

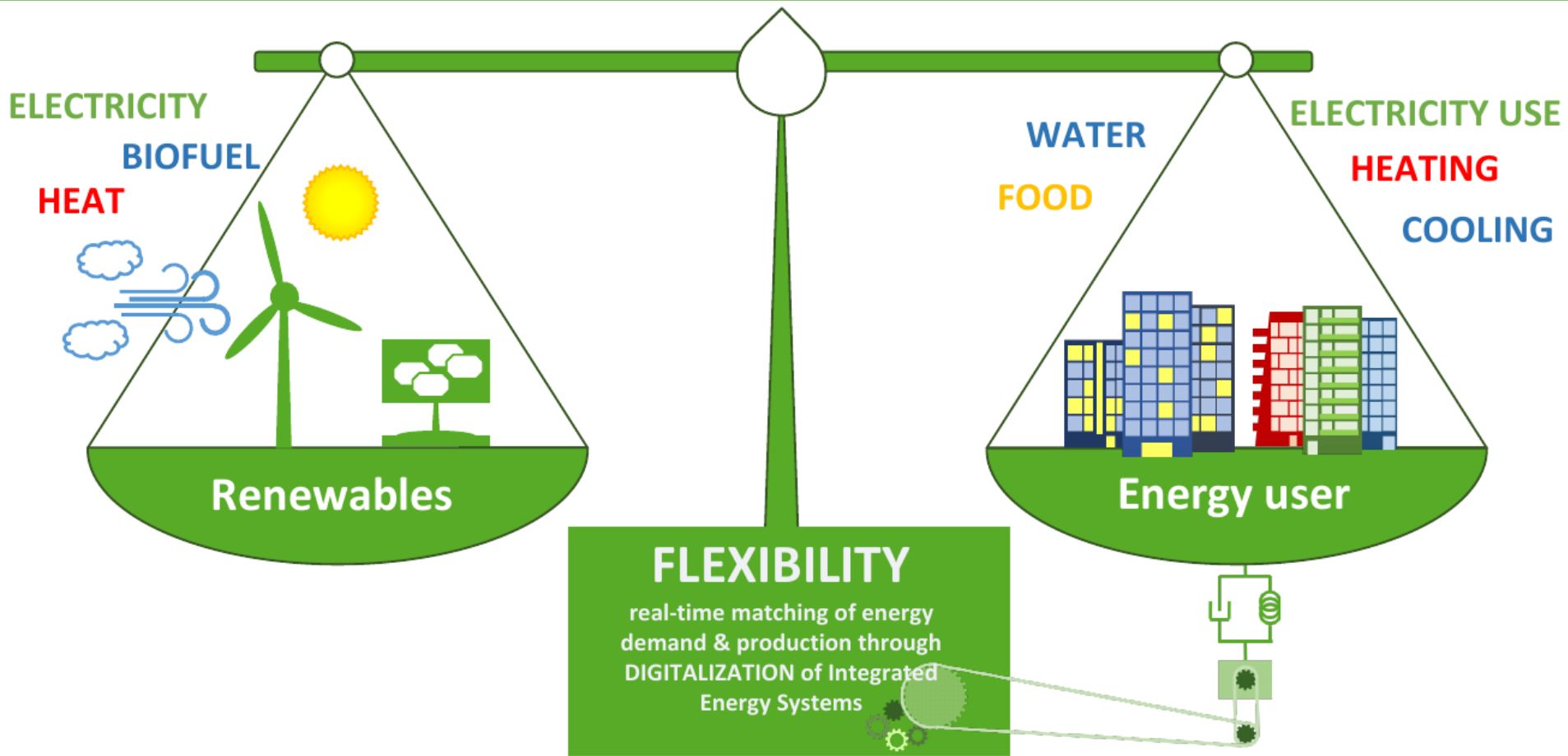
Research Seminar: Large-scale system integration
June 30, 2022

Digitalization of Energy Systems for Large-scale Integration

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(IFD project: Flexible Energy Denmark + Cool Data)
(EU/BRIDGE projects: ELEXIA +ARV+ebalanceplus)



The Challenge: Denmark Fossil Free 2050



Local Flexibility Characteristics vs Classical Markets

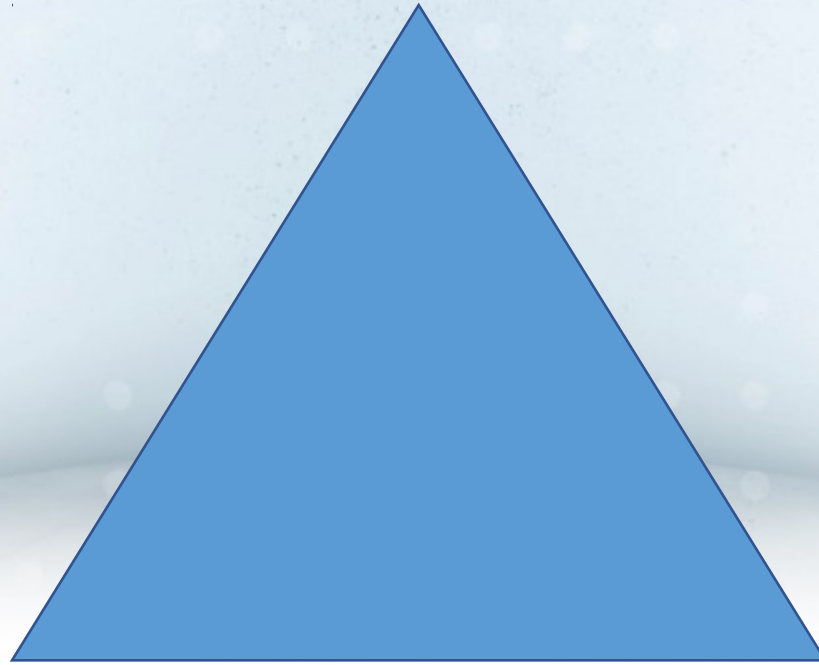
- Static -> **Dynamic**
- Deterministic -> **Stochastic**
- Linear -> **Nonlinear**
- Many power related services (voltage, frequency, balancing, spinning reserve, congestion, ...) -> **Coordination + Hierarchy**
- Speed / problem size -> **Decomposition + Control Based Solutions**
- Characterization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

Space of Solutions

Flexibility

(enabled by **AI, Digital Twins, Communication and IoT**)

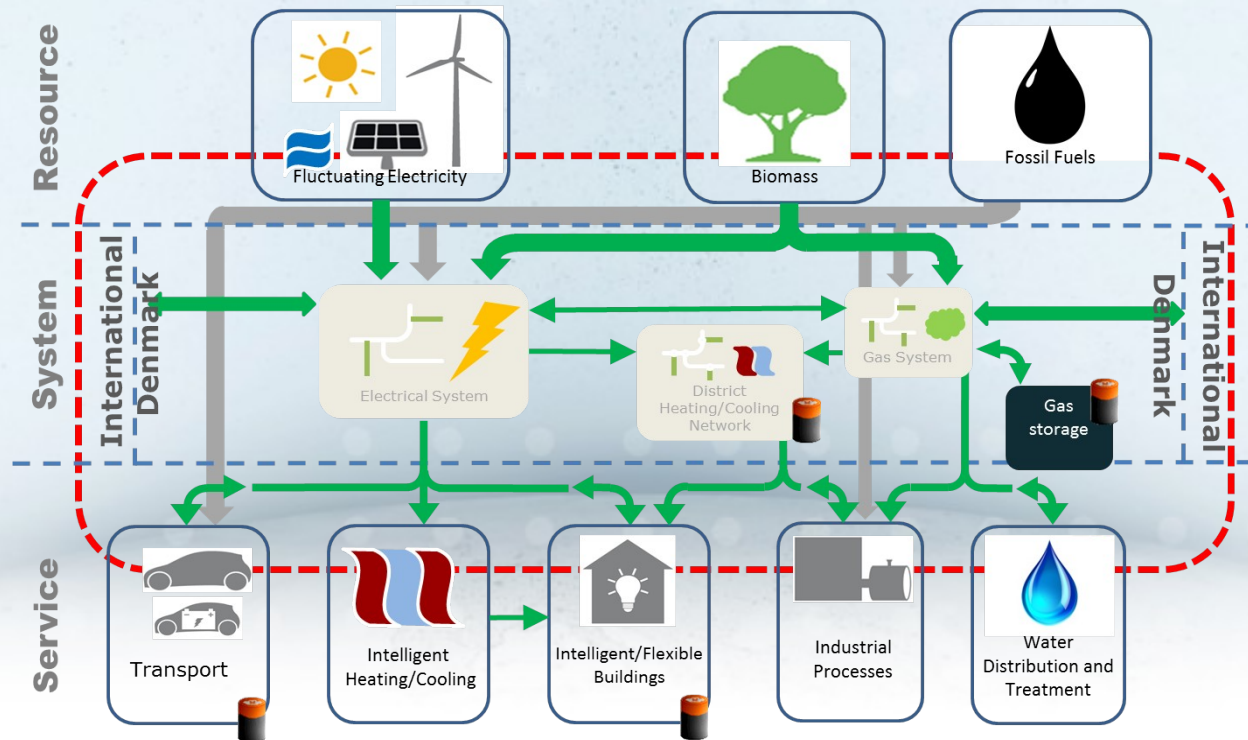
Grids



Batteries

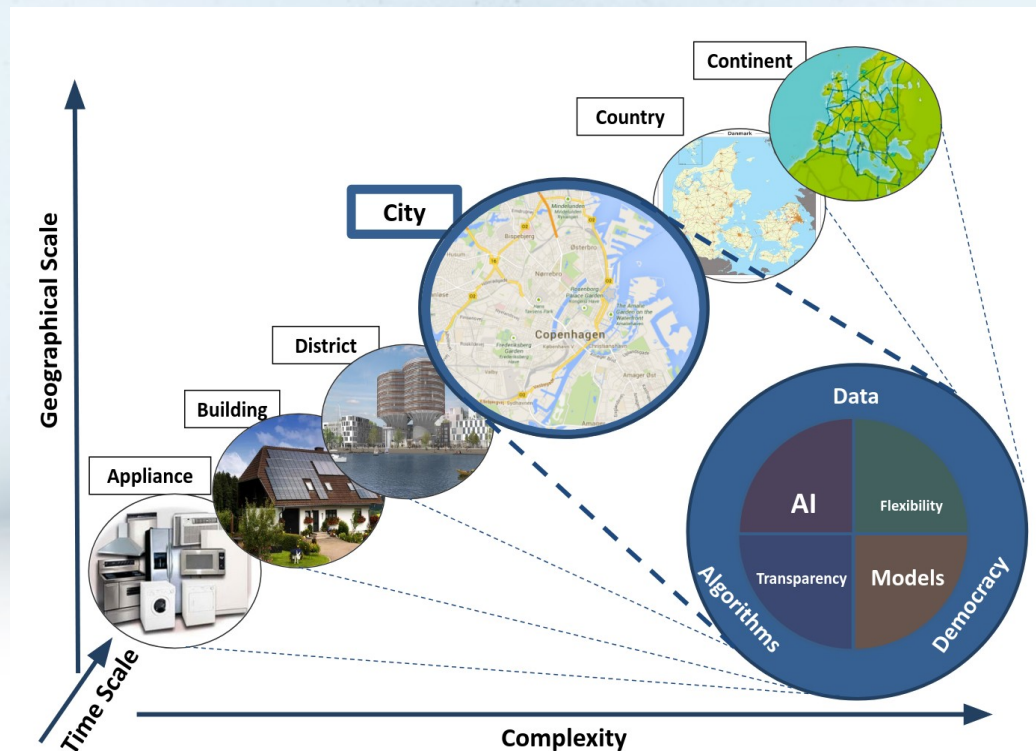
Data-driven Digital Twins for Real Time Applications

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



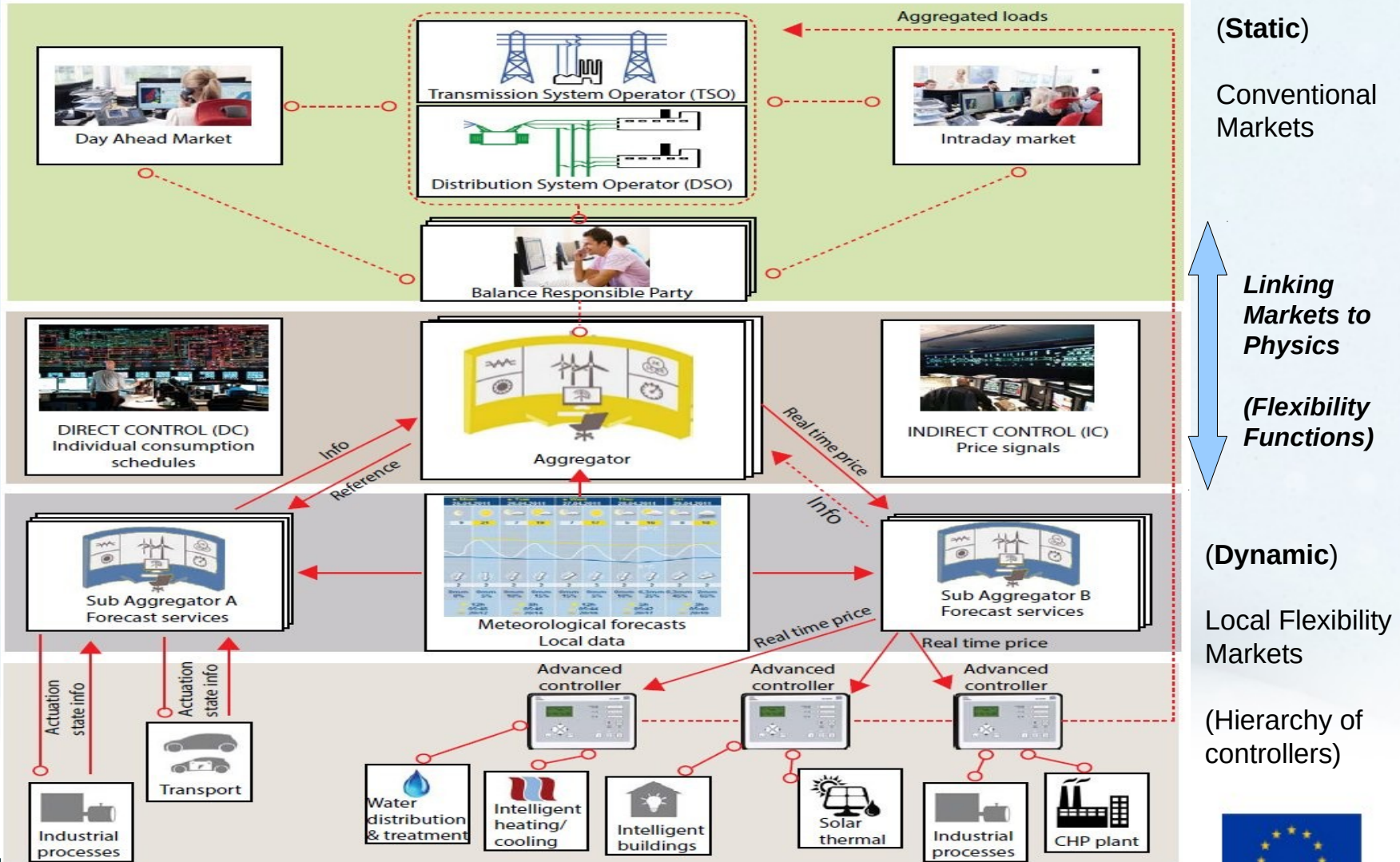
Temporal and Spatial Scales

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**.



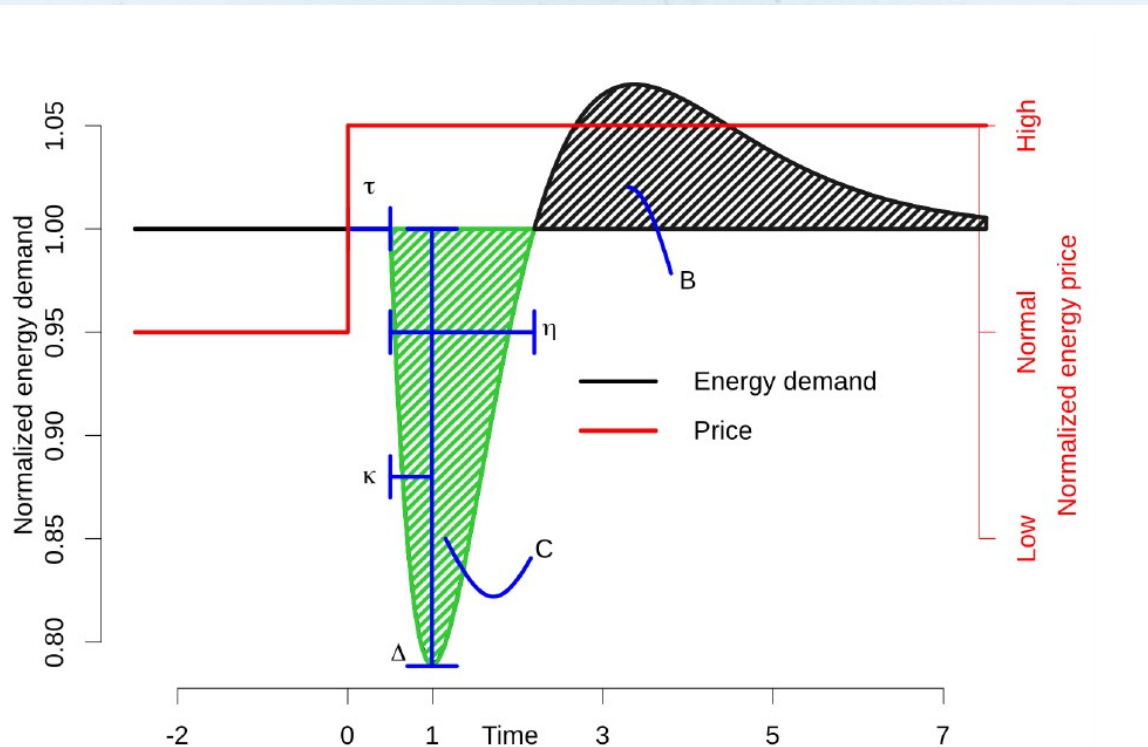
Smart-Energy OS

The Transformative Power of Digitalisation



Flexibility Function

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



Flexible Users and Penalty Signals

Penalty Generator for, e.g.:

Voltage Control,
Balancing,
Congestion Management
...

Reference

**Penalty Generator
(Controller)**

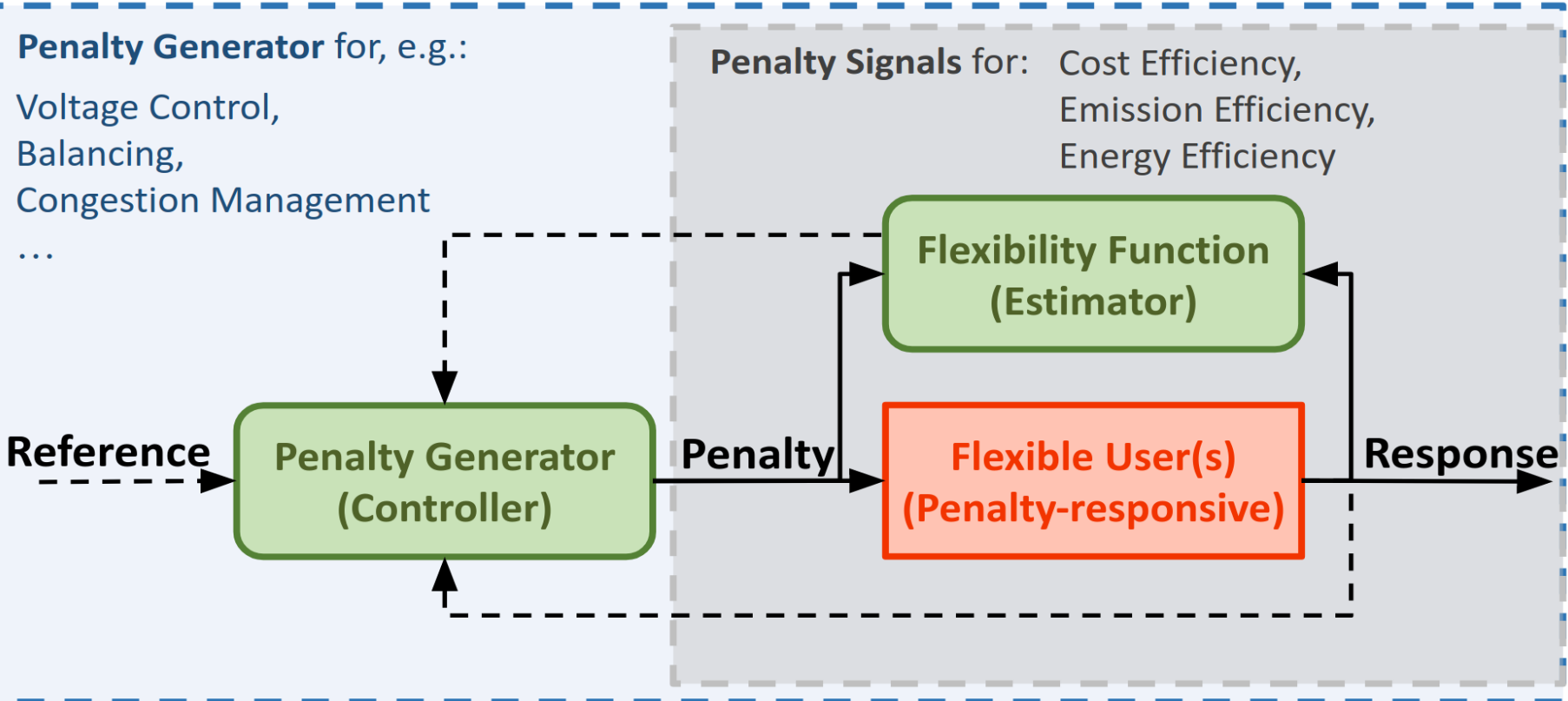
Penalty

**Flexibility Function
(Estimator)**

**Flexible User(s)
(Penalty-responsive)**

Response

Penalty Signals for: Cost Efficiency,
Emission Efficiency,
Energy Efficiency



Center Denmark Control Room and Data Space Spatial-Temporal thinking

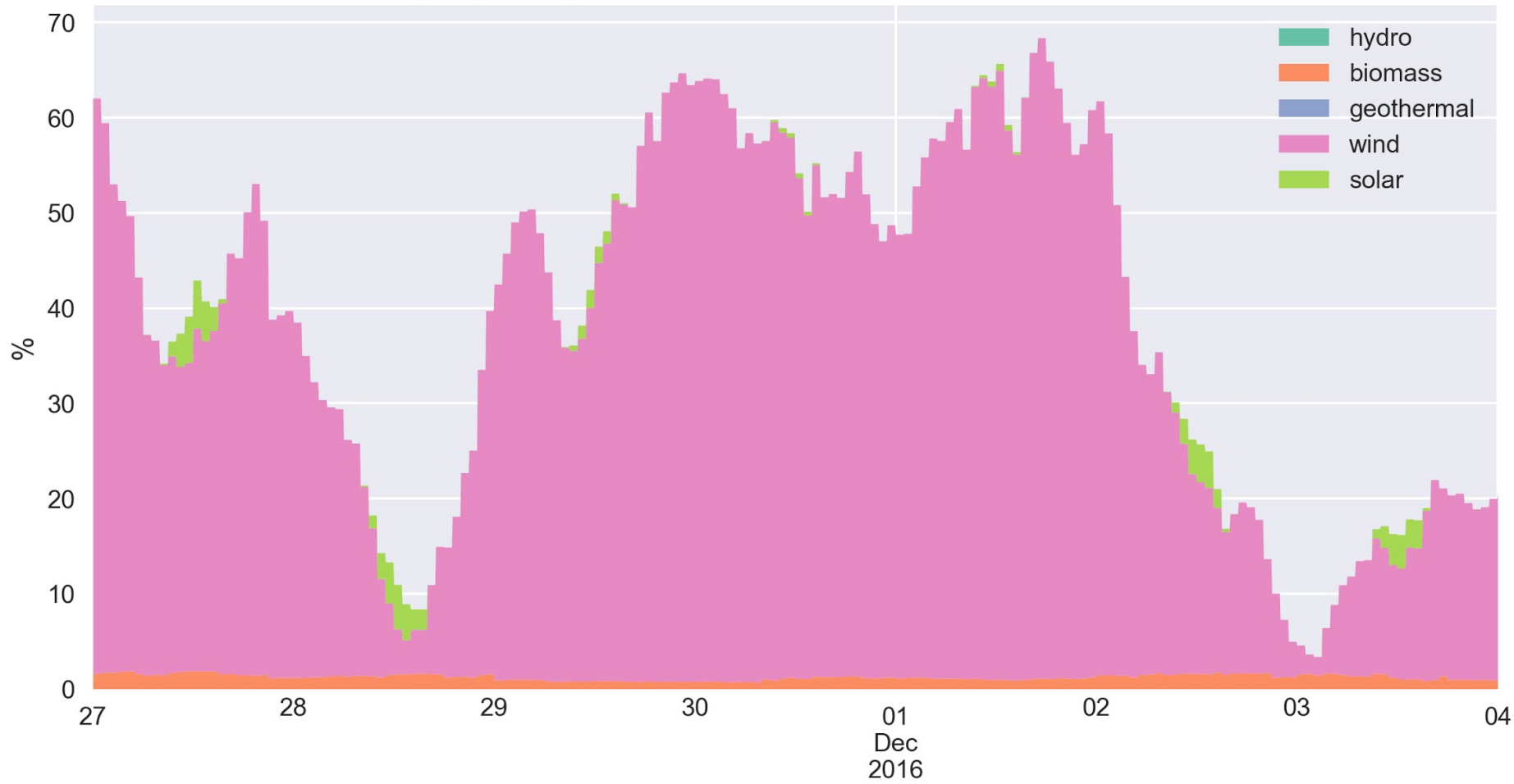


Case study

Summerhouses with a pool



Share of electricity originating from renewables in Denmark Late Nov 2016 - Start Dec 2016

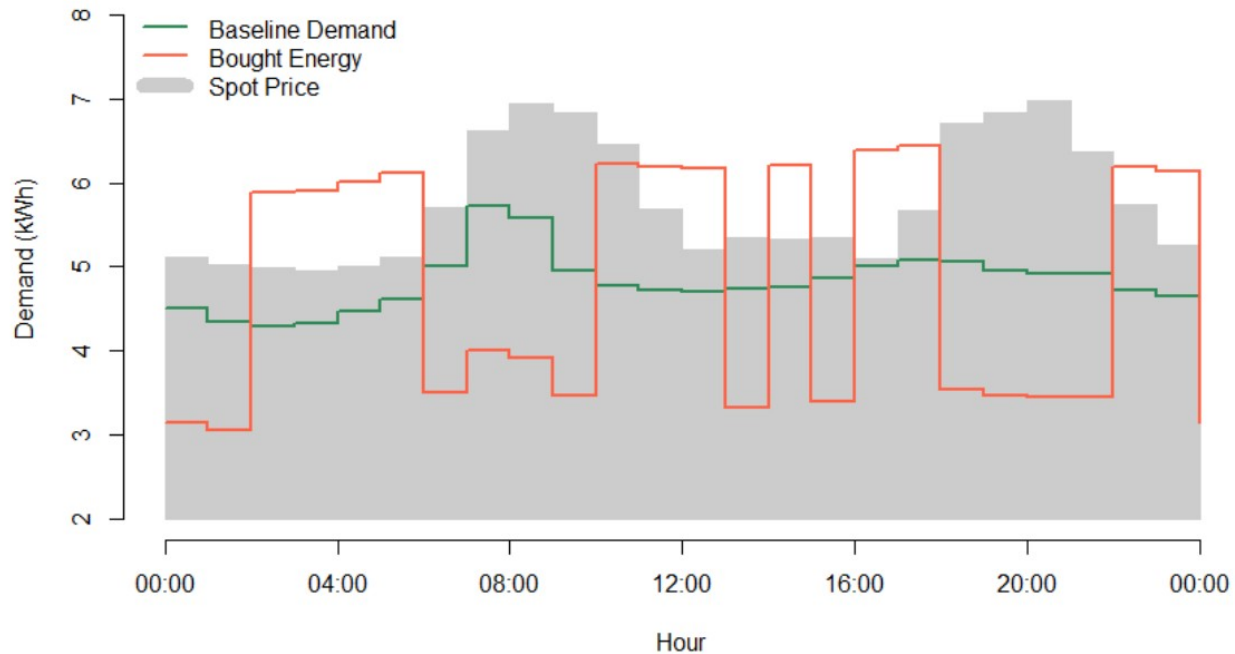


Source:
pro.electricitymap.org



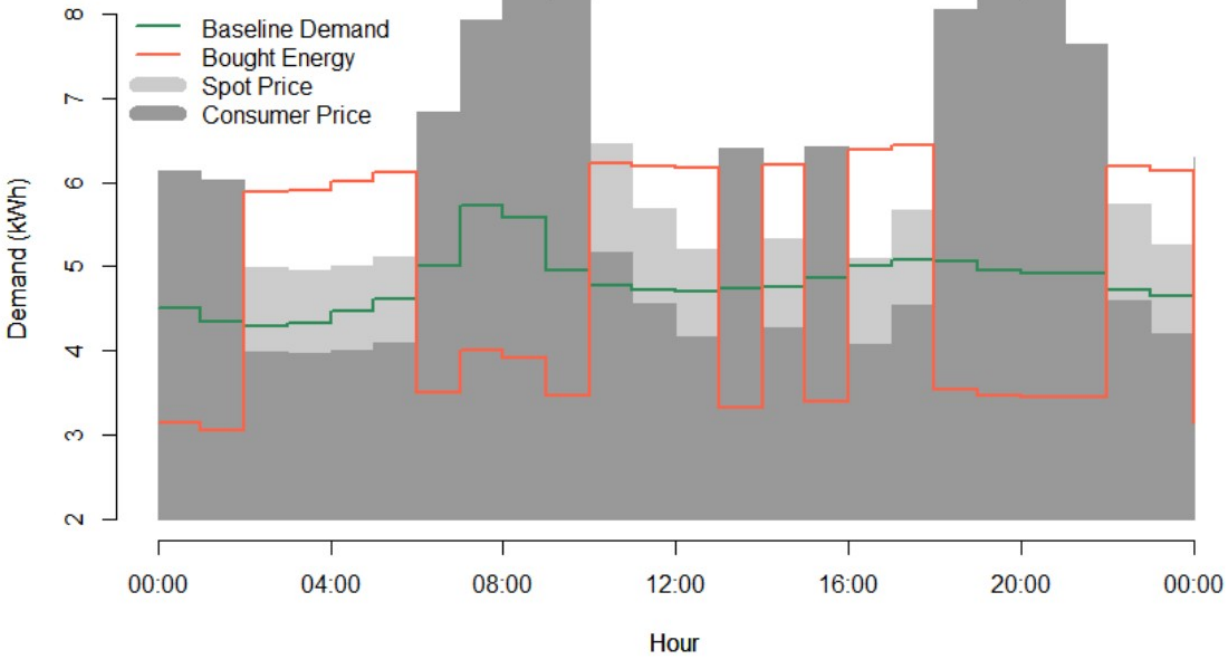
Bidding Flexibility into Markets

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



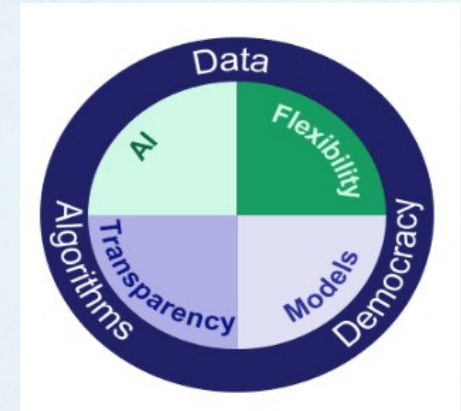
Bidding Flexibility into Markets

Solve $FF(\text{Price}) = \text{Bought Energy}$:



Summary

- An efficient implementation of the **future weather-driven** energy system calls for **digitalization and data-driven methods**
- **Flexibility Functions** are used to describe the **flexibility everywhere**
- **Flexibility Functions** are suggested as **MIMs for Energy**
(*MIMs = Minimal Interoperability Mechanisms*)
- **Flexibility Functions** are key to unlock and manage flexibility
- We need **transparent, safe, fair and democratic** solutions
- We have proposed to use **methods based on Flexibility Functions for activating flexibility at all levels (via the Smart-Energy OS)**
- We have indicated how use the Flexibility Functions and control-based methods **for providing grid services for large-scale integration**
- Implemented at the **National Digitalization Hub, Center Denmark**
- **Savings** in summerhouses: 20 – 30 pct CO₂/Cost



Thank you ECD!

Connect – Share – Innovate

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