International Energy Agency (IEA)
Implementing Agreement for Co-operation in the Research and Development of Wind Energy Systems (IEA Wind)

Task Proposal Extension of Task 36 Forecasting for Wind Energy, Phase II

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1 Scope

The current Task 36 under the *IEA Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems* (IEA Wind) focuses on **improving the value of wind energy forecasts to the wind industry**. This text is the proposal for the second phase, to run from 2019-2021.
There are three distinct areas of challenge in forecasting wind power. The first is in the continuing effort to improve the representation of physical processes in forecast models through both new high performance initializations and tailored parameterizations. The second area is the heterogeneity of the forecasters and end users, the full understanding of the uncertainties throughout the modelling chain and the incorporation of novel data into the forecasting algorithms. A third area is representation, communication, and use of these uncertainties to industry in forms that readily support decision-making in plant operations and electricity markets. This Task will facilitate coordination of efforts in all three of these areas and will work to define best practices for model evaluation and uncertainty communication.

This proposed Task supports central objectives of IEA Wind. The Strategic Plan recently released by the IEA Wind ExCo [1] includes four strategic objectives, two of which are directly supported by the proposed Task: "To reduce the cost of wind energy use, for both land-based and offshore wind" and "Increase the exchange of best practices." Further, two of the five priority areas to address these objectives in the Strategic Plan are "Wind Characteristics" and "Wind Integration", both of which this Task will facilitate. The IEA Wind statement of research needs for the time frame 2012–2030 [2], highlights short term forecasting, for both wind and power, as a mid-term priority. It highlights atmospheric complex flow modeling and experimentation, which supports the improvement of short-term forecasting, as a long-term (through 2030) priority.

Task 36 will collaborate with several other Tasks. In 2018, Task 36 had a common meeting with Task 32 Lidars, looking into minute scale forecasts [4], and we will continue that collaboration. Since the beginning, we discussed collaboration with Task 31 WindBench, and for subtasks 2.3 and 2.4 we should take their developments into account. The work on the value of forecasts (subtask 3.3) should be coordinated with Task 26 Cost of Wind, and we will investigate common themes with Task 25 Integration. At the same time, we envisage a stronger collaboration with IEA PVPS Task 14 on High Penetration of PV, as forecasting for all renewables share significant commonalities in approach and impact.

The three work streams from the first phase are essentially being transferred to the new phase. The work packages are largely connected to the stakeholders in the process working on it. WP1 is mainly for meteorologists, WP2 for power forecasters from academia and forecast vendors, and WP3 collects the view of the end users. The improvement of the representation of underlying physics is recognized by the IEA as being a long-term challenge, and the first work stream will focus on accelerating progress by enhancing communication and coordination among international groups working in this area. The second work stream will focus on coordinating, and standardizing where possible, the various approaches to establishing and expressing errors and uncertainties for wind and power forecasts for both physical and statistical models. It will also include the provision of benchmarks for testing forecast performance on various geographic and climatic areas. The third work package will engage both research and the wind related industry to develop recommendations for representations of probabilistic forecast information that are most useful for the operational environment. It will further shed light on how to use probabilistic forecasts in wind energy, and what the value of improved forecasts and forecast use can be.

The expected outcomes of this Task are increased efficiency of international research efforts to improve wind and power forecasting together with publications documenting best practices for assessing forecast model performance, the quantification and representation of uncertainties, and the communication and use of probabilistic information to industry.

2 Introduction

Forecasting the chaotic behavior of the atmosphere remains a primary challenge of the atmospheric sciences. Because atmospheric motions occur on scales ranging from 1 mm to 10^4 km (10 orders of magnitude), it is not feasible to explicitly forecast the evolution of the atmosphere at all scales at once. Consequently, prognostic numerical models generally resolve a range of scales encompassing the phenomena of interest, and the smaller scales are parameterized. For mesoscale atmospheric models, which are not only used for general weather forecasts but also to provide short-term wind forecasts, parameterizations are used to represent processes occurring on horizontal scales less than the 1–10 km grid spacing explicitly resolved by the models. These parameterizations reflect assumptions about which physical processes are dominant on the unresolved scales and generally have constants that may be adjusted according to observations. It is thus possible to ”tune” physical models of the atmosphere to optimally reproduce a phenomenon of particular interest (such as movement of weather fronts and associated precipitation) while less optimally reproducing other phenomena (such as winds at 100 m above the surface). In addition, mesoscale models often offer multiple parameterizations for a particular process, each reflecting a different concept of which unresolved processes are dominant, which allows the modeler to choose which specific set of parameterizations to use. Finally, to create a forecast, a model must be initialized with observations, and the combination of observation errors, initialization error and the highly non-linear governing equations of the models leads to additional error in the forecasts.

General challenges to modeling for wind resource characterization, including wind forecasting, have been described in numerous venues, including an international workshop sponsored by the U.S. Department of Energy (USDOE) on Research Needs for Wind Resource Characterization held in the U.S. in 2008 [5]. A subsequent USDOE workshop on Complex Flow focused more specifically on conditions of particular complexity for wind energy, such as complex terrain, low-level jets, and others [6]. This workshop identified several key knowledge gaps with respect to mesoscale modeling for complex flows. These include in particular for forecasting:

- Lack of full understanding of flow physics, including effects of stability and heterogeneous or topographically severe land surfaces, and intermittent mixing processes
- Insufficient data for validation or verification

There are several recent and planned field studies that are intended to fill some of the data gaps and thus assist in improving the physics of wind forecast models. In the U.S., the Wind Forecast Improvement Project 1 (WFIP 1) [7] used enhanced observation networks to evaluate the impact of improved initializations on wind and power forecasts over a full annual cycle. A second WFIP started in early 2015 using enhanced networks of instrumentation to validate and improve the underlying physics of wind forecast models in complex terrain. The New European Wind Atlas (NEWA) project was launched in March 2015 to develop a mesoscale to microscale model-chain validated with large field experiments in various terrain and wind climate conditions. As validation datasets become available from these experiments they will be used for international benchmarking in both IEA Task 31 Windbench and this forecasting Task. While these and other contemporary large studies provide a wealth of data with which to evaluate and improve models, the approach for doing this tends to be ad hoc with respect to each field study. These studies represent major national investments, and there is both an opportunity and a need to better structure and facilitate collaboration among international research groups in order to promote common approaches and metrics for evaluating and improving the performance of wind forecast models.

One of the conclusions of the "Forecasting Techniques" TEM [3] was that, while forecasting is a critical component of large-scale integration of wind energy into the grid, it does not have full value unless accompanied by information describing the uncertainties in the forecast. There are a variety of techniques for creating forecasts with associated uncertainties. These include generating ensembles of forecast model runs, uncertainty quantification using analog ensembles, purely statistical approaches, and various combinations of statistical and deterministic approaches. Determining the uncertainty associated with wind power forecasting is rather more involved than for wind forecasts, since wind power forecast models typically require not only the input from numerical weather prediction (NWP) models, but also local meteorological observations and supervisory control and data acquisition (SCADA) data.
The TEM report also noted that probabilistic information greatly increases the value of a forecast for risk management, generator scheduling, and dispatch and electrical markets.

The Complex Flow Workshop Report [6] characterized uncertainty quantification for mesoscale modeling as currently "*immature*." The Forecasting Techniques TEM [3] noted that in conjunction with the probabilistic wind power forecasts, "*the identification of standardized methodologies to evaluate forecast performance is needed.*" Evaluation of the uncertainties associated with forecasts ultimately requires data, and there is a significant opportunity for synergy with the efforts to improve fundamental physics in atmospheric models and the associated large-scale field studies. The standardization of evaluation of forecast performance will be an effective input into the design of these studies.

For both wind and power forecasts, there is general agreement that knowing the uncertainties is important. At the same time, there is no general understanding of what to do with the information or in what form it would be most useful. There is currently a spectrum of forecast uncertainty information that can be provided, ranging from simple means and standard deviations through additional statistical moments such as skewness or kurtosis, through quantile information and up to full distributions and scenarios. During the first phase we wrote a paper showing many use cases for probabilistic forecasts [10]. In Phase II, this activity will continue with increased interest of the industry (as shown on the last ESIG Forecasting Workshop).

3 Objectives and Expected Results

This Task will focus on facilitating communication and collaborations among international research groups engaged in the improvement of the accuracy of forecast models and their utility to the wind industry. This Task has the following specific objectives:

- To establish an active, open forum for sharing knowledge gained from field experiments, tower and remote sensing data in the atmospheric boundary layer, and

associated advances in understanding fundamental atmospheric physics to create more accurate forecast models and associated uncertainties.
- To establish standards and frameworks for the operation and evaluation of forecast model performance
- To identify paths to increased application of forecast information to the wind industry
- To identify most promising areas for new research to improve the quality of forecasts
- To provide guidelines for the implementation of forecasting solutions

It is anticipated that outcomes from this Task could include

- Increased international collaboration and transfer of knowledge regarding improvement of forecast models for the wind industry
- A generally accepted framework for the implementation, operation and evaluation of forecast models and solutions
- Guidelines for the calculation and evaluation of uncertainties in forecast models
- Guidelines for the requirements of instrumentation and measurement data for forecasting models and solutions
- Development of a general framework for the quantitative use of forecast uncertainties by the wind industry
- Special sessions in conferences or dedicated workshops
- Webinars and other outreach to inform the industry of advances in forecasting

4 Approach and Methodologies

The activities for this IEA Task are divided among three topical work packages (WPs). Additionally, Management of the Task is in its own work package. The four WPs are synergistic and will be executed simultaneously. All four WPs run throughout the whole Task period (M1-M36).

WP 0: Management, coordination and dissemination (Lead: Gregor Giebel/DTU)

A Task web site will be maintained that will provide current information regarding this Task, provide a calendar of meetings and other significant activities, host downloadable documents produced under this Task, and provide links and contact information for key datasets. The smooth operation of the Task (meetings, mailing list, …) is also part of this WP. The meetings will often be in conjunction with relevant conferences, where we will try to organize a special session. The Task will also aim at disseminating the knowledge in form of webinars. Where possible or applicable, the workshops will be streamed to e.g. the IEA Wind Forecasting YouTube channel.

Subtasks:
- Subtask 0.1: Maintaining external and internal Task web site.
- Subtask 0.2: Contractual reporting
- Subtask 0.3: Final report
- Subtask 0.4: Dissemination and Communication
- Subtask 0.5: Education

Deliverables:

- D 0.1: Website
- D 0.2 – 0.4: Annual reports
- D 0.5: Organization of two meetings per year
- D 0.6: Organization of meetings and special sessions at international conferences on wind energy
- D 0.7: Webinars to inform users about major Task outcomes
- D 0.8: Reference repository for short-term prediction literature.

WP 1: Global Coordination in Forecast Model Improvement (Lead: Helmut Frank/DWD, and Will Shaw/PNNL)

This WP brings together global leaders in NWP models as applied to the wind industry to exchange information and recommendations where to improve both the physics of these models and data assimilation methods, and the influence of various data types, such as data from drones, masts, lidars, sodars and turbines in data-sparse areas, e.g. offshore for wind energy forecasting. The emphasis will be on improvements of the wind-related forecast performance of these models especially in typical rotor heights, say, 50 to 200 m above ground, i.e., in the planetary boundary layer (PBL) beyond the surface layer. In this height range the effects of changing stability, complex terrain, air-sea interaction, and the influence of the surface and phenomena such as low-level jets still are only poorly modelled. Smaller hub heights of 30-40 m will also be considered due to their relevance in distributed wind energy systems, which are commonly installed on residential, agricultural, commercial, industrial, and community sites, and can range in size from a 5-kilowatt turbine at home to multi-megawatt turbines at a manufacturing facility [11]. Forecasting time horizons of 0-3 hours, 3-12 hours, day ahead, 2 weeks ahead, and seasonal are the relevant time scales for the power system, and will be the focus of separate investigations. This can include artificial intelligence techniques or Rapid Update Cycles. To support the development and evaluation of statistical models, the task will also explore the development of access to streaming as well as static data.
This WP primarily facilitates communication and efficient application of resources in the global wind forecast community via a set of specific Tasks. An annual summary describes current and developing field measurement campaigns that collect data suitable for testing data assimilation techniques and model physics. Both the existence of various data sets and their conditions of access will be documented. This will also serve as one path to alert investigators to opportunities for participation in these studies. This Task might lead to increased data sharing, hopefully also with industry-owned data, especially power data for verification or data assimilation.

Subtasks:

- Subtask 1.1: Compile list of available wind data sets, especially from near the hub height of modern turbines (>100m a.g.l.).
- Subtask 1.2: Annual reports documenting and announcing field measurement programs and availability of data. Ensure usable data description.
- Subtask 1.3: Verify and Validate the improvements through one or more common data sets to test model results upon and discuss at IEA Task meetings
- Subtask 1.4: Work closely together with the international modeling centers to include energy forecast metrics in NWP model upgrades.

Deliverables:

- D 1.1: Annual summary of major field studies supportive of wind forecast improvement; list of available data

- D 1.2: Common benchmark for V&V: definition, release and analysis of results as a paper
- D 1.3: Report on future issues for research in wind power prediction

WP 2: Power and Uncertainty Forecasting (Lead: Caroline Draxl/NREL + Pierre Pinson/DTU)

This second work package will review the state-of-the-art for the tools for power conversion from the wind speed forecast, and for error and uncertainty quantification for wind and wind power forecasting models, with a special emphasis on the underlying NWP forecasts. This activity will further engage both NWP and field measurement researchers to develop guidelines, best practices, and perhaps standards, for evaluating forecast uncertainties. Following recent activities in the organization of forecast competitions and benchmarking exercises [8], an aim here will be to extend the current set of publically released benchmark cases for researchers, students and practitioners to have easy and direct possibility to benchmark their approach vs. the existing. This will also encourage replication studies. For this to be successful, datasets should be complemented by a clear description of the experimental setup for all these cases (e.g., data description, period to use for genuine forecast verification, etc.).
Phase 1 wrote an IEA Recommended Practice in three parts on Forecast Solution Selection [12,13], describing the selection of a new or another forecast provider, the execution of a forecasting trial, and the benchmarking metrics used to distinguish forecast quality. Phase II will collect the first experiences with the Recommended Practice, and update the documents with the learnings.
Besides, of particular interest is the collection of probabilistic forecast datasets to be able to establish best practices for probabilistic forecast evaluation. There exist a number of mathematically sound proposals for the evaluation of such forecasts, but this does not appear to be accepted and considered broadly by forecasters and forecaster users. The evaluation of forecast uncertainties will also engage the international community of wind power forecasters to relate protocols for evaluating NWP uncertainties to those derived for full wind power forecast models. This can include a decomposition approach to understand how known uncertainties propagate through the modelling efforts into the power forecast, and their ultimate effects. Validation targets should include ramp events, storms, and weather windows for installation, operation and maintenance, mainly offshore.
For the forecast vendors and end users alike, a common data format and possibly an open-source reference implementation would streamline the process of both, conducting trials and changing the forecast vendor. This would increase the competition between forecasters, but also lower the effort on both sides. Therefore, we will analyse current data transfer standards like the IEC 61850 series on SCADA communication and their wind power brethren, 61400-25, but also look to IEA Windbench and other de-facto standards.

Subtasks:

- Subtask 2.1: Update of the IEA Recommended Practice on Forecast Solution Selection, including benchmarking.
- Subtask 2.2: Uncovering uncertainty origins and development through the whole modelling chain.
- Subtask 2.3: Set-up and dissemination of benchmark test cases and data sets
- Subtask 2.4: Collaboration on standardisation with IEC, discussion of standardisation needs for forecast vendor / user interaction

Deliverables:

- D 2.1: Second version of IEA Recommended Practices on Forecast Solution Selection, for both deterministic and probabilistic forecasts
- D 2.2 Review of uncertainty propagation in short-term forecasting models.
- D 2.3: Collection and release of forecast cases for benchmarking and replication studies. Review of forecast competition results and learnings.
- D2.4: Pre-standardisation document (IEA Recommended Practice or IEC New Work Item Proposal) on data transfer for wind power forecasting.

WP 3: Optimal Use of Forecasting Solutions (Lead: George Kariniotakis/ParisTech, Corinna Möhrlen/WEPROG + industry/end user)

The third WP will survey the current state of use of forecasting solutions by the power systems sector and generate general recommendations for the optimal use of forecasting solutions in the real-time environments, requirements of measurement data and how to select the right methodology for a given forecasting task. It will engage both actors of the wind industry and the research communities to identify how current and emerging capabilities to determine forecast methodologies that can be used to address the variety of decision-support needs of the industry. Where useful, simple indicators of forecast quality for respective methodologies will be developed. This WP will also provide outreach to users of forecasts via webinars or other means to enhance their knowledge and ability to use all available information for operations.
An important driver for improving forecast methodologies is the added value for the forecast user. The value for different stakeholders (TSO, DSO, balance responsible or the producer) will depend on the specific market design. A subtask of this WP will therefore focus on evaluating the value of forecast, and the options for added value by using probabilistic forecasts in different market setups. The value will be assessed by developing a market and forecast simulation, with input from realised and forecasted wind generation and market prices. The platform will give quantitative insights on the value created for different stakeholders with more accurate forecasting and application in day-ahead and balancing markets. Additional applications in e.g. ancillary service markets will be assessed qualitatively.
State of the art wind power forecasting methodologies utilise, besides wind speeds from weather forecasts, onsite real-time power measurements from SCADA systems and meteorological measurements from met masts or alternatives thereof to compute wind power. The combined use of the trend of the forecast and measured meteorological variables is the state-of-the-art method to be able to predict wind power in the next few hours, as well as high speed shut-down and critical ramping events. This explains the need for high quality measurements, even though similar considerations are applicable in the management of dispatch, i.e. ranging down to cover also lower wind speeds. Today, there are no standards or guidelines on the quality requirements for instrumentation or on the type of instrumentation itself that would help system operators to develop their grid codes. The IEC 61400-12 standard, guidelines from MEASNET and some recommended practices from IEA Wind Tasks are applicable only in resource assessments. The US environmental protection agency (EPA) provides a "Meteorological Monitoring Guidance for Regulatory modelling Applications", which is a guideline on the collection of meteorological data for use in regulatory modelling applications such as air quality. All these guidelines and standards provide recommendations for instrument, measurement and reporting for all main meteorological variables. However, only the EPA guidelines deal with real-time usage, but only for meteorological modelling. These guidelines and practices need to be studied and adjusted for the real-time usage in the power industry and specific guidelines or recommended practices developed for the real-time environment.

Tasks:

- Task 3.1: Use of forecasts uncertainties in the business practices (operation/management, planning of power systems, markets operation/participation) of actors in the power systems sector (TSOs, DSOs, ESCOs, traders etc).
- Task 3.2: Review of existing/proposal of best practices on how to measure/quantify the value from the use of probabilistic forecasts. Assessment of the value of probabilistic forecasts in selected market setups.
- Task 3.3: Data Requirements to be provided in the grid codes for real-time forecasting models.

Deliverables:

- D 3.1: Development of practical industry guidelines and application examples that can be used in Recommended Practices guidelines or standardization documents
- D 3.2: Recommended Practice Guideline for data and instrumentation requirements for real-time forecasting (in collaboration with Task 32)
- D.3.3: Workshop on the use of probabilistic forecasts in real-time operation
- D.3.4: Conference paper on assessment of the value of probabilistic forecasts in selected markets.
- D 3.5: A summary of emerging tools for the use of uncertainty (probabilistic) information in grid operation and related activities (e.g., stochastic system operation tools)

5 Time Schedule with Key Dates

If the ExCo accepts this proposal, Task 36 will continue for another period of three years beginning in January 2019. A kick-off meeting will be quite likely organised at the Austrian Weather Service ZAMG in Vienna, in January or February 2019.

The Task may be further extended for such additional periods as may be determined by two or more Participants, acting in the Executive Committee. Extension shall thereafter only apply to those Participants who agree to the extension.

6 Reports, Deliverables, and Dissemination of Results

Within each Work Package a number of deliverables will be elaborated to summarize the most important results. These reports/deliverables will be composed by the Operating Agents in collaboration with the work package leaders based on inputs and reviews from the participants. The planned deliverables are listed in Table 1.

Table 1: Deliverables

No.	Deliverable	Planned
D 0.1	Website	Ongoing
D 0.2	First annual progress report	M12
D 0.3	Second annual progress report	M24
D 0.4	Final report	M36
D 0.5	Biannual meetings	M1, M7, M13,

		M19, M25, M31
D 0.6	Organization of meetings and special sessions at international conferences on wind energy	M6 – M36
D 0.7	Webinars to inform users about outcomes of Task 36	M24-M36
D 0.8	Reference repository for prediction literature.	M18
D 1.1	Annual summary of major field studies supportive of wind forecast improvement; list of available data	M12, M24, M36
D 1.2	Common benchmark for V&V	M12 (release), M36 (analysis)
D 1.3	Report on Future Issues for Research in Wind and Wind Power Prediction	M30
D 2.1	IEA Recommended Practice on Forecast Solution Selection, v2	M30
D 2.2	Review of uncertainty propagation in forecasting, v1	M18
D 2.3	Collection and release of forecast cases for benchmarking and replication studies	M6
D 2.4	Data transfer standards document	M30
D 3.1	Practical industry guidelines and application document	M24
D3.2	Recommended Practice Guideline for data and instrumentation requirements in real-time forecasting	M36
D 3.3	Workshop on the use of probabilistic forecasting in operations	M9
D 3.4	Value of probabilistic forecasts paper	M30
D 3.5	Summary of tools for use of uncertainty	M15

7 Methods of Review and Evaluation of the Work Progress

The following key milestones are defined for the follow-up of the progress of the project.

Table 2: Milestones

Milestone	WP	Milestone	Planned
M 0.1	0	Kick-off Meeting	M1
M 0.2	0	Web site operational	M3
M 0.3	0	First annual progress report	M12
M 0.4	0	Second annual progress report	M24
M 0.5	0	Final report	M36
M 0.6	0	Task meeting #1	M1
M 0.7	0	Task meeting #2	M7
M 0.8	0	Task meeting #3	M13
M 0.9	0	Task meeting #4	M19
M 0.10	0	Task meeting #5	M25
M0.11	0	Task meeting #6	M31
M 1.1	1	Annual summary of field studies #1	M12
M 1.2	1	Annual summary of field studies #2	M24
M 1.3	1	Annual summary of field studies #3	M36
M 2.1	2	IEA Recommended Practice on Forecast Solution Selection v2	M30
M 2.2	2	Benchmark exercise defined; dissemination of	M12

		benchmark test cases and data sets	
M 2.3	2	Data transfer standards document	M30
M 3.1	3	Document on use cases for probabilistic forecasts	M24
M 3.2	3	Recommended Practice Guideline for data and instrumentation requirements in real-time forecasting	M36
M 3.3	3	Setup and dissemination of webinars	M33

8 Obligations and Responsibilities

It is noted that the main responsibilities of the Operating Agent are given in WP0 of section 4. All of the project partners are responsible for:

- The progress of the work in correspondence with the work program in agreement with the time schedule;
- The contributions to the project deliverables and progress reports.

9 Funding

The funding principles are summarized as follows:

- Each Participant shall bear their own costs for carrying out the scientific work, including reporting and travel expenses.
- The host country or Operating Agent shall bear the costs of workshops and meetings convened in conjunction with this Task. The Operating Agent may co-fund workshop and meeting expenses including lunch or dinner, depending on the availability of funds.
- The total costs of the Operating Agent shall be borne jointly and in equal shares by the participating countries.
- Each Participant shall transfer to the Operating Agent their annual share of the costs in accordance with a time schedule to be determined by the Participants.

The Task will be centrally managed by the Technical University of Denmark (DTU, WP0) and have three WP leaders:

- DWD (DE), to coordinate WP1,
- National Renewable Energy Laboratory of the U.S. (NREL), to coordinate WP2, and
- MINES ParisTech/ARMINES (FR), to coordinate WP3.

The WP leaders can share the function of WP lead with one or more co-lead(s).

The current Task Operating Agent is willing to continue:

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10 Budget Plan

The total costs of the Operating Agents for coordination, management, reporting, and database maintenance and operation is **54 k€/yr** during a three year period, and may not exceed this level except by unanimous agreement of the Participants. The budget is shared between the Operating Agent and the WP Leads. The transfer from the Operating Agent to the WP Leads is one lump sum per year.

Table 2. Operating Agent costs

		Euro/unit	Euro/year
Meetings, coordination work	2 PM	16.000	32.000
Reporting	0,5 PM	16.000	8.000
Travel costs	2 meetings + ExCo (OA only)	2000	10.000
Other costs	Meetings, telcos, publications, website		4.000
TOTAL			**54.000**

With the current 13 countries signed up, this means an annual participation fee of 4153€/year.

11 Management of Task

We envisage biannual meetings in connection with the two major workshops in the field, the US Energy System Integration Group (ESIG) Forecasting Workshops and the WindEurope Technology Workshop on Wind Power Forecasting, every other year in Europe. In between, an online meeting would keep track of the progress. Also, for the actual meeting, an online meeting facility will be enabled. Other conferences to attach the Task meeting to are the Wind Integration Workshop also usually held in October, the WindEurope Conference & Exhibition, the Wind Energy Science Conference, The Science of Making Torque from Wind or the International Conference on Energy Meteorology (e.g. the one June 2019 near Copenhagen).

The main form of communication in the group will be via email, and via personal contacts during various conferences including the biannual meetings.

The group of WP leaders plus the (co-)Operating Agent will meet ad-hoc online to discuss matters of Task management and direction, typically in preparation of the physical meetings.

12 Organisation

The Task will be centrally managed by DTU as a single point of contact with the IEA Wind ExCo. However, Will Shaw of Pacific Northwest National Laboratory will be internally acting as Co-Lead of the Task. The WPs will be scientifically managed by the WP leads.

Gregor Giebel - Danish Technical University (DTU) – Operating Agent
Will Shaw – Pacific Northwest National Laboratory, Co-Operating Agent and WP1 Co-Lead
Helmut Frank – DWD, WP1 Lead
Caroline Draxl – National Renewable Energy Laboratory, WP2 Lead
Pierre Pinson – DTU, WP2 Co-Lead
George Kariniotakis – MINES ParisTech/ARMINES (Centre PERSEE), WP3 Lead

Corinna Möhrlen – WEPROG, WP3 Co-Lead

The mailing list of the current phase I of Task 36 contains some 250 people. Over 100 individuals attended the Task meetings. See section 14 for an up-to-date list of the most active participants.

13 Information and Intellectual Property

(a) **Executive Committee's Powers**. The publication, distribution, handling, protection and ownership of information and intellectual property arising from activities conducted under this Annex, and rules and procedures related thereto shall be determined by the Executive Committee, acting by unanimity, in conformity with the Agreement.

(b) **Right to Publish.** Subject only to copyright restrictions, the Annex Participants shall have the right to publish all information provided to or arising from this Task except proprietary information.

(c) **Proprietary Information.** The Operating Agent and the Annex Participants shall take all necessary measures in accordance with this paragraph, the laws of their respective countries and international law to protect proprietary information provided to or arising from the Task. For the purposes of this Annex, proprietary information shall mean information of a confidential nature, such as trade secrets and know-how (for example computer programmes, design procedures and techniques, chemical composition of materials, or manufacturing methods, processes, or treatments) which is appropriately marked, provided such information:

    (1) Is not generally known or publicly available from other sources;

    (2) Has not previously been made available by the owner to others without obligation concerning its confidentiality; and

    (3) Is not already in the possession of the recipient Participant without obligation concerning its confidentiality.

It shall be the responsibility of each Participant supplying proprietary information, and of the Operating Agent for arising proprietary information, to identify the information as such and to ensure that it is appropriately marked.

(d) **Use of Confidential Information.** If a Participant has access to confidential information which would be useful to the Operating Agent in conducting studies, assessments, analyses, or evaluations, such information may be communicated to the Operating Agent but shall not become part of reports or other documentation, nor be communicated to the other Participants except as may be agreed between the Operating Agent and the Participant which supplies such information.

(e) **Acquisition of Information for the Task.** Each Participant shall inform the other Participants and the Operating Agent of the existence of information that can be of value for the Task, but which is not freely available, and the Participant shall endeavour to make the information available to the Task under reasonable conditions.

(f) **Reports on Work Performed under the Task.** Each Participant and the Operating Agent shall provide reports on all work performed under the Task and the results thereof, including studies, assessments, analyses, evaluations and other documentation, but excluding proprietary information, to the other Participants. Reports summarizing the work performed and the results thereof shall be prepared by the Operating Agent and forwarded to the Executive Committee.

(g) **Arising Inventions.** Inventions made or conceived in the course of or under the Task (arising inventions) shall be identified promptly and reported to the Operating Agent. Information regarding inventions on which patent protection is to be obtained shall not be published or publicly disclosed by the Operating Agent or the Participants until a patent application has been filed in any of the countries of the Participants, provided, however, that this restriction on publication or disclosure shall not extend beyond six months from the date of reporting the invention. It shall be the responsibility of the Operating Agent to appropriately mark Task reports that disclose inventions that have not been appropriately protected by the filing of a patent application.

(h) **Licensing of Arising Patents.** Each Participant shall have the sole right to license its government and nationals of its country designated by it to use patents and patent applications arising from the Task in its country, and the Participants shall notify the other Participants of the terms of such licences. Royalties obtained by such licensing shall be the property of the Participant.

(i) **Copyright.** The Operating Agent may take appropriate measures necessary to protect copyrightable material generated under the Task. Copyrights obtained shall be held for the benefit of the Annex Participants, provided however, that the Annex Participants may reproduce and distribute such material, but shall not publish it with a view to profit, except as otherwise directed by the Executive Committee, acting by unanimity.

(j) **Inventors and Authors.** Each Annex Participant will, without prejudice to any rights of inventors or authors under its national laws, take necessary steps to provide the co-operation from its inventors and authors required to carry out the provisions of this paragraph. Each Annex Participant will assume the responsibility to pay awards or compensation required to be paid to its employees according to the law of its country.

14 List of Participants

Table Countries and Organisations currently Participating in Task 36:

Country	Institution(s)
Austria	ZAMG
China	CEPRI, Envision, Goldwind
Denmark	DTU, DMI, ENFOR, ConWX, WEPROG, DNV GL, Energinet
Finland	VTT, FMI, Vaisala
France	MINES ParisTech / ARMINES, RTE, EDF, CNR, MeteoSwift, MetEolien, Engie Green
Germany	ForWind-Centre for Wind Energy Research, Deutscher Wetterdienst, Fraunhofer IEE, ZSW, WindForS, 4cast, Stuttgart University, Enercon

Ireland	Dublin Institute of Technology; University College Dublin
Norway	Christian Michelsen Research, Norwegian Meteorological Institute, Kjeller Vindtekknik
Portugal	INEGI, LNEG, University of Porto, INESC TEC
South Africa	CSIR
Spain	Vortex, REE, Iberdrola Renovables, EDP Renovaveis
United Kingdom	United Kingdom Meteorological Office, Strathclyde University, Reading University, UK National Grid
USA	NREL, PNNL, NOAA, NCAR, UNC Charlotte, EPRI, Meso. Inc,

15 References

[1] IEA Wind 2013. "End-of-Term Report 2009–2013 and Strategic Plan 2014–2019", 57 pp.

[2] IEA Wind 2013. "Long-Term Research and Development Needs for Wind Energy for the Time Frame 2012 to 2030", 34 pp.

[3] IEA Wind 2013. "Forecasting Techniques", Report: IEA R&D Wind Task 11—Topical Expert Meeting TEM #72, Milano (IT), 2013.

[4] Workshop results of the joint Task 32/36 workshop on minute scale forecasting, held 12/13 June 2018 at Risø, Denmark.

[5] Schreck, S, J. Lundquist, and W. Shaw, 2008: U.S. Department of Energy Workshop Report—Research needs for wind resource characterization. NREL Rep. TP-500-43521, 116 pp.

[6] U.S. DOE 2012. "Complex Flow Workshop Report." 120 pp. TEM #75

[7] Marquis, Melinda, Jim Wilczak, Mark Ahlstrom, Justin Sharp, Andrew Stern, J. Charles Smith, and Stan Calvert, 2011: Forecasting the Wind to Reach Significant Penetration Levels of Wind Energy. Bull. Amer. Meteor. Soc., 92, 1159–1171. doi: http://dx.doi.org/10.1175/2011BAMS3033.1

[8] T. Hong, P. Pinson, S. Fan (2014). Global Energy Forecasting Competition 2012. International Journal of Forecasting, 30(2), pp. 357-363. See also www.gefcom.org.

[9] Sanz Rodrigo J, Moriarty P (2015) Model Evaluation Protocol for Wind Farm Flow Models. First edition. IEA Task 31 Report to the IEA-Wind Executive Committee, June 2015

[10] R. Bessa, C. Möhrlen, V. Fundel, M. Siefert, J. Browell, S. Haglund El Gaidi, B.-M. Hodge, Ü. Cali, and G. Kariniotakis (2017): *Towards Improved Understanding of the Applicability of Uncertainty Forecasts in the Electric Power Industry*. *Energies* **2017**, *10*(9), 1402; doi:10.3390/en10091402

[11] Department of Energy, https://www.energy.gov/eere/wind/distributed-wind. Last accessed: 19 September 2018

[12] C. Möhrlen, IEA WIND RECOMMENDED PRACTICES FOR THE IMPLEMENTATION OF WIND POWER FORECASTING SOLUTIONS - Part 1: Forecast solution selection process, Proc. 17th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, Stockholm, Sweden, 2018.

[13] C. Möhrlen, J. Lerner, J. W. Messner, J. Browell, A. Tuohy, J. Zack, C. Collier, G. Giebel, IEA WIND RECOMMENDED PRACTICES FOR THE IMPLEMENTATION OF WIND POWER FORECASTING SOLUTIONS: Part 2 and 3: Designing and executing forecasting benchmarks and evaluation of forecast solutions, Proc. 17th International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants, Stockholm, Sweden, 2018.