INTERNATIONAL ENERGY AGENCY

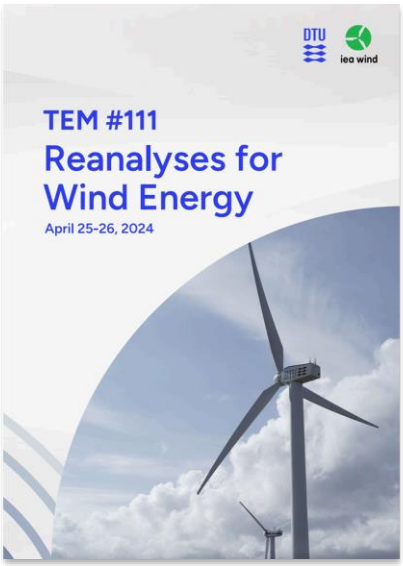
Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

Topical Expert Meeting #111 on

Reanalyses for Wind Energy

IEA Wind Task 11

April 25th -26th, 2024
Technical University of Denmark
Lyngby, Denmark



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Executive Summary of TEM#111

Introduction

Despite the widespread adoption and regular use of reanalysis datasets in wind energy applications, effective communication and knowledge exchange between reanalysis providers and researchers lack consistency and coordination. As explained in detail in Appendix 1, the Topical Expert Meeting 111 (TEM#111) “Reanalyses for Wind Energy” was held in April 2024 at DTU in Denmark, with the clear aim to:

- Collect experiences and suggestions on current- and future usage of reanalyses for wind energy, including all from data management to model validation.
- Pave the way for future actions aiming at improving/solving these issues.

Also, a proposal for the creation of a dedicated IEA Wind Task has been brought forward and discussed. Actions have been agreed upon.

Meeting Overview

The meeting took place at the DTU Lyngby Campus, and lasted 1.5 days. During the first day (25th of April 2024), presentations from key stakeholders were held, addressing the above-mentioned topics. The speakers came from three distinct groups:

- Wind Energy industry and academia.
- Global Reanalysis providers.
- Regional Reanalysis providers.

During the second day, discussions in small groups (10-15 people maximum) took place in break-out rooms, where each group focused on specific phase of wind energy projects (siting/development, offshore, grid and operations, climate change). The aim of the group work was to propose actions for short-, medium- and long-term collaboration.

The meeting agenda can be found in Appendix 2. Notes describing each presentation can be found in the Section “Summary of Presentations”.

Main Results

The IEA Wind TEM#111 fulfilled the objectives set out in the Introductory Note (Appendix 1). From the presentations given during the TEM, and the following discussions, a consensus emerged regarding two main ways forward:

1. A “wind-only” workstream, including (but not limited to):
    a. Testing of reanalysis data for wind purposes
    b. Validation and feedback on quality
    c. Ad-hoc: scoping data delivery, etc.

2. A “beyond wind” workstream, primary focused on:
    a. Advocacy for a fair, proper use of reanalysis datasets for weather-dependent energy systems (of which wind represents a very variable and important part)
    b. Coordination of user inputs during design, planning and execution of reanalysis projects
    c. Ad-hoc: wind- and energy representation in public forums linked to reanalysis.

To pursue these goals and carry out these activities, an IEA Task may not be needed. During the rest of the year 2024, the organization team will investigate what the already existing platforms and initiatives which could host these activities.

Summary of Presentations

The information in this section provides an overview and selected highlights of each of the methodologies snapshots given during TEM#111.

All meeting material from TEM#111 is available on the IEA Wind website. Access for download can be requested from the Task 11 Operating Agent.

Day 1. 25th April 2024

Introduction

Rémi Gandoin, C2Wind, Denmark, opened the TEM reminding the participants about the need to bring together reanalysis and meteorology with the wind energy experts.

Jake Badger, DTU, Denmark, welcomed the participants to DTU and gave a quick overview of DTU Wind activities related to reanalysis.

Ignacio Marti, Planair, Switzerland. Presented IEA Wind TCP and explained the role of Topical Expert Meetings (TEM).

Regional reanalysis from Australia and New Zealand

Chun-Hsu Su, Bureau of Meteorology, Australia. BARRA2: Australian Regional Atmospheric Reanalysis.
BARRA (BoM Atmospheric Regional Reanalysis for Australia started in 2016 and continue until 2028. It is an operational product with a wide range of users. Model used for producing BARRA is based on the UK Met Office Unified Model. BARRA-R2 has 12 km resolution. Applications include fire weather, ocean hazard coupled with hydrodynamics and waves or resource analysis for wind energy. Current work focus on updating Australian climatology at different heights, analyse historical wind energy generation. Collaboration would be useful on observational data, evaluation and support of downstream applications. The focus on the future will be to include a nested convective scale reanalysis in the main reanalysis.

Stuart Moore, NIWA, New Zealand. NZRA. Production and application of high-resolution regional reanalysis for Aotearoa New Zealand.
The reanalysis for New Zealand (NZRA) is used as input to wildfire, hydrological and land surface models, sea level, inundation, wave models, hazards, water management and renewable energy applications. NZRA is a downscaled regional reanalysis covering the period between 1990 to 2018, with 1.5 km horizontal resolution for all NZ, it is based on the Unified Model and RAL2M convective scale science. NZRA produces 30 min outputs on various vertical levels from surface to 40km height. Validation results were presented for surface wind values measured in four locations. The validation results show that the model captures wind direction and speeds overall. Next steps include rapid updates (30 to 60 minutes), 24 h nowcasts for wind and solar, probabilistic forecast for risk assessment and predictions blending artificial intelligence and physical models.

Questions and comments.

- Q: Tropical cyclone models could help improve the reanalysis.
- Q: What metrics should be used when validating reanalysis?

Q: Can you elaborate on the use of NZRA for deriving basic wind speeds in the NZ building code? A: Yes, new basic wind values are derived from NZRA and climate change multipliers are provided as well.

Short presentations on the use cases (state of the art)

Lasse Svenningsen, EMD International, Denmark. Reanalysis Use Cases / Wind and Site.

WindPRO software is used for wind farm design and analysis, long term wind speed corrections as well as resource and energy assessments. WindPRO uses reanalysis as input together with measurements. Main use cases for reanalysis are long term corrections, quality assessment of observations, downscaling of limited area models, offshore resources assessment, wind energy indexes, historic climate analysis, and as a source of auxiliary signals (e.g. stability, atmospheric boundary layer height, temp, pressure).

Jacob Tornfeldt Sørensen, DHI, Denmark. Offshore wind design application of reanalysis data for metocean modelling and analysis.

The main focus when using reanalysis data is to map the design conditions for offshore wind farms and sea state based on calibrated and validated hindcast time series. The challenge is to bring down time and cost of clusters of offshore wind farms. Metocean data should be accurate, reliable and flexible. Reanalysis wind data are used for forcing spectral wave models (as such, reanalysis wave data are used as boundary conditions, but are not used for site-specific studies), datasets need to be validated and documented. The outputs produced by DHI for wind energy applications include metocean data and reports (in pdf format), now moving to assisted reports and digital services for the users. Services on demand are the future trend to supply the users with the required data when needed. An online platform to access reanalysis and data was presented. Global Wave model forced using modified ERA5 winds are the basis used by DHI for the wind related services. An example of an analysis for an offshore wind farm in the Netherlands was presented.

Justin Sharp, Sharply Focused, US. The urgent need for curated weather and climate intelligence to support the energy transition.

A more transversal approach is needed for the energy transition, current data is inadequate to assess weather dependencies, validation and uncertainty quantification are key, this is an ongoing operational need. The risk to take wrong decisions is very high if they are based on insufficient or wrong data. The demand growing due to the trend towards electrification and is becoming very dependent on weather, while the generation is also increasingly weather dependent due to the nature of renewable energies. The users of reanalysis are loosely coupled with the producers of the data, which is a weakness. A more coherent plan is needed, including feedback loop from users aiming at filling the gaps like validation and education. The current situation could be described as if we are flying blind. Weather dependencies must be managed and mitigated, variability and uncertainty are key drivers that need to be understood. Risk mitigation and resilience options should include the optimal selection of storage options. Since generation and demand are correlated, continental scale is needed with high resolution and high-quality data to account for the key dependencies between them. Cross domain cooperation is needed.

Jiali Wang. Argonne National Laboratory, US. Assessment of wind conditions in reanalysis and dynamically downscaled data.
A validation of reanalysis data was presented in a range of locations in the US. Wind conditions onshore were compared with ERA5 and WRF at 4km spatial resolution. Validation results show that ERA5 underestimates wind speeds, especially over complex terrain. Offshore reanalysis for different models were compared with wind measurements, the results show that for near surface there is a bias that changes depending on the location. MERRA2 showed larger biases offshore compared to ERA5 in some locations. A validation focused on extreme wind conditions was also carried out, including tropical storm events for the past 20 years ranging for low up to high hurricane categories. ERA5 heavily underestimates the extremes, while a downscaled reanalysis (ADDA WRF) to 4 km improved capturing high category extremes. Overall ADDA 4km outperforms ERA5, especially for the high category extremes.

Julia Gottschall. Fraunhofer IWES, Germany. How reanalysis data help us improve on site measurements.
Several applications are considered for reanalysis data, numerical site assessment, wind measurements and characterization. Typically, large scale wake effects are modelled based on reanalysis as boundary conditions when analyzing large offshore areas. When focusing on the measurements, reanalysis datasets are used to monitor data quality, data gap filling and long term extrapolation. Potentially, reanalysis could end up replacing measurements if the quality is at the right level. A reanalysis validation for Germany offshore area was presented, comparing ERA5 and wind measurements at 100m above sea level. The validation results show that in summer there is a large bias but higher correlation. Uncertainty propagates from the verification or calibration to the reference; lack of data traceability is an issue. The New European Wind Atlas showed a lower correlation, but also a lower bias compared to ERA5. Other validation presented was based on lidars mounted on vessels in the area between Finland and Sweeden. Reanalysis data are very useful for offshore wind resources assessment, not replacing measurements but complementing them. R&D today is focused on how to use both reanalysis and measurements in an optimal way.

Questions and comments. More vertical levels from reanalysis would be good considering increasing size of wind turbines.

Keynotes on global reanalysis: current status and future plans
Jim Wilczak, NOAA, US. Status of reanalysis products and renewable energy applications at NOAA's physical sciences laboratory.
Part 1: NOAA products under development were presented, including CORE Conventional Observation Reanalysis for Climate Modelling, Replay Reanalysis and 20CR Twentieth Century Reanalysis. Replay reanalysis includes 0.25-degree GFS/MOM6/Cice/WW3 coupled model run in a series of 12h forecasts. The 20th Century Reanalysis provides a global 200-year history of sub daily weather by assimilating only surface pressure observations. Future plans for 20CR includes extending the simulation until present time and coupling ocean with atmosphere physics. 20CR compares well with wind speed, considering that it is based only on surface pressure assimilated inputs.
Part 2: An evaluation and bias correction of ERA5 in the US for wind and solar applications work was presented, with focus on wind and solar. Correction methods

and several drought events were considered and 157 sites in the US were used for the validation. The daily average wind speeds validation results at 100m for 6 years, showed that biases and errors are quite consistent across the US, except for the Northeast region whether using tall towers, lidars or sodars (so it is a reanalysis bias). Bias corrections of EA5 work effectively. ERA5 overestimates the weight of low wind periods compared to measurements. On the other hand, ERA5 showed a high bias on the diffuse horizontal irradiance, while having low errors for overcast and clear skies and was clearly biased when there were partially cloudy conditions. Capacity factors calculated based on ERA5 are biased around 20% downwards for wind, while solar bias is 20% upwards, which is a significant bias when considered together. ERA5 can provide a good representation of low wind and solar periods when corrections are introduced. Will next generation reanalysis provide accurate enough estimates to avoid corrections?, what is the best way to determine systematic errors?, what is the best way to compare point measurements to reanalysis?.

Questions. How do you compare measurements with reanalysis?, answer: taking nearest point without spatial interpolation. Can you use corrections in other sites?, it looks like in solar is very stable so doable, it is better to use ERA5 with corrections than without corrections.

Michael Bosilovich, NASA, US. NASA GMAO reanalysis and prospects for future collaborations.
NASA Earth Action Strategy involves an earth information center, earth action solutions, earth system science and tolls for calculating impact and earth system observations. It is key to bring together the users with the providers of reanalysis. GEOS digital replicas of the physical earth system were presented including MERRA2 and MERRA 21C, with the different models connected. MERRA21C starts in year 2000 and will include up to year 2025+. M21C polar project will produce 7km resolution. American Wind Energy Association WRA working groups started in 2016, linking the wind community to MERRA with a valuable input that facilitates wind energy deployment, pointing at the need to have a continuous communication. A validation of MERRA2 was presented showing that changes in measurements availability clearly influence reanalysis quality. MERRA2 extreme detection is available for temperature and precipitation, wind gusts and wind drought are being considered. Some trends were presented on a reduced number of icing and frost days based on MERRA2 for the US. Climate change is a multidimensional problem involving many parameters. Power prediction and energy resources project presented; the project focuses on updating building codes. MERRA2 POWER data is widely used in water service, solar energy (power.larc.nasa.gov). MERRA21C will begin production in spring 2024 with 25 km resolution will include uncertainty estimates through ensembles from year 2000. A PBL focused constant height collection for the M21C reanalysis is being considered. Another improvement is about a refined grid used for downscaling in the US. Future collaboration should include continued communication, focus on continuous evaluation and about what additional information can be extracted from models. Having more than one reanalysis offer clear benefits for the user.

Questions. Interest about keeping “old” reanalysis. It would be useful to have information about biases.

Paul Poli and Delphine Deryng, ECMWF, UK. Towards ERA6 & C3S support to the energy community.
Copernicus climate change service reach out to many users worldwide, the key focus is to support the global community with information. ERA5 global reanalysis starts in 1940 until today, on an hourly basis, providing 9km resolution data. 30 datasets and 19 applications are part of ERA5, full datasets are available for experts as well. Why redoing global reanalysis?, the different ERA versions have improved characteristics, but how do we handle changes?, extending the period analyzed is one approach, adding new observations is another approach. New observations have been added over years (e.g. satellites) which contributes to the improvement of new reanalysis. ERA6 will provide 17.5km resolution including ocean waves and uncertainty estimates at 28km resolution from ensembles. Some products will be expanded with new parameters, adding new vertical levels and daily products. Observations will be also enhanced including satellite, land and water information. Trial runs for ERA6 prototypes show a significant improvement in accuracy. Resolution is not everything, the quality of the model is the key to improve the results. Validation is a key area for collaboration, making data public results in speeding up the validation processes. Test data for ERA6 are already available.
C3S support to the energy community. User driven services within ECMWF include focus groups and a channel for gathering requirements. An ERA6 user needs workshop was organized October 2023 pointing at the need for higher resolution, storm catalogue, etc. An analysis of the wind resources in 2023 for Europe region was presented, showing an increase in the average wind resources due to higher frequency of storms. Copernicus Thematic Hub is a new approach to interact with the users. Specific datasets for energy are available. Specific data for offshore wind energy is being developed (energy.hub.copernicus.eu)

Questions. When will ERA6 released?, data will be released from 2025. What about the impact of wind in local weather conditions? this is not considered in ERA6 nor in any other of the reanalysis models. A digital twin of the earth is in development. Assimilation of near surface measurements could be an approach. There seems to be evidence about wind farms affecting local wave conditions. It would be good to have the reanalysis data together with validation, but validation is regional and dependent on the application which makes it difficult. Having a peer review on validation methods would be useful.

Regional reanalysis

Semjon Schimanke, SMHI, Sweeden. Copernicus European Regional ReAnalysis CERRA.

CERRA is based on ERA 5 and Harmonie, run 3 times a day with 5.5 km resolution and 11km for CERRA EDA that includes 10 members. Model domain includes full Europe and surrounding areas. The available reanalysis covers the period between 1984 and 2021, with hourly forecasts calculated in 11 levels between 15 and 500m. Wind speed, direction and TKE are calculated. The four forecasts per day allow to uncertainty calculation based on overlapping forecasts. Gudrun storm validation was presented in the Baltic area, showing that generally higher wind speeds are obtained in CERRA compared to ERA5, for most Swedish stations better fit was obtained for CERRA compared to ERA5. In the North Sea further validation was carried out with Fino1 measurements and different reanalysis data. The plans for future include start operational production with monthly updates in 2025. Extension of CERRA to 1961 is also planned.

Question. Validation of CERRA in complex terrain is not available.

Birgitte Furevik, Norwegian Meteorological Institute, Norway. The 3 km Norwegian reanalysis NORA3.

The focus in to produce hindcast data, which historically has been connected with oil and gas activities, for this reason it includes waves data. A wave model was developed in the 60s and a hindcast model in the 80s, in 1999 WAM was introduced in the modelling approach. NORA3 is the current latest version of the reanalysis. NORA3 is based on AROME-Harmonie, ERA5 providing hourly 3-hourly outputs for wind, while the waves calculations are based on WAM. NORA3 provides a non hydrostatic atmospheric model, increased spatial resolution and new wave model physics. Polar low pressure systems are modeled with focus on correcting maximum wind speeds, and overall, more realistic modelling. Making data FAIR is a high priority, python packages are available to extract time series and point statistics. NORA3 is open access, which provides valuable information for society.

Thomas Spangehl, DWD, Germany. User oriented evaluation of reanalysis at DWD with focus on offshore wind energy.

The federal maritime authority has conducted studies on offshore wind potential in Germany. DWD has supported the studies with modelling data. Data from Fino stations was used for validation purposes. COSMO reanalysis shows good agreement with wind speeds at Fino 1 at 100m. Another validation was done using satellite data, showing smooth distribution of biases for ERA5 and COSMO. ERA5 has been used to study interannual anomalies.

Paula Gonzalez, Met Office, UK. Using reanalysis for energy applications: a climate scientist perspective

Met Office use reanalysis for scenario building used as input in power system modelling, also focusing in weather driven risks, supporting development of new technologies and understanding the changing variability in renewable resources. The desirable features from a climate science perspective are completeness, inclusion of multivariate methods, high frequency outputs, inclusion of relevant levels, global scale, multidecadal timeframe, high resolution outputs and ensemble coupled approach. Key limitations are bias correction and resolution vs frequency issues. There is not a right approach or a best one, therefore comparison is key. NextGen research community is discussing good practices on studying climate in connection with energy.

Simone Sperati, RSE, Italy. Regional reanalysis and wind atlas for Italy.
Focus on extreme weather events, which are increasing in frequency to understand the impact of these events in the energy system. First reanalysis was done by RSE in 2009 based on ERA5 downscaling. In 2023 AEOLIAN reanalysis with 1.1km resolution was produced. Spans from 1990 to 2019, hourly values and 1.33km spatial resolution, dynamic downscaling of ERA5 with WRF ARF, including measurements from 300 stations registering 10m wind values. Extension after 2019 will be done in the future. The data is public and accessible through RSE website.

Future uses, improvements and shorcomings.
Lase Sveningssen, EMD, Denmark. Reanalysis future uses improvements and shortcomings
The main wishes for improvements are consistency over long term (which is still pending at global and regional levels), get regional information that would be useful to understand when changes happen, bias reduction over space and time, capturing seasonal and diurnal variations as well as coastal transitions. Still there are parameters missing like TKE, currents and improvements in ABL. Interactions between weather and renewables should be considered. Ensembles are needed as input to uncertainty calculations and scenario building.

Diogo Silva, Megajoule, Portugal. End user perspective on the usage of wind reanalysis.
Wind speed, direction, temperature, humidity and pressure are the main parameters considered for wind energy projects. ERA5, MERRA2 and CFSv2 reanalysis are used by Megajoule, making a comparison for specific projects in different regions. First use of the reanalysis is for validation and verification even for correction of wind data, including air density. Long term historical reference is another use for reanalysis to extrapolate short measurement campaign to longer time periods. Temperature derating and grid curtailment calculations are based on reanalysis, as well as interannual variability and climate change effect. New possibilities include better resolution and accuracy with long periods. Suggestions for the future included to increase the resolution only in complex terrain areas and to create a worldwide network of wind measurements to be used in reanalysis modelling. Main issues users experience are the lack of information about the uncertainty of the reanalysis and which reanalysis should be used in which regions.

Gil Lizcano, Climate Scale, Belgium. How reanalysis can help us understand and quantify future wind conditions.
Looking at climate change impact for wind energy is a new topic. Scenarios about what can happen when temperature raises are generated to study the impact in wind energy. The scenarios are based on ERA5 downscaled to 3 km, then climate scenarios connected to IPCC (CMIP6) are applied. CMIP6 are also downscaled statistically and dynamically. Understanding anomalous years is key and reanalysis can help on this. At the end, results need to be explained to decision makers in a simple way.

Justin Sharp. Sharply focused, US. Interactions between electric system and weather. Interactions are complex when considering weather and electricity systems, key parameters to be considered are aerosols, clouds, rain, temperature, humidity and pressure leading to wind, snow, groundwater and insolation, which affect solar PV generation, hydro, thermal generation, demand as well as transmission capacity and wind generation. An overall coordination is needed. Validation should be a key point with focus on curation and use cases. There are physical requirements, relevance and usability requirements for reanalysis. Providing wind data to validating reanalysis is crucial.

Questions. A standardized way to downscale reanalysis could help. Curating data can help to compile user requirements and use cases. Potential for an IEA recommended practice on how to use reanalysis. Lack of coordination and collaboration is making progress slower.

Rogier Floors, DTU, Denmark. Current usage and future applications of reanalysis data
DTU has developed a modelling chain from global scale to the microscale, design to calculate wind conditions and wind energy related assessments. The focus is not only on wind but also extremes, rain, etc. Boundary conditions to mesoscale models are taken through nesting with various reanalysis sources. Calculation of the 50-year extreme winds are obtained from reanalysis. Blade rain erosion is another key area where rain data together with wind speeds are taken into account, higher resolution reanalysis can improve results in this area. An example of the local effects in Østerlid test center was presented, showing how local variations related to terrain and roughness differences affect wind and the limitations of reanalysis to capture them. Examples of stability inputs from reanalysis were used as inputs to microscale models showing a positive impact. In the future, having more atmospheric stability parameters from reanalysis would be useful, also more vertical levels, on the other hand having easy interfaces to download data is needed, as well as a portal to facilitate access to all regional reanalysis.

Natasha Fery, Vattenfall, Denmark. Reanalysis in offshore wind industry and impact on metocean design parameters.
An overview on how Vattenfall is using reanalysis in all phases of offshore wind projects was presented. The first step is the feasibility study, instead of putting measurement equipment, reanalysis is used to have an initial estimate of the resources. In the design phase, more accuracy is needed, the global reanalysis is too coarse, so a downscaled version is used mainly to design wind turbine foundations. In the construction phase measurements are deployed to measure wind and waves, the requirements on measurements are depending on the region. Forecast for the next days is also developed in the design phase for access purposes. In the operational phase, only some measurements are kept in the offshore wind farm. If there is bad data at the beginning, many problems appear in the following phases affecting the business case. Atmosphere, ocean and biochemical (for biodiversity) data from reanalysis are used. Radiation is also used to consider floating PV together with offshore wind. Ice is also relevant in the north of the Baltic Sea. Regional reanalysis are used when developing the high resolution studies. Wishlist include high resolution, more parameters, longer periods and public accessibly data. Surface is as important as seabed. It is not clear which reanalysis to use when there are several available.

Waves are being affected by the wind turbines for large offshore wind turbines, coupling wave models with wind including wakes is important.

Michael Blair, The Crown State, UK. Intro to TCE's Wind, Metocean & Climate Change Data Creation Project
TCE focuses on using model data and engineering in the Bridge project. Phase 1 was focused on the identification of data uses and needs, mapping existing resources and identifying the state of the art approaches for metocean parameters. A justification for a new dataset of metocean parameters was developed and released including a draft specification of the dataset, with time series parameters, statistics, spatial and temporal coverage, validation and verification. Phase 2 of Bridge project is the technical specification and procurement for the creation of the database.

Questions. Can reanalysis support lightning?

Day 2. 26th April 2024

Improvement of existing datasets (access, usage and validation)
Offshore group:

- Proposal to get data industry, including what is already available possible to feed into Copernicus. Consider supersites concepts (site to be used for validation with large scale observations data, a+ quality sites).
- Start with what data is already available. Map existing datasets available. But data needs some work to be prepared, documented. Copernicus could pay for the preparation of the data, but not for data permissions.
- Benchmarking. Validation of reanalysis including benchmarking, test ground for downscaling models.
- Extreme conditions are important, downscaling focusing on extremes
- Certification. What is the certification (wind turbines) process?, loads need to be correct.

Preconstruction phase group:

- Differentiation should be done onshore vs offshore when validating reanalysis.
- Do we need 20 years? Time consistency. On one hand long term is needed for climate change, on the other hand consistency is challenging in long time periods. Not all information is available (e.g. what observations have been included in the reanalysis?). Should we use other products? – maybe also use reanalysis with consistent input data. What options are relevant?
- Validation and benchmarking. Interest from developers to share validation information. How to do the validation, what data to be shared. Defining the way could be part of a Task. Metrix are also important to be defined. Can we use production data from wind farms?. New regions for validation to be considered.

Operational and grid group:

- There are existing groups, IEA could play a role in the operational ongoing coordination within a new Task, providing a steering function for collaboration between data producers for validation and curation. Best practice and quality assurance. Make it clear what is needed.

- Central place to define what data is needed, provide data for reanalysis validation and assimilation.
- International cooperation, focus on emerging nations, which rely more on reanalysis. What time and space scales are needed?
- Value of an IEA Task could be to consolidate national experience, evaluate value of open data and its impact.
- Include other technologies and the full system. Consider the role of WMO.

Climate change group:

- What is the relation between climate change and reanalysis? How to deal with uncertainty and how to use data.
- Who is responsible for the use of reanalysis in a good way? Representativity of data, education of users.
- Recommended practices are needed.

Conclusions & Next Steps

The IEA Wind TEM#111 fulfilled the objectives set out in the Introductory Note (Appendix 1). From the presentations given during the TEM, and the following discussions, a consensus emerged regarding two main ways forward:

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    c. Ad-hoc: wind- and energy representation in public forums linked to reanalysis.

To purse these goals and carry out these activities, an IEA Task may not be needed. During the rest of the year 2024, the organization team will investigate what the already existing platforms and initiatives which could host these activities.

Useful References

Energy Systems Integration Group. 2023. Weather Dataset Needs for Planning and Analyzing Modern Power Systems (Full Report). A Report of the Weather Datasets Project Team. Reston, VA. https://www.esig.energy/weather-data-for-power-system-planning.

WRAG. Wind measurement- and model datasets: https://groups.io/g/wrag/wiki/13236.

APPENDIX ONE – TEM#111 Introductory Note

INTRODUCTORY NOTE

IEA WIND TASK 11 TOPICAL EXPERT MEETING #111

ON

REANALYSES FOR WIND ENERGY

Rémi Gandoin – C2Wind

Julia Gottschall – Fraunhofer IWES

Rogier Floors – DTU Wind Energy

A. VALUE FOR IEA WIND TCP

BACKGROUND

For more than two decades[1,2] reanalysis datasets[3] have been used for wind energy applications, mainly:

- For characterizing large scale spatial variations and long-term fluctuations of the wind resource;
- For driving hydrodynamic and spectral wave models and characterizing site conditions for offshore sites;
- As input to mesoscale and microscale flow models (downscaling).

The value of reanalysis datasets for wind energy applications has been demonstrated and communicated to reanalysis providers in many studies[4]. This document outlines the current state of collaboration / relationships between reanalysis providers and the Wind Energy communities, identifies challenges and opportunities and then proposes a Topical Expert Meeting (TEM). This TEM will aim at discussing these topics with a broad Wind Energy audience and pave the way for the possible creation of an IEA Wind Task dedicated to Reanalyses for Wind Energy.

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[1] (Giebel, 2000) "Equalizing Effects of the Wind Energy Production in Northern Europe Determined from Reanalysis Data" https://www.osti.gov/etdeweb/servlets/purl/20119757
[2] (Schartz, George and Elliot, 1999) "The Use of Reanalysis Data for Wind Resource Assessment at the National Renewable Energy Laboratory" https://www.nrel.gov/docs/fy99osti/26152.pdf
[3] See https://reanalyses.org/ for an introduction to reanalysis.
[4] WRAG, 2022) "Wind Energy practitioners, ERA5 and the Copernicus Data Store" https://groups.io/g/wrag

MOTIVATION

Despite the vast adoption and the routine use of reanalysis datasets for Wind Energy purposes, the communication and knowledge sharing between reanalysis providers and Wind Energy scientists/practitioners remains sporadic and uncoordinated; see *Figure 1*:

- Most knowledge sharing between reanalysis providers and Wind Energy stakeholders takes place during meteorology-focused conferences and workshops;
- Wind Energy-specific knowledge sharing about reanalyses takes places in Wind Energy-specific conferences and workshops;
- Faint, industry-led initiatives have established independent connections with some reanalysis providers, mainly for providing one-way feedback.

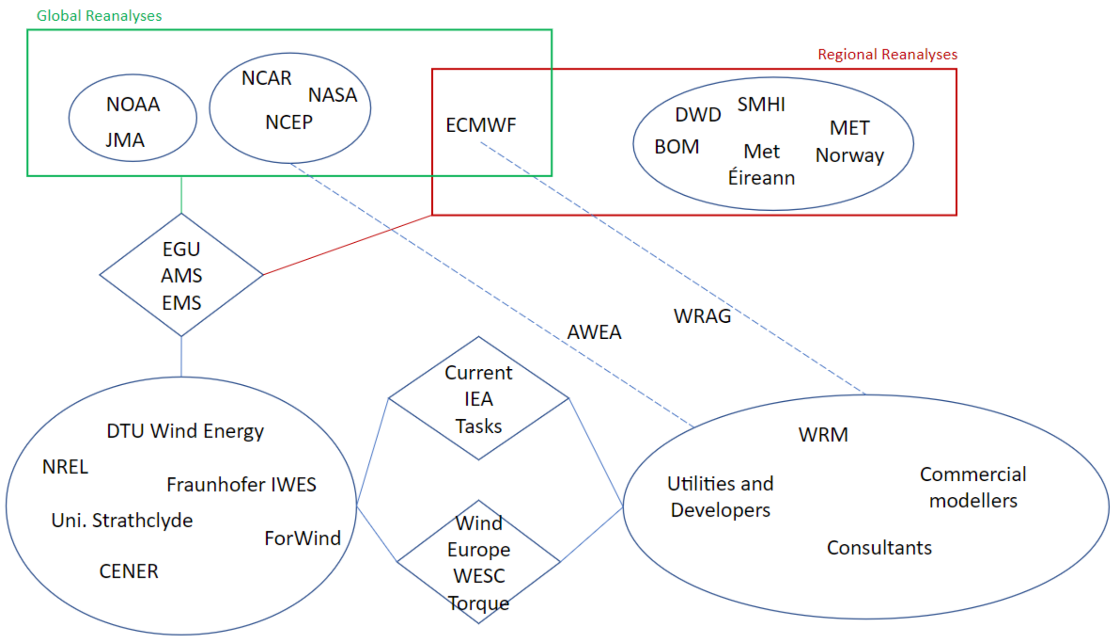

Figure 1: Current state of collaboration between Wind Energy communities and reanalysis providers. Dashed lines indicate faint, sporadic discussions.

This current situation leads to several missed opportunities and poses risks to the Wind Energy projects. In effect:

1) As communicated in public forums[5], there is often no long-term funding for reanalysis projects. Thereby, the continuous development (and improvement) of reanalyses is not guaranteed and should not be taken for granted.

2) Reanalysis providers are not always aware of Wind Energy use cases, and of the value of reanalysis datasets. This leads to misunderstandings and/or sub-optimal data deliverables[4,6].

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[5] (Dee, 2023) "Introduction to reanalysis". ECMWF Annual Seminar 2023. https://ecmwfevents.com/assets/presentations/as2023-dee1693842347.pdf

[6] (Gandoin, 2023) "Added-value and shortcomings of ERA5 for Wind- and Metocean Site Conditions Assessments" https://eo-winds.net/wp-content/uploads/2023/09/ECMWF_Seminar_2023_Poster_R_Gandoin_v1.pdf

3) A wealth of high quality, Wind Energy specific datasets can be used for validating and improving reanalysis products. However, these validations – albeit of very good quality – are carried out years *after* the reanalysis datasets are produced. As this is done routinely for Wind Energy projects, early validations during the pre-production phase of the reanalysis dataset would de-risk their applications and increase their value.

4) For future reanalyses such as ERA6 and ERA7, some coordination with ECMWF is taking shape; yet, it should be supported and sustained. At the moment this is done mainly through the Wind Resource Assessment Group (WRAG) and it involves a few individuals only (i.e., this group lacks legitimacy and representativity).

We propose to present, address and discuss a way forward on these issues during a Topical Expert Meeting (TEM) to be held during Q1 or latest Q2 2024. If deemed relevant by the participants, this meeting will also pave the way for the creation of a "Reanalyses for Wind Energy" IEA Wind Task. The task would serve both as:

- Knowledge-sharing platform within the Wind Energy community (as, e.g., the IEA Wind Task 52 for Lidar applications) and as
- Active collaboration forum between the Wind Energy community and the Reanalysis data providers.

A sketch of the envisaged central role of the IEA Wind Task is provided in Figure 2. The TEM and task's objectives are specified in Section **Erreur ! Source du renvoi introuvable.**.

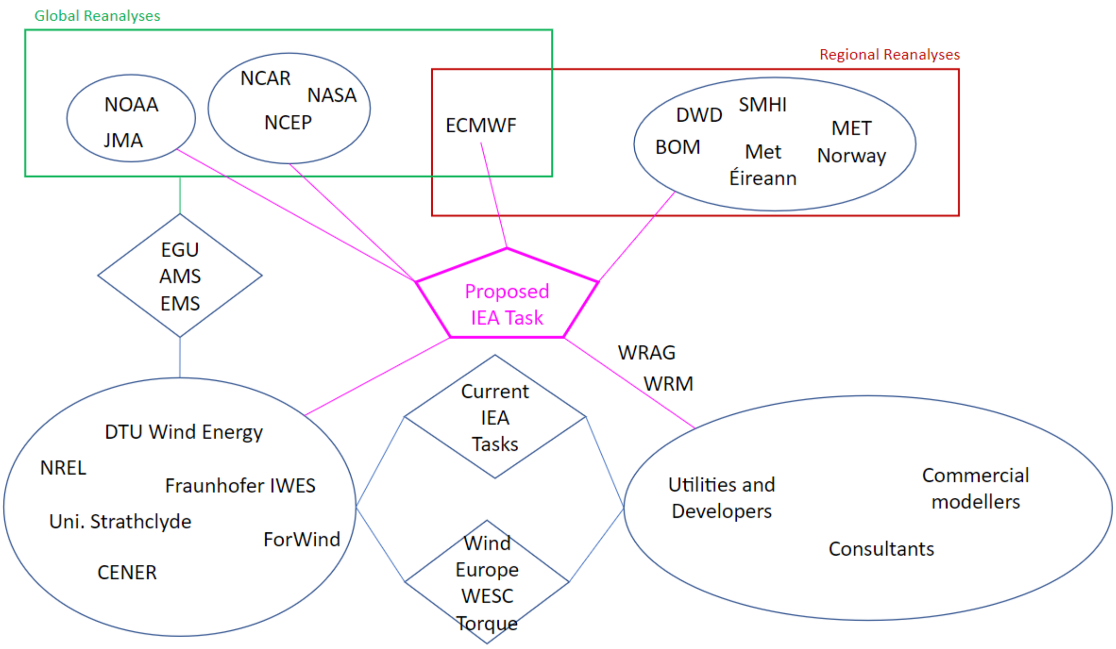

Figure 2: Desired/future state of collaboration between Wind Energy communities and reanalysis providers, after the IEA Task has been created.

ADDED VALUE OF COLLABORATION

The proposed IEA Task would form a unique collaboration forum. To the best of our knowledge, there exist no such mid-to-long term, formal collaboration initiative between Reanalysis providers and Wind Energy scientists and -practitioners.

ALIGNMENT WITH IEA WIND STRATEGY

To the best of our knowledge, there were no past TEM on this topic. As Reanalysis data feed into a great number of Wind Energy models and applications, improving Reanalysis datasets fits well with the IEA Wind strategic objectives, and the following Grand Challenges[7] (GC) in particular:

- GC1: the atmosphere:
  - Impact of atmospheric turbulence on performance and loads of wind turbines: knowledge gaps and research challenges
  - Mesoscale wind plant wakes
  - Scientific challenges to characterizing the wind resource in the marine atmospheric boundary layer
- GC3: the plant and grid:
  - Grand Challenges of wind energy science – the grid

B. MEETING FORMAT AND GOALS

OBJECTIVES

The TEM will aim at addressing the issues listed above as 1) to 4). Specifically, the TEM will aim at:

- Collecting experiences and suggestions on these issues, from a wide range of Wind Energy stakeholders (academia, utilities, developers, consultants, data providers). This will be done via:
  - An online questionnaire sent out prior to the event (see an example in footnote 4)
  - A set of presentations given during the event by the participants.

  The discussions will be logged and condensed into a publicly available compendium document.

- Paving the way for future actions aiming at improving/solving these issues. A proposal for the creation of a dedicated IEA Wind Task will be brought forward and discussed. Actions will be agreed upon.

The proposed IEA Task will serve the following objectives:

- Improve access and documentation of reanalysis datasets. While some providers have set up user-friendly data platforms such as the Copernicus Data Store (CDS), other reanalysis datasets remain under-valued because of some difficulty in accessing and/or processing the data. For the already well functioning platforms such as the CDS, the

[7] (Veers et al, 2022) "Grand Challenges: wind energy research needs for a global energy transition" https://wes.copernicus.org/articles/7/2491/2022/

Task would act as a knowledge sharing forum to improve best practice and understanding of the datasets.

- Promote and foster validation and advertise successful applications of reanalysis datasets for Wind Energy applications, and thereby improve their value.
- Act as a point of contact / collaboration forum between reanalysis providers and the Wind Energy communities. For instance, contributions to the making and validation of ERA6 and ERA7 can take place within this forum. The forum will actively seek to connect both communities.

SPECIFIC OUTCOMES

After the TEM, a compendium document will be produced. It will include:

- A summary of the above-listed issues 1) to 4).
- A summary of the presentations given during the meeting.
- A summary of the online questionnaire and the discussions which took place during the meeting.
- A list of actions addressing the issues raised during the meeting, in relation to the creation of a dedicated IEA Task in particular.

INTENDED PARTICIPATION

The primary target group are participants from Wind Energy academia and industry, listed in Figure 1 and Figure 2. Selected contacts within the Reanalysis community will be asked for their interest in participating actively, or as listeners.

TENTATIVE PROGRAM

TEM#111 will take place over 1.5 days at DTU Lyngby (Denmark), on 25th and 26th of April 2024. A preliminary agenda follows.

- During the first day, presentations will be held and a broad audience of online and in-person participants will be invited.
- For the second day, the discussions will focus on the way forward and the IEA Task proposal. Only pre-selected / interested participants will be invited, for the sake of efficiency. We expect the interested parties to coordinate with their (national) organizations prior to the TEM, in order to propose participants for Day 2.

	Day 1: Thursday 25th of April
09:15-09:30	Intro
09:30-10:30	Presentations #1
10:45-11:45	Presentations #2
11:45-13:00	
13:00-14:00	Presentations #3

14:15-15:15	Presentations #4
15:30-16:30	Online questionnaire discussion and Q&A

	Day 2 (in-person): Friday 26th of April
09:30-10:30	Way forward with TEM and IEA Task - #1
10:45-11:45	Way forward with TEM and IEA Task - #2
11:45-13:00	Wrap-up and lunch

APPENDIX TWO – Meeting agenda

DAY1 - THURSDAY 25 April 2024							
Time		**First name**	**Last name**	**Country**	**Company/Organization**	**Title**	**Topic**
08:30	**09:00**	**Welcome**					
09:00	**09:10**	**Introduction**					
		Rémi	Gandoin	DK	C2Wind	Kick-off	
		Jake	Badger	DK	DTU	Safety presentation + Welcome from DTU	
		Ignacio	Marti	CH	Planair	Introduction to IEA Wind	
09:15	**09:45**	**Regional reanalysis from Australia / New Zealand. Chair: Rémi Gandoin (C2Wind).**					
09:15	09:25	Chun-Hsu	Su	AU	BOM	BARRA: the Australian regional atmospheric reanalysis **(online)**	BARRA
09:25	09:35	Stuart	Moore	NZ	NIWA	NZRA: production and application of a high-resolution regional reanalysis for Aotearoa New Zealand **(online)**	NZRA
09:35	09:45	Q&A with all speakers					
09:45	**10:45**	**Short presentations on use cases (state of the art). Chair: Rémi Gandoin (C2Wind).**					
09:45	09:55	Lasse	Svenningsen	DK	EMD	Reanalysis Use Cases (state-of-the-art)	Wind & Site
09:55	10:05	Jacob	Tornfeldt Sørensen	DK	DHI	Offshore wind design applications of reanalysis data for metocean modelling and analysis	Metocean
10:05	10:15	Justin	Sharp	US	Sharply Focused	The Urgent Need for Quality Weather Data to Support Decarbonization	Power Grid
10:15	10:25	Jiali	Wang	US	ANL	Assessment of wind conditions in reanalysis and dynamically downscaled data	Downscaling
10:25	10:35	Julia	Gottschall	DE	Fraunhofer IWES	How reanalysis help us improving on-site measurements	Wind & Site
10:35	10:45	Q&A with all speakers					
10:45	**11:00**	**Break w food and drinks**					
11:00	**12:30**	**Keynotes on global reanalyses: current status and future plans. Chair: Julia Gottschall (Fraunhofer IWES).**					
11:00	11:30	Jim	Wilczak	US	NOAA	Status of Reanalysis Products and Renewable Energy Applications at NOAA's Physical Sciences Laboratory	
11:30	12:00	Michael	Bosilovich	US	NASA	NASA GMAO Reanalyses and Prospects for Future Collaborations	
12:00	12:30	Paul	Poli	DE	ECMWF	Towards ERA6 & C3S support to the energy community	
		Delphine	Deryng	DE	ECMWF		
12:30	12:45	Q&A with all speakers					
12:45	**13:45**	**Lunch**					
13:45	**15:15**	**Regional reanalysis. Chair: Rogier Floors (DTU).**					
13:45	14:00	Semjon	Schimanke	SE	SMHI	Copernicus European Regional ReAnalysis – CERRA **(online)**	CERRA
14:00	14:15	Birgitte	Furevik	NO	Meteorological Institute	The 3-km Norwegian reanalysis - NORA	NORA3
14:15	14:30	Thomas	Spangehl	DE	DWD	User-oriented evaluation of reanalyses at DWD with focus on offshore wind energy	DWD Reanalysis
14:30	14:45	Paula	Gonzalez	GB	Met Office	Using reanalysis for energy applications: a climate scientist perspective **(online)**	Climate
14:45	15:00	Simone	Sperati	IT	RSE	Regional reanalysis & wind atlas for Italy	Downscaling
15:00	15:15	Q&A with all speakers					
15:15	**15:30**	**Break w food and drinks**					
15:30	**17:00**	**Future uses / improvements and shortcomings. Chair: Jake Badger (DTU).**					
15:30	15:40	Lasse	Svenningsen	DK	EMD	Reanalysis Future Uses Improvements & Shortcomings	Wind & Site
15:40	15:50	Diogo	Silva	PT	Megajoule	End-user Perspective on the Usage of Wind Reanalysis	Site Conditions
15:50	16:00	Gil	Lizcano	BE	Climate Scale	How can reanalysis help us understand and quantify future wind conditions	Climate Change
16:00	16:10	Justin	Sharp	US	Sharply Focused	The Urgent Need for Quality Weather Data to Support Decarbonization	Power Grid
16:10	16:20	Q&A with all speakers					
16:20	16:30	Rogier	Floors	DK	DTU	Current usage and future applications of reanalysis data	Downscaling
16:30	16:40	Natacha	Fery	DK	Vattenfall	Reanalysis in offshore wind industry and impact on metocean design parameters	Metocean
16:40	16:50	Michael	Blair	UK	The Crown Estate	Intro to TCE's Wind, Metocean & Climate Change Data Creation Project	Project planning
16:50	17:00	Q&A with all speakers					
17:00	**17:30**	**Debriefing in small groups - unwiding - preparation of Day 2**					
19:00		**Dinner**					

DAY2 - FRIDAY 26 April 2024		
Time		
08:30	09:00	**Welcome**
09:00	09:15	**Debrief of day 1 + results of online survey**
09:15	10:15	**Session 1: improvement of existing datasets (access, usage, validation)** Group A (focus: offshore wind and metocean) - Rémi Group B (focus: pre-construction phase) - Julia Group C (focus: operational / grid / O&M) - Jake Group D (focus: others) - Rogier This session will be focused on the current situation with datasets we have today: - how do we work together today? how does your network look like? - what are the challenges we are facing? - what initiatives are required to solve these challenges? People can join one of the groups based on their interest and their expertise (or both). In each group a moderator (and one member of the organisation team) will take notes and help write down project ideas (a template will be provided).
10:15	10:45	**Debriefing Session 1 - Ignacio**
10:45	11:00	**Break w food and drinks and group picture**
11:00	12:00	**Session 2: improvement of future datasets and potential future collaboration** Group A (focus: offshore wind and metocean) - Rémi Group B (focus: pre-construction phase) - Julia Group C (focus: operational / grid / O&M) - Jake Group D (focus: others) - Rogier This session will be focused on the near and long term situation: - what do we want to achieve in the future? - what initiatives are required to solve these challenges? - what does this imply for future reanalysis datasets - how do we want to work together in the future? (there are no pre-defined approaches, all suggestions are welcome, IEA Wind Task is one out of many possibilities) People can join one of the groups based on their interest and their expertise (or both). In each group a moderator (and one member of the organisation team) will take notes and help write down project ideas (a template will be provided).
12:00	12:30	**Debriefing Session 2**
12:30	13:00	**Closure and lunch thereafter for those who can stay**

DAY2 - FRIDAY 26 April 2024		
Time		
08:30	09:00	**Welcome**
09:00	09:15	**Debrief of day 1 + results of online survey**
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		Group C (focus: operational / grid / O&M) - Jake Group D (focus: others) - Rogier This session will be focused on the near and long term situation: - what do we want to achieve in the future? - what initiatives are required to solve these challenges? - what does this imply for future reanalysis datasets - how do we want to work together in the future? (there are no pre.defined approaches, all suggestions are welcome, IEA Wind Task is one out of many possibilites) People can join one of the groups based on their interest and their expertise (or both). In each group a moderator (and one member of the organisation team) will take notes and help write down project ideas (a template will be provided).
12:00	**12:30**	**Debriefing Session 2**
12:30	**13:00**	**Closure and lunch thereafter for those who can stay**

APPENDIX THREE – Survey Results

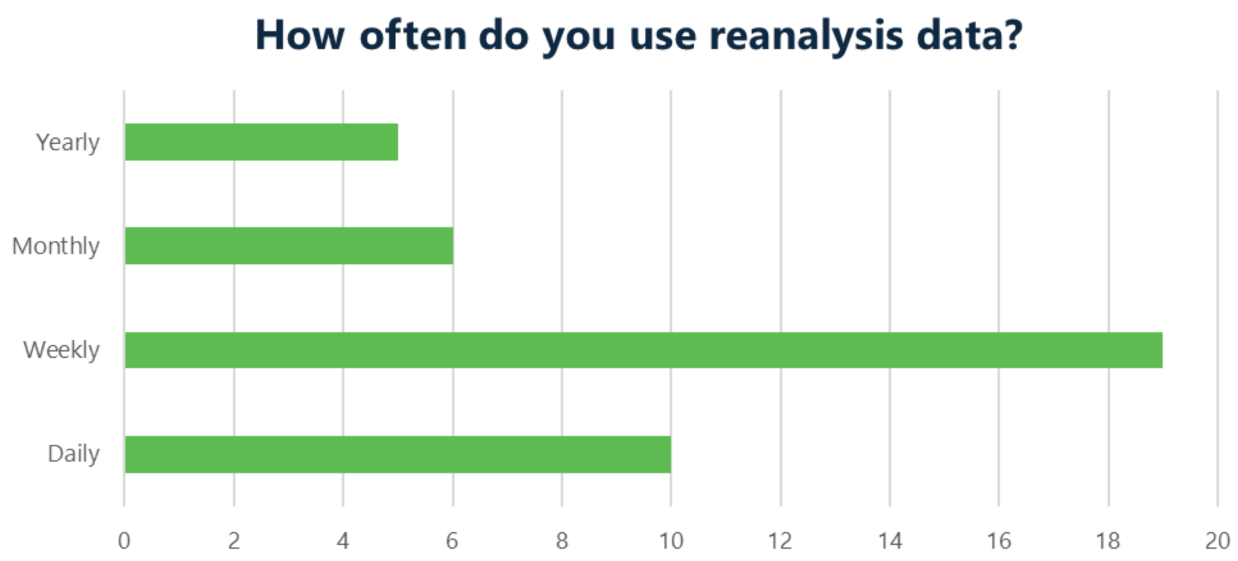
Preliminary Survey to 76 participants. Total participant response number: 31 (+ 5 partial answers)

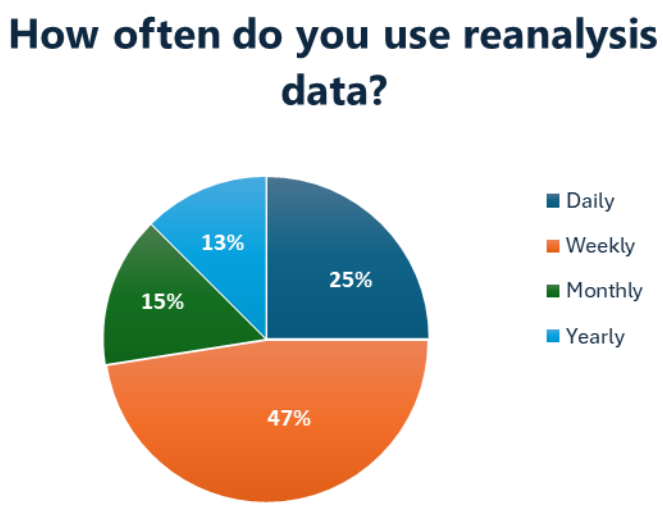
Objective:

Due to time limitations during the TEM and in order to maximise its effectiveness by encouraging focused debate on specific key issues, the participants were invited to answer the following 5 questions:

1. How often do you use reanalysis data?
2. Provide up to 3 items / topics which you would like to discuss at the TEM
3. Provide up to 3 examples of how the Wind Energy community could help improve future reanalyses
4. Provide up to 3 examples of how future Reanalyses can support Wind Energy
5. After the TEM, how would you like to contribute to the Wind Energy / Reanalysis collaboration?

Survey's results: Use of Reanalysis





- **22 comments:**

Daily
1. Mostly CFSR, ERA5, NORA03, COSMO-REA6
2. Cannot really answer this question. I have contributed to making re-analyses data / wind atlases (https://www.knmiprojects.nl/projects/knw-atlas; https://www.dutchoffshorewindatlas.nl/ and https://wins50.nl/), not usi
3. Continuous monitoring and evaluation of production
4. Downscaled ERA5 is the fundament for all our climate analyses
5. (producer but also user)
6. Looking at reanalysis products and using them is part of the daily tasks in the metocean team of Vattenfall
7. Day to day use in projects (usually via the PhD students + postdocs I supervise rather than personally handling the

Weekly
1. Mostly use it for data validation, wind variability and long term adjustment and correlation
2. I use the data often for mesoscale and global model evaluation
3. Currently, I mainly use climate model output. But I've used reanalysis data daily in 2018-2021, so weekly is a good here.
4. To initialize WRF mesoscale model forecast or compute long term adjusted wind speed in the case of an energy yie
5. Analysis of low wind events
6. We also use the derivatives of wind forcings, such as wave or HD models forced with global/regional reanalyses
7. Provision of reanalysis products and results to scientific community, public, national authorities, ...
8. I am not a direct user (that's people I supervise), and use it for some but not all projects
9. Often used as a proxy for observations, whether for further modelling or validation
10. I am only starting my PhD in which I will use reanalysis data.
11. Sometimes weekly, sometimes monthly, occassionally daily.

Monthly
1. Provision of reanalysis products and results to Federal Maritime and Hydrographic Agency in Germany (BSH)
2. We are a producer of reanalysis but we use the data rather rarely ourselfs, unfortunately
3. Mostly for WRF modeling

Yearly
1. Provision of reanalysis products and results to Federal Maritime and Hydrographic Agency in Germany (BSH)

Survey's results: Topics the participants would like to discuss at the TEM

- Data access
  - Keep it simple (w/o python, ncl or python)
  - Faster
  - Interpolation

- Accuracy
  - Before 1979, consistency
  - Improve accuracy using in-situ measurements
  - Validation and *certification,* standard metrics, tracking of accuracy against running measurements (monthly)
  - Errors in meas. used for DA
  - Database of known issues
  - Coordinated evaluation and validation (for offshore)
  - Uncertainty
  - Land use

- Applications
  - Extreme wind speeds (higher temporal resolution?)
  - O&M
  - Cross-industry
  - Comparison with climate models (grid)
  - Precipitation
  - Regional vs global reanalysis?
  - Downscaling
  - Waves, currents, etc.

- Future products
  - More elevations and variables (incl sfc fluxes for ex.)
  - Data access
  - User requirements
  - ERA6

➢ **34 comments:**

1	2	3
enhancing accuracy of reanalysis	reanalysis applications	
use of reanalysis data for the estimation of design wind speed and wave height	uncertainty of the reanalysis data	future plan of the reanalysis with finer grid resolution
reanalysis precision and consistency		
ERA5	OSWE maintenance	areas of technological/data growth
How to effectively communicate the advantages and disadvantages of reanalysis data to users outside the atmospheric sciences community. Researchers must be aware of potential problems in some energy application studies. Could we generate a best practices document?	It is often very difficult to access data on the land representation in reanalysis models. Sometimes, the surface roughness fields are not available	
Data quality before 1979	Can we use wind farm operational data to improve future reanalysis? (maybe ERA7 onwards)	
Future provision of reanalysis data	Future data access	Future variables
novel engineering use-cases for engineering data	sector cross-overs (e.g. wave, tidal, other)	value of validation/certification of data products for specific use-cases
Data validation: approaches, techniques, requirements	Uncertainty quantification	Data access (including documentation and processing libraries)
early detection of wrong analysis due to ingestion of poor observations	a centralised database of reanalysis known issues	make access and post-processing of reanalysis data easier: eliminating the need to code using cdo, ncl or python
Long term consistency	Missing/important output variables	Expected changes and improvements in ERA6
Output of wind at different height levels (100m, 120m, 150m, 200m)	Reanalysis data in the same resolution and a regular grid to facilitate comparisons with climate models (e.g. CMIP7, new EURO-CORDEX runs)	Higher temporal resolution for the investigation of extreme events
Coordinated evaluation and intercomparison of reanalysis data and products for offshore wind energy applications	Provision of reanalysis data and products including uncertainty information	User requirements, e.g. quality levels, documentation, data format, ...
faster access of time series data through the CDS or general data accessing issues	inclusion of basic meteorological boundary layer variables, like z0, heat flux, friction velocity, because these are important for developing models	interpolation of winds : best practices are providing a tool that can do this based on model level output at location where data is stored
How well can we trust reanalysis data for precipitation?		
Uncertainty of reanalyses (wind) data	Calibration of reanalyses (wind) with observation to increase the accuracy	
Sharing of observational data for evaluation and assimilation	Collaboration on assessment from application perspective, to identify strengths and limitations	Standard metrics for assessing reanalysis products for wind energy applications
Validation benchmarks for reanalysis products		

Desired output variables: mean wind speed in the monthly mean datasets; more height above ground levels (e.g., winds every 50 m from 50 to 400 m above ground level)	Tracking of accuracy of ERA5, using validation against measured winds (of high quality) that are not ingested into the data assimilation. By tracking, I mean, monthly or quarterly updated validation	ERA6 plans and update
State of art from calibration of datasets, and available data for this		
Downscaling for Wake Modelling	Reduction of phase errors	
Collect user feedback in general	What should be improved in regional reanalysis products?	In how far do users see an advantage of regional reanalyses over global products when it comes to wind energy applications?
How to communicate that reanalyses are a reliable source of data with the uncertainty comparable with measured data		
uncertainties	ERA5 before and after 1979	land use models
Methods of down-scaling reanalysis spatially AND temporally	Assessment methods of reanalysis products	Requirements of reanalysis that can be implied from big statistics
Our main interest is the usage of the reanalyses data in projects, not limited to atmospheric data. Meaning we are keen to discuss the ocean related parameters such as waves, currents, ice etc. Metocean topic in general is our main interest	We are focused on the value that such data could bring to our business cases in a meaningful way, and not purely research topics that might help offshore wind at some point in future	Also interested to hear how other developers use such data
ERA5 diurnal wind speed trend	step change between assimilation cycles	
Uncertainties?	Observations?	How far back into the past?
updates on coupled atmosphere/ocean reanalyses and their performance	updates on the upcoming reanalysis products	metocean related products (waves/currents)
fair	wave standards	validation
International cooperation on energy relevant data collection	accessibility for modelling	
Validation	Data for assimilation and ground truth	Curation
To what extent does/can the validation and tuning of reanalysis focus on performance for surface variables at relatively local scales? E.g., headline metrics reporting reanalysis performance are often Z500 ACC which is a good way to assess the large-scale circulation ... how far can these be systematically complemented by verification of finer-scale surface variables relevant to energy applications?		
Discuss wind farm/turbine and climate change effects and how to properly descibe wind climate. What I find important it that we realise that wind farms strongly affect the atmosphere (they are designed to do this and are not 'just obstacles') and that number/size of wind farms/turbines will continue to increase rapidly in the next		

decennia. A reanalyses is by definition a representation of the past climate: it does not include the effect of climate change or the effect of changes in the environment (such as growing number of wind farms). So a reanalyses is ofen not representative for the future (same for measurements by the way) . In https://wins50.nl/ we have modelled the effect of wind farms for a hypothetical wind farm scenario for the North Sea in 2050. With the knowledge we had at the start of the project, we assumed a total of 190 GW installed power on the North Sea in 2050, but ambitions continue to grow and now the aim is 300GW! (10 times more than installed in 2023). In my opinion, the only way forward for wind resource assesments is to furher improve wind farm and turbine parametrisations and to use these in mesoscale/LES models to model future years with expected wind farm scenarios. Without taking the effect of wind farms/turbines into account, we do not get realistic estimates of the wind resource in the future (35 year life span of wind farms). With regard to the undisturbed wind (without wind farm effects): we know that (1) you need to look at at least 30 years to describe a wind climate properly, (2) there is an inter-annual variability (IAV) of about 4% on the southern North Sea (https://www.knmiprojects.nl/projects/knw-atlas/documents/reports/2017/06/12/inter-annual-wind-speed-variability-on-the-north-sea) and (3) we expect no significant trend in wind climate (averages and extremes) at heights relevant for wind energy. For future climate projections it is probably interesting to also look at changes in wind speed distibutions (power curve effect on yields) not only at changes in averages and extremes.

Survey's results: How the Wind Energy community could help improve future reanalyses?

- Sharing measurements
  - Atmospheric
  - Ocean
  - SCADA
- Validation
  - Document deficiencies
- User requirements
  - Clearly expressed
  - Use cases
  - Demonstrate financial value
- Working together
  - Communication
  - PBL schemes
  - Wind Energy products

➢ **32 comments:**

1	2	3
sharing data	extensive validation of existing datasaets	
could provide more measurement data, especially offshore		
Worldwide mast systems (and other measurement campaigns like LiDAR) for reanalysis improvement with emphasizes in wind studies		
more data? sorry this is not my expertise		
Provide measurements	Provide and document deficiencies in current datasets	Clearly express user needs in terms of, for example, vertical resolution (meters above ground, hybrid sigma pressure levels, which band etc.), and variables (instantaneous winds every hour, max gusts, mean wind energy density etc.)
Better communication of how important data is for industry	Open validation of industry extensive measurements against reanalysis datasets	
Guiding specification (parameters, resolution, accuracy), demonstrating financial value		
By defining use cases	By specifying requirements	By performing specific validation studies for wind energy applications
early detection of wrong analysis due to ingestion of poor observations	a centralised database of reanalysis known issues	make access and post-processing of reanalysis data easier: eliminating the need to code using cdo, ncl or python
Feedback on performance and issues	Possibly as surface observations	

Measurement of wind directly at windturbines and at met masts (weather masts) as additional input for reanalysis data	Possibility for improvement of boundary layer paramateritation like low level jet etc.	
Providing measurements more openly, incl. SCADA data, wave data and temperature data as well as ocean currents	By keeping a good communication with reanalyses owners (ECMWF and NOAA or MetNorway etc) and highlighting the importance of their data to making a greener future	
A reanalysis is no more (or less) than a summary of all available measurements in the past using an atmospheric model (smart way of connecting all these measurements). There are not many measurements at hub height, so if the wind energy community would share their (SCADA) measurements, it would improve reanalyses providing the measurements are of good quality (so we need metadata and measurement uncertainties too)	For a reanalysis sharing historical data would already help (for forecasts we need near-real time).	
open source and standardized data to evaluate reanalysis	communicating issues with the data through a well-known open platform	
We could analyse wind and precipitation data for sites with wind farms to further understand the erosion risk for wind turbine blades		
The absolute wind speeds of reanalyses values have a lack of quality, the wind industry has the measurment data to improve that quality		
Provision of extra observations for assimilation in future reanalyses. These should include data quality information	Provide feedback on the strengths and limitations of reanalysis products. Possibly providing quality assurance and independent benchmarking	Advocate for ongoing development of future reanalysis. Communicate strengths and limitations of various reanalysis products to downstream users, ensuring they are used appropriately
Inform reanalysis makers of their needs		
Nothing at this time		
Build broad collaborations across e.g. meteorology, energy and climate communities for production of datasets		
Include wake information into reanalysis, e.g. wake parametrisation in the global model	Provide wind measurement data	
Help to examine the products and feedback to the developers weaknesses		
Provide specific objectives, for example: include reliable turbulence information, ensure proper representation of vertical profiles in the PBL		
Feedback from comparisons with measurement campaigns		
Provide feedback on user needs and requirements	Provision of wind data/information that can be used for assimilation and/or evaluation of reanalyses	
Providing uncertainty estimates of reanalysis products, separating between systematic (=bias), random (=no time correlation), and structured	Providing new observations that can be used to better understand deficiencies, and measure progress	

(=correlated over some temporal duration) components		
Sharing of in-situ measurements for validation and feedback to reanalysis research	Consultants to share the results of their long term local modelling and make it publicly available (similar to the Dutch waters)	
easier sharing of offshore data let us know what the needs are		
Provide data measured at wind and solar sites	Improve quality of measured met data at wind and solar parks	
Verification	Possible data for assimilation into reanalysis (esp regional reanalyses)	Much assessment on spatial resolution of wind in reanalysis, perhaps more investigation of temporal quality (e.g., ability to capture fluctuations hour-to-hour)?
Providing assessment of needs	Providing data for assimilation and validation	Coordinating experts/interfaces to convert data into fit for purpose intelligence
Take ownership/build partnership with climate/reanalysis model people to enable dataset production specifically for Wind Energy assessment	Enable the use of such models to be submitted to inter-comparison climate/reanalysis projects, such as CMIP	Create own reanalysis comparison project to encourage development towards wind energy data goals

Survey's results: How future Reanalyses can support Wind Energy?

- **32 comments:**

1	
wide coverage and high resolution over territories	
The uncertainty of the design condition coule be reduced, especially wave and sea current	
In early-phase studies, reanalysis can help predict the variability and evolution of the meteo and wind parameters in the following years, and allows for the assessment of measured data from measurement campaigns, allowing for more precise results	
More precision especially in measurements of wind speed originating from the sea horizon vs originating from nearby land	
Better resource assessments	Better contextualization and inclusio (decadal to multi-decadal fluctuation
Dialogue on future reanalysis roadmap	Provision of more variables of heigh
Quantifying uncertainty (spatially), engaging to understand needs, compatibility with climate change impact analysis	
As a data base for (grid) integration studies	As a data base for side assessment
using an ensemble approach for long term adjustments of wind speed to reduce the uncertainty of wind projects and improve bankability	
In important tool for renewable, and hence, intermittent sources of energy	
More reliable estimation of wind in hub height of wind turbines	Better reproduction of historical wind trend of wind energy
Higher accuracy reanalyses and help de-risk the projects which will help pushing projects forward	
A reanalysis can help understand the current climate (possibly with the effect of current wind farms if measurements in the wakes of these wind farms are included in making the reanalysis)	
Provision of information on long-term (interannual to decadal) wind variabilty and possible trends	Consideration of wake effects, e.g. u parameterization
providing variables that can be used for better resource assessment and microscale modelling	providing better wind speeds and dir at higher resolutions
Improved versions for mapping erosion risk due to precipitation	
Future Reanalyses can help to increase the quality of resource assessment	Future Reanalyses can help to incre modelling by providing better wind d
Provision of more reliable, scale-relevant and updated data	Ensure the data is complete (e.g., sp ensemble, levels), covering relevant
Provide high resolution turbulence related variables	Provide time varying roughness para
Nothing at this time	
Assessment of resource	Integration studies
Higher resolution datasets reduce downscaling efforts	Uncertainty reduction for long-term a
I do not know but I hope to learn about it at the TEM	
include reliable turbulence information, ensure proper representation of vertical profiles in the PBL	
Uncertainties in Reanalysis data could help in estimating uncertainties in wind resource	
Background information for low-frequency variability	Inter-relationships between essentia <-> waves <-> temperatures <-> win
Better spatial and time resolution	Atmospheric variables to be provide
dedicated output	

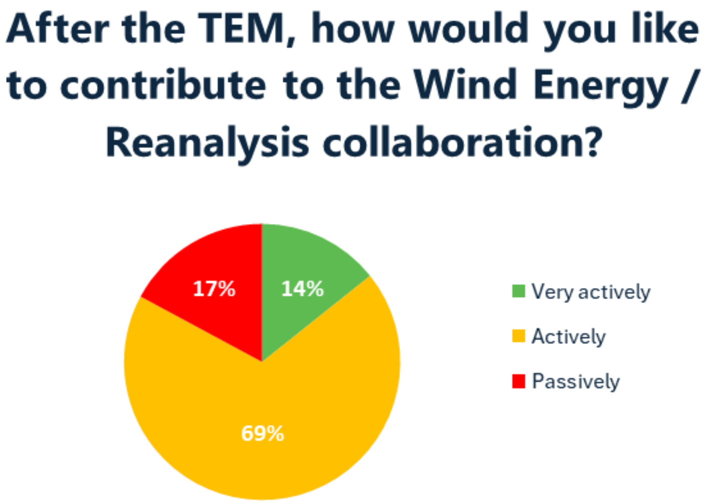
Better future projection and financing	Better training possibilities for real-ti
More extensive and better representation of near-surface wind climate	
Improved site assessment	Improved large scale planning
Allow the partnership/use of models which provide resolution (time and space) that can be used out-of-the-box for Wind energy research	Reanalysis products to be part of co energy) - give incentive to work towa used

1	2	3
wide coverage and high resolution over territories		
The uncertainty of the design condition coule be reduced, especially wave and sea current		
In early-phase studies, reanalysis can help predict the variability and evolution of the meteo and wind parameters in the following years, and allows for the assessment of measured data from measurement campaigns, allowing for more precise results		
More precision especially in measurements of wind speed originating from the sea horizon vs originating from nearby land		
Better resource assessments	Better contextualization and inclusion of climate risk in yield assessments (decadal to multi-decadal fluctuations & existing climate change)	
Dialogue on future reanalysis roadmap	Provision of more variables of height levels	
Quantifying uncertainty (spatially), engaging to understand needs, compatibility with climate change impact analysis		
As a data base for (grid) integration studies	As a data base for side assessment	As a data base for defining (wind park) operation strategies
using an ensemble approach for long term adjustments of wind speed to reduce the uncertainty of wind projects and improve bankability		
In important tool for renewable, and hence, intermittent sources of energy		
More reliable estimation of wind in hub height of wind turbines	Better reproduction of historical wind data to estimate the future climate trend of wind energy	
Higher accuracy reanalyses and help de-risk the projects which will help pushing projects forward		

A reanalysis can help understand the current climate (possibly with the effect of current wind farms if measurements in the wakes of these wind farms are included in making the reanalysis)		
Provision of information on long-term (interannual to decadal) wind variabilty and possible trends	Consideration of wake effects, e.g. usage of offshore wind farm parameterization	
providing variables that can be used for better resource assessment and microscale modelling	providing better wind speeds and directions due to model improvements at higher resolutions	clear communication of physics updates relevant for wind energy applications
Improved versions for mapping erosion risk due to precipitation		
Future Reanalyses can help to increase the quality of resource assessment	Future Reanalyses can help to increase the quality for energy system modelling by providing better wind data	
Provision of more reliable, scale-relevant and updated data	Ensure the data is complete (e.g., spatial resolution, temporal resolution, ensemble, levels), covering relevant wind energy use cases	
Provide high resolution turbulence related variables	Provide time varying roughness parameters	Provide sea state such as wave information
Nothing at this time		
Assessment of resource	Integration studies	Indirect use in e.g. dynamic line ratings and future climate/resilience
Higher resolution datasets reduce downscaling efforts	Uncertainty reduction for long-term assessment	
I do not know but I hope to learn about it at the TEM		
include reliable turbulence information, ensure proper representation of vertical profiles in the PBL		
Uncertainties in Reanalysis data could help in estimating uncertainties in wind resource		
Background information for low-frequency variability	Inter-relationships between essential climate variables (e.g. wind regimes <-> waves <-> temperatures <-> wind gusts)	Climate change
Better spatial and time resolution	Atmospheric variables to be provided at other heights than 10m	
dedicated output		
Better future projection and financing	Better training possibilities for real-time applications	
More extensive and better representation of near-surface wind climate		

Improved site assessment	Improved large scale planning	Improved operational intelligence (fuel guage)
Allow the partnership/use of models which provide resolution (time and space) that can be used out-of-the-box for Wind energy research	Reanalysis products to be part of comparison for impacts (not just wind energy) - give incentive to work towards products that can be more widely used	Assessment of impact of wind speed at height at each gridcell/location (either physically calculated in model or provided as a relationship/equation)

Survey's results: Future involvement



➢ **20 comments:**

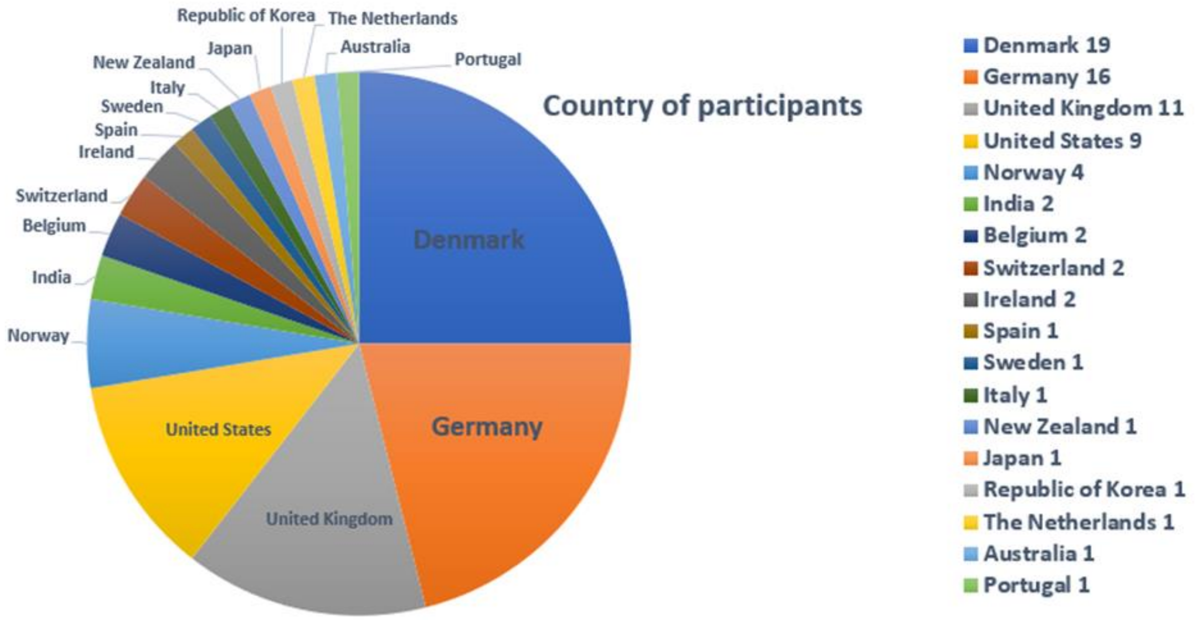
Very actively (ex: part of an IEA Wind Task management)
1. I can dedicate up to 5h a week
2. If I can secure a funding source

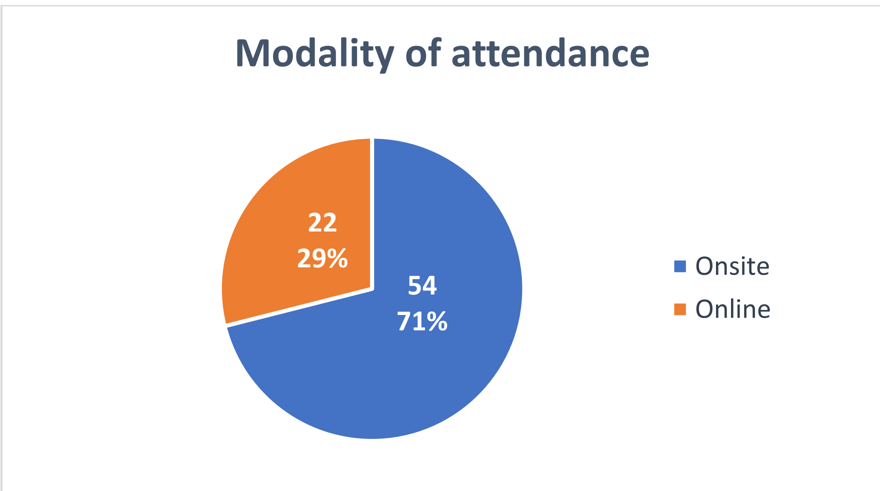
Actively (being an active participant / partner in the Task ex: data sharing, validation, modelling, etc)
1. I am an academic, so my main contribution will be through research and my expertise on long-term fluctuations and changes
2. Partner in the Task: data validation, modelling
3. Contributing to IEA task
4. Hope to be part of discussion, very happy to share data and perform validation
5. All our reanalysis (wind atlas) data are publicly available: https://dataplatform.knmi.nl/about.
6. Data sharing, validation or assessment, method development for enhancing existing reanalysis products
7. I'm not sure how much bandwidth I can commit, but would like to be involved.
8. Response is provisional pending learning more about the collaboration.
9. Modelling, Round Robin tests
10. This might depend on funding opportunities.
11. Collating new observations, quantifying reanalysis uncertainties
12. Vattenfall is open for participating in projects that could improve the outputs of the current reanalyses, and is willing to help in the validation of those products as we do have in-situ measurements at our assets.
13. As collaborator from wind task 51
14. Depends on nature of what the task involves and capacity to support dedicated activity for validation etc. However, regularly have projects that use reanalysis output.

Passively (being informed about the public results)
1. I'm an economist who likes to have deep perspectives to understand all of the dynamics in this sector from the economics perspective.
2. We would like to be informed about future development and availability of reanalysis data
3. Have limited time to contribute
4. Depends on nature of what the task involves and capacity to support dedicated activity for validation etc. However, regularly have projects that use reanalysis output.

APPENDIX FOUR - Meeting Participants

A total of 76 participants were registered to TEM#111, coming from 18 countries.





First Name	Last Name	Company / Organisation	Country
Neil	Adams	Carbon Trust	United Kingdom
Neil	Atkinson	K2 Management	Germany
Jake	Badger	Technical University of Denmark (DTU)	Denmark
Michael	Blair	The Crown Estate	United Kingdom
Nicola	Bodini	National Renewable Energy Laboratory (NREL)	United States
Michael	Bosilovich	Global Modeling and Assimilation Office, NASA GSFC	United States
David	Brayshaw	University of Reading	United Kingdom
Doron	Callies	Fraunhofer IEE	Germany
Peter	Clive	Black & Veatch	United Kingdom
Caroline	Coccoli	Carbon Trust	United Kingdom
Chris	Dent	University of Edinburgh	United Kingdom
Delphine	Deryng	European Centre for Medium-Range Weather Forecasts (ECMWF)	Germany
Mouhamet	Diallo	Tractebel Engie	Belgium
Krystallia	Dimitriadou	Technical University of Denmark (DTU)	Denmark
Martin	Doerenkaemper	Fraunhofer IWES	Germany
Matthew	Easton	Vattenfall	United Kingdom
Natacha	Fery	Vattenfall	Denmark
Jason	Flanagan	Irish Centre for High End Computing (ICHEC)	Ireland
Rogier	Floors	Technical University of Denmark (DTU)	Denmark
Birgitte Rugaard	Furevik	Norwegian Meteorological Institute	Norway
Sagar	Gade	ReNew	India
Rémi	Gandoin	C2Wind	Denmark
Maziar	Golestani	Vattenfall	Denmark
Paula	Gonzalez	UK Met Office	United Kingdom
Julia	Gottschall	Fraunhofer IWES	Germany
Andrea	Hahmann	Technical University of Denmark (DTU)	Denmark

Ásta	Hannesdóttir	Technical University of Denmark (DTU)	Denmark
Charlotte	Hasager	Technical University of Denmark (DTU)	Denmark
Marc	Imberger	Technical University of Denmark (DTU)	Denmark
Elke	Keup-Thiel	Climate Service Center Germany (GERICS)	Germany
Jinyoung	Kim	KIER	Republic of Korea
Daniel	Leukauf	Center for Solar Energy and Hydrogen Research Baden-Würtemberg (ZSW)	Germany
Gil	Lizcano	Climate Scale	Spain
Frank	Maaø	Equinor	Norway
Catherine	Mandler	Evenflow	Belgium
Jakob	Mann	Technical University of Denmark (DTU)	Denmark
Ignacio	Marti	IEA Wind Task 11 / Planair	Switzerland
David	McMillan	University of Strathclyde	United Kingdom
Heinz-Theo	Mengelkamp	anemos Gesellschaft für Umweltmeteorologie	Germany
Corinna	Möhrlen	WEPROG	Germany
James	Mollard	University of Edinburgh	United Kingdom
Stuart	Moore	National Institute of Water and Atmospheric Research (NIWA)	New Zealand
Shubham	Nayak	Technical University of Denmark (DTU)	Denmark
Anh Kiet	Nguyen	Equinor	Norway
Shane	Ó Húilín	Sustainable Energy Authority of Ireland	Ireland
Andrew	Oldroyd	Oldbaum Services	United Kingdom
Lukas	Pauscher	Universität Kassel	Germany
Suresh	Pillai	ReNew	India
Paul	Poli	European Centre for Medium-Range Weather Forecasts (ECMWF)	Germany
Semjon	Schimanke	SMHI	Sweden
Bruno	Schyska	German Aerospace Center (DLR)	Germany
Justin	Sharp	Sharply Focused LLC	United States

Lindsay	Sheridan	Pacific Northwest National Laboratory (PNNL)	United States
Diogo	Silva	Megajoule	Portugal
Laura	Slivinski	NOAA	United States
Jacob Tornfeldt	Sørensen	DHI A/S	Denmark
Asgeir	Sorteberg	University of Bergen	Norway
Thomas	Spangehl	Deutscher Wetterdienst	Germany
Simone	Sperati	RSE SpA	Italy
Peter	Stammer	EMD	Denmark
Mark	Stoelinga	ArcVera Renewables	United States
Chun-Hsu	Su	Bureau of Meteorology	Australia
Lasse	Svenningsen	EMD	Denmark
Joel	Thomas	Sowitec Development	Germany
Bjarke	Tobias Olsen	Technical University of Denmark (DTU)	Denmark
Elizabeth	Traiger	DNV	United States
Henrik	Vedel	Danish Meteorological Institute (DMI)	Denmark
Héctor	Villanueva Lopez	Equinor	Denmark
Jiali	Wang	Argonne National Laboratory (ANL)	United States
Ine	Wijnant	KNMI	The Netherlands
Jim	Wilczak	NOAA	United States
Samuel	Williams	RWE Offshore Wind GmbH	Germany
Jan	Wohland	ETH Zurich	Switzerland
Atsushi	Yamaguchi	Ashikaga University	Japan
Mark	Zagar	Vestas	Denmark
Huan	Zhang	enercast GmbH	Germany

APPENDIX FIVE - IEA Agreement

International Energy Agency Agreement

Implement Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems (IEA Wind)

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977 and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 26 contracting parties from 22 countries, the European Commission, and Wind Europe, participate in IEA Wind. Austria, Belgium, Canada, CWEA, Denmark, the European Commission, Finland, France, Germany, Greece, Ireland, Italy (two contracting parties), Japan, Republic of Korea, Mexico, Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, United Kingdom, the United States and WindEurope are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Three Subtasks

The task includes three subtasks.

The objective of the first subtask is to develop recommended practices (RP) in collaboration with the other IEA Tasks.

The objective of the second subtask is to conduct Topical Expert Meetings (TEM) in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, TEMs are arranged four times a year. Additional TEM types that would allow shorter reaction times, broader audience and augmented visibility are currently being researched.

The objective of the third subtask is to provide room for exchanges within the wind energy expert community.

Documentation

Since these activities were initiated in 1978, more than 90 volumes of proceedings have been published. In the series of Recommended Practices, 20 documents were published and six of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task. Some documents are publicly available one year after first publication.

Operating Agent

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COUNTRIES PRESENTLY PARTICIPATING IN TASK 11 (2024)	
COUNTRY	INSTITUTION
Belgium	**Government of Belgium**
Canada	**Natural Resources Canada (NRCan)**
CWEA	**Chinese Wind Energy Association (CWEA)**
Denmark	**Danish Energy Agency (DEA)**
Finland	**Business Finland**
Germany	**Federal Ministry for Economic Affairs and Climate Action (BMWK)**
Ireland	**Sustainable Energy Authority of Ireland (SEAI)**
Italy	**Ricerca sul Sistema Energetico (RSE S.p.A.)**
Japan	**New Energy and Industrial Technology Development Organization (NEDO)**
Netherlands	**Rijksdienst voor Ondernemend Nederland (RVO)**
Norway	**The Norwegian Water Resources and Energy Directorate (NVE) and The Research Council of Norway, Norges Forskningsråd**
Republic of Korea	**Korea Institute of Energy Technology Evaluation and Planning (KETEP)**
Spain	**Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)**
Sweden	**Energimyndigheten (Swedish Energy Agency)**
Switzerland	**Swiss Federal Office of Energy (SFOE)**
United Kingdom	**Offshore Renewable Energy Catapult (ORE Catapult)**
United States	**U.S. Department of Energy (DOE)**