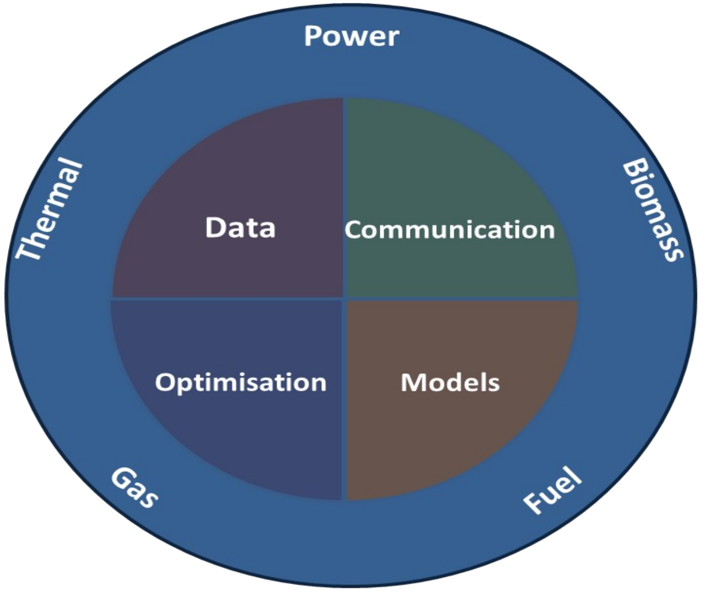
An Introduction to
Energy Systems Integration



Henrik Madsen, DTU Compute

http://www.henrikmadsen.org

http://www.smart-cities-centre.org

EERA European Energy Research Alliance

Quote by B. Obama:

(U.N. Climate Change Summit,

New York, Sept. 2014)

*We are the **first generation** affected by climate changes,*

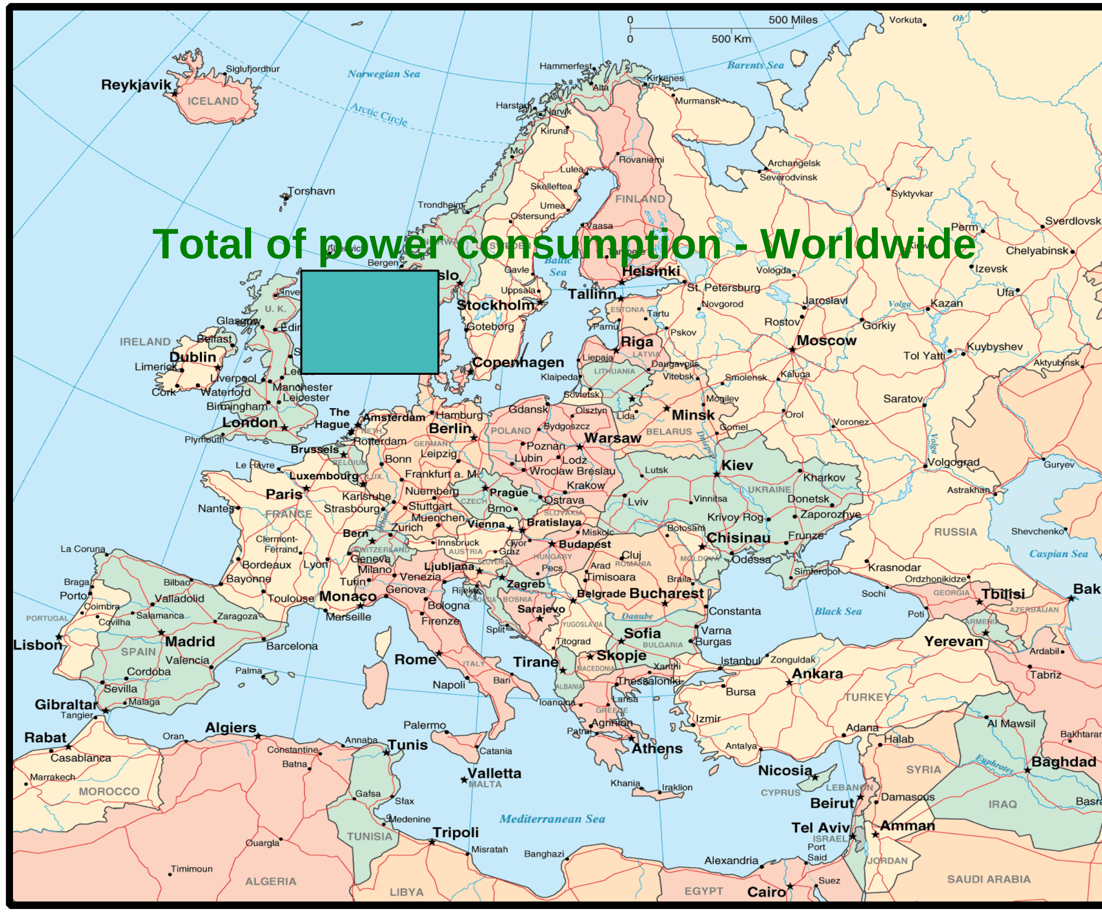
*and we are the **last generation** able to do something about it!*

Potentials and Challenges for Renewable Energy

- **Scenario**: We want to cover the worlds entire need for power using wind power.
- How large an area should be covered by wind turbines?

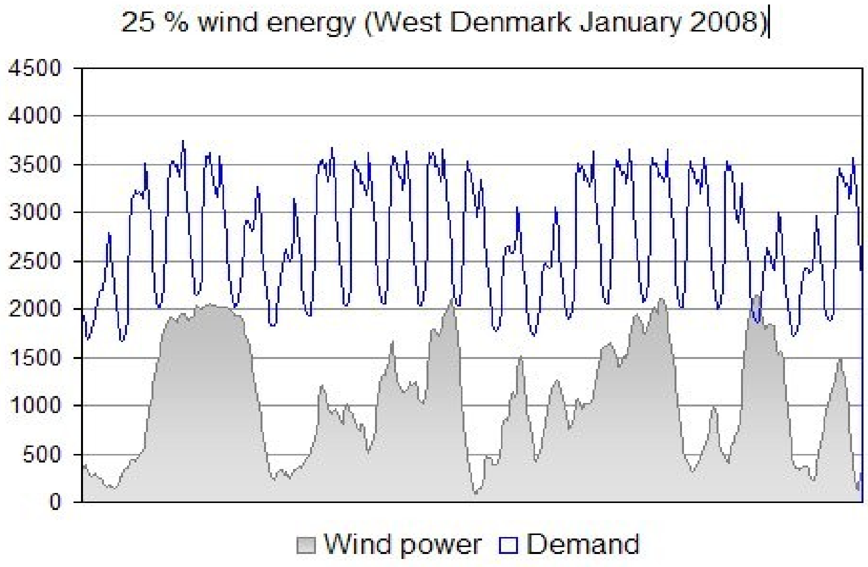
Potentials and Challenges for renewable energy

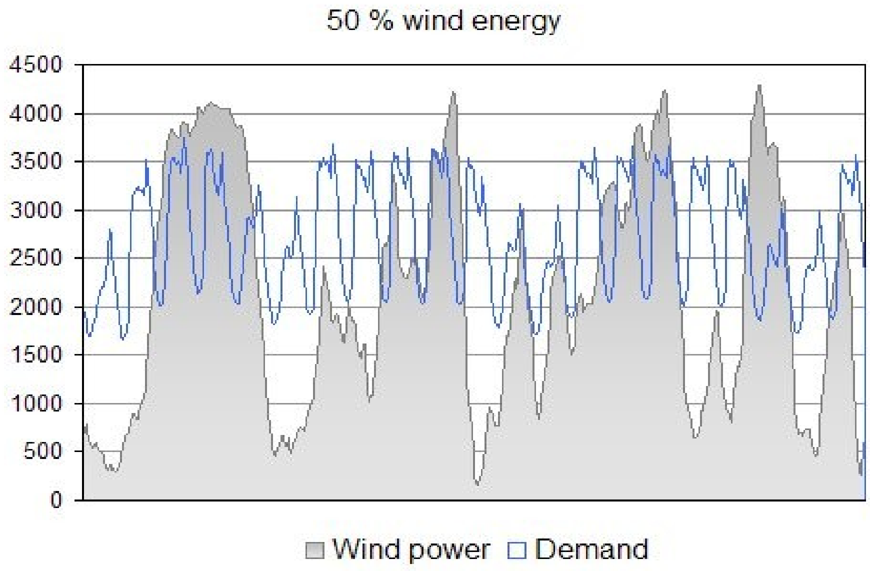
- **Scenario:** We want to cover the worlds entire need for power using wind power
- How large an area should be covered by wind turbines?
- **Conclusion**: Use intelligence ....
- Calls for **IT / Big Data / Intelligent Energy Solutions/ Energy Systems Integration**



The Danish Wind Power Case

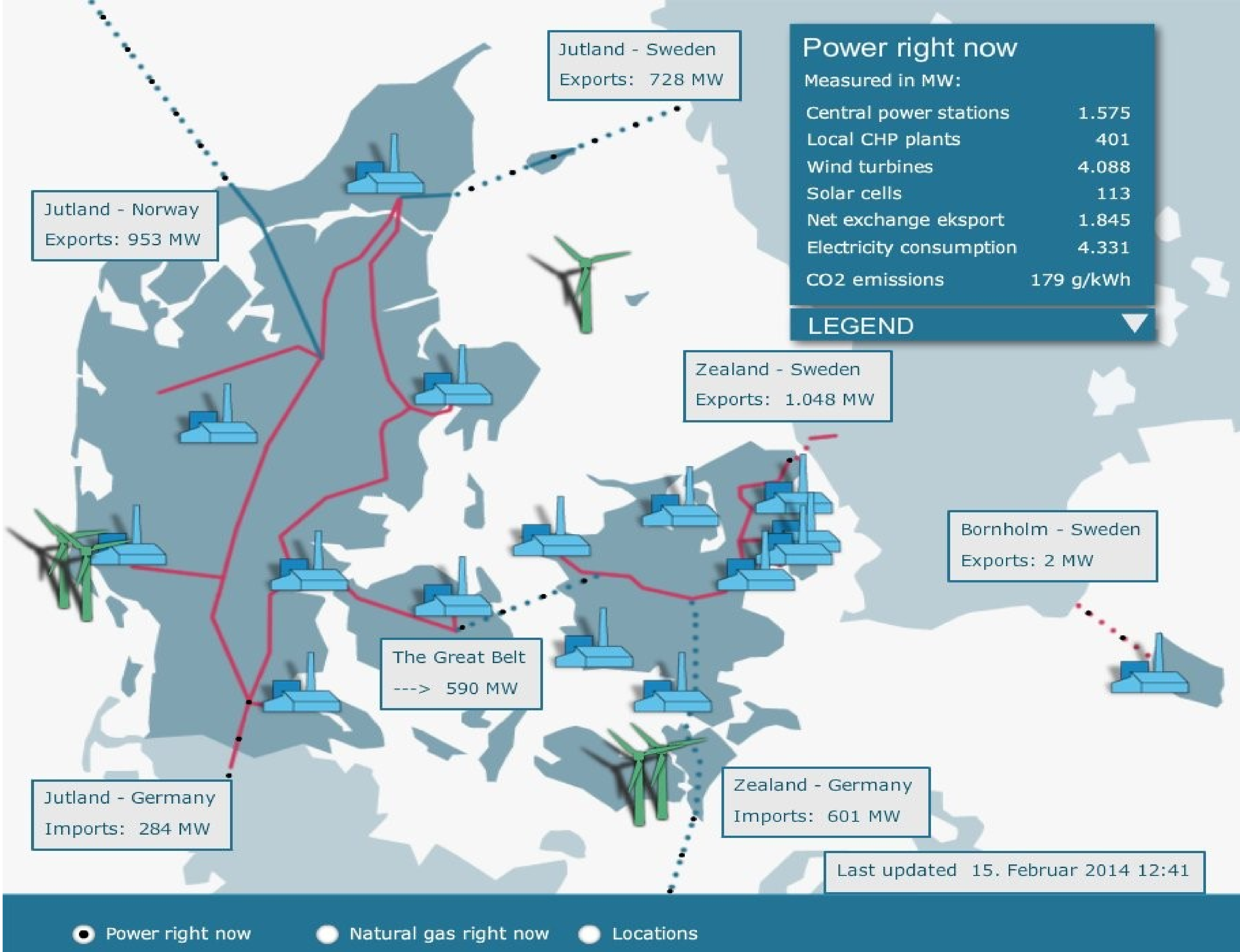
.... balancing of the power system

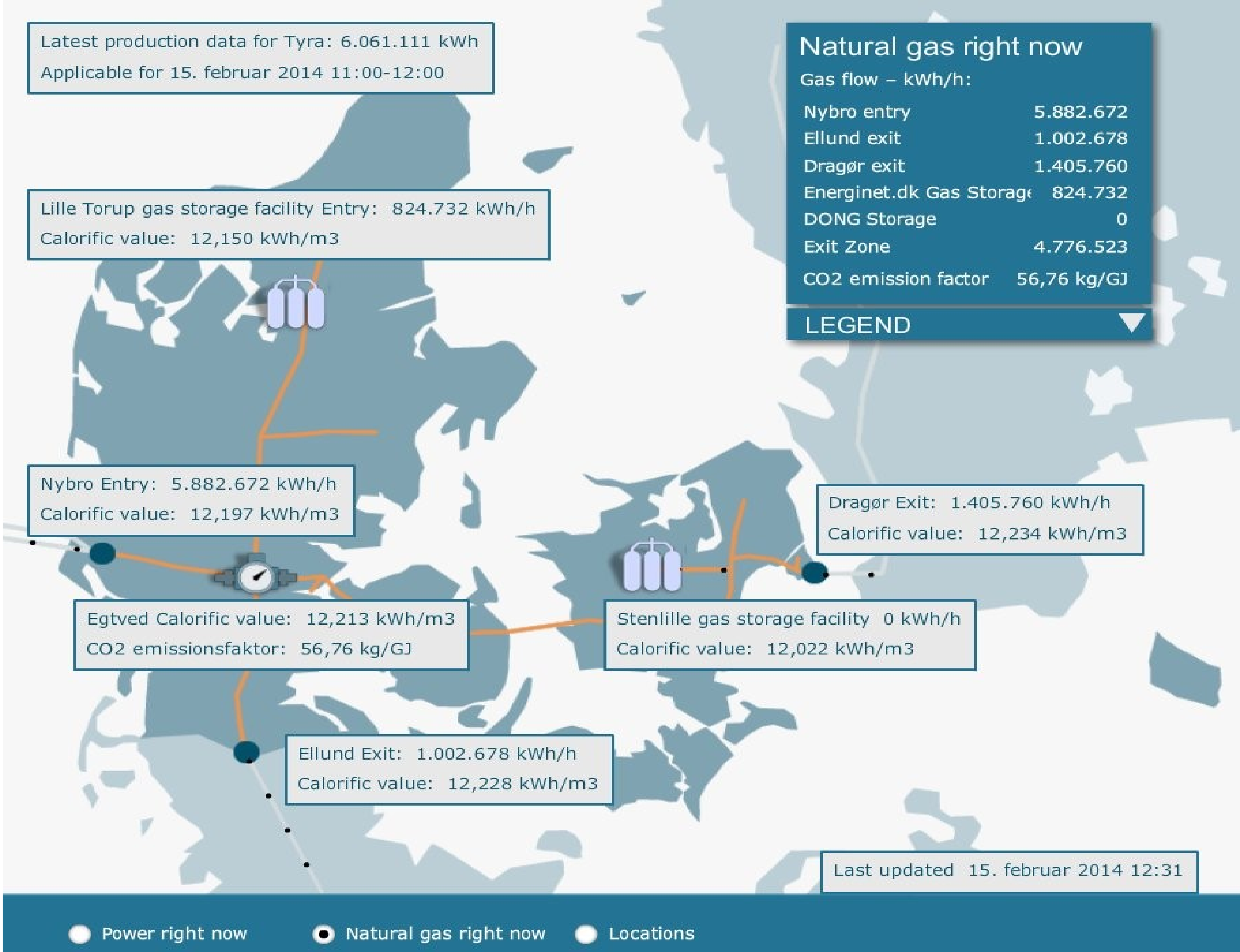




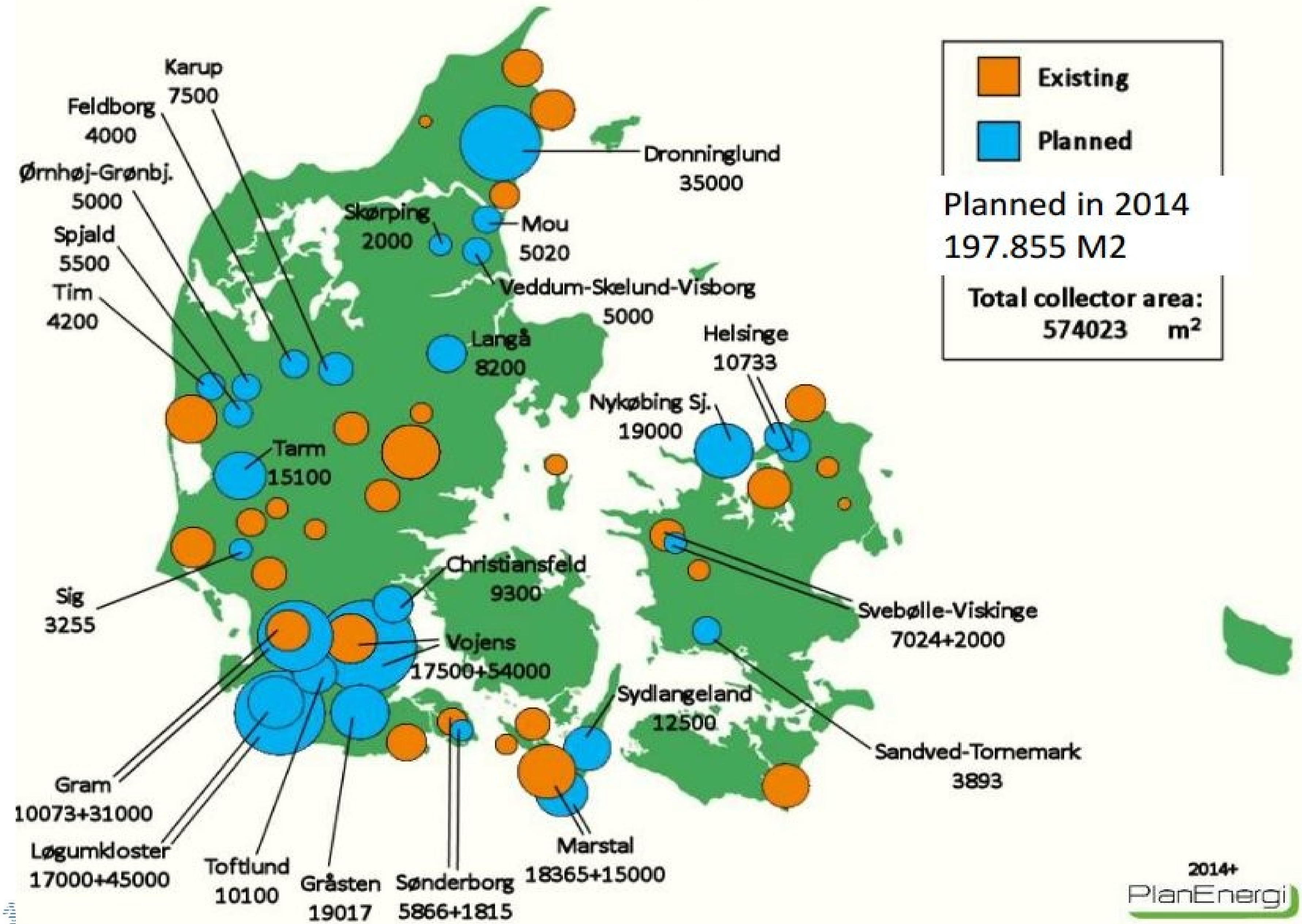
In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)

In December 2013 and January 2014 more than 55 pct of electricity load was covered by wind power. And for several days the wind power production was more than 120 pct of the power load


Power right now
Measured in MW:
Central power stations 1.575
Local CHP plants 401
Wind turbines 4.088
Solar cells 113
Net exchange eksport 1.845
Electricity consumption 4.331
CO2 emissions 179 g/kWh
LEGEND
Jutland - Sweden
Exports: 728 MW
Jutland - Norway
Exports: 953 MW
Zealand - Sweden
Exports: 1.048 MW
Bornholm - Sweden
Exports: 2 MW
The Great Belt
---> 590 MW
Jutland - Germany
Imports: 284 MW
Zealand - Germany
Imports: 601 MW
Last updated 15. Februar 2014 12:41
Power right now
Natural gas right now
Locations


Latest production data for Tyra: 6.061.111 kWh
Applicable for 15. februar 2014 11:00-12:00
Natural gas right now
Gas flow – kWh/h:
Nybro entry 5.882.672
Ellund exit 1.002.678
Dragør exit 1.405.760
Energinet.dk Gas Storage 824.732
DONG Storage 0
Exit Zone 4.776.523
CO2 emission factor 56,76 kg/GJ
LEGEND
Lille Torup gas storage facility Entry: 824.732 kWh/h
Calorific value: 12,150 kWh/m3
Nybro Entry: 5.882.672 kWh/h
Calorific value: 12,197 kWh/m3
Dragør Exit: 1.405.760 kWh/h
Calorific value: 12,234 kWh/m3
Egtved Calorific value: 12,213 kWh/m3
CO2 emissionsfaktor: 56,76 kg/GJ
Stenlille gas storage facility 0 kWh/h
Calorific value: 12,022 kWh/m3
Ellund Exit: 1.002.678 kWh/h
Calorific value: 12,228 kWh/m3
Last updated 15. februar 2014 12:31
Power right now
Natural gas right now
Locations

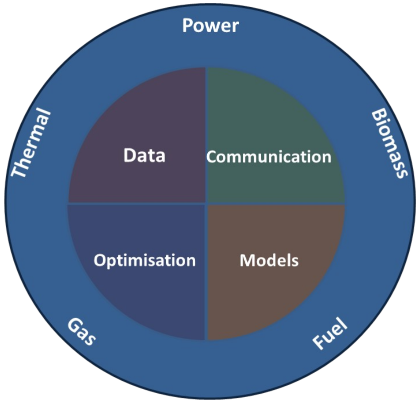
Solar district heating in Denmark



ESI – Hypothesis

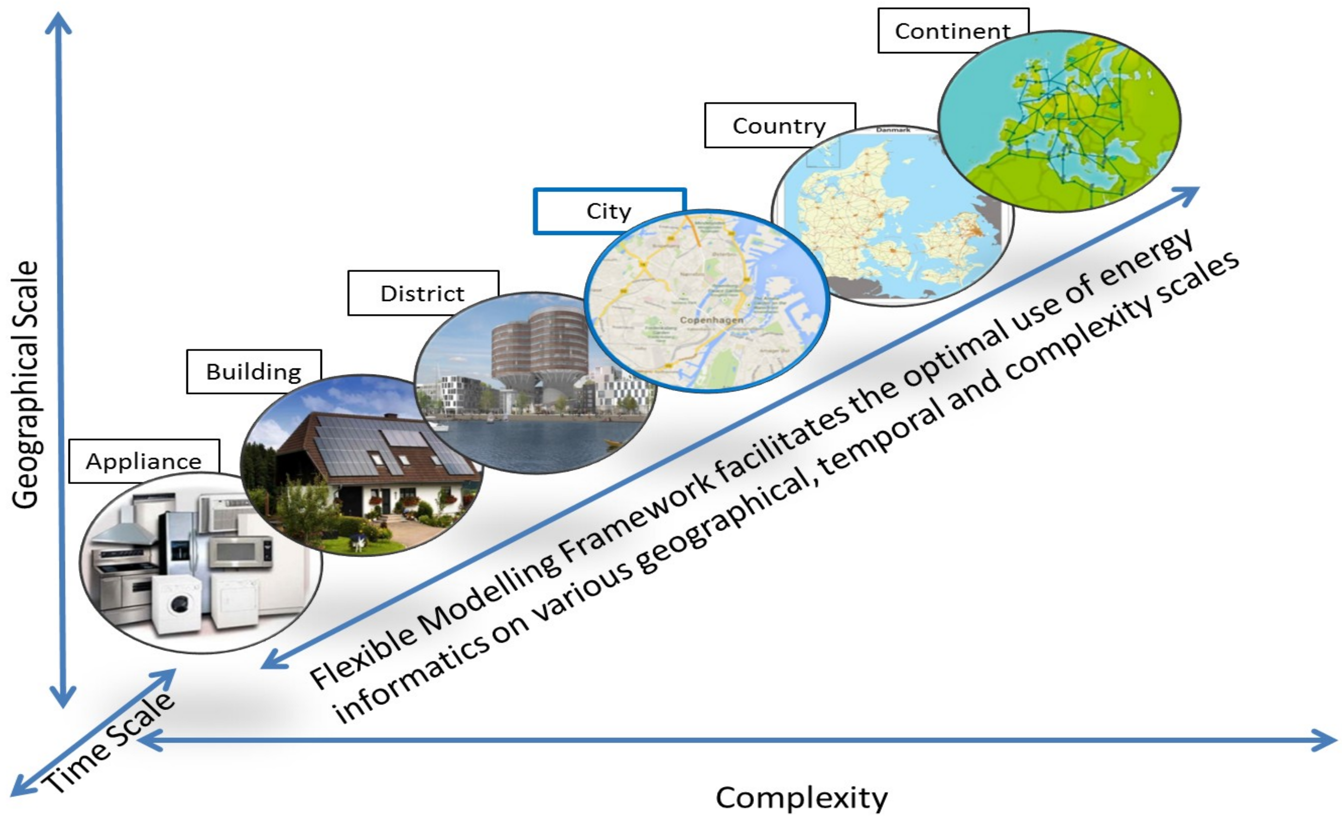
The **central hypothesis of ESI** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in we can enable very large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

Intelligent integration will (for instance) enable lossless ‘virtual’ storage on a number of different time scales.



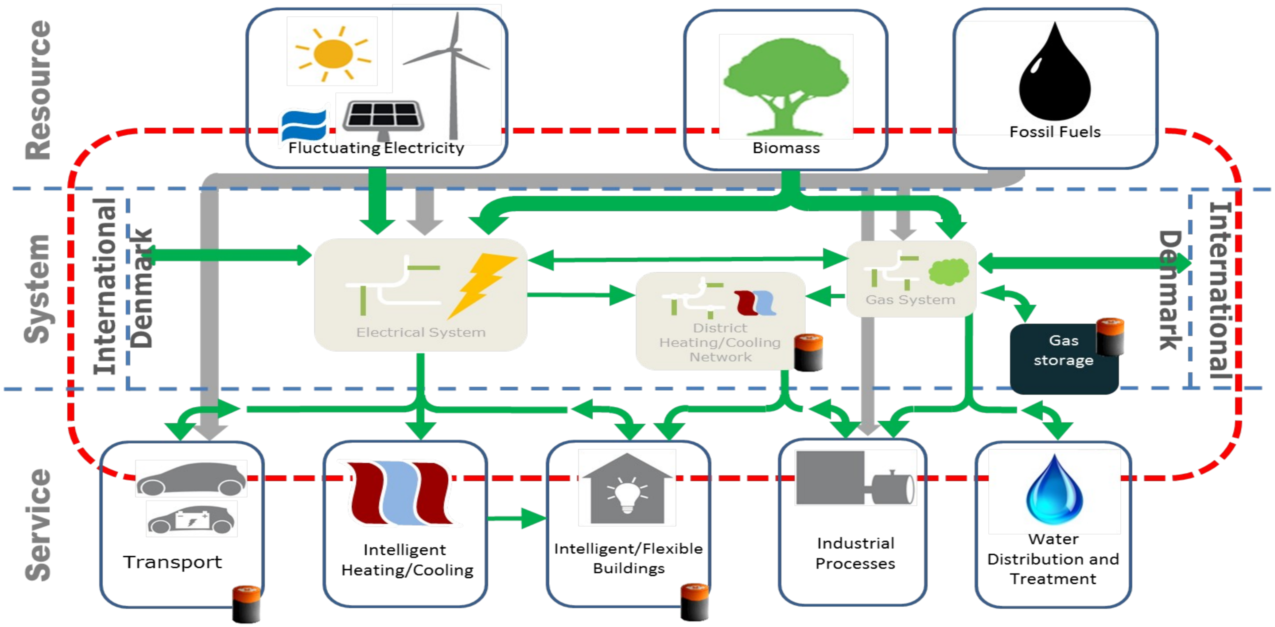
ESI – Research Challenges

To establish methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales

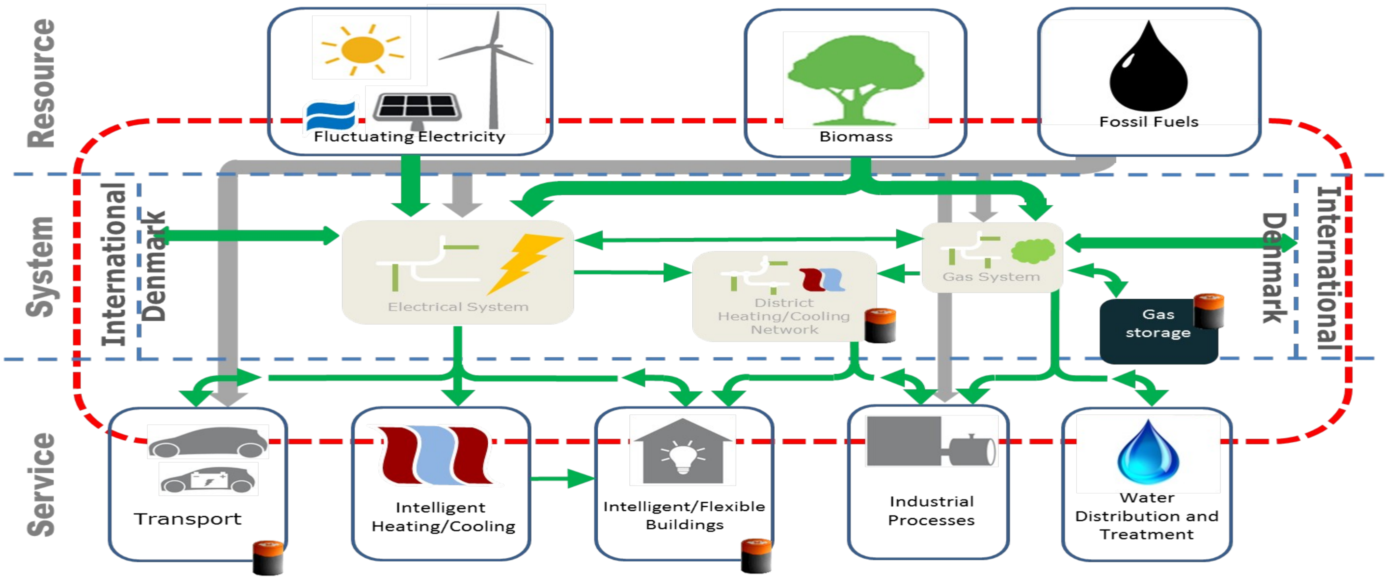


ESI – Concept Challenges

Energy Systems Integration using data and IT solutions leading to **models and methods for planning and operation of future electric energy systems.**



Example: Storage by Energy Systems Integration

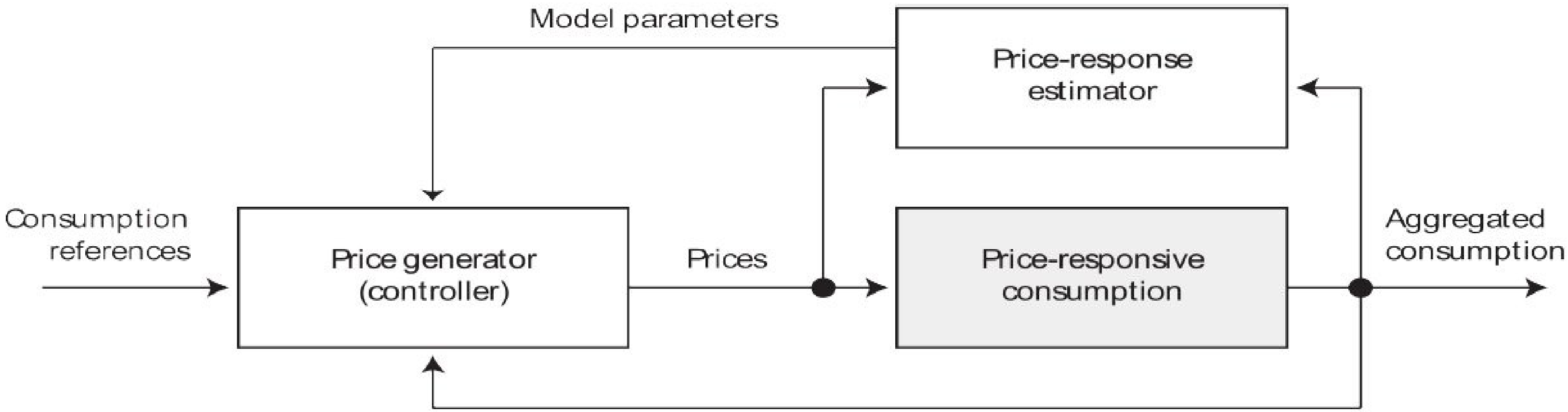


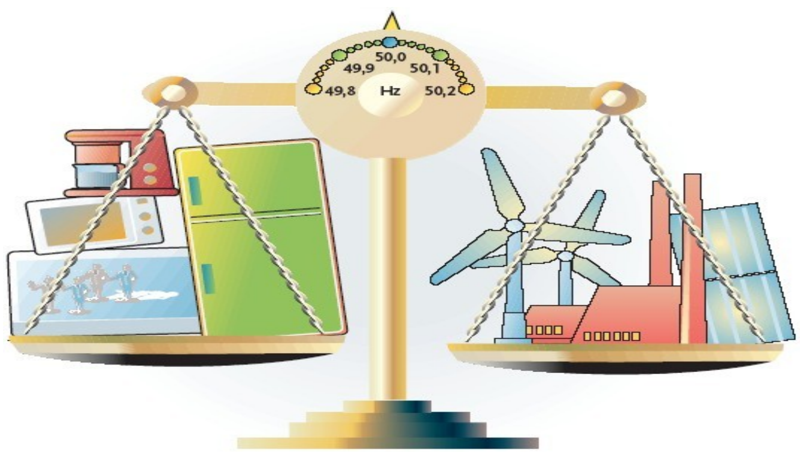
- **Denmark (2014) : 48 pct of power load by renewables (> 100 pct at some days in January)**
- **(Virtual) storage principles:**
  - Buildings can provide storage up to, say, 5-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

Case study

Control of Power Consumption (DSM)

Control of Energy Consumption

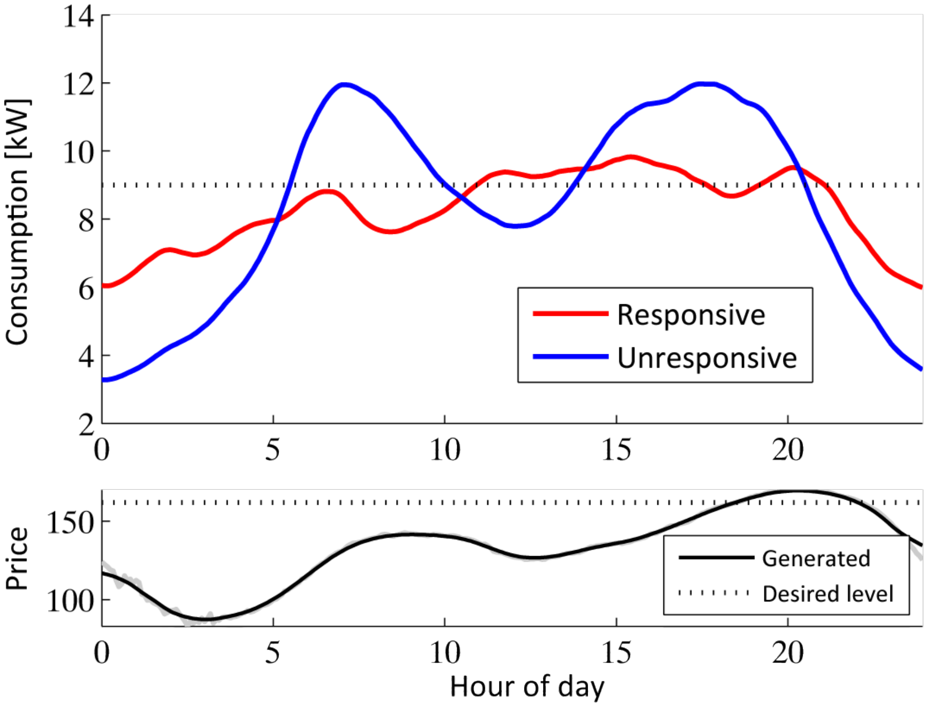




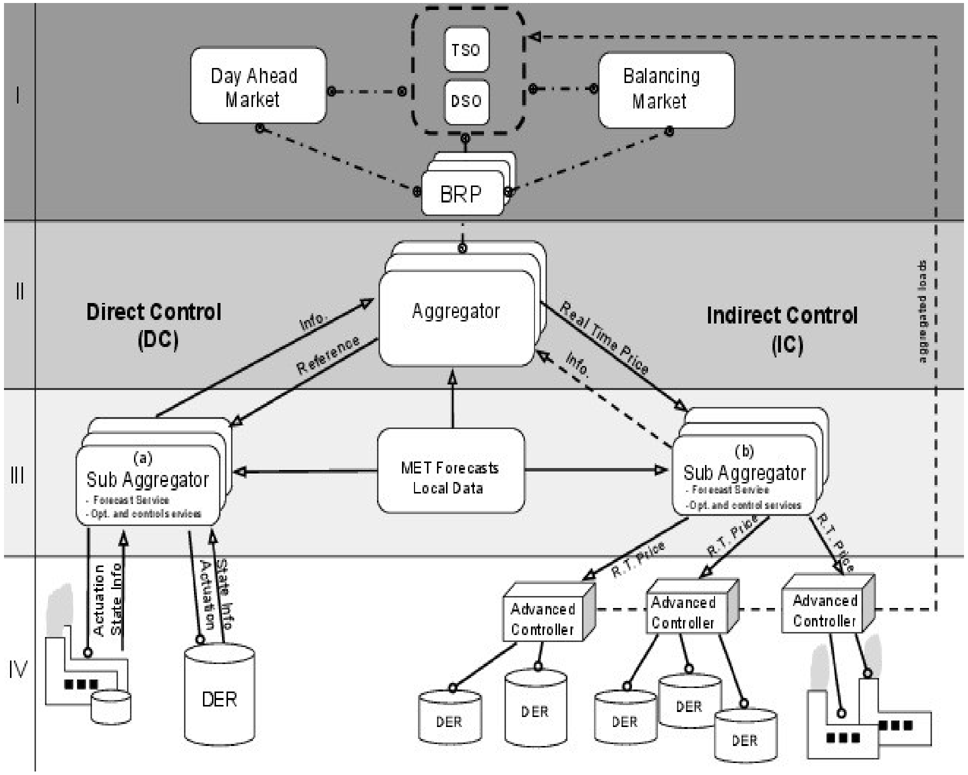
Control performance

Considerable **reduction in peak consumption**

Mean daily consumption shift



Control and Optim. Challenges



New Wiley Book: Control of Electric Loads in Future Electric Energy Systems, 2014

Day Ahead:

Stoch. Programming based on eg. Scenarios

Cost: Related to the market (one or two levels)

Direct Control:

Actuator: **Power**

Two-way communication

Models for DERs are needed

Constraints for the DERs (calls for state est.)

Contracts are complicated

Indirect Control:

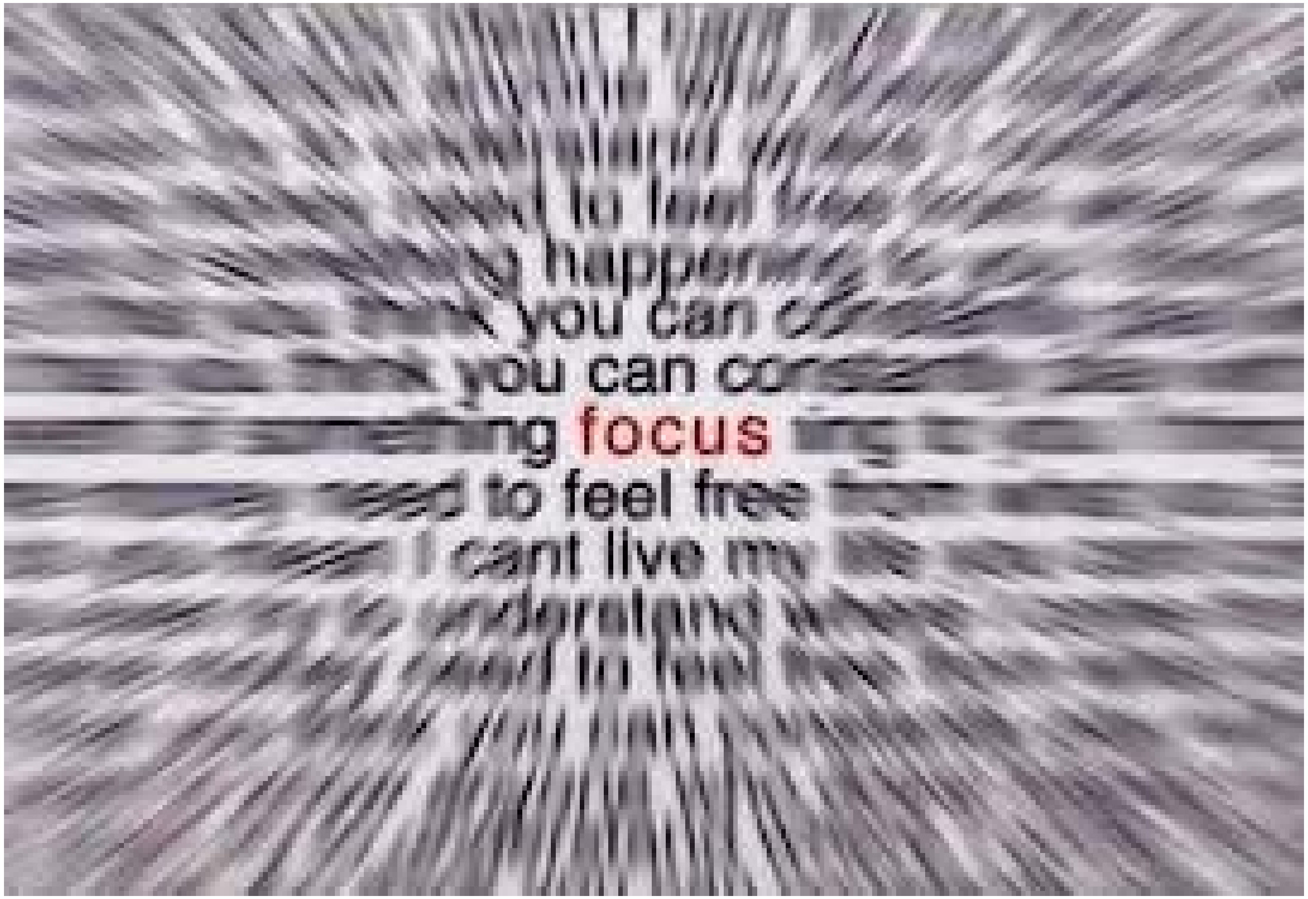
Actuator: **Price**

Cost: E-MPC at **low (DER) level**, One-way communication

Models for DERs are not needed

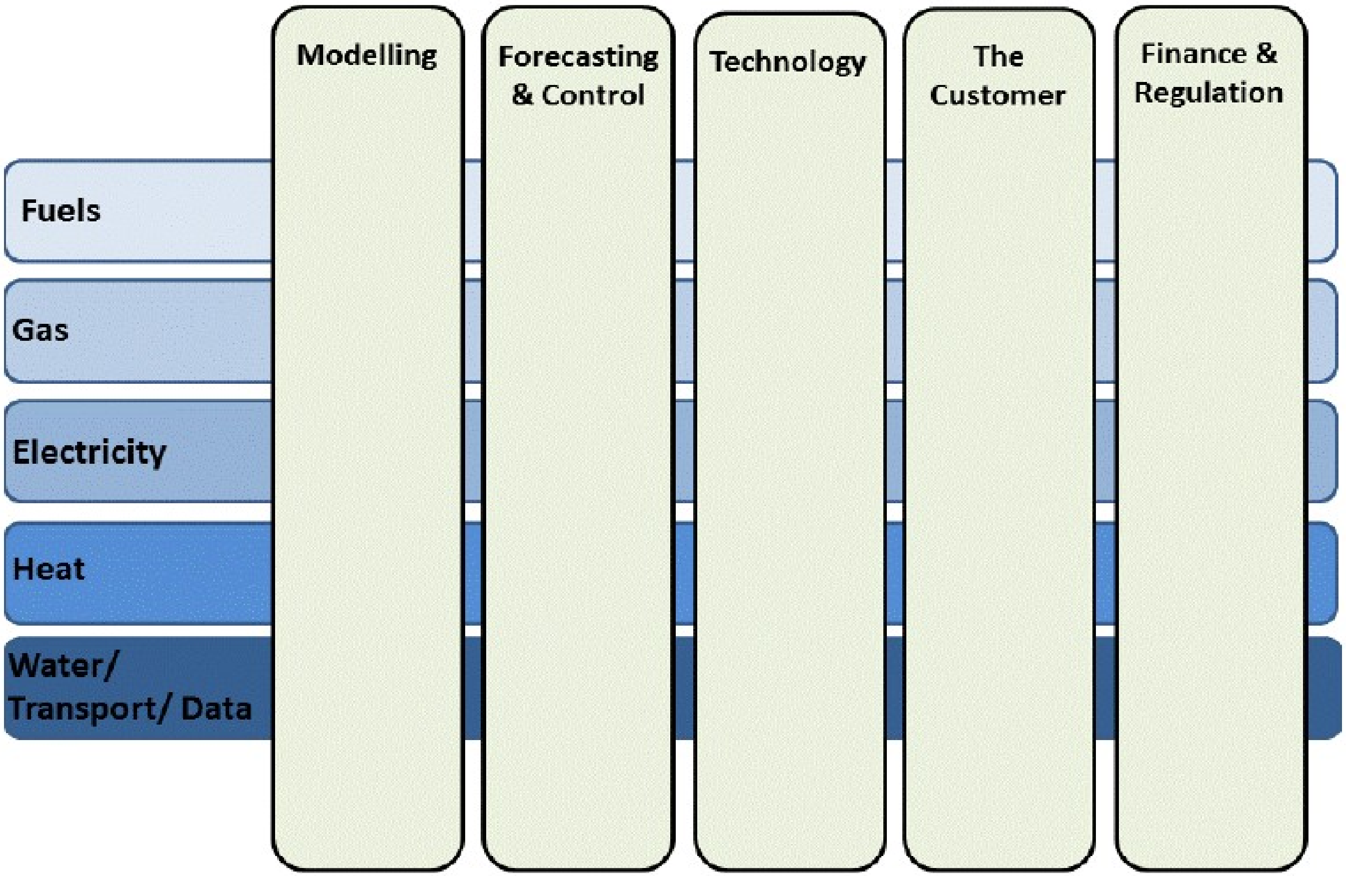
Simple 'contracts'

How can we make a difference ?



Proposal (UCD, DTU, KU Leuven):

ESI Joint Program as a part of European Research (EERA)



International Institute™ for Energy Systems Integration

Addressing energy challenges through global collaboration

Vision: A global community of scholars and practitioners from leading institutes engaged in efforts to enable highly integrated, flexible, clean, and efficient energy systems

Objectives: Share ESI knowledge and Experience: Coordination of R&D activities: Education and Training Resources

Activities 2014

- Feb 18-19 Workshop (Washington)
- May 28-29 Workshop (Copenhagen)
- July 21 – 25, ESI 101 (Denver)
- Nov 17th Workshop (Kyoto)

Activities 2015

- Dublin, Hawaii, Brussels, Australia

NREL NATIONAL RENEWABLE ENERGY LABORATORY

Pacific Northwest NATIONAL LABORATORY

EPRI ELECTRIC POWER RESEARCH INSTITUTE

UCD DUBLIN

DTU

KU LEUVEN

Conclusions / Statements for discussion

(I was asked to be a bit provocative)

- **Energy Systems Integration can provide virtual and lossless storage solutions (so maybe we should put less focus on physical storage solutions)**
- **Energy Systems Integration might be able to solve many of the problems Europe now is trying to solve by Super Grids (some of these huge investments might not be needed)**
- **Europe should put less focus on super-grids – I assume that ESI can solve a major part of the issues (the planned investements are huge – and maybe we don't need them)**
- **Focus on zero emission buildings – and less on zero energy buildings (the same holds supermarkets, wastewater treatment plants, etc.)**
- **District heating (or cooling) provide virtual storage on the essential time scale (up to a few days)**
- **We see a large potential in Demand Side Management. Automatic solutions and end-user focus is important**
- **We see a large potential in coupling cooling (eg. for comfort) and heating systems using DH networks**
- **We see large problems with the tax and tariff structures in many countries (eg Denmark). Coupling to prices for carbon capture could be advantageous.**
- **Markets and pricing principles need to be reconsidered; we see an advantage of having a physical link to the mechanism (eg. nodal pricing, capacity markets)**