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Simple solutions for complex problems

The Grand Challenges in the Digitalisation of Wind Energy: From vicious cycle to virtuous cycle

Andy Clifton

For the Drivetrain Reliability Collaborative Workshop 2023
21-23 February 2023
NREL, Golden CO

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A bit about us

We are a spin-off of the Chair of Wind energy of the University of Stuttgart.

We develop software that

- is user-friendly,
- digitalises processes,
- contains our know-how.

Dr. Andy Clifton
Co-Founder & CEO

Started out on gas turbines, detoured to avalanches and mountain hydrology. In wind energy RD&D since 2007 in Canada, Switzerland, the USA, and Germany.

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Overview

1. What digitalisation could do for wind energy
2. Digitalisation has an adoption problem
3. The Grand Challenges in the Digitalisation of Wind Energy
4. Action!

… followed by discussions.

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Acknowledgements

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… and many others - Thank you!

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Digitalisation can refresh old ideas or create new businesses

… could it do the same for wind energy?

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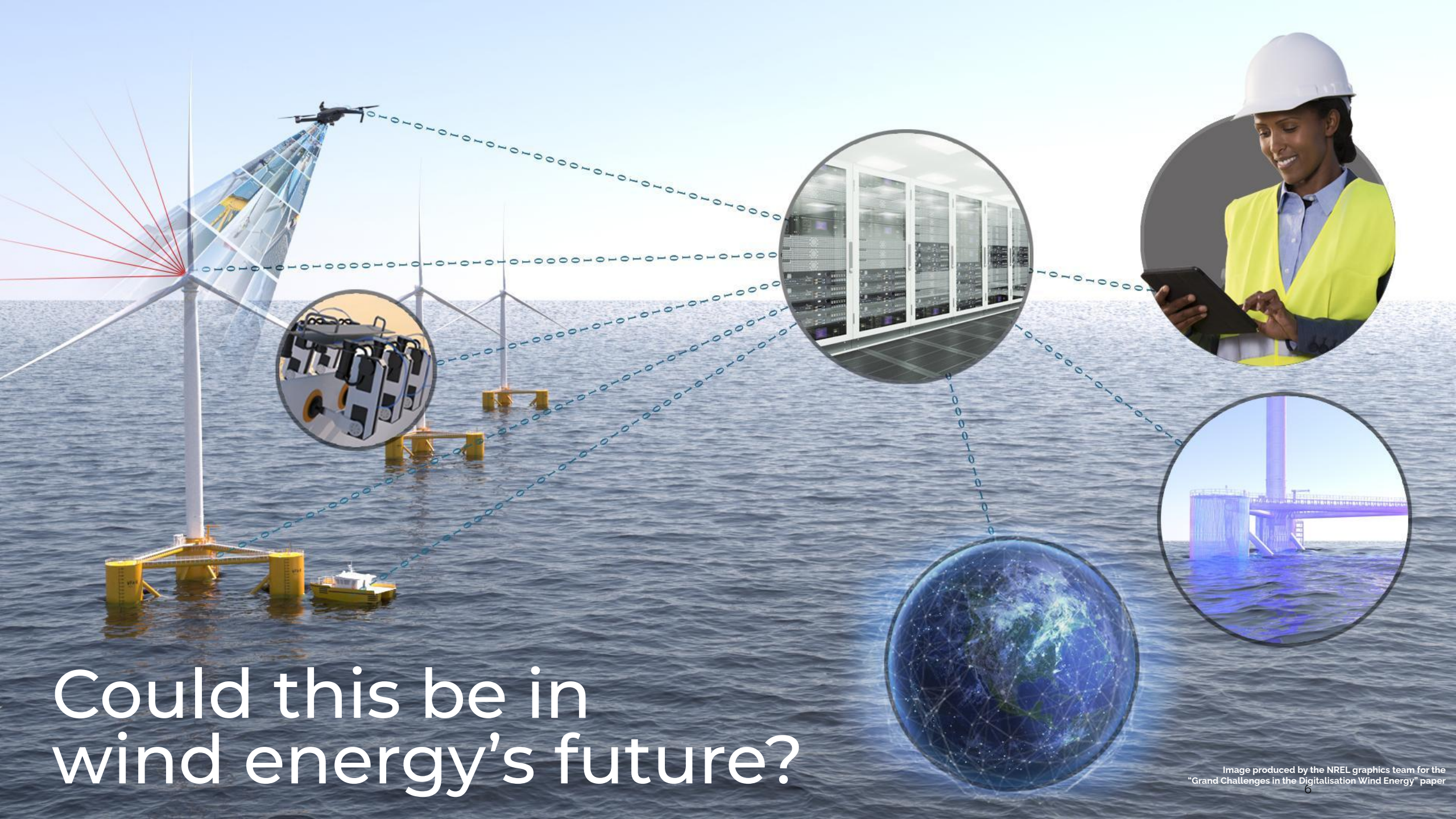

Could this be in wind energy's future?

Image produced by the NREL graphics team for the "Grand Challenges in the Digitalisation Wind Energy" paper

If digitalisation is so awesome,
why are we still
sending spreadsheets via email?

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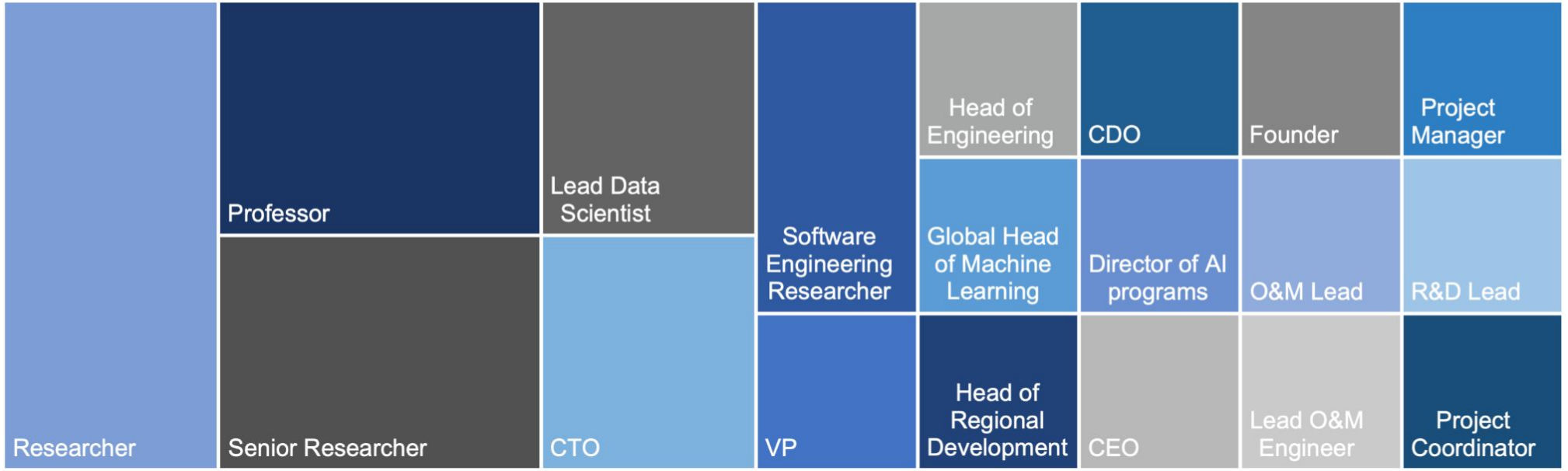
Getting the community perspective

Members of IEA Wind Task 43 held 44 semi-structured interviews in 2021-22



5. What has been your best result and greatest disappointment about digitalization efforts to date?

12. Describe your vision of the brave new world that is digitalization

17. What's needed to enable digitalization in the future?

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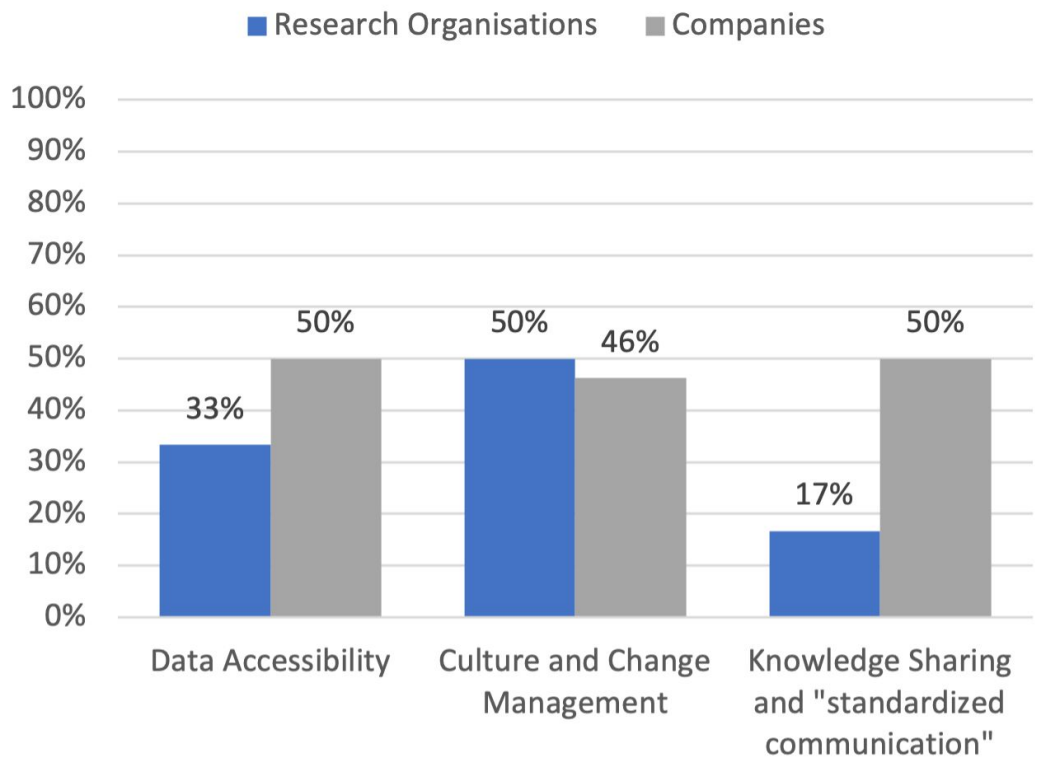
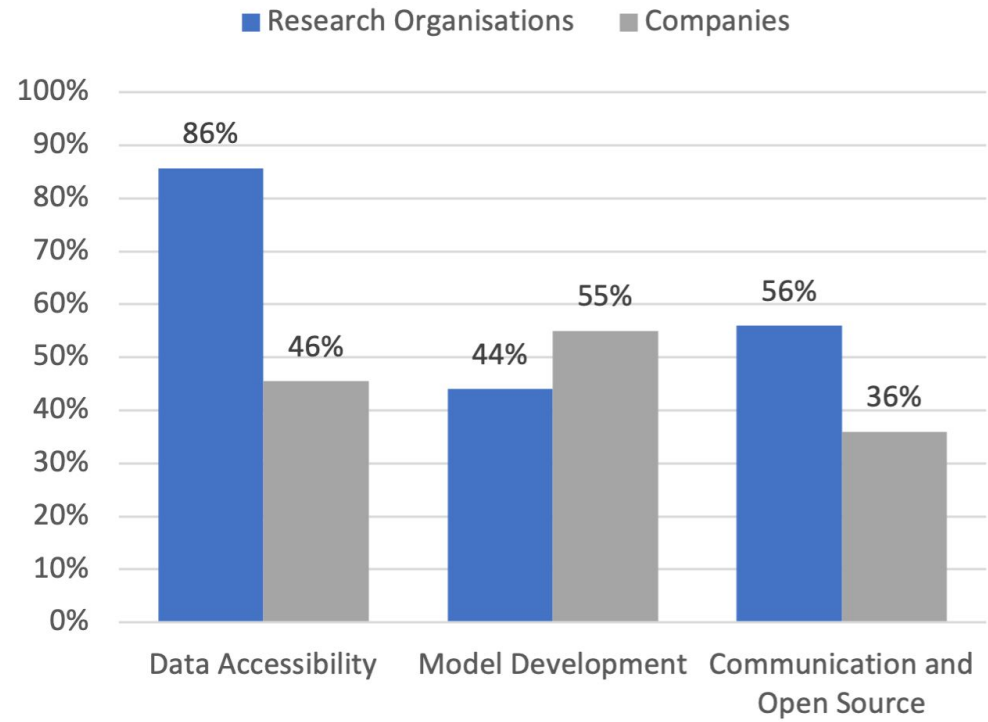
Our survey said...

Challenges



Opportunities



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Learning from Smartphones & IoT

Digital Networked Global

Users experience apps and operating systems, not hardware

There are lots of layers of services in one interaction

If you build it, they will come

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Bluetooth: cooperating to create new markets

1989: Development of short-link radio technology for headsets initiated at Ericsson Mobile

1997: Collaboration between Ericsson and IBM to connect a phone & laptop; decide to create open industry standard

1998: Bluetooth Special Interest Group formed by Ericsson, Intel, Nokia, Toshiba and IBM

1999: First device revealed

2001: First phone and notebook with Bluetooth go on sale

2009: 920 Million ICs with Bluetooth shipped

2017: 3.6 Billion Bluetooth devices shipped

2021: 4.7 Billion Bluetooth devices shipped

Coopetition: collaboration with competitors for mutual benefit

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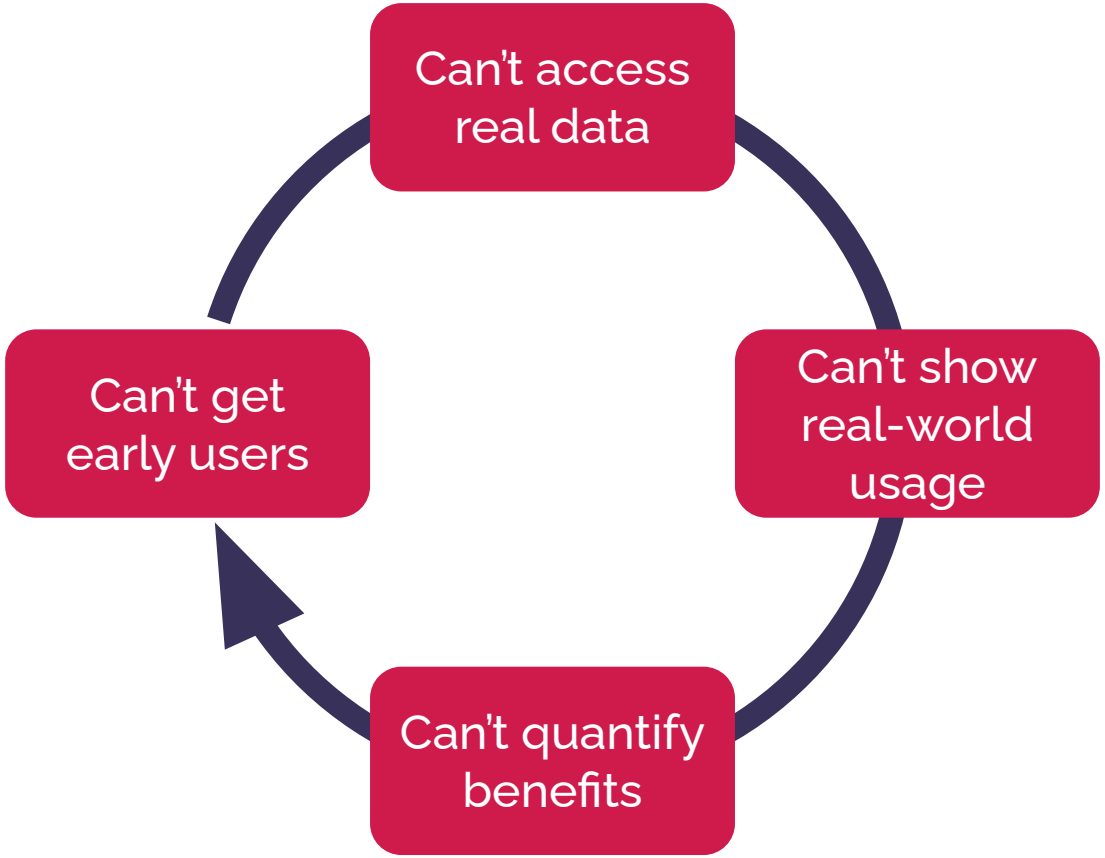
New ideas for digitalisation are trapped in a vicious cycle



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The Grand Challenges for the Digitalisation of Wind Energy

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Cycle race Photo by Florian Schmetz on Unsplash

1. Data

2. Culture

3. Coopetition

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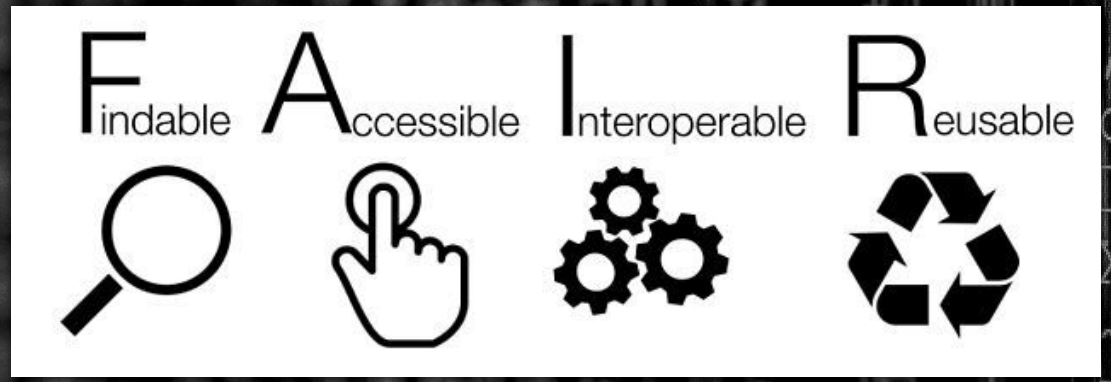
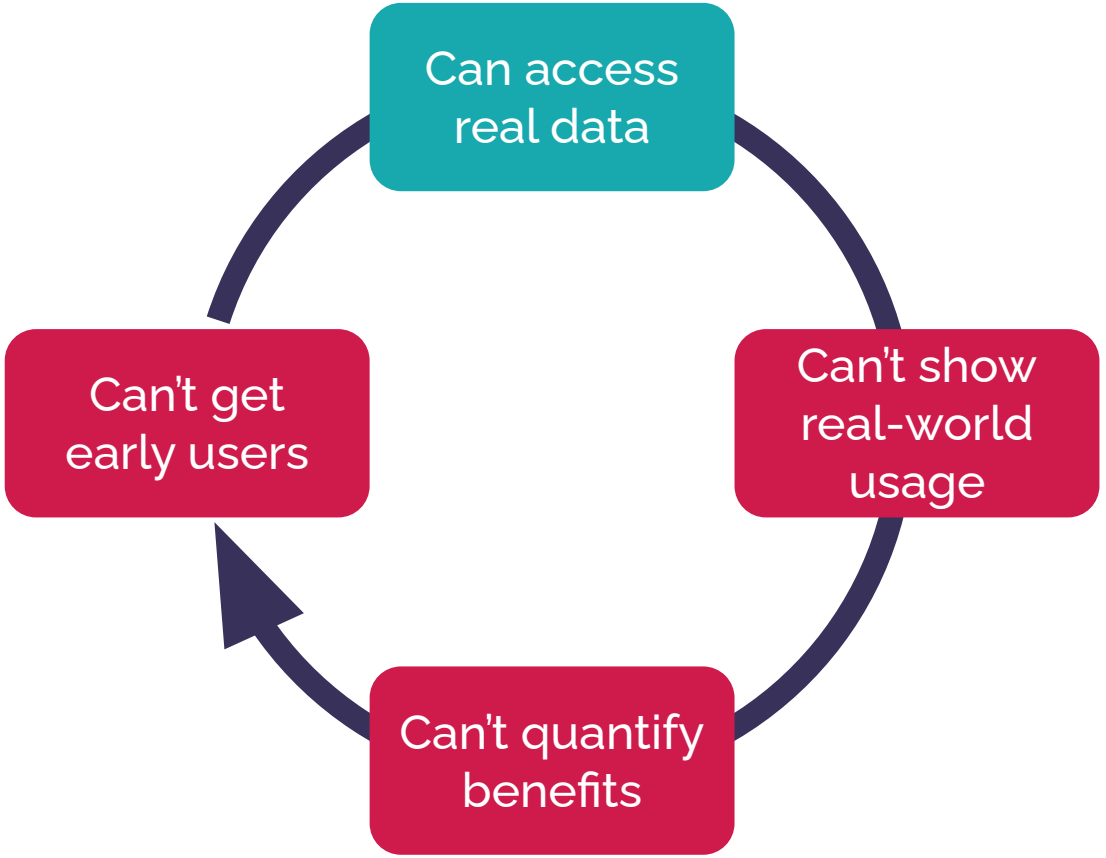
1. Data: creating FAIR data frameworks



- Give data **metadata**
- Use **community formats** or schema
- Store data in **repositories** or exchange it on **marketplaces**
- Provide **data samples**
- Build APIs in to programs or web services to **aid interconnections**



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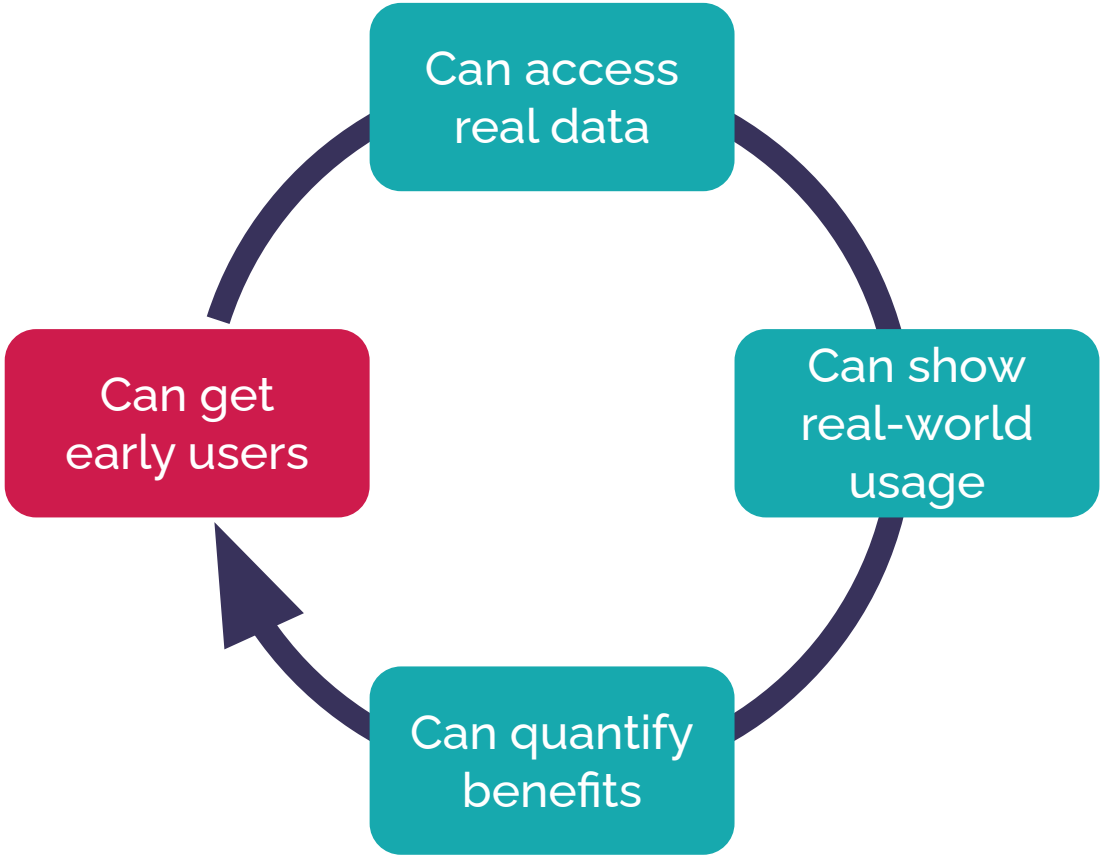
2. Culture: connecting people to data to foster innovation

Businesses:

- **Commit to digitalisation**
- Support **diversity, equity, and inclusion** in all its forms
- Focus on stakeholder buy-in

Government:

- Mitigate **digital exclusion**
- Fund **open data** and **benchmarking** data sets



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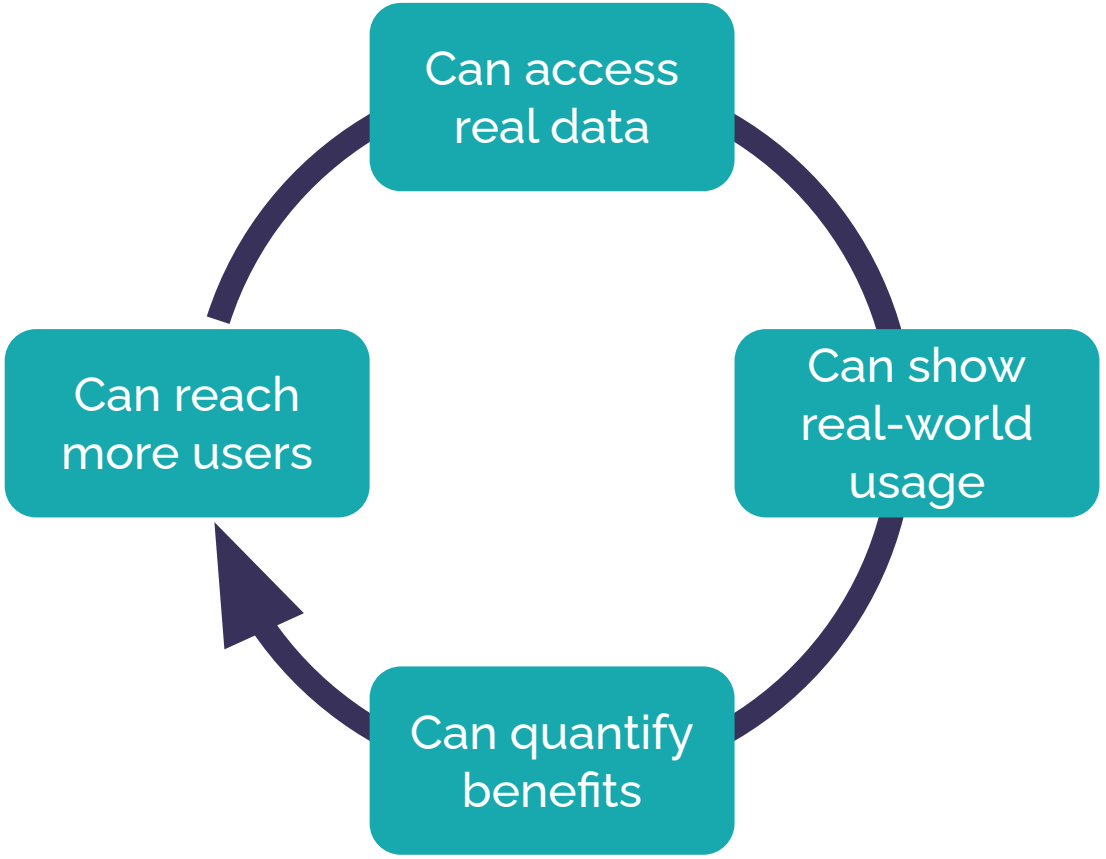
3. Coopetition: enabling collaboration *and* competition between organisations

Businesses:

- **Work together** to create markets
- Simplify **approval processes**
- **Share experiences**

Government:

- Rethink **dissemination of R&D**
- Fund **data markets** while they grow
- Require **public energy data**
- Fund real **demonstration projects**



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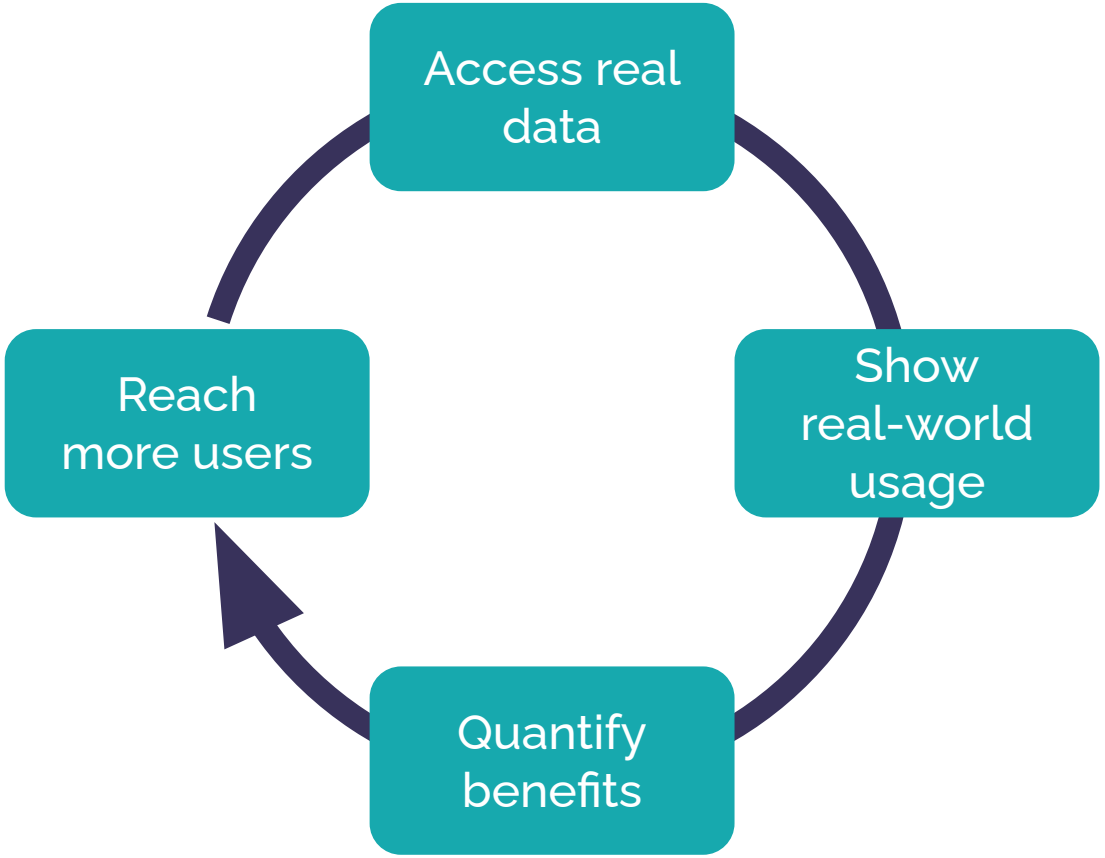
Closing thoughts

Questions to the audience:

1. **Data**: Do you know what data you have?
2. **Culture**: Can your colleagues suggest and develop new ideas?
3. **Coopetition**: Could you work together with your biggest competitor to break down data barriers?



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Read the paper

"Grand Challenges in the Digitalisation of Wind Energy"

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eawe european academy of wind energy — WIND ENERGY SCIENCE DISCUSSIONS — Open Access

Grand Challenges in the Digitalisation of Wind Energy

Andrew Clifton[1,*], Sarah Barber[2,*], Andrew Bray[3,*], Peter Enevoldsen[4,*], Jason Fields[5,*], Anna Maria Sempreviva[6,*], Lindy Williams[7,*], Julian Quick[8], Mike Purdue[9], Philip Totaro[10], and Yu Ding[11]

[1]Stuttgart Wind Energy at the Institute of Aircraft Design, University of Stuttgart, Germany
[2]Eastern Switzerland University of Applied Sciences, Oberseestrasse 10, 8640 Rapperswil, Switzerland
[3]MXV Ventures, Oakland, California, USA
[4]Centre for Energy Technologies, Aarhus University, Denmark
[5]National Renewable Energy Laboratory, Golden, CO, USA
[6]Technical University of Denmark, DTU. Department of Wind Energy Risø Campus Frederiksborgvej 399, 4000 Roskilde, Denmark
[7]National Renewable Energy Laboratory, Golden, CO, USA
[8]University of Colorado, Boulder, CO, USA
[9]NRG Sytems, Hinesburg, VT, USA
[10]IntelStor LLC, Houston, TX, USA
[11]Department of Industrial and Systems Engineering, Texas A&M University, College Station, TX, USA
[*]These authors contributed equally to this work.

Correspondence: Andrew Clifton (andy.clifton@enviconnect.de)

Abstract. The availability of large amounts of data is starting to impact how the wind energy community works. From turbine design to plant layout, construction, commissioning, and maintenance and operations, new processes and business models are springing up. This is the process of digitalisation, and it promises improved efficiency and greater insight, ultimately leading to increased energy capture and significant savings for wind plant operators, thus reducing the levelized cost of energy. Digitalisation is also impacting research, where it is both easing and speeding up collaboration, as well as making research results more accessible. This is the basis for innovations that can be taken up by end users. But digitalisation faces barriers. This paper uses a literature survey and the results from an expert elicitation to identify three common industry-wide barriers to the digitalisation of wind energy. Comparison with other networked industries and past and ongoing initiatives to foster digitalisation show that these barriers can only be overcome by wide-reaching strategic efforts, and so we see these as "Grand Challenges" in the digitalisation of wind energy. They are, first, the need to create reusable data frameworks; secondly, the need to connect people to data to foster innovation; and finally, the need to enable collaboration and competition between organisations. The Grand Challenges thus include a mix of technical and cultural aspects that will need collaboration between businesses, academia, and government to solve. Working to mitigate them is the beginning of a dynamic process that will position wind energy as an essential part of a global clean energy future.

1

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Dr. Andrew Clifton

andy.clifton@enviconnect.de

+49 174 560 20 90

enviConnect TGU
Nobelstraße 15
70569 Stuttgart
Germany

Backup slides

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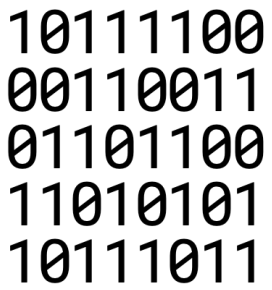
From *digitisation* to *digitalisation*



Digitisation

Converting information to digital forms

Digitalisation

Rethinking how things work, to take advantage of digitisation

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Digitalisation helps remove borders

… between physical scales

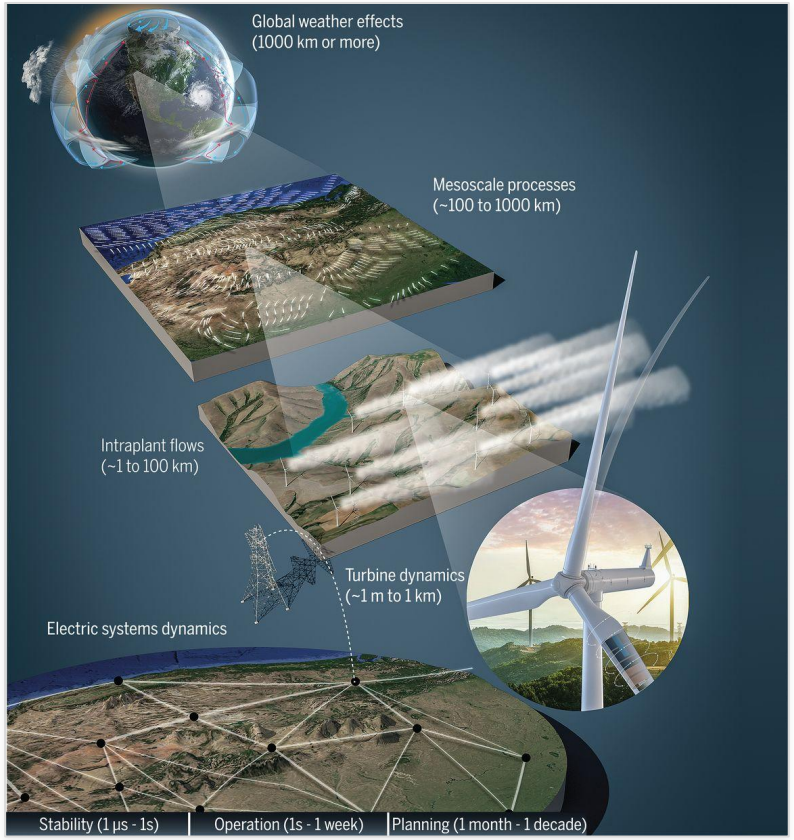

Illustration: Josh Bauer and Besiki Kazaishvilil, NREL. From "Grand challenges in the science of wind energy", Veers et al., Science, 2019. DOI: 10.1126/science.aau2027

… between disciplines

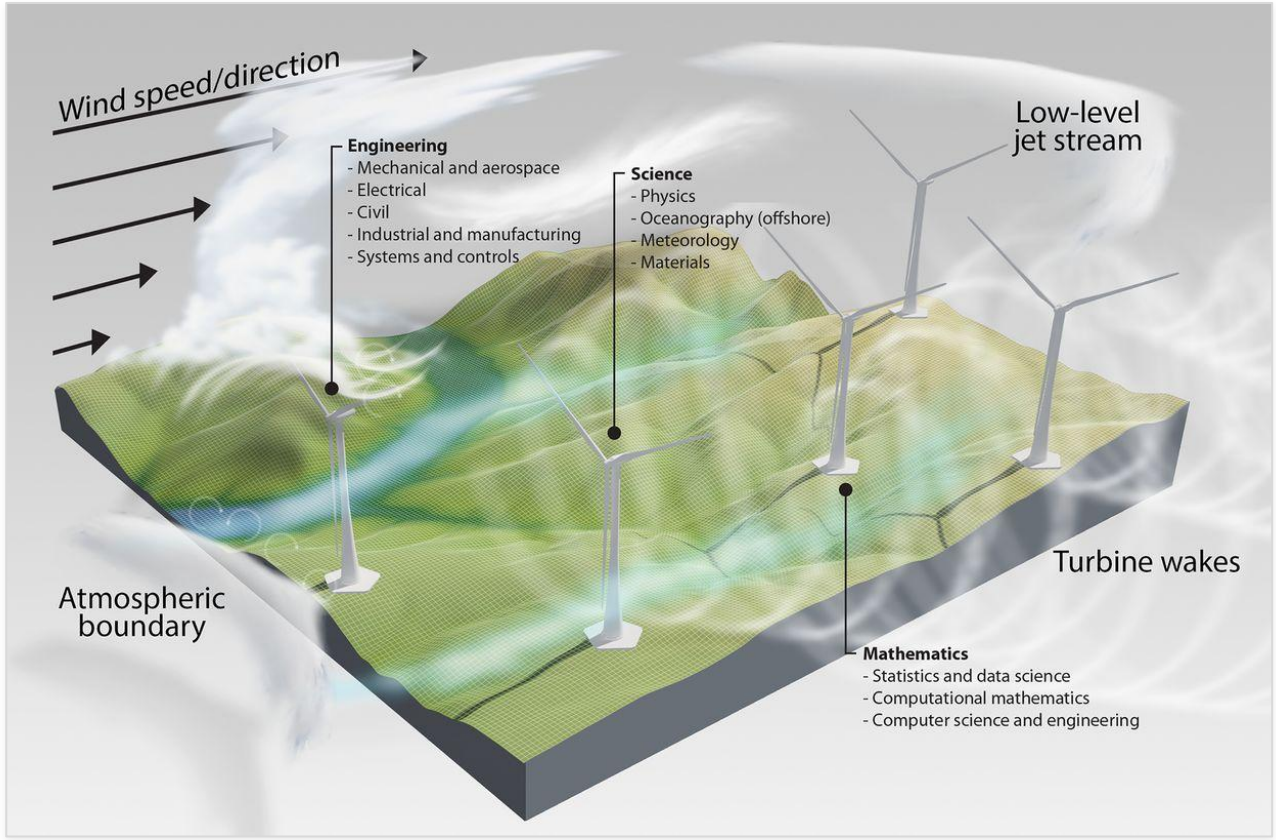

Illustration: Josh Bauer, NREL. From "Grand challenges in the science of wind energy", Veers et al., Science, 2019. DOI: 10.1126/science.aau2027

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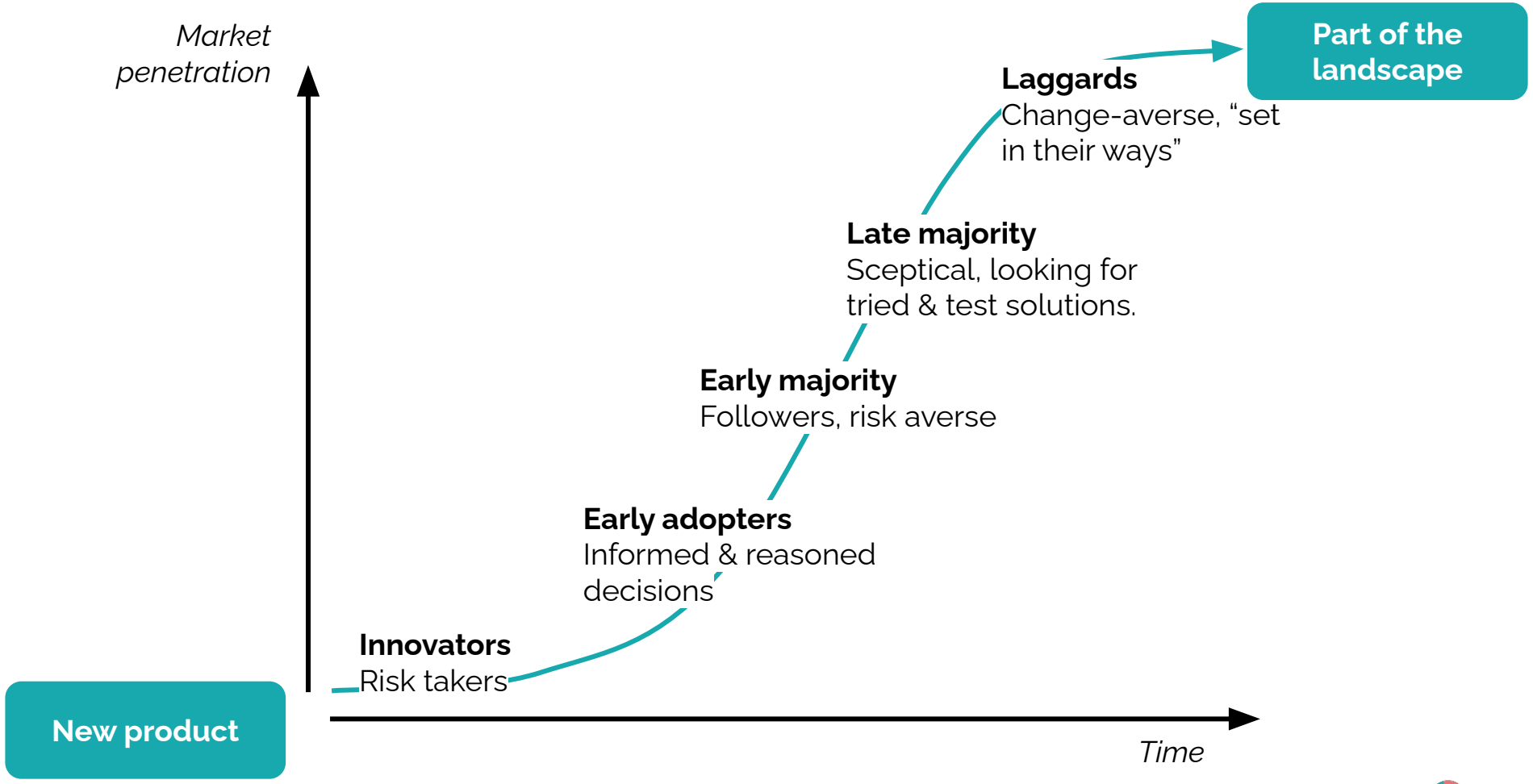
Market entry is usually difficult



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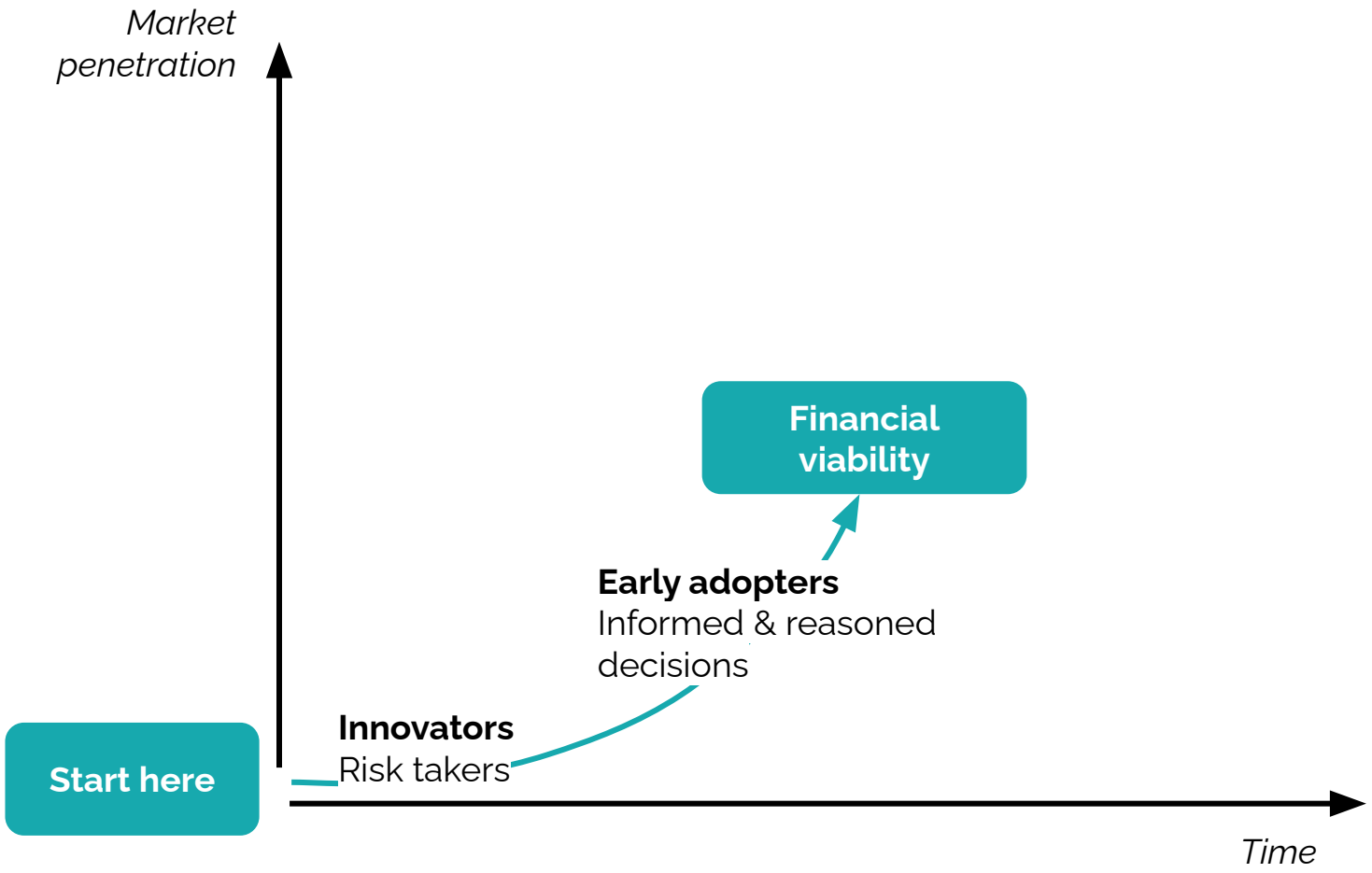
All new technologies go through an adoption process



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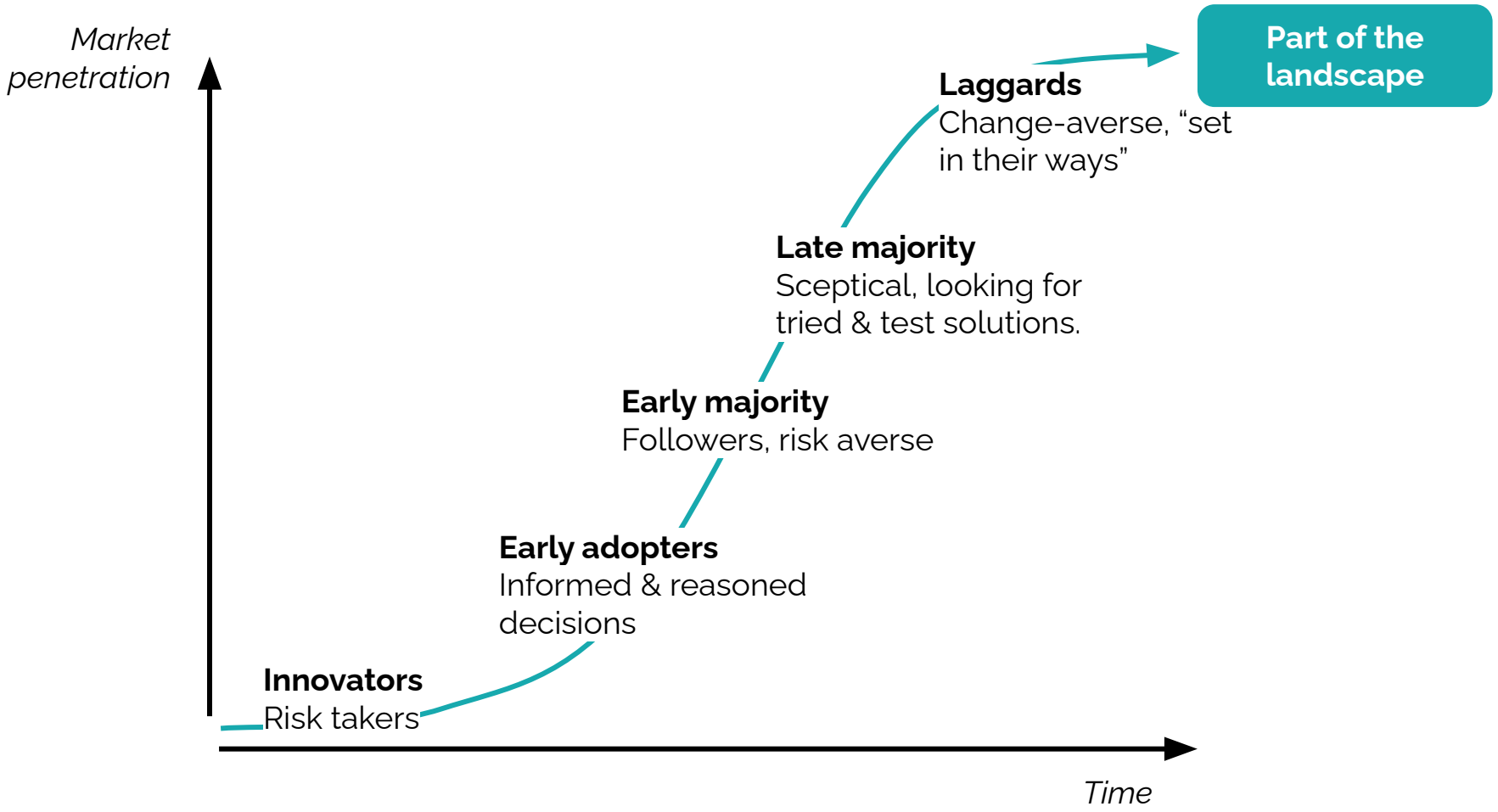
Later users look for more certainty



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The Grand Challenges in the Science of Wind Energy (2019)

Fundamental & foundational scientific challenges that need sector-wide collaboration to investigate and mitigate

Identified at an IEA Wind Topical Expert Meeting and after:

1. Improved understanding of atmospheric and wind power plant flow physics
2. Aerodynamics, structural dynamics, and offshore wind hydrodynamics of enlarged wind turbines
3. Systems science for integration of wind power plants into the future electricity grid

RESEARCH

REVIEW SUMMARY

RENEWABLE ENERGY

Grand challenges in the science of wind energy

Paul Veers*, Katherine Dykes*, Eric Lantz*, Stephan Barth, Carlo L. Bottasso, Ola Carlson, Andrew Clifton, Johney Green, Peter Green, Hannele Holttinen, Daniel Laird, Ville Lehtomäki, Julie K. Lundquist, James Manwell, Melinda Marquis, Charles Meneveau, Patrick Moriarty, Xabier Munduate, Michael Muskulus, Jonathan Naughton, Lucy Pao, Joshua Paquette, Joachim Peinke, Amy Robertson, Javier Sanz Rodrigo, Anna Maria Sempreviva, J. Charles Smith, Aidan Tuohy, Ryan Wiser

BACKGROUND: A growing global population and an increasing demand for energy services are expected to result in substantially greater deployment of clean energy sources. Wind energy is already playing a role as a mainstream source of electricity, driven by decades of scientific discovery and technology development. Additional research and exploration of design options are needed to drive innovation to meet future demand and functionality. The growing scale and deployment expansion will, however, push the technology into areas of both scientific and engineering uncertainty. This Review explores grand challenges in wind energy research that must be addressed to enable wind energy to supply one-third to one-half, or even more, of the world's electricity needs.

ADVANCES: Drawing from a recent international workshop, we identify three grand challenges in wind energy research that require further progress from the scientific community: (i) improved understanding of the physics of atmospheric flow in the critical zone of wind power plant operation, (ii) materials and system dynamics of individual wind turbines, and (iii) optimization and control of fleets of wind plants comprising hundreds of individual generators working synergistically within the larger electric grid system. These grand challenges are interrelated, so progress in each domain must build on concurrent advances in the other two. Characterizing the wind power plant operating zone in the atmosphere will be essential to designing the next generation of even-larger wind turbines and achieving dynamic control of the machines. Enhanced forecasting of the nature of the atmospheric inflow will subsequently enable control of the plant in the manner necessary for grid support. These wind energy science challenges bridge previously separable geospatial and temporal scales that extend from the physics of the atmosphere to flexible aeroelastic and mechanical systems more than 200 m in diameter and, ultimately, to the electrical integration with and support for a continent-sized grid system.

OUTLOOK: Meeting the grand research challenges in wind energy science will enable the wind power plant of the future to supply many of the anticipated electricity system needs at a low cost. The interdependence of the grand challenges requires expansion of integrated and cross-disciplinary research efforts. Methods for handling and streamlining exchange of vast quantities of information across many disciplines (both experimental and computational) will also be crucial to enabling successful integrated research. Moreover, research in fields related to computational and data science will support the research community in seeking to further integrate models and data across scales and disciplines.

ON OUR WEBSITE

Read the full article at http://dx.doi.org/10.1126/science.aau2027

Global weather effects (1000 km or more)

Mesoscale processes (~100 to 1000 km)

Intraplant flows (~1 to 100 km)

Turbine dynamics (~1 m to 1 km)

Electric systems dynamics

Stability (1 μs - 1s) | Operation (1s - 1 week) | Planning (1 month - 1 decade)

ILLUSTRATION: JOSH BAUER AND JESSICA LANDSMAN/NREL

The cascade of scales underlying wind energy scientific grand challenges. Length scales from weather systems at a global level down the boundary layer of a wind turbine airfoil and time scales from seasonal fluctuations in weather to subsecond dynamic control and balancing of electrical generation and demand must be understood and managed.

The list of author affiliations is available in the full article online.
*Corresponding author. Email: paul.veers@nrel.gov (P.V.); kadyb@dtu.dk (K.D.); eric.lantz@nrel.gov (E.L.)
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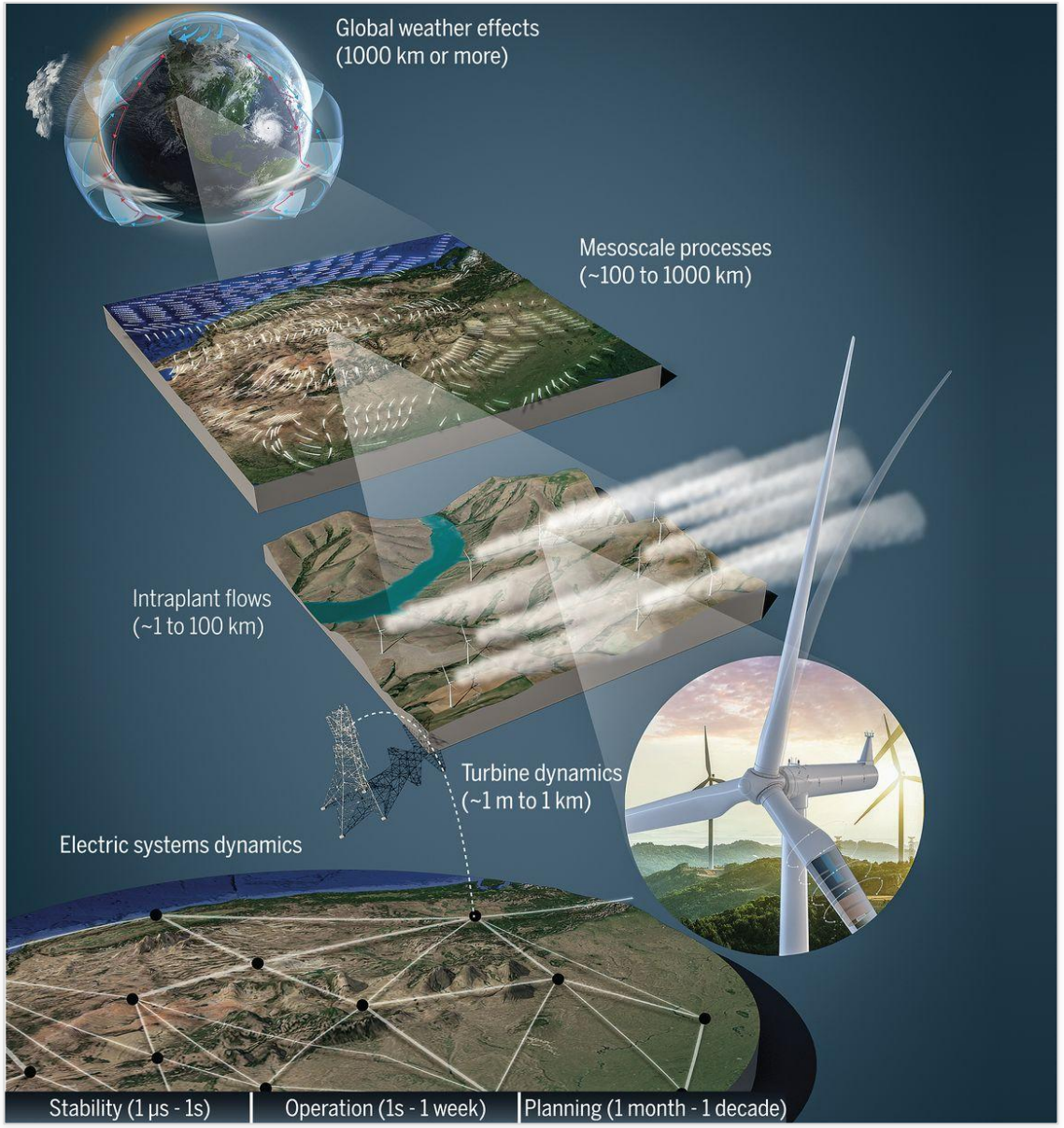
Grand Challenges cross many scales

"The cascade of scales underlying wind energy scientific grand challenges.

Length scales from weather systems at a global level down the boundary layer of a wind turbine airfoil and time scales from seasonal fluctuations in weather to subsecond dynamic control and balancing of electrical generation and demand must be understood and managed.

ILLUSTRATION: JOSH BAUER AND BESIKI KAZAISHVILI, NREL"

From *"Grand challenges in the science of wind energy",* Veers et al., Science, 2019. DOI: 10.1126/science.aau2027



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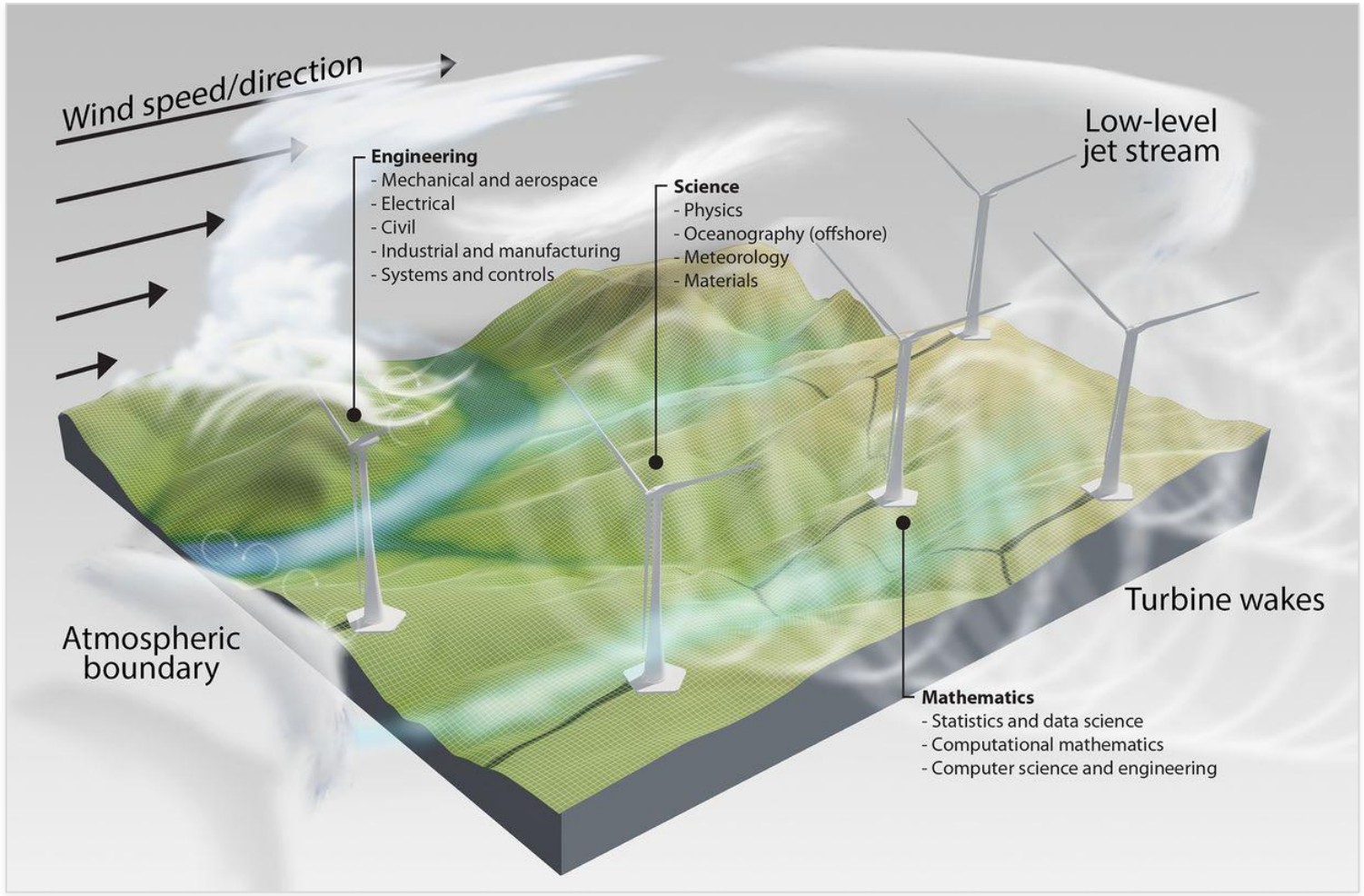
Addressing the Grand Challenges means integrating many disciplines



A spectrum of science, engineering, and mathematics disciplines *that, if integrated, can comprehensively address the grand challenges in wind energy science.*
ILLUSTRATION: JOSH BAUER, NREL

From *"Grand challenges in the science of wind energy"*, Veers et al., Science, 2019. DOI: 10.1126/science.aau2027

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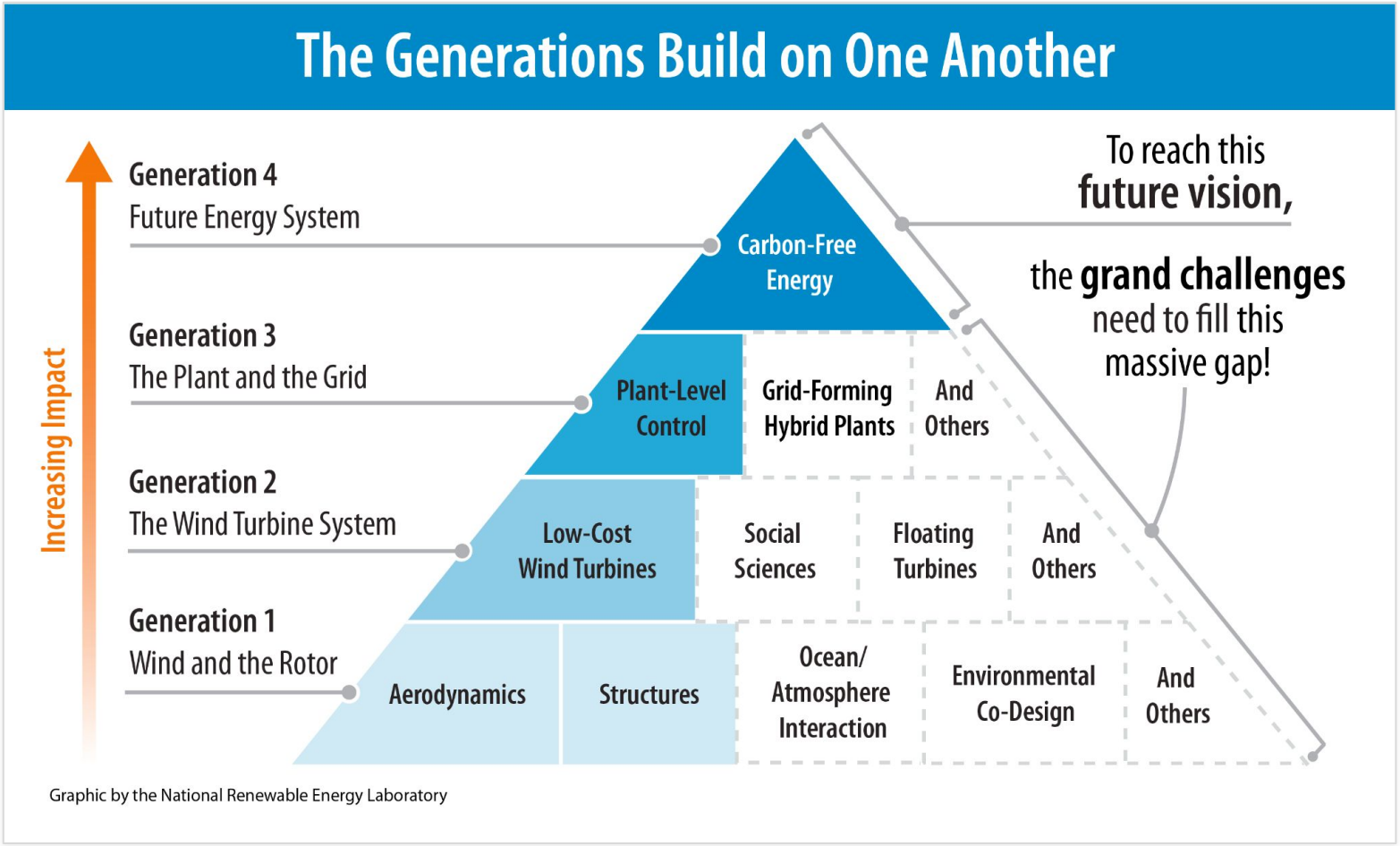
The Grand Challenges mirror the development of wind energy



*"**The generations of wind energy development.** Each generation's achievements expanded wind energy's impact (shown in the blue boxes on the left); however, in moving quickly from generation to generation, some underlying science was left unresolved (shown in the white boxes on the right)"*

From *"Grand Challenges: wind energy research needs for a global energy transition"*, Veers et al., Wind Energy Science, 2022. DOI: 10.5194/wes-7-2491-2022

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