1000 Independence Ave. SW, Washington DC 20585, USA
[3] Deutscher Wetterdienst, Frankfurter Str. 135, D-63067 Offenbach, Germany
[4] Pacific Northwest National Laboratory, 902 Battelle Boulevard, P.O. Box 999, MSIN K9-30, Richland, WA 99352 USA
[5] DTU Elektro, Ørsteds Plads, 2800 Kgs. Lyngby, Denmark
[6] National Renewable Energy Laboratory, 15013 Denver West Parkway, MS ESIF200, Golden, CO 80401, USA
[7] MINES ParisTech, PSL Research University, Centre PERSEE, CS 10207, 1 Rue Claude Daunesse, 06904 Sophia Antipolis Cedex, France
[8] Vattenfall AB, Jupitervej 6, DK-6000 Kolding, Denmark
[9] WEPROG Aps, Willemoesgade 15B, 5610 Assens

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

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

iea Energy Technology Network

iea wind

Outreach & Dissemination

- Special session at AMS Seattle, Jan 2017 plus Task meeting
- Mini-Symposium Forecasting at Wind Energy Science Conference, Lynbgy, DK in June, 25 talks, plus IEA Task meeting 28/29/30 June 2017

Thank You!!

Gregor Giebel
DTU Wind Energy, Frederiksborgvej 399, DK-4000 Risø
grgi@dtu.dk
Cell: +45 4056 5095

www.ieawindforecasting.dk

iea Energy Technology Network

iea wind