Operating and planning integrated energy systems

Mark O'Malley
mark.omalley@ucd.ie

electricity research centre

International Institute for Energy Systems Integration

Energy Systems Integration in smart buildings, communities and microgrids

University of Melbourne & International Institute for Energy Systems Integration, Melbourne Australia, March 21 – 22, 2017

Day 2

The second day will provide further insights into energy systems integration in distributed energy systems but from the perspective of the whole system (AM). Then, general discussions will be carried out before summarizing the workshop achievements and next steps.

Whole System-level aspects
Chair: Pierluigi Mancarella, The University of Melbourne
The morning session will cover whole system-level aspects associated with energy systems integration at the level of smart buildings, districts, communities and microgrids.

9.00 – 9.30 "Integrated modeling of active demand response with electro-thermal systems" – William D'haeseleer, KU Leuven, Belgium

9.30 – 10.00 "Planning and operating integrated energy systems" - Mark O'Malley, University College Dublin, Ireland

10.00 – 10.30 "Flexibility and system services from distributed multi-energy systems: a techno-economic assessment" – Pierluigi Mancarella, The University of Melbourne

10.30 – 11.00 Coffee break

11.00 – 12.00 *Discussion*: "What are the whole system level benefits from integrating distributed and centralised energy systems? How about integrating different energy vectors? What are the challenges? Are they technical, economic or what?"

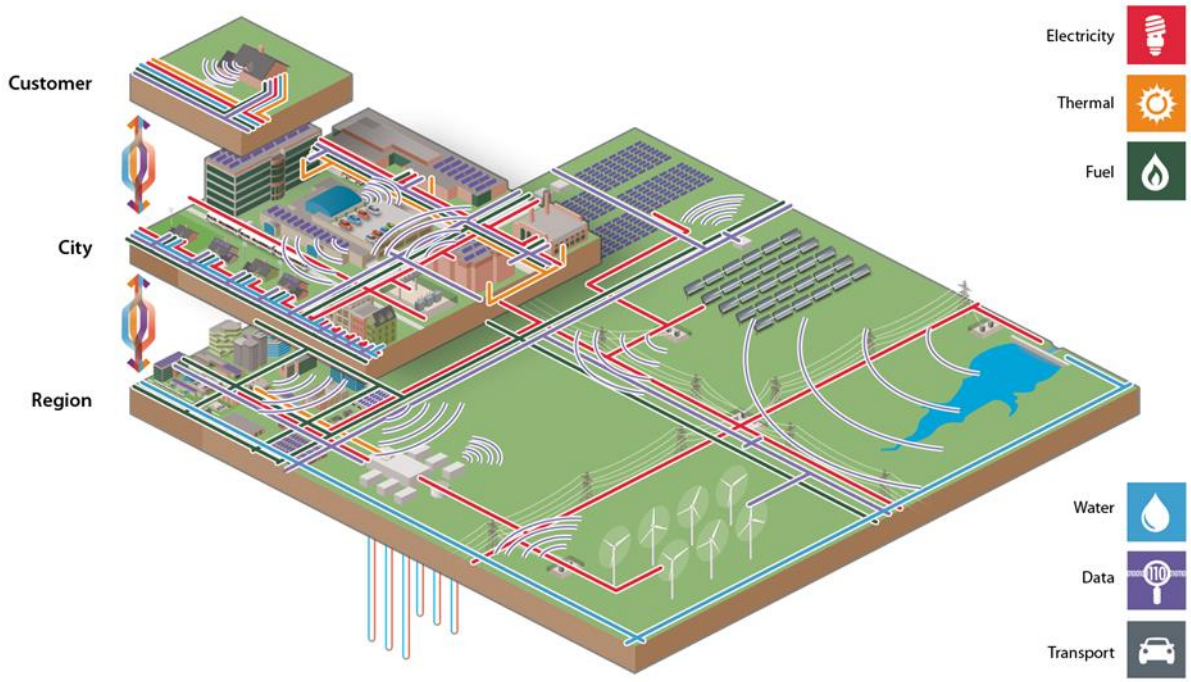
12.00 – 13.00 Lunch

PM session: Final discussions and workshop closing

13.00 – 14.00 *Final discussion with relevance to Australia, and next steps* - Chair: Mark O'Malley, UCD, Ireland
The final group discussion will be centred on consolidating and summarizing the learning from the workshop, with focus on the Australian situation and recent economic and security events. The discussion will also bridge towards next steps.

14.00 – 14.15 *Workshop closing remarks* – Pierluigi Mancarella, The University of Melbourne

Energy Systems Integration



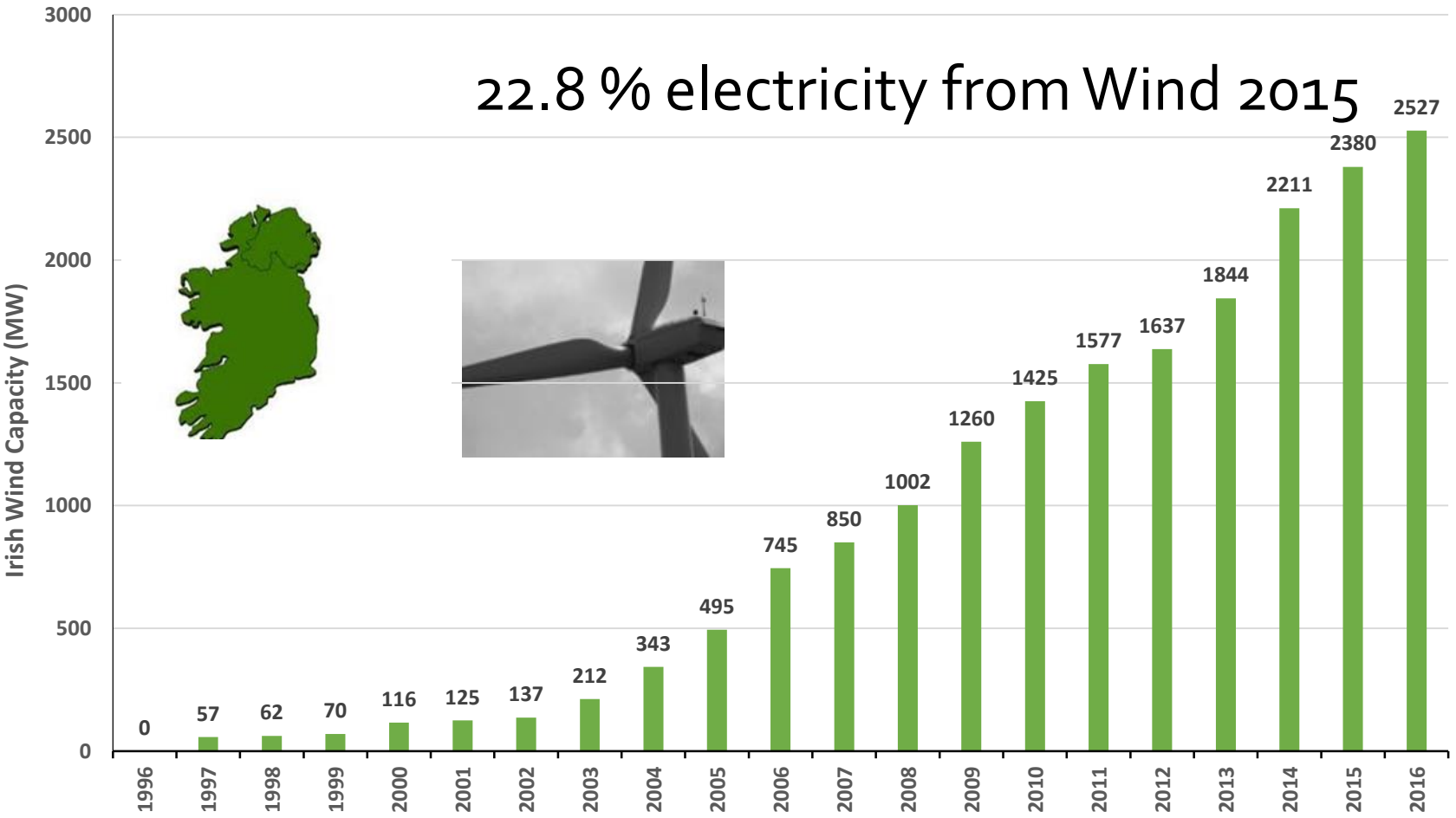
- **optimization** of energy systems across multiple pathways and scales
- increase reliability and performance, and minimise **cost and environmental impacts**
- most valuable at **the interfaces where the coupling** and interactions are strong and represent a challenge and an opportunity
- control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

IESI International Institute for Energy Systems Integration

"Whenever I run into a problem I can't solve, I always make it bigger. I can never solve it by trying to make it smaller, but if I make it big enough I can begin to see the outline of a solution." 34th President of US

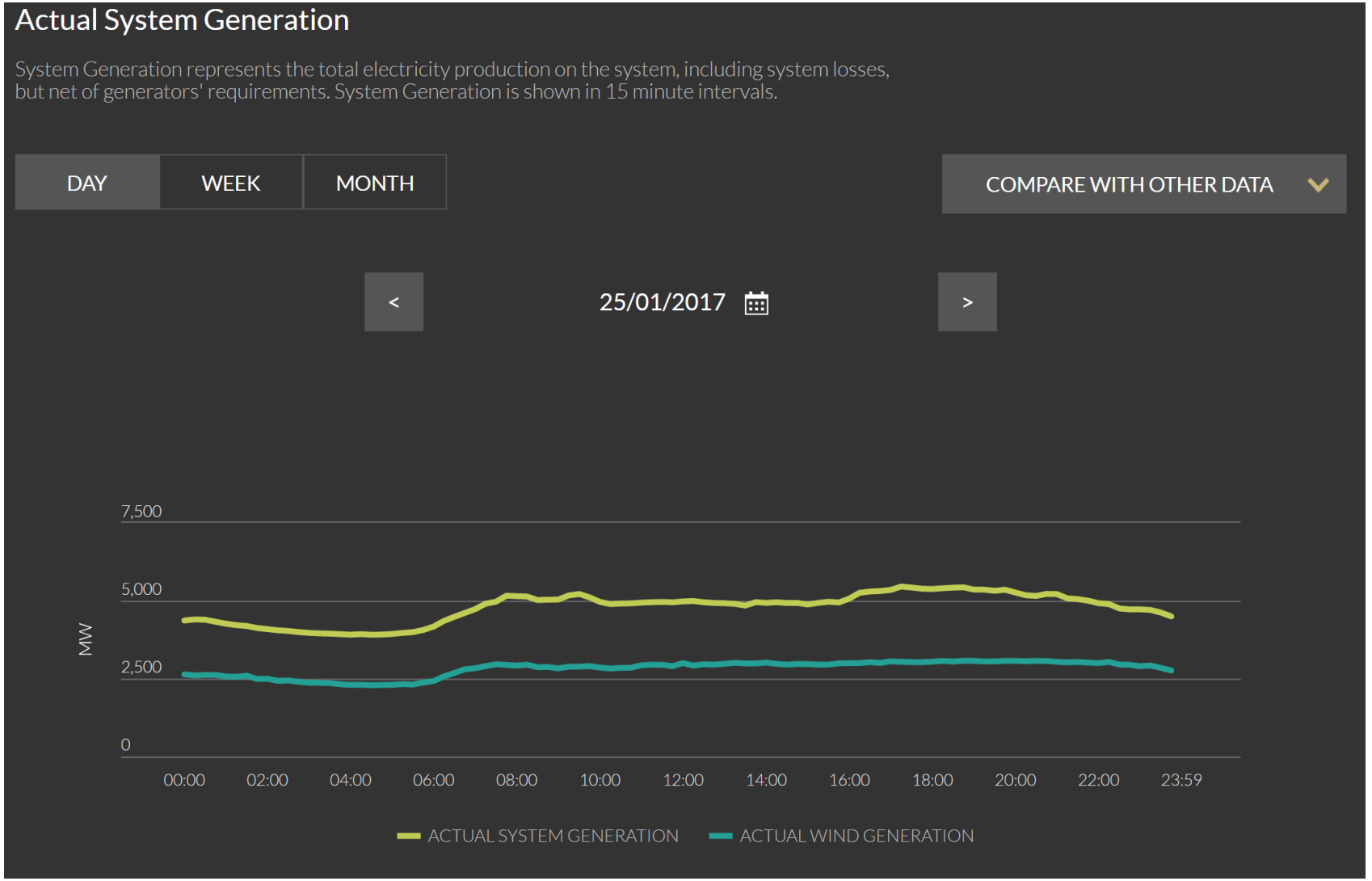
Ireland

Wind Installed in Ireland



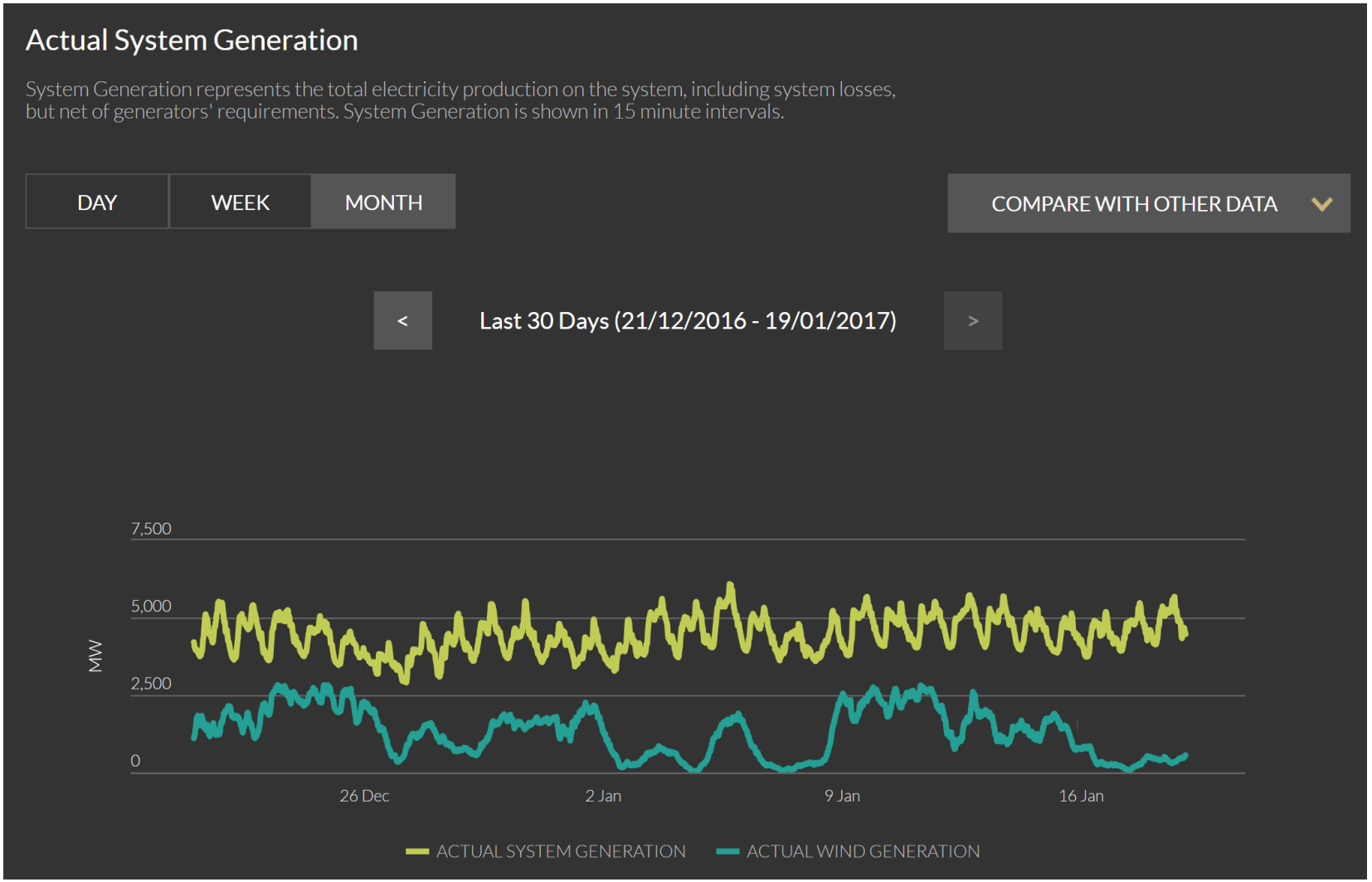
Sources: EirGrid http://www.eirgrid.com/operations/systemperformancedata/all-islandwindandfuelmixreport/ ,IWEA and Eirgrid Generation Capacity Statement 2016-2025 and Irish Wind Energy Association

Variable renewable energy penetration increasing



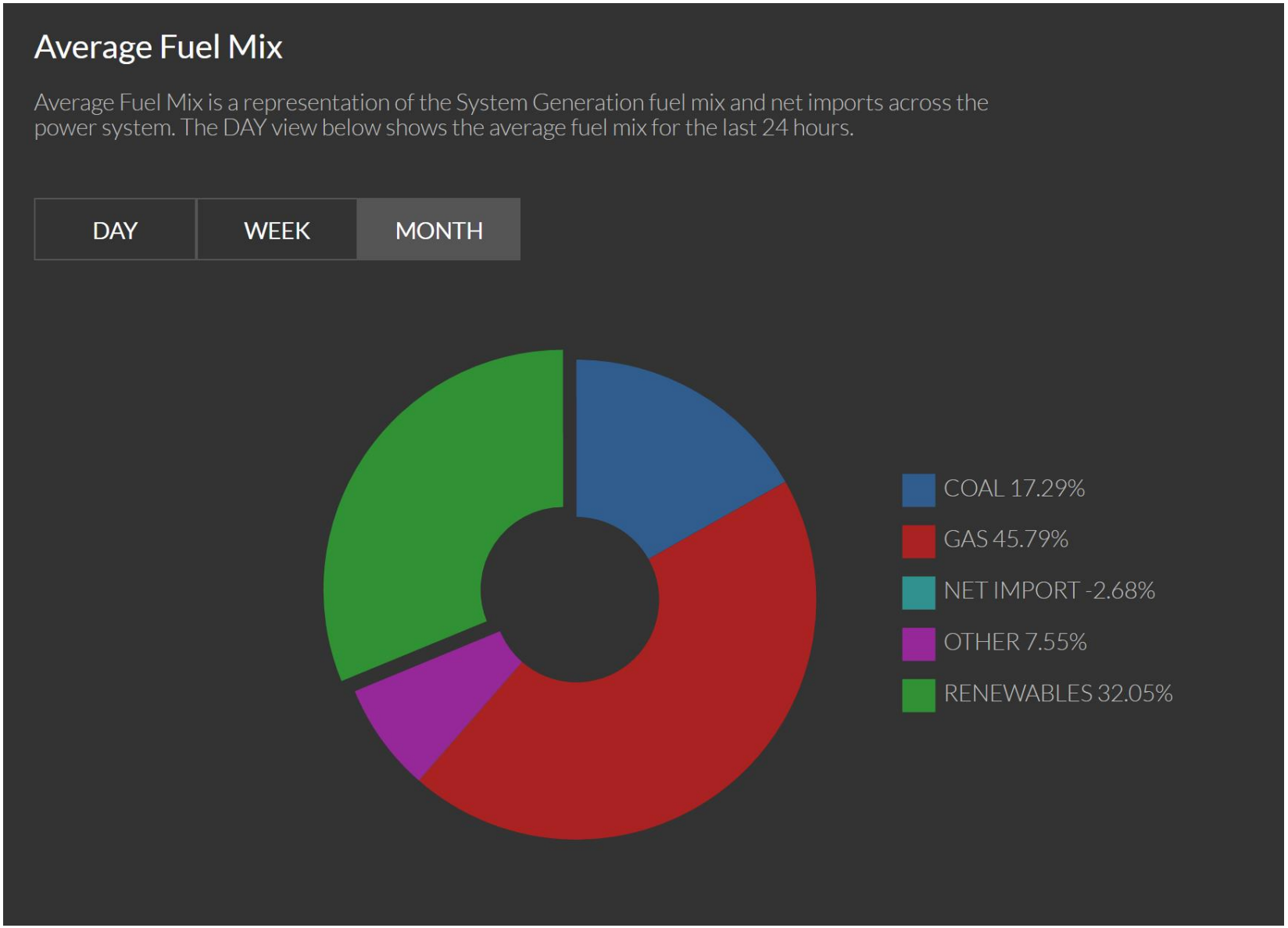
http://smartgriddashboard.eirgrid.com

Monthly Wind and Generation Ireland Jan 18th 2017



http://smartgriddashboard.eirgrid.com

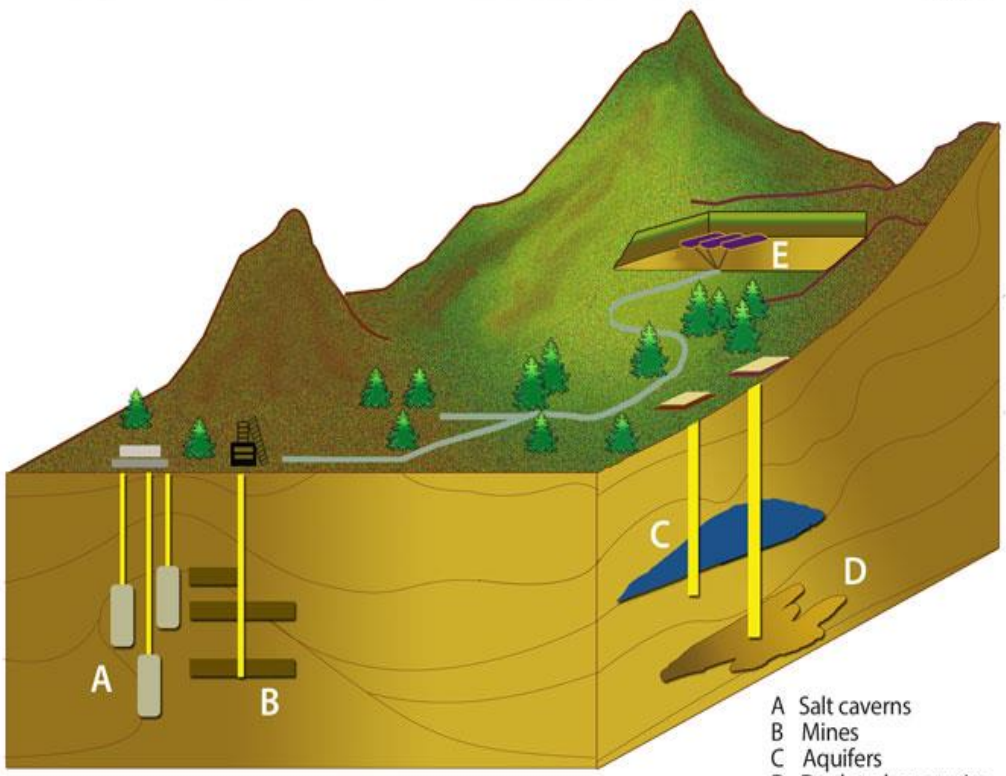
Monthly Fuel Mix Ireland Jan 18th 2017



http://smartgriddashboard.eirgrid.com

Gas grids have storage and are flexible

Figure 1. Types of underground natural gas storage facilities



Source: PB-KBB, inc., enhanced by EIA.

http://www.solarstorms.org/Pictures/AlaskanPipeline.jpg

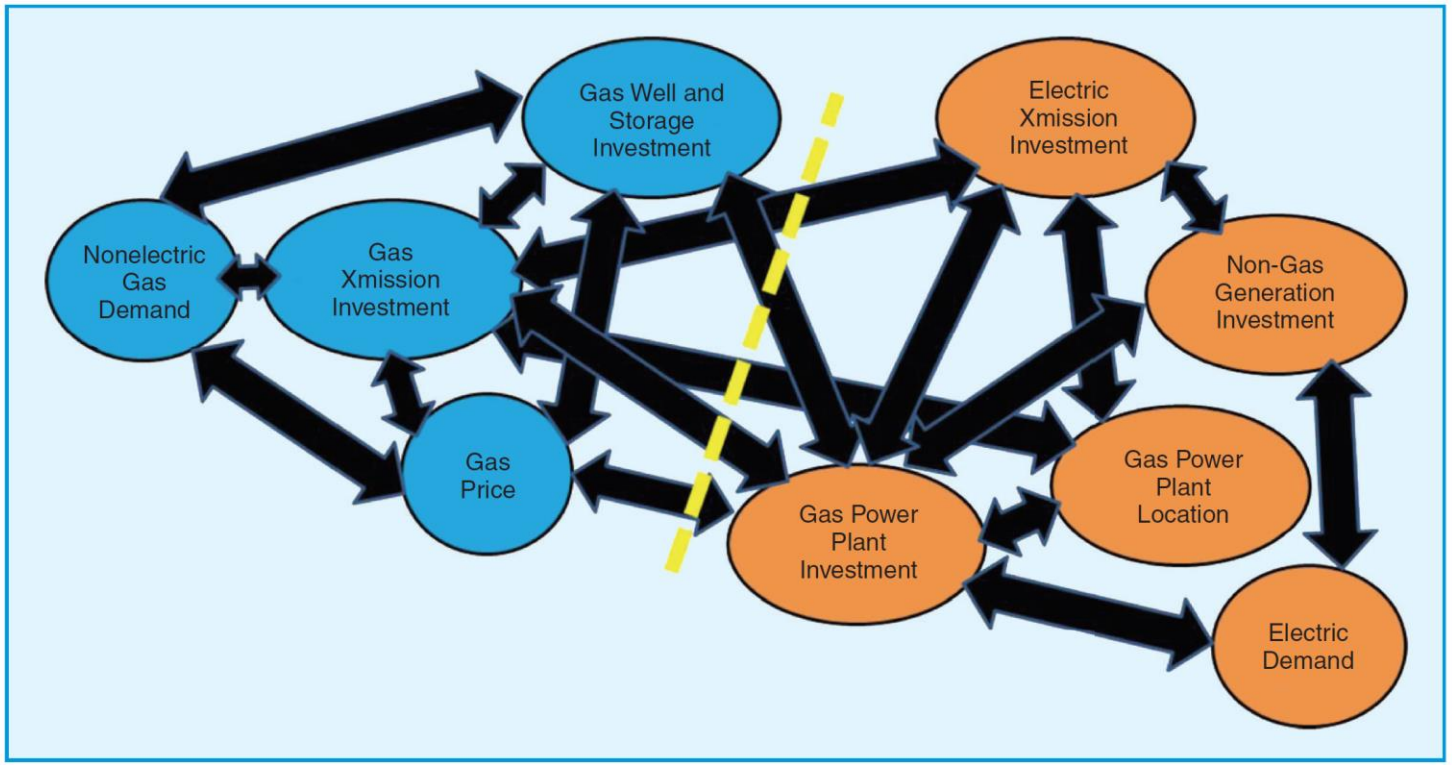


figure 3. Interdependencies in electric and natural gas systems.

McCalley et al. in Special issue in Energy Systems Integration, IEEE Power & Energy Magazine, Vol. 11, Sept/October, 2013.

Look at heat and electricity

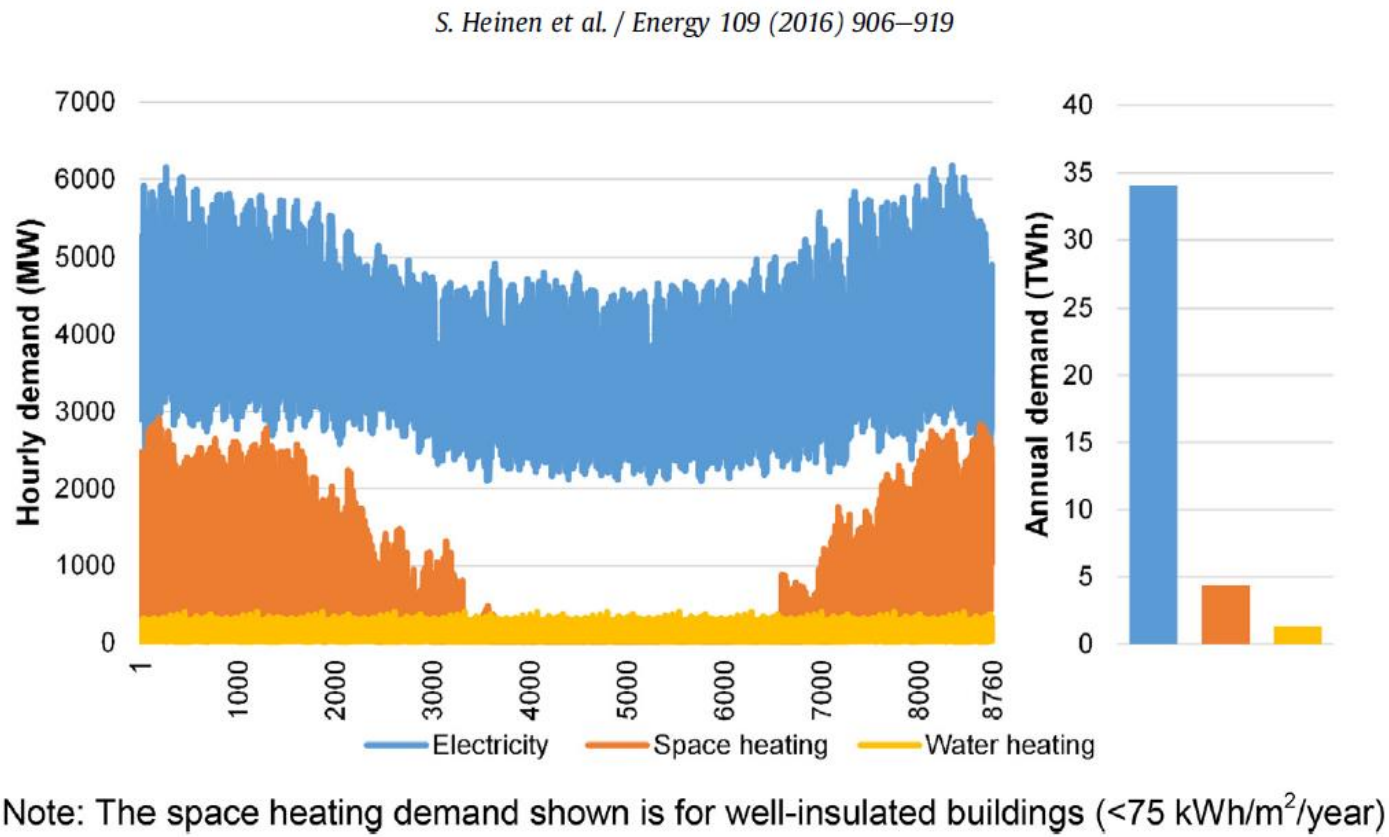


Fig. 3. 2030 hourly demand profile and annual demand for electricity in Ireland and residential heat for 400 000 well-insulated Irish households [35,46].

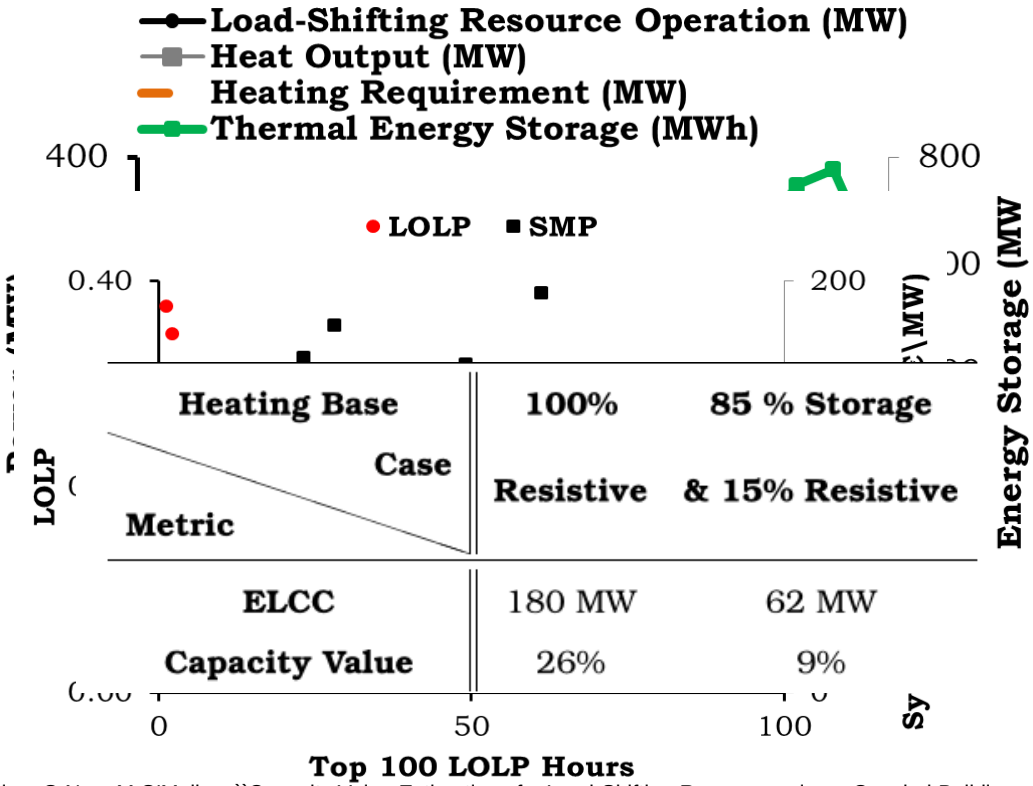
Heinen, S., Burke, D. and O'Malley M.J. "Electricity, gas, heat integration via residential hybrid heating technologies - An investment model assessment", Energy, Vol 109, pp. 906-919, 2016.

Load shifting (thermal electric storage) in Ireland

- Capacity value of resource is limited because:

- Consumer requirements

-

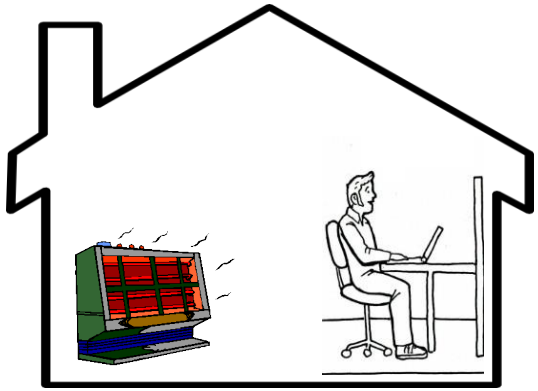


-

S Nolan, O Neu, M O'Malley. ``Capacity Value Estimation of a Load-Shifting Resource using a Coupled Building and Power System Model", Applied Energy, Vol. 192, pp. 71 – 82, 2017.

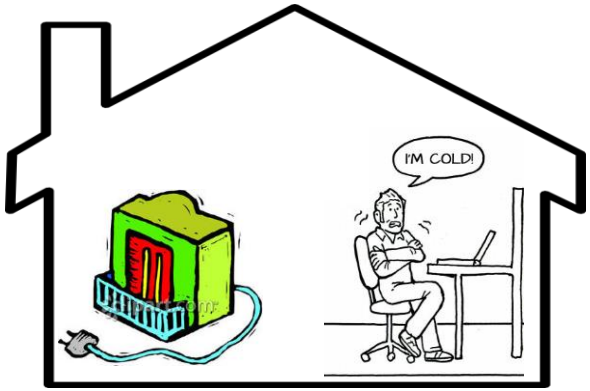
Consumer satisfaction at the heart of unlocking demand side flexibility

- Implementation of DR should not cause discomfort to end users
- Energy/**Reserve** scheduling models would overestimate DR potential if consumer comfort is not considered
- Need integration of building dynamics and consumer preferences in power systems models



Heater ON – thermal comfort

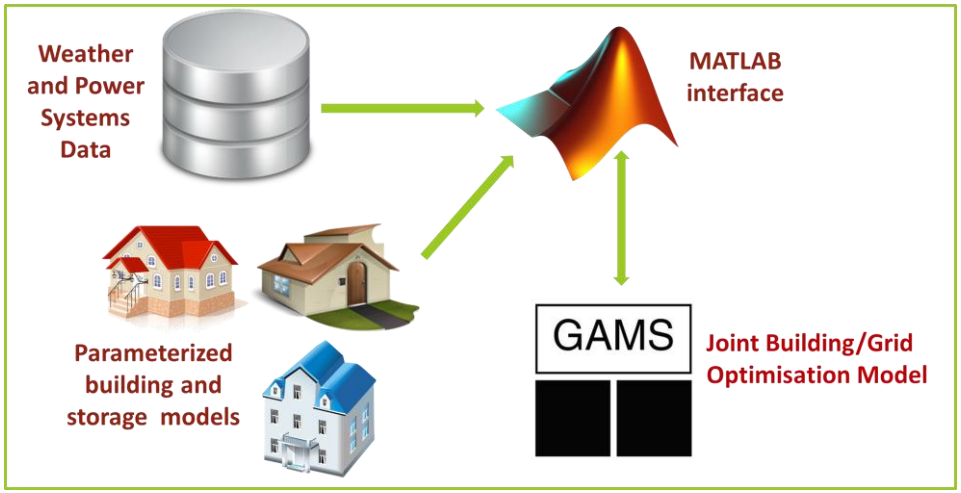
Reserve provision call

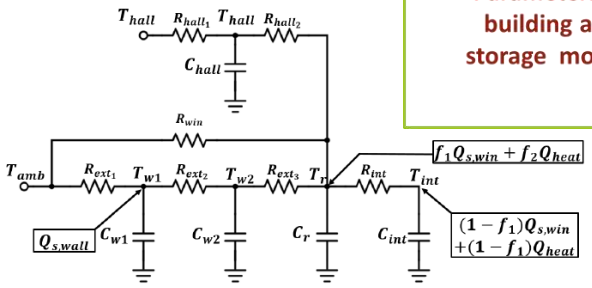


Heater OFF to provide reserve – might cause thermal discomfort

UCD's Building-to-Grid Model

Buildings' RC equivalent models





$$x_n^{j+1} = A_n x_n^j + B_{n,u} Q_{n,heat}^j + B_{n,d}\left[T_{amb}^j \; Solar_{West}^j \; Solar_{North}^j T_{n,hall}^j\right]$$

where

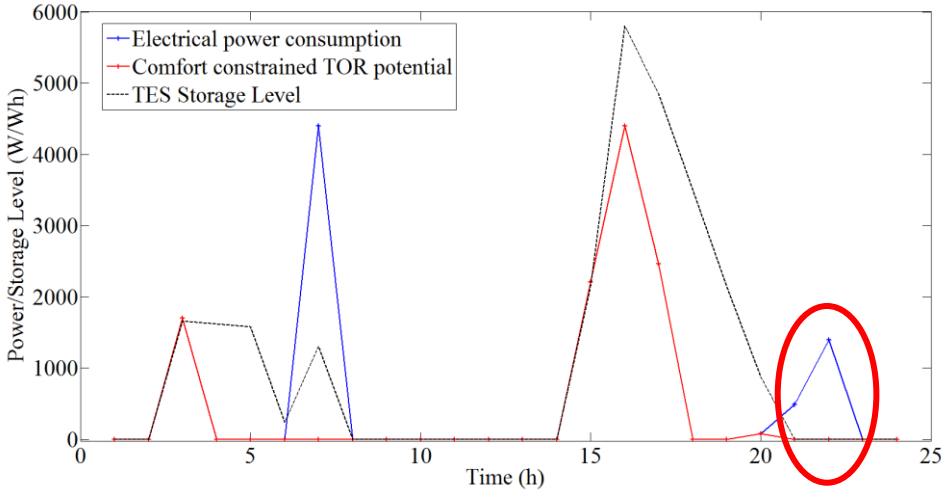
$$x_n^j = \left[T_{n,wo}^j \;\; T_{n,wi}^j \;\; T_{n,r}^j \;\; T_{n,int}^j \;\; T_{n,hall}^j\right]$$

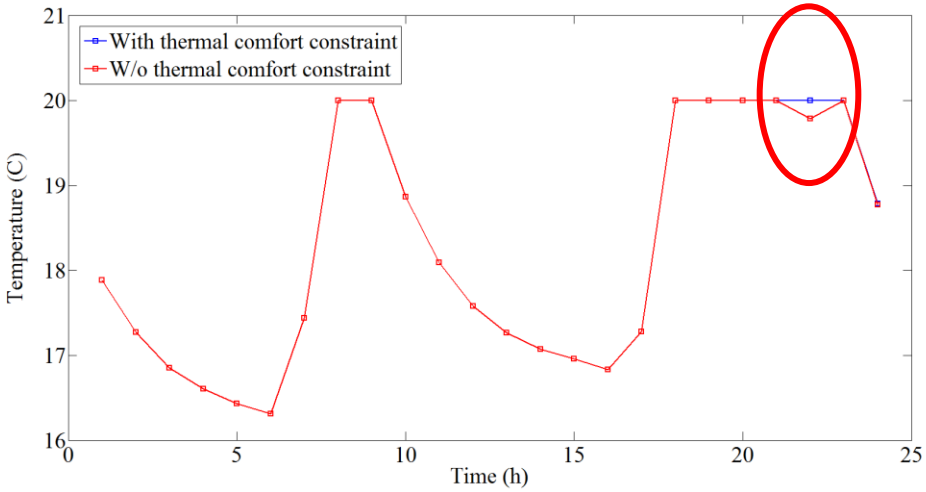
Building-to-Grid Model

- Building RC models integrated with SCUC tool
- Occupancy based thermal comfort constraints
- Reserve provision constrained by thermal comfort

Importance of Integrated Modelling

Thermal discomfort caused if reserve provision is not constrained





Reserve provision potential constrained by thermal comfort

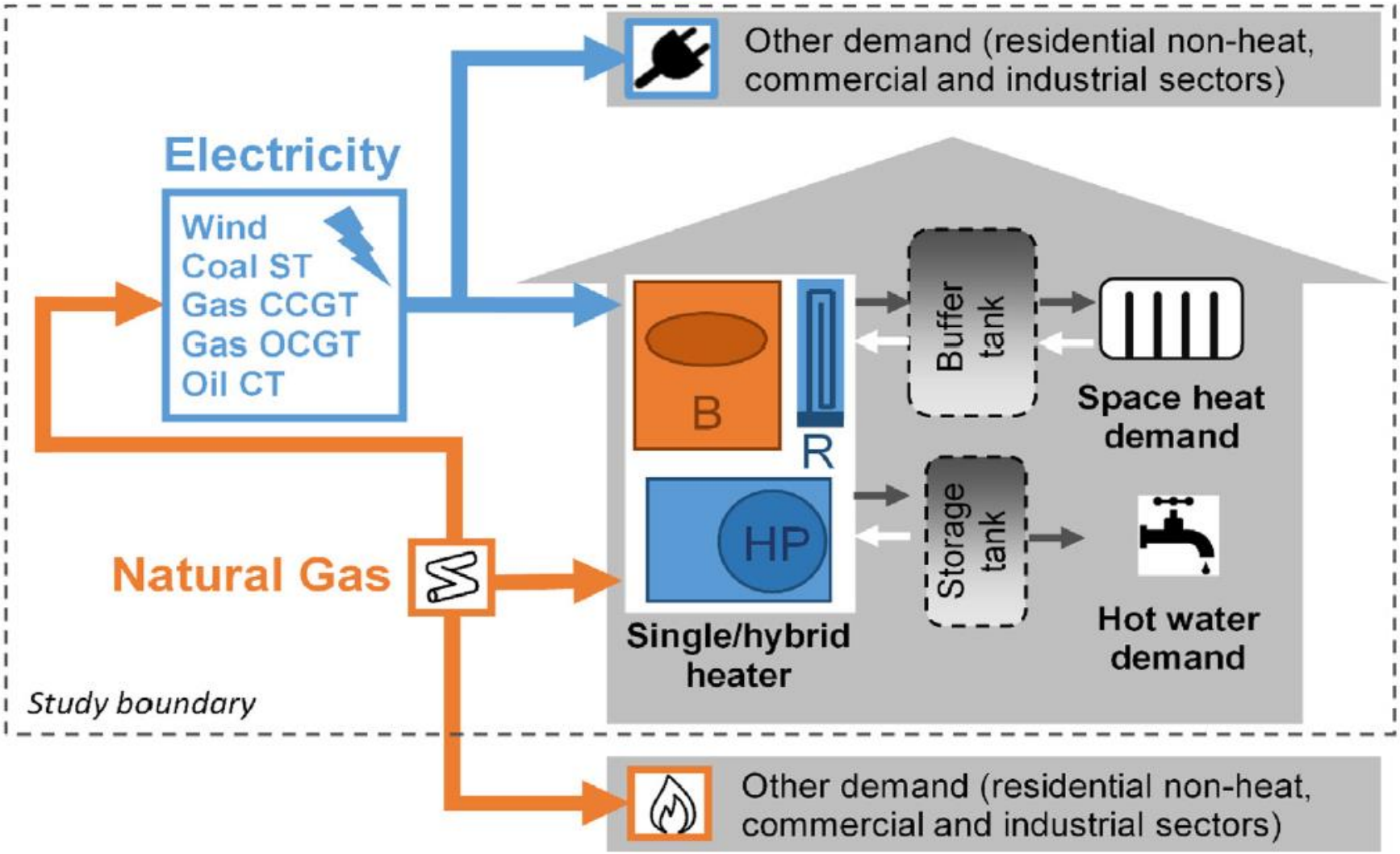


Fig. 1. Schematic of the integrated power-residential heat system studied.

Heinen, S., Burke, D. and O'Malley M.J. "Electricity, gas, heat integration via residential hybrid heating technologies - An investment model assessment", Energy, Vol 109, pp. 906-919, 2016.

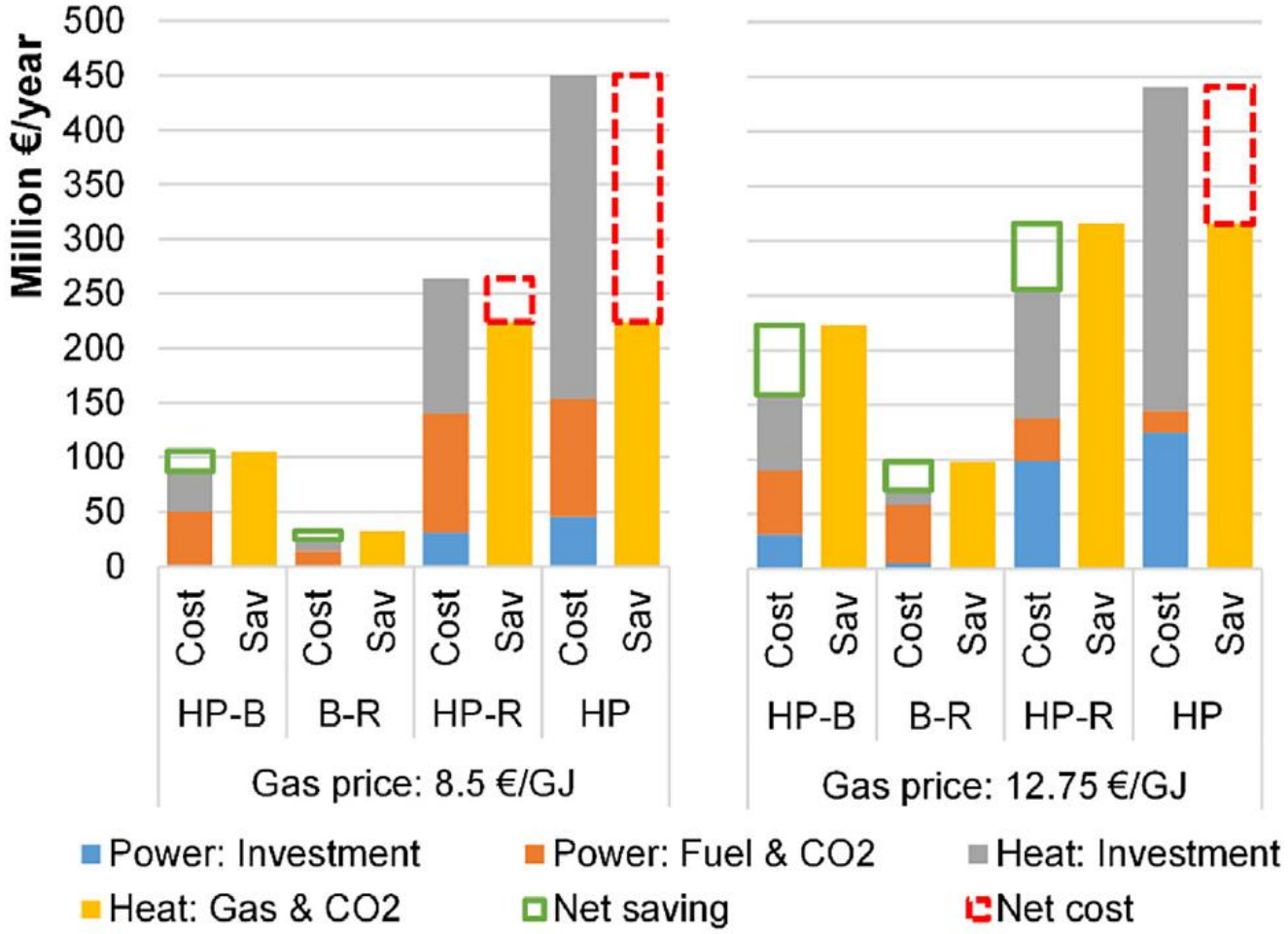
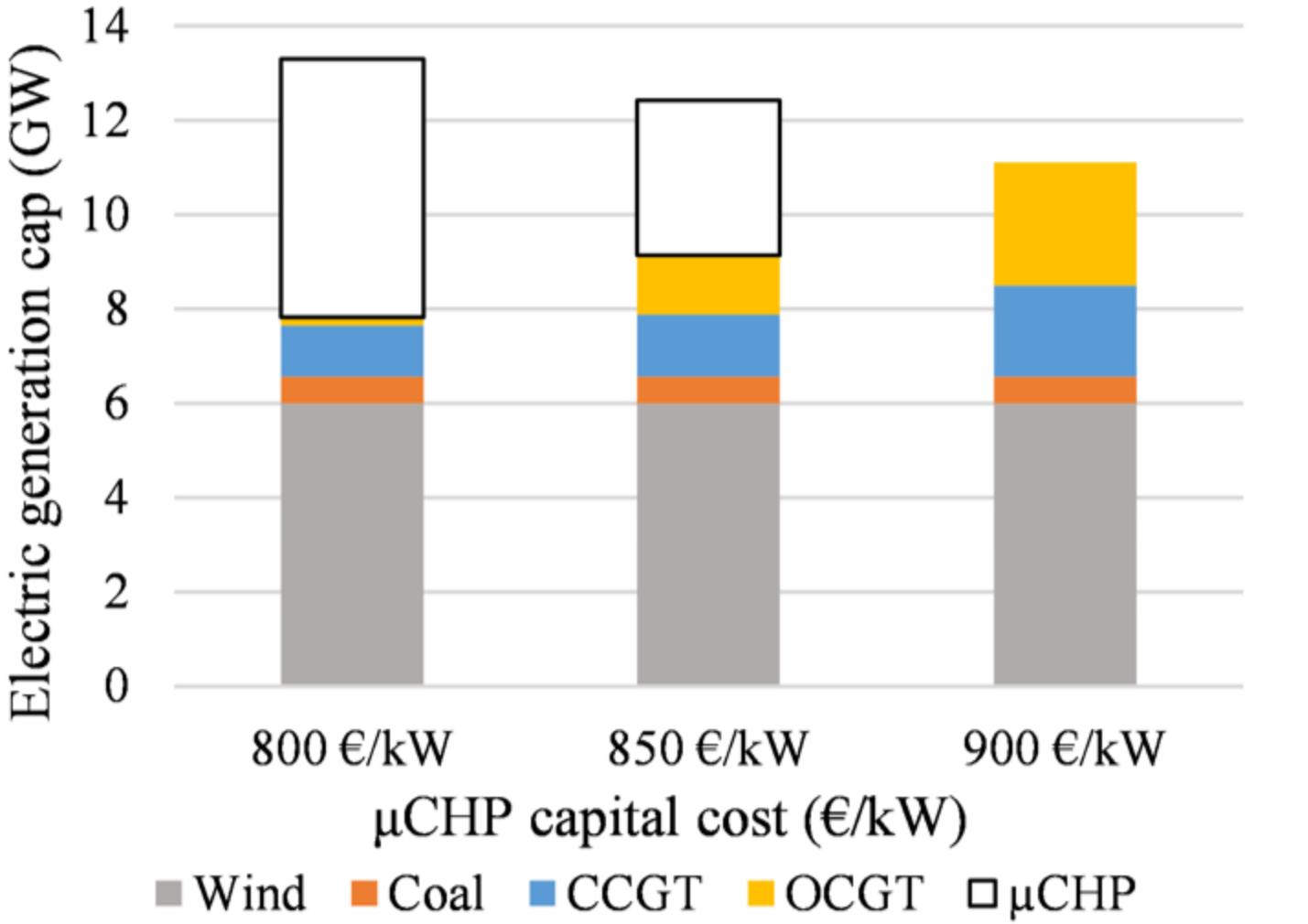


Fig. 5. Cost breakdown for deployment of different heating technologies (B-R, HP, HP-B, HP-R) relative to gas boiler (B).

An Eisenhower moment



Combined Heat and Power Economic Dispatch of a Micro-Gas Turbine Unit


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

China

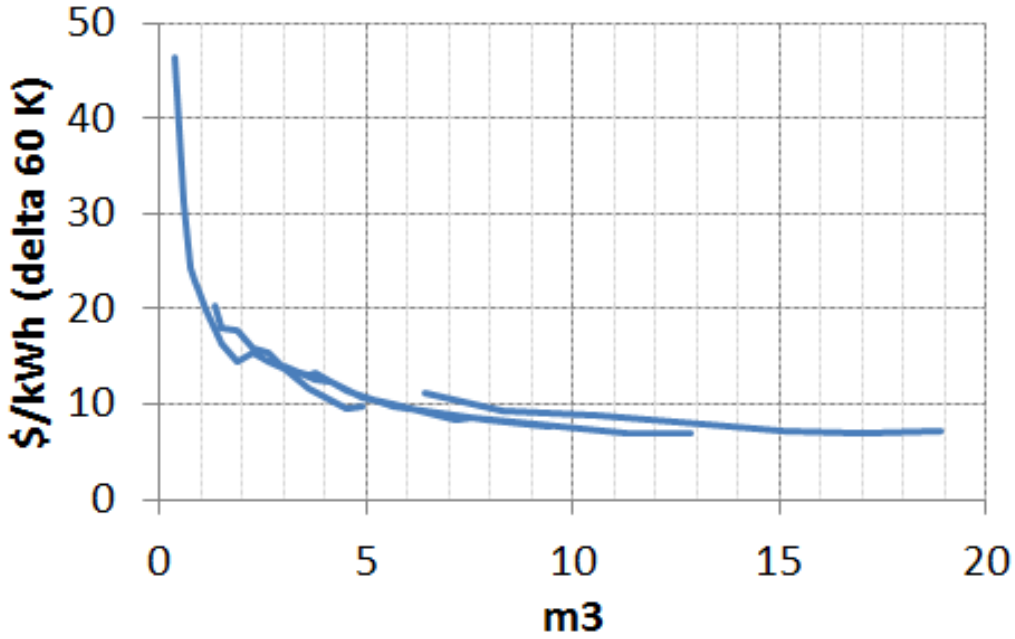
How they do it in China

- 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.

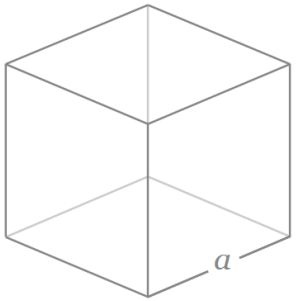
Cost of heat storage is all about scale



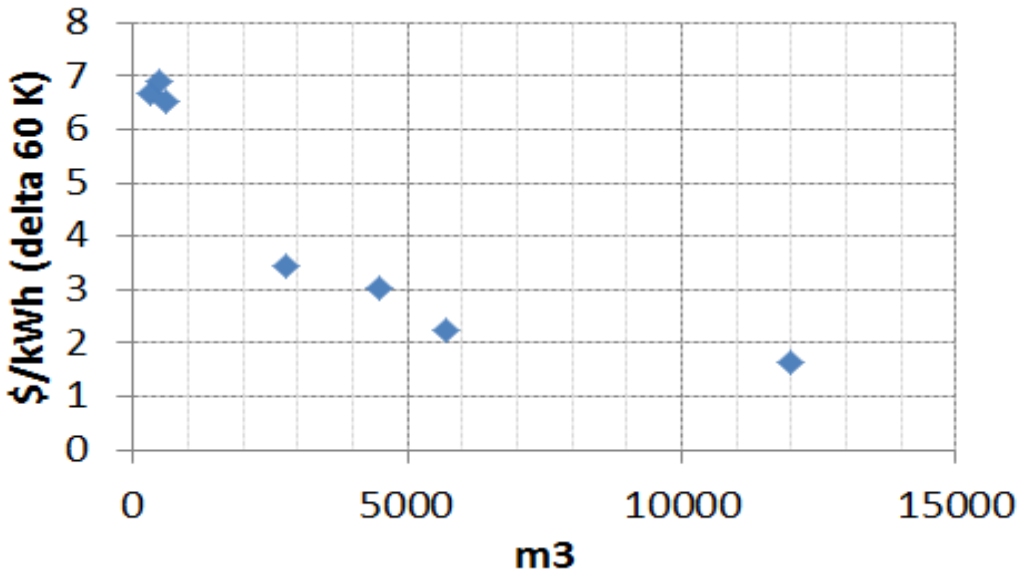
$$V = a^3$$

$$A = 6a^2$$

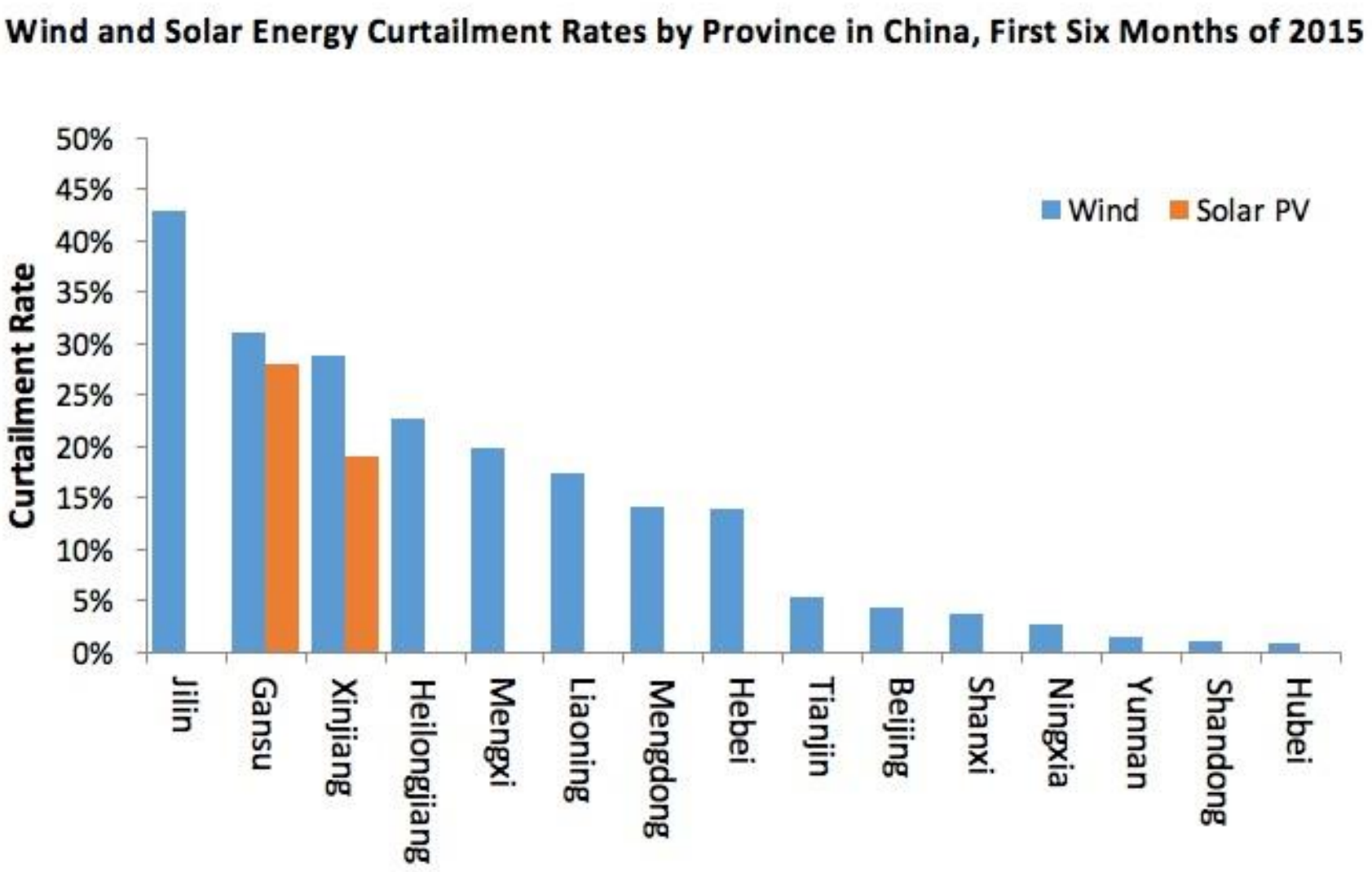
Source: Market data



Source: Juha Kiviluoma

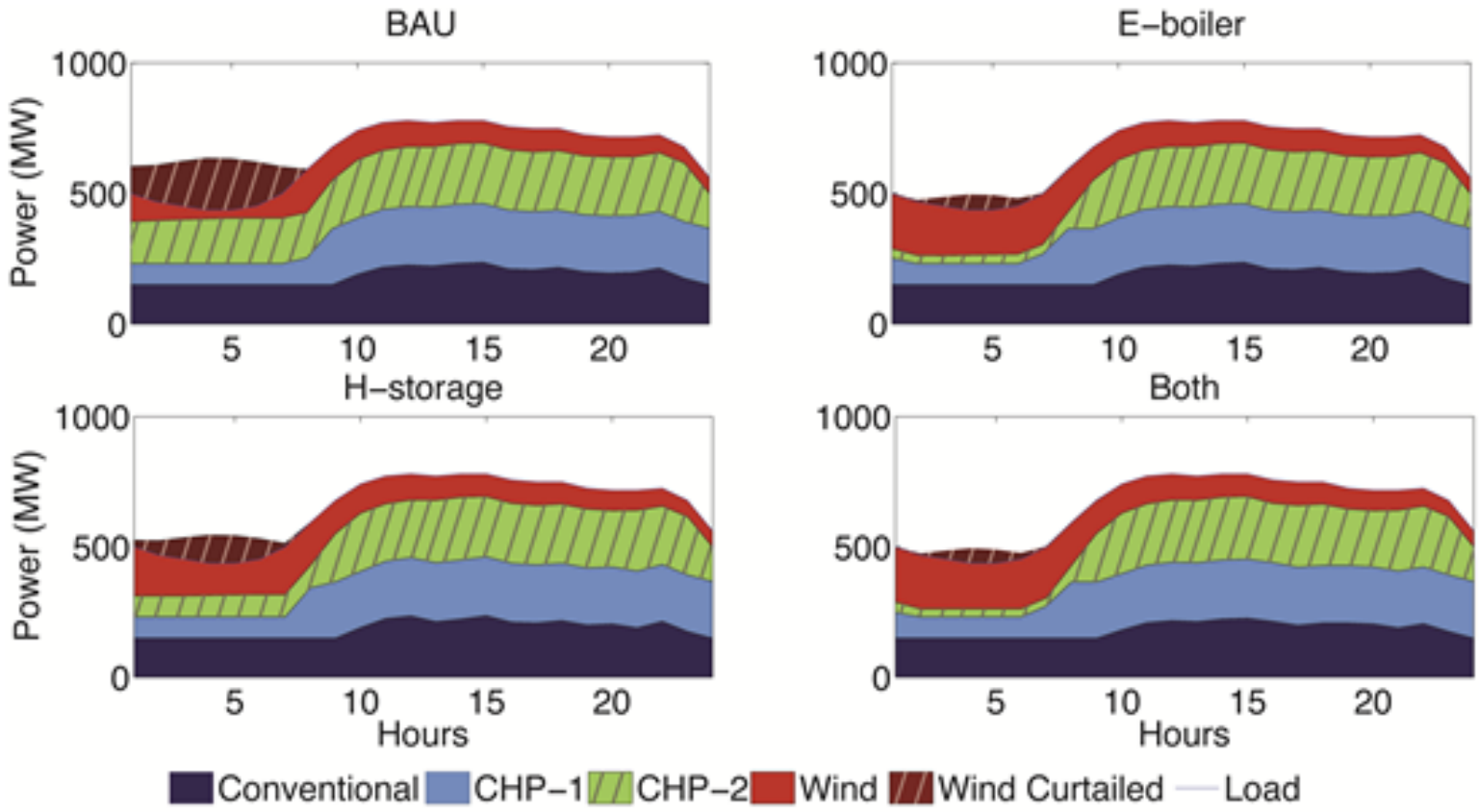


Wind & solar PV curtailment in China



Source: raponline.org

Flexible CHP can reduce wind curtailment

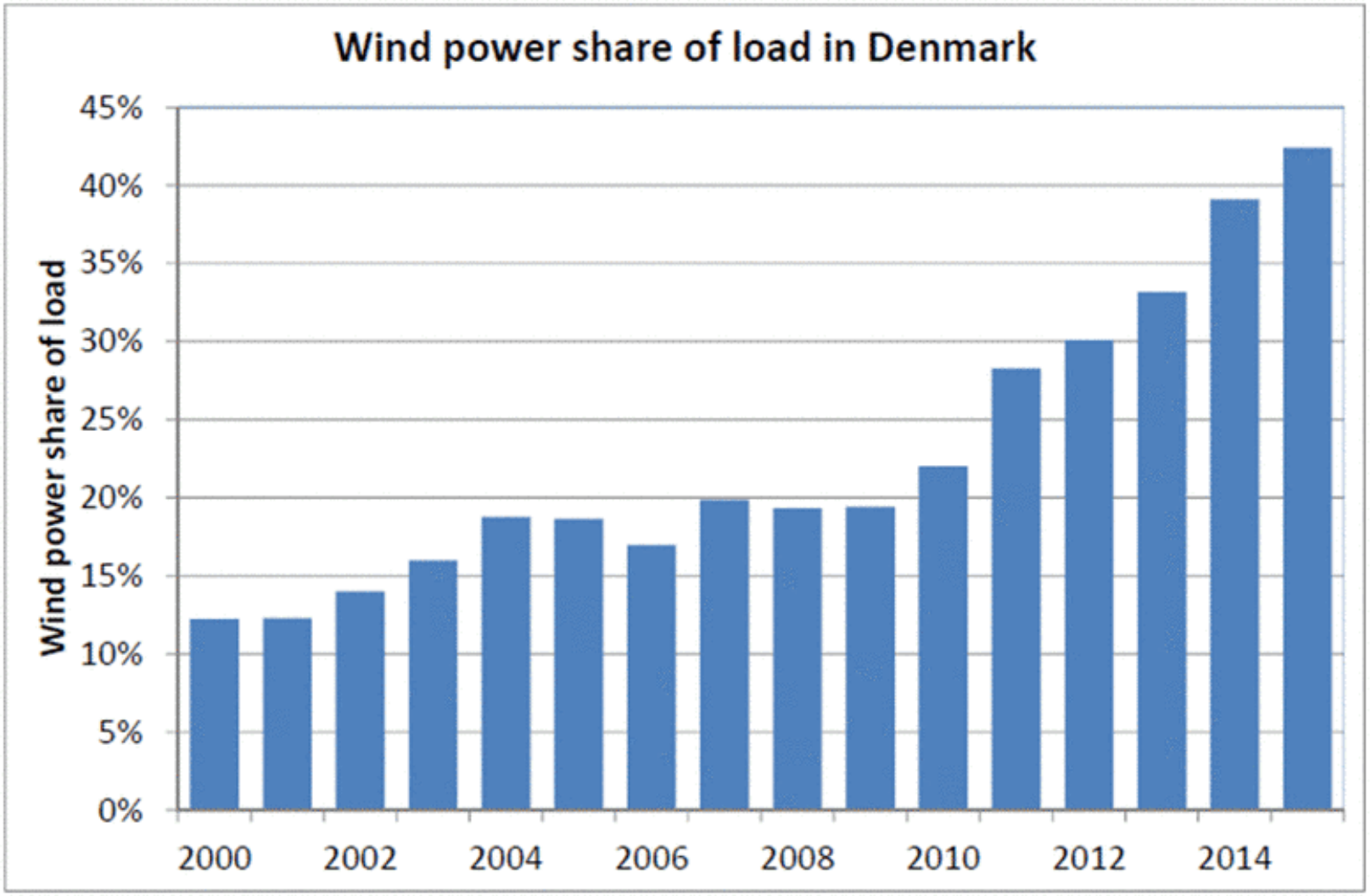


Chen, X., Kang, C., O'Malley, M.J., Xia, Q., Bai, J., Liu, C., Sun, R., Wang, W. and Hui, L., "Increasing the Flexibility of Combined Heat and Power for Wind Power Integration in China: Modeling and Implications", IEEE Transactions on Power Systems, Vol. 30, pp.1848-1857, 2015.

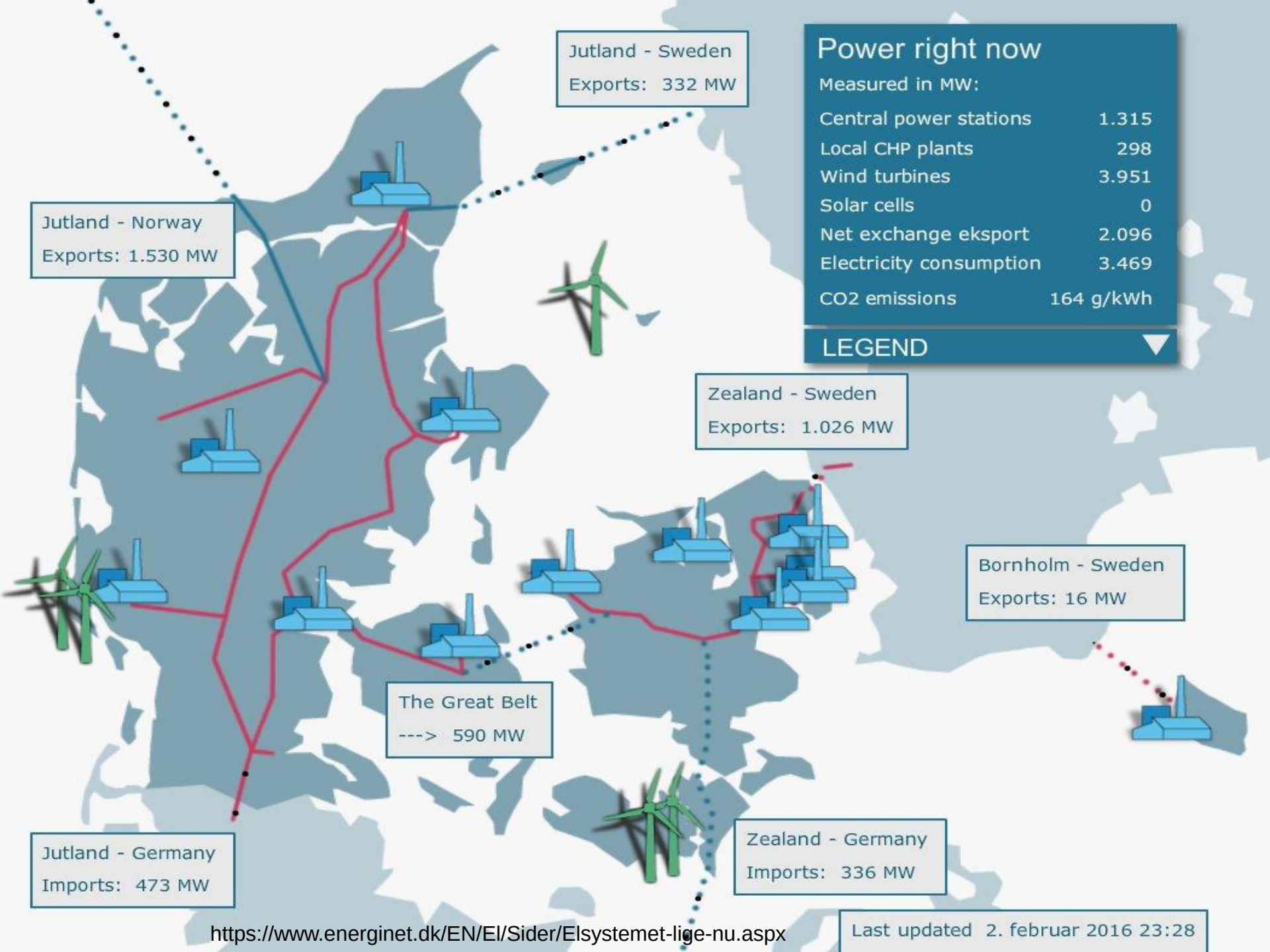

NORWAY
North Sea
SWEDEN
Alborg
DENMARK
Arhus
Copenhagen
Odense
Baltic Sea
GERMANY

Denmark

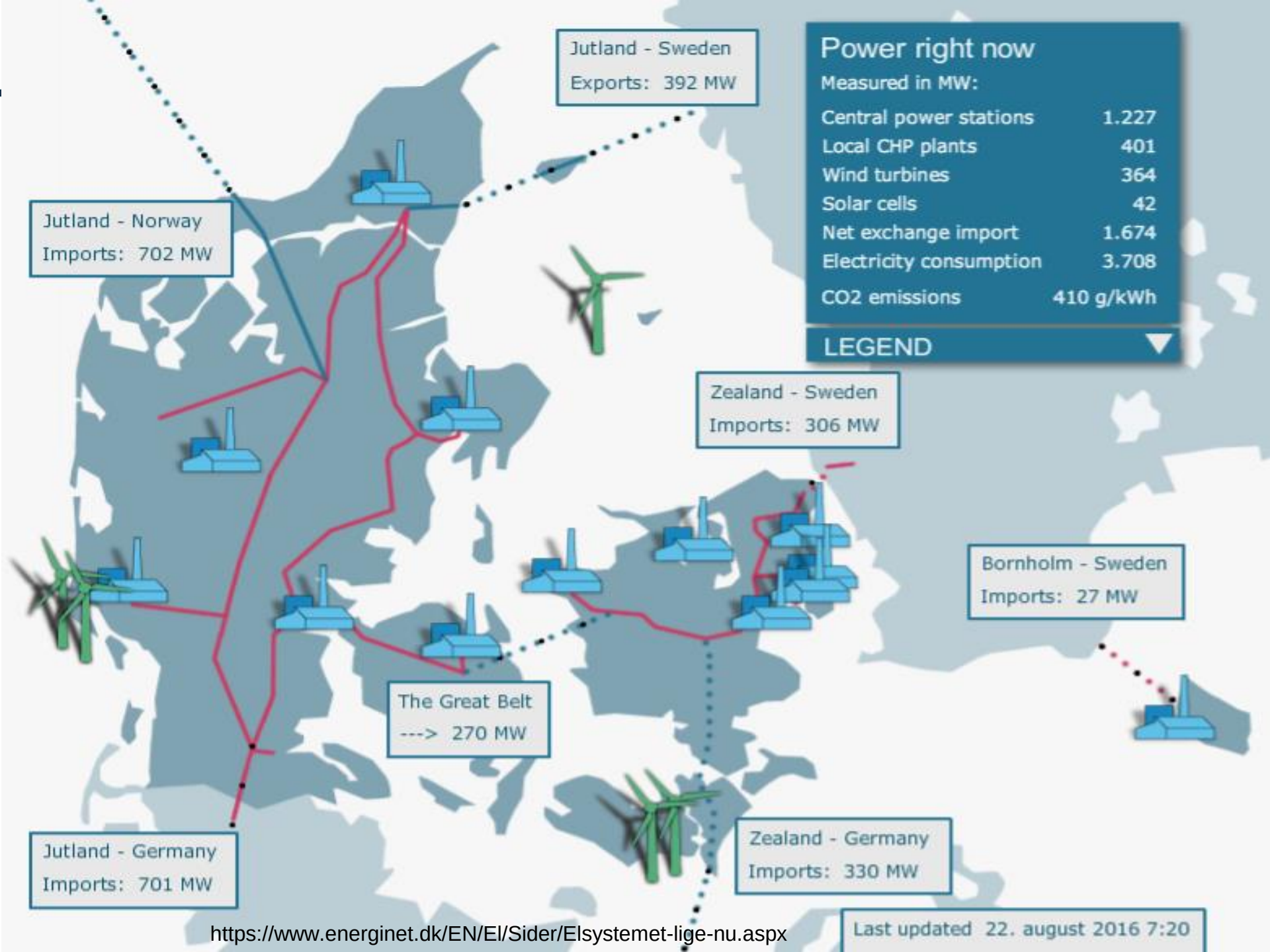
Wind energy %, electricity, Denmark



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

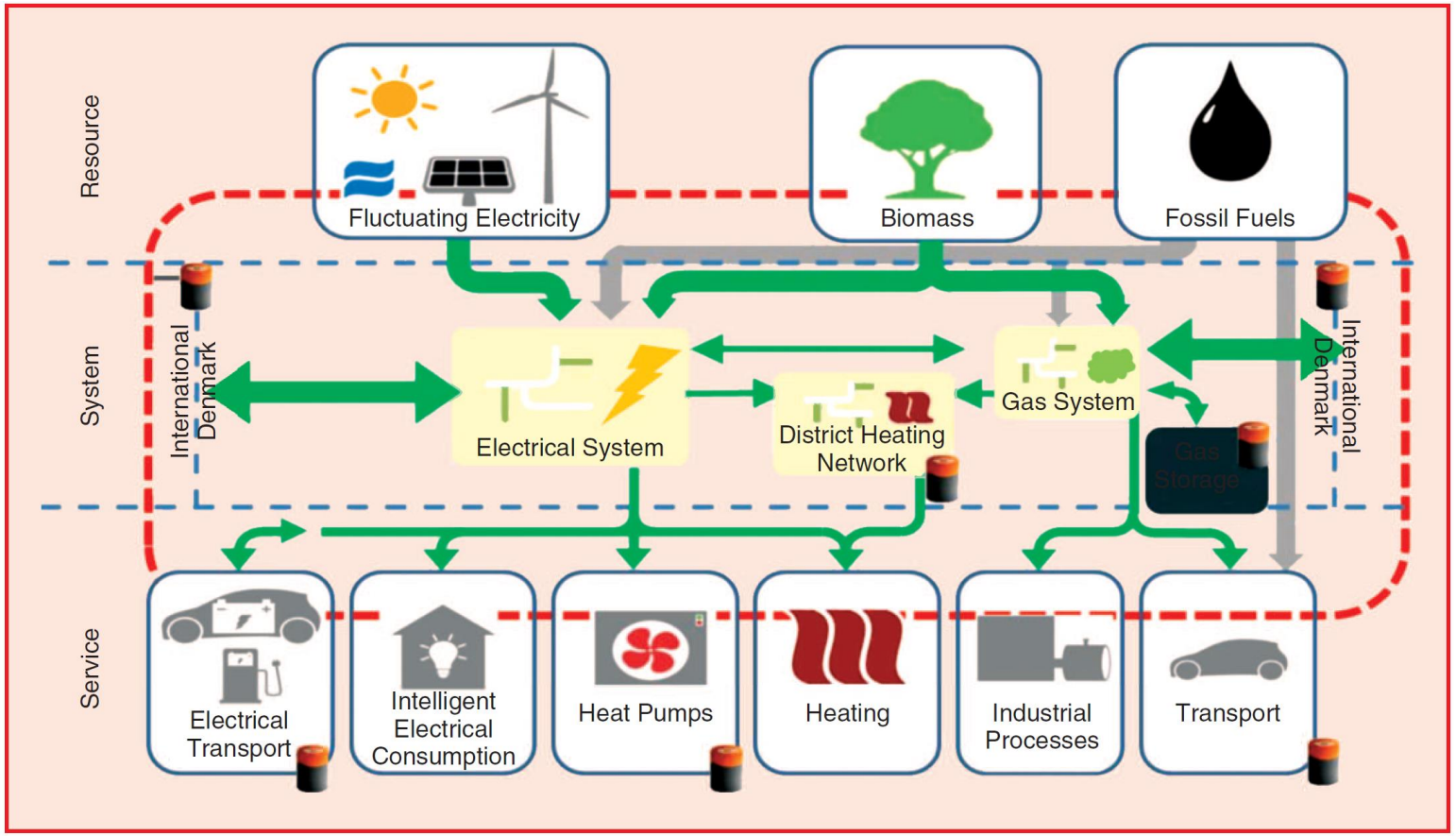
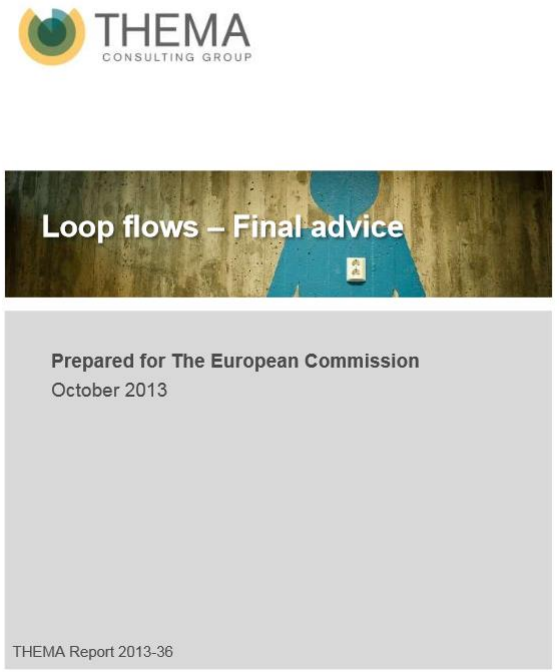


figure 1. Overview of a future Danish energy system. The orange-and-grey cylinders indicate technologies and subsystems with storage capabilities.

Meibom et al. in Special issue in Energy Systems Integration, IEEE Power & Energy Magazine, Vol. 11, Sept/October, 2013.

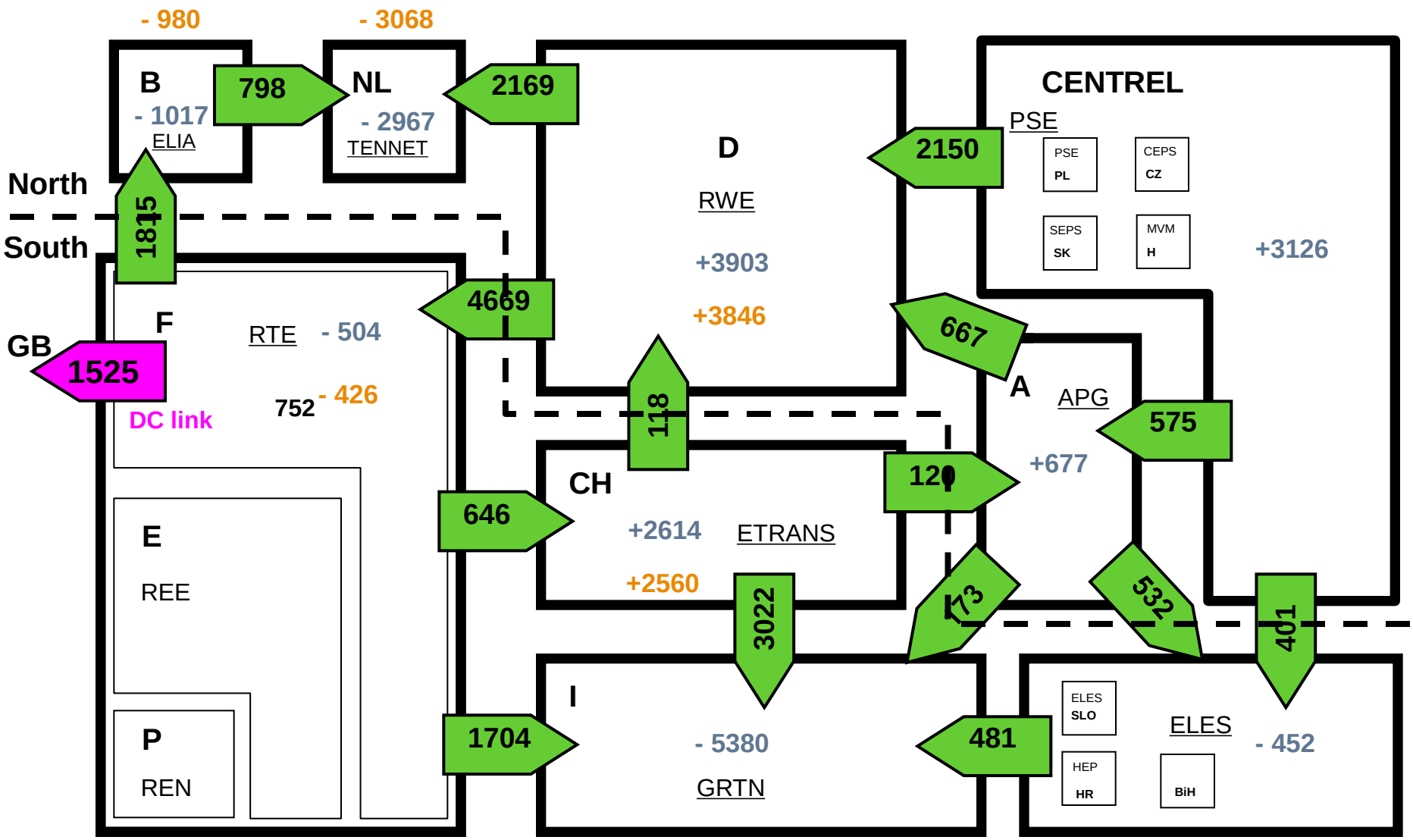
Policy

- http://ec.europa.eu/energy/gas_electricity/studies/doc/electricity/20131 0_loop-flows_study.pdf



Unannounced Wind Power in the Northern Germany

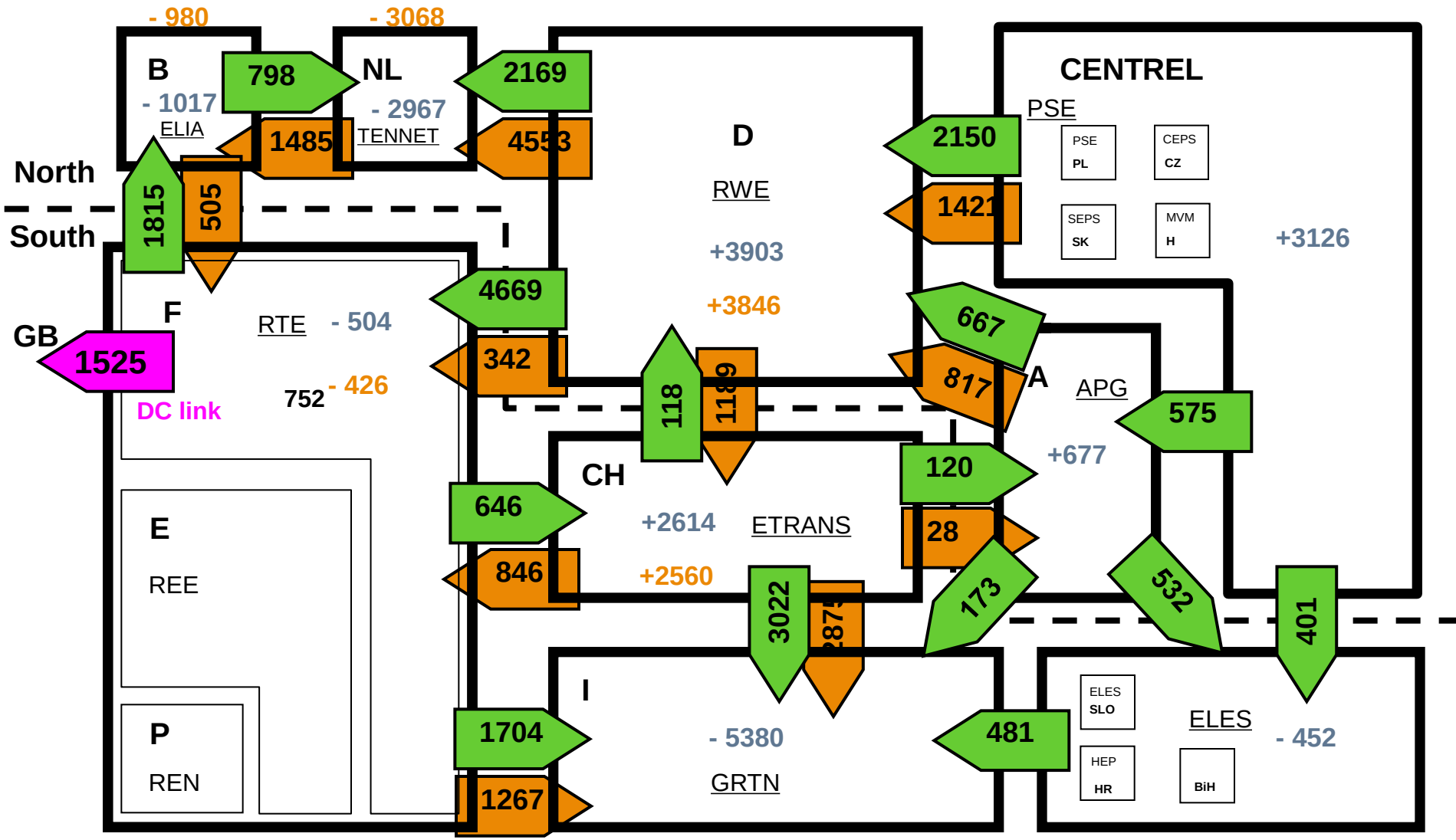
Scheduled Power Exchanges



Source: Ronnie Belmans, ELIA

Unannounced Wind Power in the Northern Germany

Scheduled Power Exchanges vs Physical Power Flows



Source: Ronnie Belmans, ELIA

Conclusions

- Planning and operating of these integrated energy systems require the inclusion of the whole system
- This includes POLICY
- Models should capture operations across the whole system
- Decentralised generation used in an integrated manner can significant value to the overall system
- Every system is different
- Social sciences research is fundamental to planning and operating an integrated energy system planning and operations

Acknowledgements:

My PhD students Steve Heinen, Sheila Nolan & Bashar Anwar

Colleagues for use of their slides