iiESI International Institute™ for Energy Systems Integration

ESIPP Energy Systems Integration Partnership Programme

EERA European Energy Research Alliance

Energy Systems Integration

a megatrend or just business as usual ?

Mark O'Malley, UCD, Ireland

NTNU

CenSES

Energy Transitions 2016
NTNU & Statoil workshop
October 20&21

Statoil

Outline

- Learning from the past
- What is Energy System Integration (ESI) ?
- ESI and the low carbon agenda, including renewable integration
- Examples Ireland, Denmark, (China etc.)
- Conclusion

Smart Grids

a megatrend or just business as usual ?

Mark O'Malley, UCD, Ireland

Energy Transitions 2016
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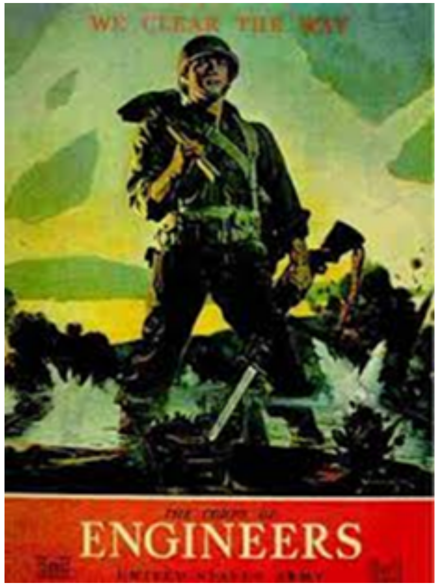
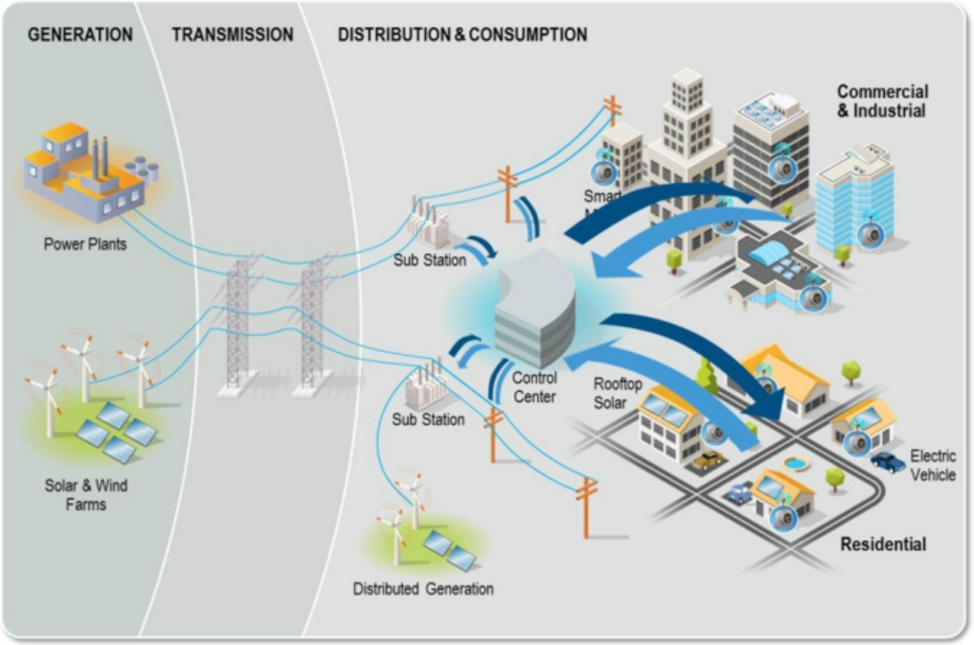
Smart Grid and the unholy Trinity

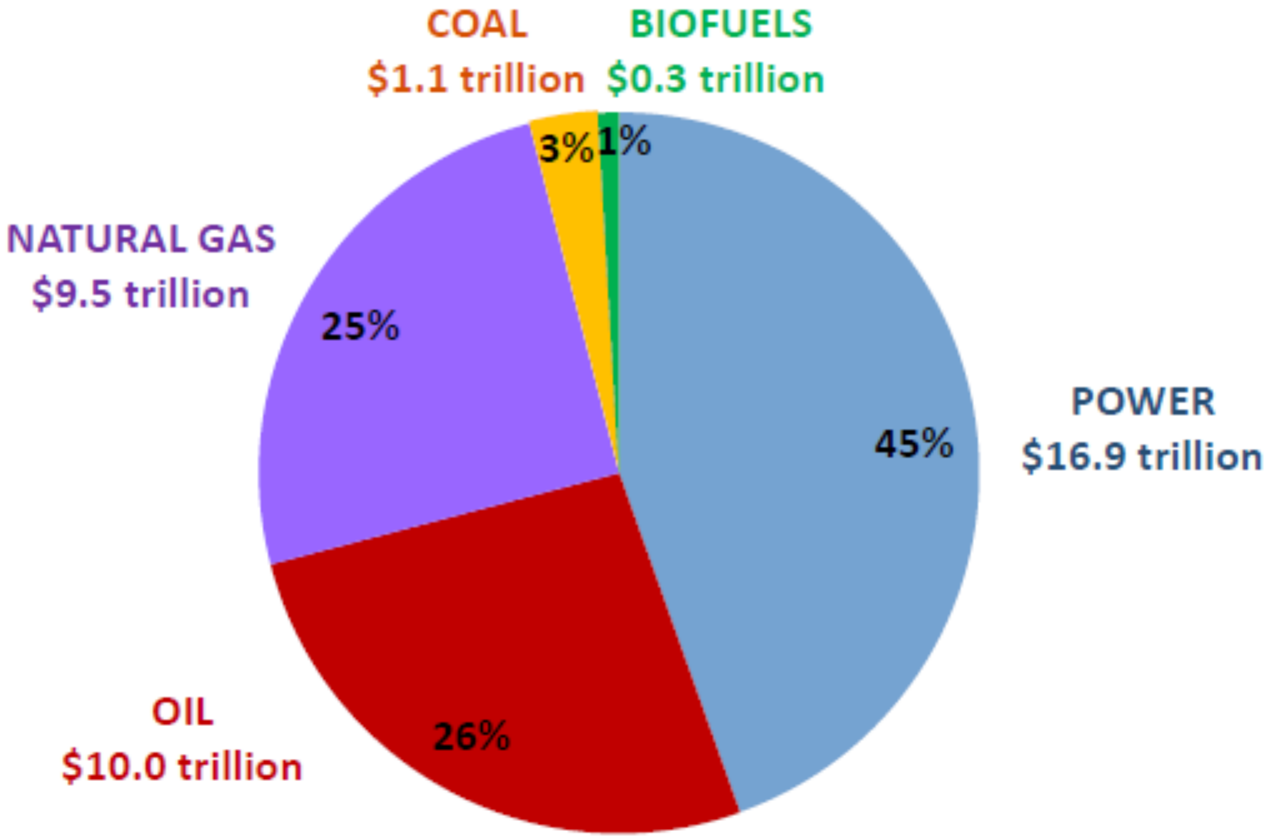




Investment: the essence of energy

WORLD ENERGY OUTLOOK 2011

Cumulative investment in energy infrastructure, *2011-2035*



WEO-2011 will show that <u>$38 trillion</u> of investment is required to meet projected energy demand through to 2035 and that investors in energy projects are facing a multitude of risks

The digital utility of the future captures opportunities all along the value chain.

McKinsey&Company

The digital utility of the future captures opportunities all along the value chain.

McKinsey&Company

English (en)

SPEECH | 1 April 2015

Energy Union and smart transition

Speech at InnoGrid2020+ conference (Check Against Delivery)

Thank you Nick for this introduction. And thanks to both you and Joao (Torres) for inviting me to this major event. I would like to use this opportunity to discuss the "smart transition" – some would even say "revolution" – that is unfolding before our very eyes.

Ladies and gentlemen, our children are very much part of a 'smart' generation - the generation for which smart phones and smart appliances are taken for granted. Smart technologies are now surrounding us. The ICT revolution, of citizens and consumer empowerment, entails a fundamental transformation of the way we live our lives and this also has a dramatic impact on how we conceive our

inclusive forums. I read it in your press release yesterday and I completely agree: "Smart grids are a prerequisite to achieving a real Energy Union".

As I have already alluded to, what **shale gas did to the US economy, smart grids can and should do in Europe**. Thus I would like to thank EDSO and ENTSO-E, not only for today but for your daily work; for your

Greatest Engineering Achievements OF THE 20TH CENTURY

♦ About ♦ Timeline ♦ The Book

Welcome!

How many of the 20th century's greatest engineering achievements will you use today? A car? Computer? Telephone? Explore our list of the top 20 achievements and learn how engineering shaped a century and changed the world.

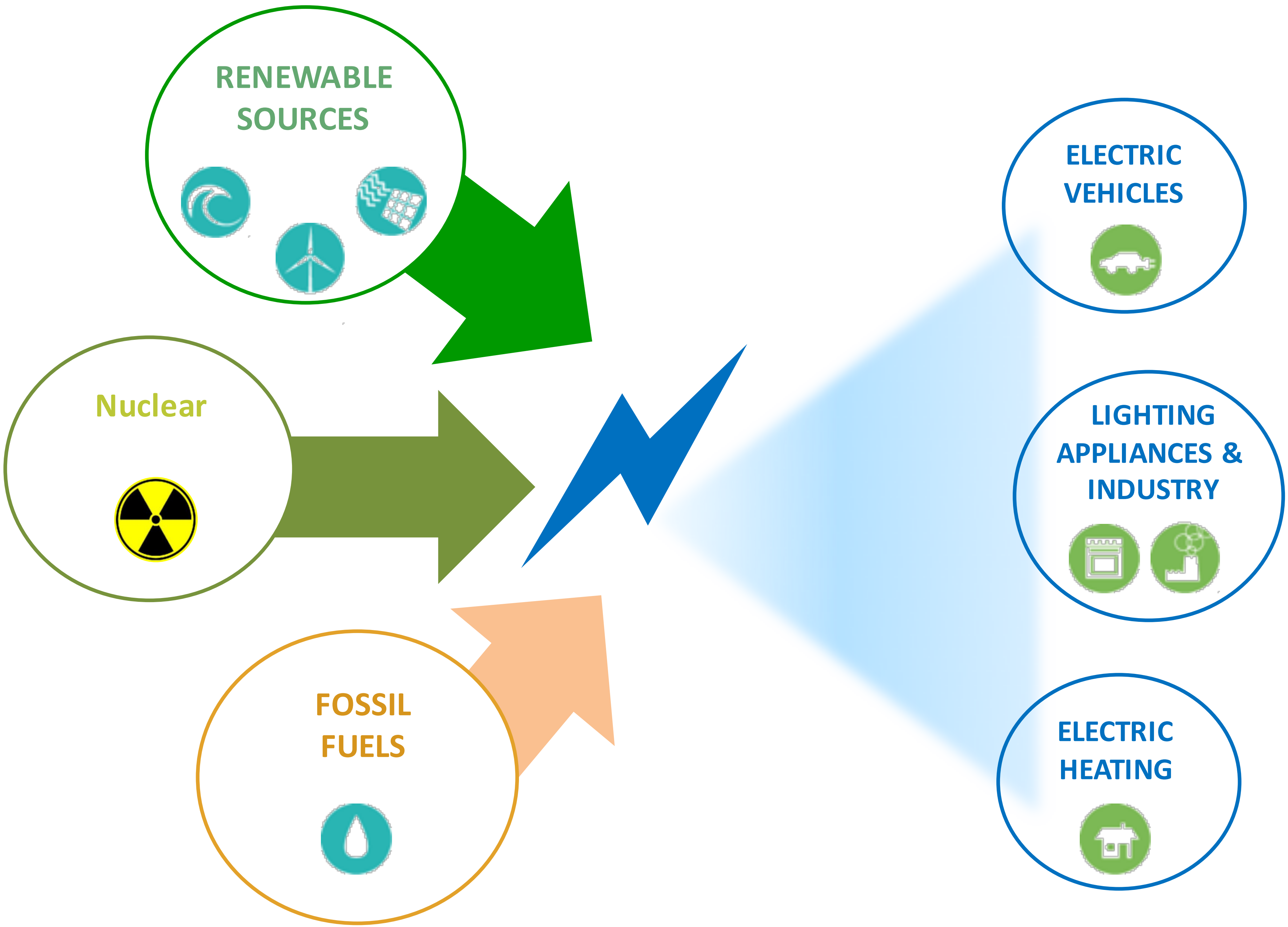
1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronics
6. Radio and Television
7. Agricultural Mechanization
8. Computers
9. Telephone
10. Air Conditioning and Refrigeration
11. Highways
12. Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Health Technologies
17. Petroleum and Petrochemical Technologies
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

21st Century Innovation Topics

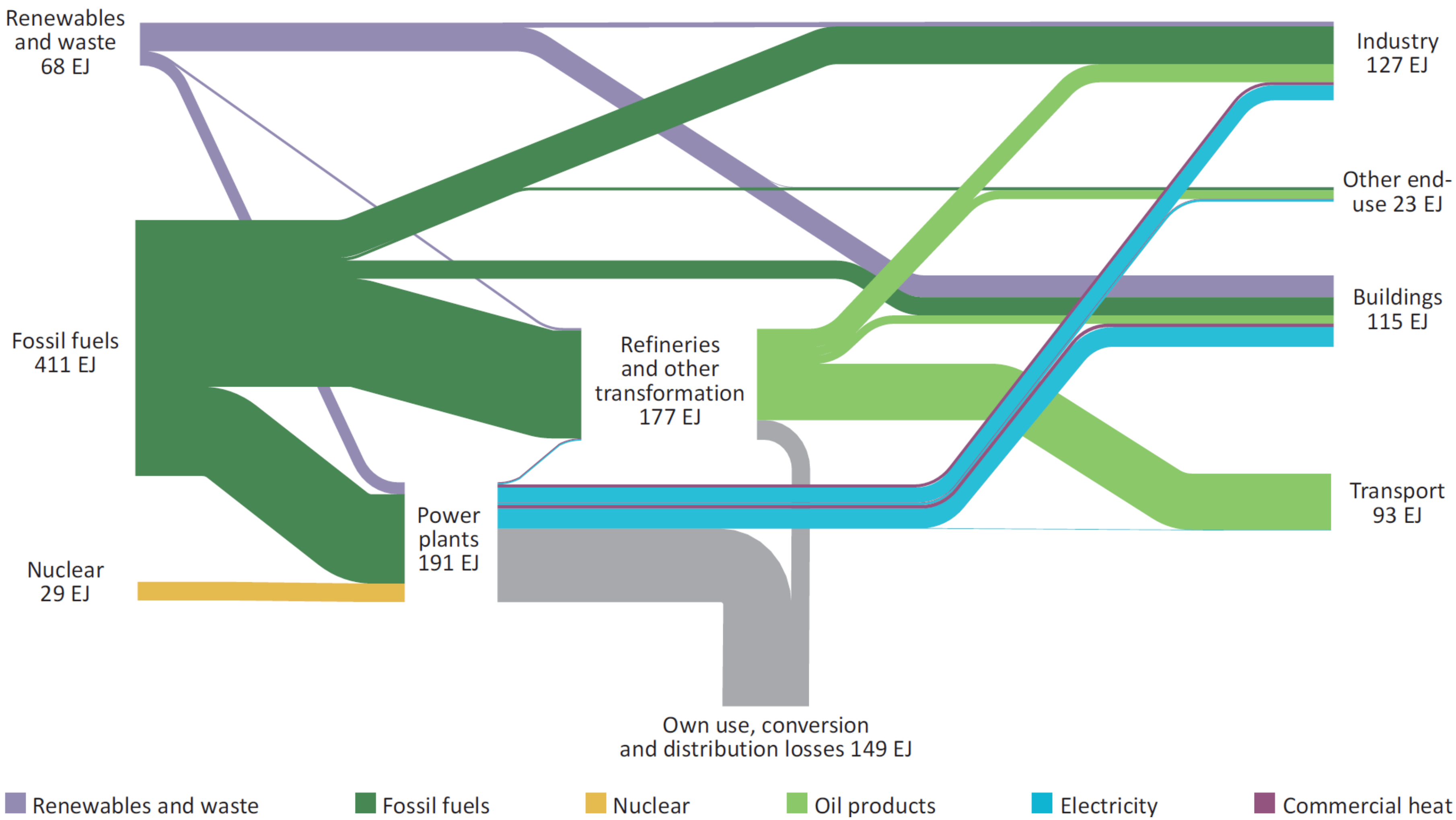
1. Energy conservation
2. Resource protection
3. Food and water production and distribution
4. Waste management
5. Education and learning
6. Medicine and prolonging life
7. Security and counter-terrorism
8. New technology
9. Genetics and cloning
10. Global communication
11. Traffic and population logistics
12. Knowledge sharing
13. Integrated electronic environment
14. Globalization
15. AI, interfaces and robotics
16. Weather prediction and control
17. Sustainable development
18. Entertainment
19. Space exploration
20. "Virtualization" and VR
21. Preservation of history
22. Preservation of species

Greatest Achievements

The Electric Future

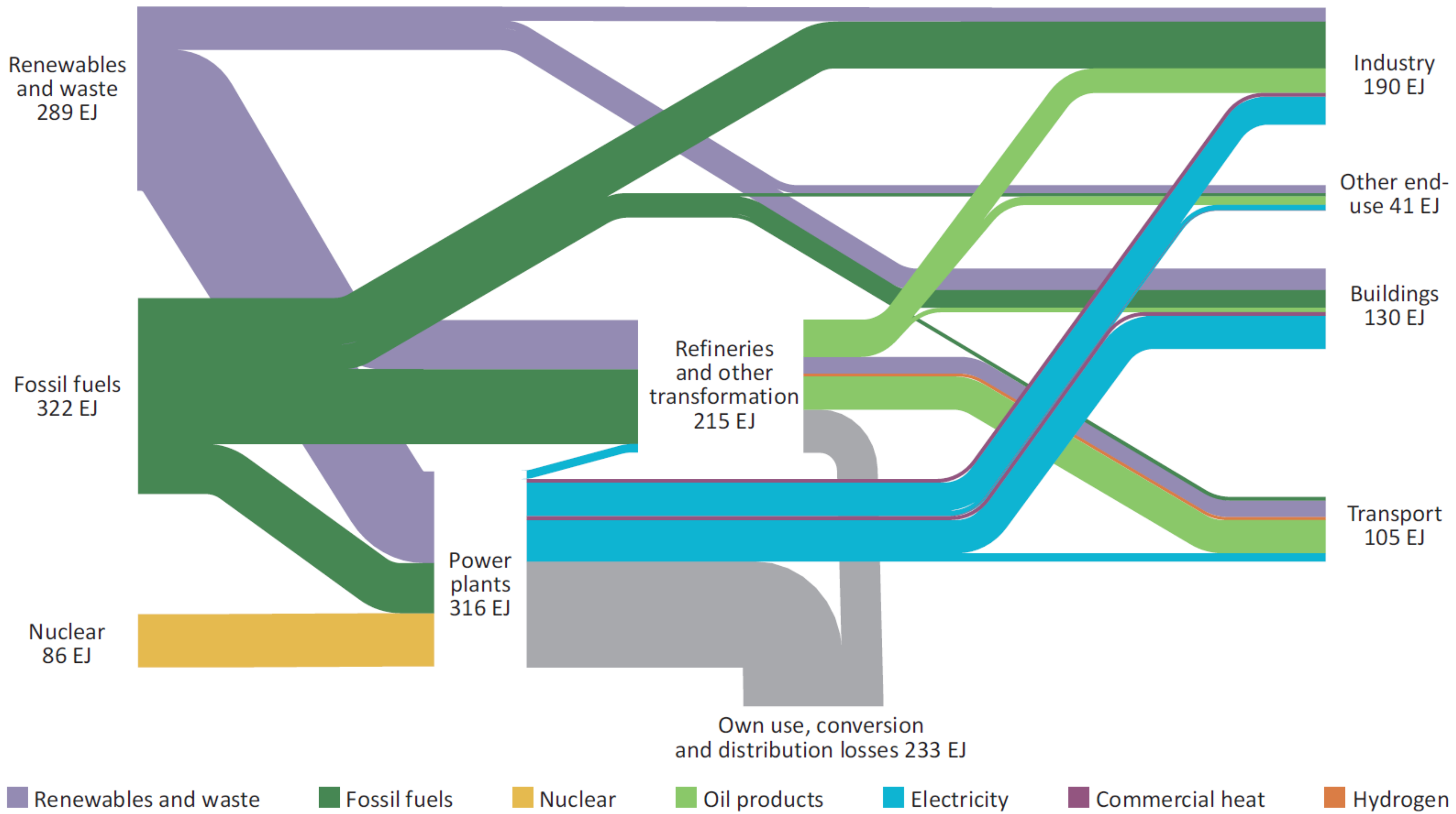


The global energy system today



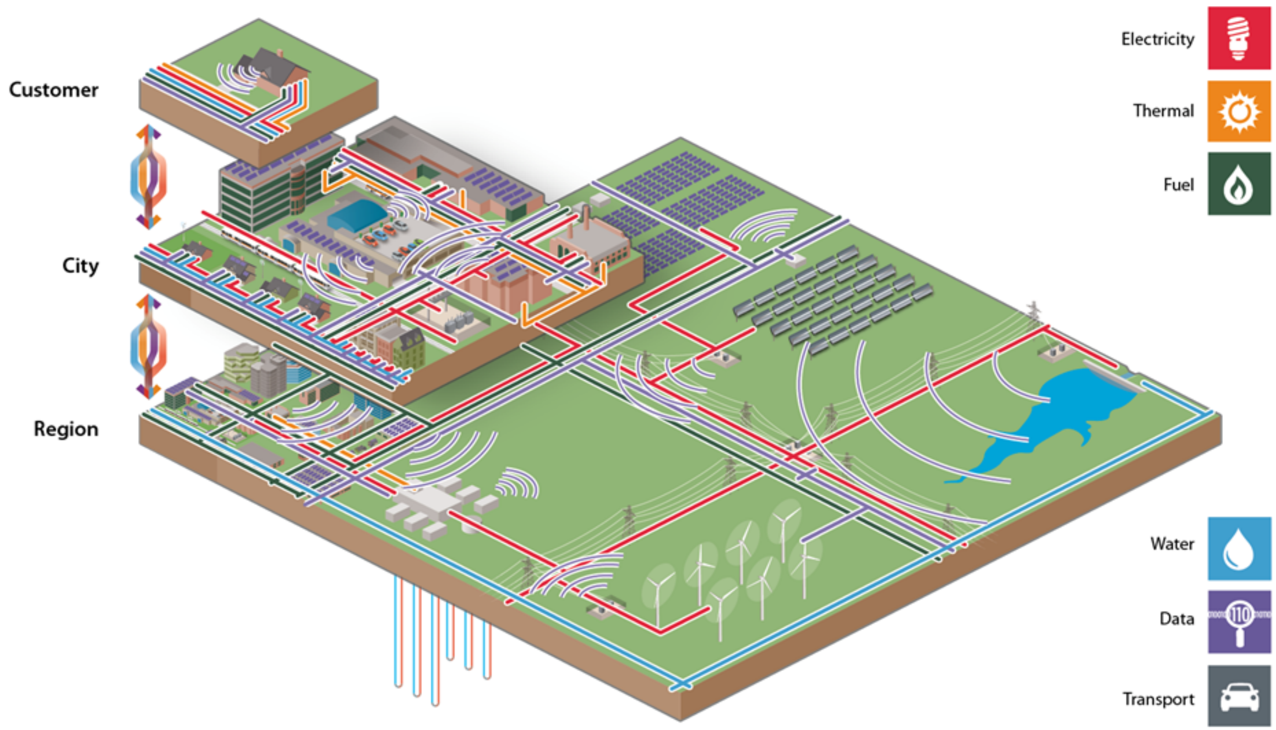
Dominated by fossil fuels in all sectors: (Source IEA)

The future low-carbon energy system



The 2DS in 2050 shows a dramatic shift in energy sources and demands: (Source IEA)

Energy Systems Integration



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

- **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**

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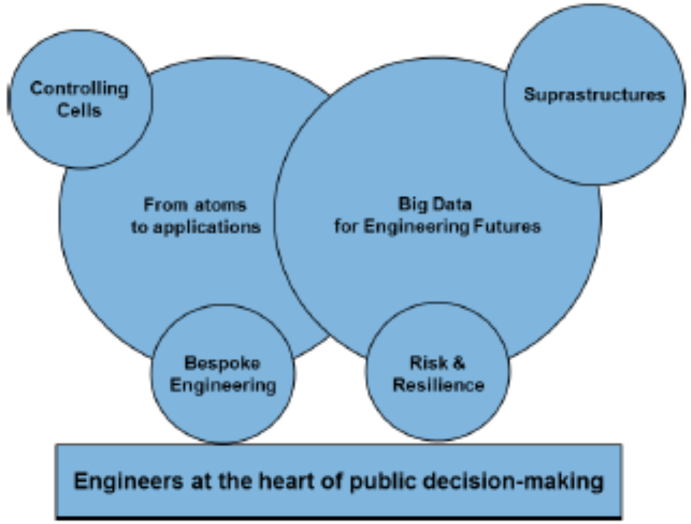
Teaching Water
Post-2015 Water and Sanitation
Water, Sanitation and Hygiene
Water and urbanization
Water resources management
Water quality
Transboundary waters

WATER, FOOD AND ENERGY NEXUS

Water, energy and food are inextricably linked. Water is an input for producing agricultural goods in the fields and along the entire agro-food supply chain. Energy is required to produce and distribute water and food: to pump water from groundwater or surface water sources, to power tractors and irrigation machinery, and to process and transport agricultural goods.

Agriculture is currently the largest user of water at the global level, accounting for 70% of total withdrawal. The food production and supply chain accounts for about 30% of total global energy consumption.

Engineering and Physical Sciences Research Council



Engineering Grand Challenges

Report on outcomes of a retreat – 07 and 08 May 2014

Ettington Chase, Stratford-upon-Avon

4.6 Suprastructures – Integrating Resource Infrastructures under Constraints

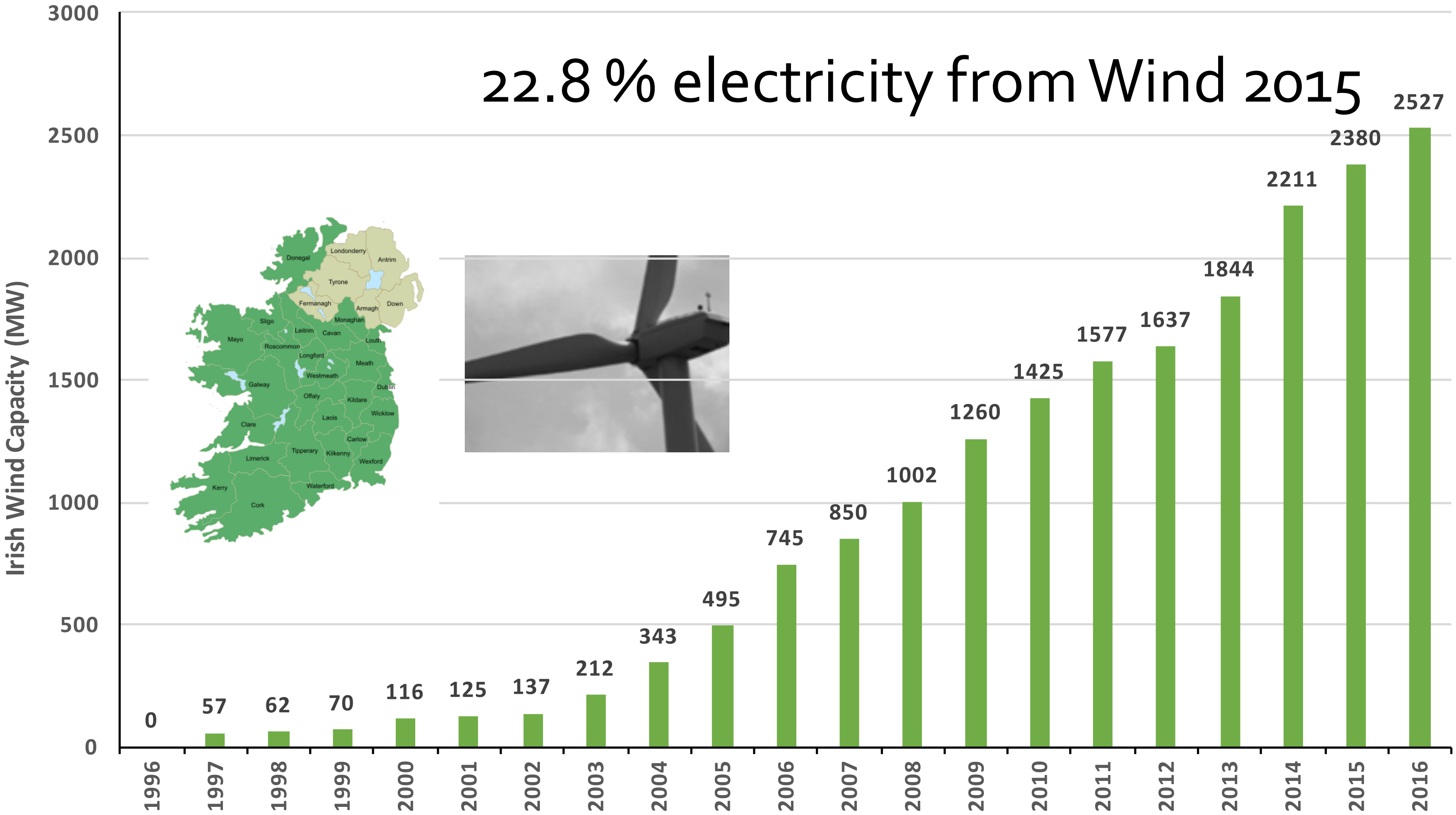
Description

Design the development and operation of optimised integrated infrastructures - both the physical and organisational structures/facilities - for an uncertain but sustainable future.

As we move to uncertain but increasingly tight resource constraints, how should we design, operate and bring about connected, integrated and holistic infrastructures for communications and information, water, energy, food, material and people to achieve resilience against environmental change, demand variation and technology evolution?

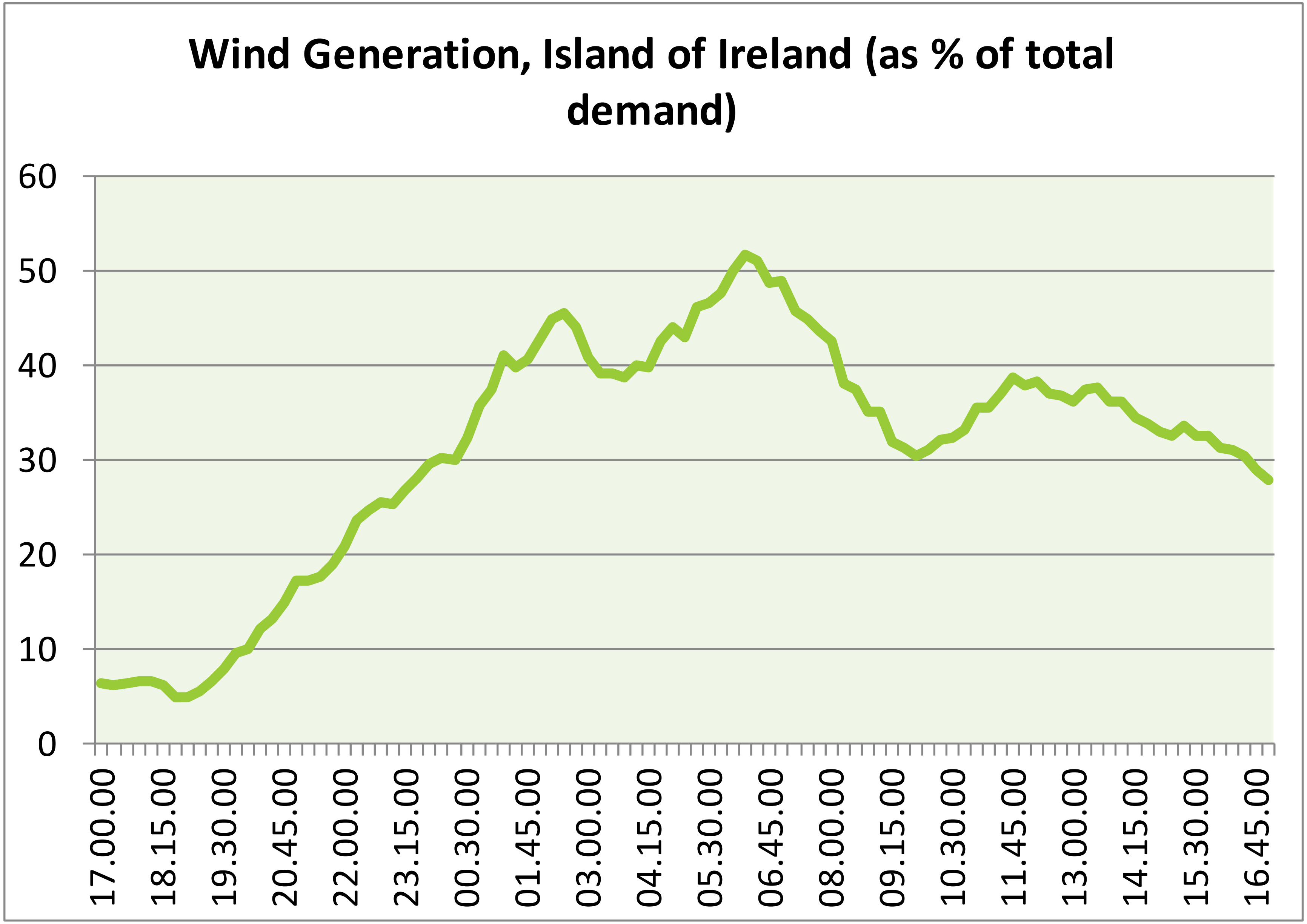
Ireland

Wind Installed in Ireland



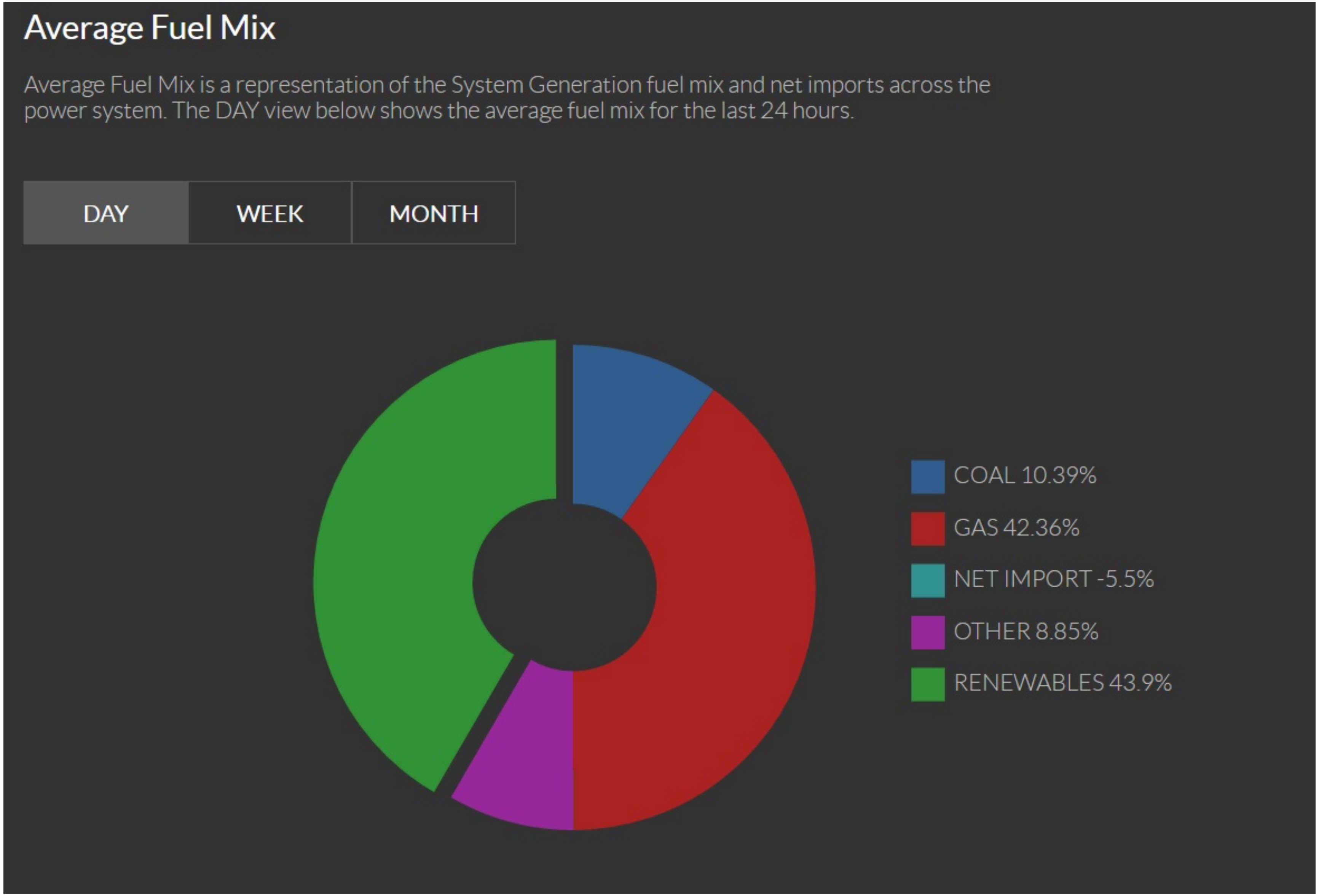
Sources: EirGrid http://www.eirgrid.com/operations/systemperformancedata/all-islandwindandfuelmixreport/ ,IWEA and Eirgrid Generation Capacity Statement 2016-2025 and Irish Wind Energy Association

26^{th} & 27^{th} of Sept. 2016 (Island of Ireland)



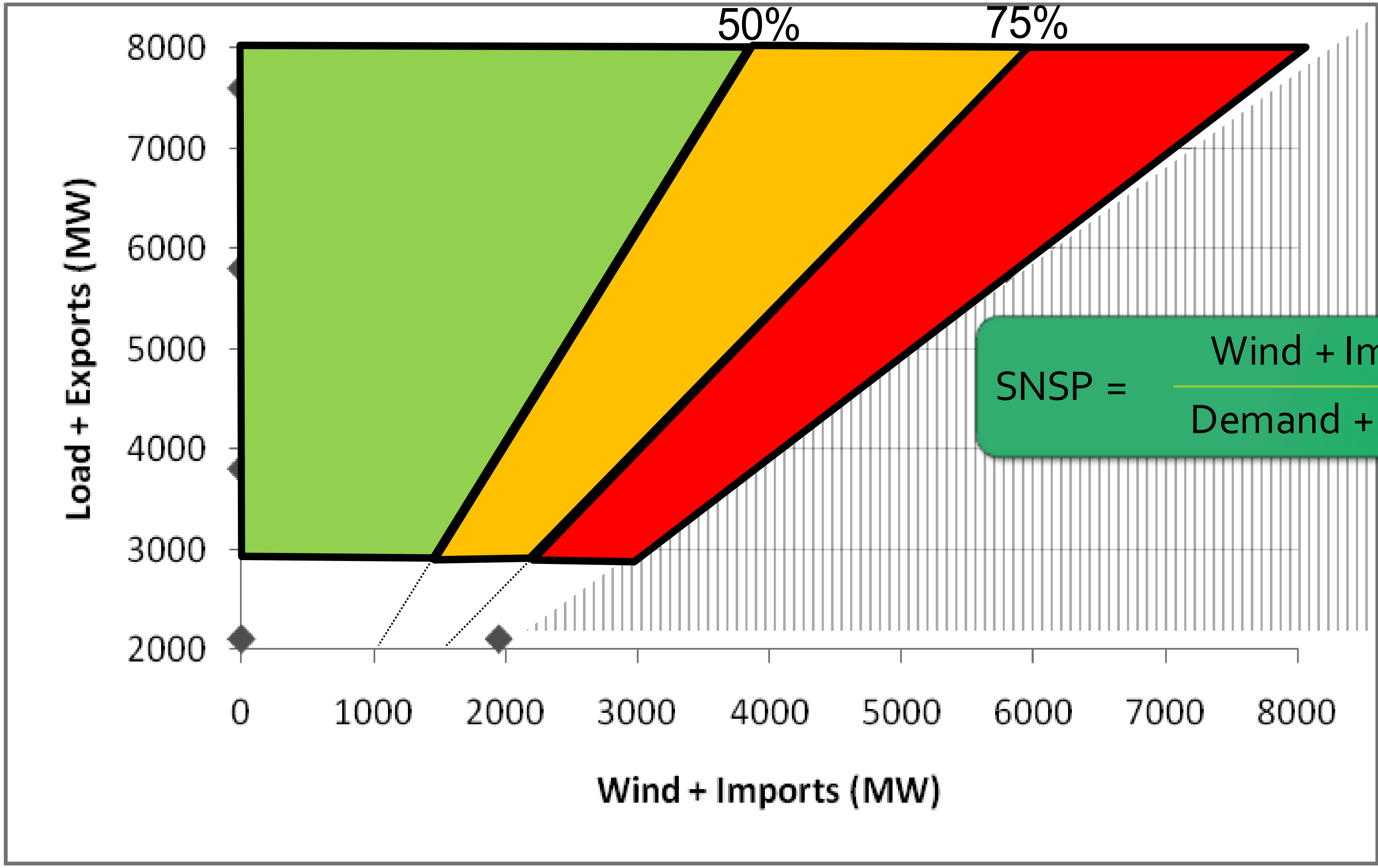
Source: EirGrid

Fuel Mix Ireland Sep 28th 2016



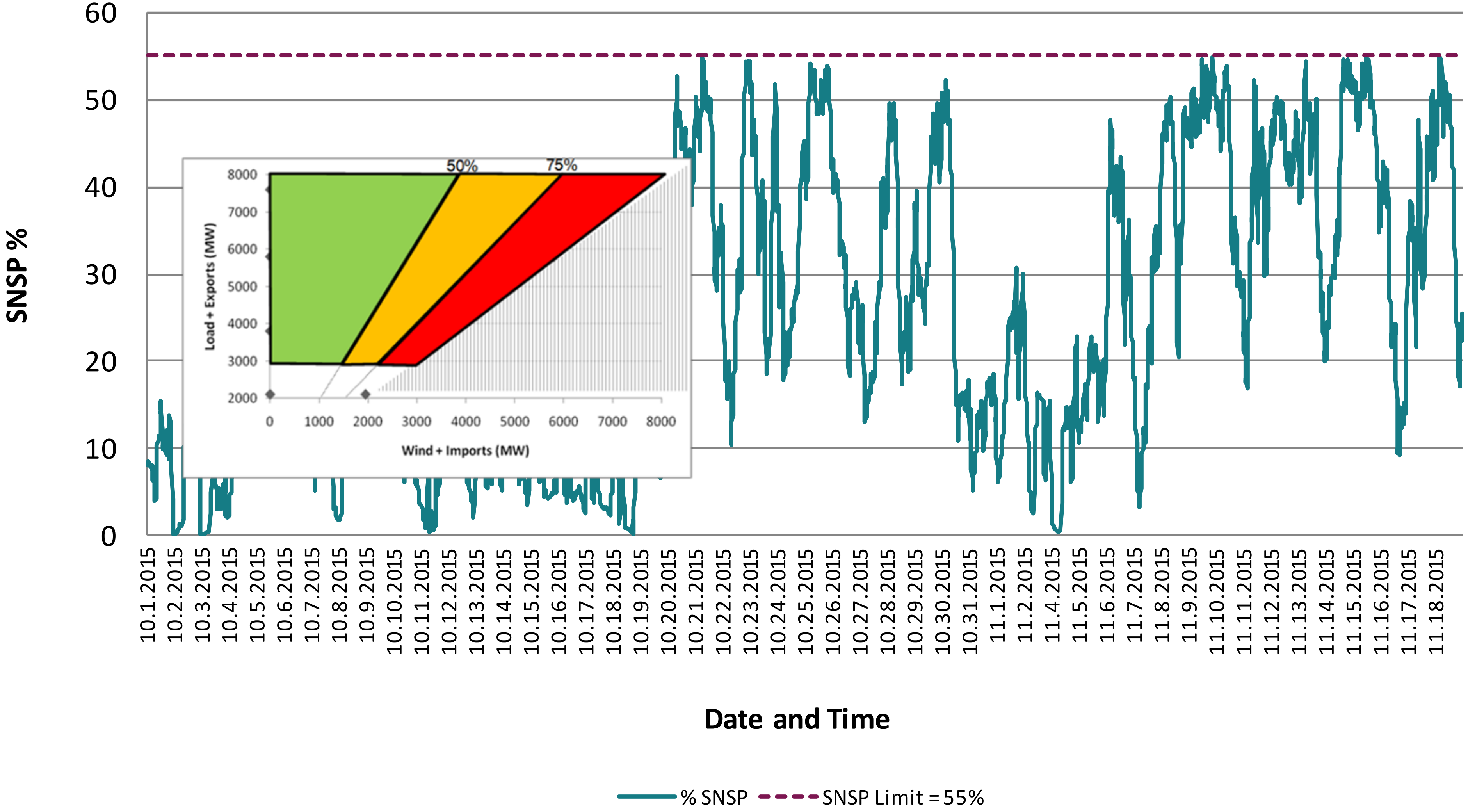
Source: Eirgrid http://smartgriddashboard.eirgrid.com

System Non-Synchronous Penetration (SNSP)



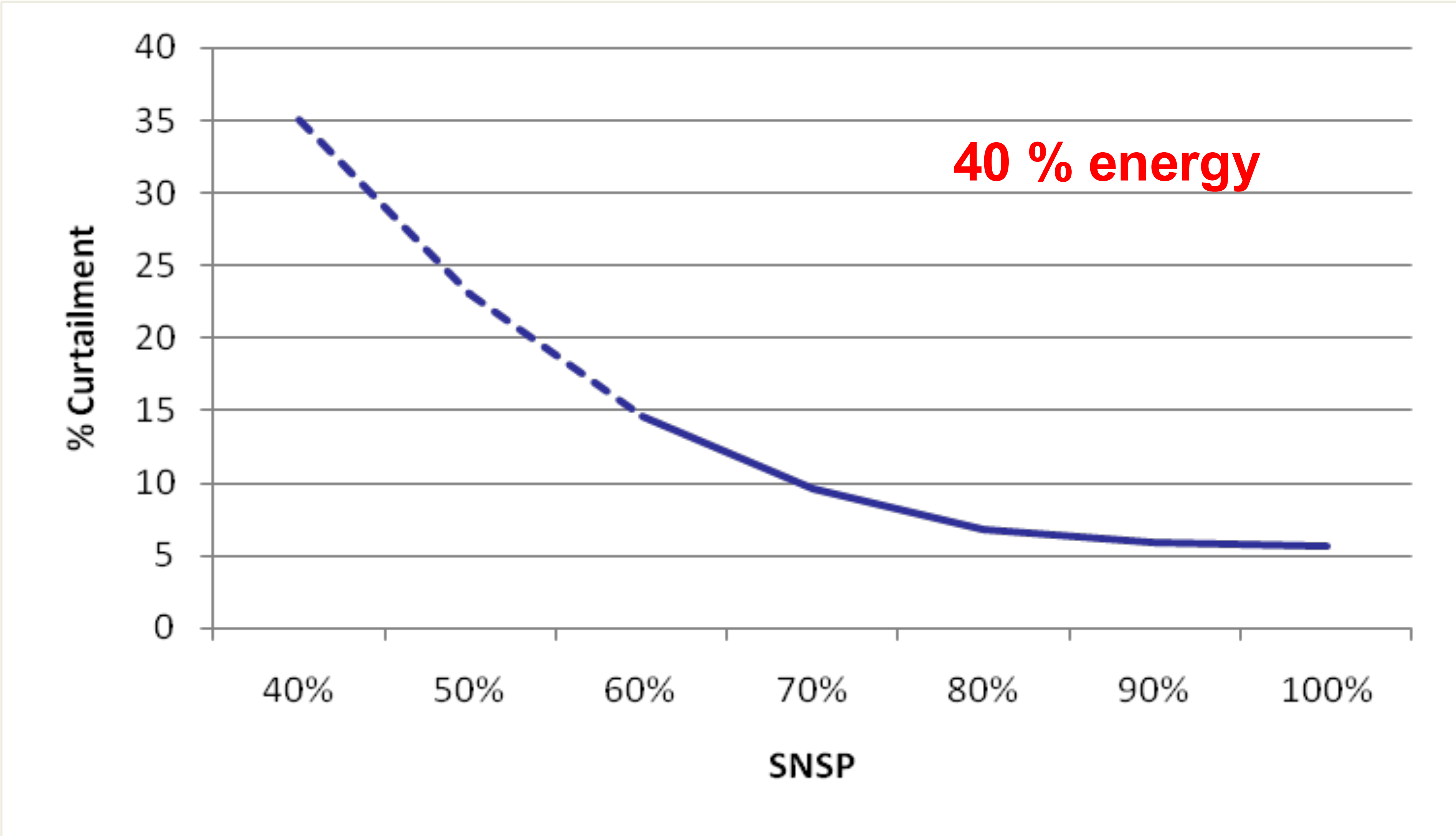
O'Sullivan, J., Rogers, A., Flynn, D., Smith, P., Mullane, A., and O'Malley, M.J., "Studying the Maximum Instantaneous Non-Synchronous Generation in an Island System – Frequency Stability Challenges in Ireland", *IEEE Transactions on Power Systems*, Vol. 29, pp. 2943 – 2951, 2014.

SNSP – Ireland – October 2015



EIRGRID GROUP

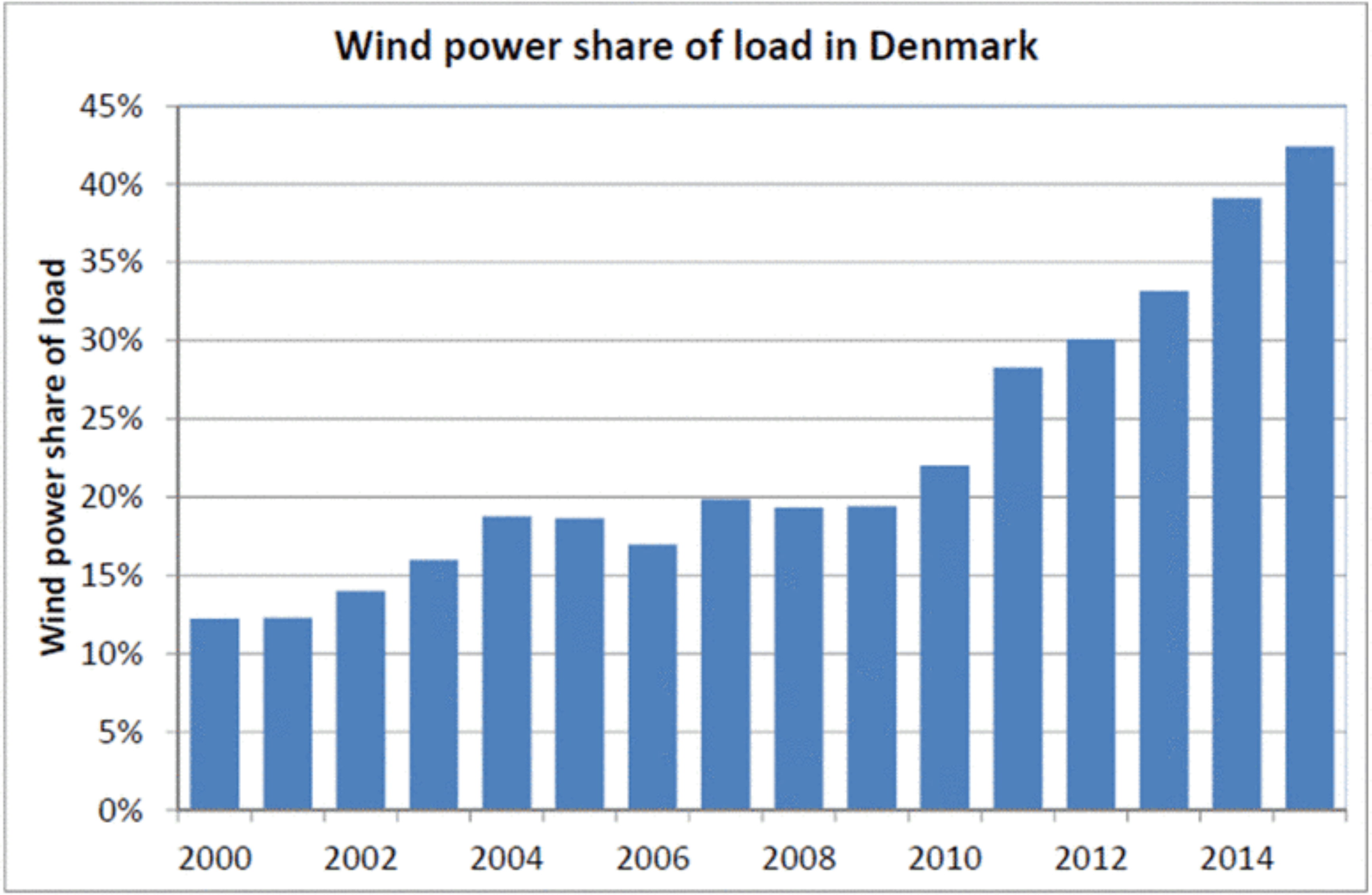
Impact of SNSP on Wind Curtailment



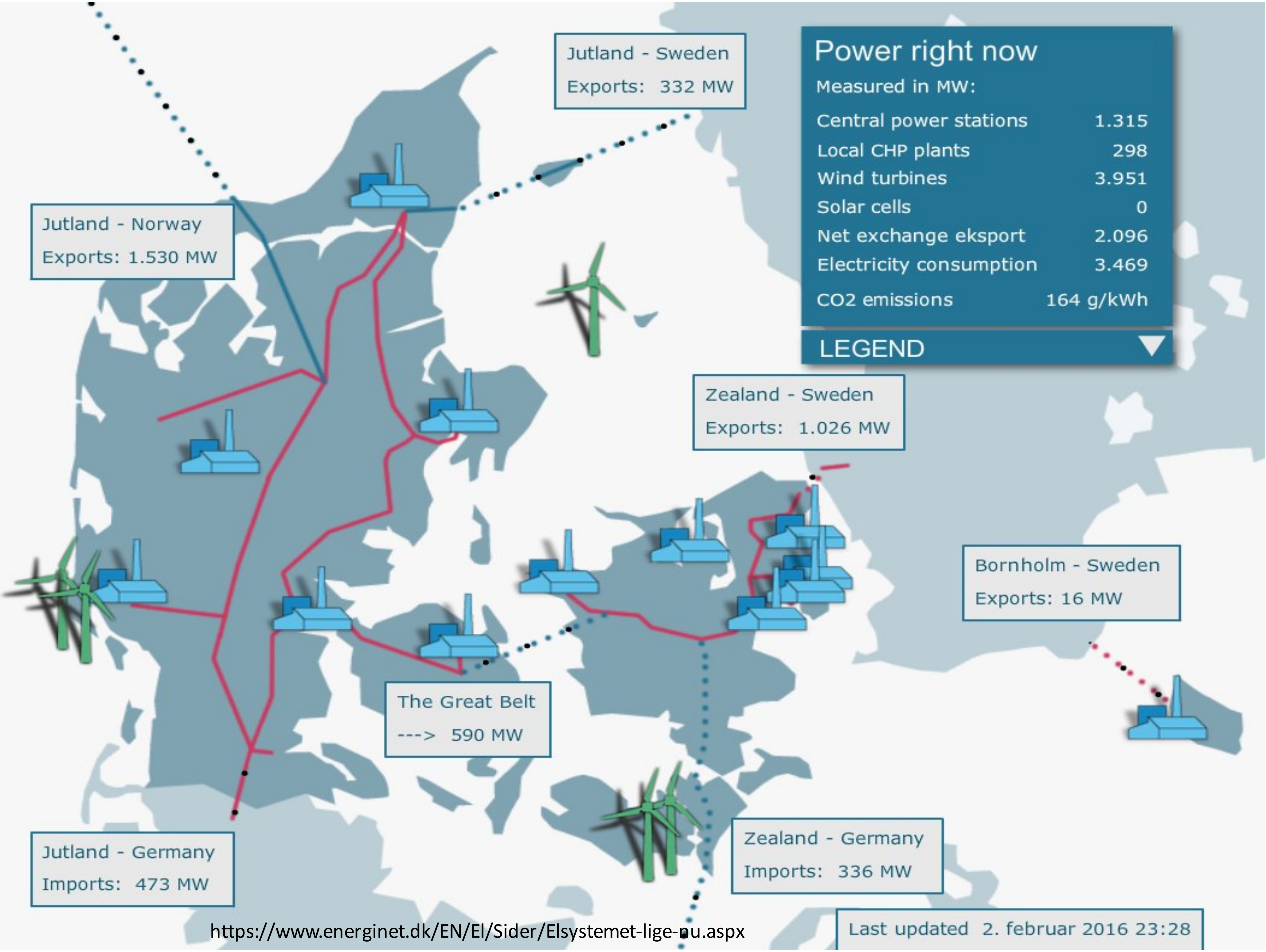

NORWAY
North Sea
SWEDEN
Ålborg
DENMARK
Århus
Copenhagen
Odense
Baltic Sea
GERMANY

Denmark

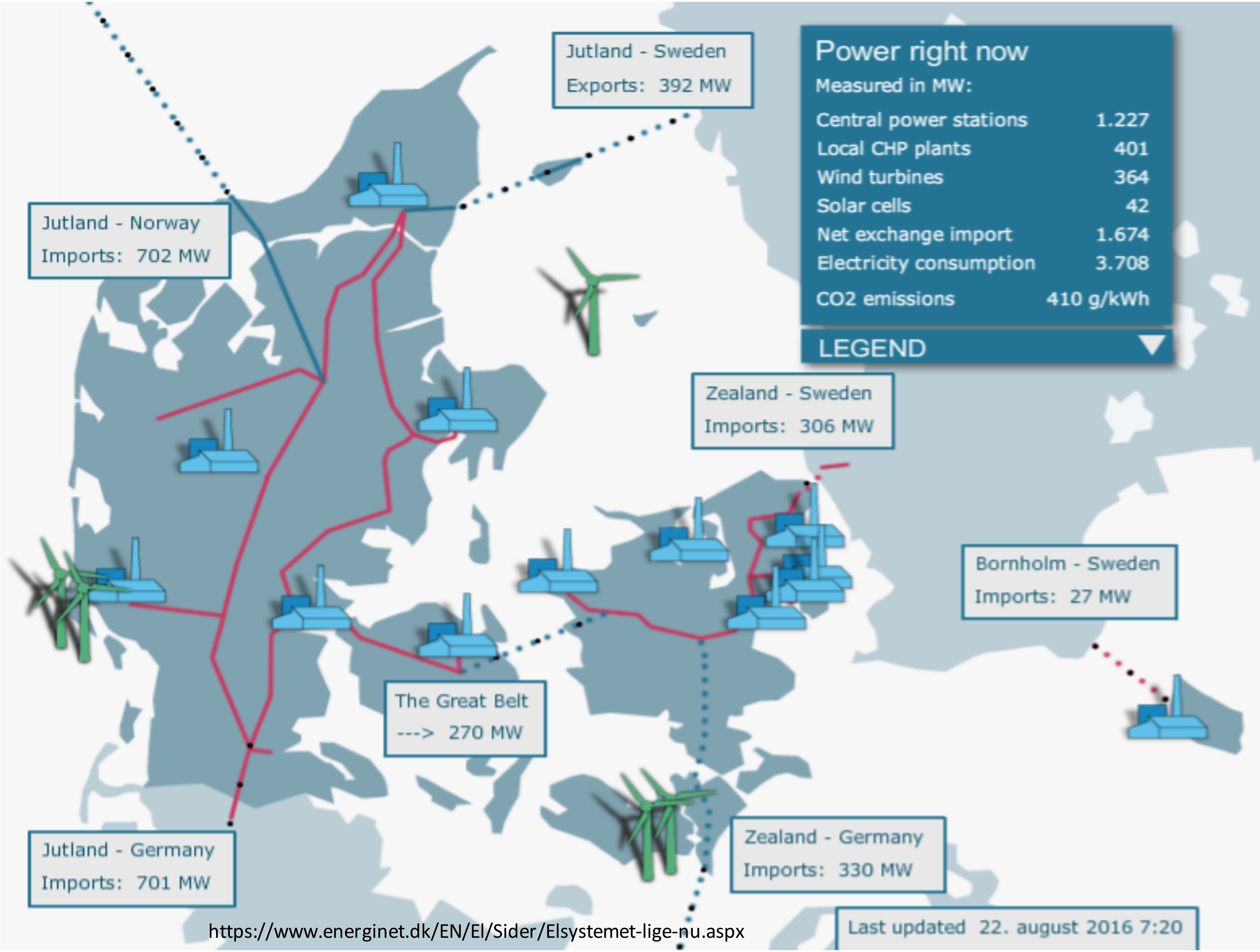
Wind energy %, electricity, Denmark



Source: Energinet.dk



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



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

Energy comes together in Denmark

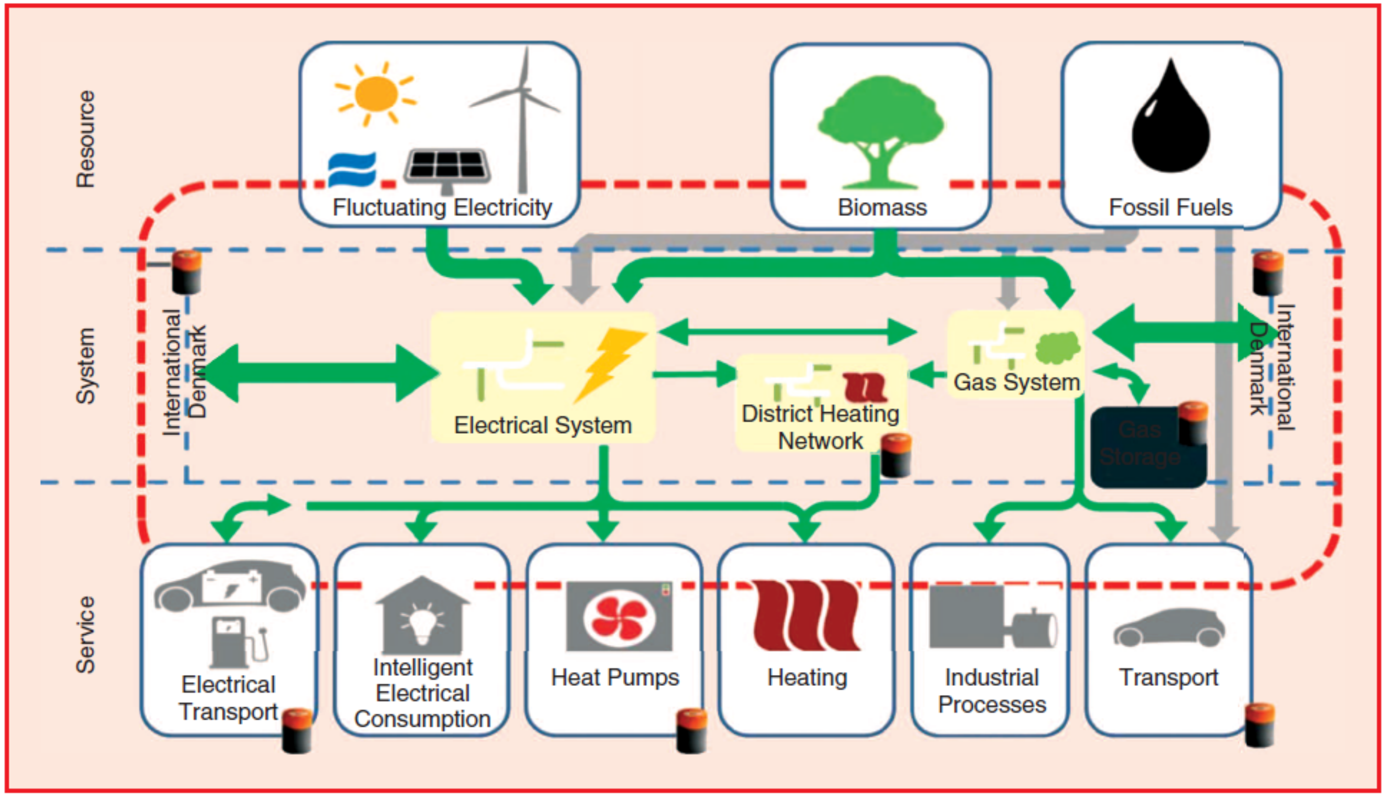
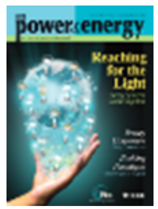
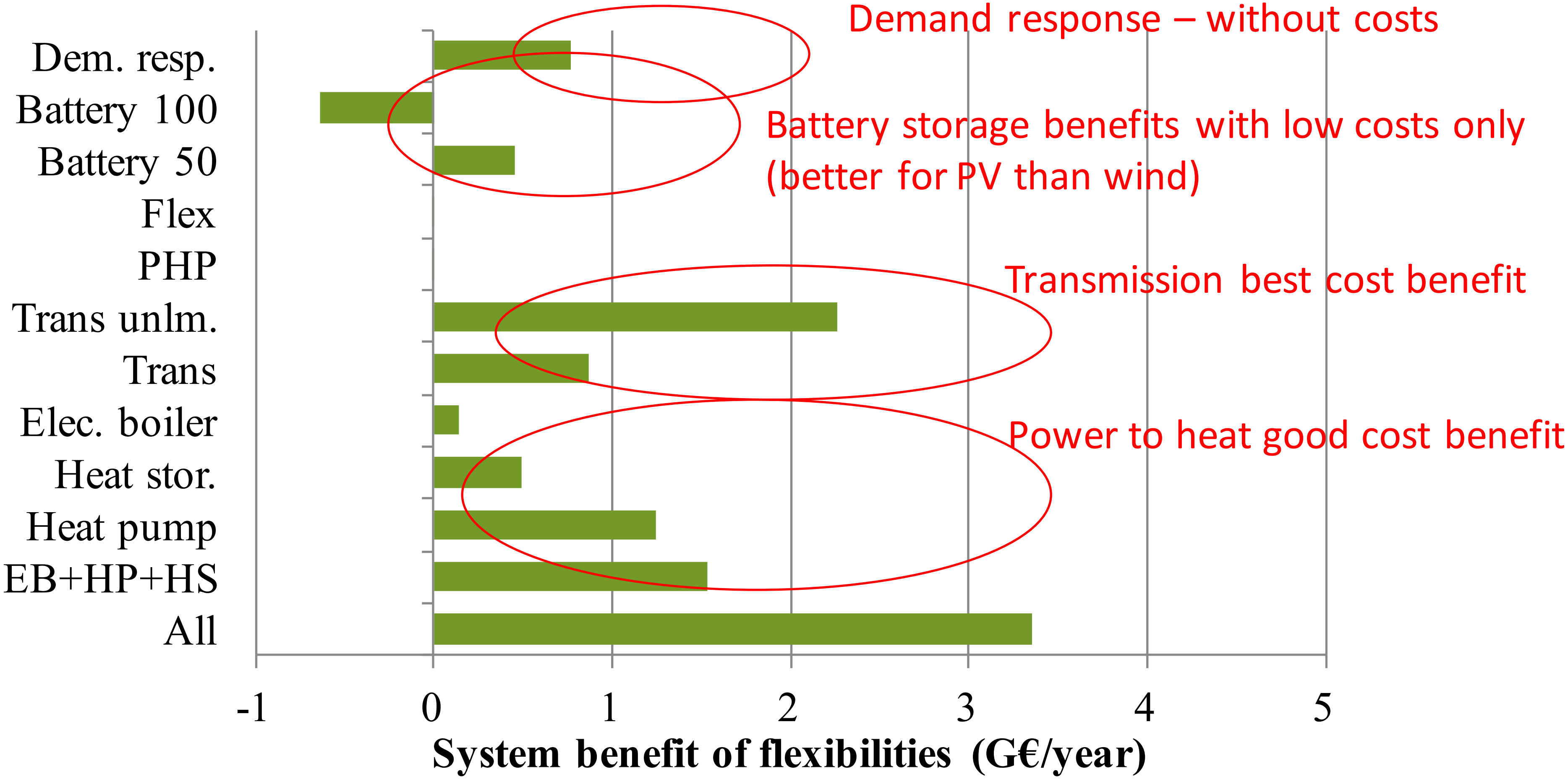


figure 1. Overview of a future Danish energy system. The orange-and-grey cylinders indicate technologies and subsystems with storage capabilities.



Meibom, P, Madsen, H, Hilger, K.B. and Vinther, D, "Energy Comes Together in Denmark", *Power and Energy Magazine, IEEE*, vol.11, no.5, pp.46-55, Sept. 2013.

Comparing the flexibility options



- Relative value of new flexibility options for Northern Europe, scenarios with lot of wind power: 42-55% of energy
- For wind, transmission, heat sector flexibility and demand response most important

(Source: Kiviluoma et al, VTT)


happytoast

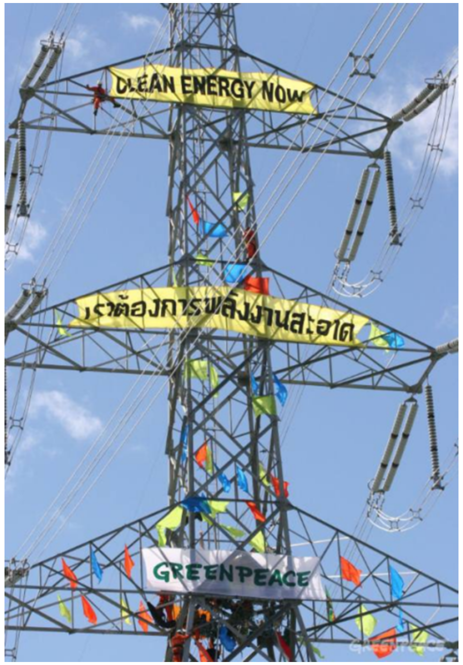
Enter the "consumer"

"Engineers (and economists) tend to be ignorant and arrogant about customers", Janusz Bialek

DETER TELEMANS/PANOS

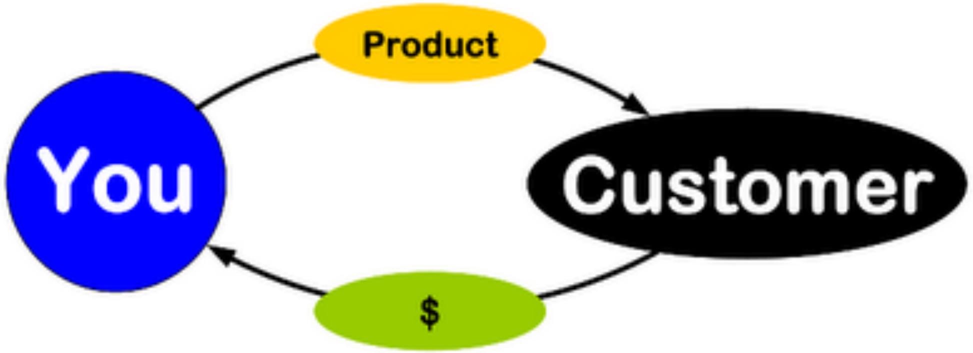
Masai women from Kenya take a course on solar energy in India.

Energy studies need social science



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

Demand response - the “consumer” and the “business model”

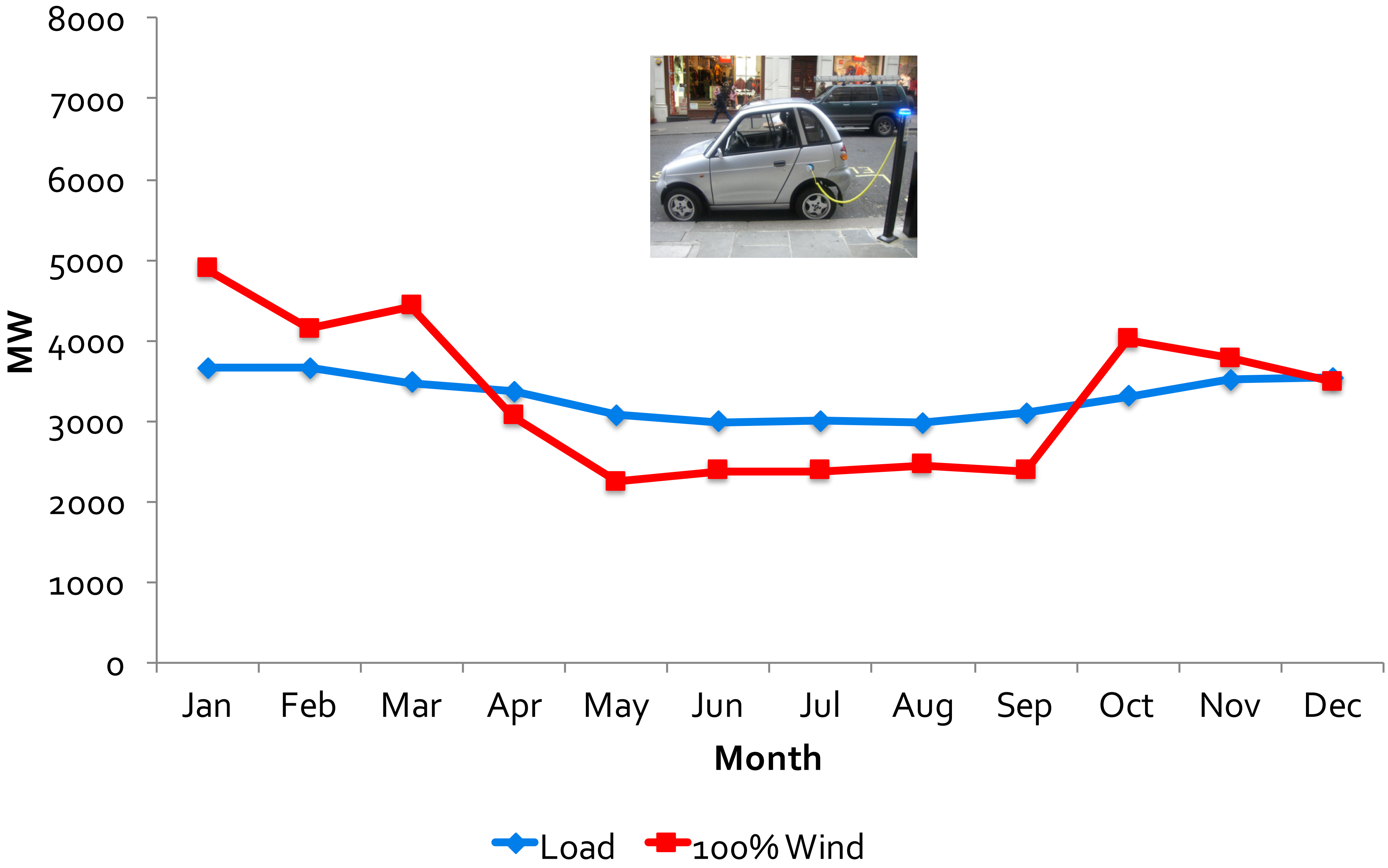


1. Nolan, S and O’Malley, M.J., “Challenges and barriers to demand response deployment and evaluation”, Applied Energy, Vol. 152, pp.1-10, 2015.
2. O'Connell, N., Pinson, P., Madsen, H. and O'Malley, M.J., “Benefits and Challenges of Electrical Demand Response: A Critical Review”, Renewable & Sustainable Energy Reviews, Vol. 39, pp. 686 - 699, 2014.

Table 1: MC-based estimates compared with the Single Year Method estimates for all cases

Case	Metric	MC	Single-Year
Full-time occupants with DR Reserve	ELCC CV	62 MW 9%	59 MW 8.5%
Part-time occupants with DR Reserve	ELCC CV	43 MW 6%	37 MW 5.3%
Full-time occupants without DR Reserve	ELCC CV	78 MW 11%	75 MW 10.8%
Part-time occupants without DR Reserve	ELCC CV	60 MW 8.6%	55 MW 7.9%

100 % Wind we will have to change how we live



Trilemma plus the "consumer" a Quadrilemma

Conclusions

- Energy Systems Integration (ESI) is an increasingly important area
- Unless somebody invents extremely cheap highly efficient storage for electricity ESI is fundamental to economic integration of large volumes of variable renewable energy
- ESI is a megatrend if we are to address climate change

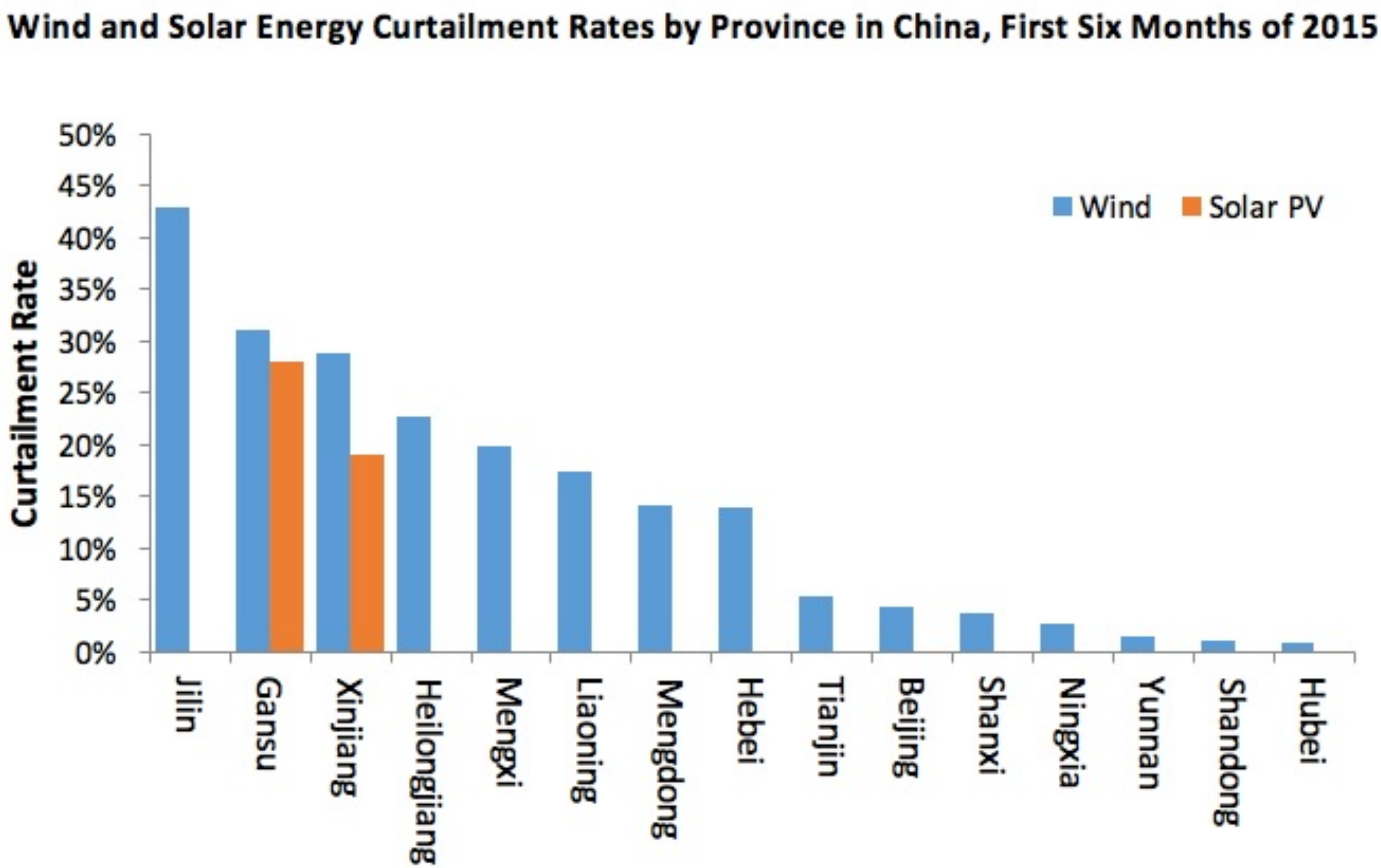
Acknowledgements

- NTNU, Statoil, Volvo, etc.
- Hugh Doyle, Moustafa Ramadan, Daniel Levei
- My colleagues for many of the slides


Russia
Kazakhstan
Mongolia
Kyr.
Taj.
China
Beijing
N. Korea
Pakistan
Shanghai
Nepal
Bhutan
Chongqing
Taiwan
India
Guangzhou
Myan.
Viet.
Hong Kong
Laos
Macau

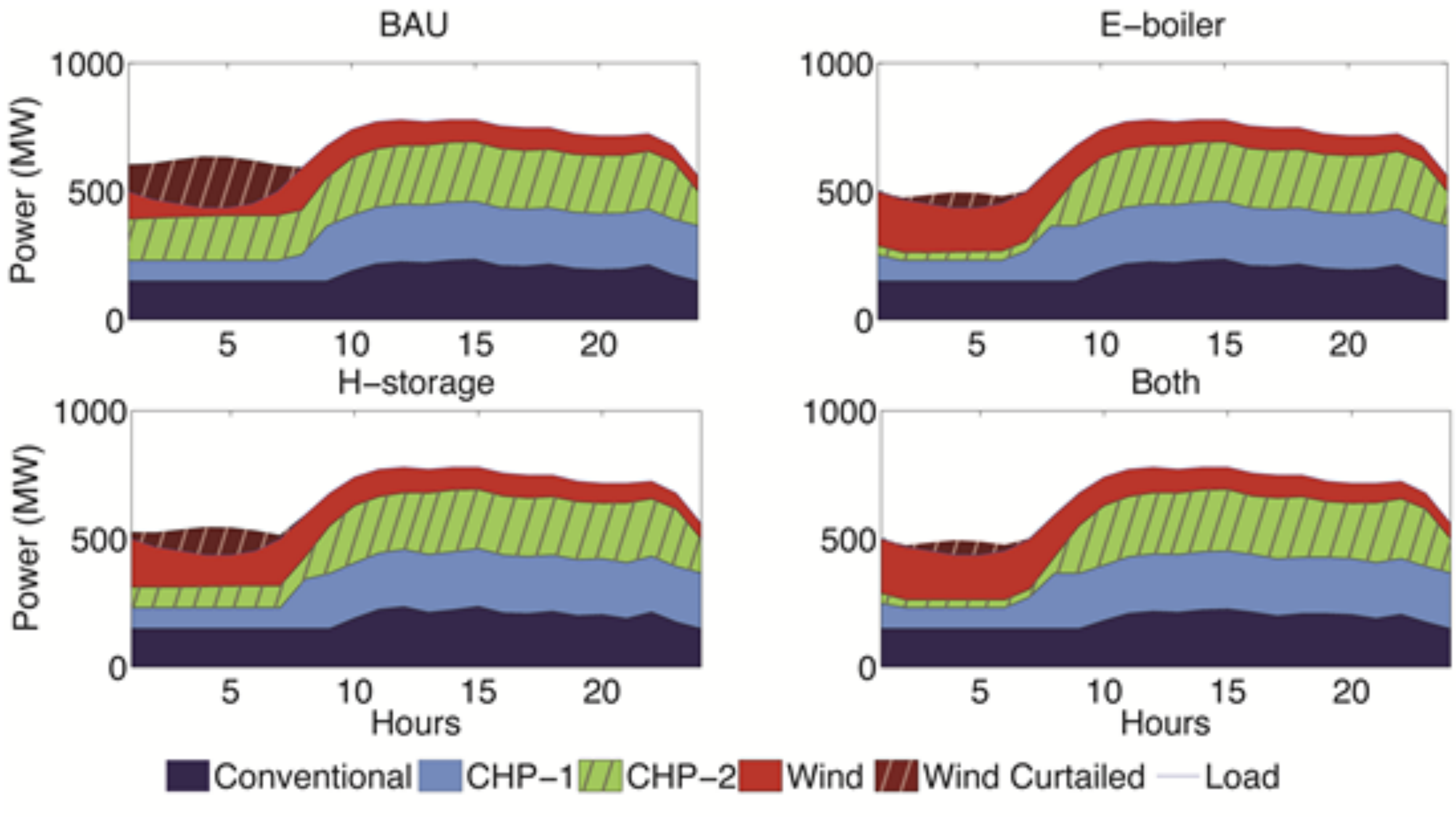
China

Wind & solar PV curtailment in China



Source: raponline.org

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.

How they do it in China

- Established in Inner Mongolia, 2014, with 20 electric boilers
- 500,000 m^3 heat supply
- 75 GWh wind power annually, equivalent to 19,000t coal
- Decrease CO_2 emission by 68,000t

Source: Chongqing Kang, Tsinghua University

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.