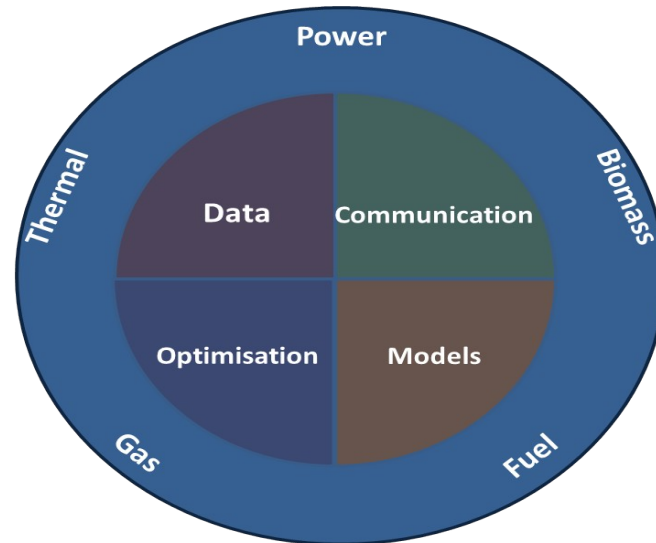


# Control of Electricity Load in Future Smart Cities



**Henrik Madsen, DTU Compute**

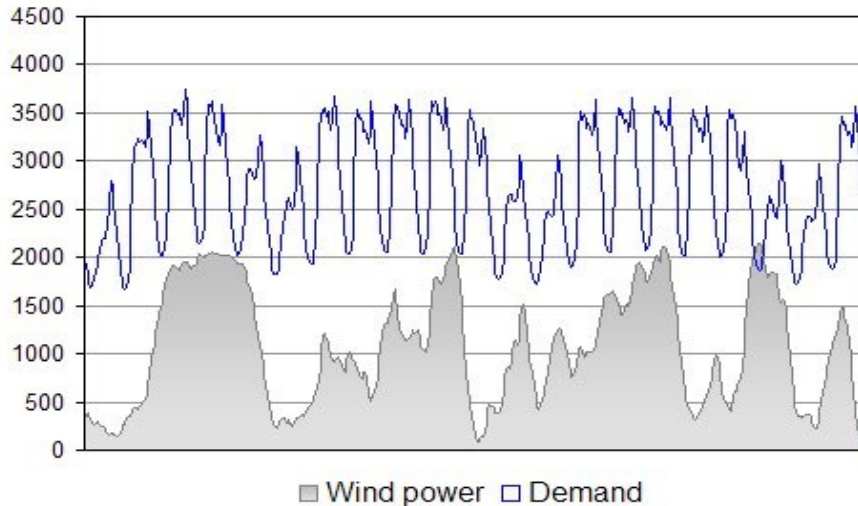
<http://www.henrikmadsen.org>

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

# The Danish Wind Power Case

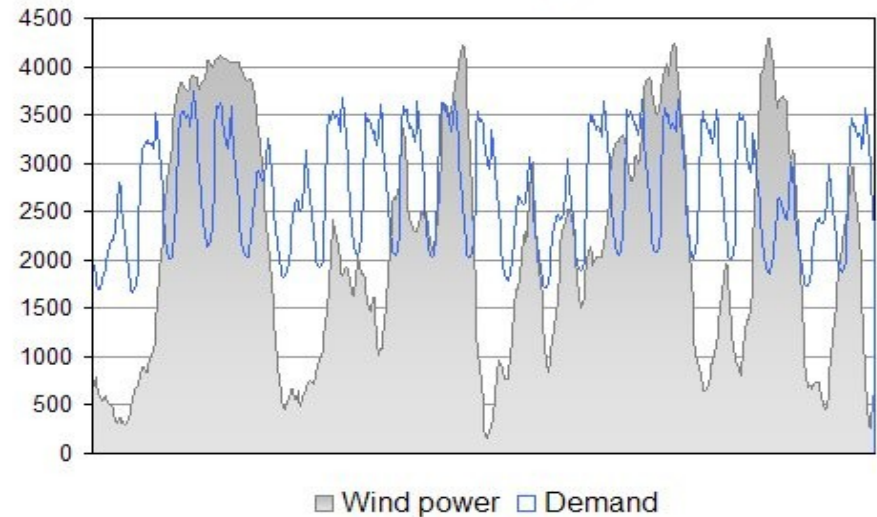
.... balancing of the power system

25 % wind energy (West Denmark January 2008)



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

50 % wind energy



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

# Intelligent Integration and Cities

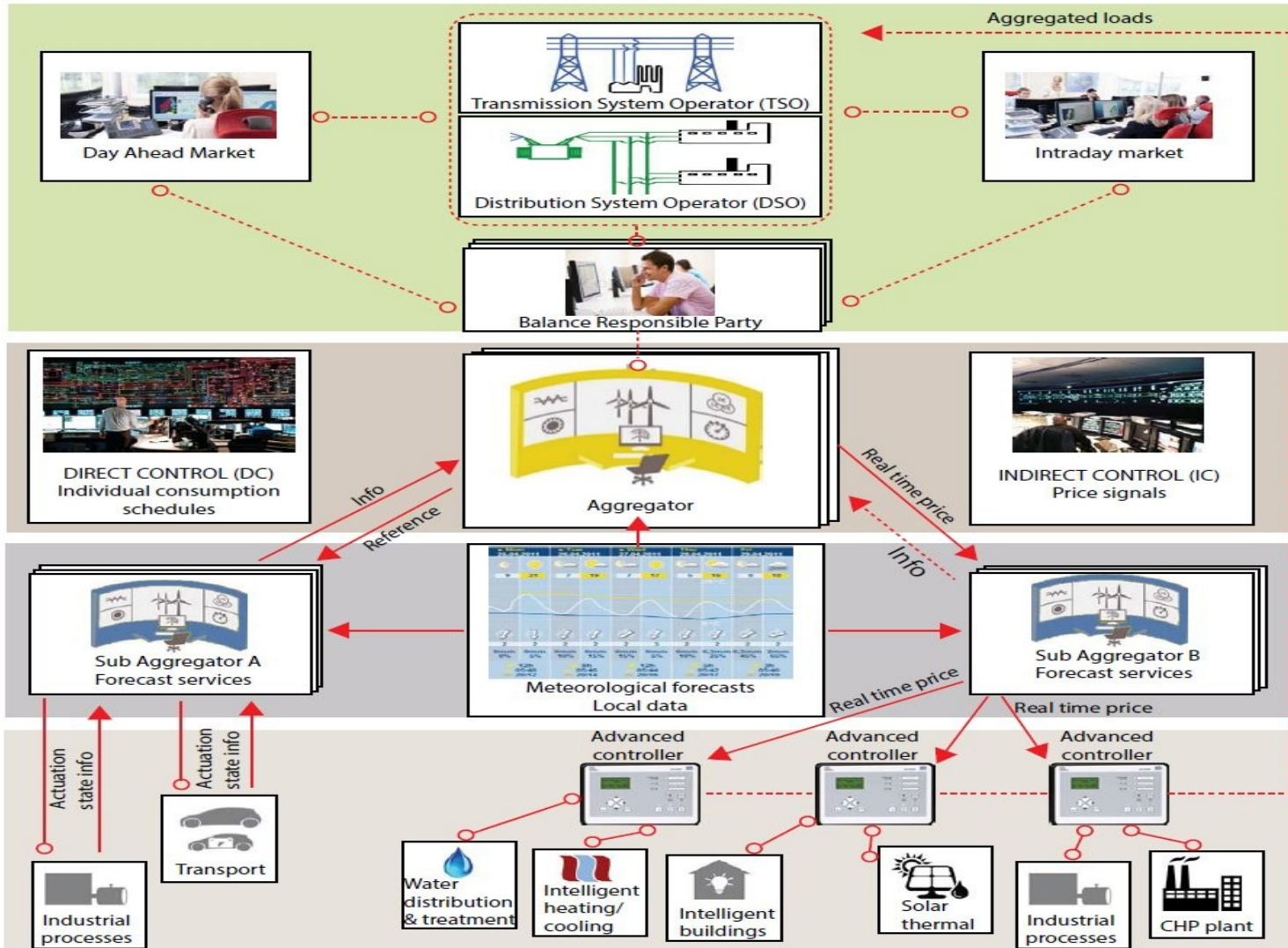
Cities play an important role – for several reasons .....

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

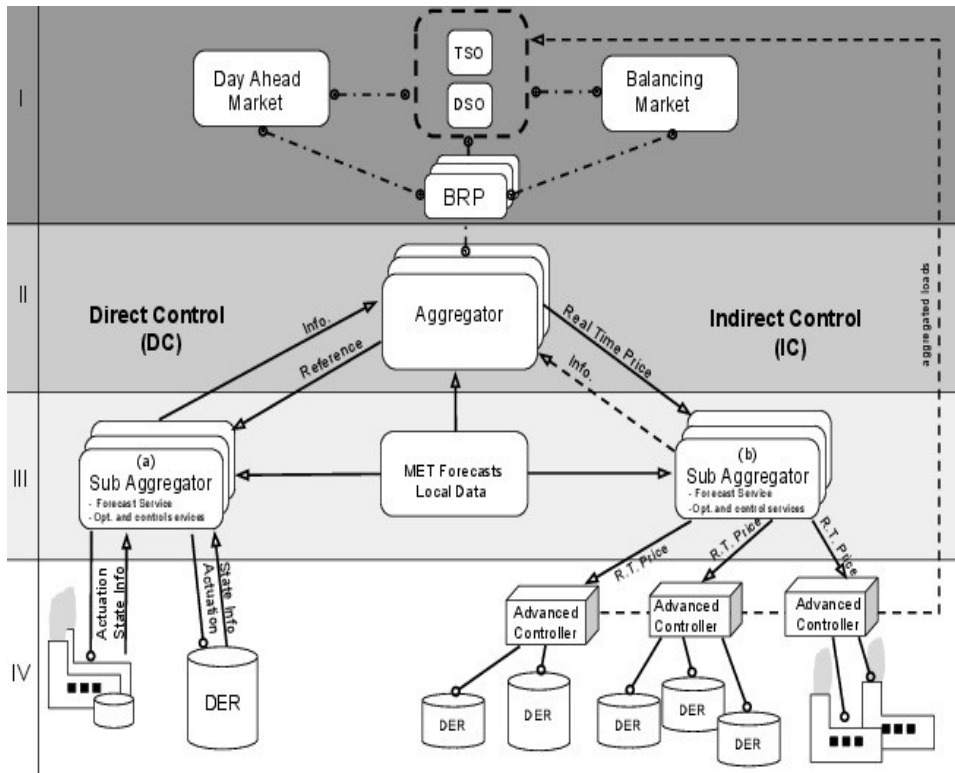
CITIES is the largest Smart Cities and ESI research project in Denmark – see <http://www.smart-cities-centre.org> .



# Future Electric Energy System



# 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**,

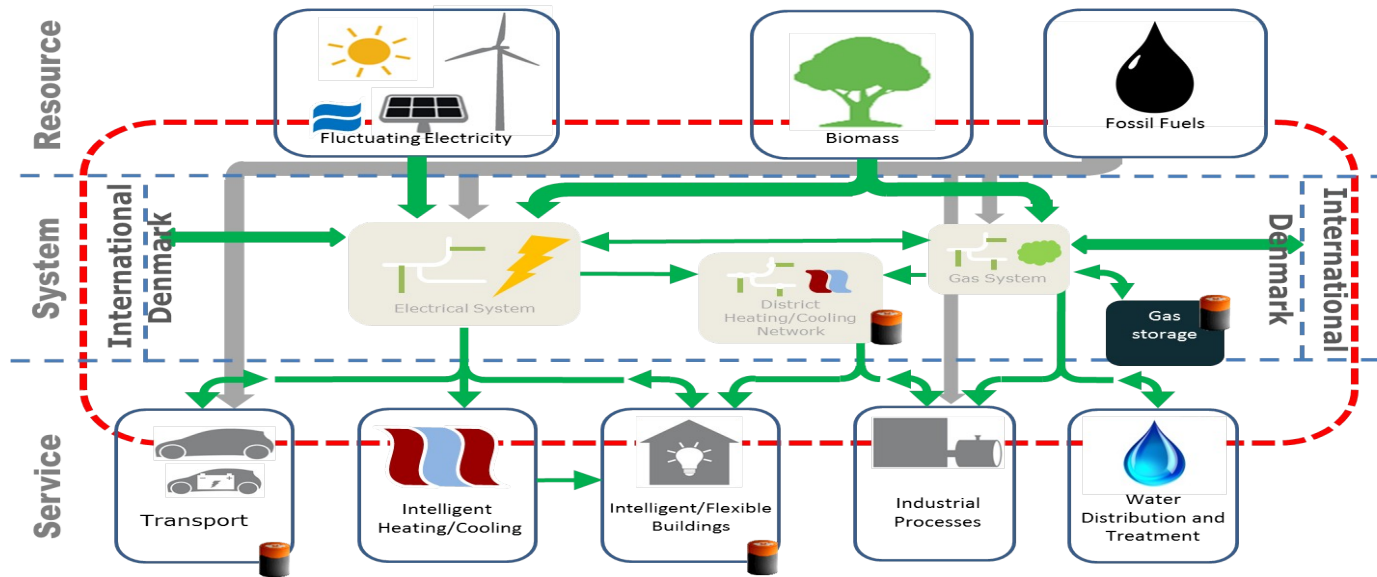
One-way communication

Models for DERs are not needed

Simple 'contracts'



# Virtual Storage by Energy Systems Integration



● **Denmark: 48 pct of power load by renewables (> 100 pct for some days)**

● **(Virtual) storage principles:**

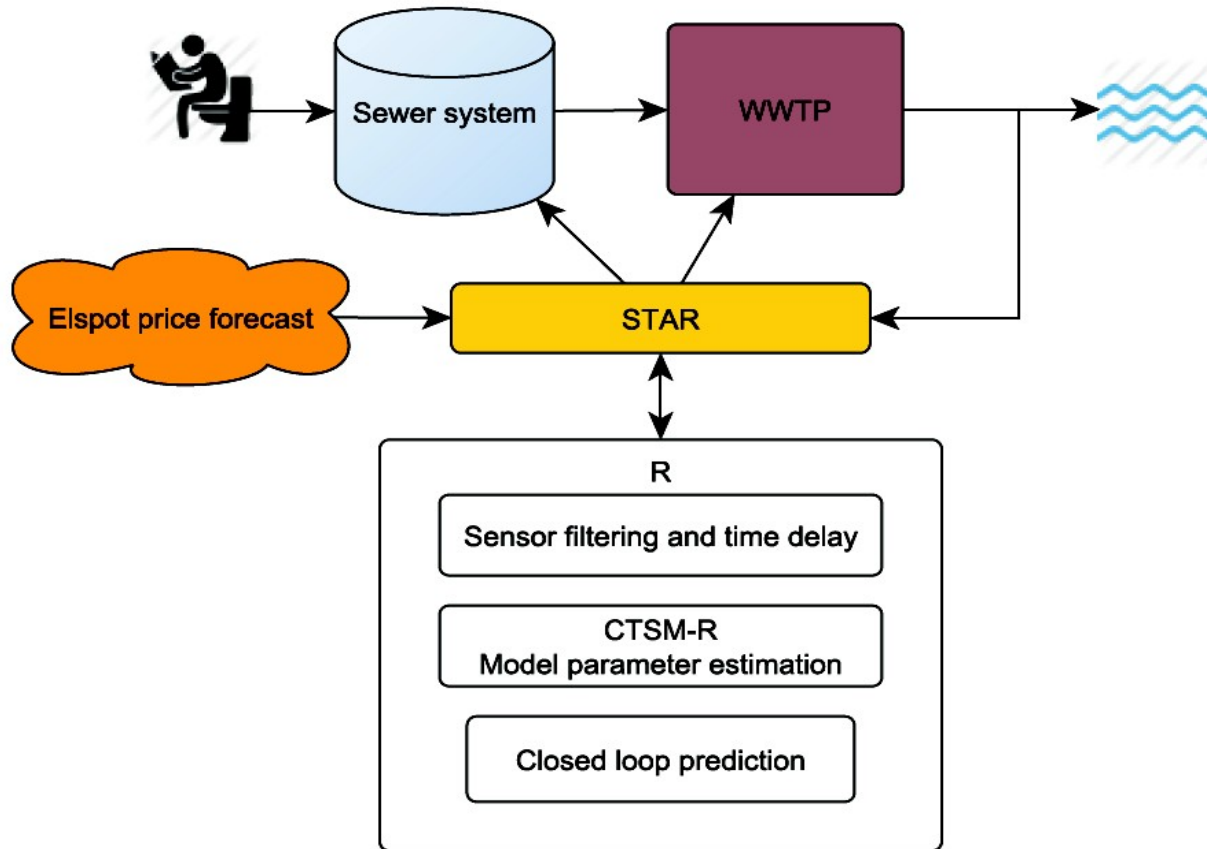
- Buildings (thermal mass) can provide storage up to, say, 5-12 hours ahead
- District heating/cooling systems can provide storage up to 1-3 days ahead
- Gas systems can provide seasonal storage

## Case study

# Control of Wastewater Treatment Plants



# WWTP Control Architecture

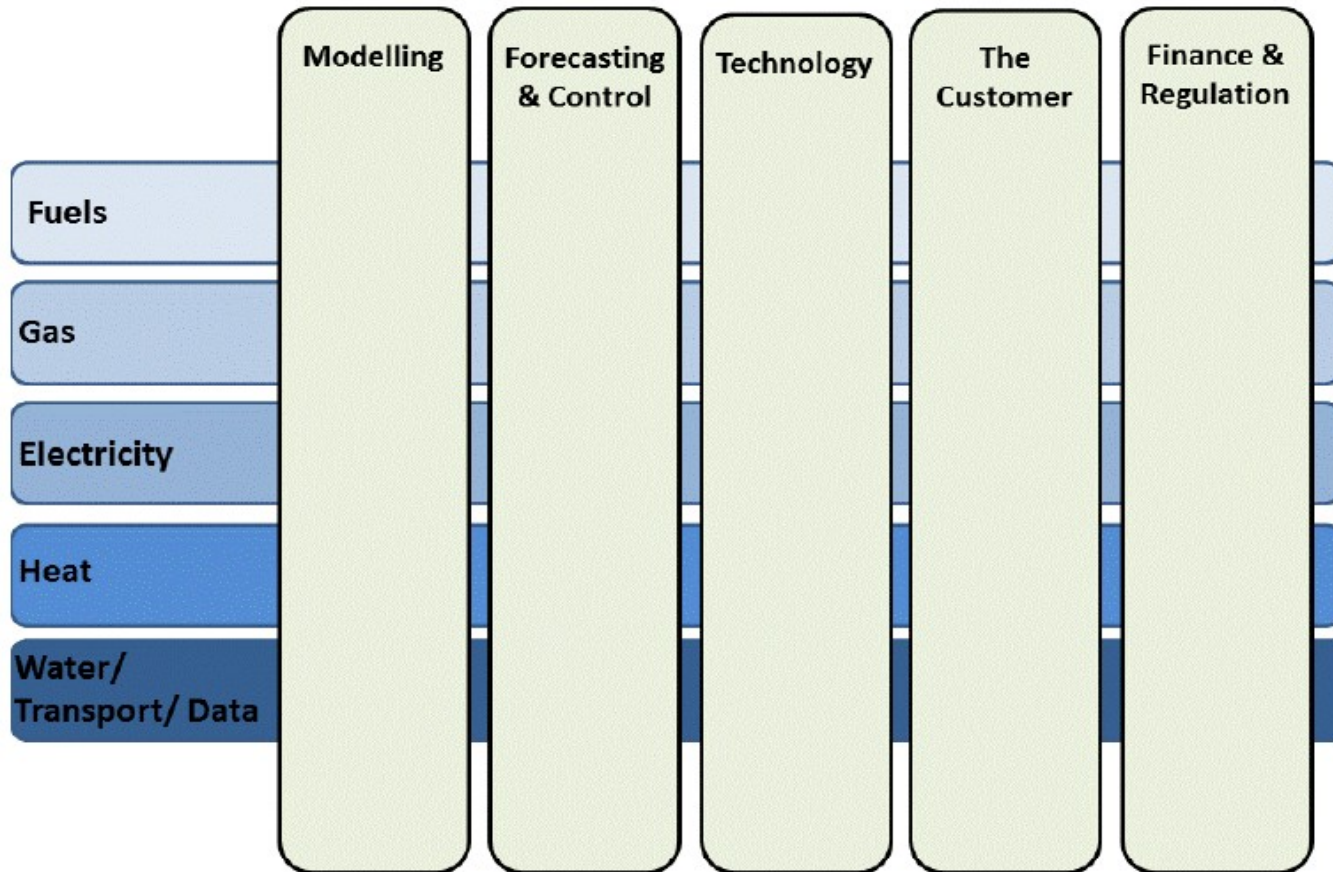




# International Alliance on Energy Systems Integration



(UCD, DTU, KU Leuven):  
**EERA JP on ESI**



# Thanks for your attention!

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