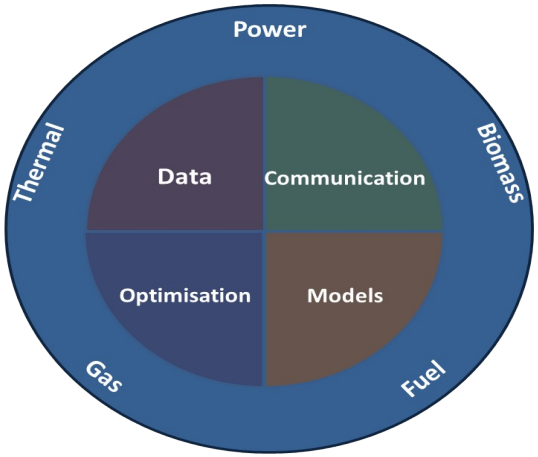
Intelligent Energy Systems Integration



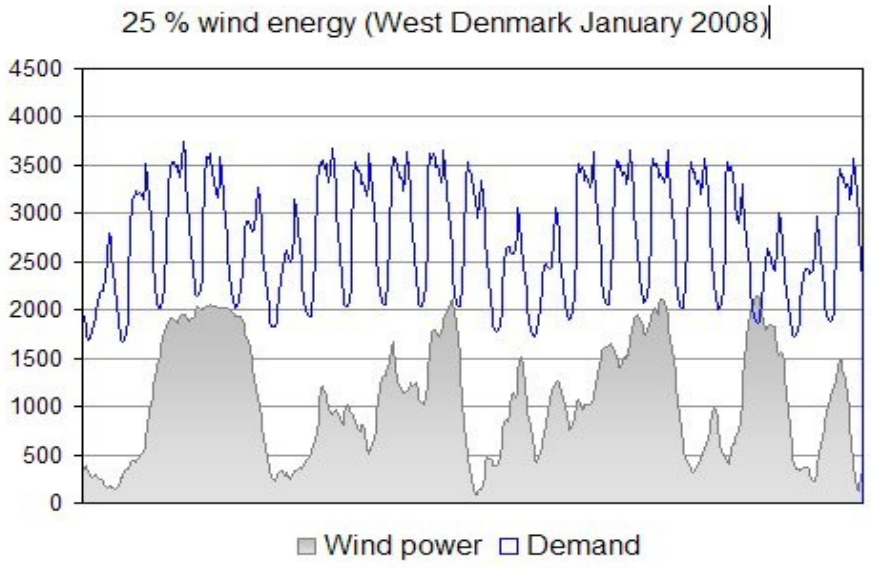
Henrik Madsen, DTU Compute

http://www.henrikmadsen.org

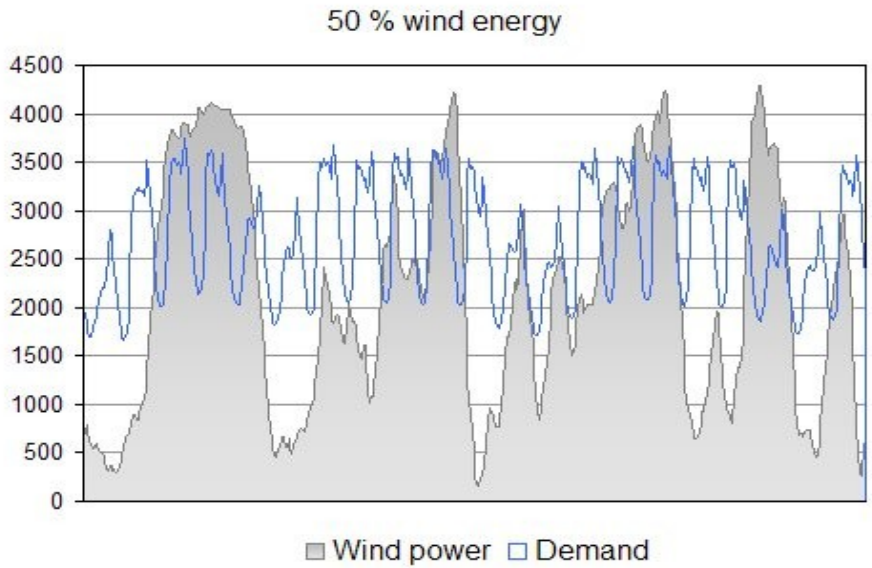
http://www.smart-cities-centre.org

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)



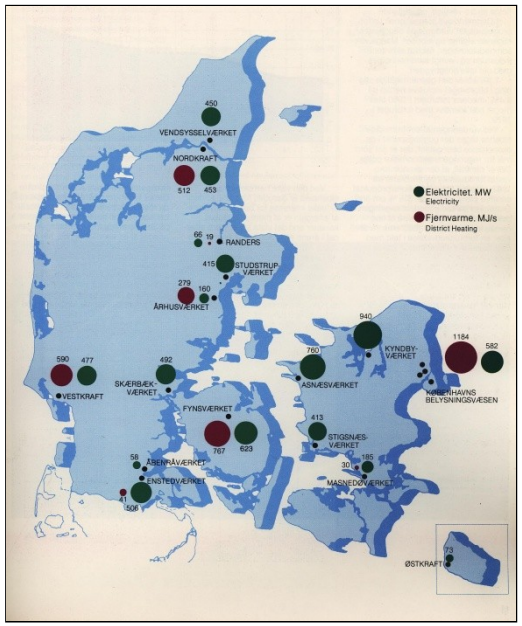
In 2014 more than 40 pct of electricity load was covered by wind power.

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

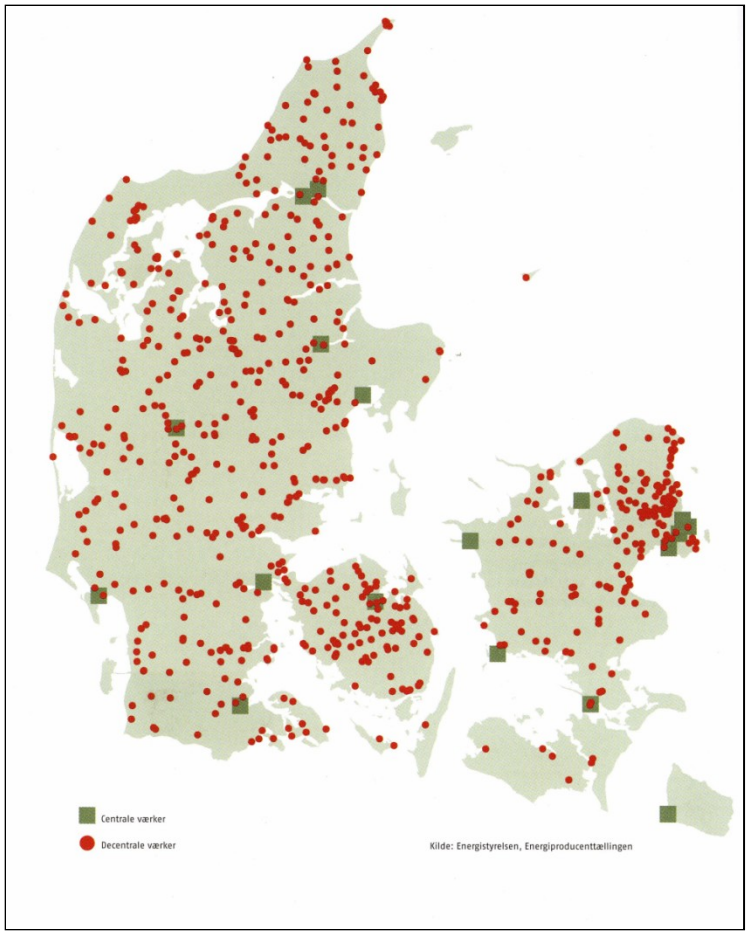
July 14th, 2015 more than 140 pct of the power load was covered by wind power

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

1980

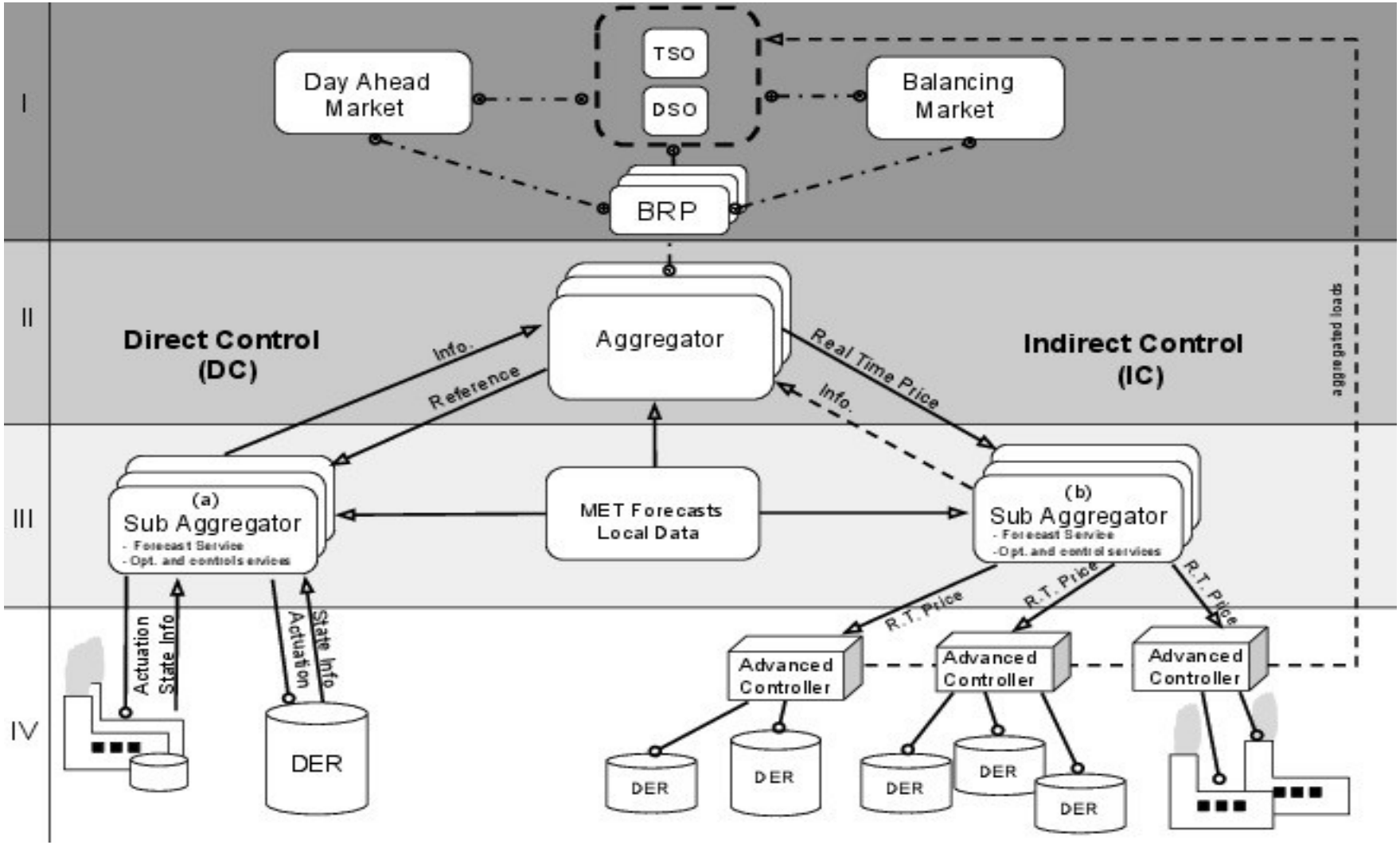


Today

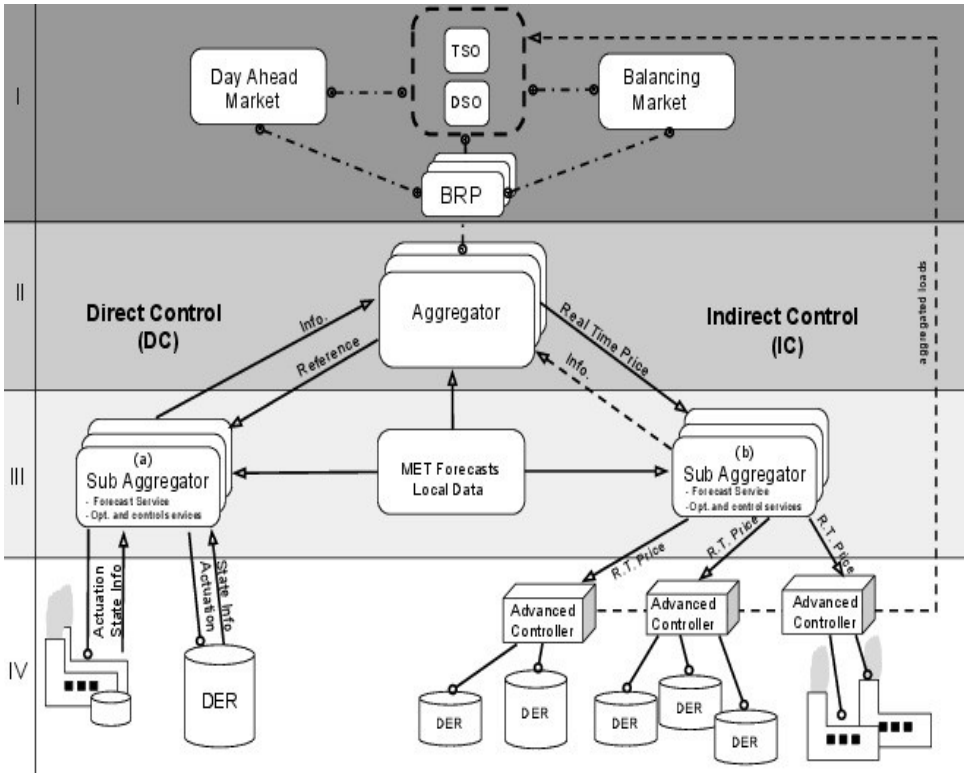


*From a few big power plants to many small **combined heat and power** plants – however most of them based on coal*

Control and Optimization



Control and Optimization



In 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

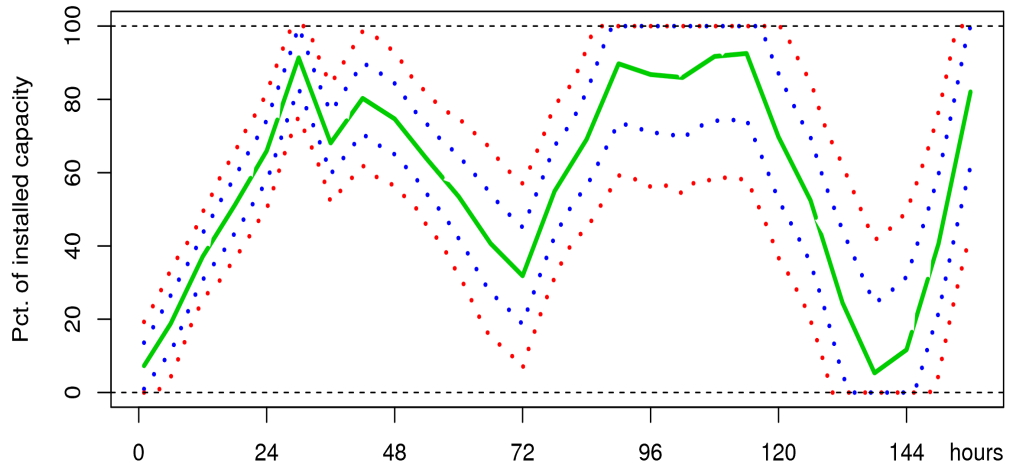
Models for DERs are not needed

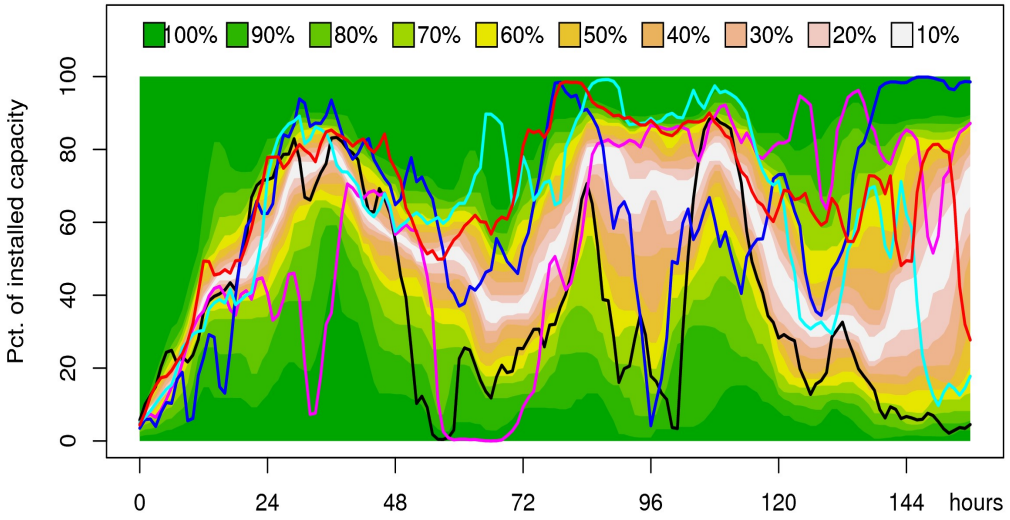
Simple 'contracts'

Forecasting is Essential

Tools for Forecasting:

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

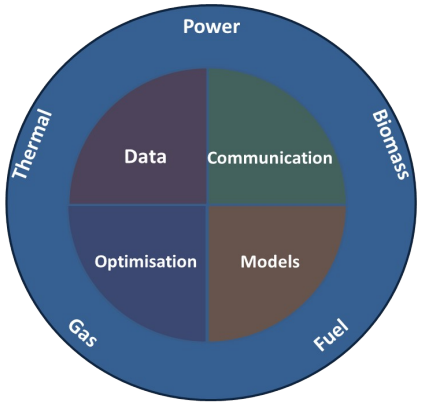




ESI Idea

The **central idea 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**.



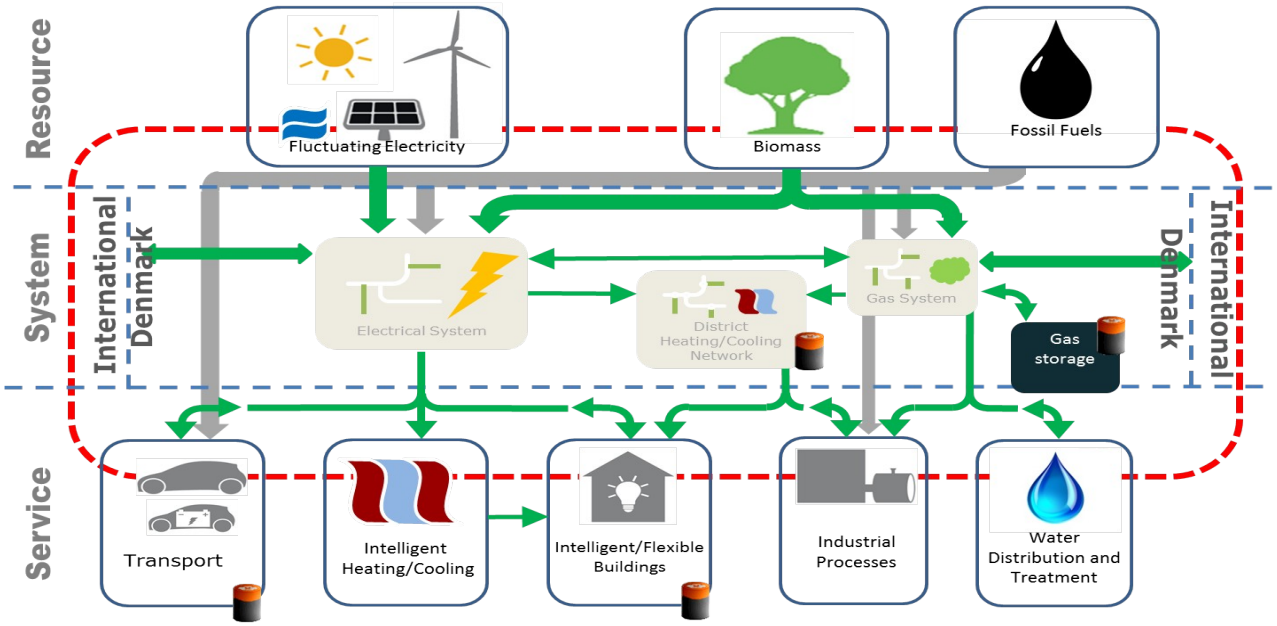
ESI Solutions and CITIES

The ***Center for IT-Intelligent Energy Systems in Cities (CITIES)*** is aiming at establishing methodologies and solutions for design and operation of integrated electrical, thermal, fuel pathways at all scales.

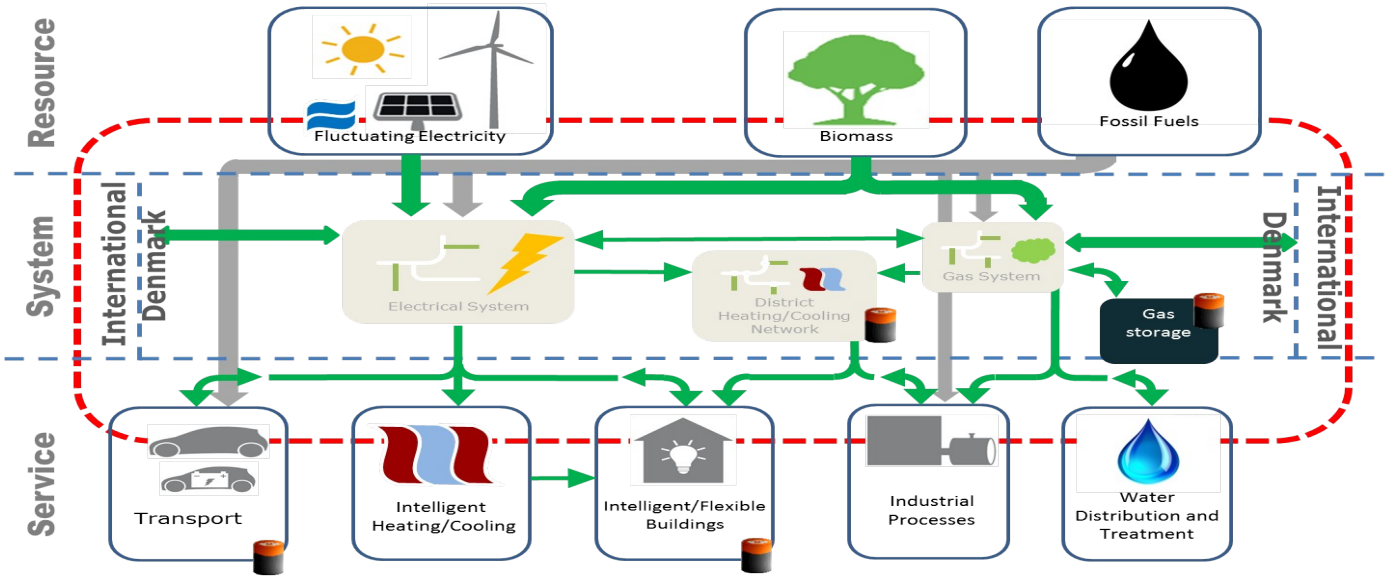
CITIES is the largest Smart Cities and ESI research project in Denmark – see http://www.smart-cities-centre.org .

ESI Concepts

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



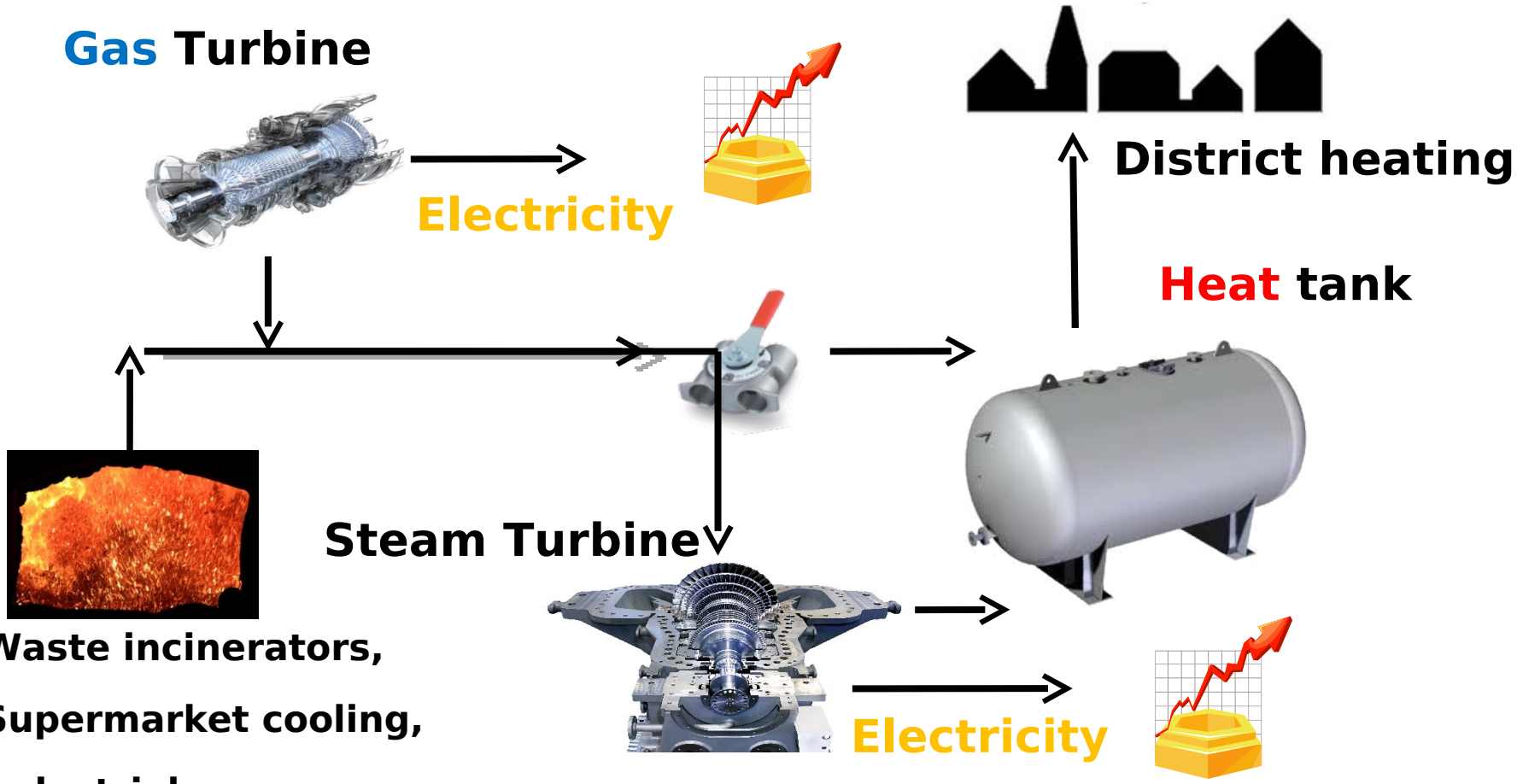
Virtual Storage by Energy Systems Integration



- **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

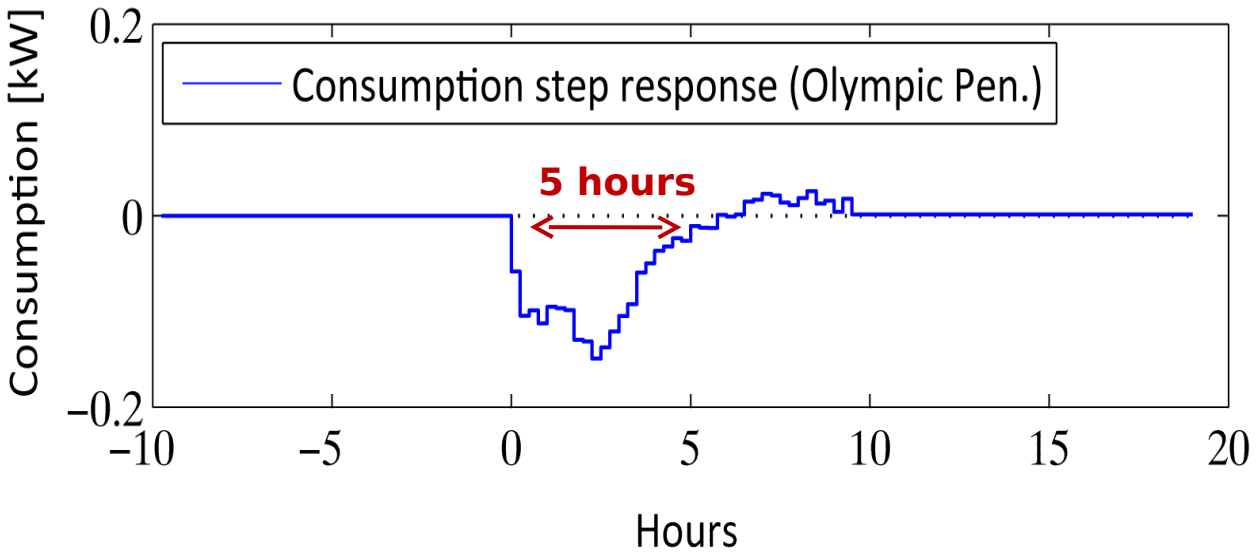
(Paradigmatic example in Denmark)



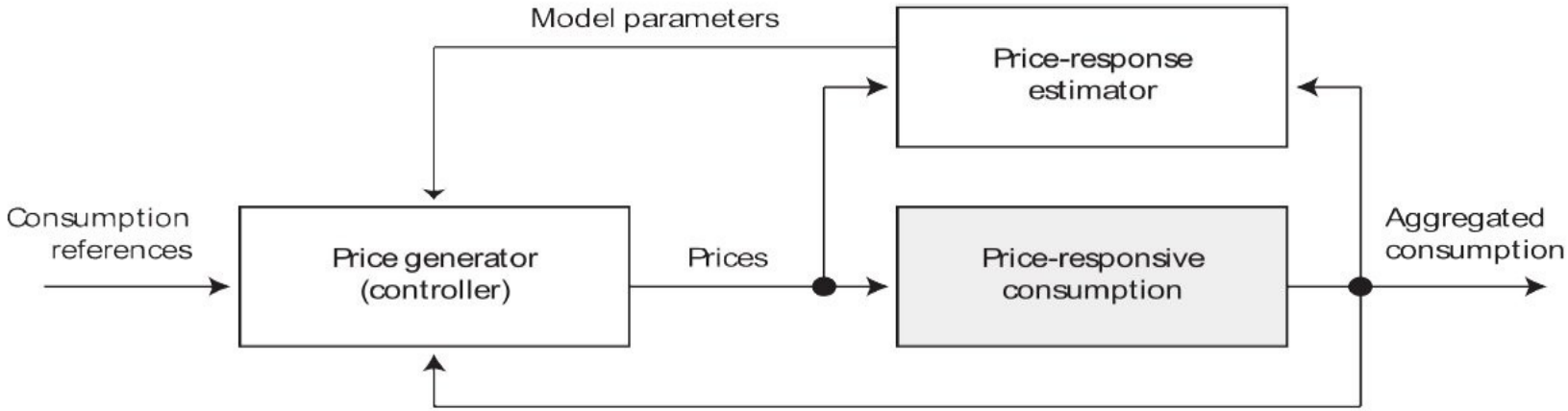
Case study

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

Response on Price Step Change

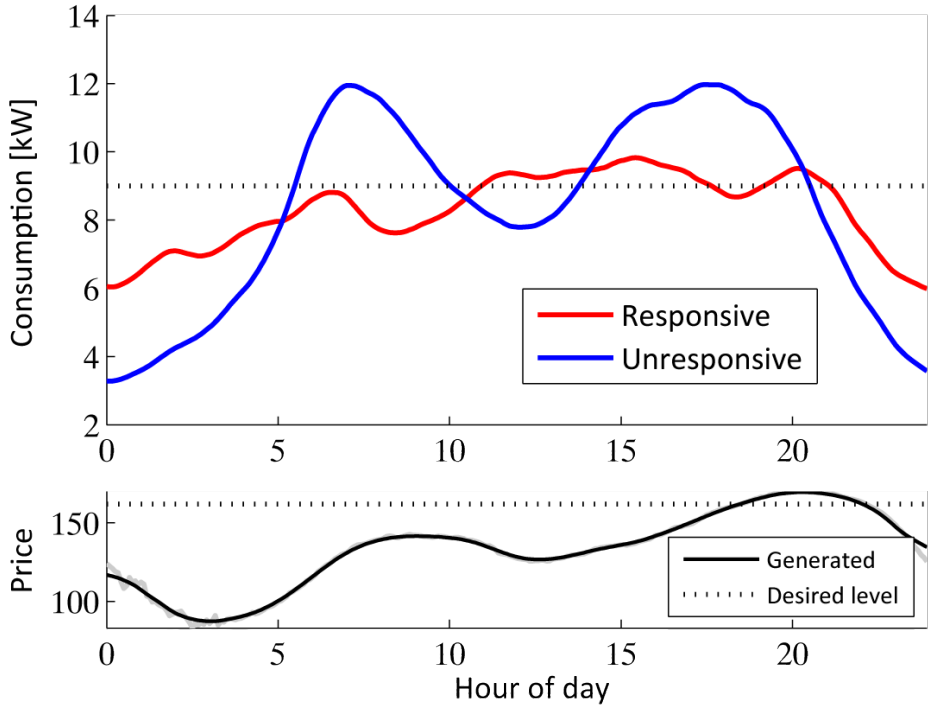


Control of Power Consumption



Control performance

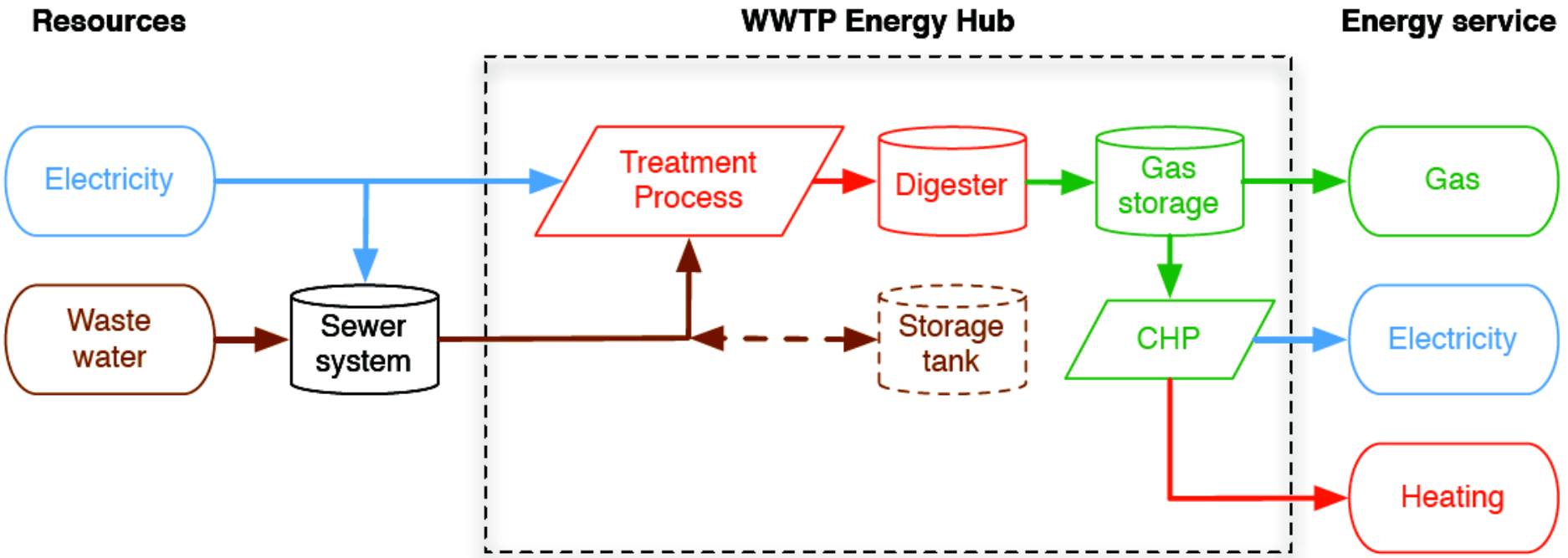
Considerable **reduction in peak consumption**



Case study

Control of Wastewater Treatment Plants

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

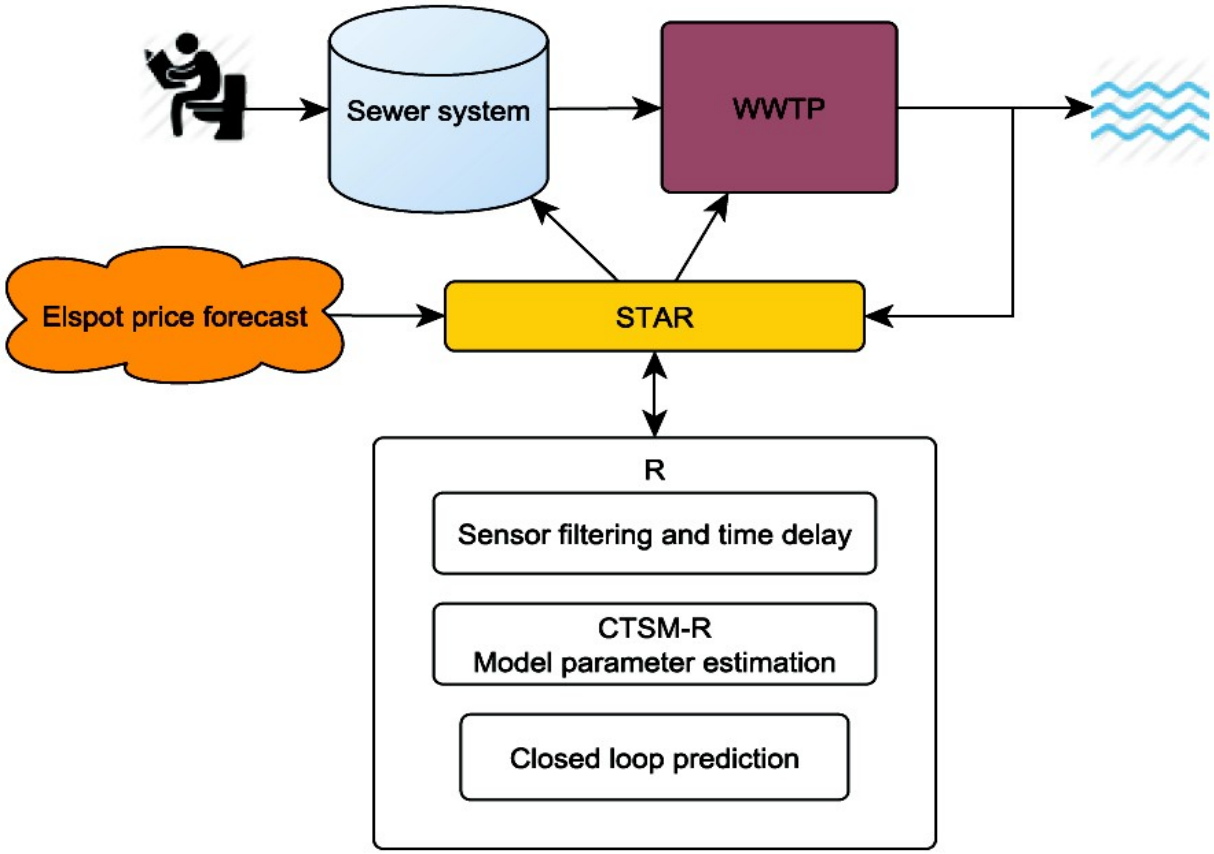
Overall goals:

Cost reduction

Minimize effluent concentration

Minimize overflow risk

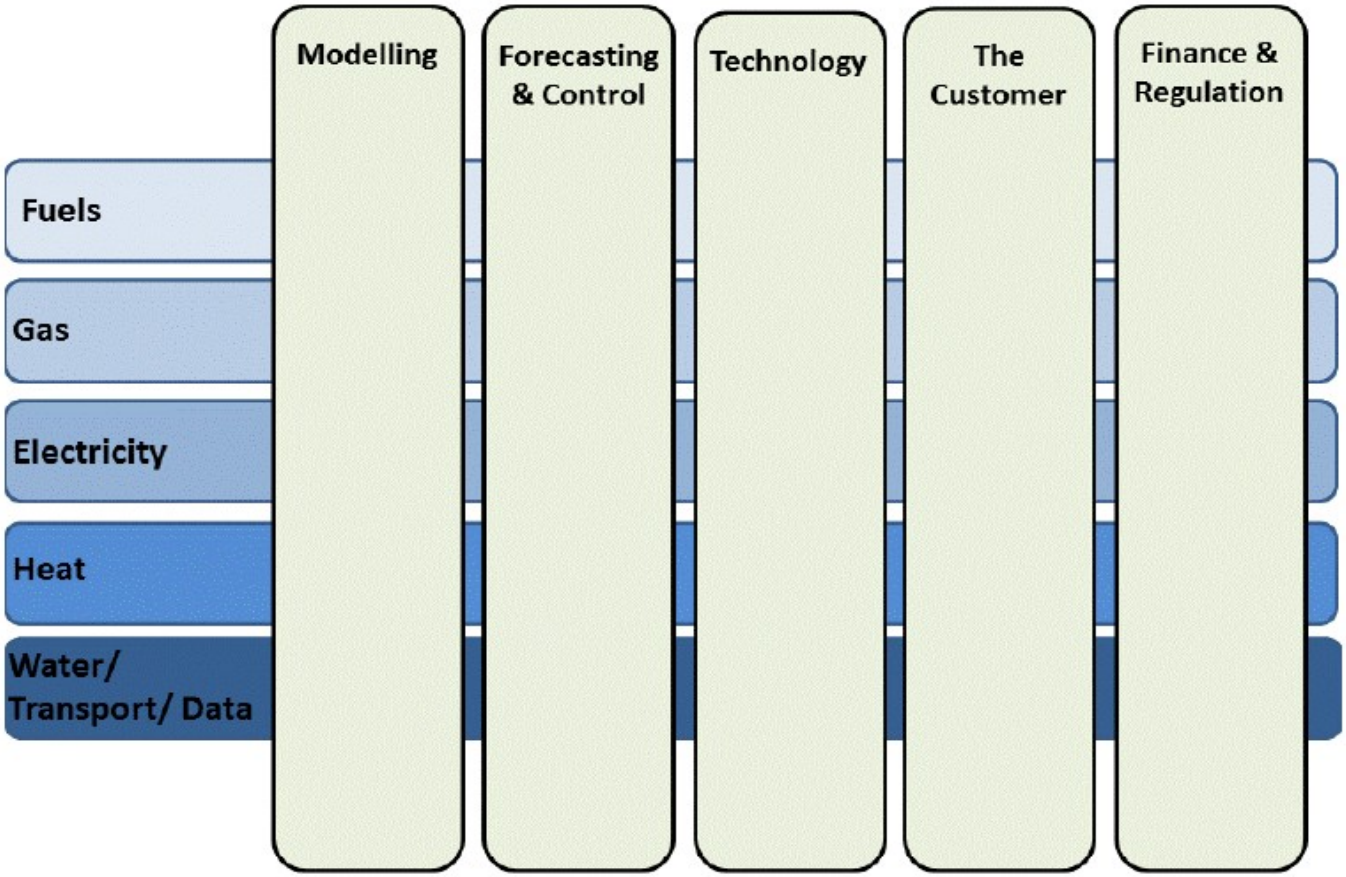
WWTP Control Architecture



International Alliances on Energy Systems Integration

Proposal (UCD, DTU, KU Leuven):

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



IESI 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

Conclusions

- **Energy Systems Integration** can provide virtual and lossless storage solutions
- The thermal mass of buildings can provide energy storage up to say 12 hours
- A flexible market structure with nested aggregators can provide the infra-structure needed (see Wiley book)
- Methods for **forecasting**, **control** and **aggregation** have been developed (see the CITIES project)
- 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
- DTU plays an important role in two international alliances on Energy Systems Integration (contact me)
- Decentralized Combined Heat and Power plants have – so far – been the key to the integration of up 100+ pct (compared to power load) in Denmark