



April 9th, 2015

Topical Expert Meeting #82 on

Uncertainty Quantification of Wind Farm Flow Models

At the IEA Wind Executive Committee meeting #73 in Newcastle it was decided to arrange a Topical Expert Meeting on "Uncertainty Quantification of Wind Farm Flow Models". Venue and date for the meeting is as follows:

*Wind Energy Campus
Gotland Department of Earth Sciences
Uppsala University Campus Gotland*

June 12th in Visby

This meeting is jointly organized in coordination with the kick-off meeting of the second phase of Task 31 Wakebench and the Wake Conference 2015, all in the same venue. Participants to the TEM are cordially invited to join attend the Wake Conference 2015. Registration is required here: (<http://space.hgo.se/WakeConferenceGotland2015>)

In order to give the meeting background and aim, an introductory note is attached to this letter. Participants in the meeting are requested to give a short and informal presentation of results from ongoing research/experiences and future plans.

Proceedings from the meeting will be distributed to members of Task 11 soon after the symposium. To assist in this, the participants are urged to bring along one copy of the material they want to have included in the documentation, preferably in digital format.

The host for the meeting is Uppsala University Campus Gotland, Section for Wind Energy. Details on travel and accommodation can be found below. The local contact is: Stefan Ivanell, *Associate Professor, Head of Section*.

Questions regarding content and the agenda will be answered by myself on Tel +34 914175042 or e-mail favia@cener.com.

Please forward an invitation to 2-4 people from your country who will be able to discuss the subject in detail and inform me and Cristina San Bruno (csanbruno@cener.com) with copy to Stefan Ivanell (stefan.ivanell@geo.uu.se) and Javier Sanz (jsrodrigo@cener.com) of the participants you would like to send to the symposium.

Best regards,



INTERNATIONAL ENERGY AGENCY
**Implementing Agreement for Co-operation in the Research,
Development and Deployment of Wind Turbine Systems Task 11**

Felix Avia (CENER - Operating Agent Task 11)



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Attachments:

1. IEA Background and Meeting Format.
2. Practical arrangements.
3. Introductory Note.



1 IEA WIND BACKGROUND AND MEETING FORMAT

The objective of IEA Wind Task 11 is to promote wind turbine technology through cooperative activities and information exchange on RD&D topics of common interest. See the following Web page for more details: http://www.ieawind.org/Task_11/task_11_homepage.html and click on "General description and meeting format". More information can be obtained from:

- IEA Wind Home Page www.ieawind.org
- Annex XI information http://www.ieawind.org/annual_reports_PDF/2013/Task11.pdf

Meeting format

The meetings are of the workshop type, where information is presented and discussed in an open manner. The participants decide by themselves what they would like to present. Guidance for presentations is given in the Introductory Note that is distributed together with the invitation to the meeting. This implies that there is no list of presentations in advance.

Usually the meetings cover two days. However due to the fact that this meeting is jointly organized in coordination with the kick-off meeting of the second phase of Task 31 Wakebench, this meeting will cover only one day.

Oral presentation is expected from all participants. The allocated time is 15-25 minutes including questions and discussion. However, the time is dependent on the number of presentations.

The agenda usually covers the following items:

1. *Collecting proposals for presentations*
2. *Introduction (Host and Operating Agent). Recognition of Participants*
3. *Presentation of Introductory Note*
4. *Individual presentations*
5. *Discussion*
6. *Summary of meeting*

Documentation

Proceedings will be prepared soon after the meeting. To assist in this, the participants are urged to bring along one copy (preferably in digital format) of the material they want to have included in the documentation. A summary of the meeting will be written by the host or persons involved in the preparation of the Introductory Note.

Miscellaneous

For presentation purposes a computer and beamer will be available. Please bring your presentation on a memory stick or CD.

2 PRACTICAL ARRANGEMENTS – TEM MEETING 2015-06-12

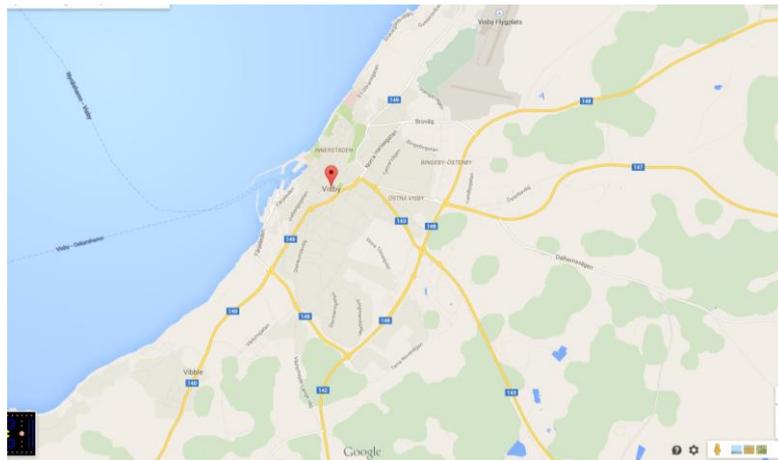
Date and venue

Date: Friday 12th of June 2015

Venue:

Uppsala University Campus Gotland
Cramérgatan 3, 621 57
Visby
Sweden
Phone +46 0498-10 82 00

The Gotland Campus of Uppsala University is located near the port and is only a few hundred meters from the beach and Visby's historic ring wall!



Campus Gotland is located on the island of Gotland in the World Heritage city of Visby, close to Stockholm and other Baltic Sea countries.

A unique and stimulating learning environment is awaiting you in the heart of the Baltic Sea region!

To learn more about Uppsala University Campus Gotland read [here](#) and to learn more about the tourist activities on Gotland read [here](#).

Hotel accommodation and travel

You can find information about lodging and travel for the event on the 2015 Wake Conference's [lodging and travel page](#). The Wake Conference takes place three days directly before the meeting. Please note that the reservation number on the web page is for the conference dates. However, if you will attend both conference and TEM meeting you can extend the reservation.

3 **INTRODUCTORY NOTE.**

Background

As wind energy computational models become more advanced to support engineering practice it also becomes more difficult to determine the confidence levels of their predictions. Uncertainty quantification (UQ) deals with the characterization of the impact of system inaccuracies on the final quality of interest. These inaccuracies come from lack of knowledge associated to the physical processes of the measurement or modeling system. Uncertainty on wind energy systems is also greatly influenced by the inherent variability of the driving boundary conditions.

This Topical Expert Meeting (TEM) on “Uncertainty Quantification of Wind Farm Flow Models” originates from the growing interest that the topic has recently experienced in various wind energy forums.

The IEA-Wind has several research Tasks related to model evaluation at various sub-system levels: rotor aerodynamics (**Task 29 MexNext**), offshore platforms (**Task 30 OC5**) and external wind conditions (**Task 31 Wakebench**). These Tasks have developed methodologies for model verification and validation and conducted a series of model intercomparison benchmarking exercises to compare models against each other and versus observational data. While systematic validation is essential to determine the level of confidence of the simulation tools, the ultimate goal of the evaluation process is to quantify the associated uncertainties, since these determine the impact of model inaccuracies on the wind energy system performance.

New IEA Tasks on wind forecasting and wind energy systems engineering are also being formulated with uncertainty assessment

The **IEC 61400-15** group is developing a standard for wind resource assessment, energy yield and site suitability that includes a large subgroup on the characterization of uncertainties of wind farm design drivers. Uncertainty in wind farm development is related to project risk assessment and financial cost. A survey conducted for the last AWEA Wind Resource Assessment Seminar (Orlando, December 2014), among various top consultants in North America, showed that uncertainty estimates based on current engineering uncertainty assessment methods are not correlated to the actual deviations observed on project performance. A debate is open on whether these traditional methodologies can be used in connection to project risk assessment or if there is a need for a more rigorous uncertainty quantification methodology.

The New European Wind Atlas project (NEWA) project (2015-2020) will develop a probabilistic wind atlas methodology to characterize not only the most probable wind resource over Europe but also the associated uncertainty. New models for downscaling the wind resource from

mesoscale to microscale will be thoroughly validated with high-fidelity experimental campaigns across Europe. This new technology shall reduce resource characterization uncertainties below 3% for flat homogeneous terrain and below 10% in complex terrain.

The Atmosphere to Electrons (A2e) research initiative (2015-2021) from the U.S. Department of Energy aims at significant reductions of the cost of energy (up to 20%) by improving the understanding of the complex physics governing the wind flow into and within wind farms. The link between performance uncertainty, financial risk and levelized cost of energy will allow a comprehensive assessment of the impact of research on the wind industry.

This TEM is organized together with the kick-off meeting of the second phase of Task 31 Wakebench in order to map the knowledge that the wind energy sector currently has on UQ applied to wind farm flow models. The definition of a UQ flow modeling framework is a new work package of Task 31. This will be incorporated in the second edition of the Wakebench Model Evaluation Protocol (Sanz Rodrigo and Moriarty, 2015).

A rigorous method for UQ is lacking in general in the wind energy community. Disparate physical scales and modeling communities make this task challenging. Nevertheless, this is an essential step to make wind energy more competitive in terms of project financing compared to conventional energy sources.

Flow Modeling Uncertainties in Wind Resource Assessment

In wind resource assessment practice, UQ is typically quantified in terms of the p_x percentiles (p_{50} , p_{75} , p_{90} are often used) or exceedance probabilities of the wind farm's annual energy production (AEP), as part of the project risk assessment during wind farm planning and financing. Hale (2015) provides a couple of examples on the financial impact of uncertainty: for a 200 MW project, a 3% difference on the AEP P_{50} means \$17MM difference in the net project value; a 1.5% difference on P_{95} results in \$1.5MM difference on the net project value. The flow model can be a large contributor to this uncertainty especially in complex terrain and large wind farm arrays.

Typical sources of flow modeling uncertainty are:

- Natural variability of the flow model inputs: wind speed, wind direction, wind rose, turbulence intensity, stability, seasonal effects, vegetation, waves etc
- Lack of user consistency on model implementation: different interpretation of model inputs, lack of standardized quality-check on measurements, meshing strategy, etc
- Lack of good characterization of input data and their variability: topographic description, limited and uncertain onsite measurements, idealized wind turbine specifications, etc
- Input dependent model "parameters" typically in connection to turbulence models
- Lack of adequacy of the flow model: too drastic assumptions in order to produce simulations in a reasonable time, etc.

- Lack of numerical convergence due to too short simulation time, instability of the turbulence model used etc.
- Too high numerical dissipation due to too coarse grids

These uncertainties are broadly classified as aleatoric (statistical) and epistemic (systematic). Aleatoric uncertainty related to the physical variability of the system cannot be reduced but needs to be characterized in order to be properly quantified. UQ intends to deal with epistemic uncertainties and aleatoric uncertainties using statistical techniques to characterize the probability distributions that govern the uncertainty process.

Objectives

The primary goals of this TEM are:

- To gather experts on UQ working in the wind energy field
- To identify state-of-the-art UQ techniques that can be reasonably applied to wind farm flow models in engineering practice
- To discuss potential challenges in the implementation of UQ methods
- To outline a work plan for IEA Task 31 to develop a UQ framework

Intended Audience

While the TEM is focused on wind farm flow models, since this is the topic of Task 31, the meeting is open to experts on uncertainty quantification in general. Wind industry practitioners of UQ are especially encouraged to participate in order to inform about current practices, limitations and impact on real life projects. Researchers are welcome to propose UQ methodologies and data needs.

References

Hale E (2015) The Uncertainty of Uncertainty. 2015 Wind Energy Systems Engineering Workshop, University of Colorado Boulder, Colorado, January 2015.

Sanz Rodrigo J, Moriarty P (2015) Model Evaluation Protocol for Wind Farm Flow Models. Deliverable of IEA-Task 31