Fleksibilitet og interoperabilitet - hvordan kan vi bedst muligt udnytte smarte enheder i energisystemet?

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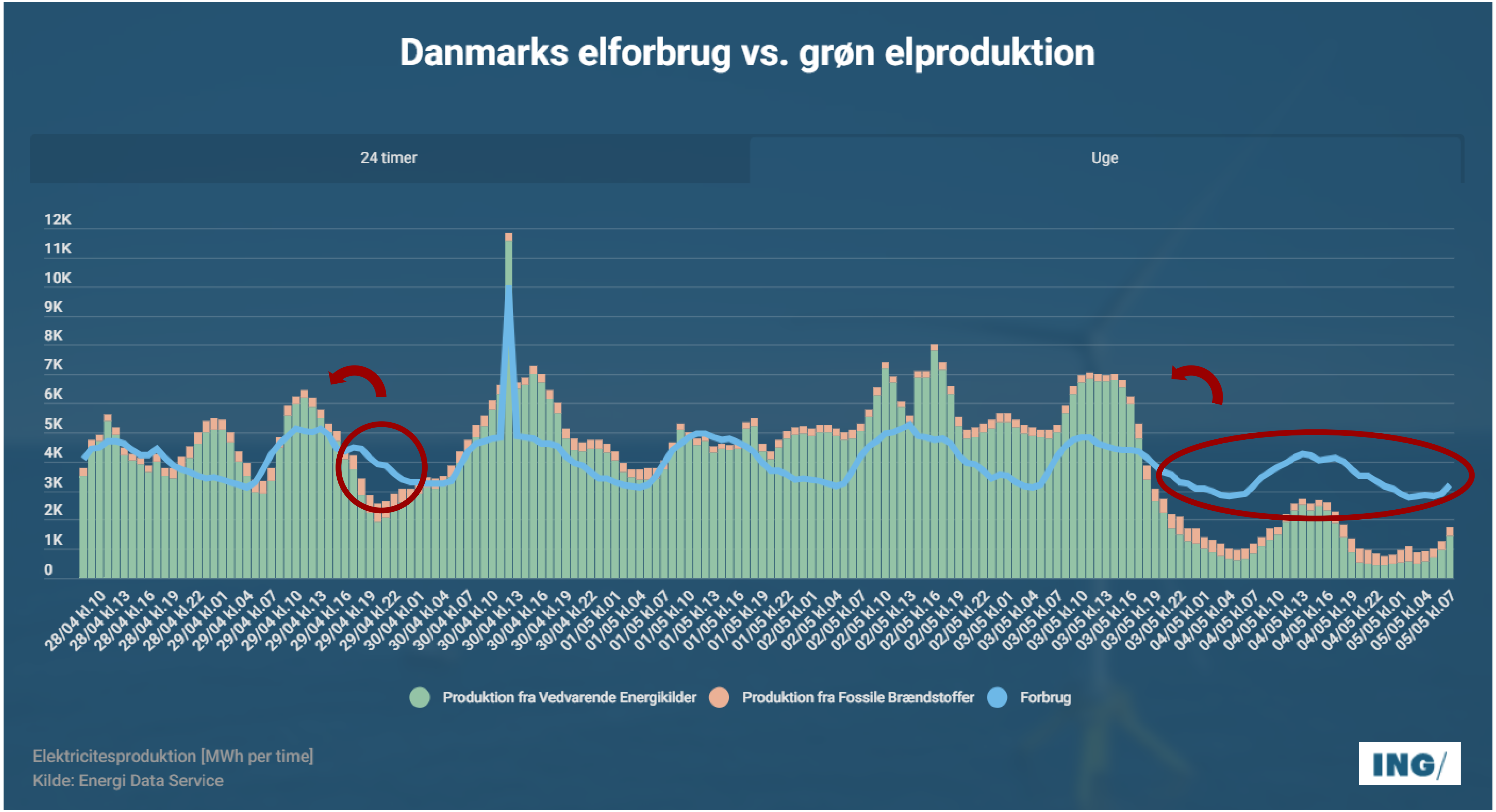
Motivation



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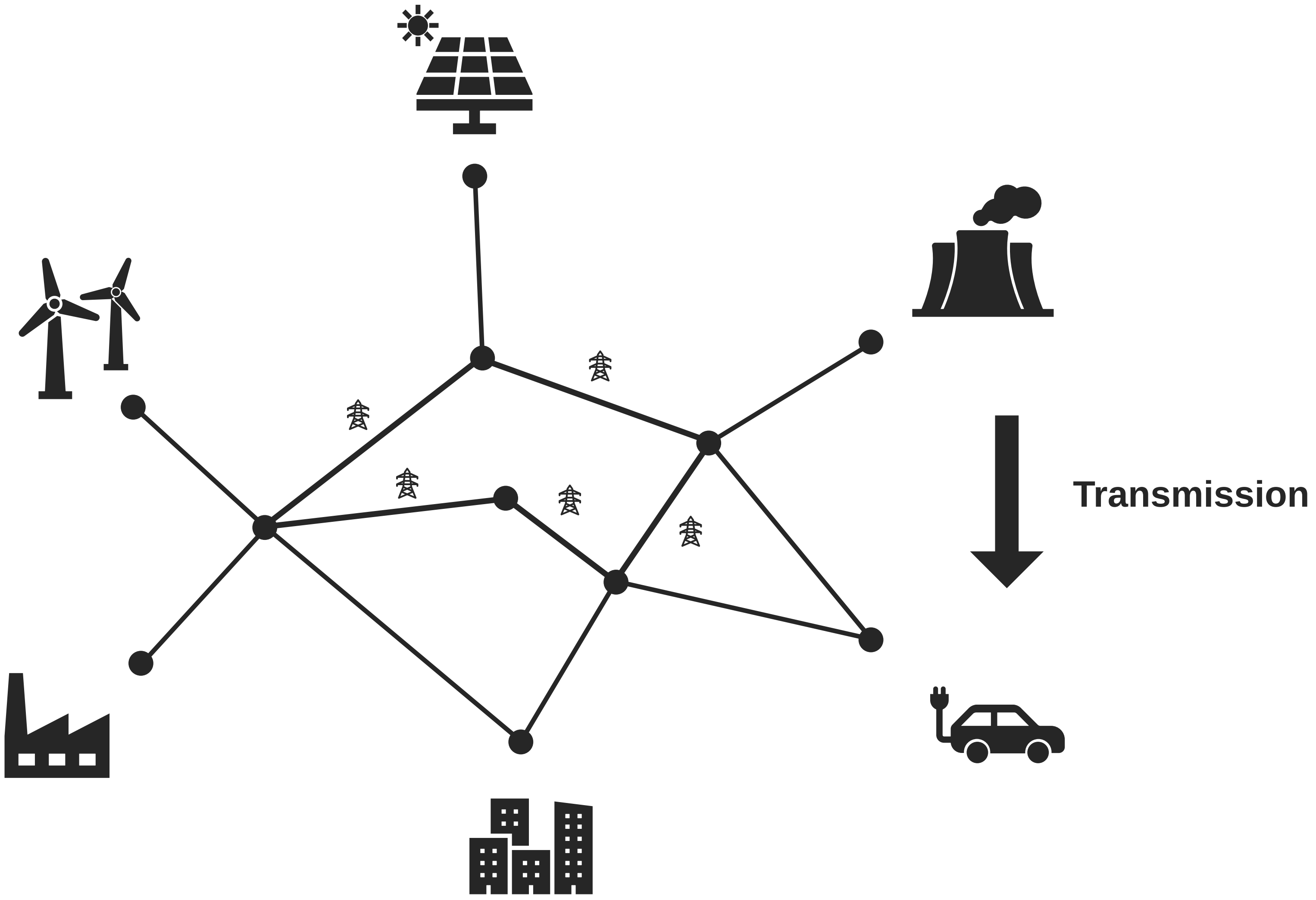
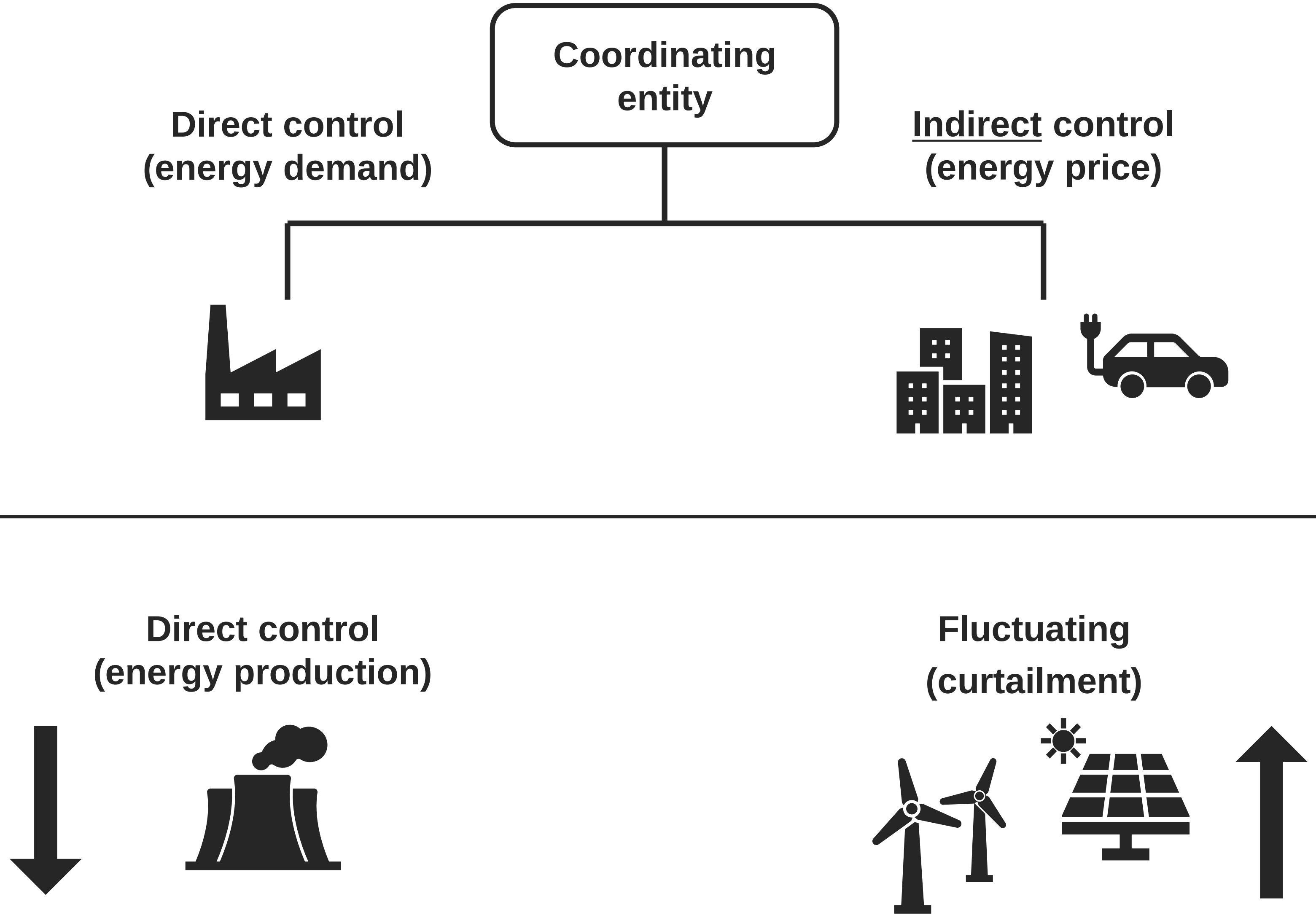
Energy consumed = Energy produced – Energy lost

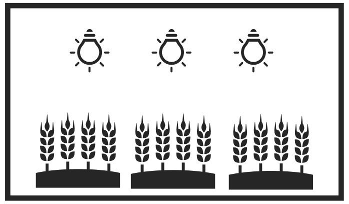


Direct vs. indirect control

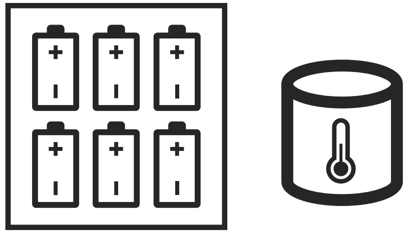


Types of flexible assets

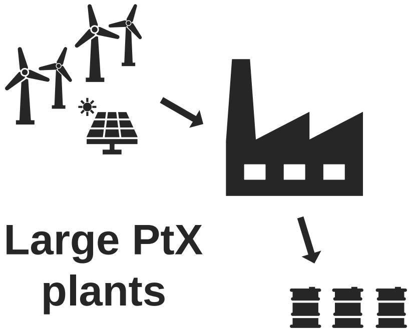
Large and concentrated
(participate directly in flexibility markets)



Greenhouses

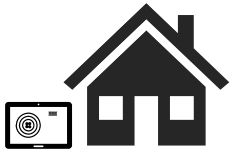


Energy storage facilities

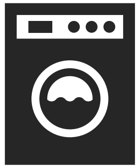


Large PtX plants

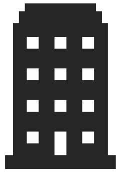
Small and uncoordinated
(participate through aggregators)



Heat pumps



Smart appliances

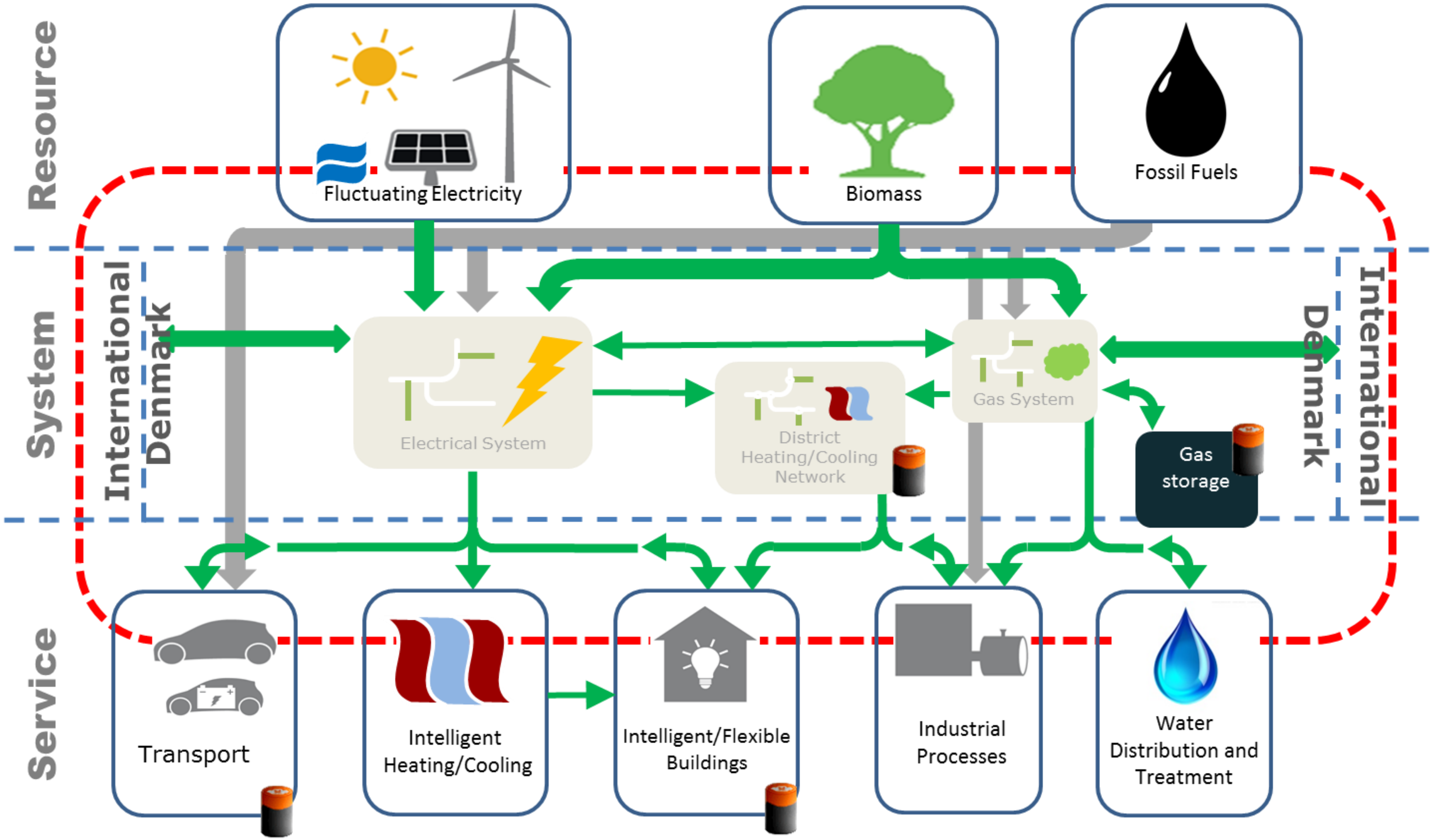


Other consumption

Electric vehicle charging

Data-driven digital twins

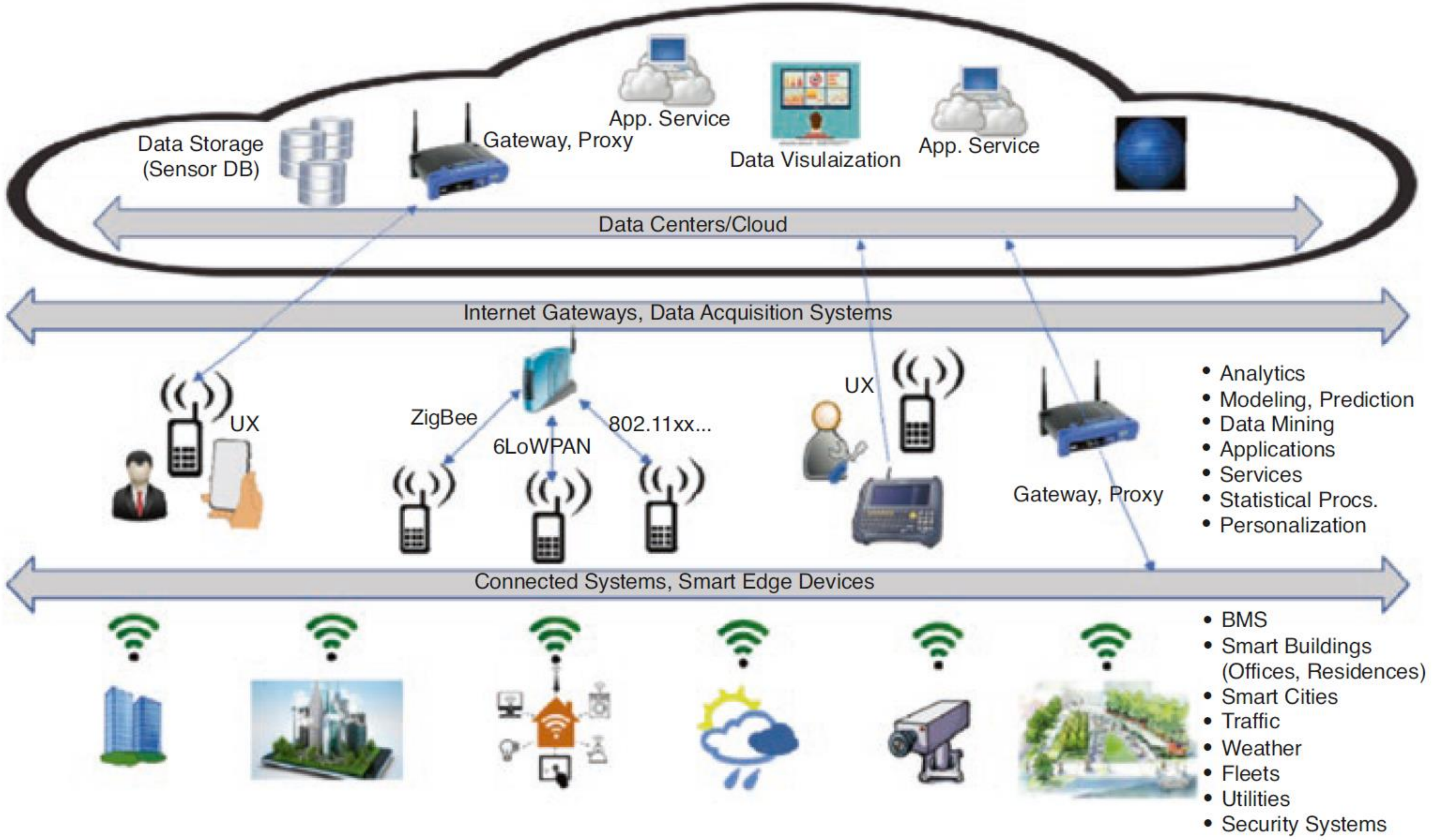
Grey-box models are simplified Digital Twin models facilitating system integration and use of sensor data in real-time



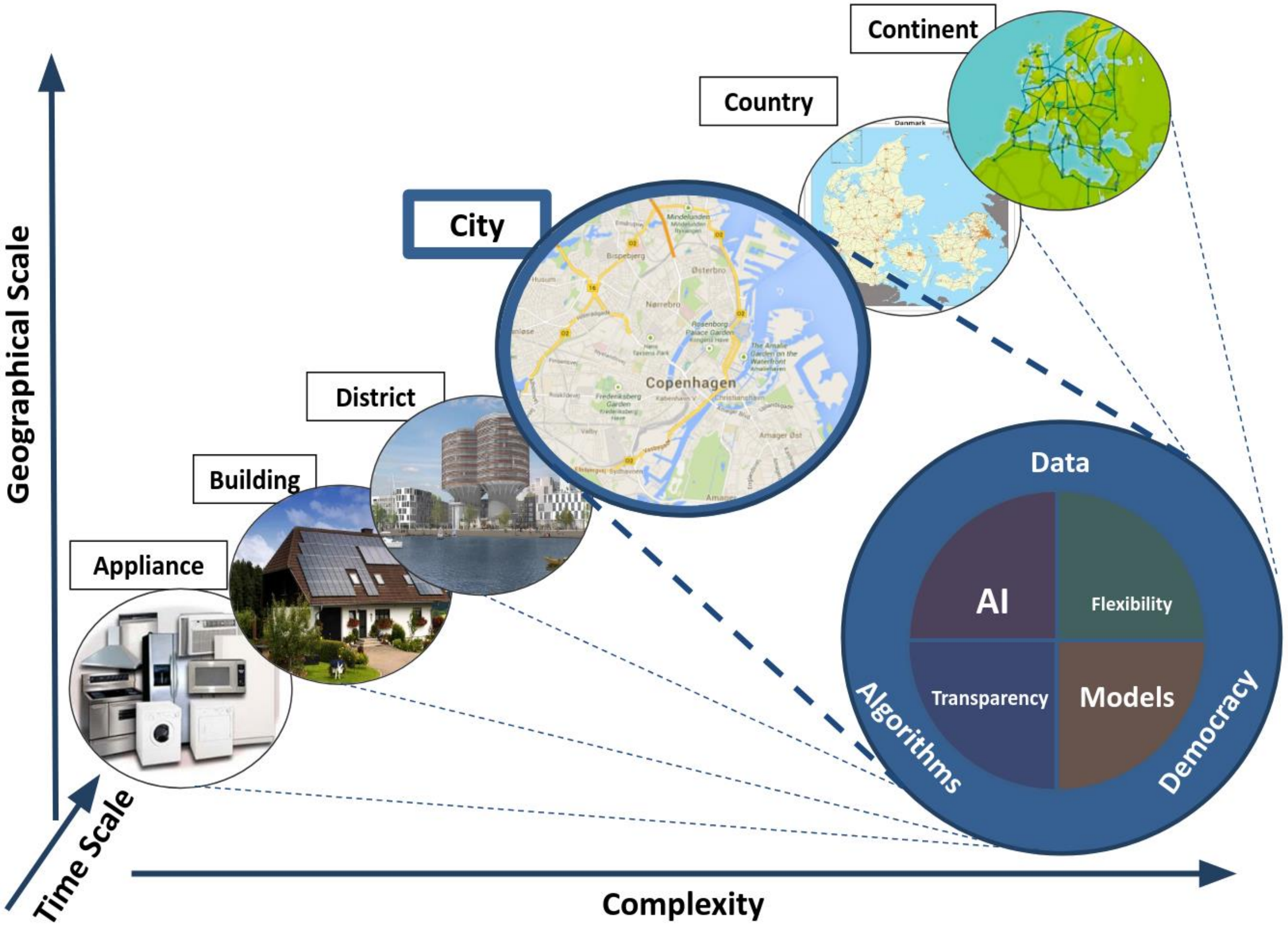
Digital twins must be

- **Data-driven:** Ensure coherency with real system
- **Flexible:** Encompass many different flexible assets
- **Data safe:** Cannot rely on sensitive information

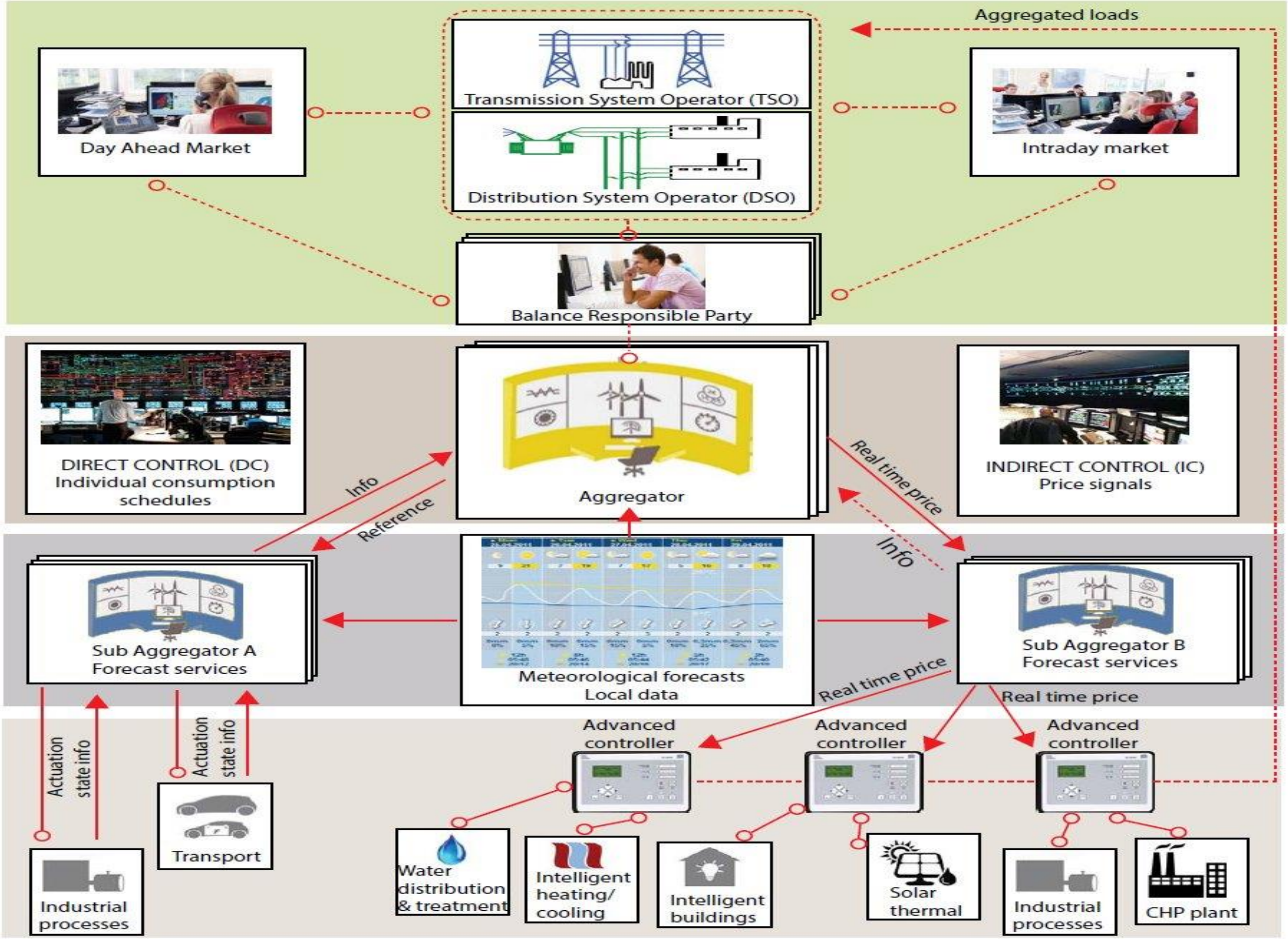
Cloud, fog, and edge computing



Spatial and temporal hierarchies



Smart Energy Operating System (SE-OS)



(Static)

Conventional markets

Link markets to physics using MIMs

(Flexibility Functions)

(Dynamic)

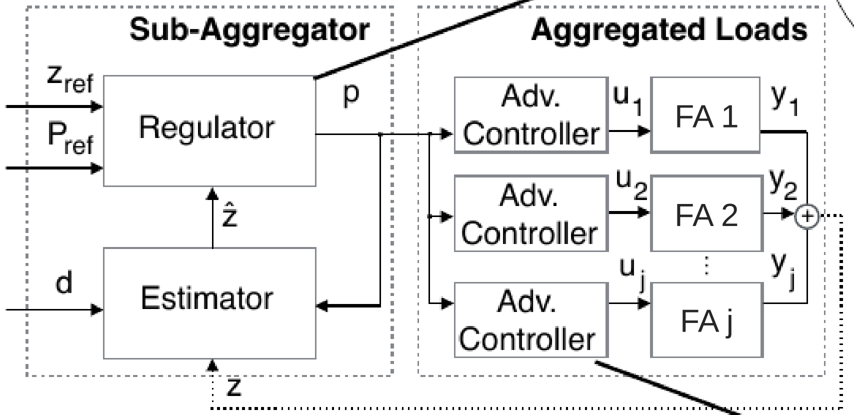
Local flexibility markets

(Hierarchy of controllers)

Interoperability through indirect control

Price signal generator

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



Price-sensitive control system

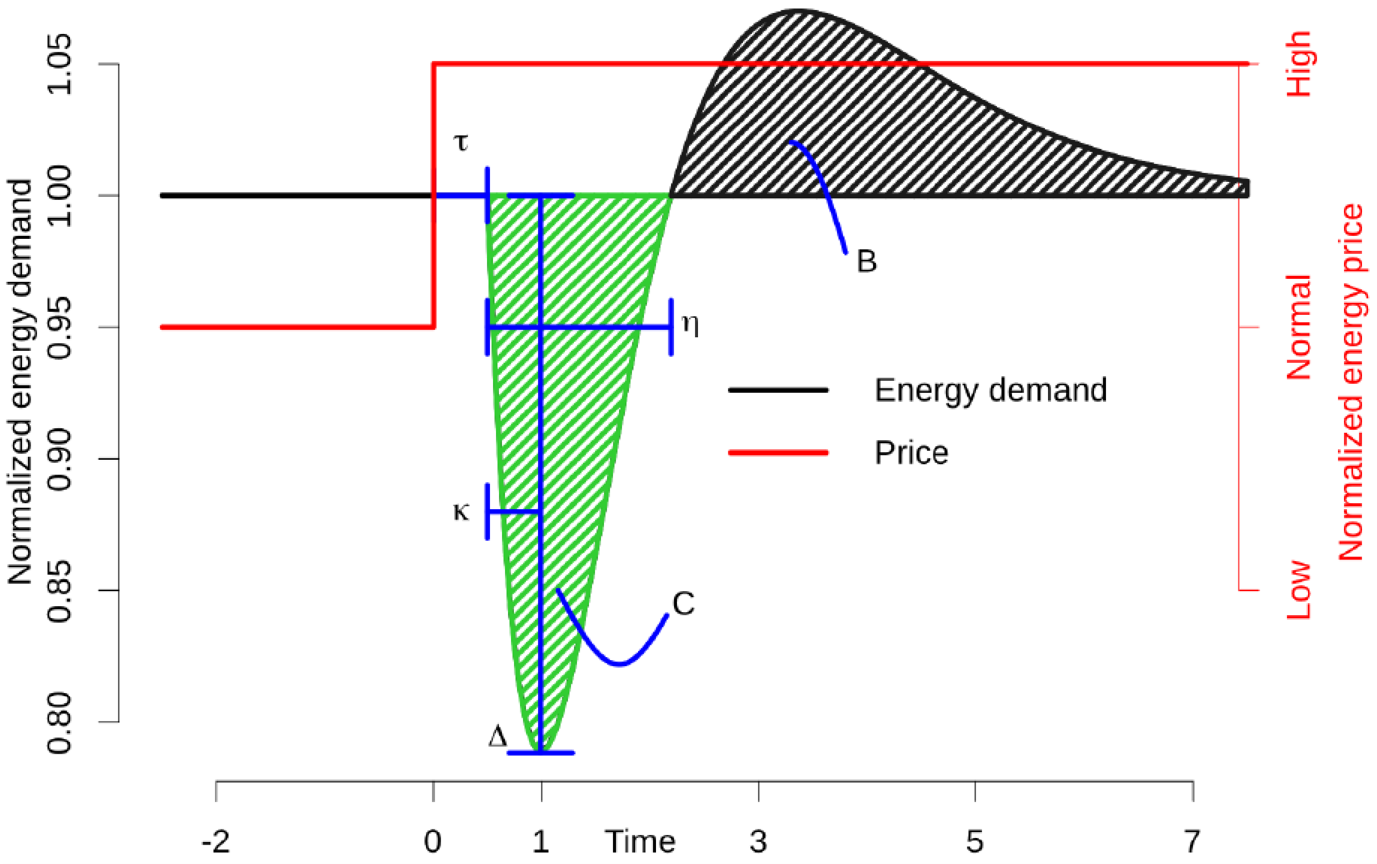
$$\min_{u} \quad \mathrm{E}[\sum_{k=0}^{N}\sum_{j=1}^{J} \phi_j(x_{j,k}, u_{j,k}, p_k)]$$
$$\begin{aligned} \text{s.t.} \quad x_{k+1} &= Ax_k + Bu_k + Ed_k, \\ y_k &= Cx_k, \\ y_k^{min} \le y_k &\le y_k^{max}, \\ u_k^{min} \le u_k &\le u_k^{max} \end{aligned}$$

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

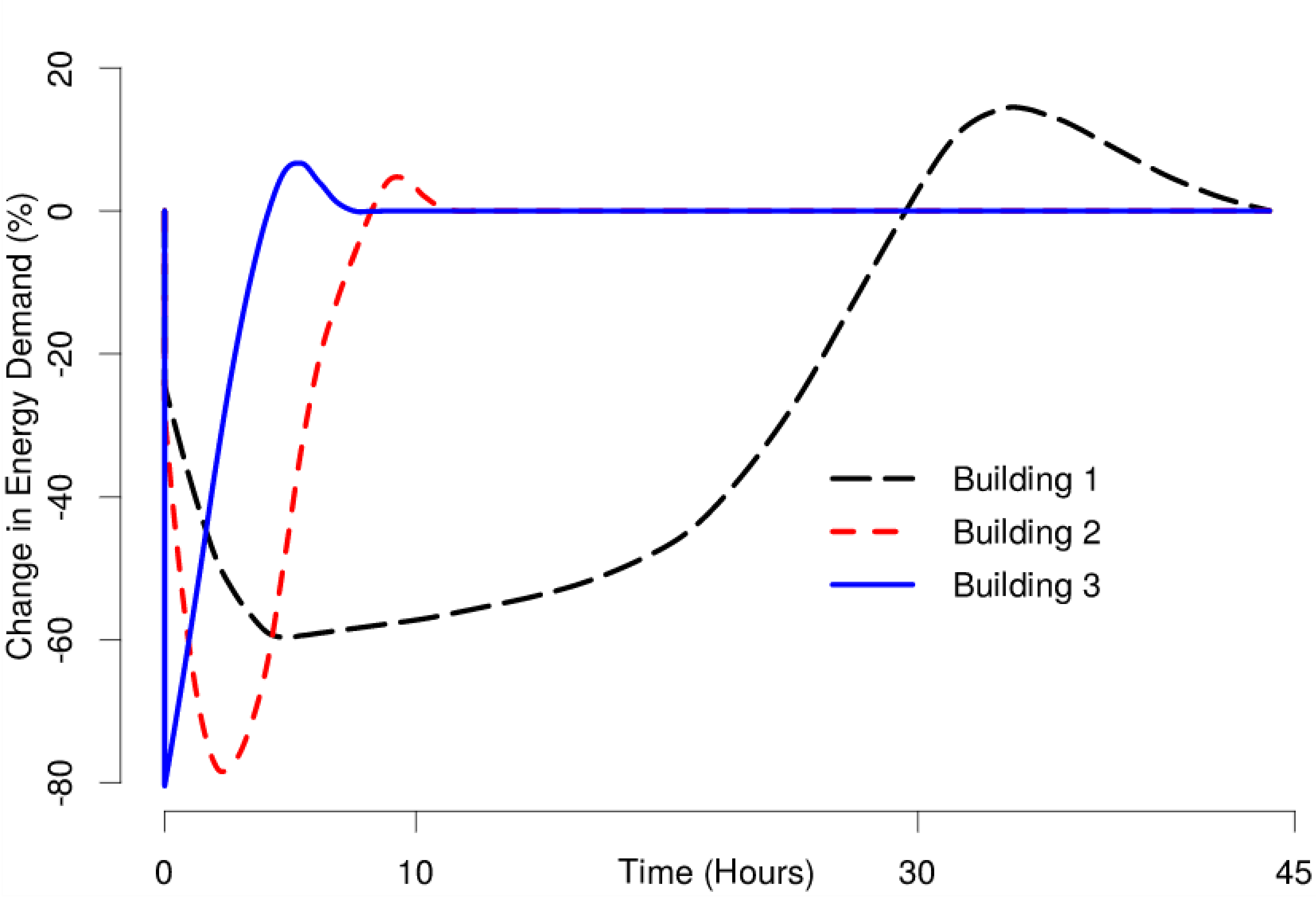
Indirect control through <u>flexibility functions</u>

Flexibility function: Predict flexible demand as function of

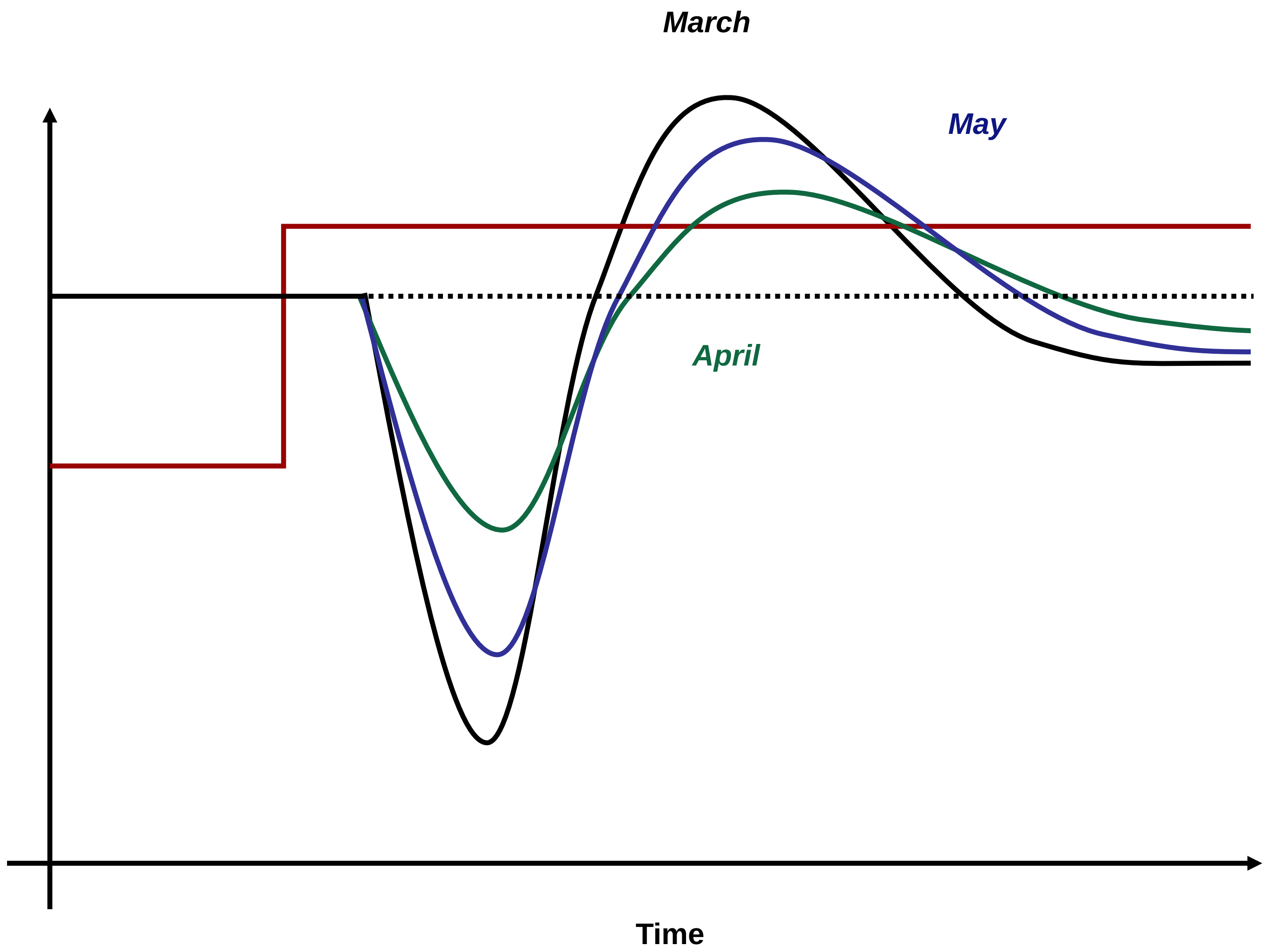
- **Price**
- **“State of charge”** (real or fictive)



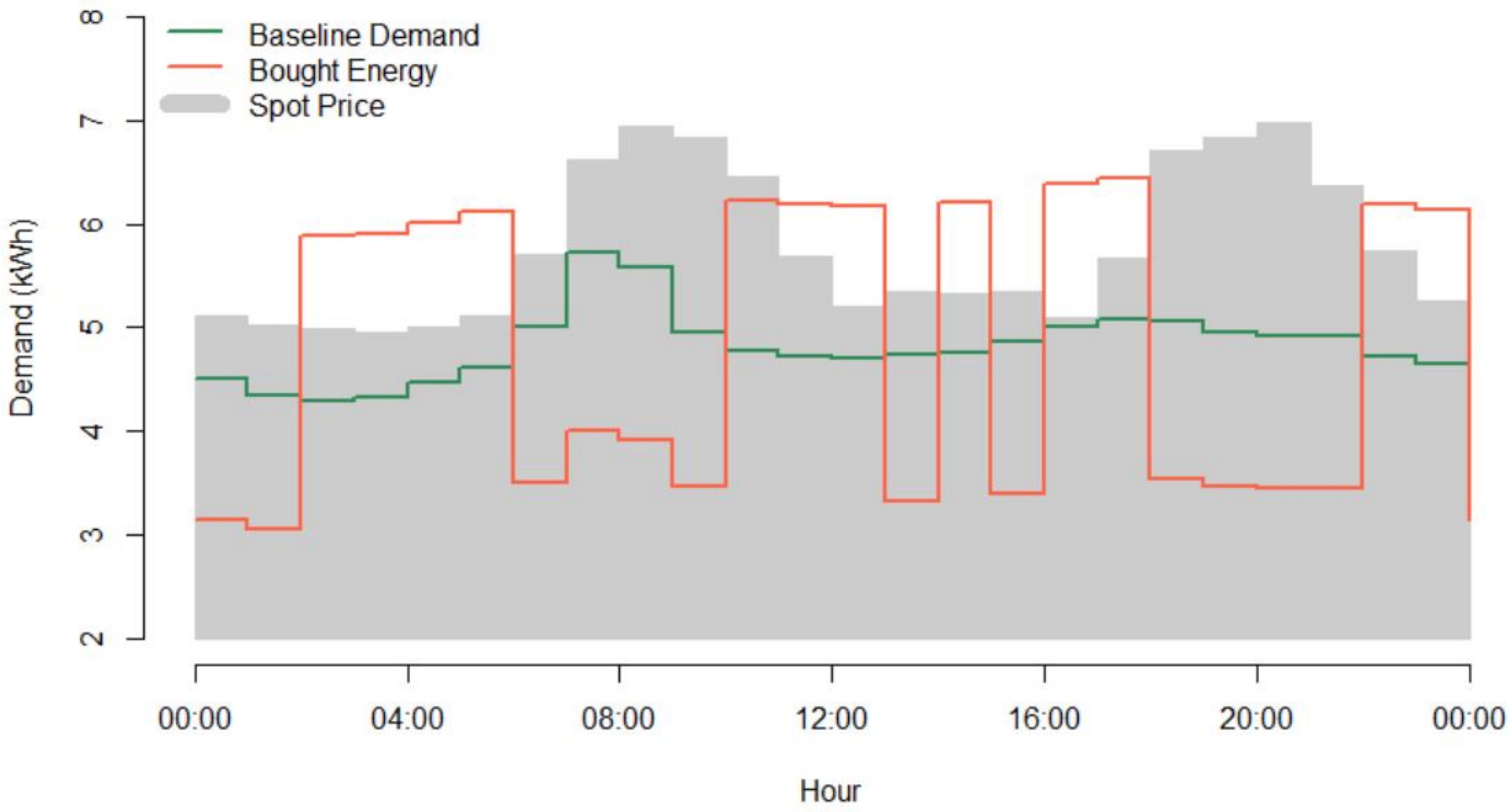
Examples of flexibility functions



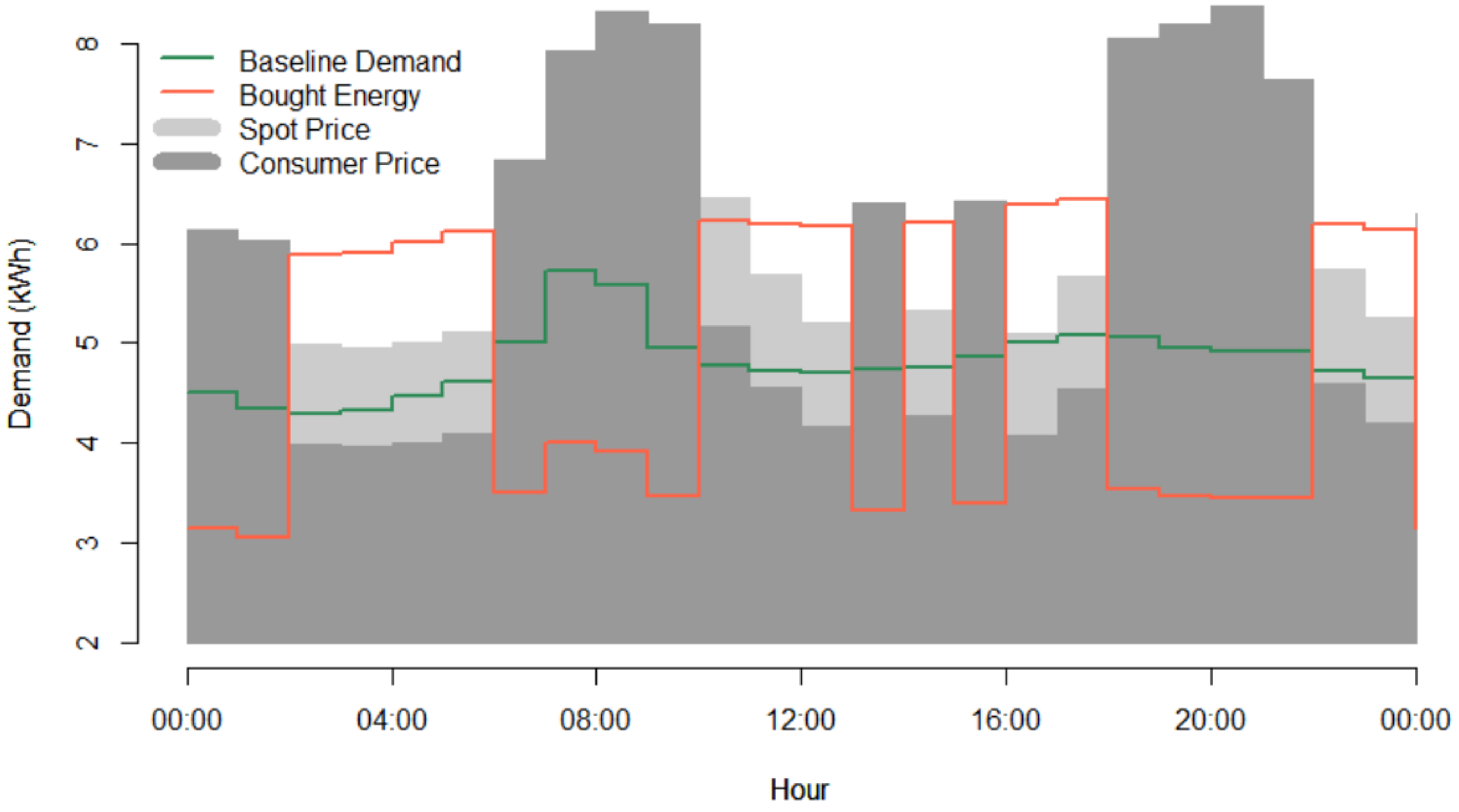
Update the flexibility functions on the fly



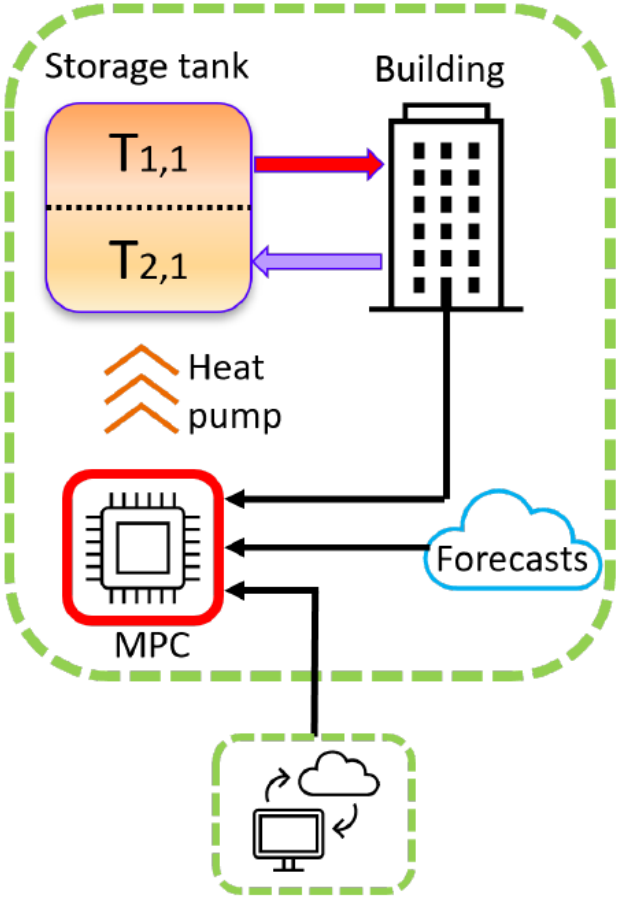
Example: Generated price signals

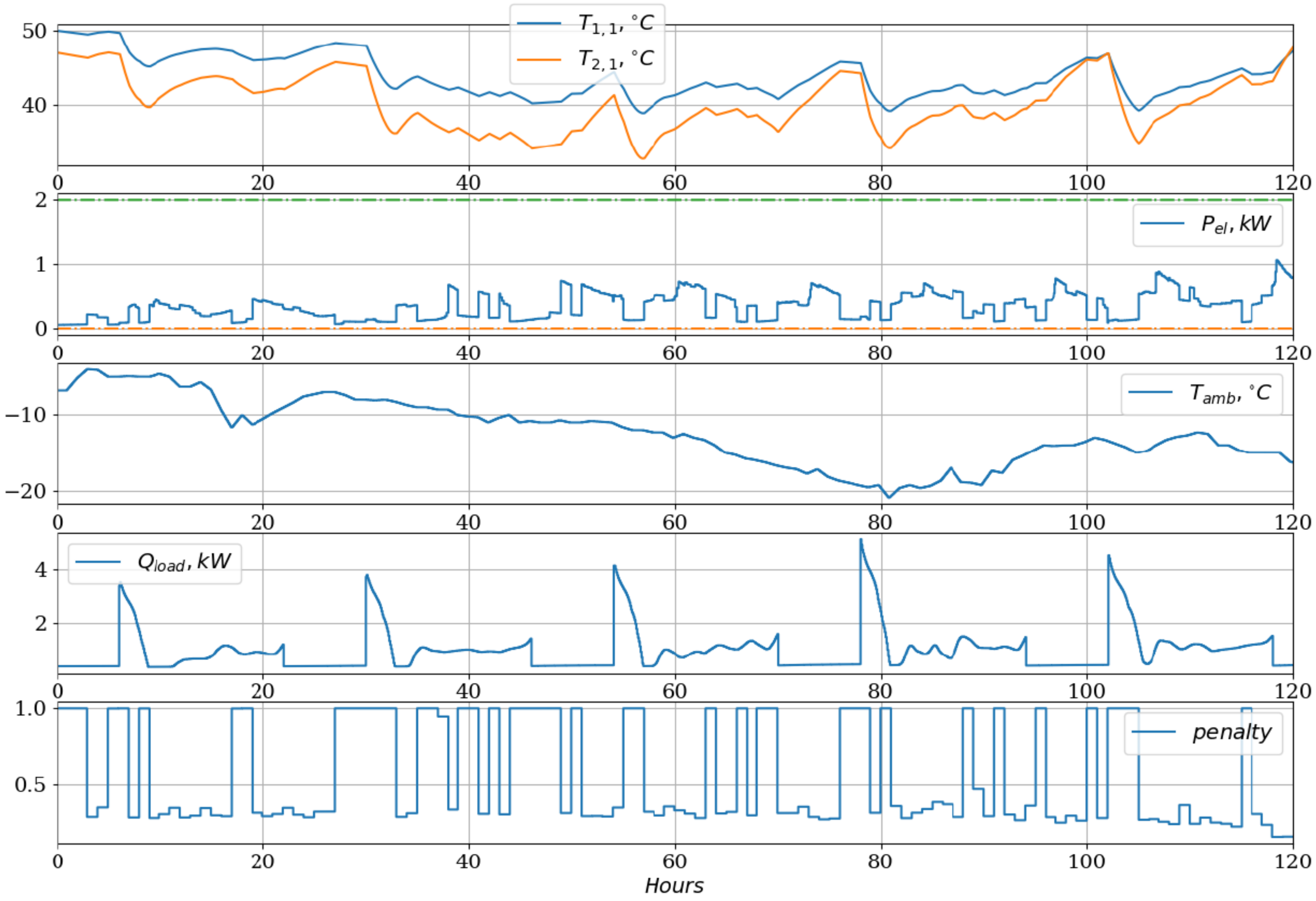


Example: Generated price signals



Example: Price-sensitive flexible asset



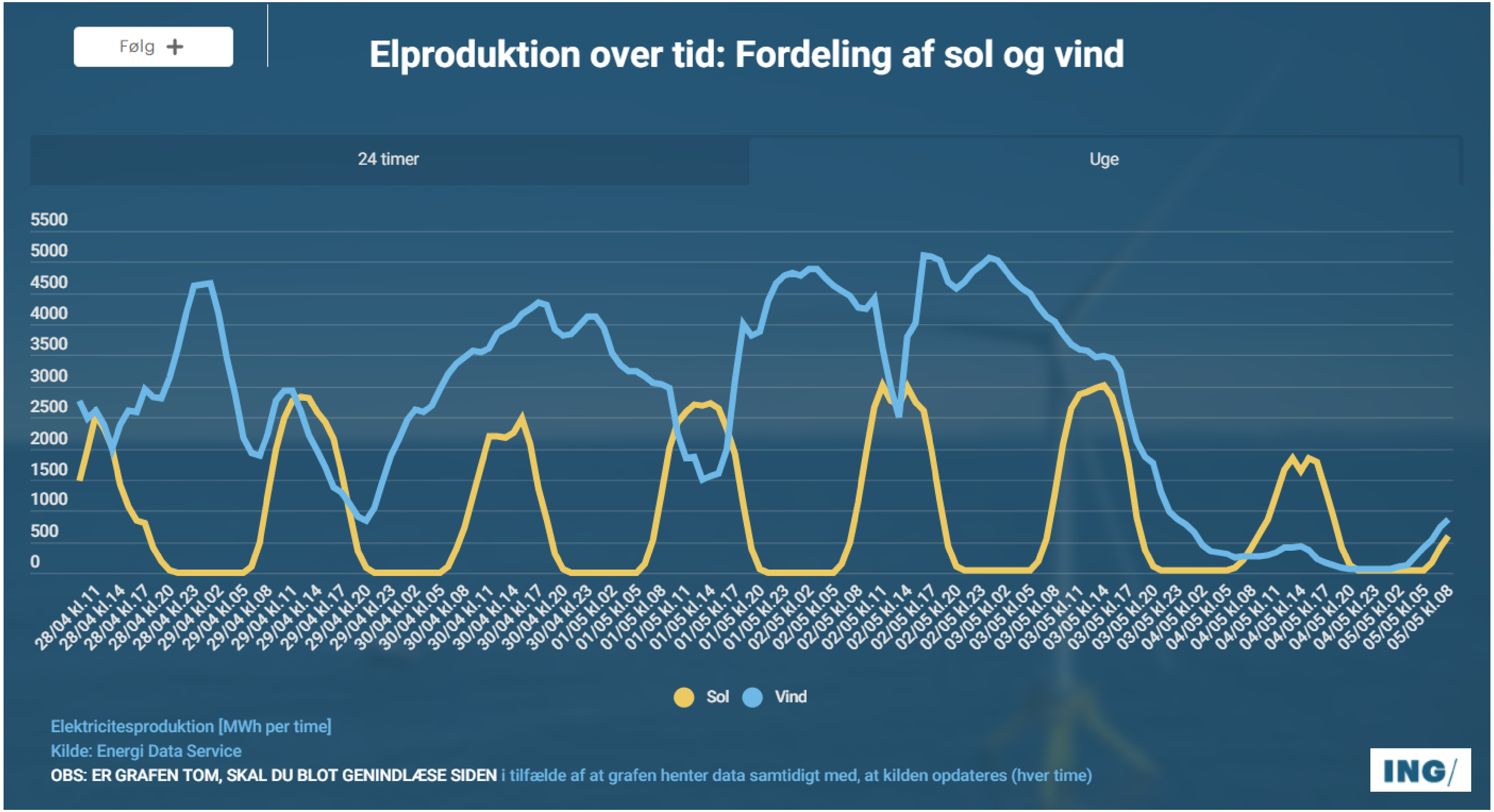


Summary

- 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 propose to use **control-based methods** for activating local flexibility (Smart-Energy OS)

Appendix

Motivation – extended



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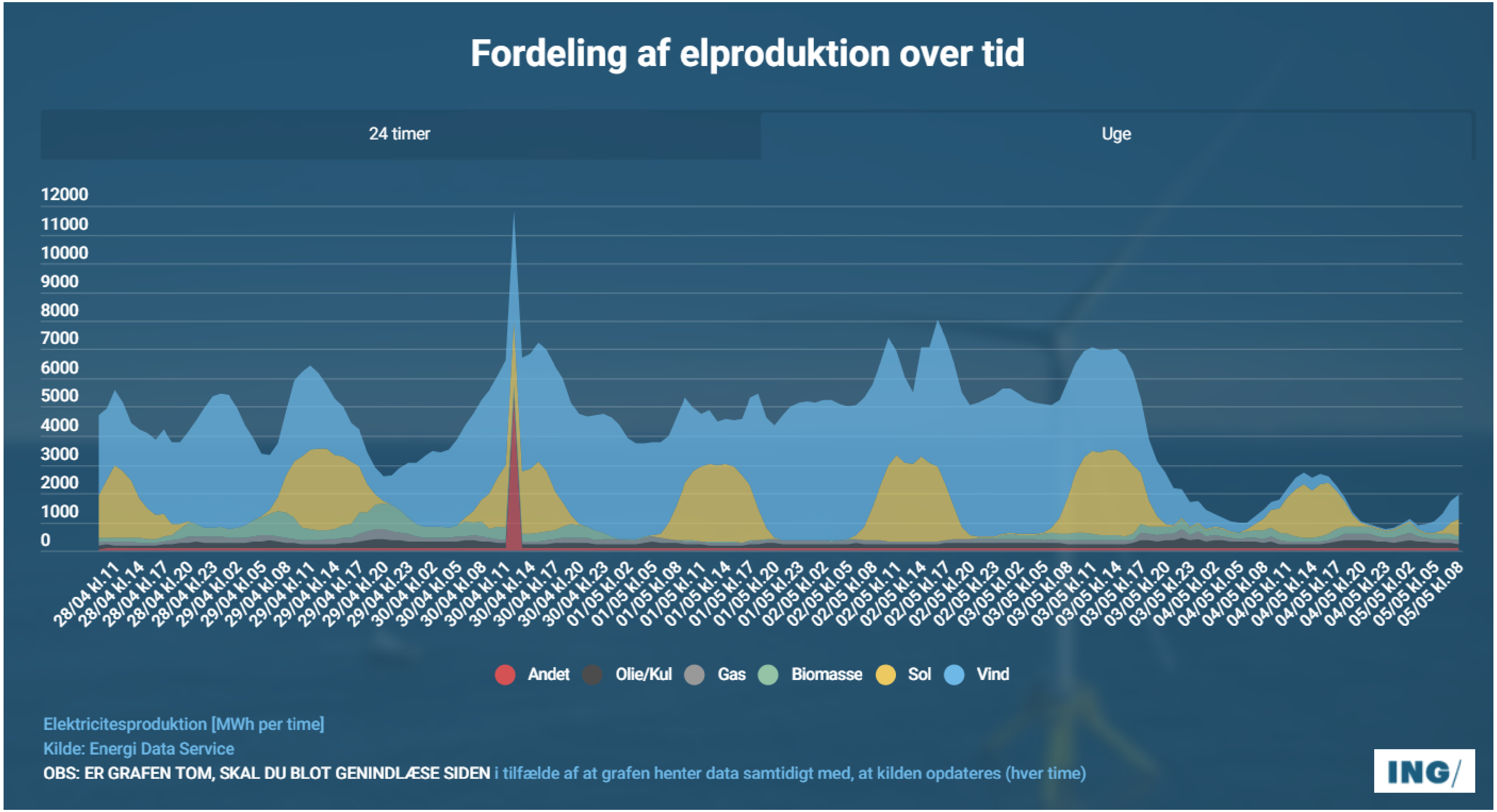
Motivation – extended



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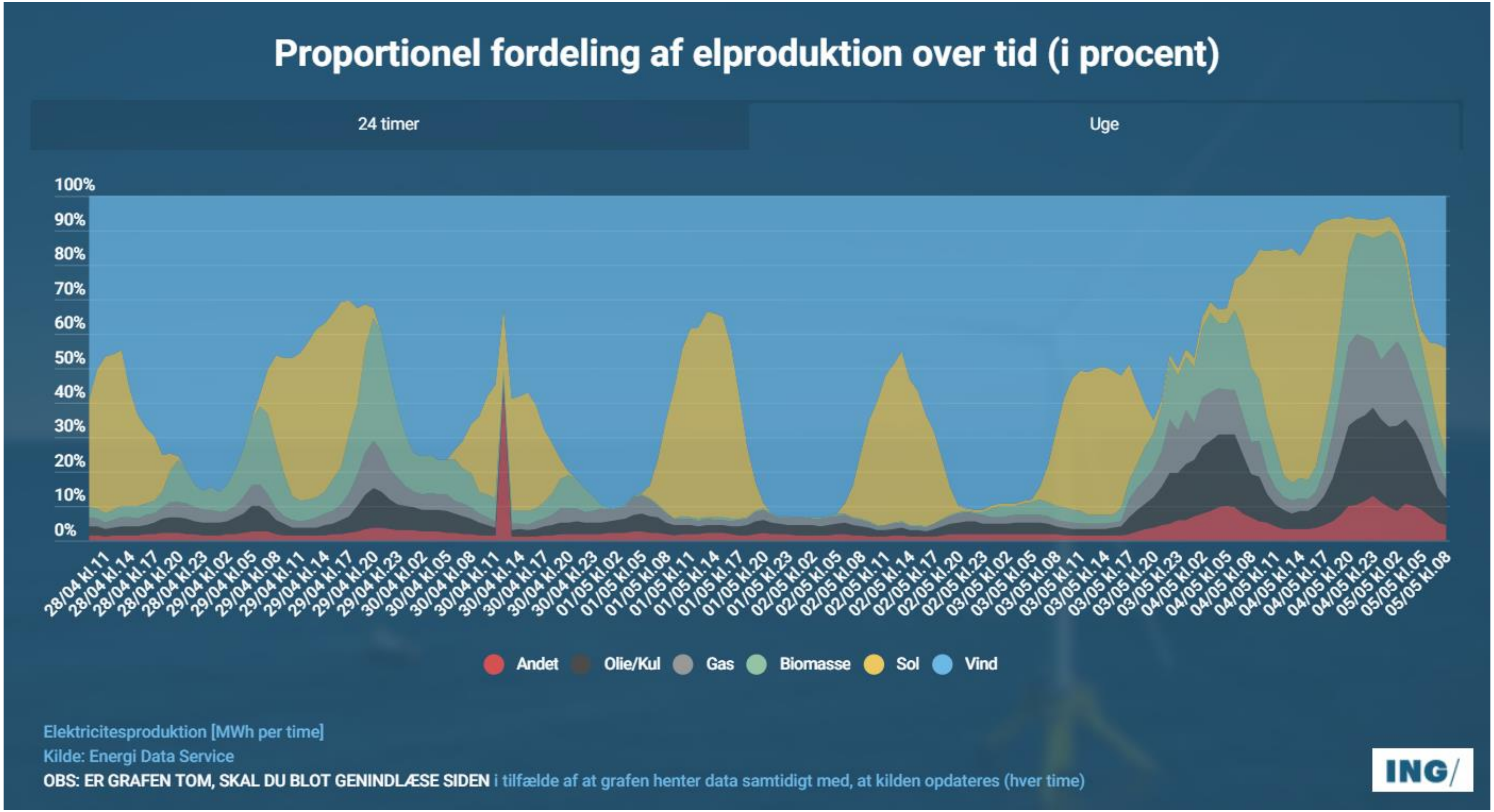

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