Unlocking End-user Flexibility

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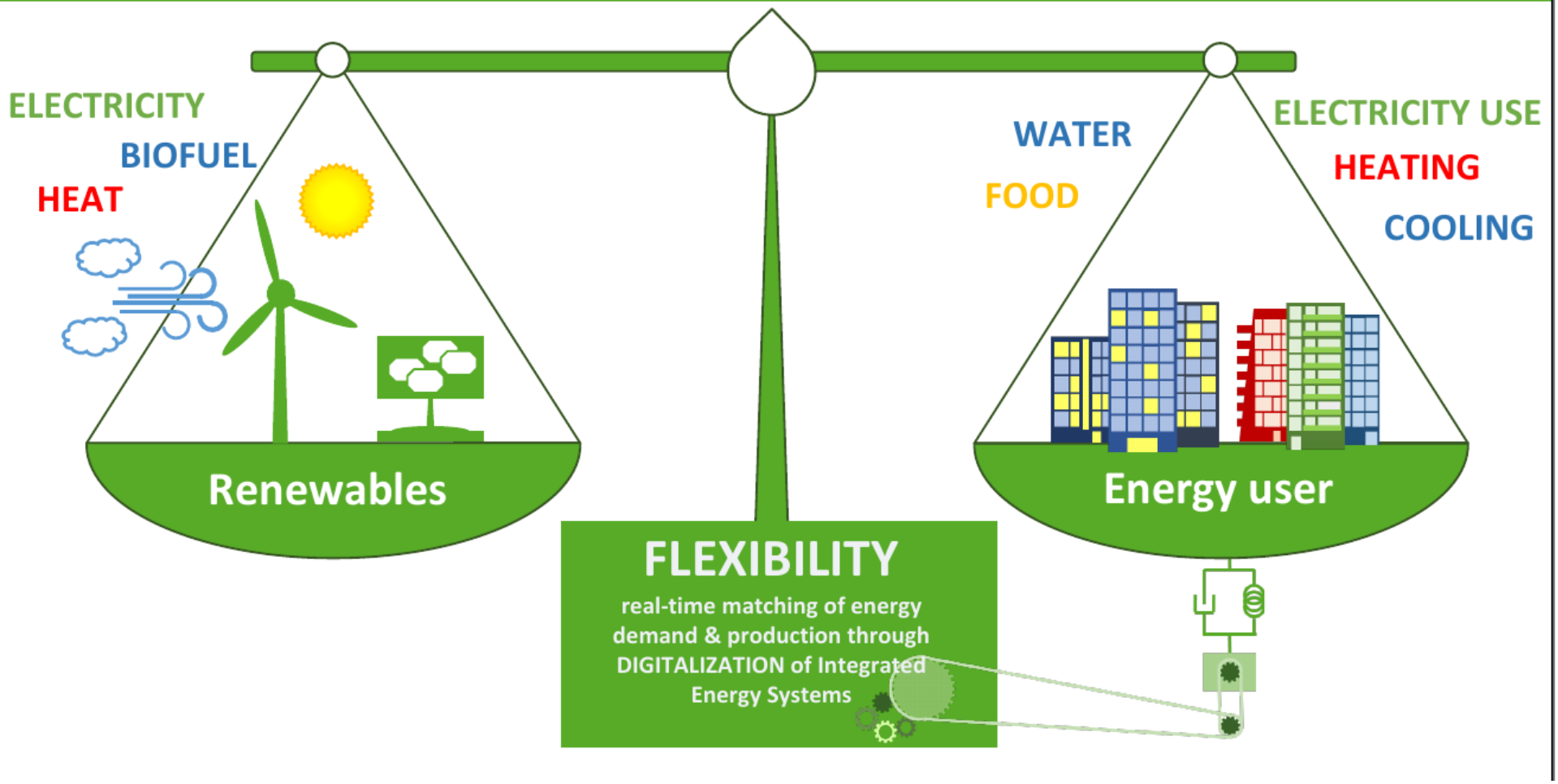
Challenges

The Challenge: Denmark Fossil Free 2050



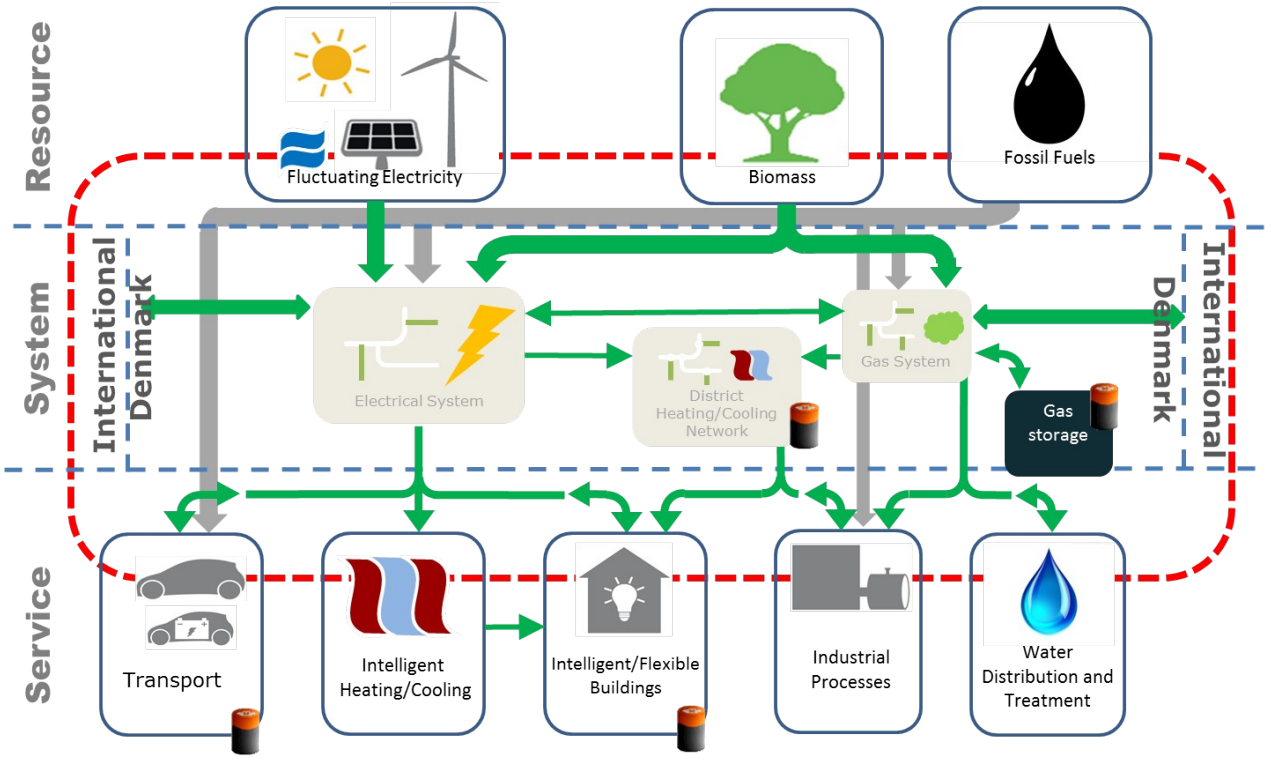
Markets – Needed changes

- 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

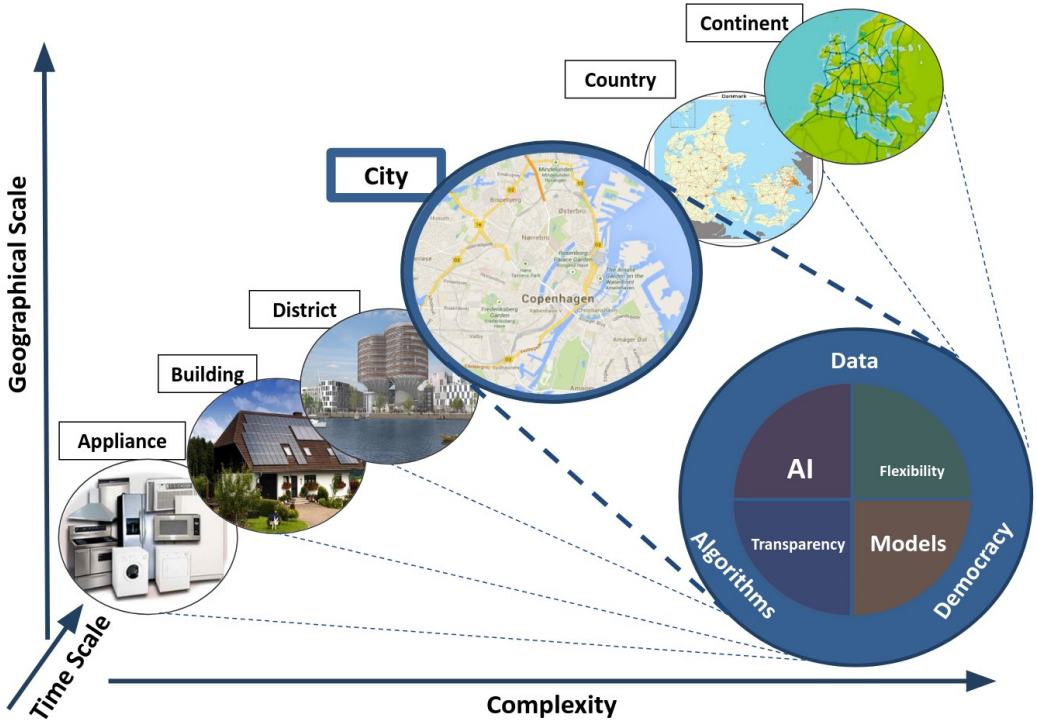
Grey-box models are simplified models for the individual components facilitating system integration and use of sensor data in real-time



CITIES
Centre for IT Intelligent Energy Systems

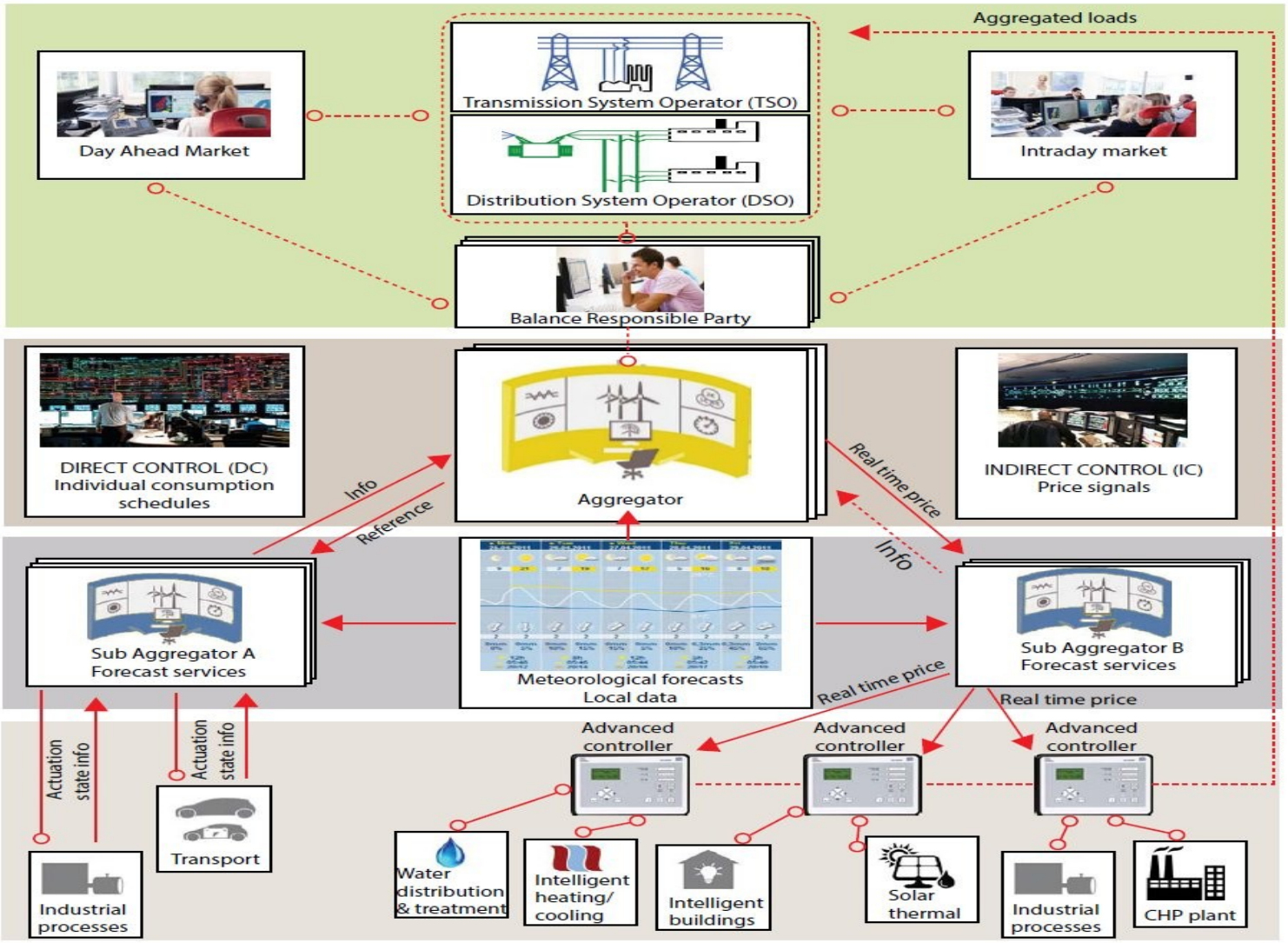
Temporal and Spatial Scales

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**.



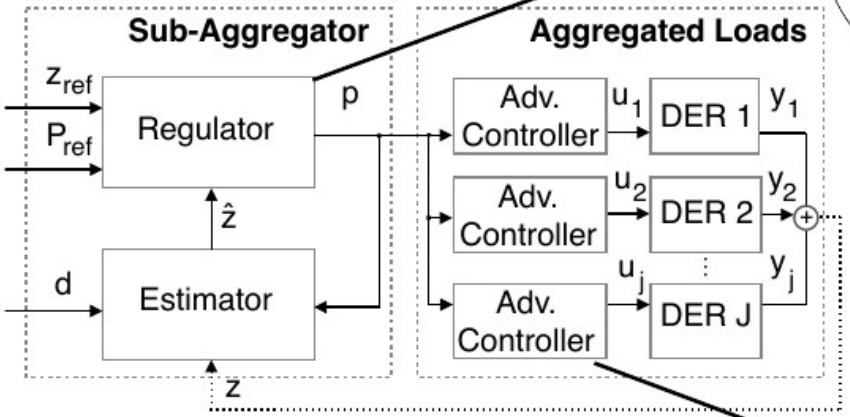
Smart-Energy OS

The Transformative Power of Digitalization



Proposed methodology
Control-based methodology

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



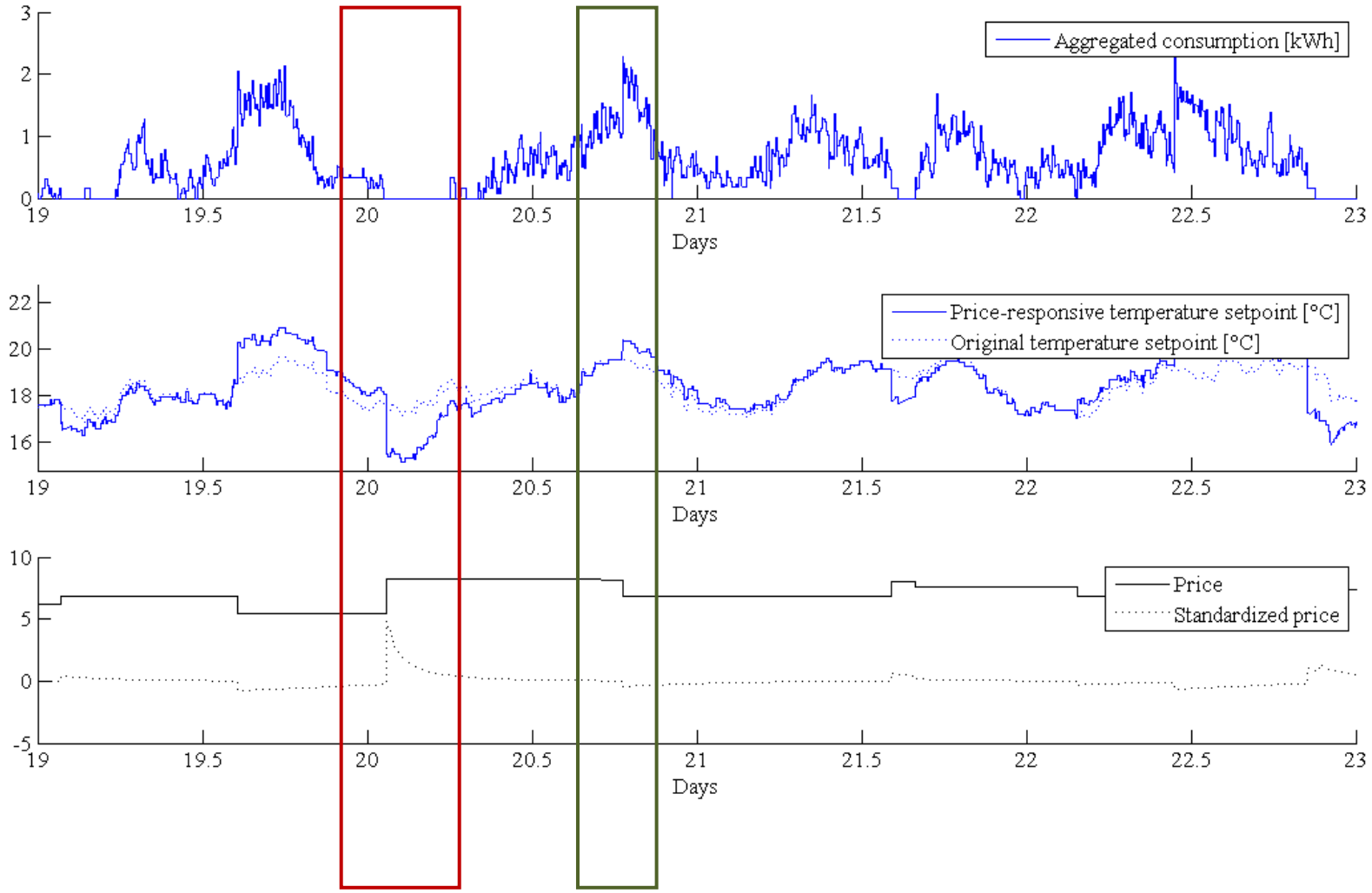
We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

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

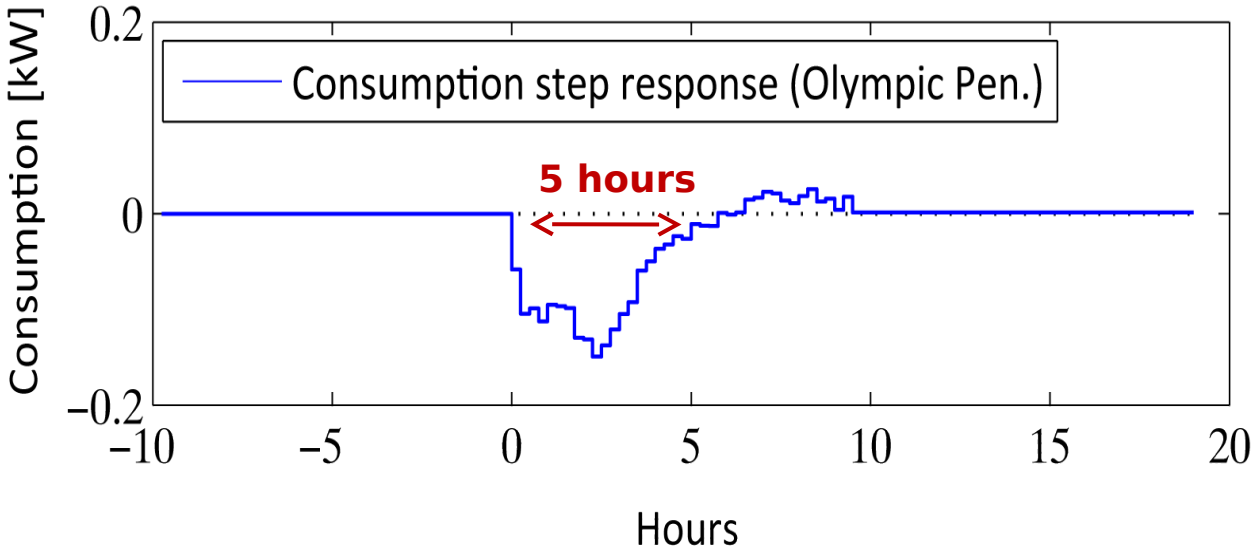
Case study (Level III)

Price-based Control of Power Consumption (Peak Shaving)

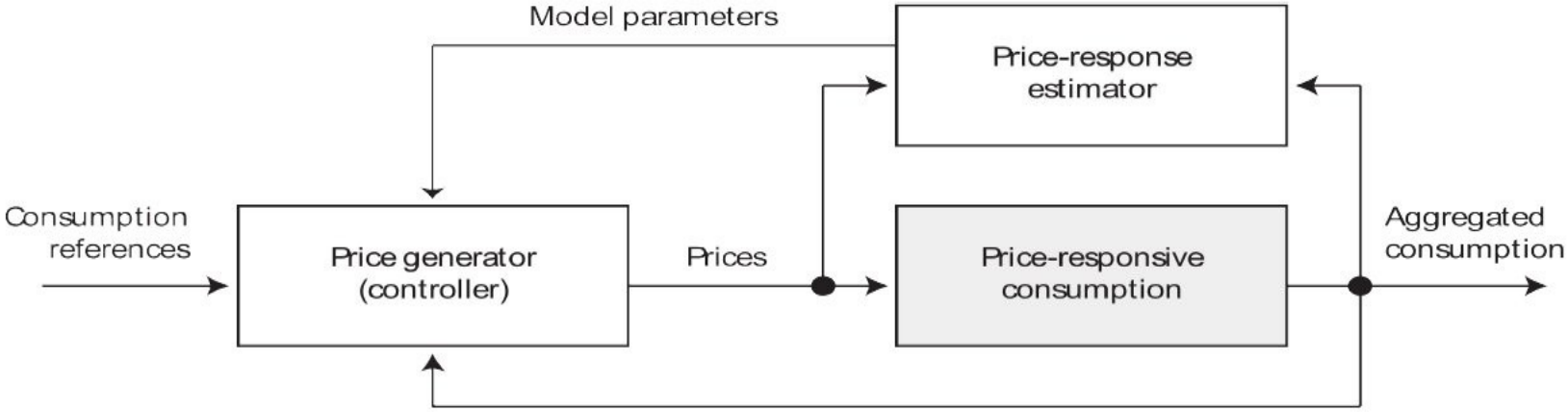
Aggregation (over 20 houses)

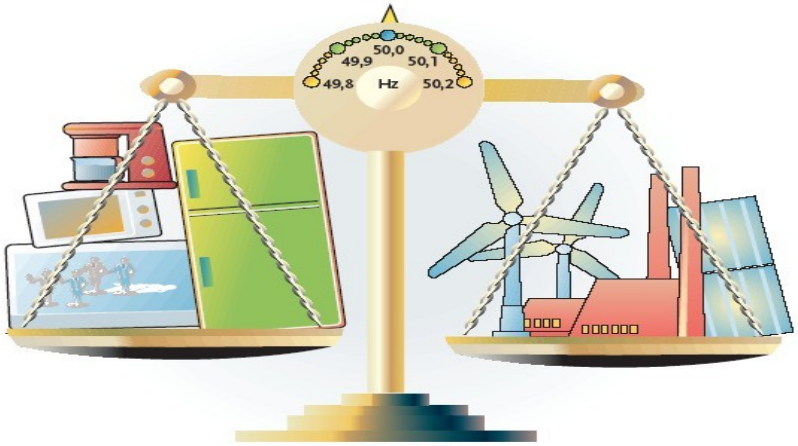


Response on Price Step Change



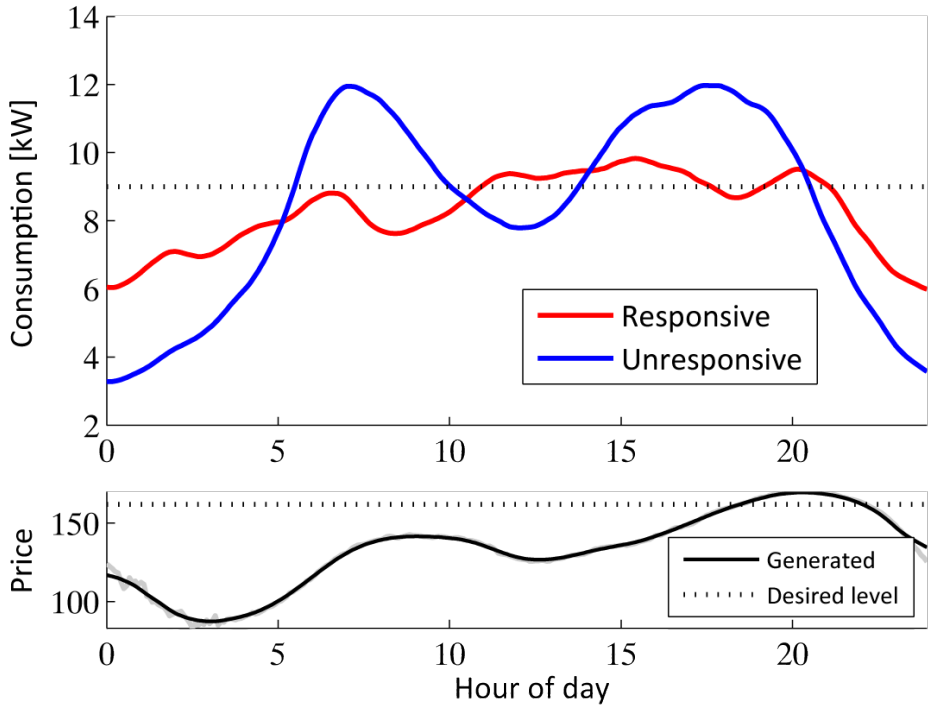
Control of Power Consumption



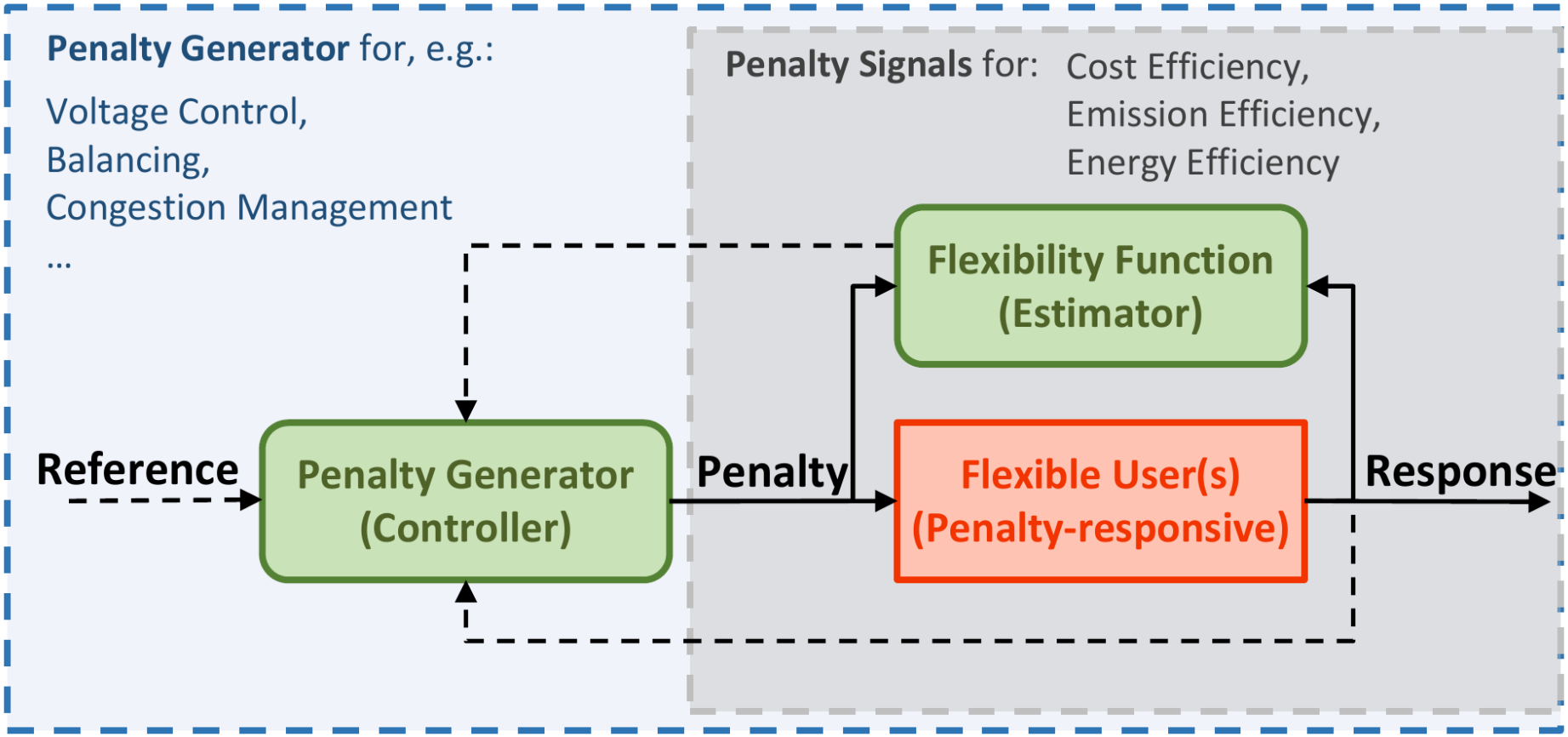


Control performance

Considerable **reduction in peak consumption**



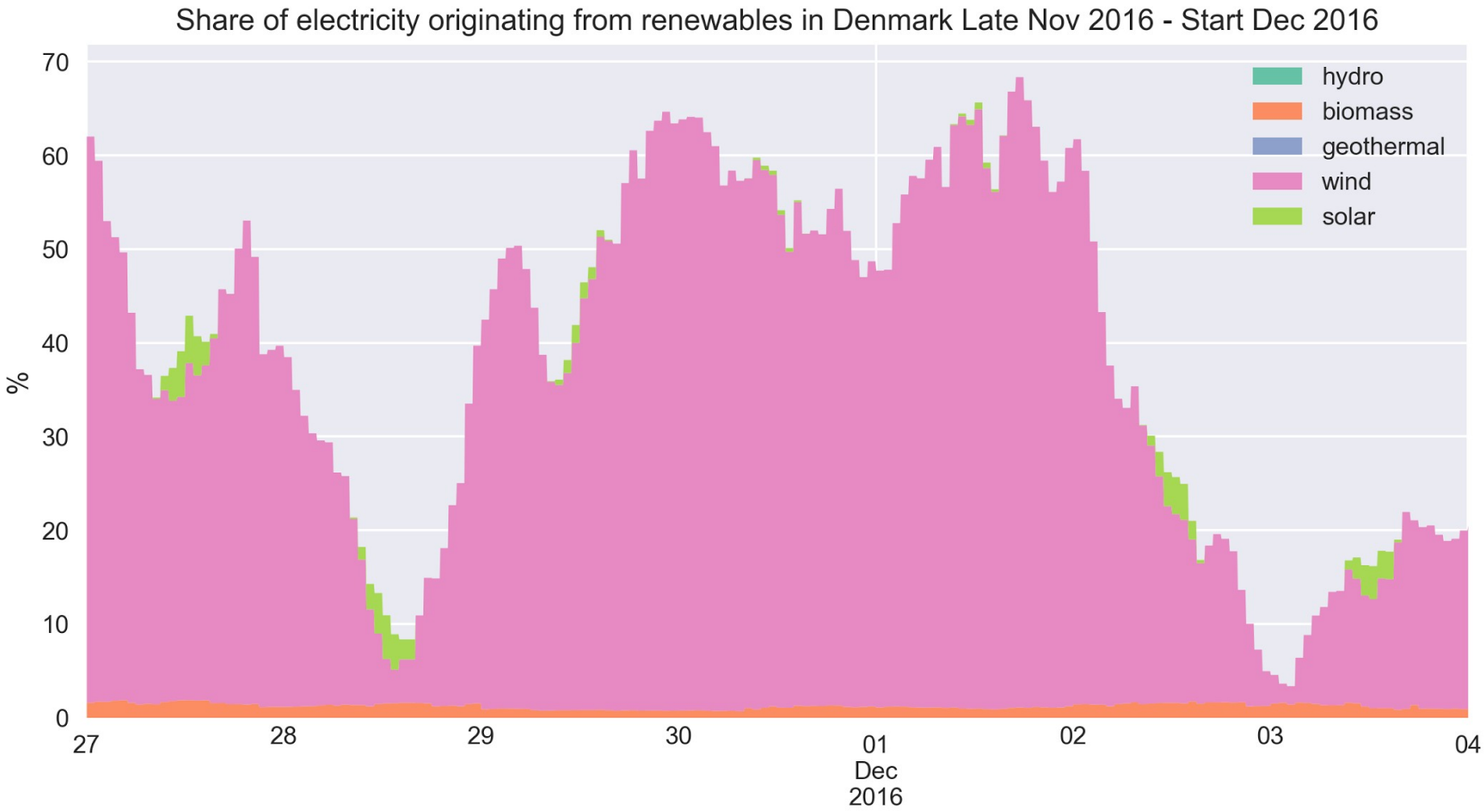
A FED example: Flexible Users and Penalty Signals



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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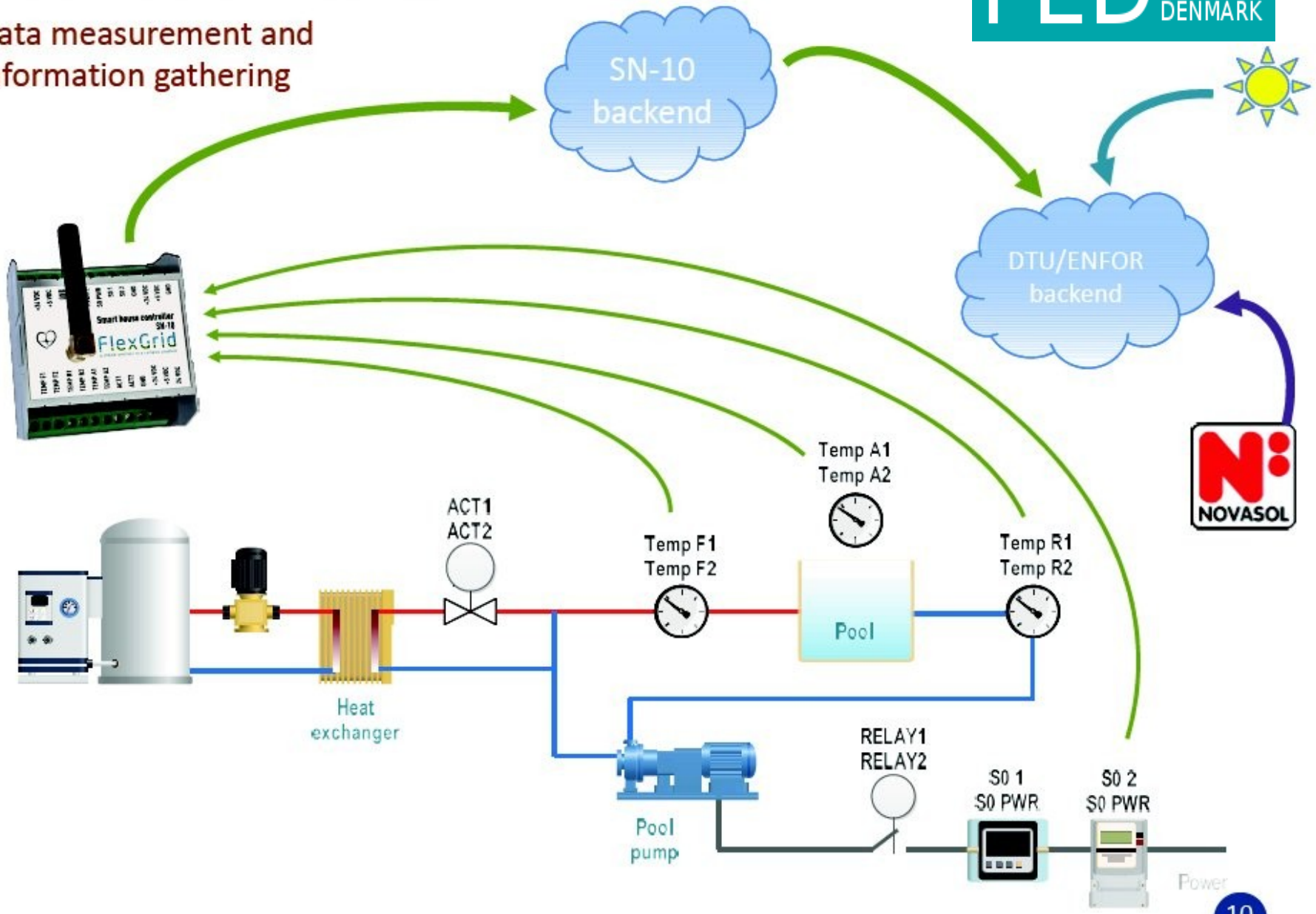

How does it work?

Price based Control

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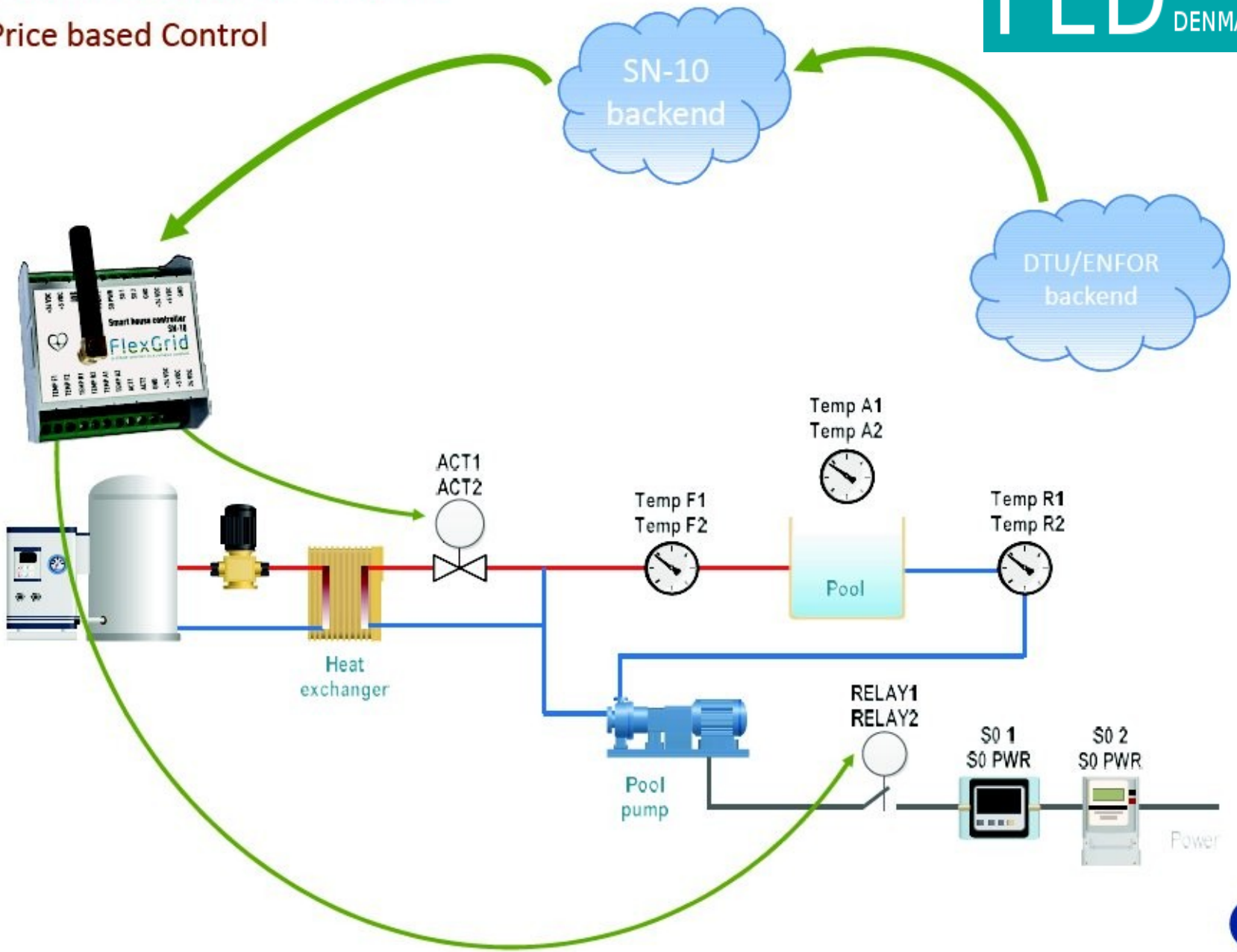

Example: Price-based control

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

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**)