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

Task 31 Extension Proposal

WAKEBENCH: VV&UQ of wind farm flow models

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1 Scope

The purpose of this 2nd Phase of Task 31 "WAKEBENCH" is to improve wind farm modeling techniques and provide a forum for industrial, governmental and academic partners to develop, evaluate and improve wind farm models. While Task 31 Phase 1 has been so far limited to the wind farm (microscale) scale, this phase 2 will **extend the scope to mesoscale and near-wake modeling** in order to cover all the relevant atmospheric scales related to wind power meteorology. This will allow a more comprehensive approach to the wind farm integrated design process, facilitating the exchange of knowledge among various research communities: meteorologists, resource/site wind engineers and wind farm/rotor aerodynamicists. The **focus will still be placed on wind resource/site assessment and wind farm design** but also allowing for a larger variety of modeling approaches. Some benchmarks will also be explored in finer detail to better quantify the uncertainty of a range of models for different phenomena.

Following Task 31 working procedures, the work will be organized around model intercomparison benchmarks, established around well-defined test cases from research and industrial measurement campaigns. The model verification and validation framework established in Task 31 will be adopted and extended to account for the new modeling approaches. Furthermore, uncertainty quantification on wind assessment will be also considered as the final outcome of the model evaluation process. As a result **a framework for model verification, validation and uncertainty quantification (VV&UQ) will be defined** as a new edition of the Model Evaluation Protocol (MEP) delivered in Task 31 and integrated in the windbench.net web portal (Sanz Rodrigo and Moriarty, 2014).

The new phase of the Task is **timely** not only to keep continuity on the activities of Task 31 but also to coincide with large research projects taking place in the next 5 years in Europe (ERA-Net Plus on the New European Wind Atlas, NEWA) and the USA (Atmosphere to Electrons, A2e) with focus on multi-scale model-chain development through high-fidelity experiments. It is expected that these projects will complement each other and will make use of the IEA framework to exchange knowledge and disseminate results to the international community. These projects will also **secure a substantial part of the necessary resources** to carry out the technical work described in this proposal.

From an industry perspective it is worth mentioning that this Task will contribute to the pre-normative activities carried out in the context of the **IEC-61400-15** working group dealing with "Assessment of site specific wind conditions for wind power stations", that has been initiated in 2014.

It is also a good opportunity to enhance **cross-Task collaboration** with neighboring groups like Task 29, dealing with rotor aerodynamics, and Task 32 dealing with Lidar measurements. The Operating Agents of these two Tasks have contributed to the setting up of this proposal in order to make this collaboration effective and compatible with their actual work plans.

2 Introduction

Wind power meteorology is building the bridge between engineering models and atmospheric science. State-of-the-art wind resource assessment and wind farm design techniques are related to the characterization of: large-scale climatology, mesoscale meteorological processes, microscale terrain and wind farm array effects and wind turbine aerodynamics (Schreck et al., 2008). The spatio-temporal scales range from hundreds of kilometers to meters and from decades to milliseconds. Due to the large span of the system, these four topics have been traditionally analyzed separately and this has given rise to different independent research communities (meteorologists, wind engineers, aerodynamicists). As a result, a wide variety of models are developed by each specialized group with little interaction with the neighboring communities.

Current wind energy models often lead to overprediction of wind plant performance leading to high uncertainties and important financial losses in the wind industry. This requires more accurate understanding of the physical processes in wind farms and **better models for industry to quantify and mitigate risks in wind turbine siting**.

The next generation of wind energy models will necessarily look for an **integrated approach** that can produce a more comprehensive characterization of the modelling system. This interdisciplinary integrated approach will lead to better understanding of the physical response of wind turbines and therefore, **more opportunities for design optimization and cost-of-energy reduction**. Nevertheless, building the bridge between the spatio-temporal scales of the different stages of the model chain is a challenging task for various reasons: need of cross-cutting knowledge across a wide range of atmospheric and engineering sciences, interfacing of models that have been developed separately, large computational resources required and lack of high-quality experimental data that can span all the relevant scales in order to validate the downscaling process and quantify uncertainties.

The standard practice in wind farm siting is to make use of built-to-purpose **wind resource methodologies** like WAsP, based on a linearized flow model, available since the late 1980's with the appearance of the European Wind Atlas (Troen and Petersen, 1989). The alternative to linearized models is to simulate with (non-linear) computational fluid dynamic (CFD) models adapted to atmospheric flows. The application of CFD in wind resource assessment is still largely based on Reynolds-averaged Navier Stokes (RANS) turbulence models (Palma et al., 2008) since large-eddy simulation (LES) still remains far more costly (Bechmann and Sørensen, 2010). In non-homogeneous terrain, surface-layer models in neutral conditions are typical choices. However, as wind turbines get larger, such a micro-scale approach needs to adopt atmospheric boundary layer models, which account for the vertical structure of turbulence up to the geostrophic wind including thermal stratification (or atmospheric **stability**) effects. This is especially relevant in offshore, coastal or mountainous terrain (Sanz Rodrigo, 2011). Atmospheric stability is progressively becoming the third dimension of the wind climate, besides wind speed and direction, to have a better characterization of the incoming turbulence and wind shear and its impact on turbine performance and array efficiency.

Wind farm **wake models** also range in complexity depending on the level of detail of rotor and flow physics, from algebraic actuator-disk to full-rotor CFD models. While array efficiency models are heavily focused on reproducing the far-wake at downwind distances of 5D or more, there is increasing interest on introducing better modeling of the transition and near wake regions where rotor aerodynamics are important. This is not only to improve array efficiency predictions but also to gain access to reliable wind turbine loading data that can be additionally used in the wind farm design process (Réthoré et al., 2013).

Alternatively to this bottom-up approach from microscale models, the meteorological community has adopted a top-down approach using **mesoscale models** (Hahman et al, 2014). These models are driven by global data assimilation models that by dynamic downscaling can resolve the scales of motion of the atmosphere to spatial resolutions of the order of a few kilometers. Regional wind maps are typical products of these methods, useful for initial spatial planning but not detailed enough for site assessment purposes. Simulating mesoscale effects of wind farms is also gaining attention specially in the offshore environment where large wind farms are developed and wake effects in stable conditions can propagate over long distances (Fitch et al., 2013).

Advances in high performance computing (HPC) enables numerical exploration of the terra-incognita that links mesoscale and microscale scales (Wyngaard, 2004). LES-based **multi-scale atmospheric models** can resolve turbulence scales down to resolutions of a few meters, integrating mesoscale to wind farm aerodynamics in a physically consistent modeling framework (Gopalan et al., 2013). The overlapping of bottom-up and top-down approaches, using dynamic or statistical methods, is a very active field of research not only for the wind energy sector but also for the wider atmospheric science community.

The objective of this Task is to develop a **VV&UQ framework** that will support a sustained improvement of wind farm models (Figure 1). This continuous evaluation process implies the simulation of as many test cases as possible in order to gain confidence and credibility on the model results towards the intended use of the model and its range of applicability. A building-block approach will progressively validate the model by adding increasing levels of geometrical and physical complexity (AIAA, 1998). This hierarchical process requires that the simulation and experimental data share the same or similar hypothesis in order to systematically analyze the results in a consistent way. Hence, a combination of theoretical, laboratory (wind tunnel) and field experiments are combined to validate the wind farm system by a division into a number of subsystem and unitary problems. Fit-to-purpose validation (error) metrics for each benchmark are defined in order to quantify model performance on a set of variables of interest (e.g. mean wind speed, turbulence intensity, etc). The uncertainty quantification (UQ) process will integrate these metrics in a probabilistic model considering the relevant range of wind climate and wind farm operating conditions and their associated uncertainty.

In wind resource assessment practice, UQ is typically quantified in terms of the p_{xx} 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. The flow model can be a large contributor to this uncertainty but not the only one. Other sources like the interannual variability of the wind resource, turbine power performance or wind farm availability losses during operation and maintenance can also be large contributors to the AEP uncertainties. This task will mainly deal with flow-modeling UQ in order to have a more focused discussion around model performance and experimental data quality. Nevertheless, the UQ statistical model shall be formulated in a generalized way in order to quantify other sources of uncertainty as well.

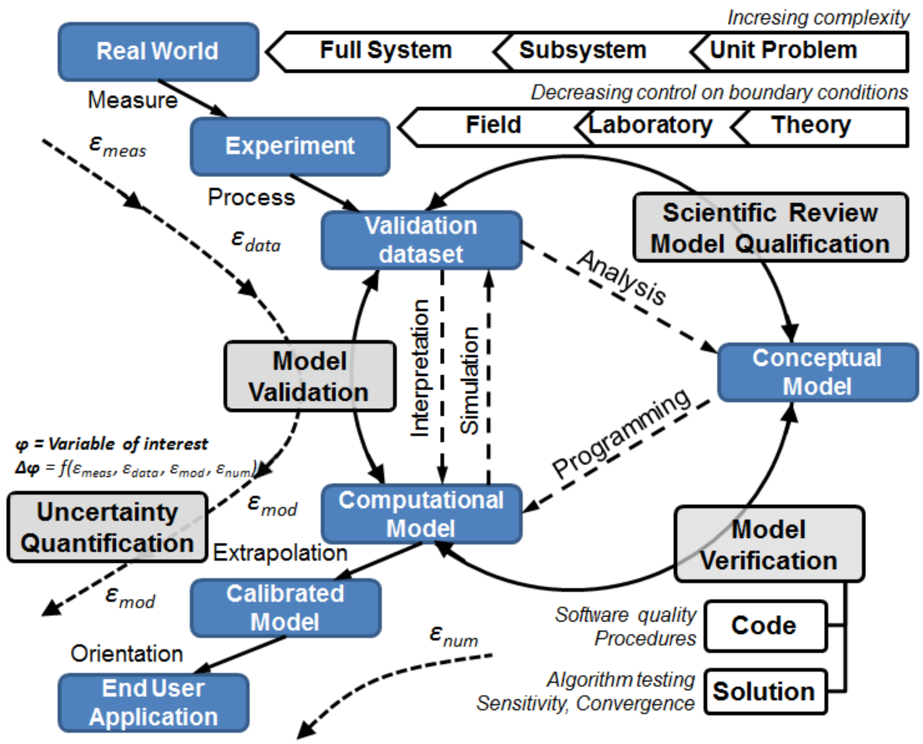

Figure 1: Workflow of the VV&UQ framework as defined in the Wakebench Model Evaluation Protocol (MEP) (Sanz Rodrigo and Moriarty, 2014)

The model evaluation process is at best only as good as the **experimental data** it is based upon. As models become more complex in their physical implementation they also become more demanding in terms of experimental data quality and quantity. High fidelity field research experiments are very costly and do not necessarily address the full complexity of the target modeling system. Hence, it is necessary to complement this deficit with laboratory and site measurements that cover the range of climatic, topographical and operational conditions of wind farms. While research programs like NEWA or A2e will carry out large high fidelity experiments, it is necessary that the wind industry commits to provide site measurements from their wind resource and wind farm operation campaigns. Based on the experiences along the first three years of Task 31, data provision and licensing procedures have been established as part of the model evaluation protocol in order to facilitate data transfer along the benchmarking process (Sanz Rodrigo and Moriarty, 2014).

Wind tunnel experiments are increasing in popularity for the study of wind conditions within wind turbine arrays under idealized conditions. This is a cost-effective solution to field testing and they have been especially useful for the study of LES models given the high spatial and temporal resolution obtained with hot-wire and stereo-PIV (3D particle image velocimetry) techniques (Porté-Agel et al., 2011). Higher Reynolds number experiments with larger rotors are also conducted to study the relationship between turbine performance and the flow in the near wake region (Krogstad and Adaramola, 2012). Similarly to numerical flow models, wind tunnel models require evaluation in order to get their data qualified for validation studies. Similarity of flow physics between laboratory and field scales have to be analyzed before extrapolating wind tunnel data to full scale.

Due to the relatively easy logistics of remote sensing devices compared to large met-masts, in particular **scanning lidars** are also being used for the study of wind turbine and wind farm wakes. Depending on the instrument set-up, three types of experiments are used to study wakes: nacelle-based downwind scans (Machefaux et al., 2014; Aitken and Lundquist, 2014), ground-based constant elevation/azimuth scans (Smalikho et al., 2013; Beck et al., 2014; Aitken et al., 2014) and concurring scanning from two or three doppler lidars (Iungo et al., 2014). The quality of validation datasets from these experiments is subject to debate considering the hypothesis adopted in the post-processing of the data to reconstruct the mean flow from the line-of-sight measurements.

Using data from **SCADA** systems of operational wind farms to generate validation data for wake models is also a controversial topic. Data quality is low and intensive filtering and bin-averaging is required in order to generate a validation dataset (Hansen et al., 2012). The challenge then is to interpret this data-processing in terms of the model so that observation and simulation data can be compared in a consistent way (Ott and Nielsen, 2014).

The wind assessment community is facing important challenges in the migration from classical engineering methods to modern numerical and experimental techniques. It is therefore essential to develop methodologies that can be mutually considered by the wind community as standard in order to unify criteria and reduce fragmentation in R&D. Also, it is critical to generate high-quality databases of experiments and benchmark simulations that can be used for validation and uncertainty quantification. This validation process allows a comprehensive transition from experience and test-based design to simulation-based design, producing more efficient and cost-effective design solutions (Oberkampf, 2010).

3 Objectives and Expected Results

The main objective of the project is to improve wind assessment models by collaborative benchmarking within a shared framework of VV&UQ. In more detail, specific objectives are:

- To extend the model evaluation framework, currently dealing with microscale wind farm models, to mesoscale and near-wake models.

- To define the most suitable benchmarks that available experimental data allow, to complement the building-block validation repository towards the integration of the new model approaches
- Explore more deeply existing and new benchmarks to better quantify the uncertainties and best practice usage methodologies for a variety of simulation tools
- To define an uncertainty quantification framework for wind farm flow models
- To reach consensus on best practice guidelines for model evaluation and integrate this into an improved model evaluation framework
- To reduce end-user dependencies by benchmarking against experienced modelers
- To determine qualification procedures for the generation of validation datasets from wind tunnel and lidar experiments

Relevant questions to guide the scientific work and discussions are:

- Which metric should we use to quantify fairly the accuracy of a flow model?
- How far can we use mesoscale or microscale models independently in terms of flow complexity?
- How is flow complexity quantified first of all?
- Is the wind industry ready to integrate atmospheric stability as a third dimension of the wind climate (besides wind speed and direction) in the wind farm design process?
- How accurate does the near rotor flow field need to be for accurate-enough array efficiency assessment?
- Which experiments/benchmarks are lacking in order to fill the building-block validation matrix?
- How similar are wind tunnel and field wakes? Can we extrapolate validation results to full scale?
- Based on model validation and UQ results can we define limits for acceptable agreement to certify the use of a model for its intended use?

4 Approach and Methodologies

In this section a high-level work plan of the next 3 years of Wakebench is provided. The project structure is composed of four work packages:

- WP0: Management and coordination
- WP1: Benchmarking from mesoscale to microscale models ("wind")
- WP2: Benchmarking from near-wake to wind farm array models ("wake")
- WP3: VV&UQ framework and user guidelines

The majority of the technical work will be around the setting-up and running of benchmarks for model intercomparison following the procedures established in the MEP. A list of potential test cases for this second phase of Wakebench is provided in the Annex. Similarly to Task 31 the benchmarking work is divided into two model categories: “wind” and “wake” models. Now “wind” is related to atmospheric boundary layer modeling from mesoscale to microscale and “wake” is related to models from near wake to wind farm scales. Management and reporting on these benchmarks will be done online at the windbench.net portal. The activity will result in an update of the MEP with the definition of a methodology for VV&UQ that can be generally applied to mesoscale and microscale models. A 2nd edition of the best-practice guidelines document that accompanies the MEP will be also released.

WP0: Management and coordination

Period: Month 0-Month 36

Description

WP0 contains the management and coordination activities. The WP primarily focuses on the communication of essential information between the Participants on the achievement of the scientific and technical objectives according to the time schedule of section 5. The WP also includes the activities which are required to inform the IEA Wind Executive Committee (i.e. the preparation of the progress reports and the attendance of the IEA Wind ExCo meetings). A dedicated project site will be available for the follow-up of the project.

Tasks:

- Task 0.1: Scientific and technical management
- Task 0.2: Administrative management
- Task 0.3: Website development and management

Deliverables:

- D0.1: Web site (M0)
- D0.2: First annual progress report (M12)
- D0.3: Second annual progress report (M24)
- D0.4: Final report (M36)

WP1: Benchmarking from mesoscale to microscale models

Period: M0-M36

Description

This WP deals with benchmarking activities for the development of atmospheric boundary layer models dealing with atmospheric scales from mesoscale to microscale, either as separate models or as a downscaling model-chain.

Participants working with microscale models will continue the activity initiated in Task 31. Topics like complex terrain, forest canopies and atmospheric stability will be considered. Modelling and characterizing atmospheric stability will be an important focus of this group, to produce a more realistic description of the wind conditions beyond the surface layer. Validation will be based mostly on mean quantities from steady and unsteady (for example a diurnal cycle) simulations.

Mesoscale models will be integrated in windbench with a dedicated catalog. Benchmarks will be established to verify model sensitivities to set-up options like: initial and boundary conditions (reanalysis data, elevation and land-use databases), boundary-layer parameterization, nesting procedures and spatial resolution. Validation will be fundamentally based on: 1) episodes of short duration on well-defined synoptic and surface conditions that allow detailed insight into model performance under specific conditions 2) long-term (various months to one year) integrations of the models to retrieve wind climate statistics and produce wind maps, as the primary application of these models.

<u>Tasks:</u>

- Task 1.1: Setting-up of the benchmark platform for mesoscale models
- Task 1.2: Definition of validation procedures for mesoscale models
- Task 1.3: Definition of benchmarks and scheduling for “wind” models

<u>Deliverables</u>:

- D1.1: Inventory of “wind” models and benchmarks (windbench)
- D1.2: “Wind” benchmark reports (windbench)

WP2: Benchmarking from near-wake to wind farm array models

<u>Period</u>: M0-M36

<u>Description</u>

This WP deals with wake modelling at turbine to wind farm scales. Farm to farm wake modelling, notably offshore, is also a possible extension of the scope but the availability of suitable test cases for validation is much more unlikely.

Wind farm wake models will continue activities initiated in Task 31 where the focus was mainly on steady-state, neutrally-stratified surface-layer models in flat/offshore conditions. Following the development of ABL models in WP1 we shall expect benchmarks from industry data on stability effects in offshore and complex terrain conditions. Progress on the statistical blending of simulations to mimic array efficiency statistics will be also an important area of discussion.

The near and transition wake region will deserve special attention during this second phase of Wakebench. Wind farm models often struggle to simulate the power deficit at the second row of a wind farm as the incoming flow develops to a wind farm “canopy” boundary layer. Turning these “far-wake” models to “full-wake” models implies better representation of near-wake flow induced by a more realistic modelling of rotor aerodynamics. Detailed experiments from wind tunnels and lidar campaigns can be very useful for this area of research provided quality-check procedures are established for the generation of validation data from these sources. IEA Task 32 is already developing a lidar use case formalism for the selection and implementation of well-documented and repeatable lidar methods addressing complex flow data requirements. This formalism will be implemented here considering validation data requirements so as to determine which flow situations can be measured with lidar methods.

A benchmark of wind tunnel experiments on a set of wind turbine configurations will be established in order to assess the dependencies of the validation data on the experimental facility and operating conditions. Comparison with similarity theory and other wind tunnel and full-scale experiments will help determining how different variables of interest relate operating conditions from the laboratory to the real world.

Tasks:

- Task 2.1: Set-up the benchmark platform for wind tunnel models
- Task 2.2: Definition of validation procedures using wind tunnel experiments
- Task 2.3: Definition of validation procedures using lidar experiments
- Task 2.4: Definition of benchmarks and scheduling for "wake" models

Deliverables:

- D2.1: Inventory of "wake" models and benchmarks (windbench)
- D2.2: Benchmark reports (windbench)

WP3: VV&UQ framework and user guidelines

Period: M0-M36

Description

The model evaluation protocol defined in Task 31 will be updated to cover the wider scientific scope of this new Task. Many aspects of the validation framework are still applicable but there are a number of elements that are specific to the new models, for instance, more variables of interest, new metrics, etc.

The objective of the validation process is to evaluate model performance based on error metrics and input uncertainty and build an estimate of the predicting accuracy of the model. Uncertainty quantification determines how likely a variable of interest is when certain aspects of the modelling system are not exactly known. The UQ process determines how the input and parameter uncertainty propagates through the model to the output variable of interest and are combined with the model inadequacy. This new Task will gather experts working on UQ for wind assessment from microscale and mesoscale models to define a common integrated framework.

The results of the benchmark exercises of WP1 and WP2 will be compiled and analyzed thoroughly. The aim of this work package is also to reach consensus about best practice guidelines and procedures for modelling wind farms and reporting the wind farm energy performance prediction accuracy.

Tasks:

- Task 3.1: Review of UQ methods and integration on a VV&UQ framework
- Task 3.2: Best practice procedures

<u>Deliverables</u>:

- D3.1: 2nd edition of MEP as a VV&UQ framework (M36)
- D3.2: 2nd edition of best practice procedures for wind farm modeling (M36)

5 Chronogram and Key Dates

Beginning on the date this Annex is formally initiated, it shall, in principle, continue for a period of three years.

The proposed time schedule is presented in Figure 2. Note that the Work Package descriptions are given in section 4 and the description of the milestones and deliverables is given in sections 6 and 7.

		Year 1		Year 2		Year 3	
		M6	M12	M18	M24	M30	M36
WP0: Management and Coordination (CENER)							
	Task 0.1: S&T Management						
	Task 0.2: AFL Management						
	Task 0.3: Website development and management						
	D0.1, **M0.2**: Website	O					
	D0.2,3,4: Annual Progress Reports/ ExCo Meetings		R/M		R/M		R/M
	M0.1: Kick-off Meeting	M					
	M0.3,4,5: Annual Progress Meetings		M		M		M
WP1: Benchmarking from mesoscale to microscale models (CENER)							
	Task 1.1: Setting-up of the benchmark platform for mesoscale models						
	Task 1.2: Definiition of validation procedures for mesoscale models						
	Task 1.3: Definition of benchmarks and scheduling for "wind" models						
	D1.1: Inventory of "wind" models and benchmarks	O	O	O	O	O	O
	D1.2: "Wind" benchmark reports	O	O	O	O	O	O
	M1.1: Benchmark platform operational for new models		Ms				
WP2: Benchmarking from near-wake to wind farm array models (NREL)							
	Task 2.1: Setting-up of the benchmark platform for wind tunnel models						
	Task 2.2: Definiition of validation procedures using wind tunnel experiments						
	Task 2.3: Definiition of validation procedures using lidar experiments						
	Task 2.4: Definition of benchmarks and scheduling for "wake" models						
	D2.1: Inventory of "wake" models and benchmarks	O	O	O	O	O	O
	D2.2: "Wake" benchmark reports	O	O	O	O	O	O
	M2.1: Benchmark platform operational for new models		Ms				
WP3: VV&UQ framework and user guidelines (DTU)							
	Task 3.1: Review of UQ methods and integration on a VV&UQ framework						
	Task 3.2: Best practice procedures						
	D3.1: 2nd edition of MEP as a VV&UQ framework						R
	D3.2: 2nd edition of best practice procedures for wind farm modeling						R
	M3.1: UQ framework defined				Ms		

Legend: M = Meeting; Ms = Milestone; R = Report; O = Online

Figure 2: Gantt chart for WAKEBENCH project

6 Reports and Deliverables

Annual progress reports will give an overview of the follow-up of the project. Within each Work Package a number of deliverables will be elaborated in order to summarize the most important results. These reports/deliverables will be composed by the Operating Agents based on the inputs and reviews from the Participants. The planned deliverables are given in Table 1.

Deliverables in this Wakebench extension are complements or updates to those of the first edition. Benchmark activity will be reported directly at the windbench.net platform. This is to allow participants to update their results with more flexibility and eventually revisit previous benchmarks for improvement. The second edition of the Model Evaluation Protocol will include a wider scope of models and a unified UQ procedure. As a technical annex to this protocol a 2nd edition of the best-practice guidelines will be published with more detailed guidance on specific topics to complement the framework.

Table 1: Planned deliverables and milestones

	WP	Deliverable	Planned
D0.1	0	Web site	M6
D0.2	0	First annual progress report	M12
D0.3	0	Second annual progress report	M24
D0.4	0	Final report	M36
D1.1	1	Inventory of “wind” models and benchmarks (windbench)	M6-M36
D1.2	1	“Wind” Benchmark reports (windbench)	M6-M36
D2.1	2	Inventory of “wake” models and benchmarks (windbench)	M6-M36
D2.1	2	“Wake” Benchmark reports (windbench)	M6-M36
D3.1	3	2nd edition of MEP as a VV&UQ framework	M36
D3.2	3	2nd edition of best practice procedures for wind farm modeling	M36

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: List of milestones

	WP	Milestone	Planned
M0.1	0	Kick-off Meeting	M1
M0.2	0	Web-page operational	M1
M1.1	1	Benchmark platform operational for new models	M6
M0.3	0	1st Progress Meeting	M12
M3.1	1	UQ framework defined	M24
M0.4	0	2nd Progress Meeting	M24
M0.5	0	Final Meeting	M36

8 Obligations and Responsibilities

It is noted that the main responsibilities of the Operating Agent are given at 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;
- Besides the annual progress meetings, the reporting of progress to the Operating Agent on a 3-monthly basis, mostly through teleconference meetings;
- The contributions to the project deliverables and progress reports.

9 Type of Funding and Proposed Operating Agent

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 shall bear the costs of workshops and meetings convened in conjunction with this Task.
- The total costs of the Operating Agent shall be borne jointly and in equal shares by the Participants.
- 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, acting in the Executive Committee (ExCo).

The Annex will be centrally managed by the National Renewable Energy Centre of Spain (CENER, WP0) and have three Scientific and Technical Operating Agents or WP leaders:

- CENER, to coordinate the “wind” aspects in WP1
- National Renewable Energy Laboratory of the U.S. (NREL), to coordinate the “wake” aspects in WP2
- Technical University of Denmark (DTU Wind), to coordinate UQ aspects in WP3

10 Proposed Budget

The total costs of the Operating Agents for coordination, management, reporting, and database maintenance and operation is **100 k€/yr** during a three year period, and may not exceed this level except by unanimous agreement of the Participants, acting in the ExCo.

Projected expense items of the operating agent are as follows (per year):

▪ Management	5 person-months	Euro	80,000
▪ Travel	3 meetings (plenary + ExCo + dissemination)	Euro	16,000
▪ Administrative	Misc (meetings, teleconferences, website, etc)	Euro	4,000

The budget will be shared in the following way: 1/2 for CENER, 1/4 for NREL and 1/4 for DTU. It is anticipated an annual **participation fee of 8333 €/year**, equivalent to 12 participating countries.

11 Management of the Task

The aim of the management activities in the Task is to achieve the scientific objectives as formulated in section 3 according to the planning and within the budgetary limits.

The monitoring of the project will be carried out by the Operating Agents at least on a 6-monthly basis through teleconference meetings. One progress meeting is scheduled every year to present the latest results, plan next benchmarks and discuss model evaluation and best practice procedures. Annual meetings are shaped as workshops (or technical expert meetings) where participants present their work in the Task and other related projects.

Following the windbench structure each benchmark will be monitored by a Benchmark Manager (very often the owner of the data), who will be responsible together with the corresponding WP Operating Agent of the follow up of the benchmark. Benchmark meetings will be held periodically through web meetings.

Dissemination activities will be centralized in the project website. Key conferences and expert meetings will be identified for the presentation of the project most relevant results.

12 Organization

The Task will be centrally managed by CENER as single point of contact with the IEA-Wind Executive Committee. NREL and DTU will also act as Operating Agents to carry out the lead on WP2 and WP3 respectively. CENER will lead WP0 and WP1.

Benchmark managers will be appointed to guide model intercomparison benchmarks. They will be supported by the corresponding WP leader to address potential participants and review their contributions.

13 Information and intellectual property

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

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

Database. The intellectual property rights of the non-public databases that constitute the validation test cases will be handled on a case by case basis. The owner of the data, as Test Case Manager, shall be responsible for the definition of the terms and conditions for using the data. The accessibility to the data will be managed by the administration of user accounts on the windbench web-platform. Users will not transmit data to external parties without the explicit consent of Operating Agents and the data owner.

Proprietary Information. The Operating Agents and the Task 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 this Task. For purposes of this Task, proprietary information shall mean information of a confidential nature, such as trade secrets and know-how (for example, computer programs, design procedures and techniques, or wind farm operational data) which is appropriately marked, provided such information:

(a) Is not generally known or publicly available from other sources;
(b) Has not previously been made available by the owner to others without obligation concerning its confidentiality; and
(c) 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 Agents for arising proprietary information, to identify the information as such and to ensure that it is appropriately marked.

Production of Relevant Information by Governments. The Operating Agents shall encourage the governments of all Agency Participating Countries to make available or to identify to the Operating Agents all published or otherwise freely available information known to them that is relevant to the Task.

Production of Available Information by Participants. Each Participant agrees to provide to the other Participants and the Operating Agent all previously existing information, and information developed independently of the Task, which is necessary to this Task and which is freely at the disposal of the Participant and the transmission of which is not subject to any contractual or legal limitations:

(a) If no substantial cost is incurred by the Participant in making such information available, at no charge to the Task therefore;
(b) If substantial costs must be incurred by the Participants to make such information available, at such charges to the Task as shall be agreed between the Operating Agent and the Participant with the approval of the Executive Committee.

Use of Confidential Information. If a Participant has access to confidential information which would be useful to the Operating Agent in conducting studies, assessments, analysis, or evaluations, such information may be communicated to the Operating Agents 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 Agents and the Participant which supplies such information.

Acquisition of Information for the Task. Each Participant shall inform the other Participants and the Operating Agents of the existence of information that can be of value for the Task, but which is not freely available, and the Participant shall endeavor to make the information available to the Task under reasonable conditions, in which event the Executive Committee may, acting by unanimity, decide to acquire such information.

Reports of Work Performed Under the Task. Each Participant and the Operating Agents shall provide reports of 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.

Arising Inventions.

(a) Inventions made or conceived in the course of or under the Task (arising inventions) shall be identified promptly and reported to the Operating Agent with a recommendation of the countries in which patent applications should be filed. The Executive Committee shall, acting by unanimity, establish procedures for processing such recommendations to determine where and when patent applications will be filed at the expense of the Task.

(b) Information regarding inventions on which patent protection is to be obtained shall not be published or publicly disclosed by the Operating Agents or the Participants until a patent application has been filed in any of the countries of the Participants, provided, however, that this restriction of publication or disclosure shall not extend beyond six months from the date of reporting the invention. It shall be the responsibility of the Operating Agents to appropriately mark Task reports that disclose inventions that have not been appropriately protected by the filing of a patent application.

(c) Patents obtained in the country of each Participant shall be jointly owned by the Participant for that country and the Operating Agent who shall hold its interest for the benefit of the Participants. Patents obtained in other countries shall be owned by the Operating Agent for the benefit of the Participants.

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 application arising from the Task in its country, and the Participants shall notify the other Participants of the terms of such licenses. Royalties obtained by such licensing shall be the property of the Participant. Other licenses under such patents and patent applications shall be granted by the Operating Agents:

(a) To each Participant, its government and nationals of its country designated by the Participant for use in all countries on favorable terms and conditions stipulated by the Executive Committee, acting by unanimity, taking into account the equities of the Participants based upon the sharing of obligations, contributions, rights and benefits of all Participants.

(b) To the government of any Agency Participating Country and nationals designated by it for use in such country on reasonable terms and conditions as stipulated by the Executive Committee, acting by unanimity, in order to meet its energy needs.

Copyright. The Operating Agents may take appropriate measures necessary to protect copyrightable material generated under the Task. Copyrights obtained shall be held for the benefit of the Task Participants, provided however, that the Task Participant 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.

Inventors and Authors. Each Task Participant will, without prejudice to any rights of inventors or authors under its national laws, take necessary steps to provide the cooperation from its inventors and authors required to carry out the provisions of this paragraph. Each Task Participant will assume the responsibility to pay award or compensation required to be paid to its employees according to the law of its country.

14 List of Potential Participants

Table 3 provides a list of potential participants on the new Task based on previous participation in Task 31 and other expressions of interest. In total 20 countries have potential interest.

Table 3: List of potential Participants to the Task

Country	Organization	
Canada	Montreal University	ETSMTL
	York University	YORKU
Belgium	von Karman Institute for Fluid Dynamics	VKI
	ATM-PRO	ATM-PRO
	CENAERO	CENAERO
	3E	3E
China	Chinese Wind Energy Association	CWEA
	China Aerodynamics Research & Development Center	CARDC
	North China Electric Power University	NCEPU
	Nanjing University of Aeronautics and Astronautics	NUAA
	Goldwind	GOLDWIND
Denmark	DTU Wind Energy	DTU
	DONG Energy	DONG
	Aarhus University	AU-INF
	Suzlon	SUZLON
	VESTAS Wind & Site Competence Centre	VESTAS
	EMD International A/S	EMD
Finland	VTT - Technical Research Centre of Finland	VTT
	Lappeenranta University of Technology	LUT
	Finish Meteorological Institute	FMI
France	EDF	EDF
	Université d'Orléans	PRISME
Germany	ZMAW Hamburg University	ZMAW
	CFD+Engineering	CFDING
	DEWI	DEWI
	Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research	HZG
	Fraunhofer IWES	IWES
	Anemos-Jacob GmbH	Anemos-Jacob
	Karlsruhe Institute of Technology	KIT
	SENVION	SENVION
	ForWind - Oldenburg University	ForWind
	Fluid & Energy Engineering GmbH	F2R
	German Aerospace Center	DLR
Greece	Center For Renewable Energy Sources	CRES
Ireland	Centre for Renewable Energy, Dundalk Institute of Technology	CREDIT
	Mainstream Renewables	MAINSTREAM
	Wind Site Evaluation Ltd.	WSE
Italy	University of Perugia	UNIPG
	University of Genoa	UNIGE
	CNR-INSEAN	CNR-INSEAN
	Karalit	KARALIT
	Sorgenia S.p.A.	Sorgenia
Japan	University of Tokyo	UNITOKIO
	Wind Energy Institute of Tokyo	WEIT
Netherlands	Energy Research Centre of the Netherlands	ECN
	Technical University of Delft	TUDELFT
	ECOFYS	ECOFYS
Norway	Windsim	Windsim
	Statkraft	STATKRAFT
	Agder Energy	AE
	Institute for Energy Technology	IFE
	Norwegian University of Science and Technology	NTNU
	International Research Institute of Stavanger (IRIS)	IRIS
	Sintef	SINTEF
	CMR Gexcon	Gexcon

Country	Organization	
Portugal	Porto University	FEUP
	Megajoule	MEGALOULE
Rep. Korea	Korea Institute of Energy Research	KIER
	Korea Aerospace Research Institute	KARI
	Pohang University of Science and Technology	POSTECH
Spain	National Renewable Energy Centre of Spain	CENER
	AWS Truepower	AWST
	Ereda	EREDA
	EDP Renovaveis	EDP
	ENEL Green Power	ENEL
	Iberdrola Renovables	IBERDROLA
	Suzlon	SUZLON
	Gamesa Eólica	GAMESA
	Politecnic University of Madrid	UPM-ETSII
	Vortex	VORTEX
	UPM Instituto de Microgravedad Ignacion da Riva	UPM-IDR
	Barlovento Recursos Naturales S.L.	Barlovento
Sweden	Upsala University	HGO
	Statkraft	STATKRAFT
	Vattenfall	Vattenfall
Switzerland	École Polytechnique Fédérale de Lausanne	EFPL
	Swiss Federal Institute of Technology	ETH
United Kingdom	Oldbaum	Oldbaum
	Centre for Renewable Energy Systems Technology	LBORO
	Renewable Energy Systems Ltd	RES
	School of Engineering and Physical Sciences Heriot-Watt University	HW
	Mainstream	MAINSTREAM
	Natural Power UK	NP
	E.ON New Build & Technology Limited	E.ON
	University of Surrey	US
	ORE Catapult	Catapult
United States	National Renewable Energy Laboratory	NREL
	Indiana University	INDIANA
	Iowa State University	UIOWA
	Los Alamos National Laboratory	LANL
	DNV Renewables (USA) Inc.	DNV
	Case Western Reserve University	CASE
	Meteodyn US	Meteodyn
	Lawrence Livermore National Laboratory	LLNL
	University of Wyoming	UWYO
	Desert Research Institute	DRI
	3Tier	3Tier
	AWS Truepower	AWST
	WindLogics	WL
	General Electric	GE
	University of Minnesota	UMN
	Johns Hopkins University	JHU
	University of Colorado	CU
	Rensselaer Polytechnic Institute	RPI
	National Center for Atmospheric Research	NCAR
	Penn State University	PSU
	Portland State University	PSUO
	AES	AES
	RES Americas	RES
	Acusim	Acusim
	University of Washington	UW

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14 Annex: List of Potential Test Cases

Test Case	Source	Where	Description	Models
Perdigao double hill	NEWA	Portugal	Hill-hill interaction. One turbine on top of one of the hills. Large instrument deployment along and across the hills as well as the surrounding terrain, including windscanners	Meso-microscale models
Alaiz complex terrain	NEWA	Spain	Hill-mountain interaction. Wind farm in complex terrain. Large deployment of mast instrumentation along the N-S transect + windscanner of the wakes and forestry efects on the test site	Meso-microscale models + wakes + forest
Ebro Valley mesoscale complex terrain	NEWA	Spain	A grid of synop stations and wind energy masts will be used to study the synop-to-mesoscale wind climate of this large-scale wind channel where Alaiz is based	Mesoscale
Offshore wind map	NEWA	North/Baltic Sea	Wind map based on ESA satellite remote sensing of ocean surface winds	Mesoscale models
Coastal winds	NEWA	Northern EU	Tall masts, long-range scanning lidars and ship-based lidar with focus on land-sea transition	Meso-microscale models + waves
Kassel forested hill	NEWA	Germany	Forested hill with long-term 200-m mast. Large instrument deployment including windscanners	Meso-microscale models
High altitude ridges	NEWA	Turkey	1600 m tall plateau cut through by several steep canyons. Campaign mainly based on lidars.	Meso-microscale models
Offshore farm-farm wakes	EERA-DTOC	North/Baltic Sea	Wake episodes in the North and Baltic Sea based on SAR images	Mesoscale + wake
TWICS Inflow and single-wake	NWTC	Colorado (US)	Wind Turbine and Inflow Characterization Study around a 2.3 MW. Influence of complex terrain and stability	Meso-microscale models + wake
CWEX scanning lidar wind farm wakes	CWEX	Iowa (US)	Crop Wind Energy Experiment. Wake measurements with long-range scanning lidar under different stability conditions	Meso-microscale models + wakes
SWiFT Inflow and wind farm wakes	SANDIA	Texas (US)	Scaled Wind Farm based on 3 x V27 300kW turbines and two 58 m masts	Meso-microscale models + wakes
WFIP Mesoscale in complex terrain	WFIP/ A2e	Western US	Wind Forecasting Improvement Project 2.0. 600 x 600 km forecasting area including operational wind farms	Meso-microscale
Høvsøre tall wind profile	DTU	Denmark	Mast + Lidar up to 600 m. Horizontally-homogeneous terrain. Episodes under various geostrophic forzing	Mesoscale and ABL
Alpha Ventus wakes	Alpha Ventus	Germany	Measurement of wakes at Alpha Ventus with scanning lidars. Inflow based on Fino1	Meso-microscale models + wakes
Falster forest edge	DTU	Denmark	Measurements before and after a forest edge under different stabilities and canopy seasonal densities	Microscale + forest
Wind tunnel wake experiments	Various	Various	Studies on near-wake to array wakes under different Re, inflow, turbine model and wind farm layouts	Microscale + wakes