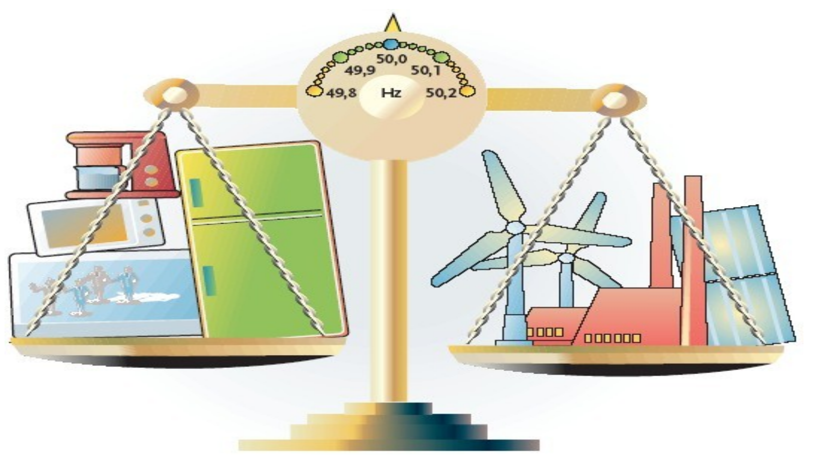
Co-Optimization of Heat and Electricity in the Danish Energy System

Panel Session on the Role of Virtual Storage



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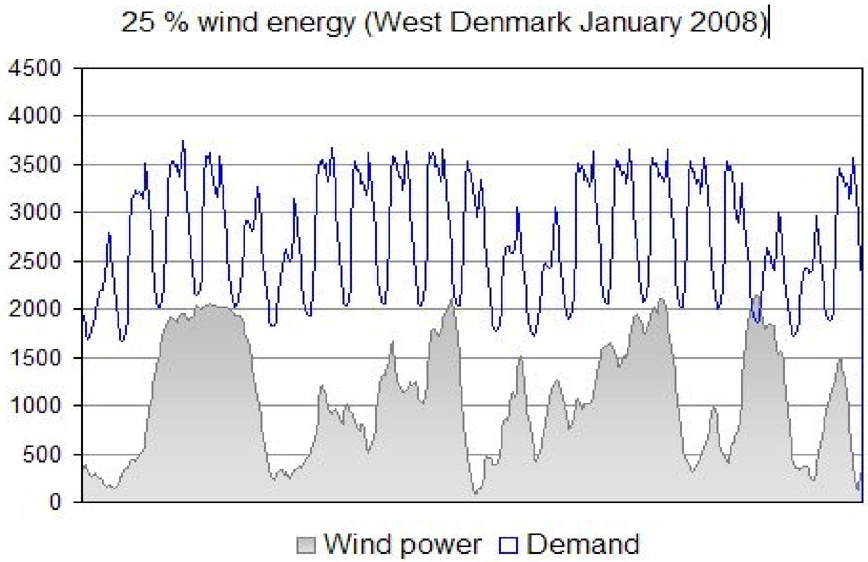
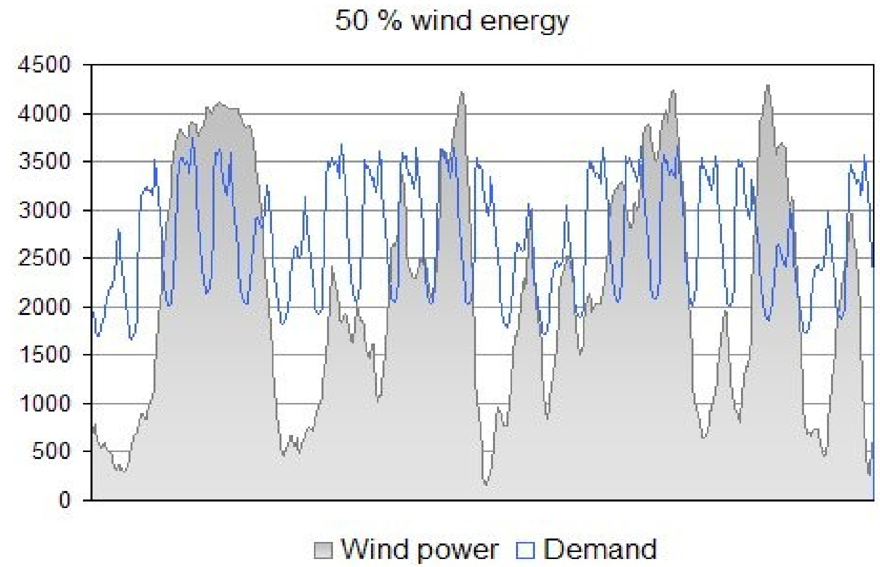
PES, Denver Colorado, July 2015

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)

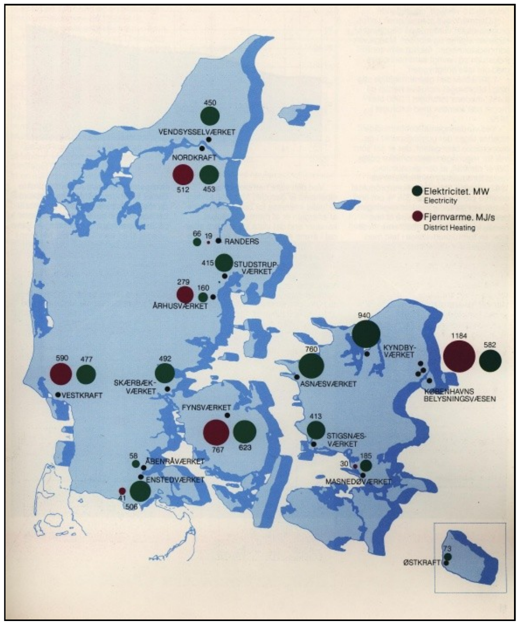
In 2014 more than 40 pct of electricity load was covered by wind power.

For several days in 2014 the wind power production was more than 120 pct of the power load.

July 14th, 2015 more than 140 pct of the power load was covered by wind power

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

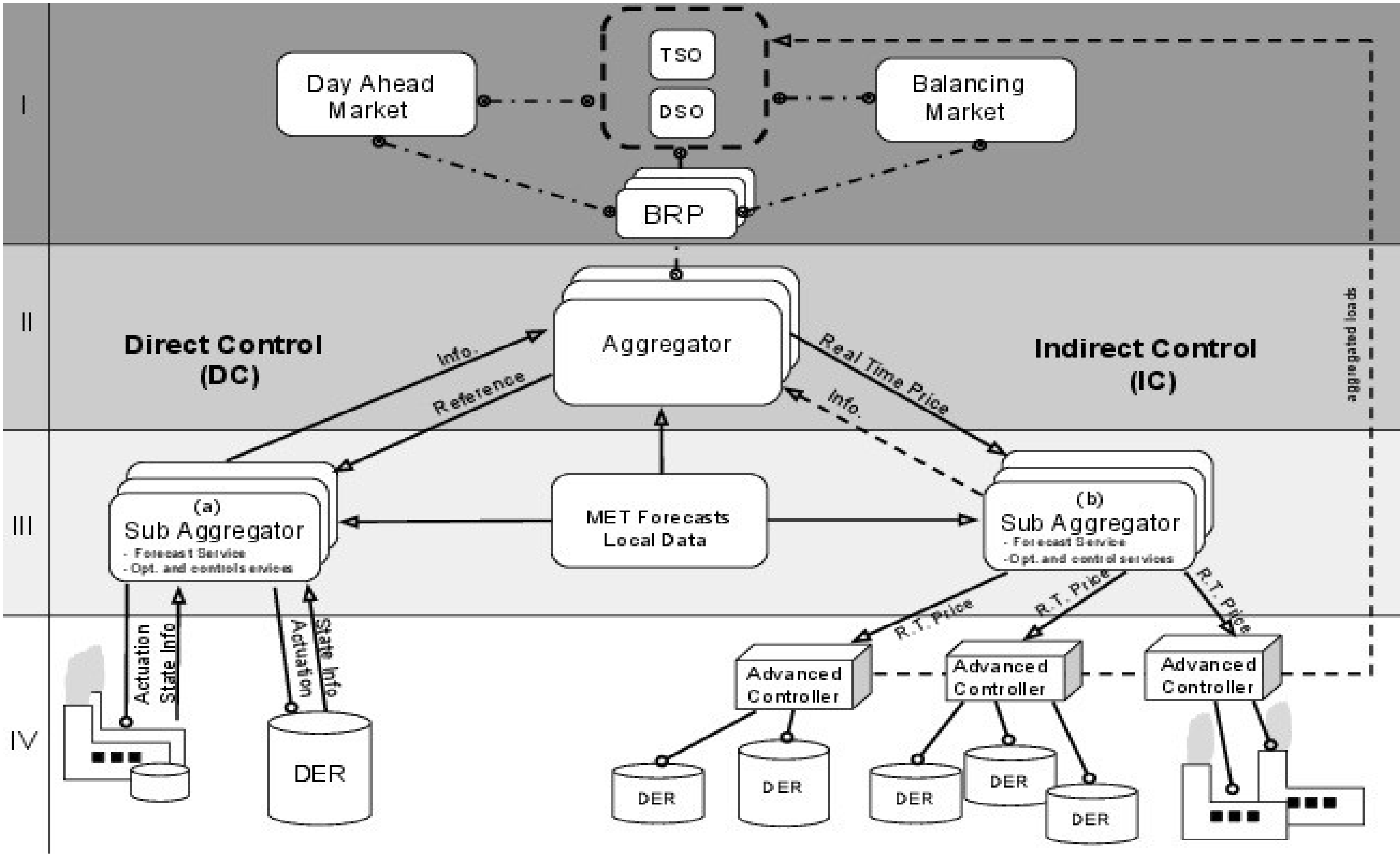
1980



Today

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

Control and Optimization



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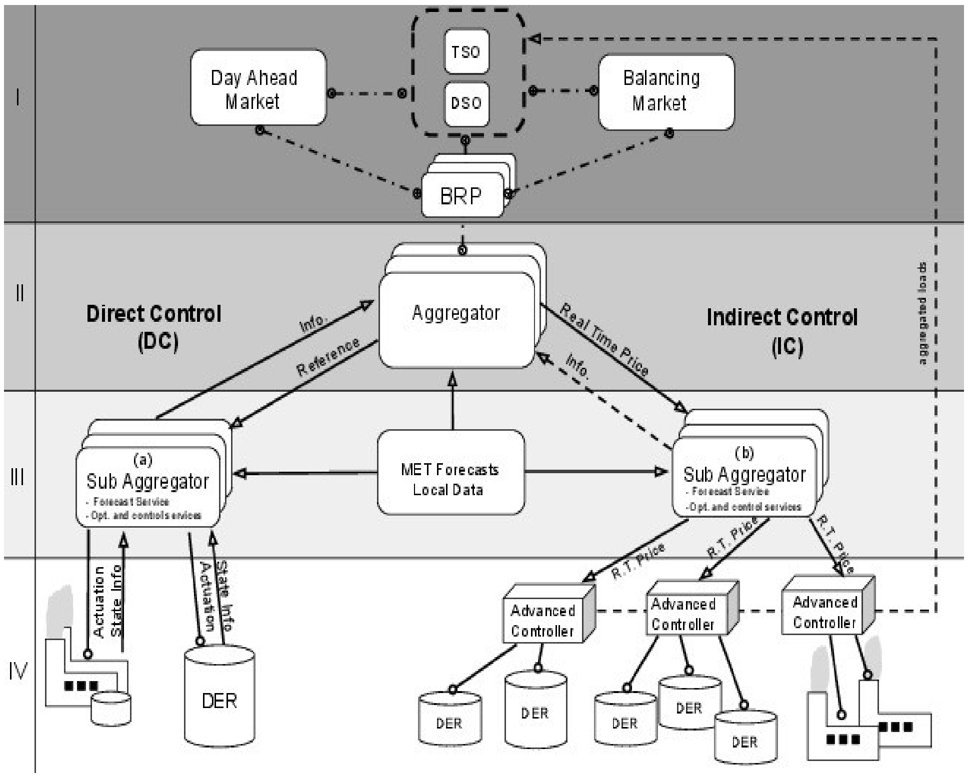
Control and Optim. Challenges



New Wiley Book: Control of Electric Loads in Future Electric Energy Systems, 2015

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

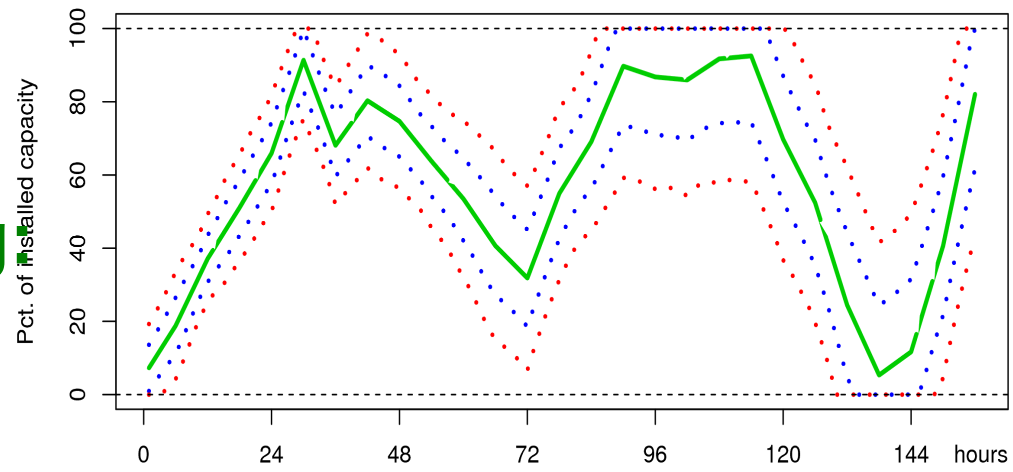
Simple 'contracts'

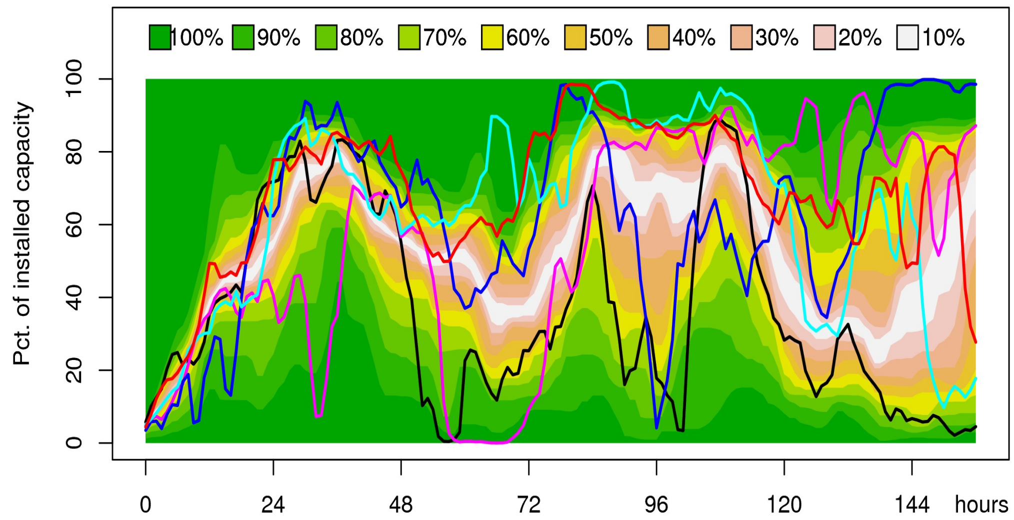
Forecasting is Essential

The major players in Denmark uses Tools for Forecasting:

- Power load
- Heat load
- Gas load
- Prices (power, etc)
- Wind power produc.
- Solar power produc.

The tools are developed by DTU COMPUTE.

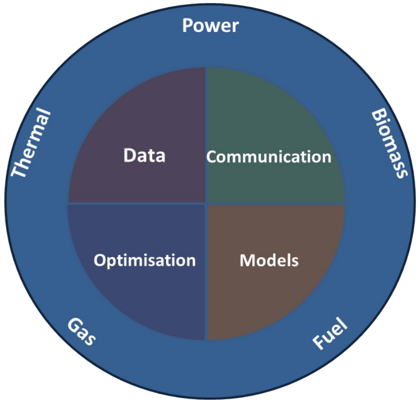




ESI Hypothesis

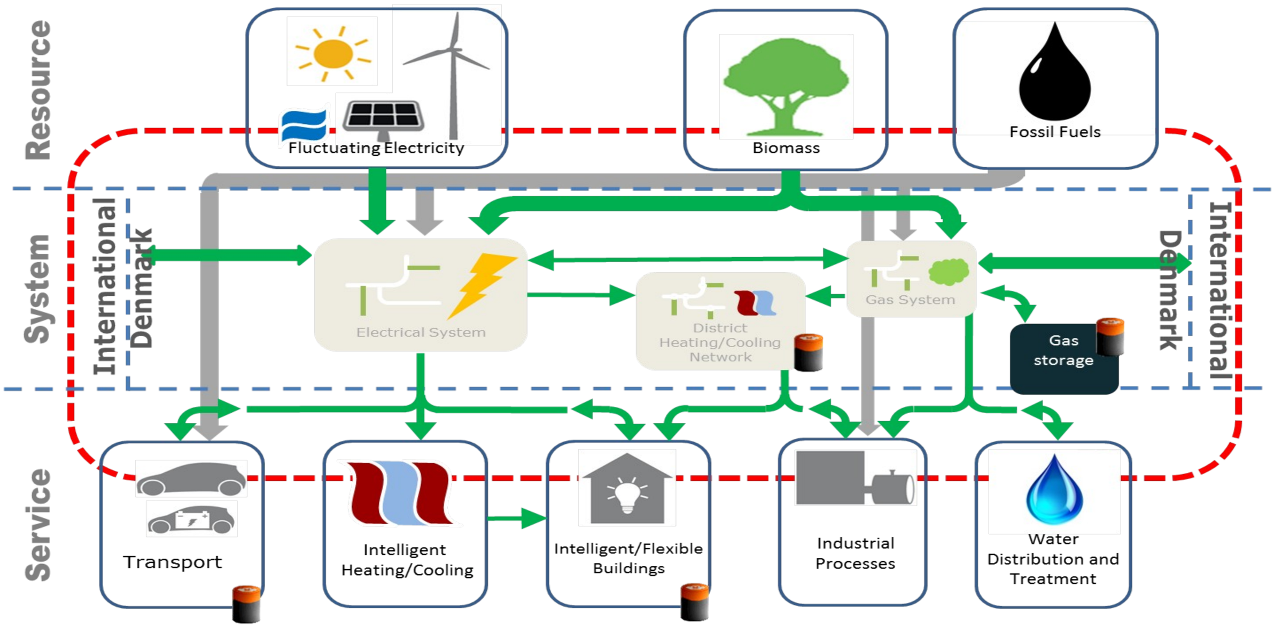
The **central hypothesis of ESI** is that by **intelligently integrating** currently distinct energy flows (heat, power, gas and biomass) in we can enable very large shares of renewables, and consequently obtain substantial reductions in CO2 emissions.

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

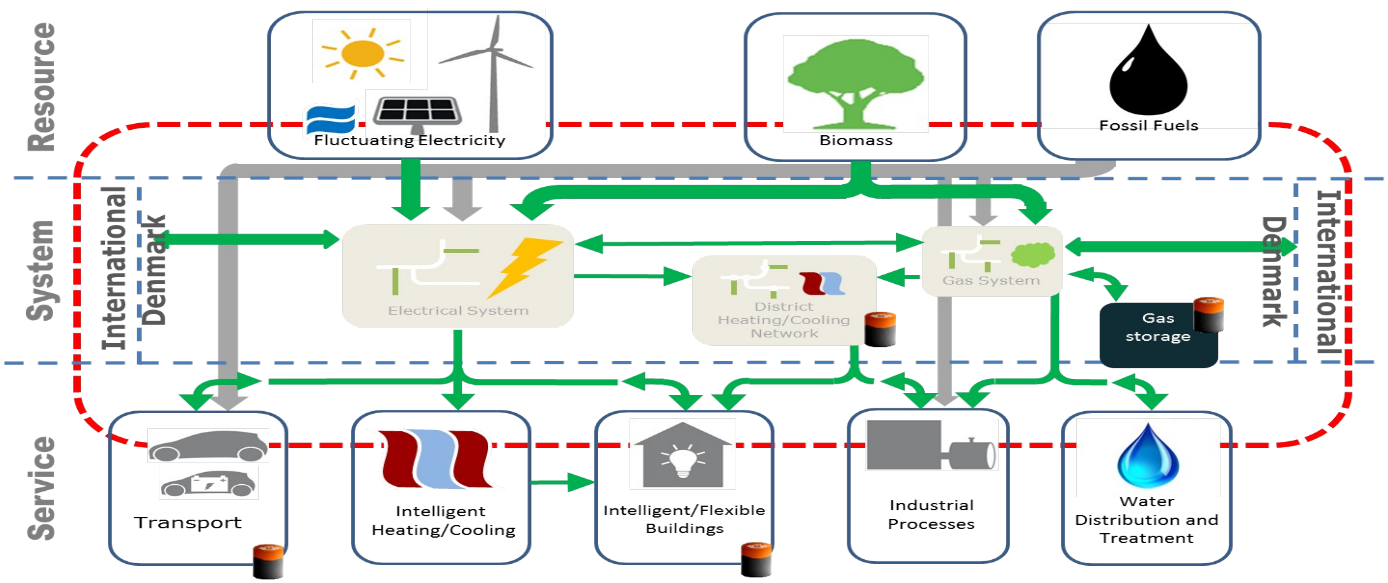


ESI Concepts

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



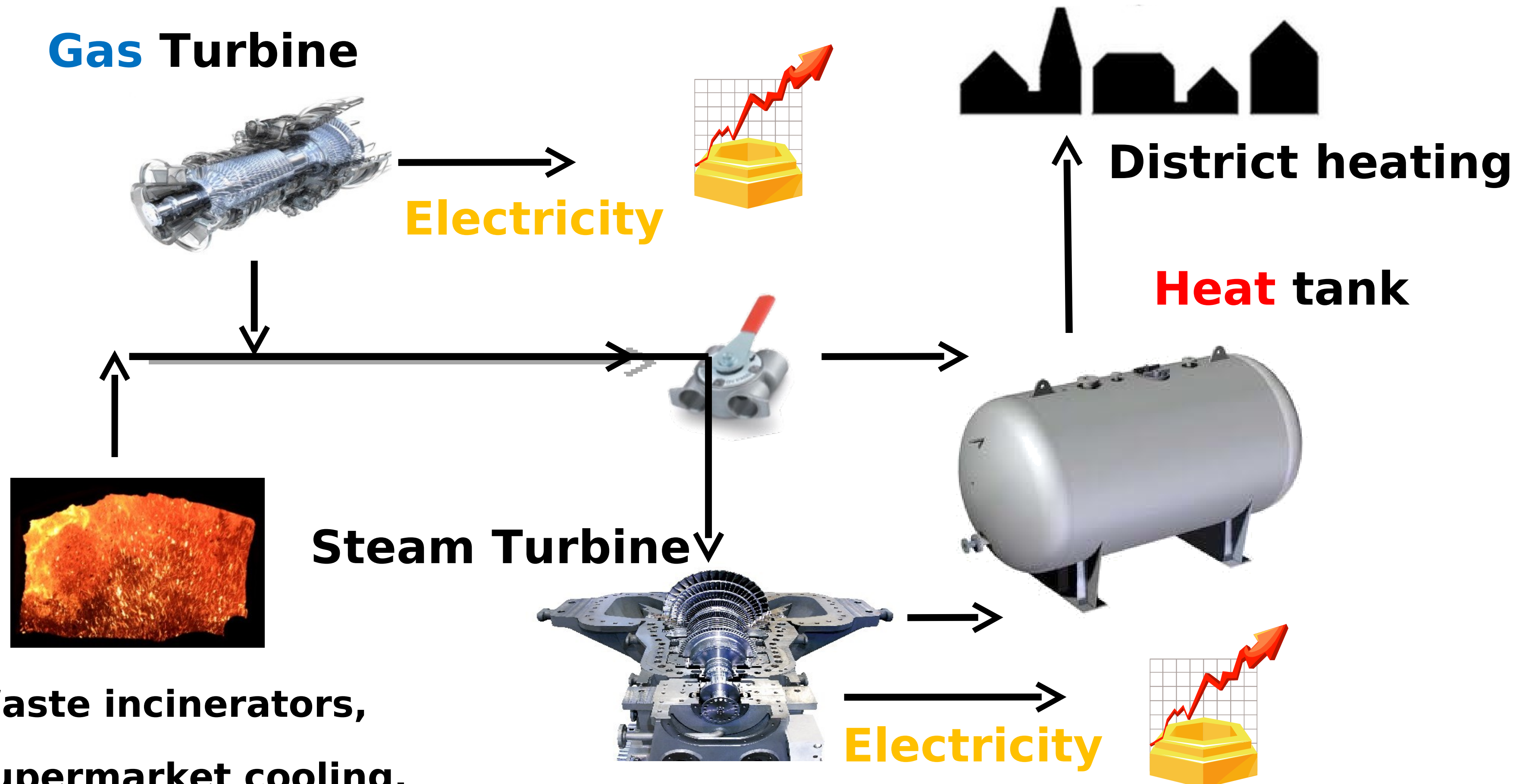
Example: Storage by Energy Systems Integration



- **Denmark (2014) : 48 pct of power load by renewables (> 100 pct for 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

Integration of Energy Systems

(Paradigmatic example in Denmark)

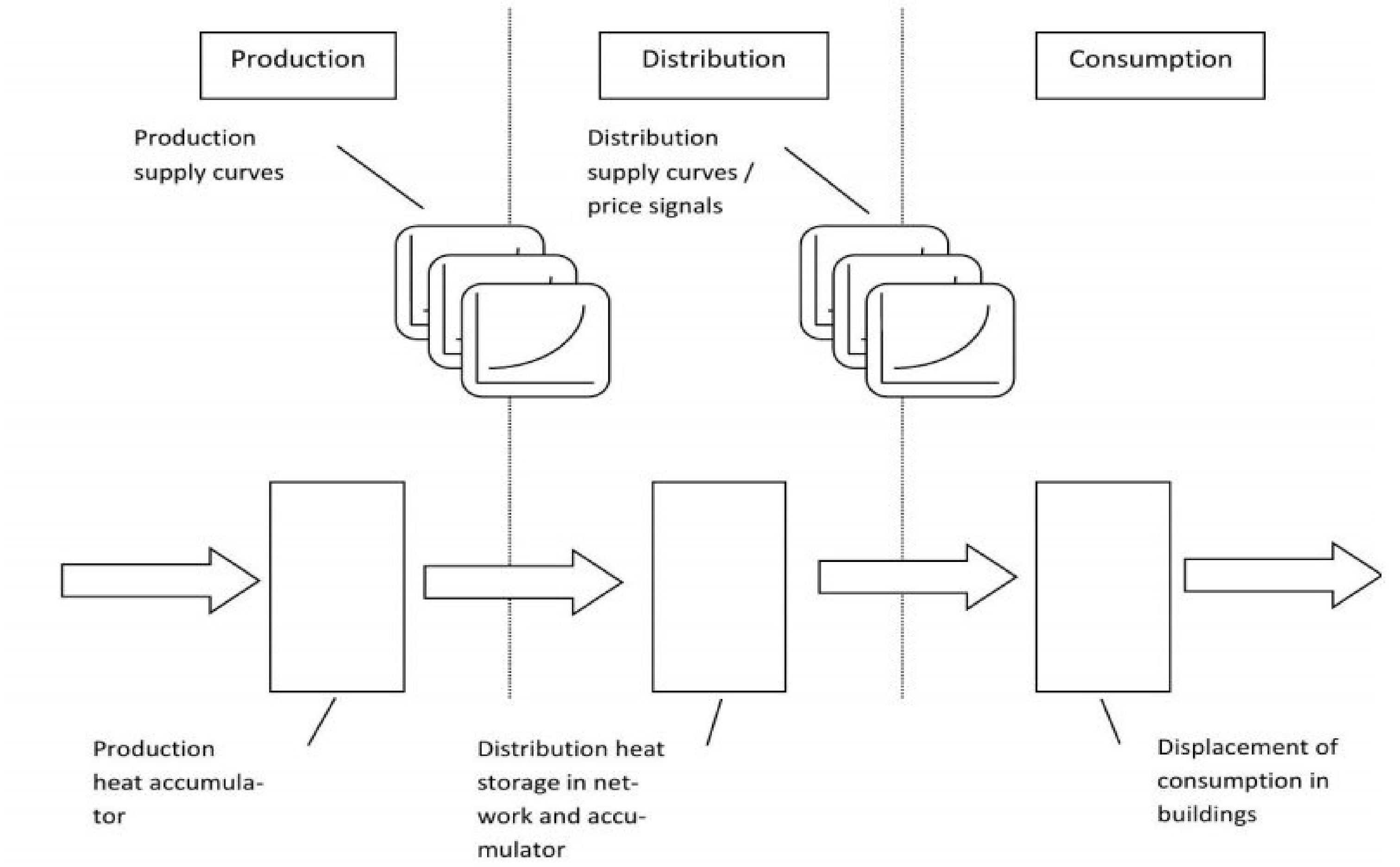


Waste incinerators,

Supermarket cooling,

Industrial processes

Flexibility in District Heating Systems



Case study

Control of Power Consumption (DSM) using the Thermal Mass of Buildings

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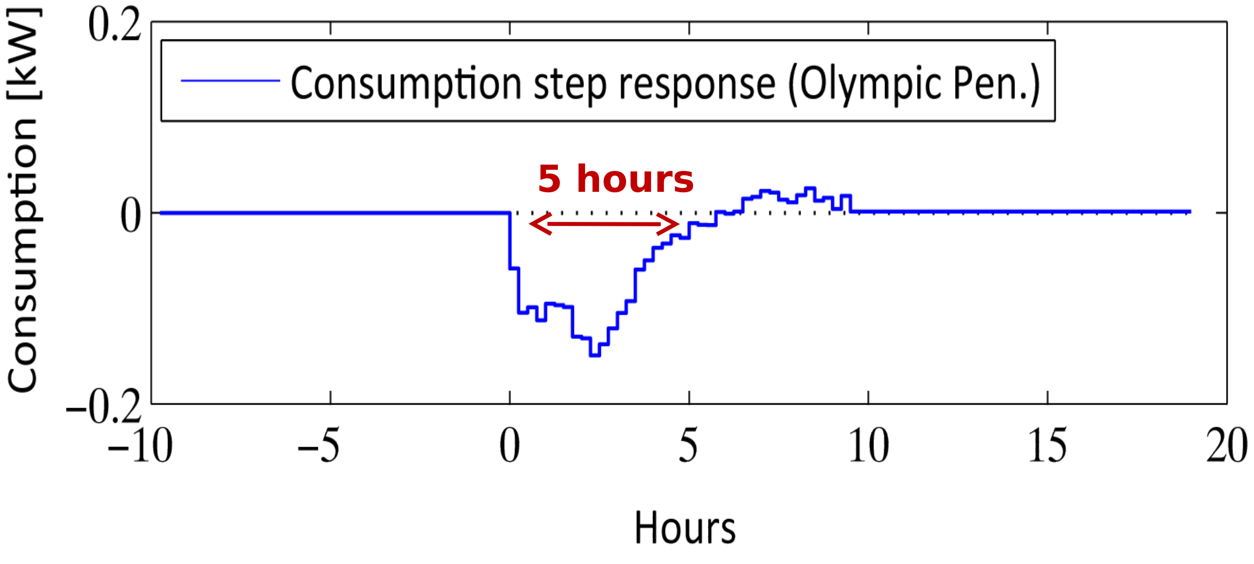
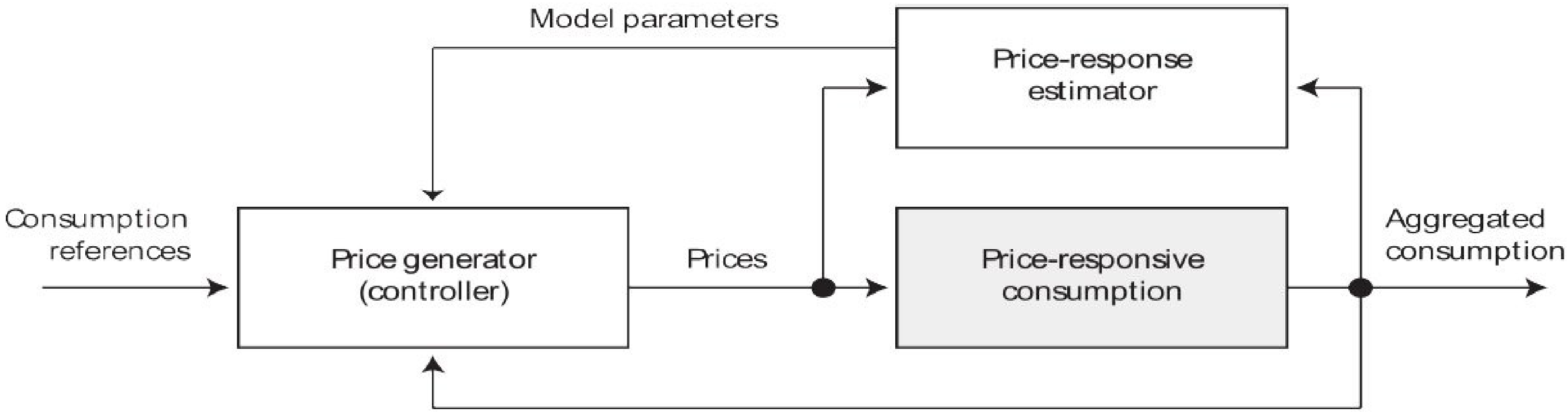
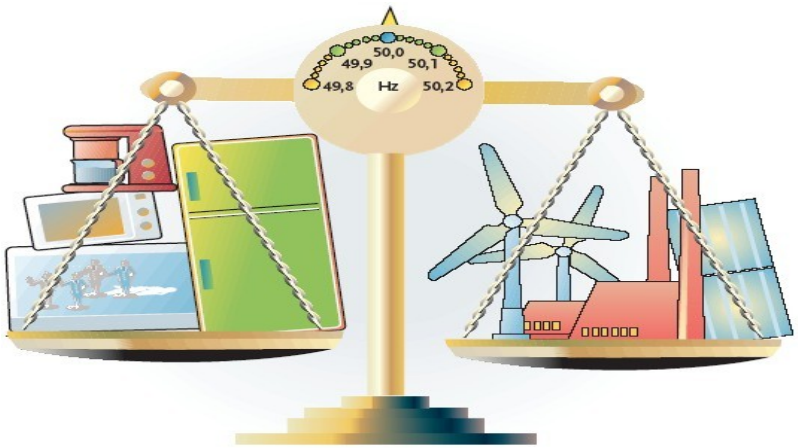
Response on Price Step Change



Control of Power Consumption

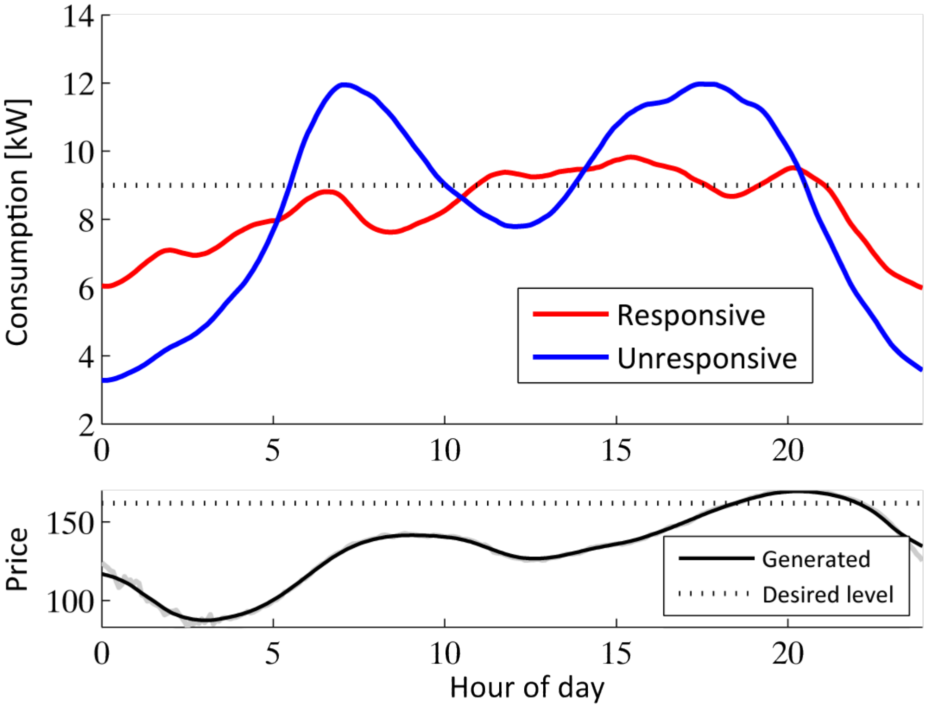




Control performance

Considerable **reduction in peak consumption**

Mean daily consumption shift



Conclusions

DTU

- Energy Systems Integration can provide virtual and lossless storage solutions
- The thermal mass of buildings can provide energy storage up to say 12 hours
- 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 scales (up to a few days)
- We see a large potential in Demand Side Management using real-time pricing. Automatic solutions and end-user focus are important
- We see a large potential in coupling cooling (eg. for comfort) and heating systems using DH networks
- Decentralized Combined Heat and Power plants have – so far – been the key to the integration of up 100+ pct (compared to power load) in the Danish Power system