



Topical Expert Meeting #109

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Grand Challenges Revisited

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“To achieve worldwide decarbonisation goals, we’re asking wind energy to increase its power-generation contribution from its current level of 5% to 35%-50% or more of future electricity demand. This will require research, design, and development of wind power plants at scales and in locations where we have little experience,” said author Paul

The good news is that the IEA Wind research community has developed a plan to address the scientific and technological challenges—which are surmountable with appropriate investments.

International wind energy experts attended Topical Expert Meetings (TEMs) under the International Energy Agency’s (IEA’s) Wind Energy Systems Technology Collaboration

Programme and identified the Grand Challenges of wind energy that, if addressed, would help to facilitate this ambitious energy system transition. These Grand Challenges are gaps in the current state-of-the-science—researchers may have an inadequate understanding of these areas and be unable to accurately model them. The five Grand Challenge areas are: 1) the atmosphere, 2) the wind turbine, 3) the plant and

grid, 4) the environmental impacts, and 5) the social interactions (Figure 1). Progress in these Grand Challenge areas is needed to make wind energy a foundational energy source for the clean energy transition.

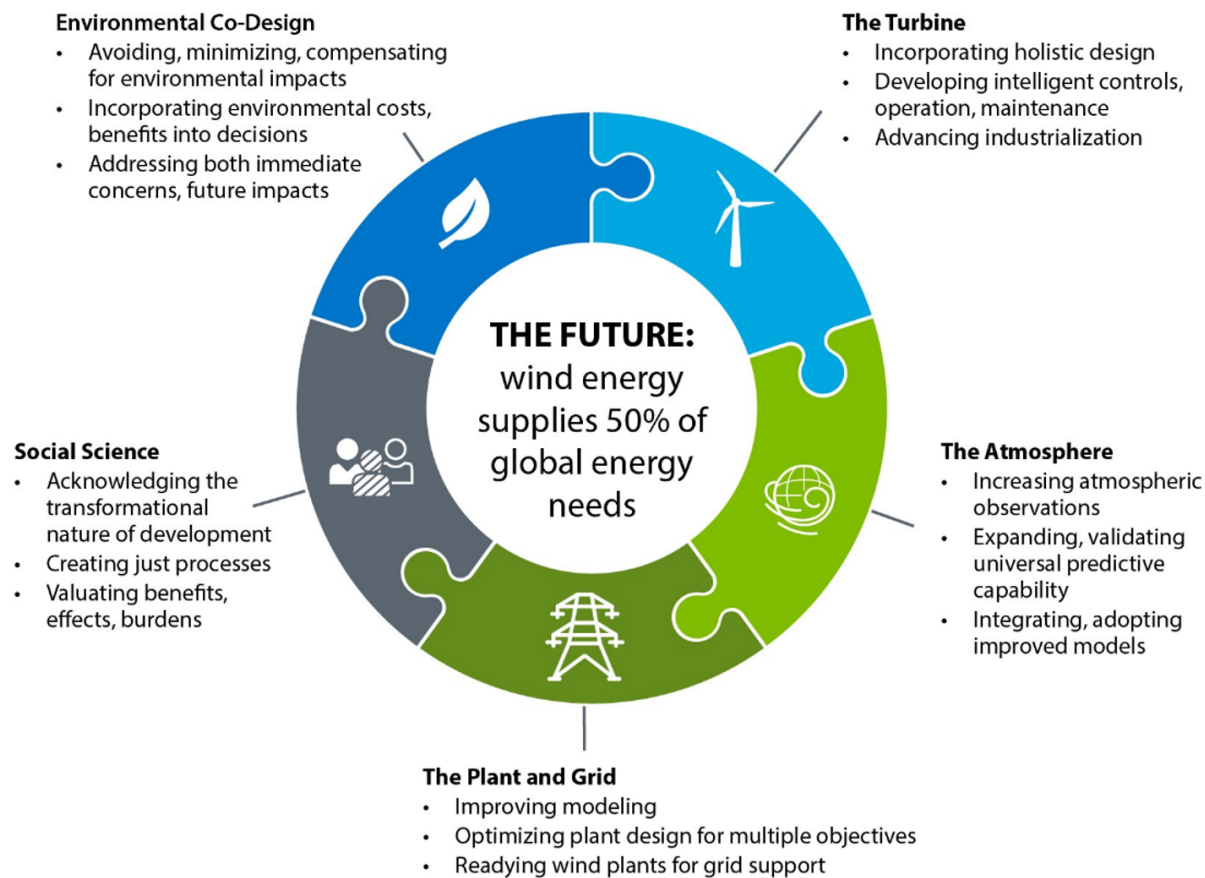


Figure 1: Addressing critical issues within each of the five Grand Challenge areas will help to ensure that wind energy is poised to play a greater role in global energy needs. *Source: National Renewable Energy Laboratory.*

In addition to exploring the Grand Challenges further, experts attending TEM #109 in 2023 examined related cross-disciplinary topic areas: environment-turbine, turbine-atmosphere, atmosphere-grid/plant, grid/plant-turbine, grid/plant-environment, atmosphere-environment, turbine-social, and social-grid/plant (Table 1). These topical intersections do not always receive the attention needed; therefore, the TEM #109 meeting agenda included time for dialogue to explore the cross-disciplinary challenges and to document critical issues.

Table 1. Wind Energy Grand Challenge Opportunities for Interdisciplinary Work and Critical Issues for Each. *Source: National Renewable Energy Laboratory.*

GRAND CHALLENGE OPPORTUNITIES FOR INTERDISCIPLINARY WORK	CRITICAL ISSUES
Environment-Turbine	Establishing a common language and definitions Understanding material needs for scale of build-out Incorporating an environmental co-design Communicating research needs Deploying dual-purpose technologies Engaging wind turbine manufacturers Improving data collection, digitalisation, and sharing
Turbine-Atmosphere	Improving open-design bases Improving annual energy production estimates Improving design standards

GRAND CHALLENGE OPPORTUNITIES
FOR INTERDISCIPLINARY WORK

CRITICAL ISSUES

Atmosphere-Grid/Plant	Improving flow control Deploying dispatchable hybrid plants Connecting the grid to the weather Leveraging real-time data Conducting a risk assessment across time scales
Grid/Plant-Turbine	Improving communication between groups Collaborating on wind turbine design requirements
Grid/Plant-Environment	Developing a shared understanding between the grid/plant-wildlife/biosphere communities Developing integrated approaches to wind energy systems engineering for environmental considerations
Atmosphere-Environment	Addressing data gaps related to interactions among landscape features, atmospheric conditions, and wildlife movement patterns Evaluating an alternative, overarching target for reducing carbon in the atmosphere
Turbine-Social	Creating environmentally just processes Investigating and characterising noise Investigating and characterising the visual impact Investigating and characterising policies
Social-Grid/Plant	Expanding data collection and decision-making processes Considering grid integration Supporting future-focused, empowered regions and communities Expanding people's understanding of potential benefits Addressing cost expectations

Findings from the TEM #109 were published in *Grand Challenges Revisited: Wind Energy Research Needs for a Global Energy Transition* [1] in December 2023 and are summarised in this IEA Annual Report chapter.

Introduction

The Grand Challenges work is conducted under IEA Wind Task 11, which promotes and disseminates knowledge of emerging wind energy topics. TEMs are workshops for experts to present the latest results on specific topics and to discuss solutions [2]. In 2017, more than 70 experts representing 15 countries gathered at the IEA Wind TEM #89 Grand Vision for Wind Energy workshop to discuss the question, "How can we enable a future in which wind energy supplies more than 50% of global electricity

consumption?" The experts drafted a vision that identified and addressed three Grand Challenge areas that would benefit from increased research and development: atmospheric and wind power plant physics, dynamics and manufacturing of larger wind turbines, and integration into the future electricity grid.

Over the next few years, experts continued to explore the Grand Challenges and identify critical research needs to help address them. They added two more Grand Challenges—environmental co-design and social science (Figure 1). TEM #109 was convened between the 28th of February and 1st of March, 2023, in Boulder, Colorado, United States. Experts from Denmark, Finland, France, Germany, the Netherlands, Norway, Portugal, the Republic of Korea, Spain, Switzerland, the United Kingdom, and the United States

attended the workshop. Table 2 lists the countries that helped organise the workshop.

Table 2. Countries Organizing TEM #109.

COUNTRY/SPONSOR	INSTITUTION(S)
United States	U.S. Department of Energy; National Renewable Energy Laboratory
Denmark	Technical University of Denmark
Germany	Technical University of Munich; ForWind: Center for Wind Energy Research

Institutions that contributed to the *Grand Challenges Revisited* report [1] include the Technical University of Denmark (DTU); Recognis Oy, Finland; National Center for Atmospheric Research, United States; Western EcoSystems Technology Inc., United States; Center for the New Energy Economy at Colorado State University, United States; and GE Vernova, United States.

Progress and Achievements

Findings from the TEM #109 workshop were summarised in the *Grand Challenges Revisited* report [1]. However, the report's impact will be limited by how widely the results are disseminated. The researchers are pursuing several pathways to publicise the findings within the wind energy community and to the general public.

The wind energy community attends major conferences each year in North America (North American Wind Energy Academy (NAWEA)/WindTech) and Europe (TORQUE), and these conferences were the targets of the Grand Challenges outreach. The conferences hosted expert panels discussing the outcome of TEM #109.

- **NAWEA/WindTech, 30th Oct.–1st Nov., 2023.** The Grand Challenges panel featured a keynote presentation by Carlo Bottasso (Technical University of Munich) with brief topical presentations by Julie K. Lundquist (National Renewable Energy Laboratory [NREL]), Paul Veers (NREL), Christopher Bay (NREL), Bethany Straw (U.S. Geological Survey), and Suzanne Tegen (Center for the New Energy Economy). The discussion was moderated by Katherine Dykes (DTU).
- **TORQUE, 29th May, 2024.** Following a keynote by Lena Kitzing (DTU) on “Social and Economic Dimensions for Wind Energy,” Katherine Dykes (DTU) moderated the panel “Wind Energy

Grand Challenges Revisited” that included comments from Kitzing, Carlo Bottasso (Technical University of Munich), Alexander Vandenberghe (WindEurope), and Paul Veers (NREL).

Researchers are also pursuing publication in high-profile journals to reach the general public with the message that wind energy research is ongoing and that a concerted effort will be needed across disciplinary boundaries to resolve outstanding wind energy issues. The review article, published in *Science* [3] following the initial Grand Challenges TEM #89, has been a tremendous aid in presenting the continuing wind energy research needs across time scales, spatial scales, and technical disciplines and has garnered more than 700 citations. A review article to expand that thinking based on the findings of TEM #109—namely, that interdisciplinary effort is needed to resolve the issues created by the substantial expansion of the wind generation footprint—is in development. Bottasso, Veers, and Dykes are leading this effort.

Finally, the effort to further explain the Grand Challenges within each research area continues. This initiative started after publication of the article in *Science* and is ongoing under the sponsorship of the European Academy of Wind Energy Publications Committee. To date, five in-depth articles have been published in *Wind Energy Science (WES)*, one has been published in *Nature Energy*, one is in the *WES* review process, and three more are almost ready to submit to *WES*. In addition, an overview perspective highlighted and explained the publication project [4]. The *WES* articles can be found under “Grand Challenges” on the [journal website](#).

Highlight(s)

In addition to identifying gaps in the current state of wind energy science to help facilitate deployment scenarios, work performed as part of Grand-Challenges-related research

also supports the IEA Wind Technology Collaboration Programme (TCP) roadmap.

The IEA Wind TCP requires coordinated and leveraged work among its member governments, as outlined in its wind energy roadmap [5]. To keep the roadmap current, the IEA Wind TCP will need to periodically convene experts to review and revise its strategic plan. TEM #109 is the first of these planned regular gatherings, and the topic areas discussed span the entire scope within the strategic plan. The Grand Challenges discussions resulted in recommendations for initiatives that also support the following four IEA Wind TCP strategic objectives:

- Maximise the value of wind energy in energy systems and markets
- Reduce the cost of land-based and offshore wind energy
- Facilitate wind energy deployment through social support and environmental compatibility
- Foster collaborative research and the exchange of best practices and data.

Next Steps

The findings of TEM #109 will be broadly communicated through external publications and implemented by wind energy stakeholders. The TEM leadership will communicate findings by publishing a condensed summary of the high-level recommendations in a highly visible journal article. The finding that solutions can best be achieved through interdisciplinary communication and collaboration requires more intentional opportunities for cross-disciplinary interaction in wind conferences and workshops. To maintain momentum, the IEA Wind leadership should revisit the Grand Challenges with a workshop like TEM #109 every four to five years at locations that make it possible for full international engagement.

Interview with the Lead Authors

The Perspective Paper with Paul Veers:



Recap of TEM #109 with Paul Veers and Katherine Dykes:



The Atmosphere with William Shaw:



Small Wind Turbines with Alessandro Bianchini:



Wind Farm Flow Control with Johan Meyers:



Digitalisation with Andy Clifton:



Social Science with Julia Kirch Kirkegaard:



The Turbine with Carlo Bottasso:



Watch more videos and subscribe to the [IEA Wind TCP YouTube Channel](#)

References

[1] Veers, P., et al. (2023). "Grand Challenges Revisited: Wind Energy Research Needs for a Global Energy Transition."

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<https://www.nrel.gov/docs/fy24osti/86564.pdf>

[2] International Energy Agency (2024). "About Task 11."

<https://iea-wind.org/task11/>

[3] Science (2019). "Grand challenges in the science of wind energy."

<https://science.org/doi/10.1126/science.aau2027>

[4] Wind Energy Science (2022).

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