SmartNet

Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

Pilot B (Denmark)

Flexibility in Summer Houses with a Swimming Pool

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691405

Overview of Pilot B

Description:

- 30 Summer houses with a swimming pool – and either boiler or heat pump.
- **Indirect control using price** (or other penalty signals)
- **One way communication**

Extension:

- **CO2-base control** since May 2017 for demonstrating how to accelerate the transition to a low fossil future.
- **DSO congestion** based on real-time measurements for better integration of PV, EV and Heat Pumps
- Optimize the end-user **flexibility** for the best **integration of wind and solar**

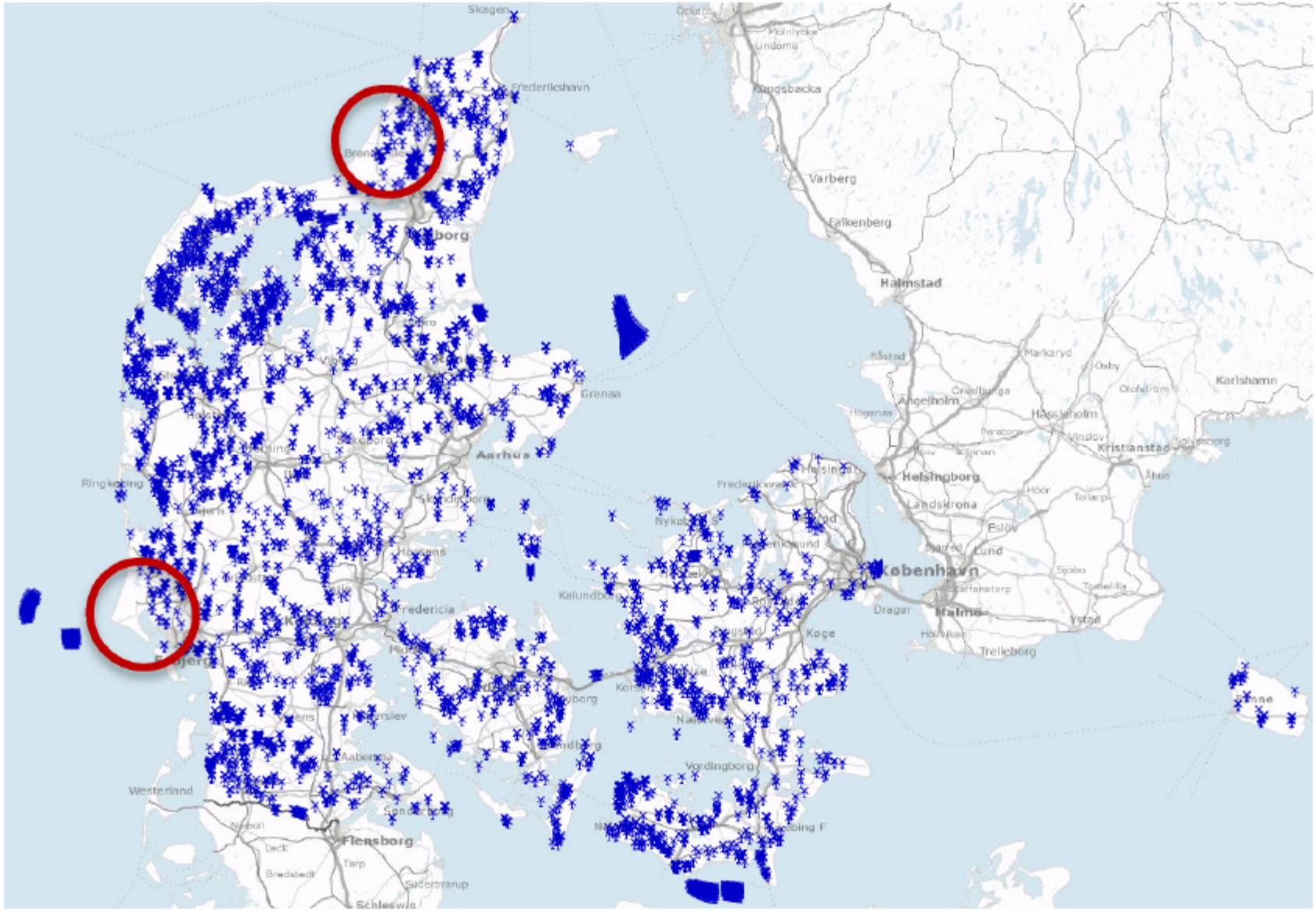
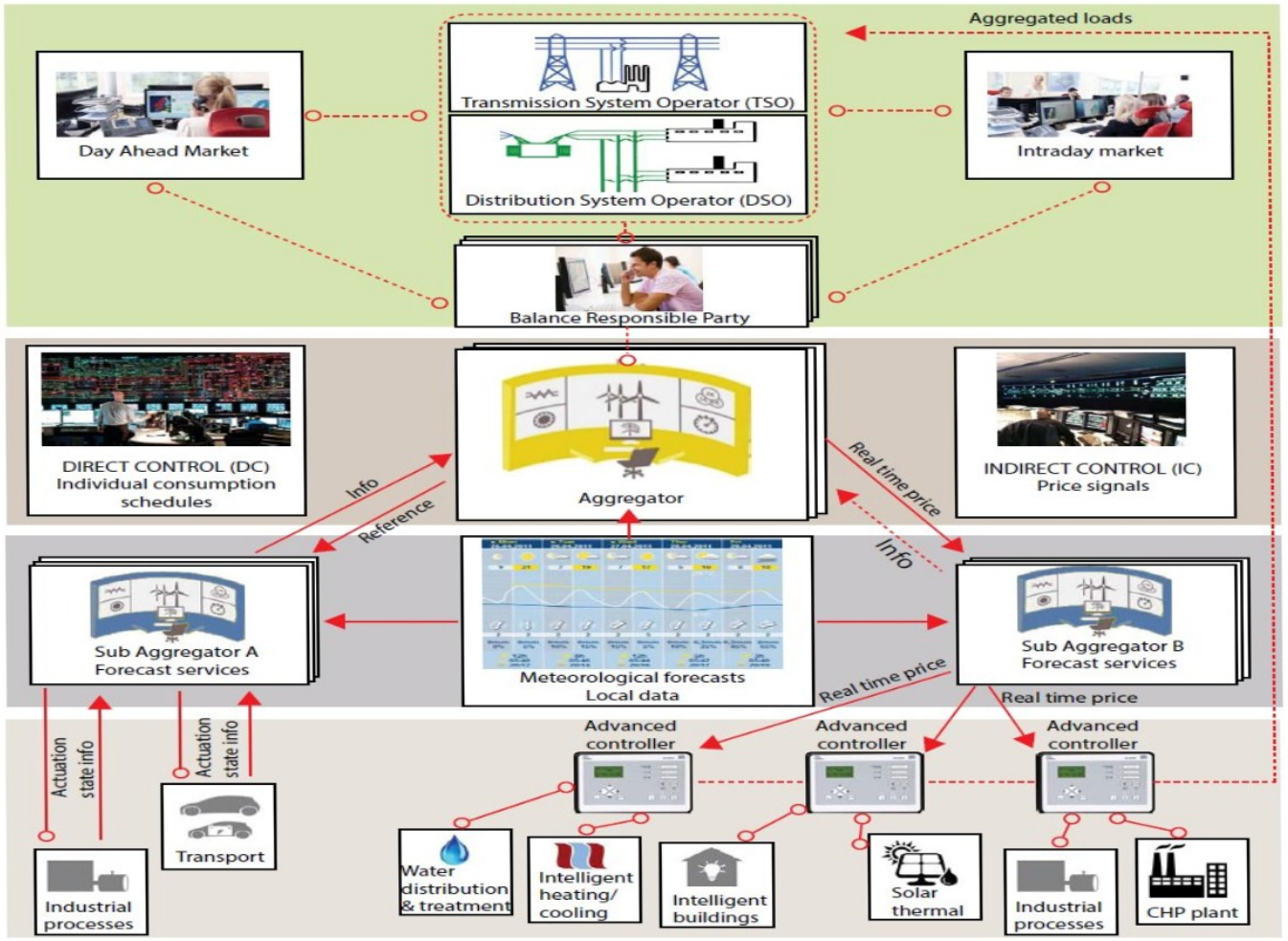


Figure 3.1 Geographical locations of summer houses in Denmark.

Pilot B

Introduction

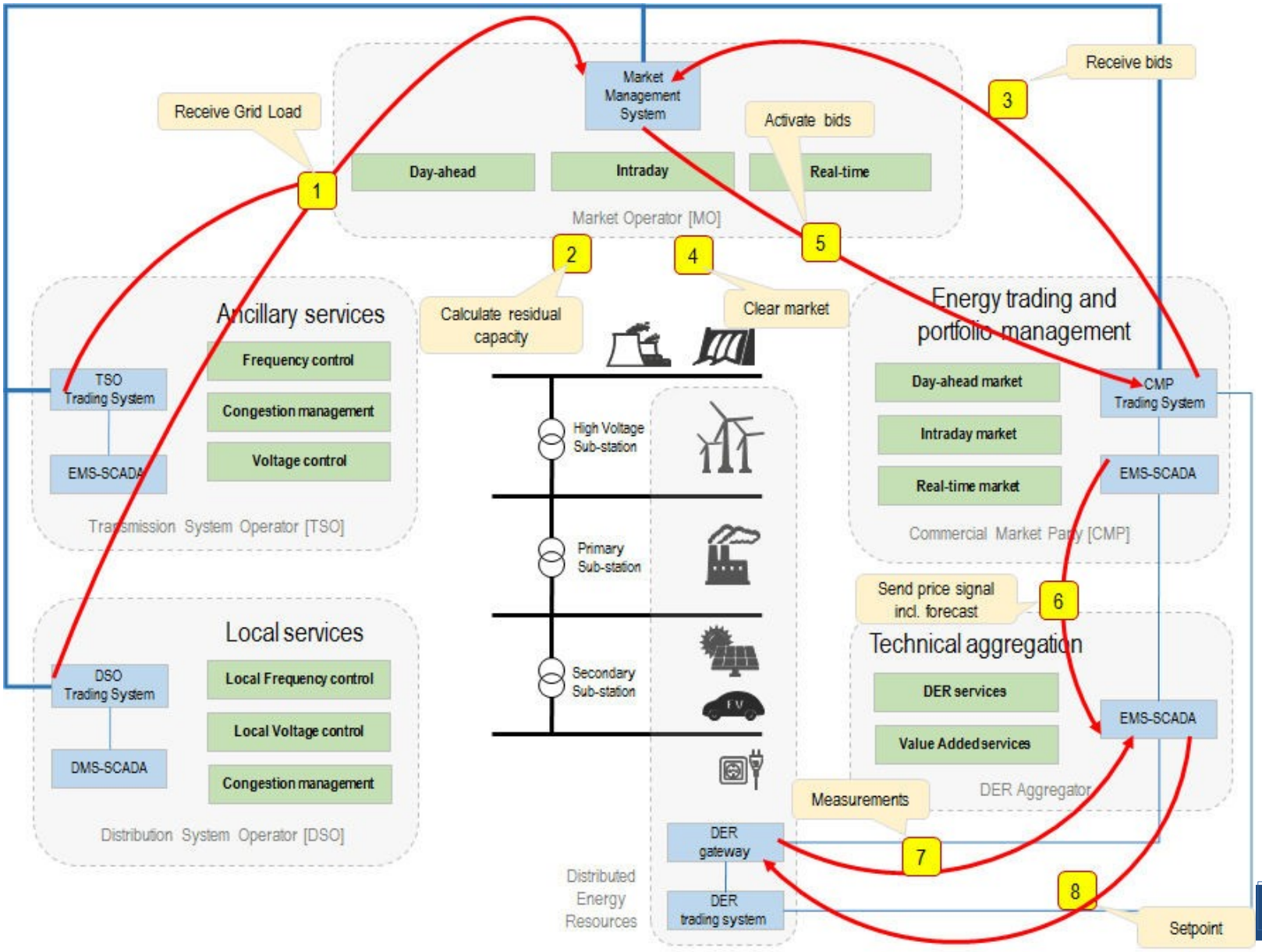
Smart-Energy OS



Maximizes the flexibility – Simple communication – No contracts

Described in Wiley Book, DTU Annual Report, and several IEEE papers

Overview Pilot B



Flexibility Function

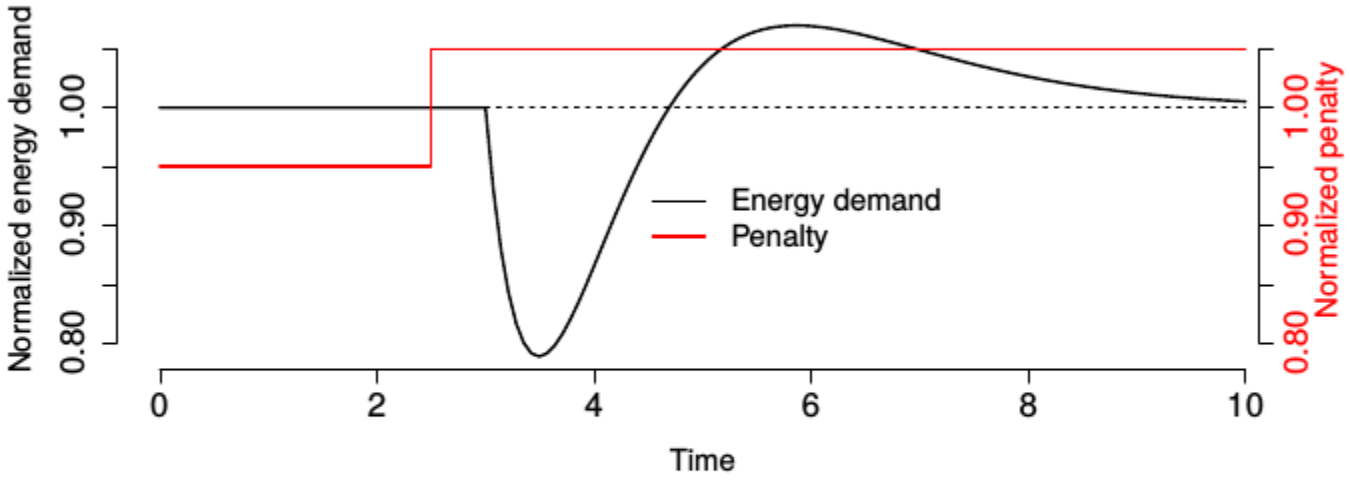


Figure 2: The energy consumption before and after an increase in penalty. The red line shows the normalized penalty while the black line shows the normalized energy consumption. The time scale could be very short with the units being seconds or longer with units of hours. At time 2.5 the penalty is increased,

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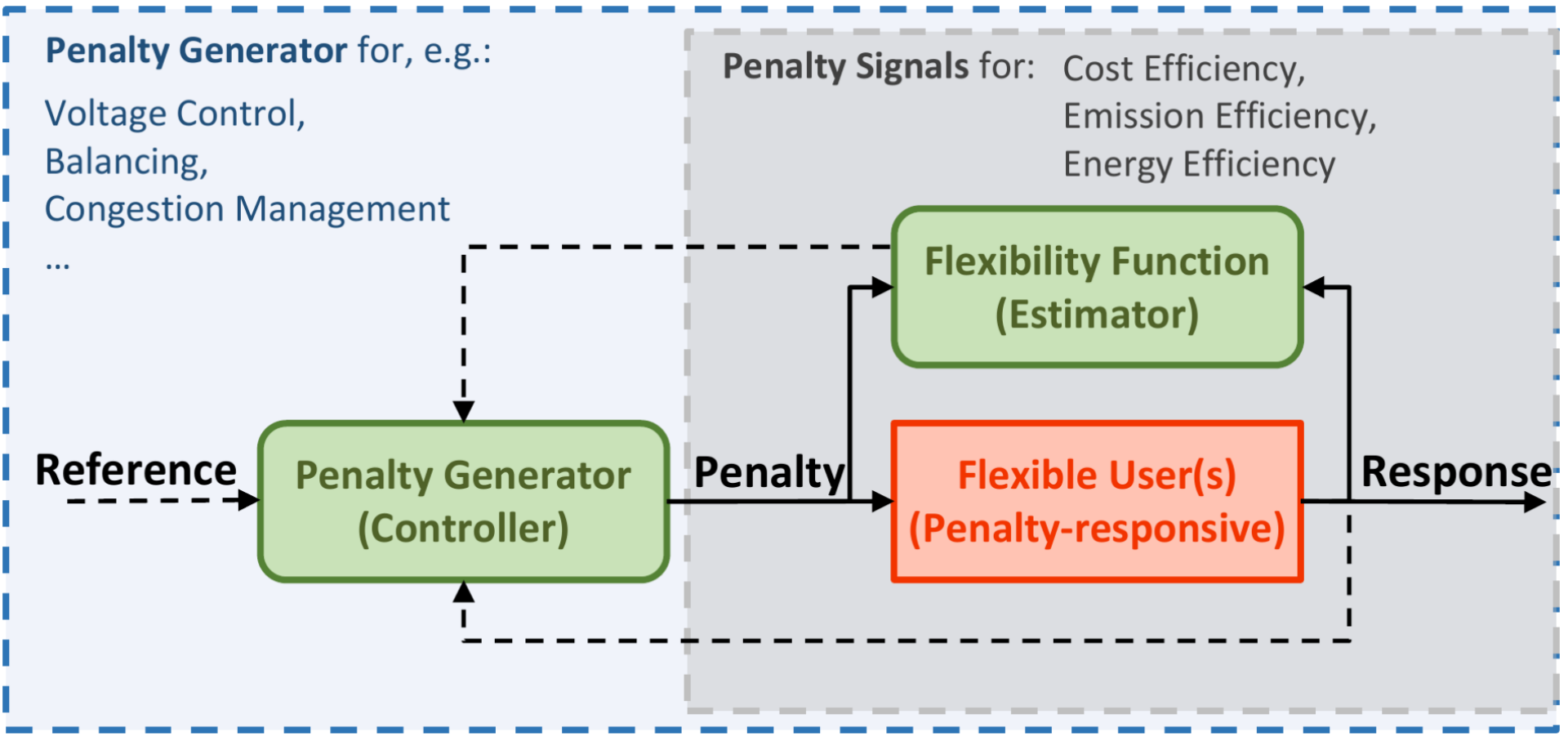
Smart Grid Applications



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Upper Level

Evonet's supply area

- Supply area in Syd- og Sønderjylland and a part of Nordjylland
- Created through 26 mergers
- Supply of app. 324.000 installations
- A part of SE-koncernen

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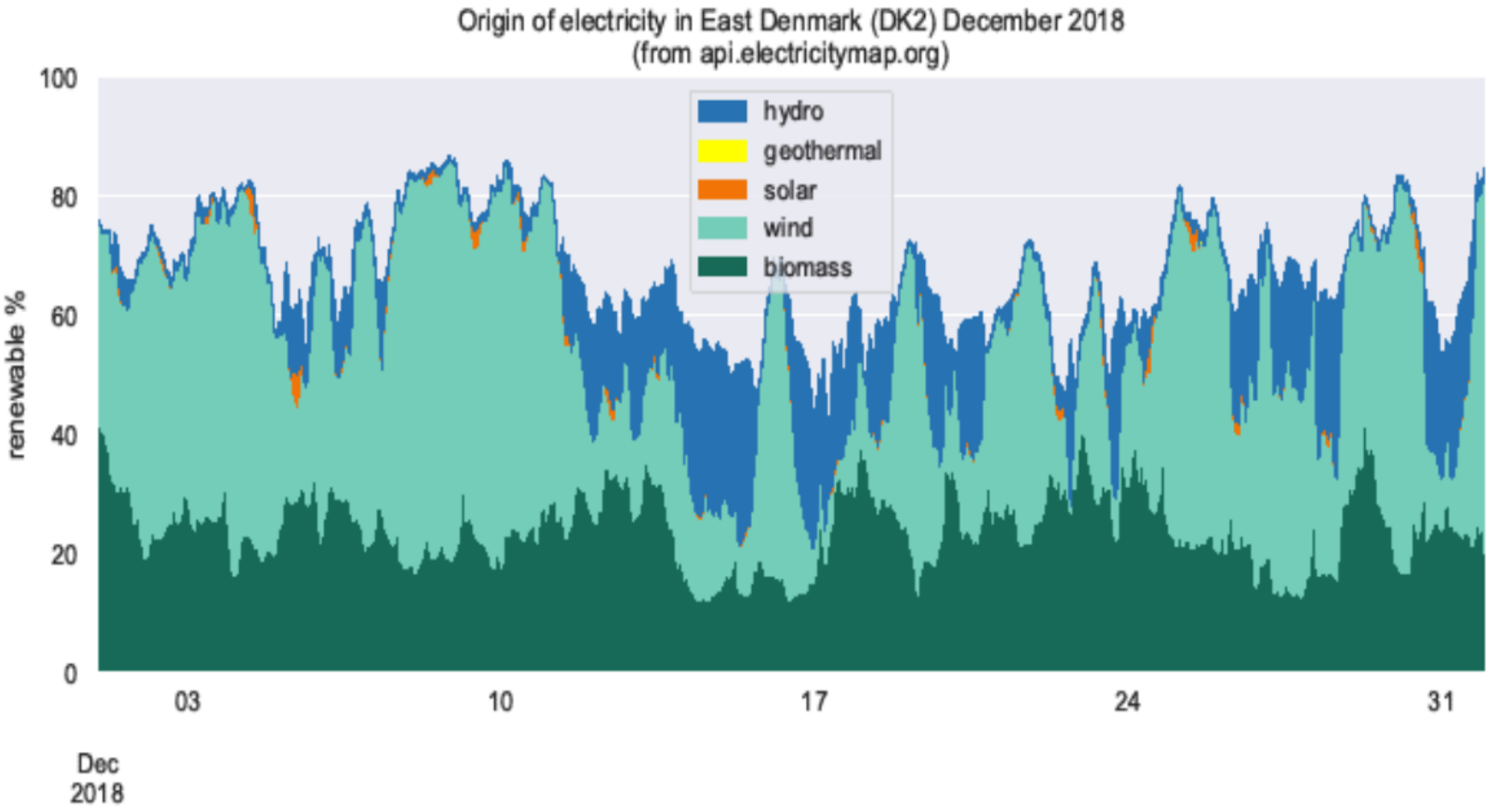
Lower Level



Source: pro.electicitymap.org

How does it work?

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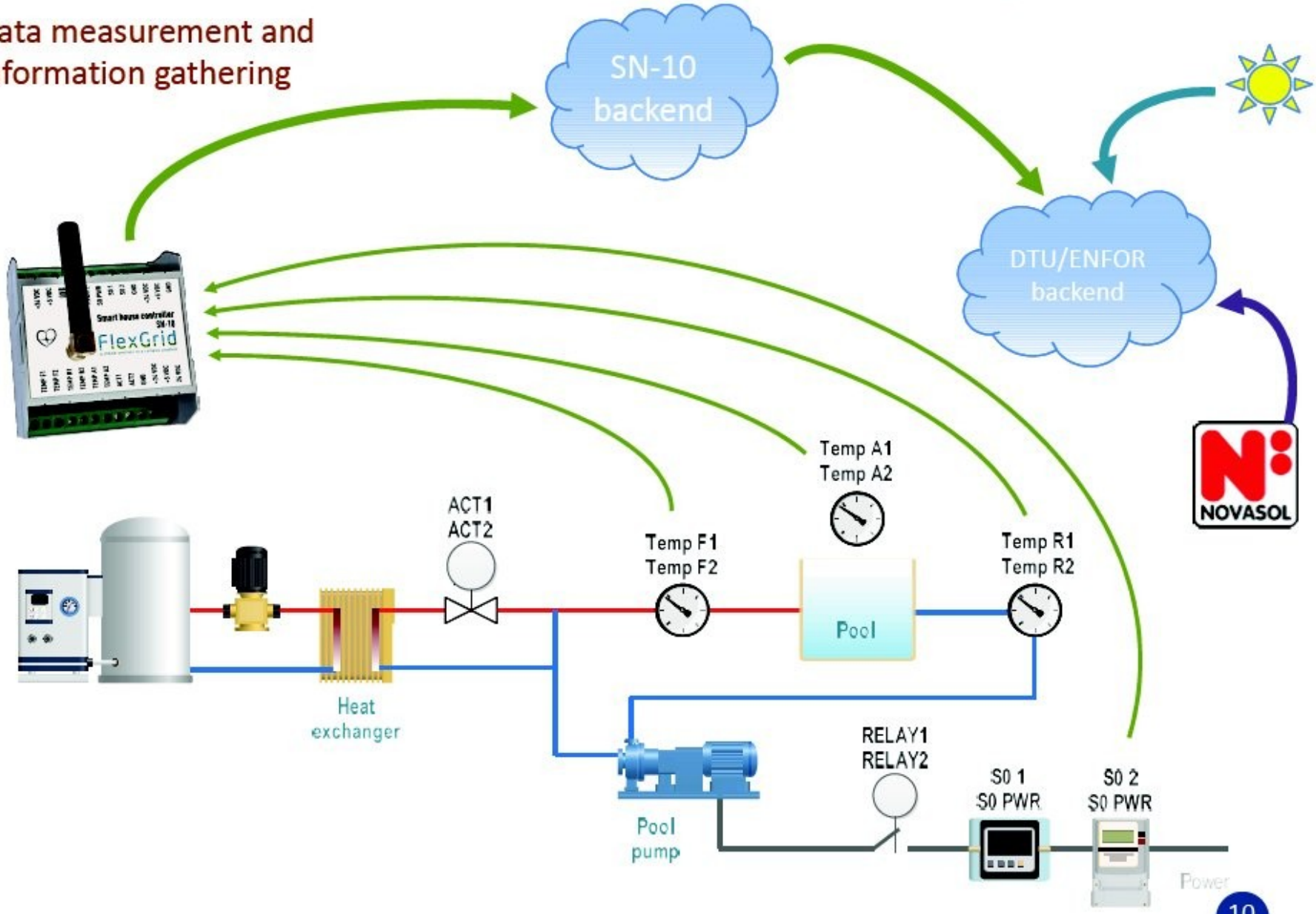
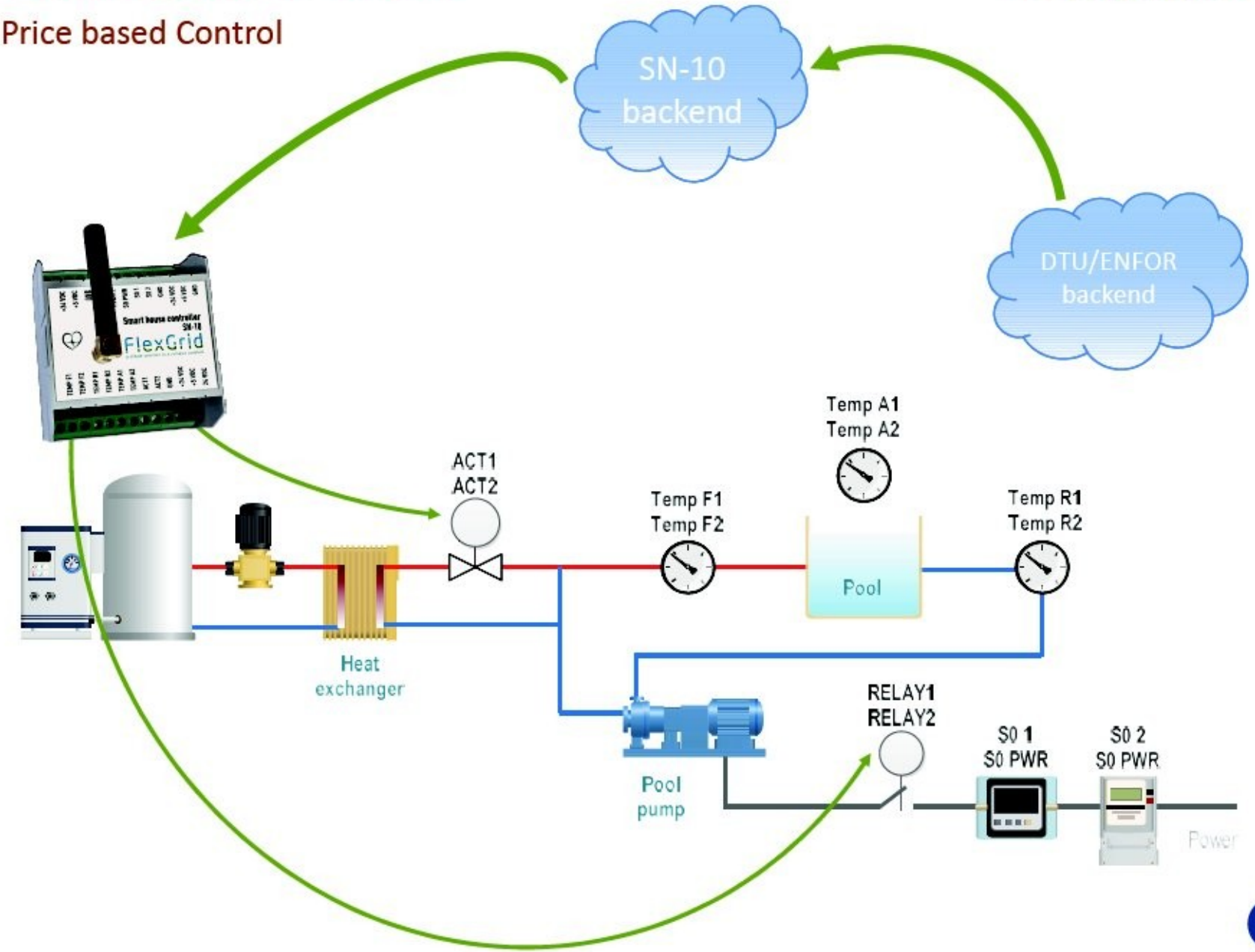
Data measurement and information gathering



How does it work?

Price based Control



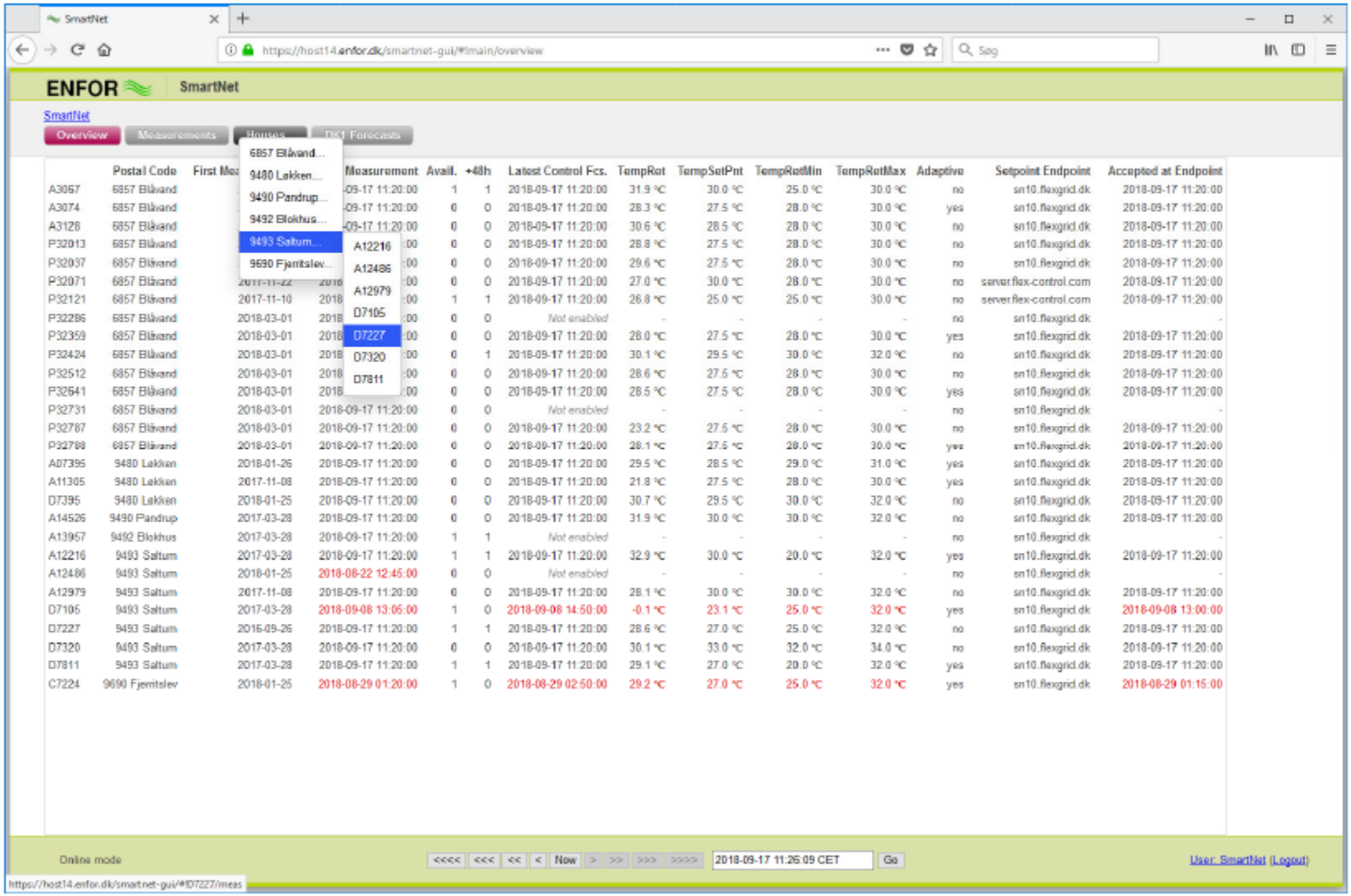
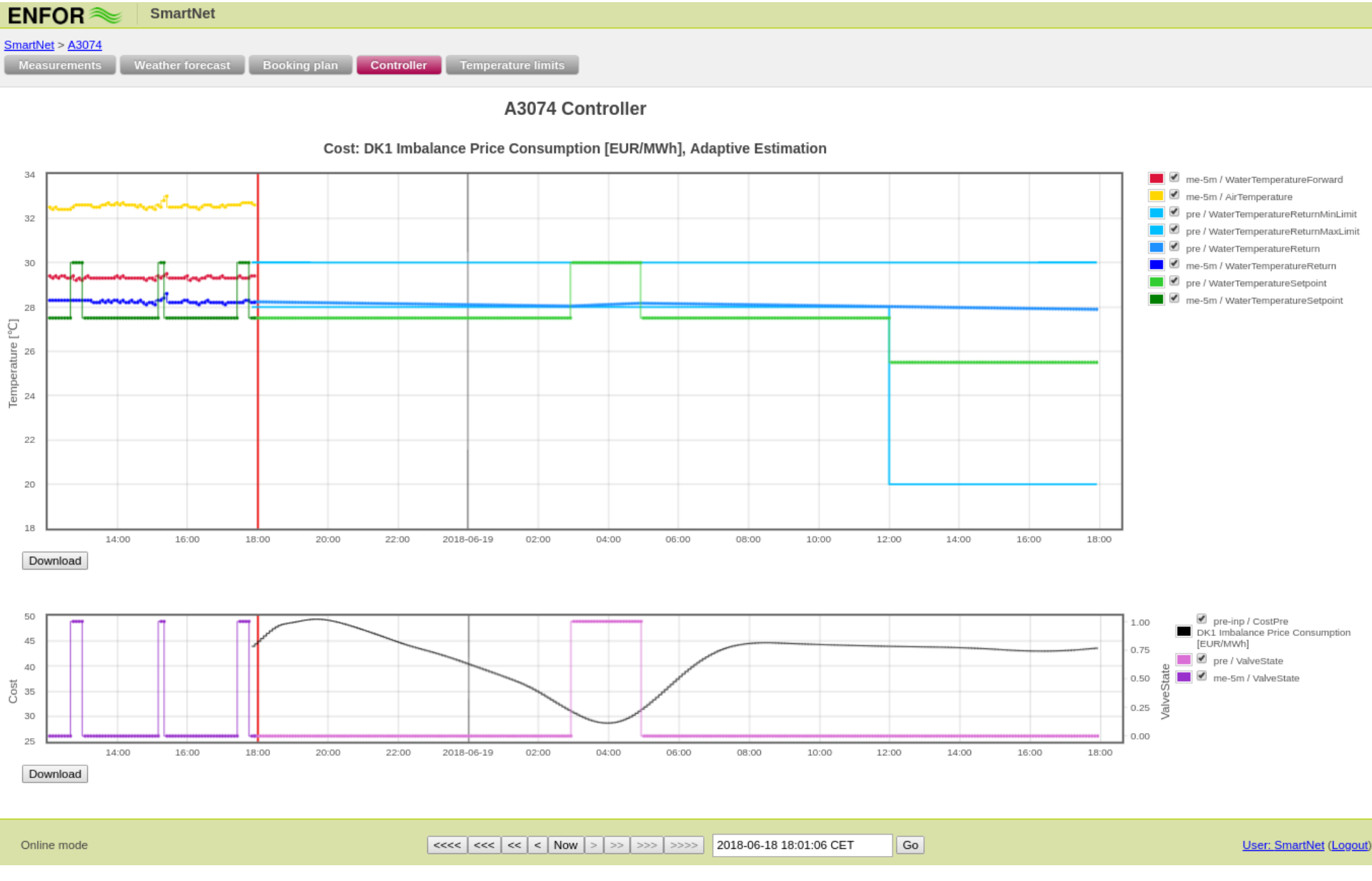


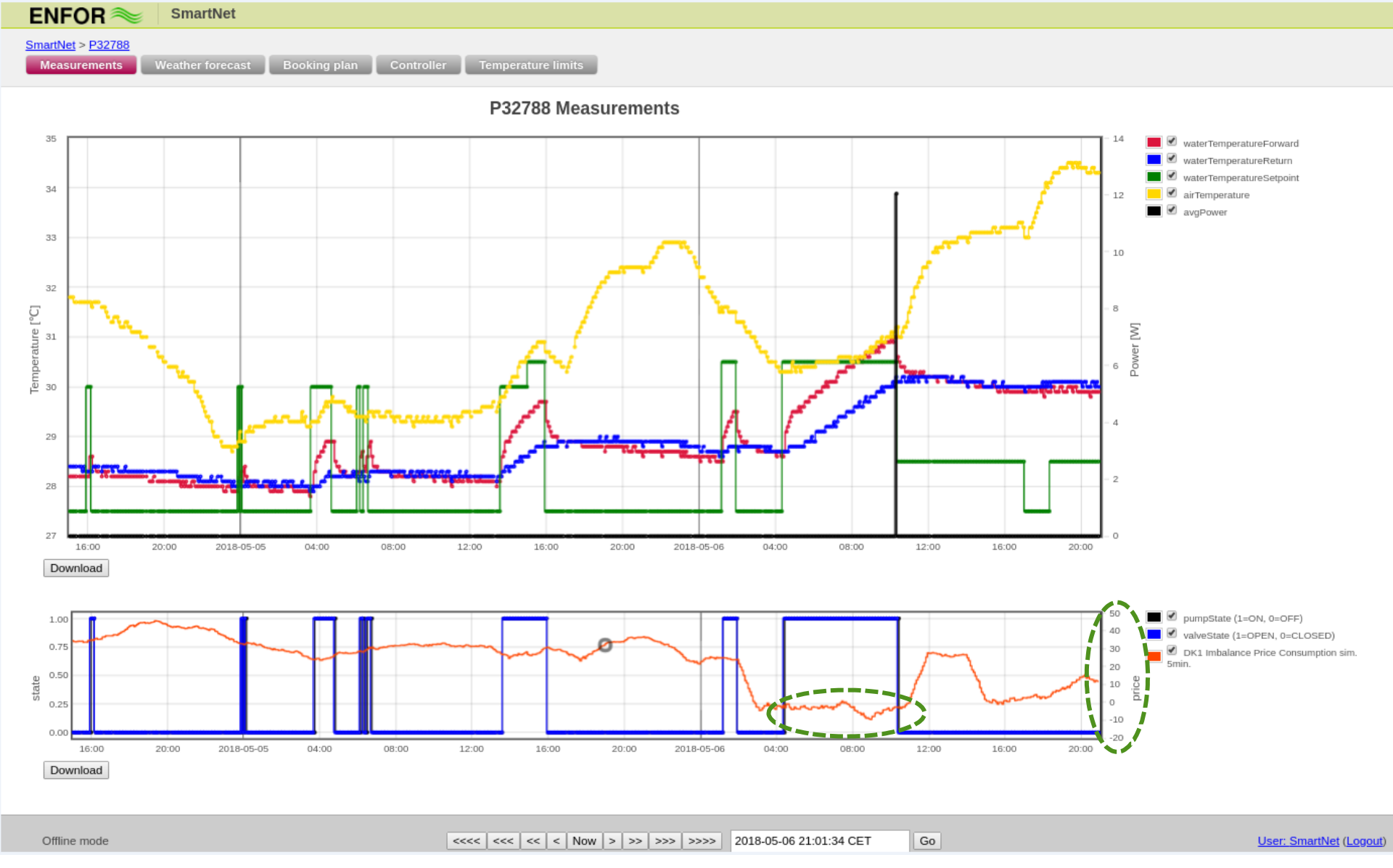
Figure 3.7 Web-based graphical user interface for monitoring the system.

Example: Price-based control



Example: CO2-based control

Example with negative power prices



Pilot B

Highlights, Perspectives and Implementations

Pilot B – Some highlights

The SmartNet Technical Aggregator at ENFOR is designed such that we can shift between any external 'penalty signal'.

We are able to shift to any 'penalty signal' with a very short notice. It can be **energy efficient, price efficient** or **emission efficient**.

A real clearing platform is established with connection from our 'TSO', DSO, Economical Aggregator and the Technical Cloud-based Aggregator/controller

We have learned a lot about how to establish a cloud-based control of smart buildings – and in such a way that they can support the future smart grid (eg. Voltage control and congestion management)

Huge national interests in the Pilot B setup due to similarities with District Heating systems wrt. flexibility

House Owner Perspectives

- We can reduce the CO2 emission with at least 10 pct
- Annual saving for each house due to the suggested new Demand Response is around 12.000 DKK
- The heating system can be operated remotely – further savings
- The heating can be scheduled optimally and according the dynamics of the house and weather forecasts

DSO Perspectives

- Good price signals needed in the balancing of the distribution grid
- New tariffs to support price signals
- Maybe a local tariff is necessary (voltage control)
- New tariffs can take care of local energy systems, which are off-grid
- New ways of integrating battery systems into the power grid
- Using the inverters as voltage stabilizing devices in the grid

TSO Perspectives

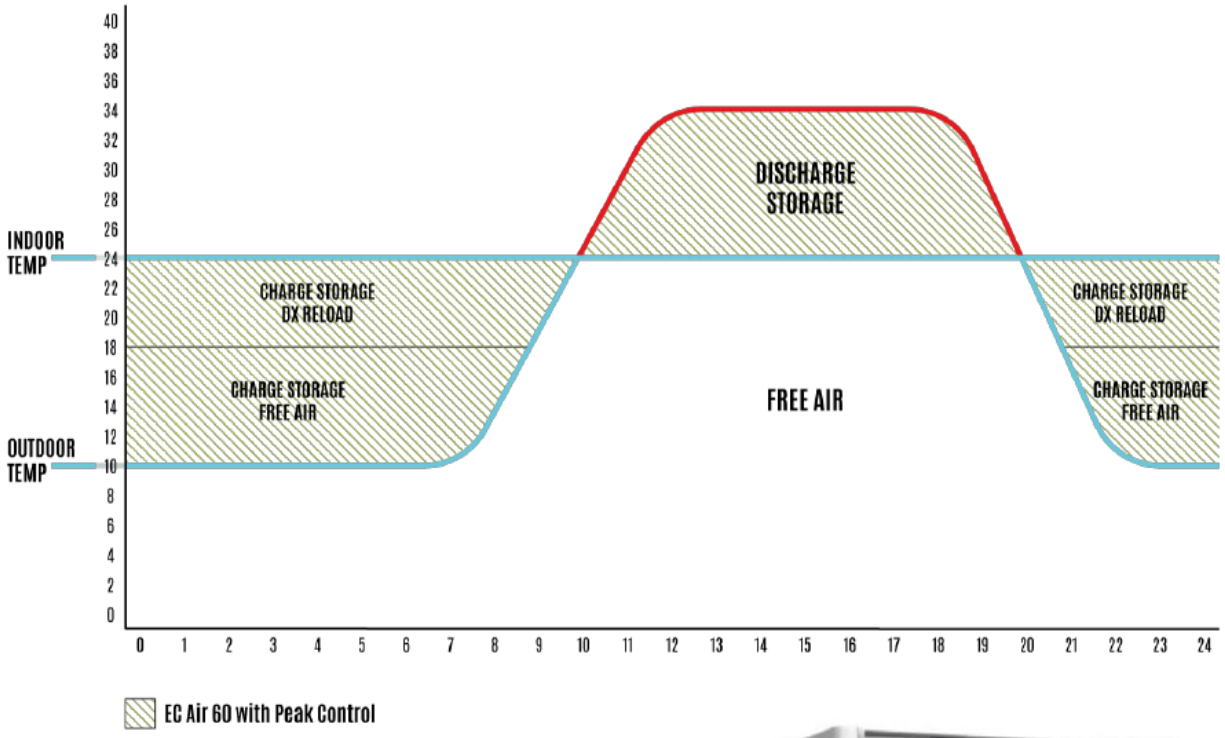
- Automatic solutions targeting small units
- External control of units
- Unlock the needed flexibility at all levels
- DSO-TSO combined optimization
- The new control and aggregator concepts are promising
- Improved flexibility and energy systems integration

National Perspectives

- We have a new national project – **Flexible Energy Denmark** – which will study how to use the flexibility for providing grid services and virtual storage
- In general we begin to see issues in DSO grids, and here solutions from SmartNet will be seriously considered
- We have got **3 new EU projects** related to the methodologies developed in SmartNet
- In another new national project – **HEAT 4.0** – we will use the SmartNet principles for heating the water using heat pumps in our District Heating systems (approx. 70 pct of buildings are heated by DH)
- The SmartNet Pilot B setup will most likely be used as a national sandbox to test and demonstrate **new regulatory conditions**
- Control based methods from SmartNet Pilot B (lower level) will be considerede by our TSO

Data Centers (+ Supermarkets - Danfoss)

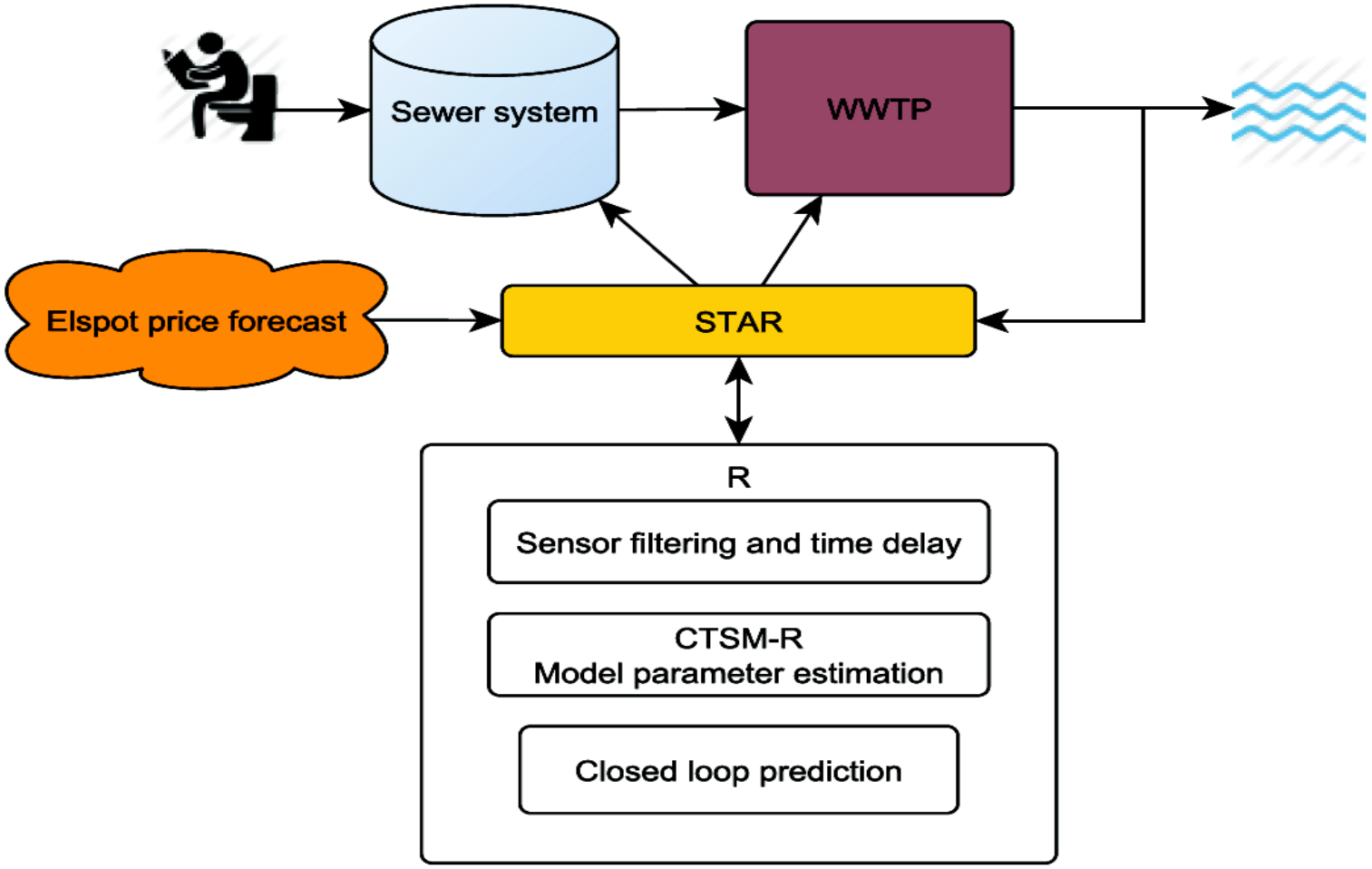
Large savings (90-95 pct) related to cooling of data centers using PCM (from Center Denmark/EnergyCOOL)



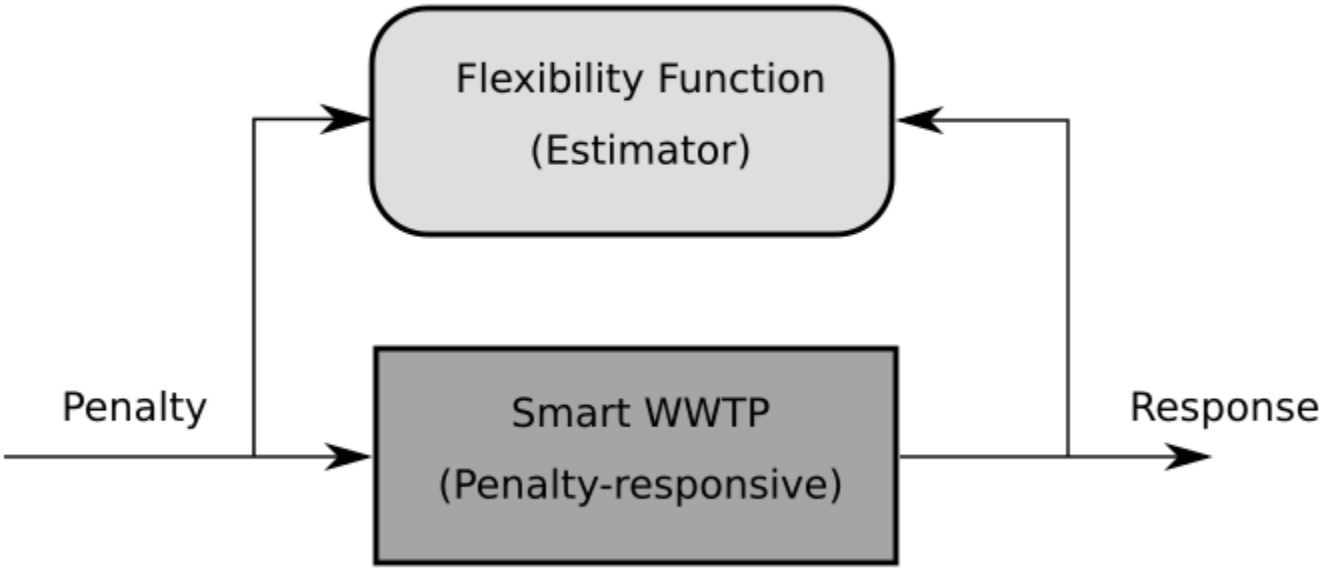
Use of SmartNet setup for

Smart Control of Wastewater Treatment Plants

(Centrica, Veolia/Krüger, Grundfos, DTU)



Flexibility Function



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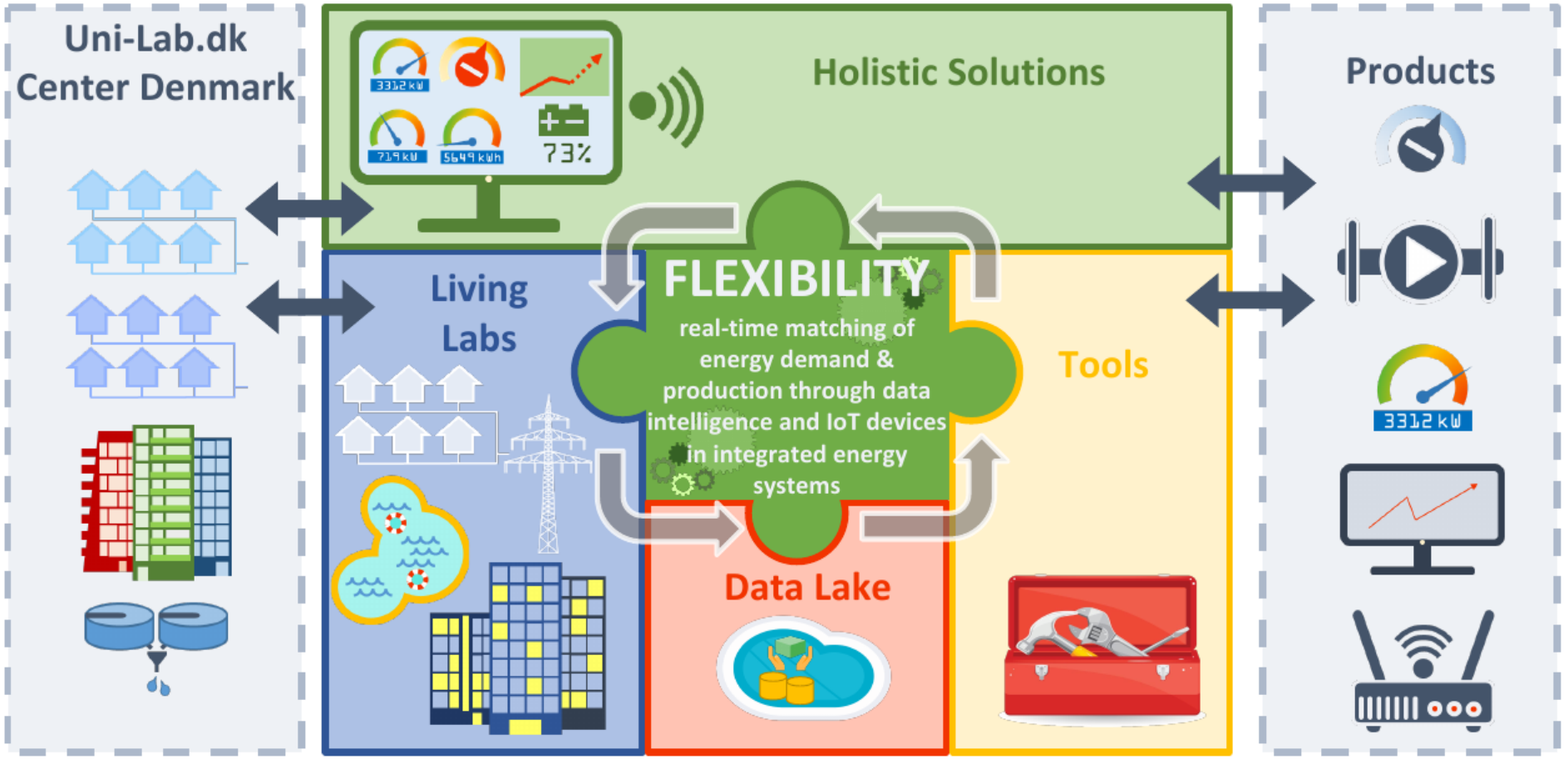
A Danish Path to a Fossil Free Society



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SmartNet-Project.eu

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Misc.

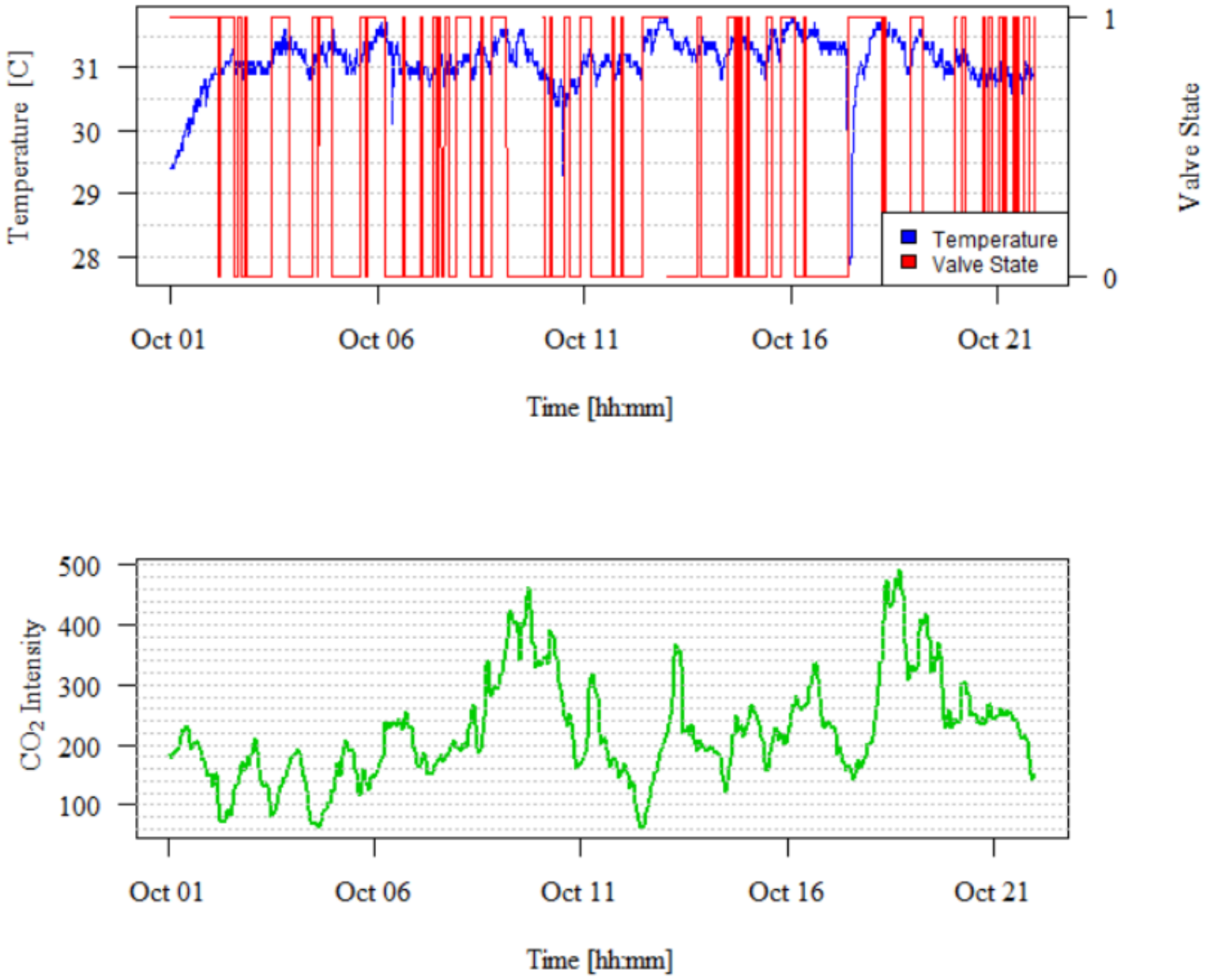
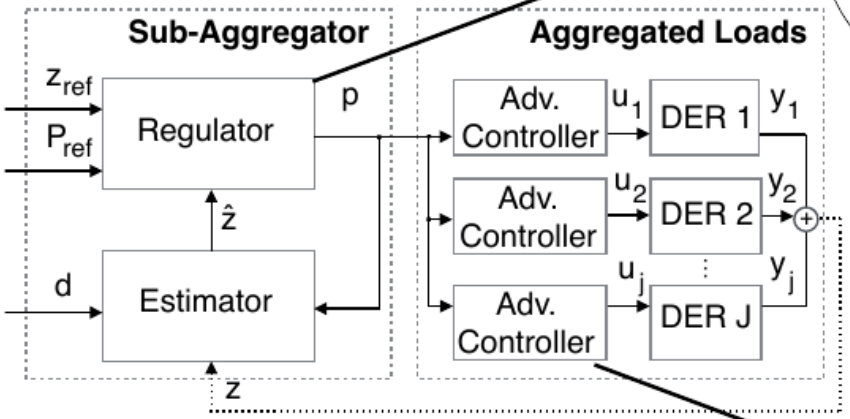


Figure 7.10 *21 days of CO_2 based control in October 2017. The top plot shows the temperature of the swimming pool in blue and the state of the heating in red (1 for on and 0 for off). The bottom plot shows the CO_2 intensity of the electricity for the same period*

Proposed methodology
Control-based methodology

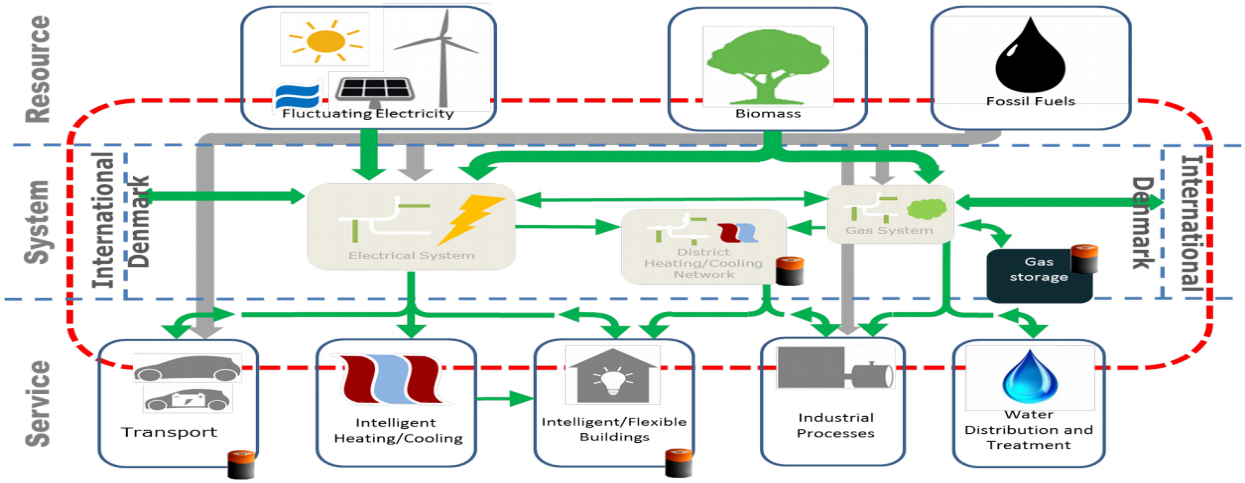
$$\min_{p} \quad \mathrm{E}[\sum_{k=0}^{N} w_{j,k}||\hat{z}_k - z_{ref,k}|| + \mu||p_k - p_{ref,k}||]$$
$$\text{s.t.} \quad \hat{z}_{k+1} = f(p_k)$$



We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

$$\min_{u} \quad \mathrm{E}[\sum_{k=0}^{N}\sum_{j=1}^{J} \phi_j(x_{j,k}, u_{j,k}, p_k)]$$
$$\text{s.t.} \quad x_{k+1} = Ax_k + Bu_k + Ed_k,$$
$$y_k = Cx_k,$$
$$y_k^{min} \leq y_k \leq y_k^{max},$$
$$u_k^{min} \leq u_k \leq u_k^{max}$$

(Virtual) Storage Solutions



- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 5-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-12 hours ahead
  - District heating/cooling systems can provide storage up to 1-3 days ahead
  - DH systems with thermal solar collectors can often provide seasonal storage solutions
  - Gas systems can provide seasonal/long term storage solutions

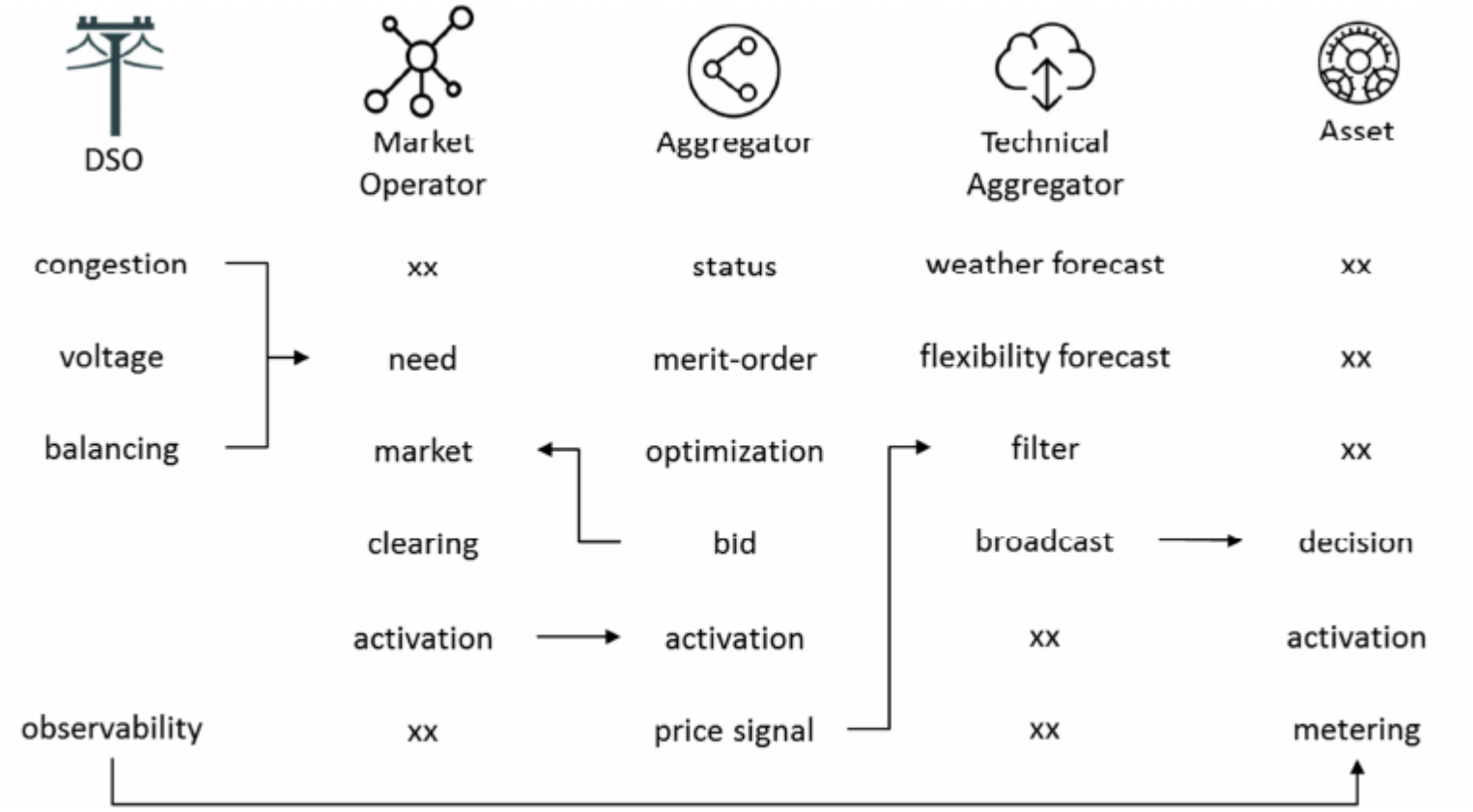


Figure 4.5 Diagram for the Danish Pilot from the (Economical) Aggregator's point of view.