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ASSESSING THE POTENTIAL FOR ENERGY EFFICIENCY

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INTRODUCTION

Within the project The pathway to energy efficient future for Latvia (EnergyPath) which is being implemented within the framework of the open project application competition "Energy Efficiency" of the State Research Program "Energy", accordingly to section 9.2. of the project application competition the following tasks are intended to be performed:

"9.2. Determination of the economic and technical energy efficiency potential of specific economic sectors: industry, services (separately analyze the public sector), agriculture, transport, households, and development of policy recommendations to acquire that potential. Provide policy recommendations for energy efficiency measures for final users. Identification of energy consumption benchmarks for widely used in technological processes in certain economic sectors (industry, services, agriculture, transport). Assessment of the current situation against these benchmarks and solutions for improvement in each sector, as well as determining the impact of the solution and the amount of saved energy."

In accordance with the project activity plan, a nationally adapted methodology for determining energy efficiency potential and benchmarks was developed in the first period of the project. The main steps of the method are presented in Figure 1.

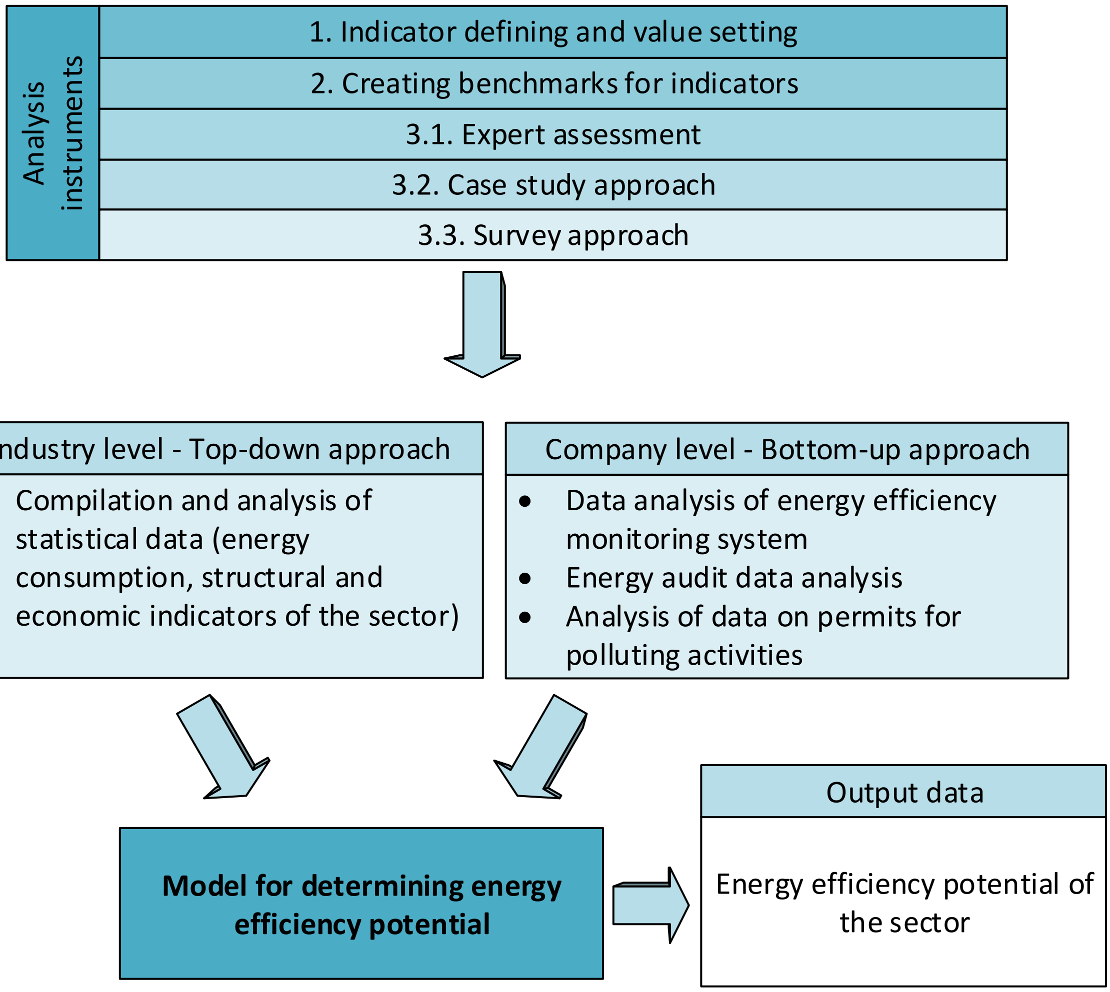


Figure 1. Methodology steps for determining energy efficiency potential

The methodology is based on the selection and use of various analysis tools, starting with the definition of indicators and their benchmarks based on available data. The methodology also envisages the use of analytical tools such as expert evaluation, case studies and a survey method. Using the above mentioned analysis tools, as well as a top-down and bottom-up data acquisition approach, a model for determining energy efficiency potential is developed by summarizing the data available at the industry and company level. As a result of modeling, the technical and economic energy efficiency potential of the energy end-use sector is determined.

This report summarizes the analysis performed so far in relation to the bottom-up data sources available in this project on the basis of a mutual agreement between Riga Technical University (RTU) and the Ministry of Economics on providing access to data for the scientific research. The data provided by the Ministry of Economics includes an energy efficiency monitoring system file (aggregated data), as well as access to companies' energy audit reports (manual data collection process). These data were used in the study to determine the total energy savings achieved so far by the energy efficiency monitoring program, as well as to look for their links with other characteristic parameters. Also, the data of energy audit reports have been used both to describe the energy consumption of companies in various industries, and to create a detailed database on potential energy efficiency measures in Latvian industrial companies, the amount of their savings and specific costs. These bottom-up data, as well as other aggregated bottom-up and top-down data, will be further used to implement the project's future activities and to identify energy efficiency potential for energy end-use sectors.

1. LITERATURE ANALYSIS ON ENERGY EFFICIENCY AND METHODS FOR ITS DETERMINATION

Within this chapter, first, the different ways of defining energy efficiency potentials and differences between them are described, followed by a description of methods for energy efficiency potential analysis. Literature analysis is performed to identify best practice for identifying energy efficiency potential across different sectors of the economy. It is based primarily on the information available in internationally cited scientific literature databases and, additionally, the results achieved by various energy efficiency improvement programs were analysed.

1.1. Types of energy efficiency potential

According to LVS EN ISO 50001:2018 standard, energy efficiency is defined as "the ratio or other quantitative relationship between the output, the amount of service, goods or energy produced, and the energy consumed in the process" (ISO/TC 242 Energy Management, 2018). Energy efficiency improvements differ from simple energy savings because energy efficiency improvements are measured for the same amount or value of output (or per unit of output) (Knoop & Lechtenböhmer, 2017). Therefore, an energy efficiency assessment takes into account whether the company has increased or decreased its production. In order to strive towards optimized systems that consume minimal amount of energy required to produce a single unit of output or service, improvement in energy efficiency in the manufacturing and service sectors is required. However, there is a so-called energy paradox, that is, a part of cost-effective energy efficient technologies are not being implemented or they are implemented very slowly (Jaffe & Stavins, 1994). This creates an "energy efficiency gap", which describes the difference between current energy consumption levels and the optimal energy consumption levels now or in the future (Jaffe & Stavins, 1994). Therefore, the energy efficiency potential can be expressed as this difference. Also, several types of energy efficiency potential can be distinguished (their hierarchy is shown in Figure 1-1).

The **technical potential** indicates the maximum theoretical reduction in energy consumption that could be achieved by implementing energy efficiency measures, provided that non-engineering barriers, including economic barriers and constraints, behavioral and regulatory barriers, are fully resolved and lower transaction costs and faster technology diffusion are promoted. (Knoop & Lechtenböhmer, 2017; Mosenthal & Loiter, 2007).

The economic potential indicates the share of the technically feasible energy efficiency measures that could be implemented in a cost-effective way at the end consumer, if cost effectiveness is defined by comparing to the costs of alternative measures at the supply side. (Mosenthal & Loiter, 2007)

Both the technical and economic energy efficiency potentials are often perceived as theoretically achievable levels, if energy efficiency measures would be implemented immediately, that is, the delays that are related to policy and program implementation, market barriers and the costs of energy efficiency promotion programs are not taken into account. (Mosenthal & Loiter, 2007)

By combining the technical and economic energy efficiency potentials, the maximum theoretical amount of the currently existing energy efficiency resources is obtained. However, in reality, this potential cannot be fully realized, even with the most aggressive policies and with unlimited financial resources. (Mosenthal & Loiter, 2007)

The achievable (or maximum attainable) **potential** refers to the share of energy consumption that could be reduced by implementing energy efficiency measures using most aggressive policy mechanisms (e.g. maximum support rates, grants instead of other financial instruments, etc.). The assessment of achievable potential takes into account the fact that not all will be persuaded to implement energy efficiency measures, as well it considers those costs that are not directly related to energy efficiency measures, such as the cost of energy efficiency programs and the delay in reaching the potential due to the necessary time for program “start-up”. (Mosenthal & Loiter, 2007)

Figure 1-1. Types of energy efficiency potential

The program potential represents the expected reduction in energy consumption due to the measures implemented within the framework of a specific energy efficiency promotion program. This potential takes into account the funding available within a given program and the design of the program. This potential can also be called the **achievable** potential (in which case the term maximum attainable potential is used for non-program related potential).This potential can be identified for a single program or for a multi-program package, as well as to analyse the impact of different levels of funding on the programme's deliverables. (Mosenthal & Loiter, 2007)

After a literature analysis, Knoop and Lechtenböhmer concluded that there is significant energy efficiency potential in EU Member States. This potential could range from 10-28% savings in 2030 compared to the baseline scenario if low intensity policy interventions would be used. (Knoop & Lechtenböhmer, 2017) In case of more significant policy changes, savings up to 44% could be achieved. Knoop & Lechtenböhmer (Knoop & Lechtenböhmer, 2017) referenced the study by Eichhammer et al. (Eichhammer, W., Fleiter, T., Schlomann, B., Faberi, S., Fioretto, M., Piccioni, N., Lechtenbohmer, S., Schuring, A., Resch, 2009) when they indicated that the technical energy efficiency potential for Latvia could reach around 30% of final energy consumption compared to the baseline scenario; the economic potential could reach around 20% in case of high policy intervention scenario or around 14% in a low policy intervention scenario.

Žogla (Zogla, 2014) has studied the energy efficiency of the Latvian manufacturing industry. She concludes that the specific energy consumption per production volume in Latvia is higher than the EU28 average, as well as higher than in Norway, and the industrial energy intensity indicator is unstable.

1.2. Methods for determining energy efficiency potential

One of the methods for determining the national energy efficiency potential is to compare the end-use energy consumption forecast in a scenario with and without the implementation of energy efficiency measures (Knoop & Lechtenböhmer, 2017). However, the shortcomings of this approach are related to the general uncertainty inherent to each scenario, as well as to possible inaccuracies in the macroeconomic data. Also, the rebound, summation and 'free-rider' effects must be taken into account, as well as the effect of autonomous improvements, which characterize improvements that would have been made without additional policy intervention. The authors point out that the best approach to determine the national energy efficiency potential would be an in-depth bottom-up approach, but such an approach is severely limited by the differences between subsectors and the availability of data in such detail. (Knoop & Lechtenböhmer, 2017)

The examples of energy efficiency analysis that are available in the scientific literature can be divided both by the considered economic sector and, in recent publications, scientists have focused on cross-sectorial analysis from the point of view of individual technologies (e.g. electric motor systems or industrial steam systems). Significantly, the specific energy consumption given in the scientific literature for different sectors (especially within the industrial sector) is often expressed by different indicators - both in relation to a specific product type (for example, in the textile sector (Çay, 2018) uses the number of sewn garments while (Hasanbeigi & Price, 2012) refer to energy consumption per kilogram or ton of output), as well as to a specific plant (case study examples) or to the industry as a whole (referring to the total volume or value of output in the industry).

Sometimes the volume of output (or services) produced is expressed in monetary equivalent, so the challenge in this area of research is to compare such indicators.

Warnken et al. (Warnken, Bradley, & Guilding, 2004) have analysed a number of methods that can be used to account for and model energy consumption in the sectors of the economy (see Table 1-1). The description of the methods characterizes solutions for forecasting the energy consumption of economic sectors, but each of them can also be adapted to identify energy efficiency potentials or benchmarks.

Table 1-1

Comparison of different energy consumption modeling methods (based on (Warnken et al., 2004))

	The floor area method[1]	The multiple regression method	Mandatory reporting method
Steps of the method	Step 1. Business survey on annual energy consumption and total area of a service company (for each of the different subgroups of the sector) Step 2. Expressing the mean values for each group Step 3. Generalization for each subsector by multiplying the average consumption by the number of enterprises in the group Step 4. Aggregation of consumption of all subgroups of the sector	Step 1. Create a multiple regression equation for different subsectors, where the dependent variable is energy consumption and independent variables are, e.g., area, number of employees, number of working hours, annual sales, for hotels - occupancy rate, number of rooms, outdoor air temperature, etc. Step 2. Regression models are used to forecast energy consumption for each subsector. Data for independent variables should be obtained from the same sources that were used to build the model - statistical reports or surveys. Step 3. Forecast of the total consumption of all subgroups of the sector	Step 1. Each company is required by legislation to report their energy consumption. Step 2. This information, together with other characteristic parameters, is provided by enterprises to the Statistical Office, for the collection and analysis of data and to the assessment of annual energy consumption, e.g., energy consumption per room for hotels.
Data availability	Business survey is required (statistical sample needed)	During the model development phase, a sample group (survey) is required to provide data on energy consumption	Data from companies are obtained by mandatory reporting
Examples of application		(Saxena & Modepalle, 1994) printing industry (Zogla, 2014)breweries in Latvia (Warnken et al., 2004) hospitality industry	

[1] in the original application, the method has been tested on companies in the service sector, therefore normalization in relation to commercial space has been used, but when adapting this method to other sectors of the economy, an appropriate unit of normalization must be used

The selection of the most appropriate method is influenced by the purpose of the study and the availability of data. The methods presented in Table 1-1 differ by the approach for obtaining of the required information and the approach for generalization of the data. However, regardless of the method used, the data required for the basic analysis of companies' energy consumption most often include:

- The annual energy consumption in a company or factory,
- Industry-specific parameters that allow the classification of different subsectors of the main production sector, e.g., production in tons, cubic meters or other units, hotel occupancy rate, retail space in the retail sector, etc. (Warnken et al., 2004).

In the context of energy efficiency potential, additional information is needed on relevant energy efficiency technologies (including best available techniques), their potential energy savings and their costs. In order to calculate future financial savings due to saved energy, it is necessary to know the forecasts of energy price development, as well as to take into account the risks of price fluctuations. (Zuberi & Patel, 2017)

The two most significant aspects that influence the acquisition of the required data are the willingness of companies to cooperate and the ability of companies to accurately and appropriately compile the required information (Warnken et al., 2004).

By using this information, various indicators that are important for energy efficiency analysis can be developed:

- The **investment cost ratio** is expressed as the total investment per unit of energy saved per year (EUR/GJ of energy saved). (Zuberi, Tijdink, & Patel, 2017)
- **Saved energy attributed to investment** characterizes the achieved savings amount in relation to unit of investments (EUR or 1000 EUR).
- **Simple payback time** is expressed as the ratio of investments to planned savings and determines how long the investments will pay off.

1.2.1. Energy efficiency cost curves

The literature analysis identified that one of currently widely applied methods for determining the technical and economic energy efficiency potential is Energy Efficiency Cost Curves (EECC). Andersson et.al. (2018) indicate that this method can be used to identify the most cost-effective energy efficiency measures for the industrial sector (Andersson, Karlsson, Thollander, & Paramonova, 2018). It has also been applied in both industrial and household sectors, as well as for analysis of individual NACE divisions such as cement production, iron and steel, paper production and others, and for analysis of individual technologies or systems such as electric motor systems (McKane & Hasanbeigi, 2011; Zuberi et al., 2017) and industrial steam systems (Hasanbeigi, Harrell, Schreck, & Monga, 2016). Appendix 1 lists the studies that used this method to determine energy efficiency potential at three different levels.

The EECC method is an analytical approach to graphically depict the potential energy savings (McKane & Hasanbeigi, 2011; Rodrigues da Silva, Mathias, & Bajay, 2018), where each individual step in the curve allows to simultaneously (1) describe the specific costs of the measure, (2) show the relative rank of this measure in comparison of other analyzed measures based on their costs, and (3) the total extent of the curve the indicates the overall energy efficiency potential to be achieved (see Figure 1-2). The total costs of the measures take into account both the costs of implementing the measures and maintaining the technology, as well as the savings made over the life of the measures (Yáñez, Ramírez, Uribe, Castillo, & Faaij, 2018). In addition, the EECC method can simultaneously characterize the technical and economic perspective of energy efficiency and can be used at national and sectorial level (Zuberi et al., 2017).

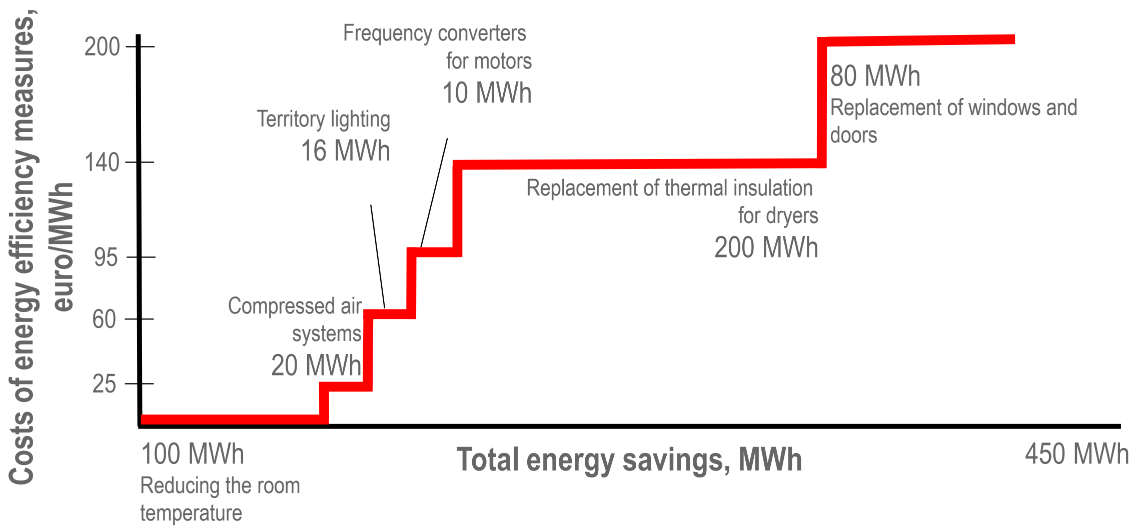


Figure 1-2. Example of the use of energy efficiency cost curves

EECC method has initially evolved from the approaches of Cost-supply curves (CSC) (also called Conservation supply curves (McKane & Hasanbeigi, 2011)) and Cost of conserved energy (CCE) (Yáñez et al., 2018). Developed in the 1970s, the CSC method was designed to easily compare energy savings with conventional energy supplies (Rodrigues da Silva et al., 2018). CCE is a customized version of CSC, specifically designed to analyse energy savings by ranking them by their costs (Yáñez et al., 2018). In some sources, these curves are also referred to as levelized costs of energy efficiency (Zuberi et al., 2017) or marginal abatement cost curves (McKane & Hasanbeigi, 2011; Yáñez et al., 2018). Marginal cost curves are used not only for the analysis of energy savings, but also for the analysis of greenhouse gas (GHG) emissions.

As well, the EECC method is an appropriate tool for decision makers to evaluate the cost effectiveness of energy efficiency measures and the resulting energy savings (Zuberi et al., 2017). Additional benefits include comparing the costs of energy efficiency measures with those of new energy sources and evaluating energy policy (Rodrigues da Silva et al., 2018).

The scheme for the application of this method is depicted in Figure 1-3. The two most important tasks for applying the EECC method include characterizing the current situation and defining the potential savings from energy efficiency measures. The first step in the application of EECC method is the collection of the necessary data on the current energy end-use structure of the analysed sector, the technologies used, their share in total energy consumption in the industry and the efficiency level of existing technologies (McKane & Hasanbeigi, 2011). The high impact of the availability of detailed data for the design of energy efficiency curves is also indicated by Rodrigues da Silva et al. (Rodrigues da Silva et al., 2018) when they note that the greatest challenge for the development of cost curves is the characterization of the current situation, including determining the efficiency of used technologies.

They also note that the challenges of data availability and detail level are greater when energy efficiency estimates for the industrial sector are only available in aggregate form, such as total energy balance, without a precise breakdown by sector and subsector (Rodrigues da Silva et al., 2018).

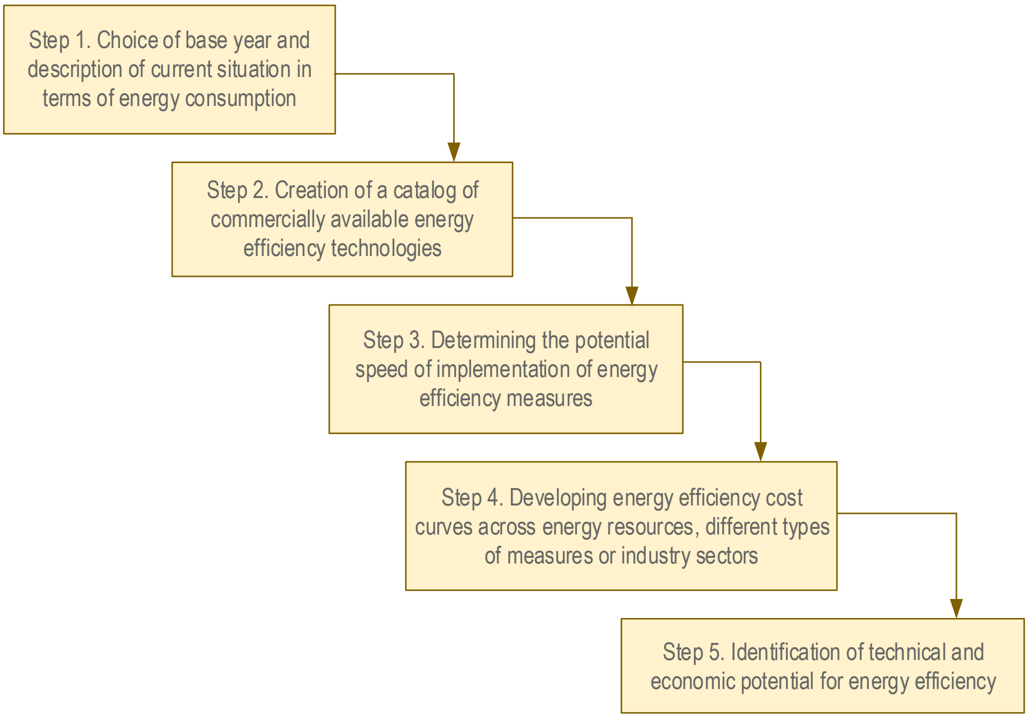


Figure 1-3. Steps of applying the energy efficiency cost curve method

The second major task (Step 2 in Figure 1-3) is to compile a list of available technologies (a catalogue), identify their costs (capital costs, operation and maintenance costs) and potential savings in terms of both energy efficiency and/or CO_2 reduction. This list shall take into account widespread technologies and technological solutions which have the potential to be economically viable. (Kong, Hasanbeigi, Price, & Liu, 2017; Rodrigues da Silva et al., 2018)

The third step involves determining the potential rate of energy efficiency measure implementation. It can be determined in the form of assumptions or based on survey data from companies, or based on expert judgment. The fourth step is the generation of energy efficiency cost curves across energy resources, different types of measures or industry sectors, and the fifth is the identification of the most cost-effective measures (economic potential) and technically feasible potential from energy and/or CO_2 emissions point of view. (Kong et al., 2017)

Zuberi et al. (Zuberi et al., 2017) additionally pointed out that when developing energy efficiency technological portfolios or scenarios it is important to take into account which measures are typically implemented together (complementary) and which cannot be implemented together. In their studies McKane and Hasanbeigi (Hasanbeigi et al., 2016; McKane & Hasanbeigi, 2011) have tried to address this problem by offering an improved method that takes into account the complementary effects of energy efficiency measures. Knowing that the implementation of each successive measure depends on the effect of the previous measures on the whole system, in their approach the cumulative energy savings are calculated by considering the complementary effect of the measures rather than assuming that each of them is carried out in isolation. The application of this method is schematically described in

Figure 1-4.

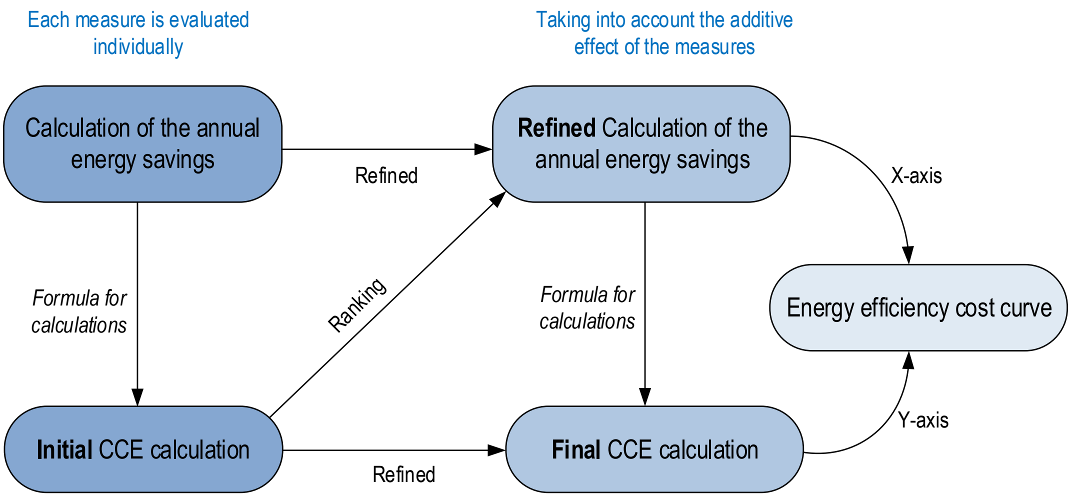


Figure 1-4. Use of energy efficiency cost curve method (Hasanbeigi et al., 2016)

As mentioned before, the cost curves that are developed by EECC method express the energy efficiency potential as a function of the marginal costs of saved energy (Hasanbeigi et al., 2016). The costs of conserved energy (CCE) are calculated according to formula (1), while annual capital costs are calculated according to formula (2) (Hasanbeigi et al., 2016; Rodrigues da Silva et al., 2018).

$$CCE = \frac{I_C + OM_C}{Es} \tag{1}$$

where

I_c – annual costs of capital investments, EUR;

OM_c – annual operation and maintenance costs, EUR;

E_s – annual reduction in energy consumption (savings), MWh.

$$Ic = I_k \cdot \frac{d}{1-(1+d)^{-n}} \tag{2}$$

where

I_k – capital investments, EUR;

d – discount rate;

n – the lifetime of the energy efficiency measure.

If the data on the reduction of maintenance and operation costs are not available, this variable can be neglected (as was done in the study of (Hasanbeigi et al., 2016)). In contrast, in a study by Zuberi et al. (Zuberi et al., 2017) for those maintenance and operation measures that lead to direct energy savings all costs are included in the calculations, while for other measures, such as technology exchange, maintenance and operating costs are not taken into account.

According to the scheme shown in

Figure 1-4, after calculating the costs of saved energy for each energy efficiency measure, all considered measures are ranked in an ascending order accordingly to their cost and depicted graphically thus forming the energy efficiency cost curve. The height of each measure relative to the Y axis indicates the specific cost of the measure, the line width (length) relative to the X axis indicates the cumulative energy savings. The graph also indicates the market cost per unit of energy, thus setting a threshold that separates cost-effective measures (which are cheaper to implement than to purchase an energy unit) from measures whose implementation per saved energy unit costs more than the energy unit price. Measures below the energy cost line in the graph are considered cost-effective. (Hasanbeigi et al., 2016; Rodrigues da Silva et al., 2018; Zuberi et al., 2017)

Other studies provide variations of the CCE equation, for example, by also taking into account the annual energy savings achieved by implementing the energy efficiency measure (see formula (3)) (Rodrigues da Silva et al., 2018; Yáñez et al., 2018).

$$CCE = \frac{I_C + OM_C + B_{Es} + Bother}{Es} \quad (3)$$

where

B_{Es} – annual savings from energy consumption reduction, EUR/year;

B_{Other} – other annual savings, EUR/year.

The annual energy savings can be calculated using the technological information, but it can also be supplement with expert opinion if accurate information is lacking. For example, in a study by McKane and Hasanbeigi (McKane & Hasanbeigi, 2011) on electric motor systems and a study by Hasanbeigi et al. (Hasanbeigi et al., 2016) on determining the technical and economic energy efficiency potential of industrial steam systems in order to supplement the input data used in the study, a survey of experts on standard technological systems offered on the market was conducted. The survey sought for the expert opinion on the energy efficiency of three reference systems (with certain parameters) and the energy efficiency measures that could be implemented (including (1) % savings by implementing each measure separately in each of the three baseline scenarios; (2) costs for the initial Low efficiency scenario and an estimate of the cost reduction in % for the other scenarios compared to the Low efficiency scenario; (3) lifetime of the measures). However (Zuberi et al., 2017) indicate that the use of the expert method increases the overall uncertainty.

In the approach of Zuberi and Patel (Zuberi & Patel, 2017) the energy efficiency cost curve is formed by graphically representing the specific or levelized costs of energy efficiency measures C_{spec} (see formula (4)).

$$C_{spec,y} = \frac{ANF \cdot NPV_y}{ES_y} \quad (4)$$

where

ES_y – energy savings potential calculated according to formula (5),

ANF - annuity factor, that can be calculated using formula (6),

NPV_y – net present value for measure ‘y’ in the defined base year calculated according to formula (7).

$$ES_y = (EIS_y + FIS_y) \cdot PR_y \quad (5)$$

where

EIS_y – the electricity savings generated by measure ‘y’ per tonne of product, (GJ/t),

FIS_y – the fuel savings generated by measure ‘y’ per tonne of product (GJ/t),

PR_y – production volume to which the measure ‘y’ applies (t).

$$ANF = \frac{(1+r)^L \cdot r}{(1+r)^L - 1} \quad (6)$$

where

r – real discount rate = actual discount rate – inflation rate,

L_y – measure lifetime, years.

$$NPV_y = \sum_{t=2016}^{Ly} CF_t \cdot (1+r)^{-t+2016} \quad (7)$$

where
CF_t – annual cash flow in year t, calculated according to formula (8).

$$CF_t = I_y + O\&M_y - B_y \quad (8)$$

where
I_y – initial investment (zero value in all subsequent years)
$O\&M_y$ – maintenance and operating costs,
B_y – annual savings over the measure lifetime.

$$B_y = [(EIS_y \cdot P_e) + (FIS_y \cdot P_f) + (CA_y \cdot P_{CO2})] \cdot PR_y \quad (9)$$

where
p_e – electricity price (euro/GJ),
p_f- fuel price (euro/GJ),
p_{CO2} – CO_2 emission costs (euro/t_{CO2}),
CA_y – CO_2 reduction (t_{CO2}/year).

Similar as Hasanbeigi et al. (Hasanbeigi et al., 2016; McKane & Hasanbeigi, 2011), also the calculations of (Zuberi & Patel, 2017) include discounting and the effect of measure lifetime. However, the calculations in the method used by Zuberi and Patel differ in that the annual savings taken into account in the cash flow estimate (NPV) are deducted from the cash flow and are therefore shown as negative values on the Y axis. In this case, all measures that appear below 0 (with negative costs) on the energy efficiency cost curve (that is they provide benefits rather than costs, see Figure 1-5) are considered cost-effective (Zuberi & Patel, 2017).

In this case, the graph does not additionally show the energy cost threshold (see example in Figure 1-5). On the other hand, Rodrigues da Silva (Rodrigues da Silva et al., 2018) in their study emphasize the use of energy efficiency curve calculation method that is independent of energy prices.

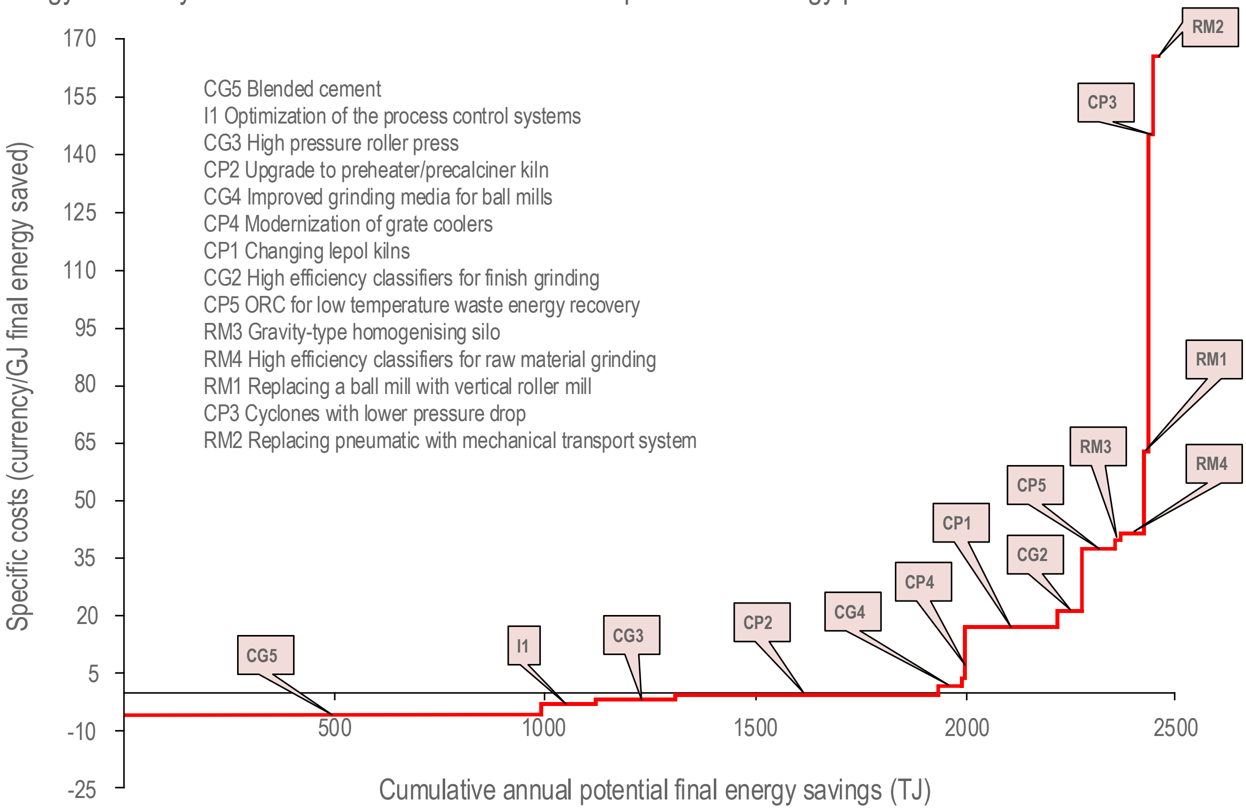


Figure 1-5. Example on the use of energy efficiency cost curves, taking into account the impact of savings on specific costs (Zuberi & Patel, 2017)

Overall, it can be concluded that the input data used for the energy efficiency cost curves, as well as, what costs exactly are taken or not taken into account, and the cost calculation over the technology lifetime differ slightly in the works of different authors. However, this means that depending on the available data, it will be possible to adapt the method to the data available in Latvia.

1.2.2. Additional considerations for using the energy efficiency cost curve method

Various scientists have studied in depth how the fact, which costs are attributed directly to energy efficiency, affects the calculation of the cost-effectiveness of energy efficiency measures. For example, according to the extended methodology proposed by the US EPA (Energy and Environmental Economics Inc., 2008), the impact of energy efficiency measure implementation can be assessed using a simple or complex method. Within the complex method, the costs of an energy efficiency measure are calculated as the difference between the costs of an energy efficient technology and the costs of a standard technology, plus the residual discounted present value of the existing installation. However, Zuberi et al. (Zuberi et al., 2017) indicate that such detailed data on existing equipment and equipment to be replaced are very rare. Therefore, it is also possible to use the simplified method, where all the total costs of the new energy efficient equipment and the installation costs are taken as the cost of the energy efficiency measure (as an alternative to not implementing any energy efficiency measures at all). In this case, potential energy savings are calculated as the difference between the electricity consumption of the previous equipment or technology and the new equipment. (Zuberi et al., 2017)

The total investments into measures can be used in the calculations, but, if data are available, the part of the investment which is directly related to energy efficiency can also be broken down in more detail. Investments related to energy efficiency are calculated by multiplying the total investment by the plant-specific factor, which depends on the age of the equipment to be replaced, and the lifetime of the implemented energy efficiency measure or the installed equipment (see formula (10)). In this way, the total costs are multiplied by a factor that characterizes each installation separately, taking into account the age of the equipment at the time of exchange. However, problems are usually caused by the fact that the specific age and potential lifetime of the equipment are unknown. (Zuberi et al., 2017)

$$EI = TI \cdot \left(1 - \frac{A}{L}\right) \tag{10}$$

where

A – age of the equipment to be replaced, years,

L – equipment or measure life, years,

EI – energy efficiency costs, euro,

TI – total costs, euro.

One of the factors that have a significant impact on the calculation results is the chosen discount rate. McKane and Hasanbeigi (McKane & Hasanbeigi, 2011) used a 10% rate and performed a sensitivity analysis to determine the effect of different discount rates on the result. Another factor that was subjected to sensitivity analysis in their study was the unit cost of energy because different costs in different countries and regions might influence results and their explanation. Zuberi et al. (Zuberi et al., 2017) indicate that in order to ensure a consistent approach in the calculations, it is desirable to assess investments excluding VAT.

The level of detail in the analysis of different energy consumers (production equipment, lighting, heating, ventilation, etc.) or the distribution (classification) of analyzed energy efficiency measures depends on the level of detail required (or desired) and the information availability. Energy efficiency measures can be classified according to the processes in which they are implemented, such as production processes or support processes, as well as according to the sub-processes of these categories (see Table 1-2).

Table 1-2

Classification of production and support processes (Andersson et al., 2018)

Production processes	Support processes
Disintegrating	Space heating
Mixing	Space cooling
Disjointing	Lighting
Jointing	Ventilation
Coating	Administration
Molding	Tap water heating
Heating	Compressed air
Melting	Transports
Drying	Other
Cooling/freezing	
Packing	
Other/impossible to categorize	

Meanwhile (Yáñez et al., 2018) divide energy efficiency measures into four categories: (1) process optimization, (2) energy recovery, (3) energy production, (4) process improvement. But the studies by (Eichhammer, W., Fleiter, T., Schlomann, B., Faberi, S., Fioretto, M., Piccioni, N., Lechtenbohmer, S., Schuring, A., Resch, 2009) and (Fleiter & Schleich, 2012) distinguish two main categories - process-specific technologies and cross-sectorial technologies. Examples of production process technologies include blast furnaces used in metallurgy, while cross-sectoral technologies can be further subdivided into (1) electricity consumers (e.g. motor systems) and (2) heat generation technologies (e.g. heating systems and industrial steam generation). (Fleiter & Schleich, 2012) point out that regarding production process technologies, the factor that influences the increase in energy consumption is the physical volume of production. Cross-sectoral technologies tend to have lower capacity per unit, but companies have a larger number of units because they are widely used, so their energy consumption can account for a large share of industrial electricity consumption. Therefore cross-sectoral technologies must also be taken into account in order to consider the overall situation regarding industrial consumption.

1.2.3. Application examples

This section describes and analyzes previous research conducted by various authors using energy efficiency cost curve method.

McKane and Hasanbeigi (McKane & Hasanbeigi, 2011) have analyzed energy efficiency measures in electric motor systems. Their study is based on UNIDO (UNIDO, 2010) developed methodology and analysis of energy efficiency supply curves for motor systems. Globally, electric motor systems consume about 60% of final electricity consumption in industry. To determine the technical and economic energy efficiency potential of three different motor systems in industry (compressed air system, pumps and fans), researchers have used a bottom-up approach to design energy efficiency supply curves. Using this methodology, the authors developed a model for determining the economic and technical potential of energy efficiency, as well as the reduction of CO_2 emissions. Within the study, three different scenarios of the initial (baseline) efficiency of the system were developed - low, medium and high. Their study differs in that the energy efficiency assessment also integrates the opinion of experts on the level of energy efficiency according to each baseline scenario. In this way, the lack of highly detailed data is addressed. The Delphi-type approach was used to integrate the expert opinion, using multiple iterations to improve the input data used in the analysis. Expert opinion was also used to determine which of the three baseline levels are most characterizing for each of the six countries/territories analyzed, as well as to assess the energy efficiency improvement and estimated costs for 36 different energy efficiency measures, the lifetime of the measure (assuming two working hour levels with threshold at 4500h/year) and the extent to which energy savings will depend on future maintenance practices. (McKane & Hasanbeigi, 2011)

Hasanbeigi & Price (Hasanbeigi & Price, 2012) analyzed 184 energy efficiency measures that can be used in the textile industry. They point out that it is possible to implement different energy efficiency measures in any of the textile plants and that, although many of them have a low payback period, they are hampered by a lack of information on energy efficiency measures and fewer resources available to SMEs for acquisition of such information. In this study, the potential for energy efficiency is examined in terms of individual measures and equipment. Therefore, the use of such data in the model requires fairly accurate information about the technologies used in companies and their current energy consumption.

Zuberi et al. (Zuberi et al., 2017) have performed a technologicaly-economic analysis of possible energy efficiency improvements in electric motor systems. By compiling data on electricity savings and investments directly related to electric motor drive systems (from the Swiss Energy Agency - energy audits and energy efficiency action plans, from the National Energy Office - data on the results of supported energy projects, and from Geneva municipal utilities on supported energy efficiency measures in industry), they created an extensive database on the energy efficiency of electric motors. Collected data include:

1. Annual energy savings and total investment.
2. In some cases, the total energy consumption before and after the introduction of the measures is also known, but in most cases it is not known. Consequently, the choice of measures is not directly based on a precise savings plan. (Zuberi et al., 2017)

Muster-Slawitsch et al. (Muster-Slawitsch, Weiss, Schnitzer, & Brunner, 2011) have used the EISTEIN methodological approach to conduct a case study to optimize the heat supply of three breweries. Within this method the minimum thermodynamic heat consumption for each technology (MEDTtech) is determined, which can be used as the maximum thermodynamic potential. Then the possibilities of process integration at the level of individual processes and whole company level are analyzed using pinch analysis. Their approach is based on a database of energy efficient technologies and optimization measures, which is based on measurement data and information from the literature.

1.2.4. Benchmarking method

Energy efficiency and its potential in industry is often analyzed using energy indicators and benchmarks that are used to describe energy efficiency in industry or another sector of the economy (Cai, Liu, Xie, & Zhou, 2017). Energy efficiency benchmarks are also used as a tool to support energy efficiency, because the use of benchmarks helps to assess fluctuations in energy consumption, tendencies and their causes, as well as to decide on the implementation of energy efficiency measures (Zogla, 2014).

Different methods can be used to create energy consumption benchmarks (for a more detailed description, see Table 3 in (Cai et al., 2019)). Žogla (Zogla, 2014) points out that for the application of the benchmark method it is important to use appropriate indicators, determine the system boundaries and correction factors. It is also important to check the relevance and reliability of the indicators calculated from the original data, and to continue using the data only if the obtained results are reliable. The determination of system boundaries depends on the purpose of the analysis, whether several plants of the same company are compared, or several companies of the same industry, or companies of different industries. Benchmarks can be divided into:

- performance benchmark against which only key indicators such as the company's energy intensity are compared,
- process benchmark,
- strategic benchmark. (Zogla, 2014)

Currently, a number of different benchmark methods are used in the iron and steel and chemical industry, as well as, in construction. Cai et al. (Cai et al., 2017) offer a multi-objective energy consumption benchmark based on energy consumption prognosis and integrated assessment. Within the framework of their research, first, a functional unit (which is one mechanical production workpiece), as well as, the boundaries of the system are defined. The benchmarking process consists of the following steps: (1) creation of an energy consumption database, (2) creation of an energy consumption prognosis, (3) integrated assessment and benchmarking. In this approach, the creation of an energy consumption database is an important part of the energy benchmarking, ensuring the long-term use of the benchmark. (Cai et al., 2017)

Specific energy consumption indicator can also be used as a performance benchmark. Specific energy consumption refers to the amount of energy consumed in physical units for a particular production process (e.g.

the production of a particular product). In the scientific literature, this indicator is used both at the level of individual industries and at the national level. (Yáñez et al., 2018)

For example, for the calculation of specific energy consumption (see formula (11)), the company's monthly energy consumption is attributed to the volume of production in that month. If the data are only available on an annual basis, then, accordingly, the annual energy consumption is related to the annual production.

$$SEC = \frac{EP}{P}, \tag{11}$$

where

SEC – specific energy consumption, MJ/unit of production.

EP – energy consumption per unit time, MJ/unit of time,

P – output per unit time, e.g., volume, number of products or their economic value units/unit of time.

One of difficult tasks is to express the production output in a uniform form, because in each industry the performance indicator is a different type of output, which can be expressed in different forms. For example, in the textile industry, output can be expressed in kilograms or pieces of clothing produced (Çay, 2018). The dairy industry produces milk, cheese, kefir, yoghurts and other products, in which case it is recommended to use the amount of processed raw milk for the calculation of specific energy consumption to ensure that that companies with different product profiles can be compared (Santonja, Karlis, Raunkjær Stubdrup, Brinkmann, & Roudier, 2019).

On the other hand, if detailed data on energy, mass and emissions balance are available for each technology unit (bottom-up analysis), the total SEC can be calculated according to formula (12) (Yáñez et al., 2018).

$$\mathrm{SEC}_i = \sum_{x=1}^{n} \frac{E_x}{P_x} \cdot W_x, \tag{12}$$

where

SEC – specific energy consumption, MJ/unit;

Wx – share of product *x* in process *i*;

x – production technology *x;*

Ex – energy consumption for production technology *x*, MJ/ unit of time;

P – output per unit time, e.g., volume, number of products or their economic value units/unit of time.

Simple payback time is calculated according to formula (13).

$$Payback\ time = \frac{Investments}{Annual\ savings}, \tag{13}$$

where

Investments – capital investments, euro,

Annual savings – annual savings due to saved energy, euro.

In the research of Yanez et al. (Yáñez et al., 2018), the specific energy consumption and the specific GHG emissions were calculated at the level of individual production units, then aggregated into process blocks, which in turn were used to create a common value chain index. Scales according to mass fractions are used to sum specific energy consumption (see equation 3.1).

2. ANALYSIS OF DATA AVAILABLE IN THE ENERGY EFFICIENCY MONITORING SYSTEM

After a data request to the Ministry of Economics based on the previously signed confidentiality agreement, the data of the energy efficiency monitoring system (EMS) were received in the format of MS Excel file. In order to ensure companies' rights to confidentiality, the names of companies had been deleted in the data provided by the Ministry of Economics. The received data included:

- Each company's main activity accordingly to NACE Rev.2.0 classification;
- Whether the company qualifies for the large company status in 2016-2018;
- Company's electricity (not total energy) consumption for 2016-2018;
- Whether the company has submitted an energy audit report or energy management system ISO50001 certificate, or supplemented environmental management system ISO14001;
- Company's planned energy savings (both heat and electricity) in MWh/year as reported by the company to the Ministry of Economics;
- Breakdown of planned savings by different types of energy efficiency measures (energy efficiency of buildings, lighting, equipment, transport, others);
- The amount of achieved energy savings reported for 2016 and 2017 in total and by types of energy efficiency measures, as well as company investments related to the implemented measures.

For the analysis hereafter, the information provided to the project executor by the Ministry of Economics from the energy efficiency monitoring system will be used. It includes unedited information on large companies and large electricity consumers.

Changes in the number of large companies and electricity consumers from 2016 to 2018 are shown in Table 2-1). The dynamics of the number of energy balances submitted by large companies and large electricity consumers are shown in Table 2-2, but

Table 2-3 provides information on energy audits submitted by large companies and large electricity consumers, as well as the number of energy management and environmental management certificates and those that have not submitted documentation in accordance with legal requirements. The Ministry of Economics website (Ministry of Economics, 2019b) provides information that

- If a large electricity consumer meets the criteria of a large company status, it is subject to the requirements of the Energy Efficiency Law that apply to large companies.
- if the self-consumption of a large electricity consumer indicated in the submitted energy balance does not exceed 500 MWh, then the requirements of the Energy Efficiency Law do not apply to it.
- if the submitted balance indicates a sub-user whose electricity consumption exceeds 500 MWh, then that sub-user must comply with the requirements of the Energy Efficiency Law within one year from the approval of the balance, but not later than by 1 January 2019.

Table 2-1

The dynamics of the number of large companies and large electricity consumers

	2016	2017	2018
Large companies (including large companies that are not large electricity consumers)	231 (69)	238 (54)	265 (47)
Large electricity consumers other than large companies	942	915	914
Total	1173	1153	1179

Table 2-2

The dynamics of the number of energy balances submitted by large companies and large electricity consumers

	2016	2017
Large companies that have submitted an energy balance	0	0
Large electricity consumers who have submitted an energy balance	2	219

Table 2-3

Number of energy audits, energy management and environmental management certificates submitted by large companies and large electricity consumers, and number of non-compliant companies

Large companies that have submitted an energy audit	118
Large electricity consumers that have submitted an energy audit	373
Large companies that have submitted ISO 50001 certificate	92
Large electricity consumers that have submitted ISO 50001 certificate	230
Large companies that have submitted ISO 14001 with supplement	13
Large electricity consumers that have submitted ISO 14001 with supplement	21
Large electricity consumers that have submitted an energy balance and their self-consumption is below 500 MWh/year	213
Companies that have not submitted any of the documents required by the law	381

Publicly available information indicates that "In 2016 the list of large companies included 228 companies, and by 20th November 2018, 199 large companies had reported that they have implemented the mandatory energy audit. Companies that have already managed to implement certain energy efficiency improvement measures in 2016 have reported energy savings of 80 gigawatt hours (GWh), while summarizing the information provided by companies on the measures they plan to take in the period until 2022, energy savings are planned at 255 GWh, which will save a total of more than € 24 million in energy costs." (LETA, 2019)

On September 11, 2018, the online portal of the newspaper "Dienas Bizness (DB)" published information that "Although currently the majority of companies whose electricity consumption in 2017 exceeded 500 MWh have met the requirements of the Energy Efficiency Law, almost 300 companies have not yet complied with the requirements. … DB has already reported that at the end of 2017, only 94 large electricity consumers had complied or partially complied with the Energy Efficiency Law requirements, in February 2018 the number of those who had fulfilled the requirements increased to 121, in March - to 300, and in April - to 590. The Ministry of Economics emphasizes that the greatest activity of entrepreneurs was observed shortly before the deadline for compliance with the requirements - in March and April 2018." (Dienas Bizness, 2018)

Figure 2-1 shows the distribution of submitted energy audits, ISO 14000 management certificates and ISO 50001 certificates depending on the company's electricity consumption. The figure shows that as the company's energy consumption increases, the number of ISO 14000 and ISO 50001 certificates increases. None of the large consumers have chosen to have an energy audit. One explanation could be the cost of energy audits for larger companies due to their higher capacity and more complex process management. Also, one of the aims of an energy management standard is that it is structurally similar to other management standards that may be of interest for companies that have already implemented other management systems.

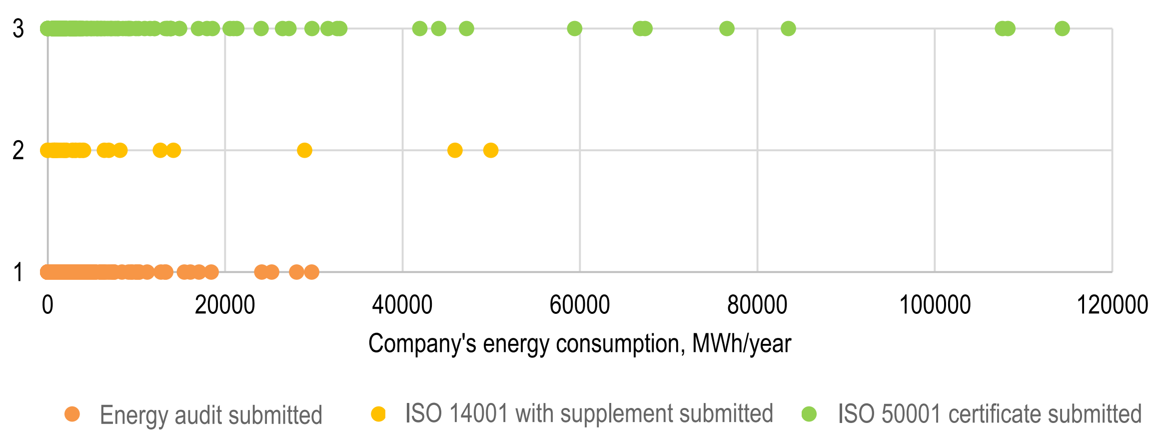


Figure 2-1. Distribution of submitted energy audits, ISO 14000 management certificates and ISO 50001 certificates depending on the company's electricity consumption

Figure 2-2 shows the total electricity consumption in large companies and large electricity consumers, for which information is available in the Ministry of Economics energy efficiency monitoring system. The electricity consumption of both groups of companies is similar and tends to increase every year.

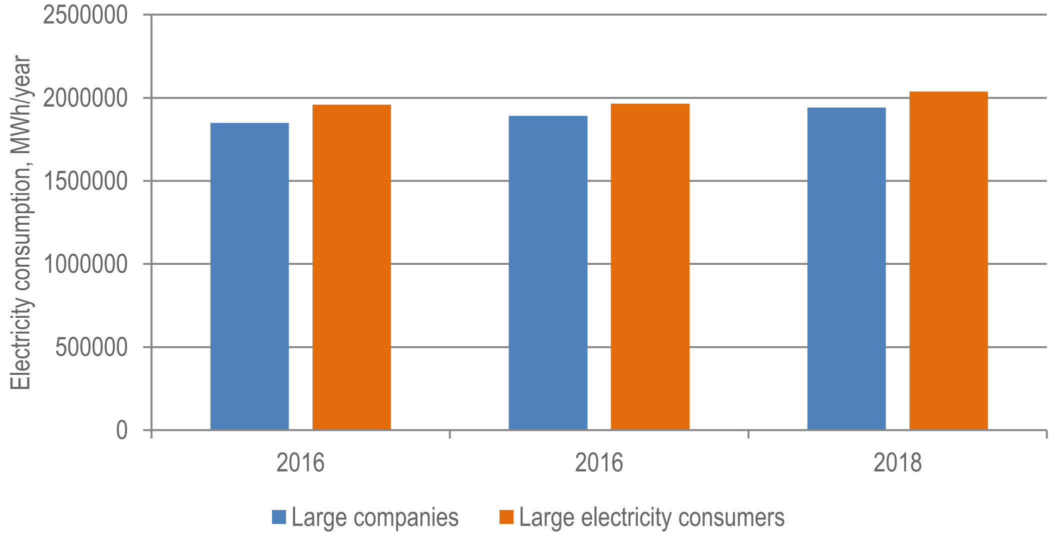


Figure 2-2. Total electricity consumption in large companies and large electricity consumers for which information is available in the EM energy efficiency monitoring system

The energy efficiency monitoring system provides information on electricity consumption in 201 large companies. This information is not available for the rest of large companies. The largest consumer consumes an average of 115 GWh per year, while the smallest consumers consume less than 500 MWh/year (see Figure 2-3). The average electricity consumption of a large company is 9500 MWh/year.

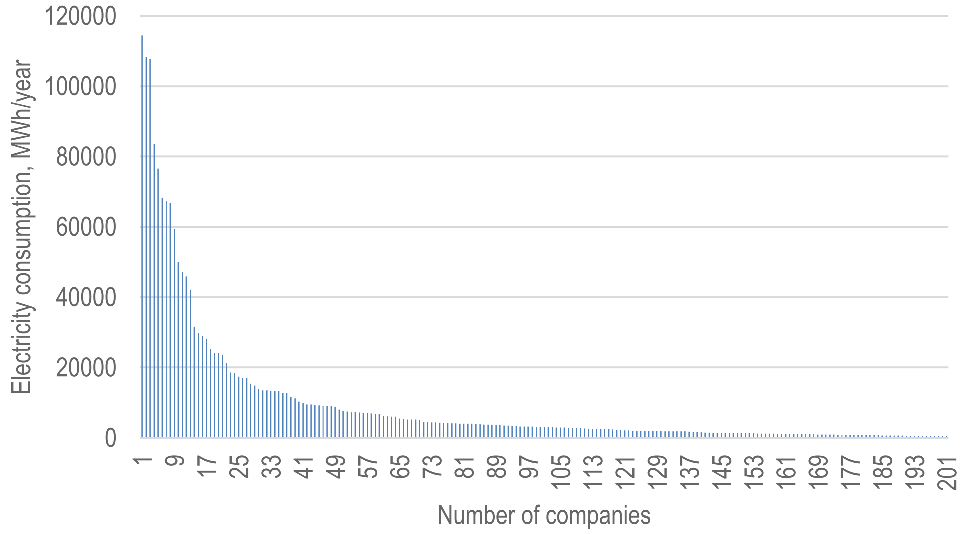


Figure 2-3. Average electricity consumption of large companies in 2016-2018

The same dispersion of consumption as for large enterprises is observed in the group of large electricity consumers, which does not include large enterprises (see Figure 2-4). The largest consumer consumes an average of 44 GWh of electricity per year, while the smallest consumes 500 MWh/year.

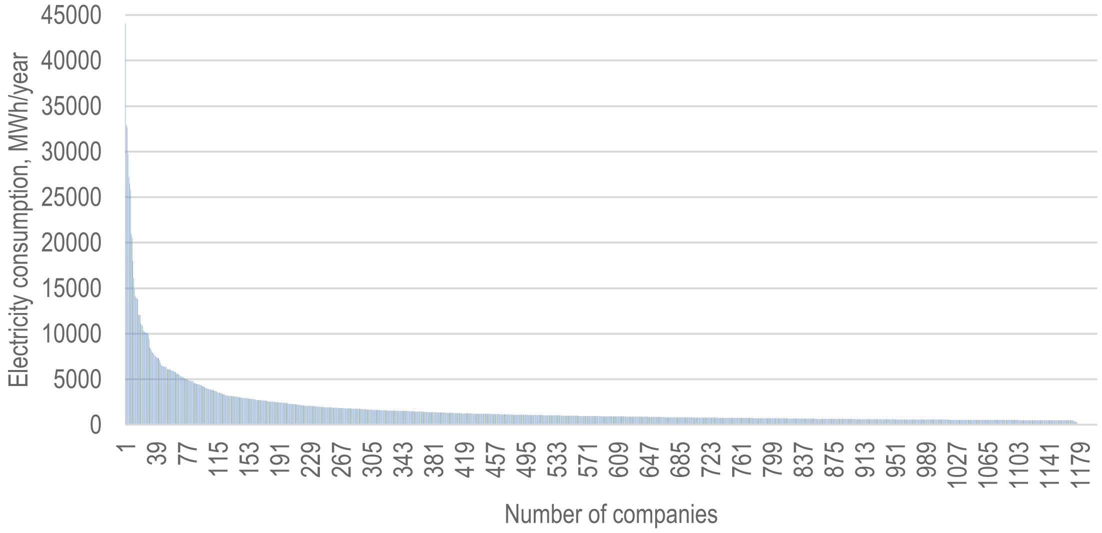


Figure 2-4. Average electricity consumption of large electricity consumers, which are not large companies in 2016-2018

Figure 2-5 shows the relationship between the company's average annual electricity consumption and the projected amount of energy savings. The trend shows that companies consuming more than 20 GWh per year (electricity costs around € 2 million per year) predict energy savings of less than 10%, with the exception of four companies that are planning larger savings. On the other hand, companies with consumption of less than 20 GWh/year project higher savings. A particularly pronounced trend is observed in companies with the lowest consumption - they have a very high projected amount of energy savings. It is possible that companies with higher electricity consumption may be more cautious in expressing their projected savings, or companies with lower electricity consumption may have a higher untapped energy efficiency potential. A more detailed explanation of the situation would be possible if data on the total energy consumption for each company were available.

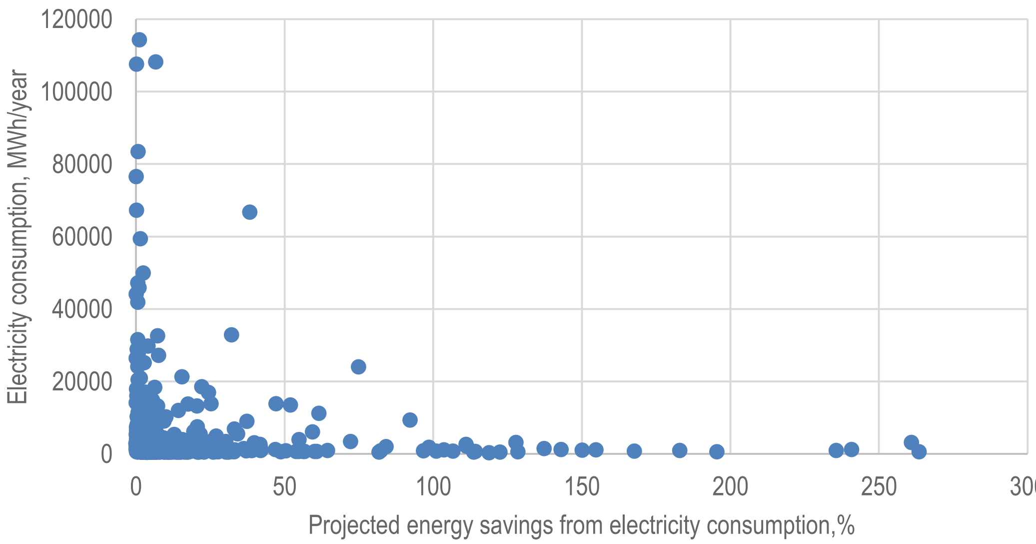


Figure 2-5. Relationship between average electricity consumption and projected energy savings for all companies together

In order to analyse of the relationship between the average electricity consumption and the projected energy savings for large electricity consumers who are not large companies, the graph shown in Figure 2-6 is used. A similar trend as for all companies together is seen – the higher the company's electricity consumption, the relatively smaller the planned energy savings are, except for few individual cases. The largest percentage savings are planned in companies with low electricity consumption. For example, one of the largest consumers of electricity plans to save only 0.11% of total electricity consumption and to do so by increasing the efficiency of production equipment and taking other energy efficiency measures. This would allow them to reduce the electricity bill by around € 5000 per year. In contrast, one average consumer planned to increase the energy efficiency of buildings and equipment and already implemented these measures in 2016 and 2017, thus reducing energy consumption by 40%, saving around € 400 000 each year and ensuring return of investment in about 2 years. This relationship may also depend on the existing competences of energy auditors and energy managers, for example, if only one or a few types of energy efficiency measures are identified and mostly in support systems, the total savings in absolute terms may even be similar for companies of different capacities, but for companies with higher overall consumption it will account for a smaller share of the consumption.

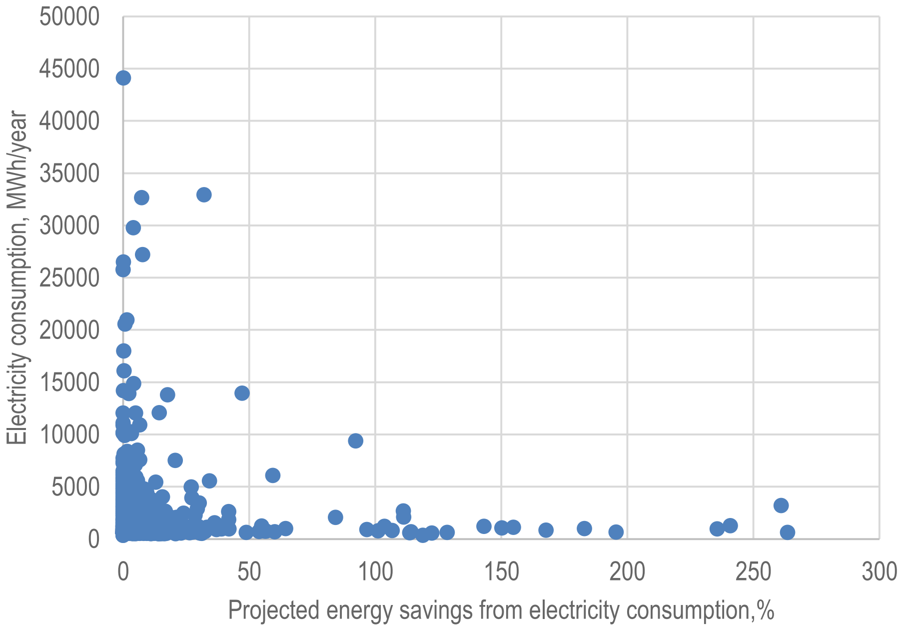


Figure 2-6. Relationship between average electricity consumption and projected energy savings for large electricity customers that are not large companies

Figure 2-7 shows that only two of the large companies plan to significantly reduce energy consumption (by 38% and 74%). A closer look at these two companies shows that in both cases the companies plan to increase energy efficiency in their production equipment and one of them has already done so in 2017 by investing 84 euros per 1 MWh saved, reducing the annual electricity bill by about EUR 2.3 million and ensuring return of investments in one year. In the case of the other company, the annual cost of electricity would be reduced by about 2 million EUR per year. In other companies, a similar relationship is observed as for large electricity consumers - the higher the energy consumption, the lower the planned relative savings.

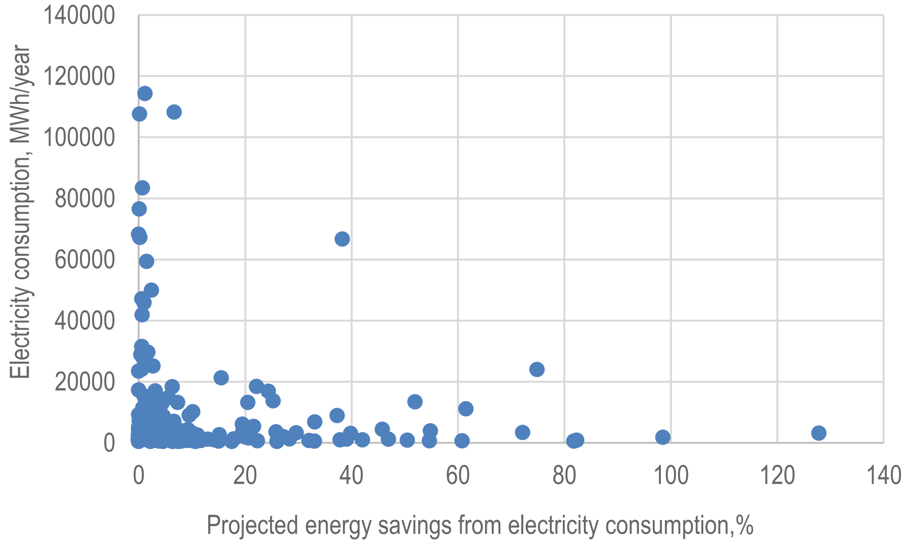


Figure 2-7. Relationship between average electricity consumption and projected energy savings for large companies

The total planned amount of savings for large companies and large electricity consumers is 390 GWh/year. The companies have reported total savings of 105 GWh in 2016 and 171 GWh in 2017. More detailed information by enterprise groups is shown in Figure 2-8. It can be seen that large companies implemented less measures in 2016; however in 2017 the savings of large electricity consumers decreased, but in large companies they increased significantly, as several companies significantly reduced energy consumption.

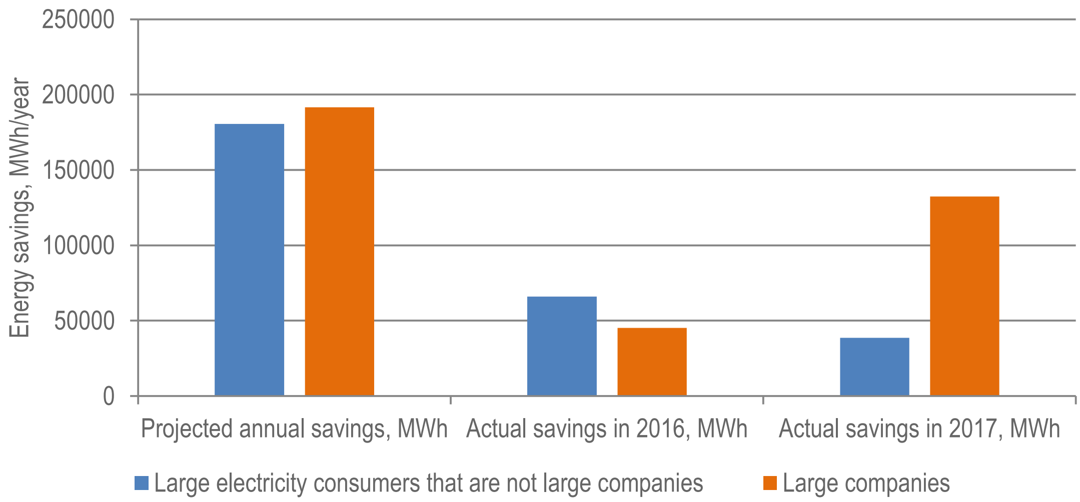


Figure 2-8. Projected and actual energy savings for large companies and large electricity consumers that are not large companies

The energy savings reported by large companies and large electricity consumers that are not large companies for 2016 and 2017 are shown in Table 2-4. They are calculated as the reported total energy savings for the year divided by the total electricity consumption for the corresponding year.

Table 2-4

Energy savings reported by large companies and large electricity consumers that are not large companies for 2016 and 2017

	2016	2017
Large companies	2,4%	7%
Large electricity consumers that are not large companies	3,4%	2%

A summary on the implementation of energy management systems and energy audits in large companies and large energy consumers in 2016 and 2017 as reported to the Ministry of Economics is given in Table 2-5. **One of the main shortcomings of the energy efficiency monitoring system is that data on energy consumption are only available for electricity. In turn, energy savings include all types of energy that are used in the company. This hinders the analysis of the distribution of energy savings, their size, cost-effectiveness and potential.**

Table 2-5

Summary of the implementation of energy management and energy audits in large companies and large energy consumers in 2016 and 2017

	Energy savings below 50%	Energy savings above 50%	Energy audit has been performed or energy management has been implemented, but no data are available on planned energy savings	Energy audit has been performed or energy or environmental management has been implemented, but no data on are available on electricity consumption	Energy balance has been submitted and the self-consumption of electricity is less than 500 MWh/year	Neither energy audit nor energy management certificate have been submitted	TOTAL
Total electricity consumption, GWh/year	3030	137	59	0	329	200	3755
Planned savings, GWh/year	182	199	0	10	0	0	390
Actual savings in 2016, GWh/year	43	30	17	14	0	0	105
Actual savings in 2017, GWh/year	90	76	4	1	0	0	171
Number of performed energy audits	410	22	15	43	0	0	490
Supplement to ISO 14001 submitted	30	2	1	2	0	0	35
ISO 50001 certificate submitted	264	27	11	22	0	0	324
Total companies	704	51	27	67	213	428	1490
Projected average savings,%	7	174	0		0		
Costs per 1MWh saved/year in 2016	81	226		262			
Costs per 1MWh saved/year in 2017	159	552		2113			
Reports for 2016 have been submitted	64	11	1	9		0	85
Reports for 2017 have been submitted	310	23	7	26		0	366

Overall, the database includes a total of 1491 companies. In order to be able to perform the analysis, the companies are divided into several groups (see Table 2-5):

- companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%;
- companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%;

- companies that have performed energy audits/energy management, but there are no data on planned energy savings;
- companies that have performed energy audits/energy management, but there are no data on electricity consumption;
- companies that have submitted an energy balance, but their electricity self-consumption is less than 500 MWh/year;
- companies that have not submitted data on implementation of energy audit or an energy management certificate, or an environmental management certificate or energy balance.

Figure 2-9 shows the enterprises belonging to different abovementioned groups as a share from the total number of enterprises that are subject to the requirements of the Energy efficiency law. The largest share of them are companies with savings of less than 50%, followed by companies that have not submitted any documents required by the law, then those companies that have submitted an energy balance and their own consumption is less than 500 MWh/year and the rest make up 10%.

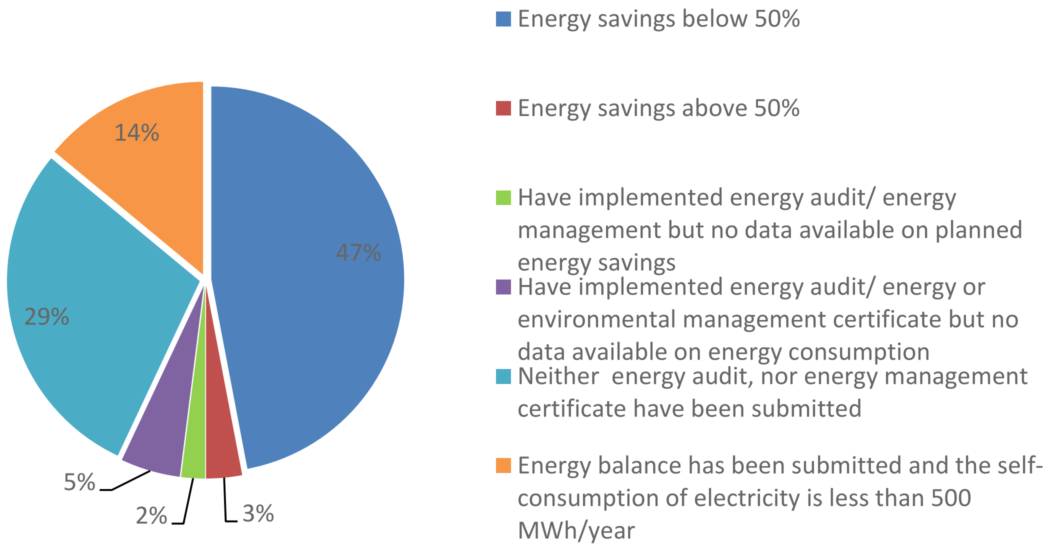


Figure 2-9. Proportion of the number of enterprises belonging to different groups from the total number of enterprises subject to the requirements of the law

A more detailed analysis of each group is provided below:

- *companies where the total projected energy savings (total energy savings divided by average electricity consumption for 2016-2018) are less than 50%*

Figure 2-10 shows the distribution of projected annual energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%. The average projected savings are around 7.3%.

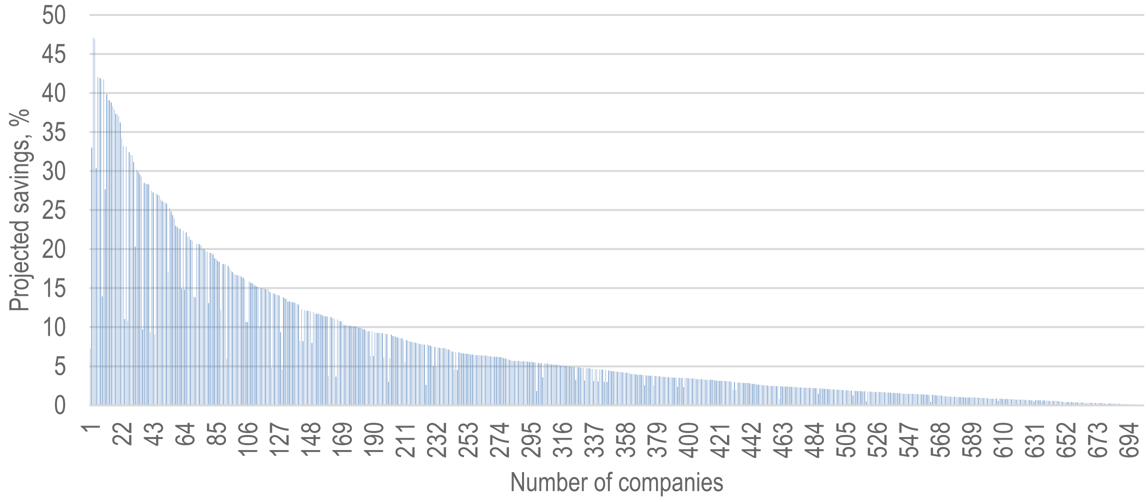


Figure 2-10. Projected energy savings in enterprises where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

Figure 2-11 shows the projected energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50% depending on the company's electricity consumption. It shows a tendency that the higher the company's electricity consumption, the lower the percentage of planned savings, except for two companies.

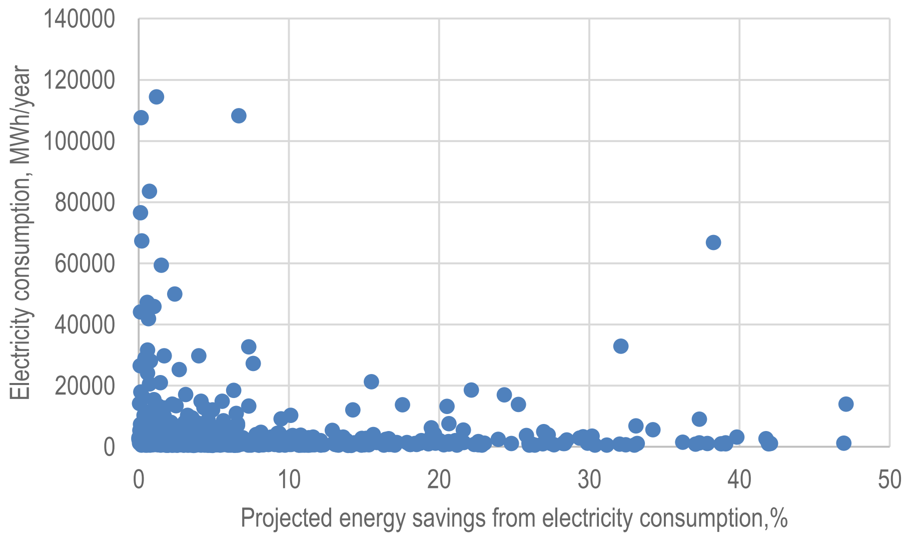


Figure 2-11. Projected energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50% depending on the company's electricity consumption

Figure 2-12 shows the total projected and actual energy savings in 2016 and 2017 in companies with total projected energy savings less than 50%. It shows that the annual reported actual savings in 2016 constituted only 19% of the planned annual savings, while in 2017 it was 49%. This can be explained both by the fact that only a little more than half (53%) of companies have reported actual savings, as well as by the fact that in most companies the actual savings are lower than expected. For some of the companies who have submitted reports, information on energy savings and their distribution is not available in the database (54% for 2016 and 59% for 2017). This may be explained by the legislative requirement that at least three energy efficiency improvement measures with the highest estimated energy savings or economic returns must be implemented by 1 April 2020 (large companies) and 1 April 2022 (large electricity consumers) and companies have postponed the implementation of measures further towards these deadlines.

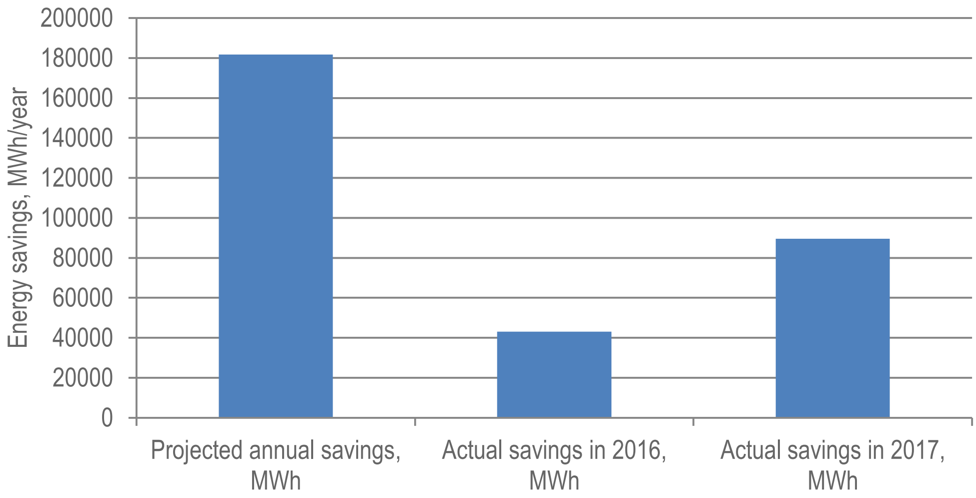
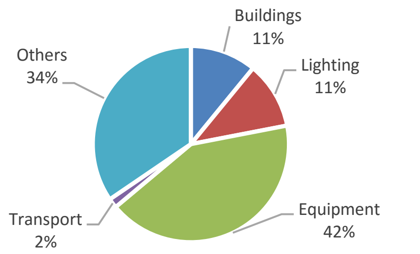
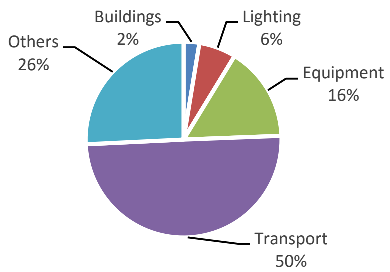


Figure 2-12. Projected and actual energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

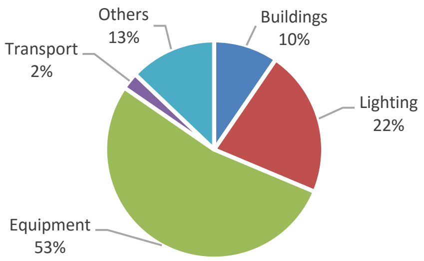
Figure 2-13 shows the distribution of projected and actual energy savings by energy consumption groups. It shows that the structure of energy savings in 2016 is significantly different from that in 2017 and that both years differ from the projected savings. In 2016, the largest savings were generated by transport related measures, but in 2017, equipment related energy efficiency measures and lighting measures increased significantly.



a) Projected savings



b) Actual savings in 2016



c) Actual savings in 2017

Figure 2-13. Distribution of projected and actual savings by energy consumption groups in enterprises where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

Figure 2-14 shows the share of energy efficiency measures in different energy consumer groups. It shows that most measures are implemented in lighting systems, followed by equipment and other measures.

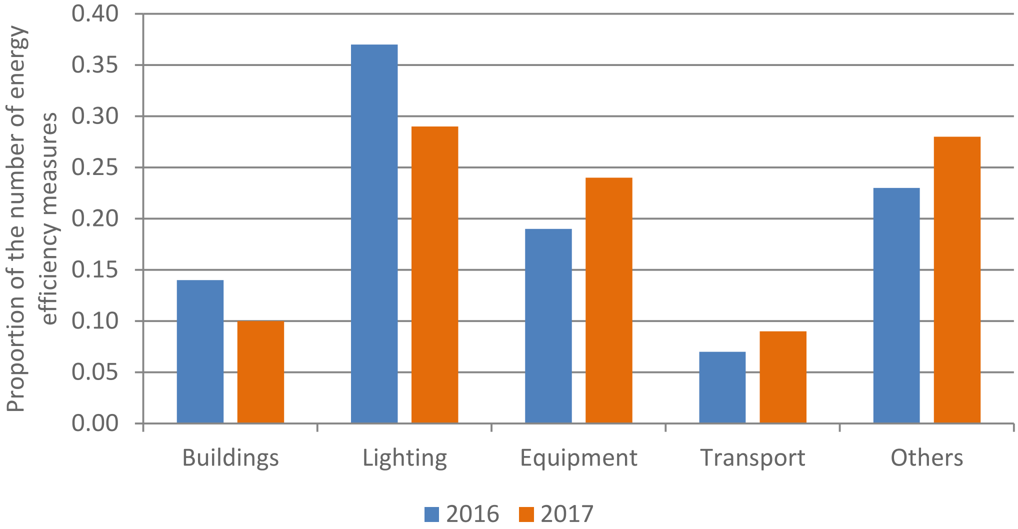
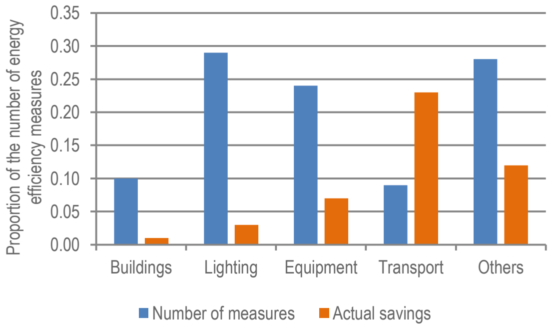
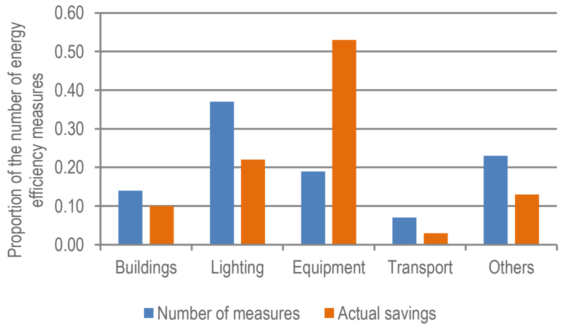


Figure 2-14. Proportion of the number of energy efficiency measures in different groups of energy consumers in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

Figure 2-15 shows the share of the number of energy efficiency measures in each of the consumption groups in 2016 and 2017, and the share of savings from each group of measures. It can be seen that the most popular energy efficiency improvement measures are related to lighting systems, which account for only 3% of total savings in 2016 and 21% in 2017. The most significant savings come from equipment (in 2016 and 2017) and transport related energy efficiency measures (only in 2016). A similar trend as for lighting is observed for other energy efficiency measures in 2017. This is due to formal compliance with the requirements of the law that requires companies to implement at least three energy efficiency measures with (1) the highest estimated energy savings or (2) economic returns and because lighting replacement meets the second condition but does not provide significantly high energy savings in absolute terms. The opposite trend is observed for measures to increase the energy efficiency of equipment and transport.



a) 2016



b) 2017

Figure 2-15. Proportion of the number of energy efficiency measures and savings in each of the consumption groups in 2016 and 2017 in enterprises where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

Figure 2-16 and Figure 2-17 show the actual energy savings (as a share from electricity consumption) as a function of the company's electricity consumption in 2016 and 2017 in companies where total projected energy savings (total energy savings divided by average electricity consumption for 2016-2018) are less than 50%. It shows that the actual relative savings are in a wide range, but the previously observed trend of differences between large and small energy consumers is even clearer here: the higher the consumption, the relatively smaller the energy savings.

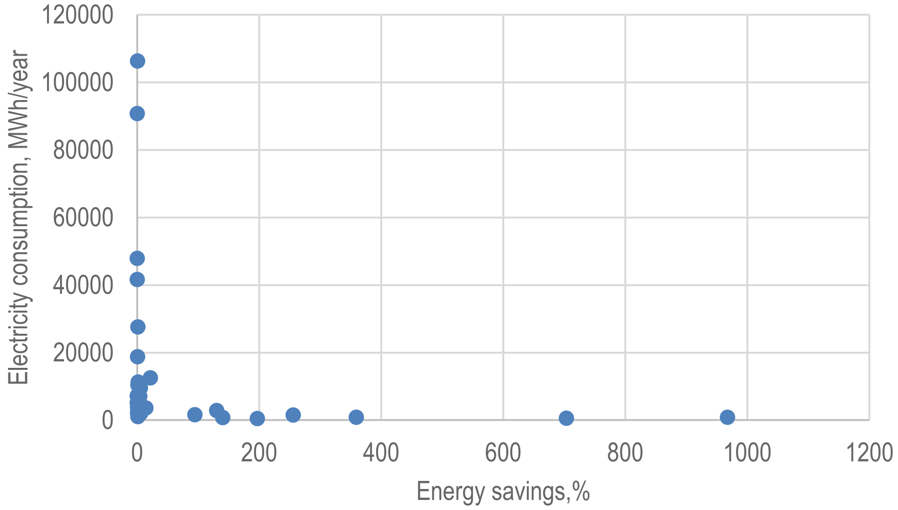


Figure 2-16. Actual energy savings from electricity consumption depending on the company's electricity consumption in 2016 in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

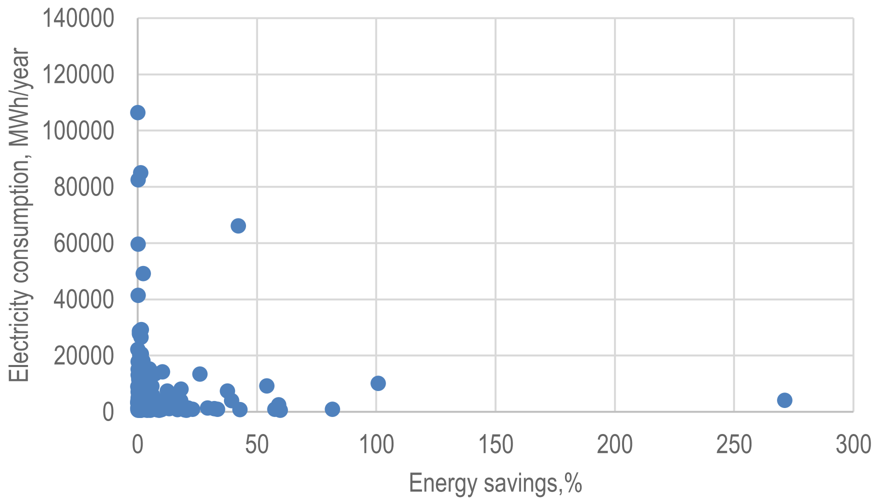


Figure 2-17. Actual energy savings from electricity consumption depending on the company's electricity consumption in 2017 in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are less than 50%

- *companies where the total projected energy savings (total energy savings divided by average electricity consumption for 2016-2018) are more than 50%*

Figure 2-18 shows the distribution of projected annual energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are higher than 50%. It shows that the relative savings range from 50% to 1500%. The large percentage range can be explained by the lack of information within the energy efficiency monitoring system on the consumption of all energy resources in enterprises, because according to Cabinet Regulation No. 668 enterprises have to report only electricity consumption, but the energy savings can originate from any energy resource savings

(Cabinet of Ministers, 2016b). According to the Central Statistical Bureau (Central Statistical Bureau, 2020c), electricity accounts for only 20% of the total energy consumption of industrial enterprises, therefore, if energy efficiency measures are applied to any other energy resource but can only be attributed to electricity consumption, then the relative savings appear very high.

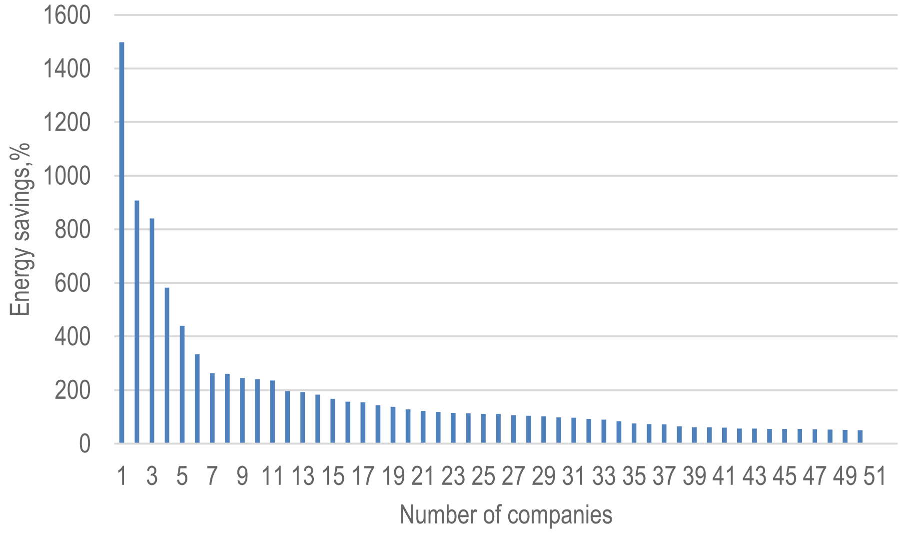


Figure 2-18. Projected energy savings in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

Figure 2-19 shows the total projected energy savings and actual savings in 2016 and in 2017, in companies where the total projected energy savings are more than 50%. It shows that the annual reported actual savings in 2016 were only 15% of the planned annual savings, while in 2017 they constitute 38%. This can be explained both by the fact that only a little more than half (53%) of companies have reported actual savings, as well as by the fact that in most companies the actual savings are lower than expected. For some of those who have submitted reports, information on energy savings and their distribution is not available in the database. This can be explained by the legislative requirement that at least three energy efficiency improvement measures with the highest estimated energy savings or economic returns must be implemented by 1st April 2020 (large companies) and 1st April 2022 (large electricity consumers).

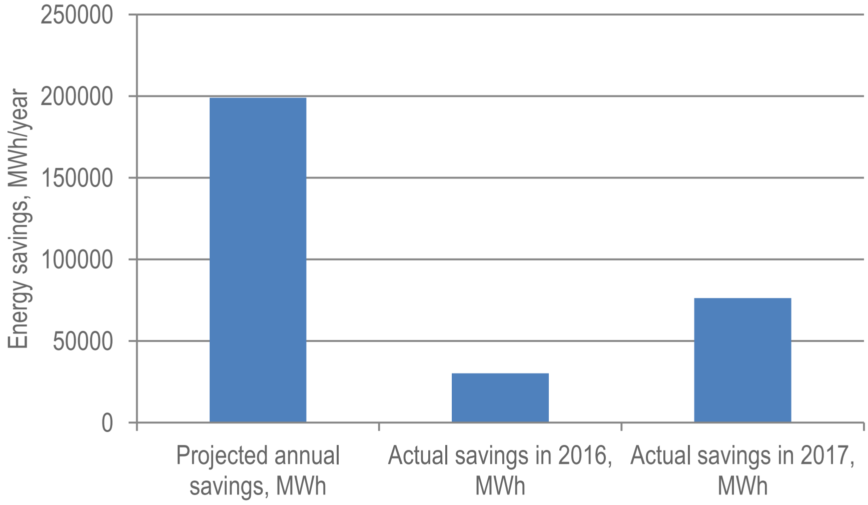


Figure 2-19. Actual and projected energy savings in enterprises where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

Figure 2-20 and Figure 2-21 show the actual energy savings as a share from electricity consumption depending on the company's electricity consumption in 2016 and 2017 in companies where total projected energy savings (total energy savings divided by average electricity consumption for 2016-2018) are greater than 50%. They show that the actual savings are small, with the exception of 4 companies that have made larger investments during these two years.

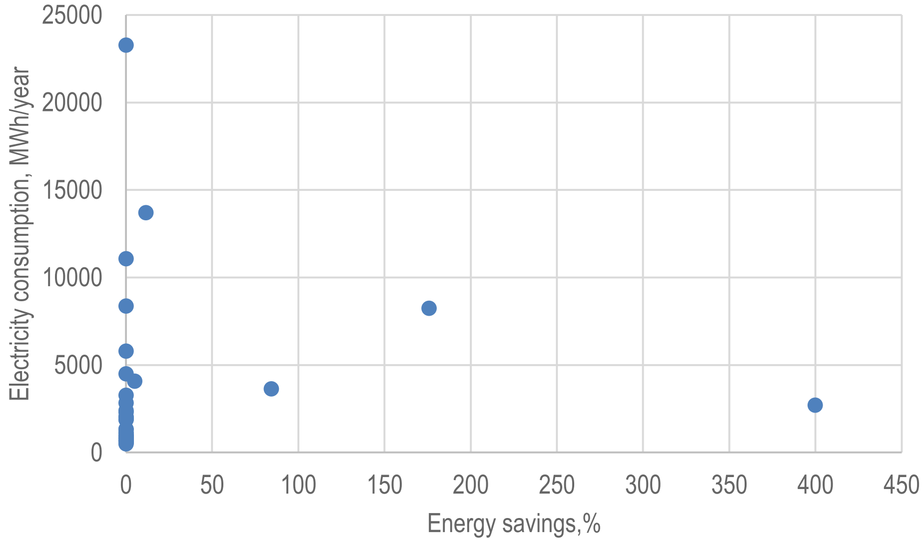


Figure 2-20. Actual energy savings from electricity consumption depending on the company's electricity consumption in 2016 in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

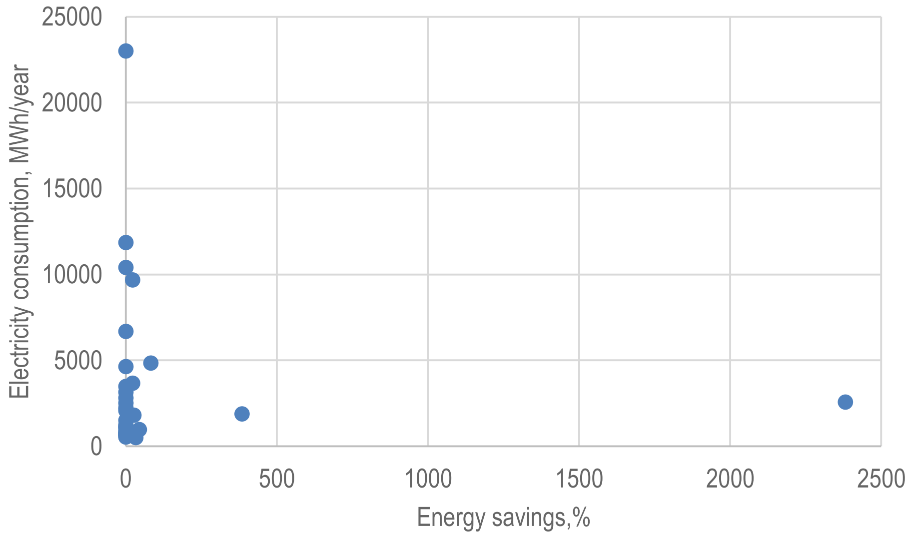
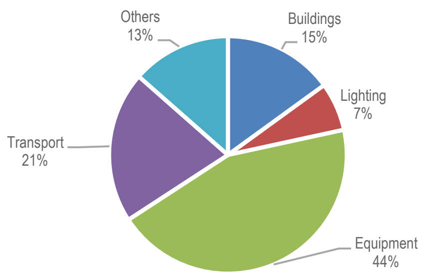
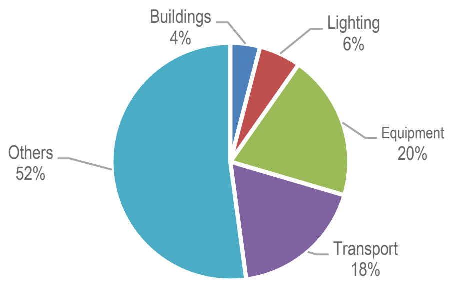


Figure 2-21. Actual energy savings as a share from electricity consumption depending on the company's electricity consumption in 2017 in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

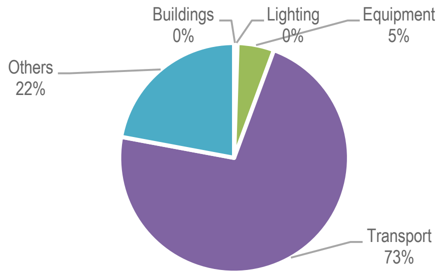
Figure 2-22 shows the distribution of planned and actual savings by energy consumption groups. It shows that the structure of savings in 2016 is significantly different from the structure of savings in 2017 and both years differ from the planned structure. In 2016, the largest savings came from other measures group, but in 2017, the number transport energy efficiency measures increased significantly.



a) Projected savings



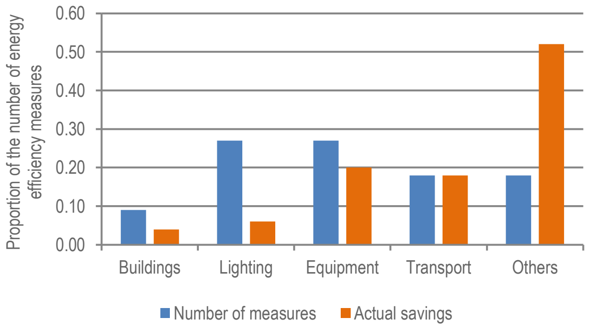
b) Actual savings in 2016



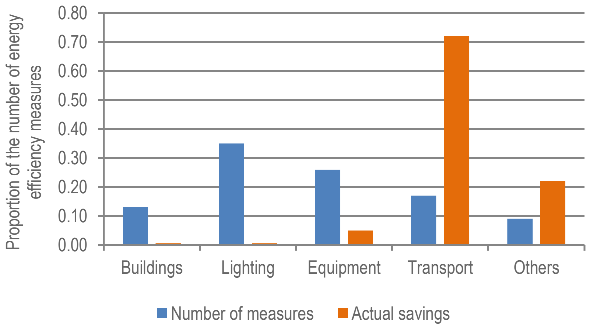
c) Actual savings in 2017

Figure 2-22. Distribution of planned and actual savings by energy consumption groups in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

Figure 2-23 shows the share of the number of energy efficiency measures and the share of savings in each of the consumption groups in 2016 and 2017. It can be seen that the most popular are the energy efficiency increasing measures for lighting systems, but they account for only 5% of total savings in 2016 and 0.01% in 2017. The most significant savings come from equipment related and other energy efficiency measures (2016 only) and transport related measures in 2017. This is due to formal compliance with legal requirements that require companies to implement at least three energy efficiency measures with (1) the highest estimated energy savings or (2) economic returns and because lighting replacement meets the second condition but does not provide significantly high energy savings in absolute terms. The opposite trend is observed for measures to increase the energy efficiency of equipment.



a) 2016



b) 2017

Figure 2-23. Proportion of the number of energy efficiency measures and savings in each of the consumption groups in 2016 and 2017 in companies where the total projected energy savings (total energy savings divided by the average electricity consumption for 2016-2018) are more than 50%

- *companies that have performed energy audits/ implemented energy management but do not have data on planned energy savings*

This group includes 26 companies with a total electricity consumption of 59 GWh/year. One company has reported savings in 2016 and 4 companies have done so in 2017. As in the previous groups, lighting and other energy efficiency measures dominate; no equipment related energy efficiency measures have been implemented. The total savings in 2016 are 0.017 GWh, but in 2017 – 3.6 GWh. The relative savings from electricity consumption in relation to electricity consumption in 2016 and 2017 are shown in Figure 2-24 and Figure 2-25.

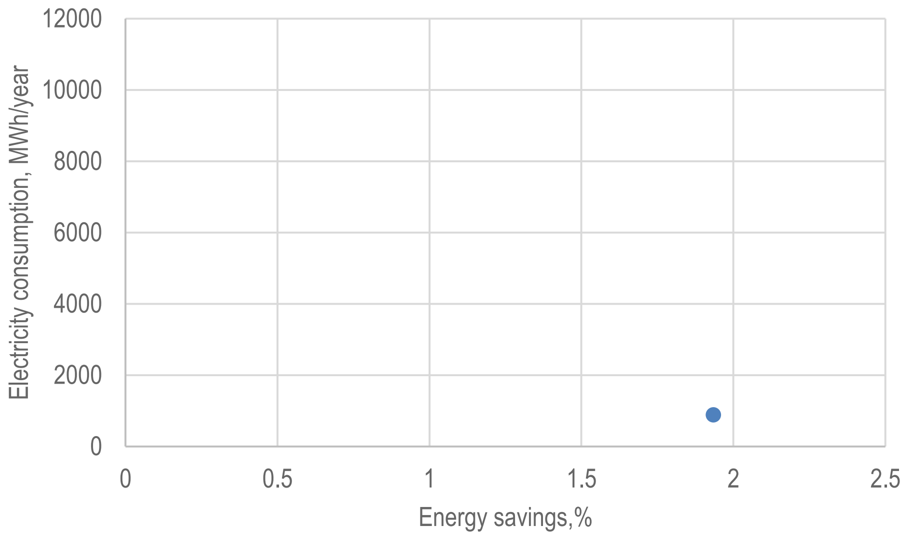


Figure 2-24. Actual energy savings as a share from electricity consumption depending on the company's electricity consumption in 2016 in companies that have performed energy audits/energy management, but no data on planned energy savings are available

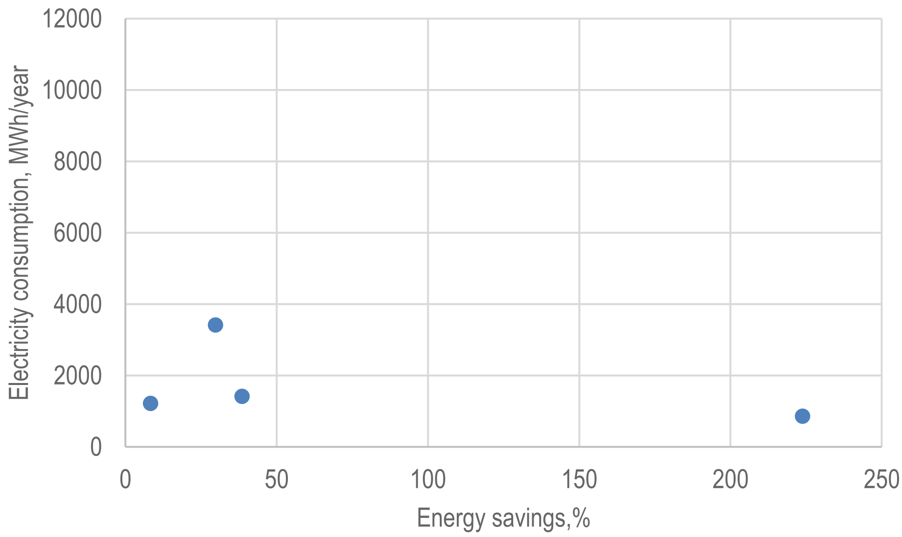


Figure 2-25. Actual energy savings as a share from electricity consumption depending on the company's electricity consumption in 2017 in companies that have performed energy audits/energy management, but no data on planned energy savings are available

- *companies that have performed an energy audit/ implemented energy management but do not have data on electricity consumption*

This group includes 67 companies. Figure 2-26 shows the total projected energy savings and actual savings in 2016 and 2017. It shows that the annual reported actual savings in 2016 exceeded the planned savings, but in 2017 it accounted for 9% of the projected savings. In 2016, only one of the companies implemented energy efficiency measures, but the savings achieved are large. The situation in 2017 can be explained both by the fact that only a part of companies have reported actual savings, as well as by the fact that in most companies the actual savings are lower than expected. For some of companies who have submitted reports, information on energy savings and their distribution is not available in the database. This can be explained by the legislative requirement that at least three energy efficiency improvement measures with the highest estimated energy savings or economic returns must be by 1st of April 2020 (large companies) and 1st of April 2022 (large electricity consumers).

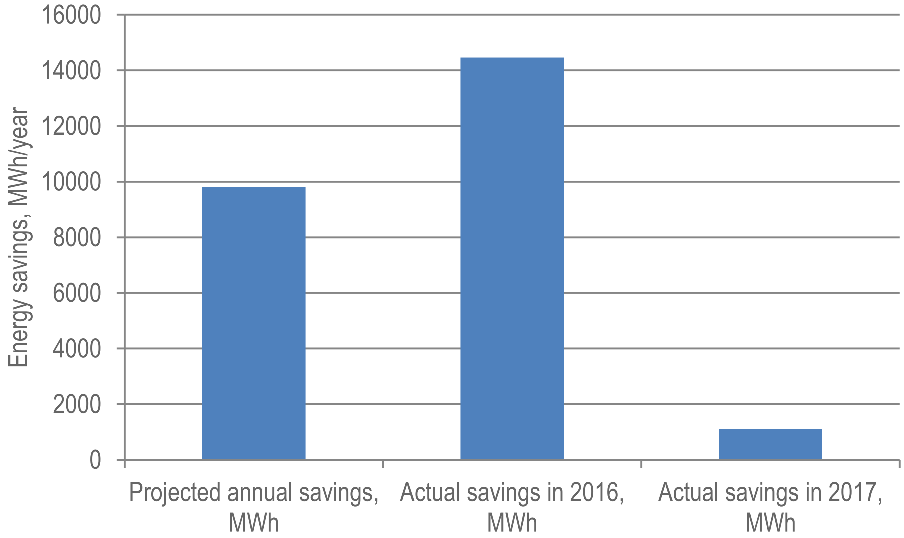


Figure 2-26. Actual and projected energy savings in companies that have performed an energy audit/energy management but do not have data on electricity consumption

Figure 2-27 shows the distribution of planned and actual savings by energy consumption groups. It shows that the structure of energy savings in 2016 is significantly different from that in 2017 and both years differ from what was planned. In 2016, the largest savings were made by one company improving the energy efficiency of production equipment, but in 2017, a significant share of energy savings is generated by energy efficiency measures in transport and lighting.

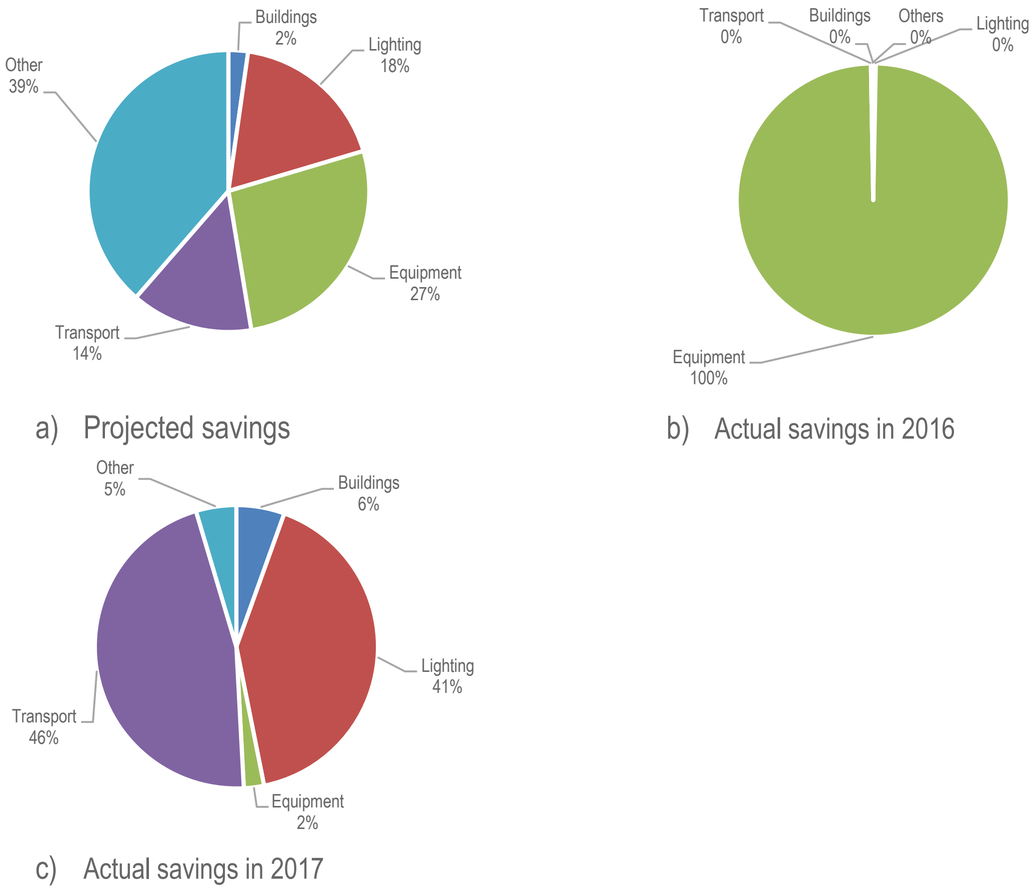


Figure 2-27. Distribution of projected and actual savings by energy consumption groups in companies that have performed an energy audit / energy management, but do not have data on electricity consumption

Figure 2-28 shows the share of energy efficiency measures in different energy consumer groups. It shows that in 2016, lighting systems dominated and were followed by other measures. In 2017, the energy efficiency measures for lighting still dominates, but the distribution the rest of the groups is changing – the proportion of other measures is rapidly decreasing, and they are being substituted by transport, equipment and building related measures.

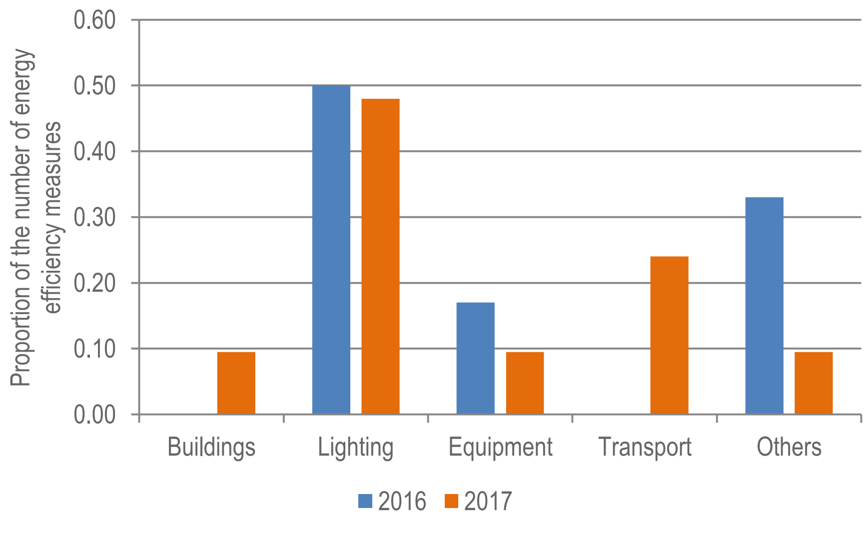


Figure 2-28. Proportion of the number of energy efficiency measures in different groups of energy consumers in companies that have performed energy audits/energy management, but do not have data on electricity consumption

Figure 2-29 shows the share of the number of energy efficiency measures in each of the consumption groups in 2016 and 2017, and the share of savings from each group of measures is shown next to it. It can be seen that the most popular are energy efficiency improvement measures in lighting systems, but they account for less than 1% of the total savings in 2016 and 4% in 2017. In 2016, the largest contribution to energy savings is made by increasing the energy efficiency of equipment in one company. In 2017, the results are different - each transport measure gives greater savings than each equipment or lighting related measure. This group of companies also has a similar trend as the other groups - formal compliance with legal requirements - companies must implement at least three energy efficiency measures with (1) the highest estimated energy savings or (2) economic return and lighting replacement meets the second condition, but does not provide significantly high energy savings in absolute terms.

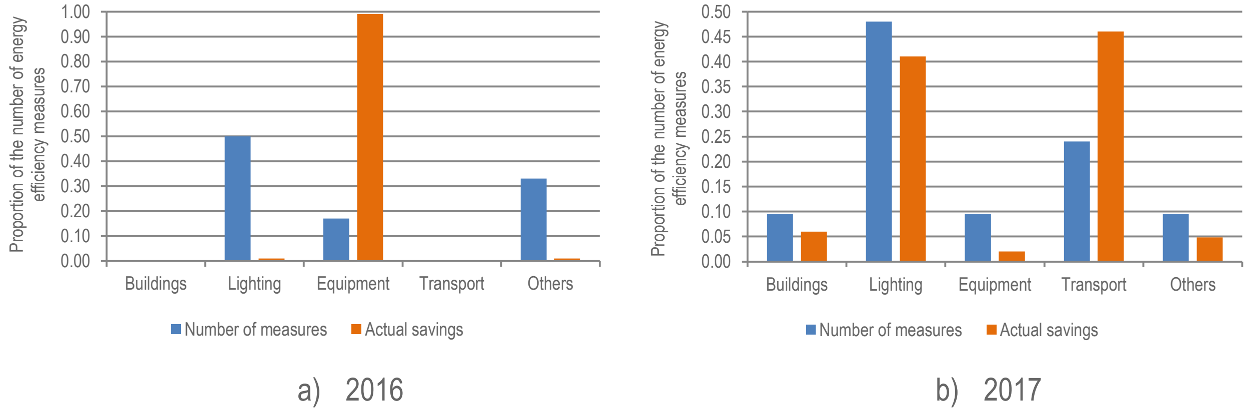


Figure 2-29. Proportion of the number of energy efficiency measures and savings in each of the consumption groups in 2016 and 2017 in companies that have performed energy audits/ implemented energy management but do not have data on electricity consumption

- *companies that have submitted an energy balance, but their electricity self-consumption is less than 500 MWh/year*

This group includes companies that rent premises and as landlords report on energy consumption. Most of the companies operate in real estate activities, in wholesale and retail trade, repair of motor vehicles and motorcycles, and in the electricity, gas, steam and air conditioning supply sectors. If these companies can prove with their energy balance that their self-consumption is less than 500 MWh/year, the requirements of the Energy efficiency law do not apply to them. The dynamics of the total electricity consumption of these companies from 2016 to 2018 are shown in Figure 2-30.

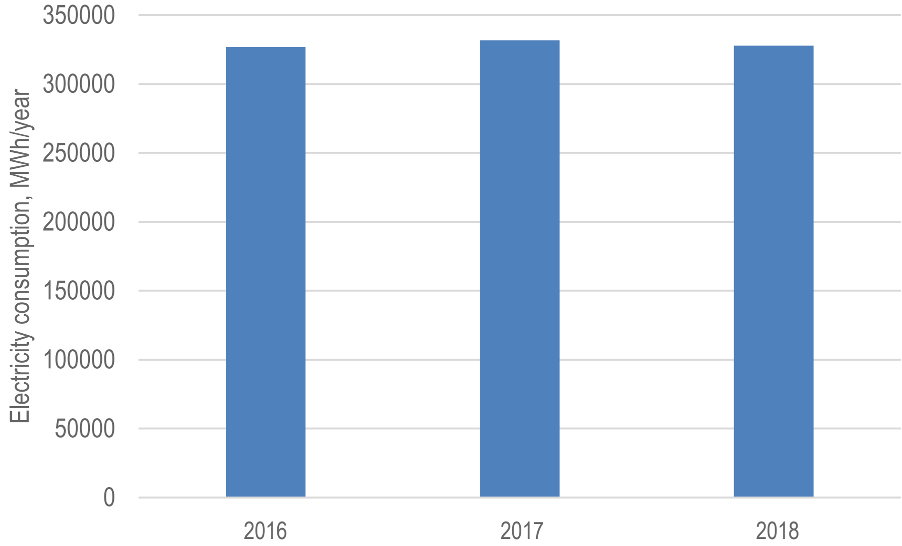


Figure 2-30. Changes in total electricity consumption between 2016-2018 for companies that have submitted an energy balance, but their electricity consumption is less than 500 MWh/year

- *companies that have not submitted data on energy audit implementation, an energy management certificate or environmental management certificate, or energy balance*

This group includes 381 company or 26% of the total number of companies. Their total average electricity consumption in 2016-2018 was 200 GWh/year and on average it is 1360 MWh/year per company. Figure 2-31 shows the annual electricity consumption in companies that have not submitted data on energy audit implementation, an energy management or environmental management certificates, or energy balance.

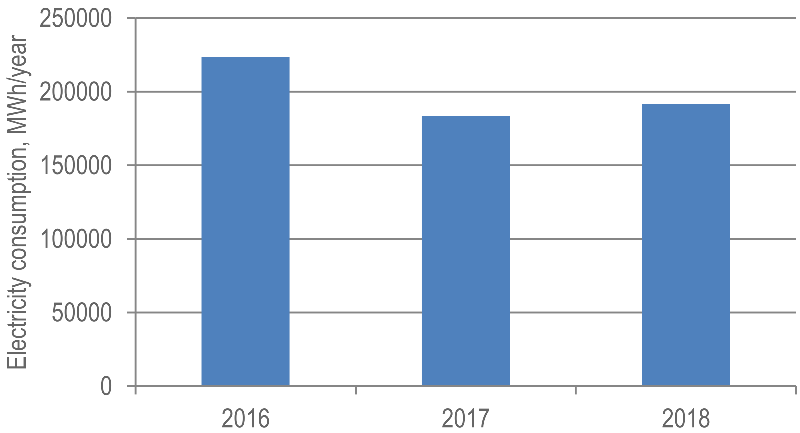


Figure 2-31. Annual electricity consumption in companies that have not submitted data on energy audit implementation, an energy management or environmental management certificates, or energy balance

The Energy Efficiency Law stipulates that a large electricity consumer who has not fulfilled the obligations specified in Section 10 paragraphs five, six and seven, as well as Section 12 paragraphs two, three and four of the Energy Efficiency Law shall pay an energy efficiency fee at the rate of 7% of the cost of electricity consumed in the previous year. These costs are calculated by multiplying the megawatt hours consumed in the respective year by the average electricity price for industry in Latvia in the previous year as published by Eurostat (EUR/MWh). The amount of the energy efficiency fee, the procedure for its calculation, application, payment and control is determined by Cabinet Regulation No. 202 (Cabinet of Ministers, 2017b)

The total annual amount of the fee for all 381 non-compliant companies could be approximately 1.21 million EUR, if the amount of the fee is 6.3 EUR/MWh (according to the annotation of the draft Cabinet Regulation No.202 (Cabinet of Ministers, 2017a). The total amount of the paid fee at the end of 2019 was approximately 0.5 million EUR.

In accordance with the annotation of the draft Cabinet Regulation No. 202 (Cabinet of Ministers, 2017b), the amount of the fee was forecasted as follows: "…. the revenue from the planned fee in 2018 is formed in accordance with the following calculation: (8780 MWh × 6.30 euros) x 10 = 553140 euros. … The total revenue from the fee in 2019 is formed according to the following calculation: (500 MWh × 6.30 euros) x 800 = 2520000 euros. Accordingly, in 2020, the potential payers of the fee could be around 460. Thus, the revenue from the fee is planned in the amount of 1449000 euros ((500MWh x 6.30 euros) x 460)). "

3. ANALYSIS OF DATA AVAILABLE IN THE ENERGY EFFICIENCY MONITORING SYSTEM FOR THE INDUSTRY

In order to estimate the predicted and achieved effect of the energy efficiency monitoring program in the energy end-use sectors, the projected energy savings in each sector were related to the total energy consumption of the sector as obtained from the official database of the Central Statistical Bureau (Central Statistical Bureau, 2020c) (see Figure 3-1).

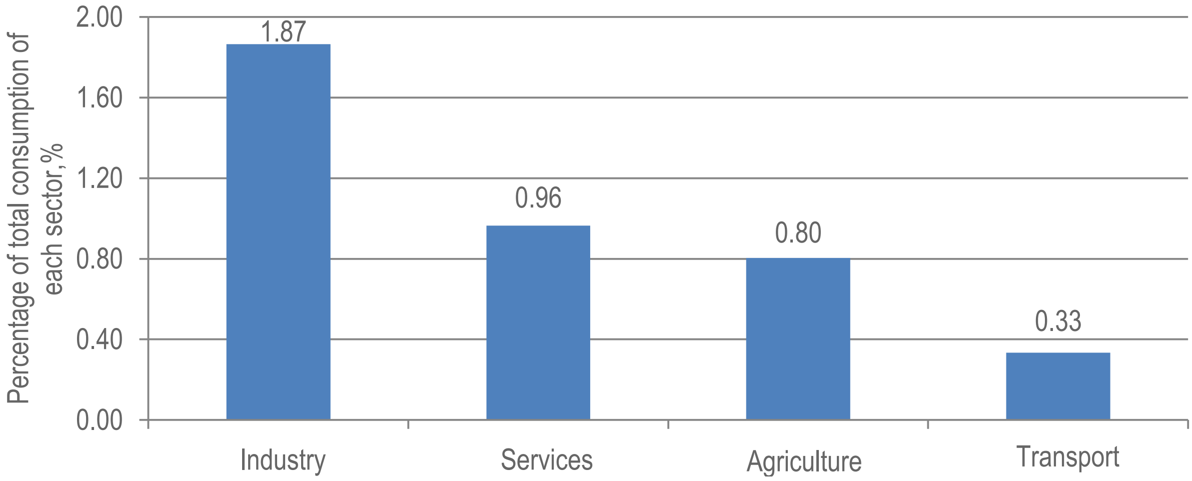


Figure 3-1. Companies' projected savings as a percentage of the industry's total consumption

Although around 500 industrial companies, around 800 service companies, around 60 agricultural companies and around 70 transport companies are subject to the mandatory energy audit and energy monitoring certification program, the largest savings potential is projected in the industrial sector. In the services sector, it is almost twice lower, while the lowest projected savings from the sector's total consumption are identified in transport sector.

However, the savings shares shown in Figure 3-1 describe specifically the results that are planned to be achieved by the particular program. In order to determine the technical and economic potential of each end-use sector with a bottom-up approach, based on the conclusions from the literature analysis, it would be necessary to create energy efficiency cost curves.

For the development of accurate curves, detailed data on the potential energy savings, costs and lifetime of each measure are required. **The data included in the energy efficiency monitoring system are not sufficient to establish complete energy efficiency cost curves,** as only the company's total cost of energy efficiency measures is available, so it is not possible to determine the average cost of individual energy efficiency measure groups (lighting, equipment, etc.) or, more specifically, for certain types of measures. Also, the available data on costs and savings may not be fully accurate in some cases, but their exclusion from the used data set cannot be fully justified without clarifying the information provided by companies. Information on the lifetime of measures is also not available in the provided data file of the energy efficiency monitoring system.

In further chapters industry related data from the energy efficiency monitoring system are analyzed in more detail. The savings achieved by the mining and manufacturing industry (NACE 2.0 C8-C33) in absolute terms for 2016 are 9.86 GWh, but for 2017 59.33 GWh, which is 5.18% and 31.18% of the initially forecasted industry savings respectively (see Figure 3-2). The total annual savings for 2016 and 2017 (69.2 GWh) account for 0.68% of the total final energy consumption of the industrial sector.

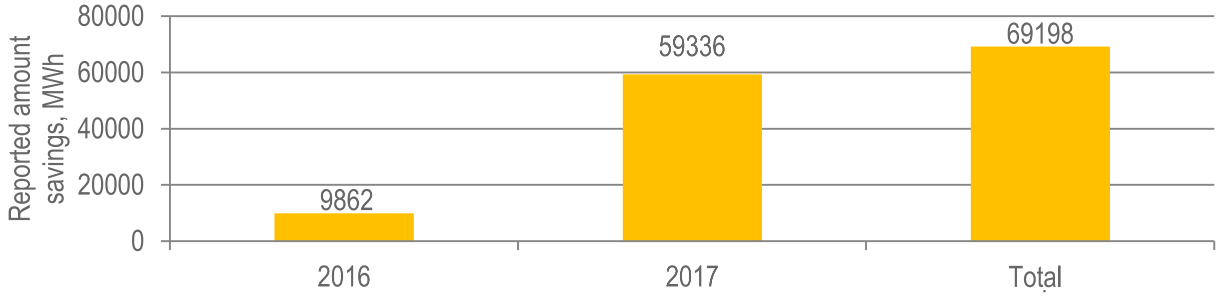


Figure 3-2. Energy savings reported by industrial companies in 2016 and 2017.

According to Article 10 of the Energy Efficiency Law, large companies must carry out energy audits on a regular basis, while according to Article 12 of the Law, large electricity consumers must implement a certified energy management system. However, the law also stipulates that large companies may implement a certified energy management system or an environmental management system with a supplement, and large electricity consumers may replace the energy management system with a regular energy audit. Depending on which of the energy efficiency requirements companies have implemented, they are distributed as follows:

- energy audits have been submitted to the Ministry of Economics by 158 industrial companies,
- 154 industrial companies have implemented certified ISO 50001 system,
- 13 industrial companies have implemented certified ISO 14001 with a supplement.

Figure 3-3 shows the number of industrial companies that have submitted energy audits and ISO 50001 certificates and their annual electricity consumption. Although the number of companies in both groups is quite similar, the total electricity consumption in the group of ISO 50001 certified companies (1125 GWh/year) is three times higher than the consumption of companies that have performed energy audits (349 GWh/year). Similar trend is seen for the projected savings in companies - the expected energy savings to be achieved by ISO implementers are 155.7 GWh, but for audit implementers only 33 GWh.

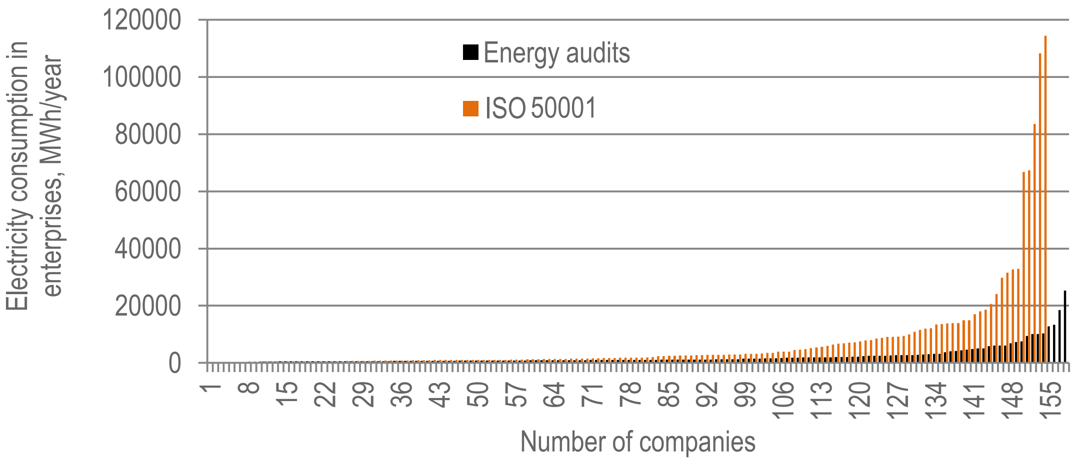


Figure 3-3. Number of companies that have implemented energy audits and ISO 50001 certification and their annual electricity consumption.

The specific costs of the savings reported by companies in both 2016 and 2017 are in a very wide range (see Table 3-1.). Average costs differ significantly from the median. **The large differences in specific costs, as well as the fact that for three companies costs for energy efficiency measures are available in the energy efficiency monitoring file, but no energy savings have been reported, indicate the need for more data control and verification.** Therefore, the results obtained are general and cannot reliably characterize the specific costs of energy efficiency.

Table 3-1.

Specific costs of savings reported by companies in 2016 and 2017

	2016	2017
Lowest specific costs, EUR/MWh	3	1
Highest specific costs, EUR/MWh	8835	184843
Arithmetic average costs, EUR/MWh	1120	3512
Median costs, EUR/MWh	117	161
Number of measures	12	70

A simplified application of energy efficiency cost curves using the costs available in the energy efficiency monitoring system for the measures implemented in the industrial sector is shown in Figure 3-4. This assessment takes into account the specific costs of energy efficiency measures (EUR/MWh), but does not take into account the lifetime of the measures introduced and the discount rates (which are definitely needed to create full-fledged curves). Also, in order to make the data more comprehensible, three extreme points have been removed - for 2016, one company with specific costs of 8835 EUR/MWh and for 2017, two companies with 0.18 MWh/year and 1.08 MWh/year savings, but the specific costs of these measures were around 29000 EUR/MWh and 184843 EUR/MWh respectively. The credibility of these data extremes should be verified by the monitoring system operator.

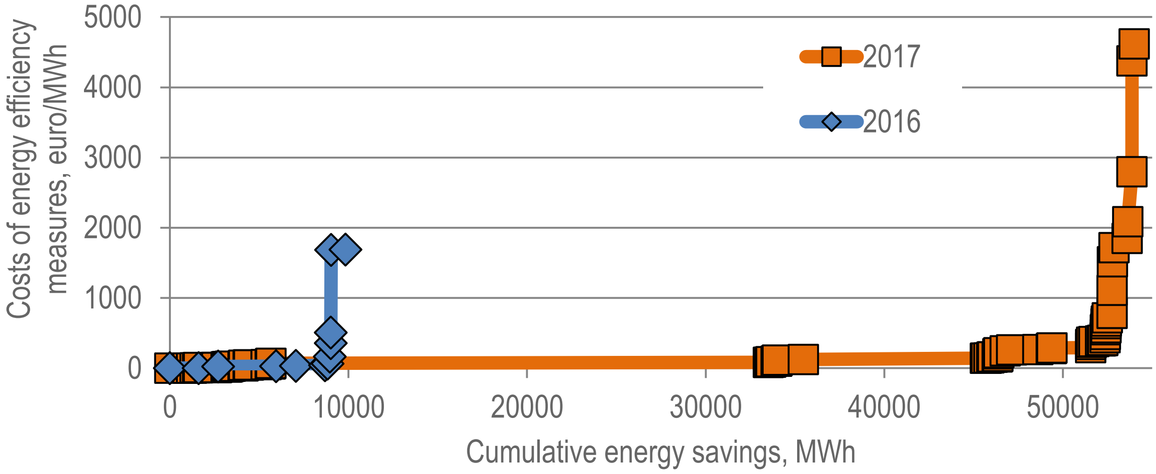


Figure 3-4. Simplified assessment of the specific costs of energy efficiency measures.

The specific energy efficiency cost curves shown in Figure 3-4 indicate that companies mostly choose to implement lower specific cost measures. In 2016, 90% of the implemented measures have specific costs of less than 100 EUR/MWh, while in 2017, 62% of measures have specific costs of less than 100 EUR/MWh. However, companies have also implemented higher cost measures, but it is not possible to tell from the data available in the energy efficiency monitoring system which measures (i.e., lighting, heating, equipment, etc.) are more expensive and which are cheaper.

As mentioned above, it is not possible to obtain full-fledged specific energy efficiency cost curves from the data of the energy efficiency monitoring system and the information provided in Figure 3-4 is not sufficient to be used to determine the technical and economic potential of energy efficiency.

4. ANALYSIS OF INDUSTRIAL ENERGY AUDIT DATA

As previously explained, the data in the MS Excel file of the energy efficiency monitoring system summary cannot be used to create accurate energy efficiency cost curves. Data on the total energy consumption are available in the company energy audit reports, which they submit to the Ministry of Economics. However, a structured summary of these data is not available in the Ministry of Economics. Therefore, more detailed data were manually collected from company energy audits available to the Ministry of Economics. The Ministry of Economics provided access to energy audits or notifications of planned measures submitted by 123 industrial companies (in total the energy efficiency monitoring system summary Excel file indicates that 158 companies have reported implementation of energy audits).

For the analysed companies, 58% of their final energy consumption consists of thermal energy consumption, 31.4% of electricity consumption, 10.5% of transport fuel consumption and 0.1% of fuel consumption for production processes. This differs from the total national statistics for industry sector, where electricity consumption is 18.5% and heat consumption is 81.5% of total final consumption (2016-2018 average) (Central Statistical Bureau, 2020c).

Correlations that would characterize the energy efficiency potential depending on various parameters were sought in the data obtained from energy audits. Figure 4-1 shows the distribution of the identified technical energy efficiency potential[1] by savings groups. For example, savings in the range between 0% to 5% of the company's total energy consumption have been identified in 64 companies, while savings of in the range between 35.1% to 40% have been identified in one company.

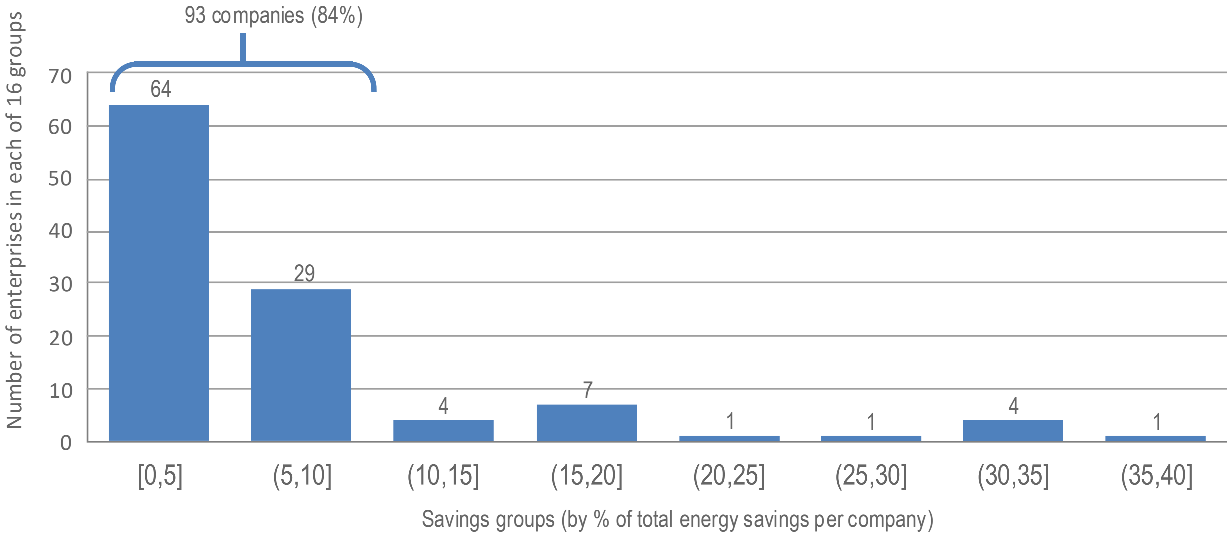


Figure 4-1. Histogram of the percentage savings of the analyzed companies

From all 123 companies, for 12 companies there was no data available on both the savings potential and the company's total consumption, so the percentage savings could not be calculated.

The histogram (see Figure 4-1) indicates that the technical savings potential identified in most audits (93 audits) is less than 10% of total energy consumption. In 18 audits it is between 10-40%. Consequently, the distribution of the determined savings does not correspond to the normal distribution. This is also evidenced by the descriptive statistical analysis of the data (see Table 4-1.) - the median differs from the mean, as well the skewness and kurtosis values exceed 2. This means that these data cannot be used in analyses that require normally distributed data, as this may affect the accuracy of the model or the interpretation of the results (Abbott, 2014).

[1] all measures proposed in energy audits, regardless of their payback time

Table 4-1.

Descriptive statistical analysis of the percentage savings of the analyzed companies

Technical potential as a percentage of the company's consumption	
Average	6.53
Standard error	0.75
Median	3.60
Standard deviation	7.93
Sample variance	62.84
Kurtosis	5.02
Skweness	2.22
Range	39.97
Minimum	0.13
Maximum	40.11
Number of records	111.00

When analysing the determined savings potential depending on companies' final energy consumption (see Figure 4-2), the R^2 value of 0.02 (maximum highest value obtained using an exponential equation; for linear equation R^2 =0.0065) indicates no relationship among the variables. Even if the analysis would not include one company with the highest annual energy consumption between the analysed companies, but with savings potential of only 0.39% of the company's consumption (see data point marked with [A] in Figure 4-2), the maximum R^2 would be 0.0013 using a linear equation.

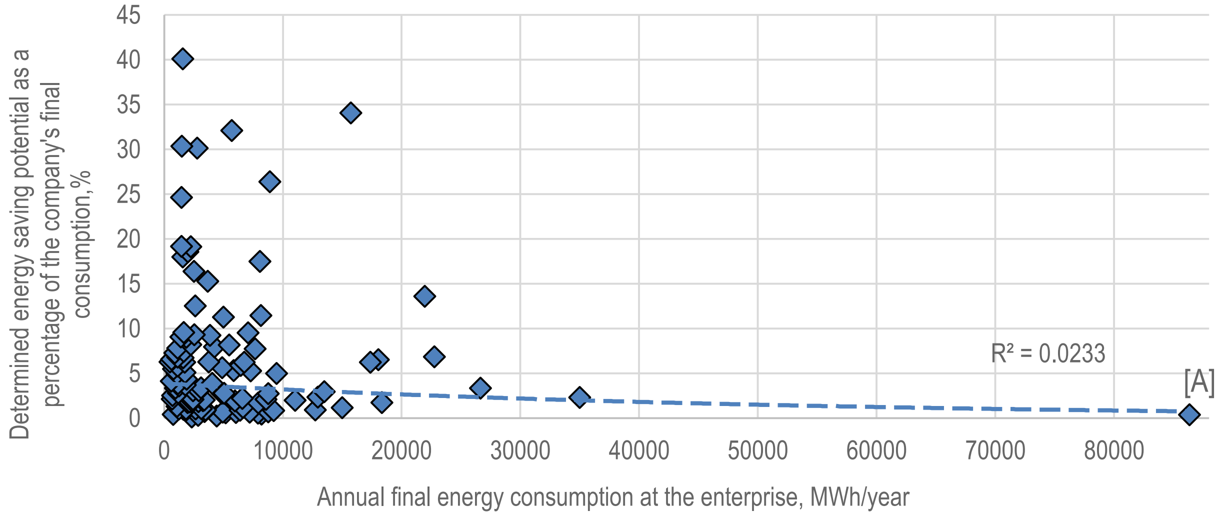


Figure 4-2. The technical potential of energy savings determined from energy audits depending on the company's final consumption for manufacturing industry companies

Energy efficiency related savings depending on the company's energy consumption are also analysed by major industrial divisions. In total, information is available for 27 food production companies (C10). Of these, energy consumption characteristics are available for 23 companies, but for 4 companies only the planned measures are available. Figure 4-3 shows the savings potential determined in food production companies depending on the company's final energy consumption. The maximum R^2 that can be obtained using a power function is 0.10 (for a linear function 0.03), so there is no relationship between the independent and dependent variables.

It can be seen that for one company with a final consumption of about 1500 MWh/year, energy auditors have indicated potential energy savings of up to 40% of final consumption, but for the vast majority the potential is up to 9%, and there are no pronounced trends that energy savings potential would depend on the company's final consumption, except that when company's annual consumption increases, the identified savings potential mostly diminishes.

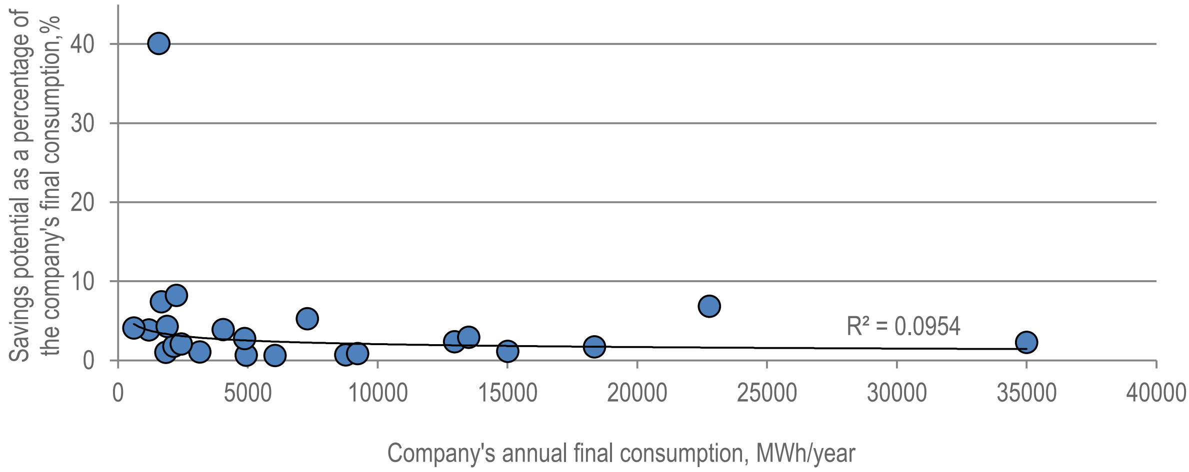


Figure 4-3. Savings potential depending on the company's final consumption for food production companies

Table 4-2. shows the results of a descriptive statistical analysis of the energy efficiency savings potential for food production companies. The arithmetic average value is 4.62% of the company's final consumption, but the median is lower - 2.36%. The difference between the median and the mean indicates that the distribution of the data does not correspond to the normal distribution. Kurtosis and skewness indicators also indicate an uneven distribution of data. Consequently, it is not possible to identify a specific trend on the basis of which it would be possible to predict the potential for savings depending on the company's final energy consumption. The estimated average potential is also very low compared to a similar study in Sweden, where the determined energy efficiency potential of the food sector was around 20% (Paramonova & Thollander, 2016).

Table 4-2.

Descriptive statistical analysis of the percentage savings in the analysed food companies

Technical potential as a percentage of the company's consumption in the food sector	
Average	4.62
Standard error	1.68
Median	2.36
Standard deviation	8.05
Sample variance	64.78
Kurtosis	19.16
Skewness	4.23
Range	39.50
Minimum	0.61
Maximum	40.11
Number of records	23

In a similar way, the wood products production sector (C16) was analysed (see Figure 4-4). The main conclusion, as in the case of food production sector, was that there is no correlation between the identified savings potential and the company's final consumption.

The average savings potential of wood product manufacturing sector is 6.68% of the company's final consumption. In comparison, in the study by (Paramonova & Thollander, 2016) the identified savings potential for the C16 department was around 17-18%.

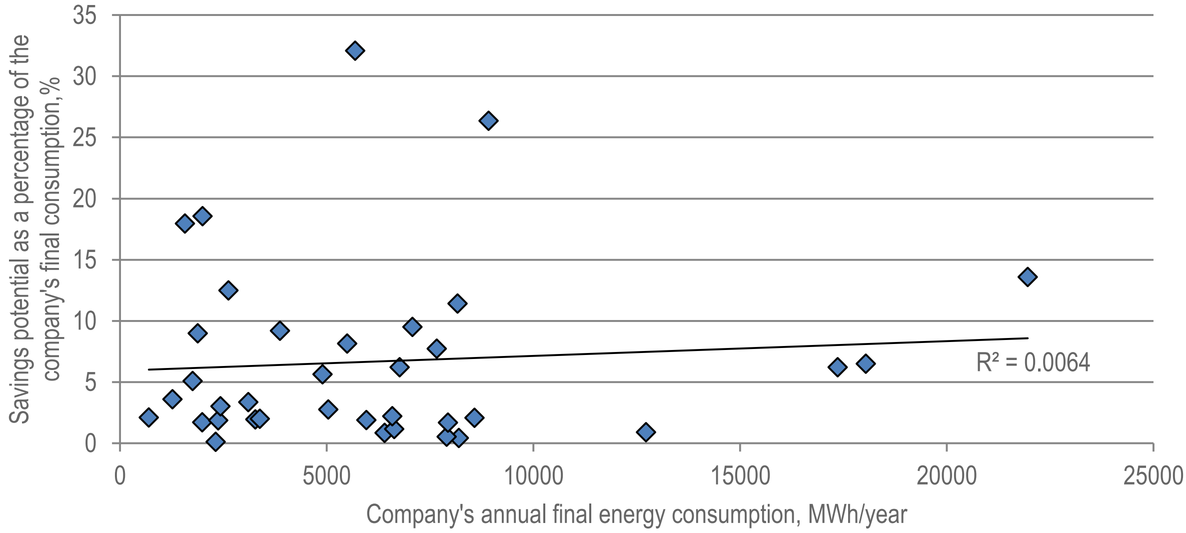


Figure 4-4. Savings potential depending on the company's final consumption for wood production companies

The analysis of other industrial subsectors, as well as the manufacturing industry data as a whole (see Figure 4-2) also indicates that no definite correlation can be established between the technical energy efficiency potential determined by energy audit analysis and the company's final energy consumption.

For those companies whose energy audits also provide data on the volume of production and it is available in comparable units, it is possible to analyse the determined energy efficiency potential depending on the volume of production. Most of such data points are available for the wood products sector, where production capacity is expressed as the volume of processed timber (see Figure 4-5). As well in this case, there is no correlation between the savings potential and the amount of processed timber.

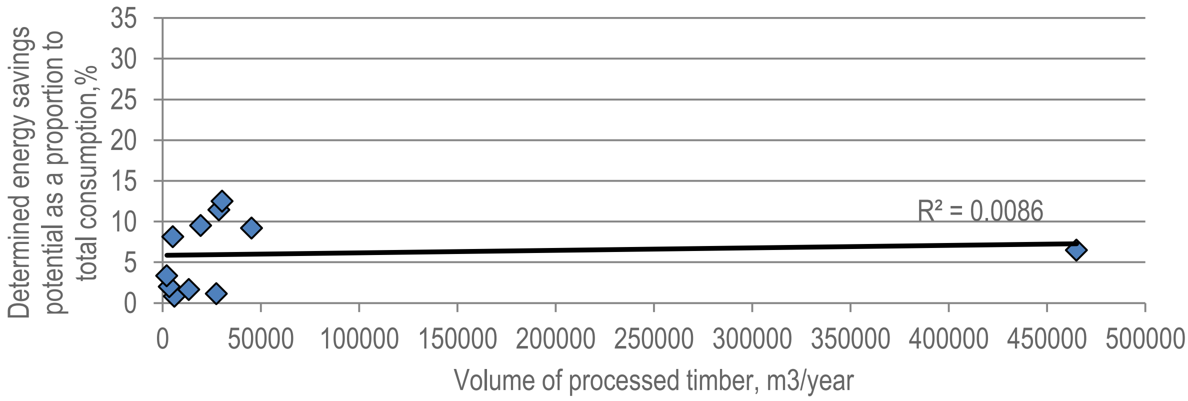


Figure 4-5. Savings potential depending on the company's production capacity

The results of the analysis indicate that, in the case of available data, the identified energy savings are not linked to the total energy consumption of the companies, the industry represented by the companies or the production capacity of the company. However, a manual analysis of energy audits shows that auditors have approached this task very differently. There are audits that identify a large number of energy efficiency measures, including those with a payback period many times longer than the lifetime of the measures, such as building insulation measures with a payback period of 100 or 200 years, or replacement of a heating piping with a payback period of 70 years. Other audits, on the other hand, identify only three minimum required energy efficiency measures, and sometimes all three measures are of the same type, such as the replacement of lighting in three different production halls.

Differences in the quality and detail of energy audits are one of the factors hindering the identification of a link between companies' energy consumption and savings potential.

For those industrial subsectors where a relatively consistent unit of output has been used, such as m^3 of wood or tonnes of processed milk, the relationship between the company's final consumption and the amount of raw materials used was assessed.

Data on 37 companies are available for the wood products subsector (C16). The volume of processed timber or manufactured products is known for 19 companies, where for one company it is known for two separate production plants. For three of these companies, production data are not given in m^3, but in product-specific units that cannot be converted to m^3, without additional information from the company. Also, for some companies, both the volume of production and processed timber are known, so they are shown in both Figure 4-6 and Figure 4-7.

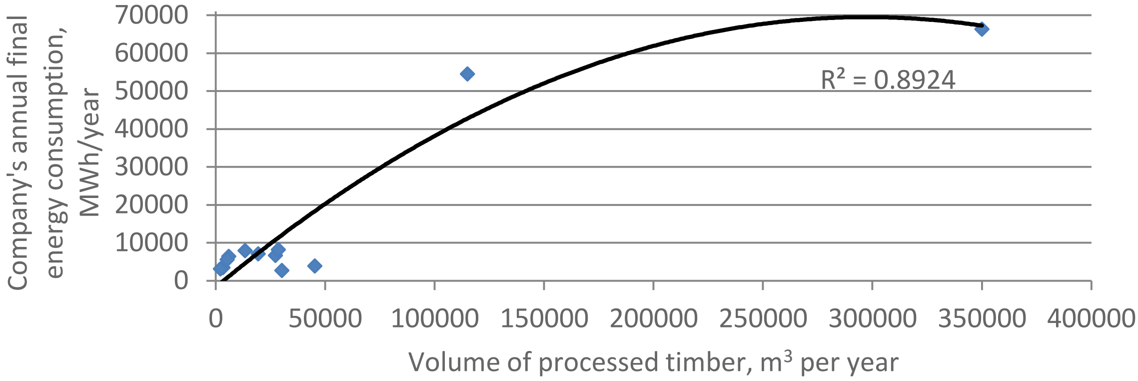


Figure 4-6. Final energy consumption of companies depending on the amount of processed timber

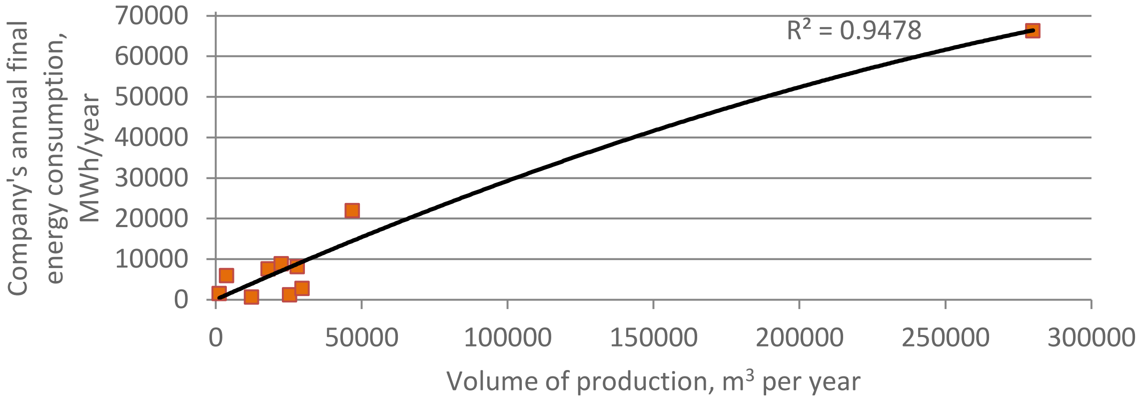
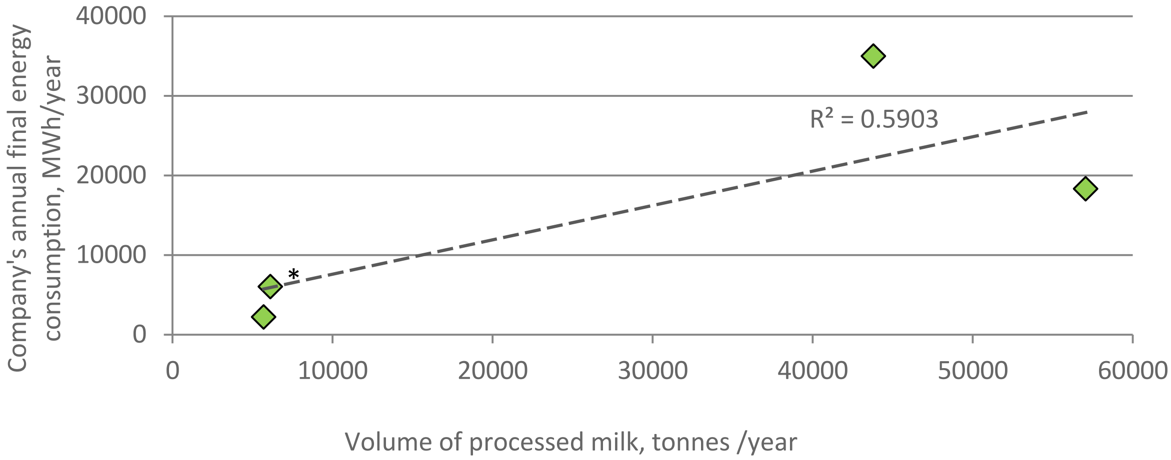


Figure 4-7. Final energy consumption of companies depending on the volume of wood products produced

There is a good correlation between final energy consumption, both depending on the amount of wood products produced and the amount of wood processed. However, in both cases, one company with significantly higher production capacity has a significant impact on this relationship. If this company was not included in the data sample, then in both cases R^2 would be less than 0.1.

For the milk processing subsector (C10.5) records are available for 6 companies, but energy audit data for 5 of them (only a report on the planned energy efficiency measures is available for one company), and the volume of processed milk is available for 4 of these companies (see Figure 4-8).

In total, Figure 4-8 shows little correlation between the available data, but only 4 data points are used, one of which is incomplete, as only data on milk production are available for the enterprise and not the amount of processed milk. The volume of processed milk would be higher than the production, but the final consumption of this company is also the lowest.



* data on the production of milk, not the volume of processed milk.

Figure 4-8. Final energy consumption of companies depending on production capacity in milk processing companies

Also for these four companies, the specific energy consumption calculated based on two different data sources – on the basis of the information specified in the polluting activity permits and information obtained from the Ministry of Economics provided energy audits – was compared. For two companies, the specific energy consumption identified in the audits is lower than that resulting from the information available in the permits (audit/permit = 0.6-0.7), so in reality the company operates more efficiently than would be assumed from the permit data. In turn, for other two companies the ratio it is higher (audit/permit = 1.7-2), so the company operates less efficiently than expected when preparing data for the permit.

4.1. Energy end use by industrial sectors

By extracting from companies' energy audits the data on energy consumption by different end-use applications, it is possible to create a specific energy consumption breakdown for each industrial subsector that can be further used as input data in the system dynamics model for characterization of each sector.

Similarly, to the approach of Andersson et al. (Andersson et al., 2018), energy consumption by different end-use applications (heating, ventilation, lighting etc.) is derived from the data provided in available energy audits. Figure 4-9 shows the total energy consumption by type of industry for those industries where more than 3 audits with energy end-use distribution were available (the number of available audits is shown in brackets).The differences between total analysed consumption by various sectors are directly linked to the number of audits available for each subsector, as well as varying company sizes and capacities. Note that these data represent the analysed sample, and the results may change if more in-detailed data is collected from Latvian industrial companies. But, as empirical data regarding distribution of energy consumption in industry subsectors in Latvia are severely lacking, these results can be used as the basis for further studies.

Based on the data summarized in Figure 4-9, Figure 4-10 shows the percentage distribution of different end-use applications in the covered subsectors. For all considered sectors energy is mainly consumed for production processes. But similarly as reported by (Andersson et al., 2018), due to lack of competence or unwillingness to interfere with production processes, energy auditors typically suggest energy efficiency measures for support processes, not production processes. Therefore the energy efficiency measures identified in energy audits might only cover a part of the actual efficiency potential.

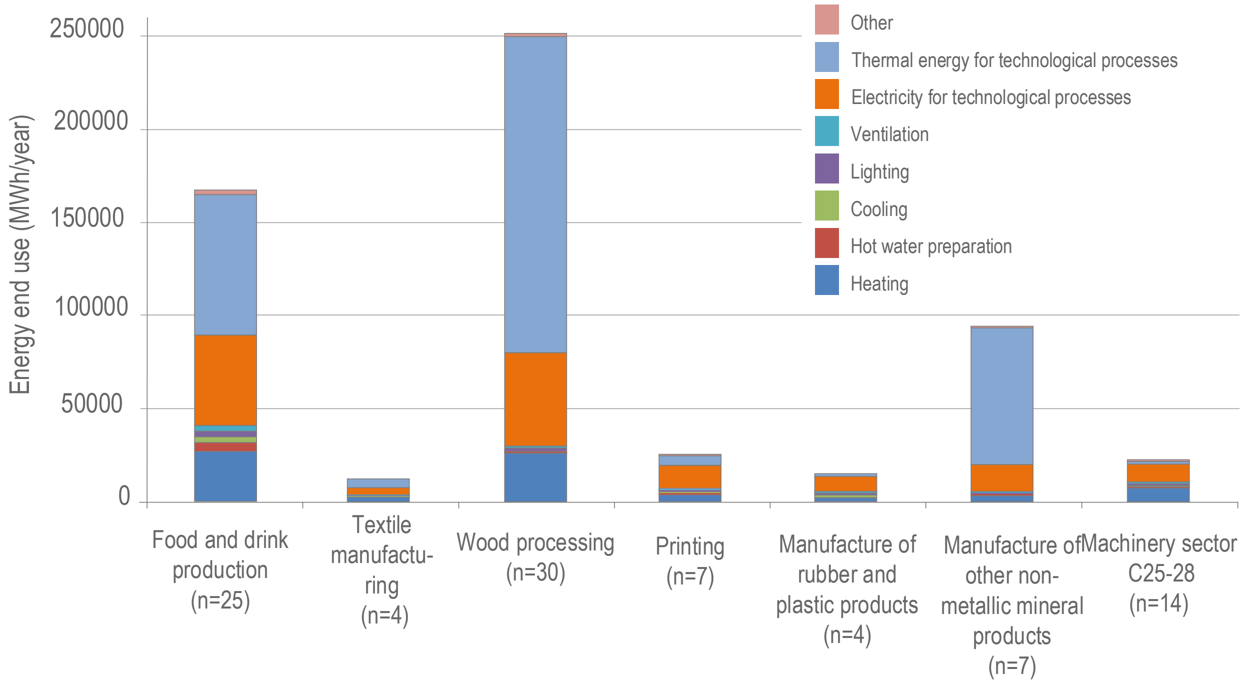


Figure 4-9. Energy end-use distribution by industry subsectors for the analysed companies

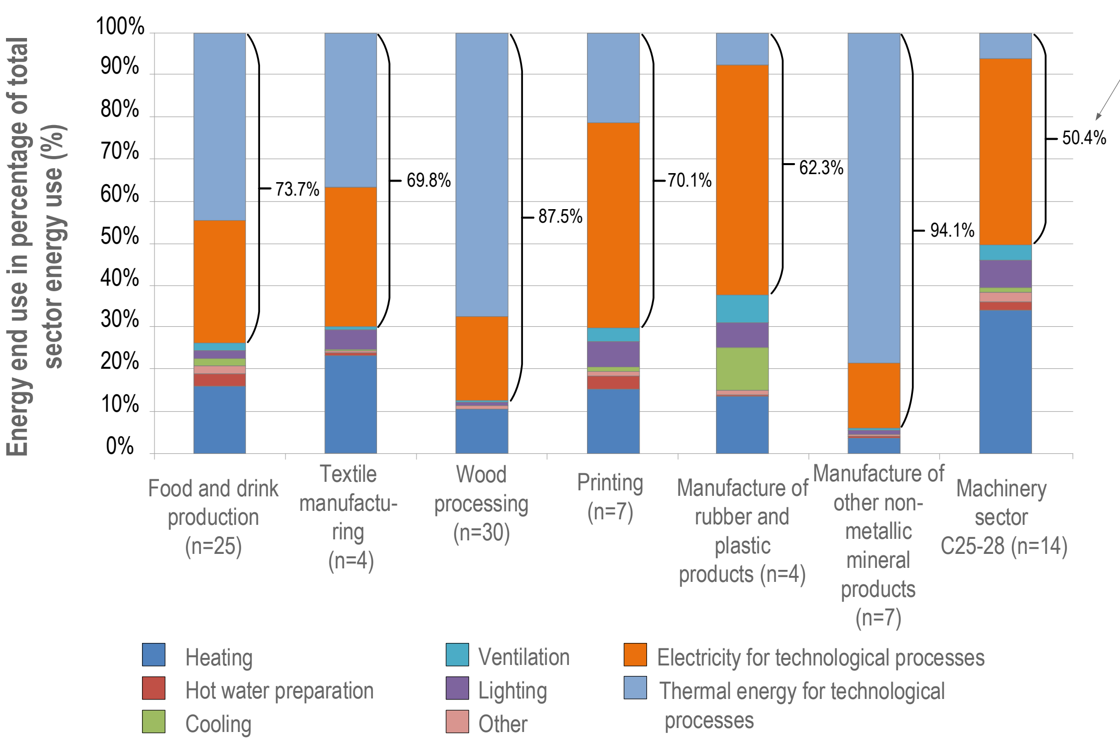


Figure 4-10. Energy end-use shares for industry subsectors

The highest identified share of consumption for production processes is for C23 (94.1%), the lowest – for C25-28 sector (50.40%). Accordingly, support processes can account for up to 50% of the sector's energy consumption depending on the subsector. Considering different support processes, the highest share is for heating (up to 34% for C25-28 sector).

For wood processing, food and metal industries the share of support processes in the overall consumption has similar tendency as reported by (Andersson et al., 2018), i.e., support processes have smaller share in wood production sector (12.5%), and higher share in metal processing (49.6%), while for food industry is in between the other two (26.3%).

4.2. Analysis of company energy efficiency potential

To determine the overall technical energy efficiency potential for each company, all per company suggested measures are summed regardless of the identified payback time. The determination of the economically feasible energy efficiency potential was hindered by the fact that in around 30% of the energy audits only the potential energy savings in MWh/year were available, without any economic data. Also, when reporting to the Ministry of the Economy, the companies are obliged to report only three energy efficiency measures that they are planning to implement, therefore the coverage of these reports is even narrower.

The identified technical energy efficiency potential as a percentage of the company's total energy consumption (as a sum of electricity, heat and transport fuel consumption) was analyzed depending on which energy audit company performed the analysis. For the implementation of the mandatory energy audit policy in Latvia additional rules were set for energy auditors – energy audits in industrial companies should be performed by certified energy auditor companies (legal entities). However, the Energy Efficiency Law also prescribes that energy audits in small and medium-sized enterprises may be performed by an independent expert on the energy performance of buildings (The Parliament of the Republic of Latvia, 2016). While there are 8 auditor companies that are officially certified to perform industrial energy audits and they have had to develop and describe a systemic approach for audit performance and a template for audit report, there are numerous independent experts on the energy performance of buildings. This leads to significant differences in approach and design of available energy audit reports, as well the competence level of the auditors may differ.

Figure 4-11 provides per company identified maximum energy efficiency potential (technical potential) depending on company's overall energy consumption and differentiating between various auditor companies.

Figure 4-11 shows that in only 18 audits, or 16 % of the analysed companies, energy auditors have suggested energy efficiency measures that exceed 10% of the company's total energy consumption. The logical analysis after manual reviewing of the audits indicates that the actual energy efficiency potential in Latvian companies could be much higher. The average technical energy efficiency potential for the companies which have reported an energy audit implementation is 6.35%.

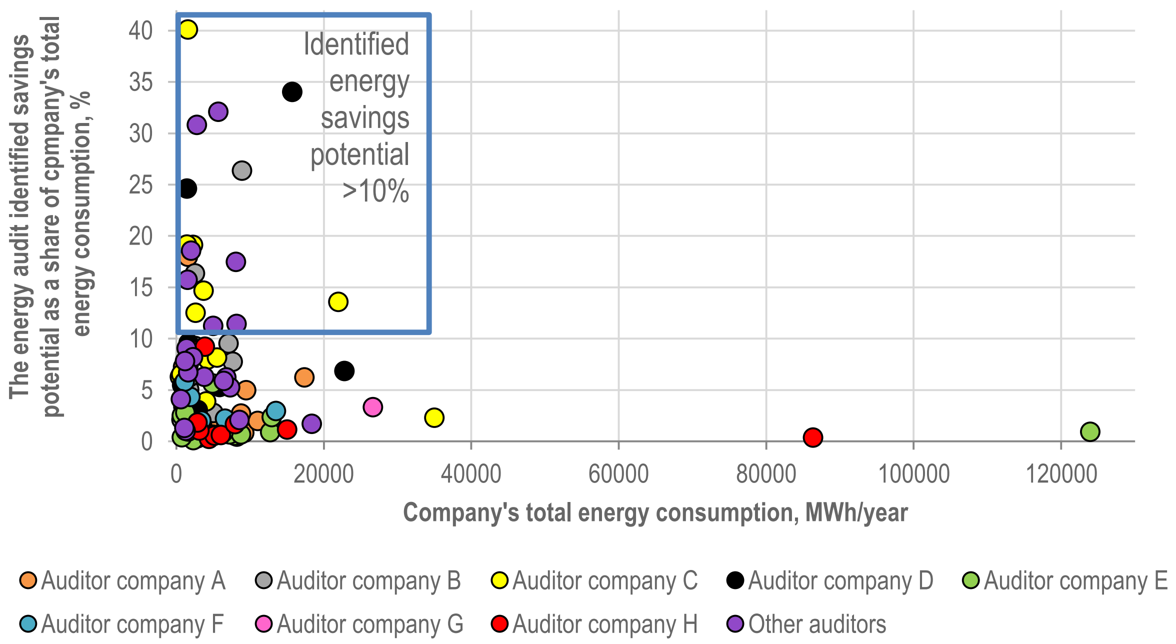


Figure 4-11. Energy savings potential of industrial companies depending on total energy consumption and energy auditor company

Regarding the differences between various energy auditors no significant correlation was found for any specific company that would suggest biased results. However, the fact that for such a large number of companies the identified technical energy efficiency potential does not exceed 10% or even 5% of total energy consumption, points to the need to set higher requirements for energy auditors regarding the potential savings to be identified.

5. ANALYSIS OF THE SPECIFIC COSTS OF ENERGY EFFICIENCY MEASURES

One of the potential sources of data for creating energy efficiency cost curves are the energy audits of companies, which are performed by certified energy auditors, who analyze the individual situation in each company. Based on an agreement with the Ministry of Economics on data confidentiality rules, an analysis of the energy audit reports available to the Ministry of Economics was performed.

5.1. Analysis of individual energy efficiency measures

Analysis of the specific costs of individual energy efficiency measures was divided into 7 subgroups accordingly to the types of energy efficiency measures, i.e., energy management, lighting, heating system, ventilation, production equipment related measures, building renovations and transport related energy efficiency measures. Most EEMs have been identified in Building renovations and Lighting groups, together these two groups account for 59% of the identified measures (see Figure 5-1). To develop the energy efficiency cost curves, some assumptions were made:

- if two improvement alternatives were provided in the energy-audit for the same equipment or system, then the alternative with lower payback period and higher energy savings potential was selected for the energy efficiency cost curves.
- for lighting measures, where numerous measures with varying individual specific costs and payback times were accounted for a single building, their overall sum was used for the company energy efficiency cost curve to reduce data fragmentation.

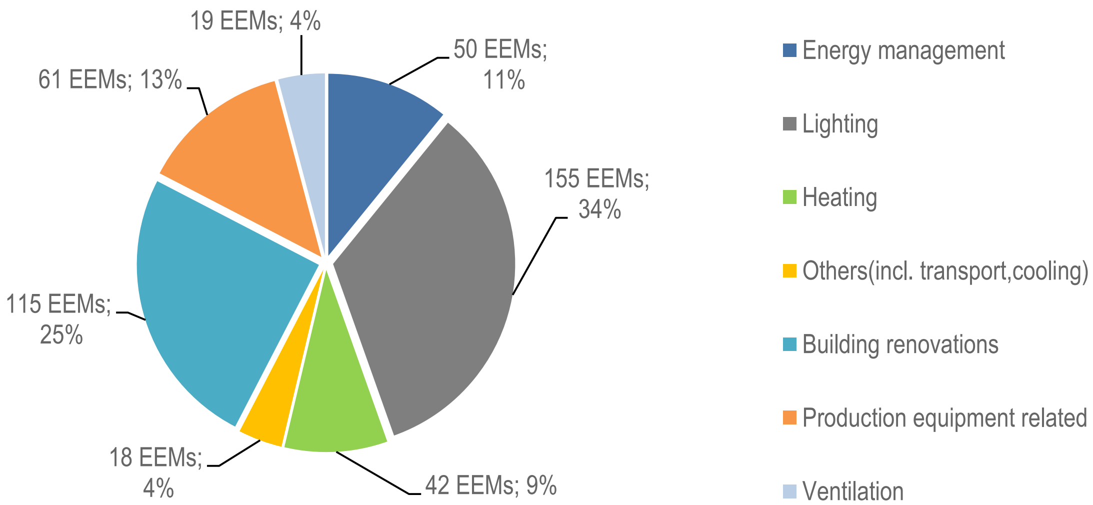


Figure 5-1. Distribution of identified energy efficiency measures by energy-end use categories

The calculation of specific energy efficiency costs also takes into account the lifetime of the measures. As most of the energy audits did not have the lifetimes of the measures available, a summary table with the lifetimes of the energy efficiency measures was created based on the information available in the Ministry of Economics energy savings catalog (Ministry of Economics, n.d.), CEN standards and the European Commission recommendations (European Commission, 2019a). The summary table is attached in Annex 2 to this report.

Figure 5-2 presents the summary results for 50 identified energy management measures for which both energy savings and investment or maintenance costs were available in energy audits. Energy management measures include installation of energy meters, monitoring of energy consumption, organizational solutions, as well as, employee trainings on energy efficiency, use of existing or implementation of new energy management system etc. For many of these measures the energy savings could start from the first day of EEM implementation, as both electricity and heat would no longer be wasted and for some energy management measures no investments in technology replacement are required.

For all considered energy management measures a 2 year lifetime was assumed accordingly to (European Commission, 2019a). These measures present a relatively high energy efficiency potential at low costs – up to 1200 MWh/year savings can be achieved with costs less than 50 euro/MWh$_{saved}$. However, another 350 MWh/year identified savings already require higher investments of up to 357 euro/MWh$_{saved}$. Companies should implement the no-cost or low cost EEMs immediately to gain the economic savings overnight. However, it was observed that in numerous reports to the Ministry of Economics companies have indicated that they plan to ensure introduction of no-cost energy efficiency measures only after a period of one or two years (the reports indicate the final implementation deadline). Of course, companies might implement these measures earlier, but, it is possible, that energy auditors have not fully explained to companies the potential of these measures or that companies indicate the implementation time very generally in their reports to the Ministry of Economics.

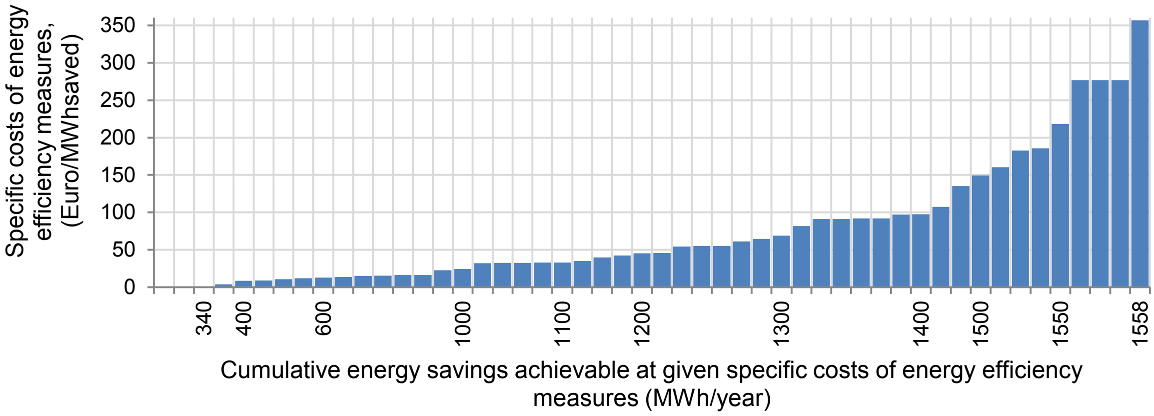


Figure 5-2. Specific costs and cumulative savings of identified energy management EEMs

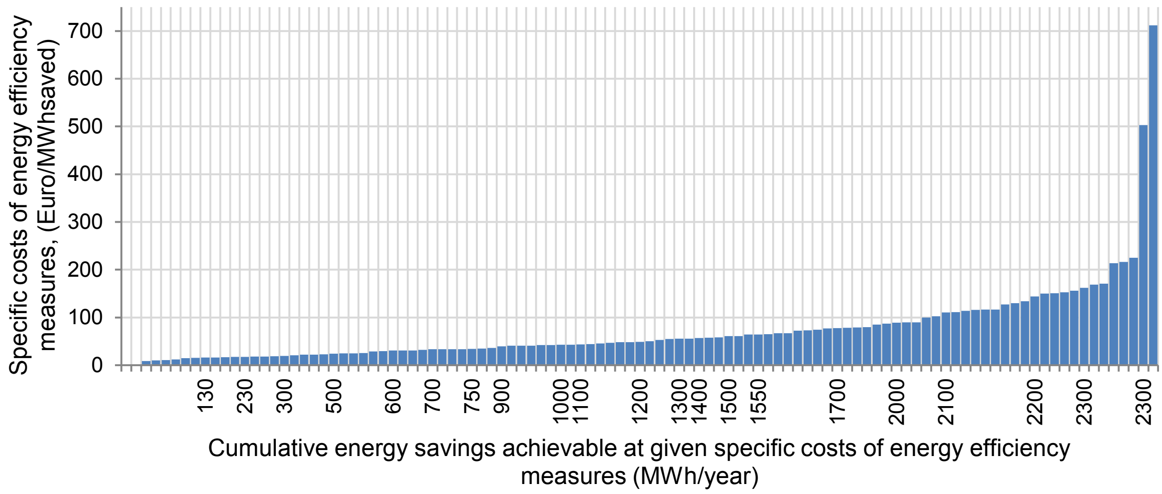


Figure 5-3. Specific costs and cumulative savings of identified lighting EEMs

In most energy audits, various lighting replacements or lighting related measures have been identified as one of the most cost-effective and offered to companies (see Figure 5-3). This can be explained by the fact that the investment costs of replaceable luminaires are relatively low in relation to the generated savings, and more expensive energy resources are saved (electricity tariff is higher than heat tariff), thus the payback times for these measures are shorter. As mentioned before, lighting measures were also the ones with largest number of individual EEMs identified by the auditors. This might be due to the fact that lighting is one of the easiest to replace and it is "the first to be noticed". However, it should be noted that the analysis of the proportion of different types of energy end-use in the industrial divisions (see Section 4.1) showed that the overall share of lighting is relatively small (up to 6%) compared to other end-use groups. Energy auditors and business representatives should first try to identify the most critical points of energy inefficiency and consider, for example, more efficient use of space by concentrating equipment in workshops rather than replacing lights everywhere, although some spaces are not fully occupied.

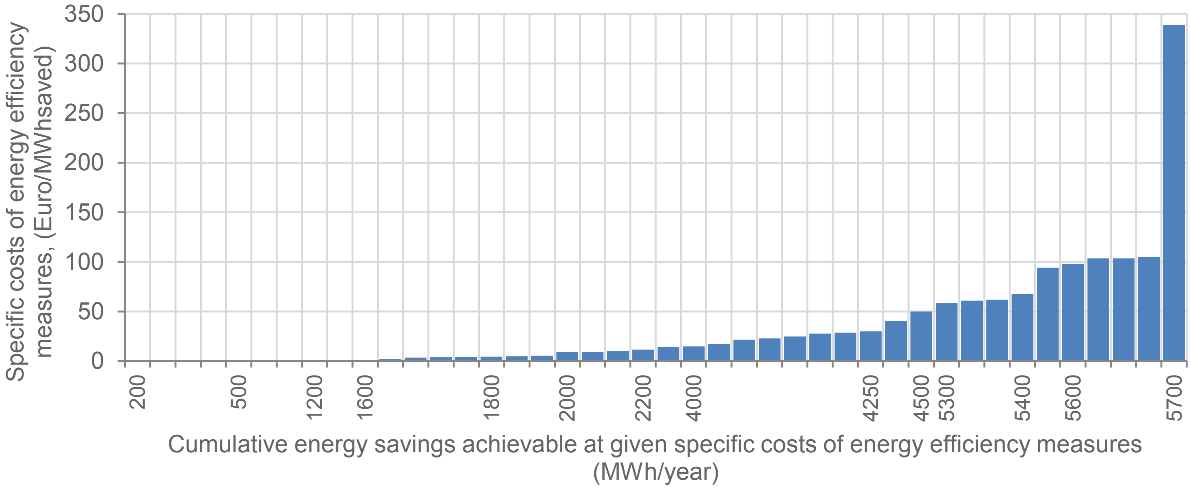


Figure 5-4. Specific costs and cumulative savings of identified heating EEMs

Heating measures include fuel saving measures, boiler adjustments, as well as replacement and insulation of piping, and lowering of the heating temperature. A total of 42 heating measures were identified. The specific-costs and obtainable energy efficiency potential of heating measures are presented in Figure 5-4. Significantly high potential is for no-cost or low-cost measures – up to almost 4000 MWh/year might be saved by measures costing less than 20 euro/MWh$_{saved}$. Such measures include reduction of the set temperature, fuel quality checks (for wood fuel), switch-off of unrequired heating equipment, boiler optimisation, heat energy recovery from various sources and minor insulation improvement works. On the other hand, various more significant heating related EEMs might require larger specific investments up to 340 euro/MWh$_{saved}$. The single most expensive EEM indicated at the right most in Figure 5-4 that would provide 9 MWh/year savings is heat network reconstruction and insulation. Such a sharp difference in the specific costs of one measure raises the question of the correctness of the energy auditor's estimated costs. It also points out that it is necessary to establish a catalogue of typical costs for different EEMs to ensure that industrial companies can verify and compare the accuracy of the information provided by the energy auditor.

It also must be recognized, that heat tariff is generally lower per MWh than electricity tariff, thus when comparing EEMs with the same specific-costs (euro/MWh$_{saved}$), electricity saving measures would lead to lower payback times. For wood processing companies, for example, heat tariff might seem insignificant if the used fuel is production leftovers, thus even low-cost investments might have long perceived pay-back time. In this case some energy auditors have accounted also for other potential benefits of fuel saving measures by calculating the sales value of the saved fuel that could be earned by reducing unnecessary fuel consumption.

In comparison to previously described EEMs, the building renovation measures present the highest overall cumulative energy efficiency potential adding up to 9300 MWh/year (see Figure 5-5). On the other hand, these measures also have the highest specific costs even considering that the lifetime of the measures is typically 20 years and up to 30 years for window replacement.

A lack of consistency in the information provided in energy audits has been observed. Although building renovation measures generally have higher investment costs when comparing the specific-costs per saved MWh, in the current analysis some energy auditors have identified measures that could provide 500 or 1000 MWh/year savings for costs less than 25 euro/MWh$_{saved}$. While other auditors report high specific-cost EEMs that only give few MWh saving yearly. Of course, the savings that could be achieved by any type of refurbishments would differ between various companies depending on the company's initial conditions. But another point is that the aim of these energy audits is to provide the companies with the necessary information to implement most feasible and cost-effective measures. In Latvian case, to improve these aspects in the future, the energy auditor competences should be increased and a focused and targeted cooperation between the company and the energy auditor must be ensured.

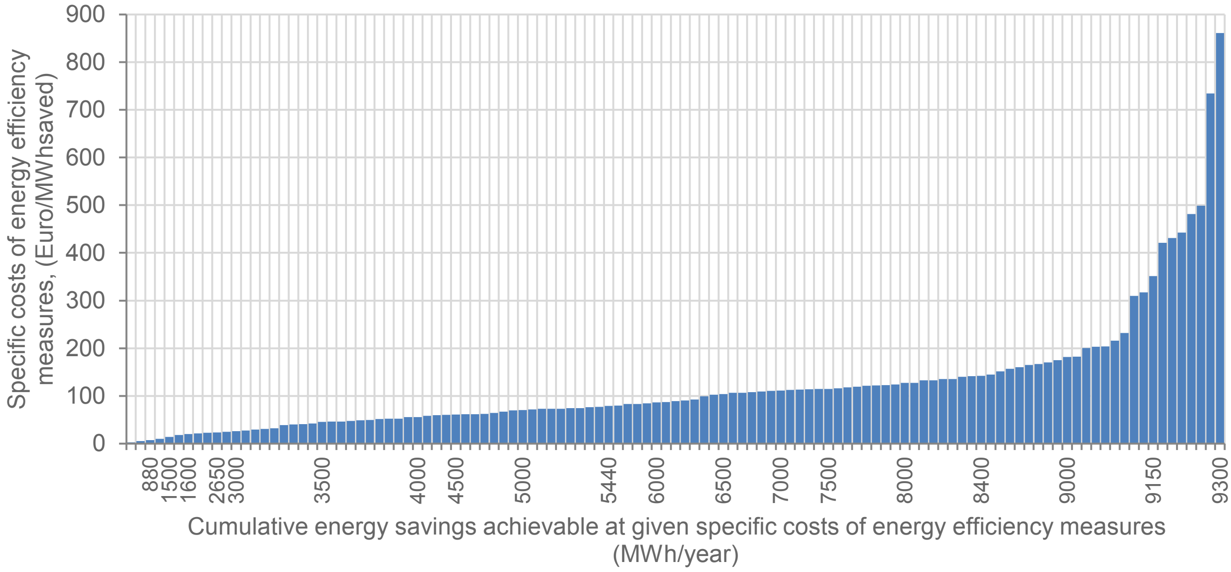


Figure 5-5. Specific costs and cumulative savings for identified building renovation EEMs

The most specific EEM category is the process equipment related measures. Each industry has its own particular technological processes and energy requirements, thus only the most experienced energy auditors (especially with extensive experience in industrial auditing) should be responsible for conducting energy audits of industrial companies. In Latvian policy this was sought by including in the legislation on industrial energy auditing a provision on the use of certified energy auditors in industrial energy audits. But these rules are not explicitly binding, and in small companies energy audits can also be performed by certified building auditors, who, in turn, may have limited knowledge to suggest technology process recommendations.

Figure 5-6 provides the specific-costs and overall cumulative energy efficiency technical potential for the production process related EEMs in the analysed companies. Similar as for other categories, numerous low cost measures (up to 20 euro/MWh_{saved}) account for up to 5000 MWh/year energy efficiency potential. Three of the process equipment related EEMs with much higher specific costs, are shown separately (in the right side of Figure 5-6) to make the graph more comprehensive. Though these measures stand out from the average trend, the explanation is not unequivocally attributable to the competence of the energy auditors. Production process related measures, e.g., the exchange of a production line would require significant investments, the benefits of which are attributable not only to energy efficiency and energy cost savings, but also to process optimization and automation, production capacity and/or quality increase. Therefore, the energy auditors, who have suggested these measures, most probably have consulted with the firms to understand which technologies the company is planning to implement and have determined the additional energy efficiency savings that would be gained.

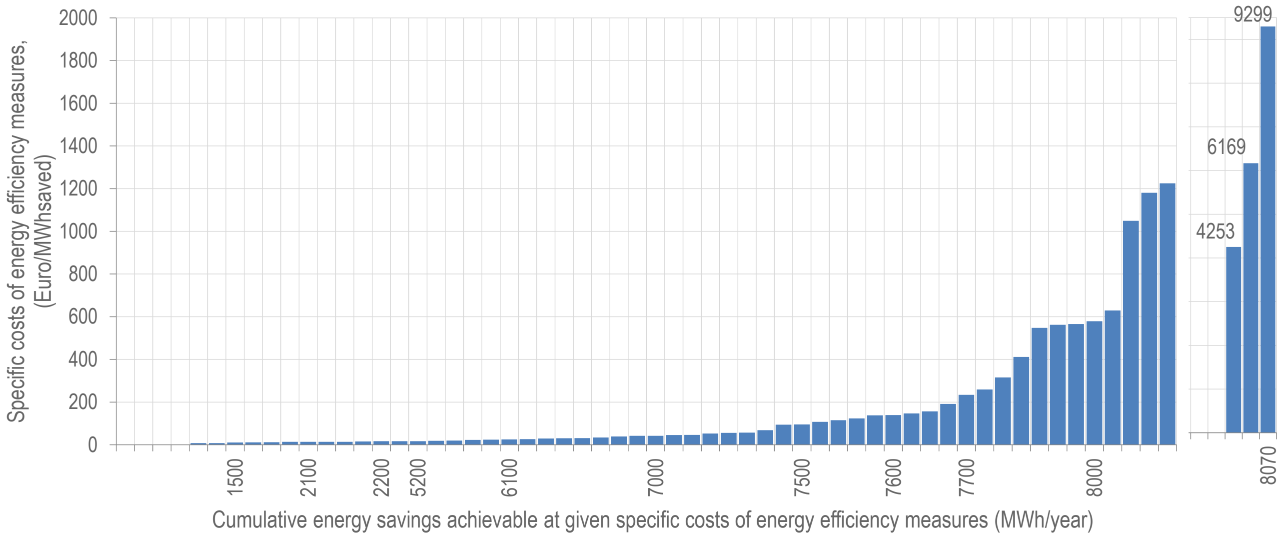


Figure 5-6. Specific costs and cumulative savings for identified process equipment related EEMs

Only 19 ventilation related EEMs were identified in the analysed energy audits (see Figure 5-7). For many of the suggested ventilation measures the overall savings were calculated as the sum of saved electricity and heat. But for some companies, where implementation of new ventilation system or a major redesign, was suggested, the auditors also account for the increase in electricity consumption due fan energy requirements for mechanical ventilation. In comparison with other EEM groups, the ventilation measures are not the least expensive ones – only 1000 MWh/year savings might be achieved with specific-costs of less than 20 euro/MWh_{saved}. The most cost-efficient measures include improved ventilation controls and automation, improving the performance of fan motors with frequency converters, and fan replacement.

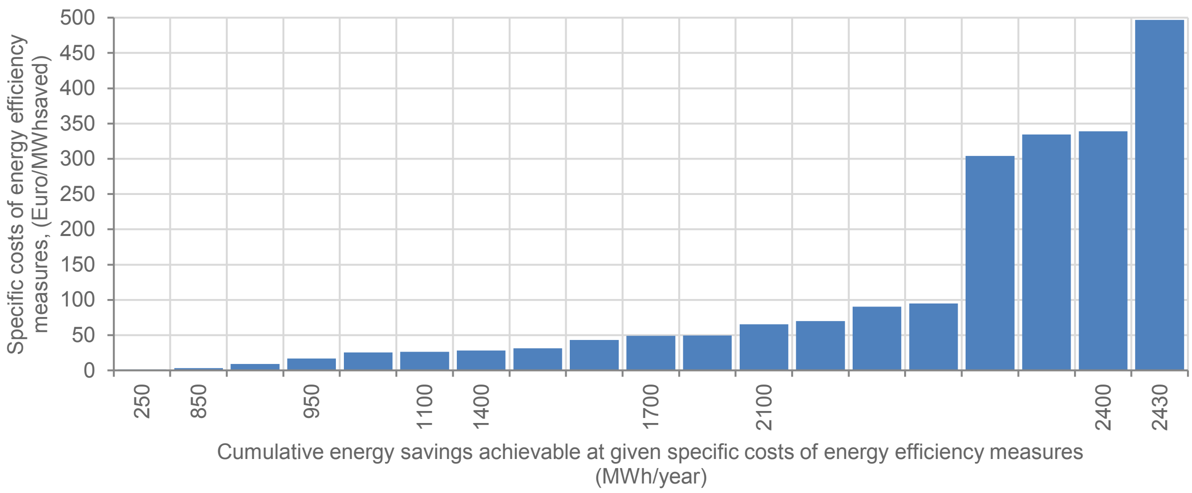


Figure 5-7. Specific costs and cumulative savings for identified ventilation EEMs

The energy audits identified 10 transport-related energy efficiency measures for which potential savings as well as costs were available. None of the measures identified in this category were no-cost measures (see Figure 5-8). The specific costs of the transport-related measures range from (4-130 EUR/MWh) for measures such as the use of lubricants and fuel-efficient tires to improve engine performance. The most expensive measure (210 EUR / MWh) envisages the replacement of old vehicles with new ones.

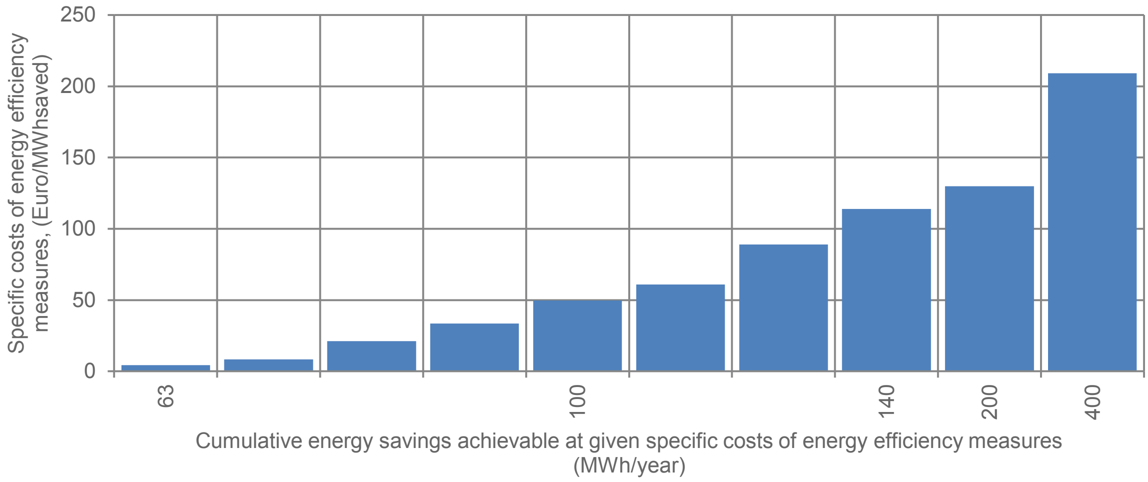


Figure 5-8. Specific costs and cumulative savings for identified transport-related EEMs

The category other energy efficiency measures (in total 8 measures) includes measures such as the installation of reactive energy compensation devices, the transition to heat and/or electricity production from renewable sources. The single identified cooling-related energy efficiency measure identified in the energy audits was also included here. If a larger data set was available, these groups of measures could also be analysed separately.

5.2. Average costs of energy efficiency measure groups based on industrial energy audits

The average costs of energy efficiency measures were determined using descriptive statistical analysis. Given the significant deviation of the energy efficiency measure cost data from the normal distribution, the values of cost extreme outliers were not taken into account in the calculation of the average costs. Decision on which data points should be excluded from the calculation was based on the difference between the mean and the median.

For lighting related measures, the five highest values in the range of 213-712 EUR/MWh were excluded, but the costs of the analysed measures ranged from 0-171 EUR/MWh. The average costs of lighting energy efficiency measures are 59 EUR/MWh_{saved}. Correlation analysis was used to assess whether there was a link between the company's final energy consumption and the specific costs of the lighting activities, as well as between the industry represented by the company and the specific costs of the lighting activities. In both cases, no correlation was identified.

For heating related measures, one extreme value (338 EUR/MWh) was excluded from the analysis of the average specific costs. All analysed measures had specific costs below 105 EUR/MWh. The average costs for the analysed 41 measures were 27 EUR/MWh. The low average costs are due to the fact that many of the measures identified are no-cost measures or heating system performance optimization measures with low specific costs over the lifetime of the measure.

The analysis of average specific costs of energy efficiency measures for buildings takes into account 113 out of 115 identified measures. The specific costs of the two excluded measures are from 734-861 EUR/MWh, but the costs of the analysed 113 measures are from 0-499 EUR/MWh. The average costs of energy efficiency measures in buildings were 112 EUR/MWh.

A total of 61 data points were available for equipment related energy efficiency measures, three of which significantly differ from the rest of the group. However, taking into account the specifics of the equipment that may be required for production, average costs were calculated, both with and without these three entries. The average cost of all production equipment related measures is 483 EUR/MWh, but without taking into account the three most expensive measures (with costs from 4253-9299 EUR/MWh) – 168 EUR/MWh.

The accuracy of the determined average costs can be improved in the future by using a wider set of data and by ensuring that the costs of the energy efficiency measures are already initially (in energy audits) calculated according to the same methodology and assumptions (e.g. measurement lifetime).

5.3. Establishment of benchmarks based on energy audit data

When compiling data from the energy audits available to the Ministry of Economics, it was considered whether it is possible to use the information available in the energy audits to create more accurate benchmarks than those based on the data of polluting activity permits. The first findings indicate that some audits provide sufficient amount of information to develop a specific energy consumption indicator (see examples in Figure 5-9 and Figure 5-10), but many audits do not provide data on the output of the enterprise, neither in physical nor monetary terms. Therefore, it is necessary to think about improving the quality of data, especially if in the future it is planned to create an electronic system for the collection and analysis of these data. As well as, for the creation of benchmarks, these data can serve as a basic reference line, but it is necessary to plan the acquisition of additional good quality data in the selected benchmark sector by questionnaire or other means.

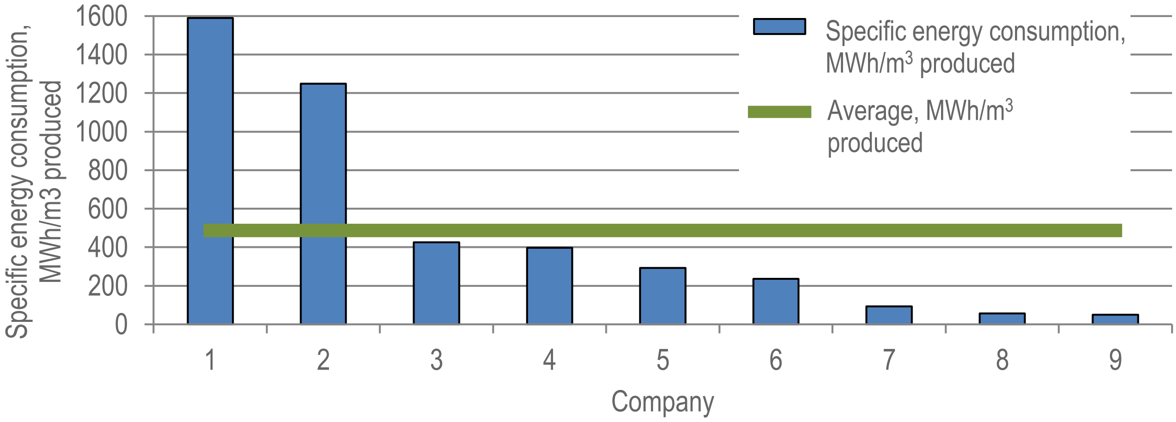


Figure 5-9. Specific consumption for benchmark analysis in the wood processing subsector by volume of production

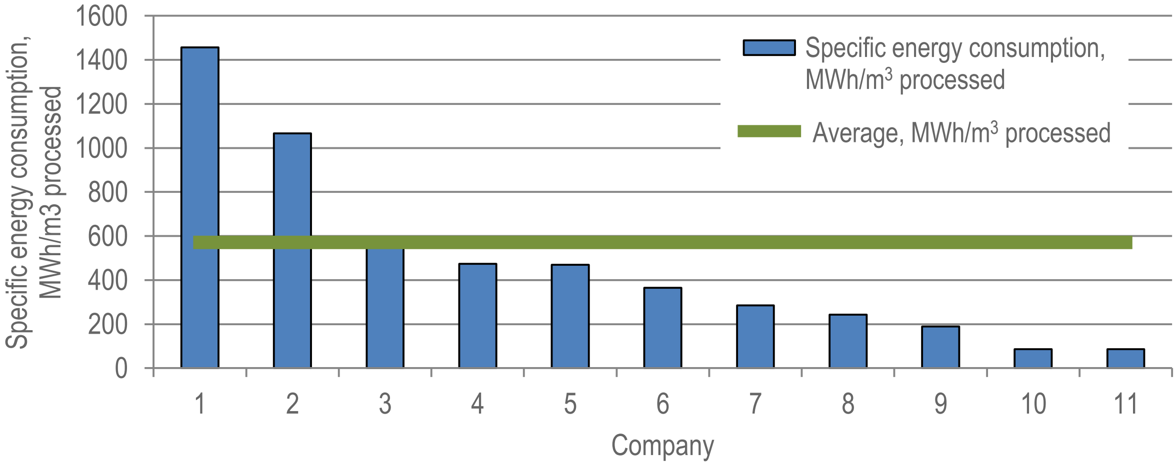


Figure 5-10. Specific consumption for benchmark analysis in the wood processing subsector by volume of wood processed

When assessing the specific energy consumption of wood production depending on the volume of production (see Figure 5-11) and the volume of processed timber (see Figure 5-12), there is a weak correlation. At similar production capacities, most of the analysed companies consume significantly different amounts of energy resources. This points to a significant potential for energy efficiency. However, broader conclusions require in-depth analysis of companies.

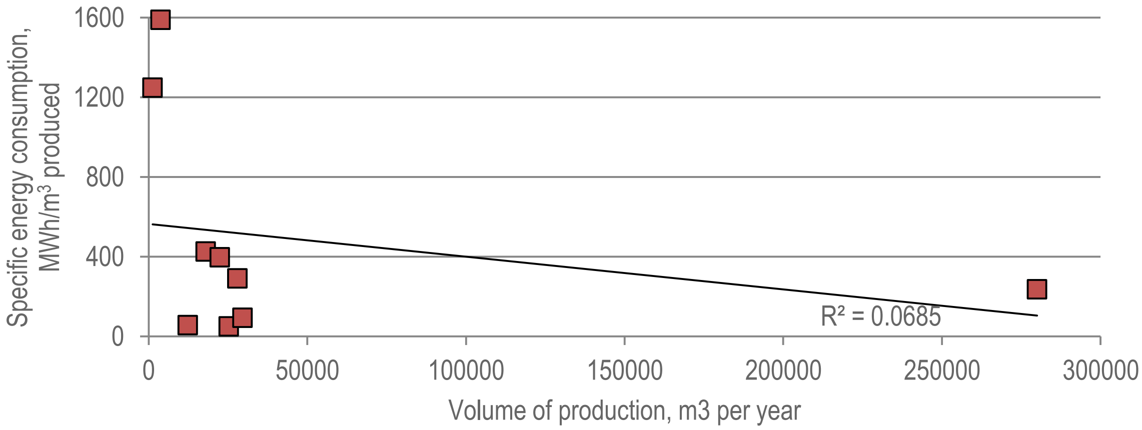


Figure 5-11. Specific energy consumption of wood processing depending on the volume of production

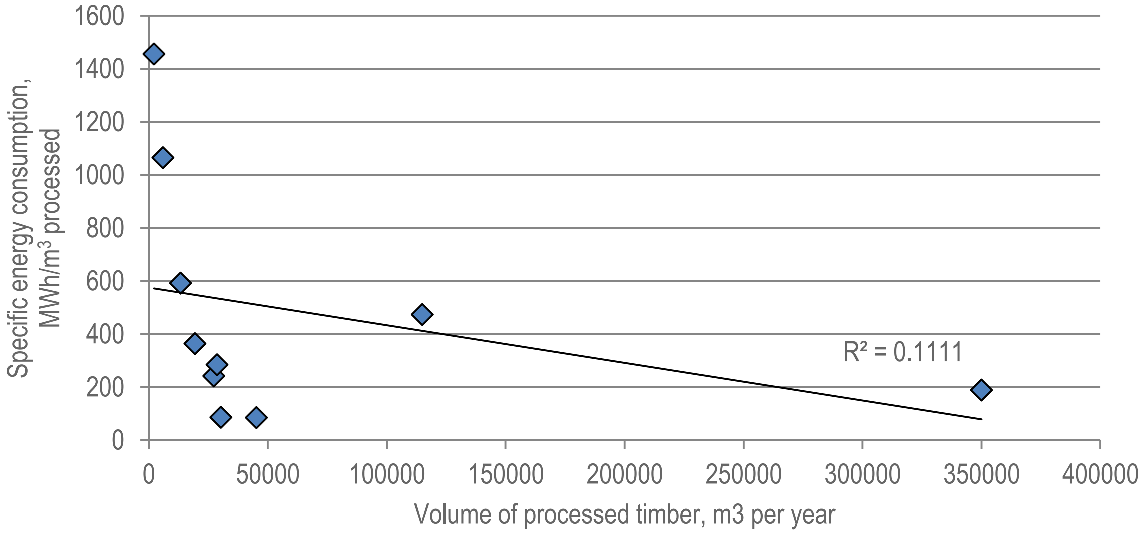


Figure 5-12. Specific energy consumption of wood processing depending on the amount of processed wood

6. PROPOSED METHODOLOGY

6.1. Energy efficiency potential assessment method

Within this research, a nationally adapted methodology for determining energy efficiency potential and benchmarks has been developed, which includes both top-down and bottom-up data acquisition approaches, data analysis, development of industry characterization (e.g., economic development, energy consumption, types of energy resources), development of a particular section regarding potential energy efficiency measures (e.g., savings potential, costs, etc. indicators).

Direct determination of energy efficiency potential from the national energy monitoring system is hindered by numerous aspects:

(1) It is not possible to develop relative indicators of the savings potential for each company depending on the total energy consumption, as in the energy efficiency monitoring system only the annual electricity consumption of companies is available, not the total energy consumption. It would not be correct to attribute the available data on the planned energy savings (all types of energy carriers) only to the company's electricity consumption. It also does not allow for an accurate assessment of the performance of mandatory energy audit programme and energy management system against the total consumption of the companies involved.

(2) Energy audit data are not available in aggregated electronic form and compiling of available audits manually is very time consuming. As there is no uniform form according to which companies should fill in the energy audit report, not all companies have included the entire information required by the Cabinet of Ministers Regulations no.487 in the energy audit reports.

(3) no data on either the thermal energy consumption or the description of the particular planned energy efficiency measures (and their investment costs and payback times) are available in the energy monitoring system or other data collections by Ministry of Economics for the companies that have implemented a certified energy management system.

Such situation with weaknesses in the initial organization of the energy monitoring system is not just a Latvian problem. When Andersson et al. (Andersson et al., 2018) analysed the results of the SEAP, they also pointed out that the program database did not have all the data needed to fully analyse energy savings. They point out that **mechanisms for collecting and analysing high quality data must be provided when designing energy efficiency policy programs in order to be able to fully assess the energy efficiency potential of measures**. Therefore, an important recommendation for the future development of the Latvian energy efficiency monitoring system and other policy measures related to the implementation of energy efficiency is the development of a good, convenient and practical data management system.

As mentioned, another problem is the quality and scope of currently available industrial energy audits. Although the Regulations of the Cabinet of Ministers No. 487 (Cabinet of Ministers, 2016a) determine what the company's energy audit report shall include, only a part of the analysed energy audits include all this information. This may be because the implementation of industrial energy audits is relatively new in Latvia and energy auditors are still improving their competences. But, on the other hand, as the companies are required to report to the Ministry of Economics only three energy efficiency measures, some audits are very simple and, even if energy consumption by various energy end-use applications is reported in the audit, only the most simplistic energy efficiency measures (as lighting exchange) are reported, so that the company would have smaller future liabilities to the Ministry. One of potential solutions to this could be setting of definite energy consumption reduction targets that are adapted the company's initial energy efficiency situation.

The methodology used is based on a top-down and bottom-up data acquisition approach, compiling and using publicly available data sources for Latvia and for each final consumption sector, as well as using bottom-up data sources to describe energy efficiency measures, sectorial energy consumption distribution by various consumers and other parameters. In the future, when more detailed sector level data would be available and/or the quality and coverage of the existing energy efficiency monitoring and energy savings database would be improved, data availability for bottom-up analysis would increase. Therefore, the methodology also envisages how these additional sources of information can be integrated into the calculation of energy efficiency potential when they become more widely available. The methodology algorithm is shown in Figure 6-1.

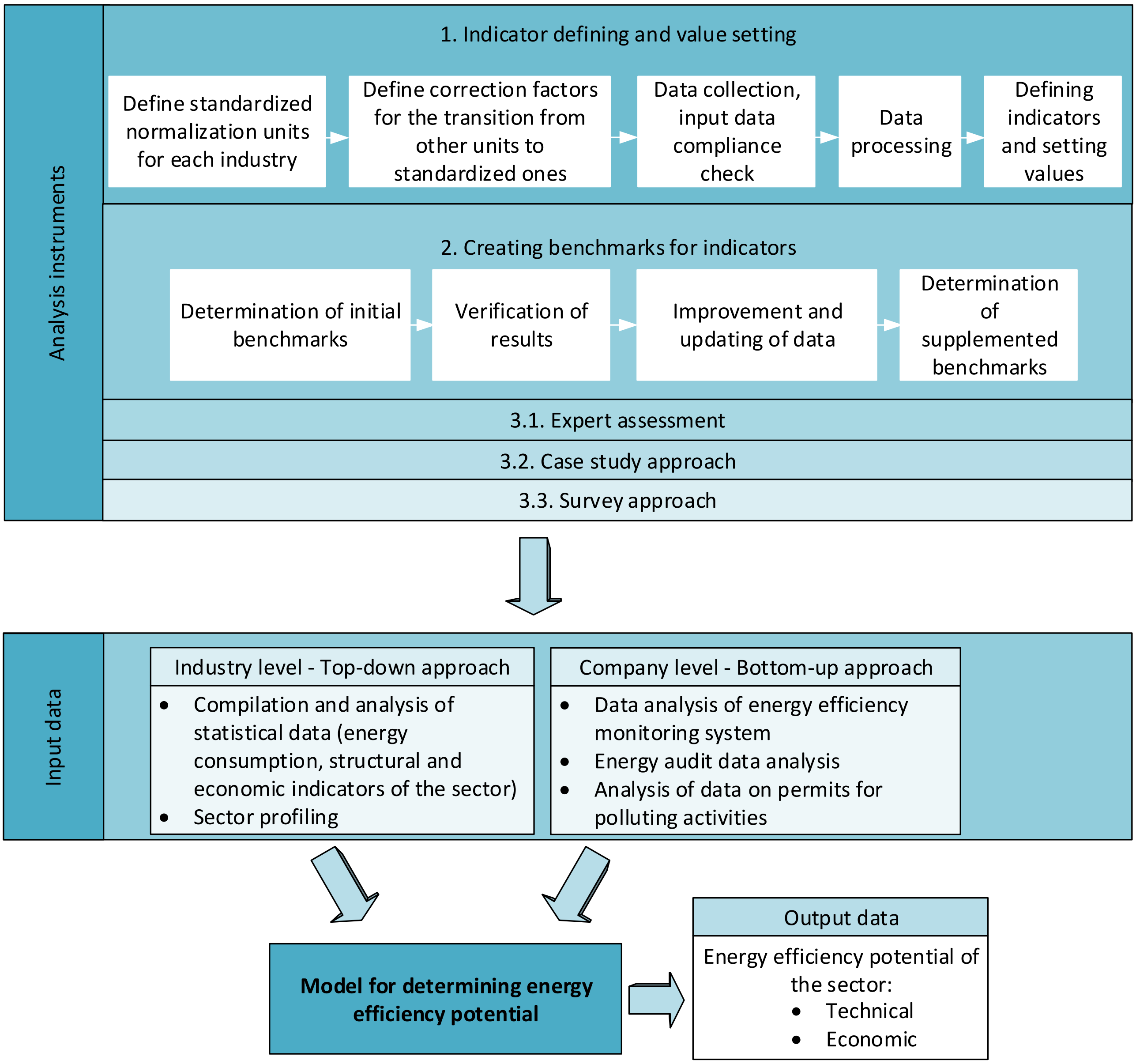


Figure 6-1. Methodology algorithm for modelling of energy consumption and determining energy efficiency potential

The methodology includes a top-down approach for characterizing industrial sub-sectors, using data sources such as the national statistical database, information from publicly available databases on energy consumption in enterprises, enterprise pollution permits and government reports on macroeconomic development and energy cost forecasts. The information gathered is then used to create a baseline scenario to describe how industrial energy consumption will develop under the current regulations. Also, the information collected from the existing energy monitoring system, especially the manually collected data from energy audits, is used to create an initial database on energy efficiency measures and their respective costs in Latvian conditions. It is then checked if the data collected provide all the information needed to assess the potential for energy efficiency. The indicators used include:

- Engineering indicators - annual energy consumption (MWh/year), electricity consumption (MWh/year), heat energy consumption (MWh/year), production volume (production units/year), specific energy consumption (kWh/production unit), savings (MWh/MWh), lifetime of energy efficiency measures (years), average costs of energy efficiency measures (EUR/measure);

- Economic indicators - energy costs (EUR/year), electricity costs (EUR/year), heat energy costs (EUR/year), savings costs (EUR/MWh), required investments (EUR/year);
- Climate indicators - carbon dioxide (CO_2) emissions (tCO_2/year), specific CO_2 reduction costs (EUR/tCO_2);
- Environmental indicators - air basin pollution (NOx, particulate matter).

If appropriate national data sources are not available, additional information is sought from the international scientific literature. At the end of the modelling process, the technical and economic potential of energy efficiency is assessed.

In addition to this system, if the national energy monitoring system is improved and a system for the electronic submission of energy audits of companies is set up, data for characterizing energy efficiency measures, determining specific cost benchmarks and speed of the implementation of energy efficiency measures, as well as subsector final consumption profiles could be obtained from this database. However, in order to ensure the quality and reliability of the data acquired from this system, considerable time and effort should be devoted to the verification, cleaning and processing of this data.

In general, the developed approach will allow to determine the technical and economic potential of energy efficiency in the Latvian industrial sector and will be adaptable to other end-use sectors, such as the service sector, agriculture and transport, if the necessary data are supplemented.

6.2. Approbation of the method for acquiring of industrial sector data

A database created by compiling the information available in energy audits will be used to characterize energy efficiency measures (savings and costs) (see Section 5). In order to characterize the existing and future economic development of industry and its subsectors, as well as energy consumption, output and other parameters, both top-down and bottom-up data acquisition approaches are used. The top-down approach has been used at the industry level to characterize the main industrial subsectors based on publicly available data. The bottom-up data acquisition approach has been used to determine and benchmark the specific energy consumption of companies.

6.2.1. Industry level: a top-down data acquisition approach

This subsection summarizes statistical data for the characterization of Latvia's industrial sectors, including such indicators as output value, value added, turnover, output volume, as well as energy consumption and its structure in the main industrial sectors.

Since the restoration of Latvia's independence in 1990, industrial development has been slow and difficult. In 2008, when Latvia was at its peak of industrial development, the economic crisis began and was followed by a sharp decline in the following years, and the lowest industrial development rate was reached in 2010. However, in the post-crisis period, Latvia has shown continuous GDP growth, as well as a significant and stable increase in export volumes (Ministry of Economics, 2019a).

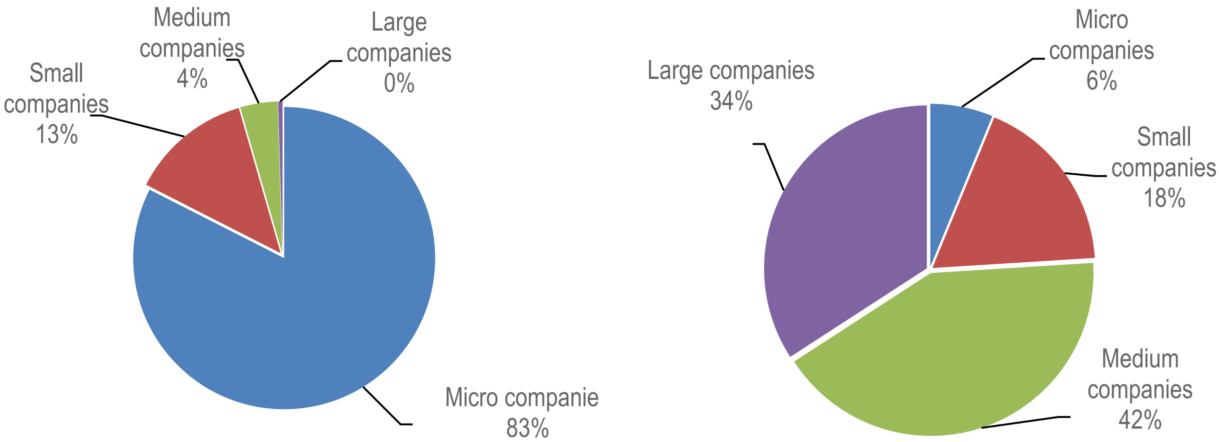
Industry is an important sector of the Latvian economy and an important generator of the country's exports. In 2018, the industrial sector accounted for 43% of the total exports (Central Statistical Bureau, 2020a). The industrial sector includes sectors B, C, D and E, however, the main export-forming sector is manufacturing (C) (in 2018 it accounted for 93% of the industrial sector export indicator (Central Statistical Bureau, 2020a)) and several important subsectors correspond to this sector (from C10 to C33) (for a detailed description of sectors and divisions see (Central Statistical Bureau, 2020h)). Considering all the manufacturing (C) subsectors the largest share of the country's total exports in 2018 was generated by production of wood, wood and cork products, except furniture, as well as manufacture of articles of straw and plaited materials (C16) - 12.2%, manufacture of food products (C10) - 4.2% and manufacture of fabricated metal products (C25) - 2.6% (Central Statistical Bureau, 2020a).

The total value added of the industrial sector (B-E sectors) in 2018 was 3 737 895 thousand EUR at 2015 constant prices. Since 2011 the total value added has increased 1.12 times. A similar increase in value added is observed in manufacturing - 1.16 times. Manufacturing accounts for 12% of the total value added structure, while the rest of the industry accounts for 4%. The latest data available for manufacturing subsectors are for 2017. The largest percentage of value added in manufacturing in 2017 was generated by divisions C16, C10, followed by divisions C25 and C23. These four largest divisions account for 55% of total value added. (Central Statistical Bureau, 2020g)

In terms of total turnover, industry has also showed an increase 1.2 times since 2011. 77% of industrial turnover is generated by manufacturing, but 17% by electricity, gas and steam supply. Latvia's manufacturing industry is quite versatile, but in terms of the largest turnover (C16, C10, C25, C23) and the number of companies (C16, C14, C25, C10) and the number of employees (C16, C10, C25, C14) few subsectors dominate. (Central Statistical Bureau, 2020j)These subsections (C16, C10-12 and C23) are also the largest in terms of total energy consumption (see

Figure 6-4). On the one hand, the greatest energy savings could be achieved by focusing on these largest consumers. However, energy consumption is largely influenced by production technologies and the specifics of each sector. Therefore, an in-depth analysis using specific indicators is needed.

Micro enterprises account for only 6.2% of the total manufacturing value added, but account for 82% of the total number of manufacturing enterprises, while other enterprises, which account for 18% of the number of enterprises, account for as much as 93.8% of value added (see Figure 6-2). (Central Statistical Bureau, 2020k)



a) by number of enterprises b) by value added

Figure 6-2. Number of manufacturing enterprises and their value added depending on the number of employees (Central Statistical Bureau, 2020k)

Figure 6-3 shows the dynamics of the volume of goods and services produced by the industrial sector over the last 15 years. Currently an upward trend is seen; the output of goods and services of the industrial sector in 2018 amounted to 11 565 721 thousand EUR at constant 2015 prices (Central Statistical Bureau, 2020f). It can be seen that manufacturing sector (C) accounts for the largest share of the total value of output of goods and services in the industrial sector. Also, changes in the total output of goods and services depend more on changes in manufacturing than in other sectors, where on average the output remains similar.

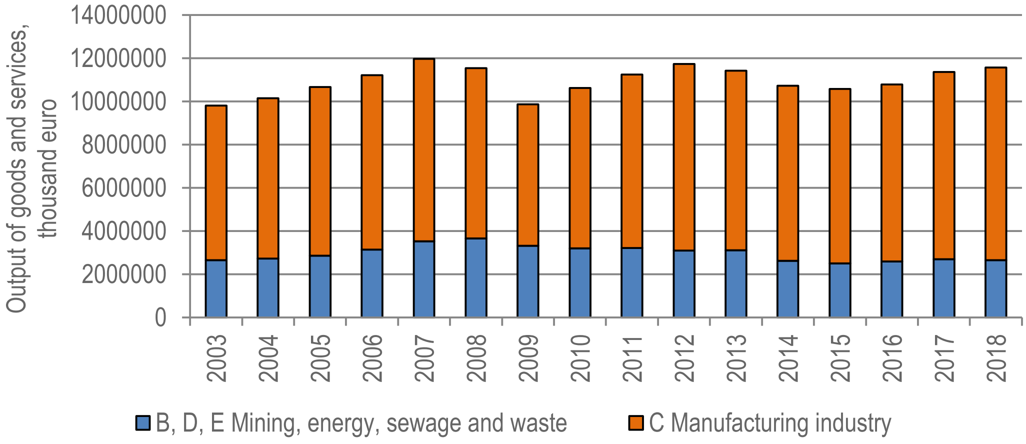


Figure 6-3. Volume of goods and services produced by the industrial sector in the last 15 years (Central Statistical Bureau, 2020f)

More detailed information on the value added, number of employees and exports of the largest manufacturing subsectors is presented in the Table 6-1.

Table 6-1.

Percentage share of manufacturing subsectors by value added, number of employees and exports (Central Statistical Bureau, 2020a, 2020g, 2020j)

	Exports in 2018, %	Value added in 2017, %	Number of persons employed in 2018, %
Manufacturing industry from total	40.1	12.4	18.3
C10 Manufacture of food products	10.6	15.4	17.5
C11 Manufacture of beverages	1.5	3.2	2.1
C13 Manufacture of textiles	1.3	1.6	2.6
C14 Manufacture of wearing apparel	2.8	2.9	7.5
C16 Manufacture of wood and of products of wood and cork	30.3	22.4	20.4
C18 Printing and reproduction of recorded media	2.4	2.8	3.0
C20 Manufacture of chemicals and chemical products	4.7	2.3	2.4
C21 Manufacture of basic pharmaceutical products and preparations	2.9	3.3	1.8
C22 Manufacture of rubber and plastic products	2.8	2.7	2.7
C23 Manufacture of non-metallic mineral products	5.9	7.5	4.9
C24 Manufacture of basic metals	1.4	0.1	0.6
C25 Manufacture of fabricated metal products, except machinery and equipment	6.5	9.2	9.4
C26 Manufacture of computer, electronic and optical products	6.3	5.9	1.8
C27 Manufacture of electrical equipment	4.8	3.0	2.7
C28 Manufacture of machinery and equipment not elsewhere classified	4.0	3.0	3.1
C29 Manufacture of motor vehicles, trailers and semi - trailers	4.9	2.4	1.9
C30 Manufacture of other transport equipment	0.7	1.1	1.4
C31 Furniture production	3.2	3.6	5.7
C32 Other manufacturing	1.5	1.4	2.2
C33 Repair and installation of machinery and equipment	0.2	4.8	4.9

Characteristics of the energy consumption of industrial sector

According to the Central Statistical Bureau, the manufacturing sector in Latvia in 2018 accounted for 73% of the total industrial production volume index weight structure and mining – for 2.9% (Central Statistical Bureau, 2020i). In turn, 24% was formed by NACE Rev. 2 code D sector – Electricity and gas supply. As mentioned above, although in the statistical accounts sectors D and E are also attributed to the industrial sectors, in the energy balance accounts NACE Rev. 2 Sector D is included in the Transformation sector and is not a direct energy end-use sector, while construction sector is attributed to industry in the energy balance accounts.

Figure 6-4 shows the changes in the final energy consumption of the industrial sector over the last ten years by industrial sub-sectors. Within this breakdown several of the industrial subsectors are grouped in the same way as commonly done within European level statistics on industrial energy consumption, but this complicates the analysis of the energy consumption of individual sectors.

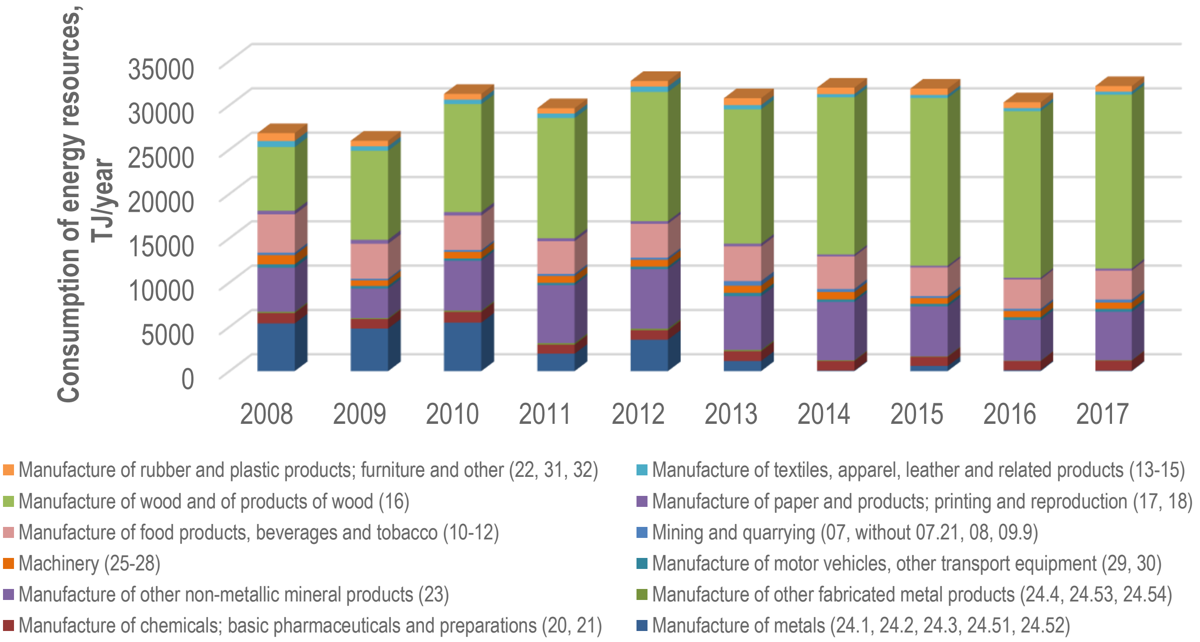


Figure 6-4. Historical energy consumption by industry subsectors

Figure 6-5 shows the relationship between manufacturing value added and specific energy consumption in relation to value added. The relationship is relatively strong $R^2 = 0.8$ (using the power function). It can be seen that as the added value of the industry increases, the specific energy consumption decreases, which indicates savings due to economies of scale are being achieved. Also, forecasting the development of this relationship in the future, as the value added of the Latvian manufacturing industry increases even more, it can be seen that the trend curve would tend to level out.

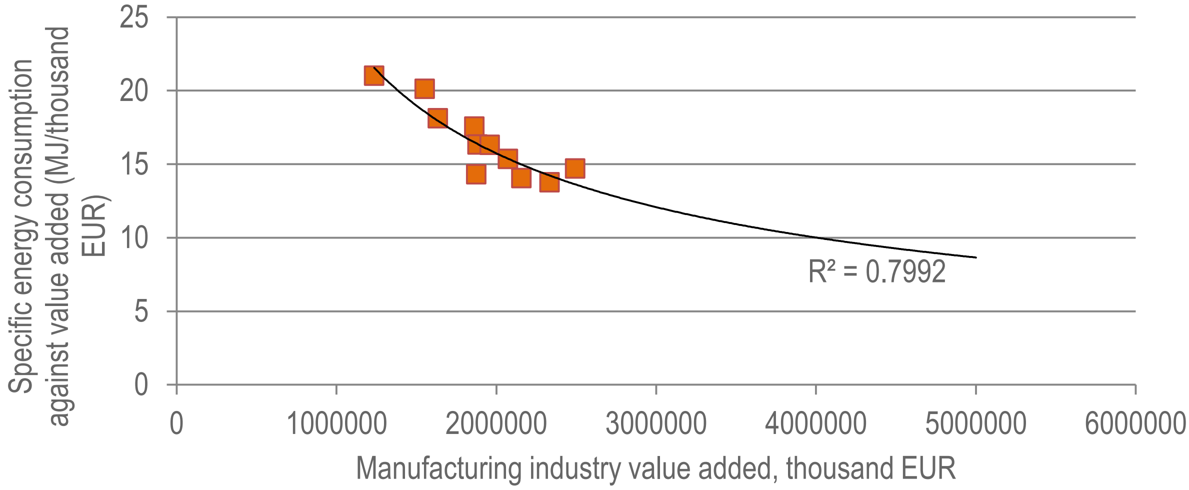


Figure 6-5. Specific energy consumption depending on the value added of the manufacturing industry (Central Statistical Bureau, 2020c)

In more detail the distribution of final energy consumption by industry (mining and manufacturing) subsectors in 2017 is shown in Figure 6-6. In 2017, the largest industrial subsector in terms of energy consumption was the manufacture of wood products (61%), followed by the manufacture of non-metallic mineral products (17%) and the manufacture of food products, beverages and tobacco (10%) (Central Statistical Bureau, 2020c). It should be noted that the tobacco products production department makes up a very small part of the total consumption, because, for example, in 2017 there are only 5 companies operating in it (Central Statistical Bureau, 2020j). Since 2014, the share of the wood processing sector in the total industrial energy consumption has grown from 56% to 61%, while the share of the other largest sectors - the food industry and the production of non-metallic mineral products - has decreased by 2% and 4%, respectively. In total, these three sectors (C10-12, C16, C23) consumed 88% of industrial final energy consumption in 2017.

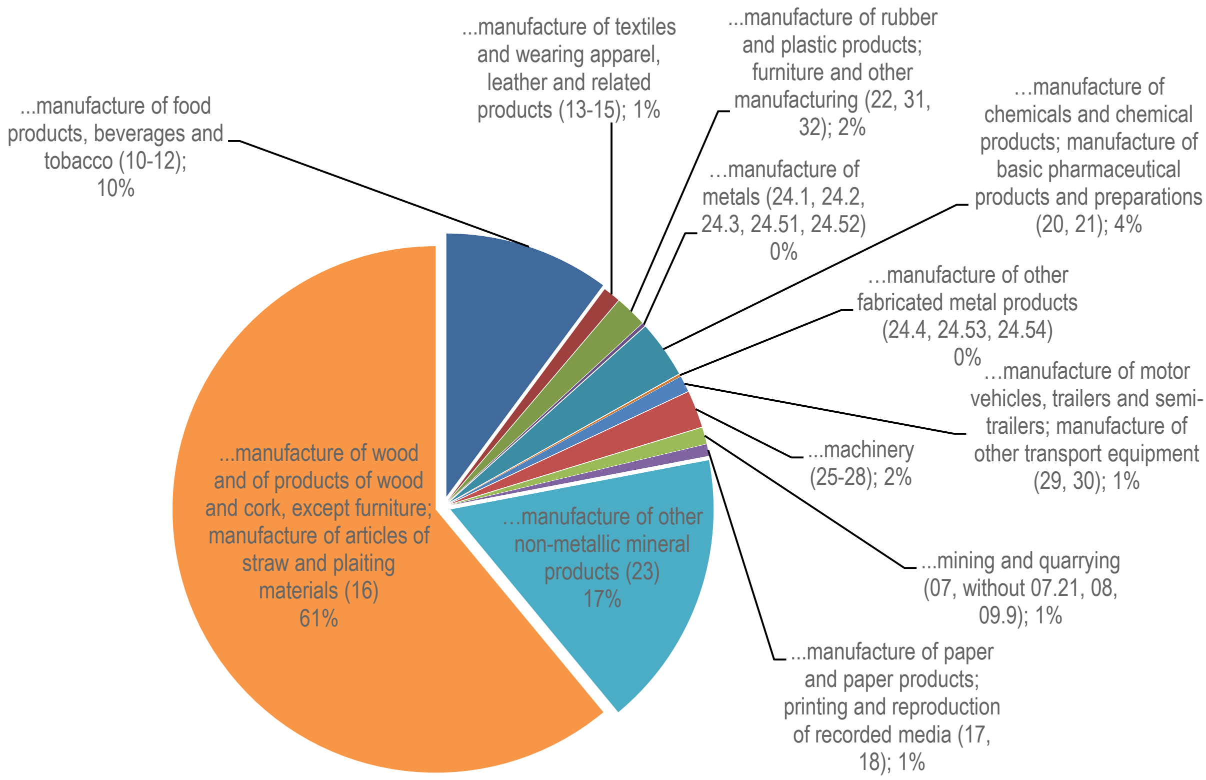


Figure 6-6. Energy consumption by industrial subdivisions in 2017, TJ (Central Statistical Bureau, 2020c)

Given that the three largest sectors in terms of energy consumption account for 88 per cent of total industrial energy consumption, these sectors are the first to be analysed in depth.

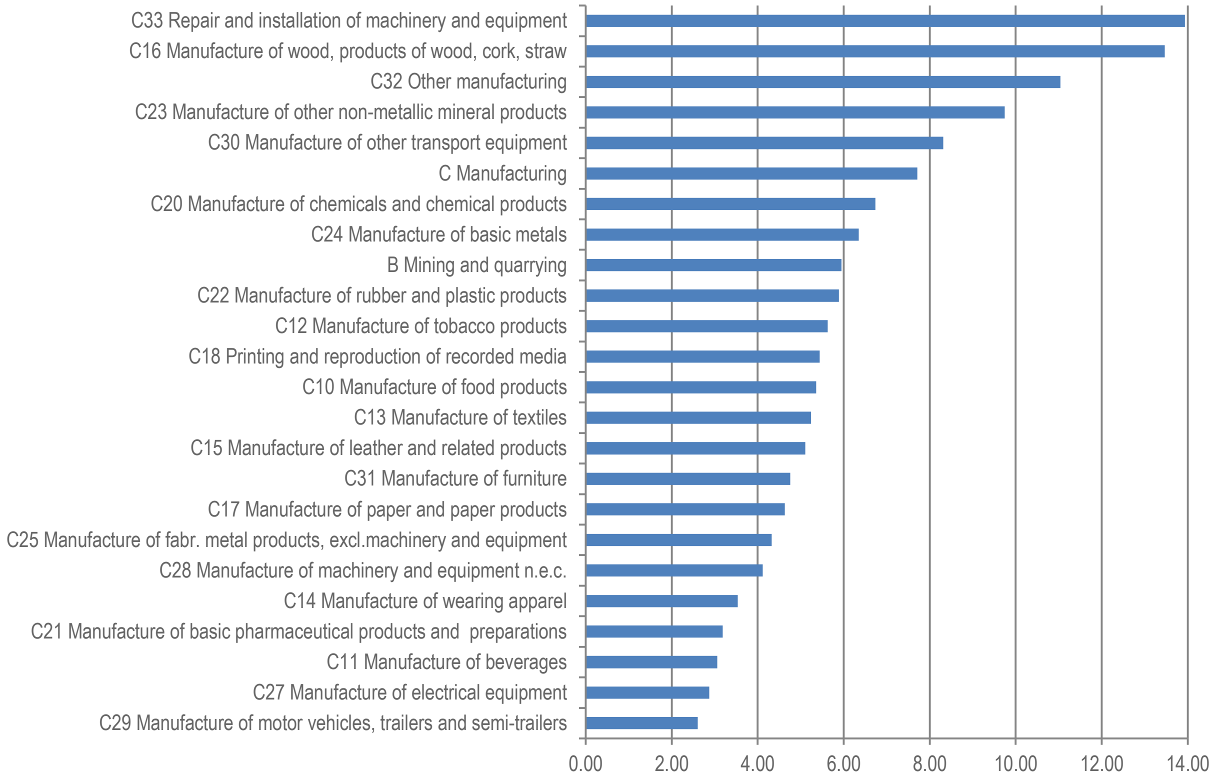


Figure 6-7. Value of energy purchases in relation to total value of production in 2016,% (Central Statistical Bureau, 2020e, 2020j)

Figure 6-7 shows the distribution of Latvian manufacturing sub-sectors according to their specific energy costs (expressed as energy costs against total production value). As can be seen, these sectors rank differently in terms of energy expenditure – C16 and C23 are among the sectors with a higher share of energy consumption in total production value, while C10 and C14 have significantly lower specific energy costs.

Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials

The wood processing subsector includes the industrial production of timber, plywood, veneer, wooden containers, parquet boards, as well as wooden rafters and prefabricated wooden buildings. The subgroups of this subsector are 16.1. Sawing, planing and impregnation and 16.2. Manufacture of articles of wood, cork, straw and plaiting materials. The group 16.2. is further subdivided according to the products produced (veneer sheets, wood panels, parquet panels, wood packaging, etc.). The production processes used in the woodworking industry include sawing, planing, milling (cross-peeling), lamination and assembly of wood products starting from logs cut into blocks or other forms of wood which can then be cut or profiled with lathes or other planing and profiling tools. Timber or other modified wood products can be further planed or sanded and assembled into end products such as wooden containers.(Central Statistical Bureau, 2020h)

The total annual energy consumption of this subsector has averaged at 14775 TJ/year over the last ten years (see Figure 6-8). In terms of energy resources, wood fuel, including wood residues, wood chips, firewood, is very important. In total, wood fuel accounts for 71.5% of the subsectors' energy consumption, electricity consumption for 15%, natural gas consumption for 7%, and oil products for 3% (average for the period 2008-2017).

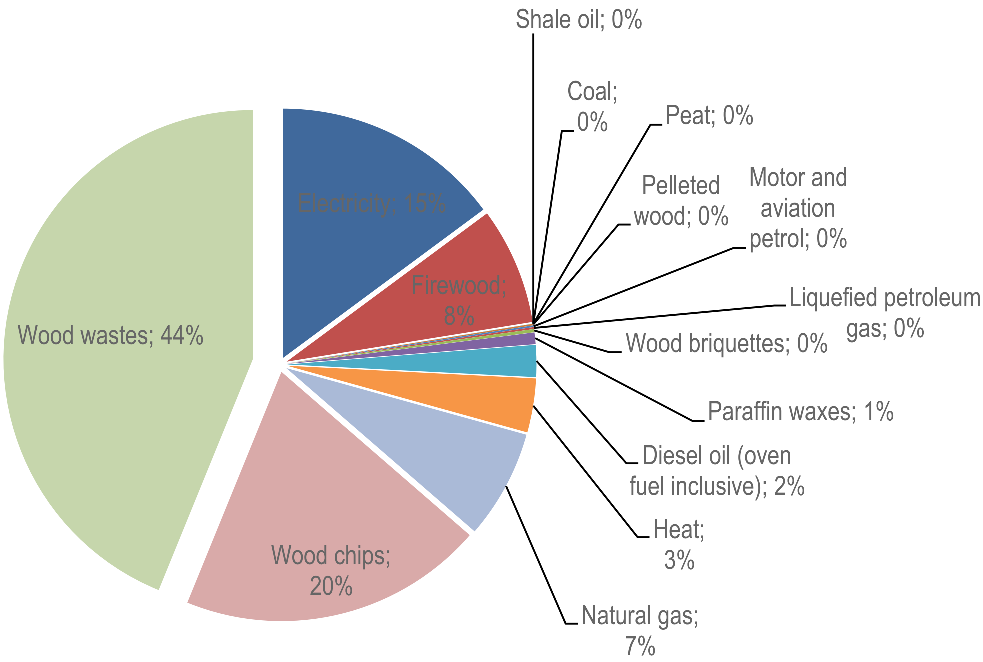


Figure 6-8. Use of energy resources in subsector C16 in 2018, TJ (Central Statistical Bureau, 2020c)

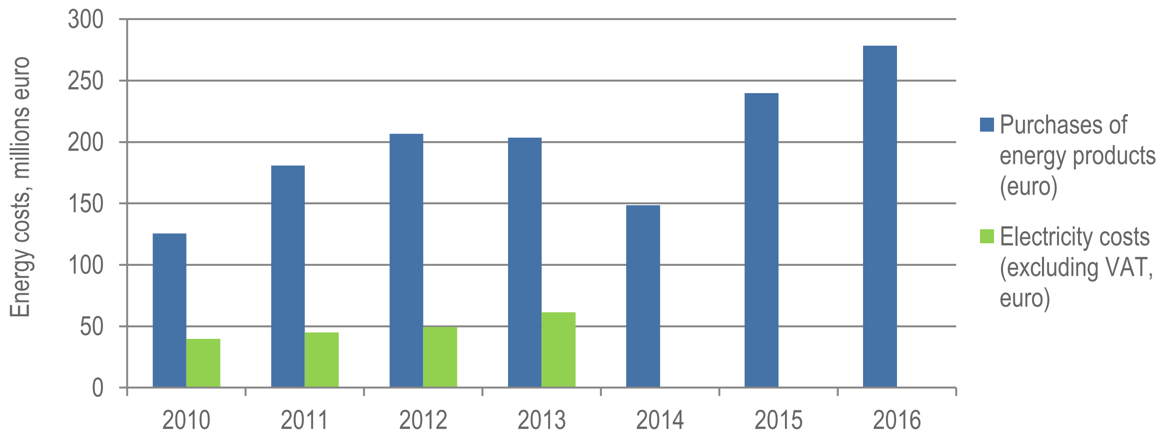


Figure 6-9. Energy costs in subsector C16 (Central Statistical Bureau, 2020b, 2020d, 2020j)

The total costs of energy products and separately the electricity costs for the wood processing subsector are summarized in Figure 6-9. On average in the period from 2010 to 2013 electricity costs accounted for 27.6% of the total costs of energy products in the wood processing subsector.

Manufacture of non-metallic mineral products

Manufacture of non-metallic mineral products or division 23 of the Statistical Classification of Economic Activities (NACE) Rev. 2 (hereinafter C23) includes such subgroups as manufacture of glass products, ceramic building materials and products, as well as cement, lime and plaster and other groups. (Central Statistical Bureau, 2020h) In terms of energy consumption, it is the second largest manufacturing sector in Latvia and in 2017 consumed 17% of the total energy consumption of industry (sections B and C), see Figure 6-6.

The average annual energy consumption of the subsector during the last ten years has been 5553TJ/year on average and 15% of it is electricity consumption (Central Statistical Bureau, 2020c). The proportional distribution of energy resources used in the sector (average values over the last ten years) is shown in Figure 6-10. The specifics of the sector are related to the use of municipal waste for the provision of heat energy for technological processes and one particular company is responsible for the use of these energy resources - the cement plant SCHWENK Latvija Ltd (formerly known as Cemex Ltd). The industry is also represented by other recognizable companies – Lode Ltd, JSC Valmieras stikla šķiedra, many cement producers, and other companies.

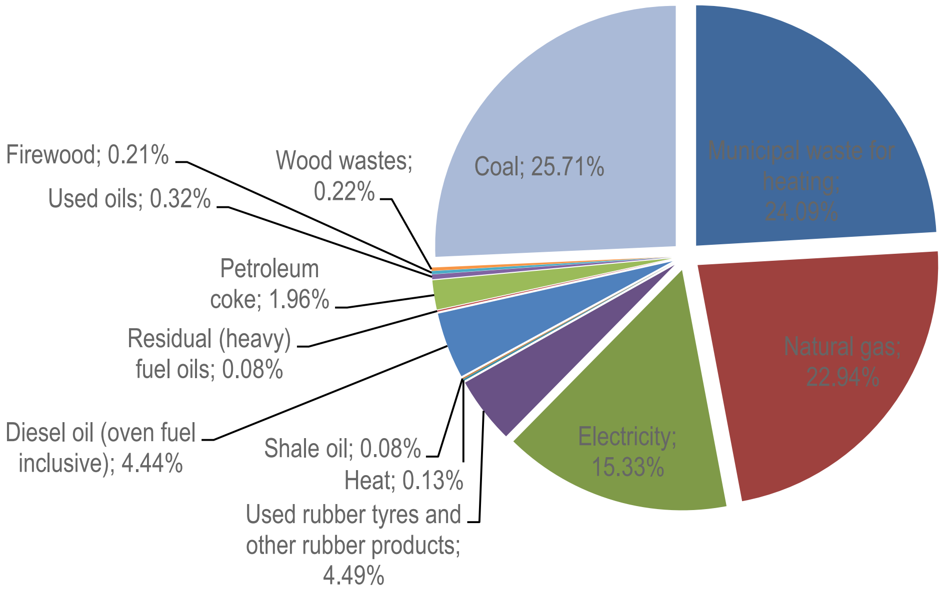


Figure 6-10. Use of energy resources in non-metallic mineral products production subsector (Central Statistical Bureau, 2020c)

Data on sector's expenditures on energy product purchases for the period 2010-2016 are shown in Figure 6-11. As mentioned above, electricity consumption accounts for 15% of the sector's total energy consumption, but electricity costs account for around 39% of total energy costs (average for the period 2010-2013). Therefore, it is important to introduce energy efficiency measures related to both fuel savings and electricity savings in this industry.

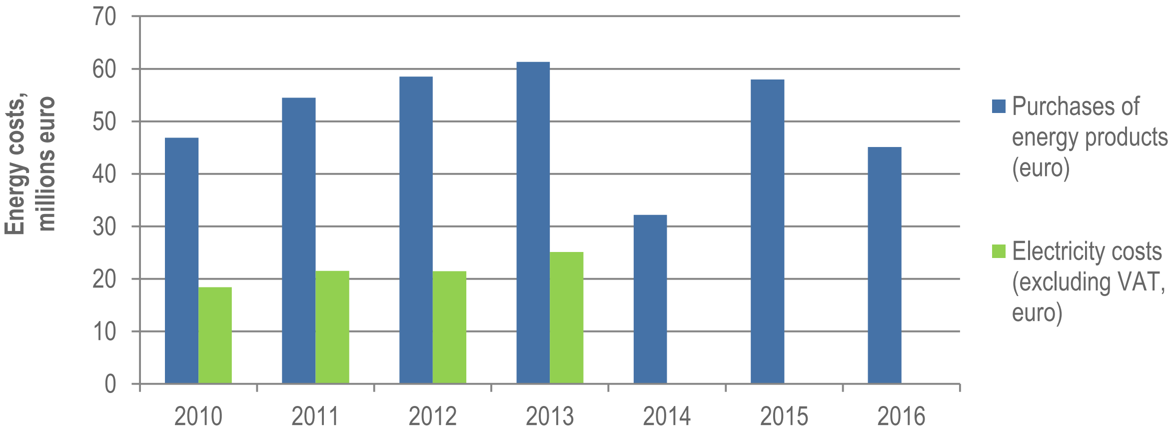


Figure 6-11. Energy costs in subsector C23 (Central Statistical Bureau, 2020b, 2020d, 2020j)

The non-metallic mineral materials sector is also a significant consumer of energy on a global scale, therefore many studies are available on the potential energy efficiency measures in this sector, as well as international studies have identified energy efficiency potential in this sector abroad, which can serve as an example in Latvia.

Accordingly to Regulation No. 1099/2008 on energy statistics (European Parliament and Council of the European Union, 2008), the Central Statistical Bureau combines data for subsectors C10, C11 and C12 in the energy balance. Consequently, energy consumption is only available for these three chapters as a whole.

The food production subsector includes the processing of raw materials from such primary production sectors as agriculture, forestry and fisheries into food or feed products or intermediate products. The subsector includes groups such as the production of meat, fish, vegetables, fruit, milk, cereals and other food products, as well as animal feed. The beverage production subsector includes the production of both soft drinks and mineral water and alcoholic beverages (including beer, wine, distilled beverages), but does not include the production of fruit and vegetable juices, milk beverages, coffee, tea. The tobacco products division includes the processing of tobacco into a product suitable for final consumption. (Central Statistical Bureau, 2020h)

The average annual energy consumption of C10-C12 over the last 10 years is 3701 TJ/year. Of this, 45% is natural gas consumption, 28.5% - electricity consumption, 12.3% - various oil products, 10.1% - fuel wood and straw (see Figure 6-12).

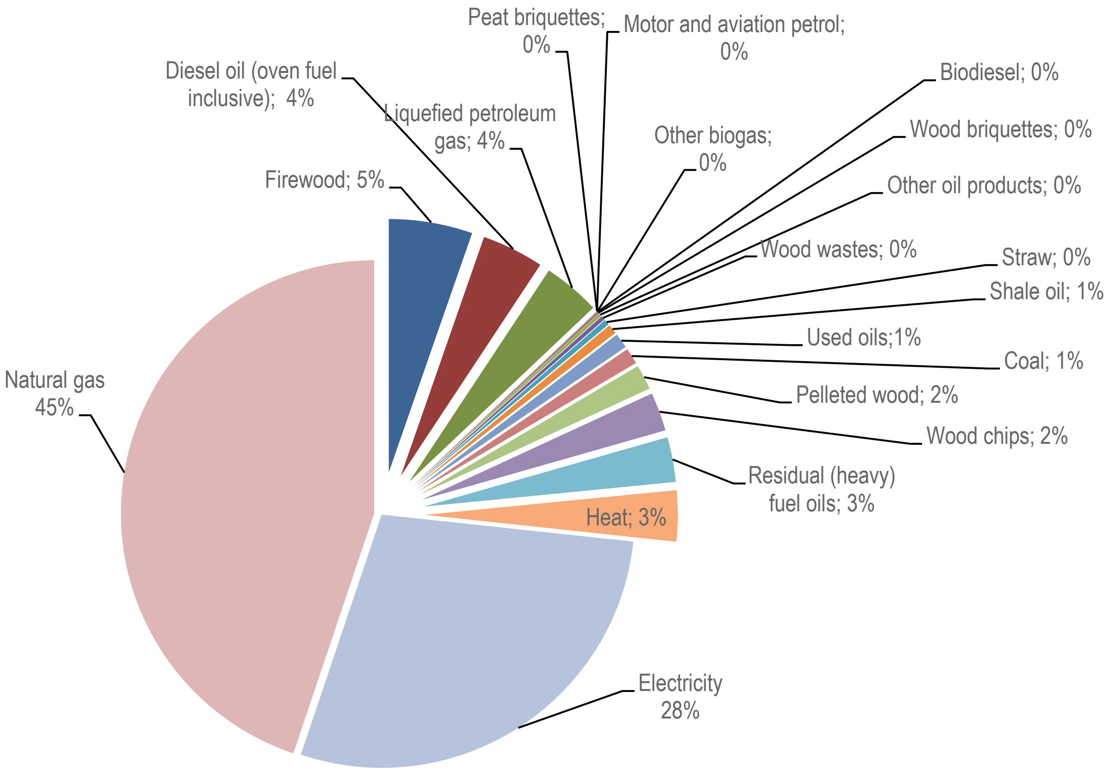


Figure 6-12. Use of energy resources in subsectors C10 - C12 (Central Statistical Bureau, 2020c)

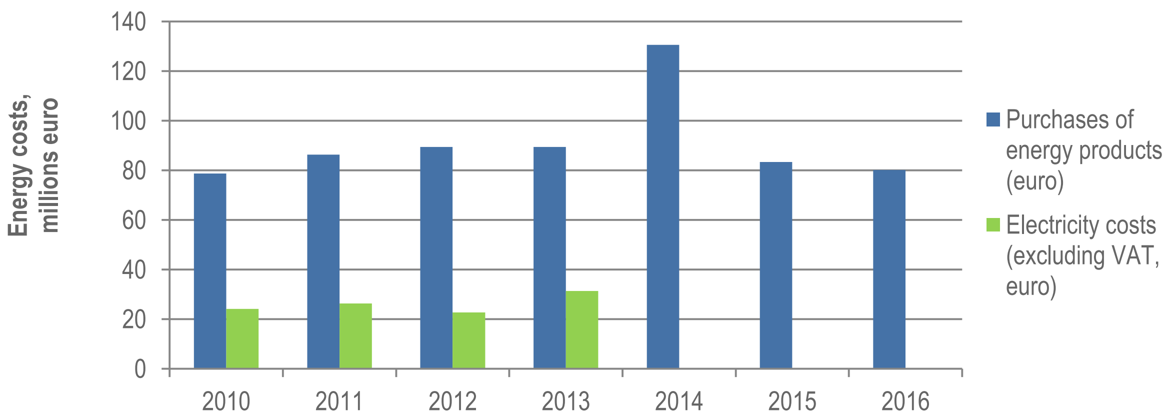


Figure 6-13. Energy costs in subsectors C10-12 (Central Statistical Bureau, 2020b, 2020d, 2020j)

In terms of energy costs, electricity accounts for about 30% of total costs (see Figure 6-13). In order to separate the energy consumption of the food, beverages and tobacco production subsectors, it would be necessary to demand from Central Statistical Bureau recasted data on the energy consumption of individual industrial subsectors.

6.2.2. Company level: bottom-up data gathering approach

The data analysis of the energy efficiency monitoring system and the analysis of the energy audit data are presented in Sections 2, 3, 4 and they are based on the analysis of the information received from and manually collected at the Ministry of Economics based on mutual data confidentiality agreement. This subsection provides an example of obtaining bottom-up data from publicly available data sources, i.e. companies' polluting permits, as well as, where possible, comparing indicators from energy audit data and polluting permits. The obtained data will be used in the next project activities in the development of the system dynamics model.

Benchmarks based on polluting activity permit data

For some industrial enterprises, data on electricity and heat consumption are available from polluting activity permits. Polluting activity permits (category A, B permits and category C certifications) issued to companies by the regional administrations of the State Environmental Service depending on the region of location of the plant and in accordance with Cabinet Regulation No. 1082 (Cabinet of Ministers, 2010) are available electronically and contain information regarding the consumption of electricity and heat in the enterprise, as well as regarding the planned maximum volume of production. Polluting activity permits must be obtained by enterprises if their type of activity and capacity comply with or exceed the activities referred to in the annexes to Cabinet Regulation No. 1082. In most cases, such conditions apply to medium-sized and large enterprises, so more information is available about them, but for small enterprises without permits for polluting activities or if the category C certificates do not include precise energy consumption data, there are no other publicly available documents containing the necessary information.

In order to develop benchmarks for the production of non-metallic mineral products and in particular for the subsector of concrete, cement and gypsum products production (C23.6), the polluting activity permits of the following companies were considered and analysed:

- TMB Elements Ltd,
- Latgalija Betons Ltd,
- KNAUF Ltd,
- Bauroc Ltd,
- DZELZSBETONS MB Ltd,
- Seastone Ltd,
- CTB BETONS Ltd,
- K-MIX Ltd,
- SKONTO PREFAB Ltd,
- KOLLE BETONS Ltd,
- Salenieku Bloks Ltd,
- EKSIM TRANS Ltd,
- Transportbetons MB Ltd,
- BMGS Ltd,
- SCHWENK Ltd (only concrete production facilities).

Although some companies have several plants, not all plant permits contain all the necessary data, so in total data on 22 plants has been compiled. The specific electricity and heat consumption was calculated using data on the output (t/year), the corresponding electricity consumption (MWh/year) and heat consumption (raw data are available as the amount of fuel used, which were converted to MWh/year using appropriate heating value for each of the fuels used). The obtained information on specific consumption of concrete plants is summarized in Figure 6-14.

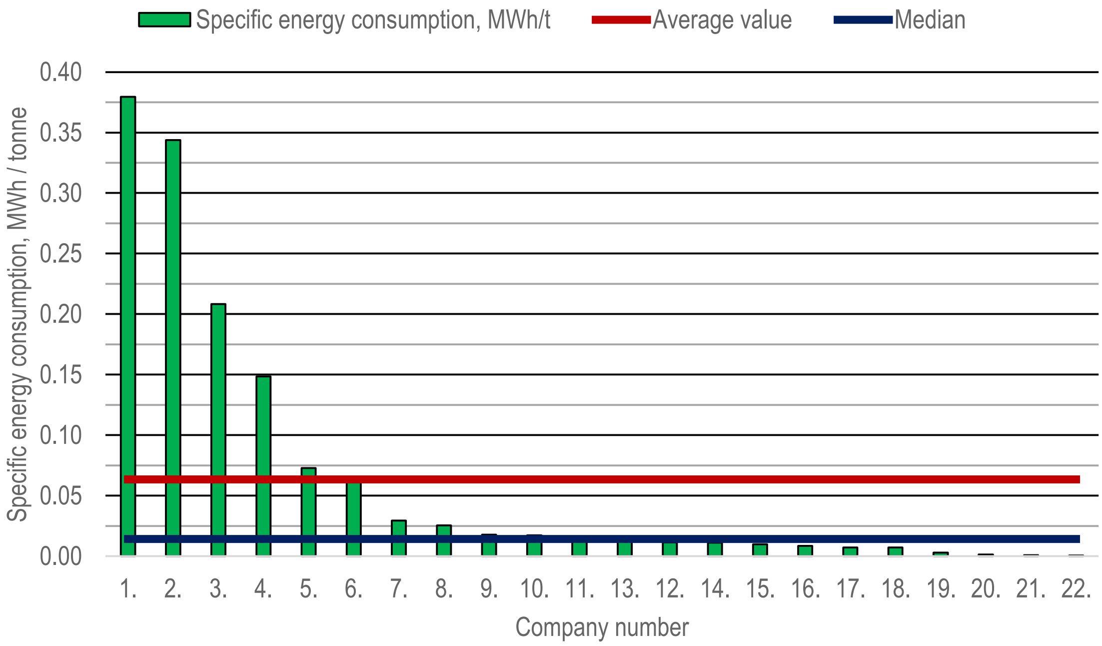


Figure 6-14. Specific energy consumption in concrete plants based on pollution permits data

The differences seen in specific energy consumption (see Figure 6-14) are due to the different organization of production facilities and processes. Companies 1 to 4 are engaged in the production of concrete products, while companies 5 to 22 are mainly engaged in the production of cement, mortar and ready-mixed concrete. Also, companies may not have specified the actual consumption and production data in the permits, but may have indicated maximum capacities.

In the wood products industry (C16), data were analyzed for 16 plants for which all the necessary input data were available:

- SEL RA ART Ltd
- Nordplay Ltd
- Inerce Ltd
- AJM WOOD Ltd
- EKJU Ltd
- LATVIJAS FINIERIS JSC - "Lignums"
- LATVIJAS FINIERIS JSC - "Hapaks"
- Garants Ltd
- VEREMS RSEZ Ltd
- Gaujas koks Ltd
- CEWOOD Ltd
- Vika Wood Ltd
- Kurekss Ltd
- KRONOSPAN Riga Ltd
- Troja Ltd
- Riga Veneer Ltd

The polluting permits of these companies do not always mention the volume of production, and even if they do, their units of measurement may vary depending on the type of production, or there may be several types of production in one company. Therefore, the amount of raw wood materials processed by the companies (tons/year) was taken as the normalization unit from the polluting activity permits. But, therefore, the specific consumption obtained here cannot be compared with the data obtained from energy audits, because they show the amount of raw materials in cubic meters, but other parameters of the specific raw material, such as density, moisture content, are not known.

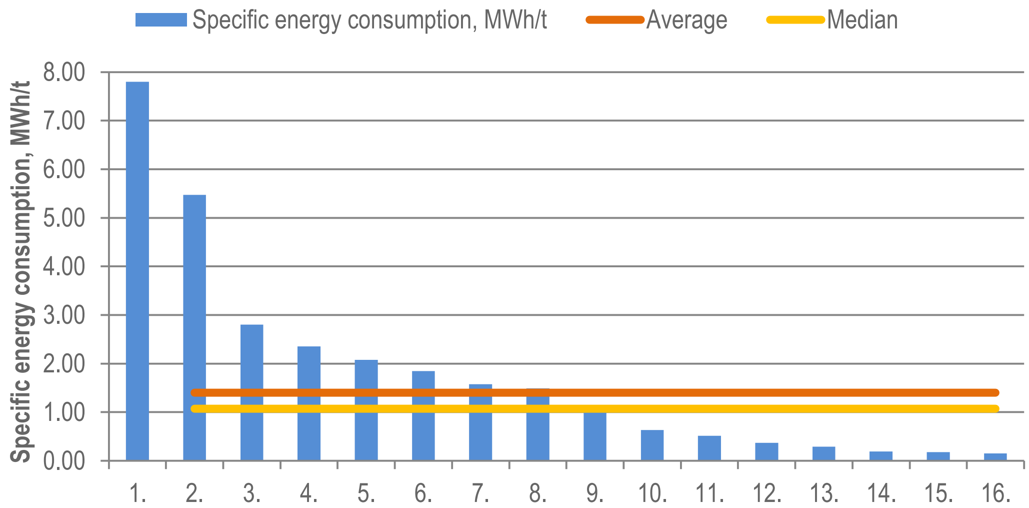


Figure 6-15. Specific energy consumption in wood product plants based on polluting activity permit data

For company no. 1, whose specific energy consumption is the highest, the heat energy consumption specified in the polluting activity permit for production processes constitutes only 15% of the total heat energy consumption. Excluding the company's heating energy consumption, its specific consumption would be only 1.4 MWh/tonne of processed wood. The availability of more accurate company-level data would allow this to be clarified.

Therefore, the data for company no. 1 are considered questionable and were not taken into account for the calculation of the average specific consumption and median. The average specific consumption of the analyzed companies is 1.4 MWh/ton of processed wood, but the median is 1.1 MWh/ton (see Figure 6-15).

By compiling data from polluting activity permits of dairy processing companies, data on 22 companies were obtained. The analysis did not take into account the three companies involved in milk collection and pre-treatment (see Figure 6-16). These companies have significantly lower specific energy consumption (less than 4 kWh/tonne), where the majority of consumption is electricity consumption (in all three companies). However, one company indicates that 60% of electricity consumption is used for heating purposes. Due to differences in the nature of energy consumption, milk collection and primary processing plants should be analysed as a separate group.

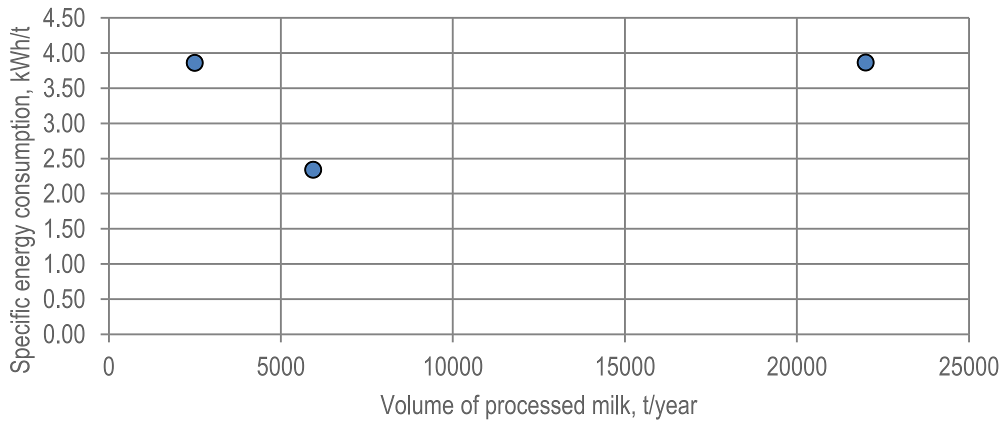


Figure 6-16. Specific electricity consumption of milk collection and processing companies

Although polluting activity permits were available for 19 dairy companies, the data in the permits of 3 companies are considered questionable. For one of the companies, the specific energy consumption exceeds 3000 kWh/tonne of processed milk. The reasons for such a deviation must be clarified by checking the accuracy of the data in the permit. The other two companies do not have data on the amount of electricity consumed (although one of them is mentioned in the list of large electricity consumers by the Ministry of Economics in 2016), therefore it is not possible to precisely calculate the total specific energy consumption.

When analyzing the specific energy consumption of dairy companies depending on the amount of milk processed annually (see Figure 6-17), it can be seen that the specific energy consumption is mostly in the range of 200-800 kWh/ton. But the negative trend seen is that the specific energy consumption does not decrease as companies' processing capacity increases, as should typically be the case for economies of scale.

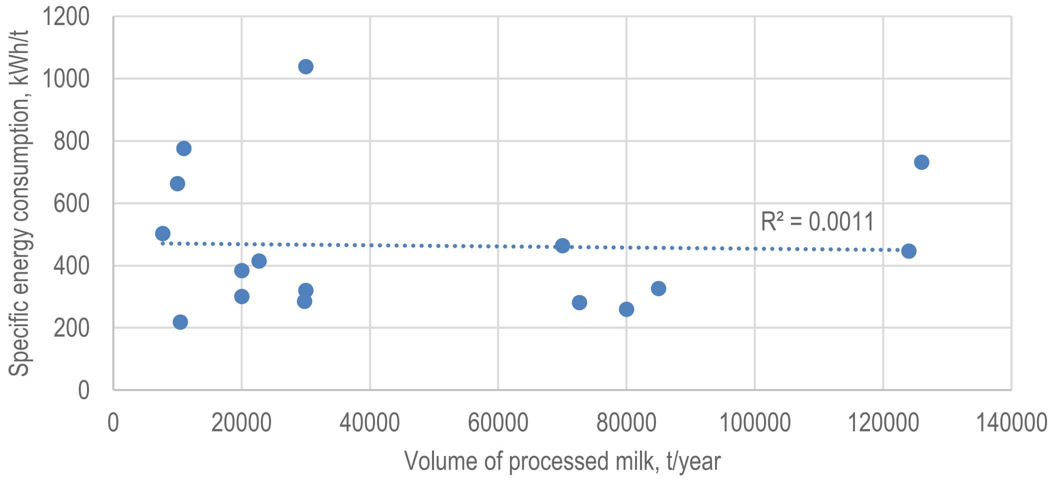


Figure 6-17. Specific energy consumption in dairy companies

Figure 6-18 shows the specific energy consumption of these companies. The average specific energy consumption of these 16 companies is 464 kWh/tonne of processed milk, while the median of the group is 400 kWh/tonne. The result for company no. 1 differs significantly, but its specific consumption is calculated on the basis of the information contained in the polluting activity permit, and there is no reason to believe that it would be incorrect. If companies with specific consumption on the left side of the graph improved their performance, the average specific consumption of the whole group would also decrease and companies currently below the benchmark could already be above it.

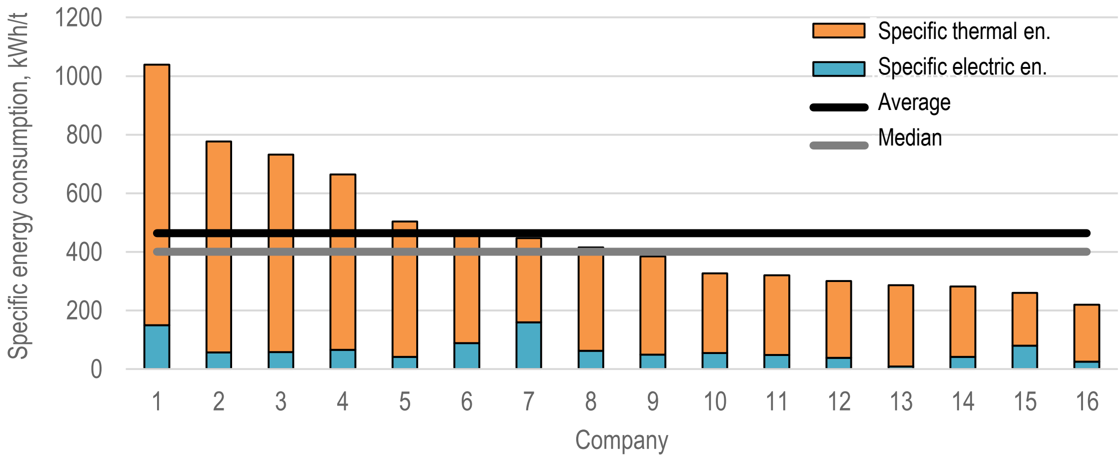


Figure 6-18. Specific energy consumption of enterprises and group average benchmark

Accordingly to the polluting activity permits, the total energy consumption of the 16 analysed companies would amount to 35% of the 2018 energy consumption in the food and beverage industry (more detailed subsector consumption breakdown is not available at the Central Statistical Bureau energy balance public database (Central Statistical Bureau, 2020c)). However, it is well known that companies specify maximum capacities within the permits for polluting activities in order to avoid exceeding capacity.

For four companies, the specific energy consumption based of the information specified in the polluting activity permits was compared to that calculated based on the information obtained from energy audits provided by the Ministry of Economics. For two companies, the specific energy consumption identified in the audits is lower than that resulting from the information available in the permits (audit/permit = 0.6-0.7), so in reality the companies are more efficient than declared in the permit data. For other two companies ratio is larger (audit / permit = 1.7-2), so the companies are less efficient than was expected when preparing data for the permit.

In order to find out the specific energy consumption of fish processing companies in Latvia, publicly available information on the capacities mentioned in the polluting activity permits of the companies was compiled. The data were collected for 18 companies. The activities of fish processing enterprises can be divided into two different areas: enterprises engaged in the sorting, packaging and chilling or freezing of caught fish (pre-processing) and enterprises engaged in the production of fish products in the form of canning, smoking, etc. Both of these activities have different specific energy consumption; therefore these groups are analyzed separately.

Figure 6-19 shows the total specific energy consumption of companies per tonne of raw material. The mean and median of the sample were also calculated. The significant differences between minimum and maximum energy consumption in the analyzed companies can be partly explained by differences in production and company-specific conditions (on-site canning, use of raw or pre-processed fish, different heating and cold production systems, etc. factors to be studied in depth).

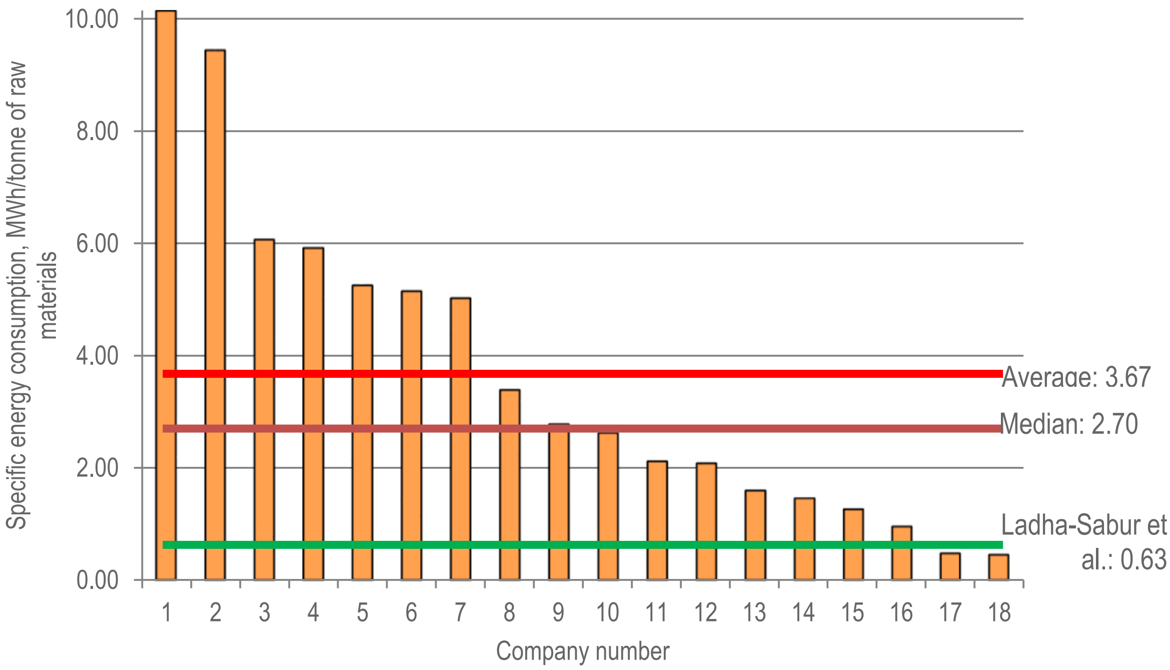


Figure 6-19. Specific energy consumption based on polluting activity permits for fish processing companies

In a research by Ladha-Sabur et al. (Ladha-Sabur, Bakalis, Fryer, & Lopez-Quiroga, 2019), the average specific energy consumption of fish processing is 0.38 MJ_{el}/kg (0.106 MWh_{th}/t) and 1.87 MJ_{th}/kg (0.519 MWh_{th}/t), forming a total of 2.25 MJ/kg or 0.625 MWh/t. The average specific heat consumption in the examined companies is 3.11MWh_{th}/t, which is 6 times higher than indicated in the literature source. The specific electricity consumption of 2,016MJ_{el}/kg is five times higher than mentioned in the literature.

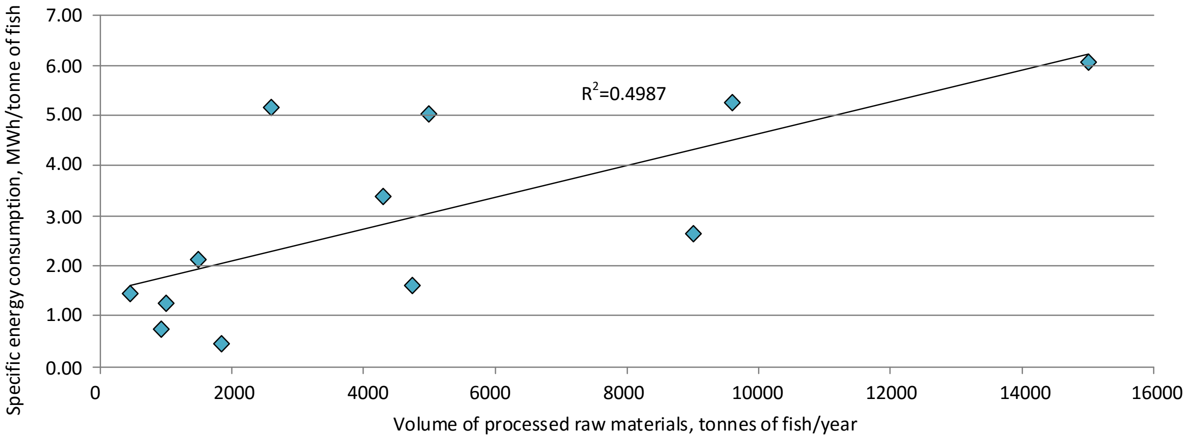


Figure 6-20. Specific energy consumption depending on the volume of fish processed

Looking at the specific energy consumption of enterprises depending on production volume (see Figure 6-20) there is a tendency that at a higher amount of processed raw materials, enterprises have a higher specific energy consumption. On the one hand, knowing the historical development of Latvian industry, it could be explained by the infrastructure of historical production facilities, but in order to substantiate it, additional research is needed. On the other hand, this trend is in stark contrast to the principle of economies of scale production savings, where specific energy consumption should decrease at higher production capacities. In order to analyze it in more detail, it is necessary to look separately at the heat consumption of companies for different production processes and heating, as mentioned above.

CONCLUSIONS

This study investigates the data available in the national energy efficiency monitoring system to determine their suitability for determining the energy efficiency potential in the energy end-use sectors. In addition, data from industrial energy audits were collected manually to obtain more detailed information on companies' energy consumption, as well as to create a database on the savings potential and specific costs of different types of energy efficiency measures. As a result of the research, a methodology has been developed for assessing the energy efficiency potential of energy end-use sectors in Latvia, and manufacturing industry is analysed first as it is a complex sector with diverse and sector-specific energy consumption patterns.

In the summary file of the energy efficiency monitoring system only electricity consumption is available for each company, but no consumption of heat and/or other energy carriers (as transport fuel) is available. **Therefore, it is not possible to attribute the energy savings forecasted and achieved by companies to the company's total consumption and to determine the savings as a percentage of the company's total consumption.** However, such specific indicators should be used to compare the technical potential of companies in order to define the energy efficiency potential of companies and the results achieved by the particular program.

The available data of the energy efficiency monitoring system are not suitable to create energy efficiency cost curves, which allow to model the potential of energy savings, as basically the only output of the system are the energy savings of specific companies in absolute values. Characteristic parameters such as the company's total energy consumption, which would allow to create even the simplest specific indicators, are not available in the system. The outputs of the existing energy efficiency monitoring system can be used to ascertain the energy savings, but they cannot be used to model future savings based on other characteristics parameters such as the company's energy consumption, turnover, product value or represented sector of the industry.

The analysis of the energy efficiency monitoring system also identified various other shortcomings that hinder the full use of the data. Technically, the energy audits submitted by companies are available in different forms (physical copies, scanned documents and electronic versions) and are not compiled in a form available for data analysis. As there is no single standardized energy audit template, the structure of audit reports by different energy auditors differs significantly, which complicates their analysis, and also not all data available in audits meet the requirements of Cabinet Regulation No. 487. Detailed information on total energy consumption and implemented energy efficiency measures is not available for companies that have implemented certified energy management systems. Therefore, the available monitoring database (based on the MS Excel file provided by the Ministry of Economics) lacks information on the total energy consumption of companies (only electricity consumption is known), so the collected information on potential savings can be attributed only to the whole industry sub-sector and not the exact consumption of the analysed group. Thirdly, the lack of specific savings targets has led to a situation where some companies identify the required energy efficiency measures only formally, reporting small energy savings that represent only a few per cent of the company's total energy consumption. The logical analysis of energy audits indicates that the actual energy efficiency potential in Latvian companies is much higher. However, this cannot be accurately determined using a bottom-up approach until more accurate and verified data collection is in place. Therefore, the authority responsible for the energy monitoring system should correct these and other shortcomings, so that it would be possible to provide the detailed data that are necessary for the modelling at national level from the energy efficiency monitoring system.

The manual collection of energy audit data allowed to analyse the potential energy savings (technical potential) of industrial enterprises depending on the industry that the enterprise represents, company's total energy consumption and production volume (for a limited number of enterprises) (see Section 4). However, this analysis shows that there is no statistical relationship between the listed parameters that could be used to model energy efficiency potential. This is partly due to the complex nature of the industry, but it is also influenced by the already mentioned lack of specific savings targets and the different approaches and extent to which energy efficiency measures have been identified by energy auditors. The energy efficiency cost curves obtained as a result of energy audit analysis (see Section 5) characterize different types of measures (heating, building renovations, lighting, ventilation, equipment, energy management, etc.) and will be used to model energy efficiency potential in subsequent project phases. Although some of the identified energy efficiency measures require significant investments, many no-cost and low cost energy efficiency measures were identified in almost all subgroups of measures, which could be used to realize significant energy efficiency potential through targeted implementation on a larger scale.

The data of the energy efficiency monitoring system are not sufficient to use a bottom-up approach to model Latvia's energy efficiency potential. Therefore, a methodological algorithm has been developed that includes the use of a top-down approach and integrates the available bottom-up data, and could be complemented by more detailed data from the energy efficiency monitoring system, if available. Four categories of indicators have been selected to be integrated into the energy efficiency assessment model, which will also include the results obtained from the analysis of energy efficiency curves, thus complementing the model with data that are not widely available in statistical databases.

A paradoxical situation has formed in the Latvian energy sector: companies, as energy users, have wide opportunities to reduce their energy consumption by increasing energy efficiency and therefore save financial resources. Thus, the company's growth opportunities increase and product competitiveness in the market increases. However, a significant level of resistance has been achieved to such profitable activities within the companies. Companies resist to the creation of a database, introduction of a monitoring system and analysis of its data, and introduce only a minimal amount of energy efficiency measures. Businesses need professional help from the Ministry of Economics. However, the information available to the Ministry of Economics does not promote understanding of the current situation and makes it impossible to help motivate companies.

RTU IESE scientists see the possibility that in cooperation with the Ministry of Economics it is possible to create a sustainable energy efficiency monitoring and implementation system in Latvia that could help companies and the country to reduce energy consumption and come closer to implementation of at least two EU 2030 targets (climate and energy efficiency).

The issue of increasing energy efficiency has become especially topical after the agreement signed by the EU member states at the end of December 2019 within the framework of the Green Deal (European Commission, 2019b).

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ANNEX 1

Studies using the energy efficiency cost curves method

Sector		Source
Households		Streicher et al.,2017. Techno-economic potential of large –scale energy retrofit in the Swiss residental building stock. Yilmaz et al, 2019. Analysis of the impact of energy efficiency labelling and potential changes on electricity demand reduction of white goods using a stock model: The case of Switzerland Agne Toleikyte, Lukas Kranzl, Andreas Müller. Cost curves of energy efficiency investments in buildings – Methodologies and a case study of Lithuania Timilsina et al., Development of marginal abatement cost curves for the building sector in Armenia and Georgia
Industry subsectors	Cement	Zuberi un Patel, 2017. Bottom-up analysis of energy efficiency improvement and CO_2 emission reduction potentials in the Swiss cement industry Morrow III et al, 2014. Assessment of energy efficiency improvement and CO_2 emission reduction potentials in India's cement and iron & steel industries Alireza Talaei, David Pier, Aishwarya V. Iyer, Md Ahiduzzaman, Amit Kumar. Assessment of long-term energy efficiency improvement and greenhouse gas emissions mitigation options for the cement industry (CO_2 cost curve) Tesema G, Worrell E. Energy efficiency improvement potentials for thecement industry in Ethiopia. Energy 2015;93(Part 2):2042e52.https://doi.org/10.1016/j.energy.2015.10.057. Hasanbeigi A, Morrow W, Masanet E, Sathaye J, Xu T. Energy efficiencyimprovement and CO_2 emission reduction opportunities in the cement in-dustry in China. Energy Pol 2013;57(0):287e97.https://doi.org/10.1016/j.enpol.2013.01.053. Sathaye J, Xu T, Galitsky C. Bottom-up representation of industrial energyefficiency technologies in integrated assessment models for the cementsector. Berkeley: Environmental Energy Technologies Division - LawrenceBerkeley National Laboratory (LBNL); 2010 Hasanbeigi A, Menke C, Therdyothin A. Technical and cost assessment ofenergy efficiency improvement and greenhouse gas emission reduction po-tentials in Thai cement industry. Energy Efficiency 2011;4(1):93e113. Hasanbeigi A, Menke C, Therdyothin A. The use of conservation supply curvesin energy policy and economic analysis: the case study of Thai cement in-dustry. Energy Pol 2010;38(1):392e405. Hasanbeigi A, Price L, Lu H, Lan W. Analysis of energy-efficiency opportunitiesfor the cement industry in Shandong Province, China: a case study of 16cement plants. Energy 2010;35(8):3461-73.
	Iron and steel	Zhang Q, Zhao X, Lu H, Ni T, Li Y. Waste energy recovery and energy efficiencyimprovement in China's iron and steel industry. Appl. Energy 2017;191:502e20.https://doi.org/10.1016/j.apenergy.2017.01.072. Rodrigues da Silva, R., Mathias, F. R. de C., & Bajay, S. V. (2018). Potential energy efficiency improvements for the Brazilian iron and steel industry: Fuel and electricity conservation supply curves for integrated steel mills. Energy, 153, 816–824.
	Food industry	Sathitbunanan S, Fungtammasan B, Barz M, Sajjakulnukit B, Pathumsawad S. An analysis of the cost-effectiveness of energy efficiency measures and factors affecting their implementation: a case study of Thai sugar industry. EnergyEfficiency 2015;8(1):141e53.https://doi.org/10.1007/s12053-014-9281-7.
	Paper production	Hasanbeigi et al, 2016. Energy efficiency in the German pulp and paper industry – a model-based assessment of saving potentials. Kong L, Hasanbeigi A, Price L, Liu H. Energy conservation and CO_2 mitigationpotentials in the Chinese pulp and paper industry. Resour Conserv Recycl2017;117(Part A):74e84.https://doi.org/10.1016/j.resconrec.2015.05.001.
	Chemistry and pharmacy	Zuberi un Patel, 2019. Cost-effectiveness analysis of energy efficiency measures in the Swiss chemical and pharmaceutical industry Ma D, Hasanbeigi A, Price L, Chen W. Assessment of energy-saving andemission reduction potentials in China's ammonia industry. Clean TechnolEnviron Policy 2015;17(6):1633e44.https://doi.org/10.1007/s10098-014-0896-3.
Technological systems	Motor systems	Aimee McKane, Ali Hasanbeigi. Motor systems energy efficiency supply curves: A methodology for assessing the energy efficiency potential of industrial motor systems. Energy Pol 2011;39(10):6595e607.https://doi.org/10.1016/j.enpol.2011.08.004. McKane A, Hasanbeigi A. Motor systems efficiency supply curves. Vienna,Austria: United Nations Industrial Development Organization; 2010. Zuberi et al. 2017. Techno-economic analysis of energy efficiency improvement in electric motor driven systems in Swiss industry.
	Steam systems	Ali Hasanbeigi, Greg Harrell, Bettina Schreck, Pradeep Monga. Moving beyond equipment and to systems optimization: techno-economic analysis of energy efficiency potentials in industrial steam systems in China
International level		Fraunhofer ISI, 2009. Study on the Energy Savings Potentials in EU Member States, Candidate Countries and EEA Countries Final Report

ANNEX 2

Lifetimes of energy efficiency measures

Category	Type of measure	Measure lifetime, years	Source
Lighting	Energy efficient lighting in industrial buildings	10	(Ministry of Economics, n.d.)
	Outdoor lighting	10	Energy audit based assumption
Management	Energy management in companies, Energy monitoring	2-5	Energy audit based assumption, (Andersson et al., 2018; European Commission, 2019a)
Equipment	Installation of a new circulation pump or replacement of an existing one	7	(Ministry of Economics, n.d.)
	Replacement of electric motors in industrial enterprises (for lower power motors)	10	(Ministry of Economics, n.d.)
	Replacement of rotary motors with lower power motors	10	(Ministry of Economics, n.d.)
	Electric motors with variable speed drive	10	(European Commission, 2019a; Ministry of Economics, n.d.)
Other equipment	Examples inclued the purchase of a new woodworking line, the replacement of a processing line, a new crushing plant, the replacement of a laser plant with a new plant, etc.	12	(Andersson et al., 2018)
Compressed air systems	Compressor replacement, frequency converters	10	(European Commission, 2019a)
	Leakage prevention, compressor operation optimization	2	(European Commission, 2019a)
	Heat recovery	10	(European Commission, 2019a)
Ventilation	Installation of ventilation system with heat recovery (installation of recuperator)	20	(Ministry of Economics, n.d.)
	Replacement of the ventilation system *(if the installation of recuperation is not mentioned)*	10	(European Commission, 2019a)
Transport	Use of engine efficiency lubricants for passenger cars	3	(Ministry of Economics, n.d.)
	Use of engine efficiency lubricants for light commercial vehicles	3	(Ministry of Economics, n.d.)
	Use of engine efficiency lubricants for commercial freight transport (up to 3.5 t)	3	(Ministry of Economics, n.d.)
	Use of engine efficiency lubricants for buses and lorries (over 3.5 t)	2	(Ministry of Economics, n.d.)
	Use of fuel - efficient tires for passenger cars	3	(Ministry of Economics, n.d.)
	Use of fuel-efficient tires for light commercial vehicles	3	(Ministry of Economics, n.d.)
	Use of fuel-efficient tires for commercial freight transport (up to 3.5 t)	3	(Ministry of Economics, n.d.)
	Use of fuel-efficient tires for buses and lorries (over 3.5 t)	2	(Ministry of Economics, n.d.)
	Car replacement	(100000km)	(European Commission, 2019a)
Buildings	Wall insulation	20 >25	(European Commission, 2019a; Ministry of Economics, n.d.)
	Replacement of windows	30 >25	(European Commission, 2019a; Ministry of Economics, n.d.)
	Roof insulation	20	(Ministry of Economics, n.d.)
Heating	Boiler adjustments (management)	2	(European Commission, 2019a)
	Improvement of the heating system	20	(European Commission, 2019a)
	Pipeline insulation	20	(European Commission, 2019a; Ministry of Economics, n.d.)
	Recovery of excess heat	10	(European Commission, 2019a)
	Boiler replacement (for high efficiency)	20	(European Commission, 2019a)
Solar panels	20 years for collectors	20	Energoauditu pieņēmums
Other	Reactive energy compensation equipment	12	(Andersson et al., 2018)
	CHP	10	(European Commission, 2019a)