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REVIEW ARTICLE

Analysis of energy audits results and impacts: case of small and medium enterprises in Lithuania

Aurimas Lisauskas · Vaclovas Kveselis · Eugenija Farida Dzenajavičienė · Sigitas Masaitis · Eugenijus Perednis

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Abstract Efficient energy use in industry is an important issue capable of reducing the overall energy consumption. Large enterprises in the European Union countries are obliged to conduct regular energy audits or implement energy management systems, while for small and medium enterprises, energy audits are voluntary. However, governments implementing their energy and environmental policy goals support energy audits in small and medium enterprises through national support programs. Another driving factor is compulsory energy audit for companies seeking financial support for their modernization and implementation of renewable energy projects. The article presents an overview of findings from energy audits of 18 small and medium enterprises in Lithuania, starting with energy management and accounting issues and their energy consumption profiles, followed by proposed energy-saving measures, estimated energy savings, and avoided greenhouse gas emissions. Buildings, technological processes, and transport are the main energy consumption sectors in audited companies. The relatively short pay-off time required by industrial small and medium enterprises limits the amount of investment and achievable energy savings. Audit recommendations containing opportunities to introduce renewable energy installations expand the environmental benefits of auditing. The cost of energy savings resulted from recommended energy efficiency measures compared with energy prices and availability of resources is one of the strongest economic arguments for accepting audit recommendations.

Keywords Energy efficiency · SME · Industry · Auditing · RES

A. Lisauskas (✉) · V. Kveselis · E. F. Dzenajavičienė · S. Masaitis · E. Perednis
Lithuanian Energy Institute, Breslaujos str. 3, Kaunas, Lithuania
e-mail: Aurimas.Lisauskas@lei.lt

Introduction

The European Union (EU) has set ambitious targets on its environment and energy policy for the coming decade where efficient use of energy resources should play an important role (European Parliament and the Council, 2018) (Official Journal of the European Union, 2012). One of the potentials for improvement in energy efficiency lies in the industrial sector. Eurostat data (Tsemekidi et al., 2020) indicate that industry made 24.6% in final energy consumption in EU-28 in 2017, following transport (30.8%) and household (27.2%).

The data of the European Environment Agency (final energy consumption 2018) states that final energy consumption between 2005 and 2016 was reduced approximately by 7.1% (or 0.7% annually) in the EU-28 (European Energy Agency, 2018). The largest decrease was in the industry, by 16.4%. Final

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electricity consumption in the industry made up 46% of total final electricity needs in the year 1990 and dropped down to 36% in the year 2016. On the contrary, electricity consumption in the services and households' sectors increased during the same period. The same source states that such a decrease was influenced by economic performance and structural changes. The impact from favorable climate conditions or more mild winters had an impact on lower heat consumption. However, final energy consumption started growing again in 2015 and is higher than the 2020 year target.

In the year 2012, the new requirements for energy efficiency improvement in the industry were defined in the Directive on energy efficiency (Official Journal of the European Union, 2012), which in Article 8 promote availability of involved mandatory and regular energy audits in large enterprises among other provisions. Such large enterprises may achieve significant savings while considering relevant or International Standards EN ISO 50001, (ISO, 2018) and EN ISO 14001 (ISO, 2015) if the latest includes resource and energy management. Nevertheless, the above standards define only general requirements for energy management systems and do not show how to implement energy efficiency improvement processes (Dörr et al., 2013).

EN 16,247 standards group on energy audits was developed in 2012–2015 by European Committee for Standardization. This standard was used as background for the development of national methodologies, which should be followed while conducting energy audits in industry and cover energy consumption in buildings, technological processes, and transport. A separate energy auditing methodology for public buildings was developed and approved in 2008 already, and methodology for audits for industrial processes and equipment—in 2010 in Lithuania (Lietuvos Respublikos ūkio ministerija, 2008).

Energy audits are not obligatory for small and medium enterprises (SMEs). The same Article 8 in the Directive of energy efficiency (Official Journal of the European Union, 2012) states Member States shall develop programs to encourage SMEs to undergo energy audits and the subsequent implementation of the recommendations from these audits. On the basis of transparent and non-discriminatory criteria and without prejudice to Union State aid law, Member States may set up support schemes for SMEs, including if they have concluded voluntary agreements, to cover costs of an energy audit and of the implementation of highly cost-effective recommendations from the energy audits, if the proposed measures are implemented.

Member States can use alternative measures for promoting the implementation of energy efficiency measures, such as financial incentives for conducting energy audits. There were 3 calls for industrial companies willing to get such support under the program "Auditas pramonei LT" during 2015–2018 in Lithuania (MF of the LR, 2015, 2017, 2018). State support intensity was 50–80% of eligible auditing costs; small companies were entitled to a higher percentage. Besides, the national regulations require energy audits for applicants for financial support from the state support programs for SME modernization including renewable energy installations.

The authors of this article have conducted a number of energy audits in recent years in both large companies and SMEs. The audited small- and medium-sized enterprises are characterized by the fact that they independently applied for audit support to modernize the company and implement renewable energy projects. The data collected during the audits on the activities of these companies and the energy resources used reveal the diversity and peculiarities of individual companies. Overview of production costs disclosed that the range of energy costs makes between 1 and 6% in most companies (11 of 18), which have provided data. However, 6 companies did not show their cost structure due to commercial reasons. The highest energy costs are at wholesale trade and logistics companies (up to 30% for one of the companies). This on average is higher than that for many SMEs in Central Europe, where it is 1 to 3%. This makes energy a rather irrelevant aspect of production (European Commission et al., 2018). Besides, this paper was written before the recent surge in energy prices.

The objectives of this analysis of the collected audit data are (1) to determine the scope and types of energy resources used in enterprises; (2) to distribute the energy resources used by consumption sectors—buildings, production processes, and transport, as well as by main consumption areas—lighting, space heating, ventilation, and various technological processes; and (3) to present the identified energy-saving measures and the amounts of potential energy savings and the payback time of the measures, as well as the price of energy savings. Also, by assessing the environmental impact of energy savings, greenhouse gas emissions are avoided.

The results of the analysis can help decision-makers to better target available resources to those energy efficiency measures that will bring the greatest benefits.

Background

The main policy objectives in EU member states are either financial support (61%), information/advice (31%), regulations (3%), and national plans or strategies (5%). With the financial support available to SMEs, the highest numbers of policy instruments were loans, subsidies, and funds. Information/advice policy instruments involve training, networks, benchmarks and tools, capacity building, energy audits, awareness-raising, and information guidance. The remaining 8% of policy instruments identified are either regulation, consisting of obligations and standards, or national plans/strategies. Linking Energy Audit Policies to enhance and support SMEs towards energy efficiency was investigated during Leap4SME project (Paffard Bex et al., 2021), implemented under Horizon 2020 Programme.

Small- and medium-sized enterprises and MURE databases show that the most energy-consuming industry branches in 28 EU member states, as well as the UK, are the chemical industry with 19% followed by the steel industry with 18% of total industrial consumption (data of the year 2013) (ODYSSEE & MURE Databases, 2015). The study performed on the data of these databases defines financial measures as dominating for improvement of energy efficiency in industry, combined with suitable policy mix, including regulatory and incentivizing instruments (ODYSSEE & MURE Databases, 2015). The findings of the study show that energy audits and energy management are the important instruments to estimate energy saving potential; however, it states that the same measures could be applied for SMEs as well if specific programs are established to address their needs.

The study on energy efficiency potential in industry and on possible policy mechanisms conducted for 8 industry branches across EU countries suggests three different energy-saving potentials: (a) technical (technically feasible savings are energy saving with a very high hurdle rate then simple payback time is more than 5 years), (b) economic with a low hurdle rate (2–5 years simple payback time), (c) economic with a high hurdle rate (up to 2-year simple payback time) (Yeen & Kantamaneni, 2015). For the period to 2030, estimated technical potential is 23.5%; economic (low hurdle rate), 4.7%; and economic (high hurdle rate), 4.1%.

Energy audits are considered to be the first and key step in improving energy efficiency in SMEs, as they provide sufficient data to identify potential areas for improvement and savings (Paramonova & Thollander, 2016). Energy management is insufficiently developed in SMEs with low energy demands (Thollander et al., 2007). The implementation rate of the promising measures proposed in the energy audits is only around 50% (Anderson & Newell, 2004). Improvement of energy efficiency means implementation of technological and/or management measures leading to reduced use of primary energy resources and lower final energy consumption in industrial processes, buildings, and transport. This should also lead to the minimization of negative environmental impacts. The case study on energy efficiency opportunities in the specific big companies shows that, for example, in grid equipment–producing company, economically feasible energy savings can reach 3% together with the respective reduction of greenhouse gas emissions (GHG) (Kinir & Bansal, 2011).

A survey of different policies for industrial energy auditing in selected countries around the world disclosed that stand-alone energy auditing programs are the best fit for small and medium enterprises (European Energy Agency, 2019). Usually, governments cover all or significant parts of auditing costs for industrial SMEs. Governments usually subsidize not only energy audits, but also training and certification of auditors, standardized tools and guidebooks, databases, follow-ups, and case studies (Lu & Price, 2011) (Palm & Backman, 2020). An example of such a standardized tool is presented in Thollander et al. (2012). Such support in Lithuania was available through the measure “Auditas pramonei LT” during 2015–2018 financed from the state budget and EU structural funds. The national EE promotion by subsidizing the industry is defined using the measure “Auditas pramonei LT” to promote identification of energy consumption volumes, define possible reduction of energy consumption, and provide respective measures for improvement of energy efficiency in companies. The target groups are large as well as SMEs and micro-companies, and the subsidy is below 18,000 € (MF of the LR, 2015) (MF of the LR, 2017) (MF of the LR, 2018).

Energy efficiency networks (EEN) can be offered as an additional tool to provide companies with the necessary support to succeed with energy management and to ensure that energy efficiency measures (EEM) are effectively implemented (Jalo et al., 2021). Subsidized energy audits make it easy for SMEs to access network services (Schlomann, 2016). It was proven that EEN double the implementation rate by providing SME support and services they need to improve their EE (Köwener et al., 2011). EEN are networks of companies with common interests. SMEs need to adopt more environmentally friendly practices. Recently, a search has been made for a balance between the environmental, economic, and social aspects of company activity (Epstein et al., 2018). Research shows that the supply chains can only become sustainable in the long term, and only then the environmental and social aspects of businesses are also considered (Yeen & Kantamaneni, 2015). The three main aspects of sustainability are ecology, economy, and social affairs. They all are connected like overlapping circles, with sustainability expressed in the middle of these intersections (Stopper et al., 2016) (Moreno-Mondéjar & Cuerva, 2020).

SMEs should carry out activities related to economic and ecological production in line with sustainable practices. There are conflicting conclusions on the correlation of social and environmental practices between a company's sustainability and the economic performance of SMEs. Sustainability indicators can be defined as a company's performance in all aspects and for all sustainability factors (Stopper et al., 2016; Pham & Kim, 2019; Schaltegger & Wagner, 2006).

Energy audits help support the increase of energy efficiency in industry; however, studies show that often only part of the recommendations are implemented in Germany (Fleiter et al., 2012b). The main barriers are short-term profitability, access to capital, and difficulties in financing the high start-up capital costs of energy efficiency measures (Gruber et al., 2011). In the absence of an approved package of new EEM, policymakers have provided additional financial measures to motivate companies to implement the recommended EEM. Though energy audits in SMEs are state supported by the governmental programs in many countries, the reason to pay a company's share of several thousand euros still seems too expensive for small and medium companies bearing in mind uncertainty if results of the audit will disclose significant energy-saving opportunities, resulting in reduction of energy bills (Schleich & Gruber, 2008).

The cost of energy-saving measures increases where comprehensive auditing and high investment into identified energy efficiency measures are needed. At the same time, small companies often have no energy consumption monitoring systems at process and equipment levels. In this case, the measurements are essential in performing comprehensive energy auditing in industry; however, such measurements are complicated due to (Giacone & Mancò, 2012):

- Existence of not one but several production processes.
- There might be several various types of products.
- Different indicators should be used for different installations.
- Specific energy consumption depends on the production rate.
- Specific energy consumption does not show the efficiency of energy generation or consumption.

System boundaries should be defined properly between installations. Swedish researchers (Thollander et al., 2012) suggested the unit process concept for energy audits in SMEs, which divides energy use of the company into small parts (processes or technological units). Such units are usually typical and exist in nearly all industrial companies. This method enables comparison between companies, even if these are of different industry sectors. The shortage of the method is that it does not cover all energy needs because of technology differences. The authors (European Energy Agency, 2019) also suggest 3 levels of energy efficiency assessment: (1) brief survey on site, investigation of energy bills, and identification of no-cost or low-cost measures; (2) more detailed survey and breakdown of energy use, based on economic and owner's constraint criteria; (3) focuses on capital intensive measures via detailed evaluation of costs and savings, including technological alternatives. The same can be said about energy management systems where insufficient infrastructure, missing measuring devices, and lack of manpower and competence related to new and innovative technologies are the main barriers to overcome for effective and continuous energy efficiency improvement in industrial sites (Dörr et al., 2013). Besides technical measures, energy management is an important issue of energy efficiency in industry, which includes efficient production planning, covering such objectives as saving of energy resources, minimizing negative environmental impacts, and cost-saving via production management and logistics (Raju et al., 2018).

Unlike energy efficiency measures in buildings, where long payback time energy efficiency measures are acceptable (Dongellini et al., 2014), manufacturing processes require much shorter pay-off times (Bagodi et al., 2022); a 3–5-year payback period for technology investments is often preferred by investors as the maximum payback time. The results of performed audits in industrial processes show that energy efficiency measures can save from 5 to 70% in energy consumption of the industrial companies respectively using energy efficiency investment with return period not exceeding 2 years (Gupta et al., 2014) (Kluczek & Olszewski, 2017).

The result of energy audits in the industry is the optimal cost and quality ratio; however, SMEs are not ready to perform costly (3rd level) energy audits with many measurements; thus, such companies should use a simplified methodology, as audits are voluntary for such companies. In Lithuania, energy audit for SMEs becomes obligatory in case the company applies for state support from the national programs for investment projects, such as renewable energy installations or energy efficiency measures (e.g., solar PV, heat pumps, and others). An analysis of energy audit program results in Latvia shows that the average technical energy-saving potential in the industrial sector is 6.35%. In Bulgaria, the results of the 2014–2020 European support exercise showed that one-third of the projects funded have a payback period of more than 20 years and only one-fifth has a payback period of less than 5 years. The median payback time for projects is 10 years (Nigohosyan et al., 2021). An average economically based energy saving potential in reviewed companies is 4.17% (Kubule et al., 2020). Real energy savings also depend on the implementation rate of audit recommendations. An analysis of the Swedish energy efficiency program SEAP showed that the implementation rate of audit recommendations was 53% with higher figures in low-cost measures (Backlund et al., 2015).

Benchmarking of energy use by different industries can disclose energy-saving potential. In most cases, only disintegrated energy use of the main common production and supporting processes such as drying, heating, disaggregation, molding, and air compression can be evaluated due to differences in energy use for other needs, site specifics, climate, and others. Swedish researchers suggest an energy efficiency indexing methodology, based on key performance indicators levelized to reference values of specific industries (Andersson et al., 2018). The investigation was performed based on the energy auditing results of 11 sawmills in Sweden. The energy efficiency index could be used as an indicator for energy managers and energy efficiency monitoring on company's and authority's levels.

The investigation has shown that the cumulative energy-saving potential for SMEs can be quite large and can be achieved at lower costs, as most improvements need to be implemented in auxiliary processes and are relatively easier to implement compared to measures in production processes (Thollander et al., 2015). Energy audits can serve as a know-how tool to change public opinion without underestimating the inadequate information on available technologies. Conducting an energy audit is the first step toward improving the energy efficiency of an SME. Energy audits alone do not lead to energy savings, but they do highlight areas for improvement and opportunities for more efficient energy solutions (Bunse et al., 2011).

Different programs have been developed in various countries and they have shown different rates of EEM implementation. The US Industrial Assessment Center has conducted 14,000 free audits for companies since 1976. The average implementation rate was 50% (Anderson & Newell, 2004; Muthulingam et al., 2010). The German KfW Reconstruction Credit Institute provided grants for 9200 SMEs, and the implementation of EEM reached 77% (Gruber et al., 2011). An energy auditing program (EEAP) for 1200 companies was conducted in Australia. The programs were partially subsidized and several measures were compared. It assessed EEM implemented as appropriate and justified the investments. The overall effectiveness of the measures was as high as 80%. Due to limited resources and lower priority given to energy issues and the low potential for energy savings per company, as well as the high diversity of SMEs in the sector, there was no strong focus on improving energy efficiency in Sweden (Paramonova & Thollander, 2016). After investigation of the Energy Audit Program (SEAP) in operation between 2010 and 2014 and carried out an impact assessment, it was defined that the program saved up to 340 GWh per year or 6% of final energy consumption in 713 companies participating in the program and the overall efficiency of implemented measures was 53%.

The Highland project in Southern Sweden implemented from 2003 to 2008, and covering 340 SMEs, should be noted. The implementation rate of the measures was 22% or 40% of the estimated and planned measures. The project aims to increase the uniformity of energy awareness through SME energy audits carried out free of charge by consultants hired by municipalities (Thollander et al., 2015). The project interviewed 200 SMEs in 140 industrial companies. The participants observed the companies' involvement in energy issues through energy audits.

Qualified energy auditors with a good engineering background will be able to provide the client with information on efficient energy-saving measures (Anderson & Newell, 2004). Three years of work experience and a diploma in engineering are required to carry out state-subsidized energy audits in Germany (Fleiter et al., 2012a). The dissemination of auditing results and the various energy audit databases encourage a better quality of energy audits (Anderson & Newell, 2004; Blomqvist & Thollander, 2015).

The above overview of research allows us to state that:

- The economic potential for energy efficiency in industry, which can be achieved without support measures, is 3–6%, with a technical potential of 20% and above.
- The best way to exploit the energy-saving potential of SMEs is through targeted support programs for audits, specialized tools, databases, training of auditors, and monitoring of progress.
- Despite the support, SMEs are often reluctant to pay for audits, especially when more complex and therefore more expensive measurements are required. This is the case for companies producing complex, variable products.
- The concept of energy consumption of individual processes can help to compare energy efficiency between companies producing different products.
- Energy planning and setting energy efficiency targets are important factors in improving energy efficiency in SMEs.
- The required short payback period limits the choice of energy-saving measures and the volume of energy saved.

Methodology

SMEs are defined under the revised User Guide (European Commision, 2015), which is staff headcount < 250, turnover ≤ 50 M €, or balance sheet total ≤ 43 M €. This definition was also valid for Lithuania in the year 2018, when the 18 audits under investigation were performed. This was defined under Article 3 of the National Law on Small and Medium Business Development (1998). However, in the National Law on Financial Responsibility of Companies, which was revised in the year 2019, the definition for national companies was revised: staff headcount < 250, turnover ≤ 40 M €, or balance sheet total ≤ 20 M € (2020). The SME sector, including also micro, constitutes 99% of all companies in the EU, provides two-thirds of private-sector jobs, and contributes to more than half of the total added value, created by all businesses (European Parliament, 2021). In the case of Lithuania, the SME sector makes 99.6% of companies, provides 71% of jobs, and contributes to 65% of the total added value (Statistics Department of Lithuania, 2020).

The energy audits presented in this overview were conducted using Lithuanian nationally approved methodologies and auditing guidelines. In line with these guidelines, only buildings, transport units, and equipment under the company's ownership are included in auditing. Therefore, in some cases, part of the production chain might be excluded from the total process if the company uses outsourcing for some components or processes. This determines specific energy consumption for similar product manufacturing even more complicated.

Regulation on energy audits determines the ranking of recommended energy efficiency (EE) measures into three groups regarding simple payback time: (A) less than 1 year, (B) 1–3 years, and (C) more than 3 years. Energy auditors should also assess the potential to reduce a company's energy bills by optimizing its peak load, switching to cheaper energy sources, reducing the use of reactive power, on-site or remote power generation, and the use of solar or other renewable energy devices. Reactive energy does no work and increases energy losses as it circulates between the energy source and the user device; however, it is accounted and taxable by the energy supplier. Opportunities for saving energy and other resources to be evaluated by the auditor include saving raw materials, reducing the waste stream and air pollution, water efficiency, and recycling. The selected eighteen audits were performed in Lithuania's companies, which could be assigned to SMEs due to their number of employees and turnover/capital figures. Table 1 provides a short description of the audited companies. In some cases, it was not easy to define exactly which company belongs to which type (medium, small, or micro) as numbers were varying significantly during recent several years and especially after the change in the legislation. Since audits were performed before the change and the initial definition was that adopted by the EU, we are keeping to this version.

The selected eighteen audits were performed on Lithuania's companies, which could be assigned to SMEs due to their number of employees and turnover/capital figures. These companies are armored doors, windows, and strongbox producers (3); mattresses and beds, healthcare furniture, modular bathrooms, and shopfitting; steel metal products producers (6); heating, ventilation and air conditioning, smart infrastructure solutions, and biofuel production companies (3); and LED luminaires (1), textile (1), wastewater treatment equipment (1), and 3 various companies with prevailing logistics activities.

During audits, the following peculiarities and bottlenecks in the EE performance of such companies were detected:

- Energy measuring is installed only in the main inlet of the company (this is valid for electricity, natural gas, and district heating meters).
- For some companies, measuring data is often fragmented (in buildings used together with other companies, recent connections, and disconnections from the grid, etc.).
- Small and medium companies often produce limited batches of their production tailored for individual orders. In such cases, production is not homogeneous, and it is complicated to assess equipment load and annual energy consumption of specific processes.
- Energy consumption in production processes is not large due to the significant amount of human or manual devices handled labor.
- A significant share of energy is consumed in buildings and transport.

Results and discussion

The annual energy consumption of 18 audited companies is presented in Fig. 1. One can see that only 8 of 18 companies exceed 2000 MWh/year; the energy consumption of others is significantly lower. The share of energy costs in the total expenditures was obtained for 12 companies out of 18, and these vary between 1 and 6% mainly, except for one company, where this share is as high as 30%. We should notice that a significant share of the activity of this company is logistics and infrastructure construction, causing increased consumption of motor fuels.

The distribution of energy consumption between buildings, technological processes, and transport is shown in Fig. 2.

There are two companies, where all energy consumption is allocated for transport needs, and one company with nearly all consumption by technological processes. The remaining companies have diverse distribution among all three or at least two sectors. SMEs have a significant share of energy costs in logistics and/or transport. Energy auditing methodology requires to include transport energy costs in case it exceeds 20% of total energy consumption. Transport needs are prevailing in 7 companies, buildings in 4 companies, and processes in 4 companies. Average energy shares of the three sectors are 30.53% in buildings, 27.17% in processes, and 42.33% in transport. Some companies seem to lack energy consumption in buildings, storage, etc.; however, auditing methodology requires an energy audit only for assets owned by the company. There are companies which hire all premises, including all utility services, such as electricity and heating. This means that their assets assigned for auditing are greatly limited and do not include buildings and services.

Table 1 Short characteristics of audited SMEs

No	No. of employees	Turnover	NACE code*	Activity	Type
1	< 246	≤ 47 M €	H49.41	Freight transport by road	Medium
			H52.10	Warehousing and storage	
2	< 242	≤ 39 M €	H49.41	Freight transport by road	Medium
			H52.10	Warehousing and storage	
			G46.74	Wholesale of hardware, plumbing and heating equipment and supplies	
3	< 170	≤ 48 M €	F42.22	Construction of utility projects for electricity and telecommunications	Medium
4	< 49	≤ 7.8 M €	C16.29	Manufacture of other products of wood; manufacture of articles of cork, straw, and plaiting materials	Small
			G46.12	Agents involved in the sale of fuels, ores, metals, and industrial chemicals	
5	< 236	≤ 32 M €	C31.01	Manufacture of office and shop furniture	Medium
6	< 48	≤ 1.7 M €	C24.20	Manufacture of tubes, pipes, hollow profiles and related fittings, and steel	Small
			C24.3	Manufacture of other products of first processing of steel	
7	< 238	≤ 23 M €	C25.11	Manufacture of metal structures and parts of structures	Medium
			C25.12	Manufacture of doors and windows of metal	
			C25.29	Manufacture of other tanks, reservoirs, and containers of metal	
8	< 245	≤ 9.7 M €	F42.11	Construction of roads and motorways	Medium
			F43.12	Site preparation	
			C22.23	Manufacture of builders' ware of plastic	
			H49.42	Freight transport by road	
9	< 242	≤ 18.8 M €	F42.22	Construction of utility projects for electricity and telecommunications	Medium
			F42.99	Construction of other civil engineering projects n. e. c	
			F41.10	Development of building projects	
			M71.20	Technical testing and analysis	
			M74.10	Specialized design activities	
10	< 215	≤ 18.9 M €	R92.00	Gambling and betting activities	Medium
11	< 94	≤ 3.1 M €	C20.60	Manufacture of manmade fibers	Medium
			C22.23	Manufacture of builders' ware of plastic	
12	< 109	≤ 4.5 M €	C25.12	Manufacture of doors and windows of metal	Medium
13	< 20	≤ 1 M €	C31.03	Manufacture of mattresses;	Small
			C31.09	Manufacture of other furniture	
14	< 20	≤ 0.7 M €	C23.19	Manufacture and processing of other glass, including technical glassware	Small
			C27.40	Manufacture of electric lighting equipment	
15	< 244	≤ 12.8 M €	C31.02	Manufacture of kitchen furniture	Medium
			C28.93	Manufacture of machinery for food, beverage, and tobacco processing	
16	< 9	≤ 1 M €	C32.50	Manufacture of medical and dental instruments and supplies	Micro
17	< 20	≤ 1.6 M €	C13.30	Finishing of textiles	Small
18	< 49	≤ 1.2 M €	C25.11	Manufacture of metal structures and parts of structures	Small

*NACE codes: Complete list of all NACE Code (nacev2.com)

A more detailed analysis of the three sectors is presented in Figs. 3, 4, and 5. As we can see from Fig. 3, space heating takes the largest share of energy consumed in buildings nearly in all companies (average 58.30%). Heating is provided from local boilers, gas air heaters, and electric heating or is supplied by

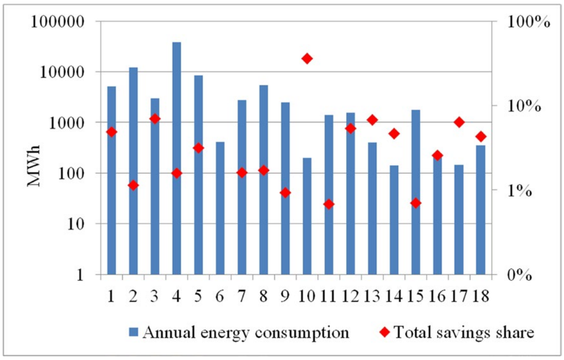

Fig. 1 Annual energy consumption of 18 SMEs

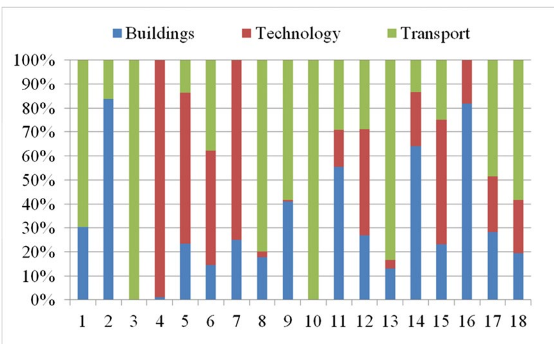

Fig. 2 Distribution of energy consumption between buildings, technology, and transport for 18 SMEs

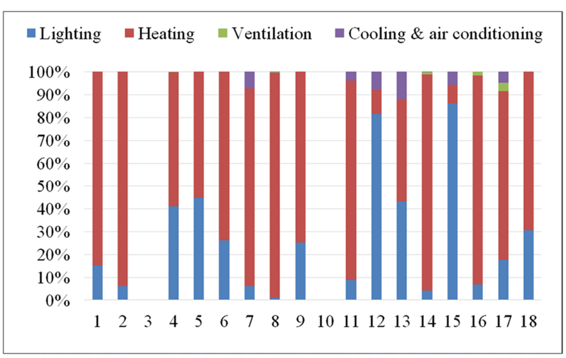

Fig. 3 Distribution of energy consumption shares for lighting, heating, ventilation, and air conditioning in buildings for 18 SMEs

district heating networks depending on local availability. Replacement or improvement of heating systems is rather expensive, and companies are usually

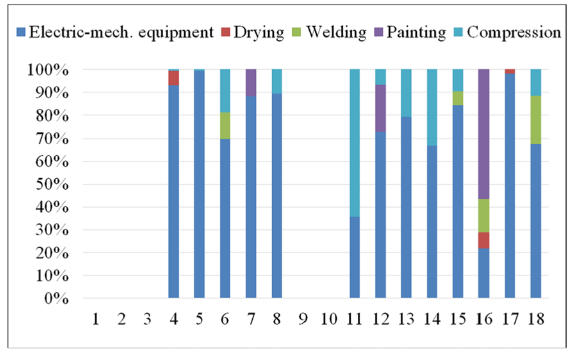

Fig. 4 Distribution of energy consumption shares of electric-mechanical equipment, drying chambers, welding, painting rooms, and air compressing facilities in technological processes for 18 SMEs

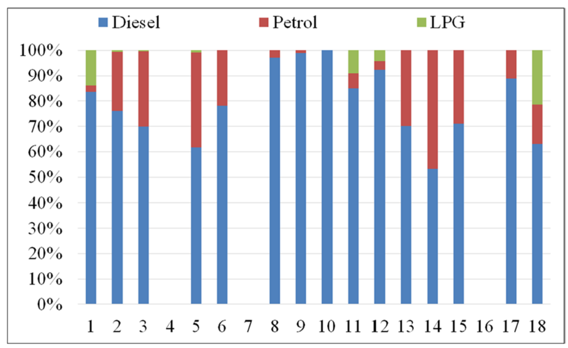

Fig. 5 Distribution of fuel consumption shares of diesel, petrol, and LPG in transport for 18 SMEs

not willing to make any changes here. On the contrary, the improvement of building insulation and windows replacement are the energy-saving measures, already found implemented in most premises.

Another significant share of the energy consumed in SMEs are indoor and outdoor lighting systems (average 23.42%). Here, improvement of energy efficiency can be assigned to inexpensive measures, as existing less efficient light sources (fluorescent tubes) can be replaced gradually with LED lighting during routine replacement where necessary. The same can be said about yard lights, where LED lights' electrical capacity can be reduced twice compared with usually installed mercury or metal halogen bulbs as they emit light at narrower angles.

Ventilation and air conditioning systems on average do not make a significant share of energy consumption in buildings making on average less than 5%. This is because a significant part of the premises uses natural ventilation. Local ventilation connected to specific equipment (welding, painting, drying chambers, grinding, etc.) is not included there and is considered as part of technological processes.

There are 5 companies involved in logistics and trade sectors without direct production. For the rest, the 13 companies' energy consumption of electric-mechanical equipment makes the largest share (average 74.17%). These types of equipment are basic in industrial SMEs and vary from sophisticated machine tools and robots to manual electric tools. Wherever possible, replacement of motors to more efficient is suggested, as well as replacement of some outdated small tools; however, this measure is costly with long payback. Here, the most popular measures can improve management and reduce reactive energy use. The latter measure does not reduce energy consumption but saves the company's money as electricity distribution companies apply charges for reactive power consumed.

Other significant energy consumption was detected in air compression facilities (average of 13.71%). Though painting chambers make an average of 6.84% of energy consumption, and drying chambers, 1.19%, this share can be as large as 65% in some SMEs (company no 16 in Fig. 4). Welding makes on average 4.09% but this technology is typical for metalwork firms only.

Regarding the transport sector, the best distribution appeared to be between types of fuel: diesel, petrol, and liquefied propane gas (LPG) (Fig. 5). It is evident that diesel fuel makes the largest share (average 66.08%) of fuel used in cargo transport, specialized transport, and even most cars, as this fuel diminishes total fuel consumption. On the other hand, this fuel is the most polluting, i.e., has the highest CO_{2eq} emissions per kWh of fuel. Thus, transport fuel savings not only improve the energy balance of the companies but also reduce negative environmental impact.

Main peculiarities of energy consumption in SMEs after initial inquests and visits at the companies were defined and are provided in Table 2.

In general, there is quite a different attitude towards energy saving in different companies. Those enterprises, which are subsidiaries of international or larger local companies, show more interest in saving and have already implemented a significant number of such measures, while others consider that the share of energy is extremely low in the balance of their costs and do not pay due attention to energy issues.

Due to the above reasons and energy consumption peculiarities, the following recommendations and measures are the most frequently suggested to SMEs, divided into three main energy consumption areas (Table 3):

Cost-free and low-cost measures with short payback are the most appropriate for small and medium companies, especially when energy consumption makes a small share in company costs. More costly measures are best implemented when the existing installations are outdated and should be replaced anyway.

Fourteen of 18 audited SMEs have ordered energy audits due to the respective requirement when applying for state support for installation of solar PV, which could reduce the electricity purchase from the grid. Since electricity consumption is not high in small companies, solar PVs on the roofs, benefiting 60–80% state support, could be a serious RES measure adding to the reduction of fossil fuel use and reduction of GHG. The solar PV share of annual electricity needs is presented in Fig. 6.

The Green Deal initiative is also supported by the Government of the Republic of Lithuania. SMEs can get subsidies for solar PV equipment and installation services. Subsidy share depends on the size of the enterprise. Subsidy share can reach from 60 to 80% for micro and small enterprises, and from 40 to 60% for medium enterprises. Payback of this measure for the company is between 2.9 and 8.9 years depending on support intensity and the capacity of the PV plant. Payback time without support can reach 20 and more years; it depends on the subsidy share and the capacity of the PV plant.

Energy savings and the volume of avoided GHG emissions are estimated as annual values; however, the cost of saved energy is estimated in Euro/MWh for the lifetime of implemented measures. It is complicated to define the lifetime for some measures, especially for management-related skills improvement, etc.

Energy savings via suggested measures could be also divided into 3 abovementioned categories: buildings, technological processes, and transport (Fig. 7). The average share of energy-saving potential in buildings is the highest and makes 42.81%; the next is

Table 2 Main peculiarities of energy consumption by sectors in 18 audited SMEs

Buildings	Technological processes	Transport
SMEs are mostly located in rather old (30–50 years) industrial buildings—some of them already renovated, some not	Lack of electricity metering inside a company for separate production lines and processes, in most cases just inlet electricity meters	Depending on specifics, SMEs use freight transport for transportation of goods and/or maintenance and repair equipment without weighting. The absence of cargo weight data disables assessment of the efficiency of the operation of freight transport
The renovation was mainly performed in administration premises, and production premises are of various conditions: some are well insulated, with replaced windows and doors, and installed recuperation and ventilation; other buildings are generally unheated with just local heating arranged for permanent working places	High reactive energy costs for the company due to lack of compensation, operation in 24/7 mode while installations operate 8 h per day excl. weekends, etc	Registration of fuel consumption and run for cars is not always precise, which disables assessment of relative fuel consumption
Main heating solutions are local natural gas boilers with gas metering; in some cases, production premises are provided with natural gas air heaters	There are only a few companies with modern automation and modernization level	Light car transport often is used by part of employees without strict distinguishing of company and their own needs
Outdated indoor and outdoor lighting solutions mainly luminescent tubes, sodium lamps, and others	Most SMEs use technologies with large amounts of manual work using sophisticated or simple instruments and tools, where energy metering is hardly possible	Managers often consider transport fuel consumption as "non-energy" costs
Motion sensors and local lighting are installed just in few companies, others use general area lighting	Varying of produced articles reduces equipment load factors and increases stand-by and idle duration	Lack of professional drivers (emigration, large logistics companies, etc.), leading to lack of competence and eco-driving skills

Table 3 Main measures for saving energy consumption by energy consumption areas in 18 audited companies

Buildings	Technological processes	Transport
Installation of metering in the places, which appear the most energy-consuming	Modernization of drying chambers, installation of moisture control	Improvement of transport sector management, the introduction of tracking systems
Modernization and/or installation of heating, ventilation, air conditioning, where necessary	Replacements of motors by IE3 class motors—high costs, possible if economic	Strict registration of mileage, fuel consumption, and cargo weights, where possible
Change of outdated lighting to LED	Installation of time relay with contactors at heating presses	Eco-driving courses for new and inexperienced drivers
Installation of motion sensors for lighting in places, where workers do not work permanently	Installation of reactive capacity compensation equipment, saving of kVArh and costs	Review and updating fuel consumption norms

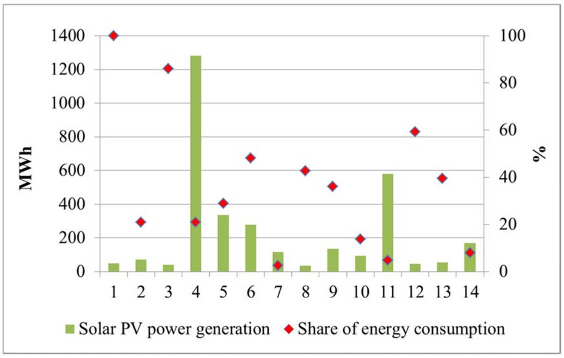

Fig. 6 Annual generation and the share of electricity need to be covered by solar PV

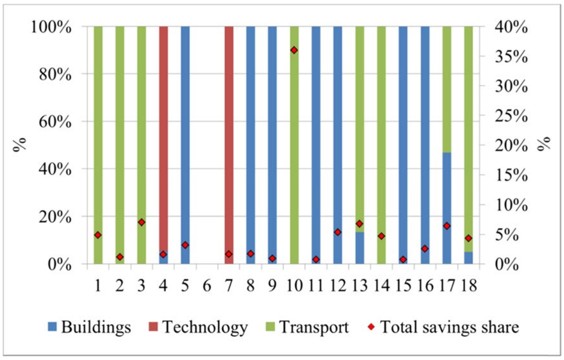

Fig. 7 Axis distribution of energy savings between buildings, technology, and transport for 18 SMEs and share of total energy savings in companies

transport with a similar share of 40.82%. The lowest average potential of only 10.81% is in the processes sector. The average percentage of energy savings on total energy consumption in enterprises will be up to 3.13% and only one enterprise stands out with an energy saving of 36% (Fig. 7).

The savings level of solar PV is mostly C and can reach a B savings level with high intensity of support. The savings level of the solar PV plant depends on the investments and annual saving costs for electricity. The solar PV plant is a possibility of producing its power. A solar power plant offers the opportunity to save costs in the technological process only. The simple payback time of solar PV plants depends on investments and annual power production. Simple payback time with the support of 70% or more is between 3 and 8 years; with the support of 45 to 60% is between 4.8 and 6.8 years; and without support can be up 10 years and more.

Total identified feasible savings for SMEs range between 0.7 and 36% in separate companies with an average saving share of 5.16%. These savings are presented in Fig. 8.

An overview of 280 SMEs over 7 European countries shows that the average energy savings are approximately 5% (Fresner et al., 2017). The largest savings possibilities were detected in medium companies, where logistics activities are prevailing. The total savings for all 18 companies are 2.89% in buildings, 3.82% in processes, and 4% in transport. The distribution of savings divided by consumption sectors is presented in Fig. 9.

The overview of all suggested measures for audited SMEs is presented in Table 4.

Savings level A for transport applies for most cases (Table 4). We do not recommend investing in an eco-driving course if savings level A is not achieved.

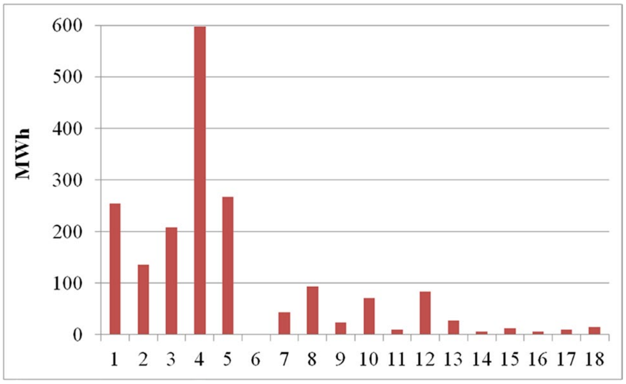

Fig. 8 Annual energy savings of 18 SMEs

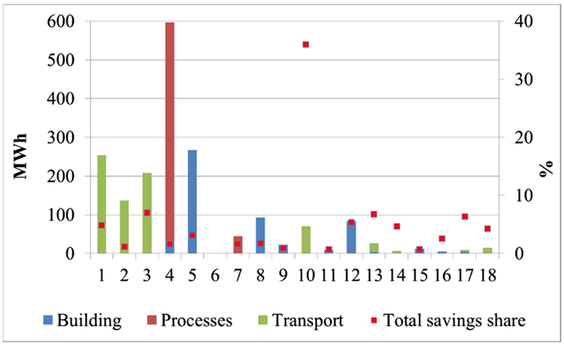

Fig. 9 Annual energy savings and total savings share by sectors of 18 SMEs

Savings level A for installation of time relays with contactors on heating presses in the cases we analyzed. We have analyzed upgrading of the raw material drying kiln and installation of moisture control of raw material in one case only. In this case, A savings level is applied. Savings level B for upgrading indoor and outdoor lighting is applied in most cases. Replacement of electric motors with IE3 efficiency class motors is assigned to level C savings due to high investments.

Only two of 18 companies could economically save energy in manufacturing processes; the other savings can be distributed between transport and buildings sectors. Comparatively low energy-saving opportunities in processes can be explained by the dominating attention from company management towards core activities and associated energy consumption which directly affects production costs and the company's profitability. Saving possibilities in processes could be detected in situations where equipment part of time operates in idle mode or there are manually controlled energy-consuming machinery. Invasion into automatically controlled production lines in most cases is not acceptable because of the possible violation of an equipment supplier warranty. In some cases, installing time relays and/or sensors could save energy with little investment.

A power factor is used for assessing the simultaneity of the peaks of electrical load tension and current. Low power factor indicates a high share of reactive energy, which is unwanted due to increased current in wiring and commutative devices and related electrical losses. Reactive energy reduction or compensation is a common measure often found in the processes sector. This measure does not provide energy savings, but rather costs savings, as distribution companies apply charges for reactive power. The charge for generated reactive power is twice higher than that for reactive power consumed.

Four companies of 18 were suggested to implement/adjust reactive power compensation and reduction measures. The total savings are measured in kVArh. The audit results for this type of measure are presented in Table 5.

The cost of saved energy is a rather important factor for small and medium enterprises. It is defined as the investment and maintenance cost of the energy-saving measure divided by the energy amount saved during the lifetime of the measure. For this analysis, the lifetime for lighting measures is 7.5 years; for processes, 10 years; and 5 years for transport was chosen. The cost of saved energy of analyzed SMEs, calculated as a weighted average of costs from different energy-saving measures, is presented in Fig. 10. All companies, except one with exceptionally low energy saving potential, can save energy with less or even significantly less than 25 €/MWh.

Table 4 The information data on suggested energy efficiency measures after the audits

Small-medium enterprises	Upgrading indoor and outdoor lighting			Solar PV			Eco-driving			Upgrading of the raw material drying kiln and installation of moisture control for raw material			Replacement of electric motors with IE3 efficiency class motors			Installation of time relays with contactors on heating presses		
	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)	Energy-saving potential (MWh/a)	Investments (€)	Payback time (years)
1	-	-	-	-	-	-	120.8	5300.0	1	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	105.2	5812.0	1	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	276.5	3168.0	1	-	-	-	-	-	-	-	-	-
4	31	3100	1.3	1280	605,000	6.0	-	-	-	40,001	11,858	0.55	71.3	48,000	6.8	-	-	-
5	300	40,000	1.5	116	150,000	15.9	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	136	55,046	6.7	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	167	234,000	23.0	-	-	-	-	-	-	-	-	-	44.2	570	0.26
8	72	19,221	2.1	96	95,000	8.9	-	-	-	-	-	-	-	-	-	-	-	-
9	23	2710	1.6	21	9500	4.8	92.0	6596.0	1	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	15.0	1276.0	1	-	-	-	-	-	-	-	-	-
11	10	320	0.3	72	39,264	6.8	-	-	-	-	-	-	-	-	-	-	-	-
12	30	5515	1.8	277	107,100	5.1	-	-	-	-	-	-	-	-	-	-	-	-
13	3	788	2.4	43	8600	2.7	11.6	531.0	0.2	-	-	-	-	-	-	-	-	-
14	-	-	-	36	8700	3.9	4.2	625.0	1	-	-	-	-	-	-	-	-	-
15	21	1846	1.8	336	123,750	8.7	-	-	-	-	-	-	-	-	-	-	-	-
16	6	1040	1.7	49	9420	2.9	-	-	-	-	-	-	-	-	-	-	-	-
17	4	832	2.7	45	120,00	3.8	5.0	625.0	1	-	-	-	-	-	-	-	-	-
18	16	7360	3.2	53	14,130	5.1	16.0	766.0	0.5	-	-	-	-	-	-	-	-	-

Table 5 The information data on reactive energy improvement measures

Company no	Reactive energy savings, %	Reactive energy savings, kVArh/a	Investment, Euro	Payback, years
6	90%	68,600	1005	2.70
7	75%	570,208	6300	1.43
11	75%	135,000	1900	2.30
16	85%	32,300	1150	4.40

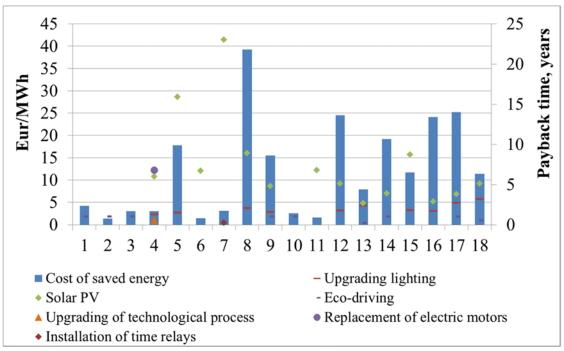

Fig. 10 Cost of saved energy expressed via investment per 1 MWh of energy savings of 18 SMEs and payback time of proposed savings measures

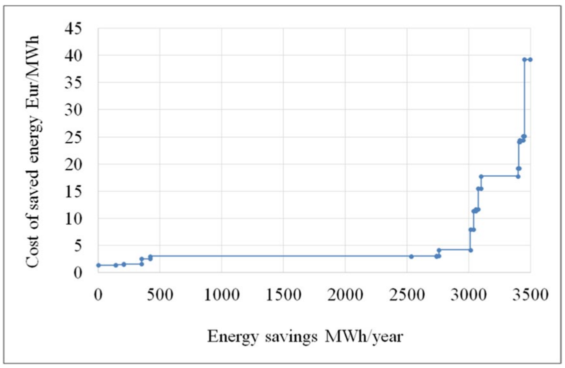

Fig. 11 Cumulative savings of energy efficiency measures at the different costs of saved energy in 18 SMEs

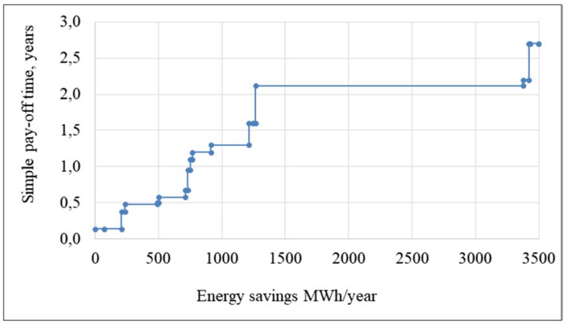

Fig. 12 Cumulative savings of energy efficiency measures at different pay-off times in 18 SMEs

The average investment costs are 41.89 €/MWh/year, and the weighted average energy saving cost is 5.23 €/MWh. As most suggested measures were low cost, the weighted average simple payback period for those measures was estimated at 2.17 years. The price of electricity for industrial users varies from 85 to 130 €/MWh depending on supplier and grid connection (high or low voltage) and heat from district heating networks—from 35 to 52 €/MWh. This can be compared to that in the overview of 280 audits, where 5% average energy saving potential was disclosed with lower than 3 years pay-off time (Fresner et al., 2017). Comparison with De-Risking Energy Efficiency Platform, where 12,474 projects were reviewed in the industry, shows that here median payback time is 2.8 years, which is comparable with 2.17 years in our research (DG Energy, 2021).

Total energy savings achievable at the given cost of saved energy are presented in Fig. 11. The result shows that a big amount of energy (in most cases, heat) can be saved at a rather low cost of saving energy, lower than 5 €/MWh.

The pay-off time of the investments into energy-saving measures depends on the value of annual savings which is different for different energy types: heat, electricity, or different types of fuel. Pay-off times of the proposed energy-saving measures for 18 companies are presented in Fig. 12.

There were more energy-saving opportunities identified and analyzed during auditing; however, they did not meet the expectations of the company's management because of a too long pay-off time. Such identified measures are not presented in this analysis.

Another important impact of implemented energy efficiency measures, identified during energy audits, is the environmental benefit—reduction of GHG, measured in tons of CO_2 equivalent per year. For 14 companies of 18, this impact is supplemented with proposed RES (solar PV) solutions (Fig. 13).

Implementation of energy efficiency measures makes app. 535 t CO_{2eq} total GHG emissions reduction and implementation of RES measures—1511 t CO_{2eq}. The emission reduction from renewable energy projects three times exceeds those of energy efficiency measures. The reason is that most companies needed an audit to qualify for support to install solar power plants and the capacity of the plants covers half or more of the needs of SMEs.

Though SMEs are not required to perform energy audits, this is highly suggestible to add significantly to energy savings and environmentally sound impact in the activities of such companies. Due to significantly lower volumes of economic activities in production processes, such companies have rather specific energy consumption patterns, which differs from those in large companies.

Conclusions

The main distinction of SMEs is expressed via a significant share of energy consumption in all three sectors: buildings, technological processes, and transport. Different from large companies, where potential energy savings are detected mainly in technological processes, and energy consumption in buildings and transport makes significantly less than 20%, auditors should assess energy-saving possibilities in all three sectors. They should often get prepared to meet such barriers as lack of metering, multi-product industries, weak management, or rather neglected energy consumption accounting, as well as a minor understanding of energy issues, including transport fuel.

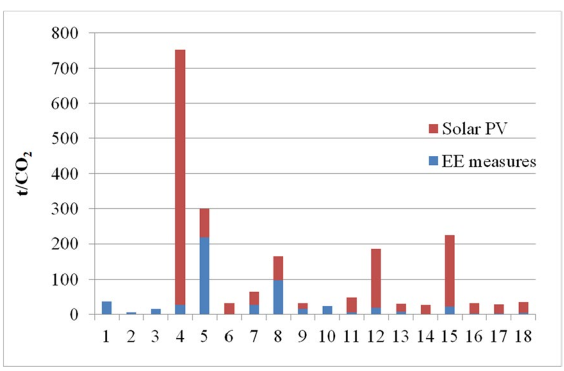

Fig. 13 Avoided greenhouse gas emissions from energy efficiency and renewable energy measures for 18 SMEs

Though heating systems make the largest share in the total volume of energy used for buildings, companies in this study are not interested in any changes here. There are several reasons why SMEs do not wish to replace existing heating systems: some companies hire premises and are not allowed to make significant changes, and some consider that the existing systems are the most convenient for them, though it might be expensive. On the other hand, replacement might be considered too expensive and require too much effort. The most popular and effective measure in buildings is the replacement of outdated indoor and outdoor lighting systems with modern LED solutions. Savings in all companies under research make 2.89%. Some companies consider the construction of the new buildings instead of renovating the old ones, as the new buildings are energy efficient and better adapted to their actual needs.

The largest share of energy consumption in technological processes of SMEs is by electric-mechanical equipment, which is basic in industrial SMEs and varies from sophisticated machine tools and robots to manual electric tools. This is due to the selection of companies: most of the companies were in metalworking, furniture, windows, doors, or metal construction, so the main savings were identified in electric motors, as they did not have dryers or no overlap could be identified (Fig. 4). Wherever feasible, replacement of motors to more efficient is possible, as well as replacement of some outdated small tools; however, this measure is costly and has long payback unless a replacement is due to wear and tear. Here, the most popular measures can improve management and reduce reactive energy use. Savings make 3.82% in total here.

Regarding the transport sector, the largest share of energy (or rather fuel) consumption is by cargo transport, using diesel fuel. However, saving opportunities lie under improvement of driving skills and improvement of management, which is insufficient nearly in all small companies. Improvement of management and eco-driving might reduce fuel consumption by about 4%. Replacement of older vehicles with new more efficient ones is economically feasible only after its full wear and tear.

The cost of saved energy is an important factor for small and medium enterprises. Nearly all companies can save energy with less or even significantly less than 25 €/MWh. The average investment costs are 41.89 €/MWh/year, and the weighted average energy saving cost is 5.23 €/MWh. As most suggested measures were low cost, the weighted average simple payback period for those measures was estimated at 2.17 years. Total energy savings achievable at the given cost of saved energy shows that a big amount of energy (in most cases, heat) can be saved at a rather low cost of saving energy, lower than 5 €/MWh. The pay-off time of the investments into energy-saving measures depends on the value of annual savings which is different for different energy types: heat, electricity, or different types of fuel.

Energy saving goes in hand with environmental impact via reduction of greenhouse gas emissions. Besides energy efficiency improvement measures, audits have suggested the implementation of RES measures (mainly solar PV), whose expansion was promoted and supported by the state. Implementation of energy efficiency measures makes app. 535 t CO_{2eq} total GHG emission reduction and implementation of RES measures—1511 t CO_{2eq}. The emission reduction from renewable energy three times exceeds those of energy efficiency measures because the amount of electricity generated in proposed solar installations is much higher than identified potential power savings. Audits add to a better understanding of energy issues for SMEs, energy consumption in lighting, heating, production processes, and transport, as due to a lack of energy experts, understanding of these as well as benefits from the implementation of energy efficiency measures is insufficient, which was detected also in other studies (Kalantzis & Revoltella, 2019; Redmond & Walker, 2016).

For mitigation of climate changes and due to the growth of prices for energy resources, the National Energy and Climate Action Plan of the Republic of Lithuania for 2021–2030 envisages measures for industry and industrial processes on the improvement of energy efficiency. These measures are directed towards investment into smart, resource-saving, and environmental pollution– and climate change–mitigating technologies and products. One measure is financially subsidizing for implementing energy efficiency in the industry for actions defined during EE audits (2021–2030). Another measure is directed towards the use of RES in industry, especially for SMEs, covering 80% of feasible costs (2021–2027).

Declarations

Conflict of interest The authors declare no competing interests.

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