Digitalisation for the future weather-driven energy system

Digital Tech Summit '22

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(IFD projects: **FED** + IoT Annex + Cool Data)
(EU projects: ELEXIA + ARV + ebalance-plus + CitCom.ai)

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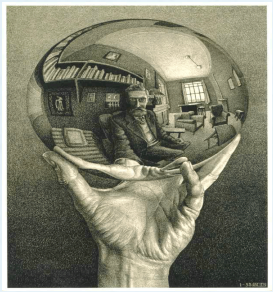
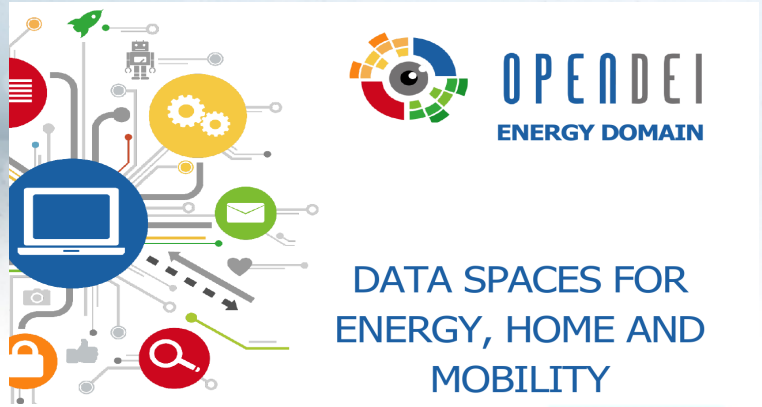
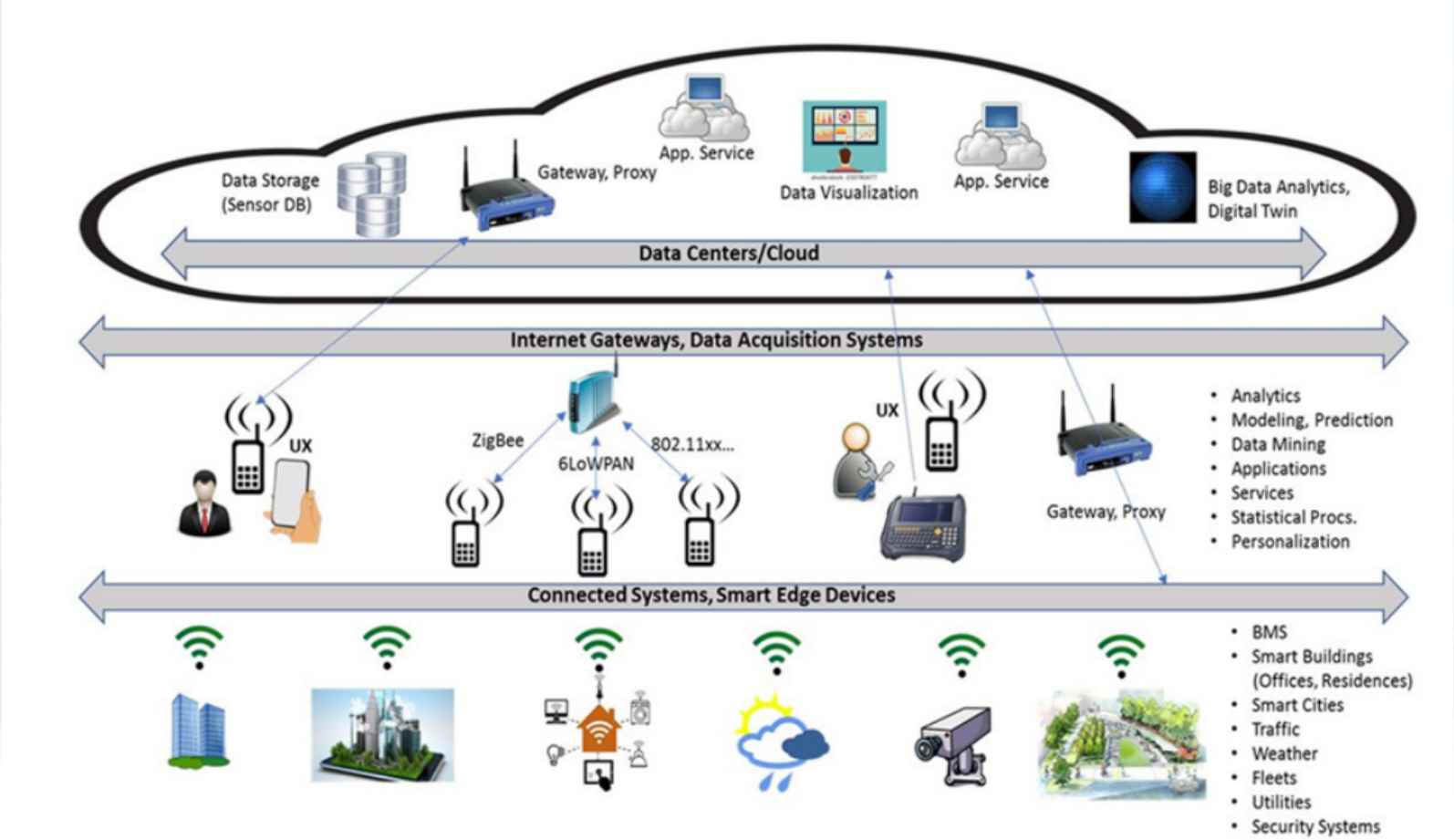


- Data Spaces for Energy Systems
- Digitalization of Energy Systems
- Key elements mentioned in EU and UN reports:
  - Minimum Interoperability Mechanicsms (MIMs)
  - Some MIMs for energy systems:

    Flexibility Functions, Digital Twins, Data Spaces, Shared Data Models, Transparent AI
  - New market structures (using also control theory)
- UN Deliverable on “Redefining smart city platforms: Setting the stage for Minimal Interoperability Mechanisms” (Martin Brynskov)
- EU Report on “Data Spaces for Energy, Home and Mobility”

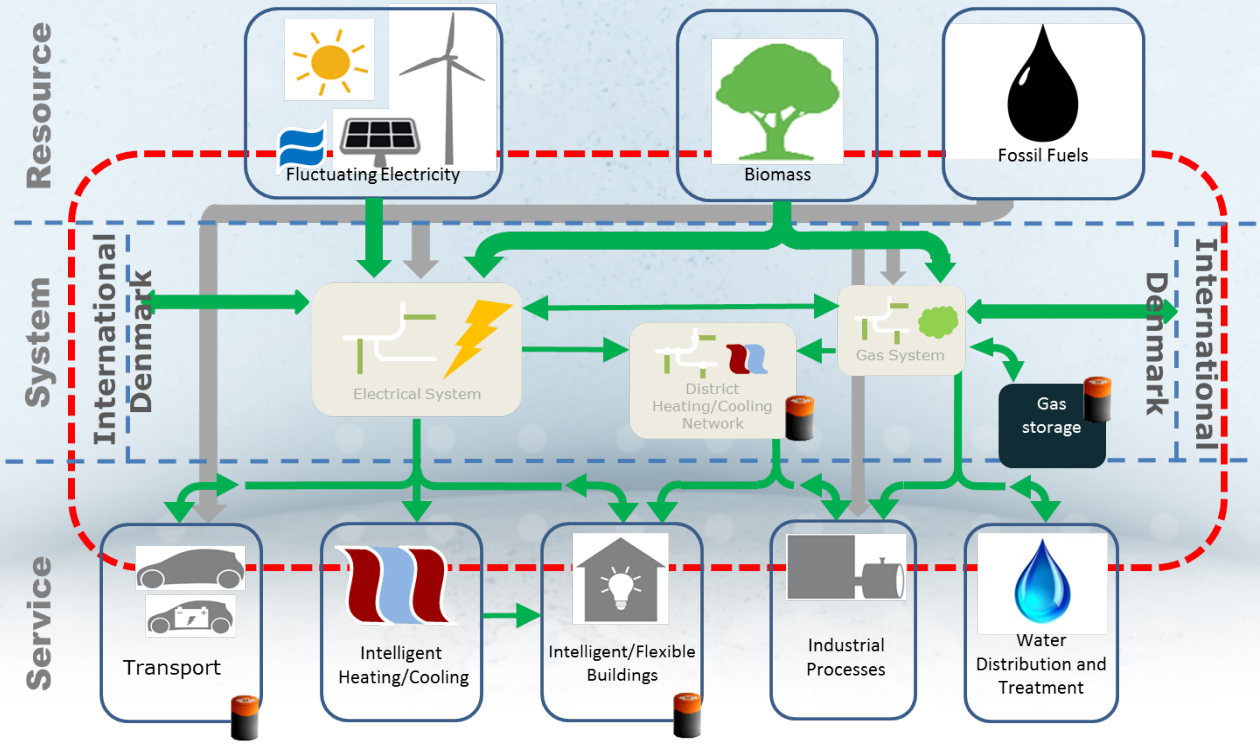


UN Report: General Architecture for Smart Buildings and Cities



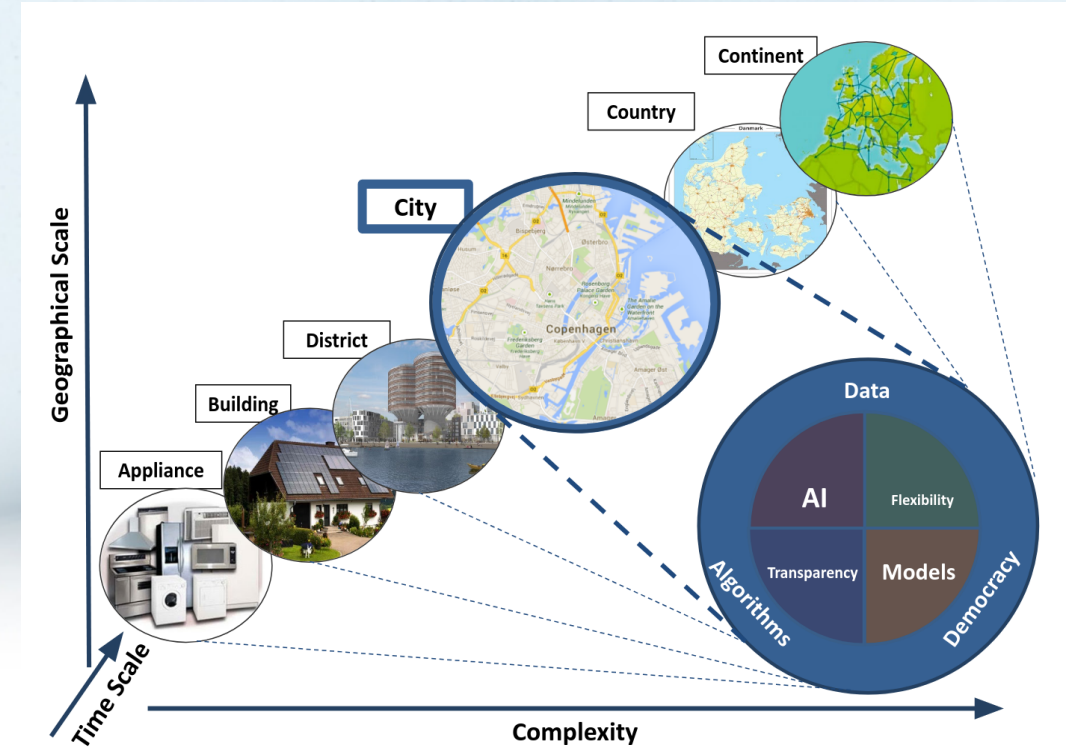
Data-driven Digital Twins for Real Time Applications

Grey-box models are simplified Digital Twin models facilitating system integration and use of sensor data in real-time



EU Report:
Temporal and Spatial Coherency

A so-called ***Smart-Energy Operating-System (SE-OS)*** is developed in order to develop, implement and test solutions (layers: data, models, optimization, control, communication) for ***operating flexible electrical energy systems*** at **all scales**.



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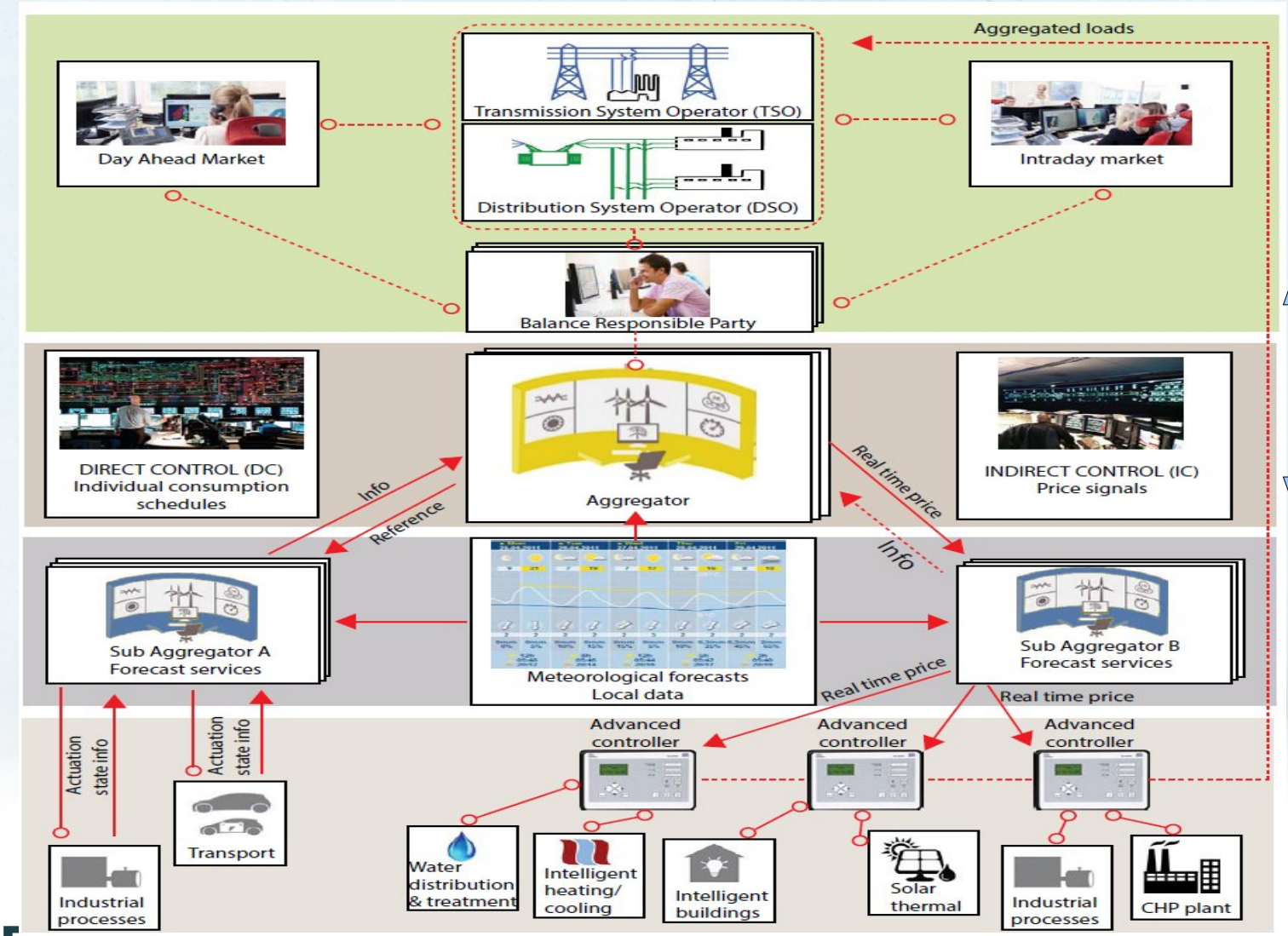
EU Report: Smart-Energy OS

The Transformative Power of Digitalization



(**Static**)

Conventional Markets

Linking Markets to Physics using MIMs

(Flexibility Functions)

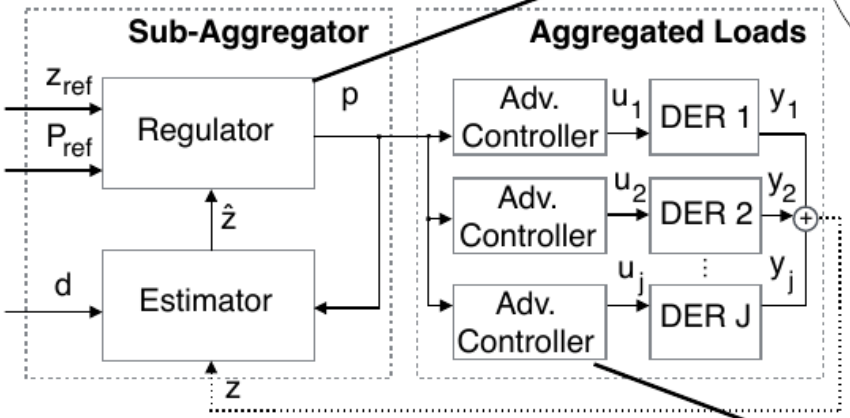
(**Dynamic**)

Local Flexibility Markets

(Hierarchy of controllers)

Proposed methodology
Control-based methodology

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

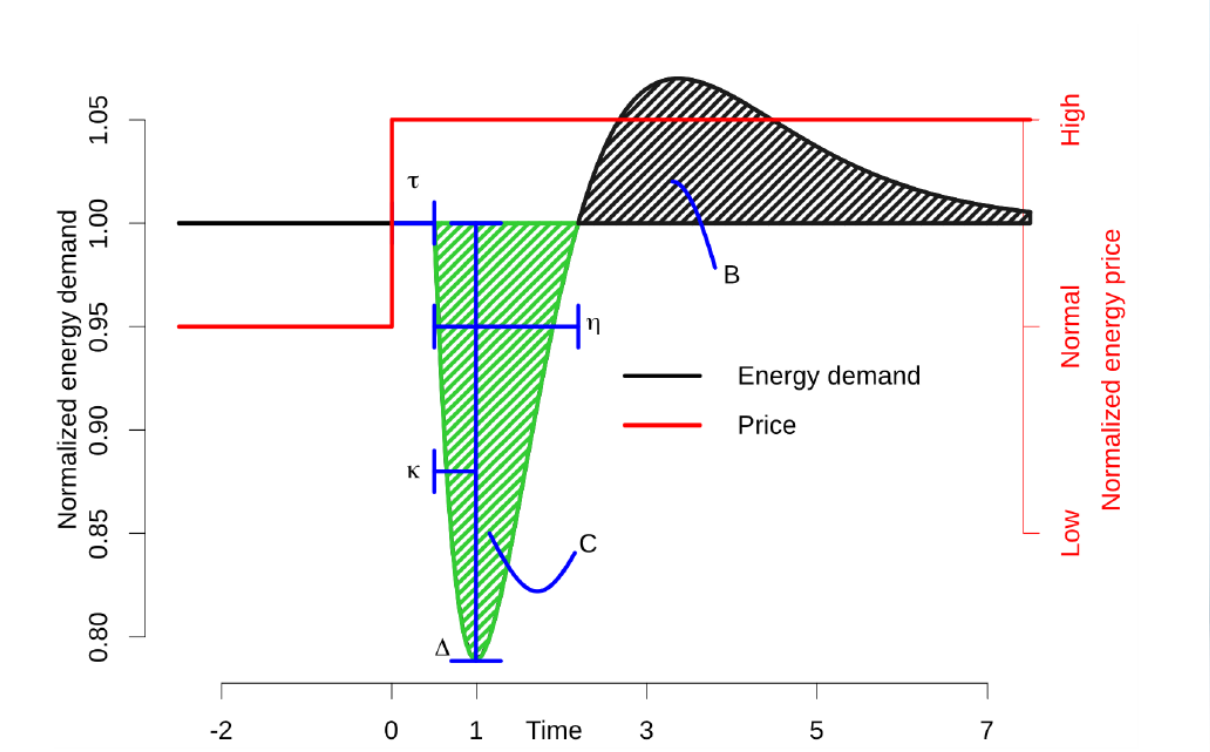


We adopt a control-based approach where the **price** becomes the driver to **manipulate** the behaviour of a certain pool flexible prosumers.

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

Flexibility Function

The ***Flexibility Function (FF)*** is a **MIMs for energy systems** used to characterize flexibility and providing an interface between local and high-level markets



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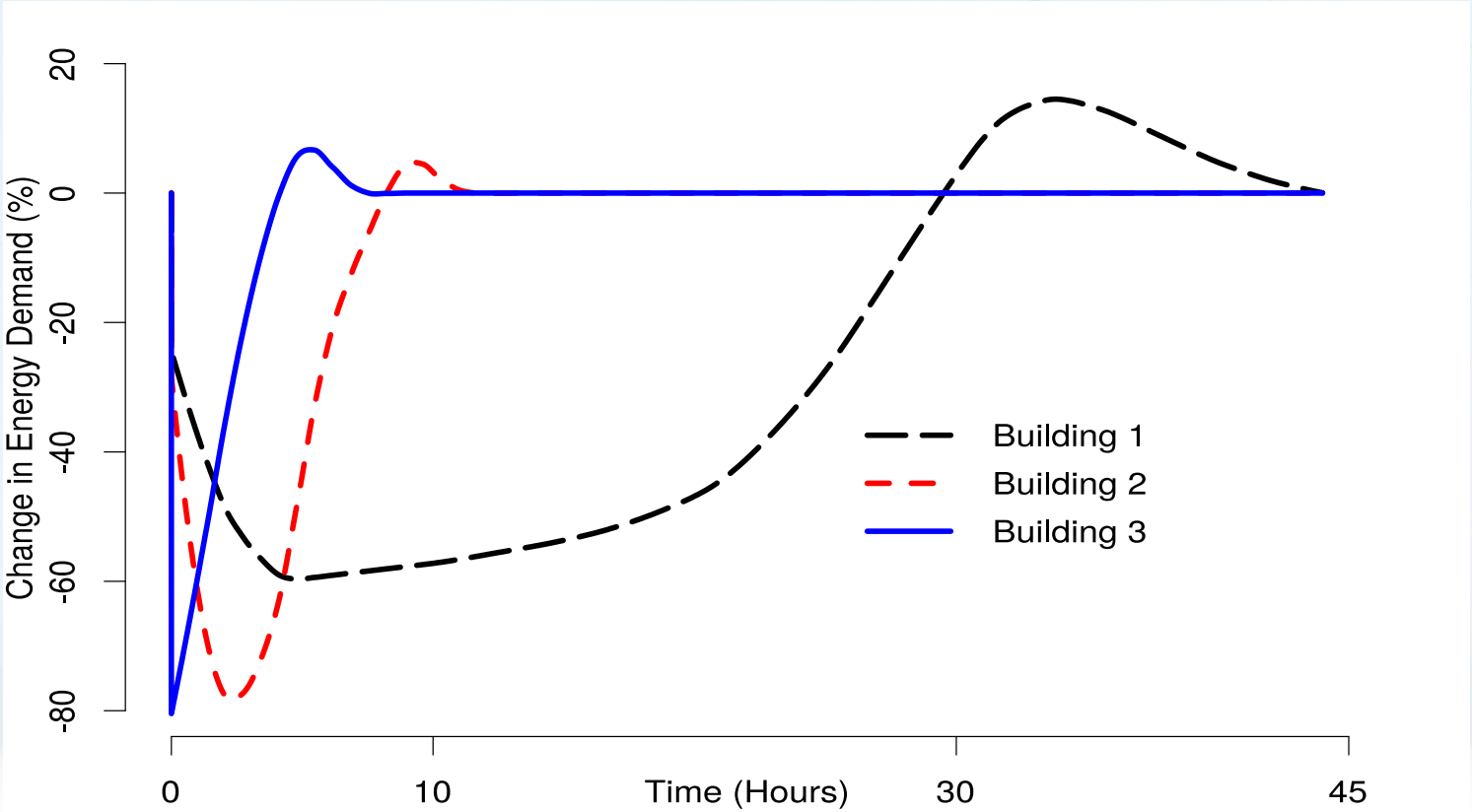
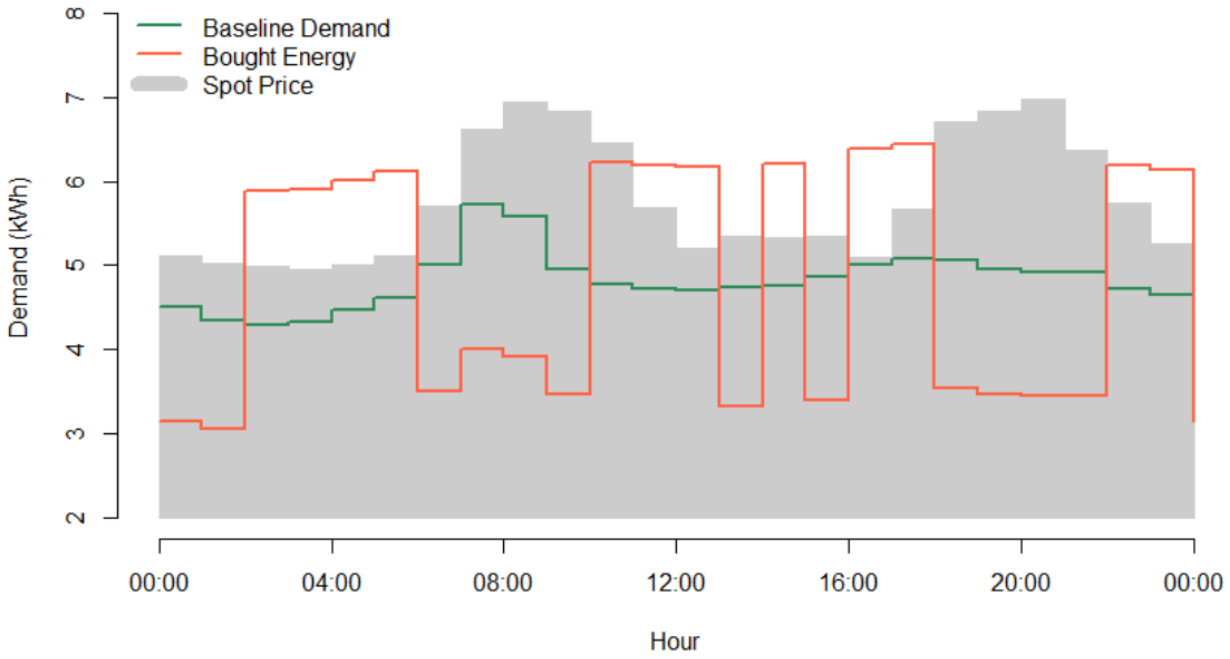
Case Study

Flexibility Function Examples



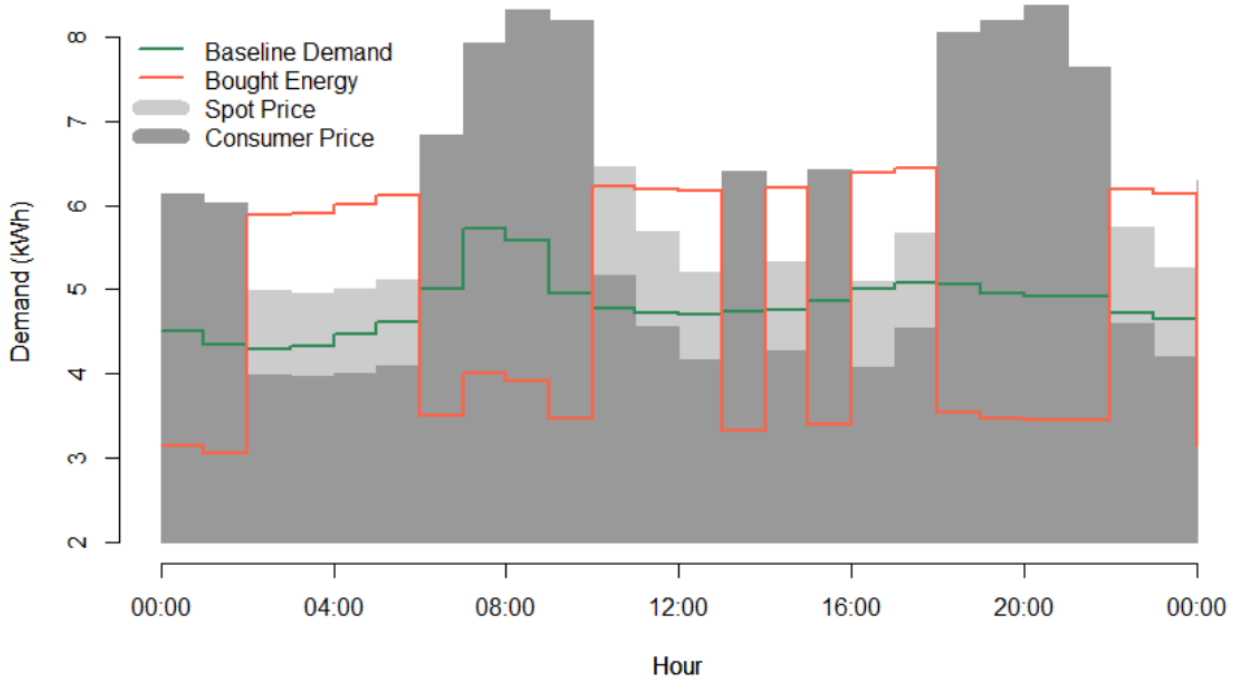
Bidding Flexibility into Markets

- 4 hours intervals consisting of 30% of consumption with durations of 2 hours:



Bidding Flexibility into Markets

Solve FF(Price)=Bought Energy:



Summary

- An efficient implementation of the **future weather-driven** energy system calls for **data-driven Smart Energy Systems**
- We need **digitalization and IoT solutions for enabling low-level flexibility markets**
- **Minimum Interoperability Mechanisms (MIMs) are building blocks** for sector coupling and for implementing IoT solutions
- We need **transparent**, **safe, fair** and **democratic** solutions
- **It must be easy**. Industry and house owners should be able to participate in **flexibility markets** without being subject to disproportionate technical requirements, procedures and charges
- We have proposed to use **control-based methods for activating local flexibility (Smart-Energy OS)**
- We have indicated how to use **control-based methods for all type of grid services**