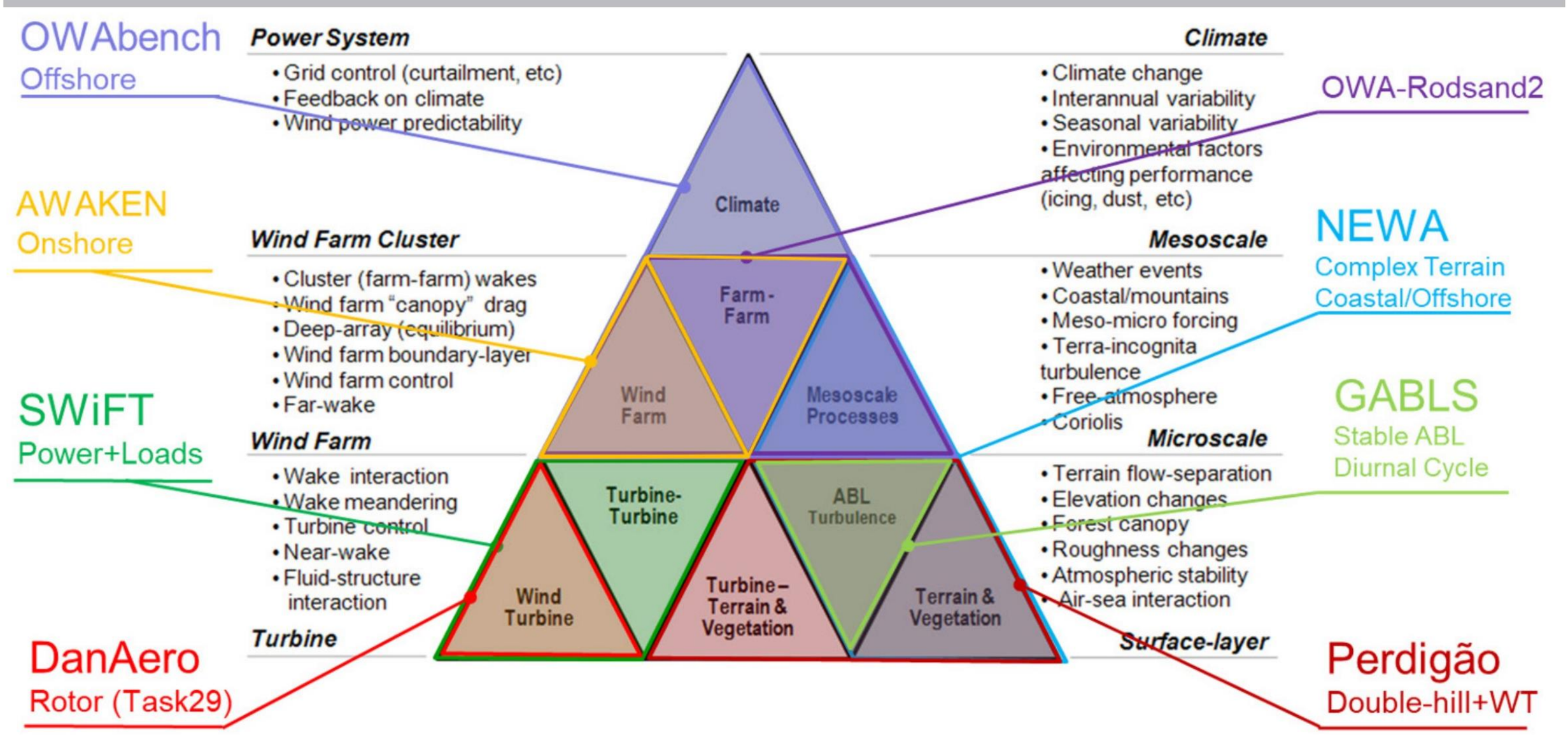

WAKEBENCH MULTI-SCALE BUILDING-BLOCK FRAMEWORK AND ASSOCIATED EXPERIMENTS AND TEST SITES.

TASK 31 REPORT 2020

WAKEBENCH: Benchmarking wind farm flow models

Current wind energy models often lead to overprediction of wind plant performance, leading to high uncertainties and significant financial losses in the wind industry. State of-the-art wind resource assessment and wind farm design techniques employ four main topics: characterization of large-scale climatology; mesoscale meteorological processes; microscale terrain, vegetation, and wind farm array effects; and wind turbine aerodynamics.

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Current wind energy models often lead to overprediction of wind plant performance, leading to high uncertainties and significant financial losses in the wind industry. State of-the-art wind resource assessment and wind farm design techniques employ four main topics: characterization of large-scale climatology; mesoscale meteorological processes; microscale terrain, vegetation, and wind farm array effects; and wind turbine aerodynamics.

Technology Collaboration Programme
by IEA

Traditionally, these topics were analysed separately, giving rise to different independent research communities (meteorologists, wind engineers, aerodynamicists). As a result, a wide variety of models have been developed by each specialized group with little interaction between them [1]. The next generation of wind-energy models need an integrated approach that can produce a more comprehensive characterization of the modelling system. The objective of IEA Wind TCP Task 31 is to develop an international verification and validation (V&V) framework that will provide sustained improvement of wind farm flow models [2]. The task leverages data from research experiments and industry alongside a formal validation strategy to provide a continuous evaluation process that improves the predictive capacity of wind farm flow models [3].

The third phase of the Task kicked-off in June 2018 and will finish in May 2021 with the objective of rolling out the validation strategy built on recent field experiments from the New European Wind Atlas (NEWA) project and the U.S. Department of Energy's Atmosphere to Electrons (A2e) programme. In addition, two industry-driven benchmarks have been added: the Offshore Wind Accelerator Wake Modeling Challenge allowing Task participants to benchmark wind farm wake models in the prediction of array efficiency using operational data from five offshore wind farms; and, in support to the IEC 61400-12-4, the Numerical Site Calibration benchmark around the Alaiz test case in complex terrain.

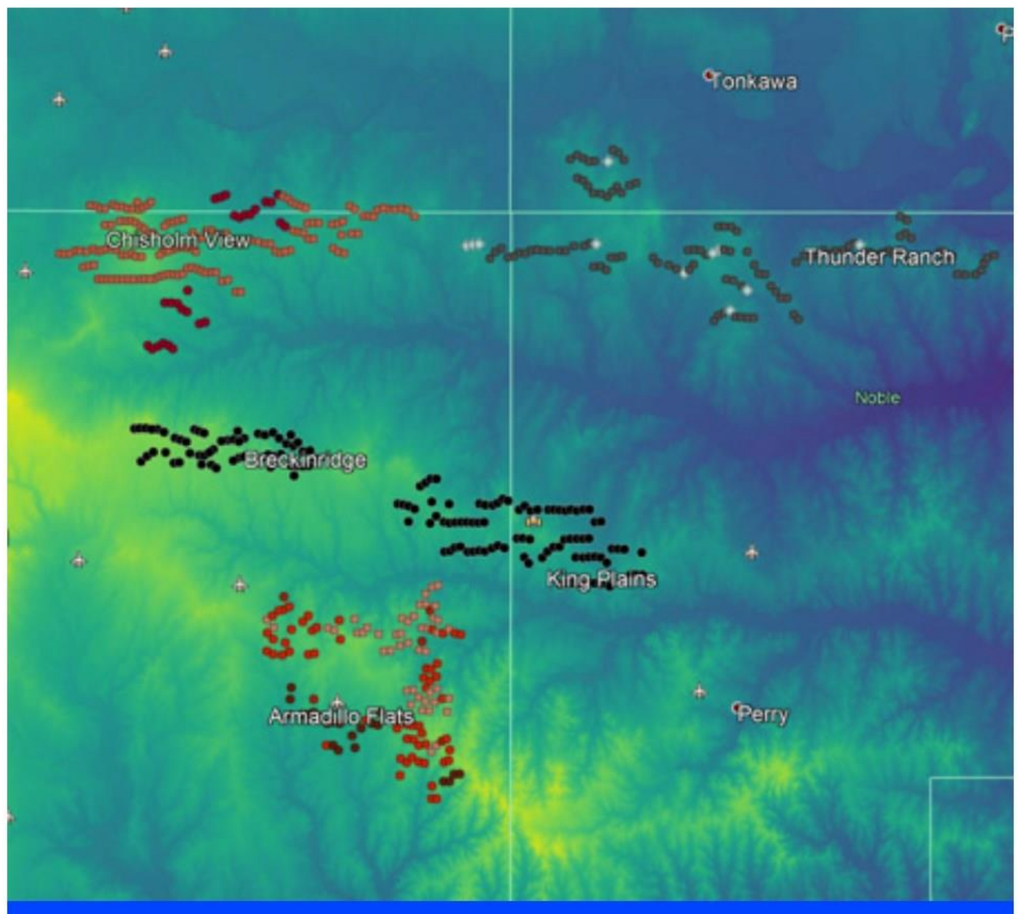
Progress and achievements

Task 31 counts with 10 participating countries: China, Denmark, France, Germany, Japan, the Netherlands,

TABLE 1. COUNTRIES PARTICIPATING IN TASK

Table 1. Task 31 Participants in 2020

	Country/Sponsor	Institution(s)	Active organizations
1	China	Chinese Wind Energy, Association (CRES)	North China Electric Power University (NCEPU) China Ming Yang Wind Power Group Ltd. Xinjiang Goldwind Science & Technology Co. Ltd. Envision Energy Co. Ltd. Huaneng Clean Energy Research Institute (HCERI)
2	Denmark	Energistyrelsen	Technical University of Denmark (DTU) EMD Vestas Wind Systems A/S
3	France	EDR R&D, IFP Energies Nouvelles, Meteodyn	EDR R&D FP Energies Nouvelles Meteodyn
4	Germany	Federal Ministry for Economic Affairs and Energy BMWi	Carl von Ossietzsky University of Oldenburg (ForWind) Fraunhofer IWES Enercon ProPlanEn
5	Japan	New Energy and Industrial Technology Development Organization (NEDO)	University of Tokyo Wind Energy Institute of Tokyo (WEIT)
6	The Netherlands	Rijksdienst Voor Ondernemend Nederland (RVO.NL)	Technical University of Delft (TU-Delft)
7	Spain	National Renewable Energy Centre (CENER)	National Renewable Energy Centre (CENER) Barcelona Supercomputing Centre (BSC) UL
8	Switzerland	Bundesamt Für Energie (BFE)	Eastern Switzerland University of Applied Sciences (OST) Ecóle Polytecnique Fédéral de Lausanne (EPFL)
9	Sweeden	Uppsala University (UU)	Uppsala University Campus Gotland (UU)
10	United States	National Renewable Energy Laboratory (NREL)	National Renewable Energy Laboratory (NREL) Sandia National Laboratories (SNL) University of Colorado Boulder (CUBoulder) University of Wyoming (UWYO)



The AWAKEN experiment addressing wind farm validation gaps

Overview of the area of interest for the American Wake Experiment (AWAKEN) near the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) research facility in Oklahoma. The experiment will address science questions and validation gaps related to farm-farm interaction, wind farm wakes and blockage, turbulence and atmospheric stability dependency on inflow and wake processes, etc.

Spain, Switzerland, Sweden, and the United States. Task 31 operates around three work packages: WP1 dealing with benchmarking of models for wind conditions, WP2 dealing with benchmarking of models for wake effects and WP3 focused on integrating these benchmarks in a model evaluation protocol that provides guidance to model developers and end-users.

The NEWA Meso-Micro Challenge for Wind Resource Assessment was launched in 2018 to determine the applicability range of meso-micro methodologies across the validation envelope of NEWA experimental sites in complex terrain such as Hornamossen forested rolling hills in Sweden [5], Rödeser Berg forested hill in Germany [6], Perdigão double-ridge in Portugal [7], and Alaiz mountain range in Spain [8]. The Ferry Lidar benchmark in Germany allows comparing mesoscale models on the prediction of wind profiles along a ship track in the Southern Baltic Sea [9]. As part of a Swiss project, the Perdigão benchmark is also used to explore comparison metrics that help wind resource analysts select suitable flow models based on skill-vs-cost transfer functions [7]. The Alaiz site is used to test multi-scale flow models dealing with diurnal cycles in complex terrain [8] and steady-state models targeting flow correction factors for numerical site calibration following the guidelines from the IEC 61400-12-4 working group [10].

From the A2e programme, the Scaled Wind Farm Technology (SWiFT) benchmarks provides a detailed characterization of wake evolution and dynamics by first calibrating the inflow and then predicting the wake effects at different stability conditions [11]. Additionally, the Offshore Wind Accelerator (OWA) Wake Modeling Challenge allowed Task participants to benchmark wind farm wake models in the prediction of array efficiency using operational data from five offshore wind farms [12].

A new design of the V&V framework is underway based on three elements: The Wind Energy Model Evaluation Protocol (WEMEP) at the core to provide online documentation and guidance maintained in a version-controlled Github repository; A series of mind maps that, through expert elicitation, map the relationships between quantities of interest, model building blocks and phenomena of interest for validation; Finally, a set of Phenomena Identification and Ranking Tables (PIRT) for gap analysis to define priorities for model development, experiments, and validation [13]. The framework is developed alongside the planning of The American Wake Experiment (AWAKEN), a large international wake observation and validation campaign carried out under the A2e programme [14].

Outcomes and significance

By adopting a framework for model evaluation, Task 31 participants expect to facilitate the development of a better integrated model chain covering all relevant scales for wind-energy flow models. This framework will also enable V&V integrated planning for wind farm performance by prioritizing experiments and simulations that can have the greatest impact on improving design tools.

Through benchmarking, researchers leverage data and share results from existing projects for wider exploitation in an international context. Industry can also use this forum to test their design tools against state-of-the-art models, provide datasets that can be used to challenge those models and end-user requirements on quality-acceptance criteria for models to meet industry standards.

Next steps

Task 31 will finish in May 2021. A new Task is under discussion with the general objective of achieving wide-industry adoption of the Wakebench framework for the improvement of wind farm engineering models and standards [16].

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