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Energy Sharing in the Commercial Sector With a Focus on SMEs in Germany

Determination of Technical Potentials

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Abstract. This thesis analyses the technical potential of energy sharing with the inclusion of flexible consumers in the commercial sector, with a focus on small and medium-sized enterprises (SMEs). The aim of the study is to use energy sharing to utilise electricity distribution grids efficiently and to reduce the electricity costs of the connected SMEs. The considerations are based on the cellular approach. The study area comprises a real rural distribution grid and the SMEs within it (brownfield planning). Ten companies from different economic sectors were analysed within this area with regard to their load profiles and flexible consumers. The load profiles of the study objects were recorded both for the company as a whole and for individual relevant consumers and producers. The results show that SMEs have relevant flexibility potential, particularly through controllable consumers such as heating systems, industrial trucks and air conditioning units as well as sector-specific systems. Based on the data collected, the analysis revealed a monthly energy sharing potential of 84 MWh for the ten companies in question - without optimising the use of flexibility. An extrapolation to the 117 SMEs in the grid area results in a total potential of 982 MWh per month. In addition to calculating the energy sharing potential, a simulation option is presented using the oemof.solph toolbox, which enables the economic and technical optimisation of flexibility deployment.

Keywords: Energy-Sharing, Flexibility-Potential, Distribution-Grid-Optimisation

1. Introduction

An increase in the concentration of greenhouse gases in the atmosphere can be observed worldwide. [1] In 2010, the annual average value was still around 390 ppm carbon dioxide [2], in 2023 at 419ppm [1] and in 2024 at 423ppm [2]. This increase in carbon dioxide concentration is accompanied by a change in the climate. The mean decadal surface temperature has already increased by more than 1.3 °C in the past 144 years, with the strongest increase occurring in the last 60 years. If this trend continues, the result will be an increase of up to 5.7°C. Limiting this increase is only possible through the use of climate protection measures and the reduction of CO2 emissions [1] One measure is to reorganise the supply away from fossil fuel power plants with high CO2 emissions towards a supply based on renewable energies. [3] However, this changeover requires efforts in the area of load and generation balancing. The background to this is that wind and PV electricity is dependent on supply, the deviation of which from the load cannot be fully balanced by regulating generation alone. [4] For this reason, the focus must be shifted away from exclusive regulation of generators towards regulation in which consumers also make their contribution to stabilising the grid. [4] This regulation of consumers could be carried out centrally by the transmission system operator or in the sense of a cellular approach at the lower grid levels. The cellular approach offers the advantage that better integration of renewable energy can be achieved and possible grid expansion can be avoided. [5]

One concept based on this cellular approach is energy sharing, which was introduced in Europe by EU Directives 2018/2001 and 2019/944. Energy sharing refers to the shared use of energy in a spatial context using the public electricity grid. [6] The law also opens the way for small and medium-sized enterprises to engage in energy sharing (Art. 22 (1) EU Directive 2018/2001 in conjunction with Section 3 No. 15 EEG 2023).

The question of the potential of small and medium-sized enterprises for a distribution network remains open, as 99.6% of companies in Germany are SMEs. [7]

2. Description of the data basis

This chapter analyses the flexibility and load profiles for small and medium-sized enterprises (SMEs) within a selected distribution grid. The data used in the subsequent calculation is described to enable comparability for other grid areas and applications. A detailed description of the individual data collection methods is given in Müller et al. (2025). [8] A brief description can be found in the following paragraph.

The information on the company's electricity consumption relates to a period of 30 days. Flexibilities were determined by measuring primary data from the individual machines and devices. A cross-method data collection was used to determine the flexibility of the available storage facilities.

Industry sector 31 – Manufacture of furniture.
The company employs around 50 people and specialises in the manufacture of acoustic panels and office furniture. The company's flexibilities include a heating system for gluing veneers (Thermoheizung), a pre-melting system for adhesives and an automated saw for cutting raw materials, which can be operated flexibly thanks to a large intermediate storage area. The greatest flexibility is provided by the extraction system with several separately controllable motors and the provision of compressed air. Flexible charging of the industrial trucks is also possible when they are at the charger. The company has a PV system with around 350 KWp. The electricity consumption in the period under review was 140 MWh. The flexibilities are broken down as follows:

Table 1. *Flexibility of IS 31 (No values are yet available for the flexibility potentials labelled with ?)*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Thermoheizung	1.254	-	-
Premelt	603	-	-
Panel saw	-	-	1.445
Industrial trucks	5.810	5.810	-
Compressed air supply	?	?	-
Extraction system	?	?	-

Industry sector 45 – Wholesale and retail trade; repair of motor vehicles and motorcycles. For the analysis in this Industry sector, a car dealership was considered that consists of several buildings, each of which has its own showroom. In the main building there is also a workshop with several lifting platforms for car repairs. The flexible consumers in the company include the provision of compressed air, the installed air conditioning units and an industrial truck. The company also has a photovoltaic system with an output of 50 kWp.

The electricity requirement in the period under review was approx. 12.7 MWh. The flexibility is broken down as follows:

Table 2. *Flexibility of IS 45*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Industrial trucks	395	395	-
Compressed air supply	72	-	-
Air conditioning	90	90	-

Industry sector 16 – Manufacture of wood and of products of wood and cork, except furniture. The company being analysed here is a veneer factory. The heat for the processes is provided by burning the waste products from processing the raw wood. The flexibility identified here is two industrial trucks. The electricity consumption here was 76 MWh in the period under review. The flexibility is broken down as follows:

Table 3. *Flexibility of IS 16*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Industrial trucks	2.086	2.086	-

Industry sector 47 – Retail trade.
The three companies analysed in this Industry sector are stores of a larger supermarket chain. Two older stores and one more modern store with more efficient appliances. Active energy management is already in place in the newer store. In each of the stores, both the refrigeration and ventilation systems are suitable for flexible use. Consumption at the stores was between 50.2 MWh and 62.6 MWh. The flexibility in the stores is broken down as follows:

Table 4. *Flexibility of IS 47*

Market 1	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Ventilation system	-	101	-
Refrigeration	-	6.754	-
Market 2	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Ventilation system	-	359	-
Refrigeration	-	10.156	-
Market 3	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Ventilation system	-	359	-
Refrigeration	-	10.156	-

Industry sector 25 – Manufacture of fabricated metal products.
The company in this sector is active in the field of surface coating. The company offers coating processes for both plastic and metal. No flexibilities could be determined in the company, as the processes are strictly synchronised and not automated. Consumption during the period under review was 37.7 MWh.

Industry sector 10 – Manufacture of food products, beverages and animal feed. The company operating in this industry sector specializes in the production of chocolate. The flexibilities identified here are the heating of the storage tanks, the air conditioning of the warehouse, and the existing industrial trucks. The company's consumption was 353.5 MWh. The flexibility in the company is broken down as follows:

Table 5. *Flexibility of IS 10 (No values are yet available for the flexibility potentials labelled with ?)*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Tank heating	-	43.038	-
Industrial trucks	2.402	2.402	-
Air conditioning	?	?	?

Industry sector 46 – Wholesale trade (except of motor vehicles and motorcycles). This company is a central warehouse location of a supermarket chain from 2021. This company mainly handles dry and non-refrigerated goods. The site offers an area of 36,000 m². The company has 31,500 storage spaces for pallets and 200,000 storage spaces for smaller containers. The identified flexibilities are the 130 existing industrial trucks in the company.

The data collection for the present operation has not yet been fully completed. Therefore, no information can currently be provided regarding energy consumption and flexibility potential.

Industry sector 56 – Gastronomy.
It has not yet been possible to find a suitable partner company for Industry sector 56. Therefore, a specifically adapted standard load profile G2 of the VDEW was used, which according to the VDEW (2000) [9] is to be assigned to this type of company. The flexibilities were determined using data from Karg et al. (2013) [10]. The company modelled here represents a restaurant with 20 employees and 180 seats. It corresponds to the company size and structure selected in the sample. The consumption in the period under review is: 76.3 MWh. It was not possible to break down the flexibility potential into individual consumers. The total potential amounts to:

Table 6. *Flexibility of IS 56*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Total	1.620	4.140	-

Industry sector 55 – Accommodation.
The hotel, which is in the network area, has 68 rooms and an adjoining restaurant, which is mainly used by hotel guests. There is also a spa area with a sauna. The flexible electricity consumers identified include the cold stores in the restaurant and breakfast area, the air conditioning systems and the electric sauna heater. The measurement results for the object under investigation are still pending, which is why the standard load profile G2 is used here, which can be assigned to this company in accordance with VDEW (2000) [9]. The data on flexibility is taken from Karg. et al. (2013) [10]. The consumption with the adjusted standard load profile is 24.0 MWh for this period. The flexibilities are as follows:

Table 7. *Flexibility of IS 55*

	Load increase [kWh]	Load reduction [kWh]	Load shifting [kWh]
Total	881	2.843	-

Industry sector 28 – Mechanical Engineering.
So far, no partner company in the mechanical engineering sector has been found for the identification of flexibilities and the analysis of the load profile. It was also not possible to generate an adapted standard load profile, as in sectors 55 and 56.

3. Calculation of the potentials without simulation

To determine the energy sharing potential, a comparison of the available flexibilities was first carried out. This involved checking whether positive flexibility (i.e. an increase in feed-in or reduction in supply) is offset by negative flexibility (i.e. an increase in supply or reduction in feed-in).

Only if this direct balancing was not possible was the next step to analyse whether there were inflexible loads in the grid that could be compensated for by the available flexibility. This ensures that surplus energy does not remain unused, and that grid consumption is optimised at the same time. The overarching aim of this analysis was to keep the load in the overall system as constant as possible.

The number of companies analysed differs from the originally planned sample size of twelve companies due to the current availability of data.

The calculation is based on the assumption of maximum utilisation of the available potential. This means that the costs for the use of flexibility or the consumption of the feed-in are always more favourable than alternative options. The utilisation times of components that are subject to time restrictions in terms of regeneration times (e.g. thermal storage) are selected in such a way that maximum availability is guaranteed.

For flexibilities where the time of use can be freely selected but is restricted by a daily energy quantity limit, the assignment of the times of use is random, as no optimisation can currently be carried out by the algorithm. Limiting the amount of energy without restricting the times of use can be done, for example, by the need to comply with specific daily limit values.

The calculation for the ten companies analysed so far resulted in a monthly energy sharing potential of **83.929 kWh**.

A breakdown of availability for one week is as follows. Data in the figure are average hourly values aggregated from quarter-hour values.

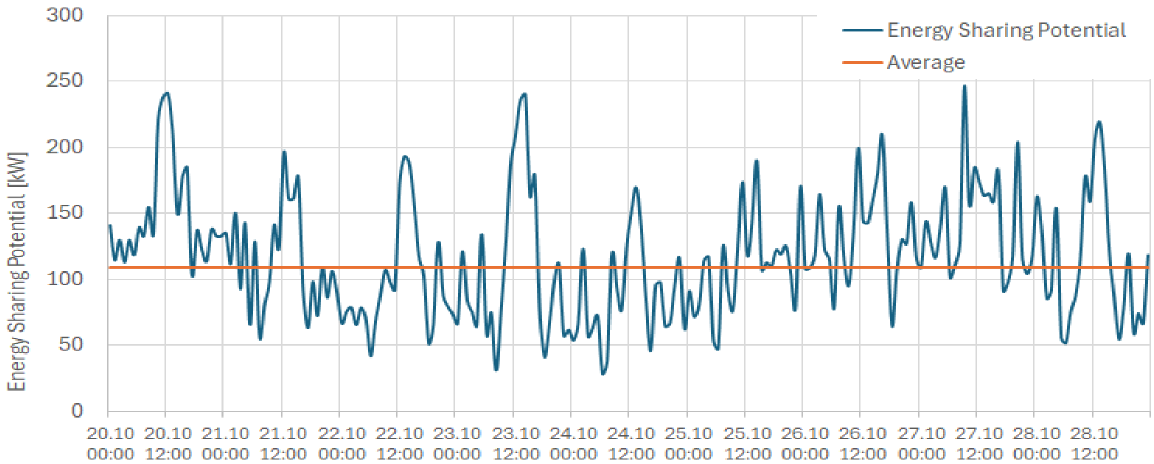

Figure 1. *Energy sharing potential of one week in temporal resolution*

A breakdown of the available potential by day (see diagram 2) shows that the energy sharing potential is greater at weekends than during the week. This deviation is due to the increased availability of the companies' flexibility on Saturdays and Sundays.

To improve clarity, the values were transferred to a heat map (see following Figure 2; red = high values, green = low values). Between 11 am and 2 pm the greatest flexibility potential exists, while in the morning and evening hours (5 - 9 am, 5 - 8 pm) the lowest potential exists. The Energy Sharing Potential is in a range of 75 kW (minimum) to 165 kW (maximum) around the average of 110 kW. The data represents the average of hourly values over a period of 4 weeks:

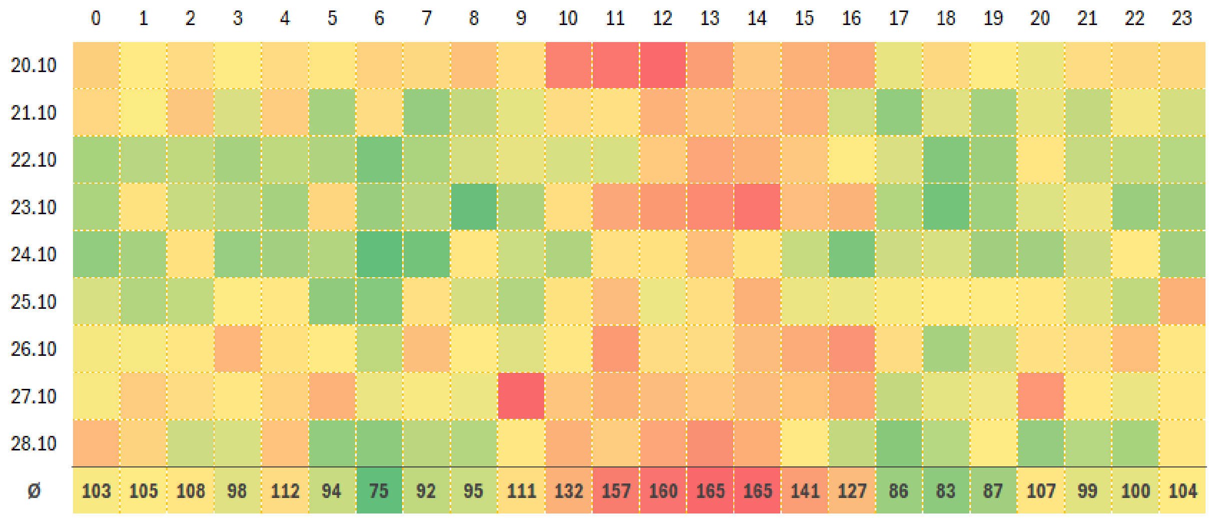

Figure 2. *Heat map of the energy sharing potential of a week broken down by day and hour*

If the monthly potential is extrapolated as the mean value of the analysed companies to all small and medium-sized companies in the grid area that were used to select the sample (117 companies in total), this results in a possible **energy sharing potential of 982 MWh** per month.

This extrapolation is based on the assumption that the flexibilities and energy flows identified in the sample are representative of the entire group of companies in the grid area. The average potential of the ten analysed companies (83.9 MWh per month) was scaled to the entire group. The underlying framework conditions, such as the availability of flexibilities, utilisation over time and the assumed maximum utilisation efficiency, were retained.

Finally, it should be noted that the load profiles and the flexibility time series from the measurement data were recorded with a time resolution of one minute and aggregated to 15-minute averages to adjust them to the values measured by the grid operator.

4. Simulation Tool

A simulation is required to fully determine the energy sharing potential of the individual participants in a distribution grid. The Oemof.solph package from the Open Energy Modelling Framework (oemof) is used for modelling and optimisation in this study. It is used to create models for the linear and mixed-integer optimisation of energy systems. The package is based on a graph structure, with directed edges representing the energy flow between the components. The graph describes the topology and the relationships between the nodes. Solph translate this graph into an optimisation model. This package is implemented in Python using the Pyomo optimisation package. Specifically, an Oemof graph model is created in the first step and the corresponding Pyomo optimisation instance is created in the next step. Finally, the optimisation model and the associated optimisation problem are solved using an external solver. [11] The selection of a solver is discussed in another chapter.

4.1 Graph – Structures

4.1.1 Graph-Structure of a Company

The Oemof framework comes with a large number of generic and specific components that can be integrated directly into the model. These components are then parameterised for the corresponding use case. The components include sources, sinks, storage, converters and buses. [12]

For modelling a distribution grid and determining the energy sharing potential of the individual companies, the model can be set up as shown below.

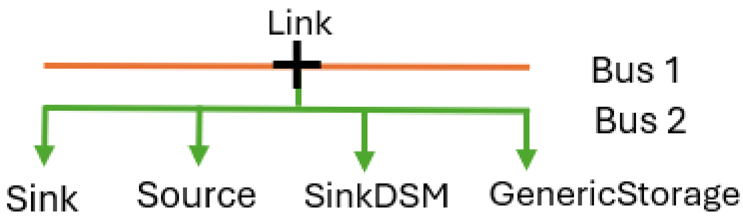

Figure 3. *Graph-Structure of a Company*

In this model, **bus 1** represents the distribution network, while **bus 2** represents the company network. The **link** component connects both buses and thus acts as a grid connection point between the two grids. The **Sink** component contains the load profile of the company, minus the consumption of the flexible consumers (modified load curve in the following). The underlying load profile is determined by the grid operator's RLM metering. The flexibilities deducted from this load curve are based on a series of measurements previously carried out in the respective company.

The **Source** component represents a decentralised generation plant of the company, if such a plant exists. The generation time series measured by the grid or metering point operator is stored here.

Each **SinkDSM** component represents a flexible system of the company that allows load shifting, for which a load curve and an associated time series of flexibility are stored. The stored load curve corresponds to that which is subtracted from the load curve of the sink component. The timing of the flexibility is based on an evaluation of the measurement series. If no measurement series are available, the corresponding data was collected using other methods. The SinkDSM component is an experimental component.

The **GenericStorage** component is used to map the company's potential energy storage systems. In this work, they are used to include the storage of electric industrial trucks in the optimisation. For this purpose, an availability time series resulting from the utilisation times of the industrial trucks is stored for the component.

The modified load curve of the sink component is required in order to model the flexible consumers individually and to be able to record the flexibility provided by them separately.

Separate modelling of the potential flexibility in a sink DSM component is not possible, as a load curve and a flexibility curve must always be assigned to it. It is necessary for the load to always be greater than the potential load reduction, otherwise an error will occur.

4.1.2 Graph-Structure of a Grid

From the structure shown in Figure 4, it can be seen that the individual companies all have the same structure and are connected to the network at the same level.

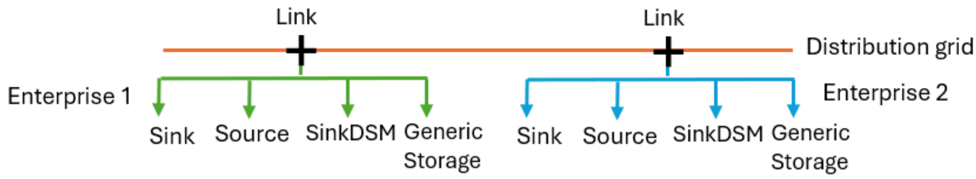

Figure 4. *Graph-Structure of a Grid*

4.2 Current challenges of modelling

It is not possible to model systems that allow a load reduction or load increase without subsequent compensation, e.g. for resolving a bottleneck in the grid. Various modelling approaches were developed within the concept, but these have not yet produced valid results.

Approach 1 was modelling using the SinkDSM component with the approach of Gils (2015) [13], which provides for the load to be compensated within a predefined delay time. However, in order to prevent compensation from actually taking place within the time steps under consideration, both the delay time and the duration of a switching cycle (shifttime) were chosen to be very large. However, the DSM component does not become active with this approach.

Approach 2 was modelling using standard components that are connected to the bus of the respective company. A source was used to model the load increase in flexibility and a sink was used to model the load reduction. This approach leads to flows between the sink and source components used (purple). This type of modelling also enables a flow between the components that represent different flexibilities in the company (red). These flows cannot be prevented and would therefore lead to excessive utilisation of flexibility.

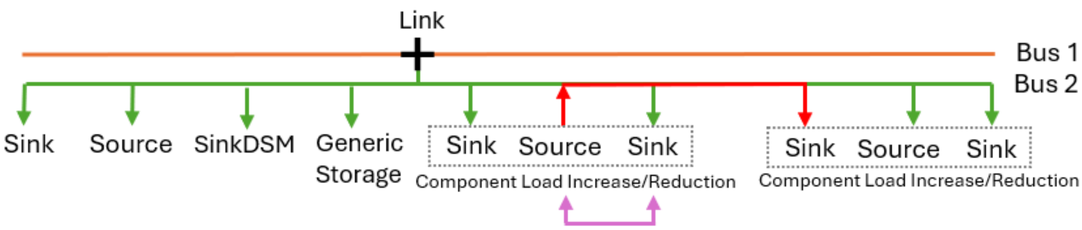

Figure 5. *Problematic load flows approach 2*

An extension of Approach 2 is the addition of a sub-bus for each component to the model (Approach 2.1). The sub-buses are connected to the company's bus using a link component so that the flows described above can be avoided due to the possible limitation of the flow direction and through suitable parameterisation of the components (sink, source).

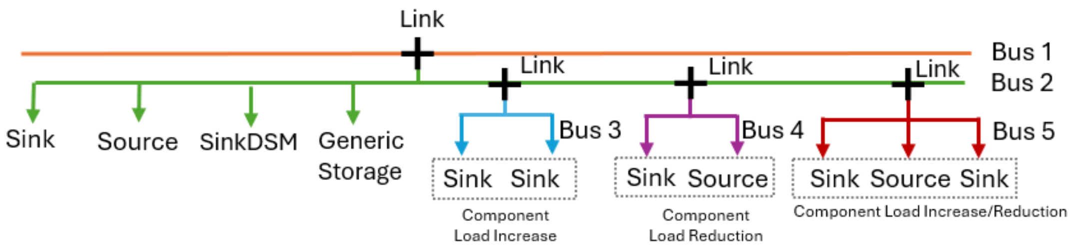

Figure 6. *Possible solution to the problematic load flows*

As it is currently not possible to include the flexibilities with a load increase or reduction without compensation in a simulation, the simulation results are not presented for the time being. This is due to the fact that the companies analysed have many of these flexibilities and carrying out the simulation without them would lead to a misjudgement of the energy sharing potential. As soon as a suitable approach has been developed that enables the integration of these components, the simulation will be realised accordingly.

4.3 Selection of the solver

The modelling of the energy system - in this case a distribution grid - is carried out using the Open Energy Modelling Framework (Oemof). This involves developing an optimisation model from which a specific optimisation problem can be derived. This problem is then solved using a suitable solver. [11]

To find the optimal solution for the problem at hand, various solvers with different properties and focal points are available. The open-source mixed-integer program (MIP) solver COIN-OR Branch and CUT Solver (CBC) is used for the given test case, which is expected to provide an optimal solution due to its algorithms. [14]

The CBC solver is ideal for this application as it is directly compatible with Pyomo (see Chapter 4) and therefore with oemof, so no further interfaces need to be configured. The performance of the solver is in the upper range compared to other freely accessible open source solvers, although CBC is inferior to solvers such as Gurobi or CPLEX in terms of computing time for larger optimisation models. [15]

5. Discussion of the approach described for determining the energy sharing potential

5.1 Influence of Grid and Company Structures

Different results when choosing a different distribution grid

The results generated using the method described reflect the potential for energy sharing in the specific distribution grid area analysed. The analysed grid area is located in a predominantly rural region that borders a large city with over 100,000 inhabitants on its outer edge. In the transition area to the large city, the structure has a more suburban character.

The specific composition of the grid area - a combination of rural and suburban structures - reflects a potential that is primarily characterised by the small number of larger industrial or commercial areas. However, in other grid areas with different spatial structures, such as urban regions with a high density of companies, a greater potential for energy sharing is expected. In such areas, the larger number of companies can have a greater equalising effect due to their different energy demand profiles and supplies, thus expanding the opportunities for energy sharing.

This makes it clear that the results depend heavily on the structural characteristics of the grid area under consideration. A differentiated view of the composition - from rural to suburban to urban - is crucial in order to correctly assess the specific potential for energy sharing and make comparable statements.

Deviating results when selecting other companies in the distribution grid

The potential was also determined on the basis of a random sample of companies in an Industry sector. However, analysing a single company from an Industry sector only provides an estimate of the available potential, as companies can vary considerably in terms of their flexibility potential even within the same Industry sector.

Therefore, different results may arise for the same grid area if other companies in the same Industry sector are taken into account. The specific characteristics of the companies analysed - such as company size, energy demand or flexibility options - have a significant influence on the results and illustrate the sensitivity of the analysis to the selection of companies.

5.2 Methodological Limitations and Data Influences

Influence of the length of the time series
The measurement series on which the simulation is based cover a period of 30 days. Potential effects that manifest themselves over longer periods of time (e.g. seasonal effects) could therefore not be taken into account. Although an attempt was made to approximate such effects by manually correcting the data on the basis of information provided by the respective company, it can be assumed that certain long-term effects would only be recognisable through measurements over an extended period. Despite the adjustments made, these effects are not taken into account in this analysis.

Activation times of the flexibilities
When calculating the energy sharing potential without carrying out a simulation, the deployment times for flexibilities with shiftable deployment periods were not optimised. It can therefore happen that a flexibility is assigned to a time at which it cannot be utilised, even though there is a demand at another time that could be covered by this flexibility.

Availability of flexibilities
The assessment of the availability of flexibilities was partly based on the statements of the managing directors of the respective companies. Technically possible flexibilities were excluded from the analysis if their use was restricted or prohibited by operational requirements or management decisions.

6. Outlook

In the next step, the companies still missing from the sample of 12 companies will be analysed and the results generated will be validated.

The Oemof framework will then be used to provide a detailed breakdown of the energy sharing potential separately for each company and the corresponding Industry sector.

The results generated here for the distribution grid are to be used to derive the energy sharing potential of small and medium-sized enterprises in Germany.

The time series generated with the help of the simulation will also be used to analyse the effects of energy sharing by small and medium-sized companies on both the distribution grid and the companies themselves.

Data availability statement

Due to contractual restrictions, the data used in this study is not publicly accessible. Interested researchers with a justified interest can send an enquiry to Sven.mueller@th-ab.de to obtain information on the availability and conditions of possible data use.

Underlying and related material

The data collection methods used to obtain the results of this work are taken from the contribution of the authors named here in the proceedings of the “Zukünftige Stromnetze 2025” conference. The programme code used for the simulation is available from the first author but is not uploaded to a repository.

Author contributions

The authors' contributions to this work can be broken down as follows: All authors were involved in the conception of the manuscript. The first author wrote the first draft, carried out the underlying series of measurements and was responsible for data acquisition and data analysis. The other authors ensured the correctness of the methods used through their professional qualifications and thus made a decisive contribution to the integrity and quality of the work.

Competing interests

The authors declare that they have no competing interests.

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