What can the mandatory energy audit database tell us about the potential of energy efficiency in Germany?

Paurnima Atul Kulkarni
Prognos AG
Goethestrasse 85
10623 Berlin
Germany
Paurnima.kulkarni@prognos.com

Dominik Rau
Prognos AG
Goethestrasse 85
10623 Berlin
Germany
Dominik.Rau@prognos.com

Keywords

Energy Efficiency Directive (EED), industrial energy saving, energy audit, energy efficiency policy, evaluation

Abstract

Enterprises, which carry out the mandatory energy audit according to German Energy Services Act, must submit an online declaration after completion of the audit process. Our team at Prognos AG analysed this database, comprising of approx. 24,000 declarations collected over a period of five years. Our aim was to gain insights about the potential of energy efficiency in German non-SMEs (larger than Small and Medium Enterprises) and assess the effectiveness of the mandatory energy audits.

The database was cleaned and unplausible entries were removed before analysis. On an average electricity and natural gas are together responsible for nearly 60 % of energy consumption of the audited companies. Only for a few sectors, more than 30 % of energy consumption comes from renewable sources. The most suggested energy efficiency measures are for illumination and heating systems. The company size (large or not large) influences the suggested measures accounting for highest energy savings and highest investment. Furthermore, the suggested measures and potential for energy savings differs depending on the business sector. While comparing the suggested efficiency measures for first and recurring audit, it is observed that during the recurring audit similar measures are suggested. This can mean, that the measures during the first audit were not or not completely implemented before the recurring audit, which takes place every four years.

This database offers significant insights into potential of energy efficiency as well as the required investment. This abstract is only a small glimpse into the total amount of results, which are shown in the paper. The results signify the importance of efficiency as a cornerstone of decarbonization of German enterprises. On the other hand, the results also suggest that energy audit is just a first step. The efficiency potential must be realized through implementing these measures to reduce demand and to achieve the efficiency targets.

Introduction

ENERGY AUDITS

The German Energy Services and Other Energy Efficiency Measures Act or (EDL-G)[1] implements the European Directive on Energy Efficiency (EED) into the national law. The regulations are intended to contribute to the European savings target of reducing primary energy consumption.

According to this, it is mandatory for all non-SMEs (larger than Small and Medium-sized Enterprises) to carry out energy audit every four years since December 2015[2]. Only a qualified and independent person is allowed to carry out the audit according to requirements given by the German and European Standard DIN EN 16247-1 – Energy audits – Part 1: General require-

1. Gesetz über Energiedienstleistungen und andere Energieeffizienzmaßnahmen (EDL-G), https://www.gesetze-im-internet.de/edl-g/EDL-G.pdf.

2. The criterion for a Small and Medium-sized Enterprise (SME), according to the EU-Commissions definition, are less than 250 employees and up to 50 million Euros annual turnover or a maximum balance sheet total of 43 million Euros. The Definition of SME based on https://www.ifm-bonn.org/definitionen/kmu-definition-der-eu-kommission.

ments[3]. With the amendments made to German EDL-G in 2018, enterprises are further required to submit an online declaration after completing the energy audit. The Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle – BAFA) is responsible for collecting these online declarations.

Even SMEs with less than 250 employees, owing to their organisational and legal structure, are obligated to carry out an energy audit in accordance with EED. For example, a legally independent company that is in a partnership or affiliated/linked relationship with other companies is not an independent company according to the EU-Commission's recommendation. These SMEs according to definition mentioned in footnote 2, will be considered non-SMEs according to EED, and are obligated to carry out an energy audit according to EED as well as report to database. The amendments in year 2018 introduced some exceptions to the rule: companies with up to 500 MWh annual energy consumption and companies with no energy consumption do not have to carry out a detailed energy audit.

Our team at Prognos AG analysed this database, comprising of about 24,000 declarations collected over the period of five years, during the period of 2019 to 2023. The data base comprises of companies which were obligated to carry out energy audit according to EED. The SMEs in the database were categorised as non-SME according to EED and hence had to carry out energy audit. The dataset is a complete set and is not a sample. Our aim was to gain insights about the status of energy consumption and energy efficiency in German non-SMEs Furthermore, we assess how effective and beneficial the mandatory energy audits are for German companies and for Germany's energy efficiency targets.

STATUS OF GERMAN ENTERPRISES

According to latest statistics there are about 3 million enterprises registered in Germany. About 99.3 % of these companies are SMEs, the remaining 0.7 % or about 20,800 are large enterprises. These large enterprises account for about 71 % of annual turnover of all companies combined[4]. The total final energy consumption in 2022 of industry sector was 667 TWh/a, and that of commercial sector was 325 TWh/a[5], resulting in 992 TWh/a of total consumption of German enterprises. A distribution of energy consumption according to size category is not available.

Data for analysis

SIZE AND CONTENTS OF DATASET

The dataset contains 23,857 declarations, each with a multitude of parameters. A few key parameters are number of employees, annual turnover, federal state, branch, and date of submission of declaration. Specific information about the audit, such as type of audit (first, subsequent), and which requirement it fulfils (requirements from DIN EN 16247-1 or enterprises with exceptions or enterprises with mixed system etc.) must be provided. Further, every enterprise must also submit their annual energy consumption and energy costs for each energy carrier respectively. Lastly, they must also provide information on the type of suggested energy efficiency measures during the audit, required investment, expected operating life and energy savings for each energy carrier. As mentioned above, it should be noted that this dataset represents a whole population of declarations and is not just a statistical sample. The results from this analysis can serve as an indicator for the German industrial and commercial sector, but the results cannot be extrapolated to all German SMEs and large enterprises.

CLEANING THE DATASET

It was observed that many values of annual turnover in the database were not given in expected unit of million Euros. Since the unit of given value was unknown, it was not possible to convert the turnover input into desired value. Since this was a key parameter to determine the size of enterprise, it was necessary to discard the implausible values. As a result, the size parameter can only be assigned for around 47 % of entries.

Out of the 23,857 declarations nearly 10,710 or 45 % are enterprises with lower than required or no energy consumption and are hence, as mentioned above, exempted from carrying out a complete energy audit according to DIN EN 16247-1. Hence these declarations are not considered for the analysis involving energy efficiency. These are, however, used for overall analysis of current trends of energy consumption and energy prices. The rest 55 % data will serve as a basis for in depth analysis. Table 1 displays the distribution of dataset with focus on company size and energy audit fulfilment.

Analysis

In this section a few key results of the analysis are discussed. For comparison, the analysis is grouped into non-SMEs and SMEs. As mentioned above, these SMEs were obligated to carry out energy audit just like other non-SMEs.

DISTRIBUTION OF DATA

The valid database, as shown in Table 1 (not including the implausible values), consists of about 5,836 large enterprises, or 54 % of overall plausible entries, followed by 3,067 medium enterprises, accounting for 28 %. Lastly the smallest and small enterprises sum up to 1,926 or 18 % of entries. The large enterprises accounting for more than 50 % of entries is no surprise since the energy audits is mandatory for non-SMEs. The SME representation in dataset is significant, even if they had to conduct energy audit mainly due to their organisational structure. When comparing the business segment, commercial enterprises account for about 70 % by count and 67 % by energy consumption of the database. The regulations are also driving the less energy intensive commercial enterprises to account for their energy consumption. Industrial enterprises, on the other hand, account for only 30 % by volume and 33 % by energy consumption. Figure 1 shows the distribution of SMEs and large enterprises and their respective business segment within the database.

3. DIN EN 16247-1:2012-10 Energy audits – Part 1: General requirements; German version EN 16247-1:2012, https://dx.doi.org/10.31030/1870694.

4. Anteile Kleine und Mittlere Unternehmen 2021 nach Größenklassen in %, English: Shares of small and medium-sized enterprises 2021 by size category in %, https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Unternehmen/Kleine-Unternehmen-Mittlere-Unternehmen/Tabellen/wirtschaftsabschnitte-insgesamt.html?nn=208440.

5. Endenergieverbrauch nach Energieträgern und Sektoren, English: End energy consumption according to energy carriers and sectors, https://www.umweltbundesamt.de/daten/energie/energieverbrauch-nach-energietraegern-sektoren#allgemeine-entwicklung-und-einflussfaktoren.

Table 1. Distribution of dataset and valid data points.

Dataset	Number of data points
Total number of declarations	23,857
Size of enterprise	
Number of large enterprises	5,836
Number of small and medium enterprises, considered as non-SME on group level according to EED	4,993
Total number of enterprises with valid size data	10,829
Number of declarations with undetermined size (invalid/incorrect)	12,375
Energy audit	
Number of declarations fulfilling requirements of energy audit as per DIN EN 16247-1	10,824

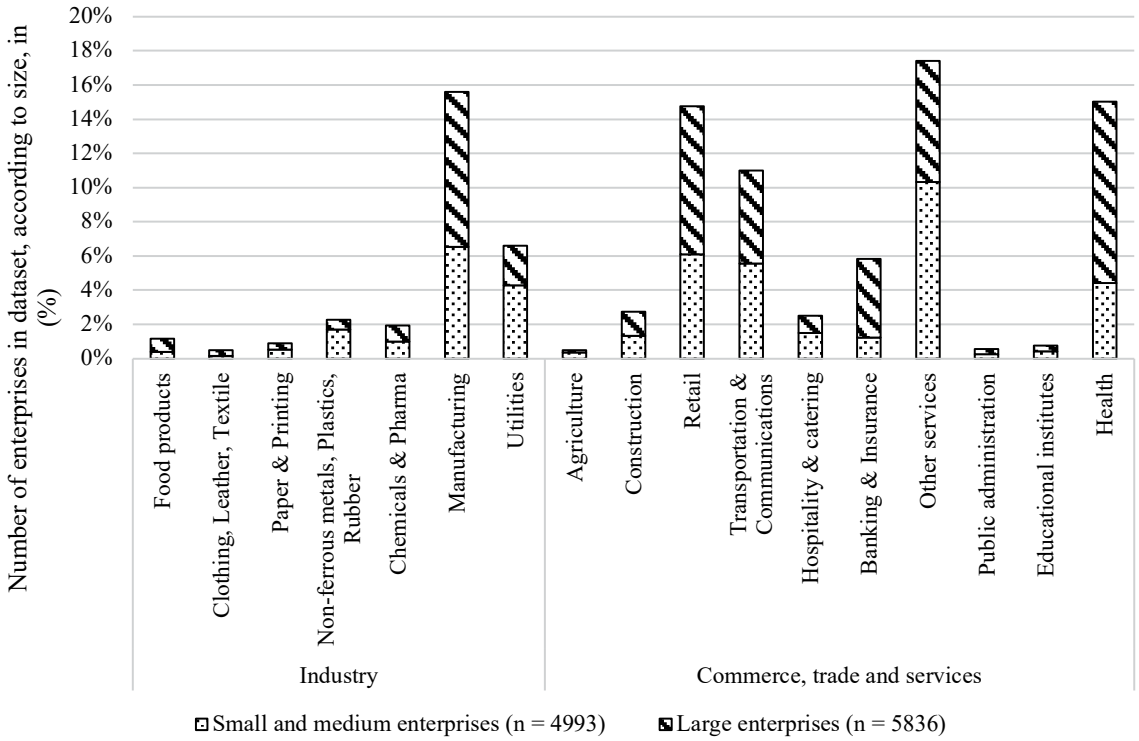


Figure 1. Distribution of enterprises in dataset according to their business segment and size.

The business segments like retail, transportation & communications, health, and other commercial services, account for a greater share of enterprises, both in large enterprises and SMEs, compared to industrial companies. On the other hand, dataset of industry is dominated by manufacturing and utilities segment. The public administration segment contains public sector enterprises, which are not mainly exercising public governance functions.

CURRENT TRENDS

The energy consumption of an average enterprise comprises of approx. 34 % of electricity and 30 % of natural gas, together accounting for nearly about 65 %, followed by diesel (13 %) and district heating (10 %). For enterprises belonging to agricultural, hospitality & catering, construction, and utilities sector, as well as public sector, more than one third of energy consumption comes from renewable sources.

Based on the yearly energy consumption and energy costs, it was possible to calculate price for each energy carrier. After analysing the spread of the calculation, some 3,000 values were found implausible. After elimination, a corrected energy price was calculated based on following limits: every price below 5 Euro/MWh and above 500 Euro/MWh was eliminated and not considered for further analysis.

Figure 2 shows progression of average energy price of significant energy carriers over the period of last five years. While comparing the energy prices of these energy carriers, as shown in Figure 2, from 2019 till 2023, an upward trend after the Russian invasion in Ukraine is visible. Electricity prices, which were also increasing till 2022, have reduced nominally in 2023.

EFFICIENCY MEASURES

While comparing the number of suggested measures during the energy audit with the size of enterprise, it is observed that the most suggested measure, for both SMEs and large enterprises, is optimising the lighting systems. Optimisation of heating systems is the second most suggested measure. The estimated average energy savings, by implementing suggested measures paint a different picture. Figure 3 shows the average estimated energy savings of six significant measures in the dataset. The highest average energy savings in large enterprises are by efficient motors and drivers, cogeneration, and optimisation of production process respectively. On the other hand, the highest energy savings in SMEs are by waste heat recovery, followed by cogeneration, and production process optimisation. Organisational measures, like awareness, maintenance, behavioural changes, and procurement of energy efficient products, also account for considerable savings essentially in large enterprises.

Figure 4 displays the average estimated required investment in dataset, expressed in thousand Euros. The highest average investment required by a large enterprise is for optimising building insulation, of about 270,000 Euros, followed by for installing a cogeneration system, of about 245,000 Euros. For SMEs the average investments are significantly lower than that of large companies. production processes and cogeneration are exception to this. The investment required for these two measures by an SME is comparable that to a large company.

POTENTIAL OF ENERGY EFFICIENCY

Occurrence of audit

Based on the parameter occurrence of audit, it was possible to compare the suggested measures during the first and the subsequent audits. Figure 5 shows the share of suggested measure during first or subsequent audit in total number of measures. It is clearly visible that during the first and recurring audits similar

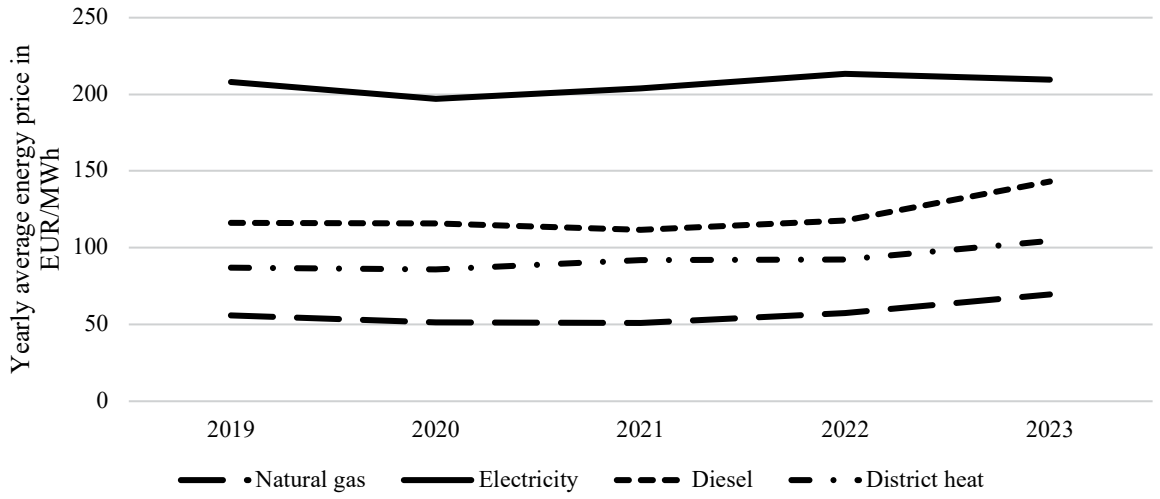


Figure 2. Progression of average energy prices of significant energy carriers over five years.

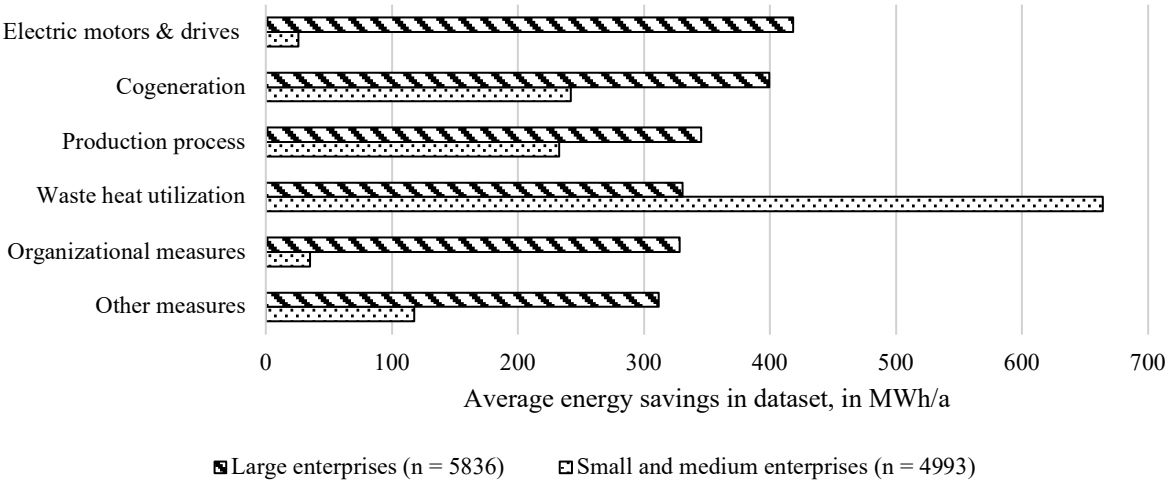


Figure 3. Average annual energy savings of six significant measures in dataset, in MWh.

measures are suggested. This could mean that the suggested efficiency measures during the previous audit were only partially or not at all implemented. According to the German Energy Services and Other Energy Efficiency Measures Act (EDL-G), the enterprises are not required to implement these efficiency measures. Hence enterprises are less likely to implement measures on their own, which is supported by this analysis.

Energy savings

To assess the potential of energy efficiency in each business segment, the following analysis is carried out. Each declaration comprises of list of energy efficiency measures and an estimation of energy savings for each measure. The potential of energy savings in (%) are calculated by dividing the sum of estimated energy savings per business segment by the sum of energy consumption per business segment. About 4 % of energy consumption of large enterprises can be saved by realising the suggested measures. In case of SMEs, nearly 7 % of energy can be saved by implementing the suggested measures. Figure 6 shows the estimated share of energy savings in percentage of total energy consumed by each business segment, within this database. From the data analysis, energy savings for an SME belonging to the business segment hospitality amounts to 57 %. This value is too high and hence seems incorrect. This could be due to the incorrect inputs of energy savings made by enterprises in the online declarations.

Figure 7 displays the average amortization time and average operating life of selected energy efficiency measures of dataset, expressed in years. For each given energy savings and investment, the static amortization time is calculated as required investment divided by given annual costs savings. The building insulation measure, excluded in the figure, has by far the highest amortization between 23 to 29 years. The size of the company

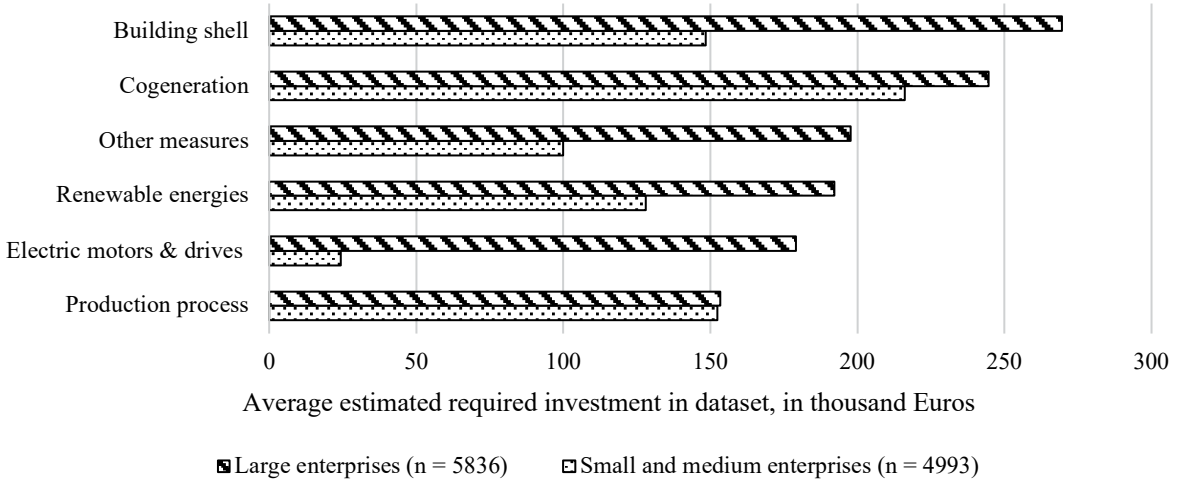


Figure 4. Average estimated required investment in dataset, calculated in thousand Euros.

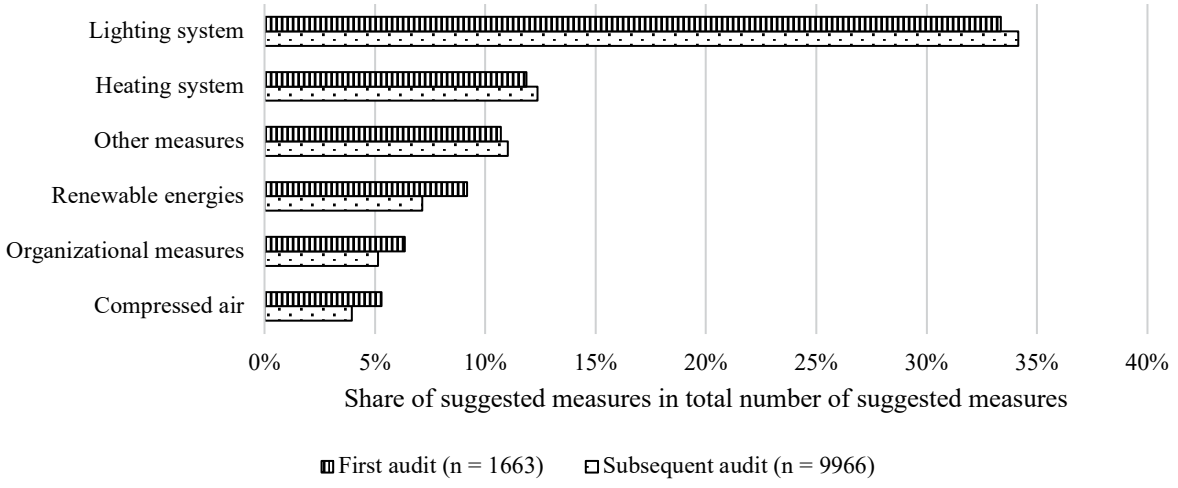


Figure 5. Comparison of measures suggested during the first and subsequent audit, represented in share of total number of measures suggested for each audit occurrence.

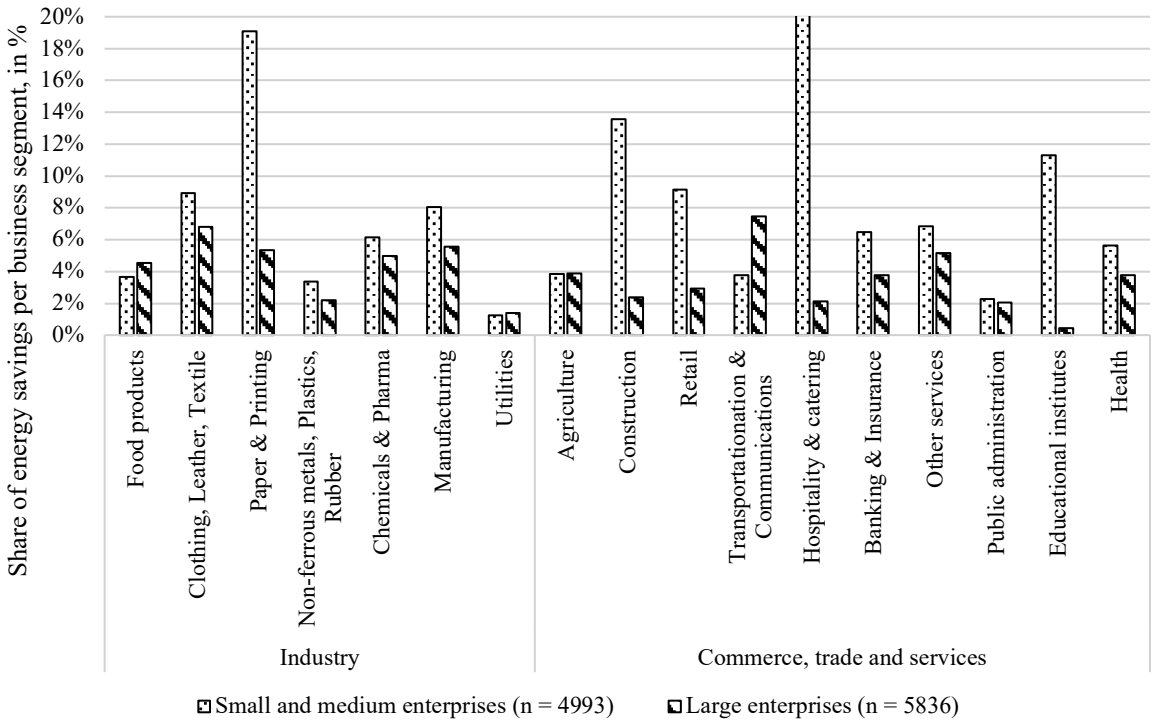


Figure 6. Estimated share of energy savings per business segment, in Percentage (%).

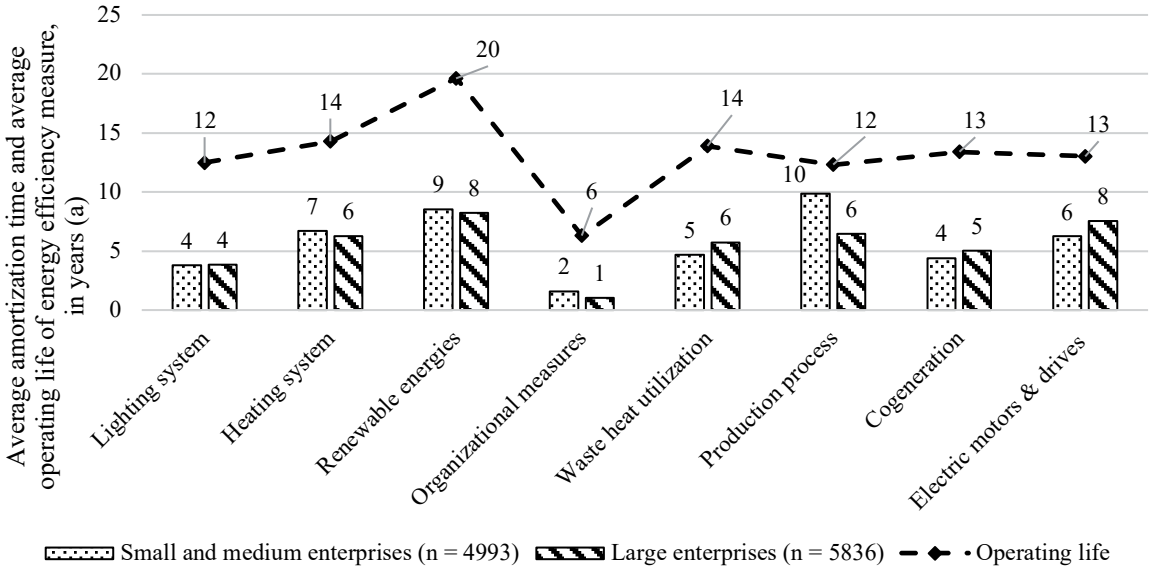


Figure 7. Average amortization time and average operating life of selected energy efficiency measures of dataset, expressed in years (a).

does not influence the amortization time, except for production process. In SMEs, the investment required for production processes are higher and/or the energy savings are lower, resulting in higher amortisation time compared to large enterprises. Renewable energies have highest amortisation but also highest operation life. On the other hand, low investment measures like organisational measures are cost effective, at the same time difficult to monitor. The operation life span of all measures is significantly greater that the static amortisation period, ensuring cost savings well after the investment is paid off.

Findings and conclusions

The database consists of valuable information about many aspects of energy audit process, many of which are covered by this paper. Out of approx. 24,000 energy audit declarations, only about 10,000 contain relevant inputs about energy consumption, energy savings and investments. It should be noted that, this data does not represent German industrial and commercial segment. Many large companies, which have certified energy or environmental management system are not part of this data. Similarly, many enterprises, which are considered as

SME according to EU-Commission and German EED are also not found in this database. Hence the results are not applicable to the whole industrial and commercial sector and should not be extrapolated but can be used as indicators. For example, the average energy savings per business segment can vary in reality but can be used as an indicative value.

Further the database highlights the significance of energy audit as an instrument to identify the significant energy potential in large enterprises, in not only industry but also in commercial enterprises. An energy audit will seldom identify the full potential in any enterprise. Currently it is not required to implement the energy efficiency measures, which are suggested and economically assessed during the energy audit. As observed from the analysis, most measures are repeatedly suggested during the subsequent energy audit, which should take place every four years. At the same time the analysis also displays the average energy savings potential between 4 % to 7 % of consumption, which amounts to a total savings of about 5.4 TWh, when all measures in the dataset are implemented. Recurring audits may discover efficiency potentials "higher up". Additionally, many of these measures amortize much earlier before the given operating life span. Conducting the energy audit is just a first step towards continually increasing energy efficiency within a company.

Energy efficiency is a cornerstone of energy transition for German enterprises. By implementing these measures, potentially significant energy savings can be realized, and energy costs can be reduced. But an energy audit cannot ensure a continual energy efficiency for an enterprise. To monitor the energy consumption and costs as well as to improve the energy efficiency, a more systematic approach is required. An energy management system maintains this continual process of improvement. The German Government has introduced a new law to improve energy efficiency in Germany (EnEfG)[6] in late 2023. With this law, it will be mandatory for high energy consuming enterprises (annual consumption equal to or more than 7.5 GWh/a) to implement an energy management system according to ISO 50001: 2018 or an environmental management system according to EMAS. Rising energy prices will increase the pressure on enterprises to improve energy efficiency and cut energy costs over a longer term. New regulations will ensure that, the enterprises achieve their efficiency targets and contribute to the energy transition.

Acknowledgements

I would like to thank Anja Happ and Martina Erler from Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle) for the opportunity of analysing the database of energy audit declarations. Furthermore, I would like to thank Dominik Rau and my team at Prognos AG in his continued support and guidance in making this paper a reality.

6. Gesetz zur Steigerung der Energieeffizienz in Deutschland (Energieeffizienzgesetz – EnEfG), https://www.gesetze-im-internet.de/enefg/BJNR1350B0023.html