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Load increase vs. load reduction: the impact of load shifting on the CO_2 reduction potential in the context of industrial demand-side flexibility

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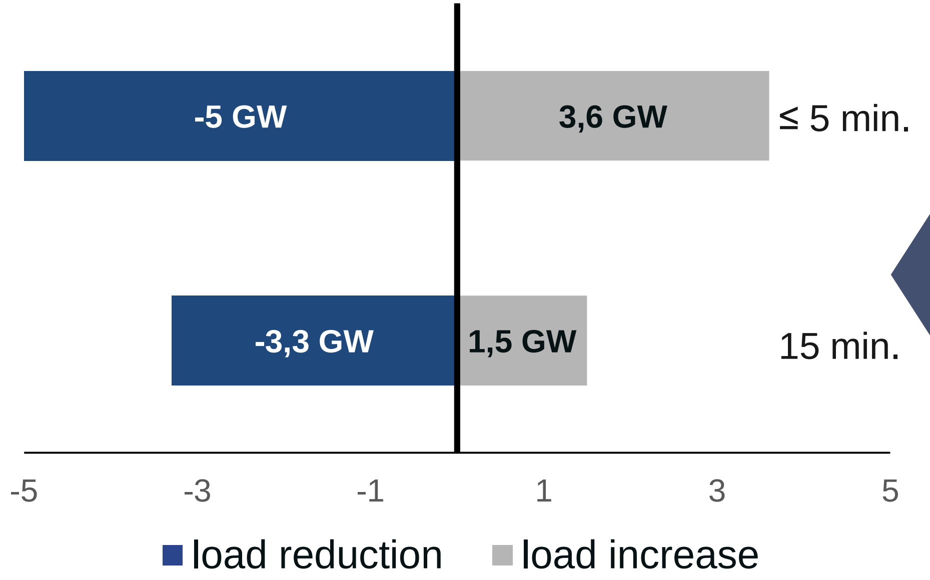
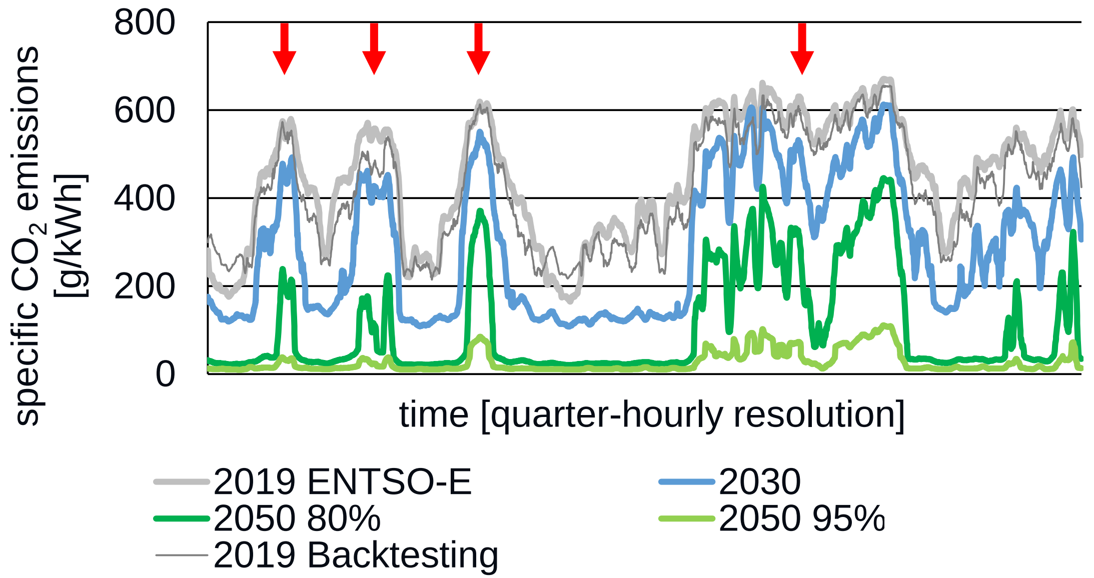
Motivation

Flexibility potential in German industry [2]



Specific CO_2 emissions for electricity mix scenarios examined by Zachmann & Seifermann [1]

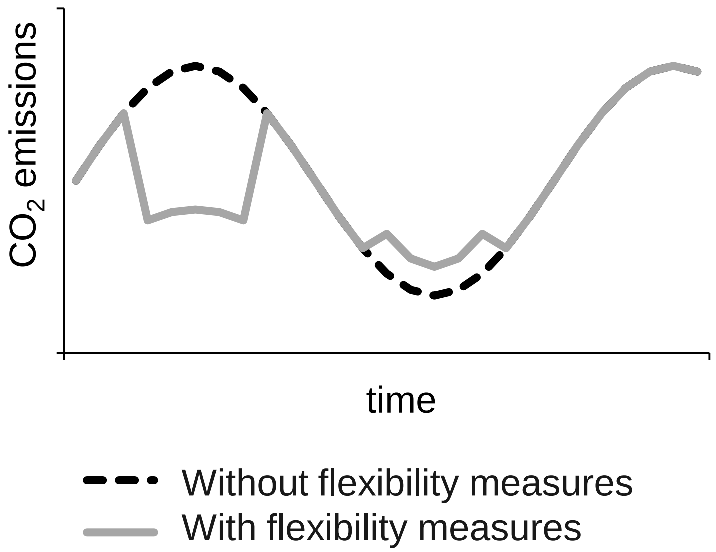


Hypothesis: „Short-term load reduction will play an increasing role in the future energy system, while short-term load increase will be of subordinate importance.“

Methods (1) – calculation of potential savings of CO_2 emission and cost [1]

- **Indirect CO_2 reduction** through improved utilization of existing generation capacities:
  - **Shifting work** from periods of **high** specific emissions **to** periods of **low specific emissions**
  - **Compensation** for work on **average specific emissions**
- **Calculation** of the possible **CO_2 reduction potential** of a flexibility measure with the retrieval duration *n* at time *i*
- **Equivalent procedure** for **determining** the economic benefits or **cost savings** of load shifting at time *i*

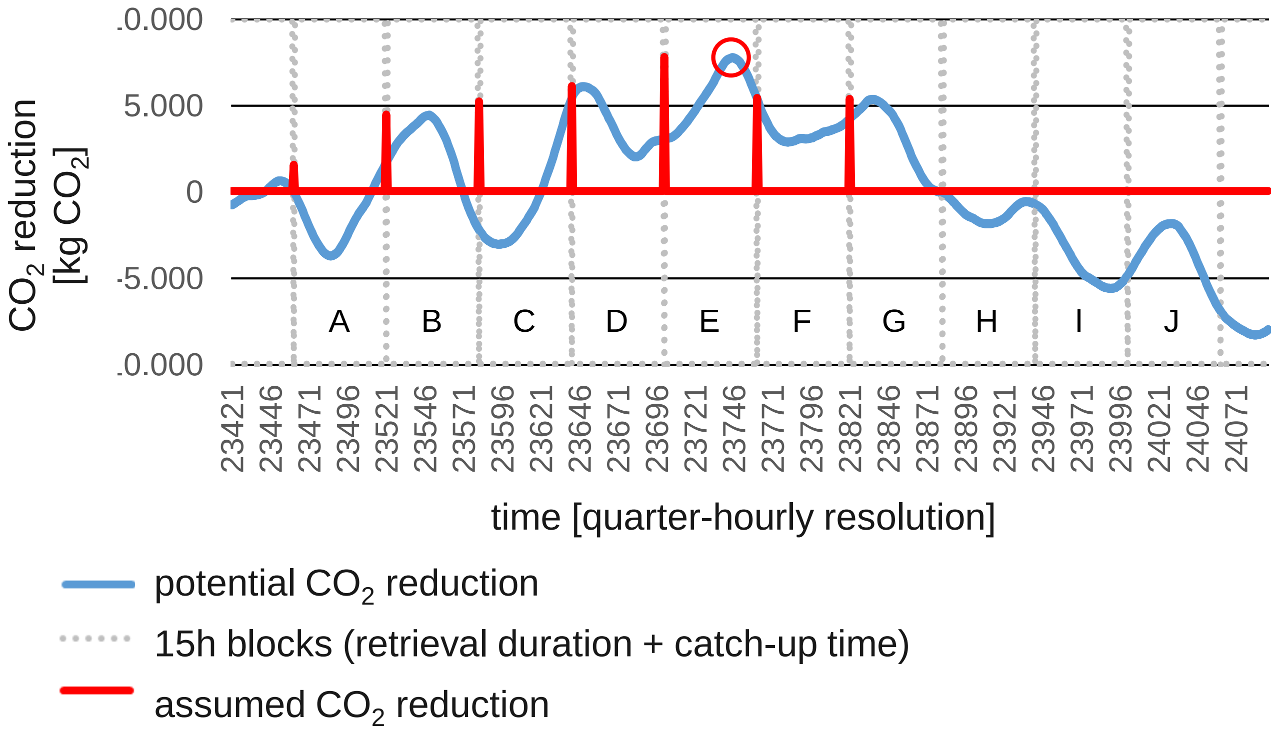
Exemplary emission curve



$$CO_2\ reduction\ potential_i = \sum_i^{i+n} load\ change_i * (-spec.\ emissions_i + average\ spec.\ emissions)$$

Methods (2) – annual CO_2 reduction and cost savings potential [1]

Time series of possible CO_2 reduction[1] [1]



[1] Extract from the load increase of a sample process in calendar week 36/2019

- **Introduction of blocks** to account for time restrictions:
  - Length: **retrieval cycle** consisting of retrieval duration and catch-up time
  - Value: **maximum** possible CO_2 reduction within block
- Aggregation based on annual **retrieval frequency *k***
- Annual **CO_2 reduction** and **cost savings potential**:
  - ***k* blocks** with **largest CO_2 reduction** potential
  - **Associated costs savings** of those blocks

Methods (3) – simplified electricity market modeling

Approach:

- **¼-hourly simulation** of the **electricity mix scenarios** for **2030 and 2045** based on ¼-hourly generation profile
- **Optimization** of operated generators based on residual load and merit order
- Introduction of an inflexibly operated **"must-run" share** for fine-tuning the generation series
- Aggregation of the **electricity prices** from generators' **marginal costs**
- **No** consideration of **negative electricity prices** → less likely to occur in the future [6]

Inputs:

- **Generation** and **demand profile** from **2019** from the *Energy-Charts* platform [3]
- **Net electricity generation** and **electricity demand** for the **target years** from the study *Towards a climate-neutral Germany by 2045* by Agora Energiewende [4]
- **Power plant portfolio** and (modified) **merit order 2021** from the *Merit Order Tool* [5]

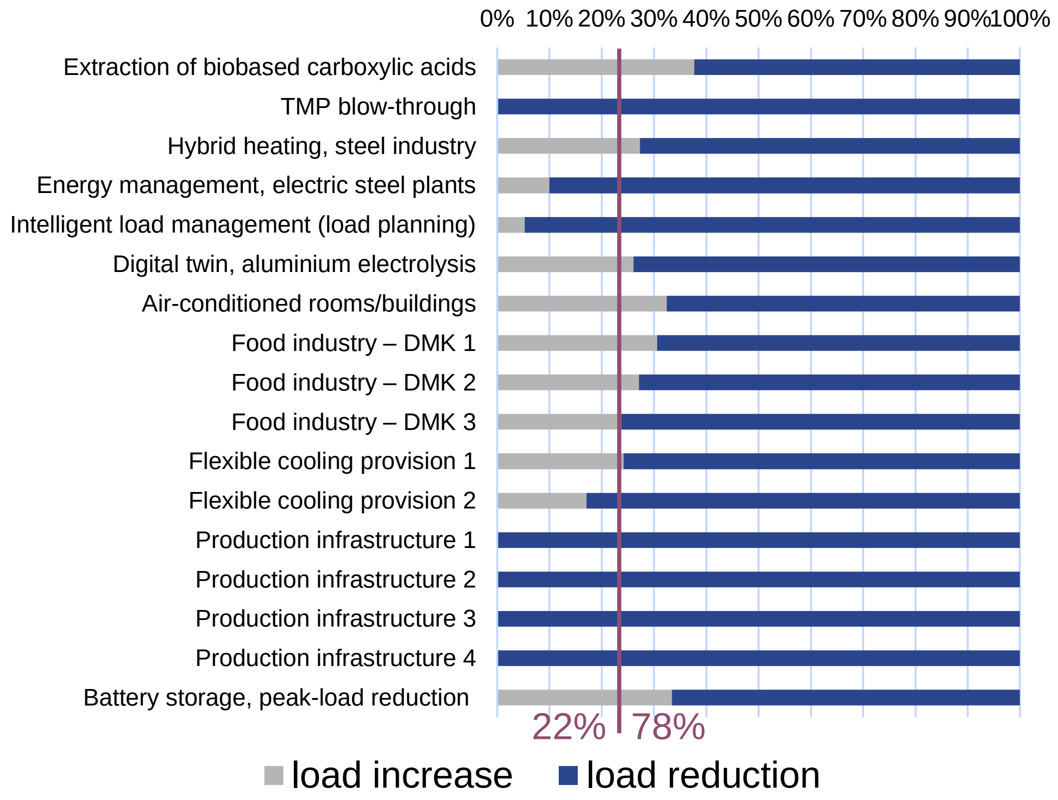
Data basis – industrial flexibility measures

- Basis: data collection of **flexibility potentials** in the context of the Kopernikus project **SynErgie**
  - 36 industrial flexibility measures from 20 industries
  - Up to eight use cases per flexibility measure
- **Calculation** of **CO_2 and cost reduction potential** for specific use cases and aggregation to overall results:
  - Only measures that allow a **combination** of load reduction and load increase
  - The **maximum CO_2 reduction** from the combination and the **associated cost savings** are determined for each block
  - The annual CO_2 and cost savings are then calculated from the *k*-largest CO_2 reduction potentials of this combination (based on retrieval frequency *k*)

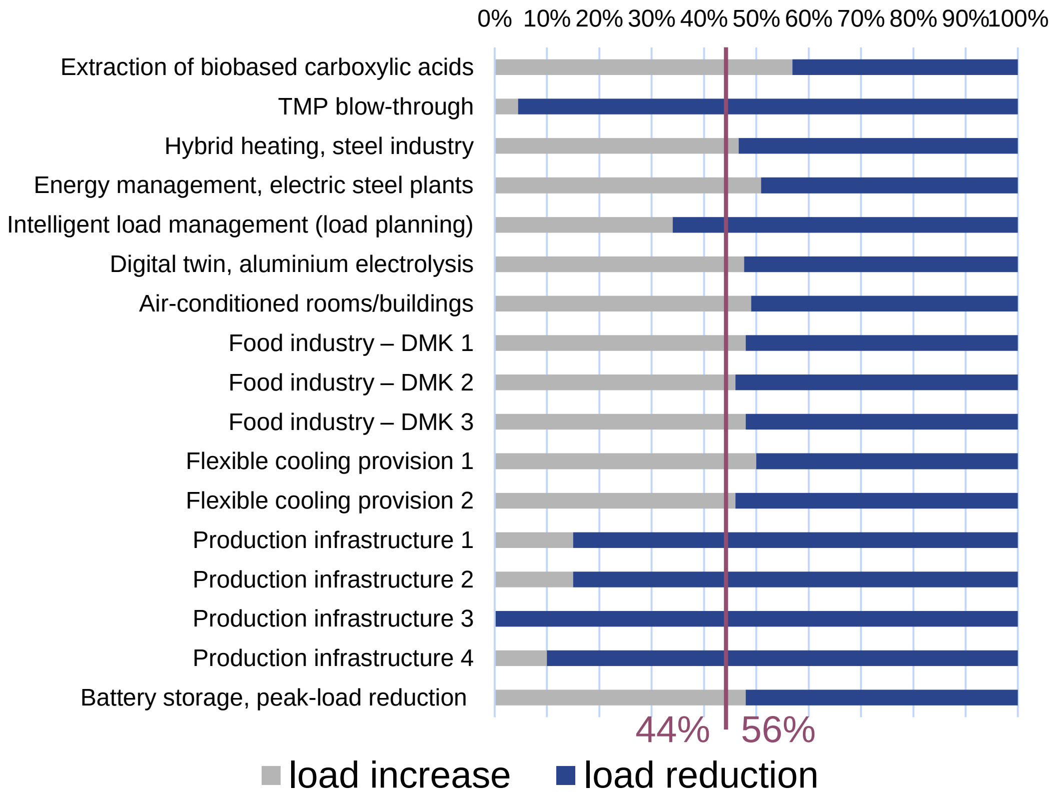
Example measure	**Load reduction**	**Load increase**
Load change [kW]	4,000	4,000
Retrieval duration [h]	10	10
Catch-up time [h]	5	5
Retrieval frequency [1/a]	365	365

Results (1) - shares of load reduction and load increase in combinations

CO_2 reduction potential 2030

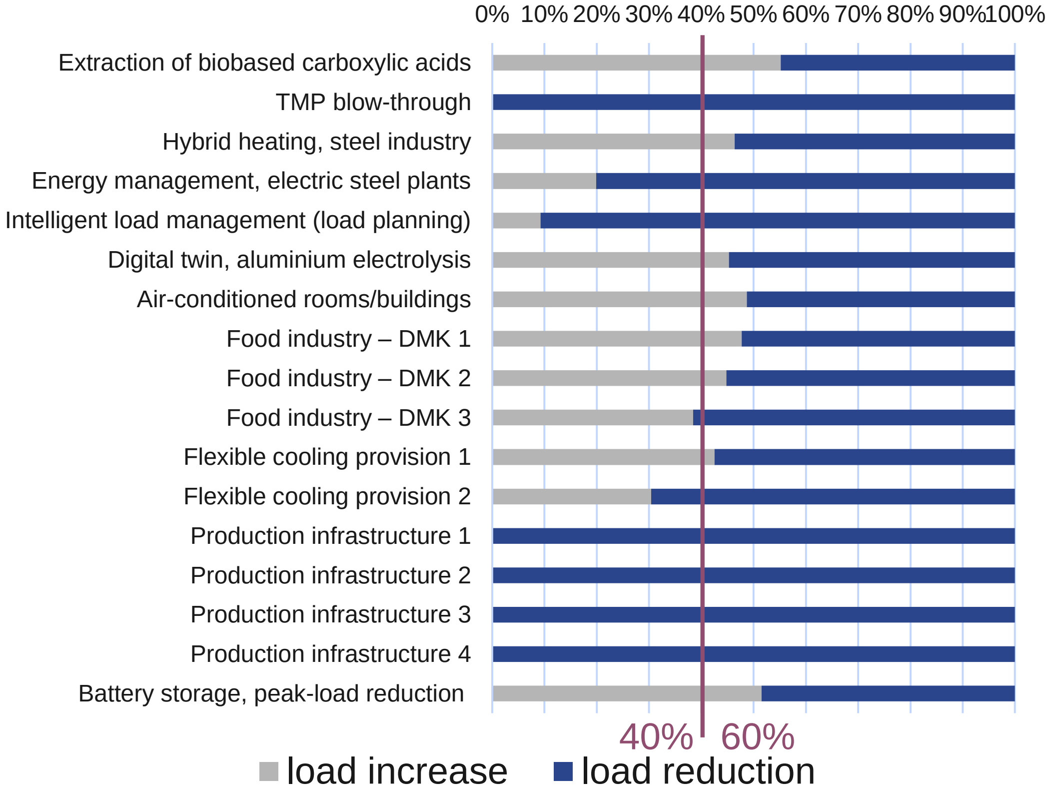


CO_2 reduction potential 2045

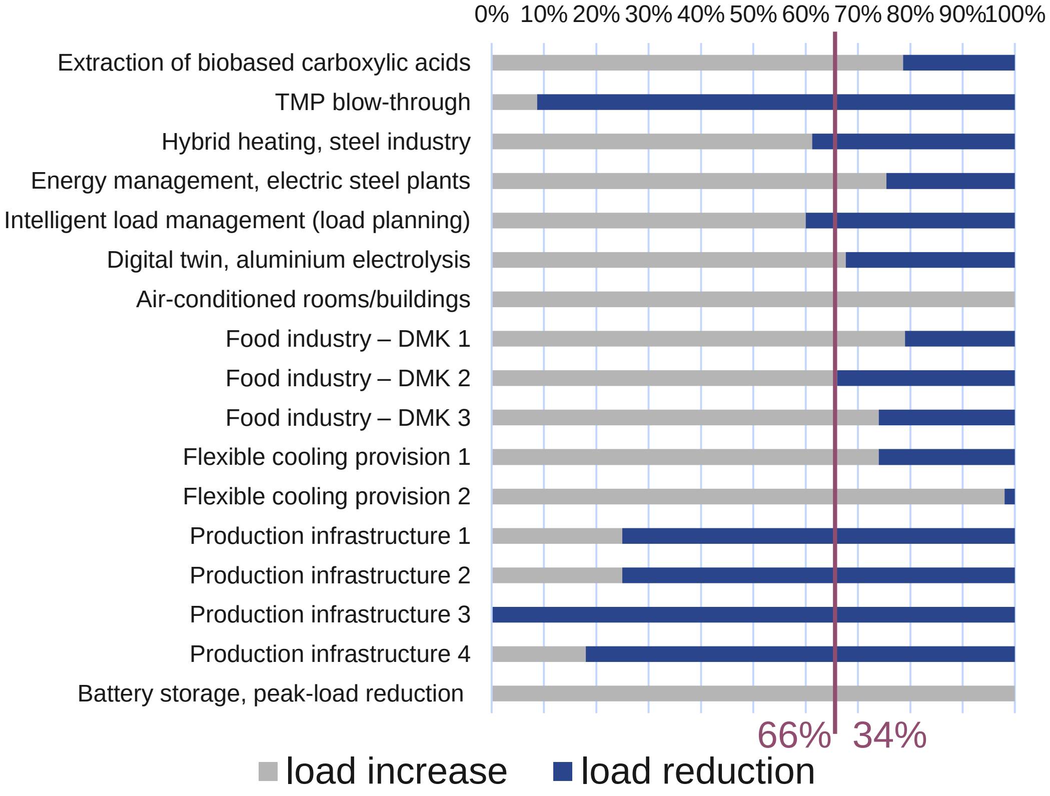


Results (2) - shares of load reduction and load increase in combinations

Cost savings potential 2030



Cost savings potential 2045



Results (3) – overview CO_2 reduction and cost savings potential

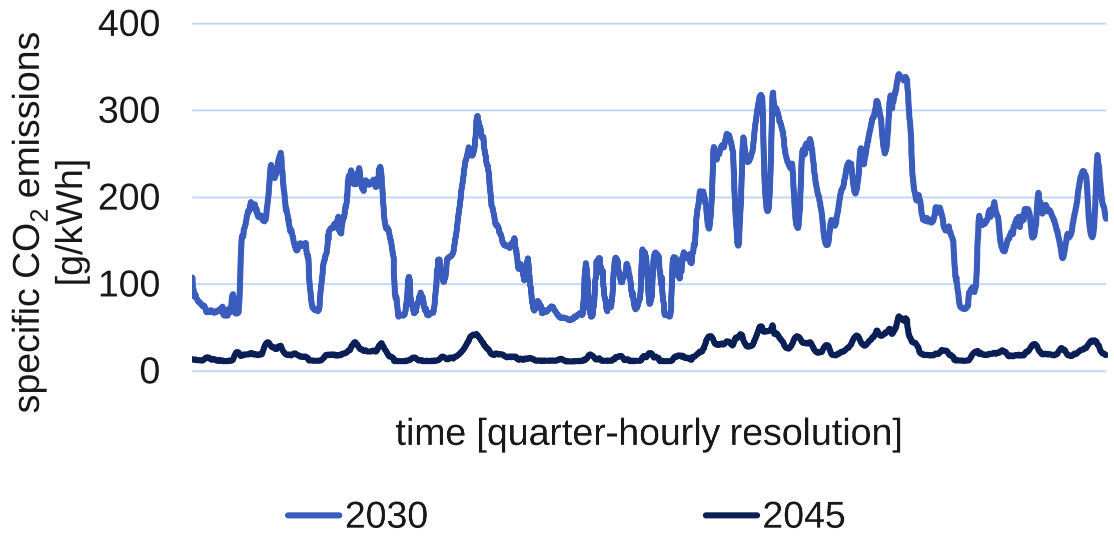
- **Decreasing importance of load reduction** for both CO_2 reduction and cost savings comparing 2030 to 2045
- Load increase with comparatively (comparison of total annual CO_2 reduction and cost savings) large share of cost savings → **Economic potential greater with load increase than with load reduction**

		CO_2 reduction [kg CO_2/a]			Cost savings [EUR/a]		
		Load increase	Load reduction	Total	Load increase	Load reduction	Total
2030	Absolute	29,612,117	102,192,795	131,804,912	49,315,100	72,984,172	122,299,272
	Percentage	22%	78%	100%	40%	60%	100%
2045	Absolute	8,209,108	10,303,880	18,512,987	49,675,834	25,708,766	75,384,599
	Percentage	44%	56%	100%	66%	34%	100%

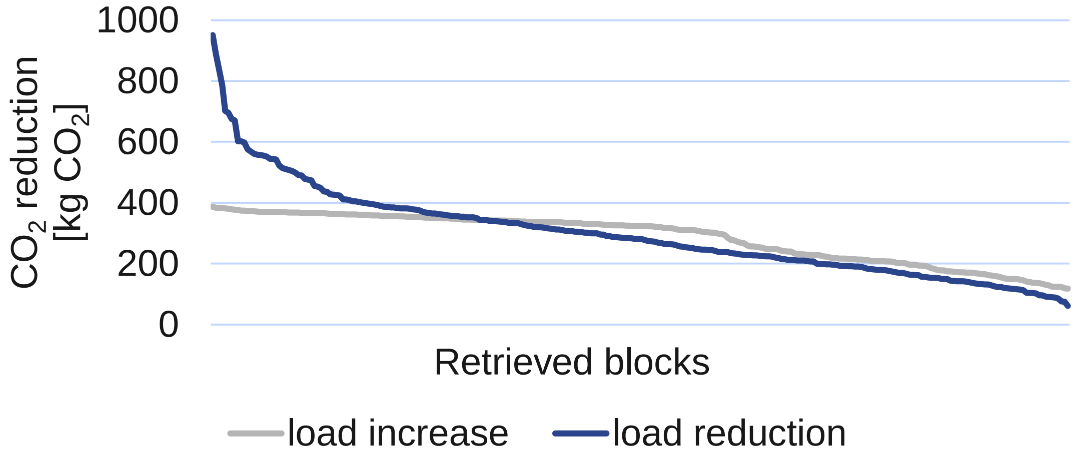
Discussion – influence of CO_2 emission peaks on reduction potential

- **CO_2 emission peaks** go hand in hand with high CO_2 reduction potential through load reduction
- After peaks are trimmed, the specific CO_2 reduction potentials of **load reduction and load increase** approach each other and **compete** in terms of **maximum CO_2 reduction**

specific CO_2 emissions (excerpt)



***k* blocks with largest CO_2 reduction (2045)**



Conclusion

? **Hypothesis:** „Short-term load reduction will play an increasing role in the future energy system, while short-term load increase will be of subordinate importance.“

- The **share of load reduction** regarding the CO_2 reduction potential and the possible cost savings is **decreasing**. This is due to the fact that the severity and frequency of **CO_2 emission peaks is decreasing**. Nevertheless, the **CO_2 reduction potential of load reduction is higher than that of load increase** in both future scenarios.
- Concerning the cost savings, a **higher economic potential** was identified **for load increase measures**. This is due to the **price range** determined as part of the **electricity market modeling and the methodology** used to shift work to average costs.

The comparison of the CO_2 reduction potential and associated cost savings does not support the initial hypothesis

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Please do not hesitate to contact us if you have any questions.

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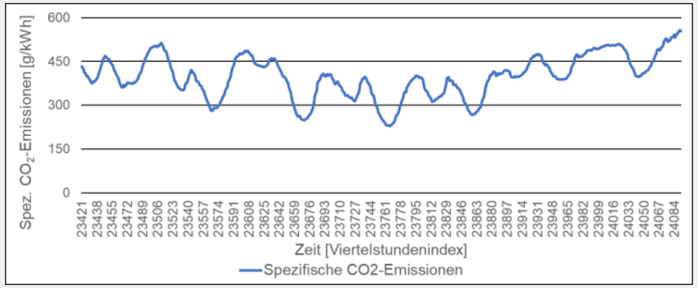
Back-up

Methodik (3) – Beispielprozess [1]

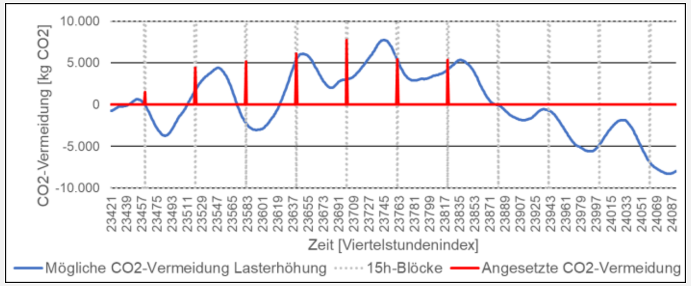
Parameter Flexibilitätsoption

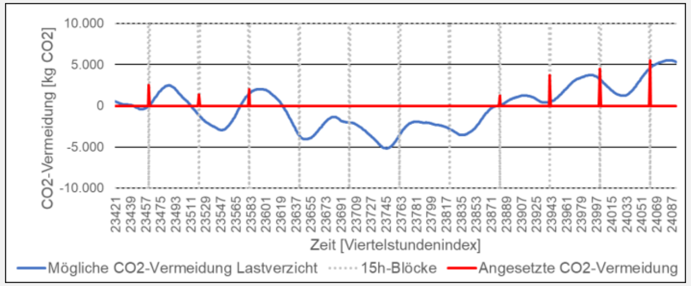
Beispiel-Prozess	Lastverzicht	Lasterhöhung
Leistungsänderung [kW]	4.000	6.000
Abrufdauer [h]	10	10
Nachholzeit [h]	5	5
Abrufhäufigkeit [1/a]	365	365

Spezifische CO_2-Emissionen[1] [X]



Mögliche CO_2-Vermeidung[1]





CO_2-Vermeidungspotential

Beispiel-Prozess	*CO_2-Vermeidungs-potential [kg CO_2]*
Lastverzicht	2.405.409,67
Lasterhöhung	1.649.252,34
Kombination	3.000.659,26
Gesamt-Ergebnis	**3.000.659,26**

[1] Auszug KW 36/ 2019

Discussion (2) – influence on cost savings potential

- The shift of work to average costs by **load increase** represents a **higher potential for cost savings**
  - **Background:** Larger difference between the lowest specific costs of 0 EUR/MWh and the mean value of 114 EUR/MWh
- **Based on the applied electricity market modeling**, a high economic potential for load increase can be derived