FLEXIBILITY MANAGEMENT FOR INDUSTRIAL ENERGY SYSTEMS

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Energieflexibilität als Chance für kleine und mittlere Unternehmen

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AGENDA

1. Energy flexibility in industry
2. Energy flexibility measures & market opportunities
3. Decision model & assessment approach
4. Case study & discussion
5. Conclusion

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1. Energy flexibility in industry
Problem statement

- European key target for 2030: at least 55% cuts in greenhouse gas emissions (from 1990 levels)[1]
- Renewable and decentralized generation has changed the characteristics of the electric energy grid.
- Industrial sector presents benefits for the grid thanks to the utilization of facility inherent flexibility [2, 3]:
  - reduction of generation capacity requirements
  - higher security of supply and higher grid reliability
  - widened competition for the provision of balancing services
  - reduced energy supply costs.
- But how can the industry contribute in practice?

[1] European Commission 2020; [2] O'Connel et al. 2014; [3] Sauer et al. 2019

1. Energy flexibility in industry
Problem statement

- From the industrial consumer's point of view, it is fundamental to:

Identify the flexibility in local industrial processes [1,2]

Energy flexibility measures (EFM)

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Energy Flexibility Audit

Identify where the flexibility can be offered [3]

Demand response opportunities on the energy market

Quantitevely assess the economic profit from offering flexibility

Decision model and economic assessment of flexibility for demand response and markets

In literature, decision models mostly lack generic definition of industrial flexibility and focus on single configuration of energy markets and tariffs → decision model for EFM cost-efficient use in multiple markets and demand response opportunities

[1] Sauer et al. 2019; [2] Tristan et al. 2020; [3] Bianchini et al. 2021

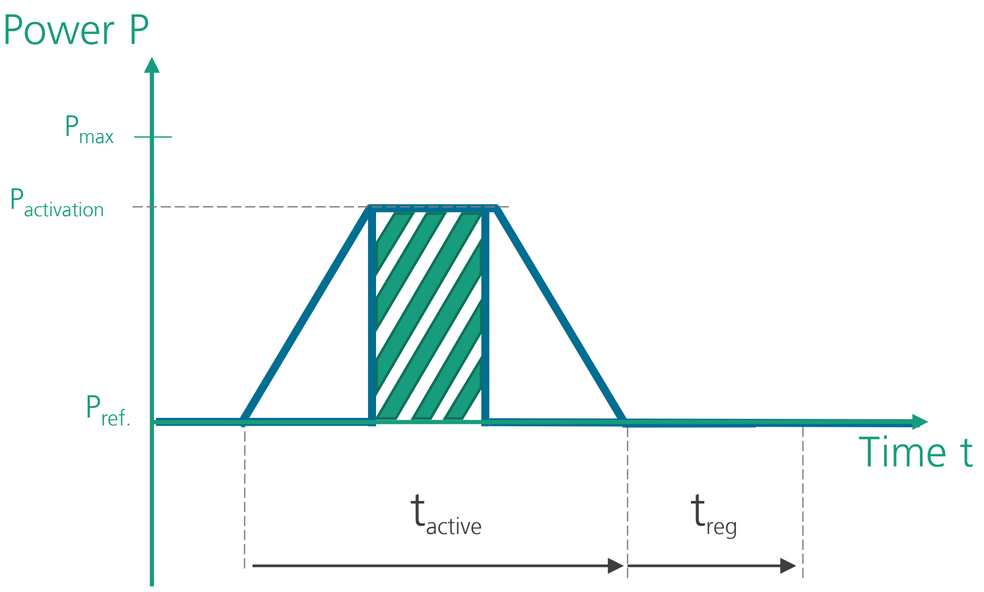
2. Energy flexibility measures & market opportunities
Definition of energy flexibility measures

Energy Flexibility Measures (EFM) [1]:

concrete and conscious actions on industrial processes that end up in a variation of consumption at the connection point

Parameter	Unit	Description
Direction	↕, ↑, ↓	Load variation: load reduction (↓), load increase (↑), load shift (↕)
$P_{EFM,min}$	kW	Minimum EFM activation power
$P_{EFM,max}$	kW	Maximum EFM activation power
$t_{EFM,active,min}$	s	Minimum EFM activation time
$t_{EFM,active,max}$	s	Maximum EFM activation time
$t_{EFM,regen,min}$	s	EFM regeneration time
$SOC_{EFM,min}$	%	Minimum state of charge of EFM, if modelled as a storage system
$SOC_{EFM,max}$	%	Maximum state of charge of EFM, if modelled as a storage system
$c_{activation}$	€/kWh	EFM activation costs based on the activated flexible energy

Table 1: Descriptive parameters of energy flexibility measures (EFM) based on power, time and costs [1, 2].



Representation of flexibility through standard parameters provides common basis for flexible device comparison, information exchange, and computation speed

[1] Sauer et al. 2019; [2] Tristan et al. 2020

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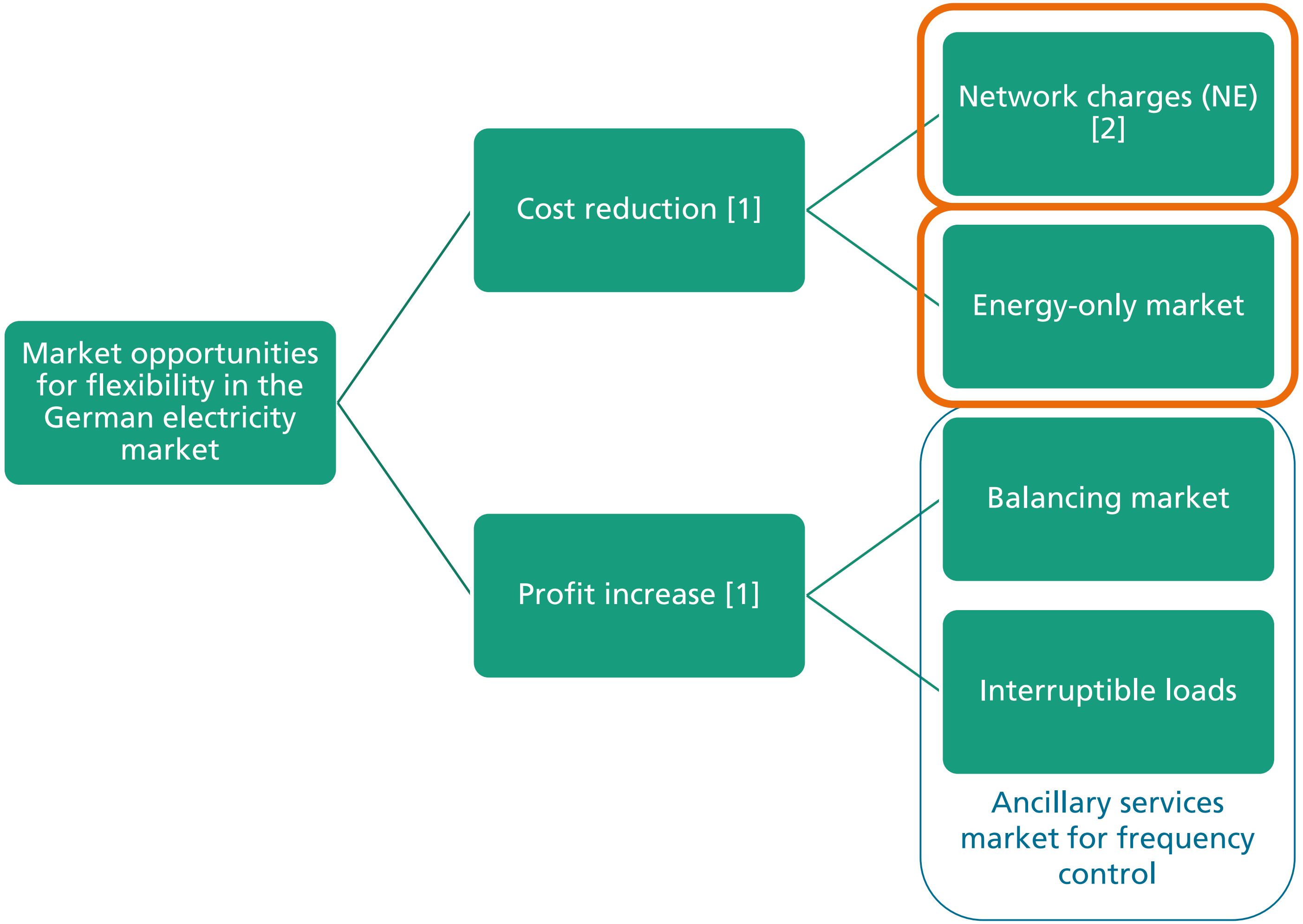
2. Energy flexibility measures & market opportunities
Market opportunities overview



- Costs for grid construction, operation and maintenance
- Intuitive calculation based on yearly consumption and yearly maximum peak load
- Individual network charges agreements possible → atypical network usage (AN)

- Long-term energy purchase on forward market
- Short-term energy trading on day-ahead market (DAM) and intraday market

Investigation of demand response strategies including network charges with trading strategies, such as the day-ahead market, or other long-term energy purchasing, is rare → NE + DAM investigated

[1] Bianchini et al. 2021; [2] Zimmermann et al. 2019

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3. Decision model & assessment approach
Decision model

- Decision model for the cost-efficient utilization of EFM for industrial systems
- Mixed-integer linear programming (MILP) solver
- Time interval t: 15 minutes
- Aim: at every time step decide whether it is the optimal time to activate EFMs for maximum energy cost reduction
- Applicable to other industrial facilities due to standard definition of flexibility

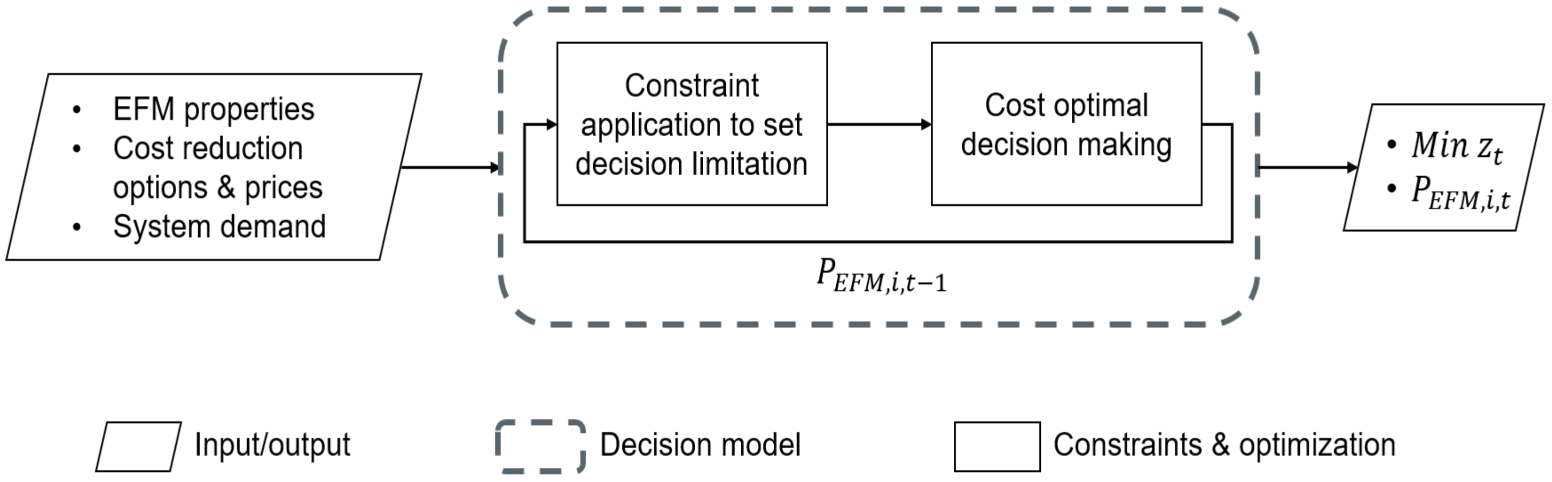


Figure 1: Overview of the decision model logic determining optimal energy flexibility measures (EFM) activation for each time step t. Results are the activation profile of each $i-th$ energy flexibility measure ($P_{EFM,i,t}$) and the relative costs, the optimized load profile at grid connection point and energy purchase costs over year T ($Min\ z_t, \forall t \in [1, T]$).

3. Decision model & assessment approach

Assessment approach

- Comparison of multiple combinations of demand response and purchase strategies → 12 scenarios
- Reference scenario: purchase and demand response strategies (without network charges reduction) with no activation of energy flexibility measures
- Standard purchase strategy adopted by the investigated company: long-term purchase on forward market and short-term purchase through retailer (fixed price) → RS2
- Comparison based on parameter $Index$:

$$Index = \left(\frac{C_{overall,scenario}}{C_{overall,RS}} - 1\right) \cdot 100$$

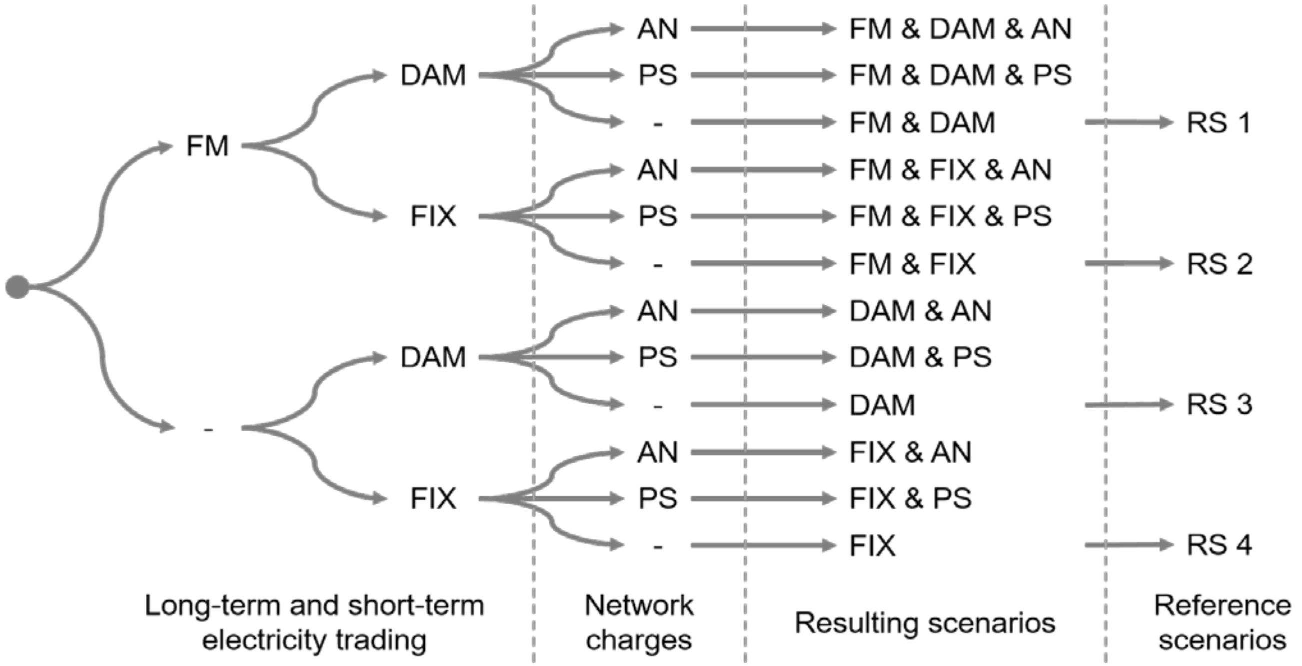


Figure 2: Branch graph of examined purchase strategies and cost reduction options.

- *FM: forward market for long-term energy purchase.*
- *FIX: energy purchase fixed price agreed with retailer.*
- *DAM: day-ahead market.*
- *AN: atypical network usage.*
- *PS: peak shaving for reduction of network charges.*
- *RS: Reference scenario.*

4. Case study and discussion
Considered industrial facility and relevant flexibility

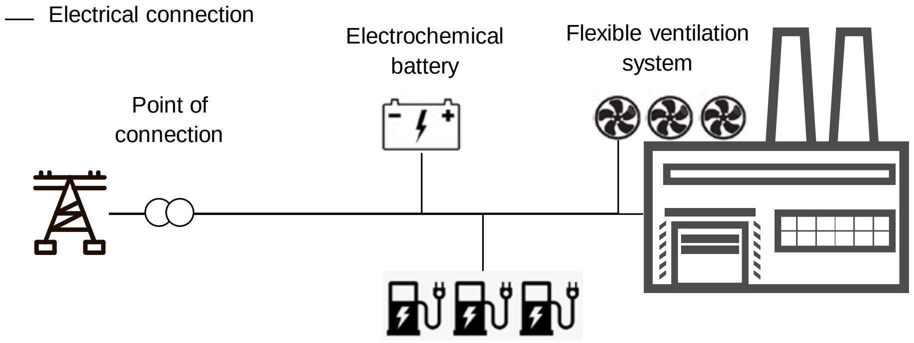


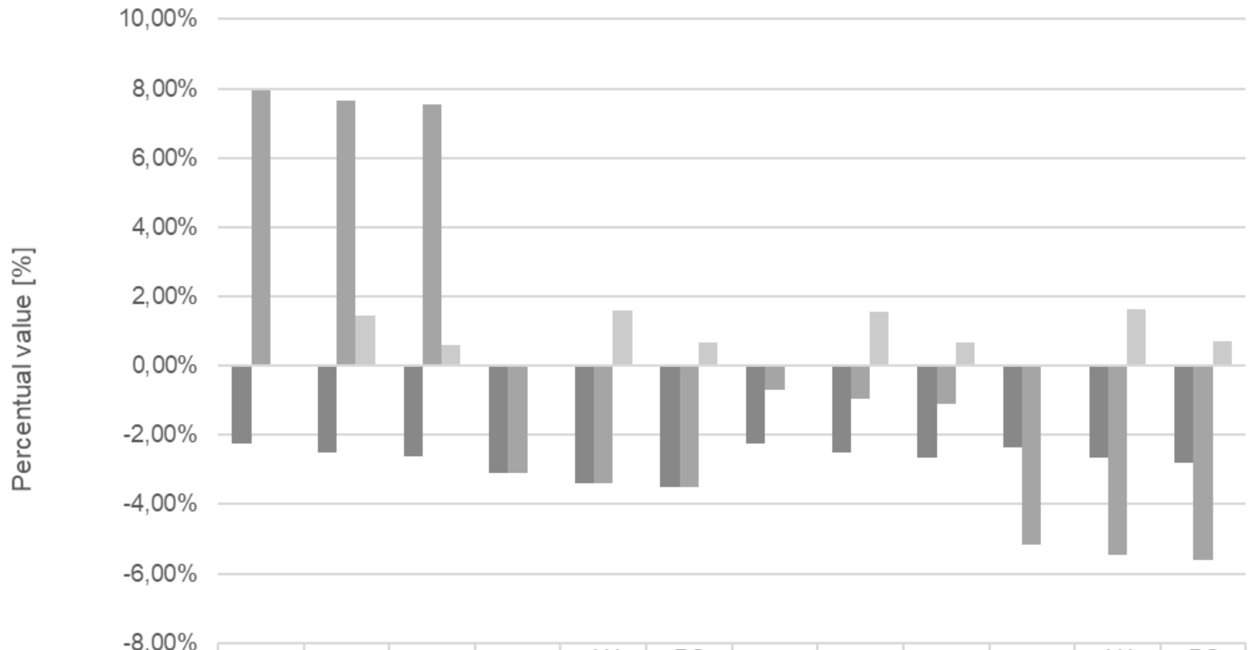
Figure 3: The case study for the decision model considers an industrial facility including an electrochemical battery, EV charging stations and a flexible ventilation system.

Parameter	Unit	EFM1: Ventilation system	EFM2: Ventilation system	EFM3: Charging stations	EFM4: Storage system
Direction	↕, ↑, ↓	load increase	load decrease	load increase	load shift
$P_{EFM,min}$	kW	0	0	0	0
$P_{EFM,max}$	kW	300	300	350	2.500
$t_{EFM,active,min}$	s	0	0	0	0
$t_{EFM,active,max}$	s	432.000	1.800	SOC dependent	SOC dependent
$t_{EFM,regen}$	s	0	1.800	SOC dependent	SOC dependent
$SOC_{EFM,min}$	%	-	-	50	10
$SOC_{EFM,max}$	%	-	-	100	90
$C_{activation}$	€/MWh	5,83	2,55	22,62	1.073,22

Table 2: Case study energy flexibility measures (EFM) specifications according to the descriptive parameters of Table 1.

4. Case study and discussion
Discussion of the results

- Energy flexibility measures activation reduces energy costs in all scenarios
- Maximum reduction through peak shaving and energy purchase on forward and day-ahead markets
- High fixed prices cause high energy purchase prices compared to the standard strategy (RS2)
- When network charges reduction is a goal, expensive energy flexibility measures (storage) are activated
  - Higher activation costs, but
  - Reduced overall energy purchase costs



	FIX	AN FIX	PS FIX	FIX-FM	AN FIX-FM	PS FIX-FM	DAM	AN DAM	PS DAM	FM-DAM	AN FM-DAM	PS FM-DAM
Comparison with respective RS	-2,25%	-2,51%	-2,64%	-3,10%	-3,38%	-3,52%	-2,23%	-2,50%	-2,65%	-2,35%	-2,64%	-2,79%
Comparison with RS2	7,94%	7,66%	7,52%	-3,10%	-3,38%	-3,52%	-0,68%	-0,96%	-1,11%	-5,18%	-5,46%	-5,60%
Activation costs over the total	0,04%	1,44%	0,61%	0,04%	1,60%	0,68%	0,04%	1,57%	0,66%	0,04%	1,64%	0,69%

Figure 4: Simulation results for each scenario with energy flexibility measures (EFM) activation. The total costs are compared to the respective reference scenario (RS) and to the reference scenario based on the forward market and fixed price (RS2). Total EFM activation costs as a percentage of the total costs are shown.

5. Summary and conclusion

- This paper:
  - proposes decision model for optimizing energy flexibility measures (EFM) activation to reduce energy costs
  - optimizes costs for energy purchase and for multiple EFM activation in multiple markets (complexity)
  - assesses the positive effect of demand response for industrial companies, in particular for network charges reduction

- Further research should (limitations):
  - investigate optimization step over a longer period, such as one day
  - pursue more realistic representation of the decision model in real-time (bidding phase, price uncertainty)
  - include risk-evaluation strategies to reduce price volatility risk

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