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POLICY REPORT ON ENERGY EFFICIENCY POTENTIAL IN THE INDUSTRY

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Introduction

Within the framework of the National Research Programme "Energy Efficiency", the Riga Technical University Institute of Energy Systems and Environment implements the project "The pathway to energy efficient future for Latvia (EnergyPath). The project aims to assess the energy efficiency potential of industry, services, agriculture, transport and the household sector. In this documenta a **policy report on the energy efficiency potential of the industrial sector** is presented in line with the objectives of the project implementation timetable.

The report contains a description of the results of the estimated economic and technical energy efficiency potential for reducing energy consumption and CO_2 emissions in the industrial sector in the division of industry sub-sectors. A benchmark is applied, to identify long-term development opportunities for the sector in terms of improving energy efficiency performance. In addition, case studies and benchmarks have been carried out for certain technological processes of the industrial sub-sectors that are widely used in the economy. Using the "top-down" approach, an industrial energy efficiency composite index has been developed, that compares different sub-sectors of industry, identifying the different energy consumption tendencies between the sub-sectors.

The methodology used for the calculation of the energy efficiency potential in this study is based on the methodological model developed in the previous stage of the project. In order to obtain more in-depth results and detailed overview, the previously-developed model was adapted and adjusted for the data analysis of the industry, as it can be seen in Figure 1.

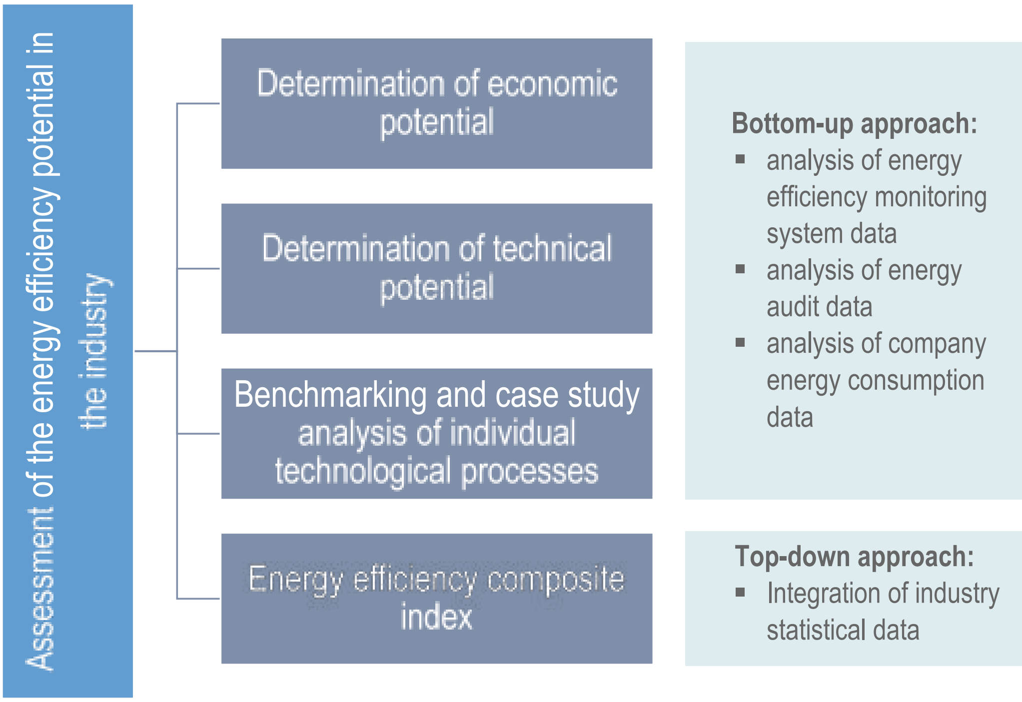


Fig. 1. Methodology for assessing the energy efficiency potential in the industry.

The study uses the energy efficiency monitoring system database provided by the Ministry of Economics (ME) and data from available energy audits of the companies operating in the industry. Data on the energy consumption dynamics by specific companies were also obtained and analysed in detail. Case studies were carried out using this data. In addition, publicly available data on energy consumtion, economic, technical and environmental ratios of the industrial sector was analyzed and integrated into the industrial energy efficiency composite index.

The content of the report is structured according to the methodological framework. The first chapter describes the evaluation of energy efficiency in industry, including the calculation of economic and technical potential. The second chapter includes the determination of benchmarks for the widely used technological processes in the economy, as well as the description of the case study analysis. The third chapter describes the results from the industrial energy efficiency composite index identifying the differences in the energy efficiency levels between the different sub-sectors of the industry.

1. IDENTIFYING ENERGY EFFICIENCY POTENTIAL

The methodology for evaluating the energy efficiency potential is based on the primary objective of the study and the project deliverable: to develop a policy report on the energy efficiency potential of the industry. In the framework of this chapter, an in-depth analysis of the Energy Efficiency Monitoring System (EMS) and available energy audits data from the Ministry of Economics (ME) has been carried out, which provides valuable conclusions for the sustainable development of energy efficiency in the industrial sector. The study uses data from the Energy Efficiency Monitoring System (EMS), which is currently the only energy efficiency monitoring system in Latvia. As a result, potential energy efficiency savings calculated in the study also reflect the efficiency of the programme in Latvia. In addition, the energy audits data of 123 industrial companies derived from the energy audits reports submitted to ME have been used.

According to the developed study methodology algorithm, the methodological framework of this chapter includes several phases of the research and the use of different data sources. A mathematical model was created for statistical analysis and calculation in *MS Excel* software. Table 1-1. summarises the methodological framework of the chapter in the breakdown by the research activity as well as the data sources used to calculate energy efficiency potential. Data from the Central Statistical Bureau (CSB) on energy consumption in 2017, was taken as the reference year in the scope of this chapter. The available statistics from the TJ units of measurement were converted into GWh units in order to ensure a uniform representation of the units of measure in the study.

Table 1-1.

Scope for calculating energy efficiency potential and used data sources

No.	Research phase	Data source
1.	Analysis of energy efficiency monitoring system data	• Ministry of Economics (ME) Energy Efficiency Monitoring System (EMS) program data • Central Statistical Bureau (CSB) energy balance (ENG020) data (CSP, n.d.-a) • *Eurostat* air emissions accounts by NACE Rev. 2 classification (env_ac_ainah_r2) data (Eurostat, 2020a)
2.	Assessment of the economic energy efficiency potential	
3.	Assessment of the technical energy efficiency potential	• Industrial energy audit data • Central Statistical Bureau (CSB) energy balance (ENG020) data (CSP, n.d.-a) • *Eurostat* air emissions accounts by NACE Rev. 2 classification (env_ac_ainah_r2) data (Eurostat, 2020a)
4.	Applying the benchmark for the technical energy efficiency potential of industry	• Calculation of the technical energy efficiency potential (from 2nd activity) • Scientific publication of Paramonova and Thollander (2016) (Paramonova & Thollander, 2016)

In the scope of the research, the data was collected on the sub-sectors of industry according to NACE Rev. 2.0 classification. Table 1-2. summarises the sub-sectors of the industry in division by their NACE code. The industrial sub-sectors were grouped according to the generally accepted statistical sectoral breakdown of energy balance (CSP, n.d.-b). The description of industry characteristics includes both the mining industry and the manufacturing industry. NACE Division C33 (repair and installation of machinery and equipment) is not included in the overall industry analysis. In the energy balance data for the industry of the Central Statistical Bureau database (CSB) and in the generally accepted statistical sectorial division of the energy balance (Eurostat, 2019) this sector is not included in the overall industry energy consumption data. Therefore, to obtain as precise calculations of energy efficiency potential as possible this sector is not included in the scope of this reseach. Moreover, only 3 records were available in the EMS dataset for companies operating in this sector, of which only 2 indicated projected savings. Consequently, the exclusion of this sector is not considered to be a significant limitation of the model, but on the contrary, it allows for a more accurate and objective assessment of the industry, in line with the generally accepted international requirements for the compilation and analysis of industrial statistics.

Table 1-2.

Industrial sector grouping according to NACE Rev. 2 classification (CSP, n.d.-b)

NACE code	Sector name
B	Mining and quarrying
C10-12	Food, drink and tobacco production
C13-15	Manufacture of textiles, clothing and leather products
C16	Manufacture of wood, wood and cork products
C17-18	Manufacture of paper and paper products; printing and reproduction of recorded media
C20-21	Manufacture of chemical and pharmaceutical products
C22, 31, 32	Manufacture of rubber, plastic products, furniture and other forms
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25-28	Manufacture of fabricated metal products, computers, electronic and optical equipment, electrical equipment, machinery and work machinery n.e.c.
C29-30	Manufacture of motor vehicles, trailers and other vehicles

1.1. Analysis of energy efficiency monitoring system data

Of the EMS data, where a total of 1490 companies were available, 431 companies were in line with the industrial classification defined above. The data of these selected companies was used in the data analysis of this chapter. The data available in the EMS database can be divided into two parts:

1. data on the total energy resources (including electricity and heat) achieved and projected savings, including the breakdown of savings by type of energy efficiency activities;
2. data on electricity consumption in a three-year period — 2016, 2017, 2018.

The structure of this sub-chapter is based on the division by the defined grpups of the available data. The first part summarises an analysis of statistical data on energy savings for industrial companies in 2016 and 2017. A large part of the analysis of the industry's EMS and energy audits data has already been demonstrated in the project report submitted previously. This report continues on what has already been done, in addition to the analysis of the data carried out in the past with statistical data aggregates and conclusions. The second part of the sub-chapter summarises the electricity consumption trends of the sub-sectors of the industry.

1.1.1. Achieved and forecasted savings

The total projected annual energy savings by the industry in the energy efficiency monitoring system (EMS) program is 189,1 GWh or 2,12% of the total energy consumption in the industry in 2017. In 2016, 12 industrial companies had identified the achieved savings, which together accounted for 9,9 GWh. That is 0,11% of total energy consumption in the industry. Meanwhile, in 2017, 84 industrial companies demonstrated the achievement of energy savings, bringing together 59,3 GWh of energy savings in the sector, representing 0,66% of total energy consumption in the sector. Figure 1-1. reflects the overall trends of projected and achieved savings in the industrial sector in the national energy efficiency monitoring system (EMS) program.

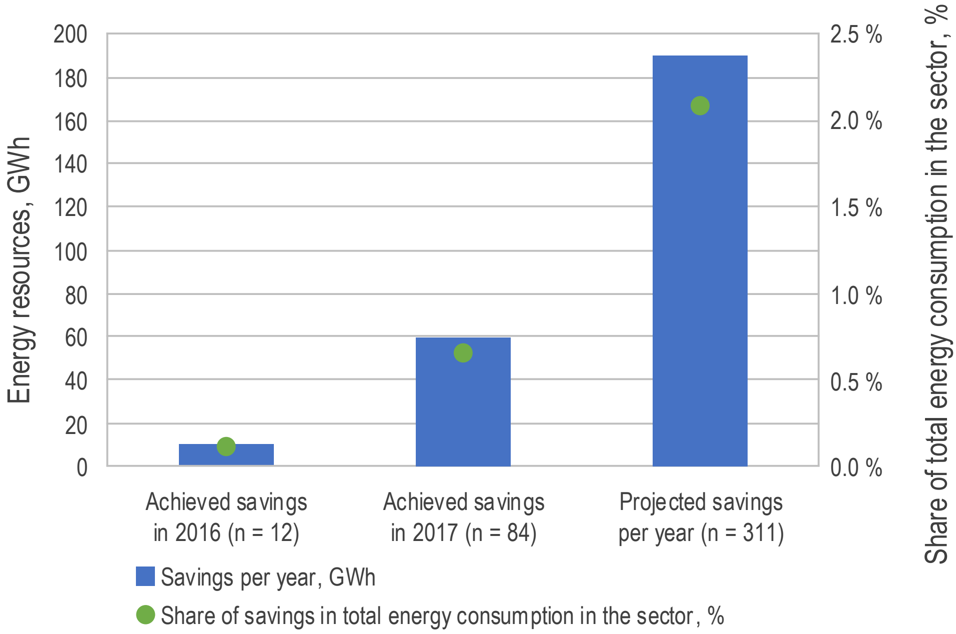
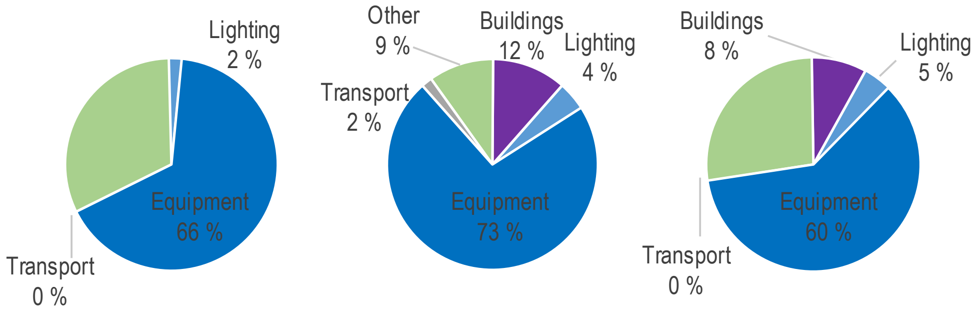


Figure 1-1. Achieved and projected energy savings in the national EMS programme by companies operating in the industry (CSP, n.d.-a).

In total, in the first two years of the programme, i.e. in 2016 and 2017, 69,2 GWh of energy savings in the industrial sector were achieved, indicating that companies plan to achieve most of the identified savings only in the last years to meet the conditions of the EMS program. This indicates that the largest potential for energy savings is expected in the accounting data for 2020 and 2022. It should be noted that the estimated share of the savings from total energy consumption reflects the economic energy efficiency potential in the industry, which is achieved through the introduction of energy efficiency activities in companies under the EMS program.

Figure 1-2. shows the breakdown of the achieved actural energy savings and projected savings by EMS companies in the industry by major energy consumption groups. In the industrial sector, the largest actual savings and the projected savings are achieved by improving the energy efficiency of the equipment. Comparing the figures reported by the consumption groups, in 2016 66% and 2017 73% of the actual savings reported by consumption groups constitute investment in the equipment. Nearly a third or 32%, of savings in 2016 consist of implementation of other activities. In 2016, the smallest proportion or 2%, consists of lighting modernisation activities.

In 2017, improvements in the energy efficiency of buildings accounted for 12% of savings by the major consumption groups. Lighting modernisation activities represented 4%, transport 2% and other activities – 9% of the energy savings reported in consumption groups. From the estimated savings data per consumption group, it can be seen that the largest savings, or 60%, are expected from the energy efficiency improvement in the equipment, 27% from other activities, 8% from buildings, 5% from lighting activities and only 0,3% from transport.



a) Actual savings in 2016; b) Actual savings in 2017; c) Projected savings

Figure 1-2. Actual and projected energy savings broken down by energy efficiency activities in the industrial sector.

It should be noted that the savings data presented by consumption groups are incomplete and not all companies have indicated them. The data shown in Figure 1-2. are derived from industrial enterprises in the EMS system that have identified the breakdown of savings by consumption groups, but do not reflect the proportional distribution of all actual and projected savings (from Figure 1-1.) by the consumption groups. In the future, it would be valuable to monitor more closely the input data of EMS from a number of industrial companies in order to ensure a complete and correct representation of data, which would provide a more accurate assessment of the overall energy efficiency performance of the sector in and the overall EMS program.

1.1.2. Electricity consumption trends

Overall electricity consumption in the industrial sector has a growing trend and electricity consumption in the industrial companies operating under EMS has increased by 151,5 GWh over the last three years. An increase of 73 GWh was observed in 2017 compared with the values of the year 2016. Electricity consumption increased by 78,4 GWh in 2018, compared with 2017 consumption figures. The total electricity consumption of the industrial sector in the EMS program amounted to 1633,2 GWh in 2018. Figure 1-3. shows the trend in the overall electricity consumption of EMS companies in the industrial sector.

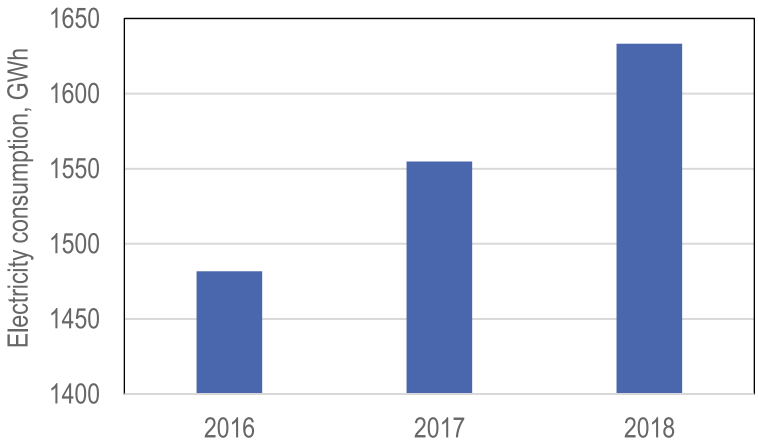


Figure 1-3. The total electricity consumption of the industry in the EMS program.

The largest electricity consumption is observed in the wood and cork manufacturing sector (C16), where electricity consumption reached 759,1 GWh in 2018. The second largest electricity consumer is the non-metallic mineral production sector (C23), which consumed a total of 274,5 GWh in 2018. On the other hand, the smallest electricity consumption is observed in sectors such as metals production (C24) with 18,0 GWh, manufacture of textiles, clothing and leather products (C13-C15) with 21.5 GWh and manufacture of paper and paper products; printing and reproduction of records (C17-C18) with 24,2 GWh electricity consumption. Figure 1-4. shows electricity consumption in each of the industrial sub-sector over the past three years.

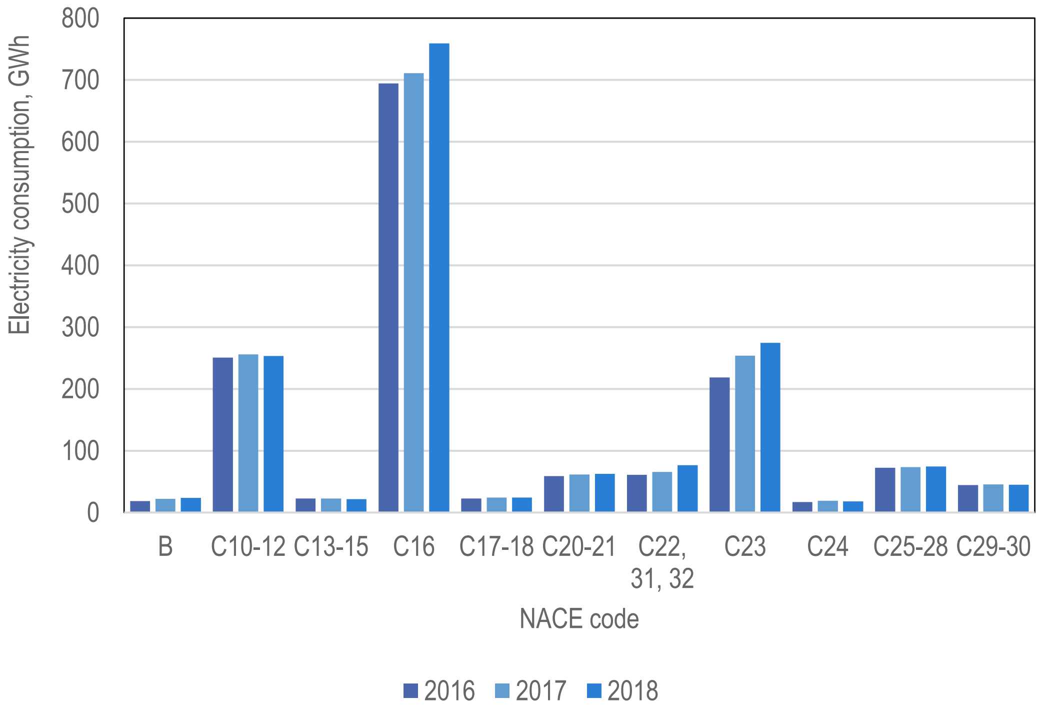


Figure 1-4. The electricity consumption of the industrial sector in the EMS program, broken down by sub-sector according to NACE Rev. 2 classification.

Table 1-3. summarises the energy consumption data of the EMS industrial companies and their electricity consumtion trends. The analysis of electricity consumption data includes all electricity data available in the EMS system for 431 industrial companies.

It is noted that only the textile, clothing and leather sector (C13-C15) has a reduction in electricity consumption in both 2017 and 2018. Half of the sectors show an annual increase in electricity consumption. However, more and more sectors have achieved a reduction in electricity consumption in 2018 compared to 2017, such as the food, drink and tobacco sector (C10-12) with 2,3 GWh, paper and paper products; printing and recording sector (C17-C18) with 0,2 GWh, metals sector (C24) 1,2 GWh and the manufacturing sector of cars, trailers and other vehicles sector (C29-30) with a savings of 0,5 GWh in 2018 compared to the electricity consumption data for 2017. Although electricity reductions were achieved in these sectors in 2018, it did not, however, offset the increase in electricity in the sectors with the highest electricity consumption, such as the wood production (C16) and non-metallic mineral production sector (C23), where there were 47,9 GWh and 20,9 GWh an increase in 2018 respectively compared to the 2017 consumption data.

Table 1-3.

Industrial EMS programmes breaking down electricity consumption trends by sector

NACE code	Annual electricity consumption, GWh			Tendency, GWh		Electricity consumption in the sector in 2017, GWh (CSP, n.d.-a)	Share of electricity consumption by EMS companies,%
	2016	2017	2018	2017–2016	2018–2017		
B	18,8	22,1	23,9	↑ 3,4	↑ 1,7	27,8	79,7 %
C10-12	250,6	255,8	253,5	↑ 5,2	↓ 2,3	288,4	88,7 %
C13-15	22,8	22,5	21,5	↓ 0,3	↓ 1,0	30,0	75,0 %
C16	694,1	711,2	759,1	↑ 17,1	↑ 47,9	762,3	93,3 %
C17-18	22,6	24,4	24,2	↑ 1,8	↓ 0,2	27,8	87,8 %
C20-21	58,9	61,4	62,5	↑ 2,5	↑ 1,1	64,4	95,3 %
C22, 31, 32	61,2	65,5	76,8	↑ 4,3	↑ 11,2	78,1	83,9 %
C23	218,4	253,7	274,5	↑ 35,3	↑ 20,9	261,1	97,1 %
C24	17,1	19,2	18,0	↑ 2,1	↓ 1,2	19,4	98,5 %
C25-28	72,6	73,7	74,4	↑ 1,1	↑ 0,8	89,2	82,6 %
C29-30	44,5	45,3	44,8	↑ 0,7	↓ 0,5	46,7	97,0 %
Total	**1481,7**	**1554,7**	**1633,2**	↑ **73,0**	↑ **78,4**	**1695,1**	**91,7 %**

Figure 1-5. illustrates the share of electricity consumption by EMS companies in the industry from the total electricity consumption by industry. In all sub-sectors of industry, the electricity consumption of EMS companies accounts for a majority, or at least 75%. Consequently, the other companies represent a very small part of the overall electricity consumption of the industry. In sectors such as food, drink and tobacco production (C13-15), manufacturing of finished products, computers, electronic and optical equipment, electrical equipment, machinery and work machines (C25-28) and the mining sector (B) account for a higher share of electricity from other companies from the total electricity consumption of the industry, compared with the other sectors.

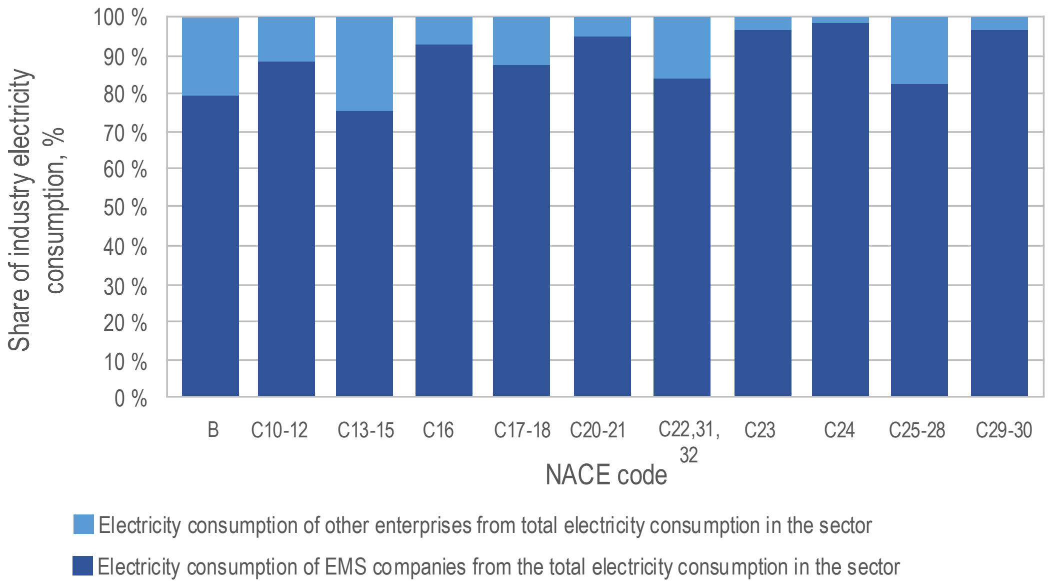


Figure 1-5. The share of electricity consumption of EMS program industrial comapnies from the total electricity consumption in industry broken down by the sub-sectors.

1.2. Identifying the economic potential of energy efficiency

This sub-chapter provides a detailed analysis of the estimated energy savings and economic energy efficiency potential identified by each sub-sector of industry (see Table 1-4.).

Table 1-4.

Outline of EMS statistics on projected savings identified by industrial companies

NACE code	Total number of records in EMS	Number of records showing estimated savings	Part of the total number of records showing estimated savings,%
B	18	13	72 %
C10-12	115	78	68 %
C13-15	9	9	100 %
C16	125	93	74 %
C17-18	16	15	94 %
C20-21	15	12	80 %
C22, 31, 32	30	25	83 %
C23	24	17	71 %
C24	8	5	63 %
C25-28	61	37	61 %
C29-30	10	7	70 %
Total	**431**	**311**	**72 %**

The lack of EMS monitoring data and a lack of complete information provided by companies that limits the accurate calculation of the economic energy efficiency potential. Nearly a third, or 28% of industrial companies, have not identified their projected savings in the EMS system, which have a corresponding impact on the results of the overall energy efficiency potential assessment. This aspect should be taken into account when drawing conclusions on the overall energy efficiency potential of the sector, considering that a relatively large proportion of companies are not included in the analysis. The smallest proportion of the companies that have identified the expected savings is the manufacturing sector of fabricated metal products, computers, electronic and optical equipment, electrical equipment, machinery and work machines (C25-28) with 61%, the metals sector (C24) with 63% and the food, beverage and tobacco sector (C10-12) with 68%.

In view of the fact that not all companies in the database reported the estimated annual savings, only those companies in each of the industry sub-sectors that indicated projected annual energy savings were selected in order to make full estimates of their energy efficiency potential. In total in the industry, these are 311 companies.

1.2.1. Assessment of the reduction in energy consumption

Overall, the vast majority of the total energy savings of industry is projected in the wood, wood and cork products sector (C16), where the estimated annual energy savings are 148,8 GWh, representing 78,7% of the total sector's projected savings. The second largest projected energy savings are expected in the food, beverage and tobacco sector (C10-12), which project to reach savings of 13,5 GWh per year. This is followed by the non-metallic mineral products manufacturing sector (C23), with a projected 5,8 GWh energy savings per year. Table 1-5. summarises the projected energy savings for the industrial sector in EMS.

Table 1-5.

Outline of energy savings projected by sub-sectors of industry

NACE code of the sector	Projected annual energy savings, GWh	Total energy consumption in the sub-sector in 2017, GWh(CSP, n.d.-a)	Projected annual energy savings,% of the total energy consumption of the sub-sector
B	1,03	91,12	1,1 %
C10-12	13,52	907,29	1,5 %
C13-15	2,45	95,29	2,6 %
C16	148,79	5450,16	2,7 %
C17-18	1,81	63,89	2,8 %
C20-21	1,89	313,08	0,6 %
C22, 31, 32	4,92	174,46	2,8 %
C23	5,78	1518,18	0,4 %
C24	0,88	29,72	3,0 %
C25-28	4,77	202,24	2,4 %
C29-30	3,21	88,34	3,6 %

On the other hand, the production of cars, trailers and other vehicles (C29-30) with 3,6% and metals production (C24), with 3%, reports the highest relative savings in the industrial sector, by measuring the projected energy savings of each sector relative to the total energy consumption of the sector in the country in 2017. In addition, in the metals sector (C24), only 5 companies indicated the expected savings, so a relatively large relative savings in the are achieved despite the fact that a very small number of company savings reported. However, production of non-metallic mineral products (C23) with 0,4% and manufacture of chemical and pharmaceutical products (C20-21) with 0,6% project relatively lowest energy savings. Figure 1-6. illustrates the economic potential of energy efficiency that will be achieved in each of the sub-sectors analysed.

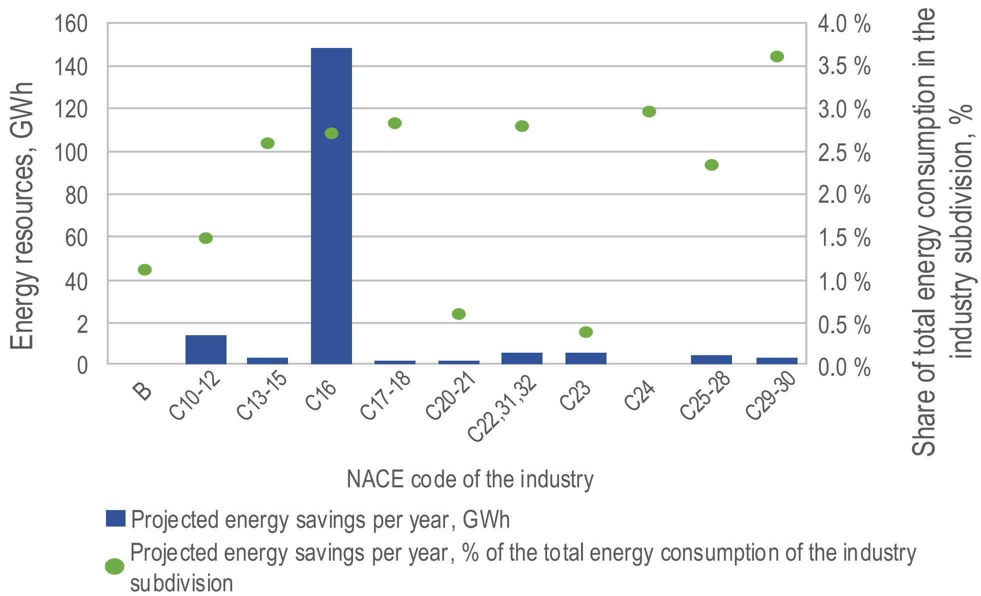


Figure 1-6. Economic energy efficiency potential in industrial sub-sectors.

The average economic energy efficiency potential among industry sub-sectors is equal to 2,1%. For the majority or 7 (out of 11) sectors, the potential values are above the average. However, in addition to the previously mentioned sector - non-metallic mineral products manufacturing (C23) and chemical and pharmaceutical products manufacturing (C20-21), mining sector (B) with 1,1% and food, beverage and tobacco production (C10-12) with 1,5% show potential values below the industry average.

1.2.2. Assessment of CO_2 reduction

Based on the previously aggregated data on the economic energy efficiency potential, which shows the share of the projected energy savings of each industrial sub-sector, the projected annual CO_2 emissions savings were calculated. In order to estimate savings of CO_2 emissions, at first CO_2 intensity was calculated for each sub-sector, which was derived from the proportion of CO_2 emission amounts per total energy consumption in the sub-sector. When CO_2 intensity was determined, from previously calculated projected annual energy savings, share of CO_2 emission amounts was estimated that will be reduced as a result of achieved energy savings. The results of the calculations obtained are summarised in Table1-6.

Table1-6.

Summary of CO_2 savings in industrial sub-sectors

NACE code	Projected annual energy savings, GWh	CO_2 intensity, tons/MWh	CO_2 emissions, tons (2017) (*Eurostat*, 2020a)	Projected annual CO_2 savings, tons
B	1,03	0,39	35679	403
C10-12	13,52	0,15	134927	2011
C13-15	2,45	0,15	13887	357
C16	148,79	0,02	112350	3067
C17-18	1,81	0,14	8632	245
C20-21	1,89	0,13	41355	250
C22, 31, 32	4,92	0,09	16163	456
C23	5,78	0,49	749839	2855
C24	0,88	0,09	2727	81
C25-28	4,77	0,14	28003	660
C29-30	3,21	0,07	6271	228
Total	**189,1**	**-**	**1149833**	**10612**

The total estimated annual CO_2 savings in the industrial sector amounts to 10 612 tons, representing around 0,92% of the total annual CO_2 emissions of the industry. The largest projected reduction is expected in the wood and cork products manufacturing sector (C16), with a total of 3 067 tonnes of CO_2 savings. The second largest emissions reduction was calculated in the non-metallic mineral manufacturing sector (C23), which foresees a reduction of 2 855 tonnes of CO_2 emissions. It should be noted that, given the high CO_2 intensity of this sector, the reduction in energy consumption in this sector constitutes a particularly large reduction in CO_2. The food, drink and tobacco manufacturing sector (C10-12) reports a savings of 2 011 tons of CO_2 emissions. Figure 1-7. illustrates the expected CO_2 reductions in each of the sub-sectors of the industry, based on calculated economic energy efficiency potential.

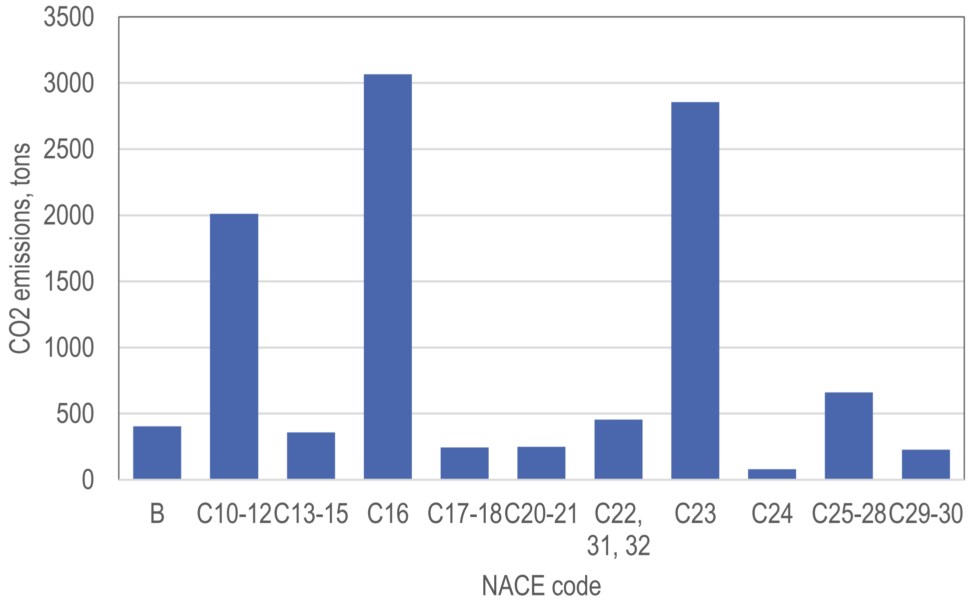


Figure 1-7. The projected economic savings of CO_2 emissions in the industrial sub-sectors.

1.3. Identification of the technical potential for energy efficiency

The technical energy efficiency potential in the industrial sector was determined based on company energy audit data. A total of 123 energy audits from the industrial sector companies were available, of which 12 companies did not have a complete dataset, i.e. no information on the maximum energy savings potential was available or no data was provided on the company's total energy final consumption. Thus, as a result of the data processing, the incomplete sections of 12 records with the missing data were excluded from the overall data set and the final analysis was based on the energy audits data of 111 industrial companies, broken down by the sub-sectors according to the NACE Rev. 2.0 classification listed in Table 1-2. .

Table 1-7.

Data analysis of the technical energy efficiency potential of the industry and its corresponding sub-sectors

NACE code	Industry (total)	B*	C10-C12	C13-C15	C16	C17-C18	C20-21*	C22, C31, C32	C23	C24*	C25-C28	C29-C30*
Average	6,35	1,03	5,58	8,13	6,53	8,33	1,98	6,51	2,57	3,56	8,46	5,66
Median	3,38	1,03	2,56	7,02	3,21	5,44	1,98	2,72	1,02	3,56	6,74	5,66
Standard deviation	7,68	-	9,55	6,88	7,43	8,49	-	7,24	2,73	3,19	7,86	3,27
Min Value	0,13	1,03	0,61	1,00	0,13	0,25	1,98	0,41	0,30	1,31	0,68	3,35
Max. Value	40,11	1,03	40,11	17,48	32,11	24,63	1,98	19,12	6,55	5,82	30,83	7,97
Range	39,97	-	39,49	16,48	31,97	24,38	-	18,71	6,25	4,51	30,15	4,62
Number of records	111	1	26	4	36	6	1	9	7	2	17	2

* Values at company level

In order to calculate the sector-specific energy efficiency potential, a methodological approach was taken from the publication of Paramonova and Thollander (2016), which evaluated the results of a similar energy efficiency monitoring system program introduced in Sweden.

The energy savings potential for each sector was calculated in two main calculation steps. At first, the energy efficiency potential of each company was calculated on an individual basis as a percentage of the estimated annual savings from the total energy consumption indicated. Secondly, the total sub-sector's potential was determined as the average value between calculated energy-efficiency potential of the companies operating in the specific industrial sub-sectors. Table 1-7.summarises the resulting energy audit statistical analysis data, where the average value indicated by each sector corresponds to the percentage of energy efficiency potential in Latvia in each of the relevant sub-sectors. In addition, the the overall energy efficiency potential of the industry, including all sub-sectors was outlined. The average value shown in Table 1-7. represents the technical potential of each sector of industry as a share of the total energy consumption of the company.

Table 1-8.

Industrial energy efficiency technical potential and benchmark calculation values

NACE code	**B***	**C10-C12**	**C13-C15**	**C16**	**C17-C18**	**C20-21***	**C22, C31, C32**	**C23**	**C24***	**C25-C28**	**C29-C30***
Energy consumption, GWh (CSP, n.d.-a)	91	907	95	5450	64	313	174	1518	30	202	88
CO_2 intensity, tonnes/MWh (Eurostat, 2020a)	0,39	0,15	0,15	0,02	0,14	0,13	0,09	0,49	0,09	0,14	0,07
Energy efficiency technical potential in Latvia,%	**1,03**	**5,58**	**8,13**	**6,53**	**8,33**	**1,98**	**6,51**	**2,57**	**3,56**	**8,46**	**5,66**
Annual energy savings identified in energy audits, GWh	0,9	50,6	7,7	355,7	5,3	6,2	11,4	39,0	1,1	17,1	5,0
Annual CO_2 savings identified in energy audits, tonnes	369	7528	1129	7332	719	820	1052	19285	97	2369	355
Technical potential for energy efficiency in Sweden,% (Paramonova & Thollander, 2016)	**5**	**20**	**22**	**18**	**22**	**16**	**21**	**13**	**3**	**30**	**30**
Annual potential energy savings (by Swedish benchmark), GWh	4,6	181,5	21,0	981,0	14,1	50,1	37,2	197,4	0,9	60,2	26,5
Potential annual CO_2 savings (by Swedish benchmark), tonnes	1784	26985	3055	20223	1899	6617	3448	97479	-	8331	1881
Annual technical energy efficiency savings potential, GWh	**3,6**	**130,8**	**13,2**	**625,4**	**8,7**	**43,9**	**25,9**	**158,3**	**-**	**43,1**	**21,5**
Annual CO_2 savings potential, tonnes	1415	19457	1926	12891	1180	5796	2396	78195	-	5962	1527

* Values at company level

It should be noted that the estimated values of the sector's technical energy-efficiency potential in the mining sector (B), chemical and pharmaceutical products manufacturing sector (C20-21), basic metals manufacturing sector (C24), car, trailer and other vehicle manufacturing sector (C29-30) were only identified at company level due to lack of data. For the above mentioned sub-sectors, data for only 1 or 2 companies were available, which do not allow to obtain objective assessment of the sector. As an explanation for it is that a high number of companies choose to introduce energy standards rather than to carry out energy audits. Company-level data in the above-mentioned sectors were left to provide a valuable insight into the energy-efficiency potential at company level in the specific industry sub-sector.

In order to identify the technical energy efficiency potential, the identified energy savings (GWh/year) were first calculated from the energy audits. This is calculated as the potential energy savings value from the total energy consumption of each sector. A benchmark was then determined based on a Paramonova & Thollander (2016) study identifying the savings potential of each industry sub-sector. The results of the study of Paramonova & Thollander (2016) are taken as a benchmark for the Latvian industrial sub-sectors, as the Swedish technical approach serves as an example of good practice to identify opportunities for achieving the long-term technical energy efficienct potential in the Latvian industry sector.

Table 1-8. summarises the values of the calculated technical energy savings potential. The annual technical energy efficiency potential in each sector is calculated as the difference between the annual energy savings potential (defined from the Swedish benchmark) and the annual energy savings identified in energy audits. Consequently, the annual potential for energy savings represents an additional part of the unused technical potential in Latvia.

The annual energy savings identified in the energy audits reflect the technical energy efficiency potential in Latvia by applying the average values of the technical potential obtained in the industrial energy audits to the specific sector as a whole. The total energy savings identified in industrial energy audits in Latvia amounts to 500,1 GWh, representing 5,6% of the total energy consumption of the industry. The wood and cork products manufacturing sector (C16) identified energy savings of 355,7 GWh, which is the highest energy savings in absolute values compared to other sectors. The savings of the wood manufacturing sector (C16) represent 6,53% of the total energy consumption in the sector. The annual energy savings identified by the food, beverage and tobacco manufacturing sector (C10-C12) report 50,6 GWh, representing 5,58% of the total energy consumption of the sector.

In relative values, the greatest technical energy efficiency potential is observed in the fabricated metal products, computers, electronic and optical equipment, electrical equipment, machinery and work machines manufacturing sector (C25-C28), with 8,46% of total energy consumption and paper and paper products; printing and recording sector (C17-C18) with 8,33% of total energy consumption that is 17,1 GWh and 5,3 GWh in each of the sub-sectors, respectively.

Figure 1-8. illustrates the technical energy efficiency potential of industrial sub-sectors identified from energy audit data.

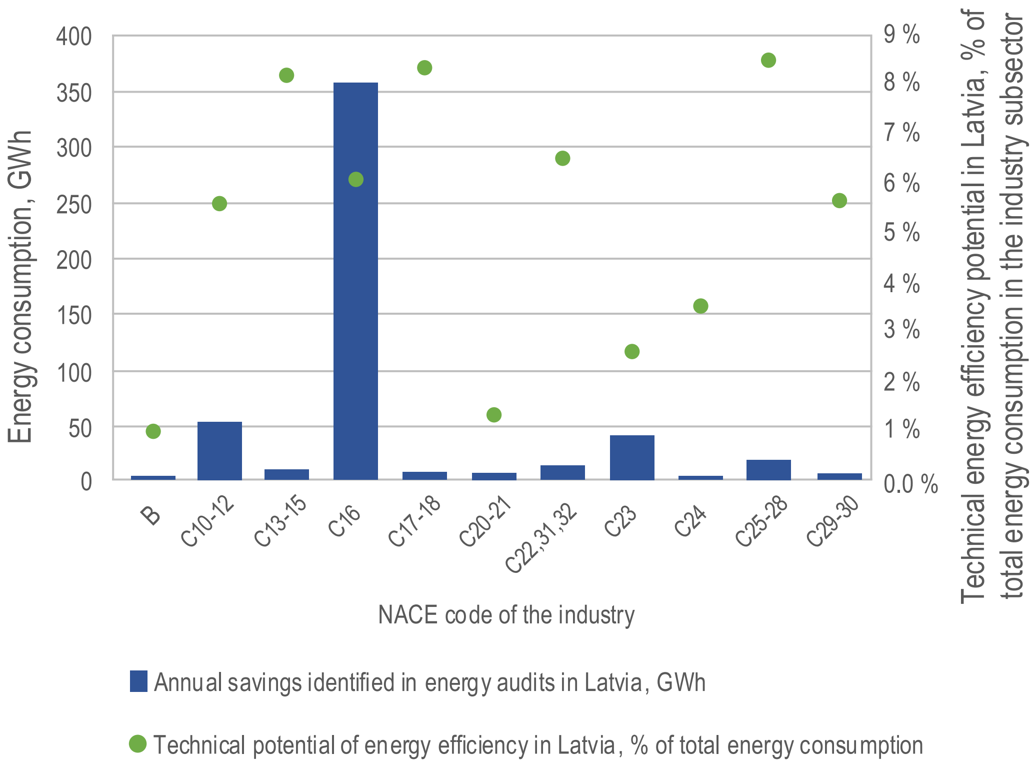


Figure 1-8. Technical energy efficiency potential of Latvian industrial sub-sectors.

The calculations show that the estimated technical energy efficiency potential is significantly higher than the economic energy efficiency potential that was outlined in the previous chapter. The projected total technical energy savings potential for industry amounts to 500,1 GWh, while the economic energy efficiency potential, or the estimated annual savings in the national energy efficiency monitoring and energy management system programme is 189,1 GWh. This leads to a valuable conclusion that companies in EMS show savings to a minimum, leading to the projected potential being incomplete and not showing the full picture and opportunities that companies could achieve in the absence of economic barriers to the implementation of energy efficiency measures.

However, given that there are differences in the calculation methodology, it is not possible to compare the economic and technical potential directly with each other. The methodological differences are explained by limits and gaps in available data, i.e. the EMS dataset does not have available data on the total consumption of energy resources of each company, which cannot result in an identical methodology for calculating economic potential, as it has been done in the calculation of technical potential.

In addition to the determination of the technical reduction in energy resources, the calculation of the potential for reduction of technical CO_2 emissions was carried out, as illustrated above in Table 1-8.

The total annual CO_2 savings identified in industrial energy audits amounts to 41 055,5 tonnes of CO_2, representing around 3,6% of the industry's total CO_2 emissions. According to EMS data, the total savings in technical CO_2 potential are nearly four times the estimated savings of economic potential.

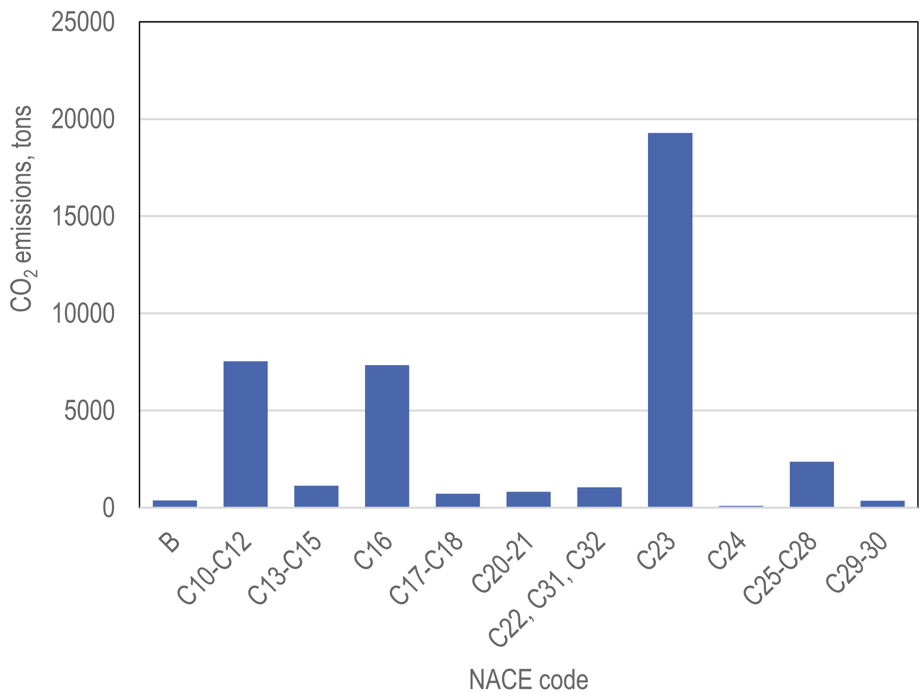


Figure 1-9. Annual savings of CO_2 emissions identified in energy audits in Latvia, broken down by industry sub-sectors.

Figure 1-9. shows the CO_2 savings identified in energy audits, broken down by industry sub-sectors. The largest reduction in CO_2 emissions is observed for the non-metallic mineral sector (C23), representing 19 285 tonnes of CO_2 savings. In the food, drink and tobacco sector (C10-12), a savings of 7528 tonnes of CO_2 was calculated, while for the wood and cork products sector (C16) a reduction of 7 332 tonnes of CO_2 was estimated. Together, these three sectors account for 34 145 tonnes of CO_2 savings, representing 83% of the total CO_2 savings identified in industrial energy audits.

1.4. Applying the benchmark to the technical energy efficiency potential

The following values of the technical potential for energy efficiency in Latvia have a suitable Swedish benchmark set out from Paramonova and Thollander (2016) study (Paramonova & Thollander, 2016). The resulting values are summarised in Table 1-8.

The largest technical potential for energy efficiency in Sweden, with a value of 30%, each is in the fabricated metals, computers, electronic and optical equipment, electrical equipment, equipment, machinery and work machines manufacturing sector (C25-C28), and the cars, trailers and other vehicles manufacturing sector (C29-C30). For these industrial sub-sectors, the technical energy efficiency potential calculated in Latvia is 8,46% and 5,66%, respectively. In Sweden, the lowest technical energy efficiency potential was obtained in the basic metals manufacturing sector (C24) with a value of 3% and in the mining and quarrying sector (B) with a value of 5% of total energy consumption.

According to the Swedish technical energy efficiency savings values, the potential annual energy savings in Latvia are calculated by applying the Swedish benchmark. As a result, the annual technical energy efficiency saving potential in each sector of the Latvian industry is calculated. It is calculated as the difference between the annual energy savings potential (determined from the Swedish benchmark) and the annual energy savings identified in Latvian energy audits.

In applying the Swedish benchmark, the highest estimated annual technical energy efficiency savings in absolute values is in the sectors of wood and cork product manufacturing sector (C16), non-metallic minerals manufacturing sector (C23) and food, beverage and tobacco manufacturing sector (C10-12), where the annual technical energy efficiency potential is 625,4 GWh, 158,3 GWh and 130,8 GWh per year, respectively. The total estimated potential for savings in energy consumption in Latvia amounts to 1074,4 GWh per year, representing 12% of total industrial energy consumption in 2017.

Figure 1-10 illustrates the difference between technical energy efficiency potential in Latvia and Sweden, as determined by the annual technical energy efficiency potential. In addition, for each industry sub-sector a benchmark is indicated.

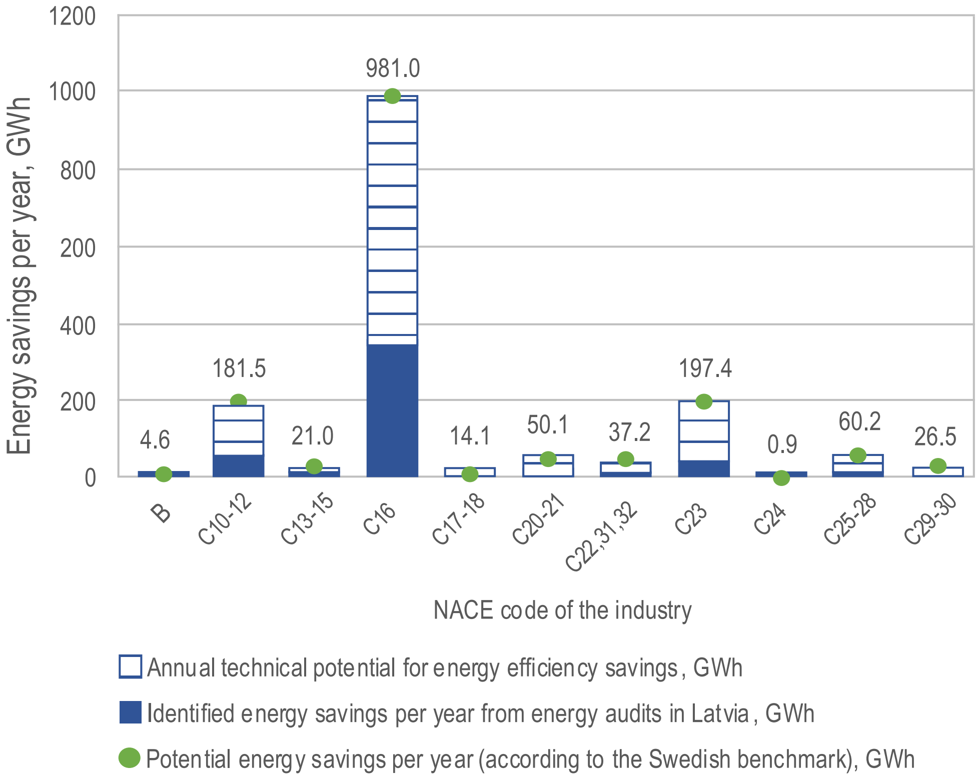


Figure 1-10. Technical savings of energy resources identified for industry in Latvia and identified potential savings from Paramonova and Thollander (2016).

All sectors of the industry, excluding basic metal manufacturing sector (C24), show a significant share of the annual technical energy efficiency potential. The metal manufacturing sector (C24) is the only one that does not foresee a higher savings potential in Sweden compared to the values of Latvia.

Using a similar approach, the values of the CO_2 benchmarks illustrated in Figure 1-11. were also calculated. The potential share of annual CO_2 savings reflects the difference between the value of the Swedish benchmark and the annual savings identified in energy audits in Latvia. In other words, this reflects an additional portion of the potential for savings that could theoretically be achieved in the sector.

The application of the Swedish benchmark resulted in a total of 171 703 tonnes of theoretical savings potential for CO_2 emissions, more than 4 times the savings identified in Latvian energy audits. The proportion of the economic CO_2 saving potential calculated for comparison represented only 10 612 tonnes of CO_2, representing 6% of the Swedish theoretical benchmark value.

More than half, or 57% of the calculated CO_2 savings benchmark value, consists of the non-metallic mineral products manufacturing sector (C23). The CO_2 benchmark for the food, beverage and tobacco manufacturing sector (C10-C12) amounts to 26 985 tonnes of CO_2, while the wood and cork products manufacturing sector (C16) is 20 223 tonnes of CO_2.

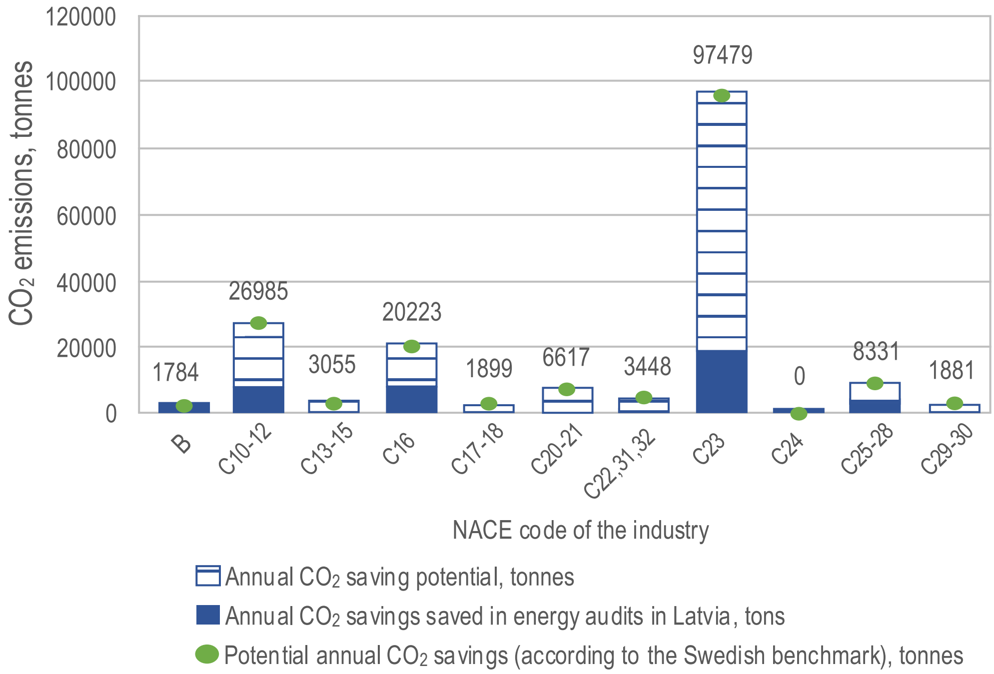


Figure 1-11. Identified CO_2 technical savings in Latvia and identified potential savings based on calculated technical energy savings.

Similarly, the percentages of technical energy savings identified in Latvia and Sweden in each sub-sector are compared. Figure 1-12. illustrates the additional unused energy savings potential of each sub-sector of the Latvian industry, calculated as the difference between the percentages of Latvian and Swedish technical energy efficiency potential.

Industry sub-sectors are divided into three groups: high, medium and low savings potential. Those sectors whose potential energy savings, following the application of the Swedish benchmark, represent 25-30% energy efficiency savings potential, have a high potential. The energy efficiency potential of 10-25% is assessed as medium and 0-10% as low potential.

Sectors with high savings potential include the manufacture of cars, trailers, etc. vehicles (C29-C30) and fabricated metal products, computers, electronic and optical equipment, electrical equipment, machinery and work machines n.e.c. (C25-C28). Meanwhile, low saving potential is for metals production sector (C24), mining and quarrying (B). Other sectors fall within the medium potential category.

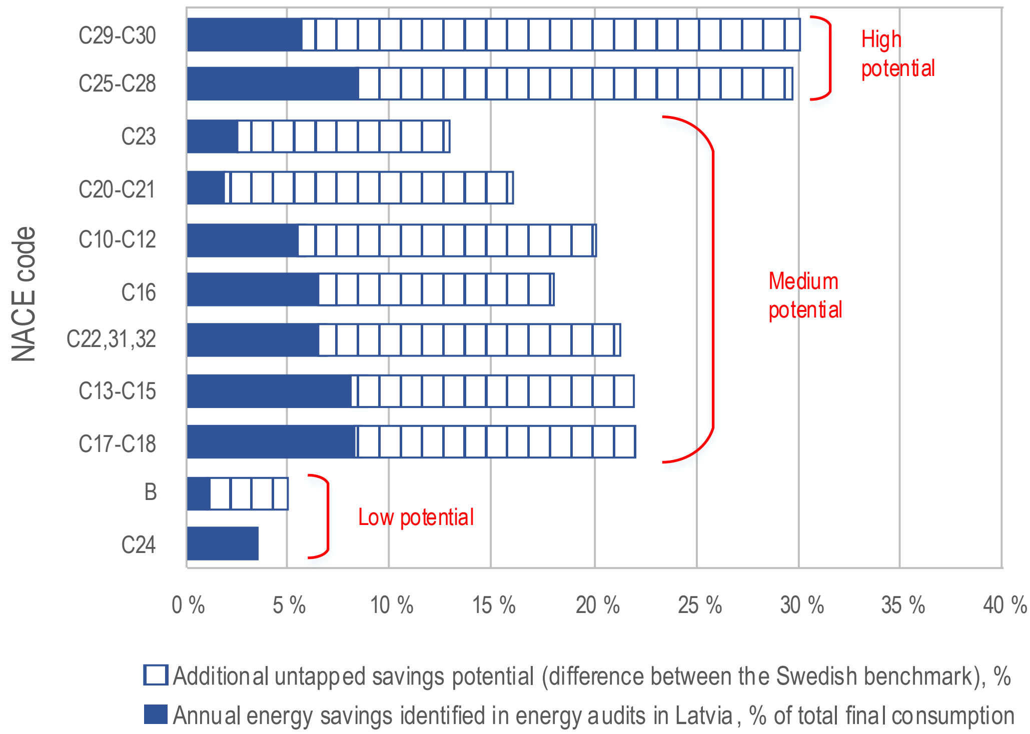


Figure 1-12. Identified energy savings and additional untapped savings potential from Paramonova and Thollander (2016).

Comparing the energy efficiency potential of Sweden and Latvia, it can be concluded that in Sweden energy savings are projected at a much higher level in the industrial sector, while more modest savings are identified in Latvia, which does not result in a large part of the savings potential that could be achieved in the absence of barriers.

The identified breakdown in potential groups allows the identification of those sectors where more monitoring of energy management and the introduction of measures is possible, which would lead to significantly higher reductions in energy consumption and also optimisation of energy costs. The energy efficiency potential group shown in Figure 1-12. shows that for all industrial sectors other than metal manufacturing secto (C24), the unused savings potential exceeds by more than half the energy efficiency technical potential identified in Latvia. Moreover, the chemical and pharmaceutical products sector (C20-21) has additional untapped savings potential 7 times higher, and automotive, trailer and other vehicle manufacturing (C29-30), non-metallic mineral products manufacturing (C23) and mining and quarrying (B) sectors have even 4 times higher than the energy savings identified in energy audits in Latvia.

In other high energy intensity sectors, such as the manufacture of wood and cork products (C16) and food, beverage and tobacco production (C10-12), the unused savings potential after the application of the Swedish benchmark is twice the technical potential of energy efficiency determined in Latvia.

Assessment of the technical energy efficiency potential in the three most energy intensive industrial sectors

In order to perform a more in-depth analysis of the estimated technical energy efficiency potential in Latvia, based on energy audits submitted bythe industry companies to ME, three sectors with the highest consumption of energy resources in the Latvian industry – food, beverage and tobacco production (C10-12), manufacture of wood and cork products (C16) and manufacture of non-metallic mineral products (C23) – audits were evaluated more critically and in more detail. This is done to select energy audits whose planned energy efficiency improvement activities are based on improving and/or replacing machinery, improving the energy efficiency of buildings, optimising the energy efficiency of production processes, etc., which, in the expert assessment of the study, are more significant energy efficiency measures with a greater impact on expected energy savings. On the other hand, energy audits, where the planned energy efficiency measures included mainly lighting improvement or replacement activities or administrative activities, were excluded from the overall data set.

The selection of energy audits data of this kind allows for a reduction in the number of companies showing modest energy efficiency targets in the EMS programme, which serve more as a formality to comply with the requirements of the legislation. Thus, it is possible to obtain a more objective assessment of the technical energy efficiency potential of the Latvian industry. Table 1-9. summarises the data resulting from the selection and estimates of the technical potential for energy efficiency of Latvia's three most energy-intensive industrial sectors.

Table 1-9.

Assessment of the technical energy efficiency potential of the three most energy intensive industrial sectors, based on energy audit data

NACE code	C10-C12	C16	C23
Total energy consumption in the sector, GWh (CSP, n.d.-a)	907,29	5450,16	1518,18
Energy efficiency technical potential in Latvia,% (based on all energy audits)	**5,58 %**	**6,53 %**	**2,57 %**
Number of records	26	36	7
Annual energy savings identified from all energy audits, GWh	50,62	355,68	39,04
Annual CO_2 savings identified in energy audits, tonnes	7529,74	7331,94	19284,56
Energy efficiency technical potential in Latvia,% (based on selected energy audits)	**7,16 %**	**8,44 %**	**2,95 %**
Number of records	18	26	6
Annual energy savings identified in selected energy audits from, GWh	64,96	459,99	44,79
Annual CO_2 savings identified in selected energy audits, tonnes	9661,20	9482,27	22123,89
Additional energy efficiency technical potential savings, GWh (difference between all energy audits and selected energy audits potential)	**14,34**	**104,32**	**5,74**
Additional CO_2 savings, tonnes (difference between all energy audits and selected energy audits potential)	**2132,46**	**2150,33**	**2839,32**

Following a careful selection of energy audits data by the industry experts, an increase in the estimated technical potential for energy efficiency was obtained in all three sectors of the industry under consideration. The technical energy efficiency potential in the food, beverage and tobacco manufacturing sector (C10-12) increased by 1,58%, reaching 7,16%, the potential for wood and cork products manufacturing sector (C16) increased by 1,91%, reaching 8,44%, and the non-metallic mineral products manufacturing sector (C23) increased by 0,38%, representing

2,95%. It was not possible for the non-metallic mineral manufacturing sector (C23) to carry out a more in-depth selection of energy audits data, as energy audits were available for only 7 sector companies where, after expert assessment, only one company's energy audit data was selected, which was excluded from the sector data set for the further calculation of the technical potential for energy efficiency.

After calculating the technical potential for energy efficiency, an additional 124,4 GWh of energy savings and 7 122,11 tonnes of CO_2 were obtained from the selected energy audit data. The largest share of additional savings, or 104,32 GWh, is achieved by the wood and cork products sector (C16). The food, beverage and tobacco manufacturing sector (C10-12) achieved additional savings of 14,34 GWh and the non-metallic mineral products manufacturing sector (C23) achieved savings of 5,74 GWh. The largest CO_2 savings, or 2839,32 tonnes of CO_2, was produced in the non-metallic mineral products manufacturing sector (C23). The wood and cork manufacturing sector (C16) constitutes an additional 2150,33 tonnes of CO_2 savings and the food, beverage and tobacco manufacturing sector (C10-12) represents an additional 2132,46 tonnes of CO_2 savings.

Figure 1-13. illustrates the share of the additional unused savings potential in Latvia derived from the selection of energy audits data. In the graph it can be observed that the inclusion of this part of the additional untapped potential results in a more precise technical energy efficiency potential of these three sectors, which stimulates their proximity to the Swedish benchmark.

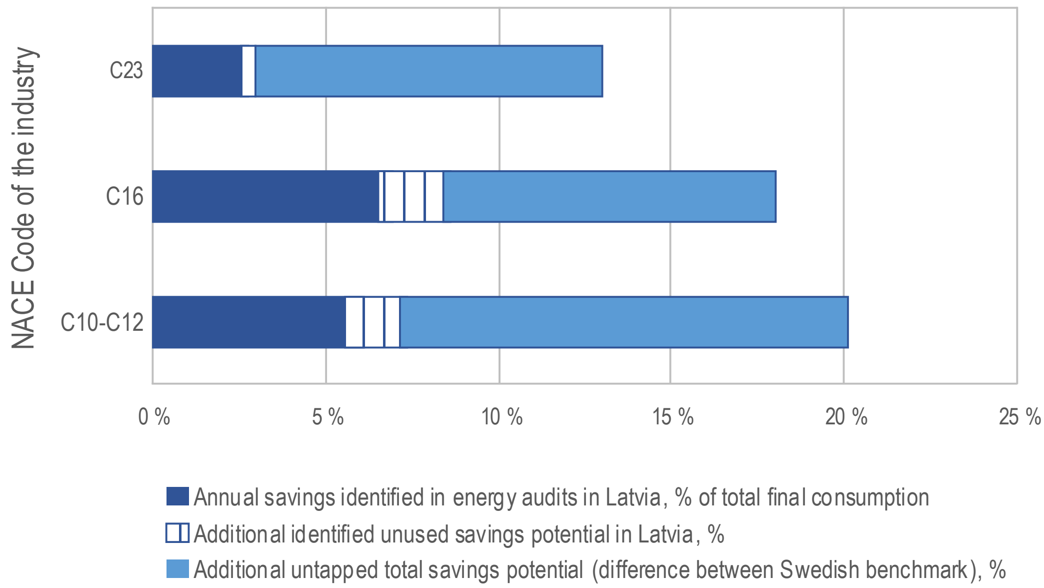


Figure 1-13. Technical energy efficiency potential of the three most energy intensive sectors following the selection of energy audit data.

Even though after the energy audit data selection for the three previously mentioned industrial sub-sectors the incriease in the estimated technical energy efficiency potential was obtained, it is still far from the theoretical Swedish benchmark. It demonstrated the savings potential that is possible if the energy efficiency activities are successfully and sufficiently implemented, based on results from the high quality energy audits.

2. BENCHMARKS FOR INDIVIDUAL INDUSTRIAL TECHNOLOGICAL PROCESSES

As part of the research implementation activities, the aim of the study is to set benchmarks for widely used technological processes in individual sectors of the economy. This includes the submission of additional policy reports in the future phases of the project, in line with the project implementation timetable. Since work on setting up the benchmarks for the largest industrial sub-sectros such as food and wood manufacturing sectors has already begun, the results of the benchmarking analysis have been incorporated and integrated into this policy report.

As identified both in the previously developed reports and as a result of this study, the food processing sector and the wood and cork product manufacturing sector are among the sectors that account for the largest share of the total energy consumption in the industry. These sectors also represent a significant share of the turnover generated from the total turnover in the sector. Consequently, these sectors are widely used in the economy and, accordingly, more in-depth investigation and assessment of the benchmarks have benn carried out for these sectors.

Two research approaches are used to obtain a full description of the energy consumption tendencies in the sector and to understand the specific nature of the companies operating in these sectors concerned, which would allow to obtain more detailed and accurate review of the situation. Firstly, benchmarks are established based on the energy audit data available from ME. Secondly, case studies are carried out to analyse the specific energy consumption values in the companies of each sector.

2.1. Food processing sector

Development of benchmarks based on energy audit data

Based on the available energy audit data from ME, benchmarks for technological processes for the food processing sub-sector (classification code of C10 according to NACE Rev. 2 nomenclature) were determined. In total, complete dataset was available on 11 food processing business companies, which allowed to calculate specific energy consumption indicators and set the overall benchmark for the sector

Some of the energy audits available from the companies operating in the industry did not contain accurate data on the output volumes in tonnes or in monetary units, which limited the possibility to calculate the specific indicators, so these companies were not included in the sector benchmark calculations. In addition, one company was the producer of animal feed. Given that the animal feed production sector has different characteristics and is subject to other requirements of the Food and Veterinary Service (FVS), which often does not require as much energy consumption as it can be seen in other sectors of the food industry, the specific consumption figures for this company were not included in the calculation for the overall sector benchmark. This was done in order to obtain as objective and accurate representation of data analysis as possible, therefore correctly describing the specifics of the sector's performance in Latvia.

Figure 2-1. illustrates the results from the obtained benchmarks for the food processing sector based on the energy audit data analysis. The average specific energy consumption among the analysed food processing companies is equal to 1,06 MWh/tons. In total, the specific consumption indicators for the three companies exceed the sector's benchmark which is calculated as the average value of the companies. The median value of the sector is 0,97 MWh/tons. Key statistical data from the analysis of the food processing sector benchmarking are summarised in Figure 2-1.

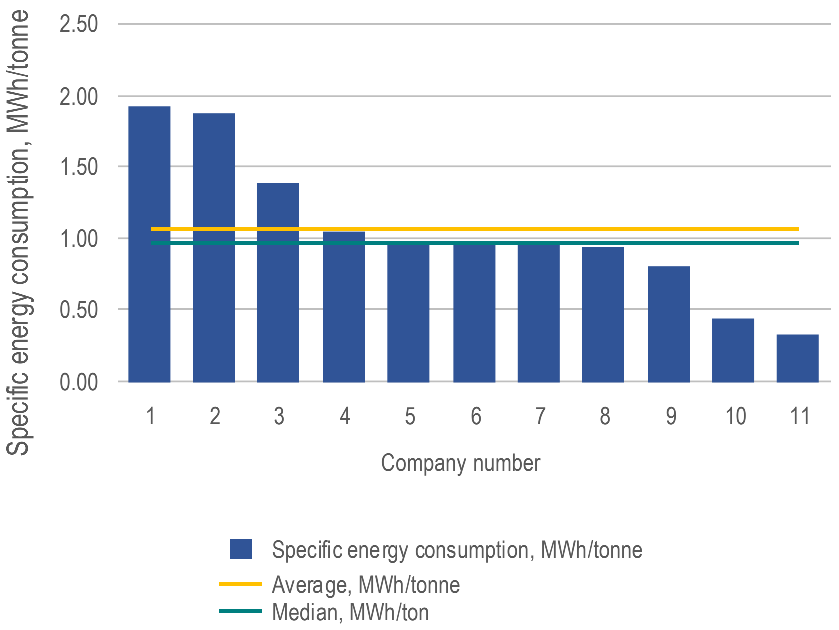


Figure 2-1. The specific energy consumption benchmark analysis of the food processing sector.

The results of the specific indicators are distributed in a relatively large range. The highest value of the specific energy consumption is equal to 1,94 MWh/tons, however, the lowest is equal to 0,32 MWh/tons. When assessing the food sector as a whole, it is essential to take into account differences in technological processes depending on the type of production produced. In addition, among the specific indicators analysed, it was observed that dairy processing companies showed the lowest specific energy consumption ratios, while meat, confectionery and fruit processing companies showed significantly higher energy consumption per tonne of produced production. Therefore, in order to define more precisely the benchmarks of sub-sectors, a more detailed breakdown by type of production should be carried out, but the existing energy audit dataset did not contain a sufficient number of food companies in each sub-sector to carry out an objective assessment.

Table 2-1.

Analysis of specific energy consumption ratios of food processing companies

Number of records	11
Highest value, MWh/tonne	1,94
Minimum value, MWh/tonne	0,32
Range of values	1,62
Average value, MWh/tonne	1,06
Standard deviation	0,51
Median, MWh/tonne	0,97

Figure 2-2. reflects the dependency of the specific energy consumption on the produced output volumes. The results show a declining trend: the consumption of energy resources per tonne of production is declining at higher output levels. The higher the production and turnover of the company, the more it can save on the specific energy costs of producing one unit of production. Total correlation factor R^2 is equal to 0,42, which states that the relationship is moderate. Consequently, more data is needed to complement the existing data set with

additional company data in order to draw more objective conclusions on the strength of the relationship.

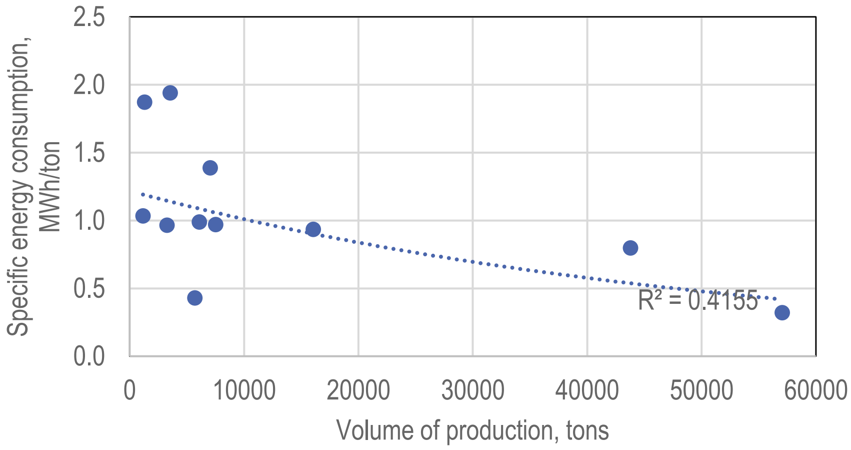


Figure 2-2. Presentation of the regression equation for the dependence of the specific energy consumption of food business on the volume of production.

Figure 2-3. shows the relationship between the maximum identified energy savings in energy audits of food sector companies (proportion from the total energy consumption) and the specific energy consumption of the company. Following the results, a declining trend can be observed, indicating that for companies with higher specific energy consumption the maximum value of savings for energy audits per total consumed energy is lower. Companies with already existing competitive specific energy consumption indicators also show greater potential for relative reductions in energy consumption. On the other hand, for companies that already indicates higher energy costs per tonne of production, the maximum energy savings potential is not determined at high levels. This can be explained by a possible lack of interest by companies to change and to improve the energy efficiency of production processes, which would increase the competitiveness of produced production through reduced energy costs. However, it is important to note that this relationship does not have a strong relationship. Its correlation factor R^2 is equal to 0,2, indicating that the data are highly distributed and that the tendency is not not valid uniformly in all cases.

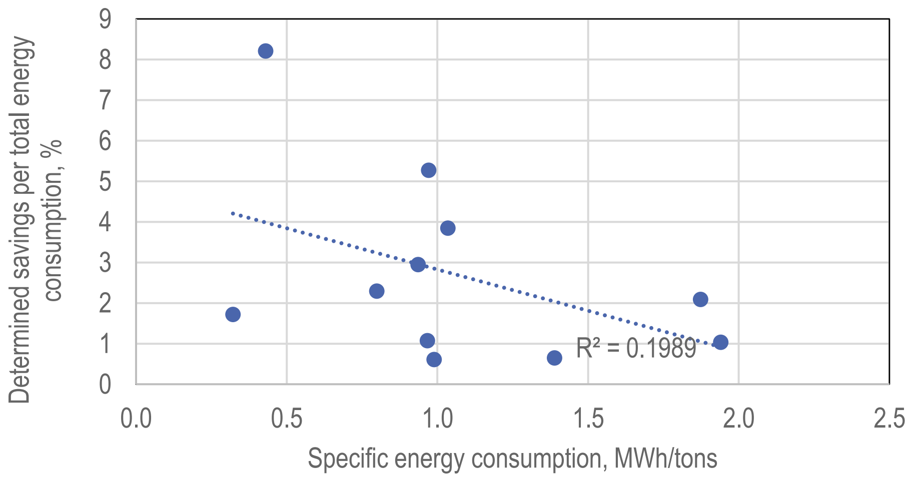


Figure 2-3. The dependency of the determined energy savings by food processing companies on the specific energy consumption indicator.

Analysis of energy consumption data for food processing companies

To obtain more in-depth analysis for the benchmarks set in the previpus chapter, a case study on historical three-year energy consumption data of a company operating in the food processing sector was carried out. The name of a company is hidden to preserve the confidentiality of data and information supplied. The specific data analysis provides an insight into tendencies and sector-specifics of energy consumption in a typical food processing company.

The boundaries of the energy efficiency assessment are determined by dividing production activities into seven parts. This is reflected in Table 2-2.

Table 2-2.

Breakdown of energy consumption by type of process

No.	Name of the economic activity process	Share of energy consumed from total amounts of energy consumed,%
1	Production	66,82 %
2	Cooling	18,12 %
3	Heating – heating and provision of hot water	4,01 %
4	Room cooling	0,65 %
5	Lighting and office equipment	0,95 %
6	Other systems, additional energy — pumps, automatically, etc.	0,91 %
7	Other manufacturing plants and transport	8,54 %

The largest share of energy resources is consumed by the production process, representing 66,82% of total energy consumption. The second largest share of energy consumption, with 18,12% of total energy consumption, is composed of a cooling process. Other production facilities and transport account for 8,54% of total energy consumption. Heating — heating and hot water supply — lighting and office equipment, other systems, additional energy — pumps, automated etc., room cooling accounts for 4,01%, 0,95%, 0,91% and 0,6% of total energy consumption, respectively.

On average, the total annual consumption of energy resources in the company is equal to 7293 MWh/year. The largest energy consumer is electricity, which accounts for 60% of total energy consumption, while thermal energy accounts for 37% and fuel consumption – 3%.

The specific heat and electricity consumption ratios have been obtained based on the available production output and consumption data. The average specific heat consumption ratio of the last three years of the company is equal to 0,36 kWh/kg, which means that the production of one kilogram of product requires a consumption of 0,36 kWh of heat. From the historical energy consumption data analysis, it can be observed that a specific heat consumtion indicator has a tendency to grow over a three-year period. The average specific electricity indicator of the last three years of the company is equal to 0,59 kWh/kg. Similarly, as for heat, also this indicator shows a growing trend over three years.

The increase in the specific energy consumption indicators indicates the need for a more in-depth analysis of the specific indicators. A regression analysis is carried out below to determine the effectiveness of the management of existing energy resources. A correlation analysis is carried out between the total production in kilograms and the specific heat consumption ratio expressed in kWh per kilogram. A regression analysis is carried out, where the dependent variable is the specific heat consumption indicator, while the independent variable is the output in kilograms. Figure 2-4. shows the resulting regression curve.

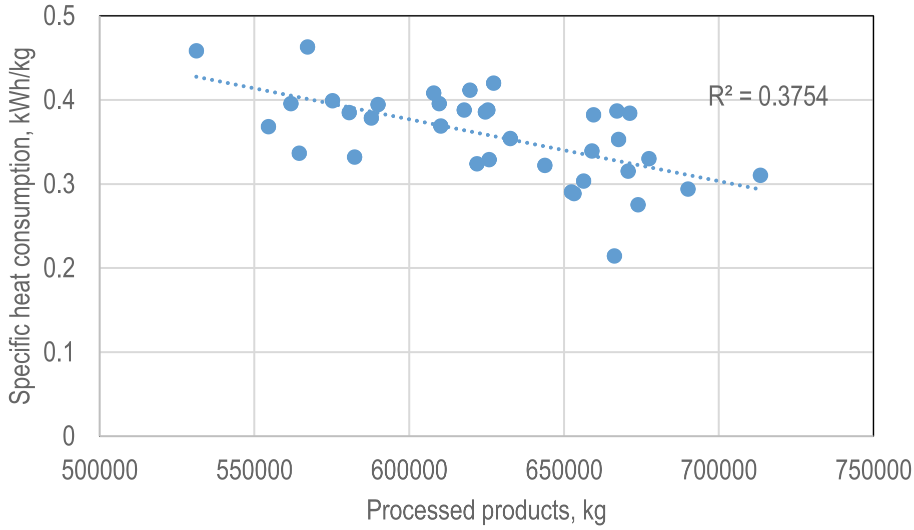


Figure 2-4. Regression curve for the specific heat consumption indicator of the food processing plant.

The R^2 obtained in the regression equation is equal to 0,37, indicating that there is an average correlation between the volume of the processed production produced and the specific heat consumption ratio. In addition to the resulting regression curve, it can be concluded that the data is relatively highly distributed.

A more in-depth analysis of electricity consumption is also carried out in a regression analysis, where the specific electricity indicator is selected as the dependent variable and the independent variable is the volume of production in kilograms. The resulting regression curve is illustrated in Figure 2-5.

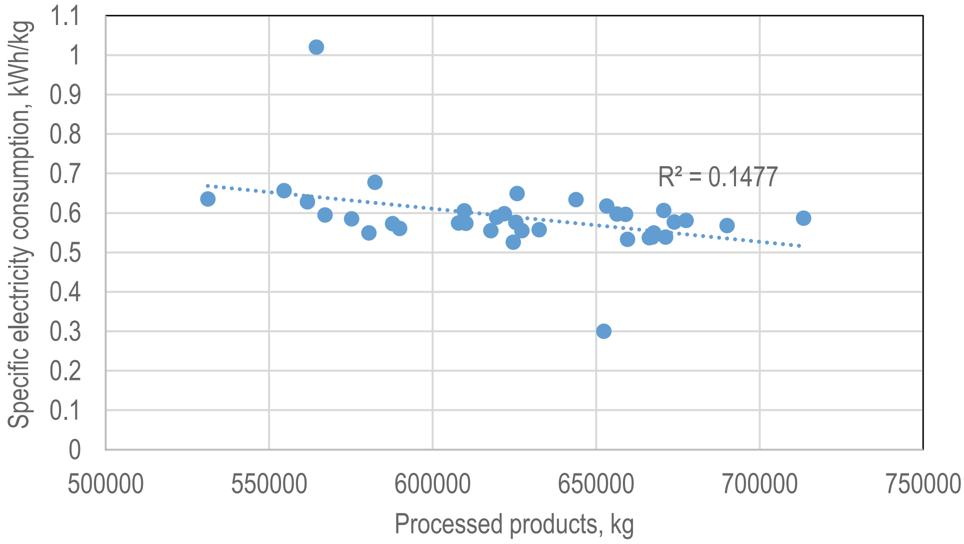


Figure 2-5. Regression curve for of the specific electricity consumption indicator of the food processing plant.

Following the resulting regression equation, it can be concluded that there is a low correlation between the volume of products produced and the specific electricity consumption determined by R^2 equal to 0,15. A large distribution of data may be observed in the resulting representation of the regression curve. In order to identify the potential reasons for low-correlation, the company needs to take a more detailed assessment of all its activities, the efficiency of manufacturing and support equipment, the effectiveness of the energy monitoring and management system and other factors that could affect the high distribution in data.

The total specific energy consumption ratio of the company concerned, representing an average of 0,97 MWh/tons, is assessed based on the sector's benchmark that was determined in the previous chapter of this study. The food processing sector's benchmark is set at 1,06 MWh/tonne. Consequently, it can be concluded that the analyzed company in operates within the line of the benchmark. The company's specific indicator corresponds to the median value of the total food processing sector. Using a similar assessment approach, indicators from other companies can also be assessed by measuring their performance in the overall industry context.

Similar data outline and specifics are also observed in other food processing plants, which means that the analysis of data from a given company provides valuable insight into the common challenges of the sector and the potential for energy efficiency improvements.

2.2. Wood and cork products manufacturing sector

Development of benchmarks based on energy audit data

In the previously submitted project report, the benchmark for specific energy consumption ratip in the wood and cork products classification code of C16 according to NACE Rev. 2 nomenclature) manufacturing sector was calculated. The benchmark was calculated from energy audits of companies where information on output and energy resources consumed could be obtained. For a large part of companies, unfortunately, it was not possible to obtain this information so that it could be included in the calculations. Full dataset was available for 9 wood manufacturing companies. The resulting benchmark is reflected in Figure 2-6.

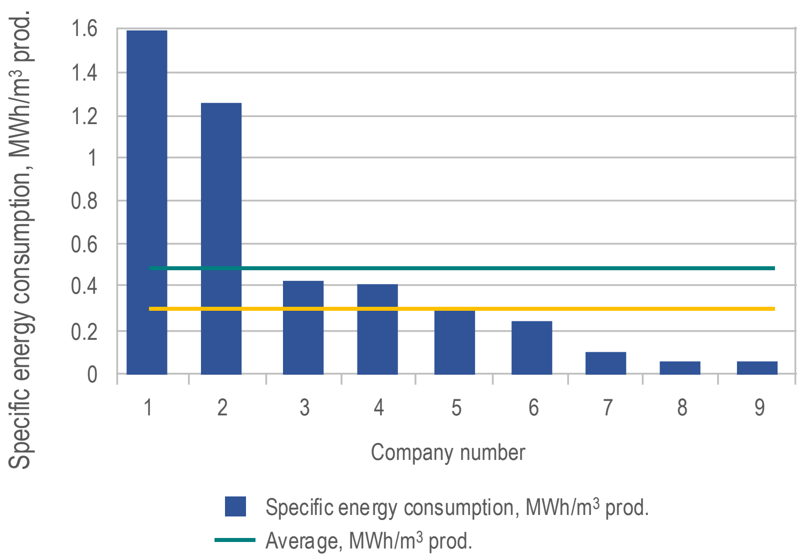


Figure 2-6. The specific energy consumption following an analysis of the output benchmark for the wood and cork products sector.

The average specific energy consumption ratio between the wood manufacturing plants analysed is equal to 0,49 MWh/m^3 and the median value is equal to 0,29 MWh/m^3. It is noted that two companies showed specific indicators above the average value of the sector. These companies are characterised by a significantly higher specific consumption indicator. In order to clarify the reason for this, a more detailed study should be carried out on the activities and specifics of the companies. Table 2-3. summarises the statistics for the specific ratios of wood manufacturing plants. Overall, a relatively high range of results equal to 1,54 MWh/m^3 might be observed. The highest specific energy consumption ratio among wood manufacturing companies is equal to 1,59 MWh/m^3, while the lowest is equal to 0,05 MWh/m^3. In the wood sector, technological processes and the amount of energy utilized differ depending on the type of production produced, companies should be looked at in more detail by sub-sectors in order to obtain more precise benchmarks.

Table 2-3.

Analysis of the specific energy consumption ratios of companiesoperating in the wood and cork products manufacturing sector

Number of records	9
Highest value, MWh/m^3	1,59
Minimum value, MWh/m^3	0,05
Range of values	1,54
Average value, MWh/m^3	0,49
Standard deviation	0,55
Median, MWh/m^3	0,29

Analysis of energy consumption data for a company operating in the wood products manufacturing sector

As part of this section, a case study on a company operating in the wood and cork products manufacturing sector has been carried out, analysing the company's specific electricity and heat consumtion ratios. Company data analysis provides a more in-depth understanding of the sector's specific economic activities and energy consumption efficiency aspects. To ensure the data confidentiality, the name of the analysed company is hidden.

One-year data on the company's monthly energy consumption and the volume of output produced were obtained. The company's average specific heat consumption ratio was estimated to be 1,65 MWh/tons and the average specific electricity consumption was 0,19 MWh/tons. The total specific energy consumption indicator is equal to 1,84 MWh/tons. It is also important to take into account the seasonality factor when assessing the changes in the specific ratios. During the winter months, higher specific ratios are observed, with the increase in heat consumption affected by the fall in outdoor temperatures. It should be noted that the data presented here are for one year only. For more accurate results, monthly data for at least 3 years would be required.

Figure 2-7. shows the equation of the regression curve for the enterprise's specific heat consumption ratio’s dependancy on the produced output. It shows a declining trend where the correlation factor R^2 is equal to 0,4994, indicating a moderate relationship. The presentation of the resulting indicators in the graph shows that, in the case of higher production, the specific heat consumption indicator decreases. In addition, it can be seen that this declining trend is steep and rapidly decreasing, so the specific heat consumption indicator is particularly sensitive to changes in production. It is possible to save more and reduce costs per tonne of production if production capacity and output turnover are increased.

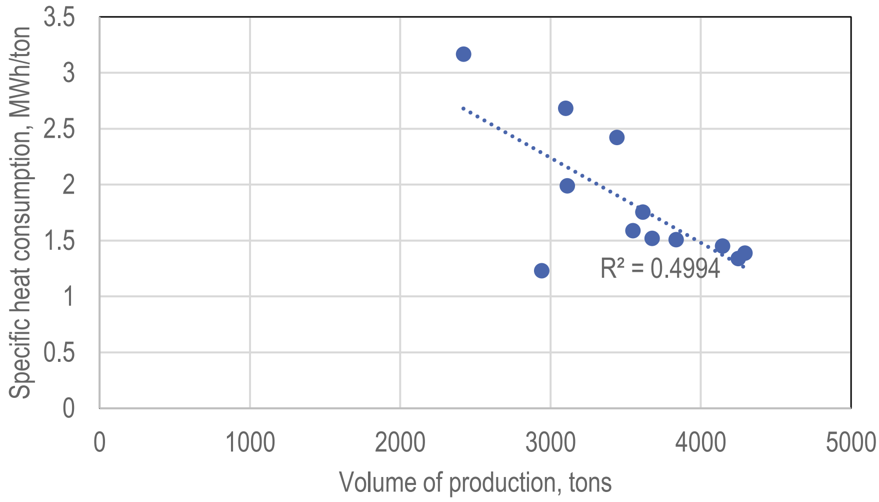


Figure 2-7. Regression curve for the specific heat consumption of the company operating in the wood and cork manufacturing sector.

Sililarly, the specific electricity consumption indicators and its dependence on produced output are analyzed. The results are illustrated in Figure 2-8. There is also observed a declining trend where the correlation factor R^2 is equal to 0,5598. This means that the marginal costs of electricity for one tonne of production will be reduced if output increases. Compared to the specific value of heat, this relationship is not as steep. Consequently, the changes in the specific electricity ratio is less sensitive to the increase in production capacity.

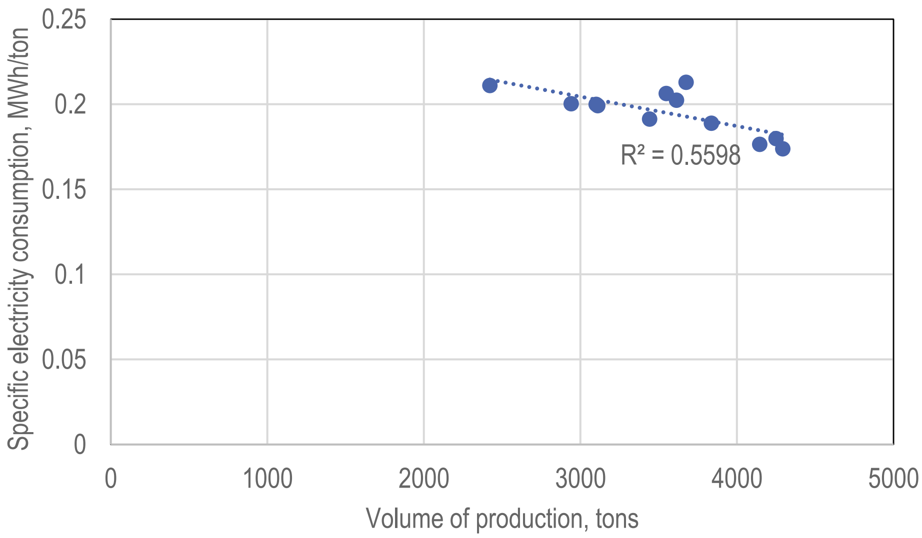


Figure 2-8. Regression curve for the specific heat output of the company operating in the wood and cork manufacturing sector.

Given that the amounts of produced wood products by the company is reported in tons, unfortunately, it is not possible to assess the specific consumtion ratios of the company compared to the benchmark set out in the sector's energy audits.

3. ENERGY EFFICIENCY COMPOSITE INDEX

The overall energy efficiency of the industry strongly depends on energy utilization practices of all the industrial sub-sectors combined. There are significant variations in energy efficiency levels across all the different manufacturing industry sub-sectors, therefore sectorial disparities should be considered when analyzing the industrial energy efficiency performance levels (*Liao & He*, 2018). Therefore, in respect to industrial energy efficiency assessment it is crucial to develop a model that measures sectors separately and investigates sectoral differences.

When it comes to macroeconomic evaluation of energy efficiency among different sectors in the industry, the question about the choice of the most appropriate and comprehensive evaluation method arises. Numerous studies investigate energy efficiency performance levels across different sectors that include in-depth analysis of several factors of energy efficiency separately. However, when there exist many different performance indicators it might be difficult to make sub-sectoral comparisons based on different units of measurement of each indicator (*Krajnc & Glavič*, 2005c).

In the scope of this chapter, the application of an innovative model for industrial energy efficiency evaluation is demonstrated. It involves the utilization of the composite index methodology, as a result industrial energy efficiency index is obtained. Composite idices are common practice in the sustainability evaluation studies, therefore, this study aims to demonstrate that a similar approach could be used in energy efficiency research to obtain valuable findings for policymakers.

In this chapter, at first detailed description of the applied methodology is portrayed, where all the calculation techniques and stages of index construction, as well as the used data sources are outlined. Secondly, the energy efficiency composite index results for each industrial sub-sector are discussed and valuable conclusions on sectorial disparencies are obtained.

3.1. Description of the methodological approach

Energy efficiency index (EEI) in this study is defined as a tool that evaluates energy efficiency performance across different manufacturing sectors in Latvia. It is a composite measure that consists of various independent indicators grouped in relevant explanatory dimensions. The construction of a composite index is a complex process that involves accurate choice of methodological approach and calculation procedures *(Lemke & Bastini, 2020; Mazziotta & Pareto*, 2013).

The model which is proposed in this study is based on methodological approaches used in similar studies on the development and application of composite sustainability indices. The presented methodology combines best practices from both - the academic studies *(Barrera-Roldán & Saldívar-Valdés, 2002; Krajnc & Glavič, 2005a; Mazziotta & Pareto, 2013; Razmjoo et al.*, 2019a) and internationally recognized sustainability composite indices of the world's top international organizations such as United Nations (human development index), European Commission (eco-innovation index), World Economic Forum (business competitiveness index), and others *(Gilijum et al., 2017; Lemke & Bastini*, 2020).

Figure 3-1. illustrates six main chronological steps that are applied in the development of the composite energy efficiency index. The calculation procedure of the composite EEI in this study follows the below-mentioned steps. The proposed procedure of the composite index calculation resembles the methodological approach used in the sustainability evaluation studies by Barrera-Roldán & Saldívar-Valdés (2002), Krajnc & Glavič (2005), Mazziotta & Pareto (2013), Razmjoo et al. (2019).

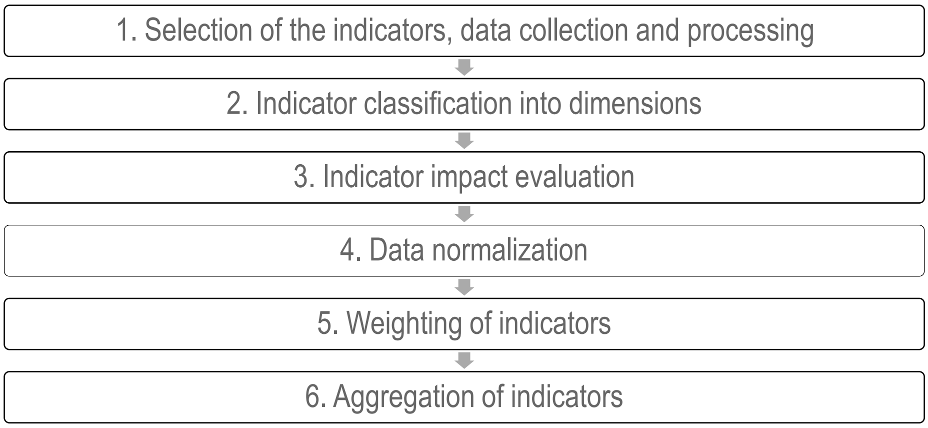


Fig. 3-1. Key steps for the construction of the composite index. Author's developed based on (Barrera-Roldán & Saldívar-Valdés, 2002; Krajnc & Glavič, 2005b; Mazziotta & Pareto, 2013; Razmjoo et al., 2019b).

3.1.1.Selection of the indicators, data collecton and processing

When the study phenomenont and conceptual framework is clearly defined, the selection of the indicators and necessary data collection is proceeded. Indicators were selected based on the energy efficiency factors and variables mentioned in the scientific literature, as well as based on the data availability. In total data for 12 indicators on 18 different Latvian manufacturing sectors were collected.

Data on industry sectors were classified according to NACE Rev. 2 classification that is generally accepted statistical classification of economic activities in the European Community (CSP, n.d.-b). Table 3-1. lists all the selected industry sectors considered in the scope of the study.

Table 3-1.

Selected Latvian industry sectors according to NACE Rev.2. classification (CSP, n.d.-b)

NACE code	Name of the sector
B	Mining and quarrying
C10-C12	Manufacture of food products; beverages and tobacco products
C13-C15	Manufacture of textiles, wearing apparel, leather and related products
C16	Manufacture of wood and cork products; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C20	Manufacture of chemicals and chemical products
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22	Manufacture of rubber and plastic products
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31-C32	Manufacture of furniture; other manufacturing

Data on most of the selected indicators were collected from *Eurostat* database, except for the data on purchases of energy products and number of ISO 50001 registered companies that were gathered from Central Statistical Bureau of Latvia (CSB) and International Organization for Standardization (ISO) databases accordingly. Table 3-2 summarizes data sources of the selected indicators.

Almost all the data were selected for the year 2017, except for data on environment protection activity from Eurostat's CIS questionnaire. Since data on this indicator is not updated systematically on a yearly basis (*Gilijum et al.,* 2017), the latest available data were collected.

Missing values for the year 2017 (due to data confidentiality) for the manufacture of computer, electronic and optical products sector (NACE code: C26) were substituted with the numbers from 2015 that was the latest available data on the sector. In the sensitivity analysis it was evaluated that it did not have an impact on the obtained results of the study. There were no other missing values detected in dataset of the study.

3.1.2. Indicator classification in dimensions

The previous researches have explored that there are various energy efficiency influencing factors such as economic power, structure of used energy resources, energy costs, technological advancement, existing legislation, and many others (*Liao & He*, 2018). The indicators for this study were selected based on data availability on the industry sub-sectors. Using the top-down research approach, three main dimensions of sustainable energy efficiency were singled out - economic, technical and environmental dimension. As a result, all the selected indicators were grouped according to the determined dimensions. Table 3-2 lists the selected indicators according to their belonging to a particular dimension.

Division in dimensions is widely used in composite sustainability index application studies *(Barrera-Roldán & Saldívar-Valdés*, 2002; *Cîrstea et al*., 2018; *Krajnc & Glavič*, 2005a), therefore the same approach was incorporated in this study. It allows to develop a broader and more comprehensive view on the key elements of energy efficiency.

Economic dimension reflects sector's ability to generate turnover and value-added per unit of consumed energy. As well as, it considers the expenses related to the amount of energy used (measured by purchases of energy products) and energy taxes relatively to production output. Viability of the economic dimension is crucial to EEI in order to evaluate if consumed energy is adequate to the generated economical contribution to the industry. Sectors with high economic power are less dependent on the amount and expenses of the consumed energy in their production process. Stronger economic and financial stability of a sector might encourage to implement more sustainable practices in the energy management in manufacturing.

Technical dimension incorporates several essential aspects that are related to the total factor performance of production process. It includes both technical and human capital inputs. Both of these factors are significant determinants of the design and capacity of the sector's manufacturing process. Technical efficiency of production processes is measured by the amount of investments made in facilities and machinery per unit of consumed energy. Thus, the indicator measures sector's investment rate in more efficient manufacturing machineries and production facilities. The share of companies that have introduced and implemented ISO 50001 standard characterizes if companies in corresponding sectors are encouraged to implement more efficient energy management practices. Moreover, share of large size companies is also included in technical dimension in order to consider organizational and structural factors of a sector. Additionally, indicator that measures energy use per employee is included to evaluate energy consumption relatively to labor inputs.

Table 3-2.

Classification of selected indicators and used data sources

Dimension	Indicator	Variable	Data source	Data code and source
Economic dimension	Value added per energy use	Value added at factor cost/Net domestic energy use	*Eurostat*	sbs_na_ind_r2 (Eurostat, 2020b); env_ac_pefa04 (Eurostat, 2020g)
	Generated turnover per energy use	Turnover/Net domestic energy use	*Eurostat*	sbs_na_ind_r2 (Eurostat, 2020b); env_ac_pefa04 (Eurostat, 2020g)
	Energy costs	Purchases of energy products/Turnover	CSP	SBG010 (CSP, n.d.-c); sbs_na_ind_r2 (Eurostat, 2020b);
	Energy taxes per generated turnover	Energy taxes/Turnover	*Eurostat*	env_ac_taxind2 (Eurostat, 2020e) ; sbs_na_ind_r2 (Eurostat, 2020b);
Technical dimension	Investment per energy use	Gross investment in existing buildings, structures, machinery and equipment, construction and alteration of buildings/Net domestic energy use	*Eurostat*	sbs_na_ind_r2 (Eurostat, 2020b); env_ac_pefa04 (Eurostat, 2020g)
	Share of ISO 50001 registered companies	Number of ISO 50001 registered companies/Total number of companies	ISO/TC; *Eurostat*	*ISO Survey* (ISO Survery, 2018); sbs_na_ind_r2 (Eurostat, 2020b);
	Share of large size companies	Number of enterprises with 250 persons employed or more/Total number of enterprises	*Eurostat*	sbs_sc_ind_r2 (Eurostat, 2020f)
	Energy use per employee	Net domestic energy use/Number of employees	*Eurostat*	env_ac_pefa04 (Eurostat, 2020g); sbs_sc_ind_r2 (Eurostat, 2020f)
Environmental dimension	Greenhouse gas intensity	Greenhouse gases in tons/Value added at factor cost	*Eurostat*	env_ac_ainah_r2 (Eurostat, 2020a); sbs_na_ind_r2 (Eurostat, 2020b)
	Use of fossil energy resources	Fossil energy products/Total energy products	CSP	env_ac_pefasu (Eurostat, 2020c)
	Environment protection activity	Percentage of companies that eliminated energy consumption or CO_2 emissions by innovation activities within the organization	*Eurostat*	inn_cis9_env (Eurostat, 2020d)
	CO_2 productivity	Generated turnover/Tons of CO_2 emissions	CSP, *Eurostat*	sbs_na_ind_r2 (Eurostat, 2020b); env_ac_ainah_r2 (Eurostat, 2020a)

Environmental dimension reflects the impact of a sector on the ecosystem and atmosphere. It is measured by the greenhouse gas emission intensity, share of fossil energy resources, and CO_2 productivity. As well as, it considers sector activity in the implementation of environment protection activities with an aim to reduce energy consumption or carbon footprint.

Sectors that produce lower impact on the environment are more sustainable and therefore closer to achieving higher energy efficiency.

3.1.3. Indicator impact evaluation

When indicators are identified and grouped into the dimensions, it is necessary to evaluate the potential impact and relationship of the indicators on the EEI (*Krajnc & Glavič*, 2005). All the selected indicators were divided in two groups – those of having a positive influence and those of having a negative influence on a sector's goal of reaching higher energy efficiency.

In order to understand whether an indicator is positively or negatively correlated with EEI, the effect on EEI of each indicator is assessed by the following rule of thumb. An indicator has a positive influence on EEI if its increasing value accelerates the increase of energy efficiency. On the other hand, an indicator has a negative influence on EEI if its increasing value hinders the improvement of energy efficiency (*Krajnc & Glavič*, 2005). Table 3-3.summarizes the results from the impact evaluation. The categorization according to the indicator's impact on EEI is required since it determines the calculation methodology for data normalization in the further steps of EEI construction.

Table 3-3.

Impact evaluation of the indicators on EEI

Dimension	Indicator	Impact on EEI
Economic dimension	Value added per energy use	+
	Generated turnover per energy use	+
	Energy costs	-
	Energy taxes per generated turnover	-
Technical dimension	Investment per energy use	+
	Share of ISO 50001 registered companies	+
	Share of large size companies	+
	Energy use per employee	-
Environmental dimension	Greenhouse gas intensity	-
	Use of fossil energy resources	-
	Environment protection activity	+
	CO_2 productivity	+

3.1.4. Data normalization

Data normalization is necessary in order to eliminate ambiguity of the indicators and achieve more consistent results. Data normalization transforms all the different scales of the indicators into a one common scale and therefore makes all the different indicators comparable among each other (*Krajnc & Glavič*, 2005). As a result, after data normalization procedure all indicators are compatible to a common composite index.

There are several normalization techniques available such as standardization (z-scores), ranking, rescaling (min-max transformation), distance-based normalization. In this study data normalization is performed using min-max transformation that is recommended for relative comparison studies (*Mazziotta & Pareto*, 2013). The advantage of min-max normalization is that it ranks the values in the range of 0 to 1, therefore it allows for easy interpretation of obtained results (*Harik et al.*, 2015). Min-max normalization technique is commonly used in the methodologies of well-known international indices such as eco-innovation index (proposed by European Commission), human development index (proposed by United Nations Development program), and others.

Each indicator is normalized according to the following equations. Indicators of positive influence are normalized using Eq. (1). Indicators of negative influence are normalized using Eq. (2).

$$I_N^+ = \frac{I_{act} - I_{min}}{I_{max} - I_{min}} \quad (1)$$

$$I_N^- = 1 - \frac{I_{act} - I_{min}}{I_{max} - I_{min}} \quad , \quad (2)$$

Where

I_N^+ is a normalized indicator of a positive influence on EEI;

I_N^- is a normalized indicator of a negative influence on EEI;

I_{act} is the actual value of an indicator in a particular sector;

I_{max} is the maximum value of an indicator from all the sectors;

I_{min} is the minimum value of an indicator from all the sectors.

The different data normalization calculation methods that depend on the indicator impact on the EEI allows for negative impact indicators to be reflected correctly. If increasing value of an indicator has a negative effect on the EEE, it obtains a low normalized value accordingly. In the contrary, if the increasing value of an indicator has a positive effect on EEI, it reaches a high value. Thus, for example, if a sector has high greenhouse gas intensity (GHG), which also has a negative impact on energy efficiency, then the normalized value of the sector will be low accordingly. If a sector has a low greenhouse gas intensity compared to the GHG intensity of other sectors, then its normalized indicator value is high. It is particularly important to take this aspect into account when interpreting the obtained results, especially when analyzing the values of the negative impact indicators in the overall dimension sub-index.

3.1.5. Weighting of indicators and dimensions

After all the indicators are normalized accordingly, weights are assigned to each indicator. There are several methods available when choosing the most appropriate weighting methodology, however, there is no single most convenient weighting method since weighting is considered to be highly controversial (*Singh et al.*, 2007).

In environmental and sustainability studies equal weights are often used to address the equal importance of all the factors included. However, equal weighting might not be sufficient in more complicated composite indices since it might fail to account for correlations among various sub-indicators *(Singh et al.*, 2007). Other common methods like expert weighting and analytic hierarchy process (AHP) method are based on subjective weight evaluation and therefore could generate highly sensitive and biased results that might lead to incorrect data interpretation and conclusions (*Mazziotta & Pareto*, 2013).

In this study equal weighting was applied. Equal weighting is based on Sustainable Development concept that emphasizes the equal importance of all the factors involved *(Barrera-Roldán & Saldívar-Valdés*, 2002). All the selected indicators and dimensions were assumed to have an equal contribution to the development of EEI since all of them are interconnected and create synergies that jointly impact energy efficiency.

3.1.6. Aggregation of indicators

The final calculation step is the aggregation of the obtained normalized and weighted indicators. At first indicators are aggregated in the corresponding dimensions using the Eq. (3).

$$I_D = \sum w \times I_N^{+} + \sum w \times I_N^{-}, \; w = \frac{1}{n_I}, \tag{3}$$

where
I_D is the sub-index of a particular dimension;
w is the value of determined weight of an indicator;
I_N^{+} and I_N^{-} are normalized indicators in each dimension;
n_I is the number of indicators in a dimension.

Then the final composite energy efficiency index (EEI) is determined by the accumulated sum for each of the dimension with its corresponding weight. The calculation is done according to Eq. (4).

$$EEI = \sum w \times I_D, \; w = \frac{1}{n_D}, \tag{4}$$

where
EEI is final composite energy efficiency index;
w is the value of determined weight of a dimension;
n_D is the number of dimensions.

Basic hierarchy of EEI is illustrated in Figure 3-2. It portrays the structure of the EEI with its representative sub-dimensions and their explanatory indicators.

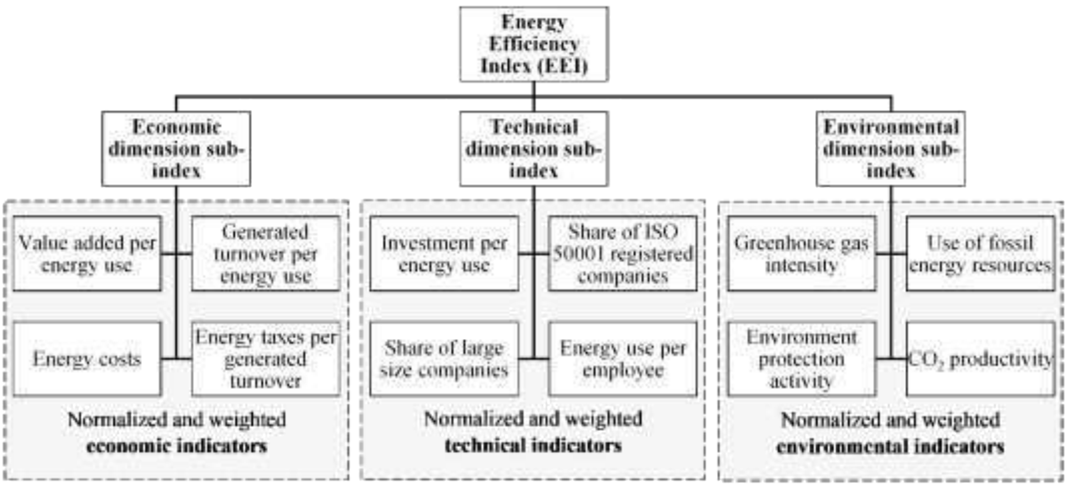


Fig. 3-2. Basic EEI construction hierarchy.

3.2. Result analusis of the energy efficiency composite index

According to the EEI hierarchy and division into dimensions, the result analysis description is structured accordingly. At the beggining the result analysis for each dimension sub-index is performed. Then the overall energy efficiency composite index results for the industry are discussed that integrate the values from all the dimension sub-indices.

3.2.1. Economic dimension sub-index

The overall results of the economic dimension sub-indices are in a wide range. The highest sub-index value is equal to 1, that is the highest possible grade. However, the lowest grade is equal to 0,03. The average economic dimension value is equal to 0,34. Already from this observation, it can be concluded that the indicator values for each sector differ. Figure 3-3. ilustrates the sub-index values of economic dimension for each sub-sector. In addition, Annex 1 outlines a table with all the values of economic indicators.

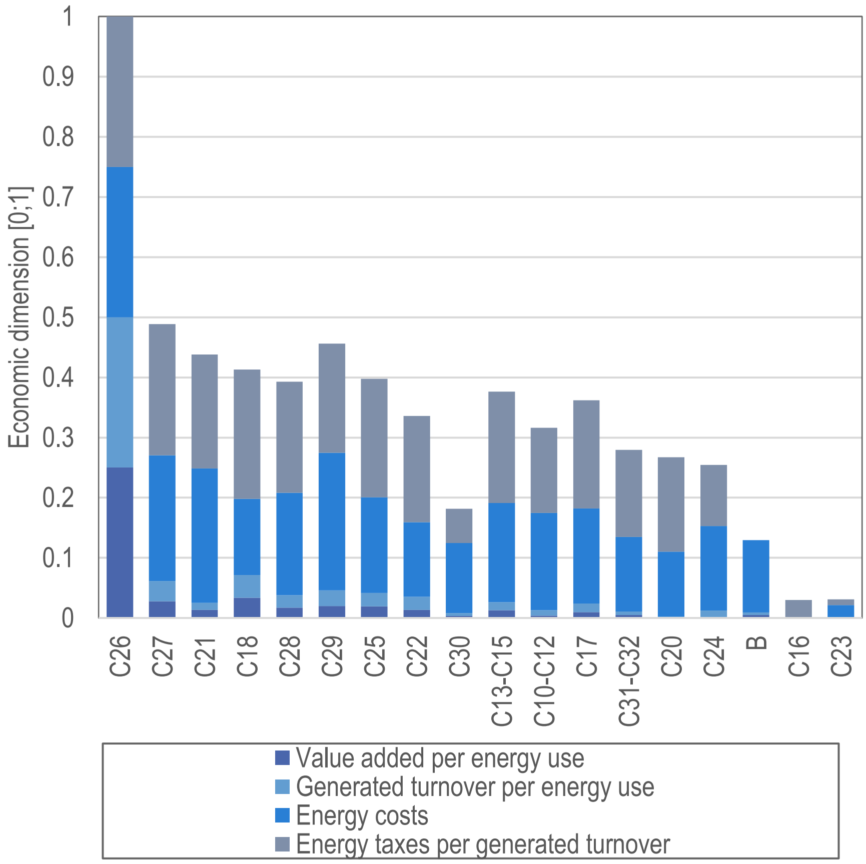


Fig. 3-3. Economic dimension sub-index.

By comparing the obtained results among the industry sub-sectors, it can be observed that the highest value achieved was for the computer, electronic and optical products manufacting sector (C26) that has reached the maximum sub-index value of 1. It means that this sector has reached the highest grades in each of the dimension indicators compared to the other industry sub-sectors. Computer, electronic and optical products manufacting sector (C26) is an absolute leader in the economic dimension category since the following sectors reached the values that are twice lower. These are sectors such as electrical equipment manufacturing sector (C27) with a value of 0,49, motor vehicles, trailers and semi-trailers manufacturing sector (C29) with a value of 0,46 and basic pharmaceutical products and pharmaceutical preparations manufacturing sector (C21) with a value 0,44. All these sectors reflected considerably higher economic dimension sub-index values that indicate sectors' ability to generate relatively high economic value and contributon by consuming less energy resources. As a result, these sectors achieve lower marginal production costs and increase sector's rentability and competitiveness.

The lowest economic dimension sub-index values were achieved by the sectors other non-metallic mineral products manufacturing sector (C23) with 0,03, wood and cork products manufacturing sector (C16) with 0,03 and mining and quarrying sector (B) with 0,13. These sectors reached low values in each of the indicators, as a result it ranked them in the lowest positions of the sub-index. When comparing the sectors that reached high economic dimension sub-index values with the sectors that reached low grades, a certain tendency can be observed. Knowledge-intensive and high-technology sectors (computer and electrical equipment production), as well as the sectors that produce lightweight products (pharmaceutical products) show much higher economic dimension sub-index values. On the other had, energy intensive sectors (non-metallic mineral product and wood and cork product manufacturing), and the sectors that produce heavier weight category products (mining and quarrying) show low economic dimension sub-indices. This observation leads to conclusion that the sectors that can generate higher economic contribution due to high realization value of the produced product also show stronger energy efficiency performance of economic dimension. Sectors that mostly produce primary products and raw materials for example, sand, gravel, clay, limestone, etc., cannot generate competitive economic value to compensate the energy resources consumed for the production proceses.

Other sectors show medium level economic dimension sub-index values that range from 0,18 that was obtained by the other transport equipment manufacturing sector (C30) to 0,41 that was achieved by the printing and reproduction of recorded media sector (C18).

When evaluating the indicator values, it is observed that the economic dimension indicators that measure energy costs and energy taxes produced higher contribution to the overall index value for all the sub-sectors. All the sub-sectors, except computer, electronic and optical products manufacturing sector (C26) obtained relatively low values for the generated value added and turnover per energy use, which as a result ranked these sectors in lower positions.

3.2.2. Technical dimension sub-index

The sub-index values of the technical dimesion are less fluctuating compared to the results in the economic dimension. The average technical dimension value equals 0,35. The dimension values range from 0,03 to 0,75. In the technical dimension none of the sub-sectors have reached the maximum value of 1 (how it was observed in the economic dimension). Figure 3-4. illustrates the sub-index values of technical dimension for each sub-sector. In addition, Annex 2 outlines a table with all the indicator values.

The highest technical dimension sub-index value equals 0,75 that was reached by the pharmaceutical products and pharmaceutical preparations manufacturing sector (C21). The sector showed high values in each of the included indicators in dimension except for the indicator value of investment per energy use. The sector reflected the highest indicator values for both – share of ISO 50001 registered companies and share of large size companies. Due to the high values in these indicators, the sub-sector achieved leading positions in the technical dimension sub-index.

Printing and reproduction of recorded media sector (C18) obtained the second highest technical dimension sub-index value of 0,58. It was achieved thanks to the sector’s investment per unit of energy consumed, as well as thanks to the sector’s ability to consume less energy per an employee. It could be explained by the sector’s specifics of the production processes that is based on the higher automatization level and ability to perform part of the activities electronically.

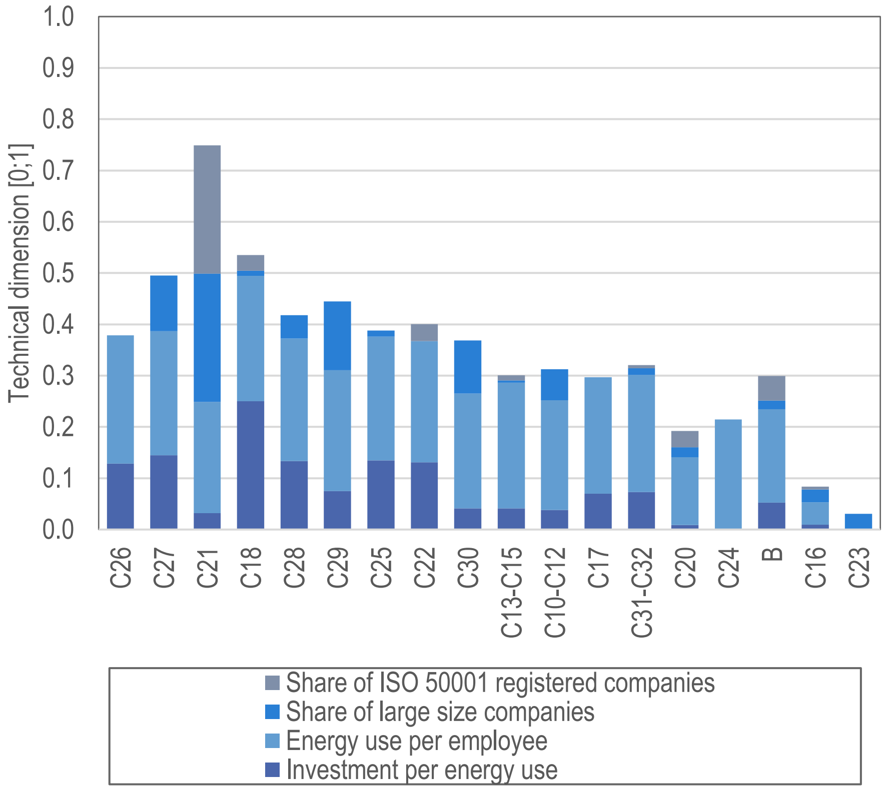


Fig. 3-4.Technical dimension sub-index.

The lowest technical dimension sub-indices were obtained by the other non-metallic mineral products manufacturing sector (C23) – 0,03, wood and cork products manufacturing sector (C16) – 0,08, chemicals and chemical products manufacturing sector (C20) – 0,19, and basic metals manufacturing sector (C24) – 0,21. These industry sub-sectors reflected low values in all the indicators of technical dimension. Among these sectors chemicals and chemical products manufacturing sector (C20) and basic metals manufacturing sector (C24) reported lower energy consumption per employee that allowed them to achieve higher sub-index values, compared to sectros such as other non-metallic mineral products manufacturing sector (C23) and wood and cork products manufacturing sector (C16).

Other sub-sectors showed medium level technical dimension sub-index values that were in a range from 0,30 that was achieved by the paper and paper products manufacturing sector (C17) and mining and quarrying (B) sector, to 0,50 that was reached by the electrical equipment manufacturing sector (C27). In addition, it can be observed that computer, electronic and optical products manufacturing sector (C26) that was in the leading positions in the economic dimension, in the technical dimension has achieved a medium level value of 0,38. Moreover, the sector obtained the lowest indicator values for the share of ISO 50001 registered companies and share of large size companies.

3.2.3. Environmental dimension sub-index

The values of the environmental dimension range from 0,06 to 0,72. The average value of the dimension sub-index equals 0,48 that is the highest average value among the all three dimensions. Figure 3-5. illustrates the results from the environmental dimension sub-indices for each industrial sub-sector. In addition, in Annex 3 a table outlining all the indicator values is presented.

The highest environemntal dimension sub-index values were reached in the computer, electronic and optical products manufacturing sector (C26) – 0,72, machinery and equipment manufacturing sector (C28) – 0,64, other transport equipment manufacturing sector (C30) – 0,58, printing and reproduction of recorded media sector (C18) and wood and cork products manufacturing sector (C16) – 0,56 in each. The high performance in the environmental dimenson for these sectors were achieved due to low greenhouse has intensity levels and lower share of fossil energy resource consumption, compared to other sub-sectors. As a result, high normailized indicator values were achieved for these variables.

The lowest environmental dimension sub-index value was obtained in the other non-metallic mineral products manufacturing sector (C23) that reached a value of 0,06. Low performance in the environmental dimension sub-index showed also mining and quarrying sector (B) with a value of 0,28 and pharmaceutical products and pharmaceutical preparations manufacturing sector (C21) with a value of 0,37. These results indicate that these sub-sectors create substantially higher impact on the environement compared to the other sub-sectors.

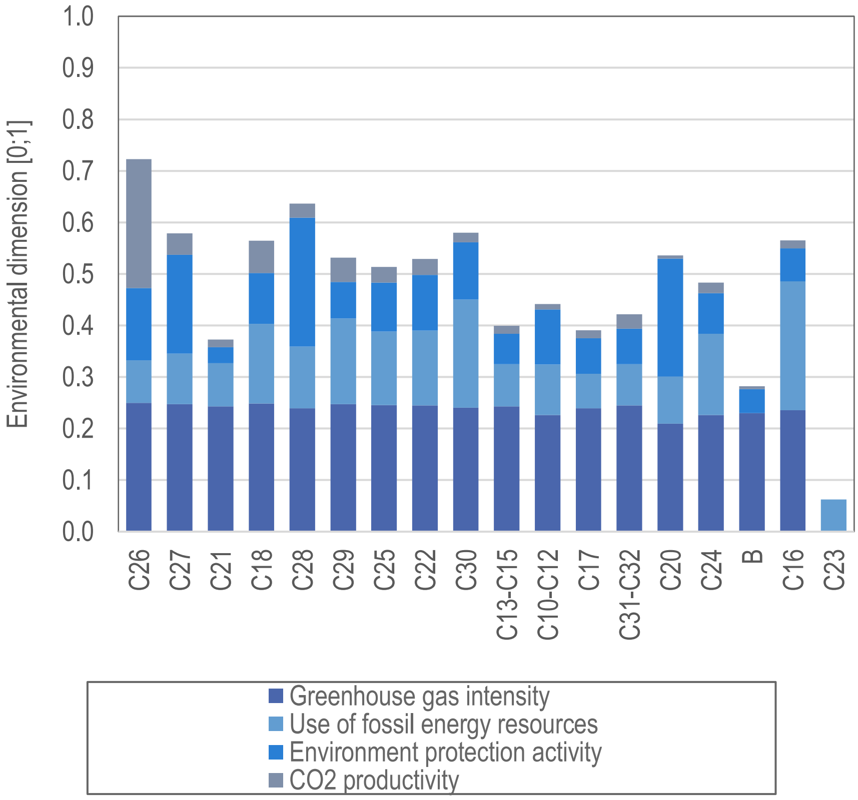


Fig. 3-5. Environmental dimension sub-index.

Other sub-sectors reflected medium values that range from 0,39 that was reached by the paper and paper products manufacturing sector (C17), to 0,54 that was achieved by the chemicals and chemical products manufacturing sector (C20).

It can be observed that wood and cork products manufacturing sector (C16) that reached one of the lowest values in the economic and technical dimension sub-indices, reflected a strong performance in the environmental dimension sub-index. It is explained by the sector's lower produced greenhouse gases and share of fossil energy resources. In this sector as a basis for heating is used wood that is a renewable energy source.

3.2.4. Energy efficiency composite index

The final results of the energy efficiency compostie index for the industry include all thee values from the dimension sub-indices. By applying the same weight categories, the final EEI grade is obtained. Figure 3-6. illustrates EEI values for the industry sub-sectors. In addition Table 3-4.outlines the obtained values for the dimension sub-indices and overall EEI grades for each sub-sector.

The average energy efficiency composite index value for the industry is iequal 0,39. The total range of the values among the sub-sectors range from 0,04 to 0,70. None of the sub-sectors obtained the highest possible grade of 1 or the lowest grade of 0.

The absolute leader of the energy efficiency composite index for the industry is the computer, electronic and optical products manufacturing sector (C26), that obtained the highest sub-index values in the economic and environmental dimension. As a result, it also contributed to the high value achievement for the overall EEI. On the contrary, the lowest value was obtained for the other non-metallic mineral products manufacturing sector (C23), that compared to the values of other sub-sectors got the lowest values in each of the dimension sub-indices.

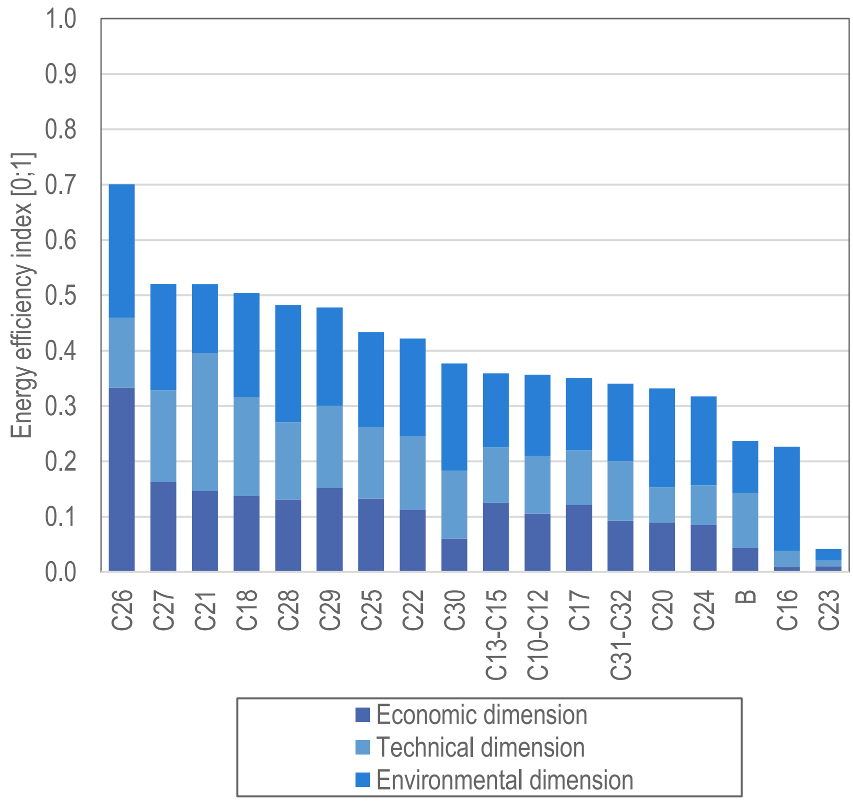


Fig. 3-6. Energy efficiency composite index for industry.

Eight sub-sectors have reached EEI values above the industry average. These sub-sectors are previously mentioned computer, electronic and optical products manufacturing sector (C26) with a value of 0,70, electrical equipment manufacturing sector (C27) and pharmaceuticals manufacturing sectorb (C21) with a value of 0,52 in each, printing and reproduction of recorded media sector (C18) with a value of 0,50 , machinery and equipment manufacturing sector (C28) and motor vehicles, trailers and semi-trailers manufacturing sector (C29) with a value of 0,48 in each, fabricated metal products manufacturing sector (C25) with a value of 0,43 and of rubber and plastic products manufacturing sector (C22) with a value of 0,42.

When analyzing the EEI structure in the division by the obtained values in dimension sub-indices, it can be observed that for computer, electronic and optical products manufacturing sector (C26) dominating is the economic dimension and the lowest impact on EEI performance comes from the technical dimension. Moreover, for the basic pharmaceutical products and pharmaceutical preparations manufacturing sector (C21) dominating is the technical dimension, and the least dominating is the environmental dimension. However, for machinery and equipment manufacturing sector (C28) dominating is the environmental dimension. These results allow to identify each sector's strong and weak aspekts in the context of energy efficiency performance.

Table 3-4.

The obtained results for economic, technical and environmental dimensions and EEI

	Dimension sub-index values			
NACE code	**Economic**	**Technical**	**Environ-mental**	**EEI**
C26: Manufacture of computer, electronic and optical products	0,33	0,13	0,24	0,70
C27: Manufacture of electrical equipment	0,16	0,17	0,19	0,52
C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	0,15	0,25	0,12	0,52
C18: Printing and reproduction of recorded media	0,14	0,18	0,19	0,50
C28: Manufacture of machinery and equipment	0,13	0,14	0,21	0,48
C29: Manufacture of motor vehicles, trailers and semi-trailers	0,15	0,15	0,18	0,48
C25: Manufacture of fabricated metal products, except machinery and equipment	0,13	0,13	0,17	0,43
C22: Manufacture of rubber and plastic products	0,11	0,13	0,18	0,42
C30: Manufacture of other transport equipment	0,06	0,12	0,19	0,38
C13-C15: Manufacture of textiles, wearing apparel, leather and related products	0,13	0,10	0,13	0,36
C10-C12: Manufacture of food products; beverages and tobacco products	0,11	0,10	0,15	0,36
C17: Manufacture of paper and paper products	0,12	0,10	0,13	0,35
C31-32: Manufacture of furniture; other manufacturing	0,09	0,11	0,14	0,34
C20: Manufacture of chemicals and chemical products	0,09	0,06	0,18	0,33
C24: Manufacture of basic metals	0,08	0,07	0,16	0,32
B: Mining and quarrying	0,04	0,10	0,09	0,24
C16: Manufacture of wood and cork products; manufacture of articles of straw and plaiting materials	0,01	0,03	0,19	0,23
C23: Manufacture of other non-metallic mineral products	0,01	0,01	0,02	0,04

The majority or 10 sectors from 18 reported EEI values that are below the industry average. Five sectors with the lowest values are other non-metallic mineral products manufacturing sector (C23) with a value of 0,04, wood and cork products manufacturing sector (C16) with a value of 0,23, mining and quarrying sector (B) with a value of 0,24, basic metals manufacturing sector (C24) with 0.32, chemicals and chemical products manufacturing sector (C20) with 0,33 sectors. When evaluating the structure of EEI for these sectors, it can be observed that for all the sectors, except for the mining and quarrying sector (B) dominating is the environmental dimension, that had the highest contribution to reaching higher overall EEI grade. For mining and quarrying sector (B) dominating is technical dimension, but economic and environmental dimensions have less dominating power.

In general, it can be concluded that the sector's economic performance plays a significant role on obtaining the final EEI value. Three sub-sectors that have reached the highest values in the economic dimension sub-index obtained also the highest values in the total energy efficiency composite index.

Overall the relatively low average EEI for the industry indicate that there are possible energy efficiency improvements in each of the industrial sub-sectors depending on the reflected indicator values in the representative dimensions. In general, the level of total energy utilization efficiency of an industry can be investigated and explained by exploring (1) individual sector's concentration in the industry; (2) individual sector's generated monetary turnover to account for sector's energy productivity; (3) individual sector's energy intensity that is an inverse of energy productivity (*European Commission*, 1970; *Mulder & de Groot*, 2013). Figure 3-7. represents the overall outlook of the Latvian manufacturing industry structure and energy intensity.

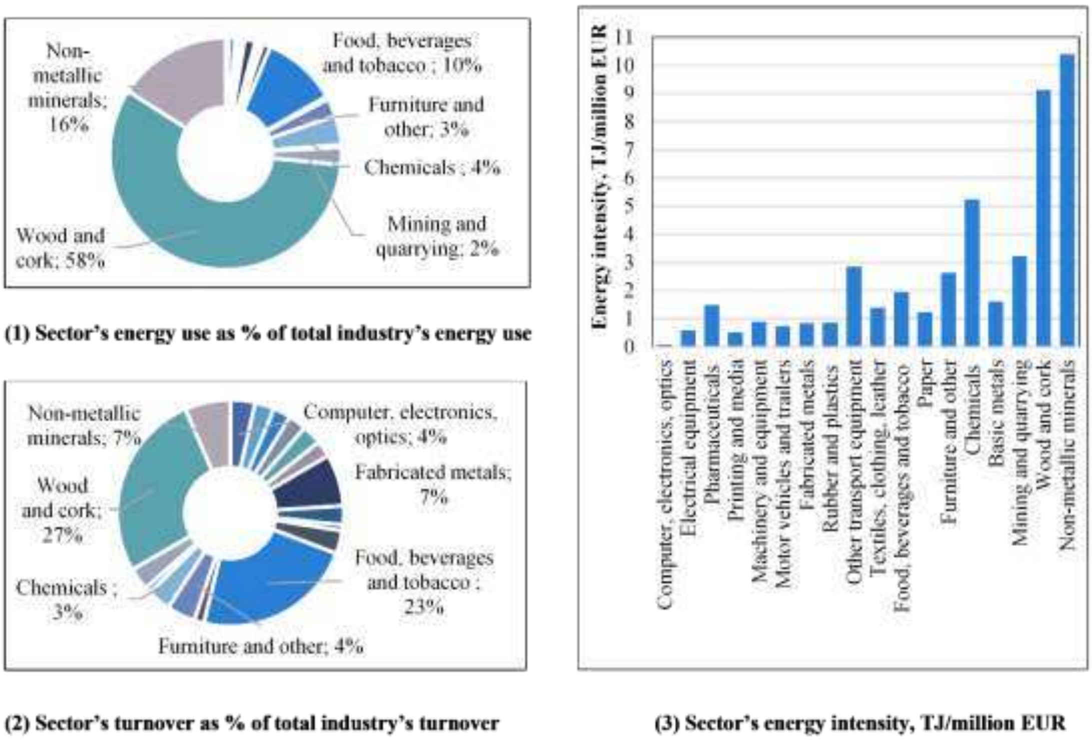


Fig. 3-8. Structure of the overall Latvian manufacturing industry and energy instensities of all sub-sectors in 2017 (CSP, n.d.-a, n.d.-c).

When analyzing total energy efficiency performance in manufacturing industry including all the sectors involved in the study, from the above-mentioned result analysis it can be concluded that overall the energy efficiency performance of Latvian manufacturing industry in

2017 can be considered as weak. It can mainly be explained by the country's unequally diversified structure of manufacturing industry sectors. More specifically, Latvian manufacturing industry is largely composed by energy-intensive sectors such as manufacture of wood and of products of wood and cork and manufacture of other non-metallic mineral products that constitute 58% and 16% of total net domestic energy use and 27% and 7% of total turnover of Latvian manufacturing industry respectively (see Figure Fig. 3-8.). However, both sectors demonstrate worst EEI in the scope of this study. Moreover, both sectors recorded the lowest values in all the dimensions and their representative indicators, except for manufacturing of wood products that reported high numbers in the environmental dimension since the sector mostly relies on the use of renewable energy resources. However, relatively high performance in the environmental dimension did not compensate the weak results in the economic and technological dimension which in result lead to low EEI in total for wood manufacturing sector.

All in all, combining the EEI results from Figure 3-9. and the insights on the manufacturing industry outlook and structure in Figure 3-10., it can be seen that there is huge potential in improving energy efficiency in wood, wood products and cork manufacture and manufacture of other non-metallic mineral products since both sectors combined take up almost two thirds of the total manufacturing energy consumption in Latvia. These insights suggest that in order to enhance industry's overall energy efficiency performance, extra attention should be put on these two sectors since both sectors have the highest concentration and impact in the overall portfolio of manufacturing industry sectors in Latvia. Therefore, it is recommended for the government to focus on developing sector-specific energy efficiency policies that would encourage enterprises in these sectors to implement better energy efficiency practices.

CONCLUSIONS AND POLICY RECOMMENDATIONS

In this policy report an assesment on the industrial energy efficiency potential has been performed. The assessment is based on the utilization of a versatile methodology that includes several energy efficiency evaluation techniques. As a result, a comprehenzsive and detailed industry energy efficiency description has been obtained. The conclusions of the report and following policy recommendations are structured according to the research stages that have been described in each of the chapters of the report.

In the first chapter of the report the calculations on the economic and technical potential has been performed. Economic energy efficiency potential was determined based on the energy effictniency monitoring system (EMS) data. Economic energy efficiency potential reflects the projected energy savings reported by the EMS program companies. Total economic energy efficiency potential for the industry equals 189,1 GWh or 2,12 % from the total energy consumption in the industry. The projected economic CO_2 emission savings potential is equal to 10,6 thous. tons of CO_2. In order to obtain technical energy efficiency potential company energy audit data from Ministry of Economics was uded. It was calculated that the technical energy efficiency potential for industry account for 500,1 GWh or 5,6 % from the total energy consumption in the industry. Total identified technical potential for the reduction of CO_2 emissions make up 41,1 thous. tons of CO_2, that is approximately 3,6 % from the total CO_2 emissions in the industry. For the calculated technical energy efficiency potential un each sector a theoretical bechmarks were applied. The benchmars were obtained from the results of a similar energy efficiency program evaluation in Sweden (Paramonova & Thollander, 2016). After the application of the benchmarks it was concluded that unused energy savings potential is twice higher than identified technical energy efficiency potential in Latvia. It means that the total energy savings potential in industry is considerably higher than the determined economic and technical energy efficiency potential values. In the long term it can be achieved in case of the utilization of the best available technologies and reduction in the barriers for the implementation of energy effieciency activities. As the most significant obstacles for the implemention of energy efficiency activities are mentioned the lack of knowledge and information, lack of motivation and interest from the management, lack of time, lack of capital investment, and others (Paramonova & Thollander, 2016). Policymakers should consider the introduction of support mechanisms and political instruments in order to stumulate the implementation of energy efficiency activities in the companies operating in the industry. Therefore, ir would stimulate the achievement of the calculated theoretically possible energy savings. In addition, the authors of the research point out that, in order to fully evaluate the efficiency of the implemented energy efficiency monitoring system program (according to the Energy Efficiency law), there should be improvements made in the existing data monitoring system. At the moment, the existing data quality do not allow to make precise and objective energy efficiency potential evaluation calculations, therefore it seriously limits the application of the develped metdodological model.

In the second chapter of the report the benchmarks for the individual technological processes have been obtained for two industry sub-sectors: food processing and wood and cork products manufacturing. The benchmarks were obtained based on the energy audit data from the companies of the representative sectors. Benchmarks were calculated for the specific energy consumption indicator that measure the consumed energy per one ton of produced product (for food) or m^3 (for wood). In addition, case studies for companies that operate in each of these sectors were analyzed and described in detail. It was concluded that there are significant differences observed between the specific electricity and heat consumption sensitivity dependance on the changes of the amounts of produced energy. The specific energy consumption ratios in each of the industry sub-sectors differ because the utilized energy amounts and structure is different.

In the third chapter of the report, the results of the industrial energy efficiency index (EEI) is demonstrated for 18 industrial sub-sectors in order to compare the energy efficiency performance among them. The index included 12 different indicators that were grouped into 3 dimensions: economic, technical, and environmental. The obtained results from EEI and dimension sub-indices indicate, that the energy efficiency performance levels differ significantly among sectors and the differences appear in all three energy efficiency dimensions. High energy efficiency was achieved mostly in high-tech sectors that produce more sophisticated and complex products, e.g. computers, electronics, optics, and electrical equipment. On top of that, lightweight sectors that include highly automated production processes and produce serial products of relatively light weight and high economic value, e.g. pharmaceuticals, printed and reproduced media materials, likewise held considerably higher energy efficiency performance levels. On contrary, low energy efficiency was observed in highly energy intensive sectors that produce primary products with low added value, e.g. wood, non-metallic minerals (sand, gravel, clay, limestone, etc.). Since energy intensive sectors account for the highest share or more than two thirds from the total energy consumption in the industry, then energy efficiency improvements are especially important in these sectors. The developed method allows to identify unique characteristics of each sector and it provides valuable information for designing and developing efficient sector-specific energy policies and future development strategies. The obtained results highlight significant sector differences, therefore in order to accelerate the energy efficiency improvement in the underperforming sectors, development of different policies is recommended when implementing energy efficiency legislation.

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ANNEX

Annex 1. Economic dimension sub-index of the composite EEI

Dimension	Economic dimension				
NACE code	Value added per energy use	Generated turnover per energy use	Energy costs	Energy taxes per generated turnover	Economic dimension sub-index
C26: Manufacture of computer, electronic and optical products	0,25	0,25	0,25	0,25	1
C27: Manufacture of electrical equipment	0,03	0,03	0,21	0,22	0,49
C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	0,01	0,01	0,22	0,19	0,44
C18: Printing and reproduction of recorded media	0,03	0,04	0,13	0,22	0,41
C28: Manufacture of machinery and equipment	0,02	0,02	0,17	0,18	0,39
C29: Manufacture of motor vehicles, trailers and semi-trailers	0,02	0,03	0,23	0,18	0,46
C25: Manufacture of fabricated metal products, except machinery and equipment	0,02	0,02	0,16	0,20	0,40
C22: Manufacture of rubber and plastic products	0,01	0,02	0,12	0,18	0,34
C30: Manufacture of other transport equipment	0,00	0,01	0,12	0,06	0,18
C13-C15: Manufacture of textiles, wearing apparel, leather and related products	0,01	0,01	0,17	0,18	0,38
C10-C12: Manufacture of food products; beverages and tobacco products	0,00	0,01	0,16	0,14	0,32
C17: Manufacture of paper and paper products	0,01	0,01	0,16	0,18	0,36
C31-32: Manufacture of furniture; other manufacturing	0,01	0,01	0,12	0,14	0,28
C20: Manufacture of chemicals and chemical products	0,00	0,00	0,11	0,16	0,27
C24: Manufacture of basic metals	0,00	0,01	0,14	0,10	0,25
B: Mining and quarrying	0,00	0,00	0,12	0,00	0,13
C16: Manufacture of wood and cork products; manufacture of articles of straw and plaiting materials	0,00	0,00	0,00	0,03	0,03
C23: Manufacture of other non-metallic mineral products	0,00	0,00	0,02	0,01	0,03

Annex 2. Technical dimension sub-index of the composite EEI

Dimension	Technical dimension				
NACE code	Investment per energy use	Energy use per employee	Share of large size companies	Share of ISO 50001 registered companies	Technical dimension sub-index
C26: Manufacture of computer, electronic and optical products	0,13	0,25	0,00	0,00	0,38
C27: Manufacture of electrical equipment	0,14	0,24	0,11	0,00	0,50
C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	0,03	0,22	0,25	0,25	0,75
C18: Printing and reproduction of recorded media	0,25	0,24	0,01	0,03	0,54
C28: Manufacture of machinery and equipment	0,13	0,24	0,05	0,00	0,42
C29: Manufacture of motor vehicles, trailers and semi-trailers	0,07	0,24	0,13	0,00	0,44
C25: Manufacture of fabricated metal products, except machinery and equipment	0,13	0,24	0,01	0,00	0,39
C22: Manufacture of rubber and plastic products	0,13	0,24	0,00	0,03	0,40
C30: Manufacture of other transport equipment	0,04	0,22	0,10	0,00	0,37
C13-C15: Manufacture of textiles, wearing apparel, leather and related products	0,04	0,24	0,00	0,01	0,30
C10-C12: Manufacture of food products; beverages and tobacco products	0,04	0,21	0,06	0,00	0,31
C17: Manufacture of paper and paper products	0,07	0,23	0,00	0,00	0,30
C31-32: Manufacture of furniture; other manufacturing	0,07	0,23	0,01	0,01	0,32
C20: Manufacture of chemicals and chemical products	0,01	0,13	0,02	0,03	0,19
C24: Manufacture of basic metals	0,00	0,21	0,00	0,00	0,21
B: Mining and quarrying	0,05	0,18	0,02	0,05	0,30
C16: Manufacture of wood and cork products; manufacture of articles of straw and plaiting materials	0,01	0,04	0,02	0,01	0,08
C23: Manufacture of other non-metallic mineral products	0,00	0,00	0,03	0,00	0,03

Annex 3. Environmental dimension sub-index of the composite EEI

Dimension	Environmental dimension				
NACE code	Greenhouse gas intensity	Use of fossil energy resources	Environment protection activity	CO_2 productivity	Environ-mental dimension sub-index
C26: Manufacture of computer, electronic and optical products	0,25	0,08	0,14	0,25	0,72
C27: Manufacture of electrical equipment	0,25	0,10	0,19	0,04	0,58
C21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	0,24	0,08	0,03	0,02	0,37
C18: Printing and reproduction of recorded media	0,25	0,15	0,10	0,06	0,56
C28: Manufacture of machinery and equipment	0,24	0,12	0,25	0,03	0,64
C29: Manufacture of motor vehicles, trailers and semi-trailers	0,25	0,17	0,07	0,05	0,53
C25: Manufacture of fabricated metal products, except machinery and equipment	0,25	0,14	0,10	0,03	0,51
C22: Manufacture of rubber and plastic products	0,24	0,15	0,11	0,03	0,53
C30: Manufacture of other transport equipment	0,24	0,21	0,11	0,02	0,58
C13-C15: Manufacture of textiles, wearing apparel, leather and related products	0,24	0,08	0,06	0,02	0,40
C10-C12: Manufacture of food products; beverages and tobacco products	0,23	0,10	0,11	0,01	0,44
C17: Manufacture of paper and paper products	0,24	0,07	0,07	0,02	0,39
C31-32: Manufacture of furniture; other manufacturing	0,24	0,08	0,07	0,03	0,42
C20: Manufacture of chemicals and chemical products	0,21	0,09	0,23	0,01	0,54
C24: Manufacture of basic metals	0,23	0,16	0,08	0,02	0,48
B: Mining and quarrying	0,23	0,00	0,05	0,01	0,28
C16: Manufacture of wood and cork products; manufacture of articles of straw and plaiting materials	0,24	0,25	0,06	0,02	0,56
C23: Manufacture of other non-metallic mineral products	0,00	0,06	0,00	0,00	0,06