Third Annual Trottier Symposium on Sustainable Engineering, Energy and Design

The Trottier Institute for Sustainability in Engineering and Design (TISED) and the Institut de l'énergie Trottier (IET) present:

Renewables: What holds us back? What moves us ahead?

March 8 & 9, 2016

Montréal, Québec, Canada

#energyhorizon

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TISED Trottier Institute for Sustainability in Engineering and Design

IET INSTITUT DE L'ÉNERGIE TROTTIER

POLYTECHNIQUE MONTRÉAL

Variable Renewables Integration:

The Good, the Bad, and the Ugly

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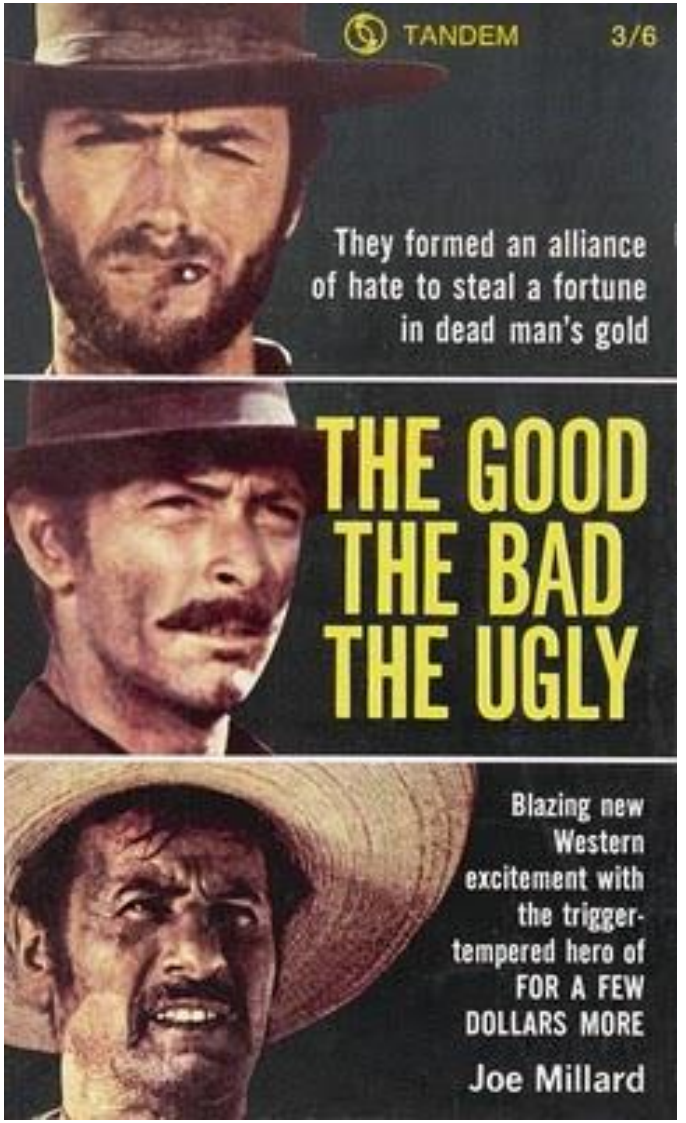
University College Dublin

Third Annual Trottier Symposium in Sustainable Engineering, Energy and Design

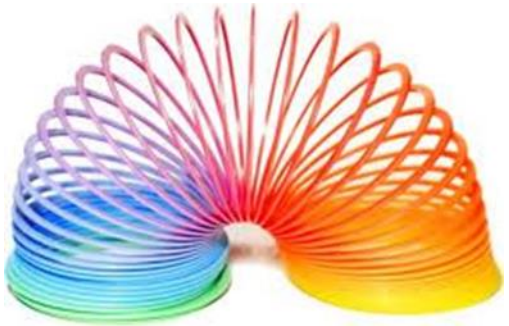
March 8th, 2016

Methodology



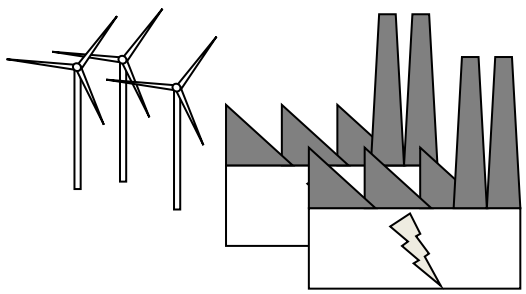
Outline

- **Background – supply demand balance & flexibility**
- **What moves us ahead ? & what holds us back ?**
  - The Good: Who is integrating large volumes of variable renewables and how ?
  - The Bad: Myths & Mistakes
  - The Ugly: What are the really difficult challenges and how can we solve them ?
- **Energy Systems Integration**
  - Importance for high penetrations
  - International collaboration and human capacity building
- **Conclusions**

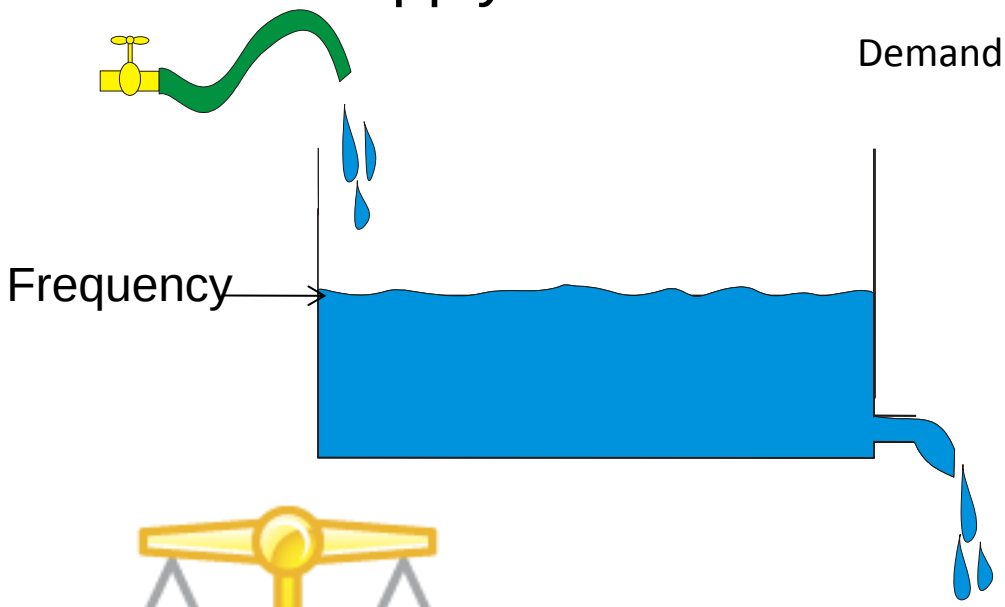


Supply demand balance and flexibility

Supply demand balance & frequency control

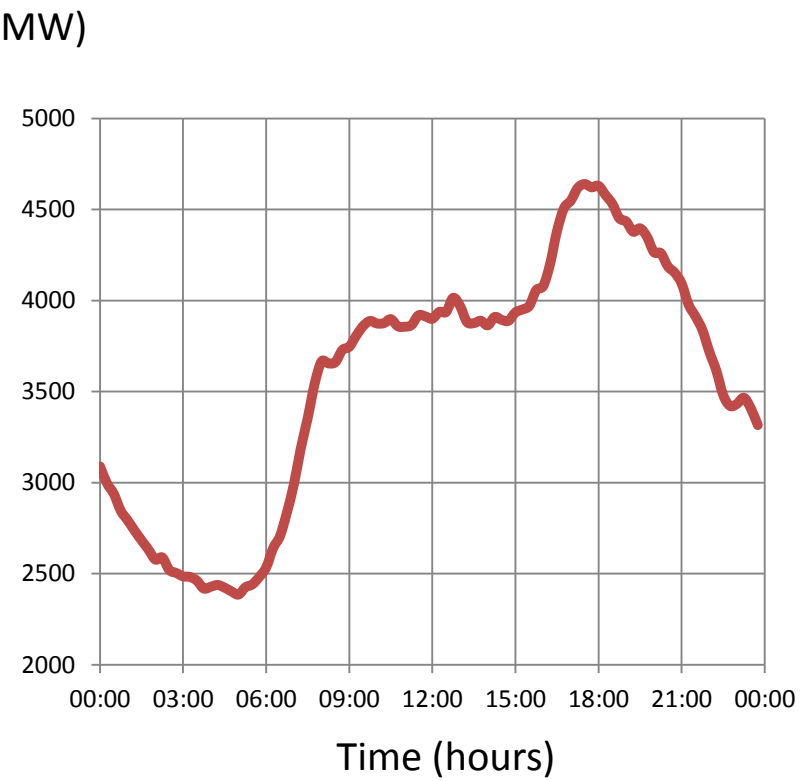


Supply

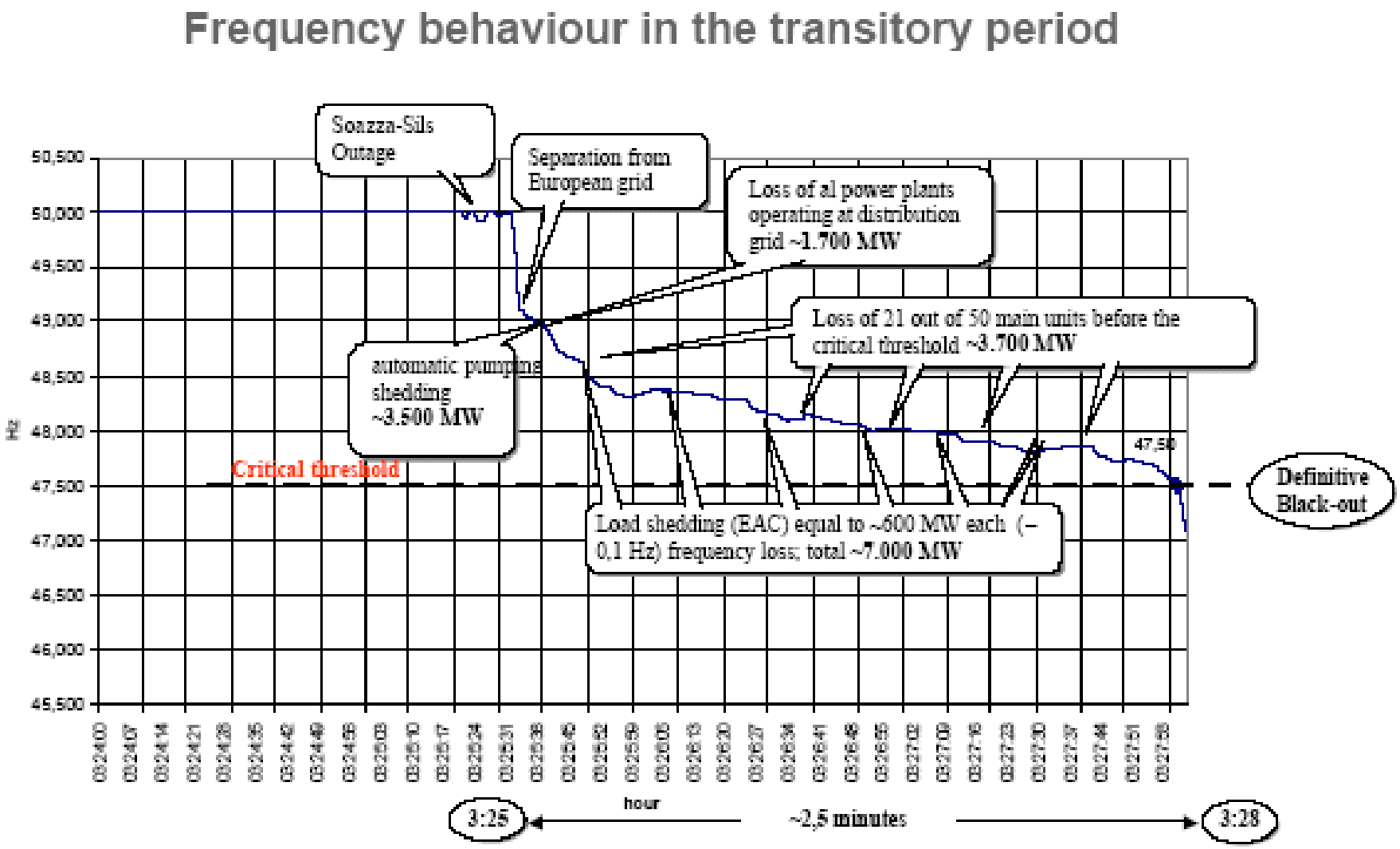


If generation and demand are matched, water level (system frequency) will remain constant

Mismatches will result in a change in water level (system frequency)

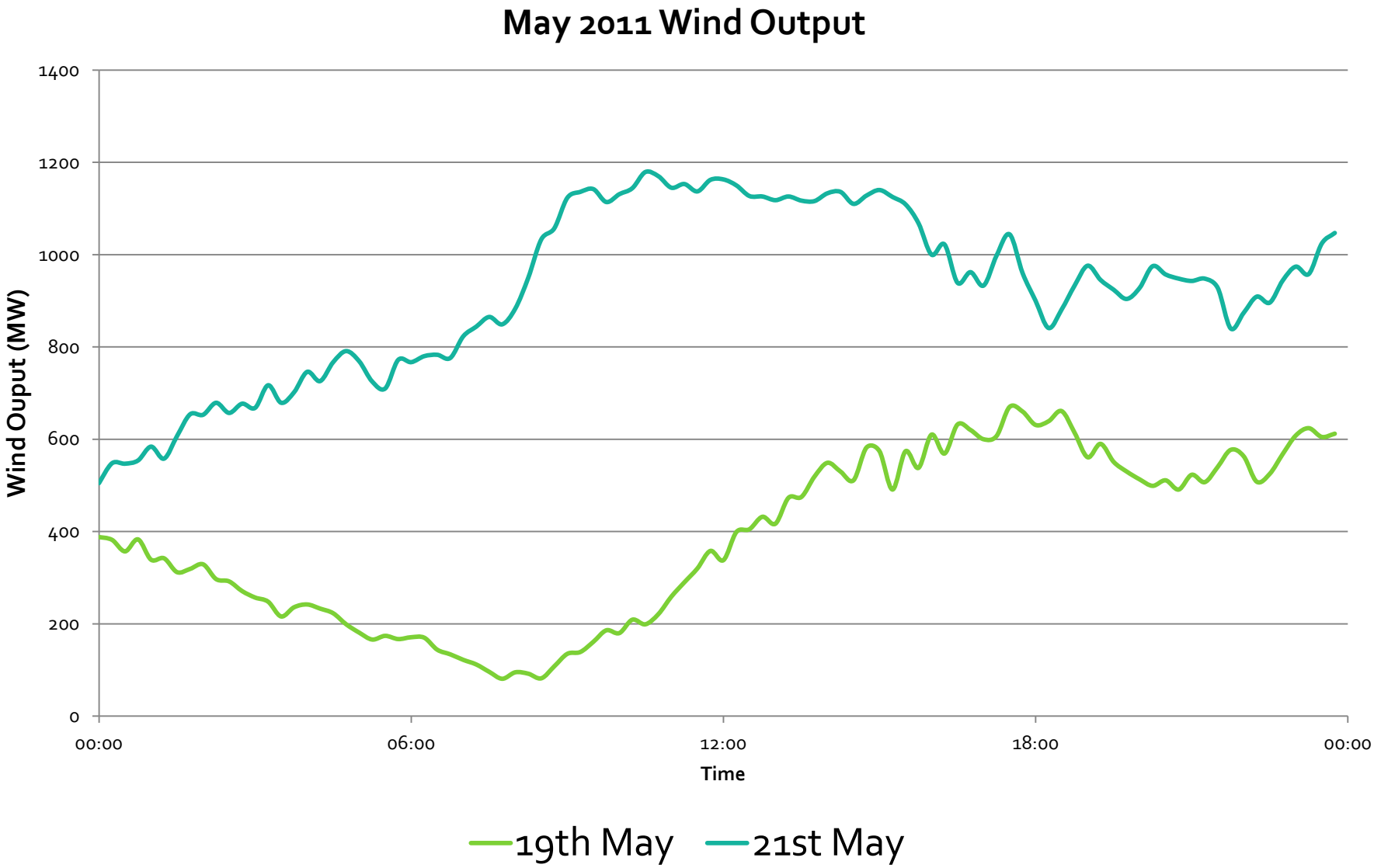


Italian blackout 28th September 2003



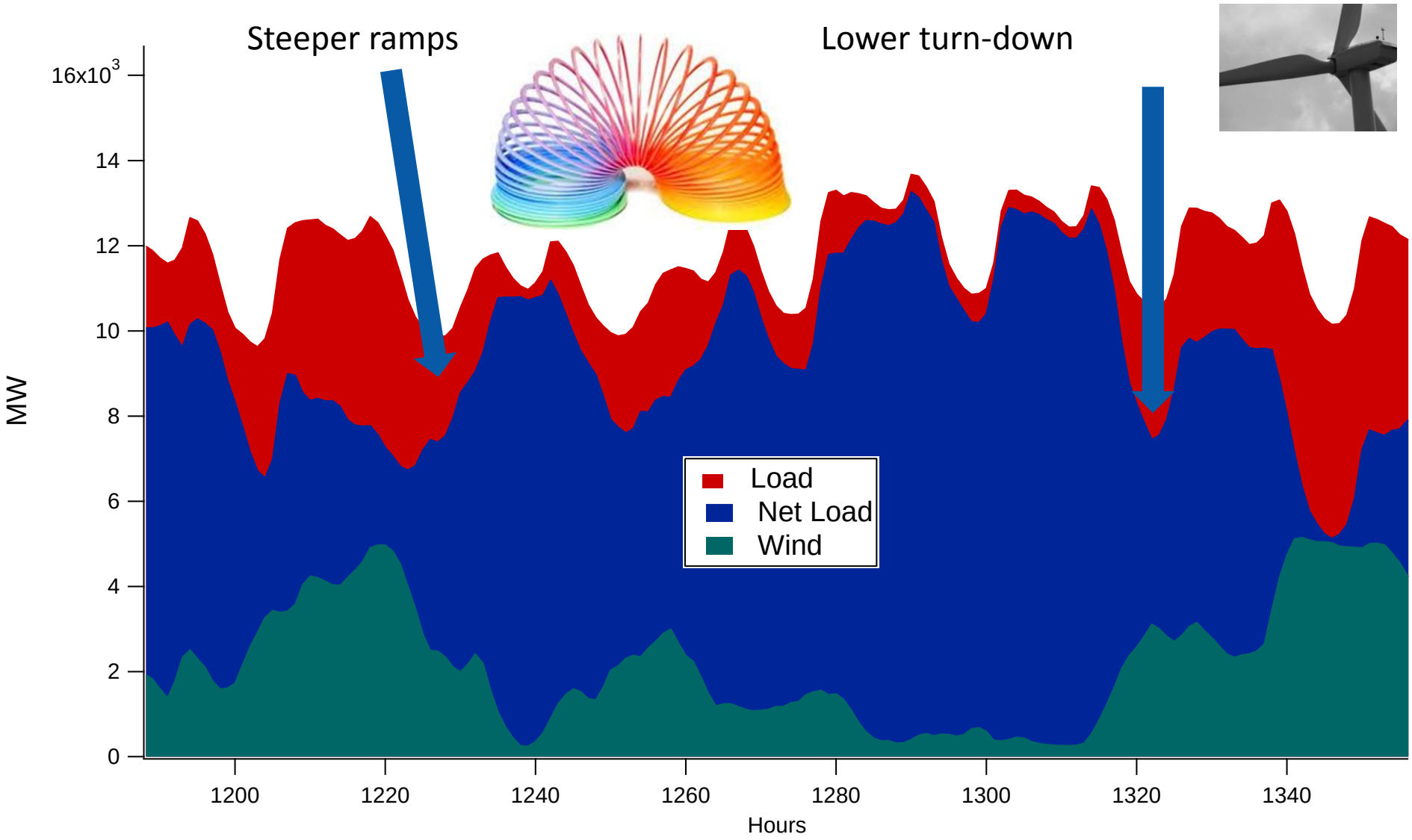
Italy in the dark

Wind Generation Hourly Variability



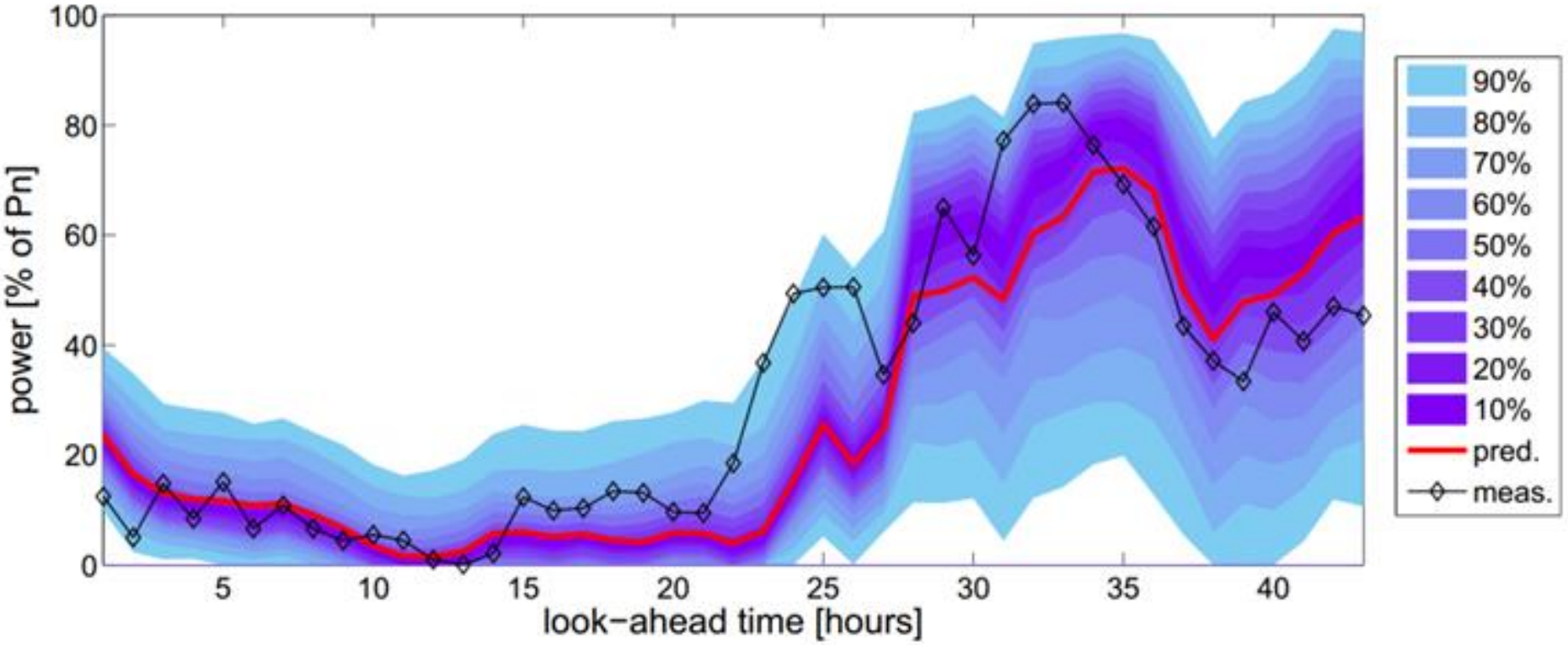
Source: EirGrid

With variable renewables, more flexibility is needed



Michael Milligan , NREL

Uncertainty

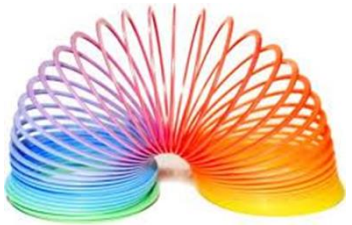


Pinson, P., Madsen, H, Nielsen, H., Papaefthymiou, G. and Klöckl, B., From probabilistic forecasts to statistical scenarios of short-term wind power production, Wind Energy, volume 12, issue 1, January 2009

Scope and time frames







Operations

Planning

Unit Commitment (on/off)

Economic Dispatch

(power level)

Real Time

Years

Weeks - Hours

Minutes

Time

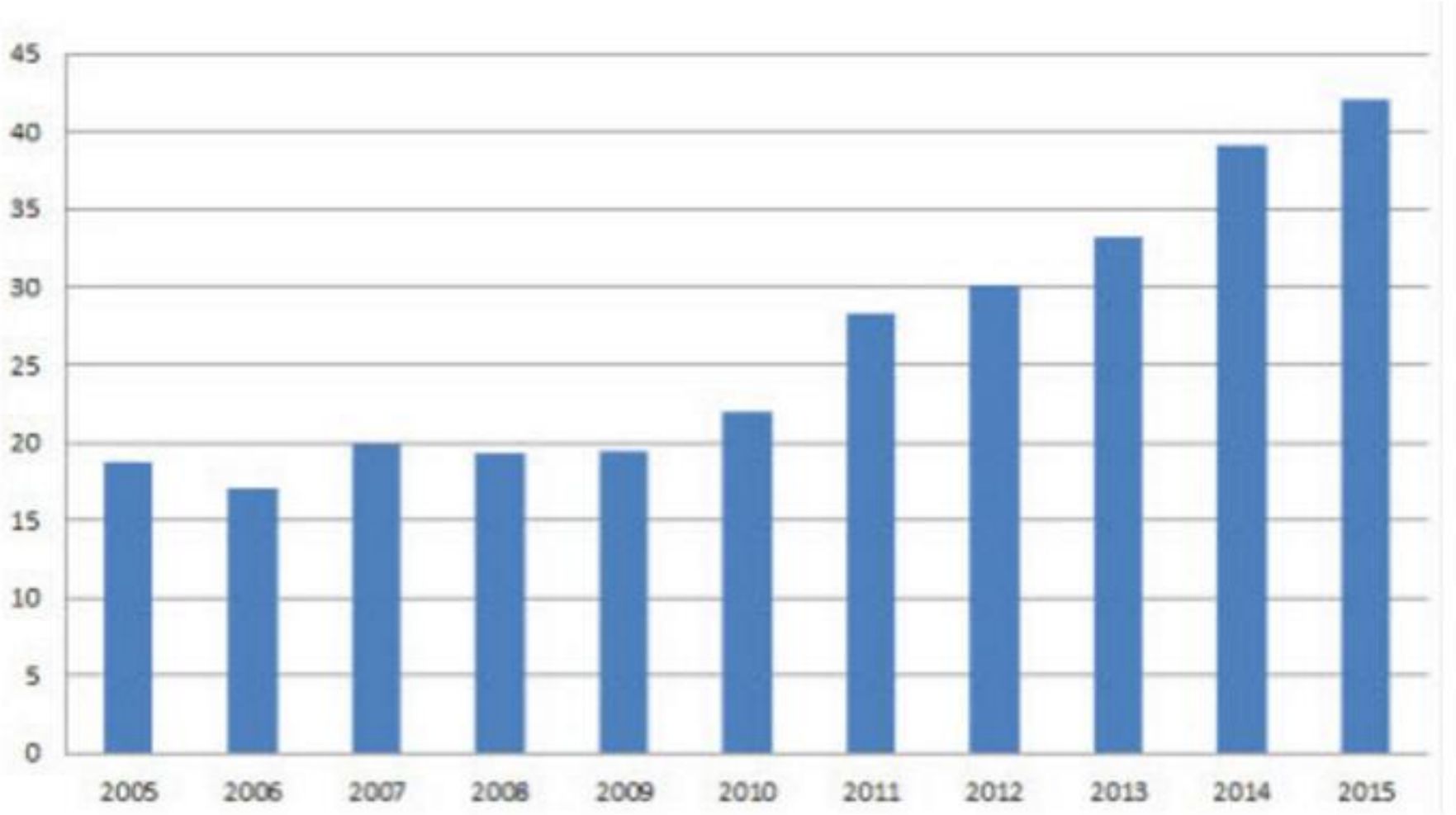


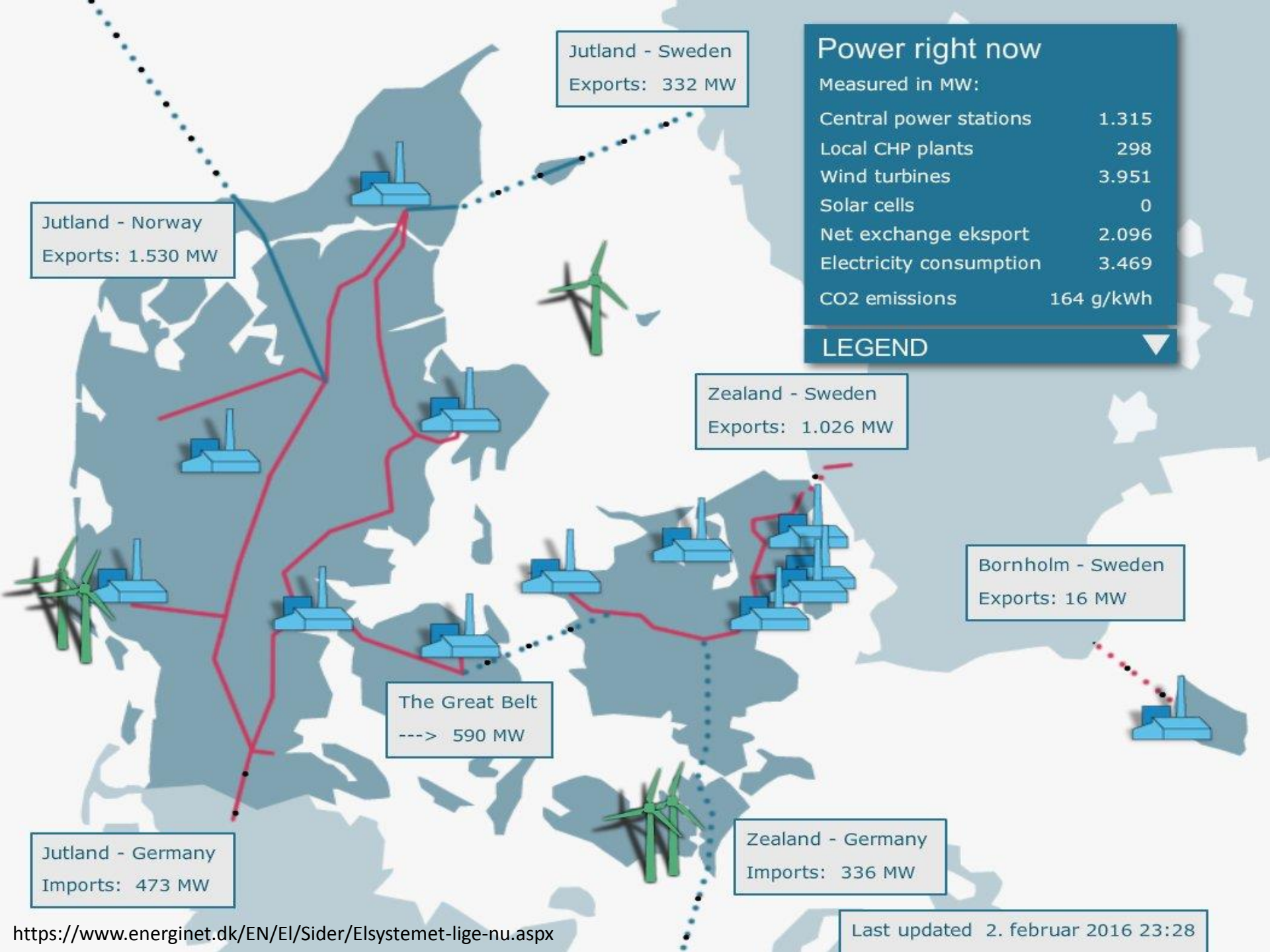
Key Messages

- Variable renewables require more flexibility
- Supply demand balance is about reliability and cost
- Pick the cheapest cost solutions from the set of possible solutions.
  - A complex problem with many actors and across many time scales

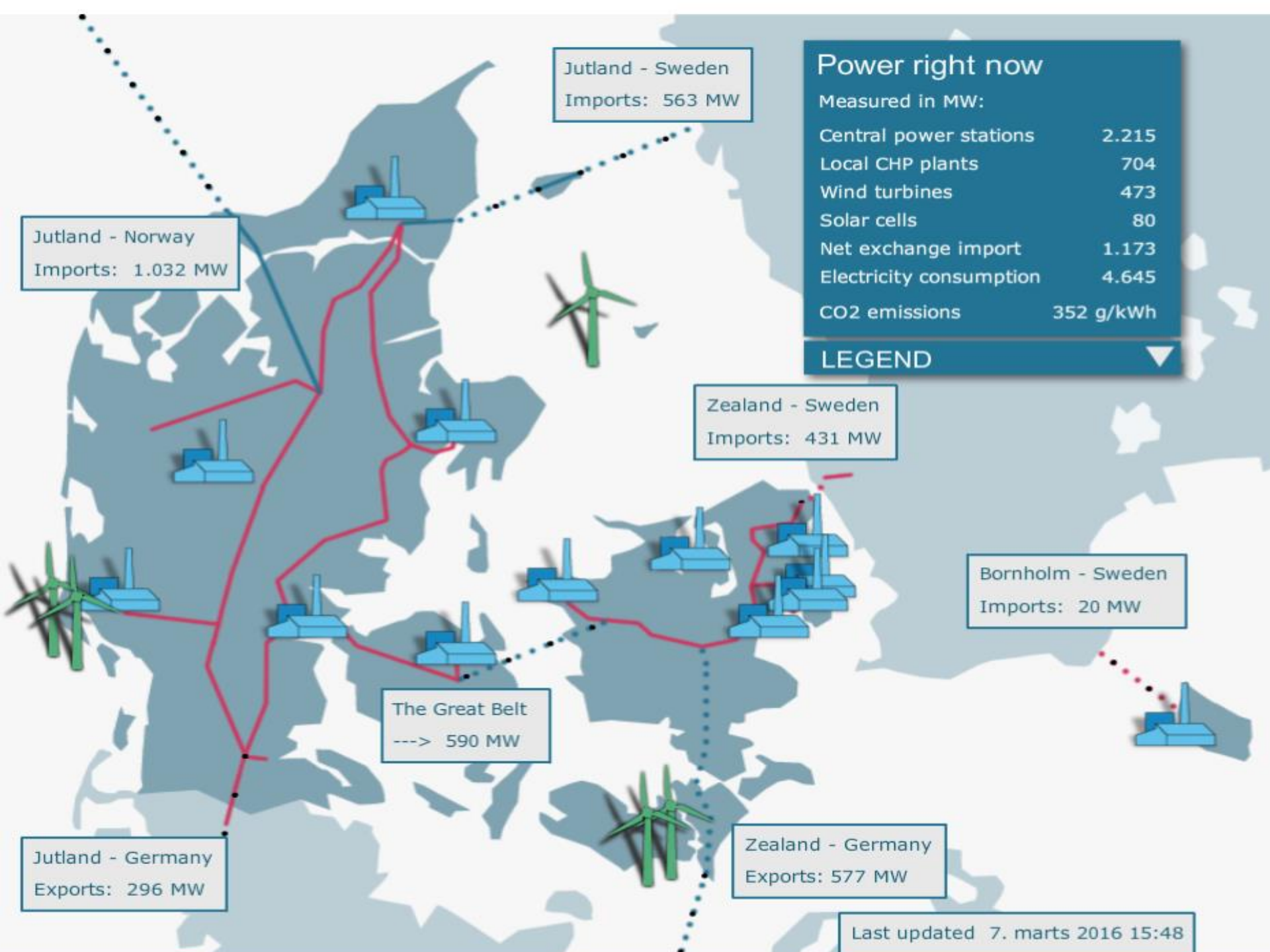
The Good

Wind energy %, electricity, Denmark

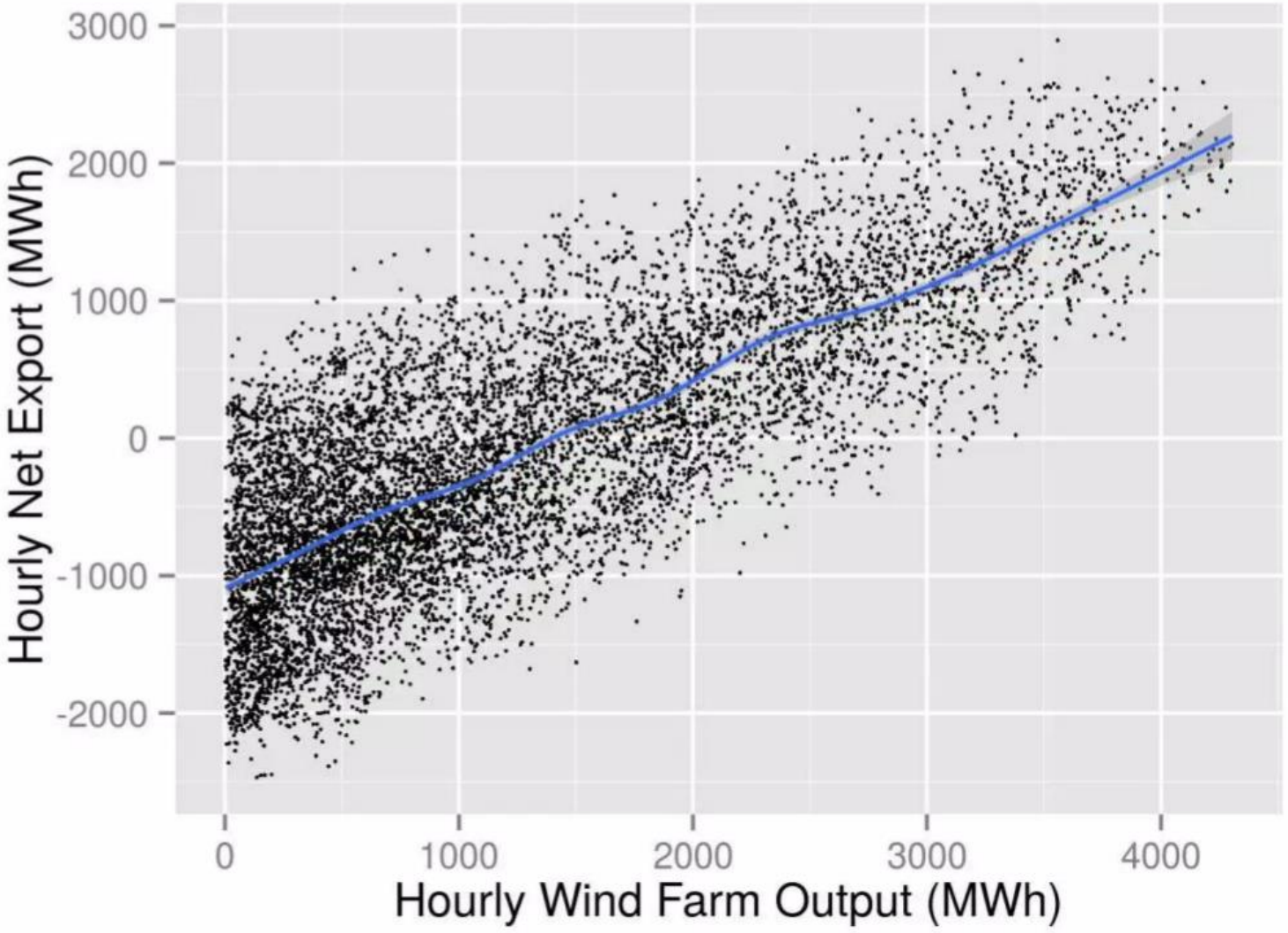




https://www.energinet.dk/EN/El/Sider/Elsystemet-lige-nu.aspx

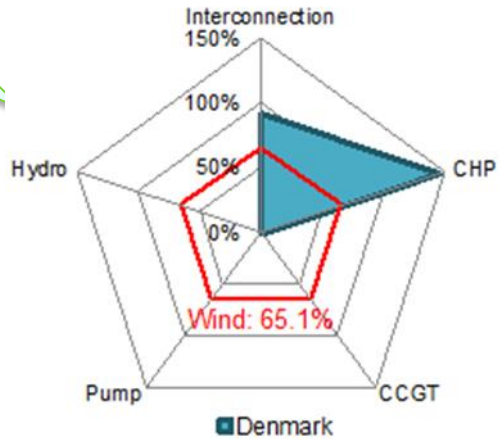

Jutland - Sweden
Imports: 563 MW
Power right now
Measured in MW:
Central power stations 2.215
Local CHP plants 704
Wind turbines 473
Solar cells 80
Net exchange import 1.173
Electricity consumption 4.645
CO2 emissions 352 g/kWh
LEGEND
Jutland - Norway
Imports: 1.032 MW
Zealand - Sweden
Imports: 431 MW
Bornholm - Sweden
Imports: 20 MW
The Great Belt
---> 590 MW
Jutland - Germany
Exports: 296 MW
Zealand - Germany
Exports: 577 MW
Last updated 7. marts 2016 15:48

Denmark integration of wind: the role of interconnection

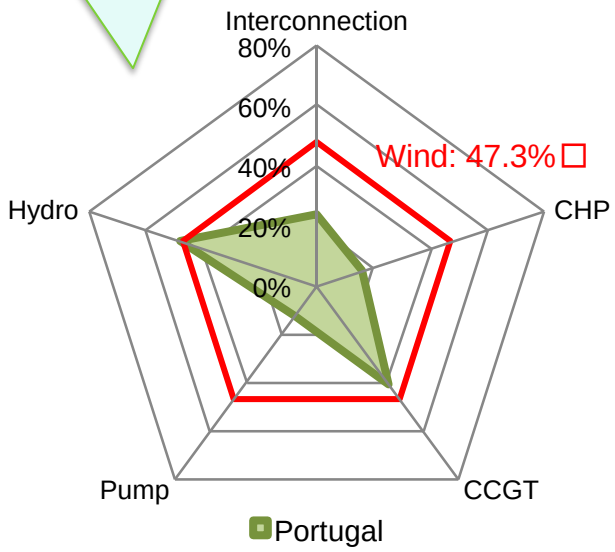


Flexibility chart

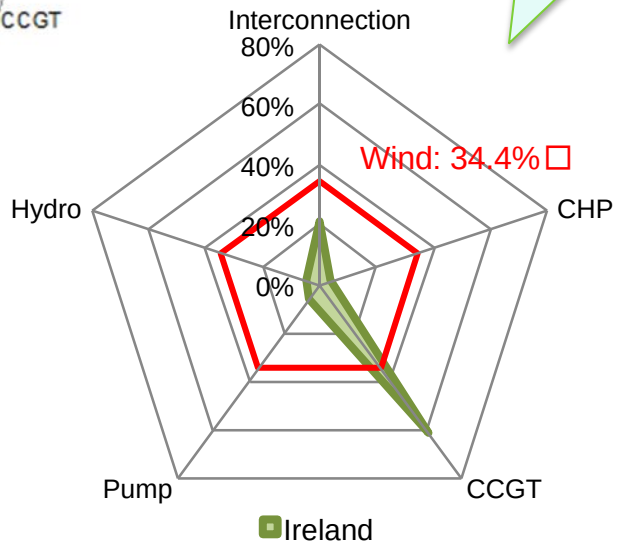
Denmark(Interconnection-oriented)



Portugal (Hydro-oriented)

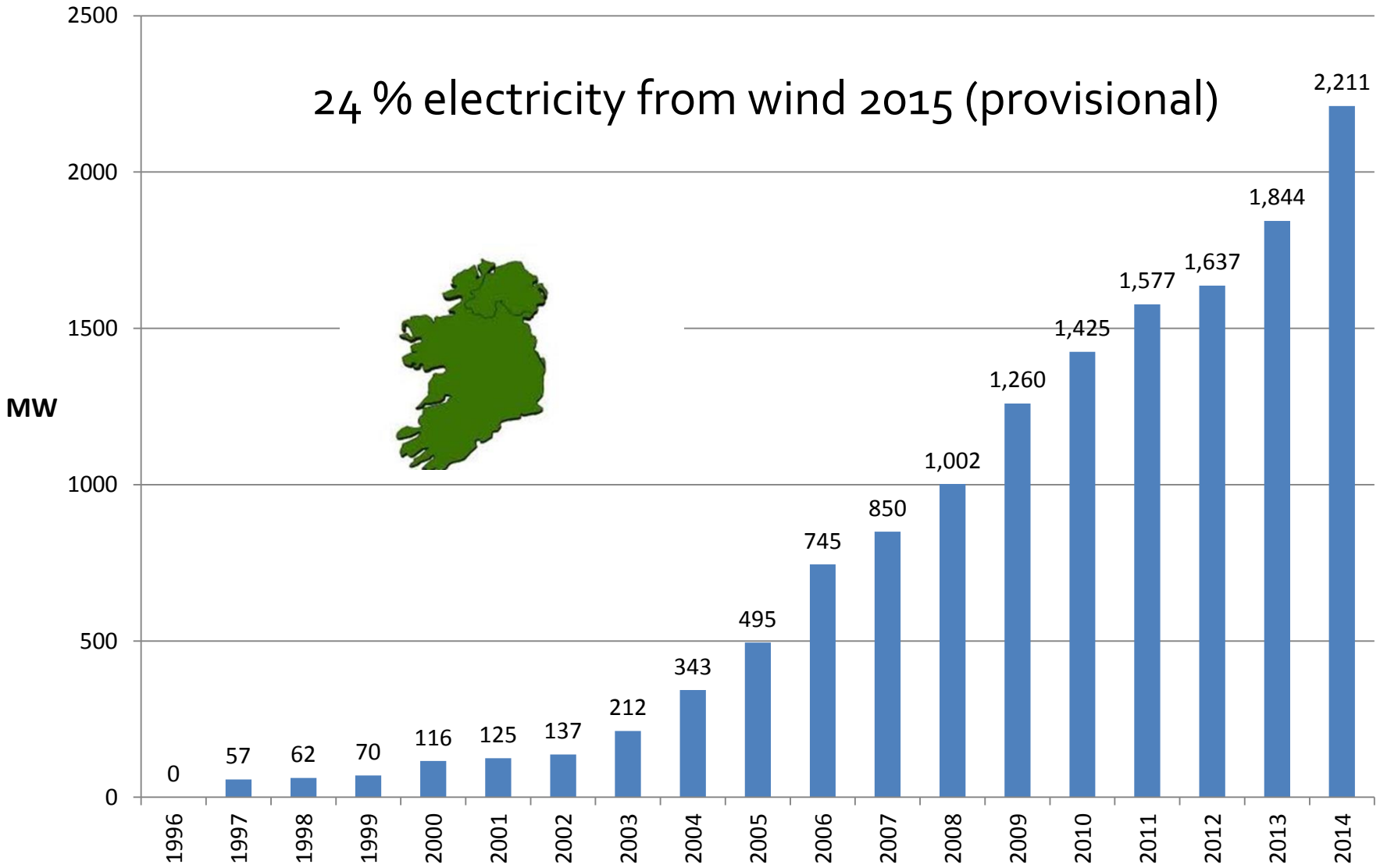


Ireland (CCGT-oriented)



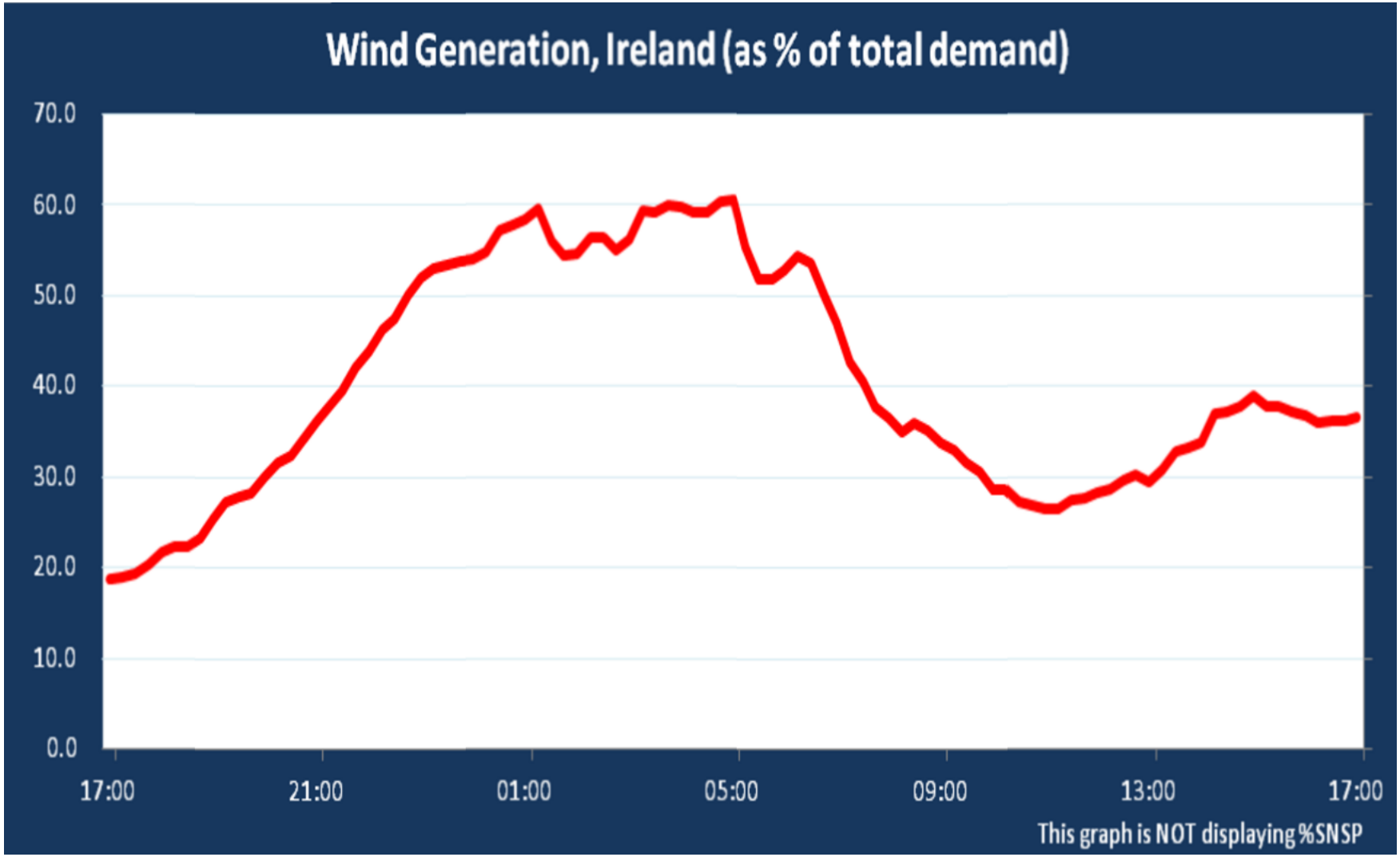
Y. Y asuda et al.: “Flexibility Chart – Evaluation on Diversity of Flexibility in Various Areas”, 13th Wind Integration Workshop, WIW13-1029, (2013, 10, London).

Wind Installed in Republic of Ireland

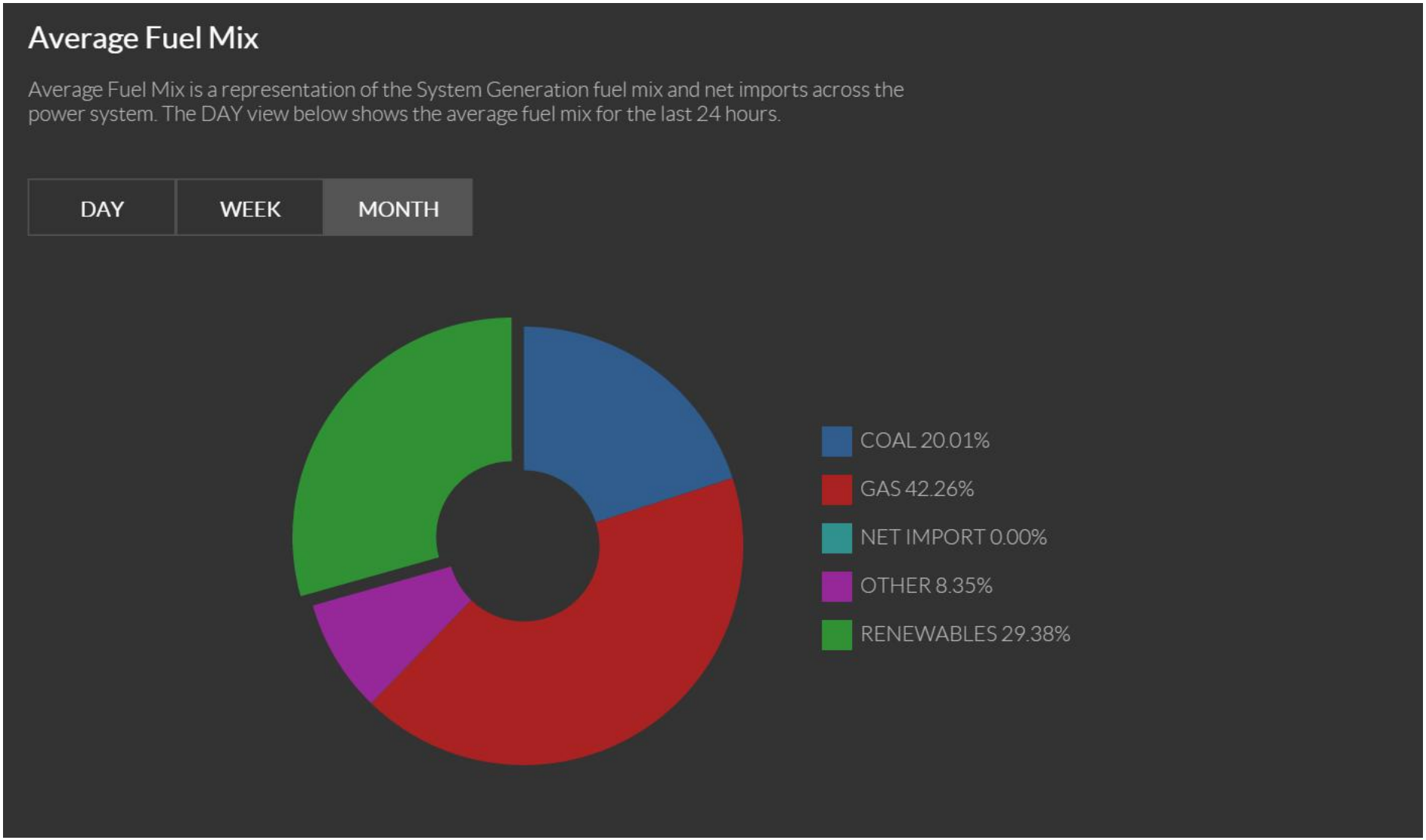


Source: EirGrid http://www.eirgrid.com/operations/systemperformancedata/all-islandwindandfuelmixreport/

6th & 7th March 2016 (Ireland)



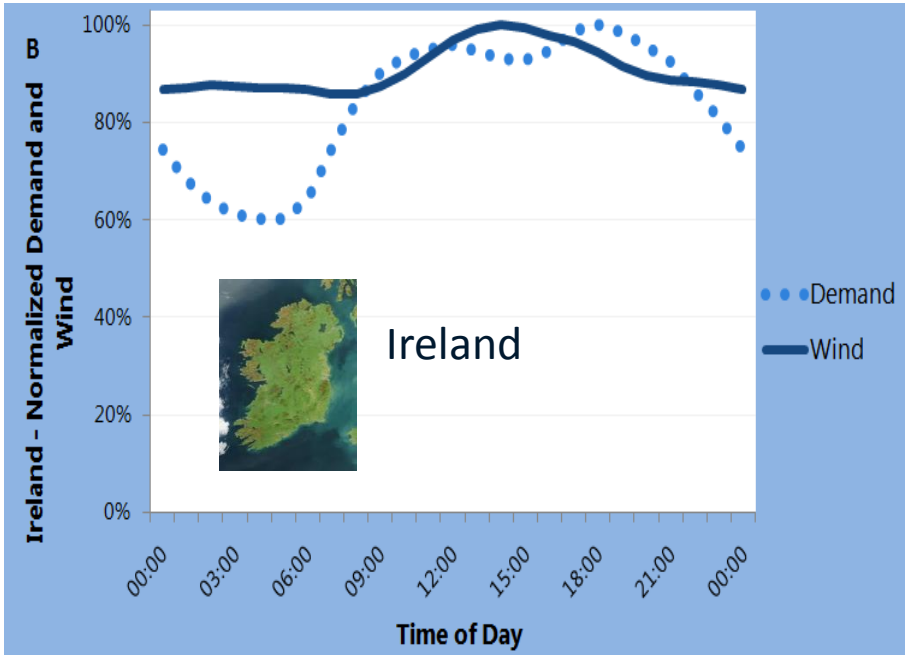
Monthly Fuel Mix Ireland Feb 2016

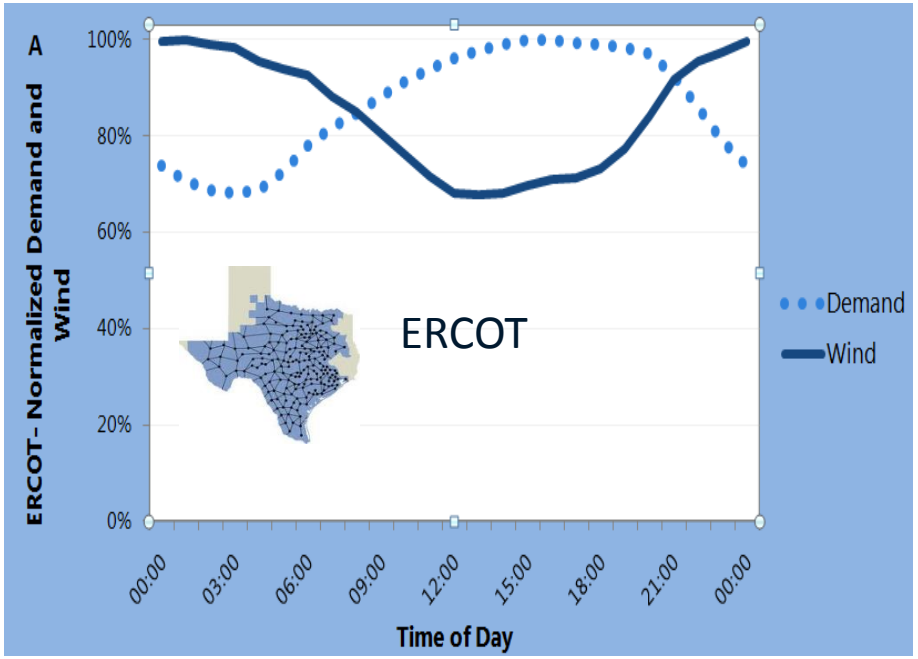


http://smartgriddashboard.eirgrid.com/#all/generation?scroll=fuel

Renewable energy and load characteristics

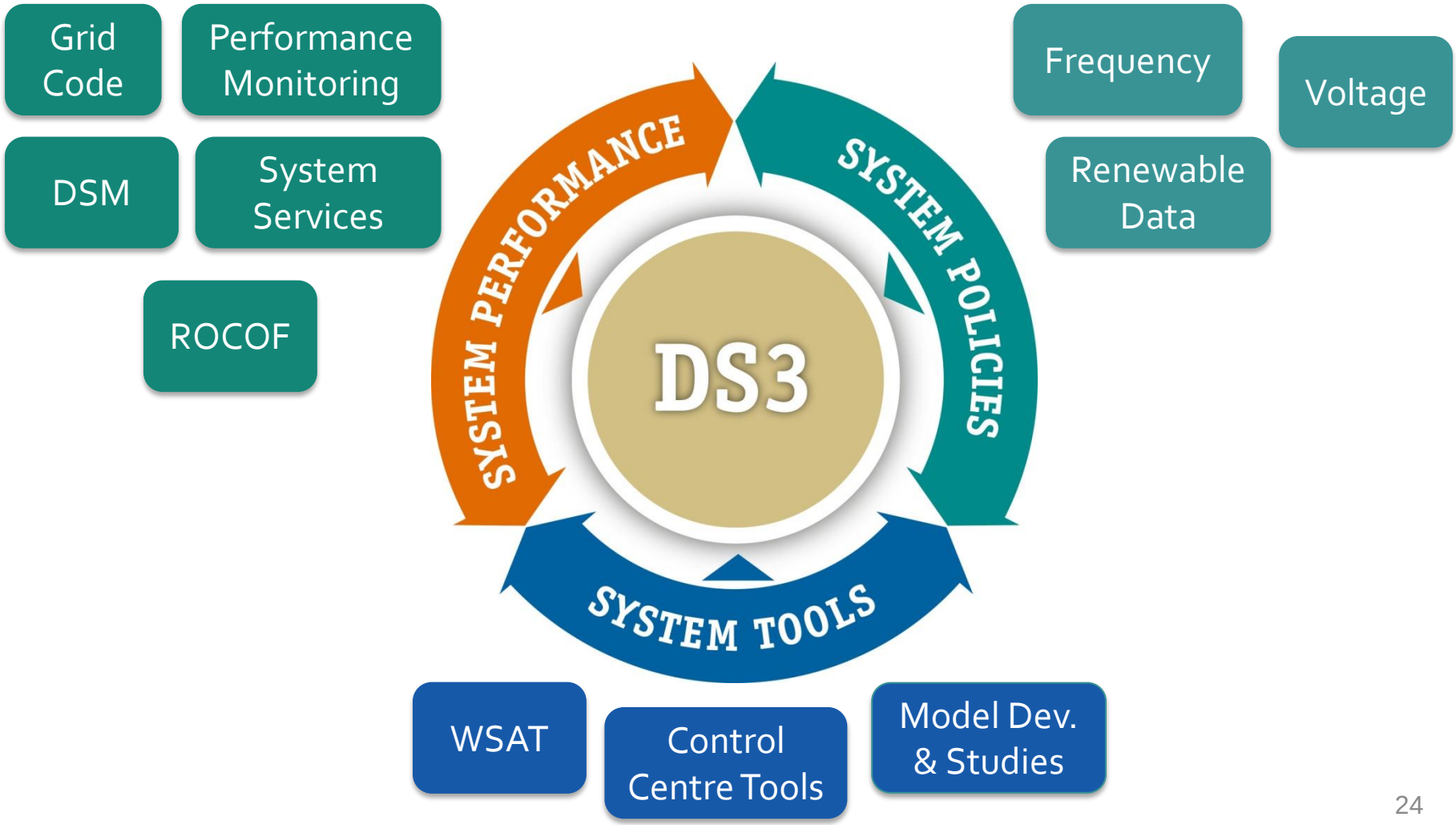
Dance partners





AEMO, Australian Energy Market Operator, "Wind Integration In Electricity Grids: International Practice And Experience" Work Package 1, 2011.
http://www.aemo.com.au/~/media/Files/Other/planning/0400-0049%20pdf.pdf

DS3 Programme (Delivering a Secure Sustainable Electricity System (DS3))



Key Messages

- Denmark, Ireland, Portugal etc. are “good”
- Every system is different
- They have worked hard at it and had a plan

The Bad

Wind Power Myths Debunked

Common Questions and Misconceptions

THE RAPID GROWTH OF WIND POWER IN THE UNITED STATES AND worldwide has resulted in increasing media attention to—and public awareness of—wind-generation technology. Several misunderstandings and myths have arisen due to the characteristics of wind generation, particularly because wind-energy generation only occurs when the wind is blowing. Wind power is therefore not dispatchable like conventional energy sources and delivers a variable level of power depending on the wind speed. Wind is primarily an energy resource and not a capacity resource. Its primary value is to offset fuel consumption and the resulting emissions, including carbon. Only a relatively small fraction of wind energy is typically delivered during peak and high-risk time periods; therefore, wind generators have limited capacity value. This leads to concerns about the impacts of wind power on maintaining reliability and the balance between load and generation.

This article presents answers to commonly asked questions concerning wind power. It begins by addressing the variability of wind and then discusses whether wind has capacity credit. The article addresses whether wind can stop blowing everywhere at once, the uncertainty of predicting wind generation, whether it is expensive to integrate wind

By Michael Milligan, Kevin Porter, Edgar DeMeo, Paul Denholm, Hannele Holttinen, Brendan Kirby, Nicholas Miller, Andrew Mills, Mark O'Malley, Matthew Schuerger, and Lennart Soder

Digital Object Identifier 10.1109/MPE.2009.934268

1540-7977/09/$26.00©2009 IEEE

Myths

Doesn't Wind Power Need Backup Generation? Isn't More Fossil Fuel Burned with Wind Than Without, Due to Backup Requirements?

Does Wind Have Capacity Credit?

Isn't All the Existing Flexibility Already Used Up?

Doesn't Wind Power Need New Transmission, and Won't That Make Wind Expensive?

Isn't There a Limit to How Much Wind Can Be Accommodated by the Grid?

Can Grid Operators Deal with the Continually Changing Output of Wind Generation?

How Often Does the Wind Stop Blowing Everywhere at the Same Time?

Isn't It Very Difficult to Predict Wind Power?

Isn't It Very Expensive to Integrate Wind?

Is Wind Power as Good as Coal or Nuclear Even Though the Capacity Factor of Wind Power Is So Much Less?

Does Wind Need Storage?

Milligan, M., Porter, K., DeMeo, E., Denholm, P., Holttinen, H., Kirby, B., Miller, N., Mills, A., O'Malley, M.J., Schuerger, M. and Soder, L., "Wind Power Myths Debunked", IEEE Power & Energy Magazine, pp 89-99, Vol. 7, No 6, 2009.

Windmills Overload East Europe's Grid Risking Blackout: Energy

By Ladka Bauerova and Tino Andresen - Oct 26, 2012 12:01 AM GMT

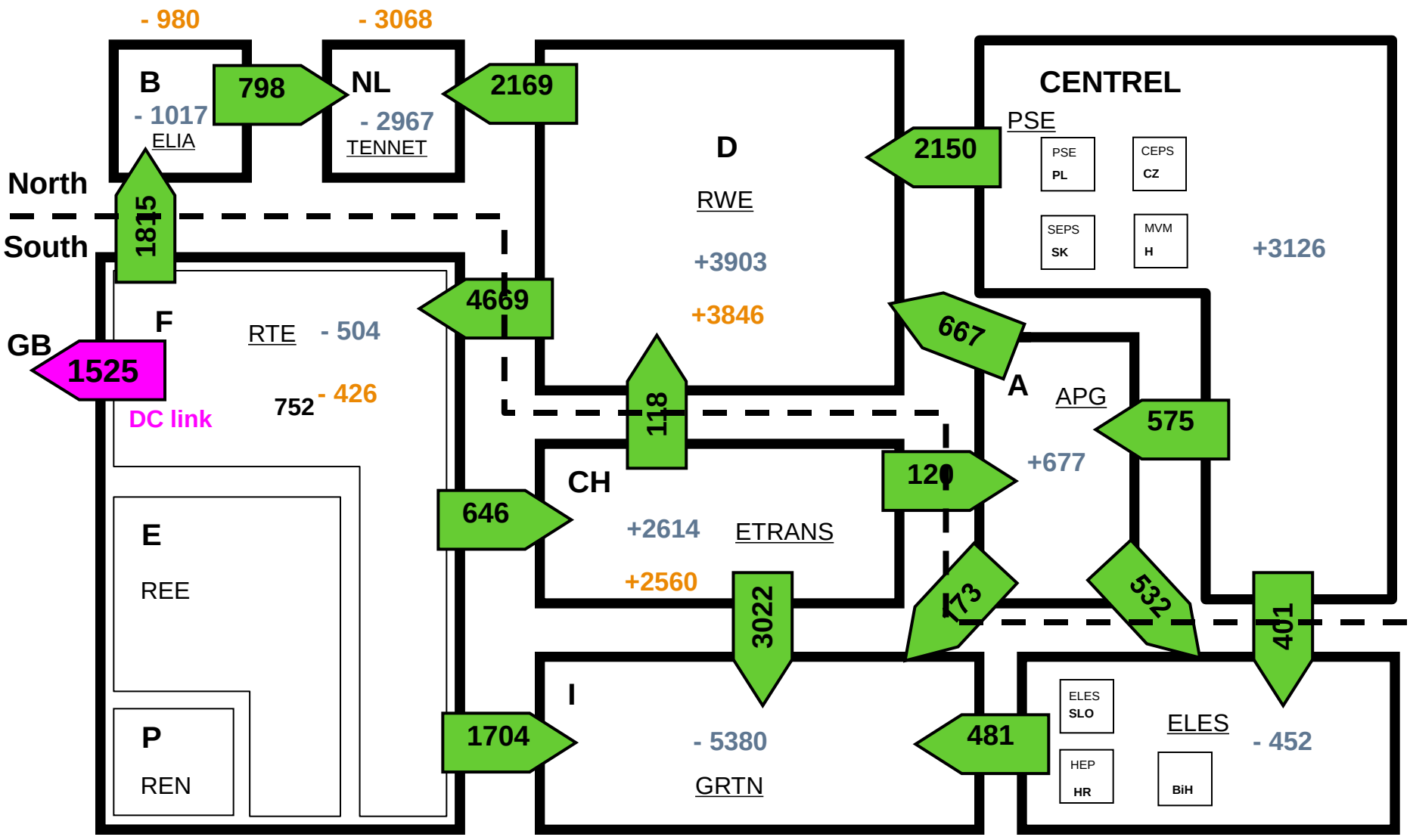
Sean Gallup/Getty Images

Germany is dumping electricity on its unwilling neighbors and by wintertime the feud should come to a head.

Germany is dumping electricity on its unwilling neighbors and by wintertime the feud should come to a head.

Unannounced Wind Power in the Northern Germany

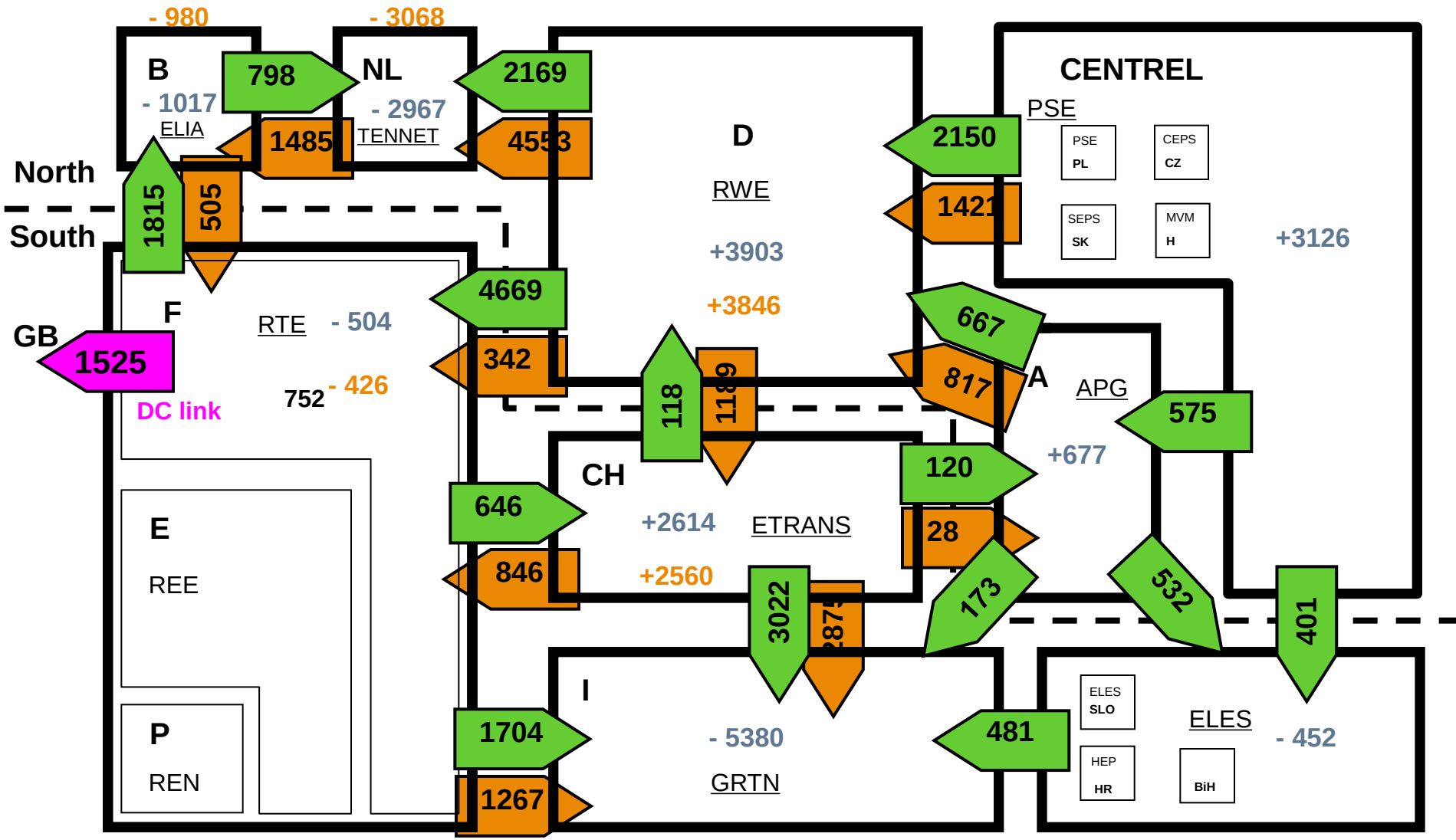
Scheduled Power Exchanges



Source: Ronnie Belmans, ELIA

Unannounced Wind Power in the Northern Germany

Scheduled Power Exchanges vs Physical Power Flows



Source: Ronnie Belmans, ELIA

Coordination is the key

Mackay, M., Bird, L., Cochran, J., Milligan, M., Bazilian, M., Neuhoff, K., Denny, E., Dillon, J., Bialek, J. and O'Malley, M.J., "RES-E-NEXT, Next Generation of RES-E Policy Instruments", IEA RETD, July 2013.
http://iea-retd.org/wp-content/uploads/2013/07/RES-E-NEXT_IEA-RETD_2013.pdf

Key Messages

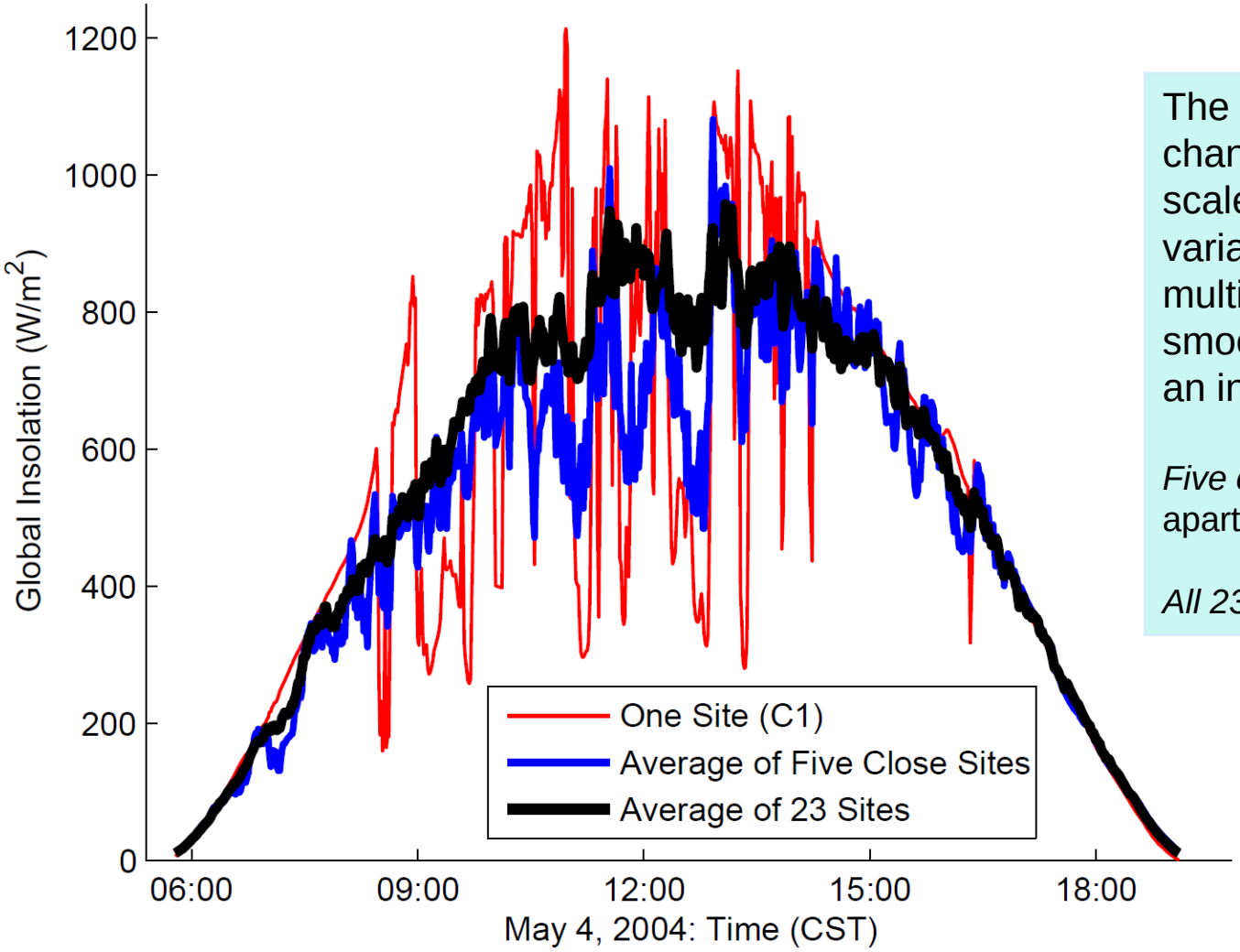
- There are many “bad” myths
  - “Education” is required
- There are also some “bad” mistakes
  - Coordination is the key

The Ugly

An opportunity

Grid Flexibility

Aggregation of solar



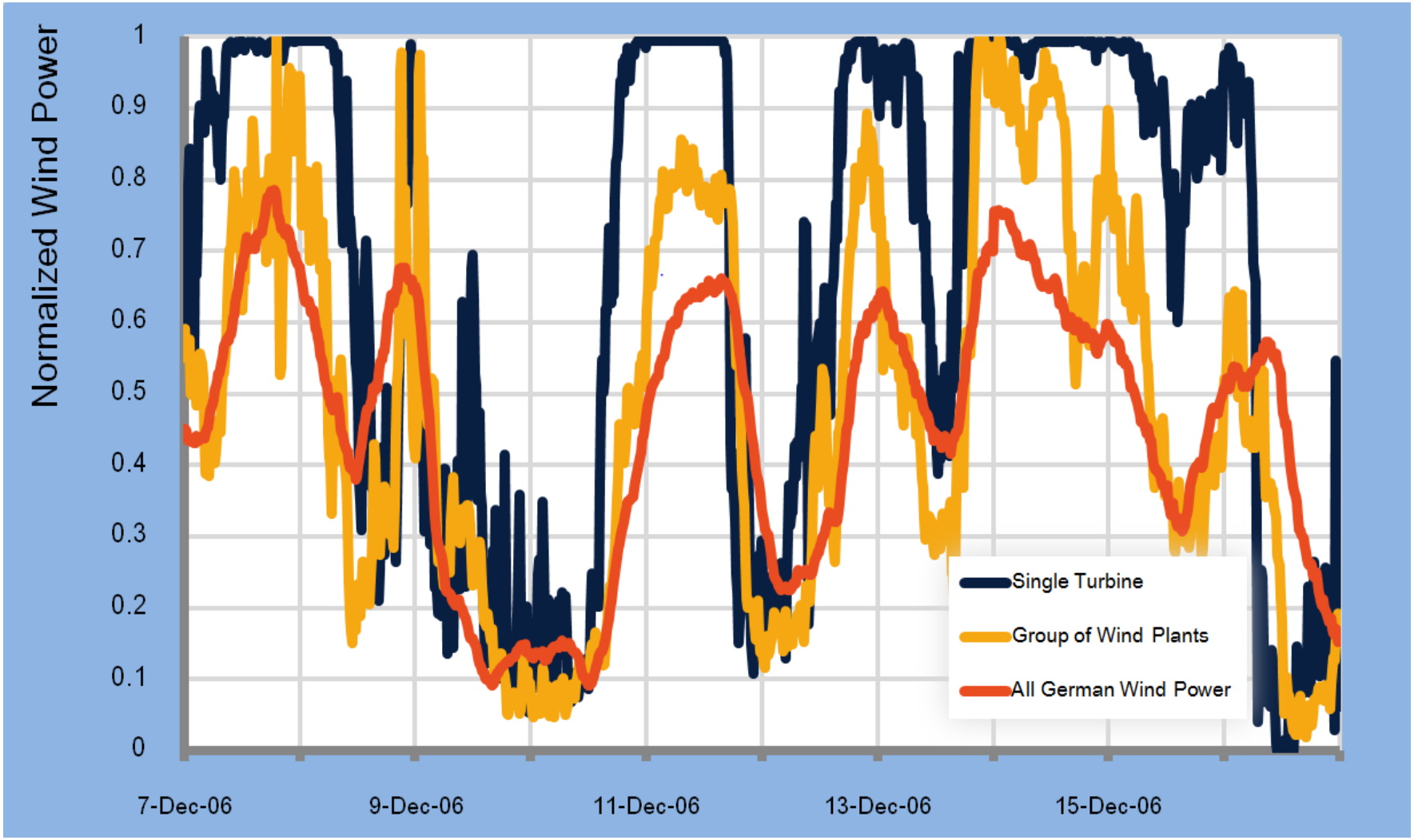
The lack of correlation in changes solar over short time scales means that the variability of the aggregated multiple sites is significantly smoother than the variability of an individual site.

Five closest sites: 50 – 170 km apart

All 23 sites: 20 – 440 km apart

Mills, A. D, and R. H. Wiser. 2011. Implications of geographic diversity for short-term variability and predictability of solar power. In 2011 IEEE Power and Energy Society General Meeting, 1-9. IEEE, July 24. doi:10.1109/PES.2011.6039888.
Source: Andrew Mills, LBL

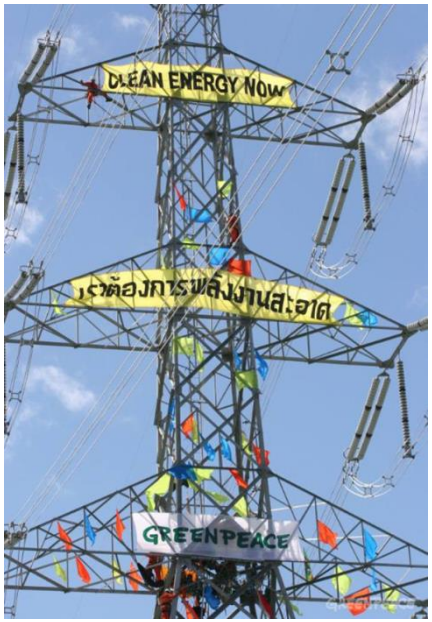
Aggregation of wind with transmission



Krewitt, W. et al. Integration of Renewable Energy into Present and Future Energy Systems. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2011.

If you love wind and/or solar, you have to at least like Transmission!

Enter the “consumer”



‘Engineers and economists are ignoring people and miscasting decision making and action’, *Sovacool, B.K. (2014) Nature 511, 529-530*


DIETER TELEMANS/PANOS

Masai women from Kenya take a course on solar energy in India.

Energy studies need social science

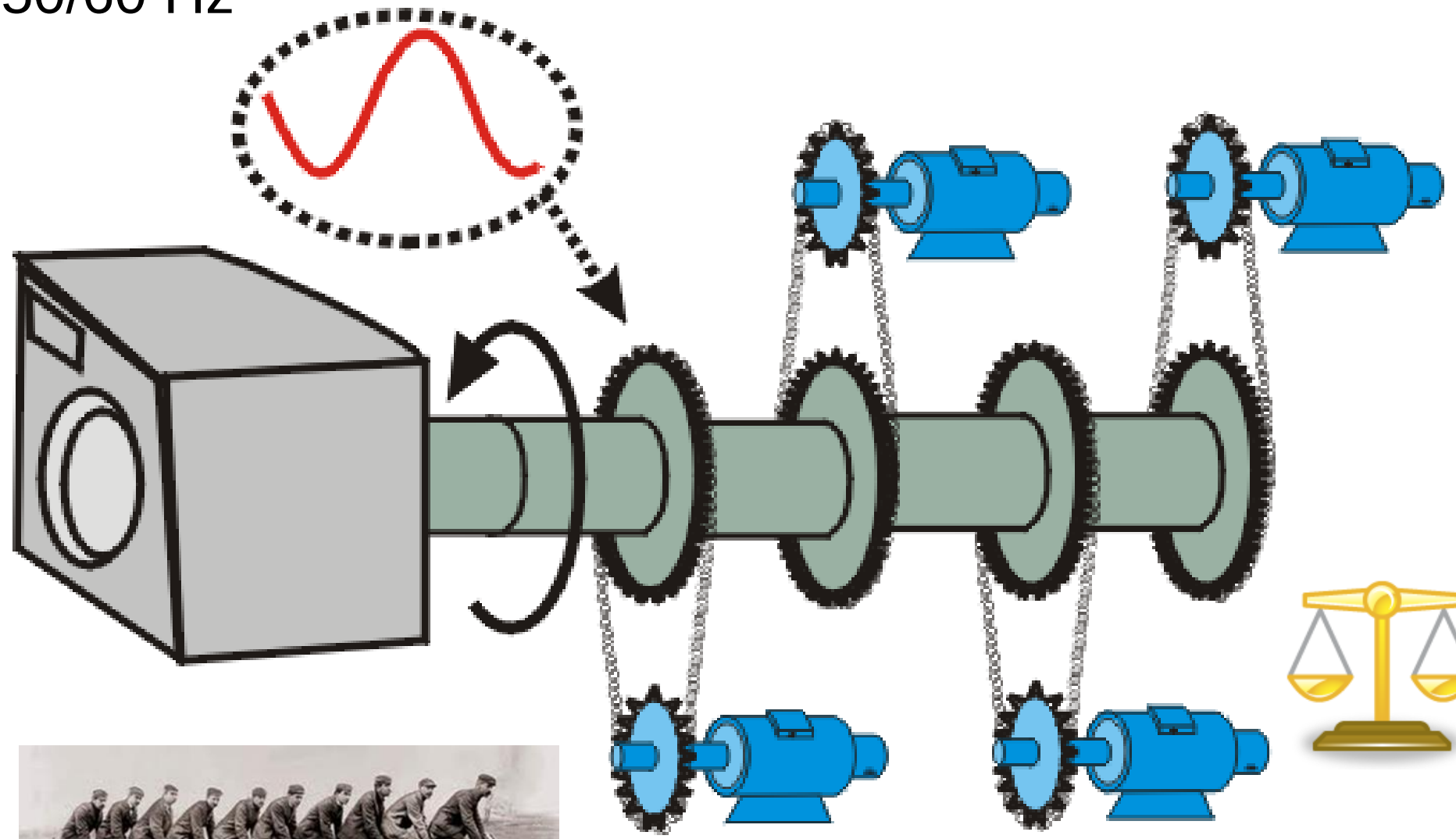
Key Messages

- Transmission is the key enabler of flexibility
- But society is not supportive of its construction
- This is a social science and political problem not an engineering one

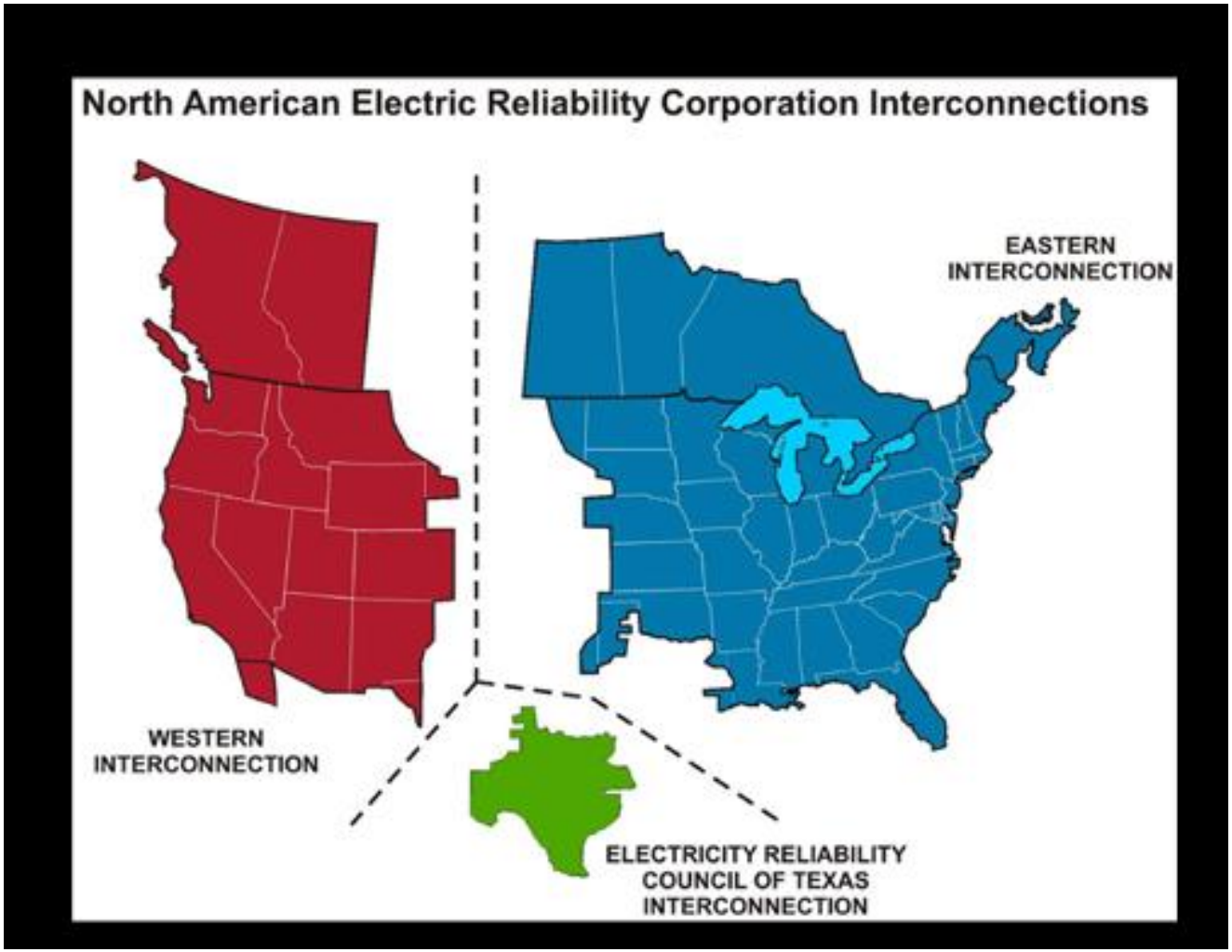
Synchronous Electrical Energy Systems

Synchronous System

50/60 Hz



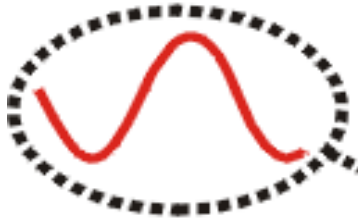
North America 60 Hz

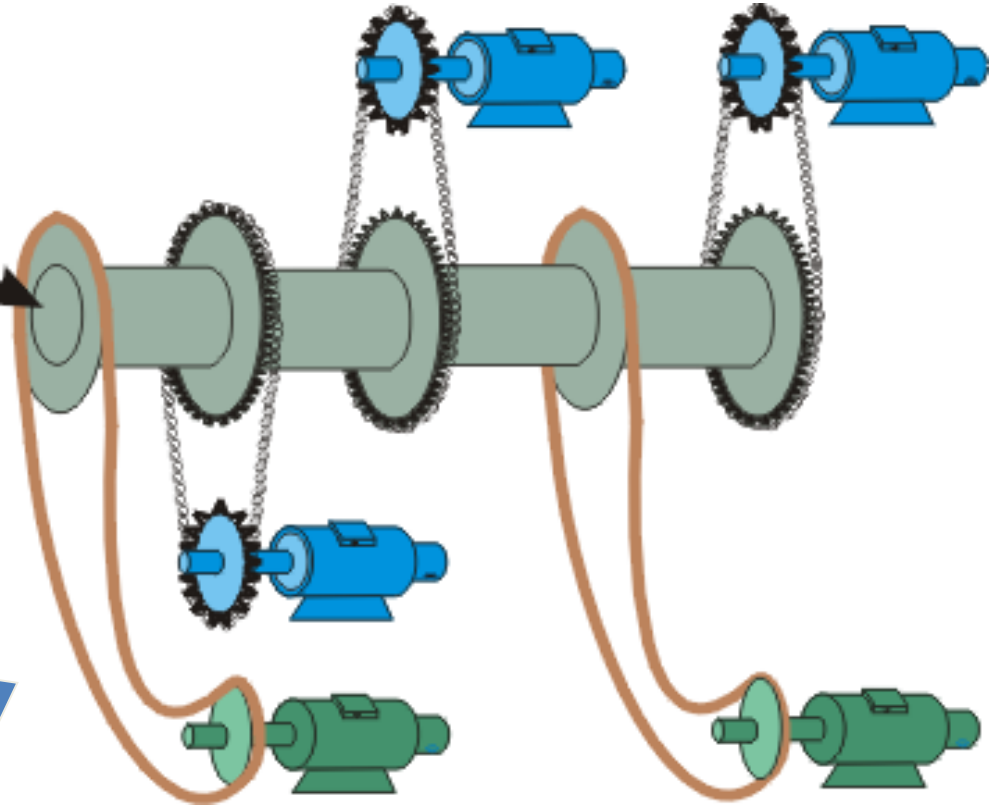


Adding non synchronous generation

Synchronous generator

50/60 Hz



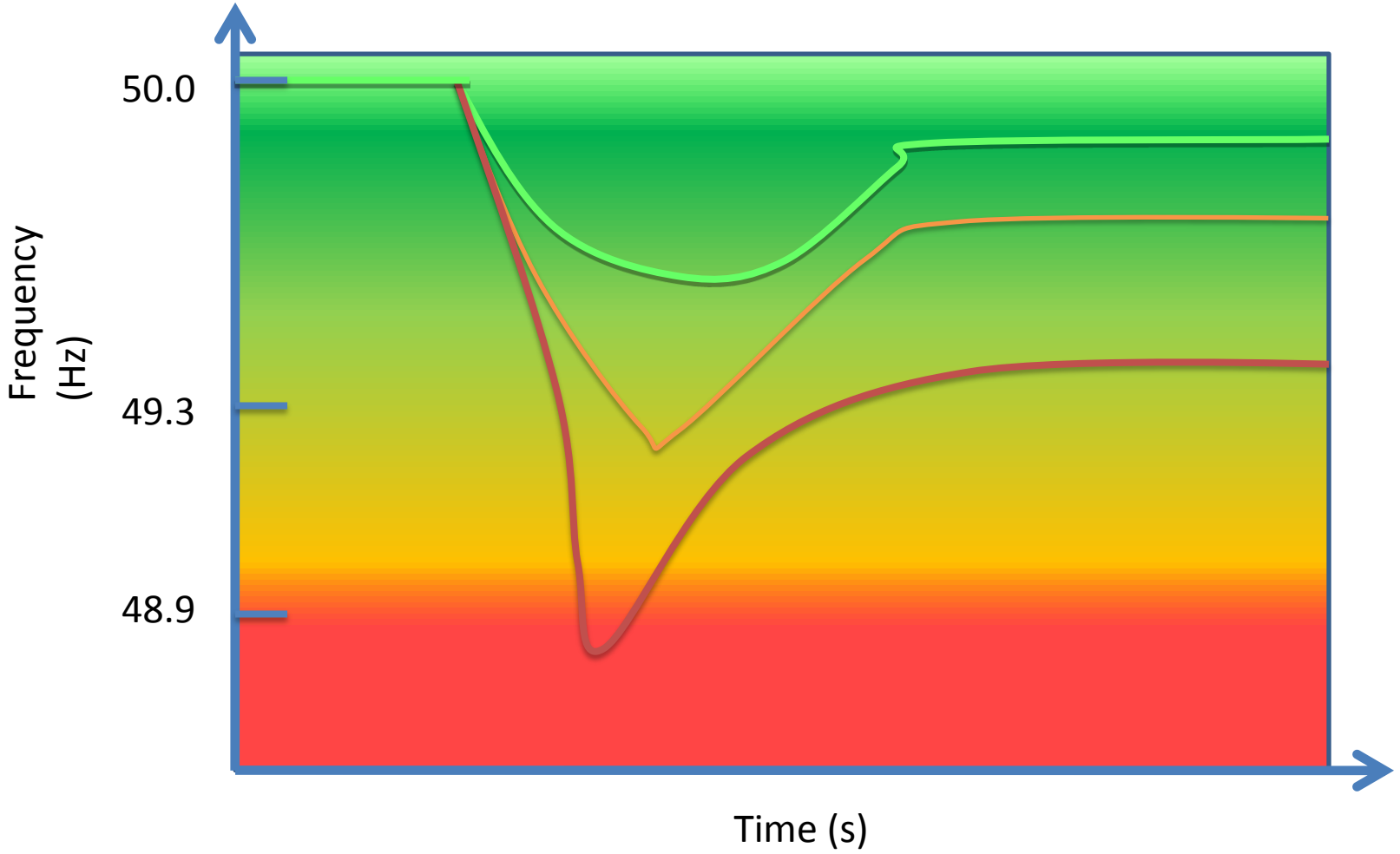


Does not add
to system inertia

Modern wind turbine designs (& solar PV)

Older wind turbine designs

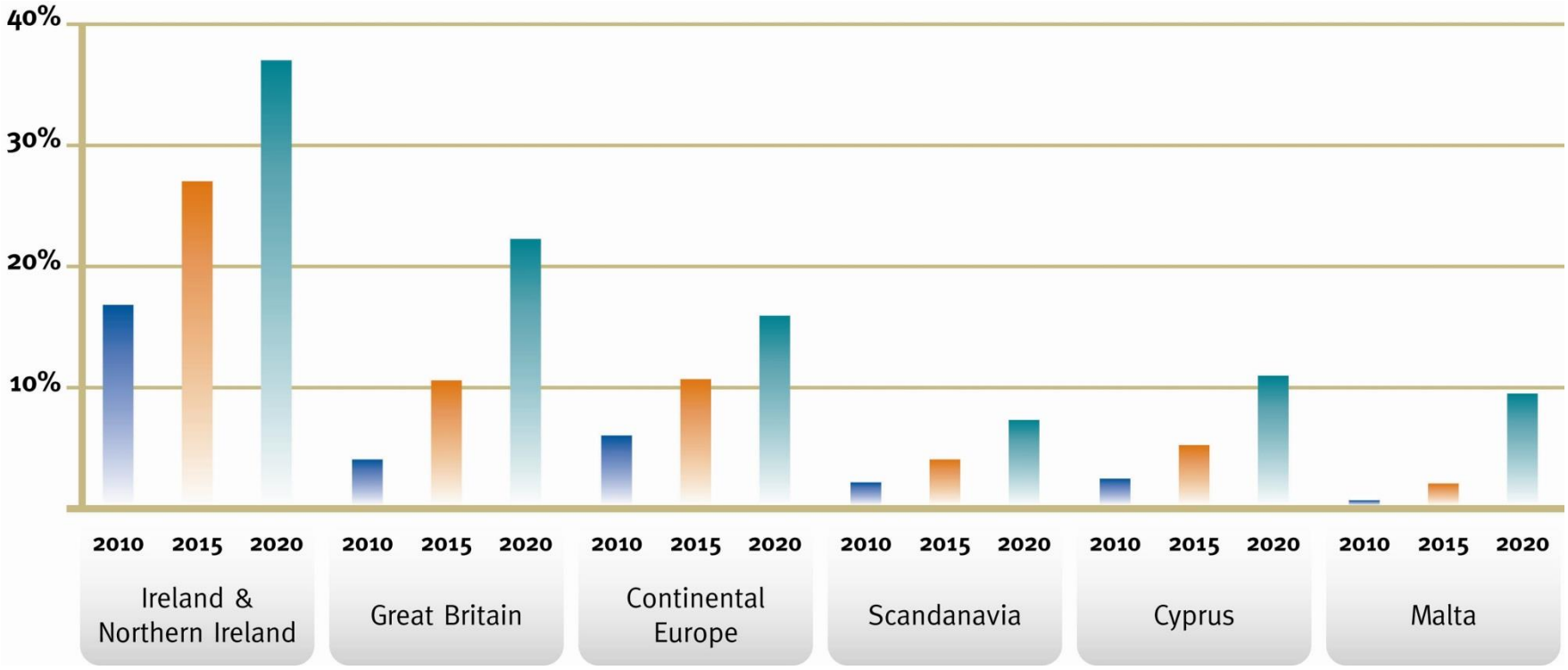
Frequency stability & the nadir



Source: Jonathan O'Sullivan, EirGrid

Synchronous systems in Europe (50 Hz)

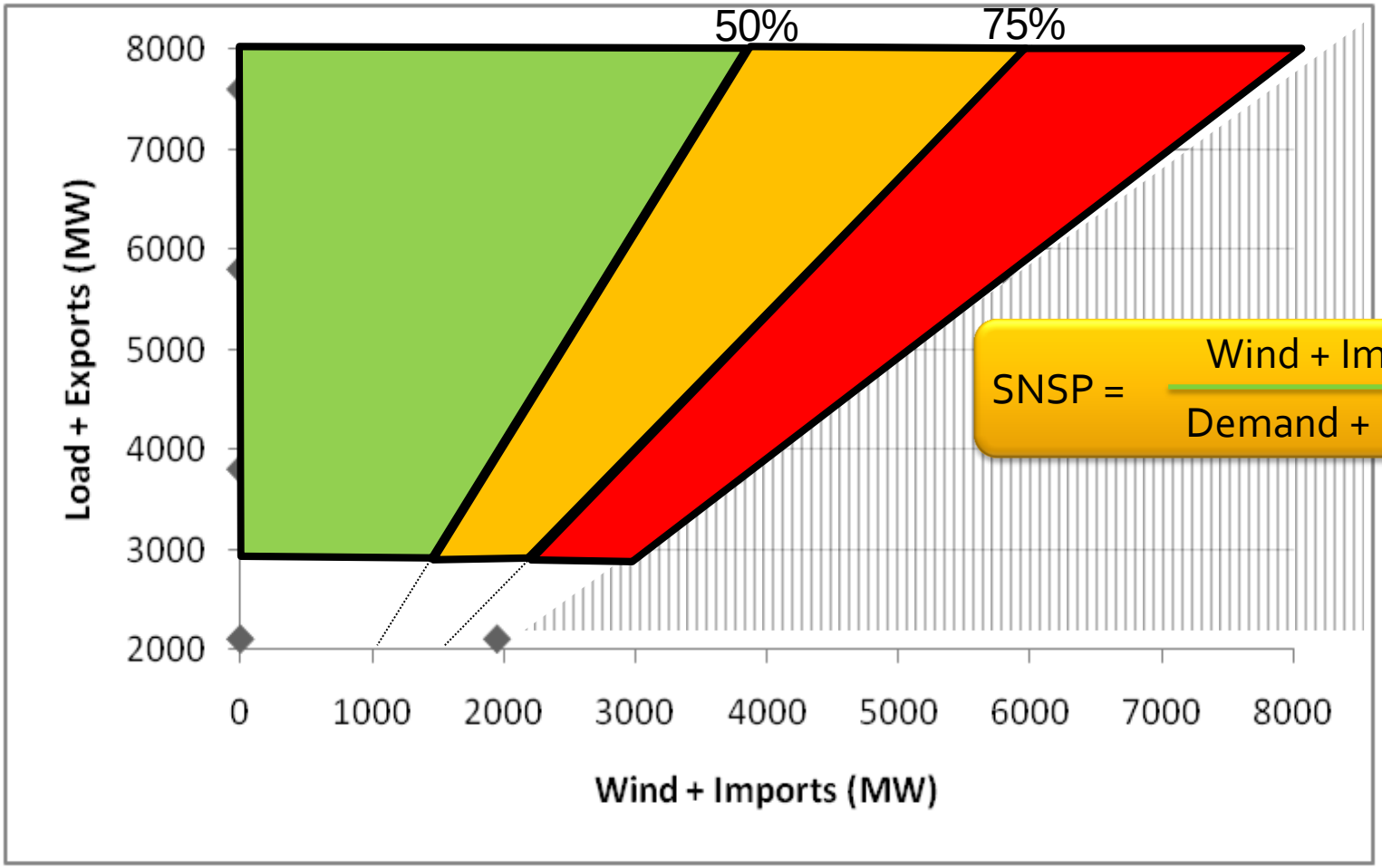
Targets for non-synchronous sources in European Systems



* Based on analysis of National Renewable Action Plans (NREAPs) as submitted by Member States

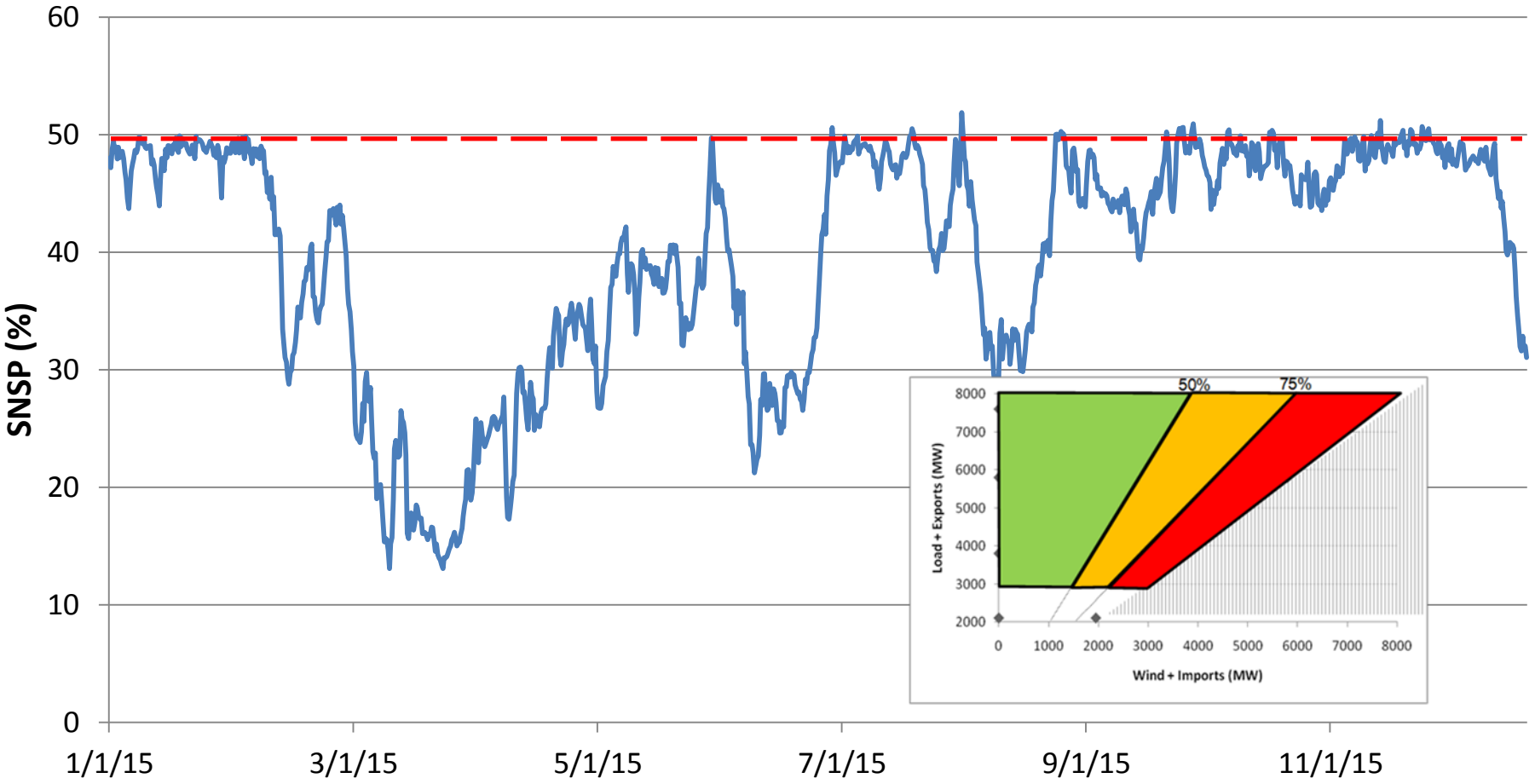
http://www.eirgrid.com/operations/ds3/

System Non-Synchronous Penetration (SNSP)

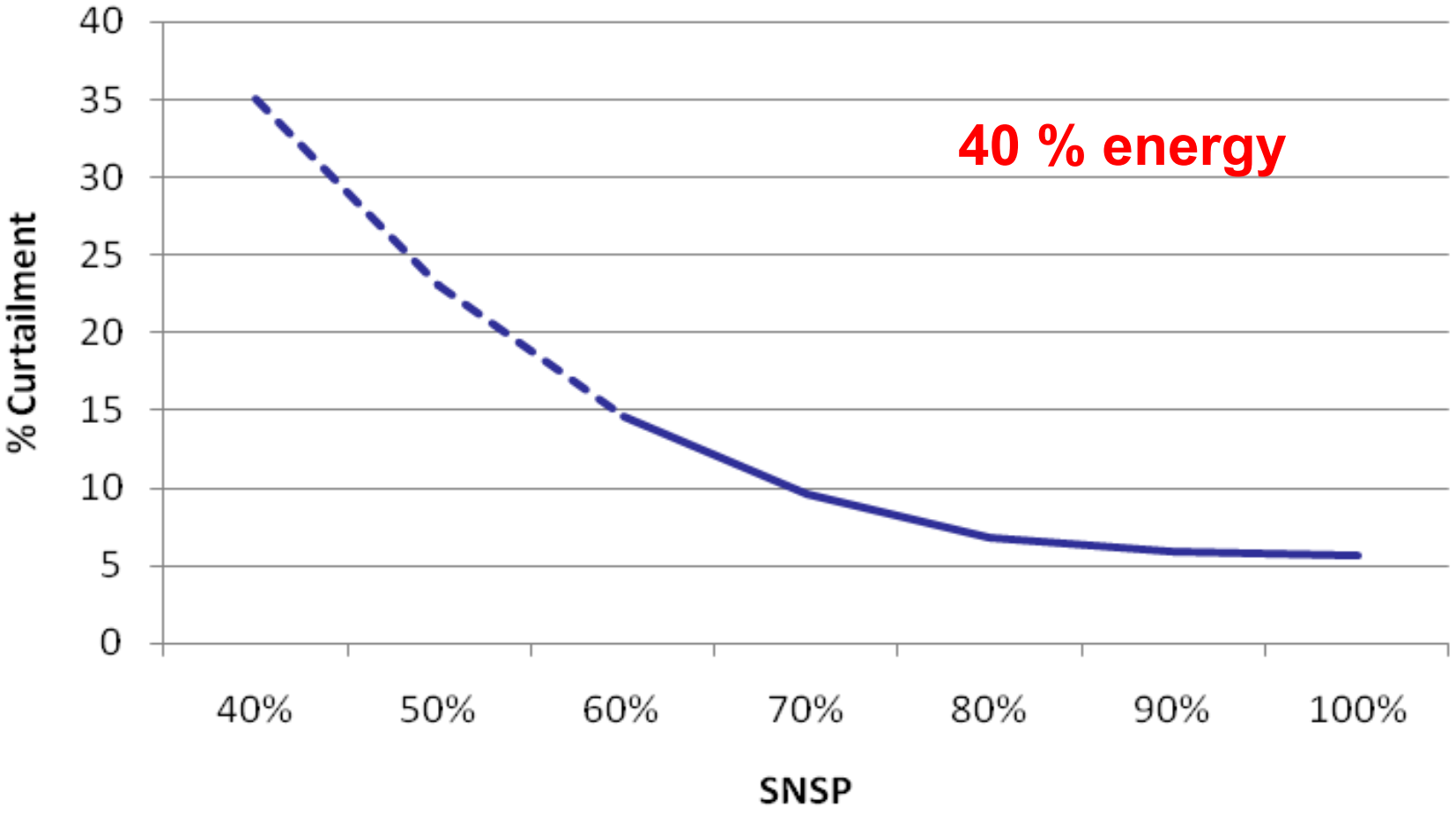


O'Sullivan, J., Rogers, A., Flynn, D., Smith, P., Mullane, A., and O'Malley, M.J., "Studying the Maximum Instantaneous Non-Synchronous Generation in an Island System – Frequency Stability Challenges in Ireland", IEEE Transactions on Power Systems, Vol. 29, pp. 2943 – 2951, 2014.

SNSP – Ireland – Early 2015



Impact of SNSP on Wind Curtailment



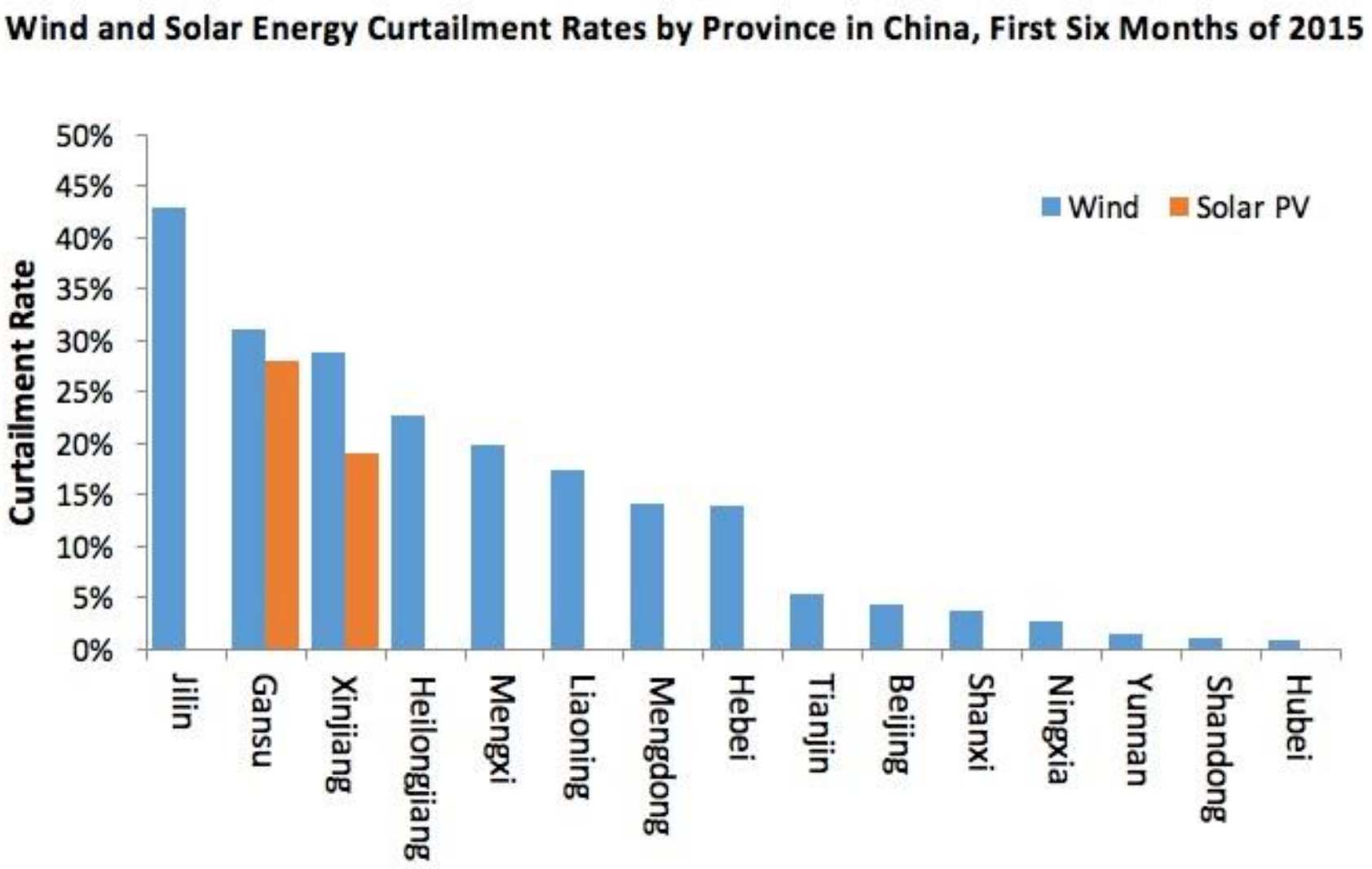
Curtailment is form of flexibility –
Can the markets get the balance right ?

Key Messages

- Non synchronous generation is a challenge for integration at high penetrations
  - Like changing the engines on an A380 while crossing the Atlantic
- Ireland is a unique place for the integration of variable renewables (now at 55% SNSP)
- We need to research on how a near zero inertial system could operate
- Curtailment is a related challenge

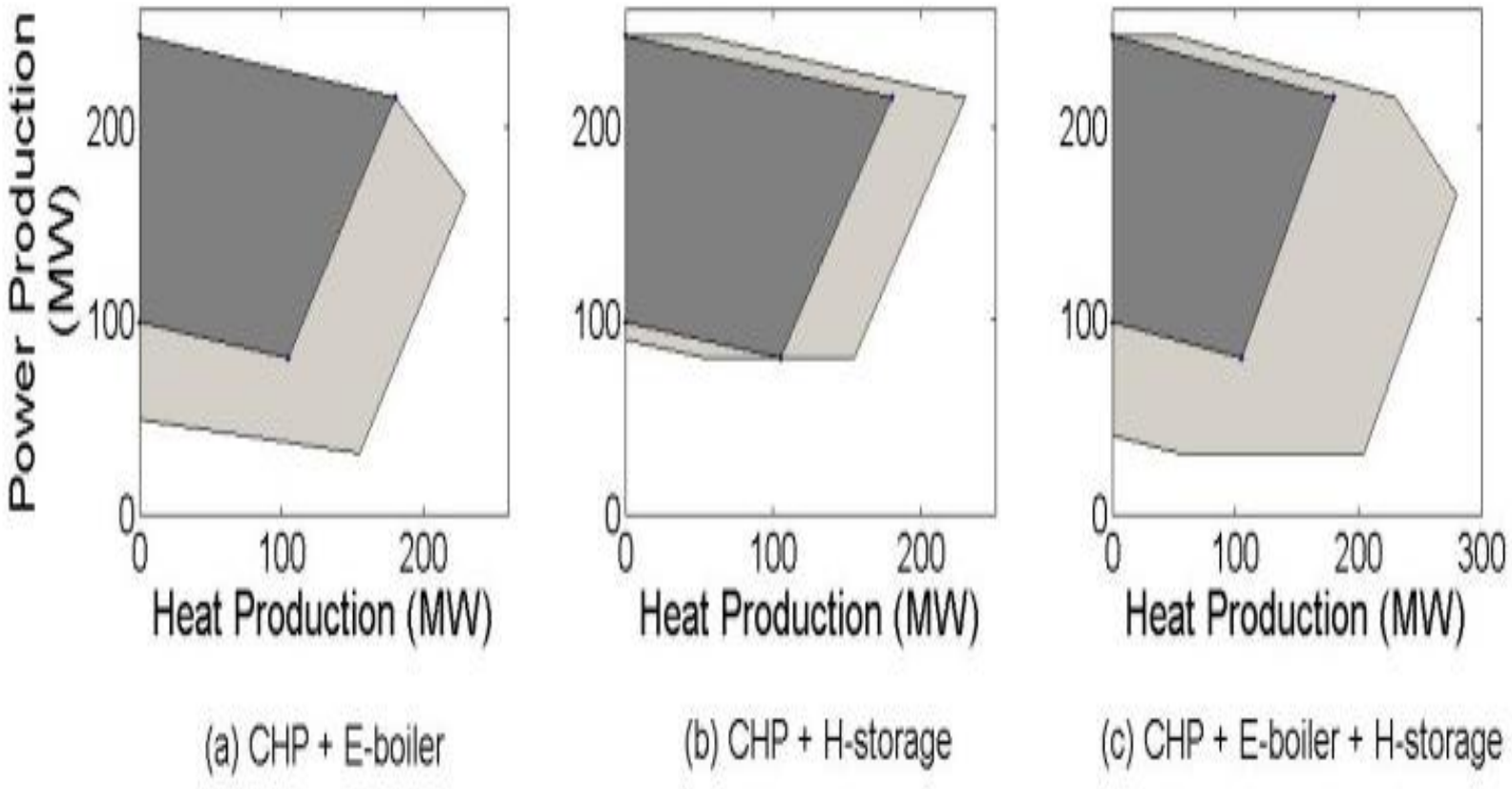
Curtailment

Wind & solar PV curtailment in China



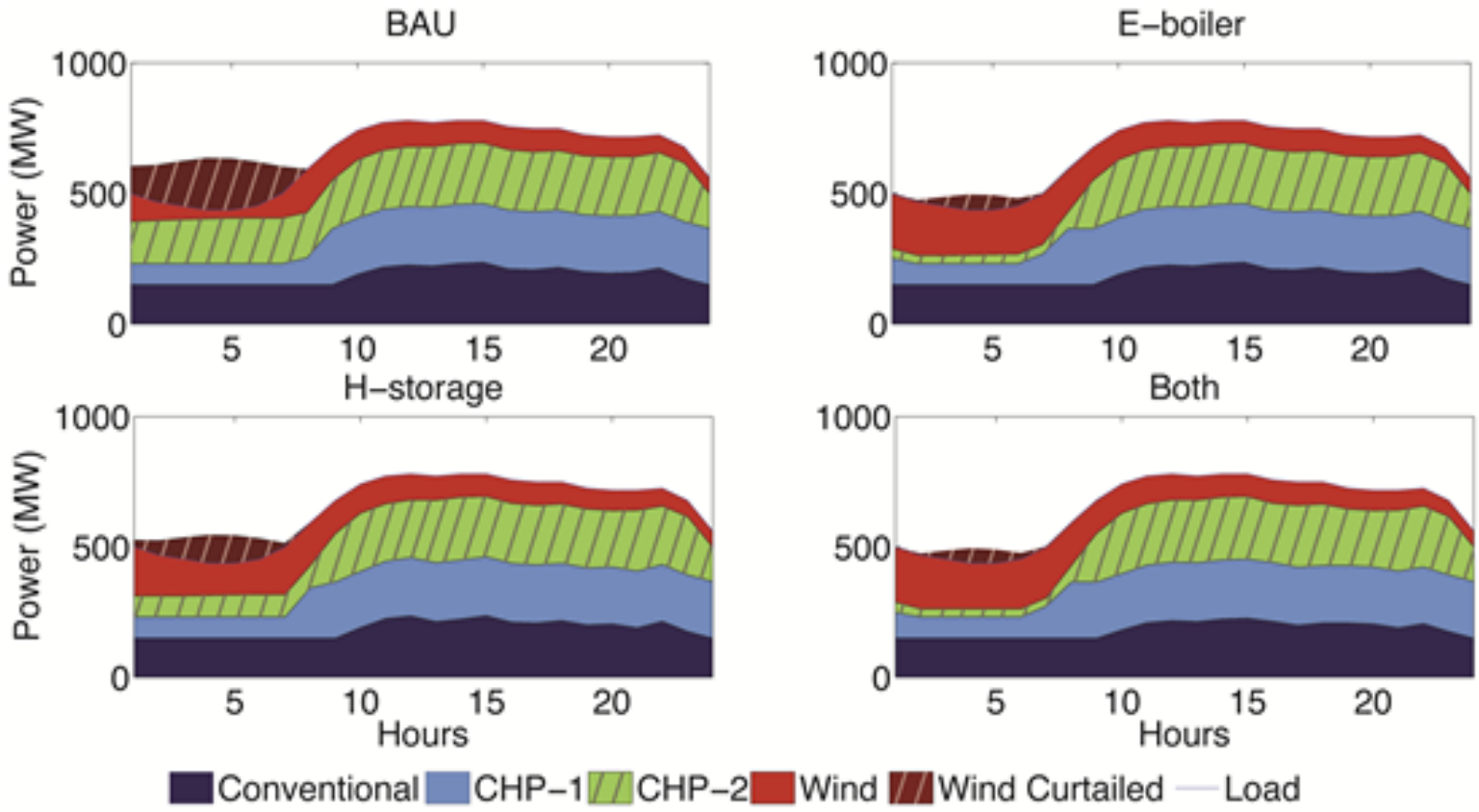
Source: raponline.org

Combined heat and power (CHP) can be made flexible



Chen, X., Kang, C., O'Malley, M.J., Xia, Q., Bai, J., Liu, C., Sun, R., Wang, W. and Hui, L., "Increasing the Flexibility of Combined Heat and Power for Wind Power Integration in China: Modeling and Implications", IEEE Transactions on Power Systems, Vol. 30, pp.1848-1857, 2015.

Flexible CHP can reduce wind curtailment



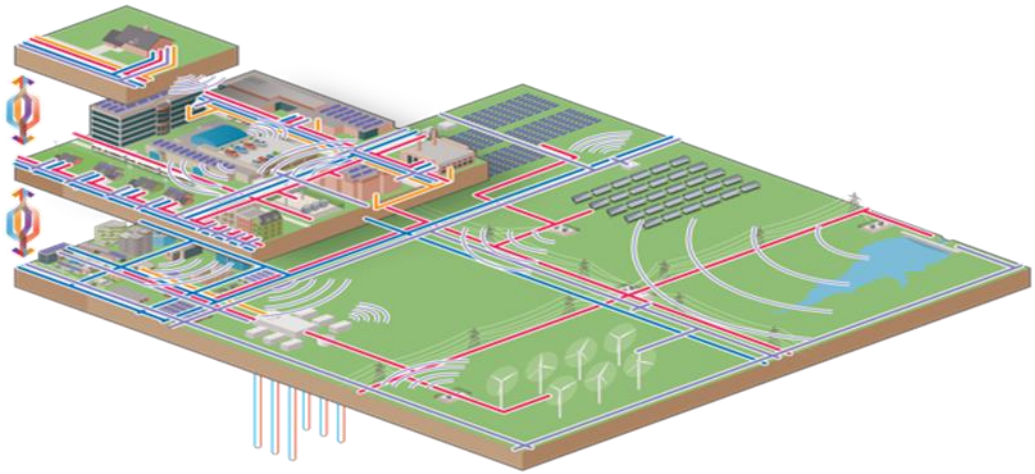
Chen, X., Kang, C., O'Malley, M.J., Xia, Q., Bai, J., Liu, C., Sun, R., Wang, W. and Hui, L., "Increasing the Flexibility of Combined Heat and Power for Wind Power Integration in China: Modeling and Implications", IEEE Transactions on Power Systems, Vol. 30, pp.1848-1857, 2015.

100 % Wind: We will have to change how we live

Key Messages

- Coupling electricity and heat (and other vectors) across scales can help integrate variable renewable energy

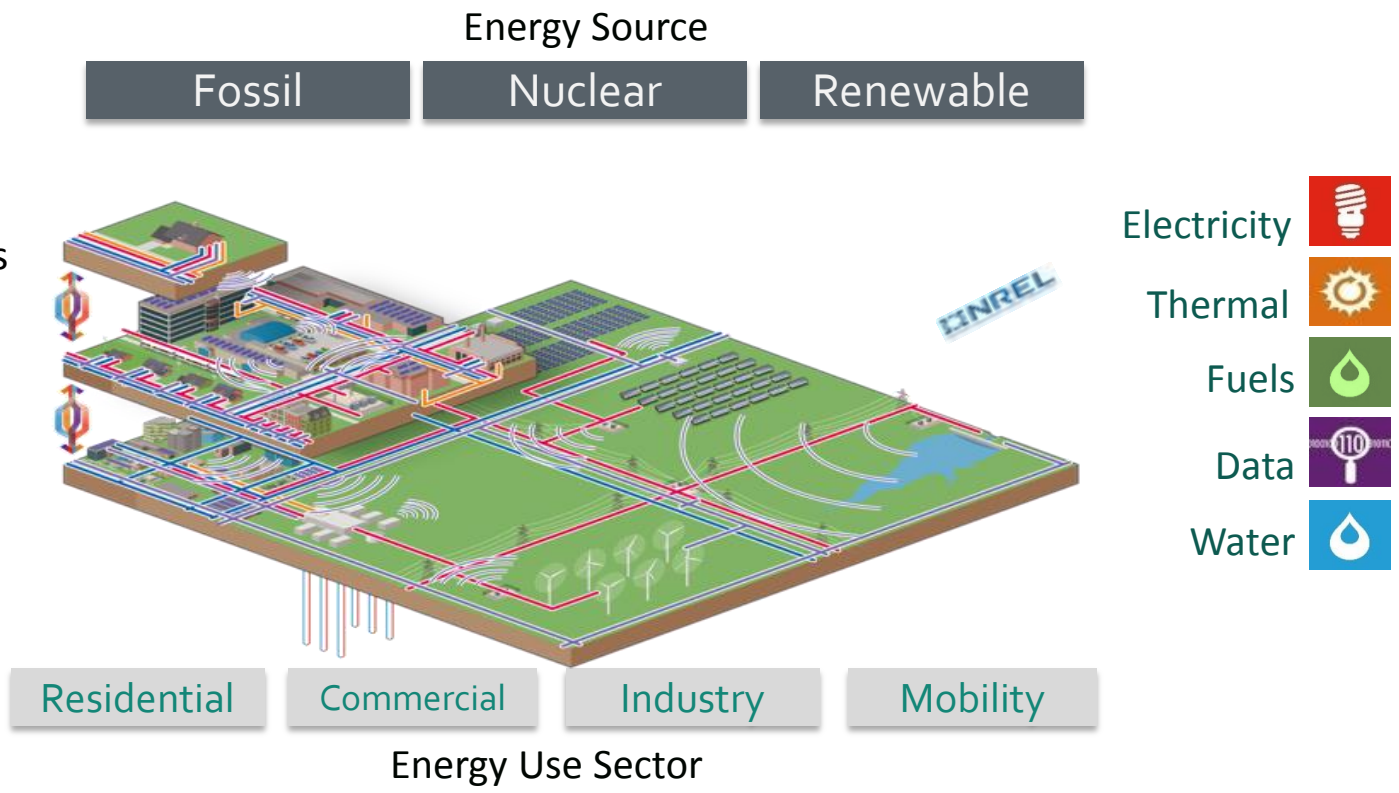
- To make a real impact it probably requires changes at the planning stage



Energy Systems Integration (ESI)

Energy System Integration (ESI) is the process of coordinating the operation and planning of energy systems across multiple pathways and geographical scales in order to deliver reliable, cost effective energy services with less impact on the environment.

Energy Systems Integration (ESI)



- **optimization** of energy systems across multiple pathways and scales
- increase reliability and performance, and minimise **cost and environmental impacts**
- most valuable at **the interfaces where the coupling** and interactions are strong and represent a challenge and an opportunity
- control variables are **technical economic and regulatory**

iiESI International Institute for Energy Systems Integration

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Solving complex global energy challenges requires changing the way we THINK about energy systems, providing opportunities to SHARE knowledge, and helping nations EVOLVE by informing the discussions that are guiding energy investments and policy decisions.

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Capacity building and succession planning

Conclusions

- High penetrations of variable renewables currently exist
- Every region/country
  - Can do it
  - Are different
  - Need a plan
- There are a lot of myths and mistakes
- Very high penetrations have challenges & opportunities
  - Transmission – social science & politics
  - Low inertia systems – electrical engineering
  - Curtailment – multidisciplinary
- Energy System Integration is a key enabler
  - Engineering, economics, policy etc.
- International collaboration and human capacity building is crucial


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