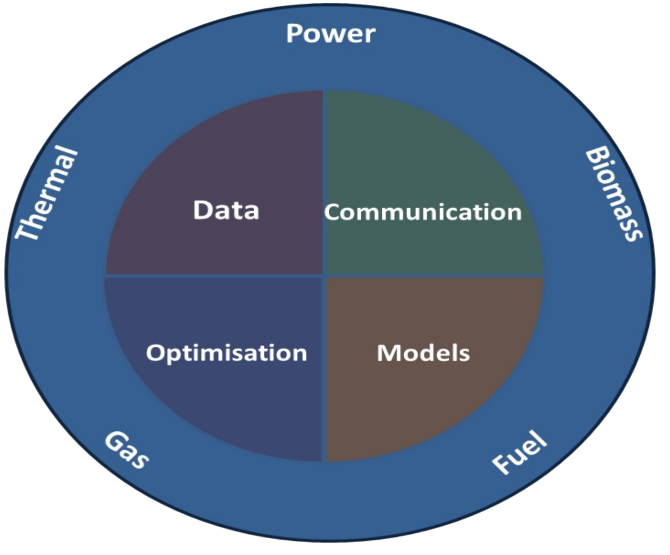
CITIES

Center for IT-Intelligent Energy Systems in Cities



Henrik Madsen, DTU Compute

http://www.henrikmadsen.org

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

CITIES
Centre for IT Intelligent Energy Systems

Quote by B. Obama at the Climate Summit 2014 in New York:

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

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

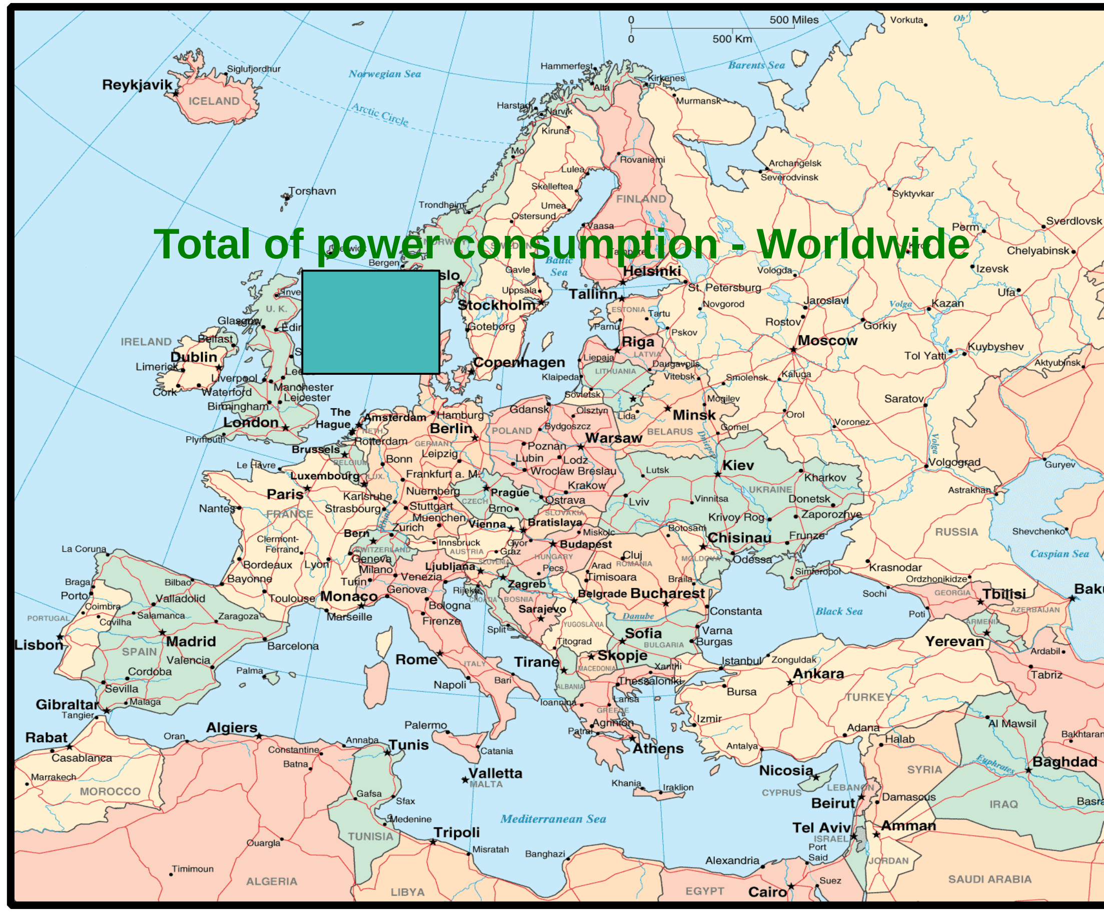
CITIES
Centre for IT Intelligent Energy Systems

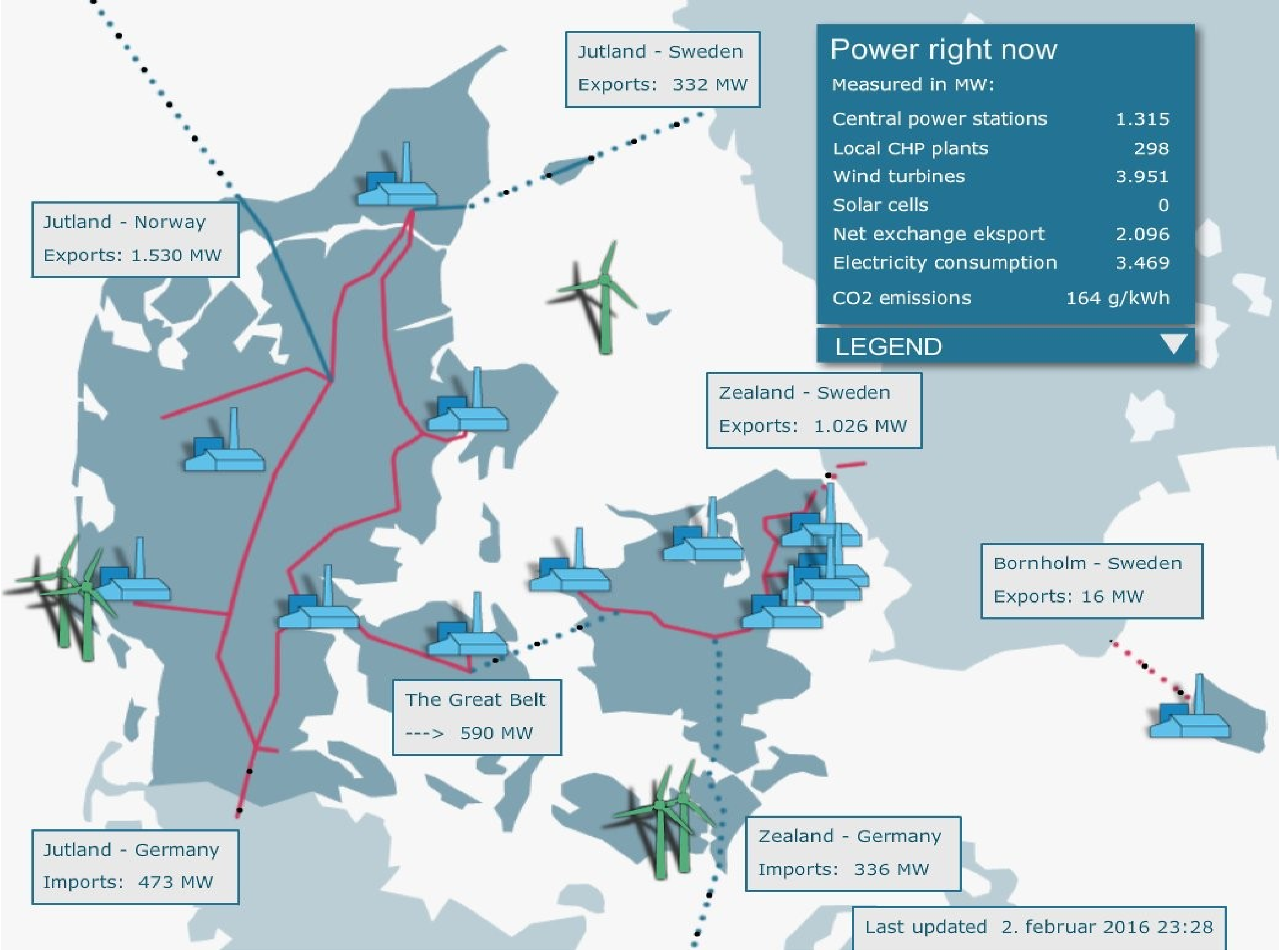
Potentials and Challenges for renewable energy

- **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

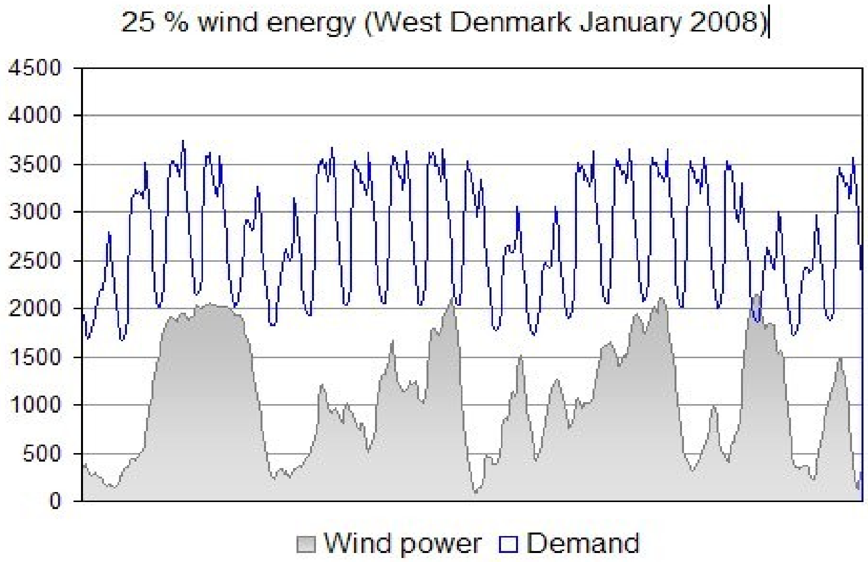
- **Scenario:** We want to cover the worlds entire need for power using wind power
- How large an area should be covered by wind turbines?
- **Conclusion**: Use intelligence ....
- Calls for **IT / Big Data / Smart Energy/Cities Solutions/ Energy Systems Integration**

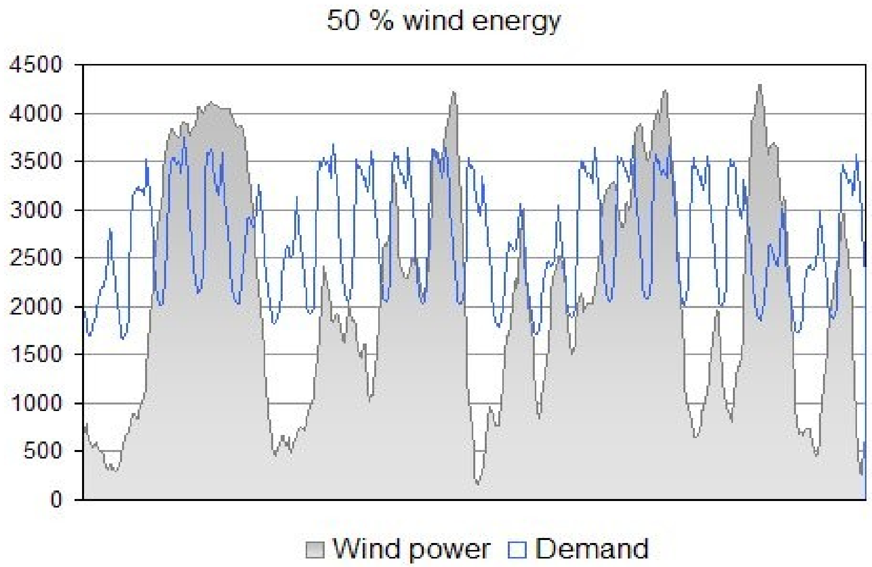



Jutland - Sweden
Exports: 332 MW
Power right now
Measured in MW:
Central power stations 1.315
Local CHP plants 298
Wind turbines 3.951
Solar cells 0
Net exchange eksport 2.096
Electricity consumption 3.469
CO2 emissions 164 g/kWh
LEGEND
Jutland - Norway
Exports: 1.530 MW
Zealand - Sweden
Exports: 1.026 MW
Bornholm - Sweden
Exports: 16 MW
The Great Belt
---> 590 MW
Jutland - Germany
Imports: 473 MW
Zealand - Germany
Imports: 336 MW
Last updated 2. februar 2016 23:28

The Danish Wind Power Case

.... balancing of the power system





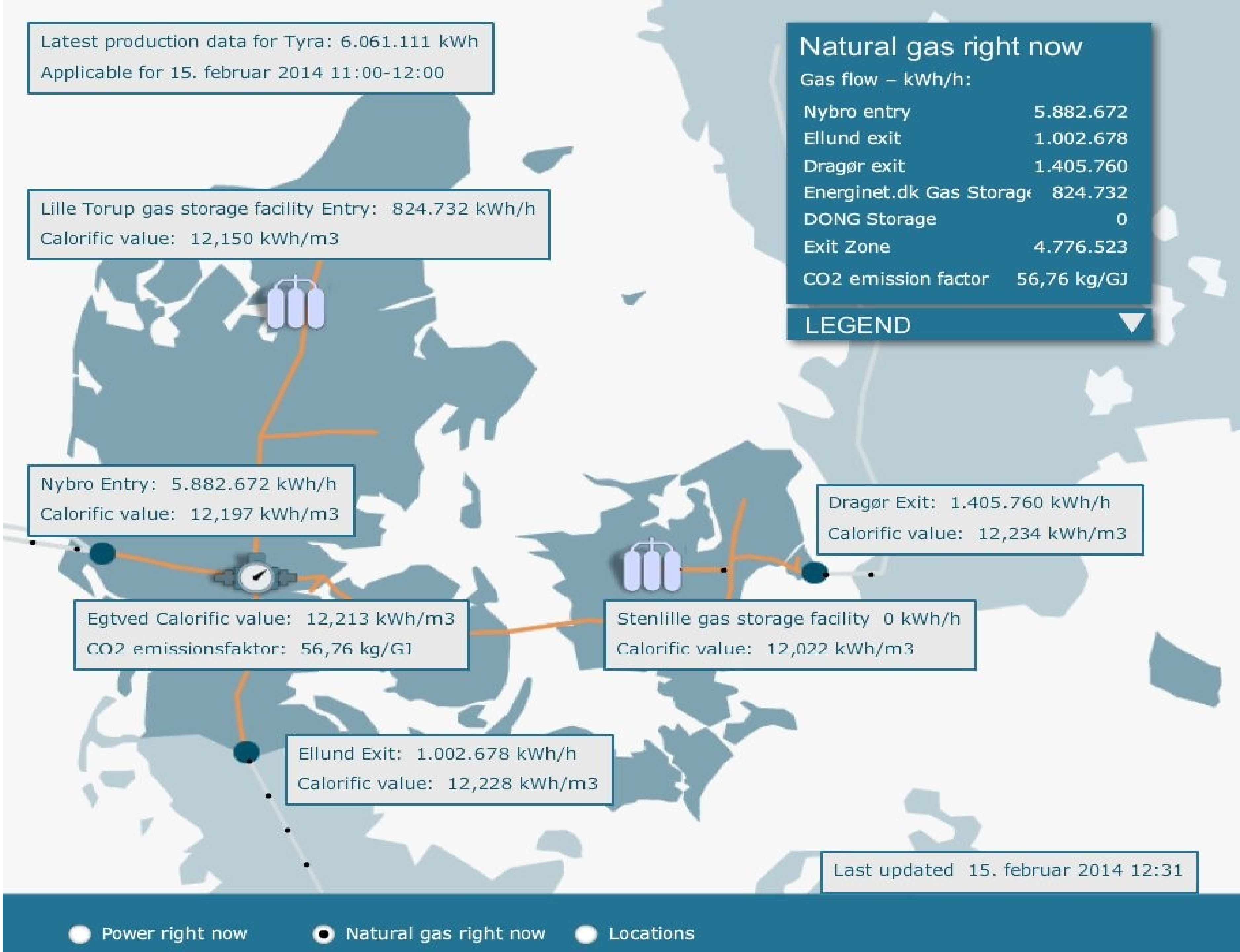
In 2008 wind power did cover the entire demand of electricity in 200 hours (West DK)

In 2015 more than 42 pct of electricity load was covered by wind power.

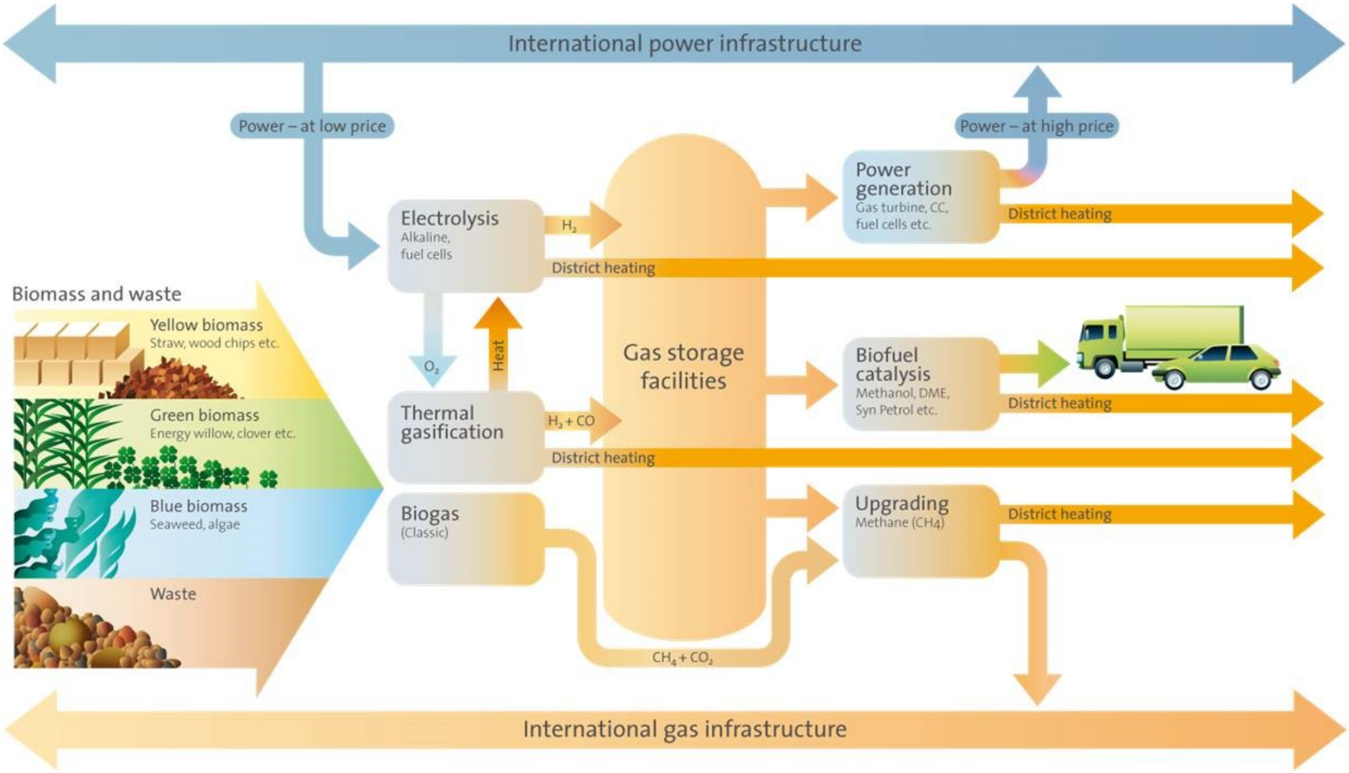
For several days the wind power production was more than 100 pct of the power load.

July 10th, 2015 more than 140 pct of the power load was covered by wind power

CITIES
Centre for IT Intelligent Energy Systems


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

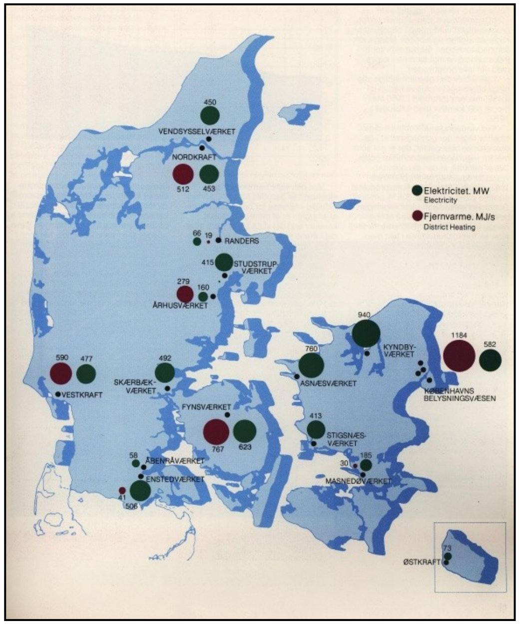
Gas system is very important ... (Storage capacity approx. 40 Tesla Powerwalls in each house)



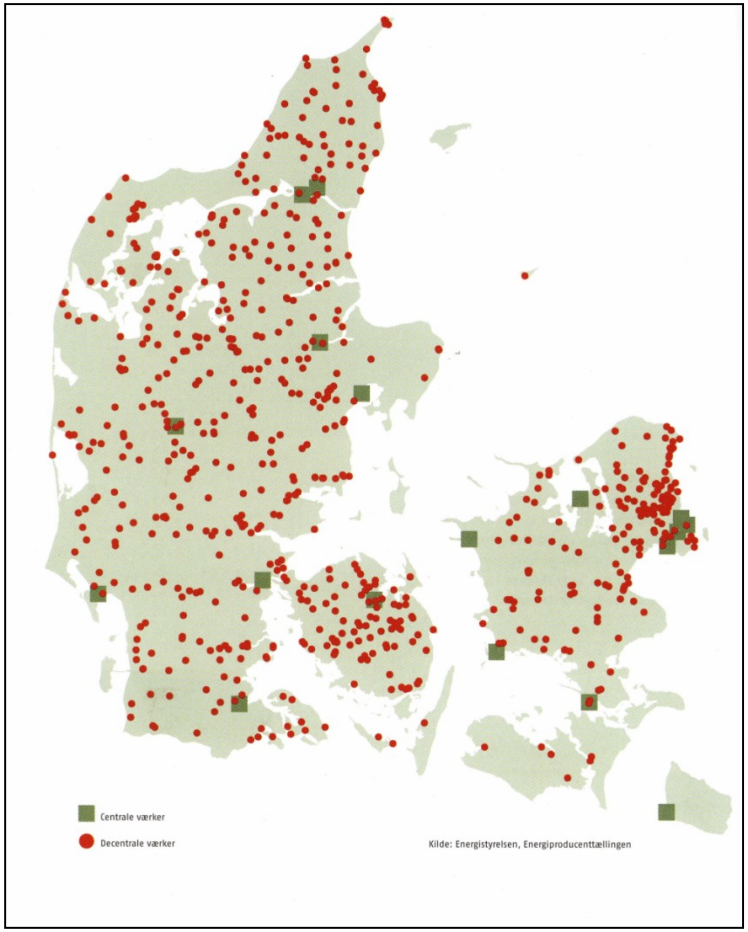
Meibom, P.; Hilger, K.B.; Madsen, H.; Vinther, D., "Energy Comes Together in Denmark: The Key to a Future Fossil-Free Danish Power System," *Power and Energy Magazine, IEEE* , vol.11, no.5, pp.46-55, Sept. 2013.

From large central plants to Combined Heat and Power (CHP) production

1980



Today

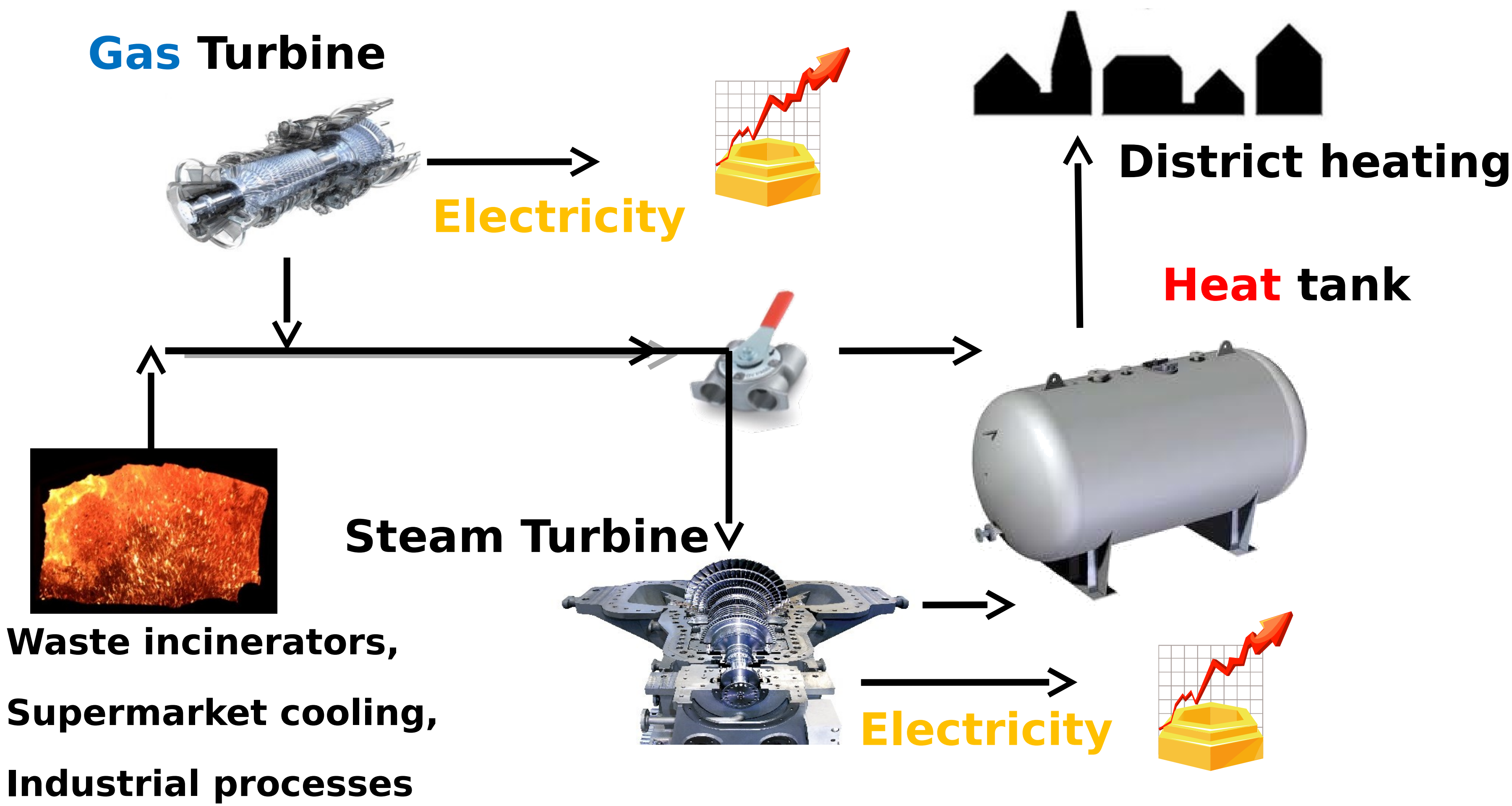


From a few big power plants to many small ***combined heat and power*** *plants – however most of them based on coal*

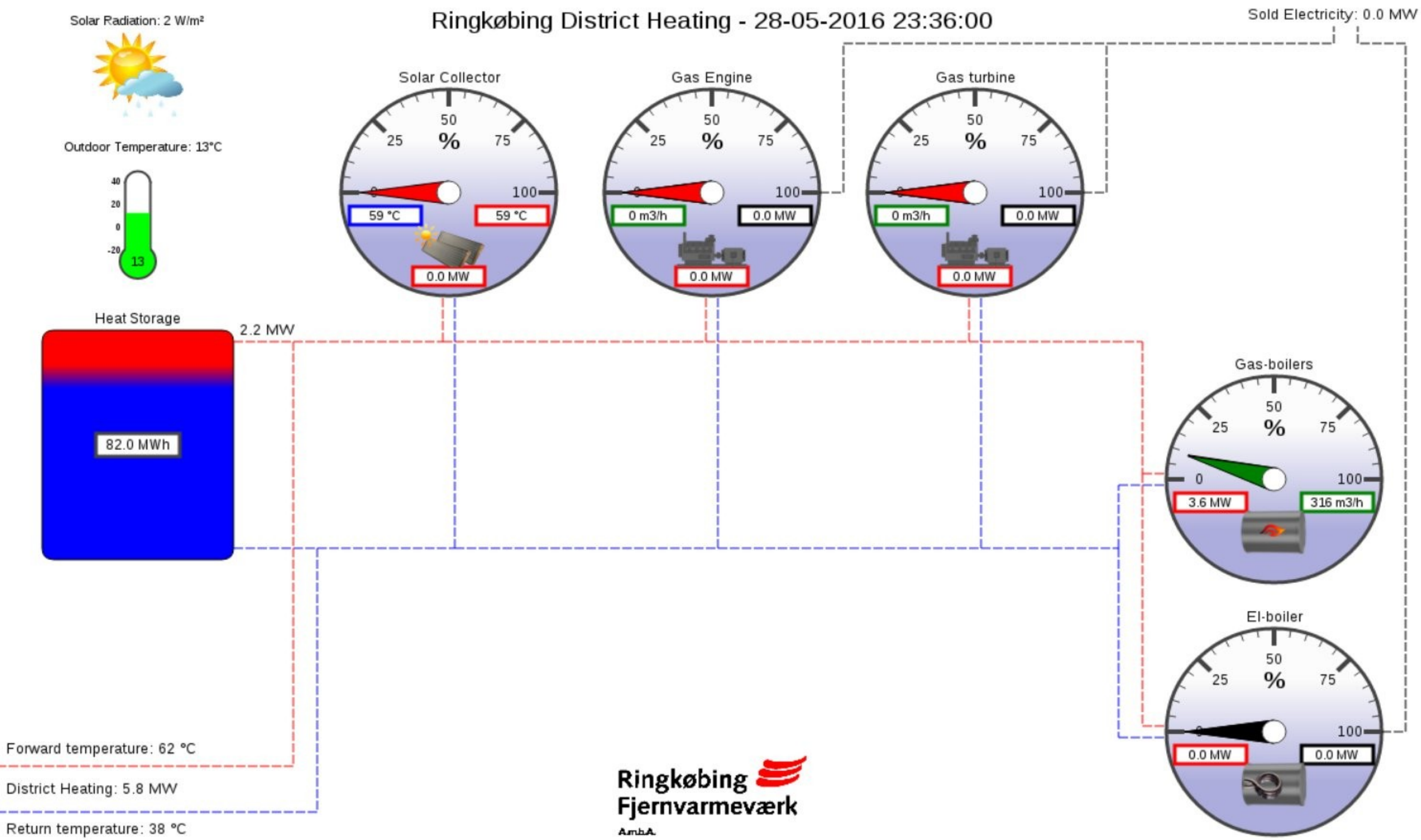
DK has enough excess heat to cover the entire need for heating .... but ...

CHP and Integrated Energy Systems

(Paradigmatic example - Denmark)

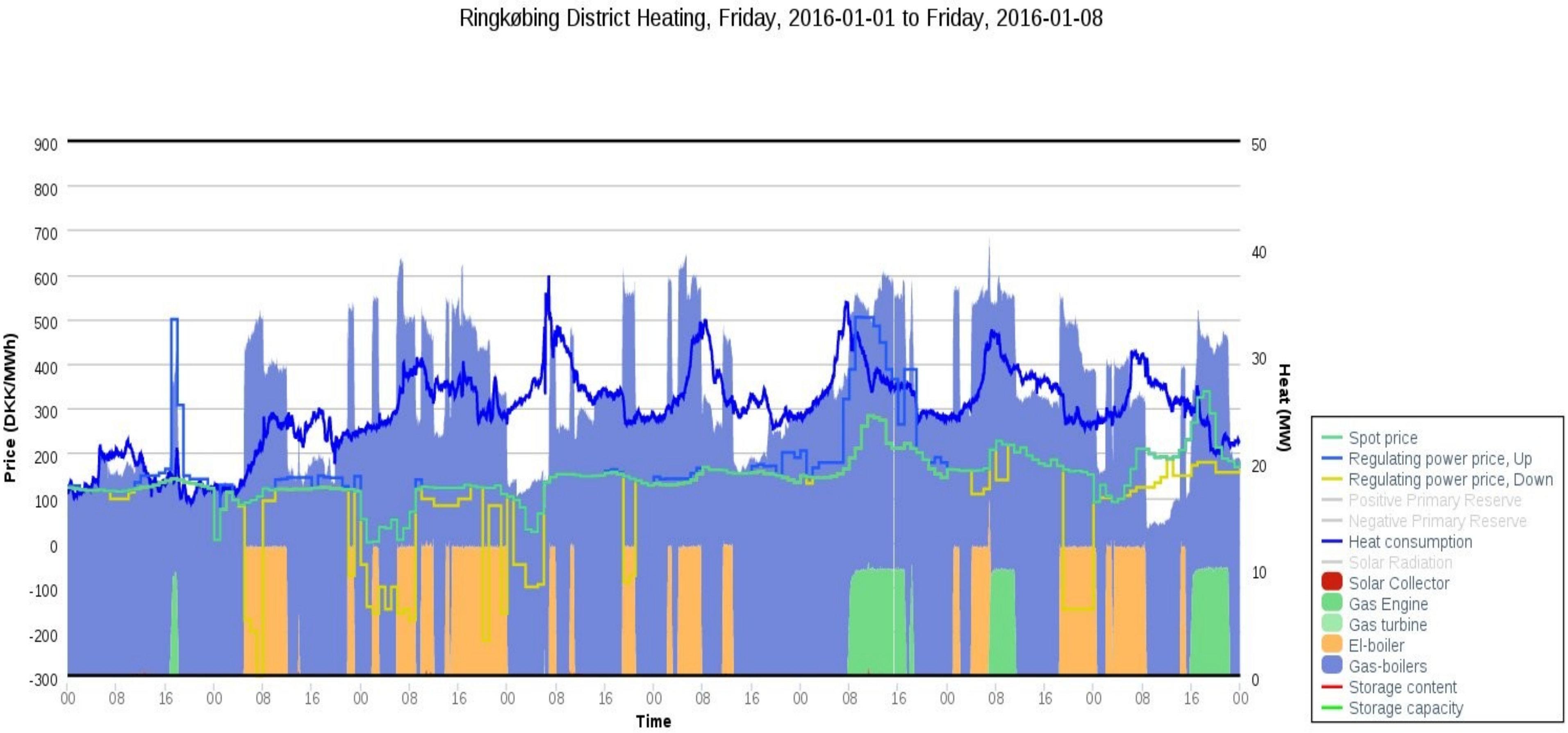


Flexibility – Ringkøbing CHP



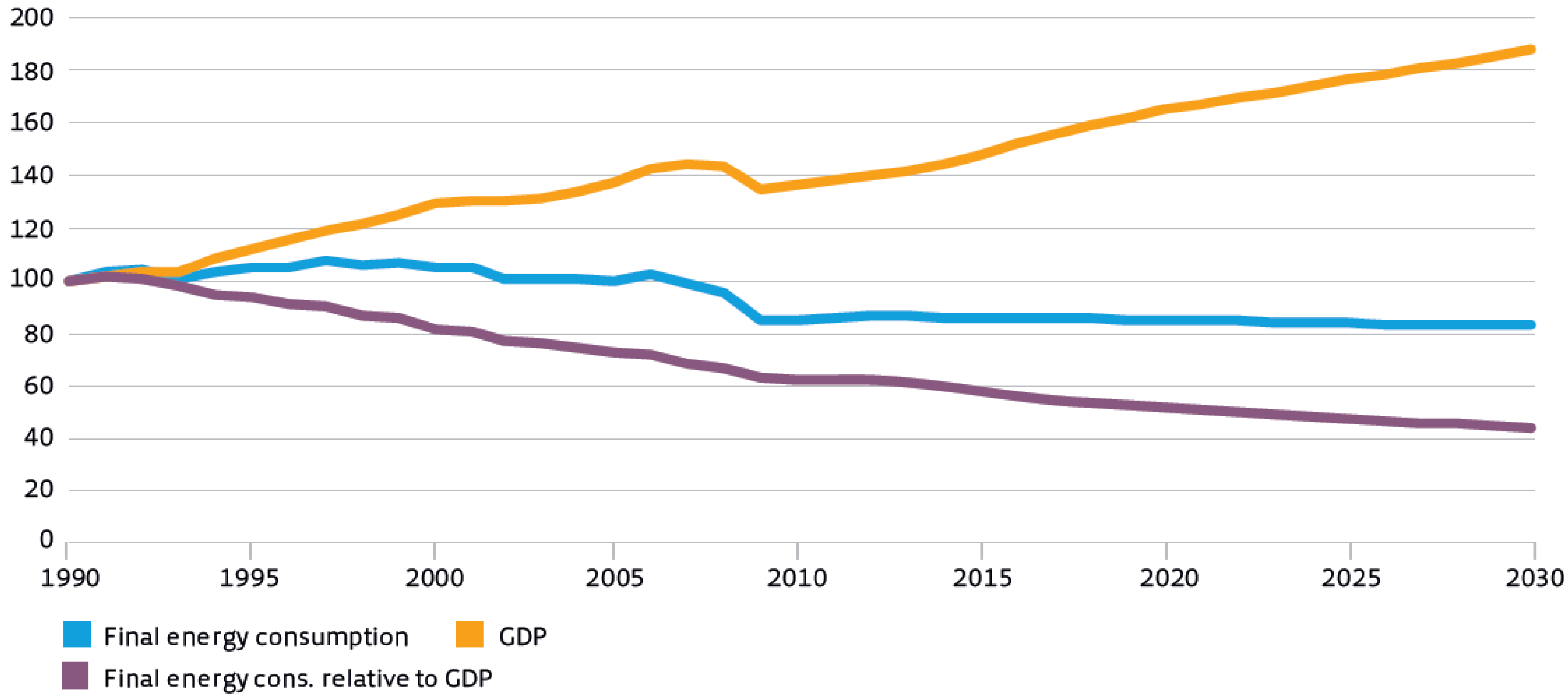
CITIES
Centre for IT Intelligent Energy Systems

Flexibility – Ringkøbing CHP



CITIES
Centre for IT Intelligent Energy Systems

What has since been achieved: De-coupling of consumption and GDP growth



Source: Energy Policy in Denmark. Danish Energy Agency. December 2012

Danish Climate and Energy Policy / Goals

- **2020: 50 pct of electricity from wind power, and 35 pct of total energy consumption from renewable sources**
- **2035: 100 pct of electricity and heating from renewable sources**
- **2050: 100 pct of all (electricity, heating, transport, industry) from renewable sources**

CITIES

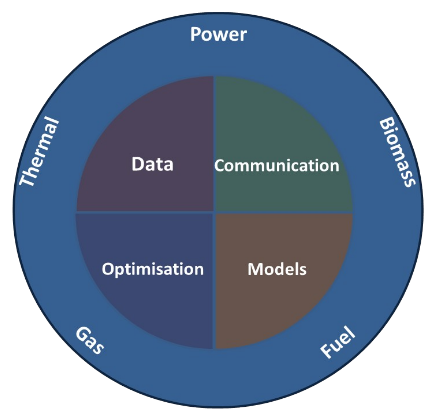
Assumptions, Goals and Methods

CITIES
Centre for IT Intelligent Energy Systems

CITIES – 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.

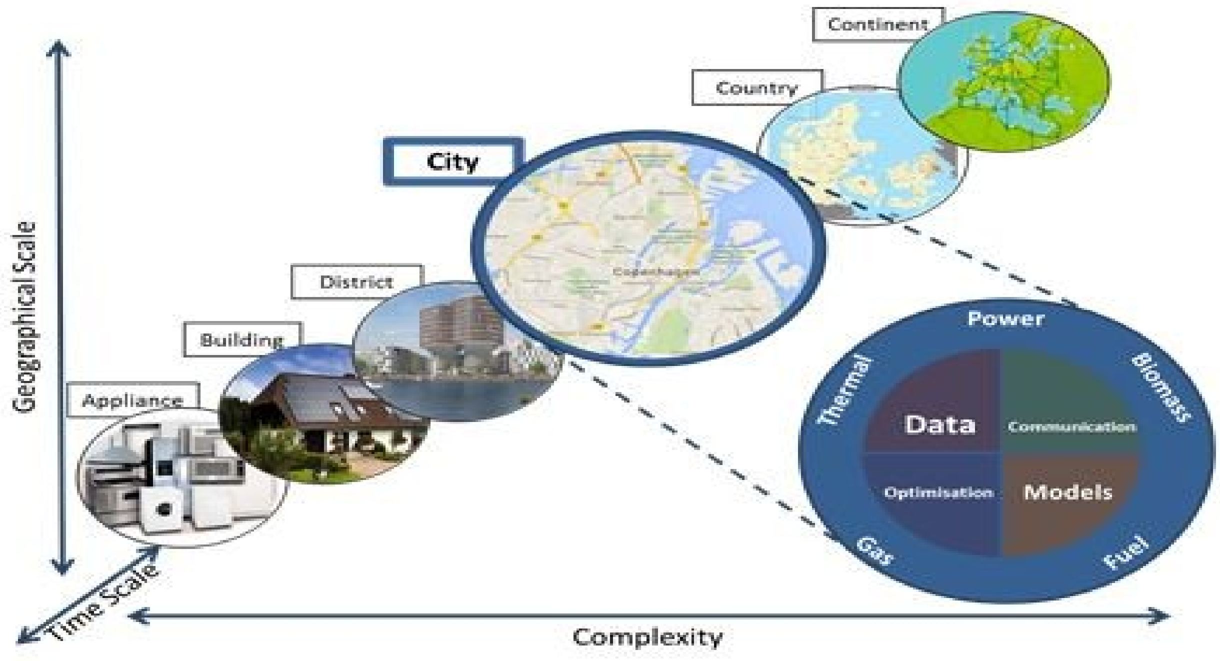
Intelligent integration will (for instance) enable lossless 'virtual' storage on a number of different time scales.



CITIES
Centre for IT Intelligent Energy Systems

CITIES – Research Challenges

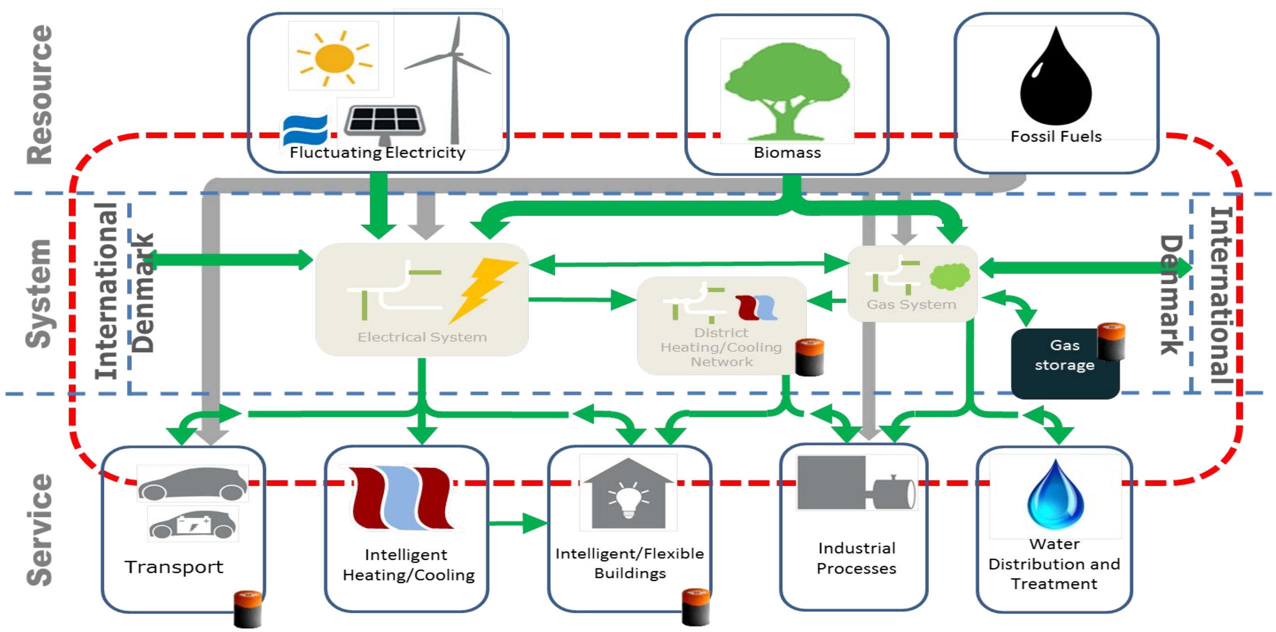
To establish methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales



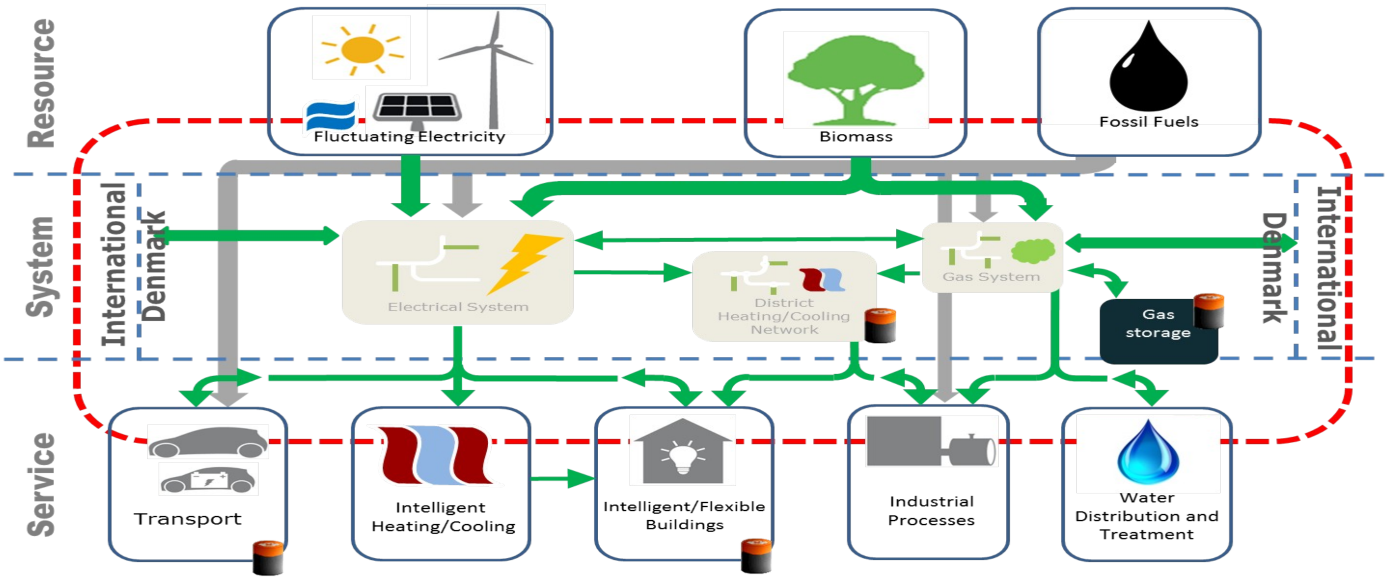
CITIES – Concept Challenges

DTU

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

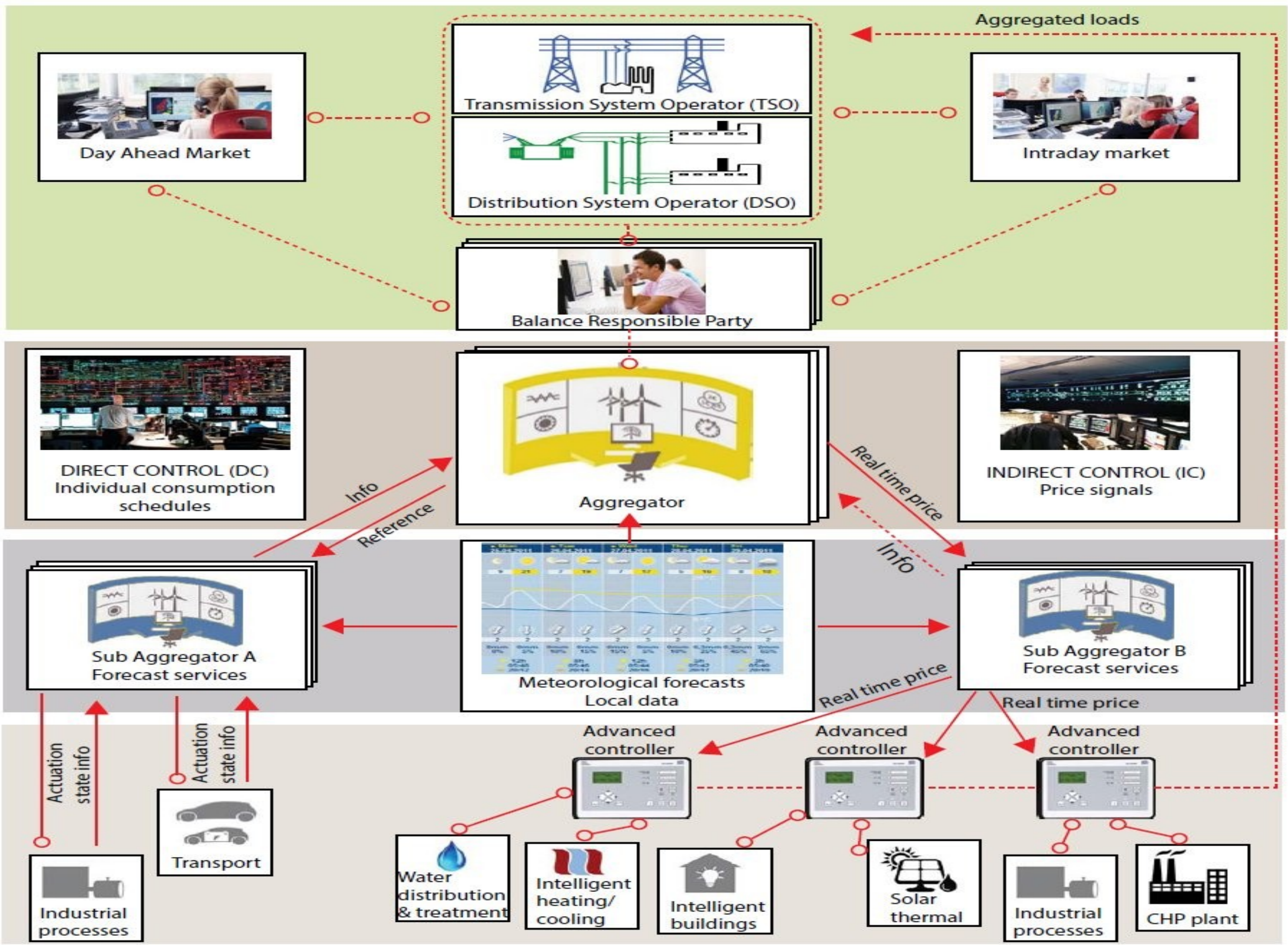


Example: Storage by Energy Systems Integration

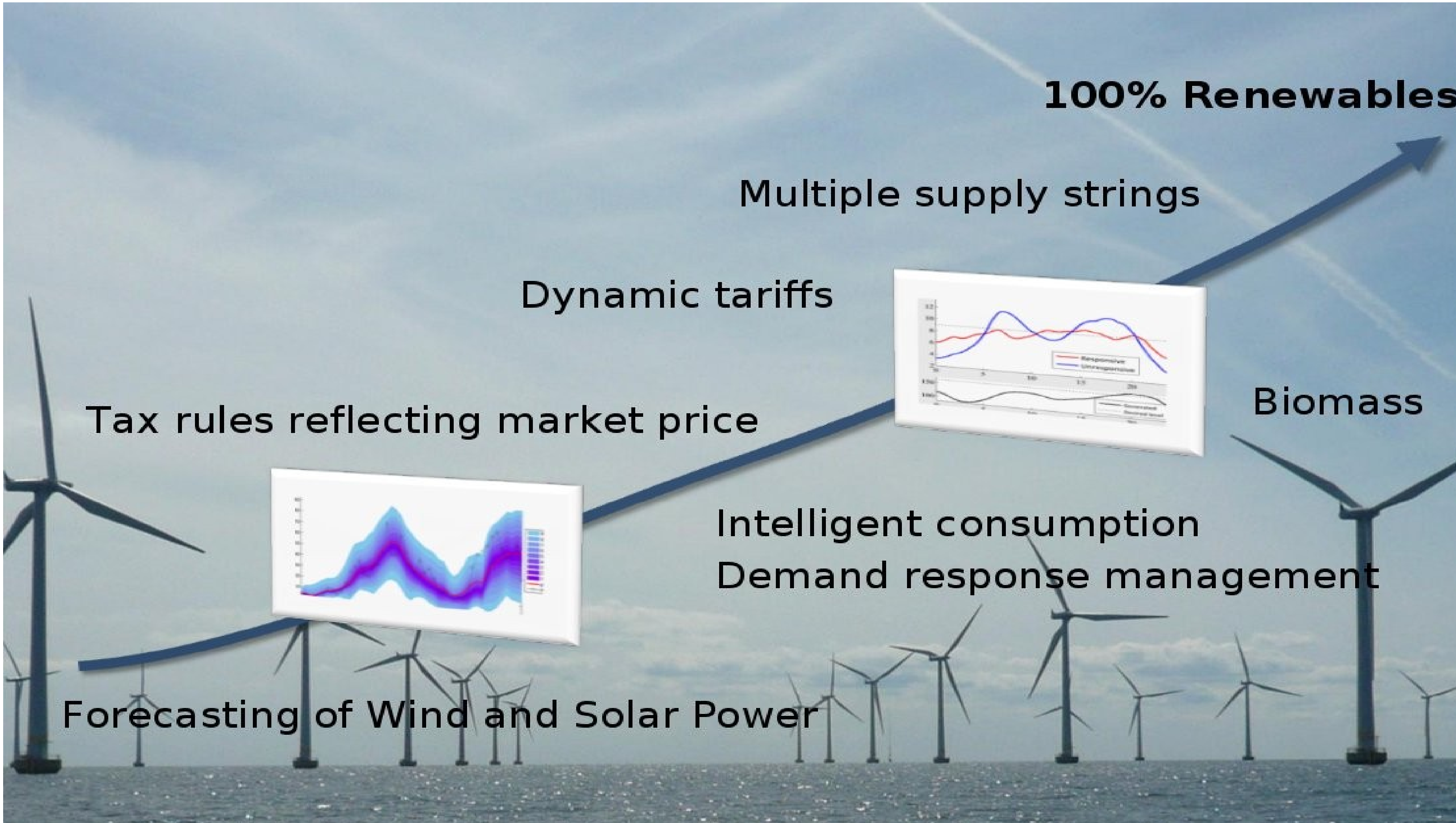


- **Denmark (2014) : Approx 42 pct of power load by renewables (> 100 pct at some days in January)**
- **(Virtual) storage principles:**
  - Buildings can provide storage up to, say, 5-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

Smart-Energy OS



How to reach a fossil-free society

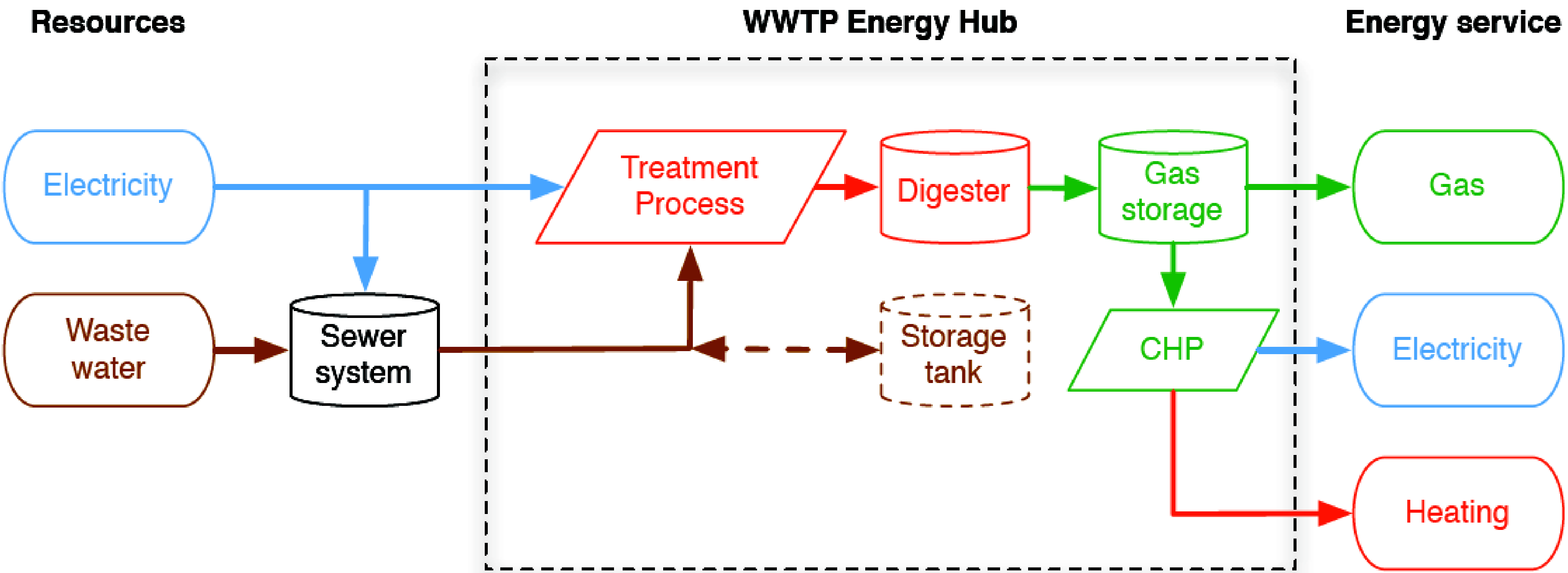


Case study

Control of Wastewater Treatment Plants

CITIES
Centre for IT Intelligent Energy Systems

Waste-2-Energy



Energy Flexibility in Wastewater Treatment

- Sludge -> Biogas -> Gas turbine ->Electricity
- Power management of the aeration process
- Pumps and storage in sewer system

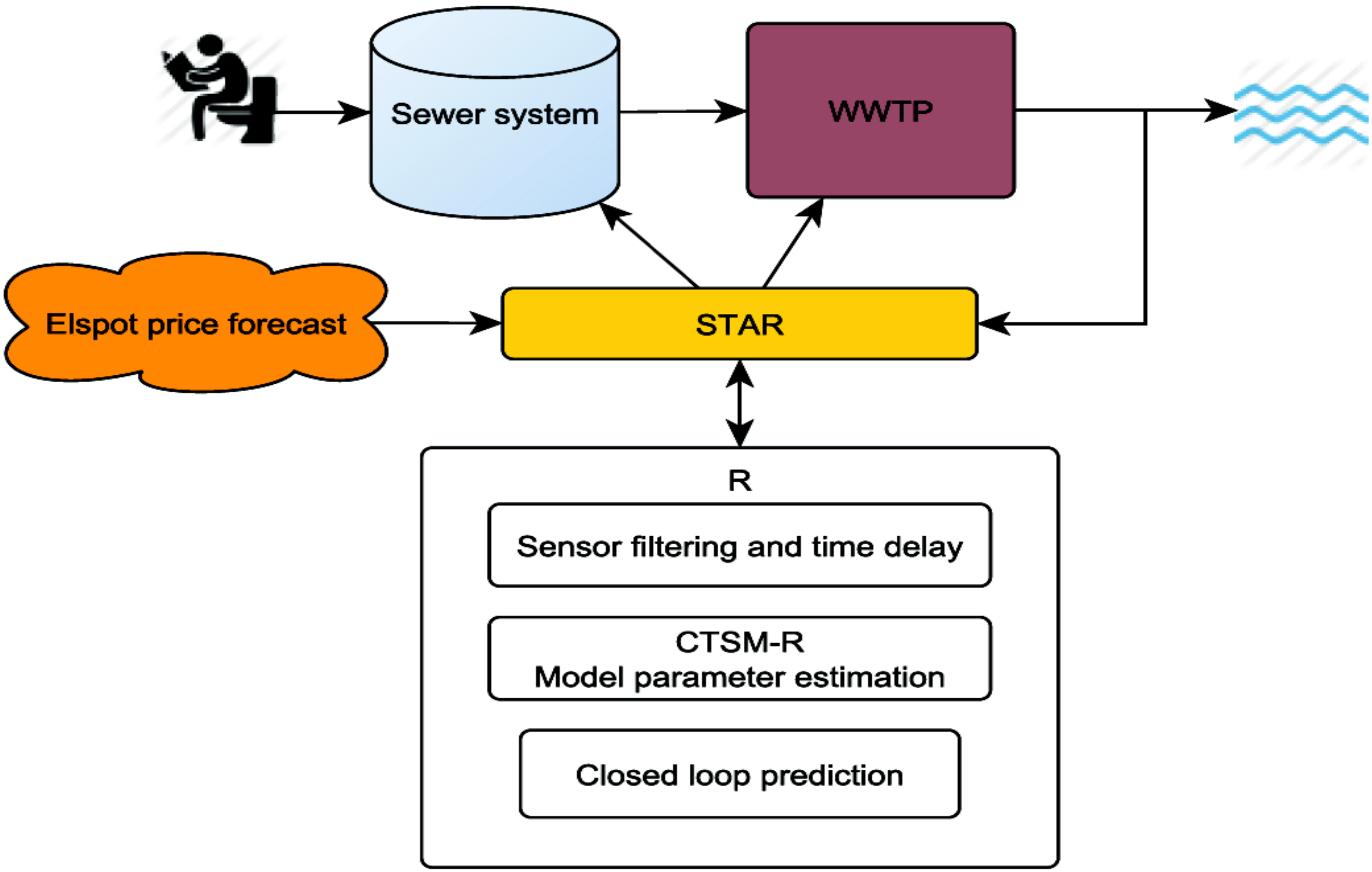
Overall goals:

Cost reduction

Minimize effluent concentration

Minimize overflow risk

Energy Flexibility in Wastewater Treatment



CITIES

Centre for IT-Intelligent Energy Systems in cities

Software solutions

Software for combined physical and statistical modelling

Continuous Time Stochastic Modelling (CTSM) is a software package for modelling and simulation of combined physical and statistical models. You find a technical description and the software at CTSM.info.

Software for Model Predictive Control

HPMPC is a toolbox for High-Performance implementation of solvers for Model Predictive Control (MPC). It contains routines for fast solution of MPC and MHE (Moving Horizon Estimation) problems on embedded hardware. The software is available on GitHub.

MPCR is a toolbox for building Model Predictive Controllers written in R, the free statistical software. It contains several examples for different MPC problems and interfaces to opensource solvers in R . The software is available on GitHub.

Search ...

Latest news

Summer School at DTU, Lyngby, Denmark – July 4th-8th 2016

Summer School – Granada, Spain, June 19th-24th 2016

Third general consortium meeting – DTU, May 24th-25th 2016

Smart City Challenge in Copenhagen – April 20th 2016

Guest lecture by Pierluigi Mancarella at DTU, April 6th

Case study

Use of Heat from Supermarket Cooling in DH Systems

Using Heat from Supermarket Cooling in the District Heating System

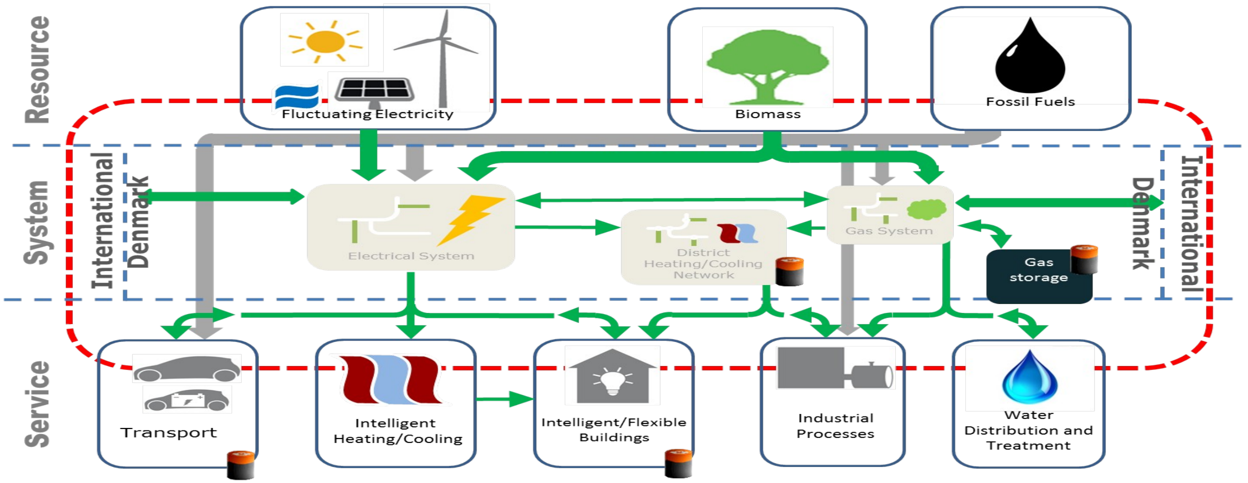
SuperBrugsen in Høruphav

- Area: 1000 m^2 from 2010
- Compressors: 5 MT (1 VS), 4 LT
- Cooling Capacity: 160 kW
- Heating :
  - Sanitary water (1800 l tank (65 °C)
  - Floor heating/low temp coils (35 °C)
  - District heating production

Using Heat from Supermarket Cooling in the District Heating System

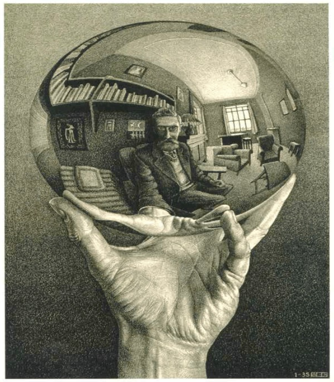
- SuperBrugsen gets paid for energy they would have otherwise have paid for to get removed
- Corresponds to the total consumption of 15-20 households
- Payback time for SuperBrugsen is 1-2 years
- Payback time for DH system is 3-4 years
- This is a small supermarket. Business case even better for large supermarkets

Virtual Storage or Flexibility Characteristics



- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 5-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

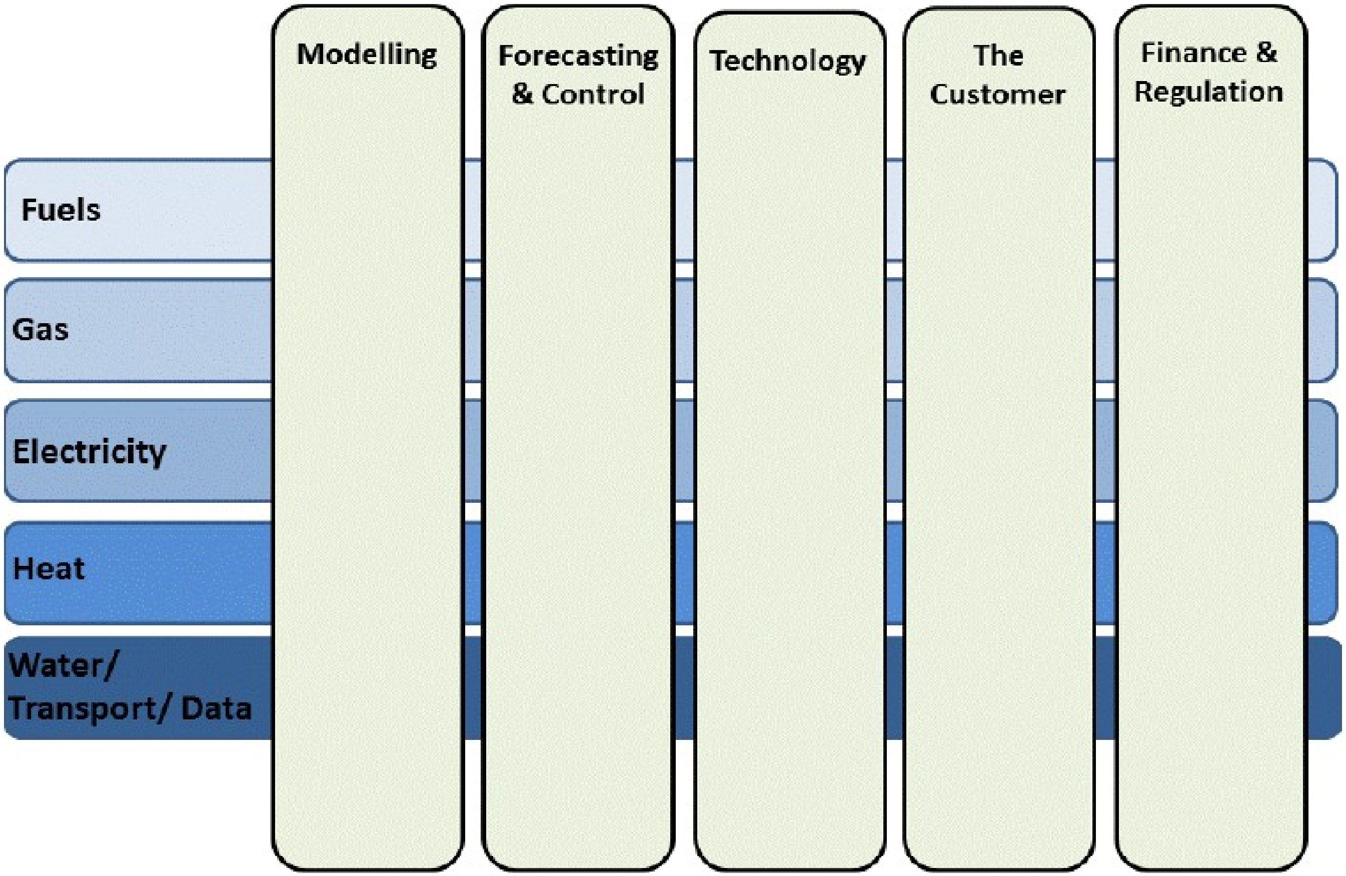
Energy Flexibility
Some Demo Projects in CITIES



- Control of WWTP (ED, Krüger, ..)
- Heat pumps (Grundfos, ENFOR, ..)
- Supermarket cooling (Danfoss, TI, ..)
- Summerhouses (DC, SE, Energinet.dk, ..)
- Green Houses (NeoGrid, Danfoss, F.Fyn, ...)
- CHP (Dong Energy, FjernvarmeFyn, HOFOR, NEAS, ...)
- Industrial production (DI, ...)
- VE (charging) (Eurisco, ED, ...)
- ....

UCD, DTU, KU:

ESI Joint Program ESI European Research (EERA)



iiESI 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, Denver, Brussels, Seoul

NREL NATIONAL RENEWABLE ENERGY LABORATORY · Pacific Northwest NATIONAL LABORATORY · EPRI ELECTRIC POWER RESEARCH INSTITUTE · UCD DUBLIN · DTU · KU LEUVEN

Discussion

- Intelligent Energy Systems Integration can provide virtual storage solutions (... less need for physical storage)
- District heating (or cooling) systems can provide flexibility on the essential time scale (up to a few days)
- We have enough waste heat to cover the entire need for heating (but ... !)
- Gas systems can provide seasonal virtual storage solutions (but ... !)
- We see a large potential in Demand Response. Automatic solutions, price based control, and end-user focus are important
- We see large problems with the tax and tariff structures. 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)

Discussion (2)

- Smart Cities is a part of a Smart Society
- Within CITIES a number of solutions have been developed
- A huge potential in the use of smart meter data
- It is our impression that by intelligent energy systems integration we could rather easily obtain a fossil-free society, however ....
- We need stronger decision makers ...

Thanks for
your attention !

Use of Meter Data

- Reliable Energy Signature.
- Energy Labelling
- Time Constants (eg for night set-back)
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - ......
- Optimized Control
- Integration of Solar and Wind Power using DSM