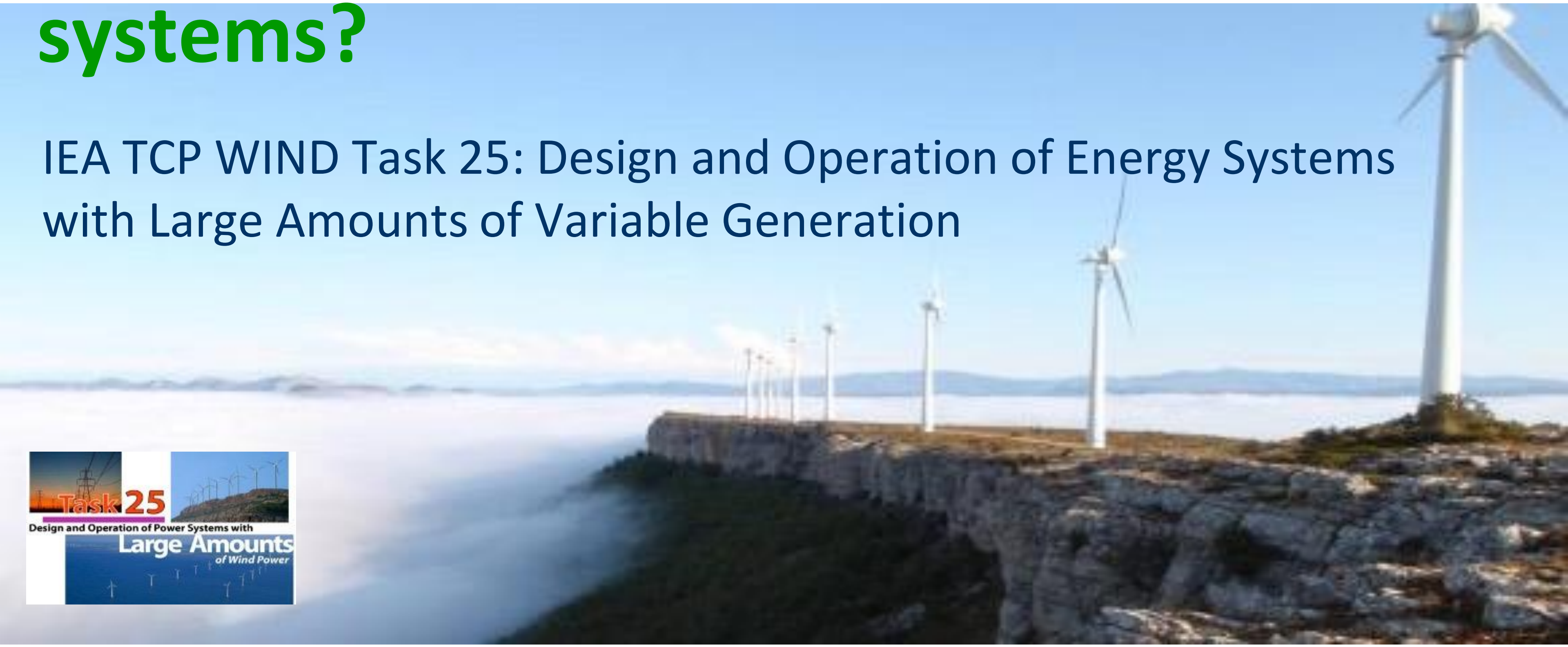
Towards 100% renewables – can wind and solar be the backbone or power systems?

IEA TCP WIND Task 25: Design and Operation of Energy Systems with Large Amounts of Variable Generation



Hannele Holttinen, Operating Agent Task25

Partner, Recognis Oy

Wind power in focus, 13th Oct, 2020

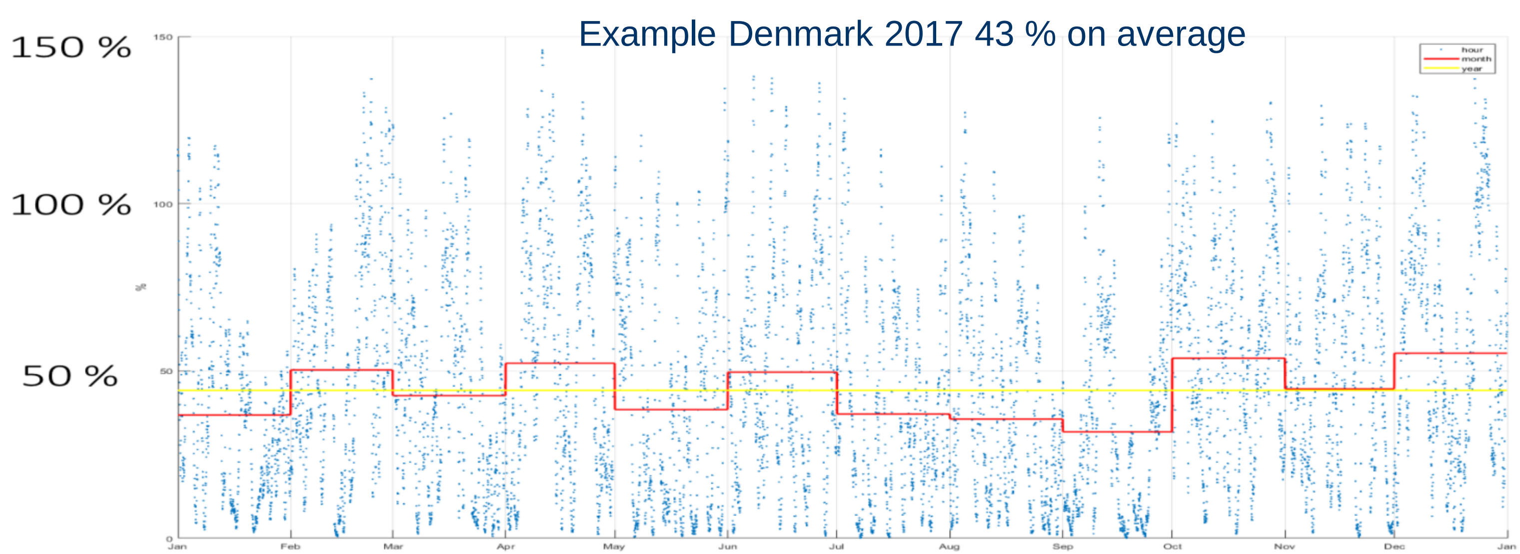
Contents

- Energy transition towards 100% renewable systems: challenges and opportunities
- Wind power role as a backbone of future power and energy systems

Energy transition – towards 100% renewable / low carbon power and energy systems

– Some power systems have hydro/geothermal, biomass and nuclear – but many will depend mainly on wind and solar, the cheapest options

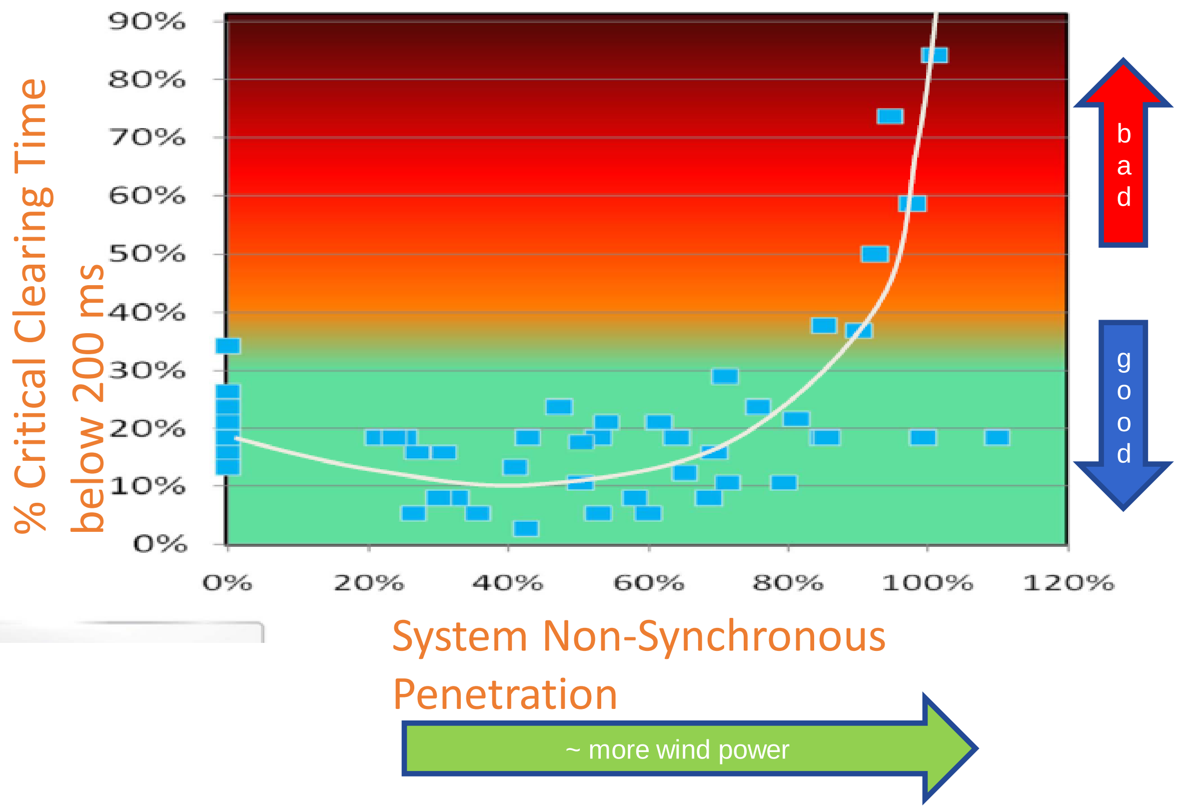
– Most systems will have hours and days with wind and solar covering all of the demand (30-40% wind and solar share on average)



ENERGINET

Ireland study: current power systems ok for 80-90% wind

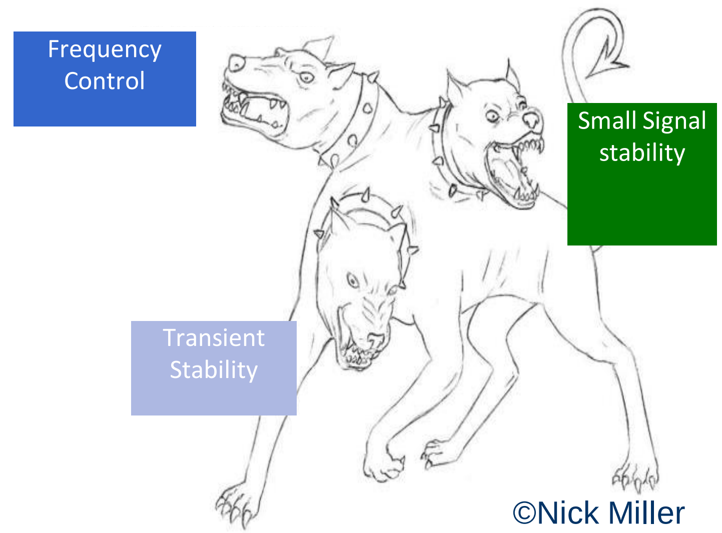
- Transient stability (as measured by critical clearing time) first slightly improves, until around 80-90%, where instability becomes a big issue.



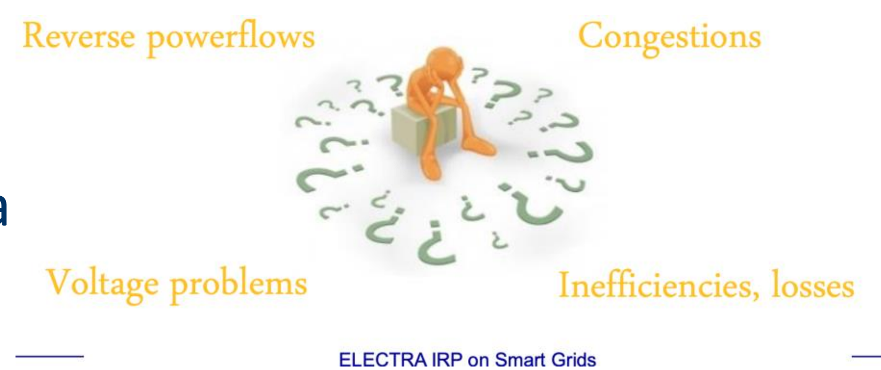
EIRGRID GROUP

Challenges to tackle

- Stability at high VIBRES. What new methods and technologies to use?
- Balancing, flexibility and adequacy: how much new loads can help, for short term operation and for seasonal mismatch?
- Market operation: market design with new services, how to design so that paying for the new services as they become beneficia for the system? Local versus global, DSO/TSO collaboration



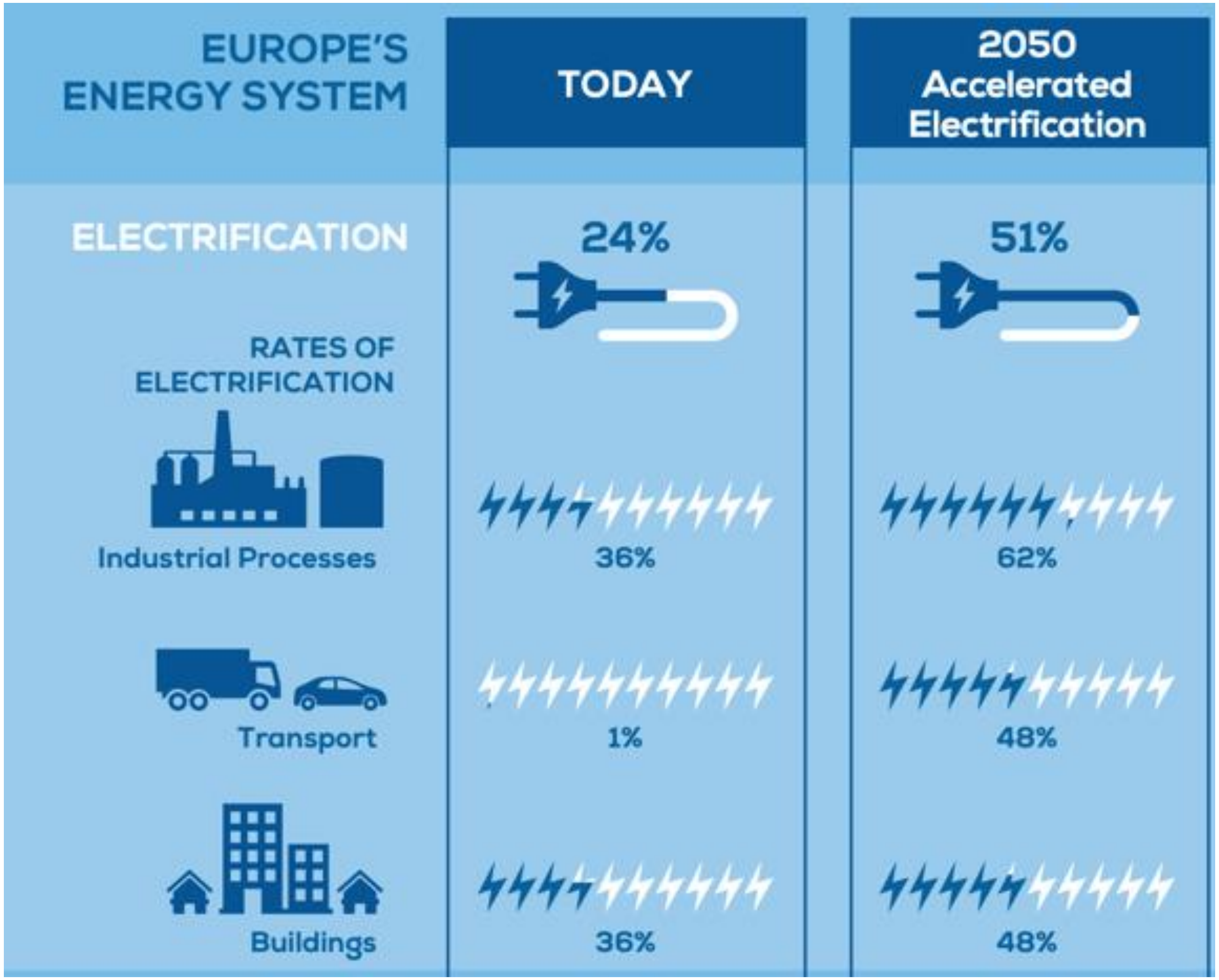
©Nick Miller



Energy transition is also a load transition

Energy system decarbonisation:

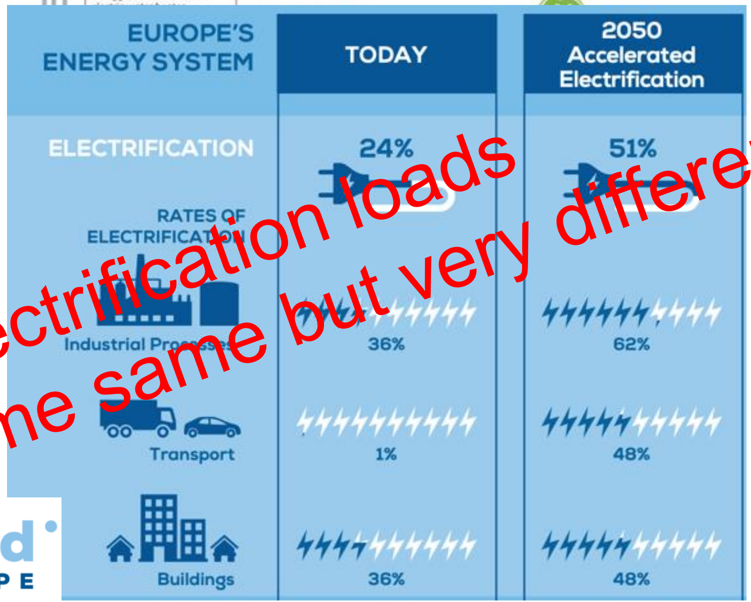
- electrification of transport, heating and industry will ~double the electricity demand



Energy transition - opportunities

- Smart grids:
  enabling distributed resources, prosumers, HEMS/BEMS operating with price signals
- Load transition:
  changing the fixed load paradigm

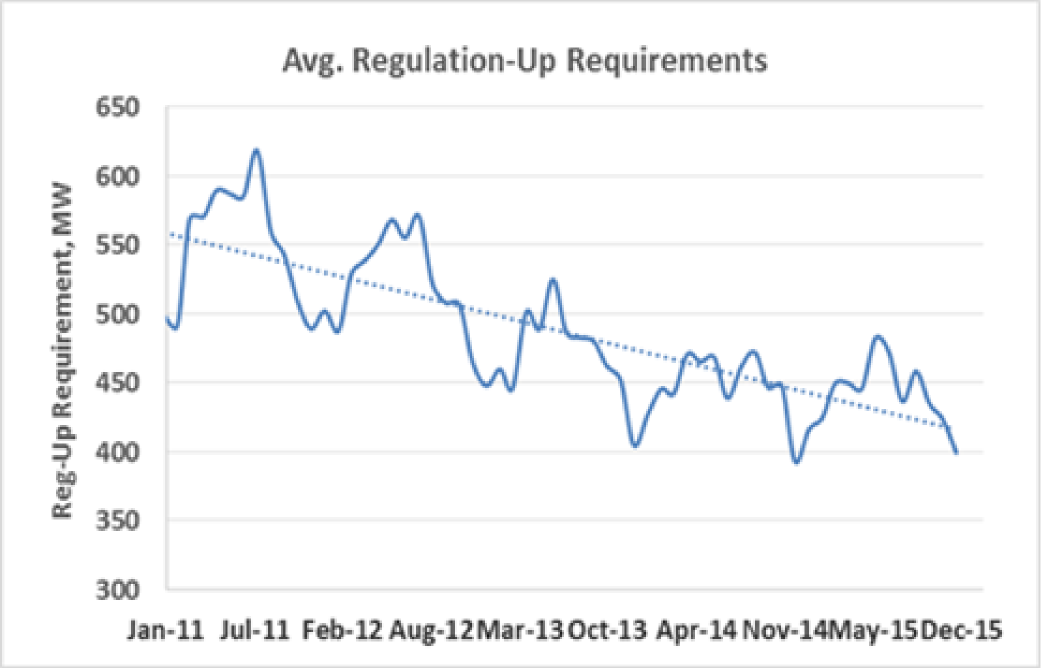
Aggregators and prosumers
same same but different



New electrification loads
not same same but very different

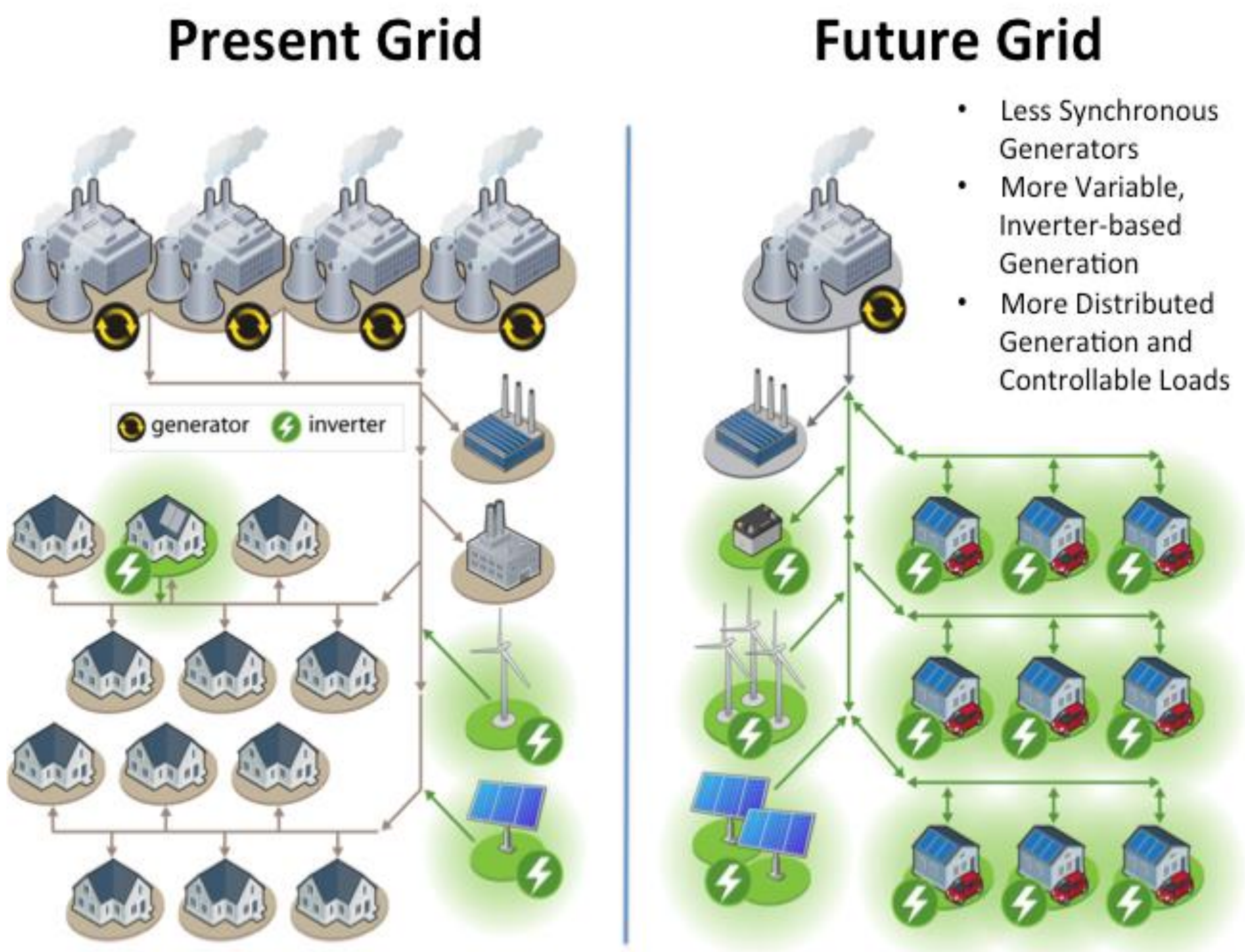
Wind power plants have opportunities:

- Inverter controls: rapid responses, synchronous machine characteristics and they don't swing against each other (more stable).



Texas experience, less need for fast frequency support after wind power plants provide good response (Source: Julia Matevosjana, ERCOT)

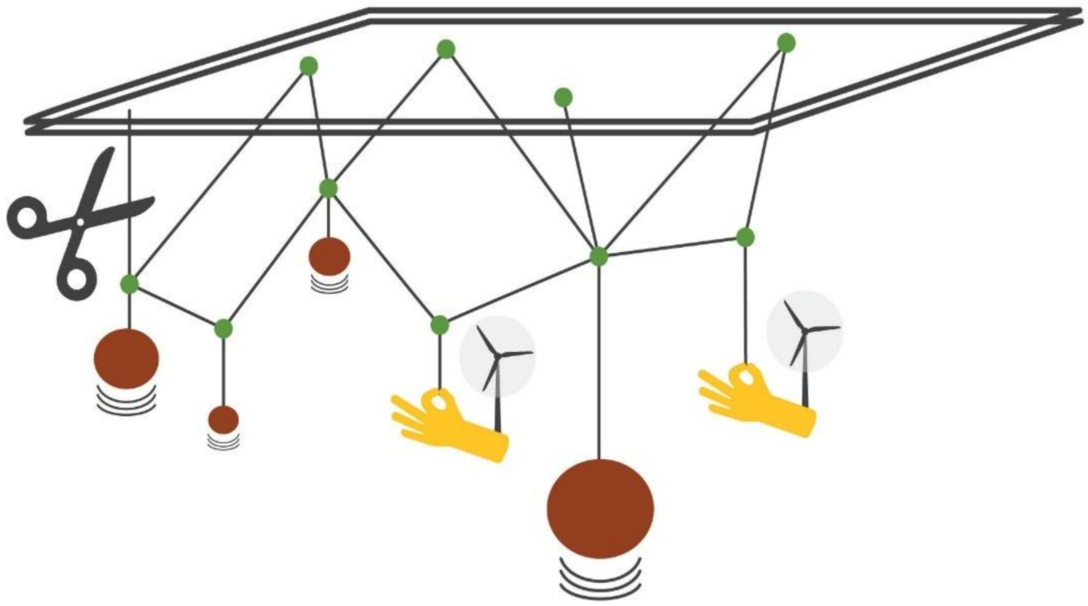
Stability challenge



Source: B-M Hodge et al: Towards 100% Variable Inverter-based Renewable Energy Power Systems. WIREs Energy and Environment vol 9, iss. 5, e354 https://doi.org/10.1002/wene.376

Stability challenge

- Is it stable?*



Source: NREL based on a figure created by Nick Miller, formerly GE Energy Services

*Wind turbines are all brains, no mass

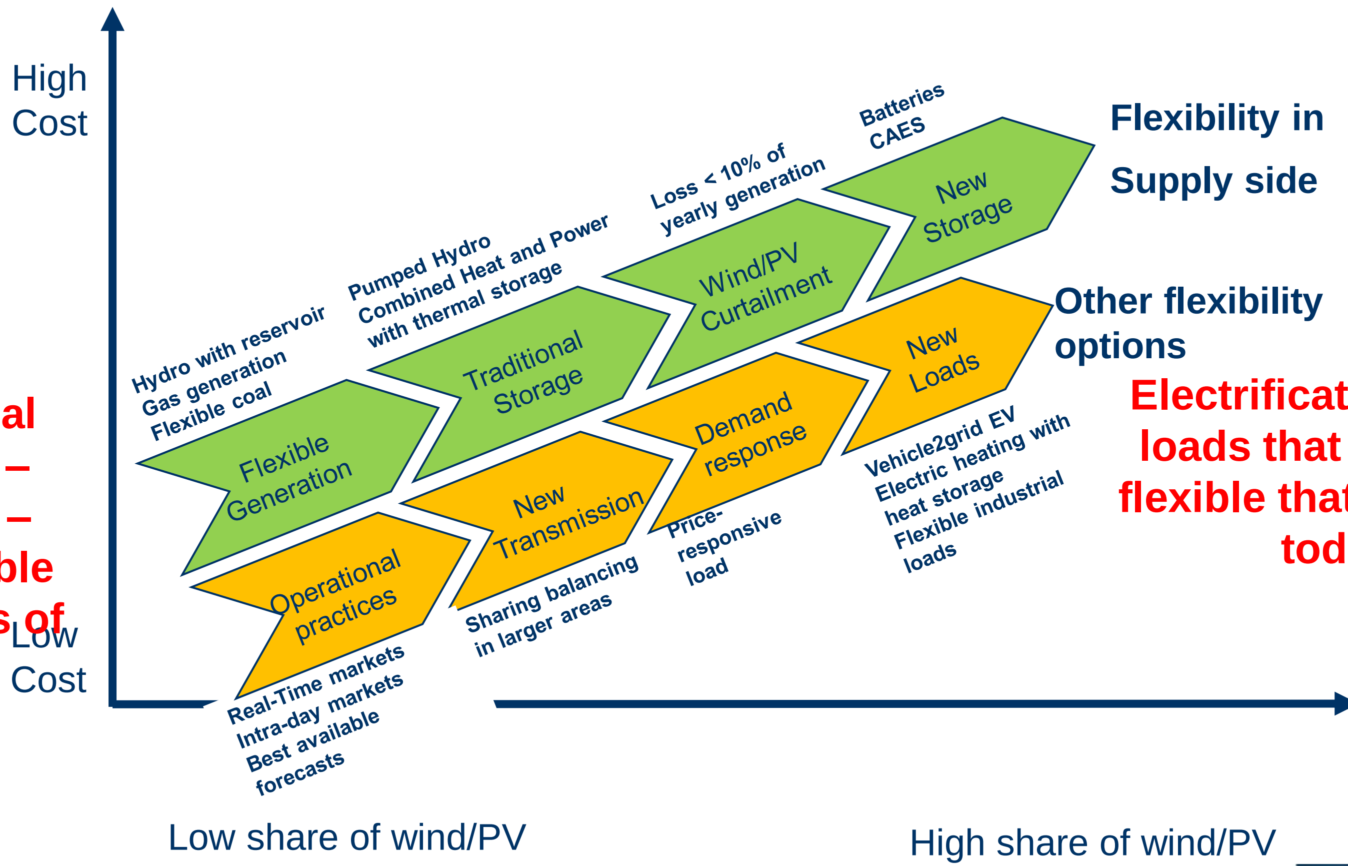
So… maybe even better than physical inertia!

Options to support stability

- Maintain inertia
  - Keep synchronous machines running that would otherwise not run
  - Find other sources of synchronous inertia (i.e. synchronous condensers)
- Speed up frequency response
  - Faster primary frequency response (on synchronous machines)
  - Fast frequenncy response and other clever frequency controls, especially on inverters
- Make inverter behavior “better”
  - Grid forming inverters and Virtual synchronous machines

Courtesy of Nick Miller

Balancing challenge: Using more of the flexibility solutions we know



Operational practices – and tools – key to enable high shares of VIBRES

Electrification – new loads that are more flexible than the loads today

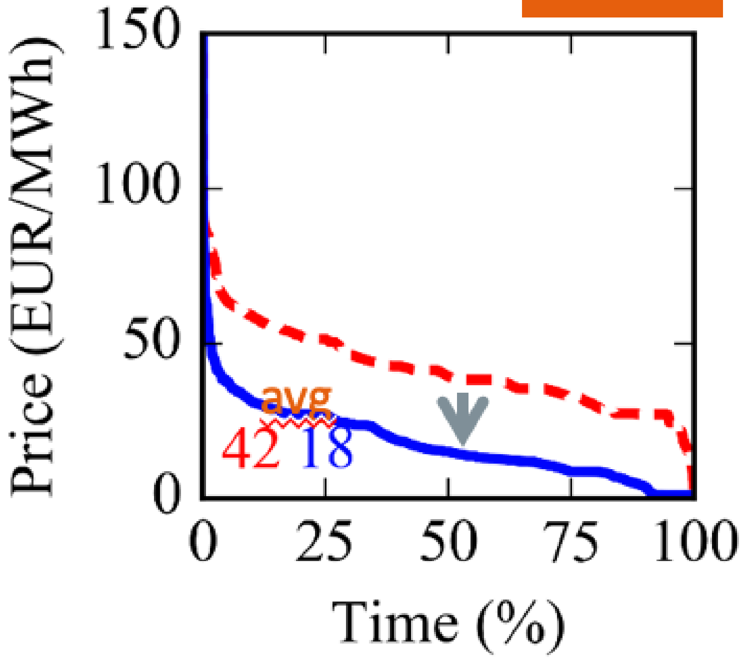
VIBREs – and loads and electrical storage can provide the system support services provided by generators today

Long term flexibility challenge

- Traditionally build gas turbines for back up – expensive use as peakers <1000h/a
- With wind/solar dominating, this will be expensive. Two other pathways possible:
  - Load becomes flexible – also in weeks time scale, electrolysers for power2X, thermal storages for heat etc
  - Electric storage becomes very cheap, and new seasonal options for storage developed
- Probably a mix of these three?

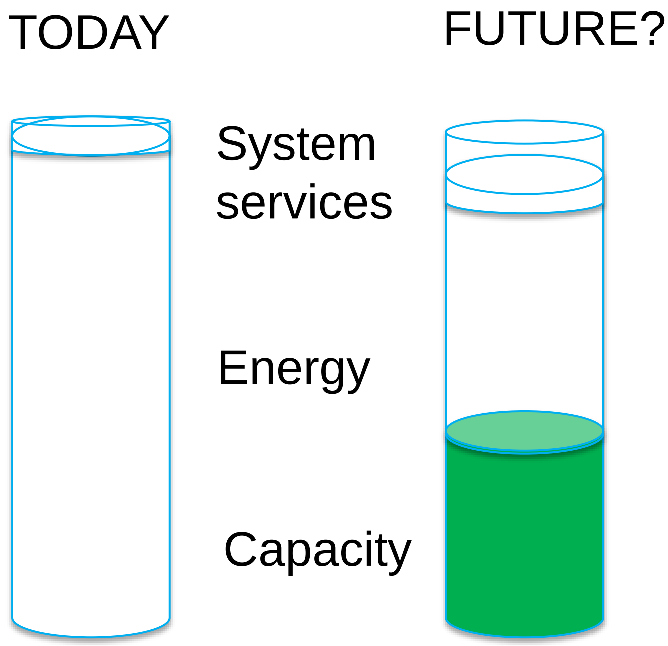
Market challenge: revenue sufficiency

- Due to 0 marginal cost renewables
- Due to flexible loads
- Stakeholder changes
- Can P2X loads change the picture?
  - If timing when wind/PV available
- Storage may be an option



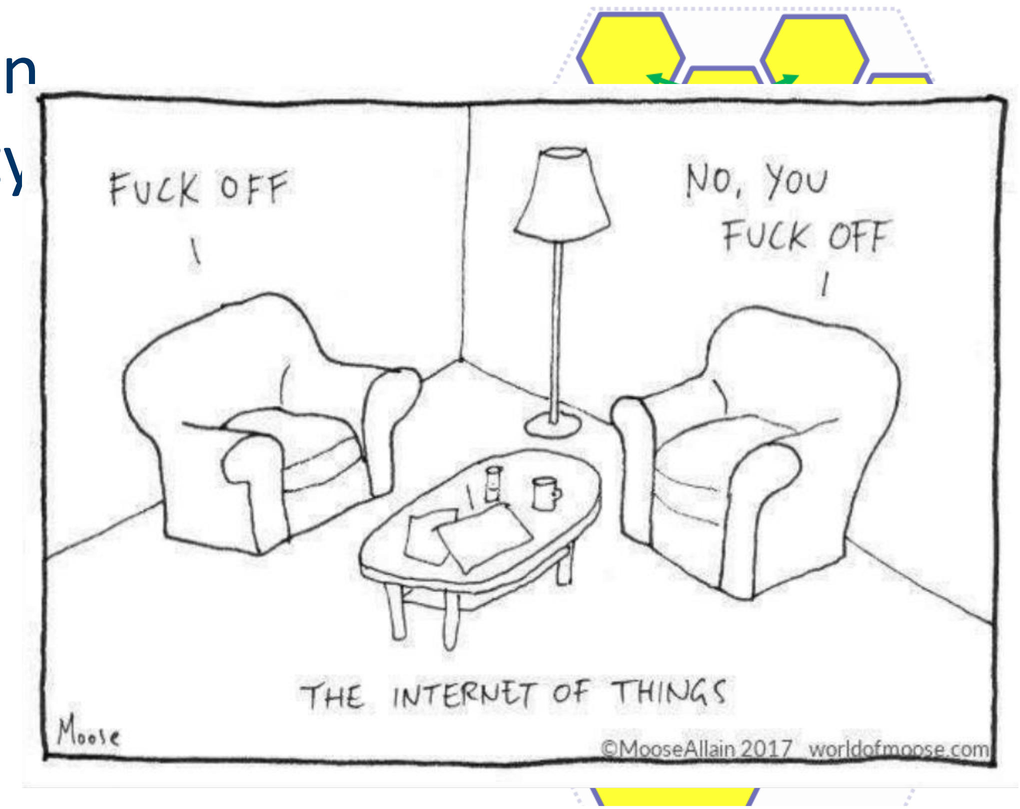
Market challenge: price incentives

- Paying for new services
  - More grid support services: inertia, ramping, voltage,..
  - Transition: introducing services at the stage when system benefits and need (before that no use/payments for providers)
  - Remunerating for capabilities or grid code requirement?
- Scarcity pricing or capacity payment



Using the local flexibility to system benefits

- Market based DSO/TSO collaboration through local flexibility markets
- Flexibility value as price signals to DER
- Vision: web of cells, with local smartness, utilising large system benefits when no grid bottlenecks



EERA
European Energy Research Alliance
Smart Grids Joint Programme

Task 25
Design and Operation of Power Systems with Large Amounts of Wind Power

REVIEW SUMMARY

RENEWABLE ENERGY

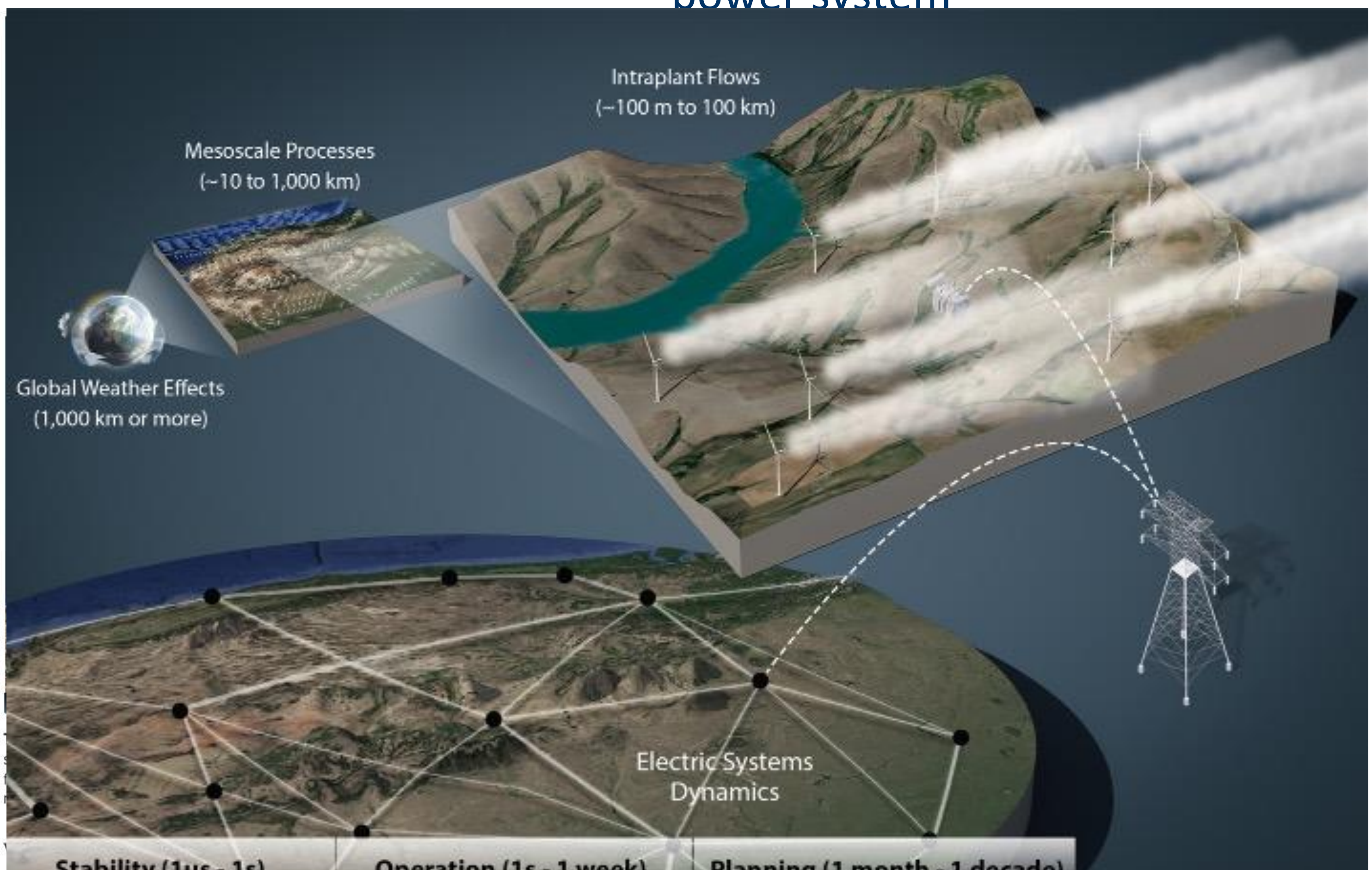
Grand challenges in the science of wind energy

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 re-

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



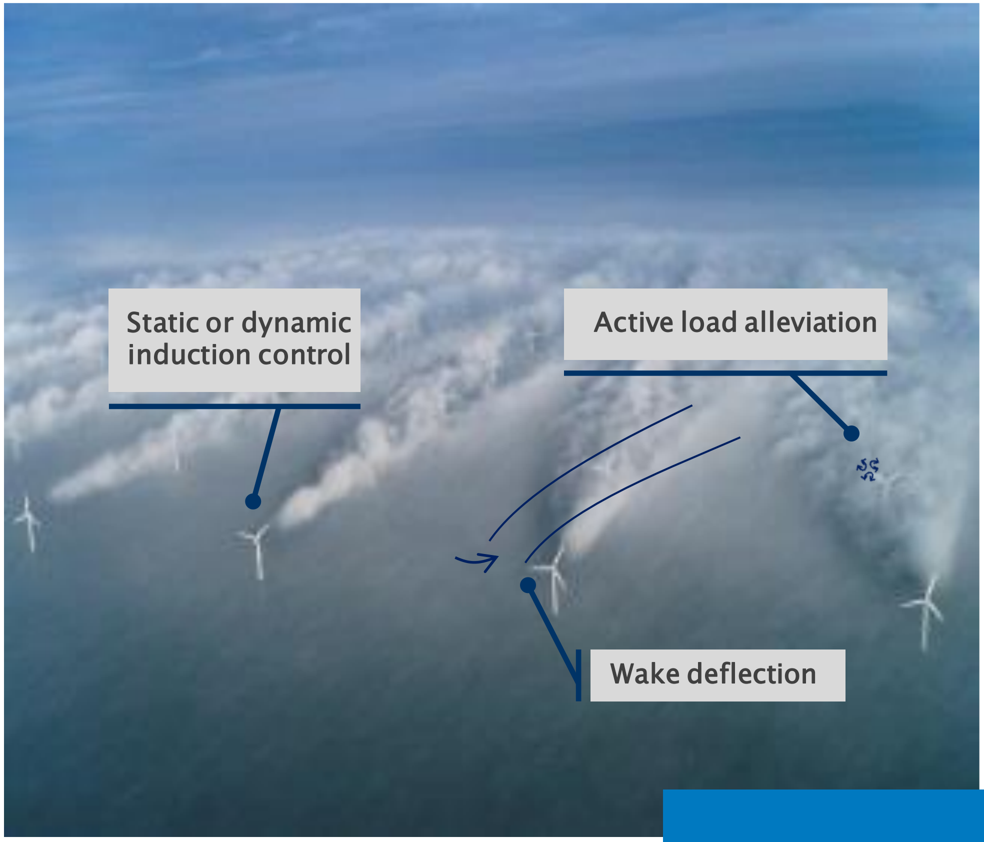
NREL
Transforming ENERGY

Grand Challenge #3 Tasks:

- Opportunities to **add value** through increased output and provision of grid support **depends on advanced plant control**
- Moving to high penetration **wind and solar will require "grid forming"** through inverters
- **Wind provides real rotational inertia but this can only be accessed through control**
- **Data analytics research is needed** to deal with the massive amount of information available **for plant operations and control**

Wind farm control for:

- Power/energy
- Loads/reliability
- Grid



Dont forget to use the data!

- Digitalization, data-driven modeling, control systems across thousands of miles and millions of assets is both an opportunity and a challenge

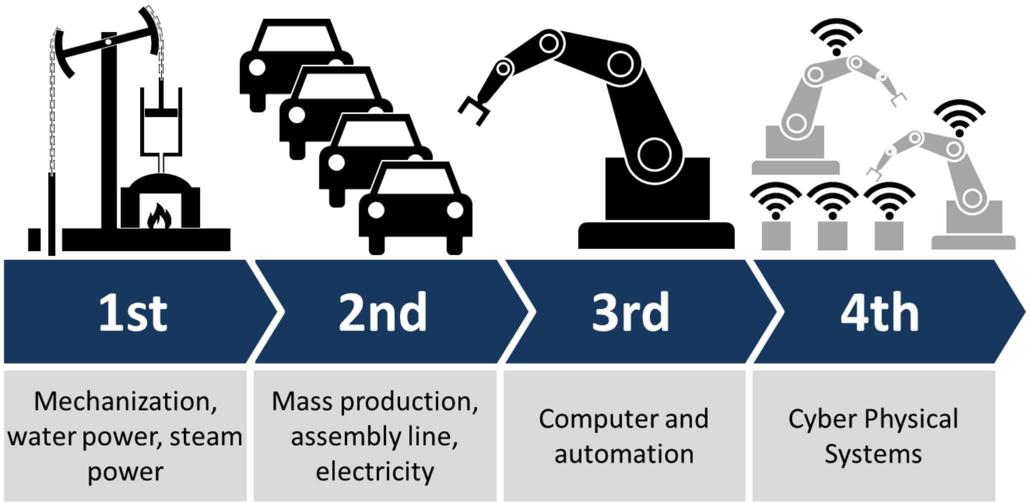


Illustration of Industry 4.0, showing the four "industrial revolutions" (Source: Rose 2016)

Need for research

- Stability: better understanding, which requires improved simulation tools and generator models and better predictive tools and metrics
- System operation: agile market rules to make revenue from solutions that are optimal for the system – also taking benefits from local trade
- Adequacy: new methods to optimise the varying generation and flexible loads (from LOLP metrics)

New ways of modelling loads for all of these!

+ Wind turbine and wind farm controls, and grid forming capabilities

Based on

- ESIG https://www.esig.energy/resources/toward-100-renewable-energy-pathways-key-research-needs/ and background document ”100% Renewables” by GE, Debbie Lew and Nick Miller
- Science article: Veers P., Dykes K., Lantz E., Barth S., Bottasso C.L., Carlson O., Clifton A., Green J., Green P., Holttinen H., Laird D., Lehtomäki V., Lundqvist J.K., Maxwell J., Marquis M., et al. (2019). Grand challenges in the science of wind energy. Science Vol. 366, Issue 6464, https://doi.org/10.1126/science.aau2027
- IEA WIND Task 25 collaborative article: ”Towards 100% Variable Inverter-based Renewable Energy Power Systems” by Bri-Mathias Hodge, C Brancucci, H Jain, G Seo, B Kroposki, J Kiviluoma, H Holttinen, J C Smith, A Estanqueiro, A Orths, L Söder, D Flynn, M Korpås, T K Vrana, Yoh Yasuda. WIREs Energy and Environment vol 9, iss. 5, e354 https://doi.org/10.1002/wene.376

Thank You!!

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The IEA Wind TCP agreement, also known as the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems, functions within a framework created by the International Energy Agency (IEA). Views, findings, and publications of IEA Wind do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

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Country	Institution
Canada	Hydro Quebec (Alain Forcione, Nickie Menemenlis); NRCan (Thomas Levy)
China	SGERI (Wang Yaohua, Liu Jun)
Denmark	DTU (Nicolaos Cutululis); Energinet.dk (Antje Orths); Ea analyse (Peter Börre Eriksen)
Finland (OA)	VTT (Hannele Holttinen, Juha Kiviluoma)
France	EdF R&D (E. Neau); TSO RTE (J-Y Bourmaud); Mines (G. Kariniotakis)
Germany	Fraunhofer IEE (J. Dobschinski); FfE (S. von Roon); TSO Amprion (P. Tran)
Ireland	UCD (D. Flynn); SEAI (J. McCann); Energy Reform (J. Dillon);
Italy	TSO Terna Rete Italia (Enrico Maria Carlini)
Japan	Kyoto Uni (Y. Yasuda); CRIEPI (R. Tanabe)
Mexico	INEEL (Rafael Castellanos Bustamante, Miguel Ramirez Gonzalez)
Netherlands	TUDelft (Arjen van der Meer, Simon Watson)
Norway	NTNU (Magnus Korpås); SINTEF (John Olav Tande, Til Kristian Vrana)
Portugal	LNEG (Ana Estanquiero); INESC-Porto (Ricardo Bessa)
Spain	University of Castilla La Mancha (Emilio Gomez Lazaro)
Sweden	KTH (Lennart Söder)
UK	Imperial College (Goran Strbac); Strathclyde Uni (Olimpo Anaya-Lara)
USA	NREL (Bri-Mathias Hodge); UVIG (J.C. Smith); DoE (Jian Fu)
Wind Europe	European Wind Energy Association (Vasiliki Klonari, Daniel Fraile)

https://community.ieawind.org/task25/