Unlocking End-user Flexibility

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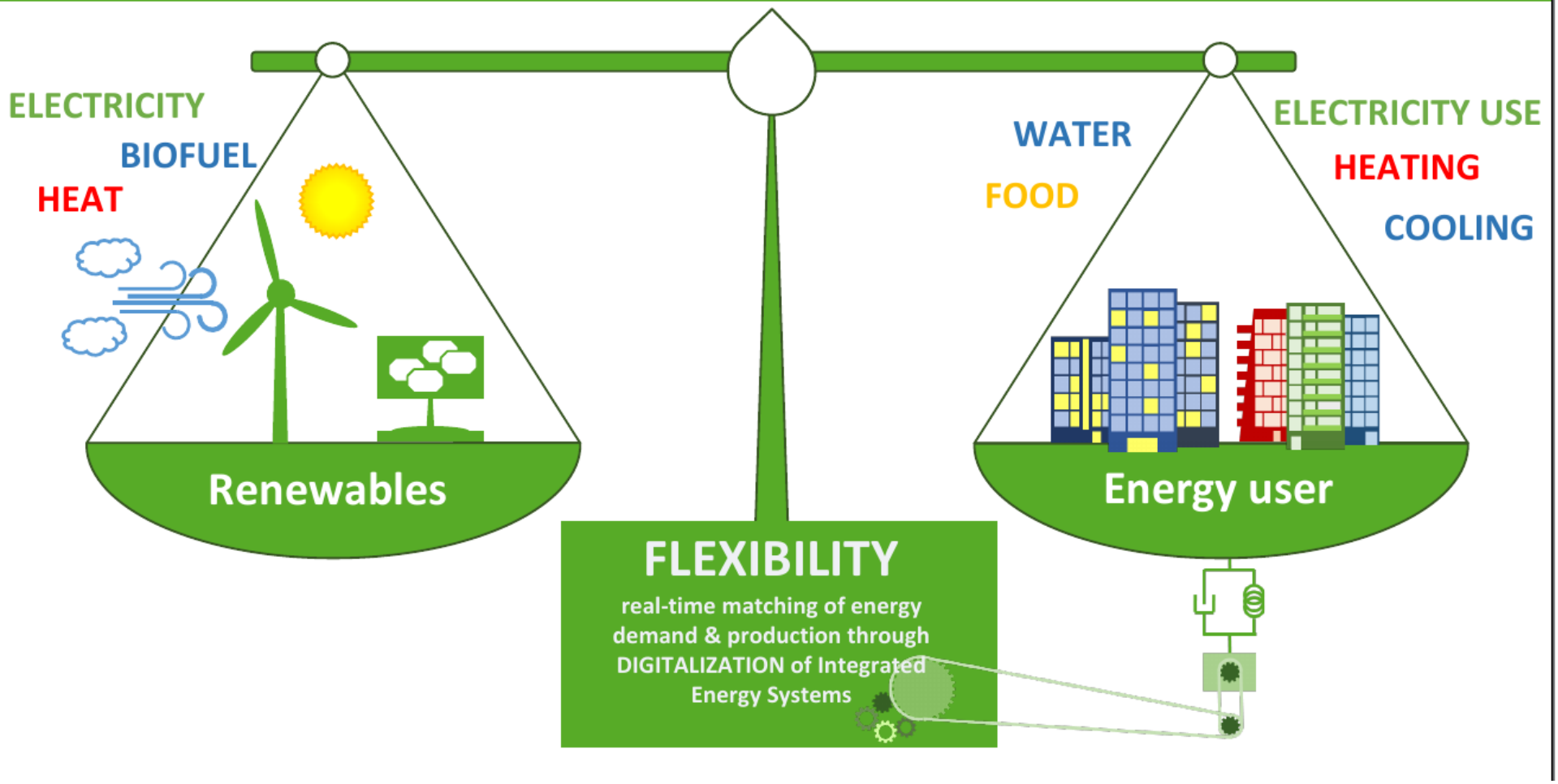
Challenges

The Challenge: Denmark Fossil Free 2050



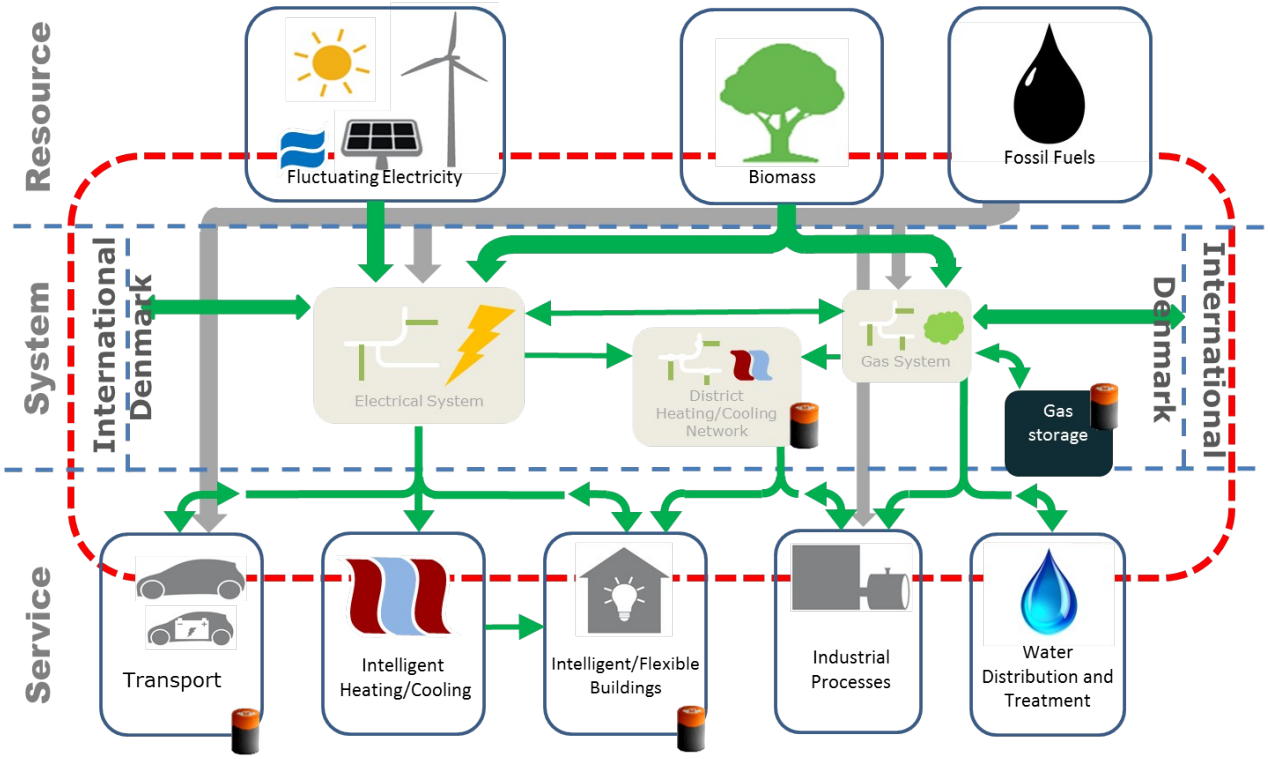
Markets – Needed changes

- Static -> **Dynamic**
- Deterministic -> **Stochastic**
- Linear -> **Nonlinear**
- Many power related services (voltage, frequency, balancing, spinning reserve, congestion, ...) -> **Coordination + Hierarchy**
- Speed / problem size -> **Decomposition + Control Based Solutions**
- Characterization of flexibility (bids) -> **Flexibility Functions**
- Requirements on user installations -> **One-way communication**

Data-Intelligent and Flexible Energy Systems

Energy System Models for Real Time Applications and Data Assimilation

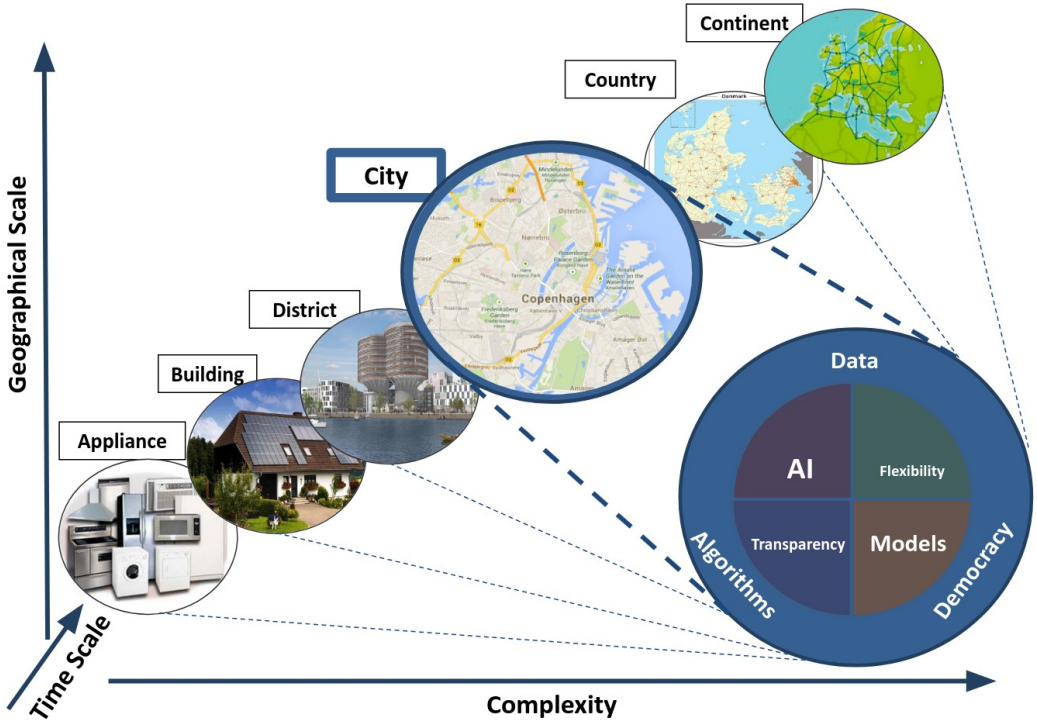
Grey-box models are simplified models for the individual components facilitating system integration and use of sensor data in real-time



CITIES
Centre for IT Intelligent Energy Systems

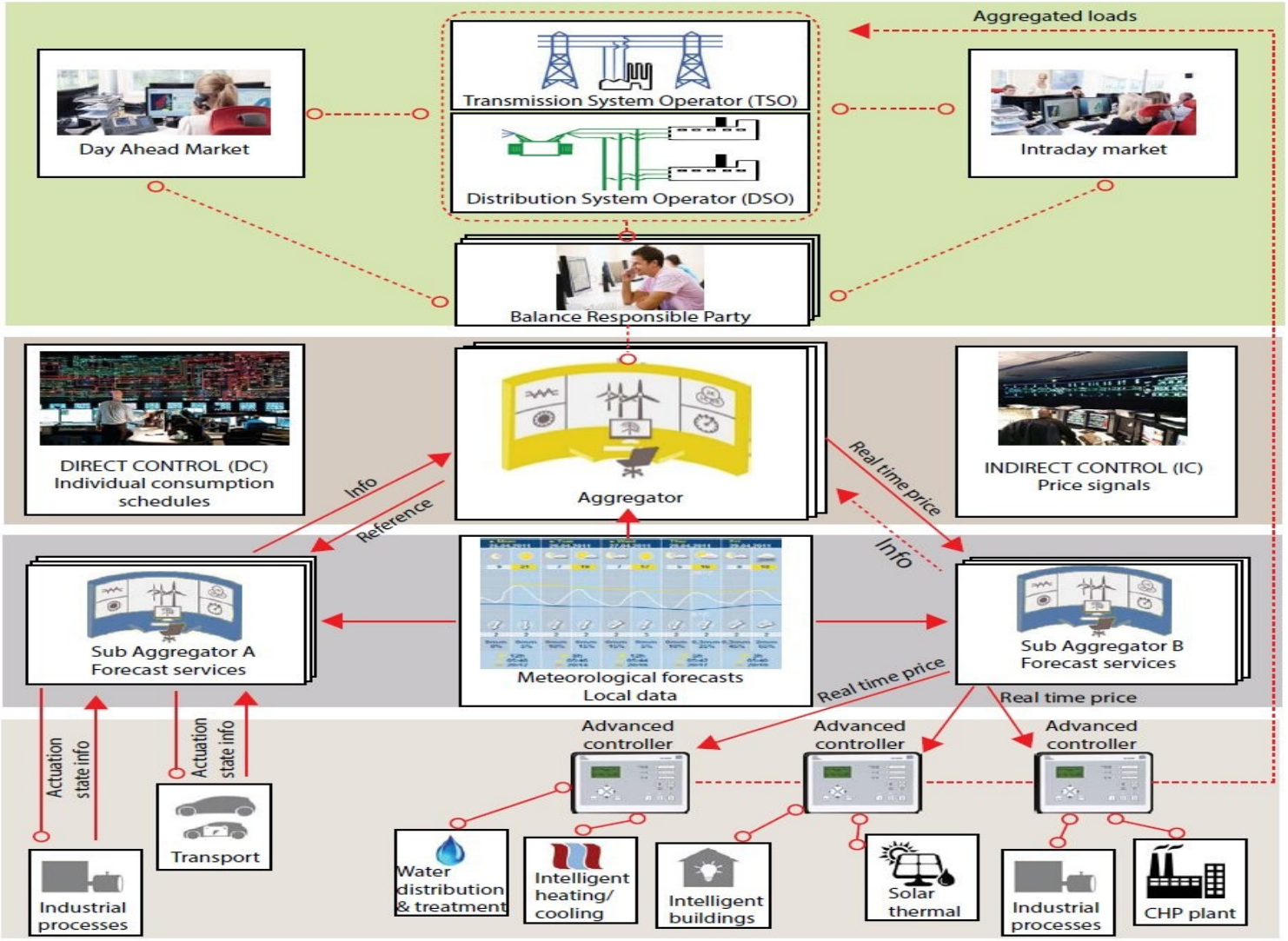
Temporal and Spatial Scales

A so-called ***Smart-Energy Operating-System (SE-OS)*** is developed in order 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

The Transformative Power of Digitalisation



(**Static**)

Conventional Markets

Linking Markets to Physics

(Flexibility Functions)

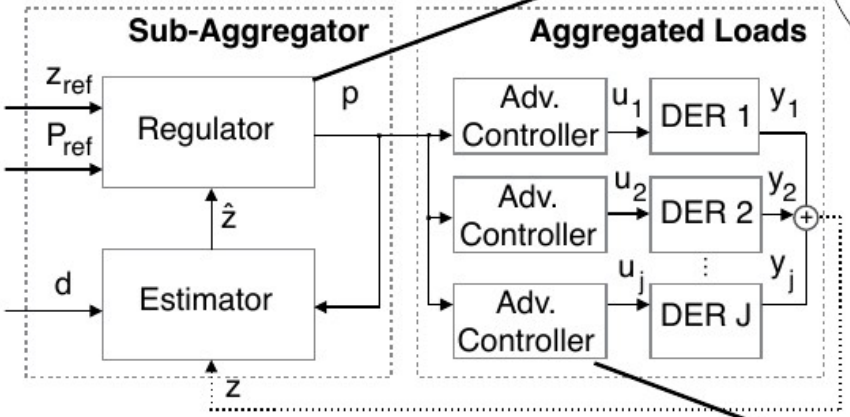
(**Dynamic**)

Local Flexibility Markets

(Hierarchy of controllers)

Proposed methodology
Control-based methodology

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



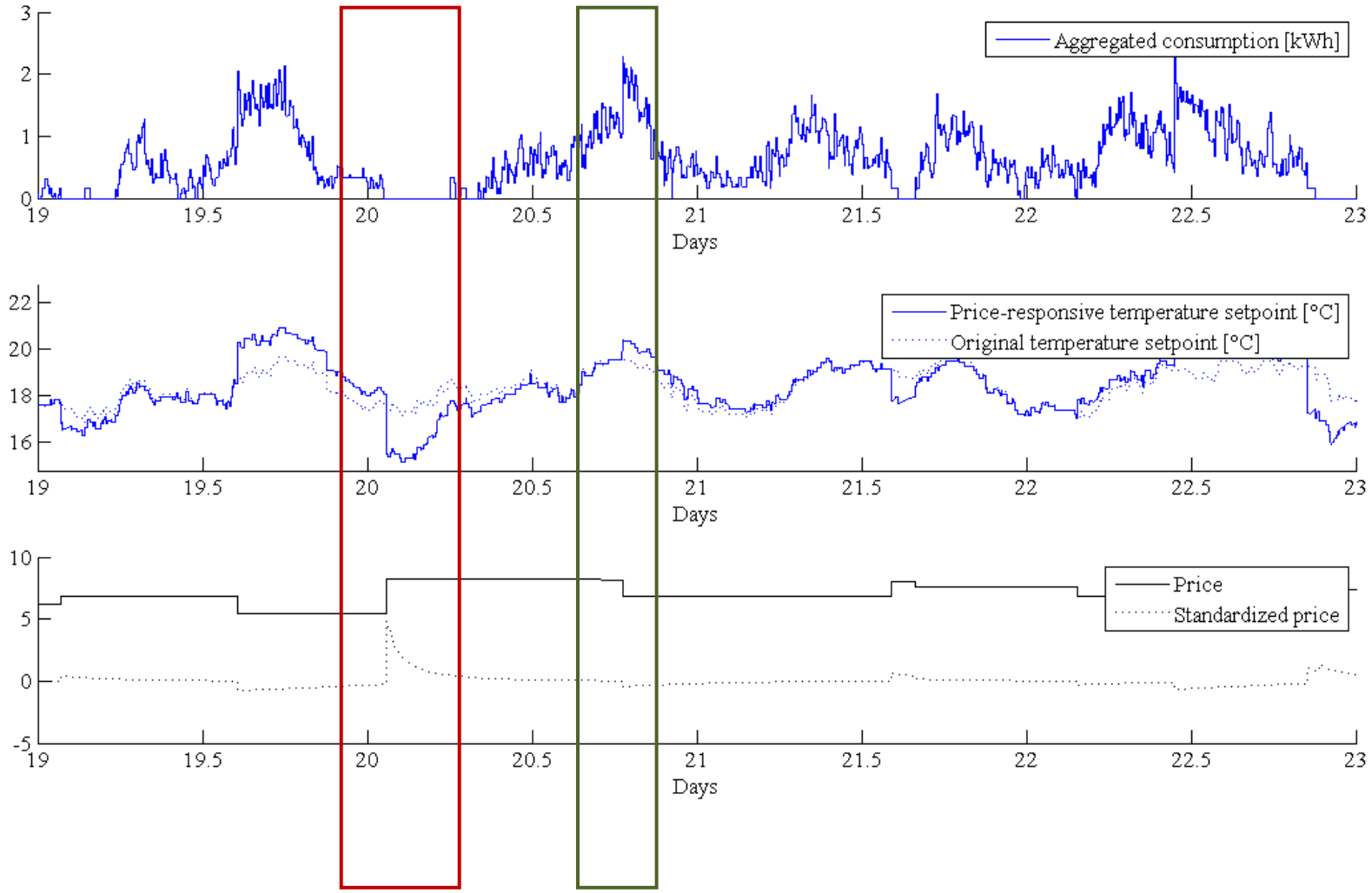
We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

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

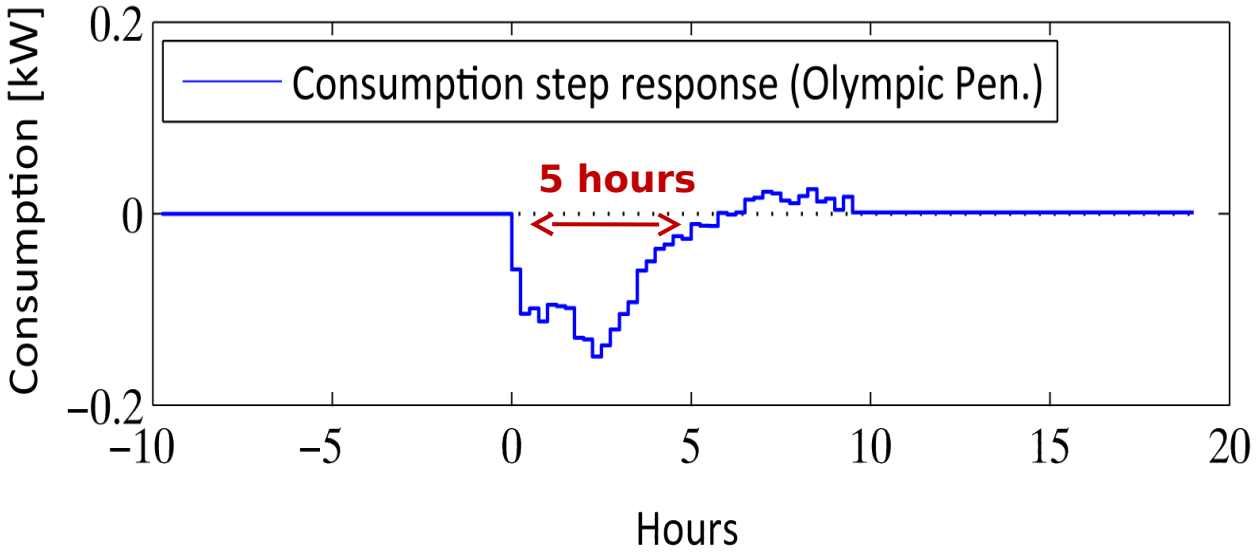
Case study (Level III)

Price-based Control of Power Consumption (Peak Shaving)

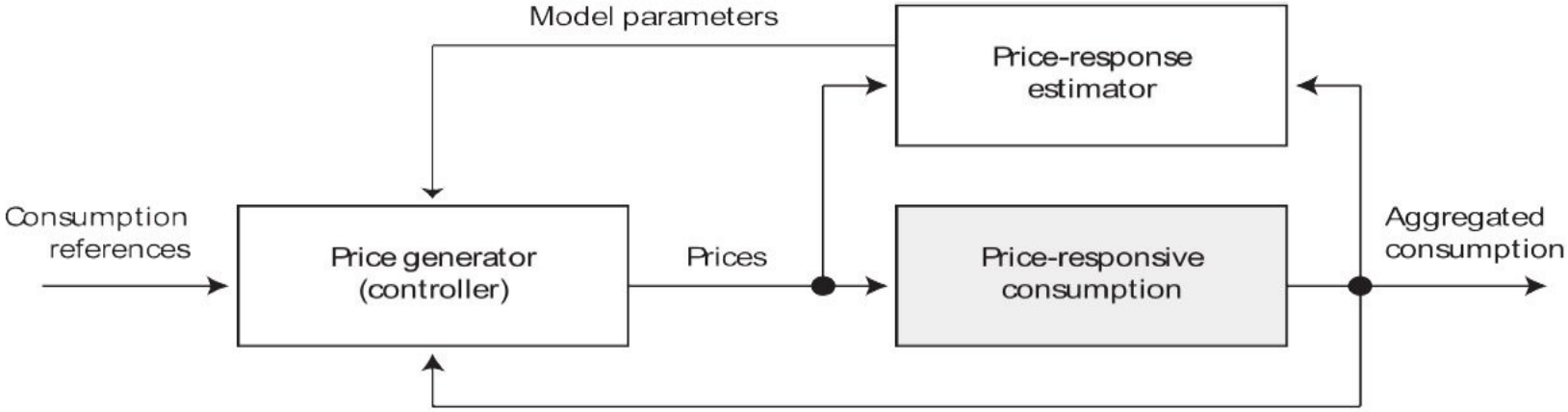
Aggregation (over 20 houses)

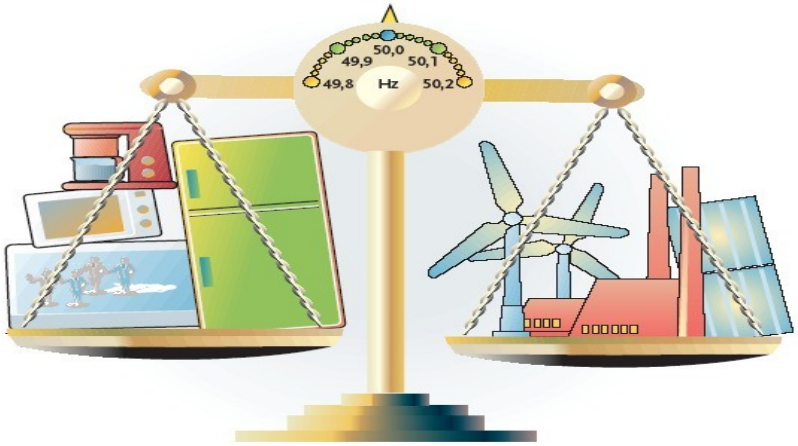


Response on Price Step Change



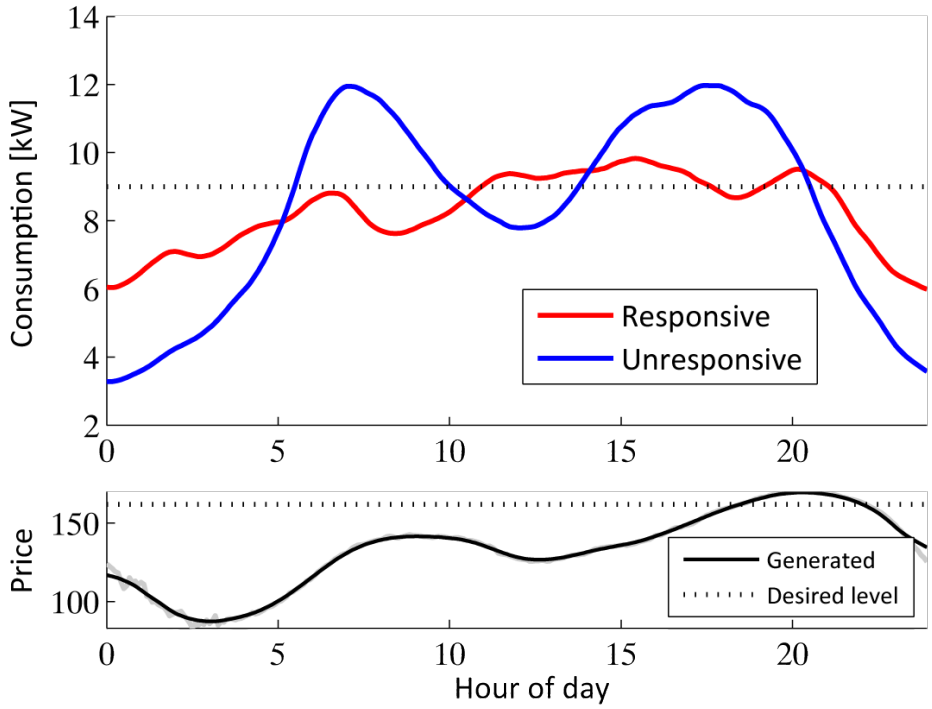
Control of Power Consumption



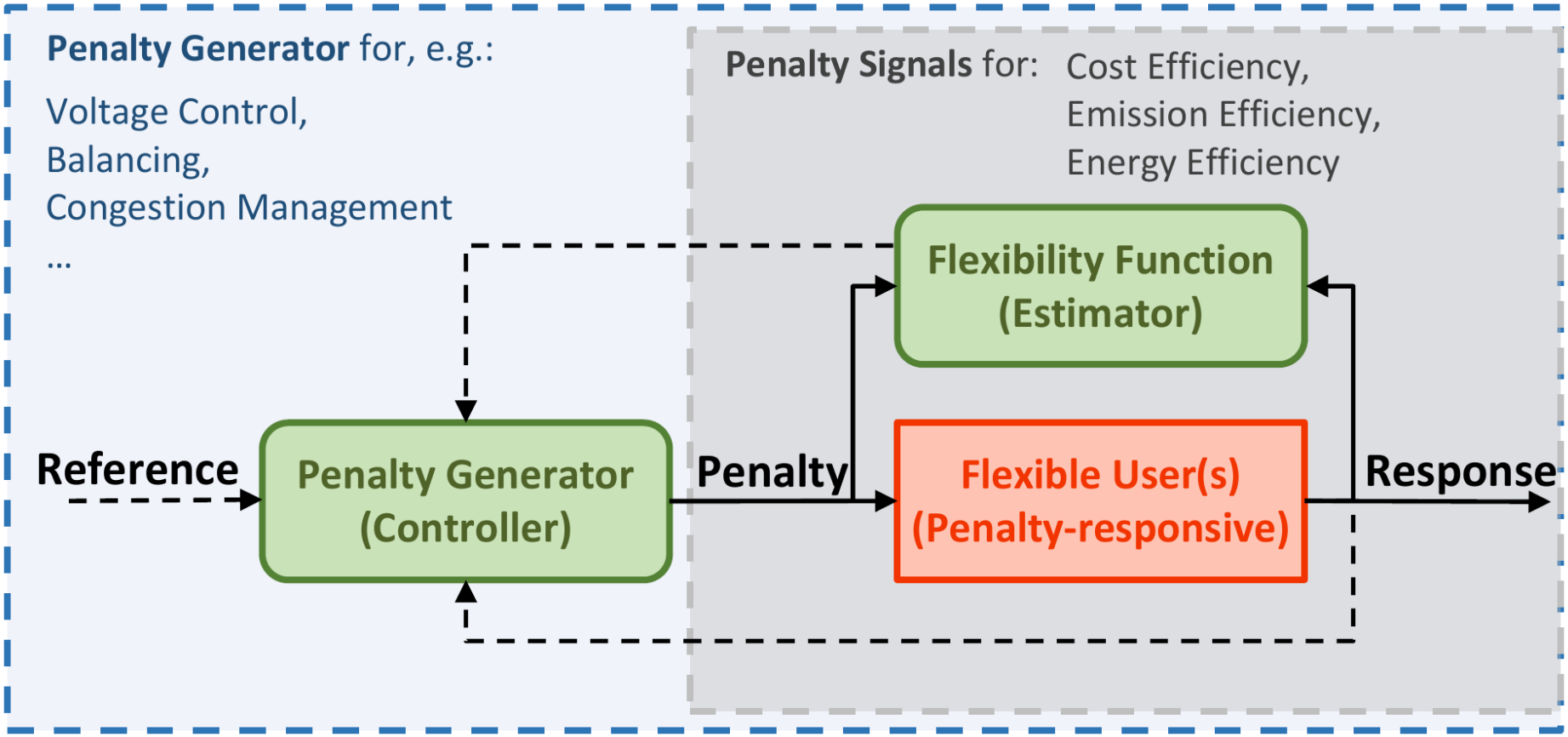


Control performance

Considerable **reduction in peak consumption**



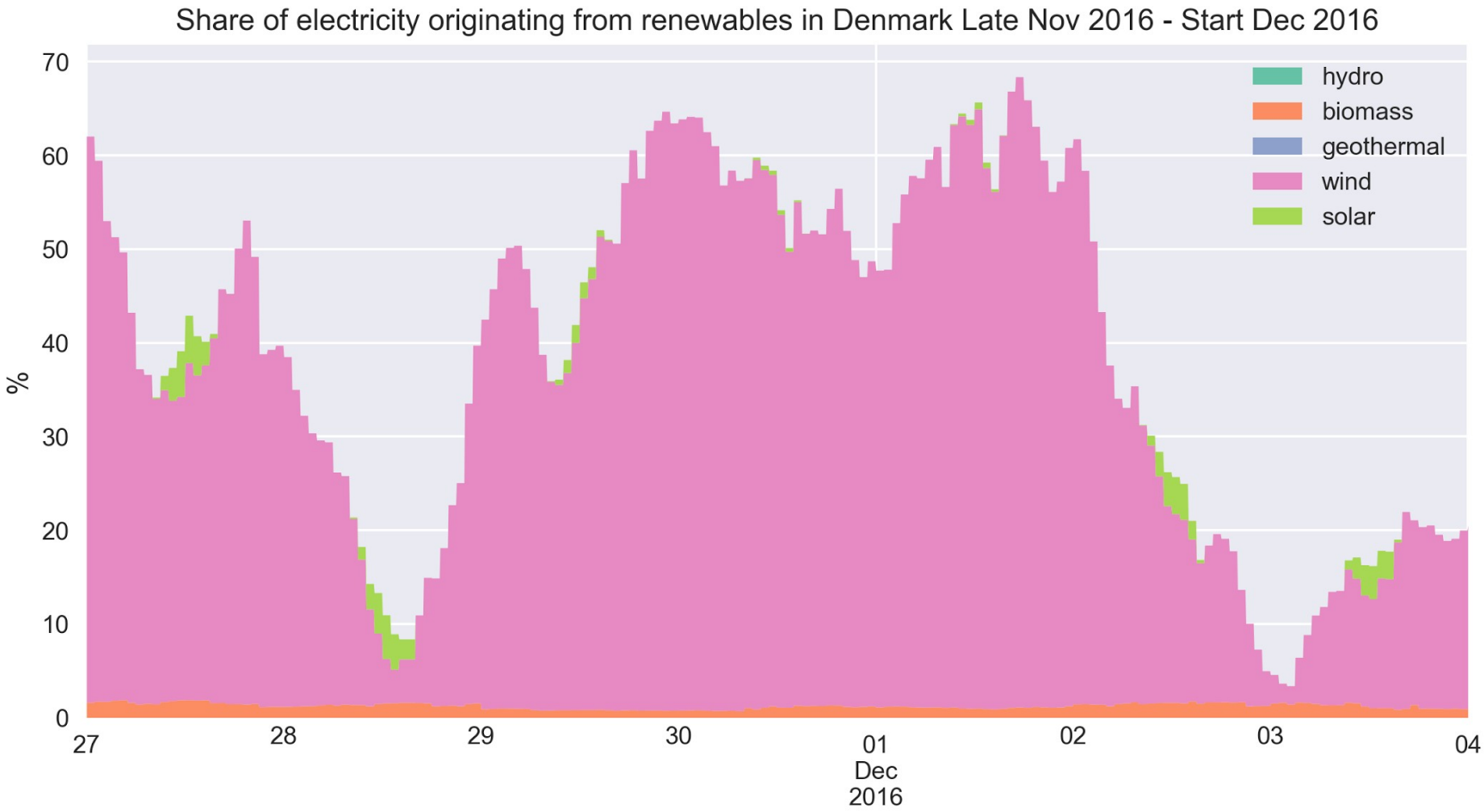
A FED example: Flexible Users and Penalty Signals



Case study (level IV)

Control of heat pumps for buildings with a pool

(Price/CO2-based control)



Source: pro.electicitymap.org

How does it work?

Data measurement and information gathering

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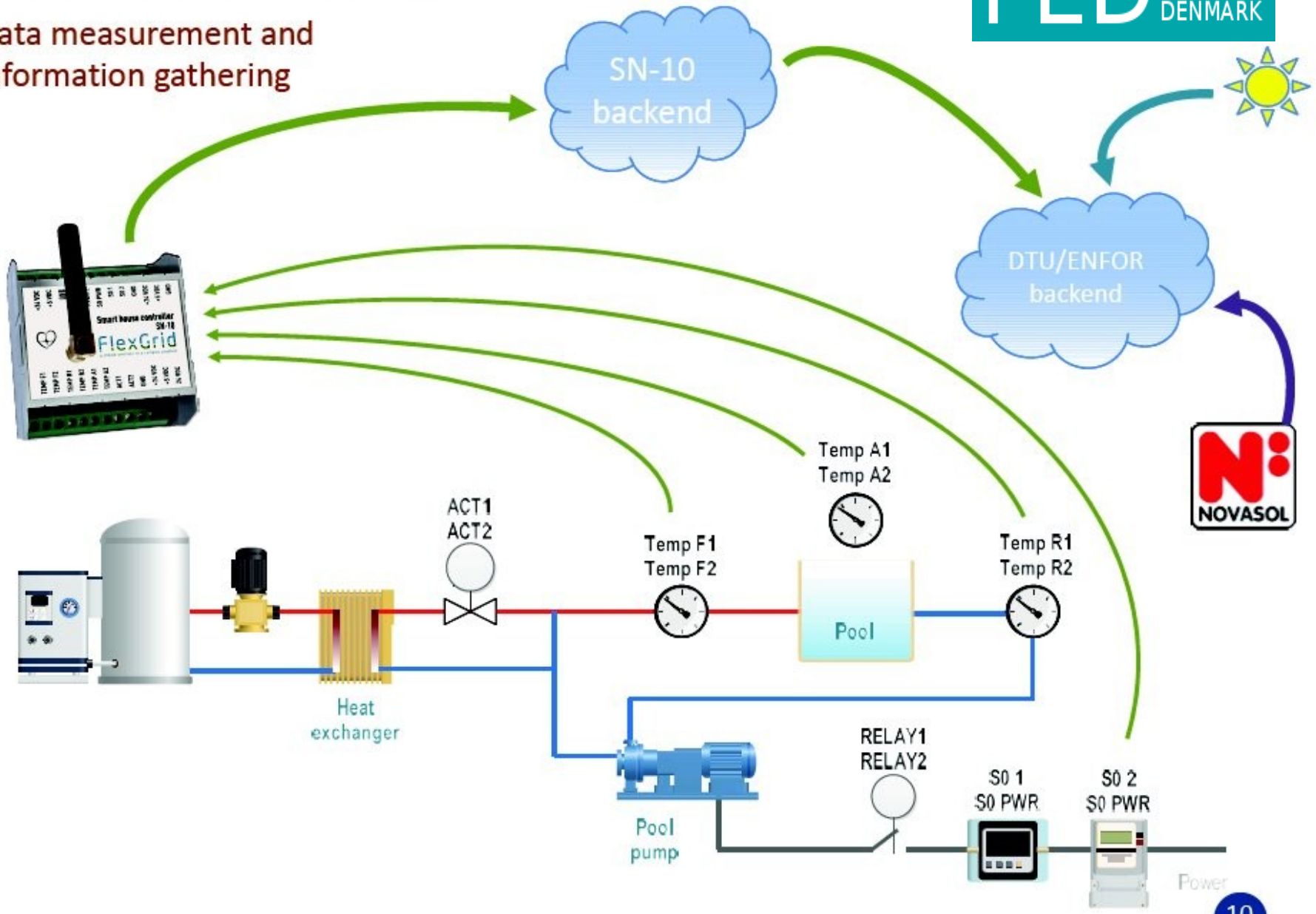

How does it work?

Price based Control

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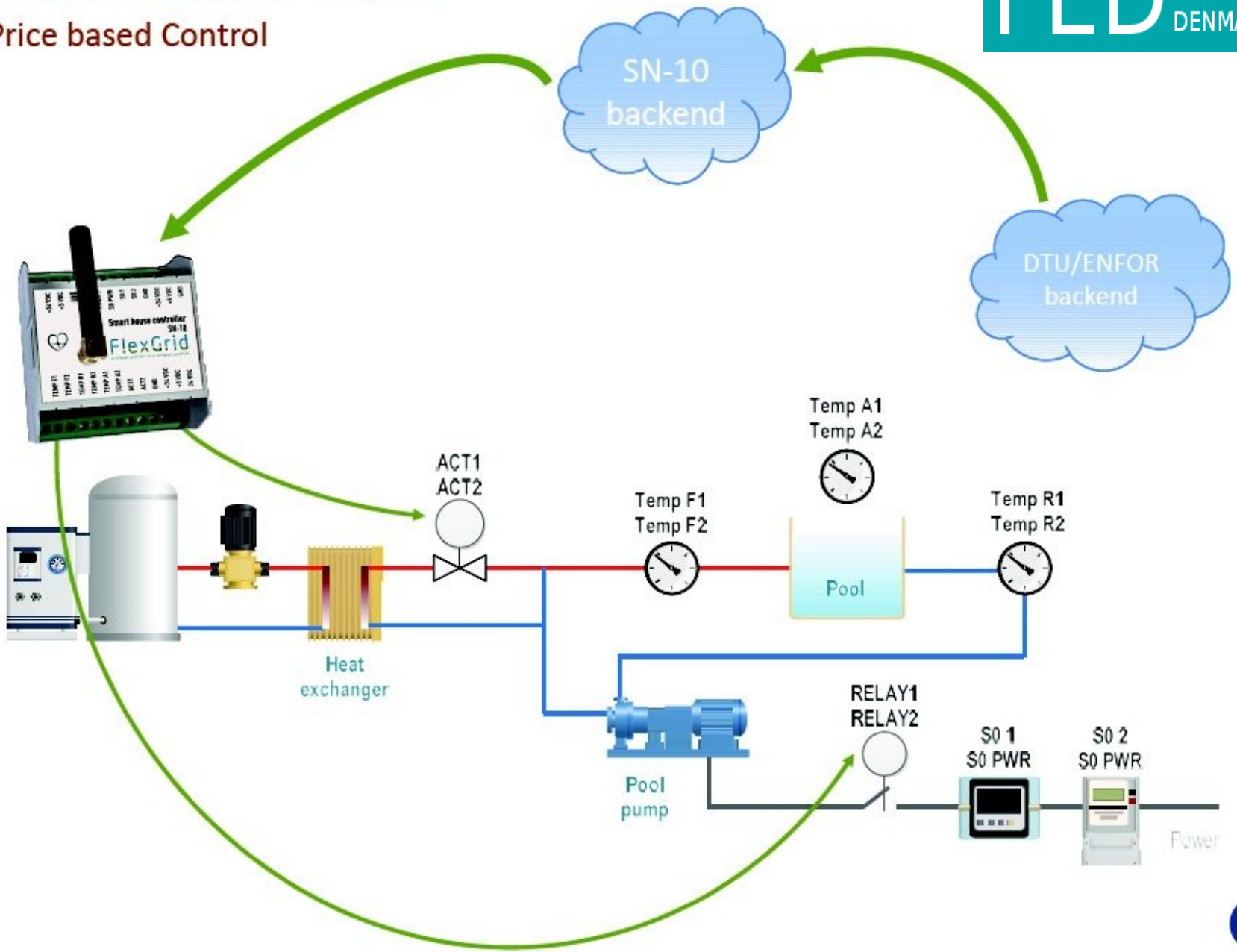

Example: Price-based control

Example: CO2-based control (savings 10-30 pct)

Center Denmark
Control Room and Data Space
Spatial–Temporal thinking

We aim at enstablishing a trusted data-sharing data space which put priorities in cyber security and in enpowering the customers such that they are able to provide flexibility without being subject to disproportionate technical requirements, administrative requirements, procedures and charges

Summary

- The **future weather-driven energy** system calls for digitalization of the energy systems in **Buildings** and **Smart Cities**.
- We need **a deep digitalisation** (AI, IoT, Cloud/Fog/Edge Computing, etc.)
- Buildings can provide **grid flexibility** (peak, voltage, congestion, temperature of transformators, ...)
- We need **data hubs** for energy related streaming data (like **Center Denmark**)