Emission/Cost Saving by Data Intelligent Control of Motor Systems

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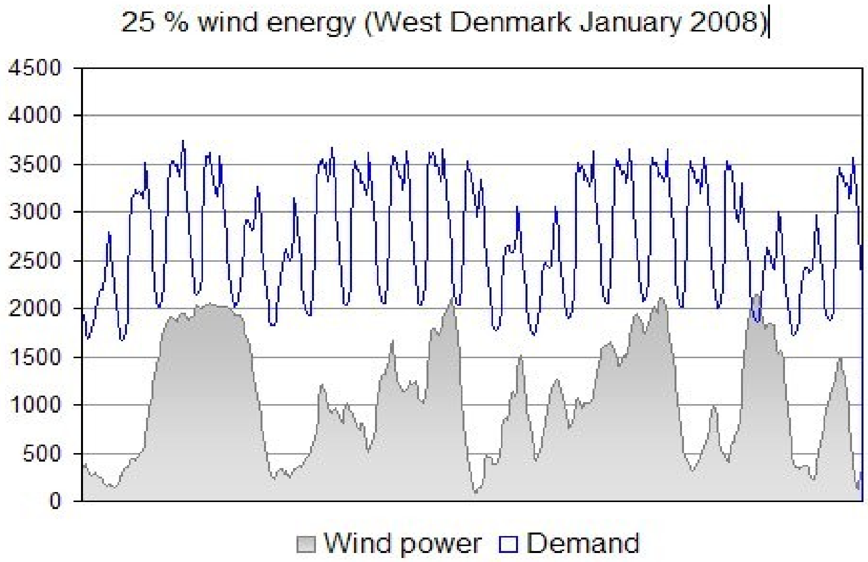
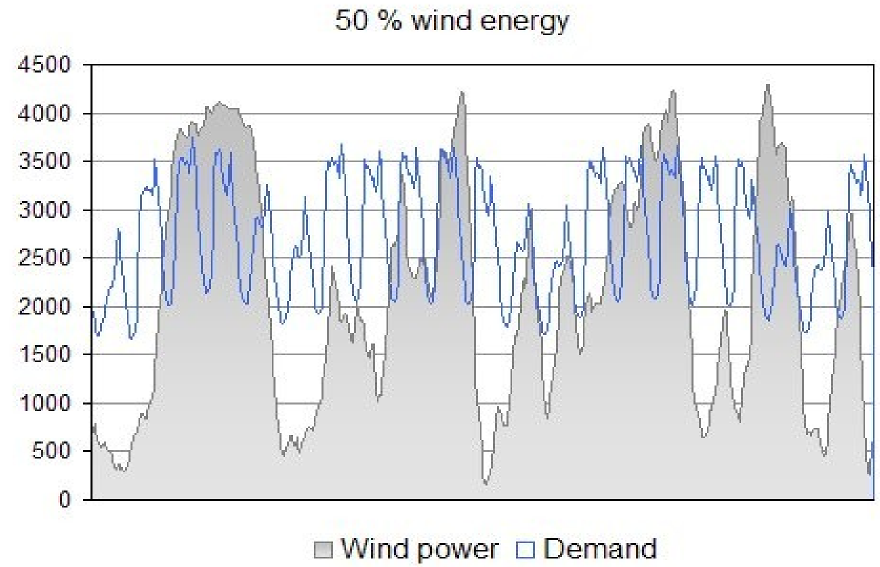
The Danish Wind Power Case

…. balancing of the power system





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

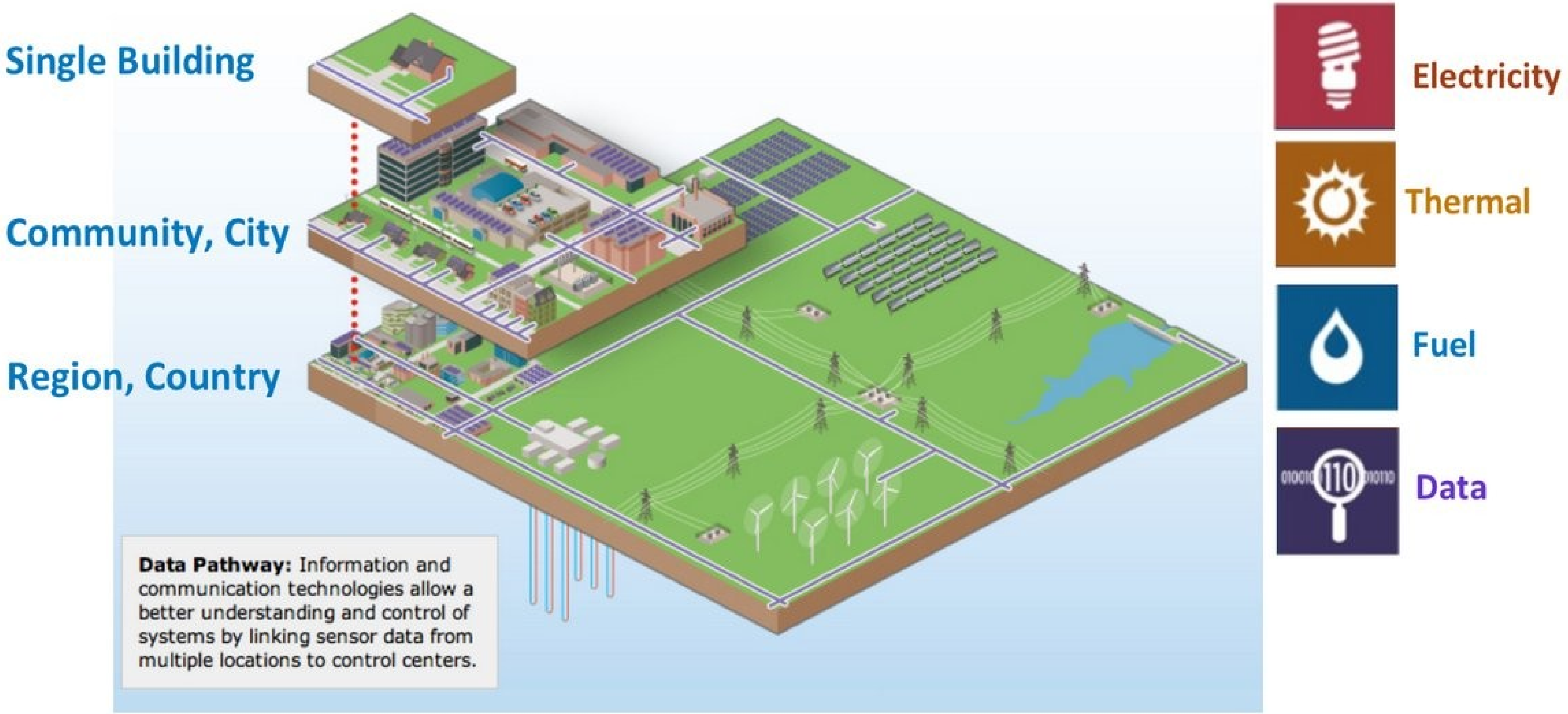
In 2015 more than 42 pct of electricity load was covered by wind power.

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

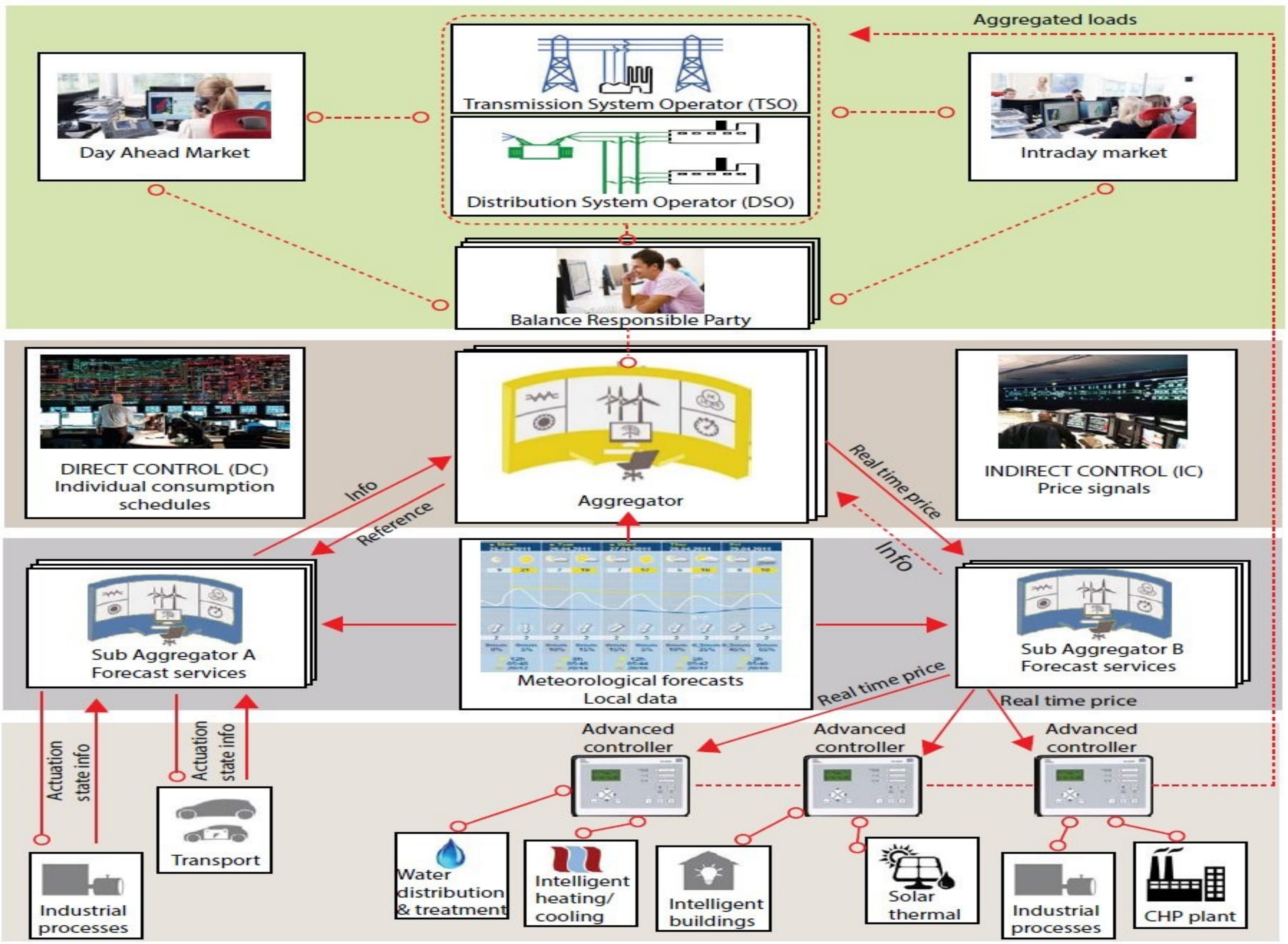
July 10th, 2015 more than 140 pct of the power load was covered by wind power

Energy Systems Integration

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



Smart-Energy OS



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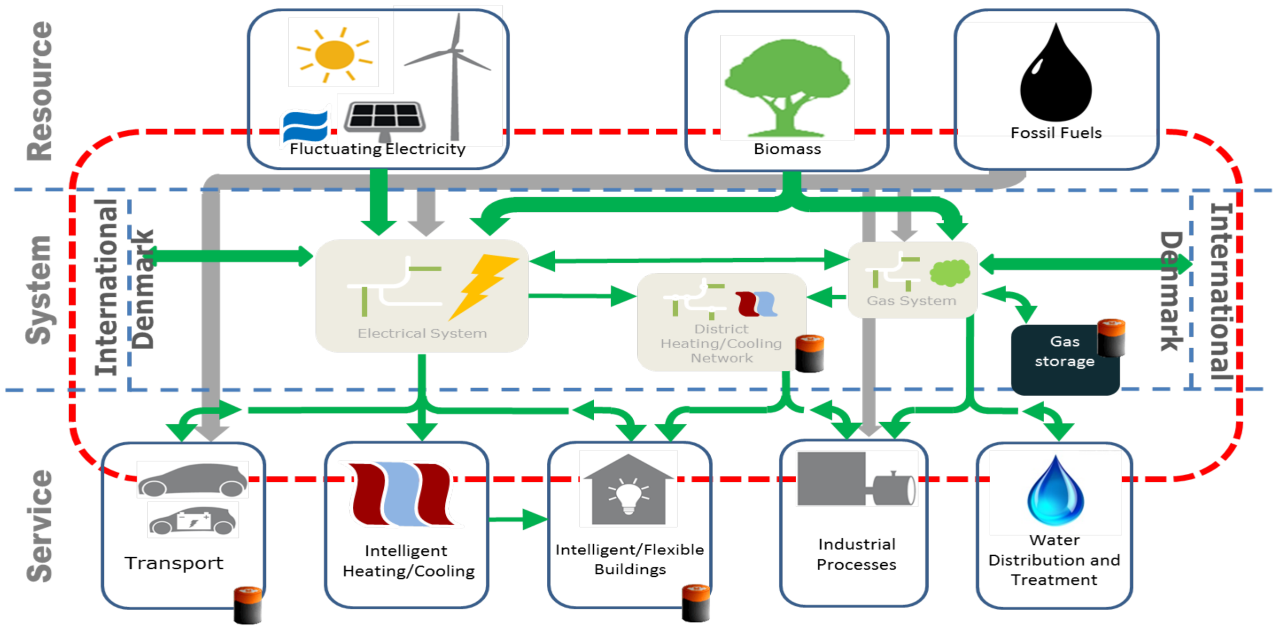
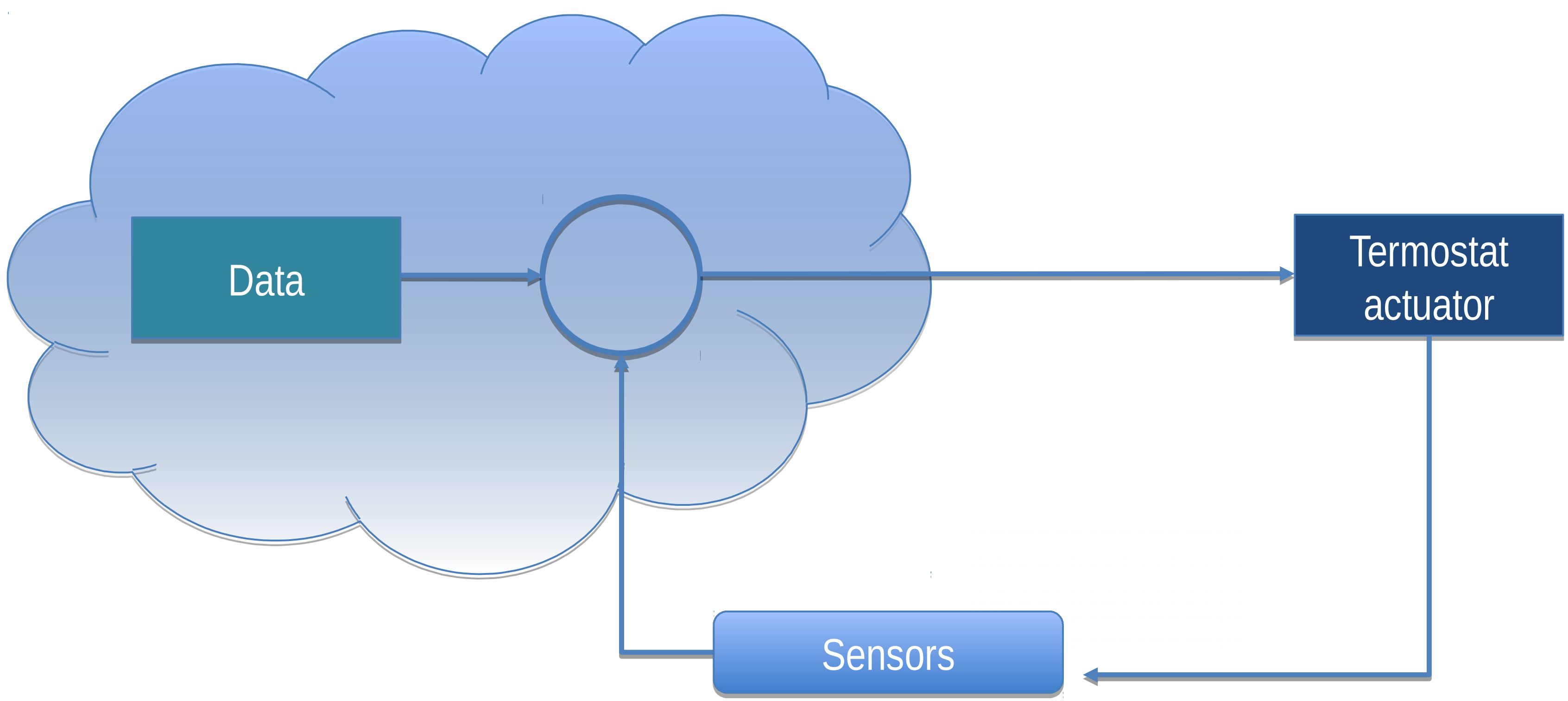
Cyber-physical Models

Grey-box modelling techniques is used to establish models for real-time and data intelligent operation of *future electric motor systems*



Cloud-based control and optimization

Logical drawing of control-loop



Case study

Control of Power Consumption to Summer Houses with a Pool

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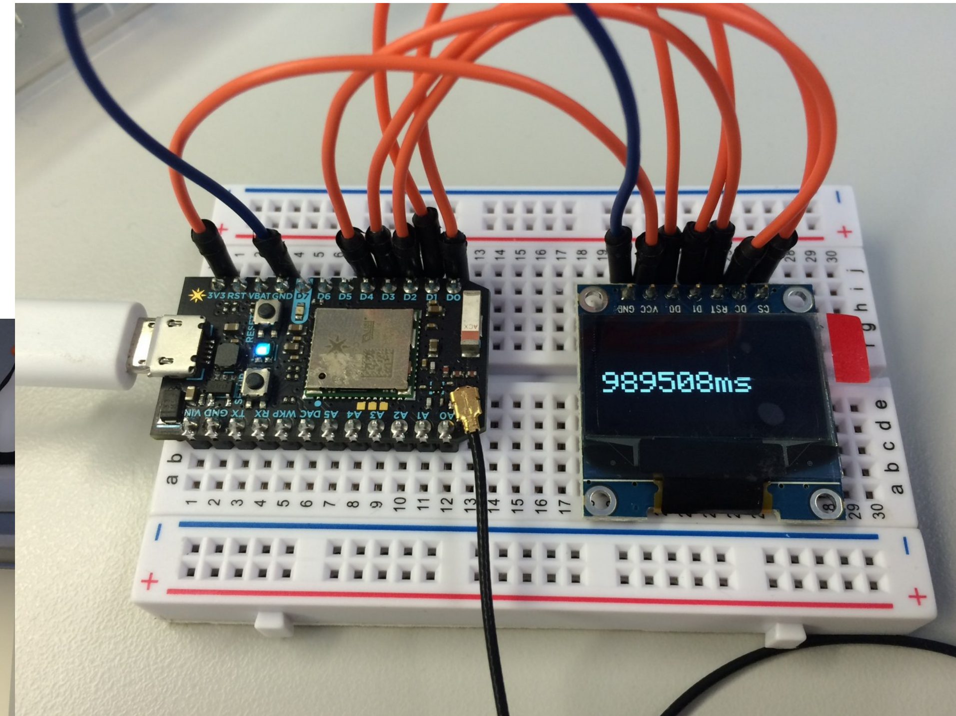
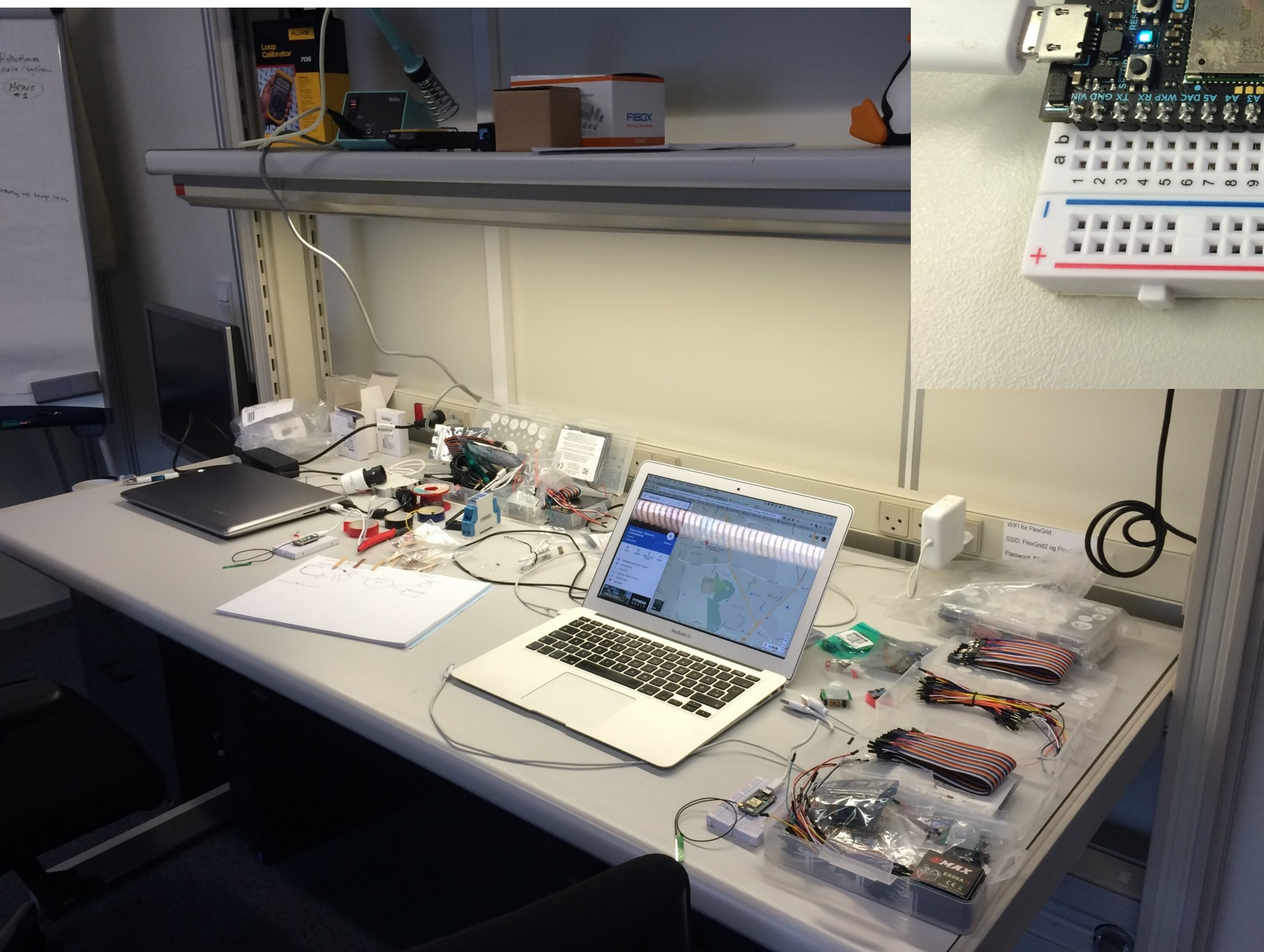
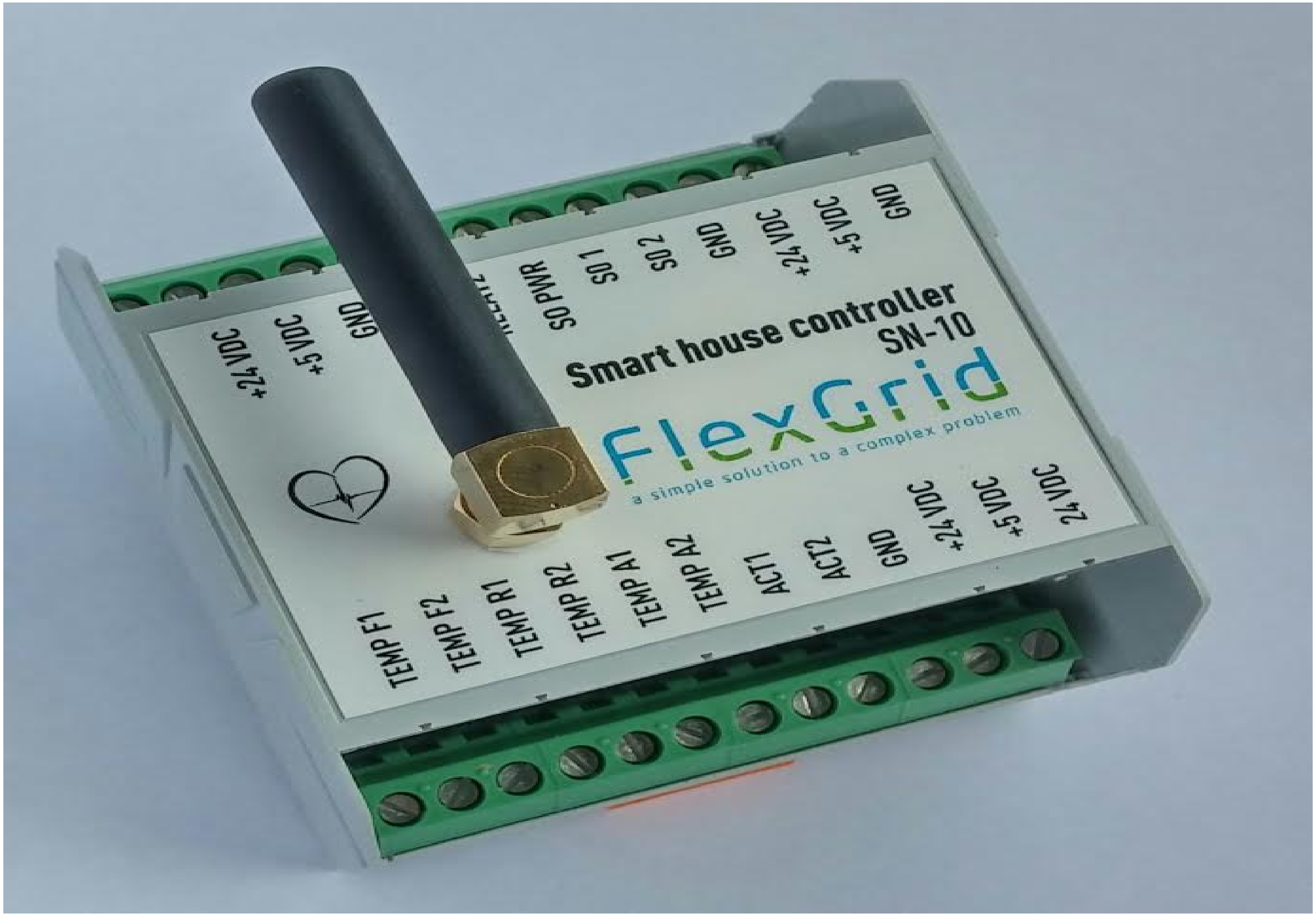
Lab testing ….





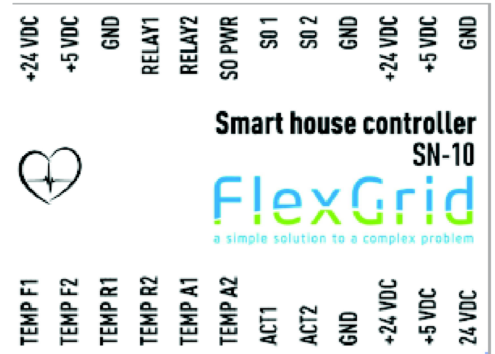
SN-10 Smart House Prototype

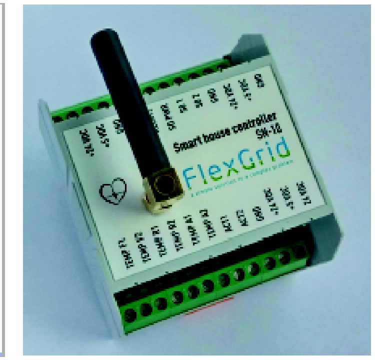


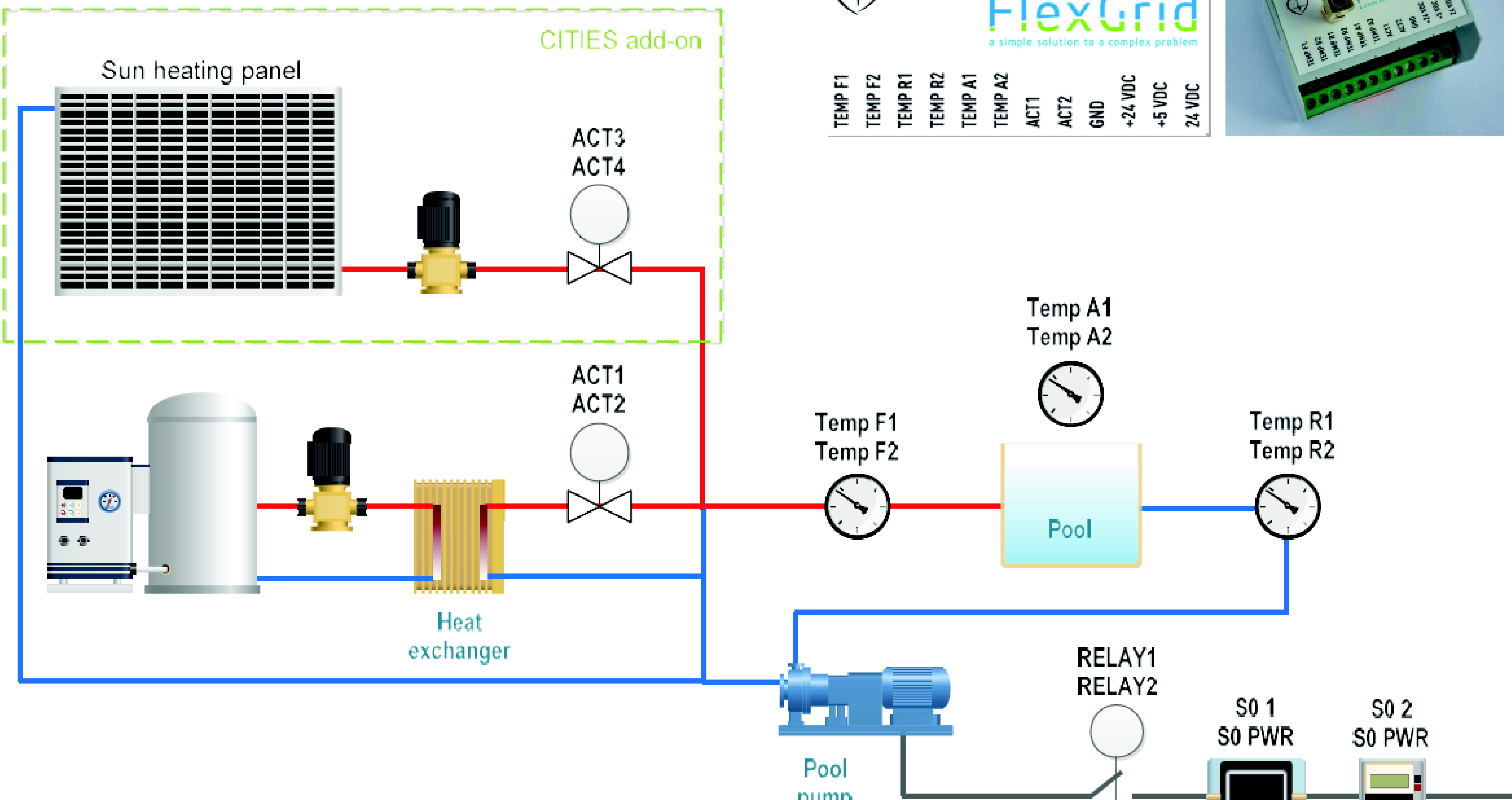
Smart Control of Houses with a Pool

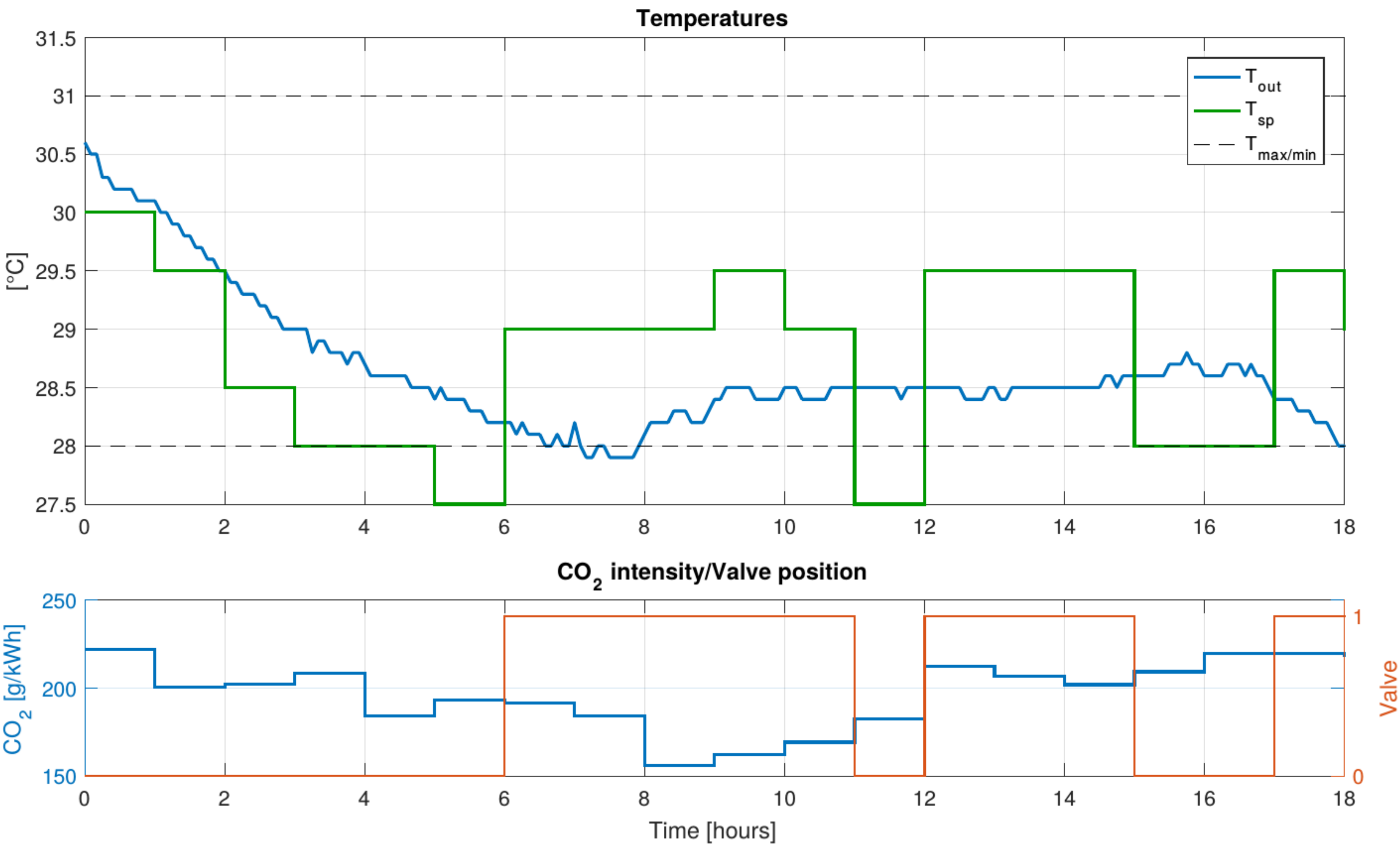
PilotB SN-10 signal overview

revision 1.0 (CITIES add-on)









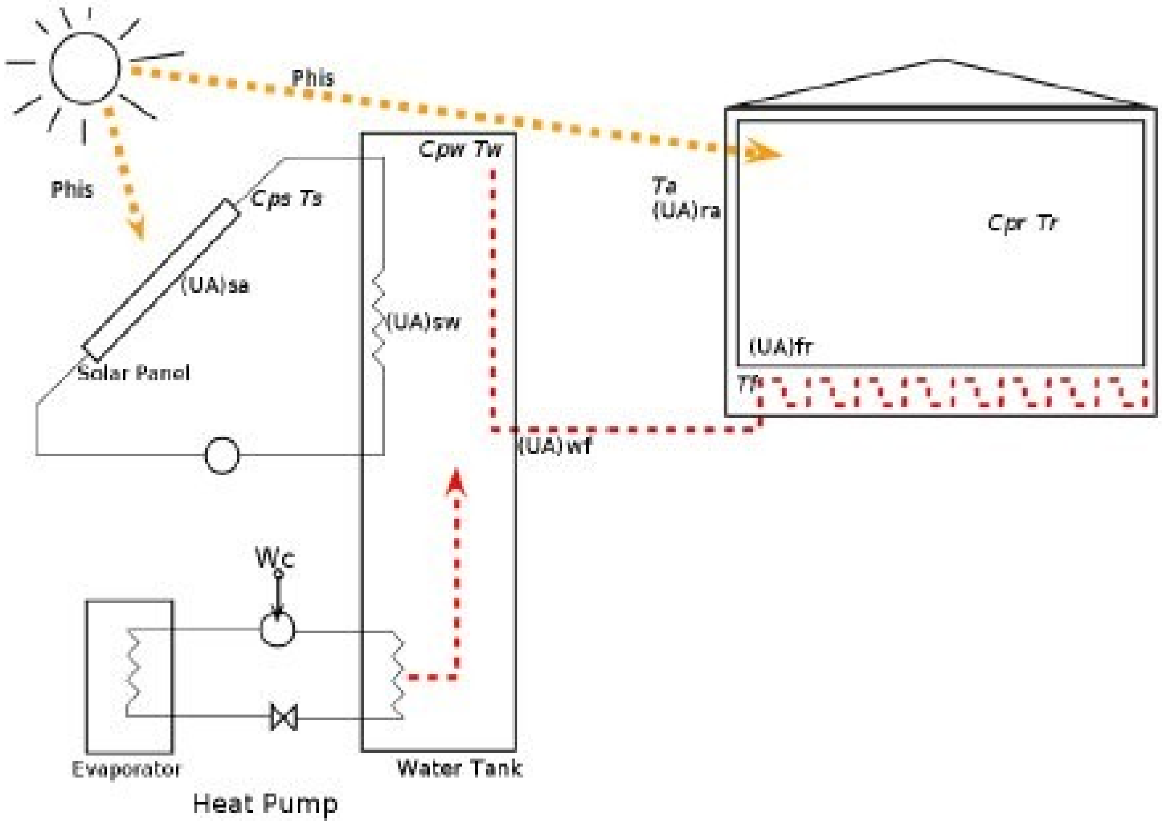
Temperatures
[°C]
31.5
31
30.5
30
29.5
29
28.5
28
27.5
0
2
4
6
8
10
12
14
16
18
T_{out}
T_{sp}
$T_{max/min}$
CO_2 intensity/Valve position
CO_2 [g/kWh]
250
200
150
Valve
1
0
Time [hours]

Case study

Price-based Control of Heat Pumps

Modeling Heat Pump and Solar Collector

Simplified System



Avanced Controller

Economic Model Predictive Control

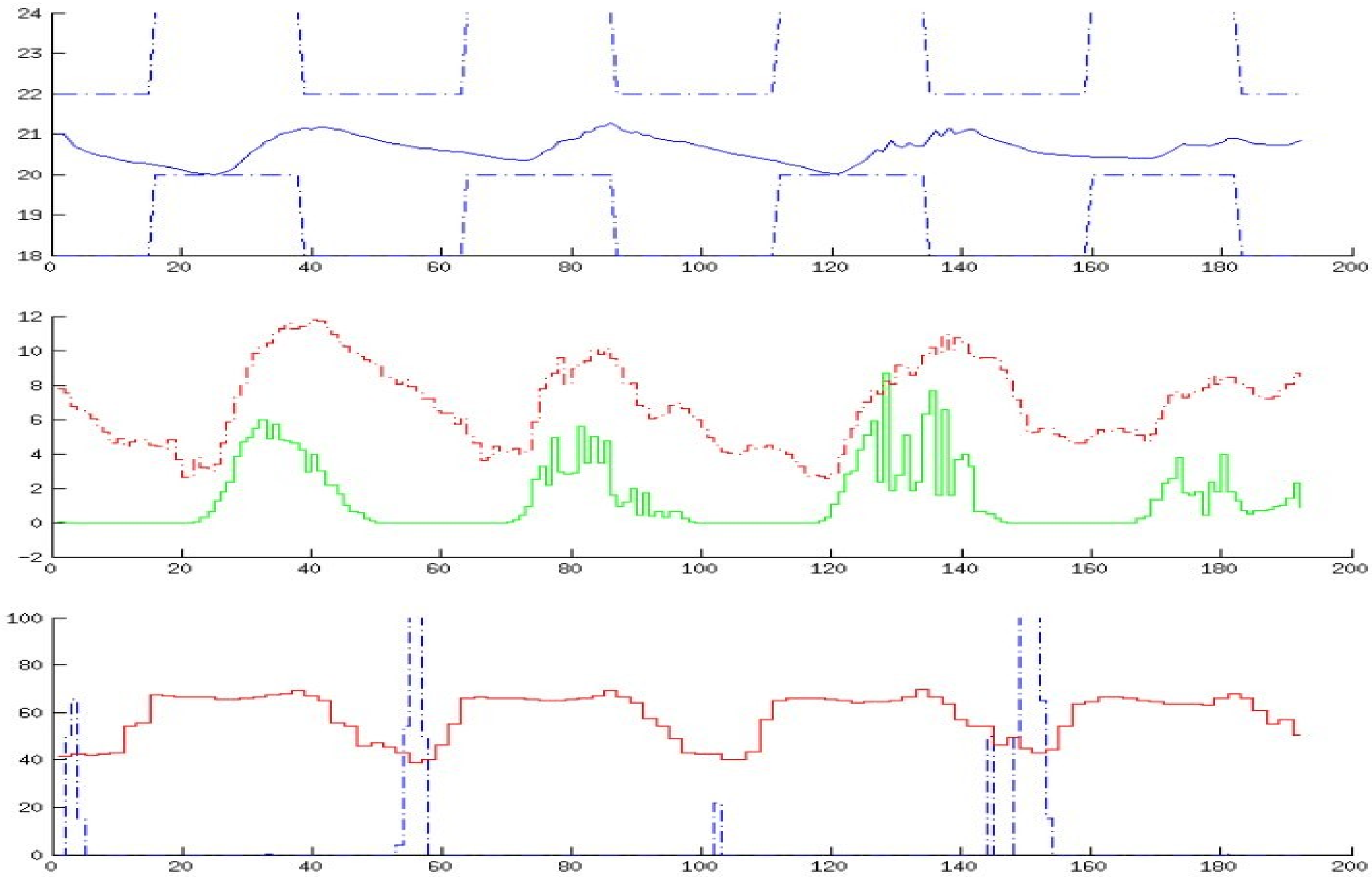
Formulation

The Economic MPC problem, with the constraints and the model, can be summarized into the following formal formulation:

$$\min_{\{u_k\}_{k=0}^{N-1}} \phi = \sum_{k=0}^{N-1} c' u_k \tag{4a}$$

$$\begin{aligned}
\text{Subject to} \quad & x_{k+1} = Ax_k + Bu_k + Ed_k & k = 0, 1, \dots, N-1 \quad & (4b) \\
& y_k = Cx_k & k = 1, 2, \dots, N \quad & (4c) \\
& u_{min} \leq u_k \leq u_{max} & k = 0, 1, \dots, N-1 \quad & (4d) \\
& \Delta u_{min} \leq \Delta u_k \leq \Delta u_{max} & k = 0, 1, \dots, N-1 \quad & (4e) \\
& y_{min} \leq y_k \leq y_{max} & k = 0, 1, \dots, N \quad & (4f)
\end{aligned}$$

Heat pump with thermal solar collector and storage (cost/CO2 savings up to 25 pct – energy consumption +8 pct)



Case study

Data Intelligent Control of Wastewater Treatment Plants

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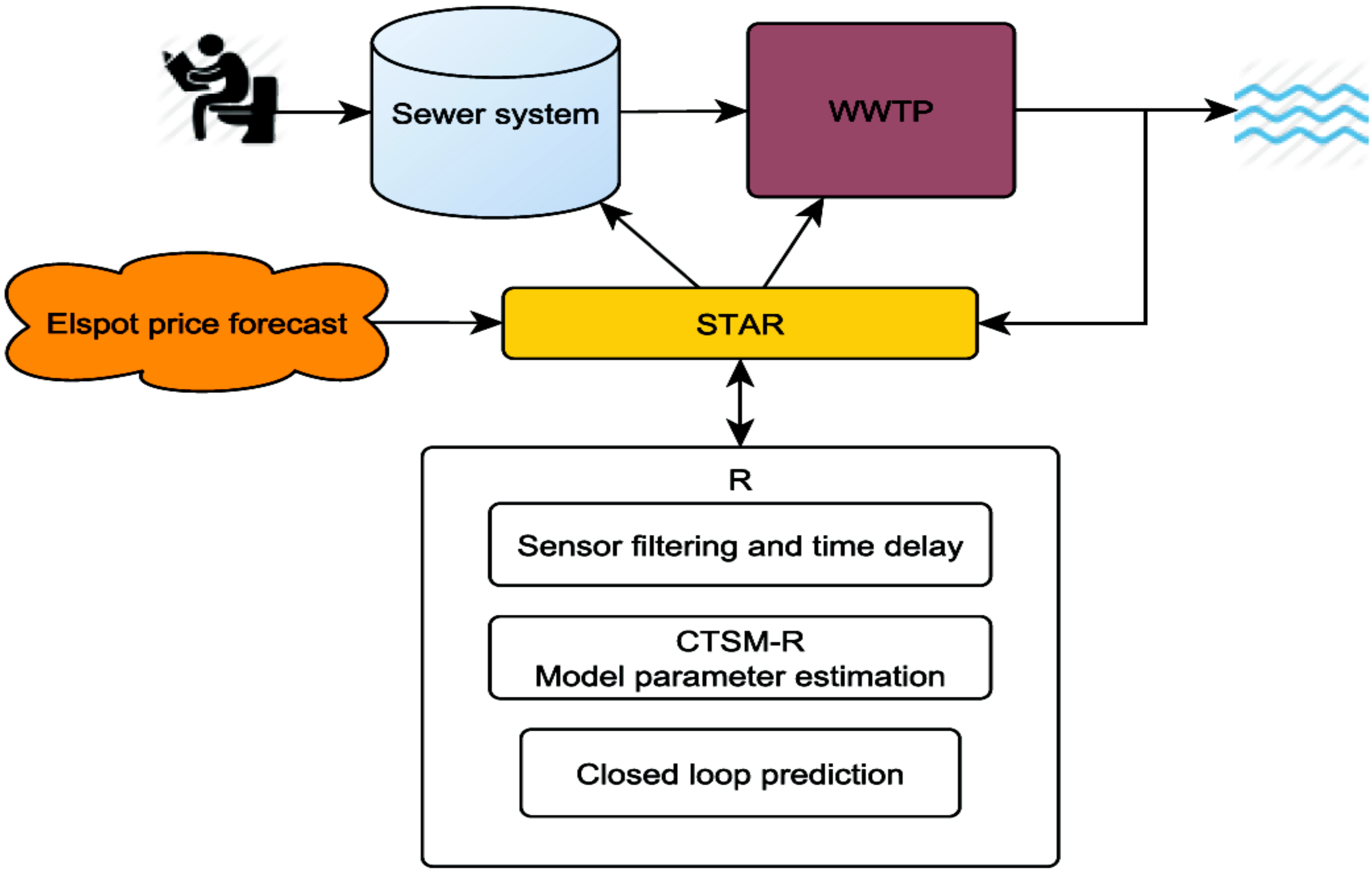
Kolding WWTP

Energy Flexibility in Wastewater Treatment

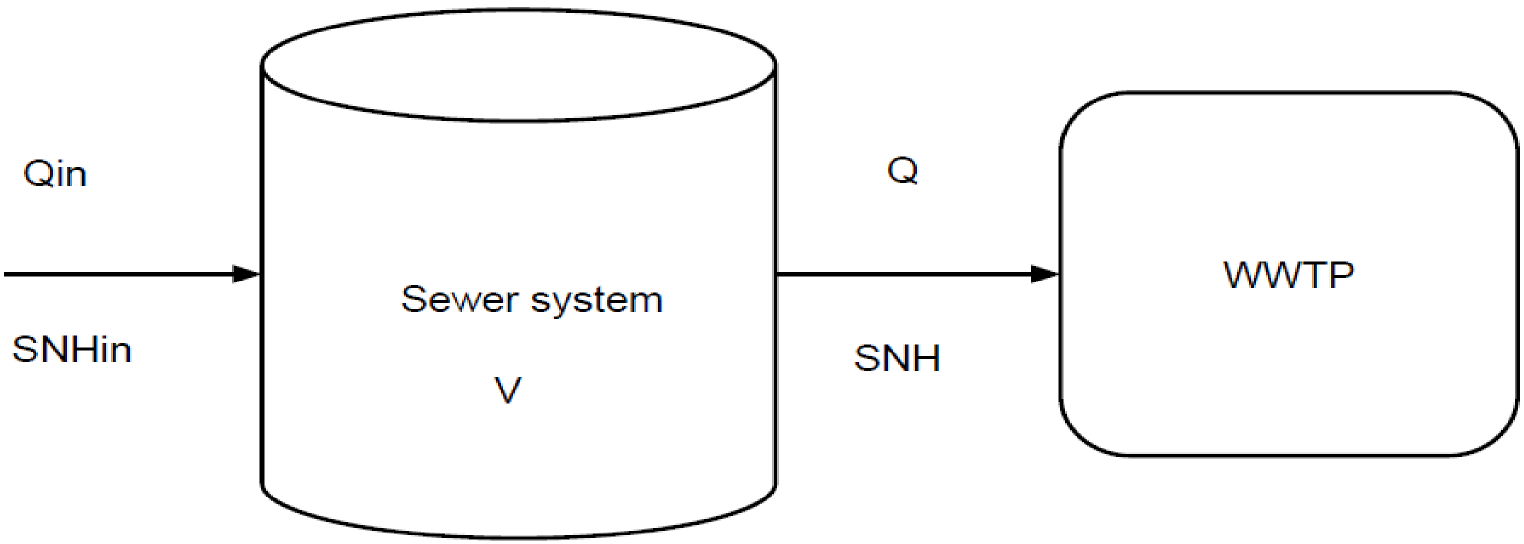


WWTP Control goal

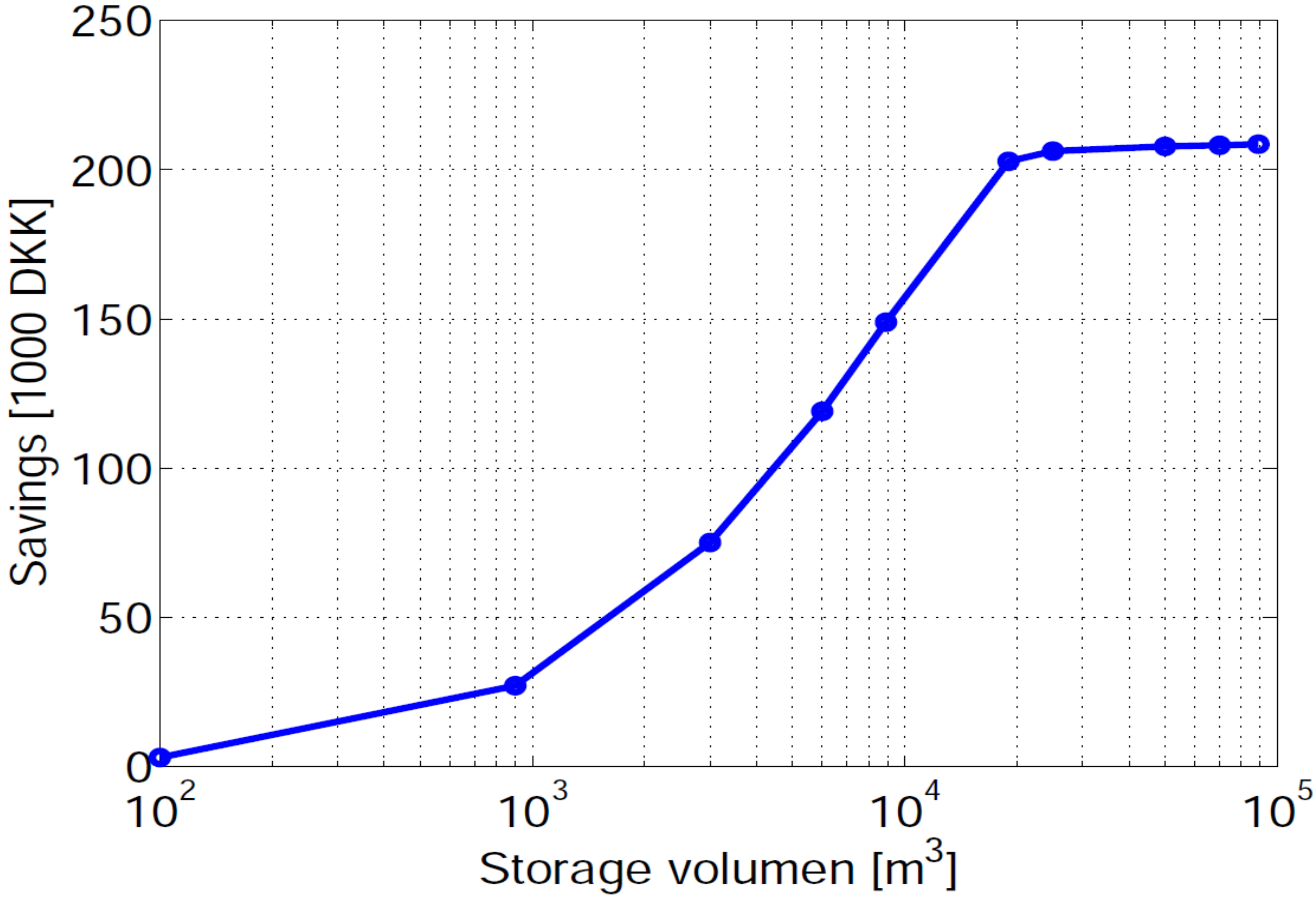
$$\text{minimize} \;\; p_{fee} Q^T S_N + p_{elspot}^T u$$

Sewer System Control Goal

$$\text{minimize overflow} + p_{elspot}^T f(Q)$$



Sewer System Annual Elspot Savings



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Summary

- A Smart-Energy OS for implementing data intelligent price and/or CO_2 based control of motor systems in integrated energy systems has been described
- Built on: Big Data Analytics, Cyber Physical Models, 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.