NEW ENERGY FOR INDUSTRY

Industry4Redispatch

Industry4Redispatch (I4RD)

Deliverable 3.4

Estimated industrial redispatch potential

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

CSTs - Cross-sectoral technologies

fle - Full-load equivalent

1. Introduction

Aim of this document is to summarize the activities and results of Task 3.3 (Analysis and design of engagement strategies for industrial customers) and Task 3.6 (High-level analysis of redispatch potential in the Austrian industrial sector) in the project Industry4Redispatch.

The objective of Task 3.6 – High-level analysis of redispatch potential in the Austrian industrial sector – is to estimate the actual expected technical flexibility potential in the Austrian manufacturing industry. The motivation for this task is that the manufacturing industry is seen to have several advantages compared to conventional redispatch providing assets:

- the geographical distribution of sites, whose decentralized location can be used in the event of bottlenecks in the distribution network.
- production processes have the potential to provide flexibility, such as load shifting, reduction, or increase, while at the same time reducing emissions.
- Ability to provide services for a shorter minimum run time than thermal generation units.

Estimating the technical flexibility potential is based on preliminary studies, a comprehensive literature review and numerous expert assessments. Special attention is paid to the quantification of the technical potentials in industrial processes, cross-sectional technologies and self-generation plants of the industry, their expected call-up durations, and the geographical distribution of flexibility among the federal states.

The remainder of this document is organized as follows. Section 2 gives an overview and background information on flexibility in industry in general and the possible use of industrial flexibility for redispatch and congestion management as well as a summary of the most relevant definition of terms. In Section 3 the method to estimate the Austrian flexibility potential is presented, followed by a presentation of the results in Section 4.

In addition, a summary for the analysis and activities in Task 3.3 is given. Activities performed to identify incentives for redispatch provision, and their outcomes are summarized in Section 5.

2. Background

A short introduction in the topic of flexibility in the context of industrial system and the applied terms and definitions is given.

2.1. Flexibility in industry

Flexibility in the context of power systems in general and specifically for power grids and manufacturing industries has been discussed in the literature for decades. From the perspective of the power system, flexibility is often traded as a success factor for decarbonizing power generation. In the manufacturing industry, flexibility is sometimes seen primarily as a competitive advantage to realize economic operation. Figure 1 provides a brief insight into the various keywords used in the context of "flexibility in the energy system", without claiming to be exhaustive.

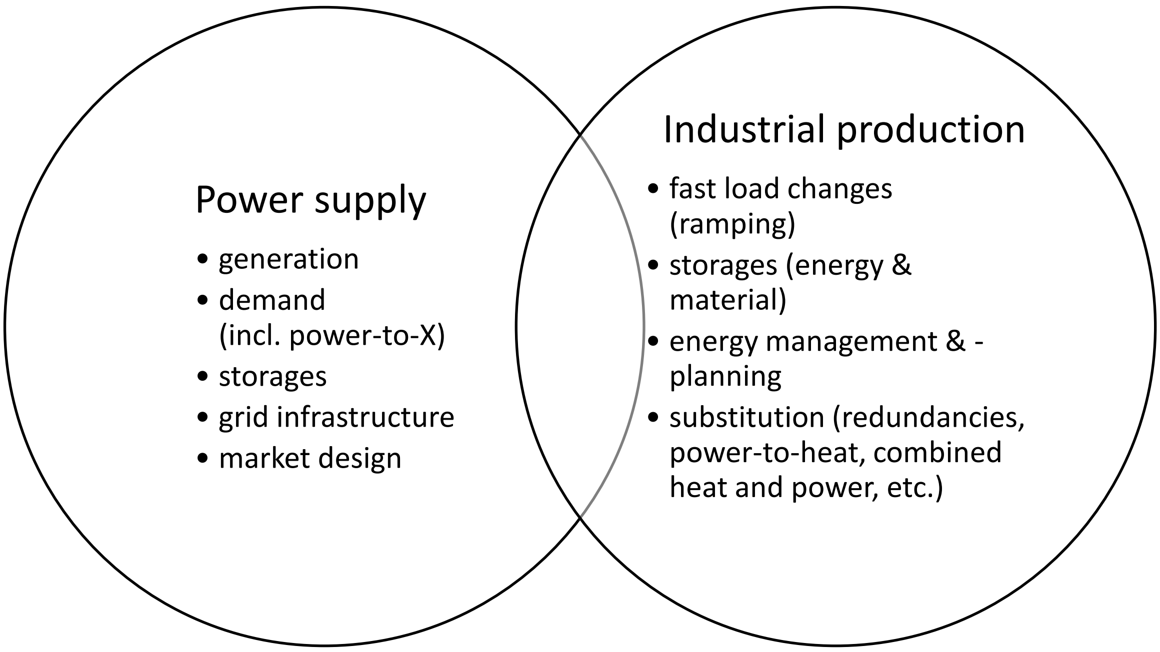


Figure 1: Exemplary excerpt of keywords in the context of flexibility in the energy system

According to scientific publications, flexibility in general can be attributed the following properties and characteristics:

- Understanding and interpretation of flexibility are mostly strongly dependent on the perspective. To date, there is no uniform definition of flexibility in the context of the energy industry [1]. However, a common understanding is seen as a prerequisite to make the best use of flexibility [2–4]. This requirement is also supported by the creation of a VDI guideline in the subject area of *energy-flexible* factory [3,4] in the last three years.

- Luo et al. [5] evaluate flexibility as a "relative value". In general, one specification (e.g. a single plant or an entire energy supply system - the system boundaries can cover different areas) is more or less flexible than another. Compared to flexibility, other properties of a system, e.g. costs, emissions or primary energy consumption, are absolute values that can also be compared for different specifications (e.g. single plants or an entire energy supply systems - the system boundaries can cover different areas), but also allow an interpretation without comparison.
- Another property of flexibility is that it usually serves a higher purpose. In other words, there are typically incentives or goals (cf. [3,5]) to increase the flexibility of a specification.
- Golden and Powell [6] define flexibility as the ability of a system to adapt (*capability* instead of *capacity*) and as a polymorphic and multi-dimensional property of a system, whereby a corresponding definition has a clear meaning only through context and identified dimension.
- In a recent comprehensive review, Degefa et al. [2] present various definitions as well as classifications of flexibility. One conclusion of this work is the relevance of taxonomies for a comprehensive description of flexibility.

In general, industrial production systems and their subcomponents pose an important option of contributing flexibility to the electricity system (power grid). Both the industrial demand side (electricity-intensive processes of the core business but also cross-sectional technologies such as cooling supply and power-to-heat plants for process heat supply) and the storage and generation side through industrial self-generation (e.g. plants with combined heat and power) contribute to this.

2.2. Industrial flexibility for redispatch and congestion management

Flexibility of industrial plants, especially industrial self-generation plants, has already been marketed for several years, usually on spot or balancing energy markets, with *Flexibility Service Providers* often forming the interface between industry and market. In the following, already established marketing strategies are compared with an assessment of possible future framework conditions for the provision of industrial flexibility for congestion management i.e., redispatch.

Time component: For redispatch or congestion management, information about the deployment of a bid is usually provided on the evening of the previous day up to a maximum of a few hours before the time of flexibility delivery (activation of the bid). Consequently, start-up times and ramps can be planned for industrial operations. Balancing markets are different from congestion management as they are split in a balancing capacity and a balancing energy market. In the balancing capacity markets a capacity premium is awarded for a guaranteed participation in the balancing energy market. In the balancing energy market bids are placed for the delivery periods and the selection of bids takes place with a lead time of several hours (Picasso/MARI). The actual activation of energy-delivery for balancing however depends on the current imbalance in the system and therefore, information about an actual activation takes place automatically (<1 s before the call) or up to a few minutes before the activation. If flexibility is used to react to fluctuating prices on the day-ahead spot market, the procurement profile is also known the day before for the industrial operation. For trading on the intraday market, this span is shortened to a few minutes.

Economic component: When flexibility is marketed on the day-ahead spot market, predicting prices is usually an essential basis for an industrial operation. If algorithms are used to plan power purchases, mathematical optimization approaches with the objective function "minimum cost" are suitable, for example. For redispatch, from the current perspective, bids must include not only a power quantity but also associated costs that are then compensated. Thus, for the determination of flexibility, modified methods are required compared to flexibility marketing on the day-ahead market.

Geographic Component: The geographic location of a generation facility relative to the expected congestion affects how well the facility can contribute to removing the congestion. In contrast to the marketing of flexibility on the balancing energy market or spot markets, the position in the power grid within a control area thus plays a role in the marketing of redispatch.

2.3. Definition of Terms

Not least because of different views on the topic of flexibility, for example from the perspective of industrial companies or from the point of view of electricity suppliers, no uniform definition of the term exists to date [1,2]. In order to successfully tackle the challenges of the upcoming energy transition, all stakeholders need to develop a common understanding and a consistent definition of the terms used [2].

In this chapter, the most important terms according to VDI Guideline 5207 for the *Energy Flexible* Factory [3] are defined, delimited from each other and explained in more detail.

2.3.1. Definition of potentials according to VDI Guideline 5207 for the "Energy Flexible Factory"

Theoretical Potential: This is a "mathematical factor determined by the connected load of all forms of final energy" (note: in this case installed electrical loads).

Technical potential: Share of the theoretical potential that can be varied "within the scope of the technological conditions". This includes technical restrictions on power consumption and different time periods (request time, rise time, etc.).

Practical potential: This is a "subset of technical potential which takes into account factors such as regulatory and administrative obstacles."

Economic potential: Economically exploitable proportion of the technical potential.

Realizable potential: "Intersection of economic and practical potential".

Prospective potential: "Future potential which, though technically possible, is not yet in a mature state of readiness." Possible reasons are technical or regulatory barriers.

2.3.2. Strategies for load adaptation according to VDI 5207

Load increase and load reduction: Corresponds to an increase or reduction of power consumption compared to the reference operation, without the need for subsequently higher consumption to make up for energy losses. Energy losses occur e.g. in thermal or electrical energy storages when the energy consumption is shifted from one point in time to another - here the flexibility provision typically comes along with a catch-up effect.

Load Shift: Corresponds to an "increase or reduction in power consumption compared to reference case" where load catch-up (reverse direction at an earlier or / and later time) may be required. Here, also energy losses can occur in case of application of an energy storage. If production processes are shifted energy losses are less likely to occur.

The difference between load increase/reduction and load shift is depicted in Figure 2-2.

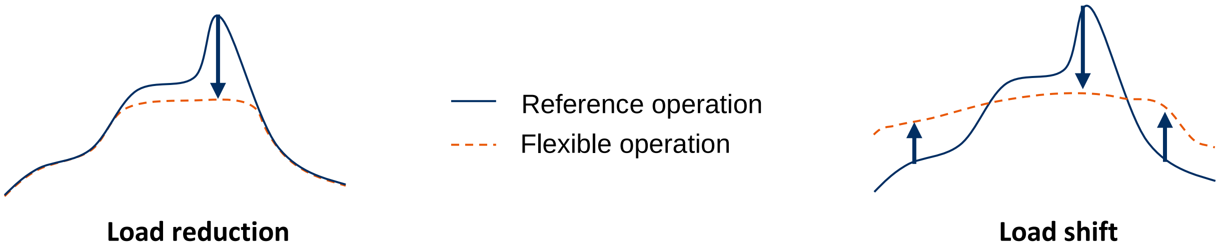


Figure 2-1: Difference between load increase/reduction and load shift

2.3.3. Positive and negative Flexibility

Positive flexibility: Due to reduced power consumption (industrial processes) and/or increased self-production of electricity (autoproduction plants), the power consumption at the grid connection point is reduced compared to the reference operation.

Negative flexibility: Due to increased power consumption (industrial processes) and/or reduced self-production of electricity (autoproduction plants), the power consumption at the grid connection point is increased compared to the reference operation.

Figure 2-2 shows an example of the actions by which plants can provide negative and positive flexibility in an industrial context. All types of industrial processes and CSTs (e. g. heating, ventilating and air-conditioning; pumps; compressed air systems …) can provide flexibility by either increasing or decreasing their load. On-site energy provision units include fossil and renewable energy generation units (e. g. battery storage, combined heat and power plants, steam, gas, photovoltaic, run-of-river hydro, …) and power-to-heat units (heat pumps, electro boilers) and therefore can provide all three kinds of flexibility.

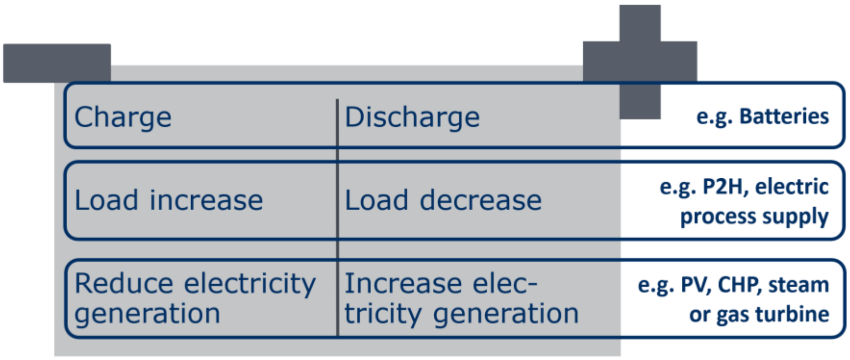


Figure 2-2: Types of negative and positive flexibilities in the industrial context (P2H – power to heat, PV – photovoltaic, CHP – combined power and heat unit)

3. Method to estimate Austrian industrial flexibility potential

In the following, the applied method is presented. First used references and the general workflow are described. Furthermore, the method to estimate installed (electric) capacities in the industrial sector, shares of installed capacities that can operate flexible and further limitations for flexibilization are presented.

3.1. References

Statistical databases

- Statistics Austria
  The annually published useful energy analysis (NEA) of Statistics Austria [7] provides a comprehensive insight into the use of all major energy sources in Austria's manufacturing industry. In this analysis, final energy consumption is broken down into four relevant dimensions. These are:
    - Industrial sector: 13 sectors of the manufacturing industry in Austria according to ÖNACE 2008 classification. These sectors[1] are:
        - Bau (Construction)
        - Bergbau (Mining and quarrying)
        - Chemie und Petrochemie (Chemical and Petrochemical Industry)
        - Eisen- und Stahlerzeugung (Iron and Steel)
        - Fahrzeugbau (Transport equipment)
        - Holzverarbeitung (Wood and wood products)
        - Maschinenbau (Machinery)
        - Nahrungs- und Genußmittel, Tabak (Food, tobacco and beverages)
        - Nicht Eisen Metalle (Non-ferrous metals)
        - Papier und Druck (Paper, pulp and Print)
        - Sonst. Produzierender Bereich (Non specified industry)
        - Steine und Erden, Glas (Non-metallic minerals)

[1] As the Austrian data base is used the German sector names are used in the remainder of this document – English sector names are stated in brackets)

        - Textil und Leder (Textiles and leather)
    - Useful energy category: energy use for process heat below or above 200 °C, stationary motors, lighting and IT, electrochemical purposes
    - Energy source: electric power, natural gas, diesel, coal, ...
    - Spatial resolution: federal state level
- Eurostat

  The data points from the statistical database of the statistical office of the European Union (Eurostat) [8] supplement the data from Statistics Austria with regard to the information on the installed capacity of autoproducer plants for electricity in the Austrian industry, the existing technology mix of these conversion plants and the electrical energy converted annually as a result.
- EU-ETS

  The European *Union Emissions Trading System* (EU-ETS) is the trading scheme for emission allowances used in the EU, which operates according to the "cap and trade" principle. By issuing a defined number of emission allowances, the permissible pollutant emissions of all plants subject to emissions trading are limited ("cap"). Emission allowances are either allocated free of charge by the member states or must be purchased in auctions. The possibility of trading these allowances provides an economic incentive to reduce emissions and thus monetize the emission allowances saved. Both the companies that are subject to emissions trading and the number of emissions allowances allocated to them are recorded in the emissions trading registry [9]. This allows companies with emitters, e.g. autoproducer plants, to be identified and their plant capacity to be estimated with domain knowledge.

Subsector load profiles

In the *DemandRegio* research project and a corresponding publication Seim et al. [10] derived 32 sector-specific electrical load profiles for industry and commerce using multiple regression analysis of more than 1100 measured load profiles from individual German economic sectors.

Literature

The estimation assumptions used in the following analysis are largely based on preliminary studies, such as a study on flexibility potential in Austria conducted for Energie-Control Austria [11] and extensive research in the relevant literature. This includes, among others, research activities within the SINTEG funding program (*Flexibilitätspotenziale und Sektorkopplung). Synthesebericht 1 des SINTEG Förderprogrammes* [12]) and publications by Forschungsstelle für Energiewirtschaft on *Merit Order der Energiespeicherung im Jahr 2030 [13,14]* . Other important references for the analysis include reports from industry associations, the Austrian Federal Environmental Agency (Umweltbundesamt), company presentations, and lecture slides.

3.2. General Workflow

The methodological approach used in the following analysis of the technical flexibility potential in Austria's manufacturing industry is shown in Figure 3-1. In a first step, the installed electrical plant capacity was derived, among other things, from statistical energy consumption data and compared and combined with existing bottom-up estimates. By assigning the flexible shares of the determined installed capacities based on expert assessments, literature and consultation with industry representatives, the technical flexibility potential was determined. In a subsequent categorization of the flexibilities according to temporal availability of different periodicity (intraday, daily, seasonal), a further top-down delimitation of the available technical potential was carried out. Due to the lack of information on internal processes, a final assessment of the practical flexibility potential is only possible by looking at the company level.

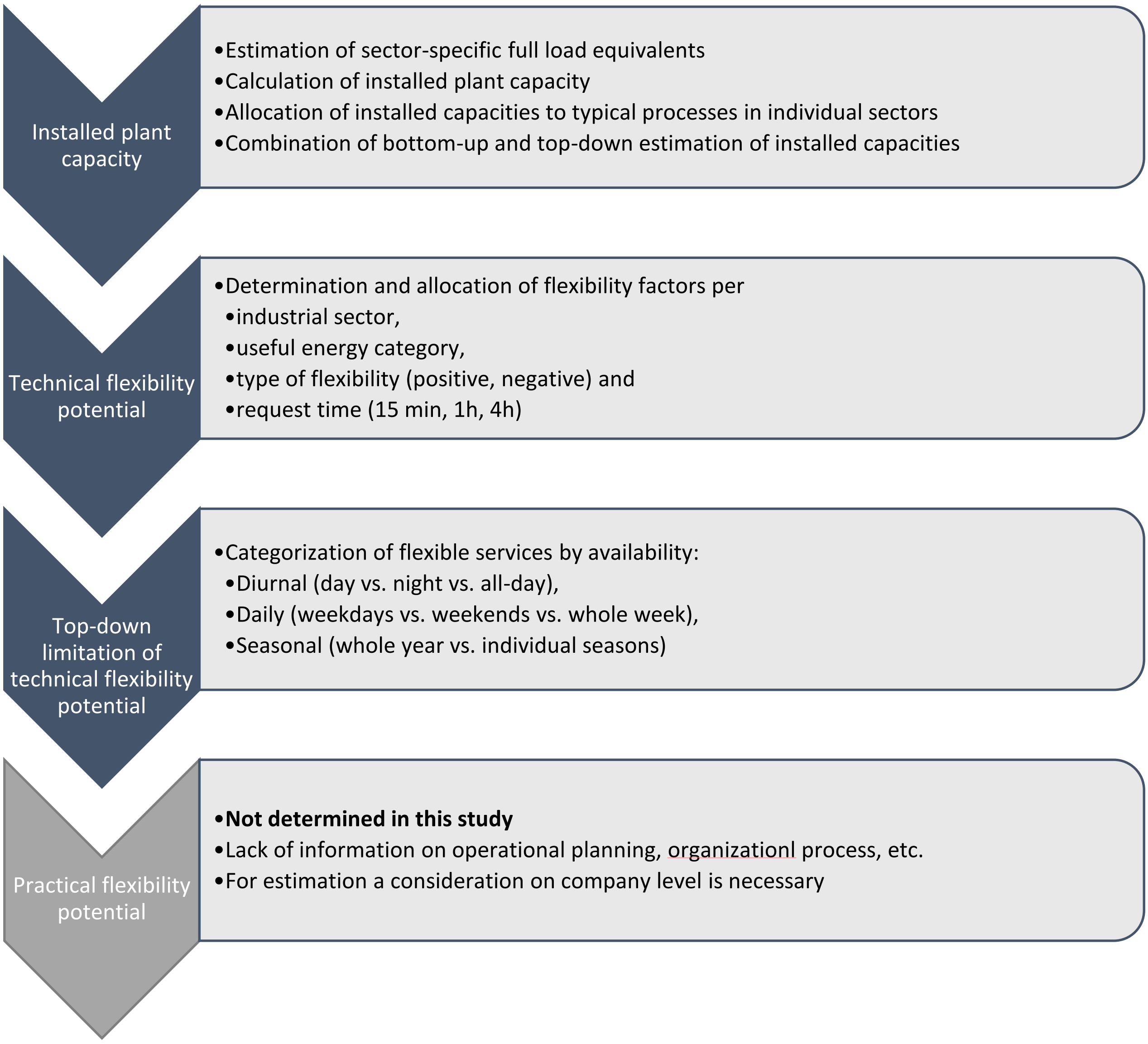


Figure 3-1: Procedure for estimation of the technical flexibility potential in the manufacturing industry in Austria. The practical flexibility potential can only be determined by detailed analyses at individual company level

3.3. Estimation of installed plant capacities

To determine an estimation of installed (electric) capacities in the Austrian industrial sector three relevant tasks need to be performed. As the annual electric energy is available for 13 sectors [7] and five usage groups in Austria an estimation of sector-specific full-load equivalents (Section 3.3.1) is necessary to derive installed power (Section3.3.2). With knowledge about electricity intensive production processes and their sites the installed capacities per usage group is corrected – for some provinces, sectors and usage groups the installed capacity is divided into power for energy-intensive process and residual power (Section 3.3.3).

3.3.1. Sector-specific full-load equivalents

For the following estimation of installed plant capacities in the sectors of the manufacturing industry in Austria, average sector-specific full-load equivalents T_{fle} were determined. On the one hand, these were determined by analyzing regression models of electrical load profiles from a wide range of German industries by Seim et al. [10] and on the other hand based on expert estimates. The concrete procedure is described in more detail below.

Subsector load profile analysis

Average full load equivalents of six of the 13 sectors of the manufacturing industry could be derived by analyzing load profiles of German industries by Seim et al. The load profiles were determined from industry load profiles recorded in 2018 using multiple regression and have a temporal resolution of one hour.

The average full load equivalents are calculated using the capacity factor a_S of the sector s according to the following formula:

$$a_S = \sum_{i=1}^{N} \frac{P_{\text{act,i,s}} * t}{P_{\text{max,s}} * t} = \frac{E_{\text{act,s}}}{E_{\text{max,s}}} \qquad \textbf{Eq. (1)}$$

N corresponds to the number of existing time steps (here, $N = 8760$) , t to the time step length in hours (here, $t = 1h$), $P_{\text{max,s}}$ to the maximum load occurring in the sector in the year under consideration and $P_{\text{act,i,s}}$ to the actual power demand occurring in the sector at the time step i, while i is in the range of $[1{,}8760]$. $E_{\text{act,s}}$ corresponds to the actual energy demand of the sector, $E_{\text{max,s}}$ corresponds to the fictitious energy demand of the sector for year-round ($N = 8760$) production with maximum load $P_{\text{max,s}}$.

The underlying assumptions and associated limitations of the analysis are:

- The load profile (qualitative trend) and capacity utilization of Austrian industry are in line with those of the German industry.
- Full load equivalents are by definition related to the rated capacity of plants. In this evaluation, it is assumed that the maximum load occurring in the sector corresponds to the installed nominal power in the sector. Simultaneity effects are not taken into account, which, in consequence, leads to an underestimation of the actual installed nominal capacity and thus an overestimation of the calculated full load equivalents.
- For six of 13 sectors no load profile is available.
- Sectors with a large number of subsectors may not be fully covered by the available load profiles.

A graphical representation of Eq. (1) is shown in Figure 3-2. Here, the load profile of a sector is shown in the form of a duration line. The capacity factor corresponds to the actual energy demand $E_{\text{act,s}}$ of an industrial sector in relation to the fictitious energy demand of the sector at full load over the entire year $E_{\text{max,s}}$.

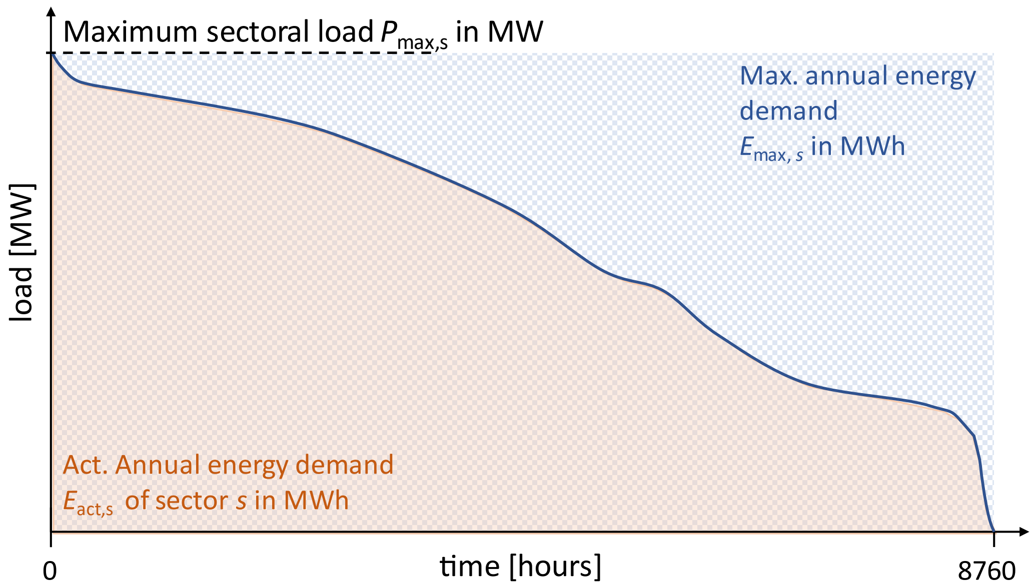


Figure 3-2: Generic load duration line of the industrial sector s. The capacity factor a_s corresponds to the quotient of $E_{act,s}$ [MWh] (orange area) and $E_{max,s}$ [MWh] (blue rectangular area)

The sector-specific full load equivalents can be calculated with formula Eq. (2).

$$T_{\mathrm{fle,S}} = a_{\mathrm{S}} * 8760 \left[\frac{\mathrm{h}}{\mathrm{a}}\right] \tag{Eq. (2)}$$

Domain knowledge

To determine typical full load equivalents of sectors for which no regression-based load profiles were available in the analysis of Seim et al. [10] (six of the 13 industrial sectors), additional sources were used. At the same time, this methodology was also used to validate and adjust the calculated full load equivalents of the other sectors. Adjustments were particularly necessary for sectors where load profiles were only available for some of the subsectors and which, from experience, tend to be heterogeneous in terms of their utilization.

These expert assessments incorporated a wide variety of estimates based on energy consumption, knowledge from previous projects, data on company demographics [15], information from industry associations and other data described in Section 3.1.

3.3.2. Calculation of installed capacities

Statistics Austria's useful energy analysis breaks down the final energy consumption of the individual industrial sectors according to energy sources, provinces and useful energy categories, i.e. the purpose for which the energy is used. This granular breakdown subsequently allowed both an allocation of the calculated outputs to different sector-typical plant types (processes, cross-sectional technologies, power-to-heat applications) and a geographical allocation of the calculated outputs to federal provinces.

The installed power is calculated according to Eq. (3):

$$\frac{E_{\mathrm{el}} \left[\frac{\mathrm{GWh}}{\mathrm{a}}\right]}{T_{\mathrm{fle}} \left[\frac{\mathrm{h}}{\mathrm{a}}\right]} = P_{\mathrm{el,installed}}\ [\mathrm{GW}] \tag{Eq. (3)}$$

E_{el} corresponds to the final electrical energy consumption per year from the useful energy analysis of Statistics Austria, T_{fle} to the values determined in chapter 3.3.1 the sector-typical full-load equivalents in hours per year determined by the method described in Section 2.4.1, and $P_{\mathrm{el,installed}}$ corresponds to the installed electrical capacity determined.

3.3.3. Combination of top-down and bottom-up analysis

By combining the results of the top-down analysis performed with the findings in the bottom-up analysis from Esterl et al. [11], which was supplemented in this work, it was possible to confirm the assumptions for the estimation, and on to further increase the granularity of the subsequent analysis of the technical potential. For this purpose, the two estimates were checked for agreement and the known processes, and their installed capacities were integrated into the existing top-down analysis.

3.4. Determination of technical flexibility

The quantification of technical flexibility is based on the installed capacities determined in the previous steps and the flexible shares assigned to them. These designate the share of the installed capacity that is technically capable of providing a type of flexibility (positive or negative) for a certain activation duration (15 min, 1 h and 4 h). The allocation of the flexibility shares is based on expert knowledge of the processes in their context of use, literature data on flexibility in industrial processes and close coordination with process experts.

3.5. Top-down limitation of technical flexibility

To further increase the information content of the evaluation, all technical potentials were evaluated and categorized in terms of their availability over time for different periodicity (see Table 1). The information for this comes primarily from the analysis of the data described in Chapter 3.3.1.

Table 1: Additional categorization of technical flexibility potentials by availability

Availability	Possible characteristics
diurnal	day, night, all day
daily	weekdays, weekends, whole week
seasonal	whole year, individual seasons

Through this categorization, the technical potentials are further delimited by certain administrative barriers (e.g. working hours, shift work, ...). However, regulatory barriers are not yet considered, which is why the identified potentials do not yet correspond to the practical potentials.

4. Results for Austrian industrial flexibility potential

In the following, typical flexibility potentials from industrial processes (sector-specific) and cross-sectoral technologies (lighting, cooling and energy supply) are described. The characteristics listed in the introduction, which have to be fulfilled when providing flexibility for redispatch or congestion management, were basically considered qualitatively, whereby it was assumed, especially for small potentials (kW range), that aggregation via *flexibility service providers/aggregators* is carried out if required. However, the actual feasibility (e.g., the early transmission of a schedule, creation of the necessary interfaces, etc.) must always be evaluated on a site-specific basis. The flexible shares refer to the installed capacity of the process or technology.

4.1. Flexibility Potential – Industrial Processes

According to the literature [11] the following sectors and individual industrial processes with a high connected load are considered to have flexibility potential:

- Pulp, paper and print: mechanical wood grinders, pulpers and refiners, paper machines
- Chemical and petrochemical industry: chlorine electrolysis, air separation, calcium carbide production
- Iron and Steel: electric arc furnace
- Non-ferrous metals: aluminum electrolysis (primary route for aluminum production)
- Non-metallic minerals: Mills for ceramic products (e.g. cement production), presses for ceramic products, electric glass tanks

For the potential estimation for the provision of flexibility for redispatch in Austria, the following processes were not considered:

- aluminum electrolysis, since no aluminum is produced via the primary route at any site in Austria,
- the paper machines, as these can only be made flexible to a limited extent due to complex start-up and shut-down processes and the risks of paper breaks
- Glass production and pressing of ceramic products - here, the installed capacities determined were estimated to be significantly lower than the other processes that made more flexible. They are considered as part of the top-down approach for cross-sectoral technologies.

The further processes as well as the estimation of the potential for Austria are described in the following. Based on Esterl et al. [11] installed capacities as well as the geographical location of the flexible processes are supported by means of industry reports, published company reports as well as statistical databases.

The magnitude and frequency of flexibilities are estimated based on feedback from the manufacturing industry and an analysis of regional load management potentials for the German industry [16]. A more precise, individual site-based determination of potential can only be made through a large number of interviews, for example, according to the procedure described in the VDI guideline for energy-flexible factories published in the VDI guideline for energy-flexible factories [4].

4.1.1. Sector Paper, pulp and print

Characteristics of **mechanical wood grinders**:

- High rated electrical capacity of the individual plants, with a grinder usually having several MW (see data in Berger, et al. [17]).
- Total capacities in large plants are often in the range of 30 to 40 MW [18].
- Batch-type operation is possible in a few plants only, which would mean a large load-shifting potential for these plants.
- Apel et al. attribute part-load operation to wood grinders [19]. Depending on the type of plant, the load can be reduced either continuously or gradually in the order of a few megawatts.
- The main limiting factor is the limited storability of the intermediate product produced [20] with a few hours up to a maximum of one day [21]. According to company information, however, this duration can be extended by heating the intermediate storage tanks.
- The specific electrical energy input depends on the technology of the grinder and the required quality of the end product. According to the *EU IPPC BAT & BREF document,* this can range from 1.1 to 4.3 MWh/t [22].

According to Austropapier, the sectoral association in the pulp and paper sector in Austria, there are three locations with groundwood pulp production in Austria [23]. The installed capacity in Austria is estimated at approx. 70 MW according to the quantities produced, full load hour equivalents and specific energy consumption. In practice, high production capacity utilization and thus high operating hours (range: 7000-8000 h/a, calculated full load hour equivalent 7200 h/a) as well as limited storage capacity limit the amount and frequency of flexibility (see feedback from industry and [16]). The resulting potential for load reduction is estimated at up to 20 % for a maximum of 100 activations per year based on literature review and feedback from industrial actors).

In general, also for recycling paper preparation or in mills where market pulp is used, the raw materials are dissolved in special plants (pulpers and refiners). This requires a high specific power input and connected loads in the high kilowatt range. According to the *EU IPPC BAT and BREF document* [22]*,* **pulpers** *and* **refiners** have the following characteristics: Continuous pulpers for waste paper defibering have a specific energy input of 20 to 40 kWh/t of processed raw material. Batch plants have higher specific values. The total process chain for recovered paper pulping including refiners is 150 to 600 kWh/t of the final product, depending on the product. Similar values are given for the purchase of dry market pulp. [22]

For the estimation of potential in Austria, the electrical energy consumption of stationary motors was used. The power determined for this was reduced by the estimated installed power for mechanical wood grinders. The resulting power is 434.5 MW, which also includes other components such as drives for paper machines, compressed air and refrigeration. An estimate of the E-Control study resulted in approx. 125 MW for pulpers and refiners, which corresponds to about 30% of the above-mentioned capacity. According to the literature, these plants can reduce their power consumption by up to 100 % for a few hours. However, in practice, there are also limitations due to high utilization rates as well as often small intermediate product storages. Based on discussions with industrial partners and stakeholders a lower potential of pulpers and refiners compared to the total capacity of stationary motors (approx. 30 % of the before-mentioned value from the E-control study) is assumed. For this work, this results in a resulting installed power for stationary motors without wood grinders of 434.5 MW and a flexibilization potential for pulpers and refiners (positive and negative) of 10 % for 15 and 60 minutes.

4.1.2. Sector Iron and steel

According to literature data, the operation of electric arc furnaces can be flexibilized to a small extent in the iron and steel sector. In Austria, there are three (large) locations where electric steel is produced on a large scale. Electric steel is produced by typically melting steel scrap in batches in electric arc furnaces. The melting process at up to 3,500 °C has an electrical energy requirement of between 350 and 500 kWh/t of crude steel and takes around 40 to 60 minutes. Considering annual revisions, malfunctions, repair, charging, etc., it can be assumed that the process is effectively operated for about half of the year [26].

An estimate of the installed electrical capacity of such plants in Austria gives a total of approx. 115 MW. The share that can be used as positive or negative flexibility is estimated at 5 % for 15 minutes, which is a conservative assumption compared to load flexibility of ±10 % shown in a Hamburg steel mill [13]. Medium-term shifts for sites without full capacity utilization, e.g., production at night vs. day or vice versa, can additionally be realized by appropriate organizational measures and are estimated at approx. 65-75 % of the total installed capacity of those three big electric arc furnaces in Austria.

4.1.3. Sector Chemicals and petrochemicals industry

Depending on the size of the plant, several electrolysis cells are connected to form a module for **chlorine production**. Operation at the highest possible current density is favorable, as the thereby produced brine has a higher product quality (lower NaCl content). On average, between 2.1 and 2.6 MWh of electrical energy per ton of chlorine is used for production [24]. In Austria, large-scale chlor-alkali electrolysis is carried out at only one site. For the nominal load of the site, values between 20 to 22 MW [19,27], as well as 30 MW [11] are reported. In this paper, it is estimated to be 24 MW, and the frequency is assumed to be up to 100 activations per year and 50 % power reduction for 15 or 60 minutes, respectively [11].

According to Esterl et al. [11] in Austria, **air** has been **separated** on a large scale at six sites (three companies) in recent years, producing a total of between 700 and 900 million m³ of oxygen [25]. According to company reports, the single largest plant has a production capacity of up to 400 million m³ per year. Assuming 7,500 full-load hours and a specific electrical energy input of 0.45 kWh/m³, this results in almost 25 MW of electrical connected load, while according to the literature the usual electrical individual plant outputs are in the range of 10 to 15 MW [21]. The load reduction of the compressors or a shutdown of the air liquefaction can be used flexibly. The installed capacity in Austria is estimated to be about 50 MW. The power reduction is given with 100 % (which means a shutdown of the plant) as well as shifting of the production.

Calcium carbide production takes place at one site in Austria. According to the company, the installed capacity of the electric arc furnace for calcium carbide production is 19 MW. Based on the estimates of production volumes, specific electricity input and installed capacity in Esterl et al. [11] high full load hours can be assumed. The flexibility potential is estimated according to the literature [18] with a load reduction of 50 % for a maximum of 15 minutes.

4.1.4. Sector Non metallic minerals (Steine, Erden und Glas)

In this work, the flexibilization of mills for raw grinding but also for cement grinding in cement production is considered. For this purpose, the following assumptions are considered. Installed capacities of such mills are usually a few megawatts (approx. 3 MW, see [24]) the operating times are often coupled to the operation of the rotary kiln, but also to seasonal influences (less or no production in winter) [24].

According to an analysis of emissions in the Austrian cement industry [26] there are nine producing locations with 20 cement mills in Austria. The installed capacity of the cement and raw meal mills was estimated as follows: The number of cement mills per location (2-3) calculated according to [26] is assumed to be 2.25 MW each. According to the literature, the electricity input for grinding processes is about 70 %, with cement and raw meal grinding accounting for about 50 and 20 %, respectively [16]. The calculated power for the cement mills is subsequently multiplied by a factor of 1.4 ($= * {}^{7}/_{5}$). This results in an installed capacity of approx. 63 MW. Technically, this nominal capacity can be reduced or increased during mill shutdowns. For the estimation in this study, it was assumed that the full capacity can be reduced for 15 or 60 minutes. Due to high-capacity utilization, no load increase is planned, or the reduction is limited in its frequency.

4.2. Flexibility Potential – Cross-sectoral Technologies

4.2.1. Electricity auto-production

Industrial energy supply plants that already offer the use of flexibility to a significant extent, for example on spot markets or for the provision of balancing energy, can be assigned primarily to the following categories:

- (Conventional) power auto producers, often used as positive and negative flexibility in spot and balancing power markets, with a capacity of approx. 2000 MW in 2021 according to Eurostat statistics on energy infrastructure and generators [27]. These include:
  - Gas turbines (58 MW installed according to Eurostat)
  - Steam turbines (707 MW installed in 2018 and 1304 MW in 2021, according to Eurostat).
  - Cogeneration plants (according to Eurostat, 378 MW were installed in 2018 and 497 MW in 2021).
  - Internal combustion engines (according to Eurostat, 145 MW were installed in 2018 and 72 MW in 2021).
- Power-to-heat plants, which are sometimes used as negative flexibility such as
  - Electric boilers or electrode boilers
  - and increasingly industrial heat pumps, although these are currently still used to a lesser extent to provide flexibility.

Approximately 8,500 GWh of electricity was generated annually in the above-mentioned electricity autoproduction plants in the period from 2018 to 2021. This figure is derived as an estimate from data of about 8,000 GWh according to Eurostat data [28] and 7,500 GWh in 2021 and 10,900 GWh in 2018 (from fuel-fired power plants and cogeneration plants in companies with auto-production) according to the energy balance of Statistik Austria [29]. Across all plant types, the estimated average full-load equivalents are at approximately 4,400 hours per year. However, the actual operating hours were estimated to be significantly higher or significantly lower for a large proportion of the plants.

The first group, plants with higher operating hours, includes for instance the sectors *Paper, pulp and print* and *Iron and steel*, according to literature comparisons and feedback from industrial companies. According to information from the industry report of the *Paper, pulp and print* sector [23] 3,294 GWh were accounted for by this sector in 2021, and according to the energy balance of Statistics Austria for 2021 of about 2,000 GWh by the iron and steel sector (coal gases). An estimation with the assumption of 7,000 full load hours for these two sectors results in an installed capacity of about 750 MW. In addition, an analysis of emission certificate allocations in Austria allows the conclusion, that medium to large-scale electricity auto-production plants can also be found in the wood processing, chemical and food production sectors. Based on the auto-produced electricity according to Statistik Austria, based on the assumption of 7,000 full load hours for electric auto-production in operation, an installed capacity of almost 1,100 MW is estimated. According to estimates and use-case simulations of flexibility provision from an industrial energy supply system, the flexible positive and negative share is estimated at 5-10 %. For this purpose, the conservative assumption of a request time of up to one hour is made. Longer time intervals will also be possible in some cases.

An initial estimate based on the figures summarized above yields a flexibility of 55-110 MW, which, however, will generally not be available at the same time and depends strongly on the actual utilization situation in the industrial plants. Thus, this flexibility may also be subject to change over time. The usable flexibility and especially the temporal resolution is strongly dependent on the utilization of the industrial plants. In addition, many plants are designed with cogeneration. In this case, the actual flexibility depends on the number of degrees of freedom. Steam storage or flexible withdrawal stages thus have a direct influence on the usable flexibility

Lower operating hours are mainly found in plants that are used as emergency generators and whose main task is the constant readiness for a fast and flexible energy supply for the site. For such plants, this study assumes, that no flexibility potential is available. Thus, for both categories, the potential for flexibility provision cannot be estimated at a comparable level to the installed plant capacity.

4.2.2. Heat supply systems

An initial indicator for the use of power-to-heat plants, in particular electric and electrode boilers, for (high-temperature) hot water or steam generation is provided by the electricity demand from the useful energy category *process heat <200°C.* The pulp and paper sector stands out in particular, where 753 GWh of process heat below 200°C is supplied with electrical energy. Assuming a full load duration of 4,000 hours, this corresponds to an installed capacity of 185 MW. Considering the fact that auxiliary drivers are also operated in steam generators, it is estimated that the installed connected load is below this value and can be assumed to be 100 MW as a first approximation. Known individual plants in this sector have outputs up to 20 MW. A negative flexibility potential of 100 % for 15 min up to 4 hours was assumed for known single electric/electrode boilers.

For the remaining installed capacity in this useful energy category and sector, an average positive and negative flexibility potential of 10 % for 15 and 60 minutes, respectively, was estimated for electrification in process heat supply. This assumption was also made for the sectors *Nahrungs- und Genußmittel* as well as *Chemie und Petrochemie*, *Holzverarbeitung* and *Textil und Leder*, since relevant shares of the required energy are to be allocated to the useful energy category *process heat <200°C* here.

For the useful energy category *process heat >200°C*, 5 % load reduction for 15 and 60 minutes was assumed for electrical shares in heat supply in the following sectors: *Fahrzeugbau*, *Maschinenbau*, *Textil und Leder* as well as *Nahrungs- und Genußmittel*. For the last sector, additionally, a negative potential of the same order of magnitude was assumed.

Based on the analysis within the study *Regionale Lastmanagemente Potenziale in Deutschland bis 2045* [16], in which 11 % load reduction potential for up to 1 hour is given for the cross-sectional technology ventilation, the following assumption was made for this work: A load reduction potential of 5 % for 15 and 60 minutes, respectively, is assumed for the installed capacity for the useful energy category *space heating and hot water supply.* The construction and mining sectors were excluded due to their mobile nature.

In conclusion, it can be stated that the perspective potentials for heat supply are becoming increasingly larger since progressive electrification of heat supply in industry is a recognizable trend.

4.2.3. Lighting

As a basis for the estimation of flexibility through lighting, the useful energy analysis of Statistics Austria (category *lighting and IT*) as well as the determined full load hour equivalents per sector were assumed. Based on the specification of 7 % for up to a maximum of 4 hours from the study *Regional Load Management Potentials in Germany* [16] it was assumed that 5% of the installed power for IT and lighting can be reduced for up to 4 hours. The construction and mining sectors were excluded due to their mobile nature. A load increase (negative flexibility potential) of lighting installations is interpreted as technically possible, but generally corresponds to a pure increase in energy consumption and is not assumed here for efficiency reasons.

4.2.4. Cooling systems

First, based on analyses of the flexibility from the cooling supply in Germany [30] the following sectors were identified as relevant consumers of process cooling: *Chemical and Petrochemical Industry* (incl. plastics manufacturing and pharmaceutical industry), *Transport equipment*, *Machinery*, *Food, tobacco and beverages*. Relevant cooling demand for the construction industry was also identified in the study, but in this work, the sectors *Construction* and *Mining and quarrying* were excluded due to their mobile nature. In the report, between 2 % and 30 % of the electricity demand in the sector was reported for cooling supply. Due to the heterogeneity of the subsectors of the above sectors, a potential for load shift or load reduction of 5 % for 15 and 60 minutes (see [16]), respectively, for process cooling supplies in the used energy category *stationary motors* was assigned.

4.3. Prospective Flexibility Potential

The potential in the industry is expected to increase in the future. A higher prospective negative potential is expected especially in the field of electrification of heat supply, e.g. by industrial heat pumps - see information in the report *Innovative Energy Technologies in Austria: Market Development* 2021 [31]. There, it was estimated that 680 GWh/a of heat were already provided by industrial heat pumps in 2021. In Windholz et al. [32] the technical potential for the use of industrial heat pumps up to 150°C is estimated for Austria in the sectors of paper and pulp and some subsectors of the food industry with about 400 MW heating capacity (corresponding to about 200-250 MW_{el}). Trends toward electrification can also be identified for furnaces, for example in the metalworking industry and in iron and steel production, but also for processes in the 200°C range in the food industry and in dryers. Process changes, for example, higher recycling rates and increased use of recovered paper in the paper industry, sometimes have the potential to increase the flexible capacities of wood grinders in terms of height and frequency.

For the current energy supply infrastructure (auto producers) the probability of flexibility increase in the future is estimated to be low. With the frame conditions such as long life times, economics, need for decarbonization or very limited availability of fossil fuels, a significant increase in flexibility potential with the might only happen with a simultaneous reduction in production volumes leading to new, free capacities.

The probability of relevant changes in existing plants for energy auto production of companies (e.g. gas turbines, etc.) is neither estimated to be excessively high. Probably on the medium- to long-term time horizon hydrogen fired gas turbines might be an interesting option for industrial energy plants. Today, auto production plants are characterized by a long service life and complex procurement processes. Frame conditions making investment decisions complex include environmental impact assessments, uncertainty for investments, increasing requirements regarding decarbonization, which require holistic new concepts. Furthermore, the role of limited availability of fossil fuels, a market-situation where electricity generation from gas is not feasible etc. need to be considered in investment decisions for electricity auto production.

4.4. Obstacles and limitations

A comprehensive overview of barriers, often technical or organizational, based on a large number of publications is presented by Ausfelder et al. [24]. Esterl et al. [11] further differentiate technical, regulatory, economic and cultural barriers. Examples of causes of technical and organizational (or cultural) limitations in the use of industrial flexibility potential include the following:

- Lack of measurements, data processing and control capability, which means that small flexibility potentials in particular cannot be identified and exploited
- High-capacity utilization of the plants, because of which a load reduction or load shift leads to production losses
- Risk of production downtime or quality reduction due to flexible operation of a process
- Coupled operation of energy supply plants, e.g. power-to-heat or combined heat and power plants, reduces availability for flexible plant operation
- Organizational restrictions in plant operation (qualified personnel not available in every shift)

Regulatory restrictions can result from the risk of violating limits for noise emissions or specifications such as efficiency targets with flexibility measures. As a result, processes cannot be shifted to nighttime or the potential from changes in the energy supply technology (combined heat and power plant vs. fuel-fired steam generator) cannot be exploited.

4.5. Summary

Installed electrical capacity

According to the analysis, the installed electrical capacity in the manufacturing industry amounts to about 6,290 MW in industrial processes and cross-sectional technologies (excluding autoproduction plants). Furthermore, about 1,100 MW of installed electrical capacity is expected in autoproduction plants for electricity in industry. The distribution, based on the method described in Section 3) of the absolute and relative shares of the existing installed capacity among the provinces is shown in Figure 4-1 . As expected from the distribution of energy-intensive industrial enterprises in Austria, two-thirds (67.7 %) of the installed capacity are located in the three provinces Upper Austria, Styria and Lower Austria. In addition, the sectoral shares of the installed capacity in the individual provinces differ. This can be seen, for example, in the very large installed capacity in the iron and steel sector in Styria (369 MW) or the share of the wood processing sector in Salzburg (109 MW).

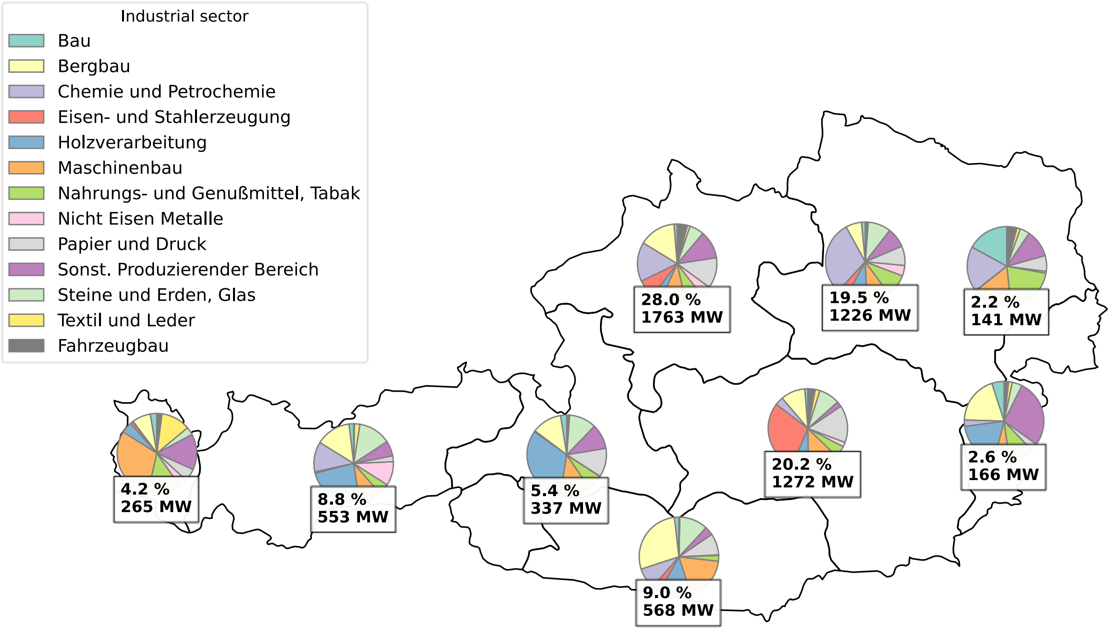


Figure 4-1: Estimated installed electric capacity in MW for industrial processes and cross-sectional technology excluding autoproduction plants and share of total installed capacity in the manufacturing industry in 2020. The size of the pie charts is not proportional to the installed capacity.

The following translations for sector names are used: Bau (Construction), Bergbau (Mining and quarrying), Chemie und Petrochemie (Chemical and Petrochemical Industry), Eisen- und Stahlerzeugung (Iron and Steel), Fahrzeugbau (Transport equipment), Holzverarbeitung (Wood and wood products), Maschinenbau (Machinery), Nahrungs- und Genußmittel, Tabak (Food, tobacco and beverages), Nicht Eisen Metalle (Non-ferrous metals), Papier und Druck (Paper, pulp and Print), Sonst. Produzierender Bereich (Non specified industry), Steine und Erden, Glas (Non-metallic minerals), Textil und Leder (Textiles and leather)

Technical flexibility potential by sector

Figure 4-2 shows the positive and negative technical flexibility potentials in processes and cross-sectional technologies (excluding autoproduction plants). The largest positive potential is assumed to be in the energy-intensive sectors *Chemical and Petrochemical Industry; Non-metallic minerals*; *Paper, pulp and print; Machinery* und *Transport equipment*. Negative potential is expected primarily in the sectors *Paper, pulp and print*; *Chemical and Petrochemical Industry* and secondary steelmaking sectors with electric arc furnaces.

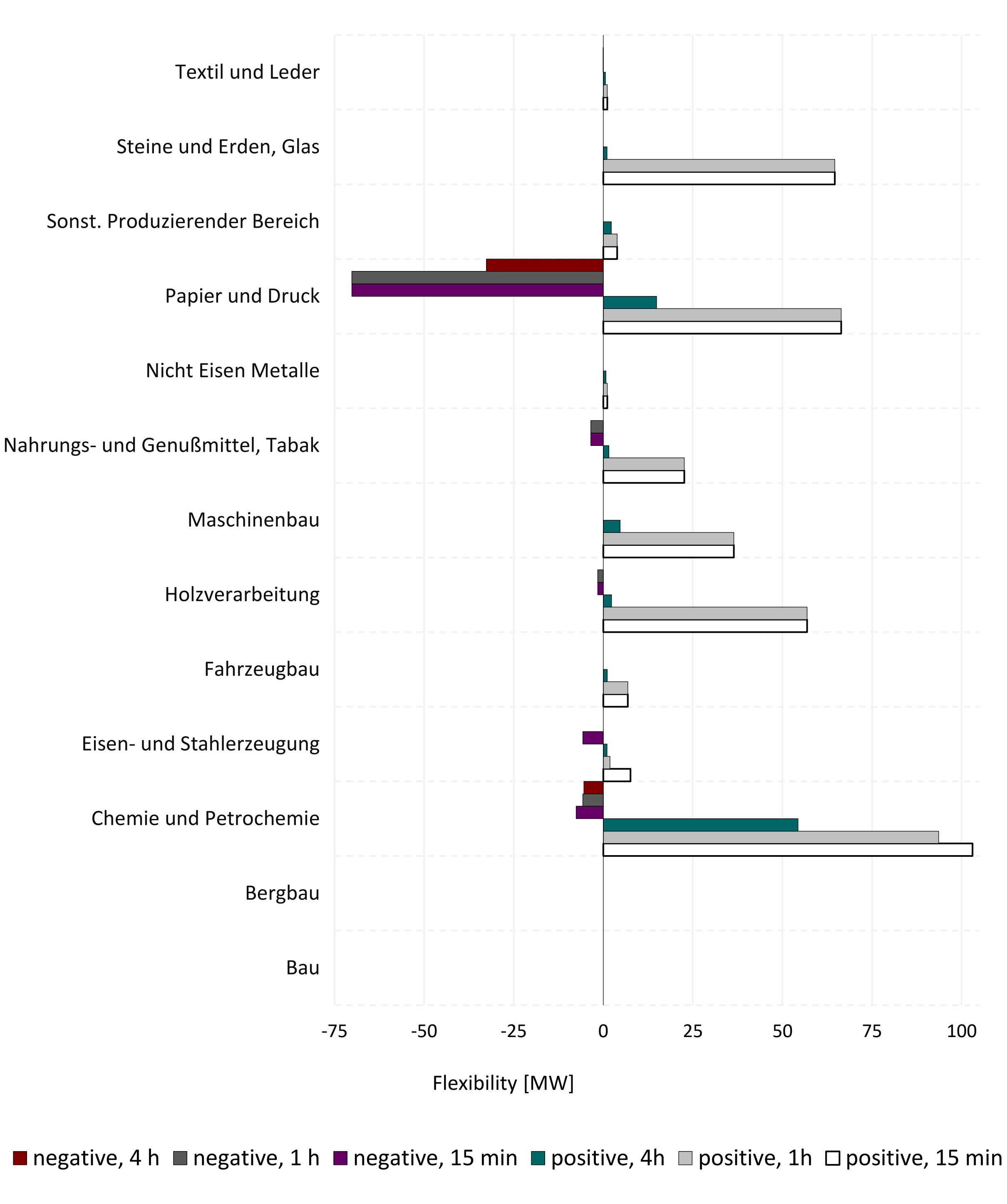


Figure 4-2: Technical positive and negative flexibility in the manufacturing industry sectors (excl. autoproducer plants) in MW for the request times 15 min, 1 h and 4 h.

The following translations for sector names are used: Bau (Construction), Bergbau (Mining and quarrying), Chemie und Petrochemie (Chemical and Petrochemical Industry), Eisen- und Stahlerzeugung (Iron and Steel), Fahrzeugbau (Transport equipment), Holzverarbeitung (Wood and wood products), Maschinenbau (Machinery), Nahrungs- und Genußmittel, Tabak (Food, tobacco and beverages), Nicht Eisen Metalle (Non-ferrous metals), Papier und Druck (Paper, pulp and Print), Sonst. Produzierender Bereich (Non specified industry), Steine und Erden, Glas (Non-metallic minerals), Textil und Leder (Textiles and leather)

Geographical distribution of flexibility potential

As expected, the concentration of installed plant capacity in the central region of Austria is also reflected in the technical potential of the flexibility (see Figure 4-3 and Figure 4-4).

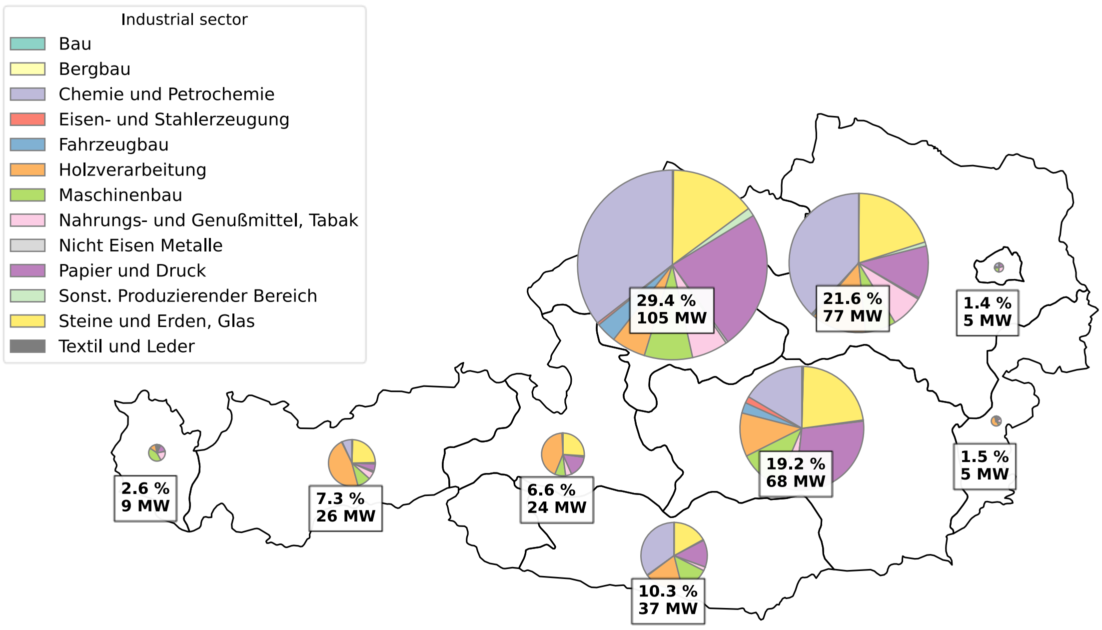


Figure 4-3: Distribution of the positive technical flexibility potential (excluding autoproduction plants) with a request time of 1h among the provinces and industrial sectors. Positive technical potential in MW and relative shares of the total available positive technical potential in Austria. The size of the pie charts is proportional to the share of the total available positive potential.

The following translations for sector names are used: Bau (Construction), Bergbau (Mining and quarrying), Chemie und Petrochemie (Chemical and Petrochemical Industry), Eisen- und Stahlerzeugung (Iron and Steel), Fahrzeugbau (Transport equipment), Holzverarbeitung (Wood and wood products), Maschinenbau (Machinery), Nahrungs- und Genußmittel, Tabak (Food, tobacco and beverages), Nicht Eisen Metalle (Non-ferrous metals), Papier und Druck (Paper, pulp and Print), Sonst. Produzierender Bereich (Non specified industry), Steine und Erden, Glas (Non-metallic minerals), Textil und Leder (Textiles and leather)

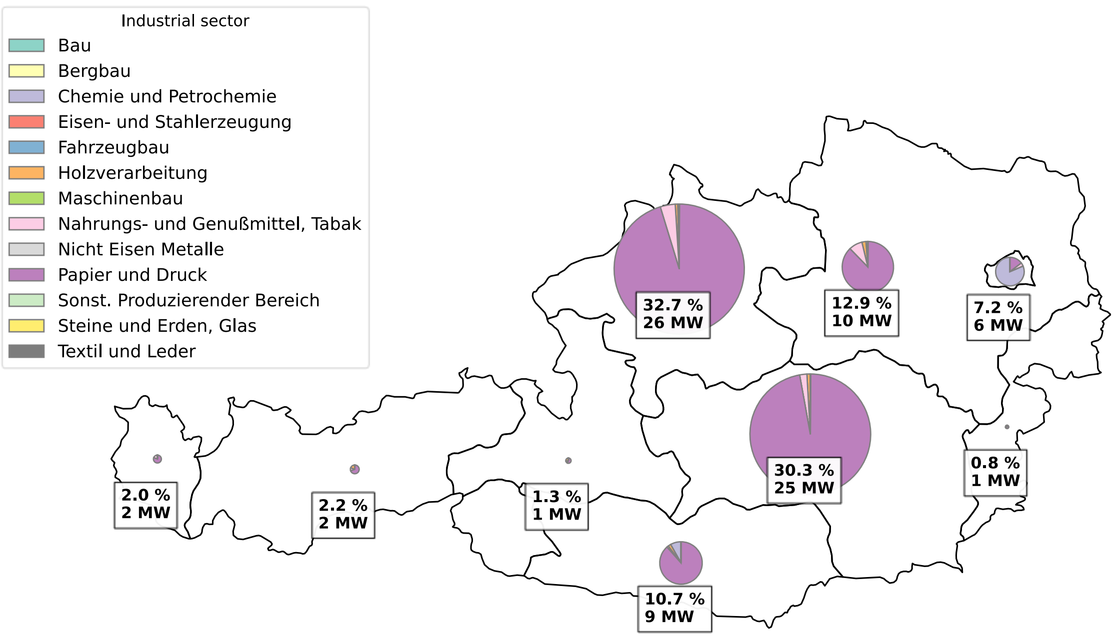


Figure 4-4: Distribution of the negative technical flexibility potential (excluding autoproduction plants) with 1h request time across the provinces and industrial sectors. Negative technical potential in MW and relative shares of total available negative technical potential in Austria. The size of the pie charts is proportional to the share of the total available negative potential.

The following translations for sector names are used: Bau (Construction), Bergbau (Mining and quarrying), Chemie und Petrochemie (Chemical and Petrochemical Industry), Eisen- und Stahlerzeugung (Iron and Steel), Fahrzeugbau (Transport equipment), Holzverarbeitung (Wood and wood products), Maschinenbau (Machinery), Nahrungs- und Genußmittel, Tabak (Food, tobacco and beverages), Nicht Eisen Metalle (Non-ferrous metals), Papier und Druck (Paper, pulp and Print), Sonst. Produzierender Bereich (Non specified industry), Steine und Erden, Glas (Non-metallic minerals), Textil und Leder (Textiles and leather)

Total available technical flexibility potential (including autoproduction)

In total, Austria's manufacturing industry is expected to have 410 MW of positive and 190 MW of negative technical flexibility potential in processes and cross-section technologies, including autoproduction plants, for a request time of one hour (see second and fifth bar in Figure 4-5, while the other bars represent the potential for 15 min and 4 hours, respectivly). For the interpretation of Figure 4-5 it needs to be considered that the amounts can be subsets from the biggest potential (15 min) While the positive flexibility potential is evenly distributed across all energy-intensive sectors, negative potential is mainly present in processes in the paper sector. A not insignificant amount of flexibility is seen in the autoproduction plants of all industrial sectors, estimated at about 55 MW (positive flexibility) and 110 MW (negative flexibility) for 15 min and 1 h, respectively.

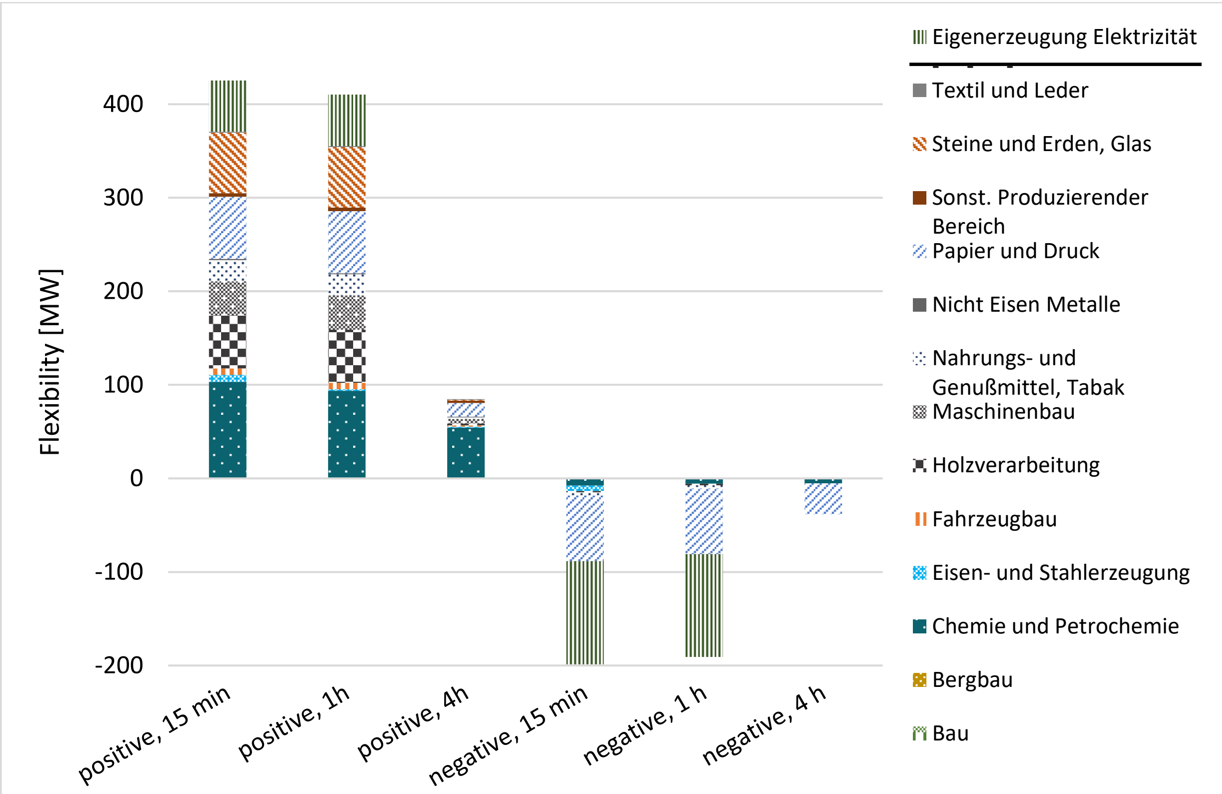


Figure 4-5: Determined technical flexibility potential in Austria's manufacturing industry in MW in 2020

4.6. Conclusion

In comparison to the flexibility potential of other technologies, the industrial flexibility potential determined in this work in the range of approx. 200 MW (negative) to 400 MW (positive) is currently still very low. I.e., according to Esterl et al [12], the potential of pumped-storage and storage power plants in 2020 was 8844 MW (positive) and 4200 MW (negative), respectively.

5. Incentives to provide flexibility for redispatch

This section provides an overview of stakeholder dialogue activities to analyze incentives for industrial flexibility (e.g. Redispatch) provision and the results of a short survey which has been conducted.

5.1. Activities

The following activities have been performed within Task 3.3 to determine incentives for industrial manufacturing companies to provide redispatch (and flexibility in general).

5.1.1. Incentive pyramid, Long Survey and Interviews

Inspired by Maslow's hierarchy needs levels (pyramid) and a categorization of influences by Mohaupt et al. [33], see Table 2, within the project team a categorization and ranking (from basic need to decision criteria) of incentives to provide flexibility was developed within this project. This pyramid was discussed within the consortium, results are summarized in . The feedback was used for further steps – the development of a comprehensive survey regarding flexibility and incentives for industrial stakeholders (description follows below). The incentive pyramid is shown in Figure 5-1.

Table 2: Categorization of influences by Mohaupt et al. [33]

Factors related to the acceptance subject	Factors related to the acceptance object	Context factor
Attitude	Costs and benefits	Social constellation
Personal norms / values	Risks / reliability	Legal framework
Emotions	Ease of use	Economic situation
Social demographic factors	Aesthetics	Social norms
Knowledge and experience		Way of introduction (participation, communication)
Trust		

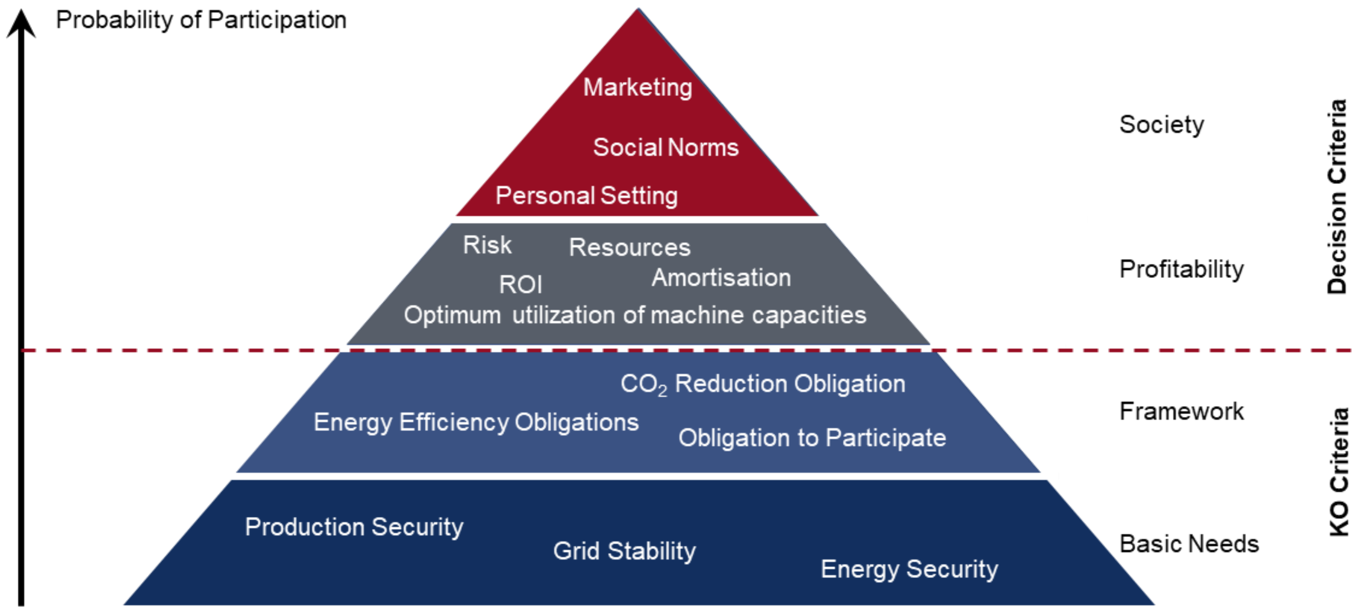


Figure 5-1: Classification of incentives in pyramid form and distinction between KO criteria (basic needs) and decision criteria

The following feedback regarding the single categories was given within the project consortium.

Table 3: Summary on feedback for incentive categories

Category	Named Criteria
Basic Needs	• Physical network connection determines maximum flexibility • Obstacles are, in particular, production downtime or product quality risks followed by additional personnel expenses and increase in the complexity of the operating process • Wear and tear of equipment or maintenance effort depends on the machine used, is evaluated differently • Postponement of production schedule rather not possible → even with risk compensation and 10 % surcharge - Core business must not be impaired - Working time is too expensive - Organizational effort - Legal challenge • "Smaller" sites do not prepare load forecasts and tend not to have dealt with flexibilities yet • "Large" operations depending on location, from exact day-ahead schedule to rough monthly schedules, already active in the flexibilities market • The need for grid security measures is recognized.
Framework	• A crediting for the EEffG or EU emissions trading system or comparable is considered a significant incentive • Contribution to the prevention of blackouts in Austria is perceived as positive but is not a sufficient incentive • In principle, additional legal requirements are expected in the next few years and proactive preparation is taking place
Profitability	• Own installation of control and marketing is not considered attractive, in any case intermediaries are needed: - For "large" sites (NE 3-4) especially for the marketing of the flexibilities - For "small" sites (NE 5-6) a contractor who takes over everything | Alternatively an intelligent control system • Workload is estimated to be < 1h per week (less with automatic control). • "Big" companies have staff that is responsible anyway, therefore no additional effort • If it would be financially attractive, "small" sites would build up additional generation capacities, "large" ones rather not • Financial incentive (selected so far). - Compensation for each kWh made available. - Reduced grid fee - Reduction of costs of purchased electricity peaks - Compensation for each kWh made available at a price set by me • Surcharge could be specified as an off-set to the exchange price • "Large" sites tend to have low targeted payback period (internal competition, effort financing) (1-3 a) • "Small" operations tend to have higher targeted payback period (strategic thinking, preparation) (< 7 a)
Society	• Customer demand "Green Products • Stay in business ("natural" renewal of factories) • Strategic development aspect (expansion of production) • Participation in flexibilities market also dependent on capacity utilization of the plant

In Autumn 2021 a long survey (>80 questions) was designed, tested with the industrial partners in the project and set-up in SurveyMonkey. This survey included logical links and connections to skip questions that are no longer relevant due to previous answers. Besides general questions, also questions regarding current load characteristics and flexible assets were included to determine the flexibility potential. The survey is added to this deliverable in Annex A – Long survey for industrial companies.

For sending out the survey different channels were used (including Wirtschaftskammer, Industriellenvereinigung und NEFI channel). Unfortunately, there was no feedback in terms of completed or mostly completed surveys. As a corrective measure direct interviews, which were much more time consuming, were performed. Three interview partners, one from the energy supply sector and two from the pulp and paper sector were found.

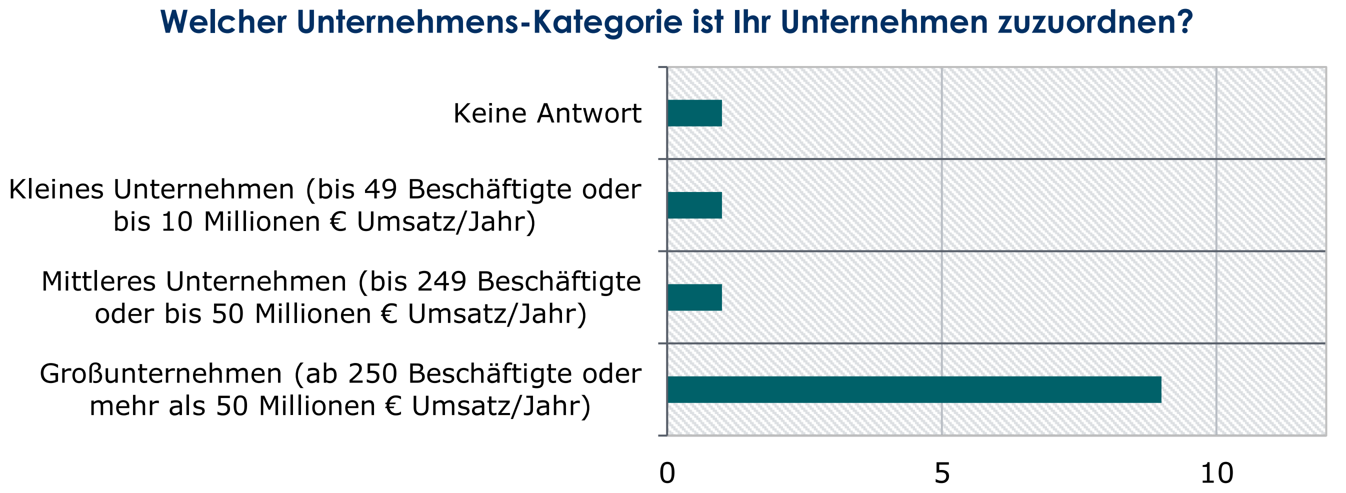
5.1.2. Short Survey

As a second corrective measure, a shorter survey (15 questions) with a general part and a part regarding incentives, remuneration, risks, and organization was designed. This survey was set-up in June 2022 and sent via different channels to industrial stakeholders in summer 2022. The same channels as for the long survey were used. The survey is added to this deliverable in Annex B – Short survey for industrial companies. The results are shown in Section 5.2.

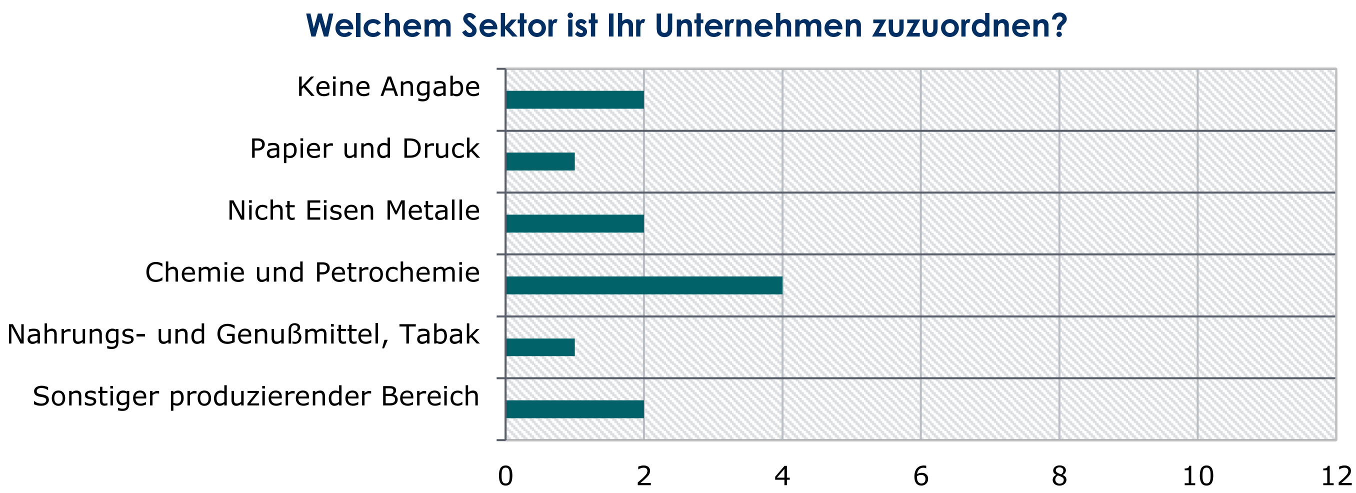
5.2. Results of short survey

In the following, the results of the short survey, which was set-up in German, are presented. As the survey, the answer possibilities and the answers are German, also the evaluation is held in German to avoid misinterpretation caused by translation.

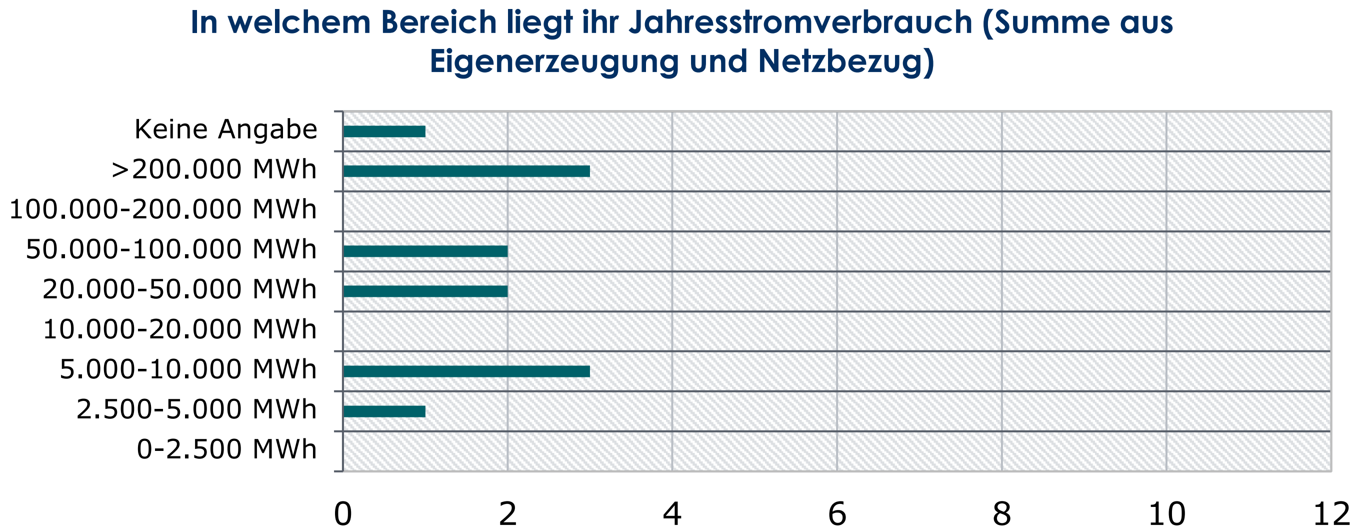
5.2.1. Question 1



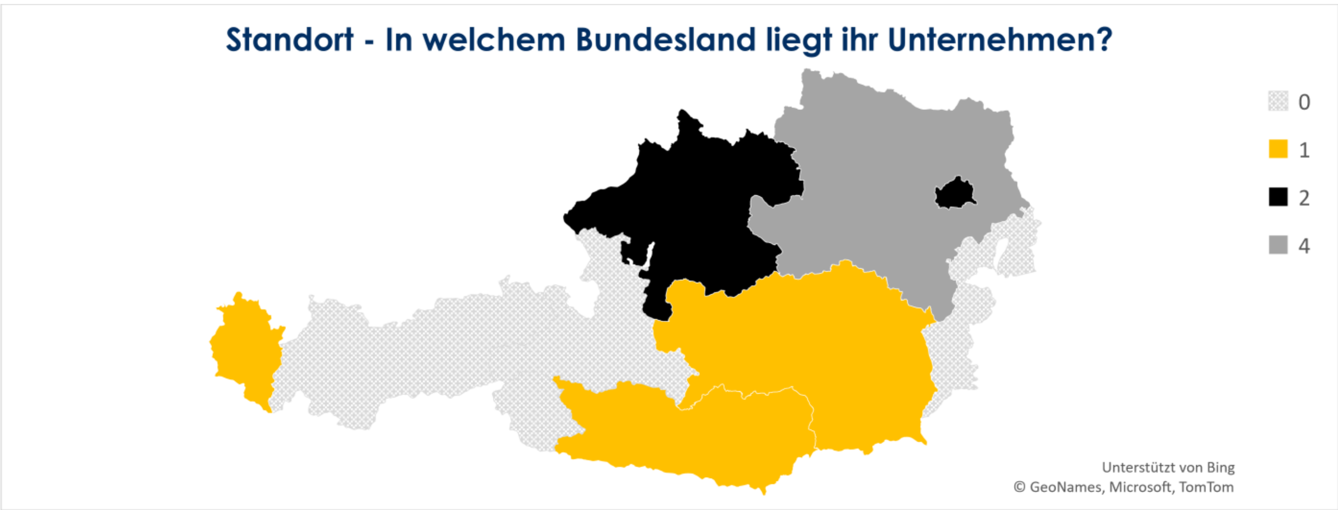
5.2.2. Question 2



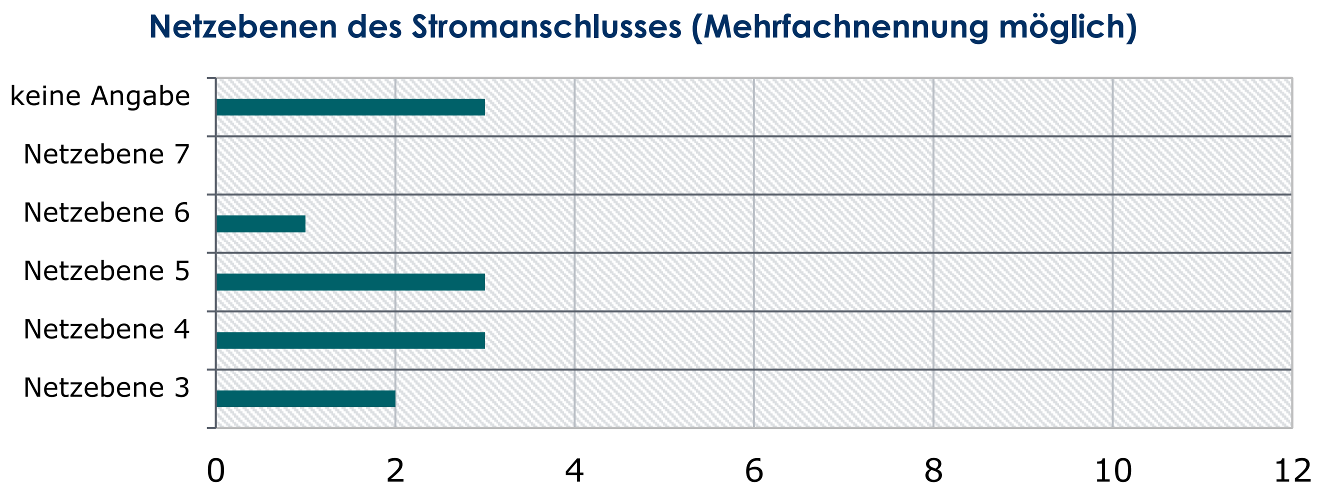
5.2.3. Question 3



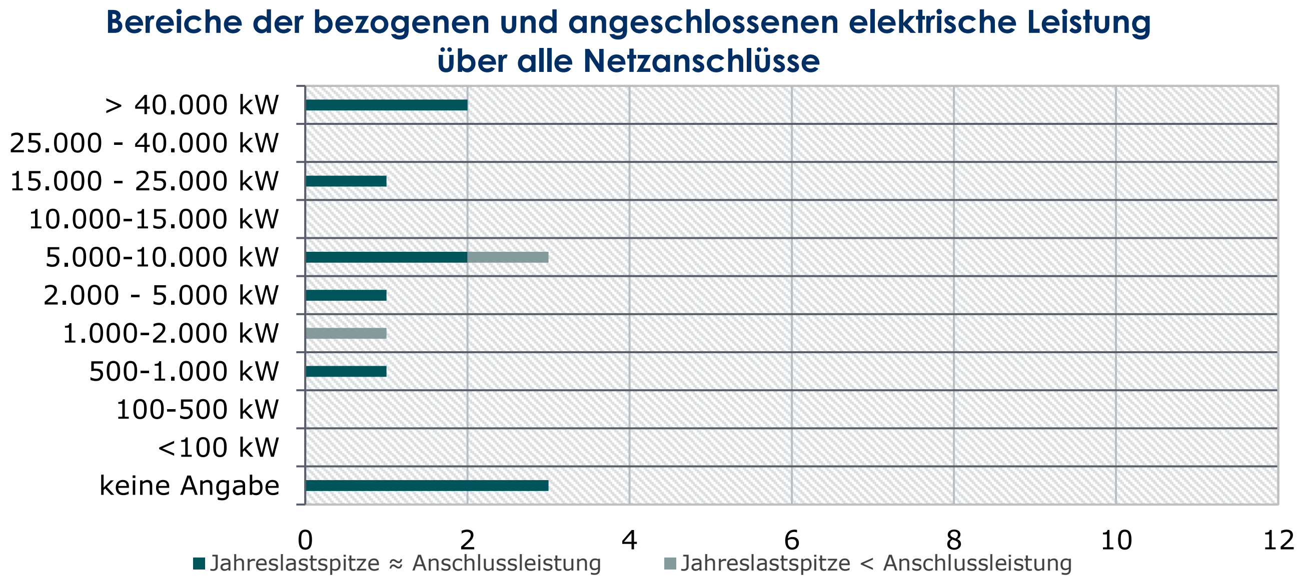
5.2.4. Question 4



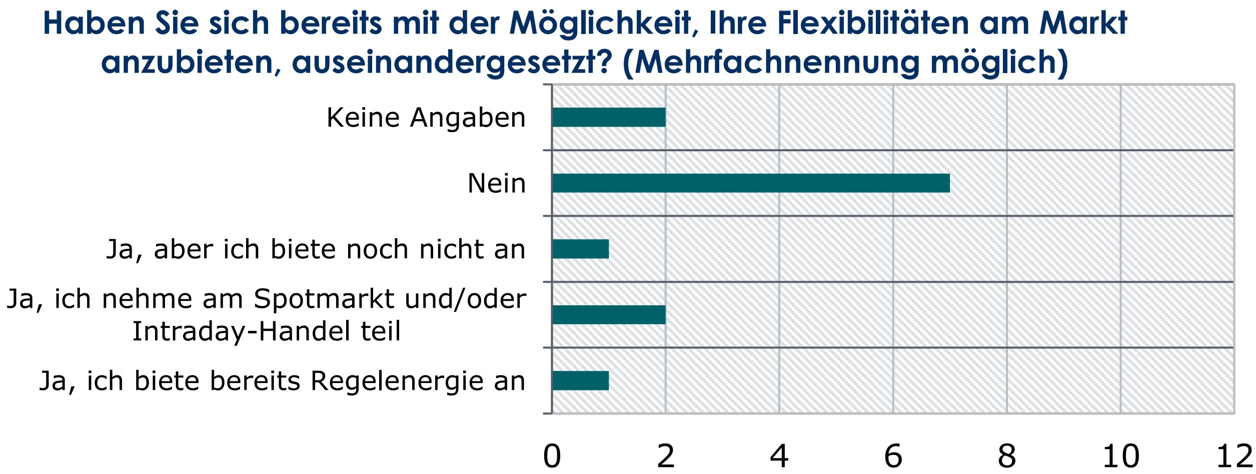
5.2.5. Question 5



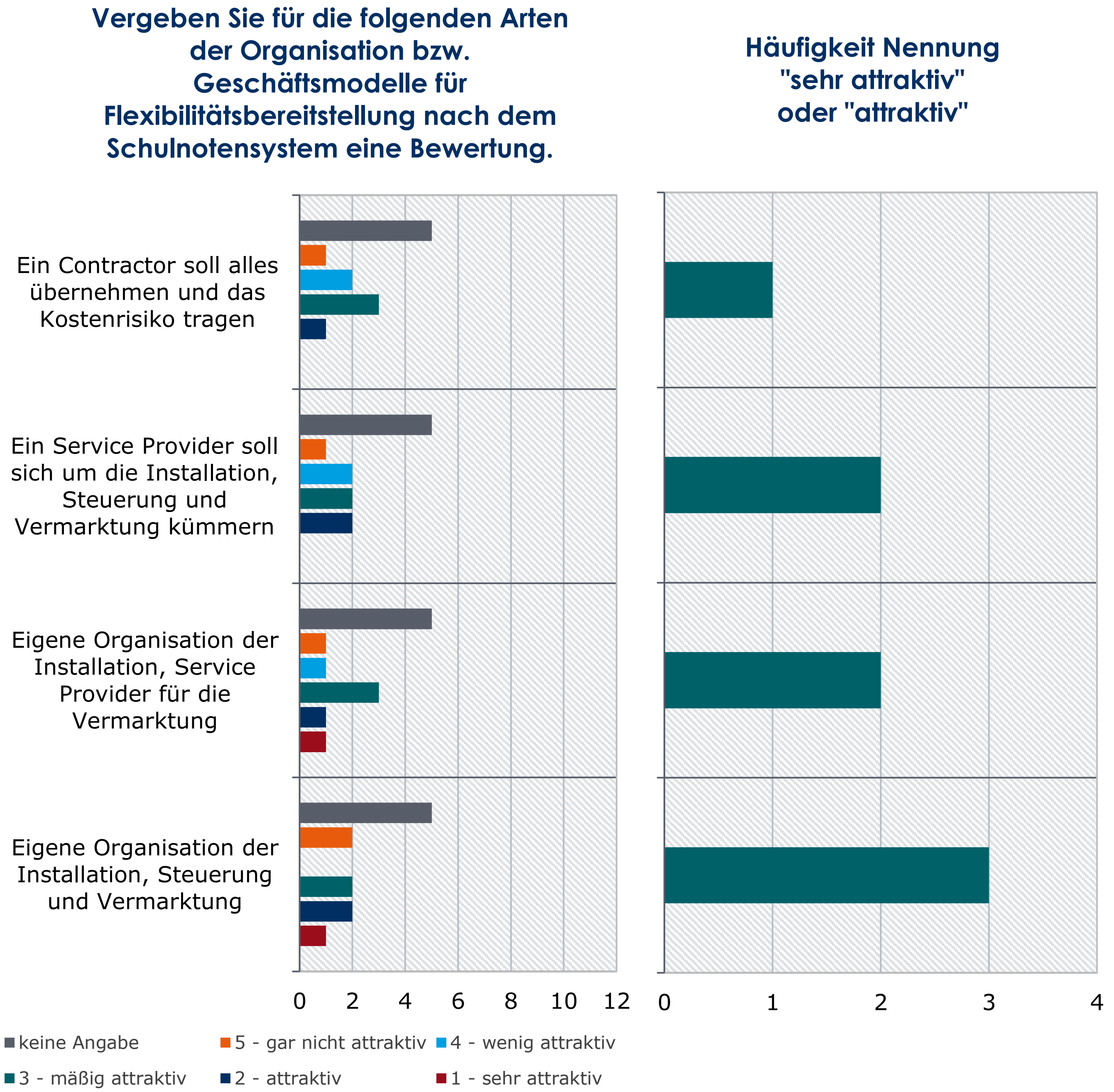
5.2.6. Question 6



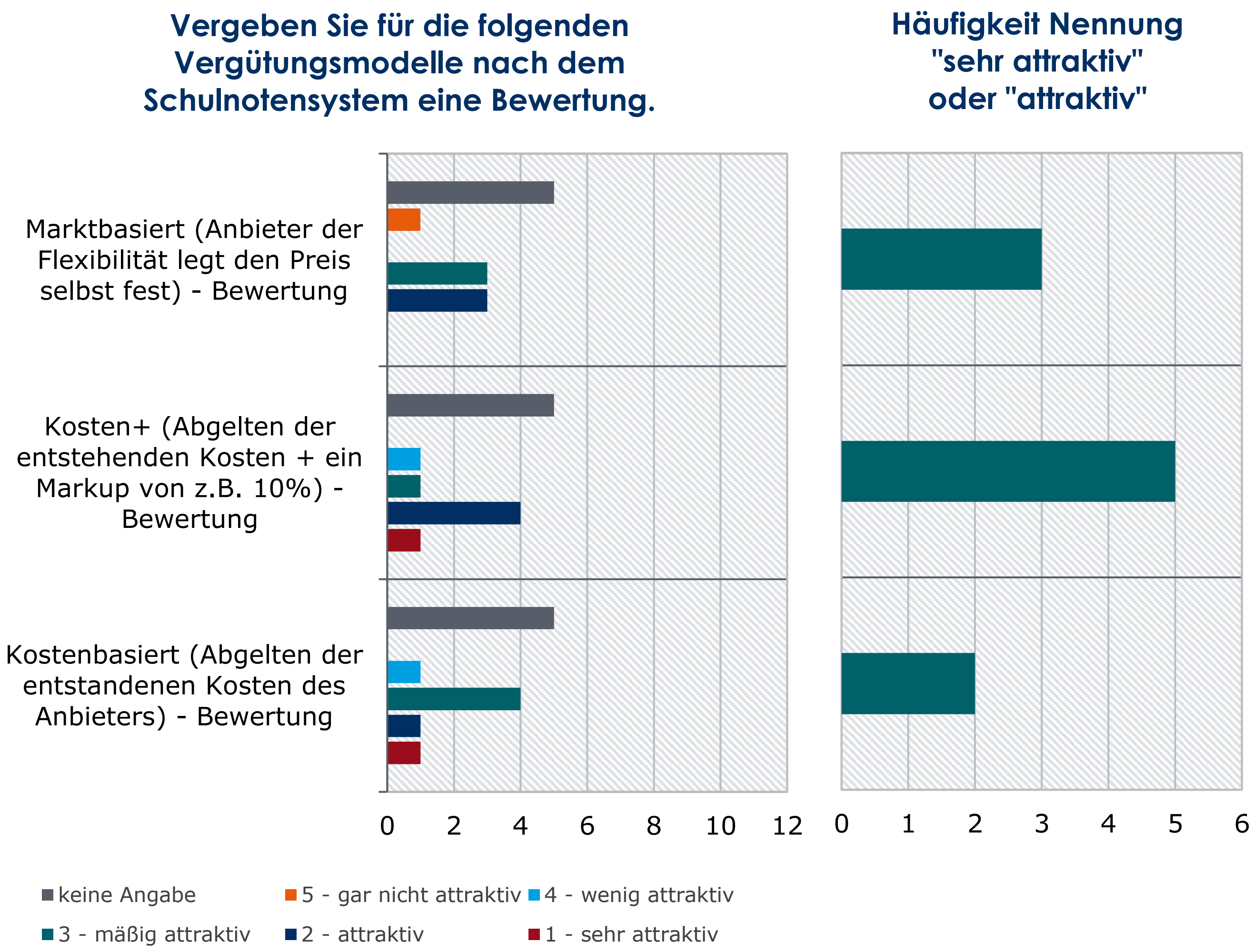
5.2.7. Question 7



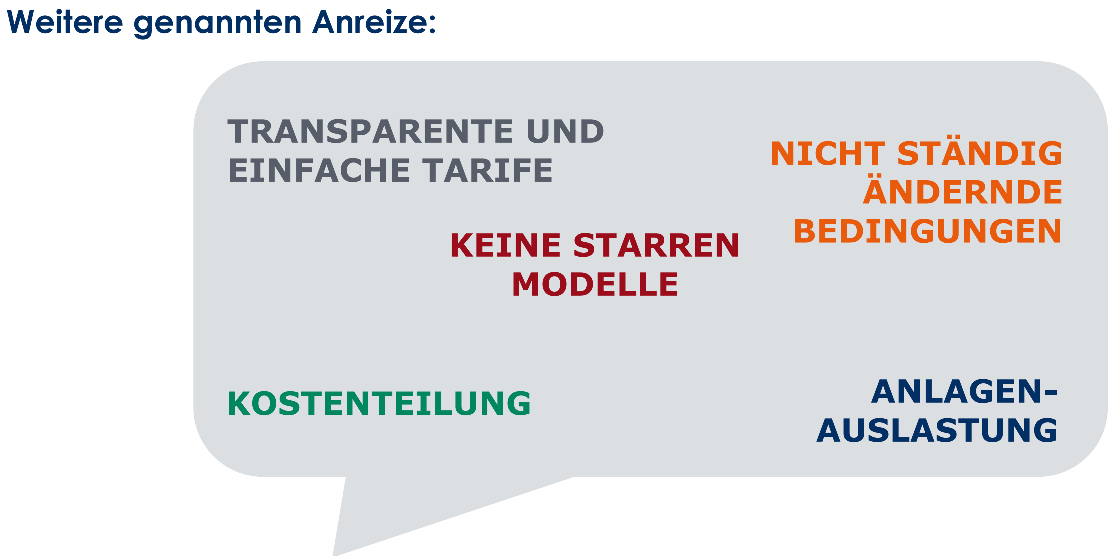
5.2.8. Question 8



5.2.9. Question 9

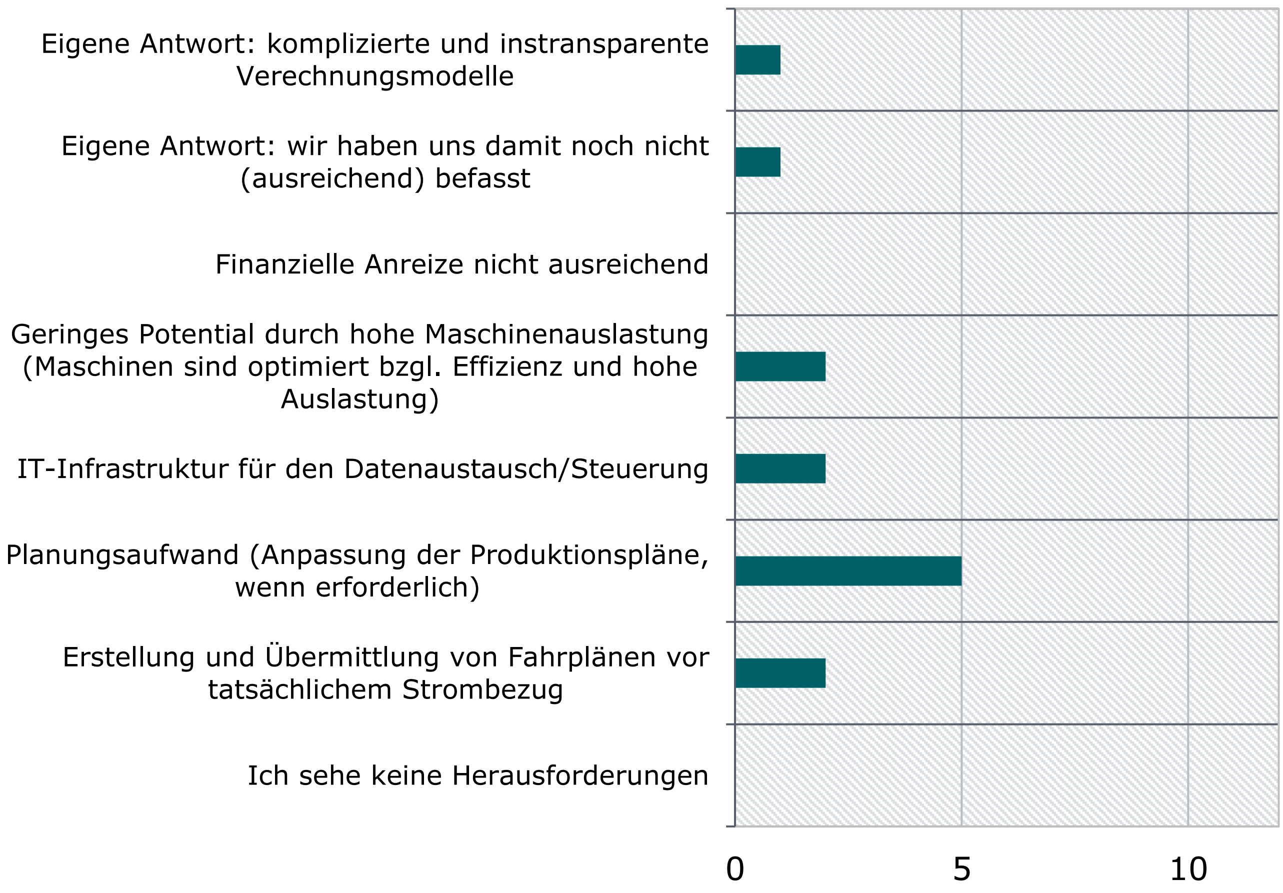


5.2.10. Question 10



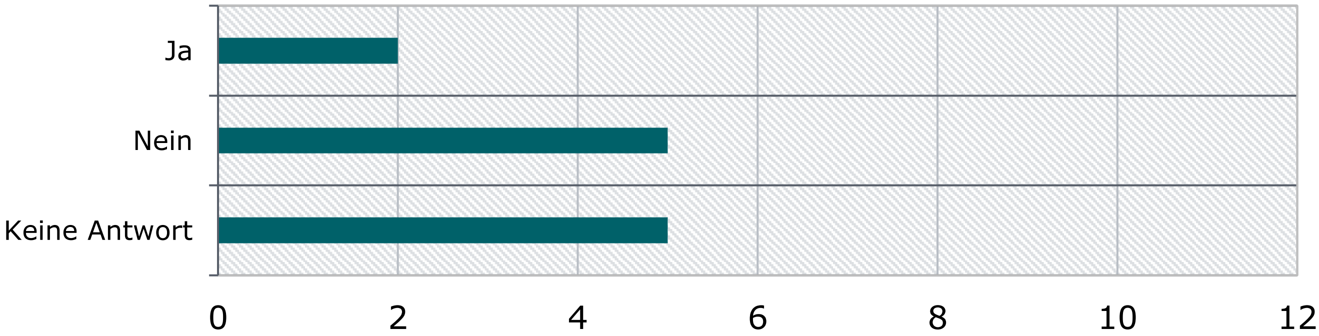
5.2.11. Question 11

Wo sehen Sie die größten Herausforderung für Flexibilitätsbereitstellung? (mind. 1, max. 3 wählbar)

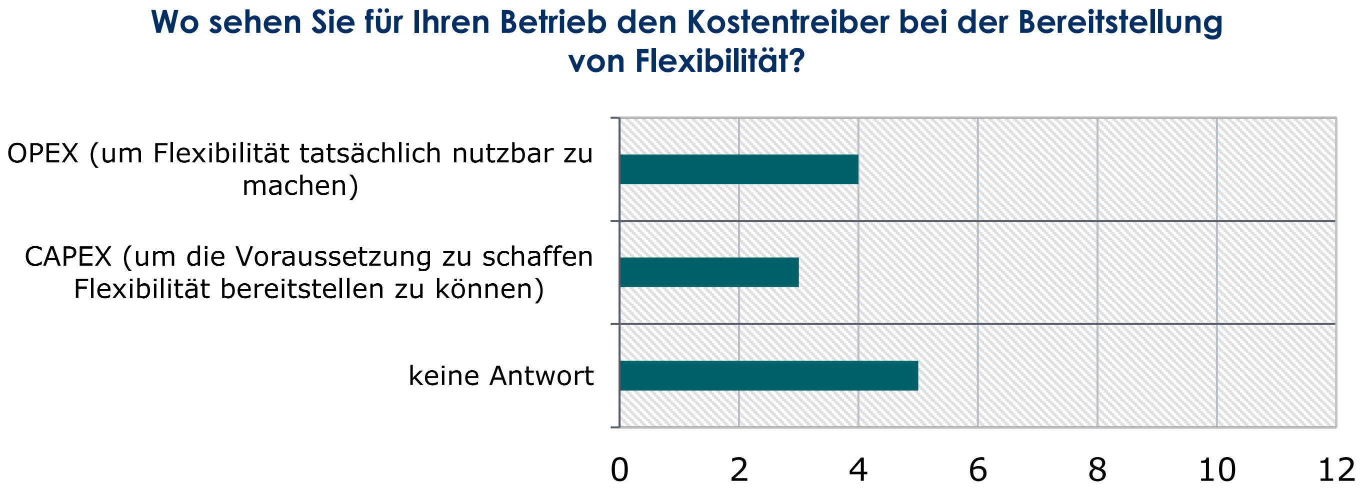


5.2.12. Question 12

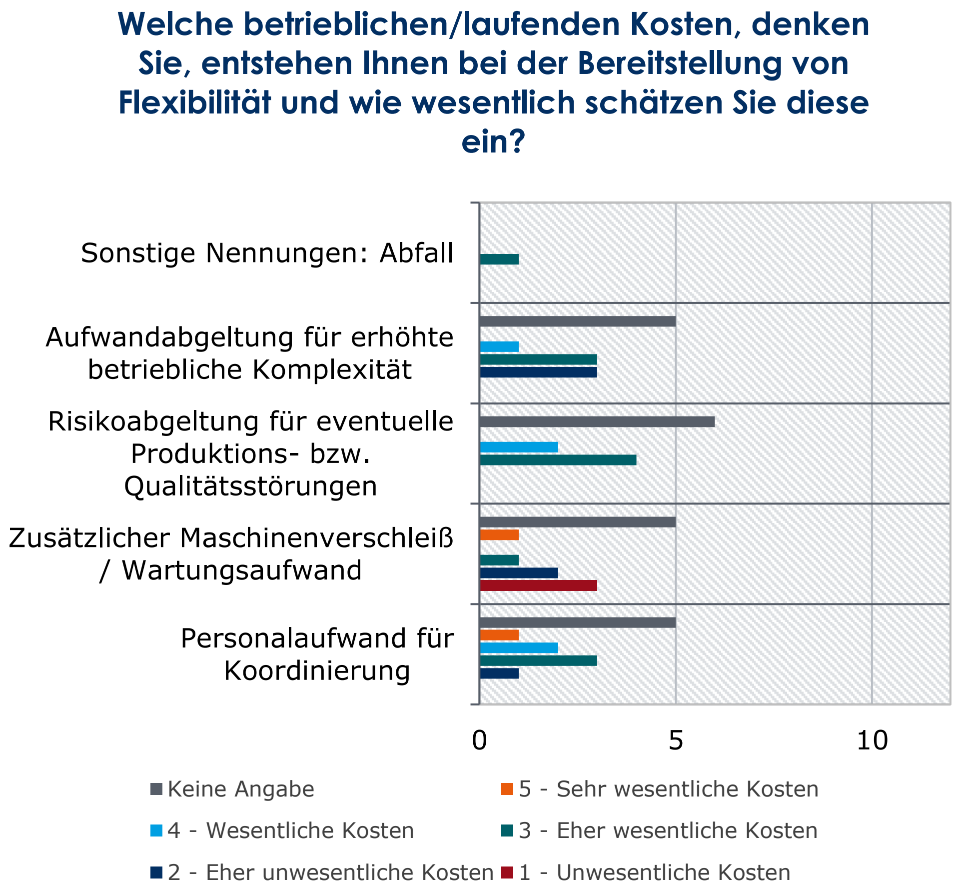
Haben Sie bereits eine zentral automatisierte Produktionsplanung mit Schnittstelle zur Steuerung/Regelung und Erfassung von Prozess- und Energiedaten in der Produktion?

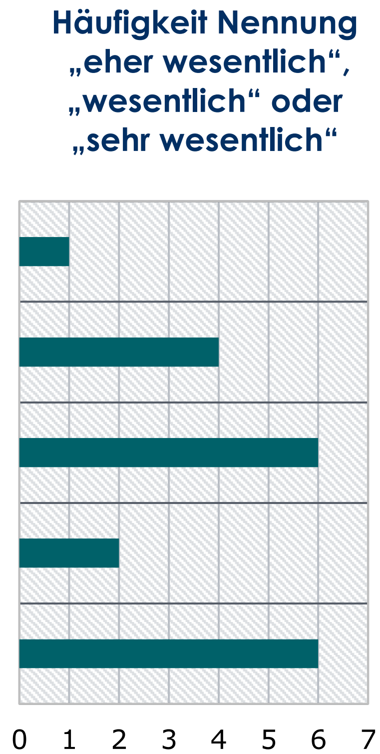


5.2.13. Question 13

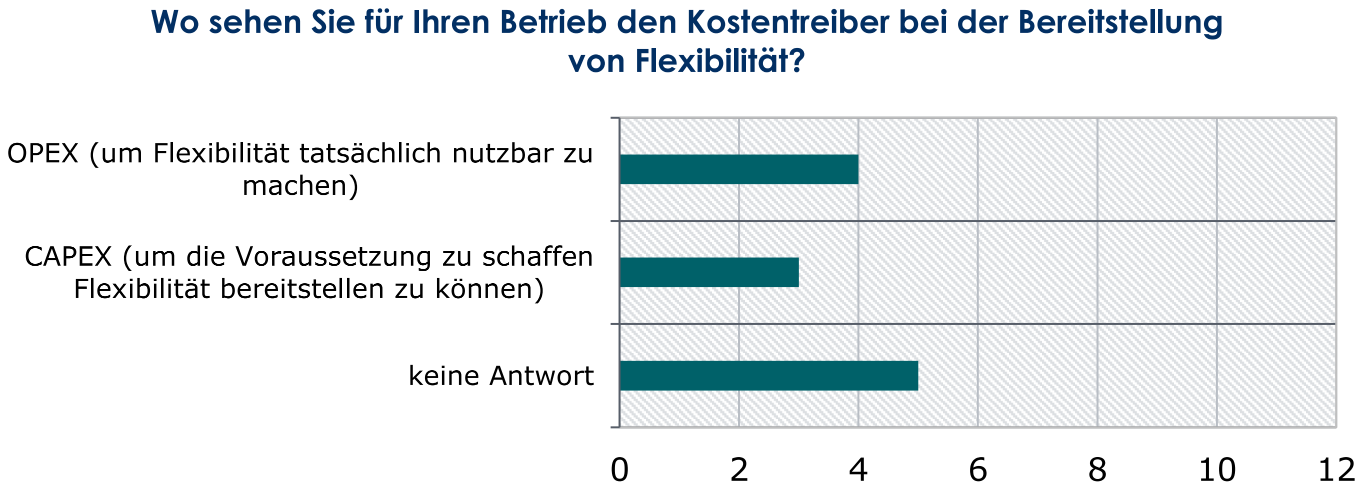


5.2.14. Question 14





5.2.15. Question 15



5.3. Additional remarks and summary

For the short survey it has to be mentioned, that the majority of companies answering the survey did not deal with providing flexibility either via spot markets or for balancing energy so far. Thus, the answers regarding the remuneration and organization of potential future redispatch have to be interpreted within this background. Here, the most relevant comments from the interviews and interpretation of answers including the surveys and the interviews are summarized:

- Participants from non-energy intensive industries hardly take advantage of existing flexibility to date
- Survey participants and interview partners from energy-intensive industries already profit from flexibility (spot markets and balancing energy)
- Automated energy planning & control has been identified as a key factor to realize flexibility provision – here differences have been identified between non-energy intensive and energy intensive industry
- Remuneration
  - If redispatch shall be attractive the participation must not lead to disadvantages for the participant (e.g. negative impact on participation in balancing energy provision)
  - If the effort outweighs the benefits, no participation will occur.
- Cost disclosure
  - Is seen as a critical aspect but not as a knock-out criterion for participation
- To be able to use existing technical but unrealizable potentials, the following differences can be identified in particular regarding the costs incurring for the company:
  - Automation and predictive control of cross-sectional technologies → investment in process control system → high initial investments
  - Postponement of (power-intensive / maintenance / ....) processes are associated with increased personnel requirements in previously unused times → high share of OPEX
  -

Summarizing, the question of how industry can be engaged in more grid friendly behavior, especially, providing flexibility for redispatch, the following can be said:

1) Awareness of the benefits and importance of a reliable grid and the future increased necessity of grid stabilization measures is prevalent at mid- and top management level
2) The main driver of commitment for providing flexibility is risk reduction of possible grid failures and associated high step costs of subsequent production halts
3) However, the premium of this risk reduction is often not considered in firms' business case considerations
4) The necessary technical but mostly the organizational effort is perceived as very high

In response to these findings, three implications were derived:

1) Role model firms and best practice examples highly reduce perceived risk and hurdles
2) Providing flexibility must yield a minimum extra return in order of the internal hurdle rate to be even considered due to basic business prudence principles.
3) Presenting the business case and incentives for providing flexibility must involve all benefits, not just direct monetary ones, as e.g. risk reduction of grid failure represents a much larger driver.

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Industry4Redispatch

Annex A – Long survey for industrial companies

(Available on request)

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NEW ENERGY FOR INDUSTRY

Industry4Redispatch

Annex B – Short survey for industrial companies

(Available on request)

This project Industry4Redispatch (I4RD, FFG #886469) is supported with the funds from the Climate and Energy Fund and implemented in the framework of the RTI-initiative "Flagship region Energy".