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Local Flexibility Markets in Smart Cities: Interactions between Positive Energy Blocks (PEBs)

Stian Backe, Pedro Crespo del Granado,
Güray Kara, Asgeir Tomasgard

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Outline

- Motivation for Local Flexibility Markets
- Market Design
- Modelling Framework
- Case: P2P trading at an Industrial Site

Motivation for
Local Flexibility Markets

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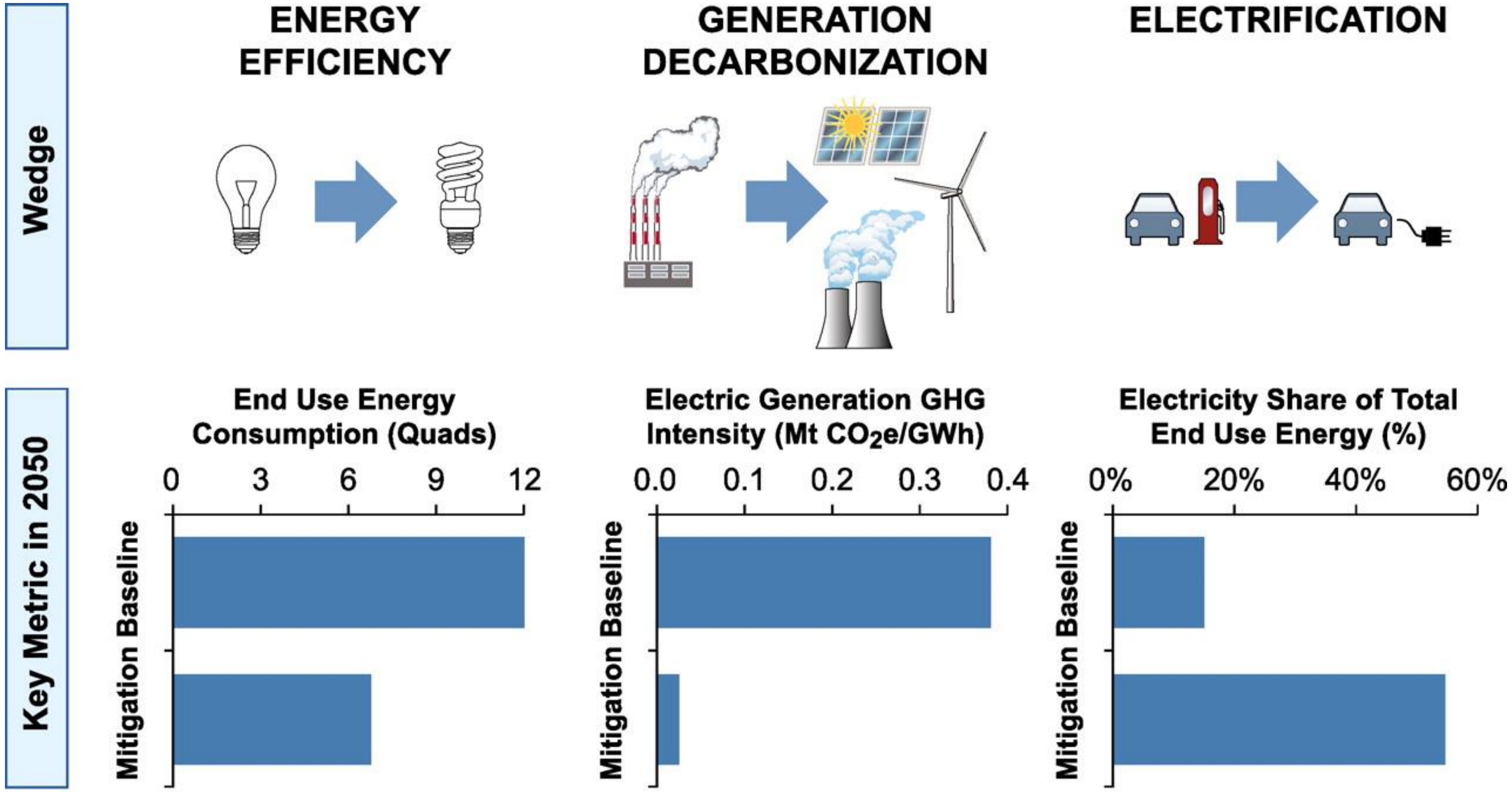
Decentralization



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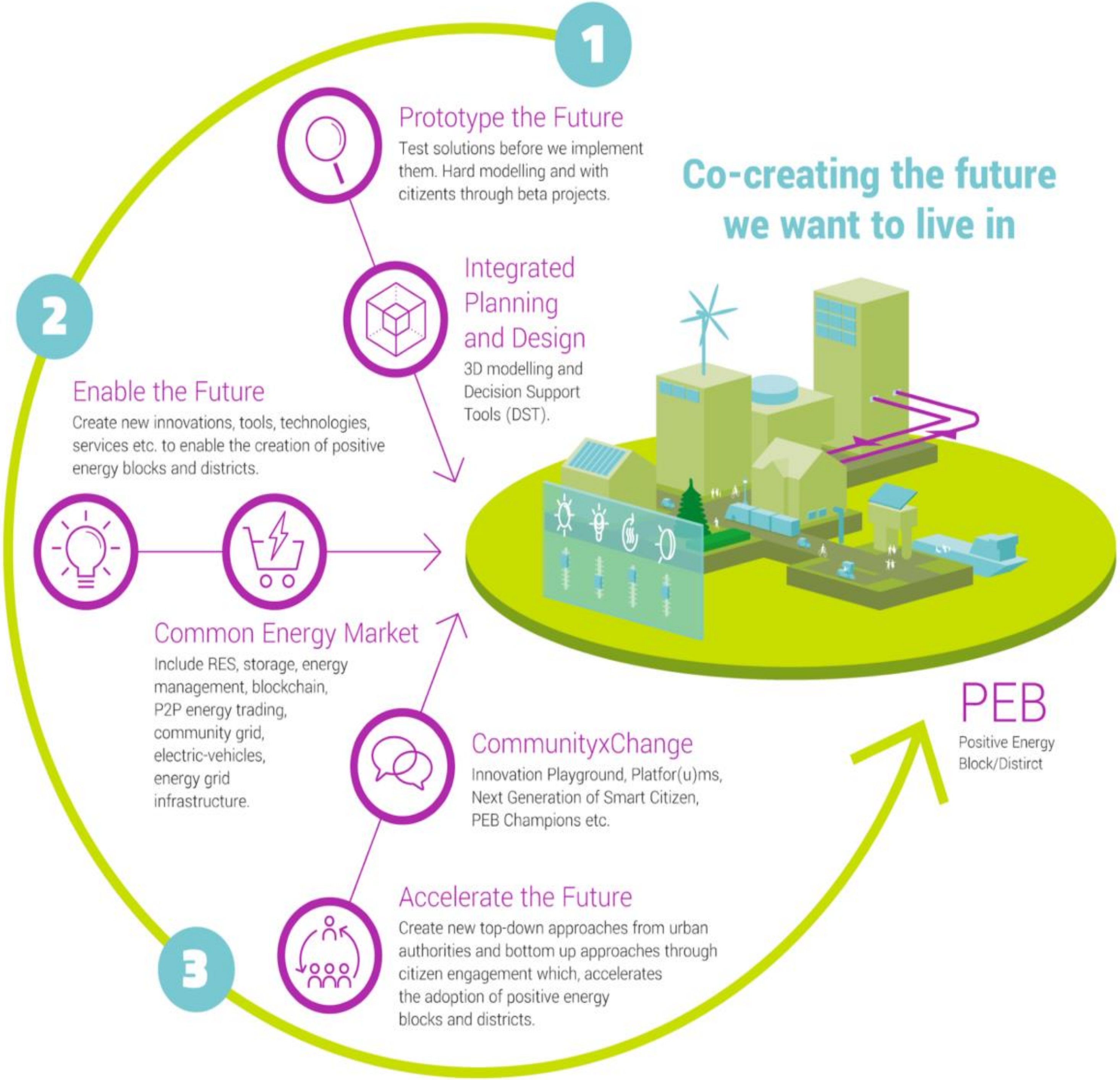
Williams, James H., et al. "The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity“. Science 335.6064 (2012): 53-59.



Co-creating the future
we want to live in
1
Prototype the Future
Test solutions before we implement them. Hard modelling and with citizens through beta projects.
Integrated Planning and Design
3D modelling and Decision Support Tools (DST).
2
Enable the Future
Create new innovations, tools, technologies, services etc. to enable the creation of positive energy blocks and districts.
Common Energy Market
Include RES, storage, energy management, blockchain, P2P energy trading, community grid, electric-vehicles, energy grid infrastructure.
CommunityxChange
Innovation Playground, Platfor(u)ms, Next Generation of Smart Citizen, PEB Champions etc.
3
Accelerate the Future
Create new top-down approaches from urban authorities and bottom up approaches through citizen engagement which, accelerates the adoption of positive energy blocks and districts.
PEB
Positive Energy Block/Distirct

Market Design

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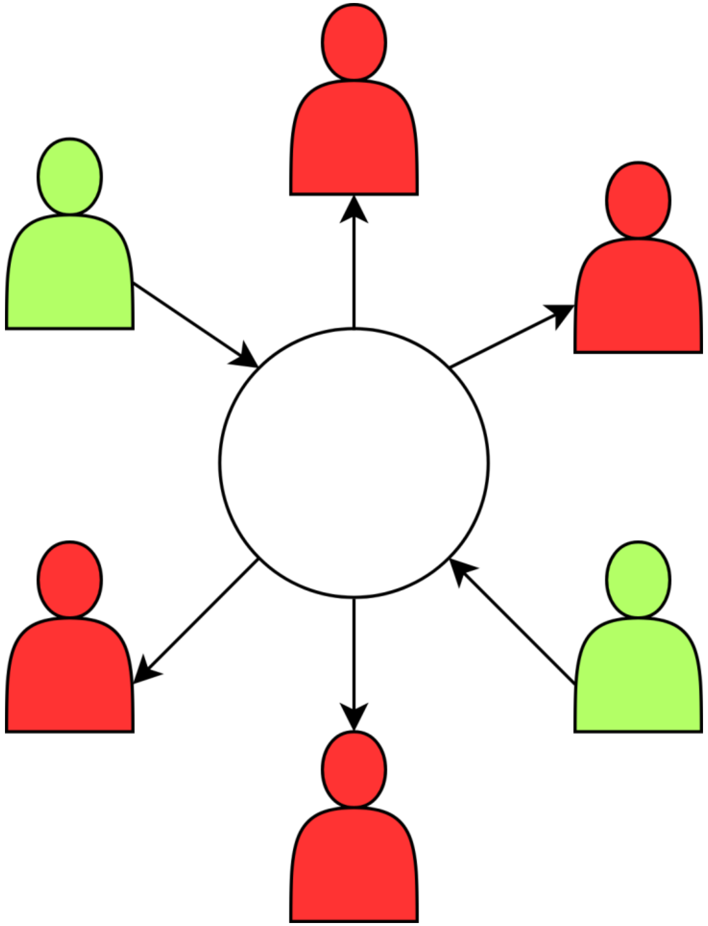
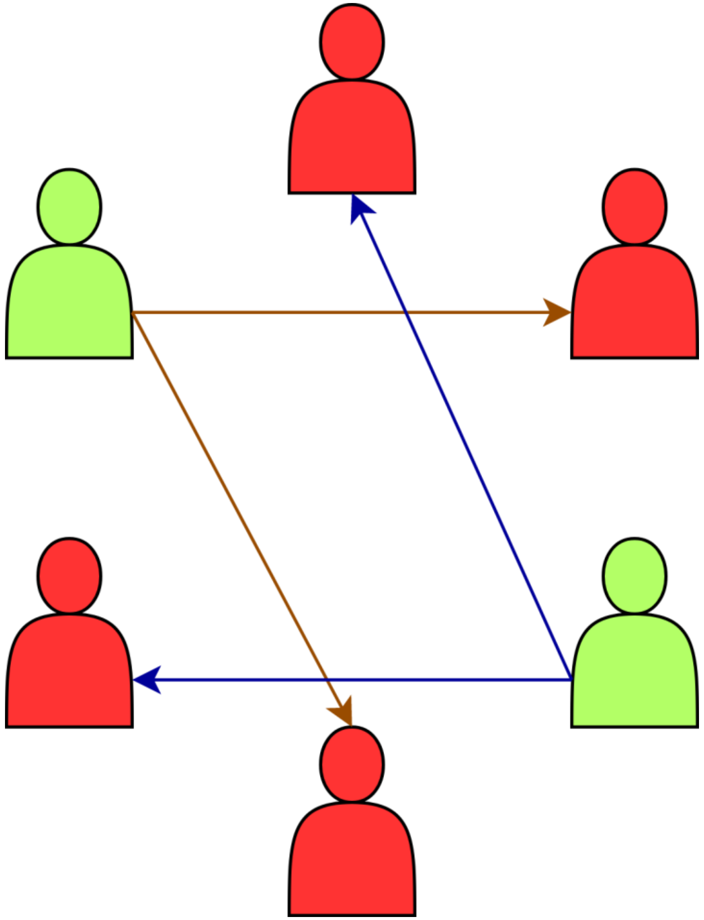
Pool-based trading

- Uniform terms
- Consecutive clearings (Day-ahead, intra-day, etc.)
- One-sided/Two-sided
- Price volatility
- Coordinated dispatch



Bilateral trading

- Customized terms
- Contract clearings
- Long-term bilateral relationships
- Lowered risk
- Decentralized dispatch



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Key principles of electricity markets

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Key principles of electricity markets	Principle in a local market?
Free choice of suppliers	Challenged
Non-competitive development of grid infrastructure	Challenged
Market liquidity	Challenged

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Market access	Strengthened
System adequacy	Strengthened
Asset utilization	Strengthened

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Market access	Strengthened
System adequacy	Strengthened
Asset utilization	Strengthened
Practical feasibility	Depends
System security	Depends

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Modelling Framework

Linear programming and rolling horizon

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Local Flexibility Markets

Objective

- Deferring grid investments
- Facilitate local RES
- Preserve power quality
- Reduce energy transport

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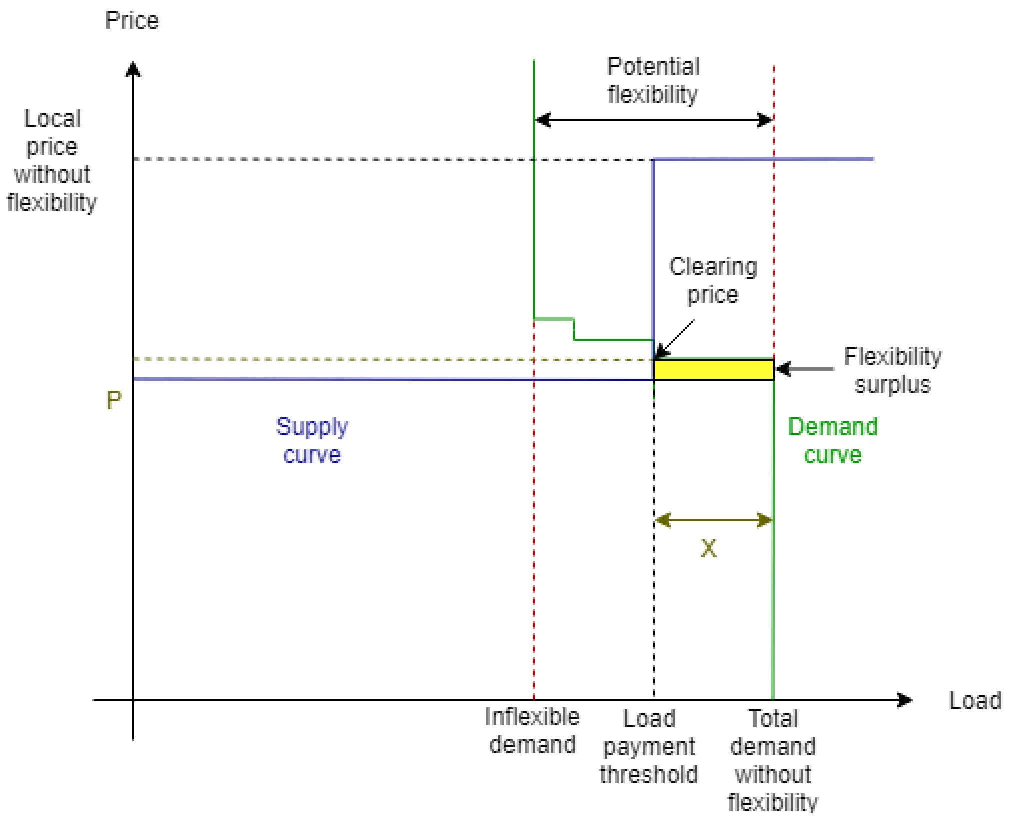

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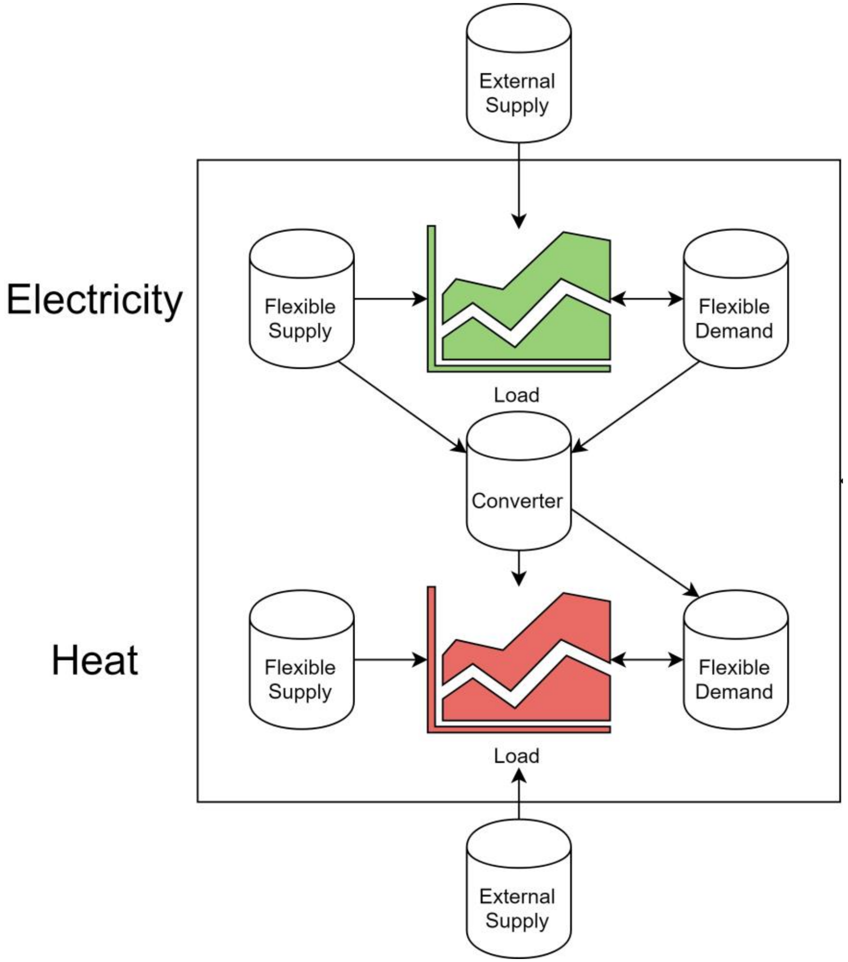
Categorization of Assets



Inside the PEB

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Categorization of Assets

Temporal link between all time steps

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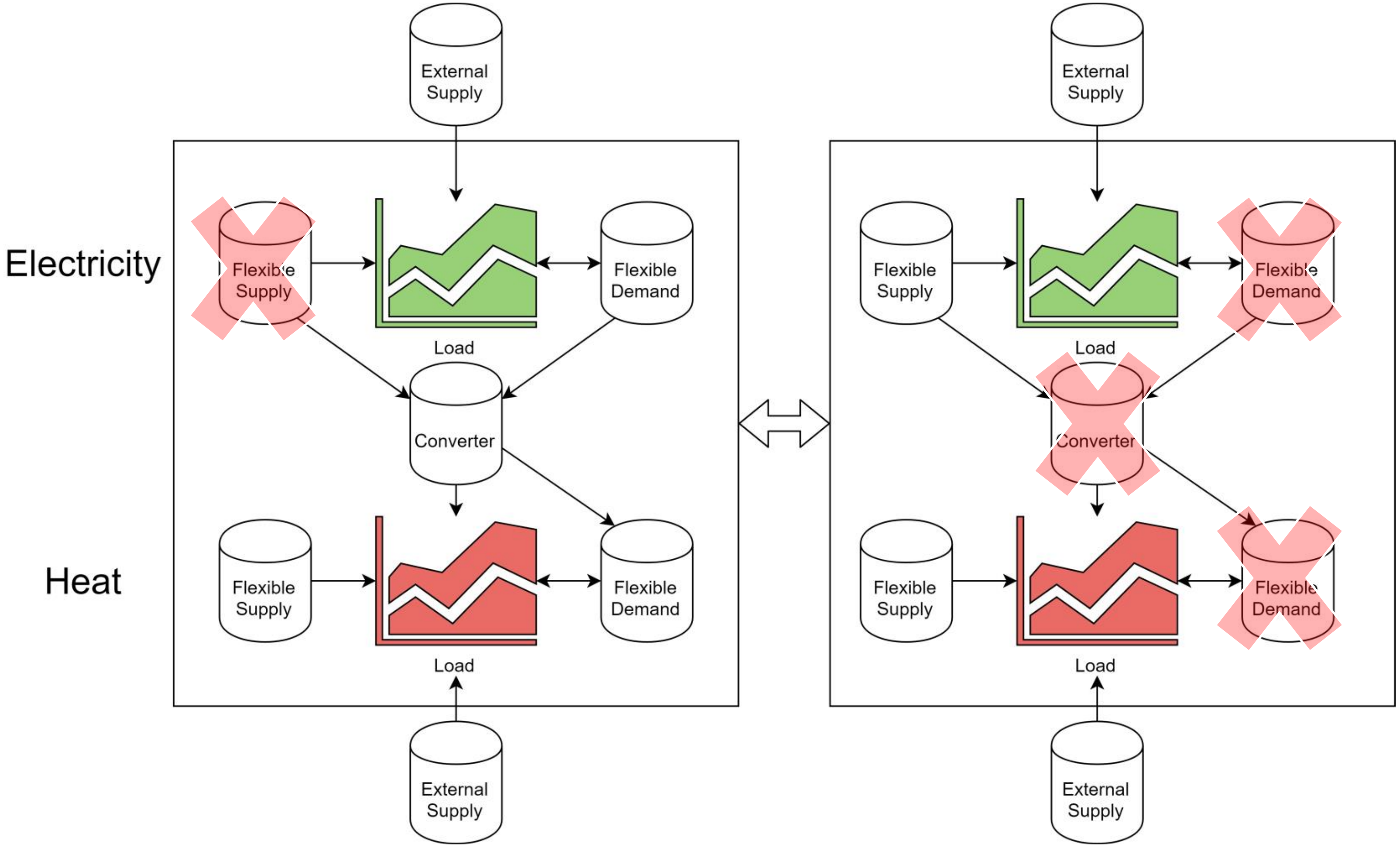
Categorization of Assets



Trading between PEBs

Case: P2P trading at an Industrial Site

Value of peak load reduction and shared flexibility assets

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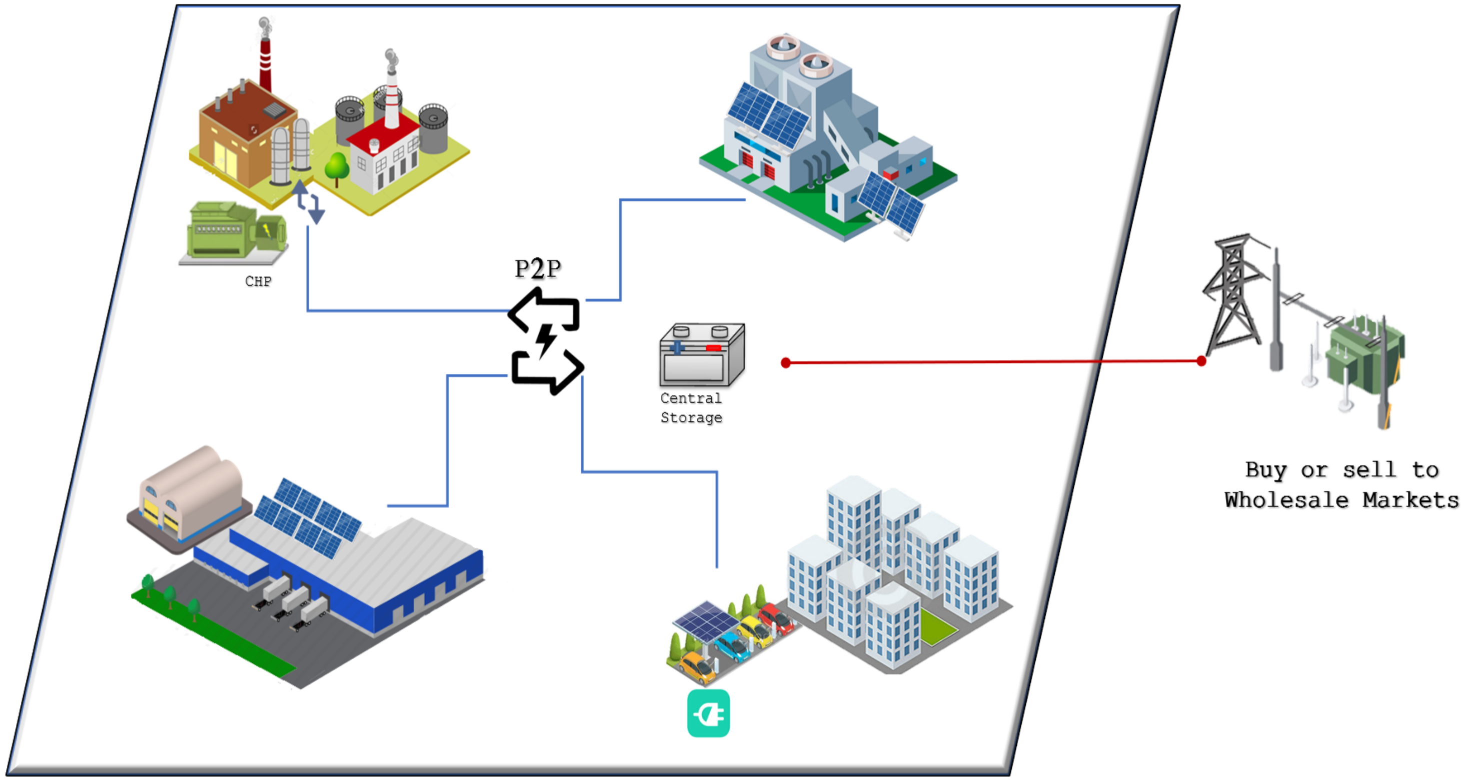
Conceptual study of Norwegian site

- Value of P2P trading at an industrial site
- Peak power pricing



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Sæther, Guro. "Peer-to-Peer Energy Trading in Combination with Local Flexibility Resources in a Norwegian Industrial Site“. Master thesis (2019).

Cases

Base Case:

Flexible buildings

$c_{feed-in} < c_{g,tot}$

Each customer dispatch flexibility with only an individual perspective

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Case 1:

P2P trading

$c_{feed-in} < c_{p2p} < c_{g,tot}$

Trading between customers to utilize flexibility collectively

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Case 1:

P2P trading

$c_{feed-in} < c_{p2p} < c_{g,tot}$

Trading between customers to utilize flexibility collectively

Case 2:

P2P + Central storage

$c_{feed-in} < c_{ch} < c_{p2p} < c_{dch} < c_{g,tot}$

Trading between customers with the option of using a shared battery for flexibility

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Further assumptions

- Electricity only
- Linear model (Kirchoff’s laws are neglected)
- No investments
- Perfect information
- No storage degradation

Input data

	Building 1	Building 2	Building 3	Building 4	Building 5
Area of business	Construction material production	Mechanical workshop	Food processing	Food processing	Forestry
Yearly demand $[kWh/yr]$	1 170 000	250 000	1 400 000	360 000	2 800 000
Yearly peak demand $[kWp/yr]$	345	157	261	115	789
Roof top area $[m^2]$	5 500	2 000	6 000	6 000	9 000
Assumed energy features	PV, CHP and load shifting	EVs during work hours	CHP and load shifting	PV	PV and CHP

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Flexible demand

No flexible demand

Flexibility assets

- Load shifting (10% of peak load)
  - **Building 1** – 34.5 kW, 138 kWh
    - Initial available 100%, available during work hours
    - Load shifting cost: 0.4 NOK/kWh
  - **Building 3** – 26 kW, 104 kWh
    - Initial available 100%, always available
    - Load shifting cost: 1.2 NOK/kWh

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- EV flexibility (V2G) – 30x20 kW, 30x50 kWh
  - **Building 2**
    - Initial available 60%, available during work hours
    - Required available 70% at the end of each work day

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    - Initial available 60%, available during work hours
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- Central storage – 33.3 kW, 1 000 kWh

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Results

	Base Case (Reference)	Case 1 (P2P trade)	Case 2 (P2P & storage)
Total costs [NOK]	*2,334,921*	*2,175,170*	*2,077,326*
Total savings [NOK]		*159,751*	*257,596*
Total savings [%]		*6.8 %*	*11.0 %*

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Total savings [%]		***6.8 %***	***11.0 %***
Yearly peak demand [kWp]	1,412	-7.0 %	-19.5 %
Cost of peak power	1,017,800	-15.0 %	-25.6 %

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Yearly peak demand [kWp]	1,412	-7.0 %	-19.5 %
Cost of peak power	1,017,800	-15.0 %	-25.6 %
Power sold to grid [kWh]	110,346	-67.0 %	-87.9 %
P2P export [kWh]		206,208	260,537
Central storage charge [kWh]			56,894

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Results - Savings per building

	BC: reference	C1: P2P		C2: P2P & Shared storage	
	Tot costs [NOK]	Tot costs [NOK]	Tot savings	Tot costs [NOK]	Tot savings
B1	422,847	404,073	4.4 %	378,984	10.4 %
B2	201,494	176,569	12.4 %	172,827	14.2 %
B3	443,605	413,391	6.8 %	412,649	7.0 %
B4	182,655	147,645	19.2 %	140,137	23.3 %
B5	1,083,698	1,033,493	4.6 %	972,728	10.2 %

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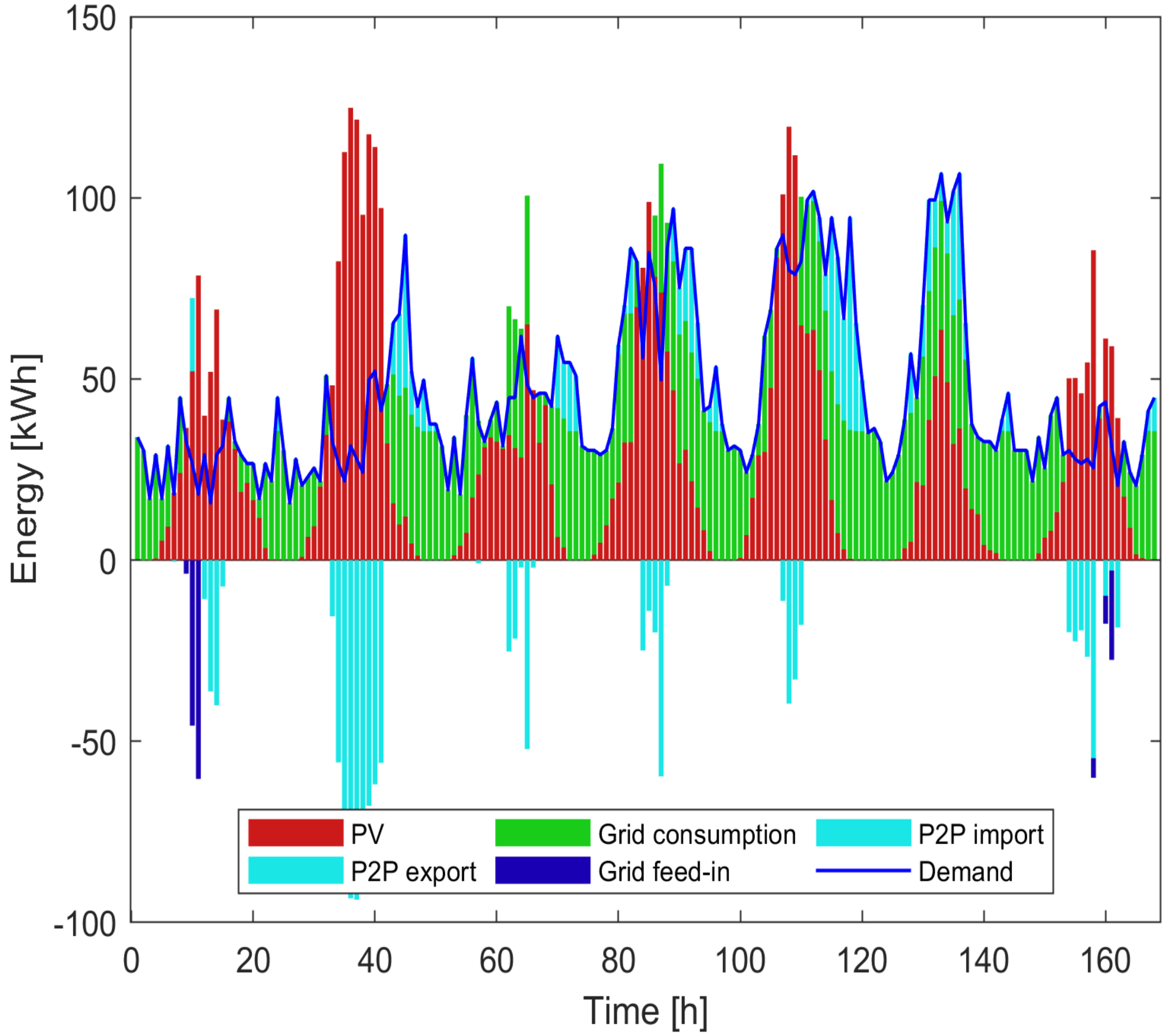
Results – B4 (summer week)



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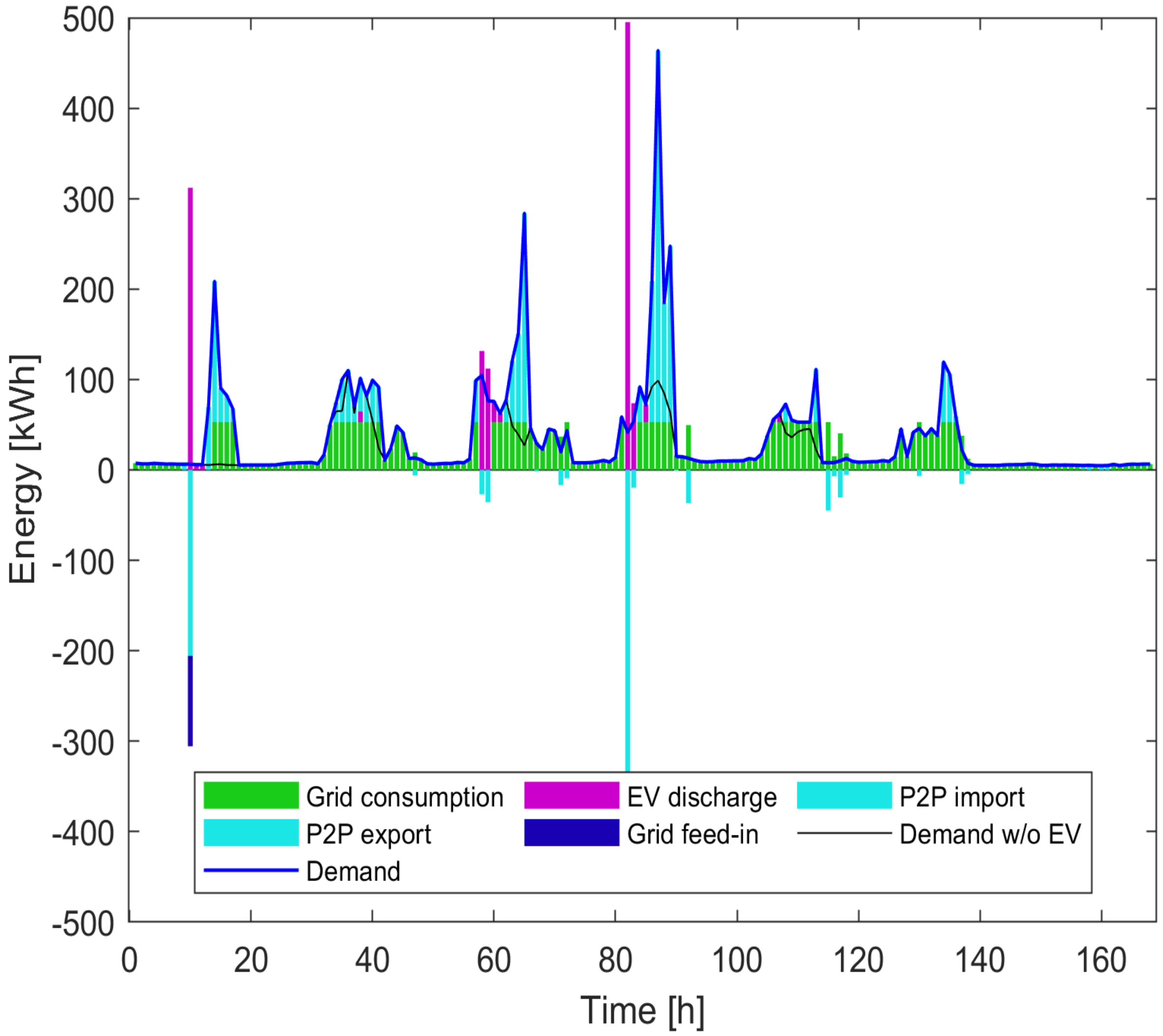
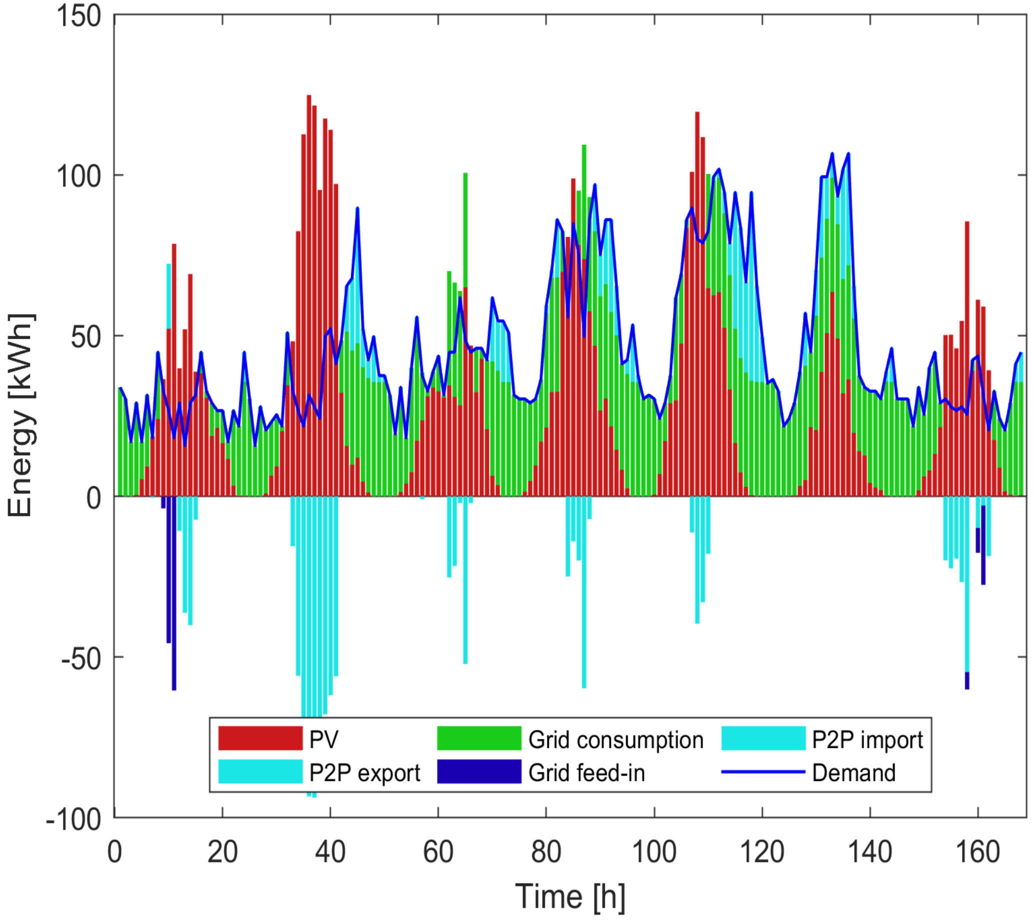
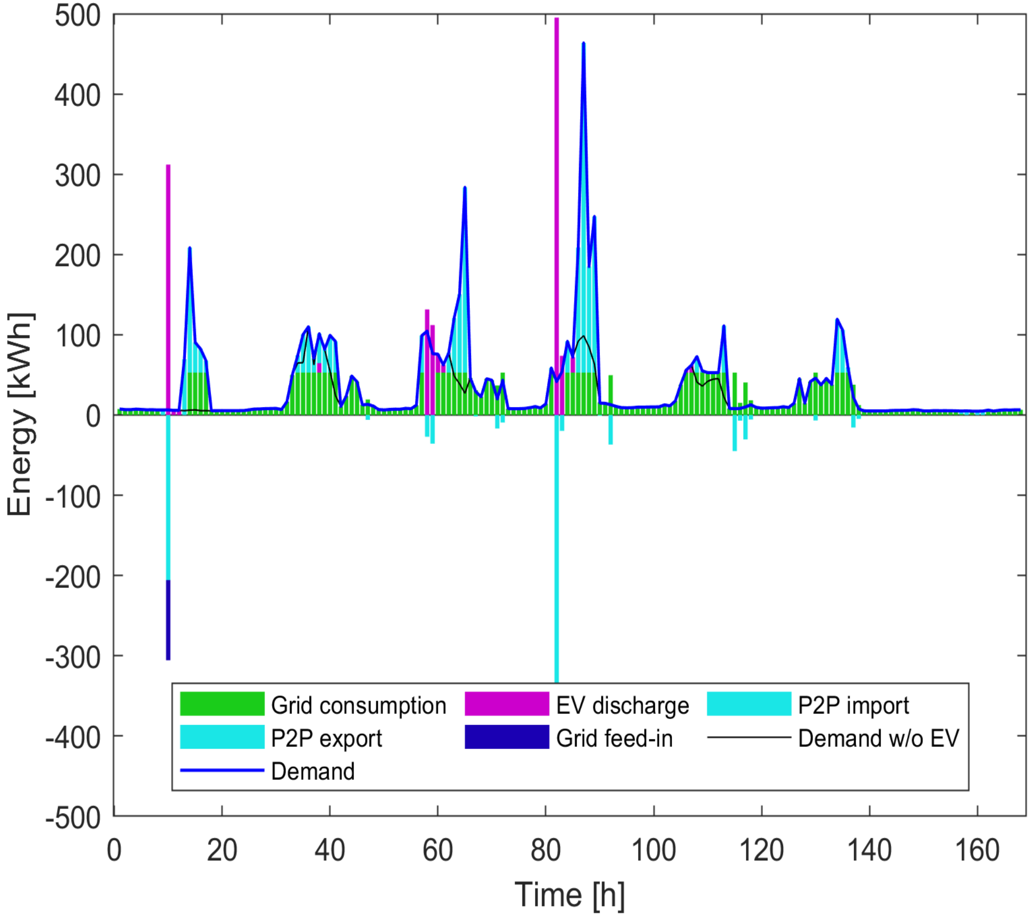
Results – B2 (summer week)



Results – B4+B2 (summer week)





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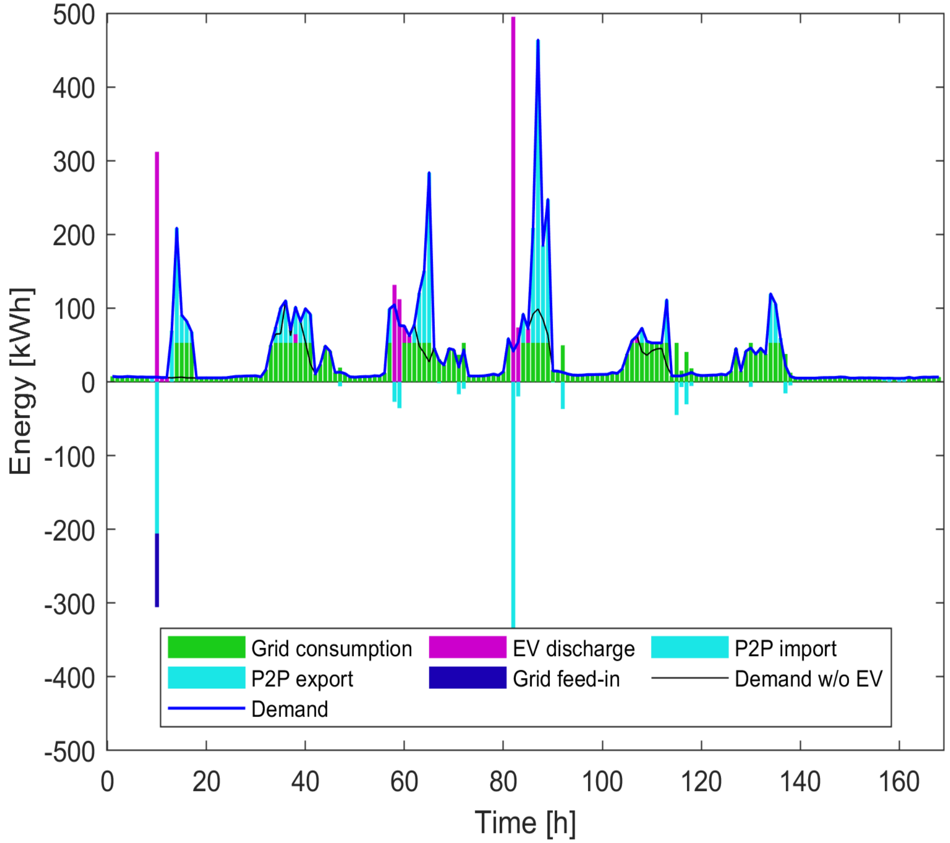

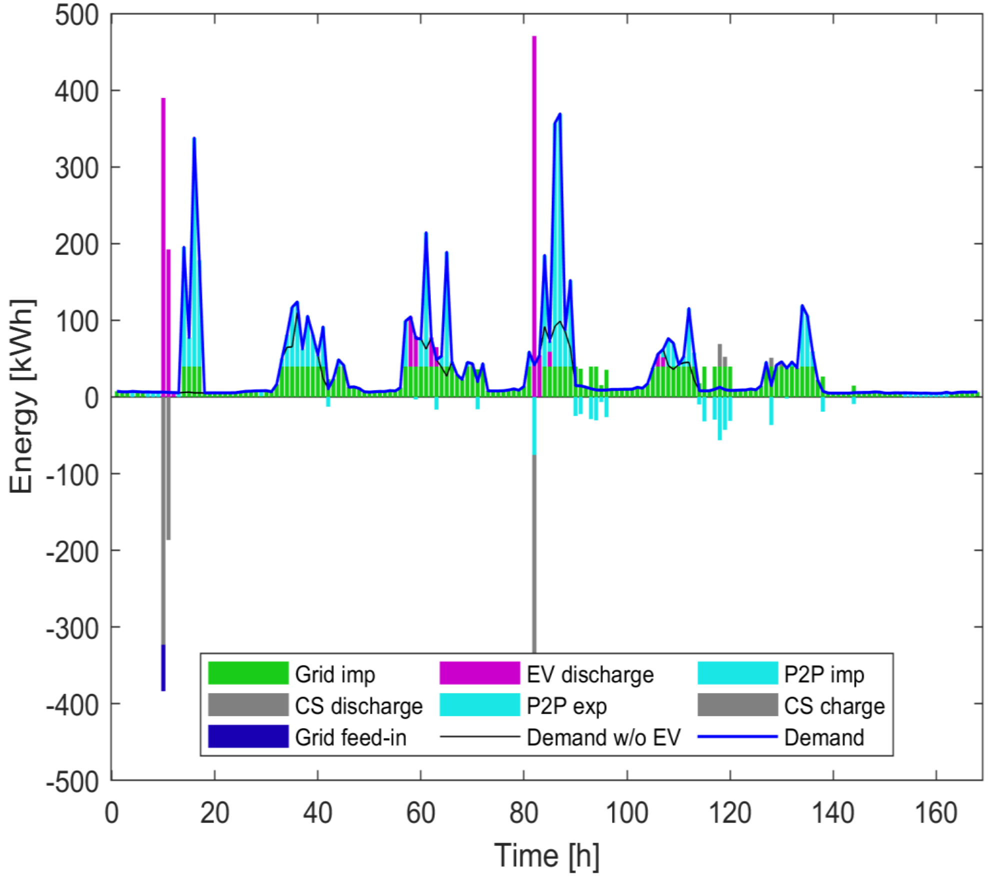

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Case study - Conclusions

- Peak shaving amplified
  - Central storage gives large peak shaving
- Local generation valued on-site
  - No curtailment of local generation
  - Large reduction in grid feed-in

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- Backe, S., del Granado, P. C., Kara, G., & Tomasgard, A. “Local Flexibility Markets in Smart Cities: Interactions between Positive Energy Blocks,” 16th IAEE European Conference, 2019.
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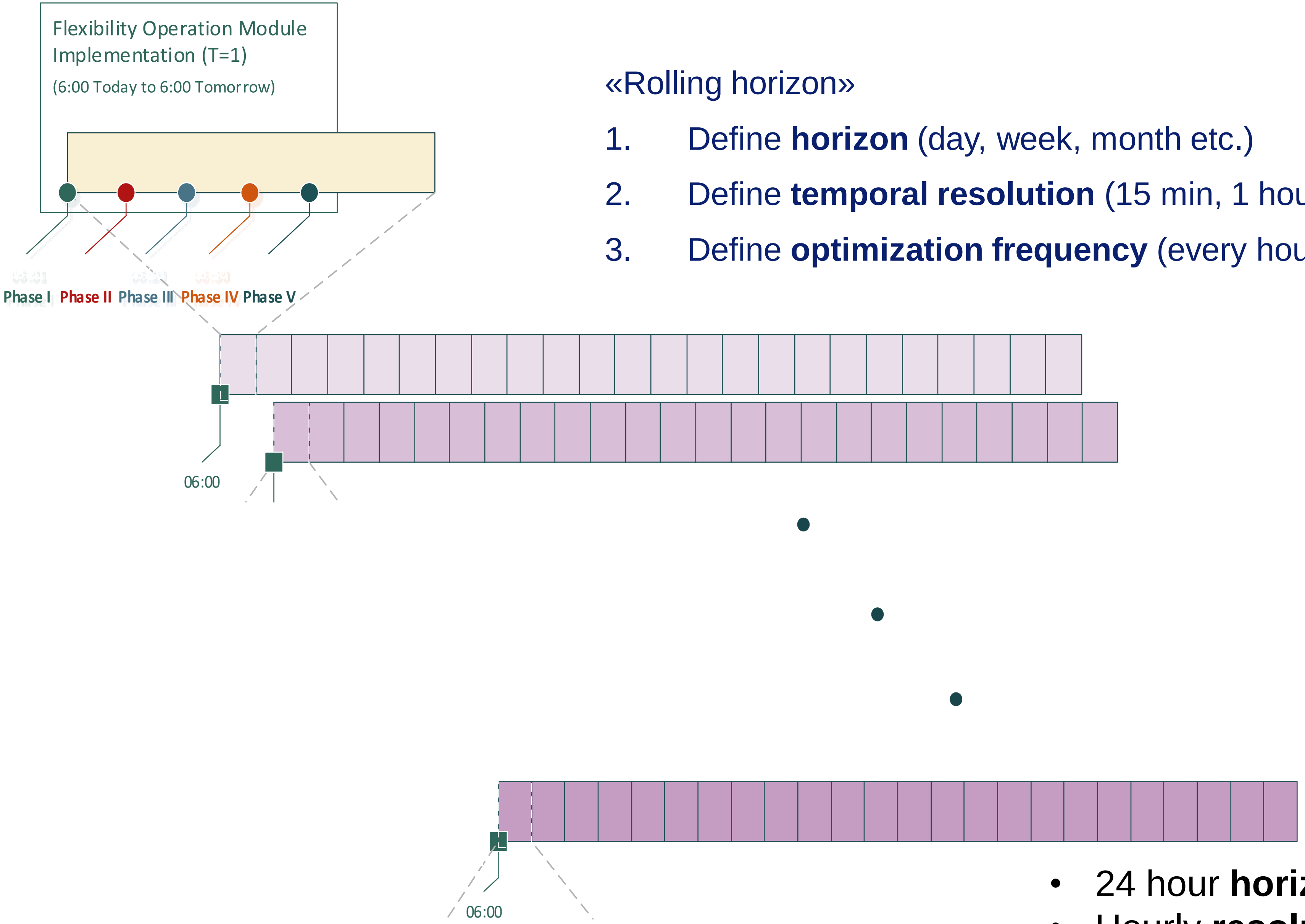
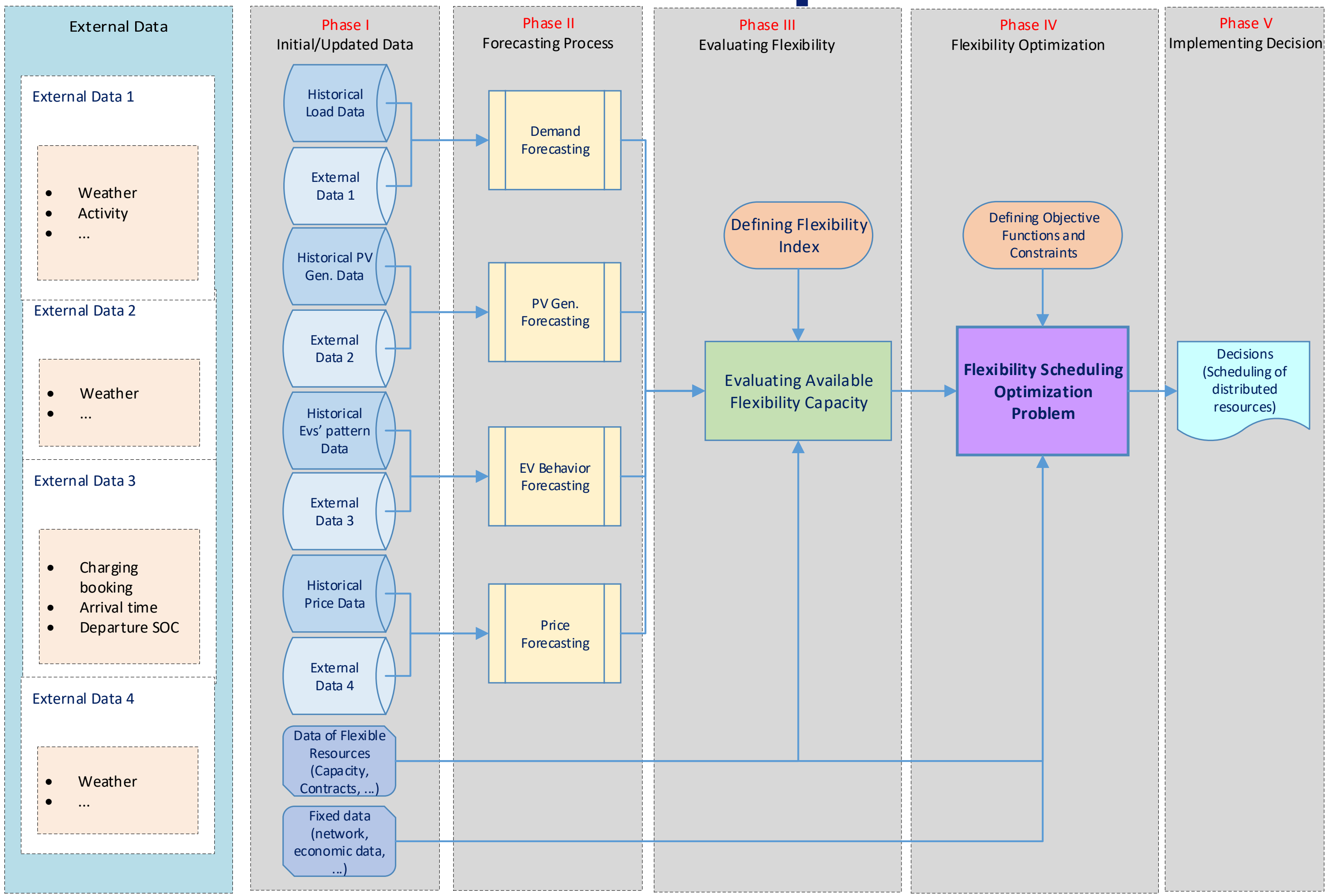


«Rolling horizon»

1. Define **horizon** (day, week, month etc.)
2. Define **temporal resolution** (15 min, 1 hour, 2 hours etc.)
3. Define **optimization frequency** (every hour, every 6th hour etc.)

- 24 hour **horizon**
- Hourly **resolution**
- Hourly **optimization frequency**

Link between data and optimization model



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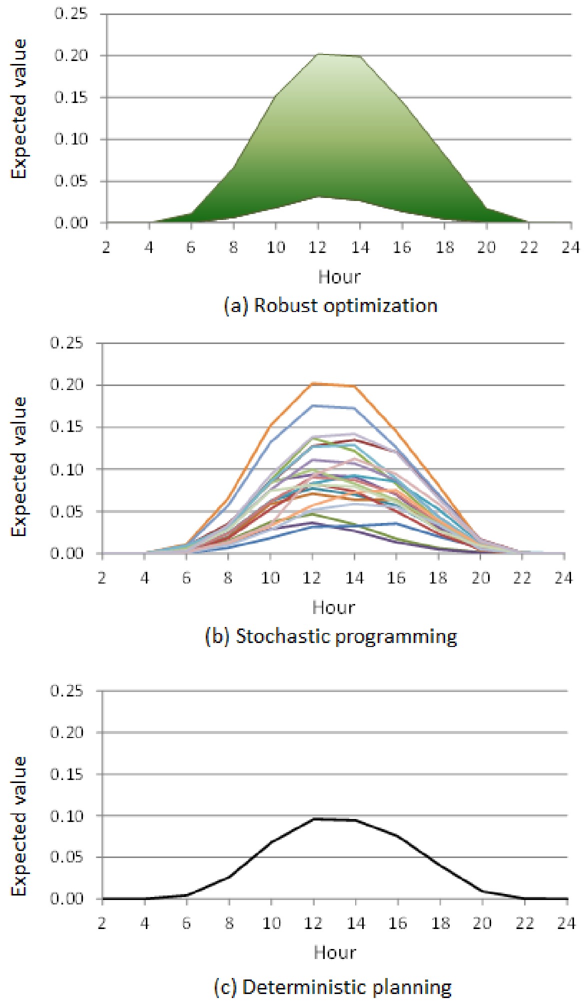
Decision making under uncertainty

- Robust optimization
- Stochastic programming
- Deterministic planning (with a high optimization frequency)



(a) Robust optimization
(b) Stochastic programming
(c) Deterministic planning

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