EUROPEAN BIG DATA VALUE FORUM

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European Commission

BDV BIG DATA VALUE ASSOCIATION

Inria inventors for the digital world

Control of Future Smart Grids Using Big Data Analytics

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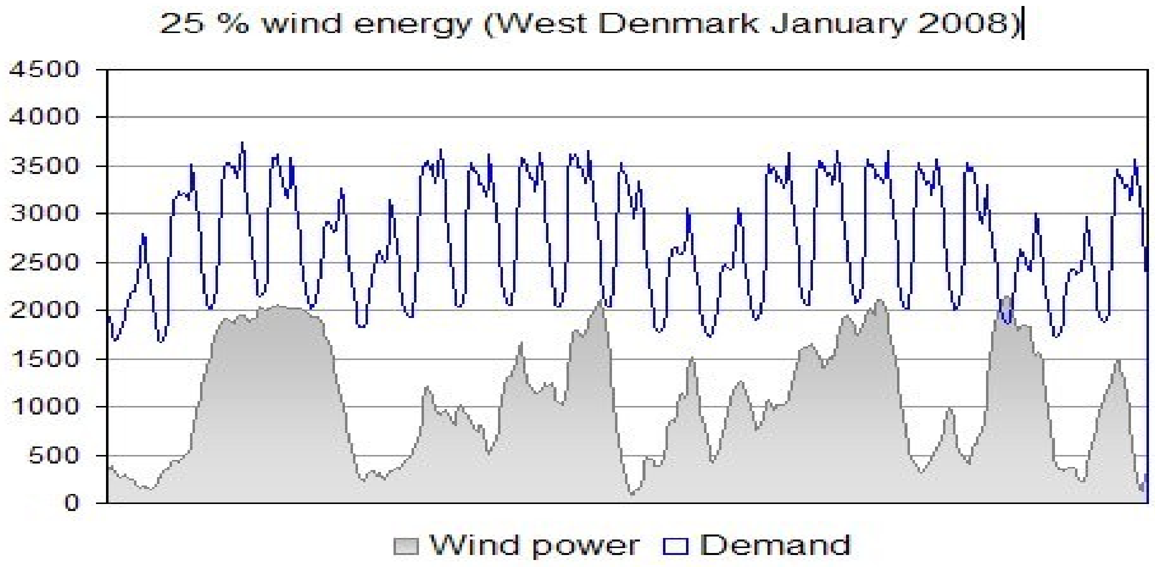
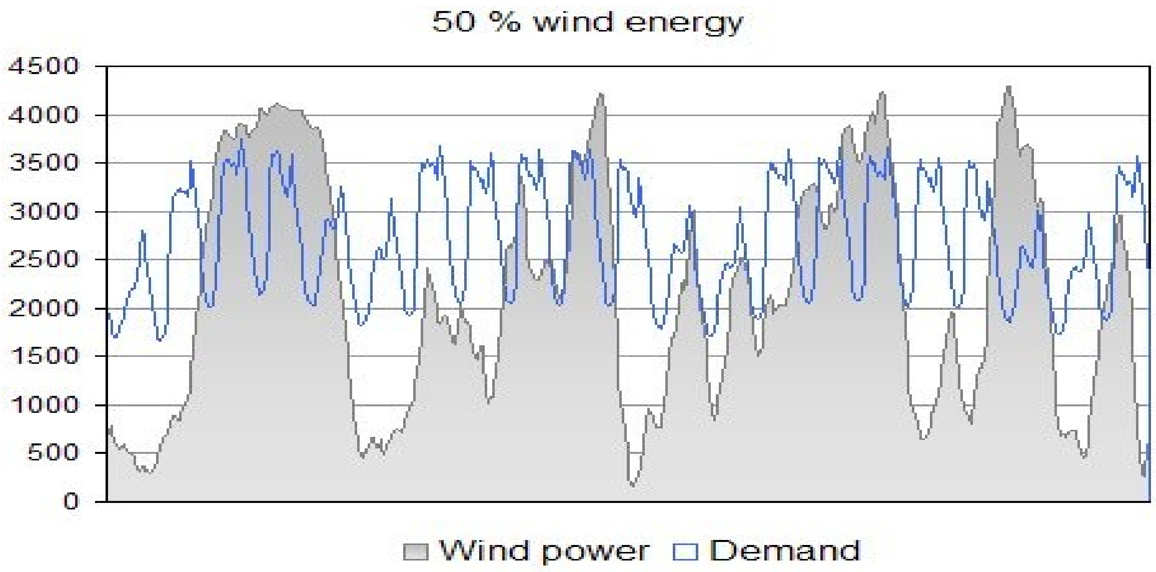
The Danish Wind Power Case

…. balancing of the power system





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

In the first half of 2017 more than 44 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.

For some hours more than 140 pct of the power load was covered by wind power

Existing Markets - Challenges

- Dynamics
- Stochasticity
- Nonlinearities
- Many power related services (voltage, frequency, balancing, spinning reserve, congestion, …)
- Speed / problem size
- Characterization of flexibility
- Requirements on user installations

Challenges (cont.)

Preparatory Study on Smart Appliances

European Commission

Ecodesign Preparatory Study performed for the European Commission

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Project Summary

The Ecodesign Preparatory Study on Smart Appliances (Lot 33) has analysed the technical, economic, market and societal aspects with a view to a broad introduction of smart appliances and to develop adequate policy approaches supporting such uptake.

The study deals with Task 1 to 7 of the Methodology for Energy related products (MEErP) as follows:

- Scope, standards and legislation (Task 1, Chapter 1);
- Market analysis (Task 2, Chapter 2);
- User analysis (Task 3, Chapter 3);
- Technical analysis (Task 4, Chapter 4);
- Definition of Base Cases (Task 5, Chapter 5);
- Design options (Task 6, Chapter 6);
- Policy and Scenario analysis (Task 7, Chapter 7).

An executive summary of the project results can be downloaded here.

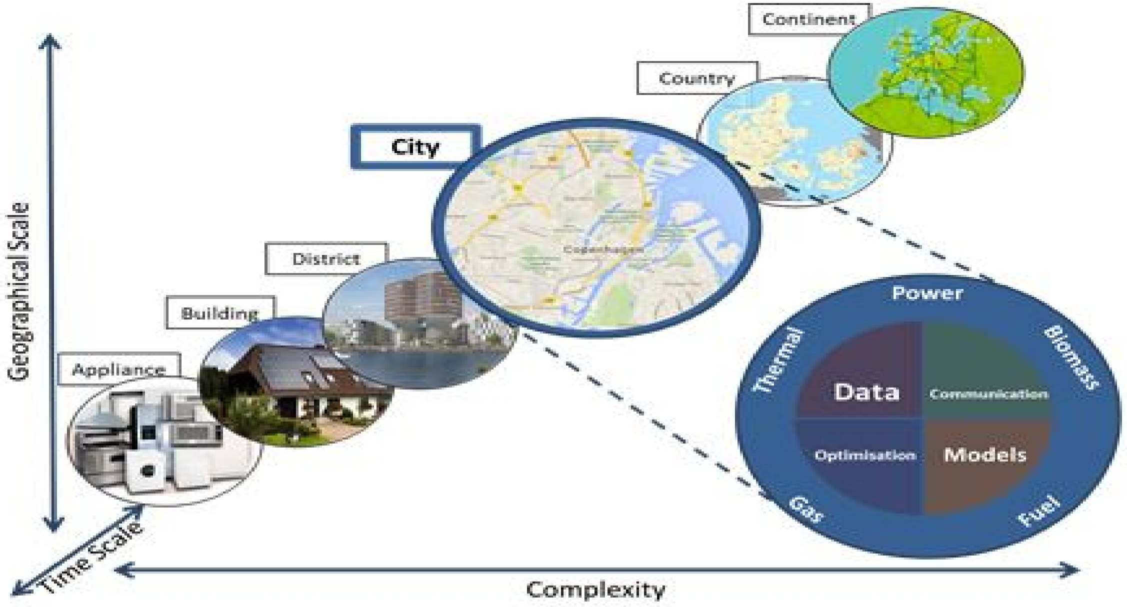
Throughout the study, new relevant aspects have come up which will be covered in a second phase of the Preparatory Study:

- Chargers for electric cars: technical potential and other relevant issues in the context of demand response.
- The modelling done in the framework of MEErP Task 6 and 7 will be updated with PRIMES data that recently became available, and with the EEA-countries.
- The development and assessment of policy options that were identified in the study will be further elaborated and deepened.

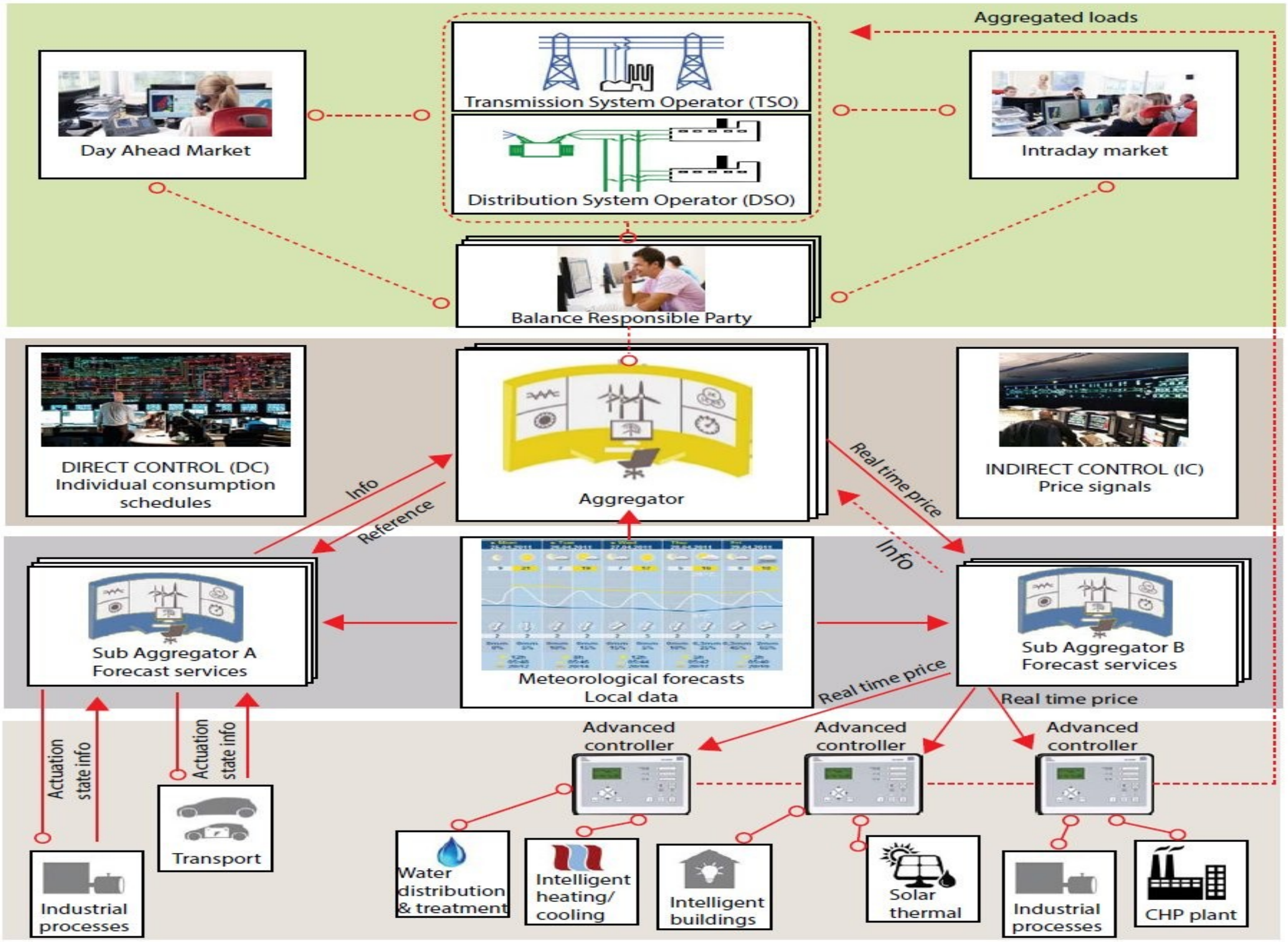
Conclusion: Almost no flexibility ?!

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



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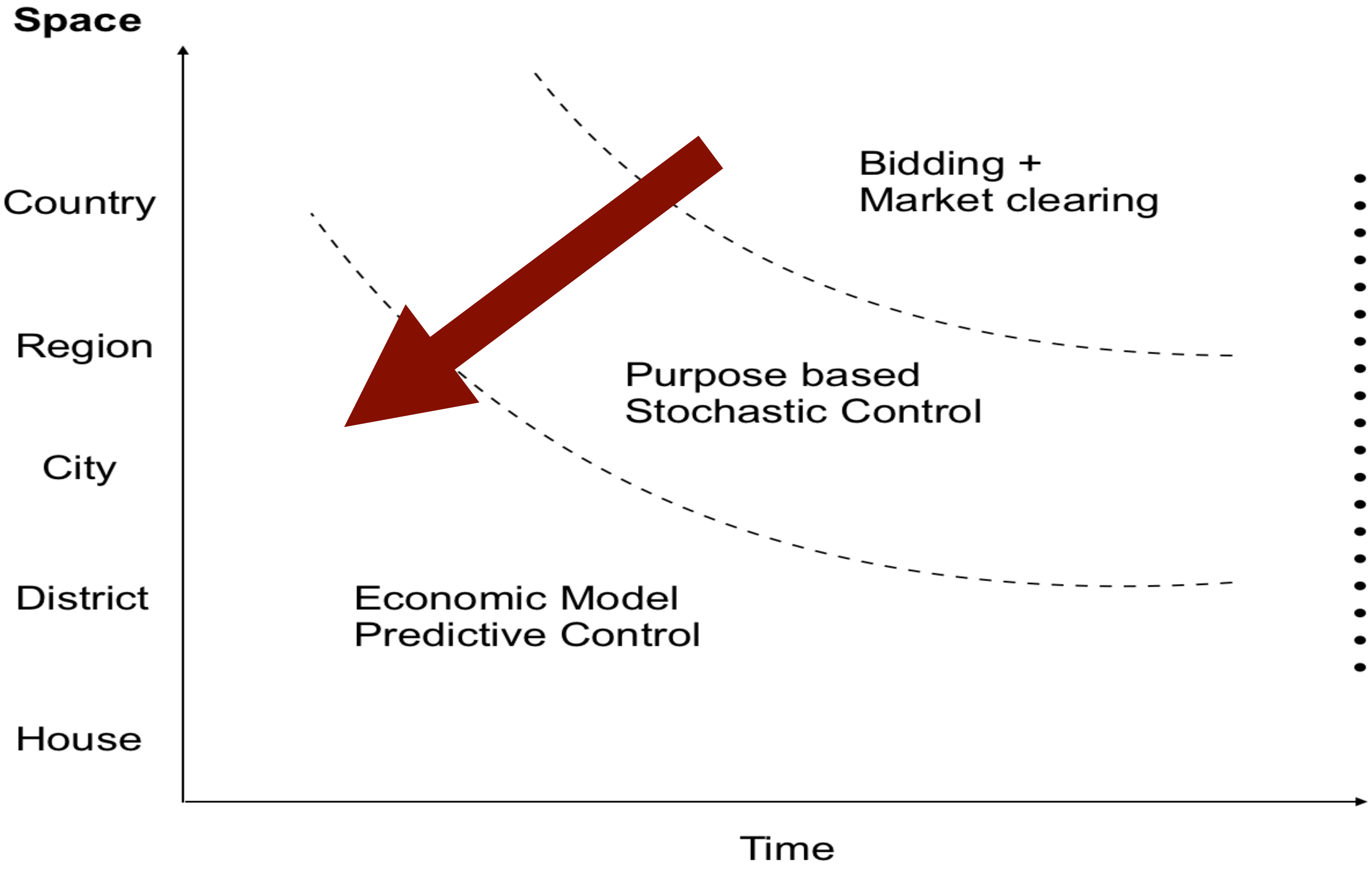
The ‘market’ for the future Smart Grid



Bidding & Clearing

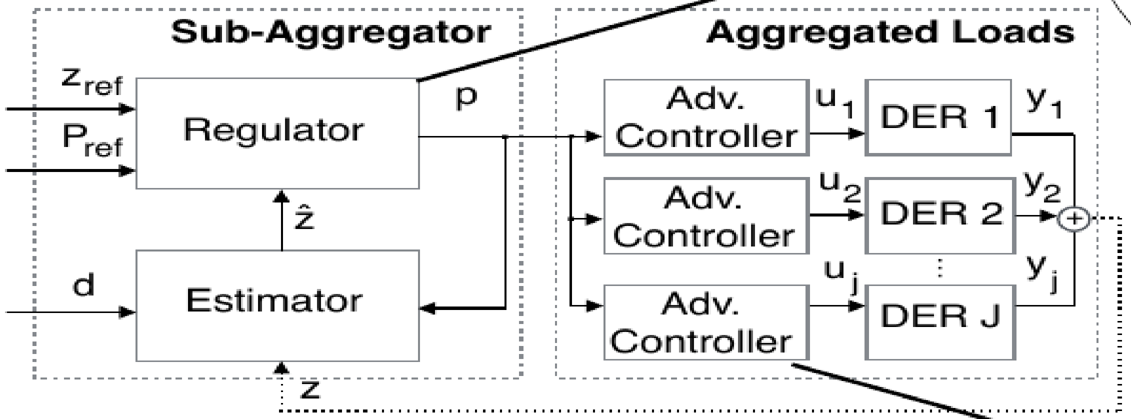
Control based

$$\min_p (U - U_{ref})^2$$

$$\min \sum (pU)$$

Proposed methodology
Control-based methodology

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

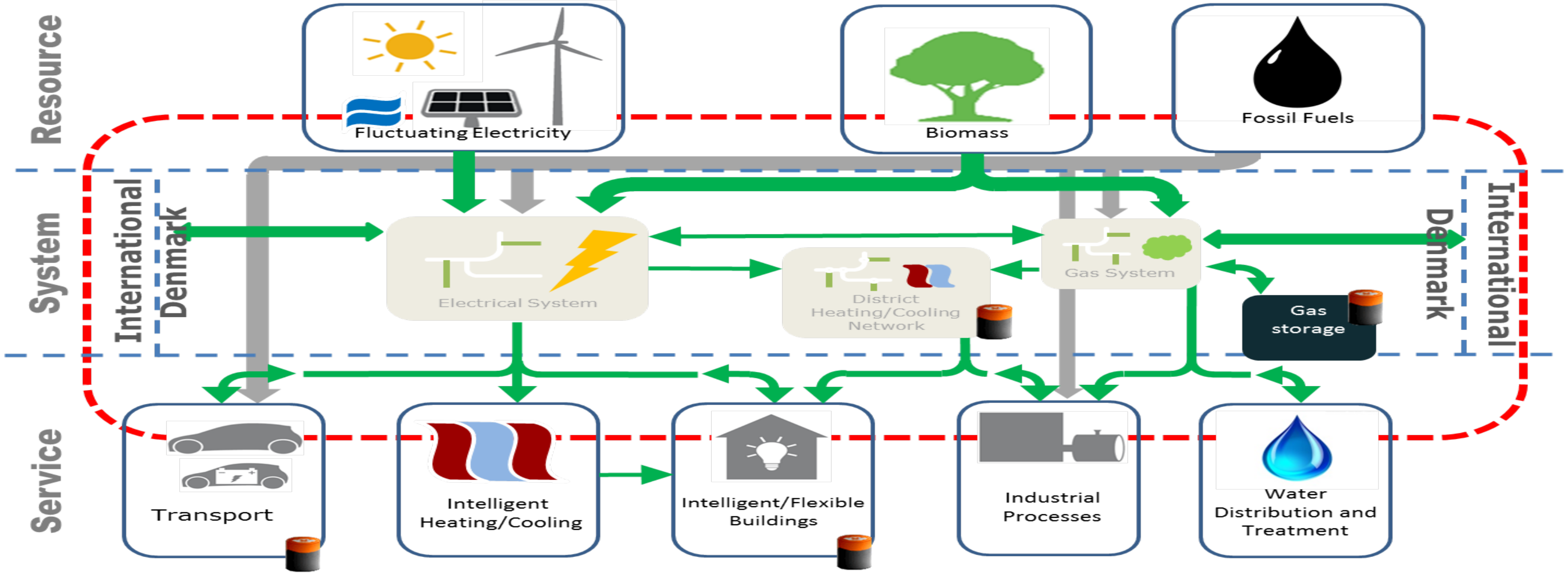


$$\min_{u} \quad \mathrm{E}\left[\sum_{k=0}^{N}\sum_{j=1}^{J} \phi_j(x_{j,k}, u_{j,k}, p_k)\right]$$
$$\begin{aligned} \text{s.t.} \quad x_{k+1} &= Ax_k + Bu_k + Ed_k, \\ y_k &= Cx_k, \\ y_k^{min} \le y_k &\le y_k^{max}, \\ u_k^{min} \le u_k &\le u_k^{max} \end{aligned}$$

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

Models for Systems of Systems

Intelligent systems integration using ***data and ICT solutions*** are based on **grey-box models obtained by Big Data Analytics for real-time operations**



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Flexibility Function (based on Data and AI)

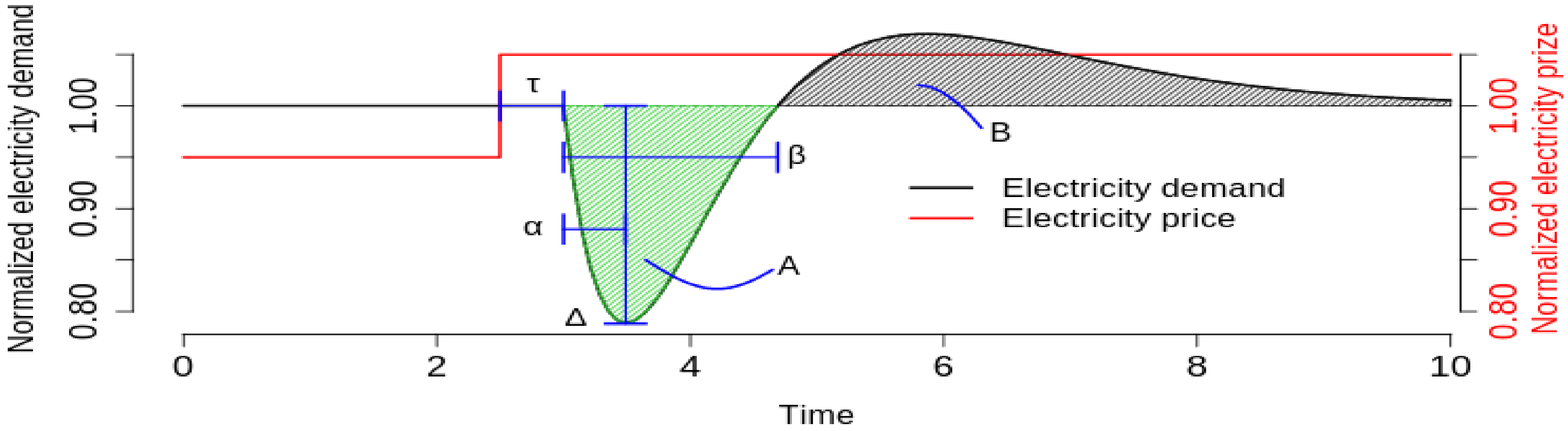
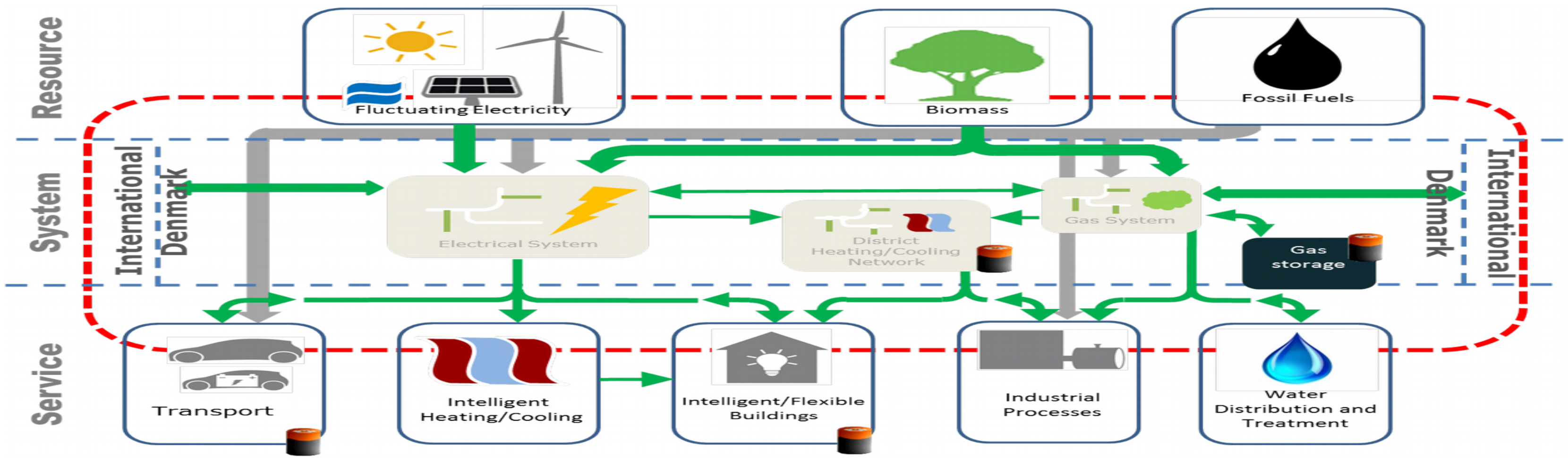


Figure 4: Six characteristics of the demand response to a step increase in electricity price. τ: The delay from adjusting the electricity prize and seeing an effect on the electricity demand, equal to approximately 0.5 here. Δ: The maximum change in demand following the price change, in this case close to 0.2. α: The time it takes from the change in demand starts until it reaches the lowest level, approximately equal to 0.5 here. β: The total time of decreased electricity demand, roughly equal to 2 here. A: The total amount of decreased energy demand, given by the green-shaded area. B: The total amount of increased energy demand, given by the grey-shaded area.

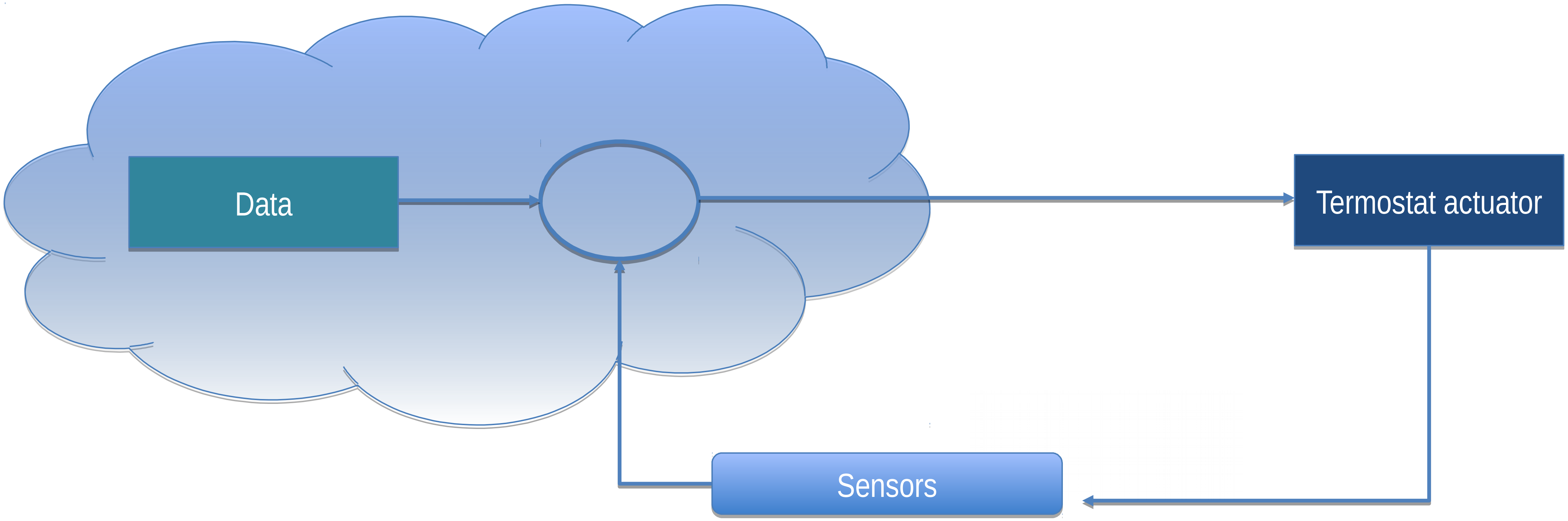
(Virtual) Storage Solutions



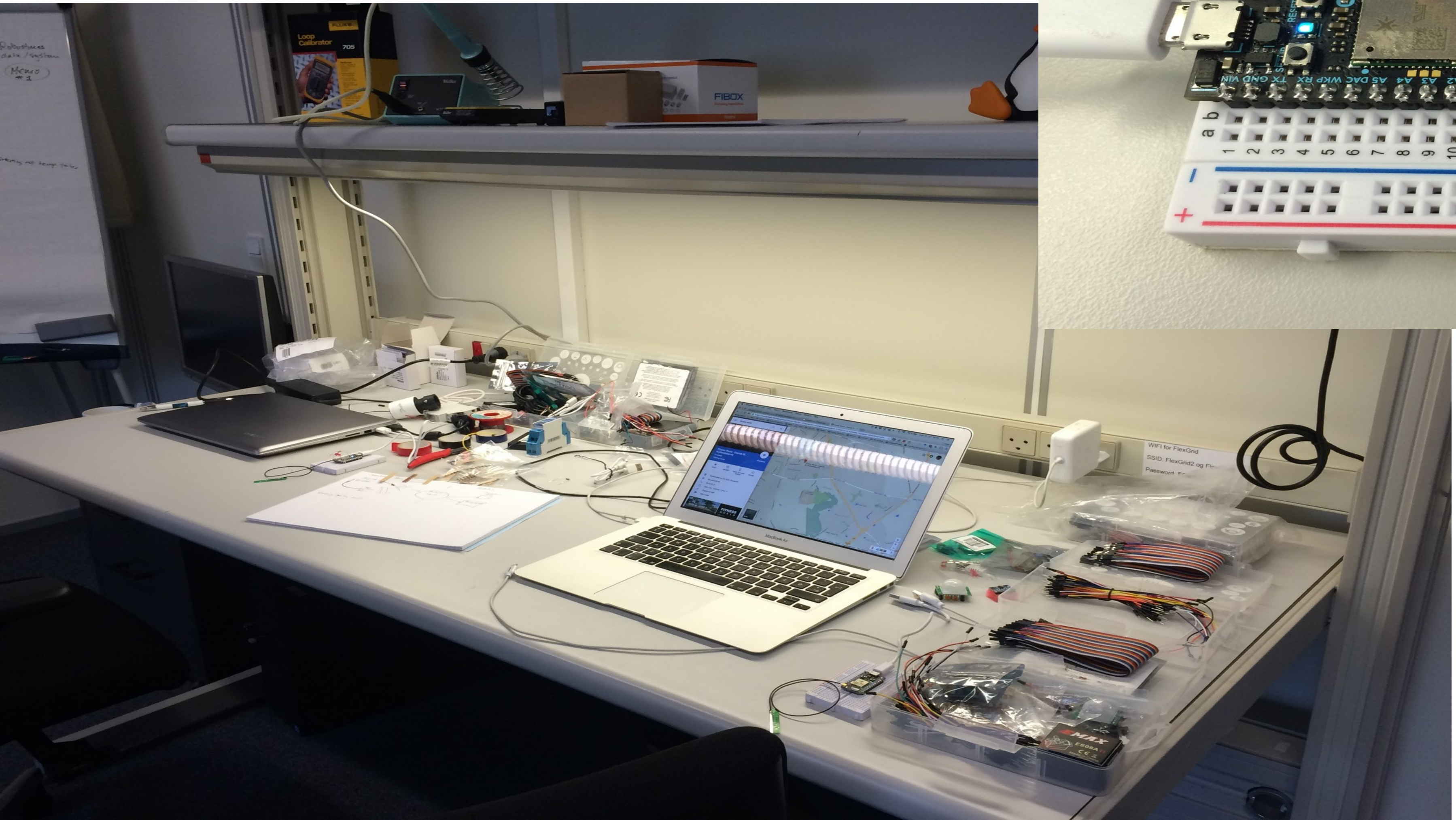
- **Flexibility (or virtual storage) characteristics:**
  - Supermarket refrigeration can provide storage 0.5-2 hours ahead
  - Buildings thermal capacity can provide storage up to, say, 5-10 hours ahead
  - Buildings with local water storage can provide storage up to, say, 2-16 hours ahead
  - District 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

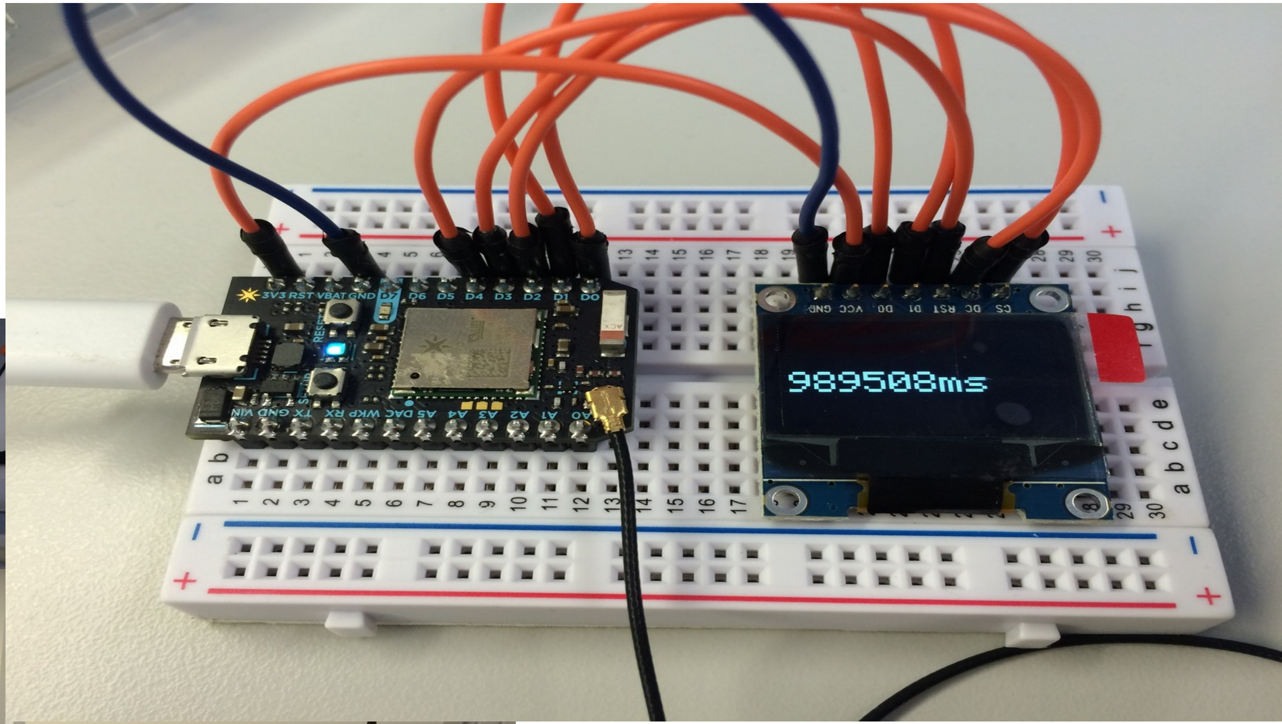
SE-OS implemented as a Cloud solution

Control loop design – **logical drawing**



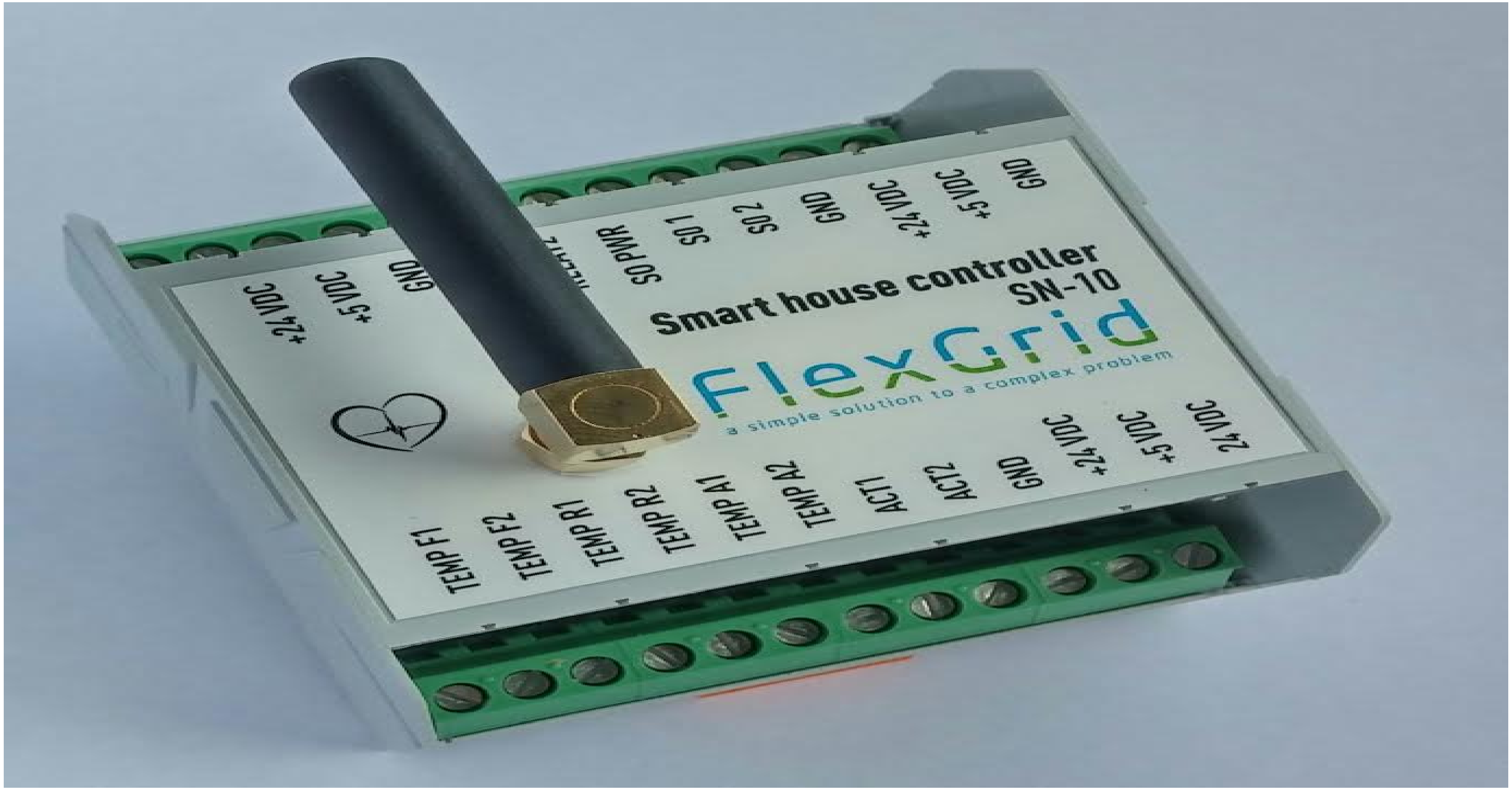
Lab testing ....





SmartNet

SN-10 Smart House Prototype



SE-OS Characteristics

- ‘Bidding – clearing – activation’ at higher levels
- Nested sequence of systems – systems of systems – models based on **Big Data Analytics**
- Hierarchy of optimization (or control) problems based on **AI technologies**
- Control principles at higher spatial/temporal resolutions
- **Cloud, Fog or Edge Computing** based solutions – eg. for forecasting and control
- Facilitates **Energy Systems Integration** (power, gas, thermal, ...)
- Allow for new players (specialized aggregators)
- Simple setup for the communication and contracts
- Provides **a solution for all ancillary services**
- Harvest flexibility at all levels

Case study No. 1

Control of Power Consumption using the Thermal Mass of Buildings (Peak shaving)

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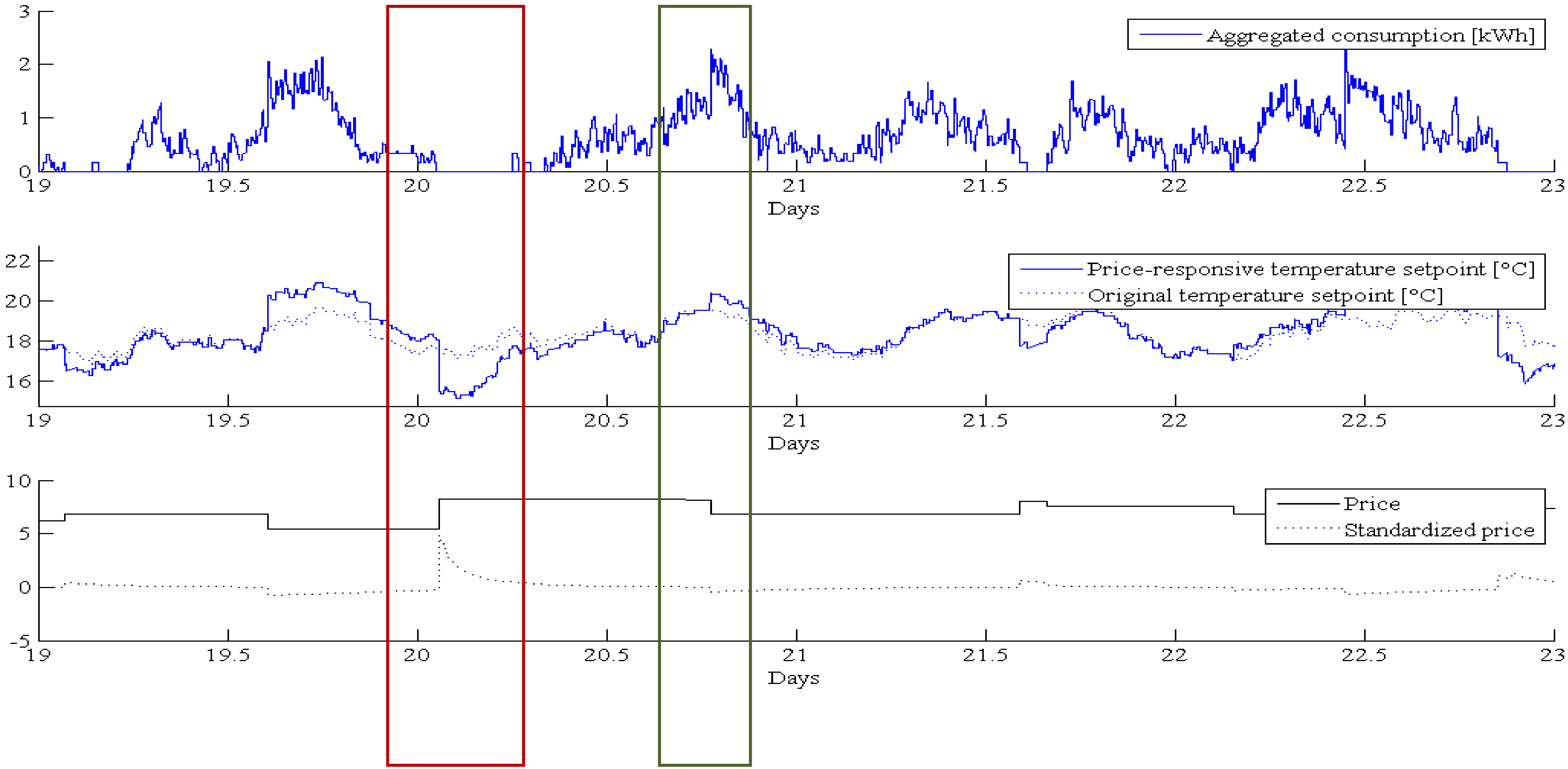
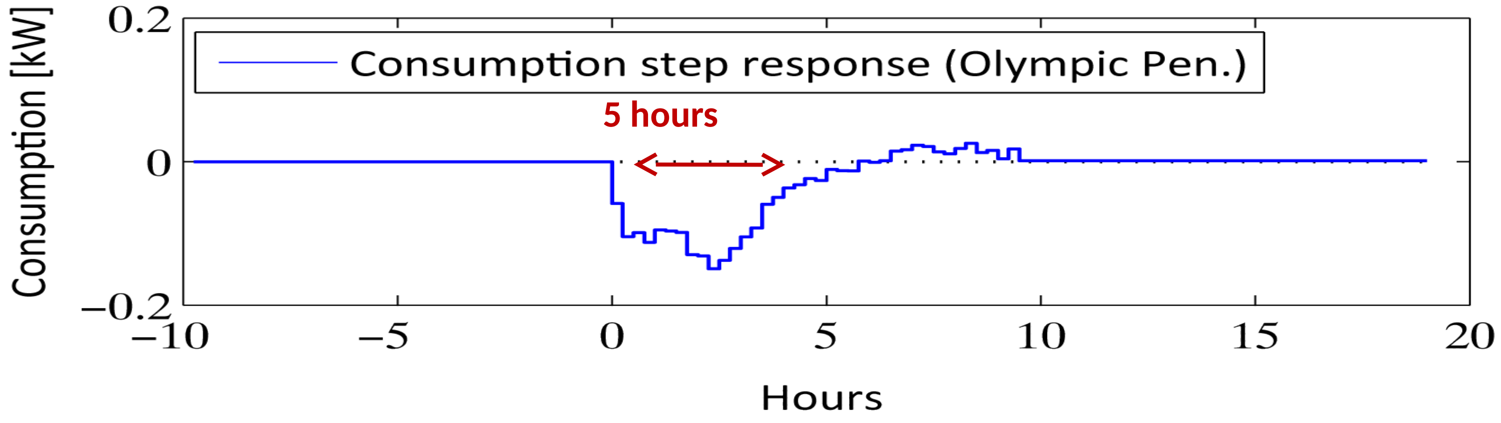
Aggregation (over 20 houses)

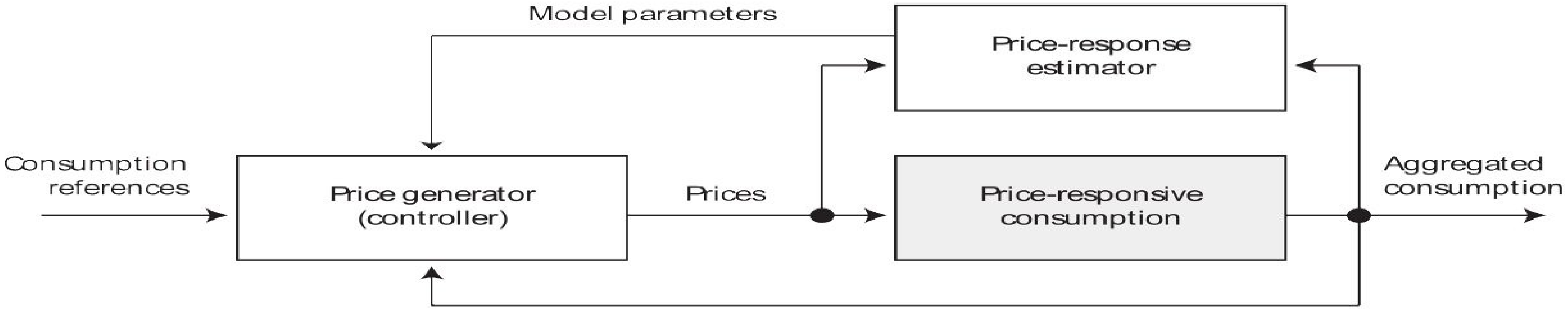


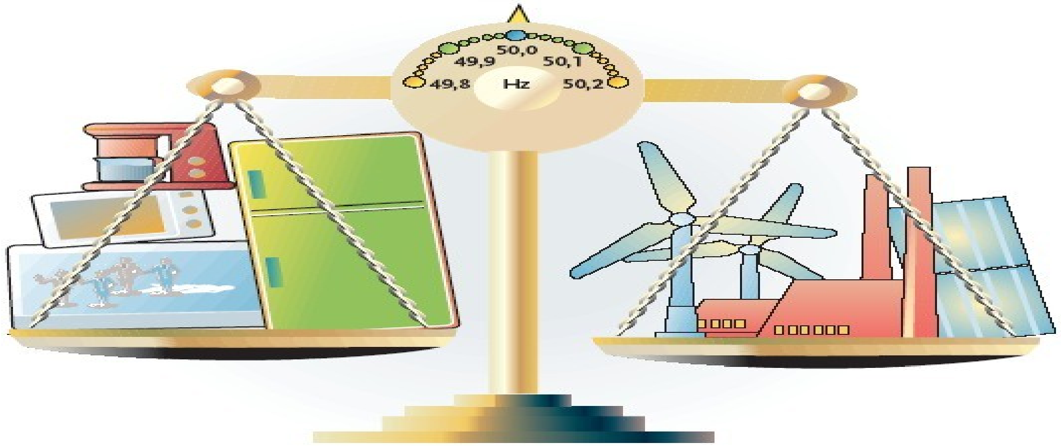
Non-parametric Response on Price Step Change

Olympic Peninsula



Control of Energy Consumption

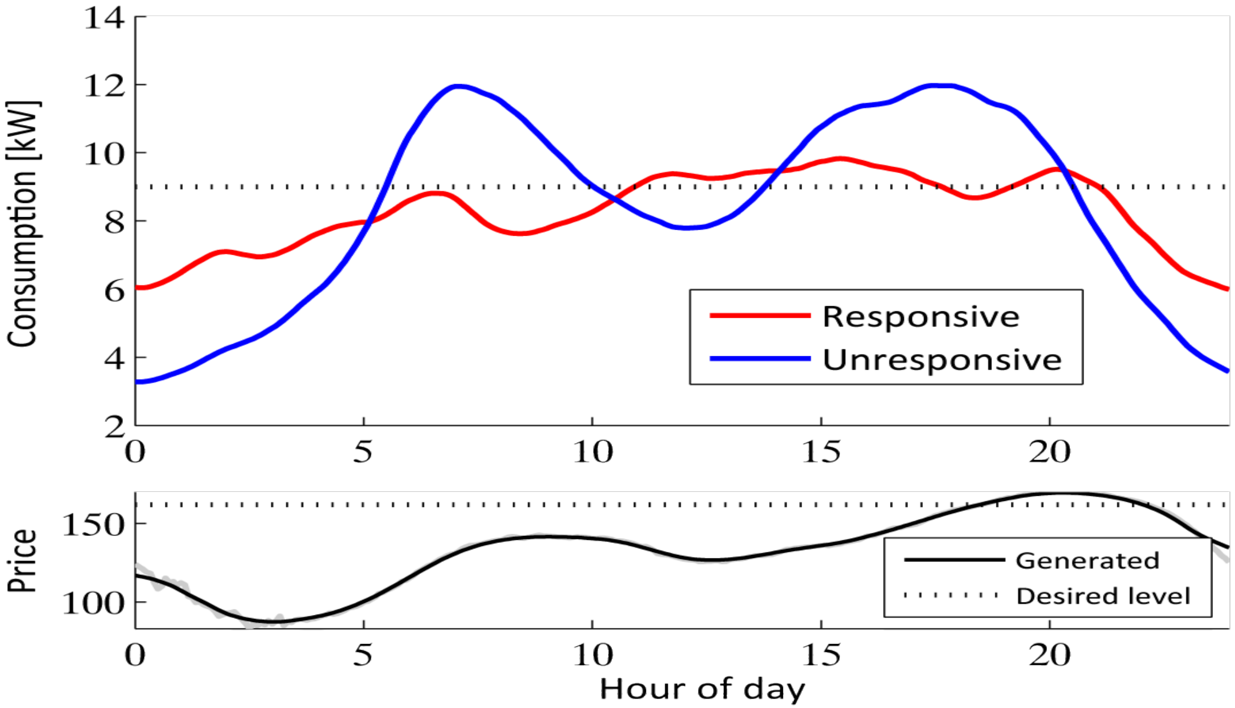




Control performance

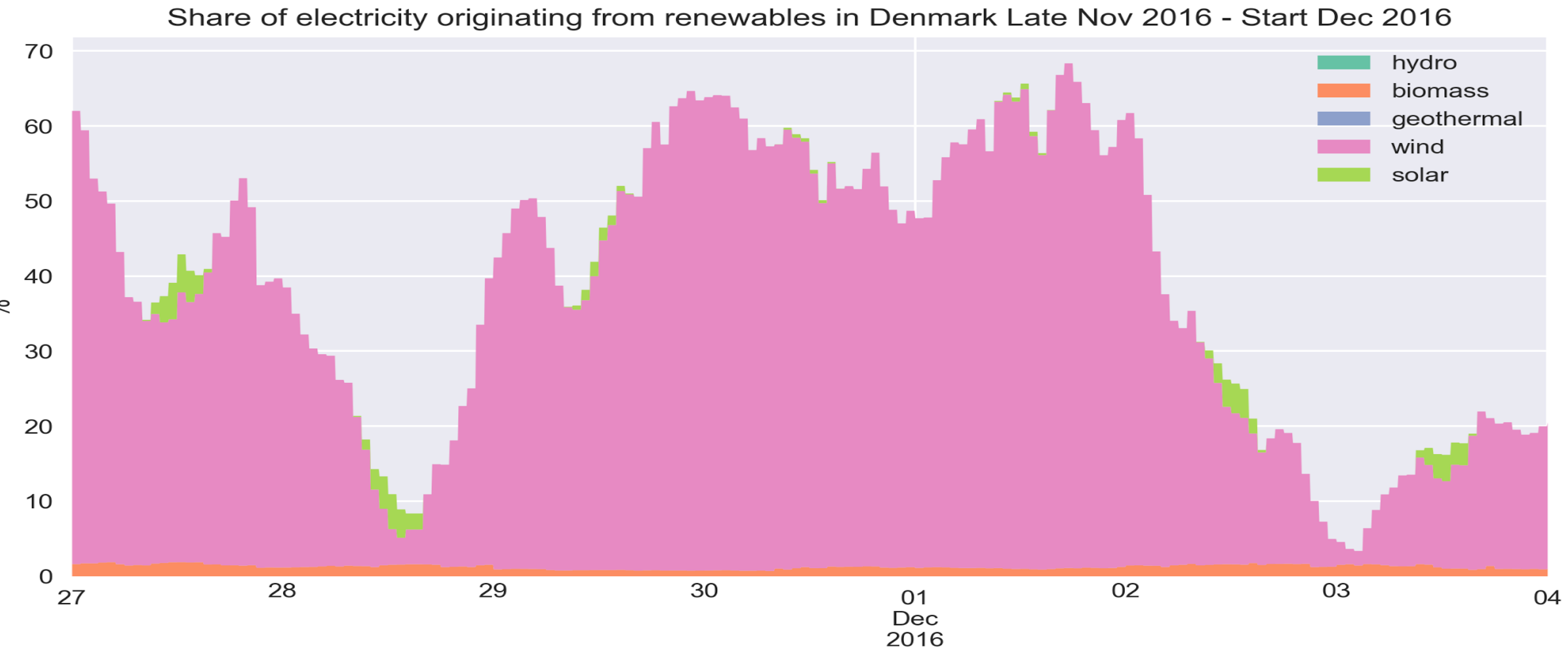
Considerable **reduction in peak consumption**

Mean daily consumption shift



Case study No. 2

Control of heat pumps for swimming pools (CO2 minimization)



Source: pro.electicitymap.org

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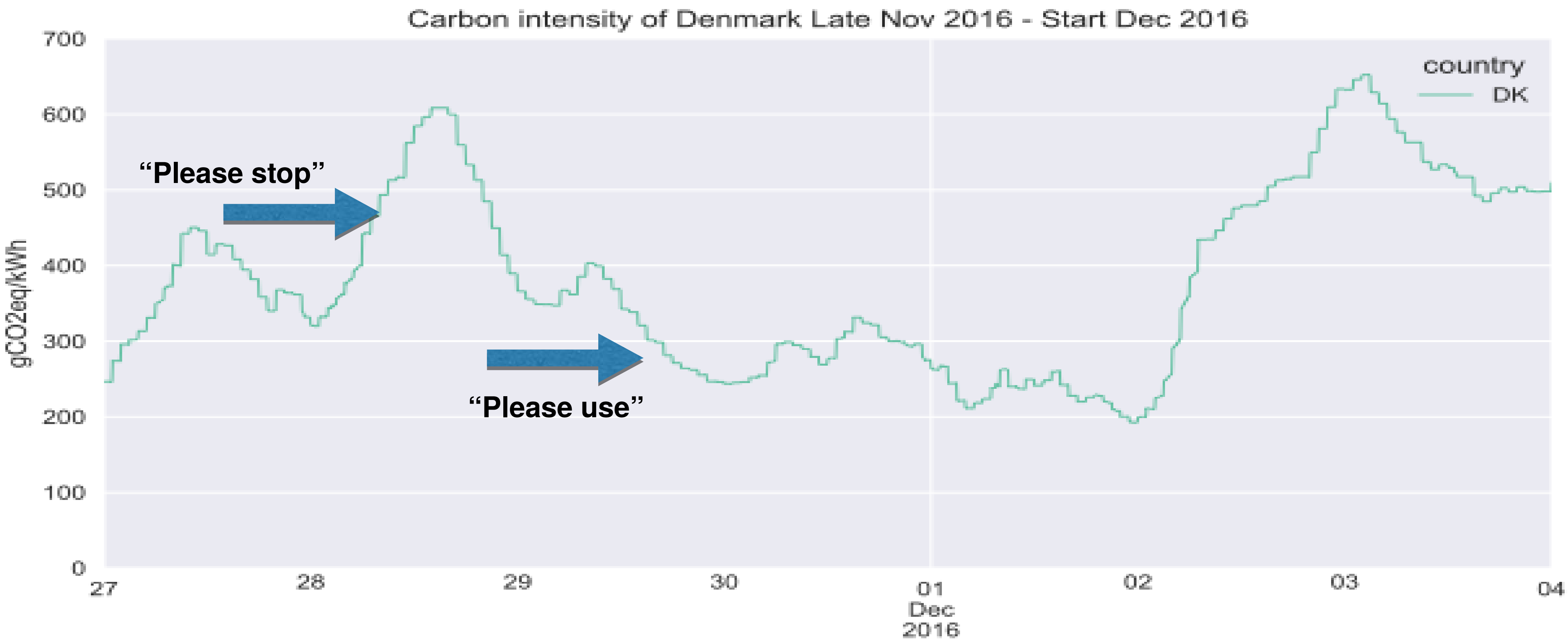
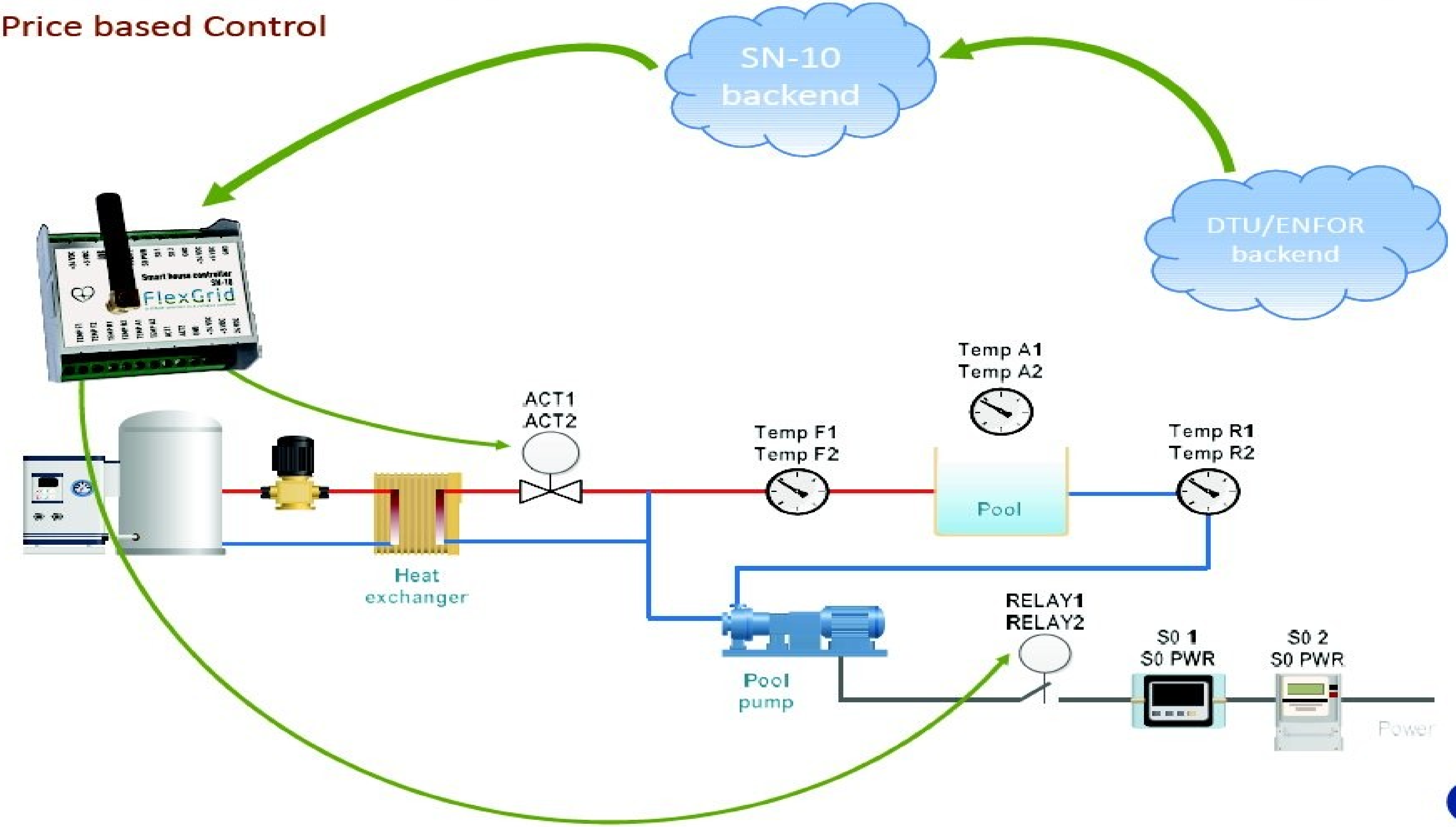


Source: pro.electicitymap.org

How does it work?

Price based Control



CO_2 based control of power consumption

- A procedure for Big Data Intelligent (AI based) control of power load, using the Smart-Energy OS (SE-OS) setup, is suggested. Here the control is mimizing the CO_2 footprint of the heating systems
- The reduction in CO_2 emission is maybe around 25 pct
- The increase in power consumption might be 5 pct
- However, the SE-OS controllers can focus on
  - Peak Shaving
  - Smart Grid services (like ancillary services needs, ...)
  - Energy Efficiency
  - Cost Minimization
  - Emission Efficiency

Summary

- A procedure for Big Data Intelligent (AI based) control of power load, using the Smart-Energy OS (SE-OS) setup, is suggested
- The SE-OS controllers can focus on e.g.
  - Peak Shaving
  - Smart Grid services (like ancillary services needs, ...)
  - Energy Efficiency
  - Cost Minimization
  - Emission Efficiency
- We have demonstrated a large potential in Demand Response. Automatic solutions based on machine learning, 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)

For more information ...

See for instance

www.smart-cities-centre.org

www.smartnet-project.eu/

...or contact

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THANK YOU