Grand Challenges in the Science of Wind Energy

Katherine Dykes, DTU Wind Energy
Paul Veers, National Renewable Energy Laboratory
Eric Lantz, National Renewable Energy Laboratory
And many others

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Overview

1. Global Trends and Energy Use
2. Changing Paradigms and Needs for Wind Energy
4. Expertise to Achieve Success
Global population is expected to reach 9.8 billion by 2050, up from about 7.6 billion in 2017.
Increasing access to electricity coupled with growing population could support increased demand for clean electricity as the developing world strives for a higher standard of living.

Electricity Consumption (MWh/capita, 2016)

Global wind penetration is estimated at approximately 5%.

Projections suggest global wind capacity could increase from about 0.6 TW today to between 2 TW and 6 TW by 2050.


Source: GWEC (2016)
What will it take to achieve 50% or more of the global electricity supply?
IEA Wind TCP Topical Experts Meeting #89:
A Grand Vision for Wind Energy

• **Purpose:** Explore the question of how to enable a future in which wind energy achieves its full potential as global energy resource

• **Participants:** Over 70 experts representing 15 different countries

• **Outcomes:** *Grand Challenges of Wind Energy Science*
To Realize the Potential of the Resource, Costs Will Need to Continue to Fall

• Wind energy competitive in many places globally

• Costs of other technology (especially solar) also still falling
A Grand Vision for Renewables

- IEA Wind Grand Vision for Wind Energy explores a future scenario of 80% of the world electricity supply coming from renewables – a paradigm shift in system architecture, technologies and markets.

*Future electricity system market structure (Source: Dykes et al 2019 based on Ahlstrom et al 2015)*
Options for wind energy in a changing environment

• Success of wind energy in the future:
  – If storage, power-to-x ubiquitous, highly elastic demand, then do nothing, focus on cheap electrons (LCOE)

  – If dispatchability, capacity value dominate revenue, then rethink options and increase value of wind energy (Beyond LCOE)
Realizing the future Grand Vision for Wind Energy

Research → Innovation → System Improvement

Research → Innovation → Reduce LCOE

Research → Innovation → Increase Value

April 2019
IEA Wind TCP
Results of IEA Wind TCP
Workshop on a Grand Vision
for Wind Energy Technology
The grand challenges in wind energy science and engineering to enable the wind-based future energy system
Realizing and Passing 6 TW Will Require New Fundamental Knowledge and Integration of Ideas across Several Domains

• The Grand Challenges of Wind Energy Science include:
  – The **physics of atmospheric flow**, especially in the critical zone of wind power plant operation
  – The **system dynamics and materials** of the largest, most flexible machines that have yet to be built
  – **Optimization and control of fleets of wind plants** made up of hundreds of individual generators working to **support the electric grid**
Grand challenges in the science of wind energy

Harvested by advanced technical systems honed over decades of research and development, wind energy has become a mainstream energy resource. However, continued innovation is needed to realize the potential of wind to serve global demand for clean energy. Here, we...
The Grand Challenges extend from the global weather system to the minutiae of materials science to sub-second power system stability.
Visualization by James Neher

Courtesy Sue Haupt of NCAR and colleagues

Courtesy Jeff Mirocha, LLNL
Grand Challenge #1: Mastering the physics of resource from the atmosphere to the intra-plant flows
Grand Challenge #2: Characterizing the structural, aero and hydrodynamics of some of the largest standing structures ever built coupled with access to the most advanced material properties at commodity prices.
Grand Challenge #3: Systems science and control of wind power plants to orchestrate wind turbine, plant, and grid formation operations to provide low cost energy, stability, resiliency, reliability and affordability in the future power system.
Optimal electrical control depends on atmospheric conditions and grid.
The wind energy research and technology pathway forward
Closing

• There remains a great deal of work to drive Wind Power to its full potential

• Much of the need is in fundamental knowledge that can catalyze subsequent innovations in the public and private sectors

• Both industry and the research community need talented minds to apply themselves to the problems of wind power

• Inter-disciplinary training and groups as well as concentrated discipline focused expertise are expected to be essential to future success
Thank You