Towards Low Carbon Societies

A Framework for Controlling the Power Load in Future Electric Energy Systems

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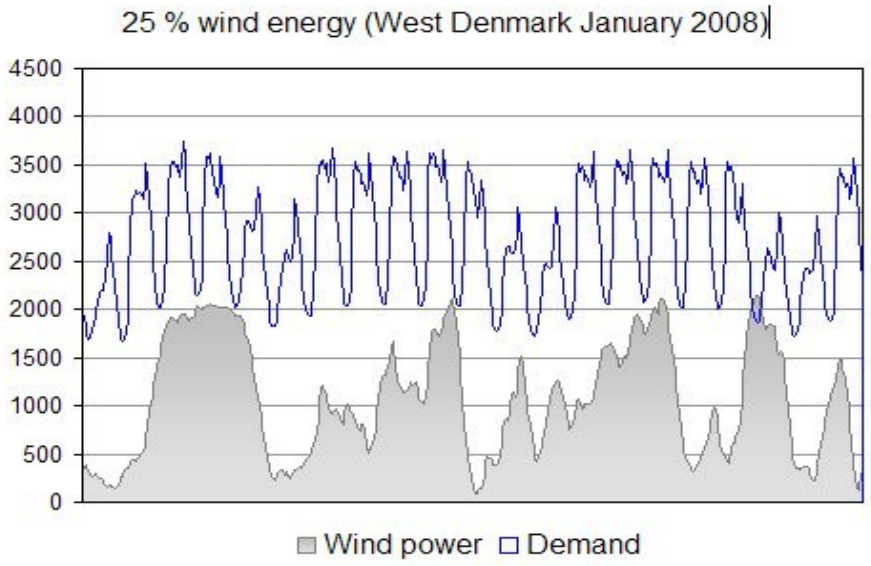
Our Setup

- A Systematic Framework for Controlling the Power Load in Future Smart Cities

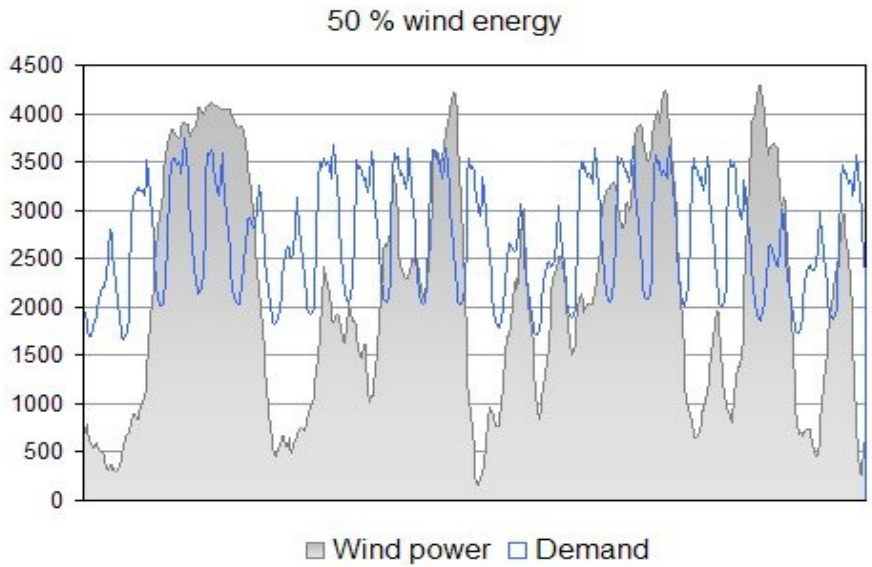
- Showcase: Living-Lab - Aspern Smart City/District

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)



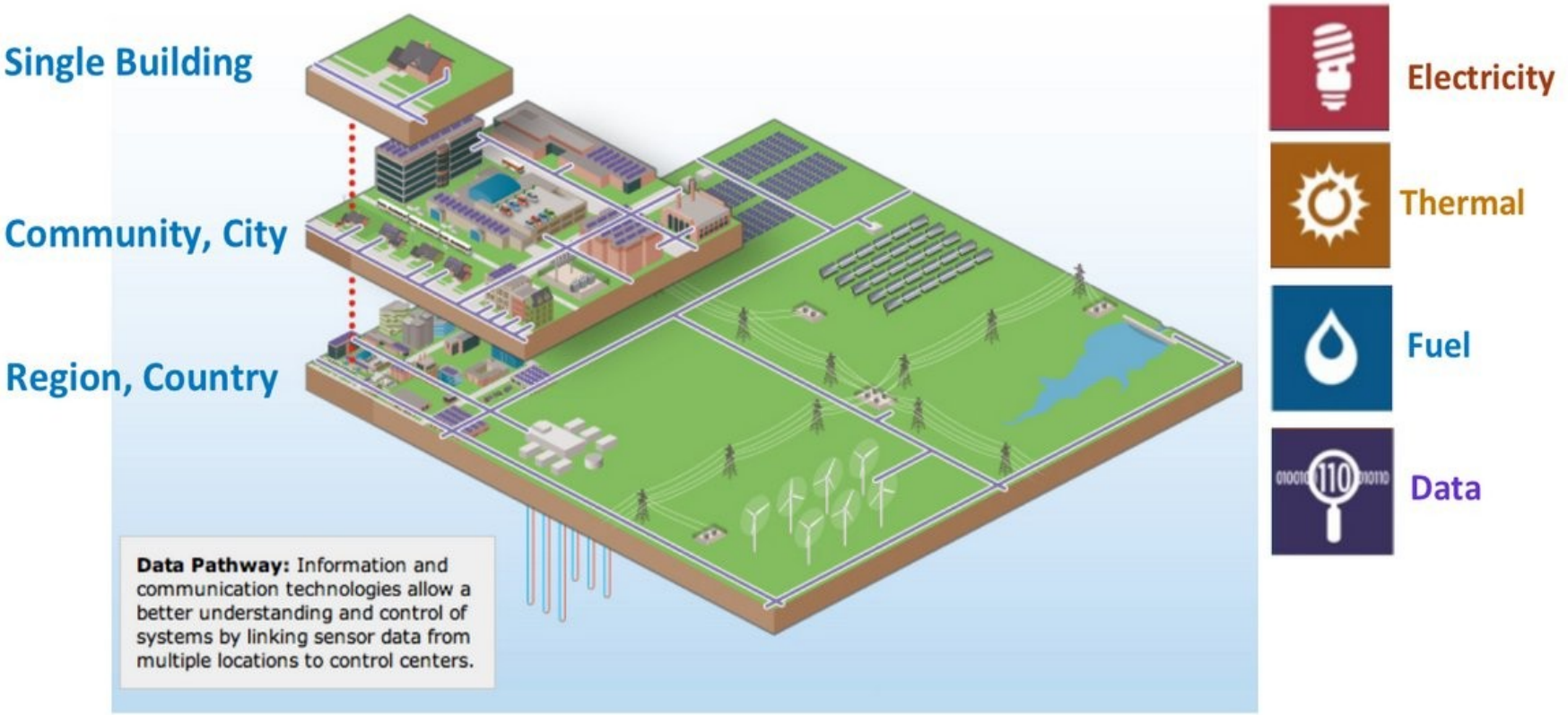
In 2015 more than 42 pct of electricity load was covered by wind power.

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

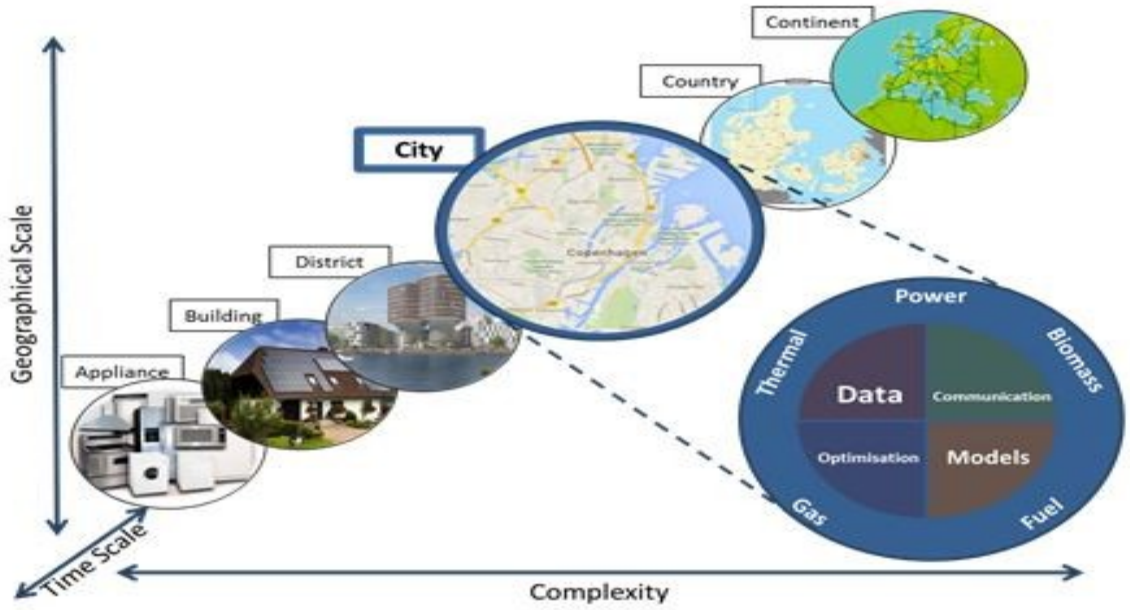
Energy Systems Integration in Smart Societies

Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales

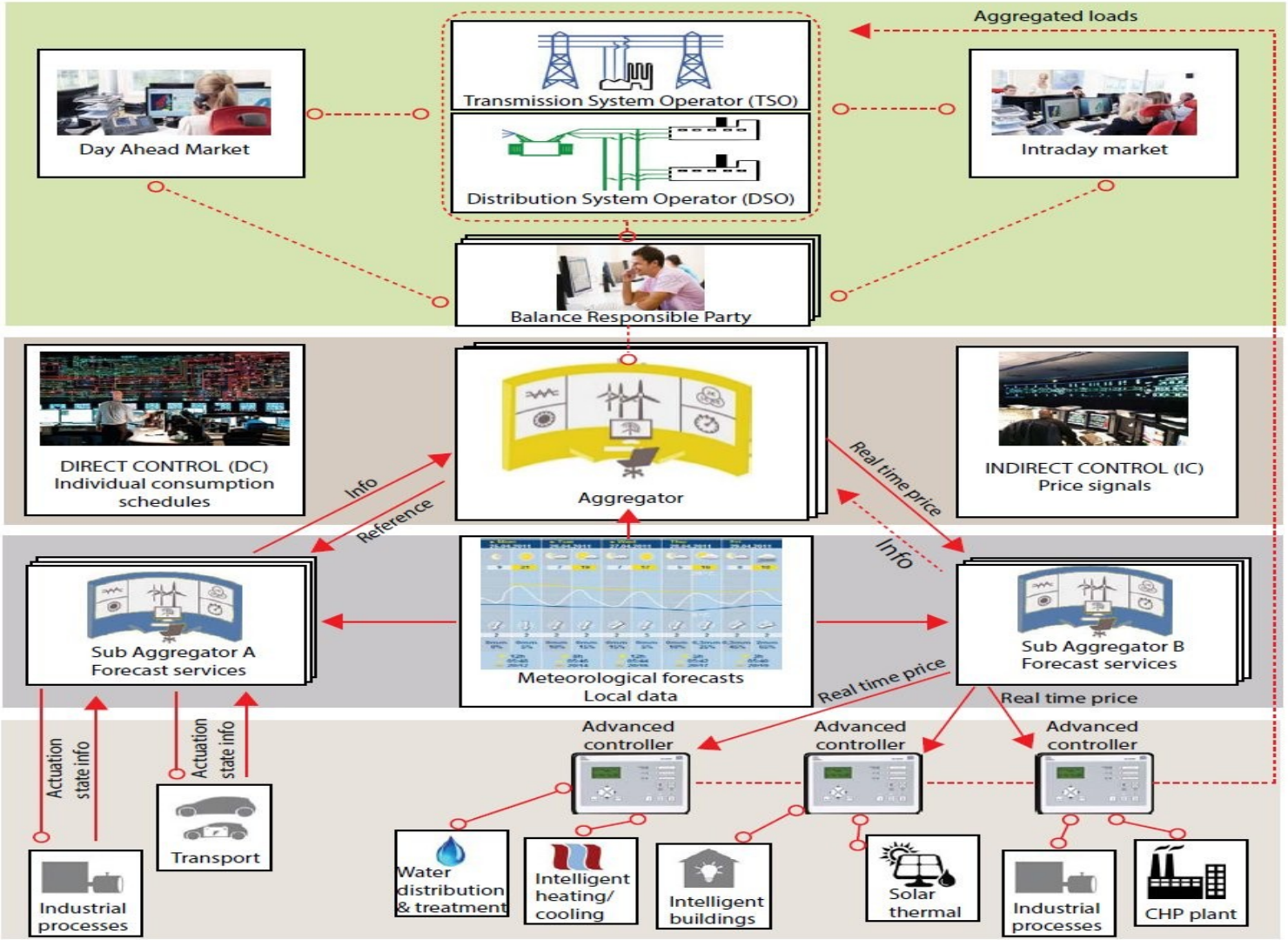


Temporal and Spatial Scales

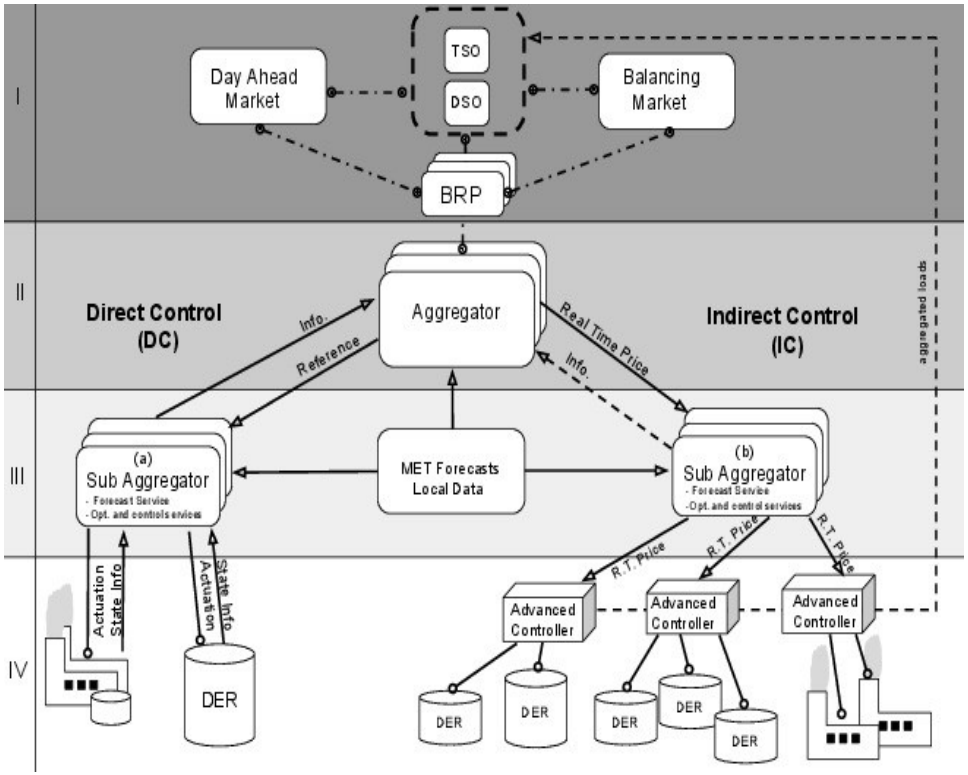
The ***Smart-Energy Operating-System (SE-OS)*** is used to develop, implement and test of solutions (layers: data, models, optimization, control, communication) for ***operating flexible electrical energy systems*** at **all scales**.



Smart-Energy OS



Control and Aggregation



In 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**

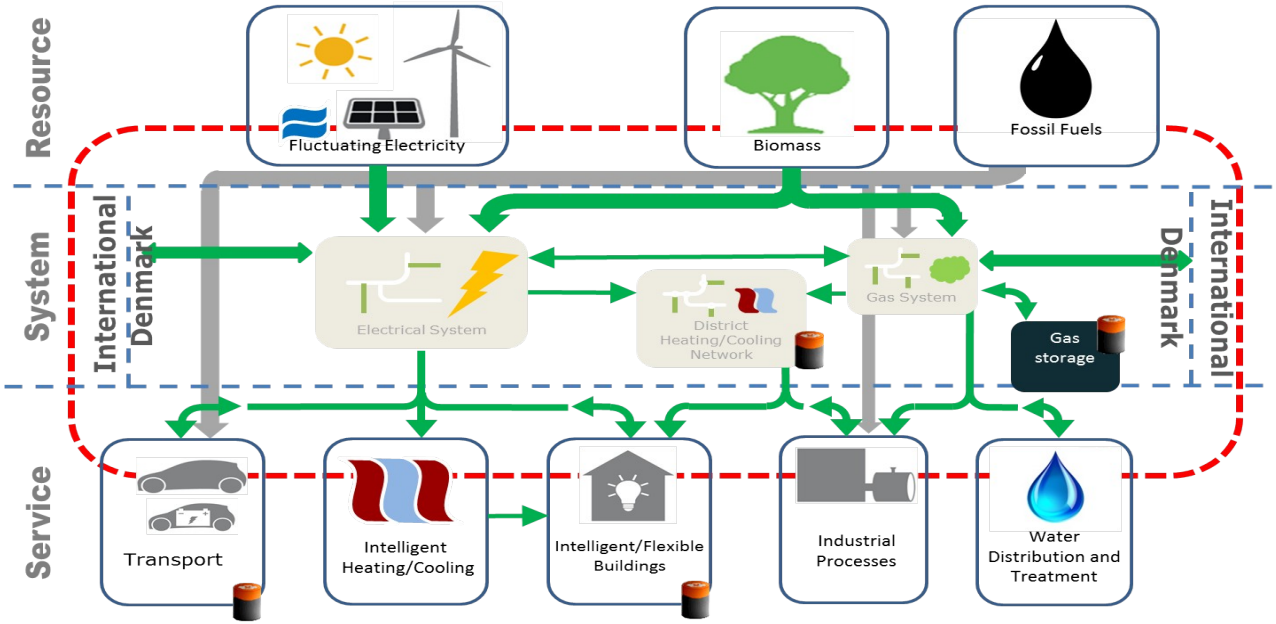
Cost: E-MPC at **low (DER) level**, One-way communication

Models for DERs are not needed

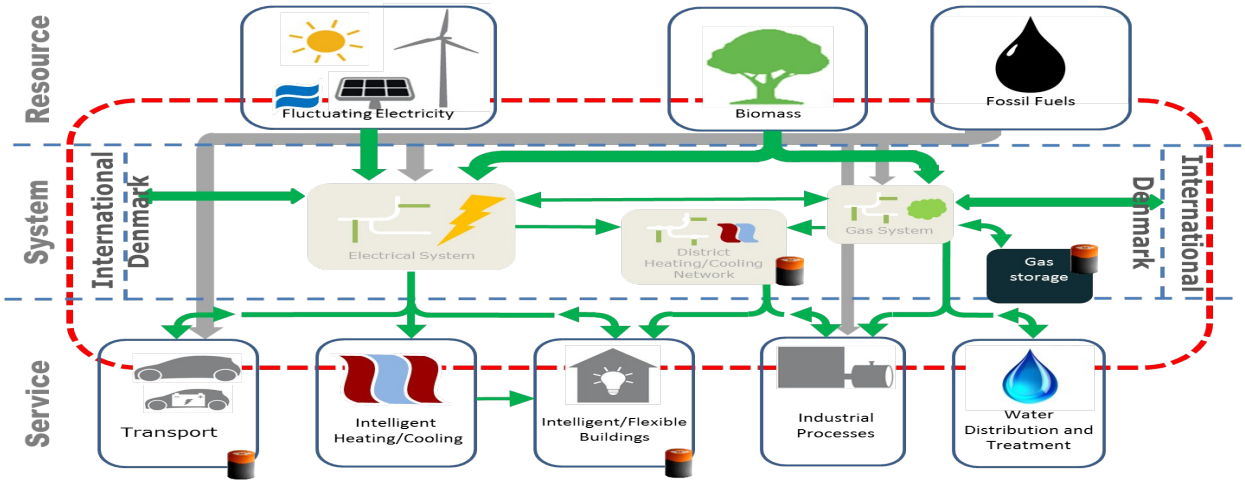
Simple 'contracts'

Models

Grey-box modelling are used to establish **models and methods for real-time operation of future electric energy systems**



Virtual Storage solutions in Smart Cities



- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal mass can provide storage up to, say, 5-8 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-24 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - Gas systems can provide seasonal storage

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

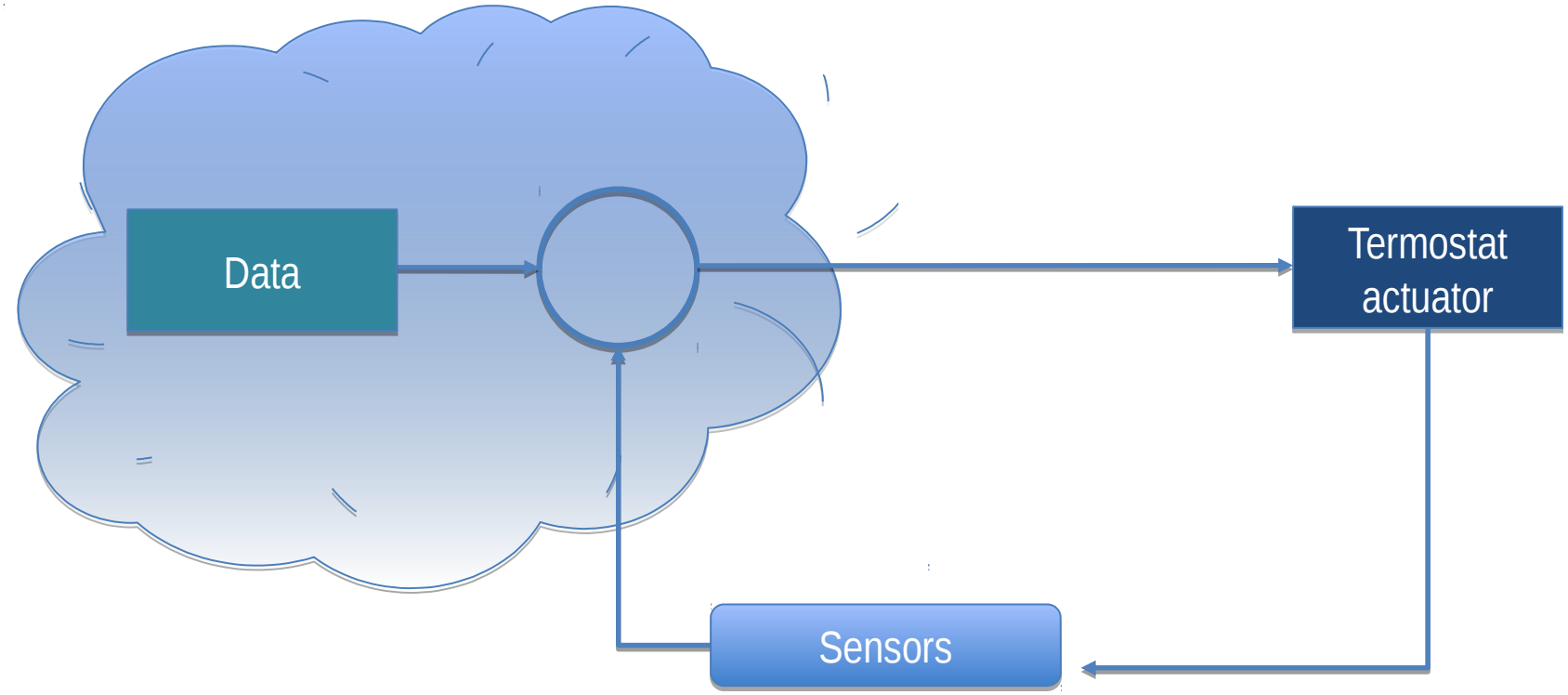
Summer School – Granada, Spain, June 19th-24th 2016

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

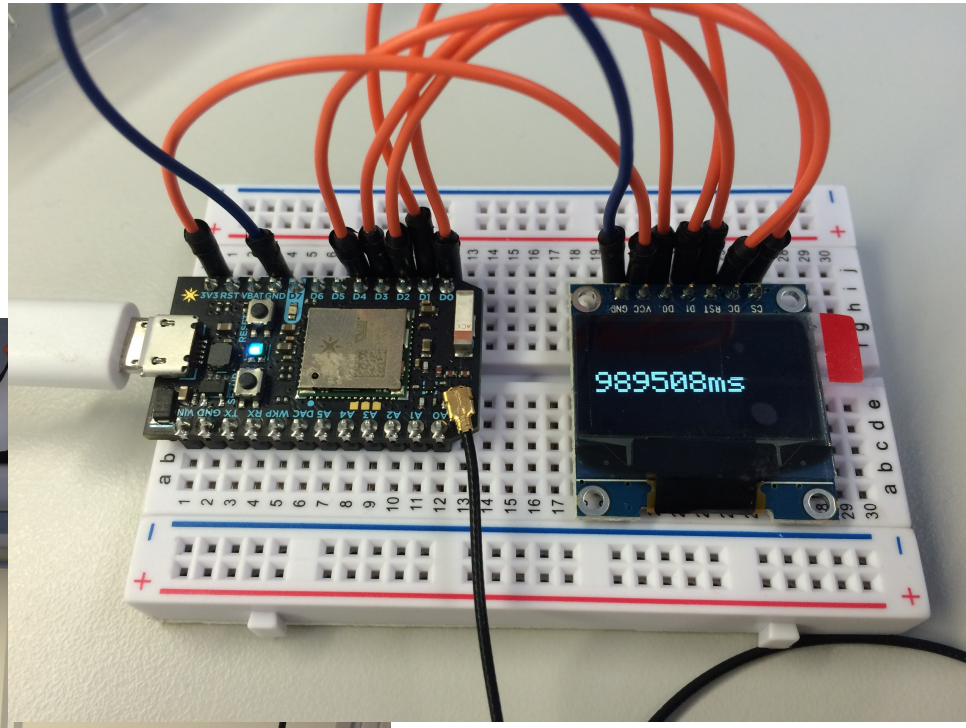
Smart City Challenge in Copenhagen – April 20th 2016

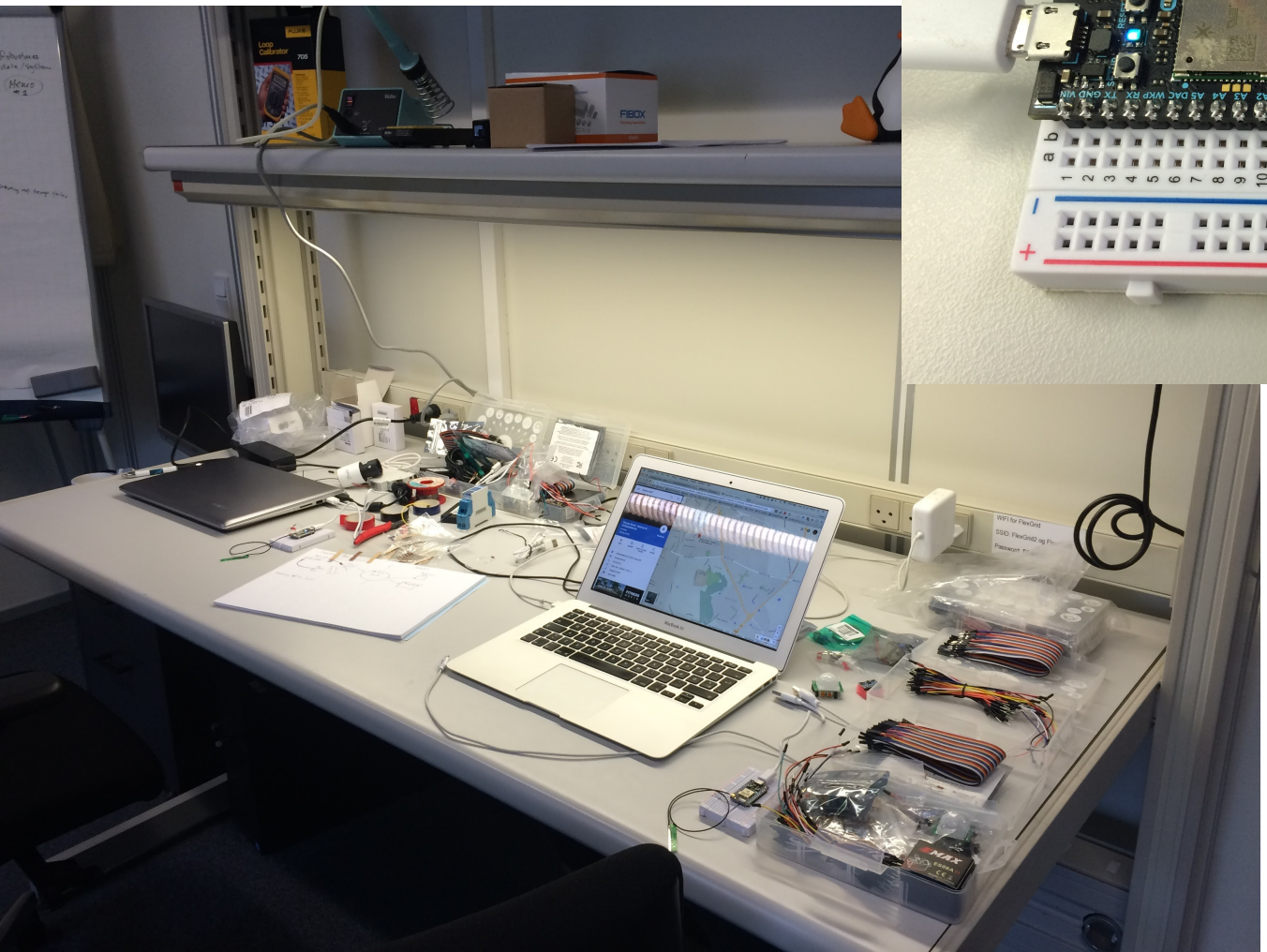
Guest lecture by Pierluigi Mancarella at DTU, April 6th

SE-OS
Control loop design – **logical drawing**

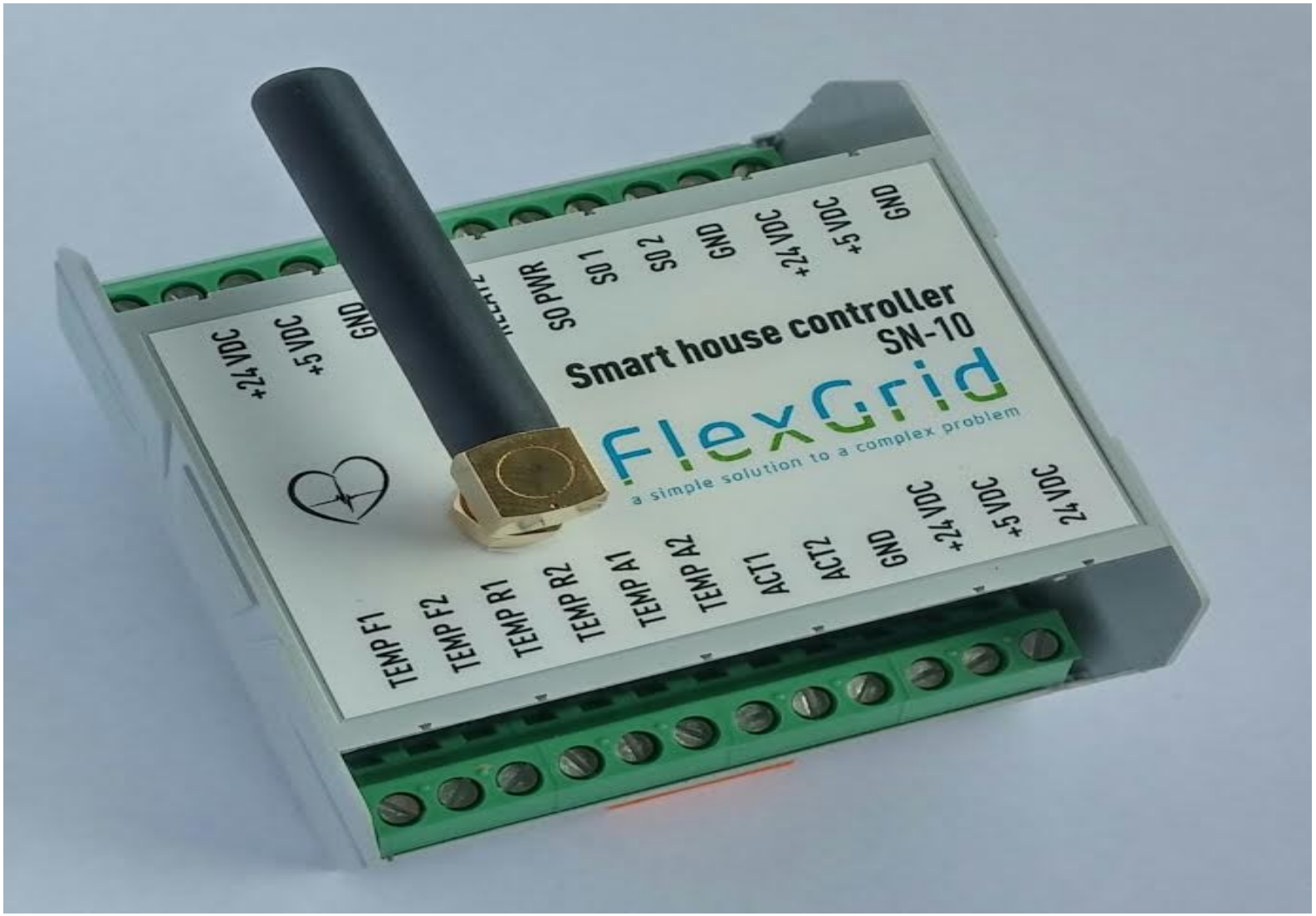


Lab testing ….





Smart House Controller



Case study

Control of Power Consumption to Summer Houses with a Pool

Services – H2020 SmartNet

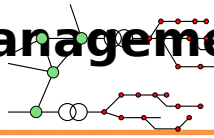
Balancing

- The large inertia of pools allows for shift of electricity consumption by several hours.

Voltage regulation (DSO)

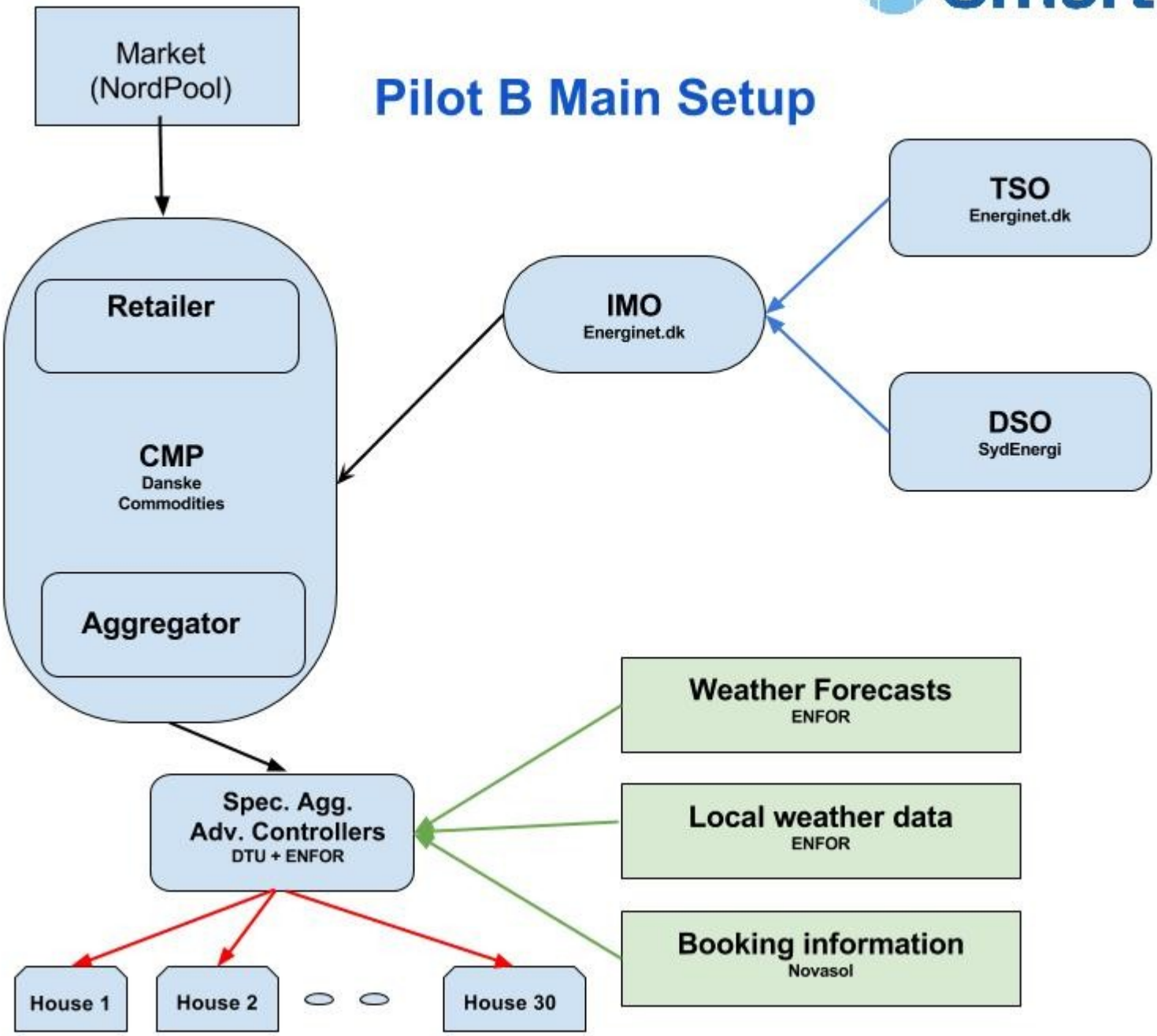
- Via active coordination of the flexibility below a critical node on the DSO grid.

Congestion management



- Active load management to help finding an optimal routing of the power.

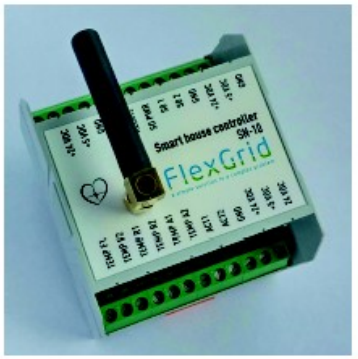
Pilot B Main Setup

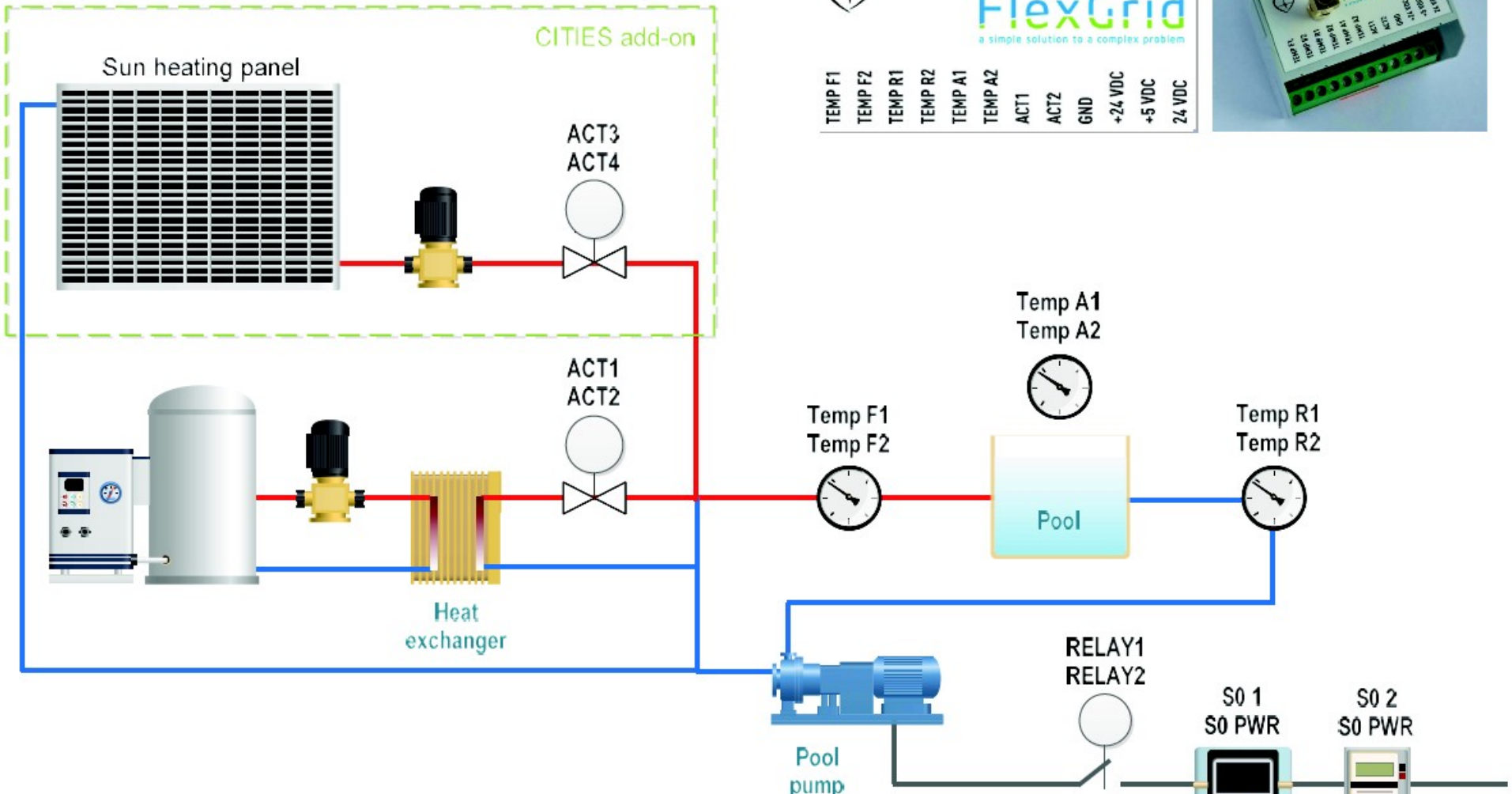


Smart Control of Houses with a Pool

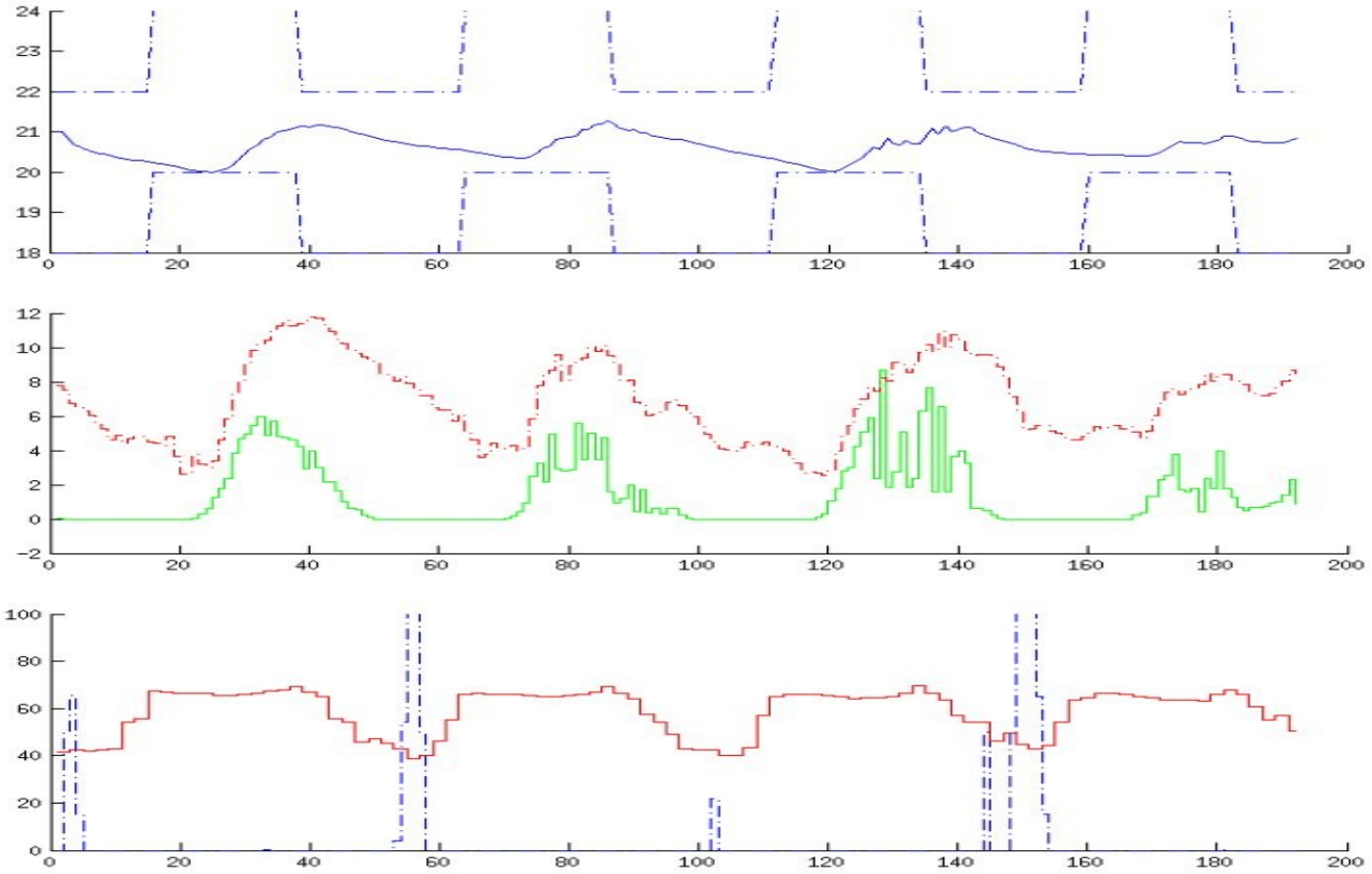
PilotB SN-10 signal overview

revision 1.0 (CITIES add-on)

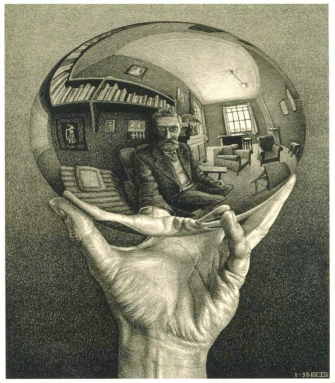




Heat pump with thermal solar collector and storage (savings up to 35 pct)



Smart-Energy OS
Examples from the CITIES project



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

Summary

- A Smart-Energy OS for implementing flexibility energy systems in smart societies has been described
- Built on: Big Data Analytics, Cyber Physical systems, Stochastic opt./control, Forecasting, IoT, IoS, Cloud computing, ...
- **Modelling**: Toolbox – CTSM-R - for combined physical and statistical modelling (grey-box modelling)
- **Control:** Toolbox – MPC-R - for Model Predictive Control
- **Simulation:** Framework for simulating flexible power systems.

Discussion

- IT-Intelligent Energy Systems Integration in Smart Cities can provide virtual storage solutions (so maybe we should put less focus on electrical storage solutions)
- District heating (or cooling) systems can provide flexibility on the essential time scale (up to a few days)
- Gas systems can provide seasonal virtual storage solutions
- Smart Cities are just smart elements of a Smart Society
- 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 in many countries (eg. Denmark).
- 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)