RIGA TECHNICAL UNIVERSITY
Faculty of Electrical and Environmental Engineering
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LATVIA’S ENERGY EFFICIENCY POLICY FOR THE MANUFACTURING INDUSTRY IN THE GREEN DEAL TRANSITION

Summary of the Doctoral Thesis

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DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for the review to Riga Technical University for the promotion to the scientific degree of Doctor of Science (Ph. D.) is my own. I confirm that this Doctoral Thesis had not been submitted to any other university for the promotion to a scientific degree.

Kristaps Ločmelis……………………………. (signature)
Date: ………………………

The Doctoral Thesis has been written in Latvian. It consists of an Introduction; 5 Chapters; Conclusions; 44 figures; 8 tables; 8 publications attached; the total number of pages is 159. The Bibliography contains 90 titles.

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INTRODUCTION

For more than two decades the European Union (EU) has been among the front runners in terms of ambitious climate and environmental goals, giving a significant attention to the energy sector. The EU climate and energy policy for 2030 sets ambitious targets and challenges to current energy use patterns across Europe. At the same time, policy objectives are to maintain energy affordability for businesses and consumers, which means that energy and climate goals should be achieved in the most cost-effective way.

Costs of energy transition are passed on to the consumers mostly via electricity bills that have previously raised the energy costs of industries and created risks to global competitiveness for the EU industry. To address the concern for competitiveness of Europe's energy intensive industries, the European Commission (EC) offers the energy efficiency policy, which is one of the most crucial cornerstones in the EU climate and energy framework, as a tool to reduce the energy intensity of industrial activities. Energy efficiency is considered to be one of the most cost-effective ways to ensure energy security, reduce carbon emissions and ensure economic competitiveness.

To meet its ambitious energy efficiency goals, the EU has adopted the Energy Efficiency Directive (EED), which imposes mandatory energy efficiency targets on Member States, with a special focus on the industrial sector as one of the largest emitters of greenhouse gases (GHG) (EP, 2018). On December 11, 2019 the EC led by the President *Ursula von der Leyen* came up with even more ambitious climate goals by publishing *the European Green Deal*, aiming at EU GHG neutrality by 2050, which cannot be achieved without a rapid and significant involvement of industry, while acknowledging the potential risks to competitiveness with global players, especially where remarkable differences in climate ambition levels worldwide persist (EC, 2019). Significantly, the EC does not offer to address the cross-border "carbon leakage" risks through subsidies or tax rebates, but emphasizes the importance of energy efficiency policies in energy-intensive industries as one, if not the only, sustainable way to maintain global competitiveness.

The Latvian industrial sector is already facing the rise of energy prices and decline of competitiveness, therefore the energy efficiency policy issues are also topical in Latvia. At present, energy-intensive manufacturing industries have benefited from rebates on electricity payments in the form of a refund of the mandatory procurement component (MK, 2015), but such a mechanism is not considered sustainable, especially from the European Green Deal perspective. Another important energy efficiency policy that has been introduced in Latvia since 2017 via the Energy Efficiency Law is the introduction of mandatory energy audits or energy management systems in large companies[1] and large consumers[2] (Saeima, 2016). In general, Latvia's energy efficiency policy for industrial enterprises should contribute to increasing industrial competitiveness, moving towards a GHG-neutral economy and security of energy supply, especially with regard to energy supplies from the third countries.

[1] Enterprises employing 250 or more employees or having a turnover of more than 50 million euros in the reporting year and an annual balance sheet exceeding 43 million euros.
[2] Consumers with annual electricity consumption that exceeds 500 MWh.

Research Topicality

Energy efficiency is seen as one of the cornerstones of the EU's energy and climate policy by 2030, with overall target of a 32.5 % reduction in energy consumption compared to the 2007 baseline projection (EP, 2018). Latvia's National Energy and Climate Plan (NECP) also includes a trajectory of energy efficiency targets, in which the energy efficiency of the manufacturing industry is expected to play a significant role (MK, 2020).

In addition, the Green Deal and strategy of Latvia's climate neutrality by 2050 presume a reduction of GHG emissions in all sectors of economy (including industry) and balancing the climate impact by implementing the "energy efficiency first" principle.

A successful implementation of an ambitious energy efficiency policy requires an identification of the current status of existing policies, and a focus on new initiatives to address identified energy efficiency gaps. By the end of 2022, an evaluation of Latvia's current energy efficiency policy is expected within the framework of the NECP, and the conclusions of the evaluation will shape improvements of the energy policy for the next decade.

Aim and Objectives

The objective of this research is to assess the impact of Latvia's energy policy on the industrial sector and to provide recommendations for further policy improvement, in the context of the EU and Latvia's long-term goals to achieve the climate-neutrality.

In order to meet the objective, the following tasks were performed.

1. The profiling of the industrial sectors of Latvia and other EU countries at the macroeconomic level:
    a) comparison of electricity prices for industrial consumers;
    b) comparison of energy intensity using different macroeconomic indicators by industry;
    c) comparison of CO_2 emissions by industry.
2. Analysis of Latvia's policy that promotes and hinders energy efficiency measures for energy-intensive industries:
    a) profiling of energy-intensive industrial industries and subsidies received;
    b) policy impact on energy efficiency decision-making at company level.
3. Analysis of energy efficiency potential in Latvia's dominant industries, using the data from industrial energy audit reports, and benchmarking with results of a similar program in Sweden.
4. Analysis of goals set by the Latvia's energy efficiency policy and the implementation trajectory in the context of the European Green Deal.

Scientific Novelty

The research is based on the analysis of various implications of Latvia's energy efficiency policy by applying different research methods and integrating the research results for the development of recommendations for future policy instruments. The Doctoral Thesis offers to use an innovative complex methodological approach, which is shown in Fig. 1.

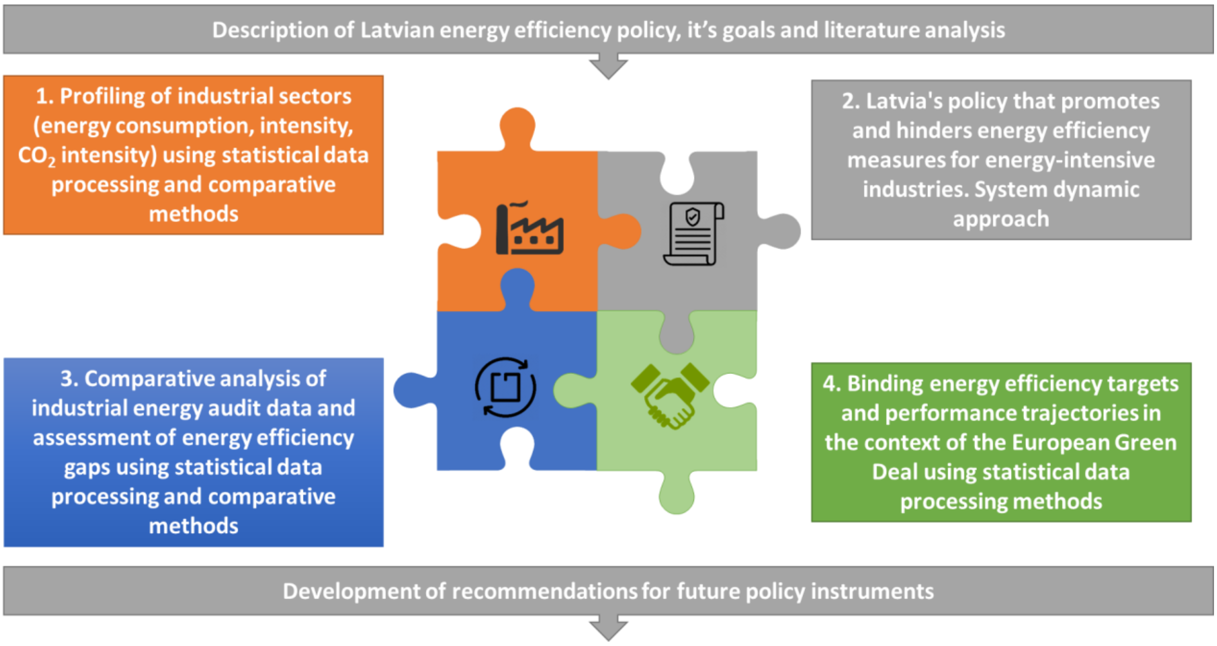

Fig. 1. Methodological approach of the research.

Several methods (statistical data processing, system dynamics, benchmarking analysis) are applied in the research to study different policy implications, which are interrelated and integrated into each other.

1. The profiling of industrial sectors is based on the processing of statistics on energy consumption, energy intensity and CO_2 intensity of industrial sectors and on comparative analysis with other countries. The obtained results allow to identify the most dominant industrial sectors of Latvia by energy consumption and gross value added (GVA), determining the differences in their energy and CO_2 intensity, as well as to perform a comparative analysis with other countries. The results can be used to determine industry-specific solutions for climate-neutrality goals.
2. A system dynamics model has been developed for modelling the individual decision-making of energy-intensive industrial enterprises regarding the implementation or non-implementation of energy efficiency measures, a subject to the requirements of the energy intensity support policy. The aim of modelling is to observe the impact of contradictory policies on the energy efficiency of energy-intensive companies, and to propose solutions to eliminate these contradictions.
3. The developed benchmarking methodology of industrial energy efficiency and CO_2 emission reduction potential by using processed statistical data obtained for industrial energy audit reports ensures the comparison of energy efficiency potential between

industrial sectors and countries. By using the developed methodology, the undiscovered energy efficiency and CO_2 emissions reduction potential in Latvian most dominant industries have been determined.

4. Analysis of Latvia's energy efficiency targets for industry, taking into account historical and targeted data on industrial energy intensity, using statistical data processing methods and interpreting the necessary trajectory in the context of the European Green Deal, provides valuable information on the current level of energy efficiency target ambitions in Latvia.

Based on the author's experience and knowledge, this is the first time that energy efficiency policy has been studied using such a wide range of methods, covering both macroeconomic industry parameters and individual decision modelling.

Research Hypothesis

1. Latvia's energy efficiency policy encourages the reduction of energy efficiency gap, however, its successful implementation is not possible without appropriate monitoring.
2. Latvia's energy efficiency policy for different industrial sectors should be more goal-oriented, applying different instruments to carbon-intensive and less carbon-intensive industries.

Practical Significance

The findings and conclusions gained in the research are useful to improve Latvia's energy efficiency policy, taking into account the so far modest achievements of industrial energy efficiency in Latvia and expected increase in targets in the coming decade, especially in the transition to climate neutrality by 2050.

The methodologies developed in the research allow to assess the energy intensity, CO_2 intensity, energy efficiency potential of industrial sectors and benchmark with each other, as well as with industrial sectors of other countries. The developed methodologies are practically applicable in scientific research and energy policy making.

Approbation of the Research Results

Publications on the Topic of Thesis Work

1. Locmelis, K., Bariss, U., Blumberga, D. Latvian Energy Policy on Energy Intensive Industries. *Energy Procedia*, 2017, Vol. 113, pp. 362–368. ISSN 1876-6102. https://doi.org/10.1016/j.egypro.2017.04.008 (indexed in SCOPUS, Web of Science).
2. Locmelis, K., Blumberga, A., Bariss, U., Blumberga, D. Energy Policy for Energy Intensive Manufacturing Companies and Its Impact on Energy Efficiency Improvements. System Dynamics Approach. *Energy Procedia*, 2017, Vol. 128, pp. 10–16. ISSN 1876-6102. https://doi.org/10.1016/j.egypro.2017.09.005 (indexed in SCOPUS, Web of Science).

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4. Locmelis, K., Bariss, U., Blumberga, D. Energy Efficiency Obligations and Subsidies to Energy Intensive Industries in Latvia. *Environmental and Climate Technologies*, 2019, Vol. 23, No. 2, pp. 90–101. ISSN 1691-5208. e-ISSN 2255-8837. https://doi.org/10.2478/rtuect-2019-0057 (indexed in SCOPUS, Web of Science).
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8. Locmelis, K., Blumberga, D., Blumberga, A., Kubule, A. Benchmarking of Industrial Energy Efficiency. Outcomes of an energy audit policy program. *Energies*, 2020. https://doi.org/10.3390/en13092210

Other Publications

1. Zigurs, A., Balodis, M., Ivanova, P., Locmelis, K., Sarma, U. National Energy and Climate Plans: Importance of Synergy, *Latvian Journal of Physics and Technical Sciences*, 2019, 56(6), pp. 3–16. https://doi.org/10.2478/lpts-2019-0031 (indexed in SCOPUS).
2. Žīgurs, Ā., Ločmelis, K., Bunkovskis, J. Eiropas Enerģētikas savienība. Rīgas process. *Enerģija un Pasaule*. 2015, No. 2(91), pp. 8–10. ISSN 1407-5911
3. Ločmelis, K., Jansons, L., Elektroenerģijas tirgus jautājumos un atbildēs. *Enerģija un Pasaule*. 2012, No. 3(74), pp. 50–52. ISSN 1407-5911

Reports at International Scientific Conferences

1. Locmelis, K., Bariss, U., Blumberga, D. Latvian Energy Policy on Energy Intensive Industries: International Scientific Conference "Environmental and Climate Technologies", CONECT 2016, October 12–14, 2016, Riga, Latvia.
2. Locmelis, K., Blumberga, A., Bariss, U., Blumberga, D. Energy Policy for Energy Intensive Manufacturing Companies and Its Impact on Energy Efficiency Improvements. System Dynamics Approach: International Scientific Conference "Environmental and Climate Technologies", CONECT 2017, May 10–12, 2017 Riga, Latvia.

3. Locmelis, K., Blumberga, D., Bariss, U. Energy Efficiency in Large Industrial Plants. Legislative Aspects: International Scientific Conference "Environmental and Climate Technologies", CONECT 2018, May 16–18, 2018, Riga, Latvia.
4. Locmelis, K., Bariss, U., Blumberga, D. Latvian Energy Policy on Energy Intensive Industries: International Scientific Conference "Environmental and Climate Technologies", CONECT 2016, October 12–14, 2016, Riga, Latvia.
5. Locmelis, K., Blumberga, A., Bariss, U., Blumberga, D. Energy Policy for Energy Intensive Manufacturing Companies and Its Impact on Energy Efficiency Improvements. System Dynamics Approach: International Scientific Conference "Environmental and Climate Technologies", CONECT 2017, May 10–12, 2017, Riga, Latvia.
6. Locmelis, K., Blumberga, D., Bariss, U. Energy Efficiency in Large Industrial Plants. Legislative Aspects: International Scientific Conference "Environmental and Climate Technologies", CONECT 2018, May 16–18, 2018, Riga, Latvia.
7. Locmelis, K., Bariss, U., Blumberga, D. Energy efficiency obligations and subsidies to energy intensive industries in Latvia: International Scientific Conference "Environmental and Climate Technologies", CONECT 2019, May 15–17, 2019, Riga, Latvia.
8. Locmelis, K., Blumberga, D. Energy taxation exemptions for energy intensive industries and its impact on energy efficiency in Latvia: 2019 IEEE 60th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), October 7–9, 2019, Riga, Latvia (received an award for the best paper and the most outstanding presentation in section Environmental Assessment in Electrical Engineering).
9. Locmelis, K. Sustainability of National energy and climate plans in Baltics: The 6th WEC EU Baltic Sea Round Table 2019, August 12–13, 2019, Riga, Latvia.
10. Locmelis, K. RES and energy efficiency policy in LATVIA from the stakeholder's point of view: The 6th Japan-Baltic Seminar "Challenges of Energy Security that the Baltic States and Japan face", Waseda University, March 11, 2014, Tokyo, Japan.

1. ENERGY EFFICIENCY POLICY FOR INDUSTRY

1.1. National Energy Efficiency Targets of Latvia

Energy efficiency policy has been one of the top priorities in the EU for more than 25 years. Energy efficiency is considered to be one of the most cost-effective ways to ensure security of energy supply, reduce carbon emissions and economic competitiveness. EED imposes mandatory energy efficiency targets on Member States, but it is up to the Member States to decide how to achieve their energy efficiency targets (EP, 2018). Taking into account different ambition levels of energy efficiency targets set by various EU directives, Latvia's energy efficiency targets have changed over time, however, it is noticeable that the targeted energy efficiency savings have increased with each reporting period which confirms the growing importance of energy efficiency policy.

Latvia's binding energy efficiency targets for 2030 are set out in the NECP. According to the NECP, the cumulative energy end-use savings for the period 2021–2030 should reach 73.7 PJ or 20.5 TWh (for comparison, cumulative energy efficiency savings target for the period 2014–2020 is 9.9 TWh) (MK, 2020). The largest contribution (around 44 %) will come from energy savings in industry (see Fig. 1.1), of which approx. 80 % should be achieved in thermal industrial processes and only 20 % in electricity (see Fig. 1.2).

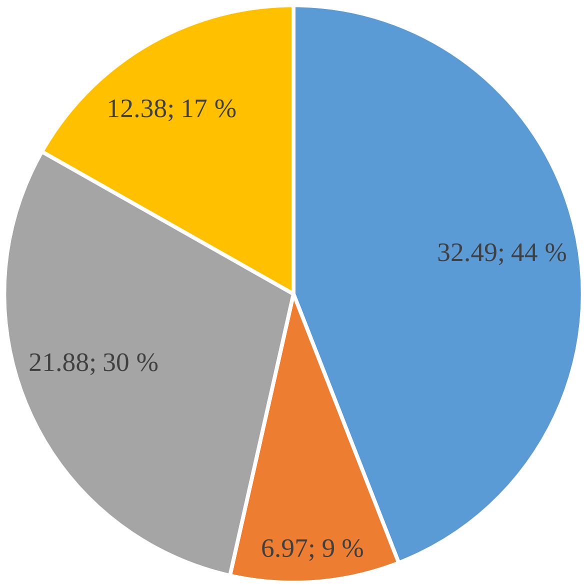


Fig. 1.1. Targeted cumulative energy savings in 2021–2030 (PJ and %) by sectors.

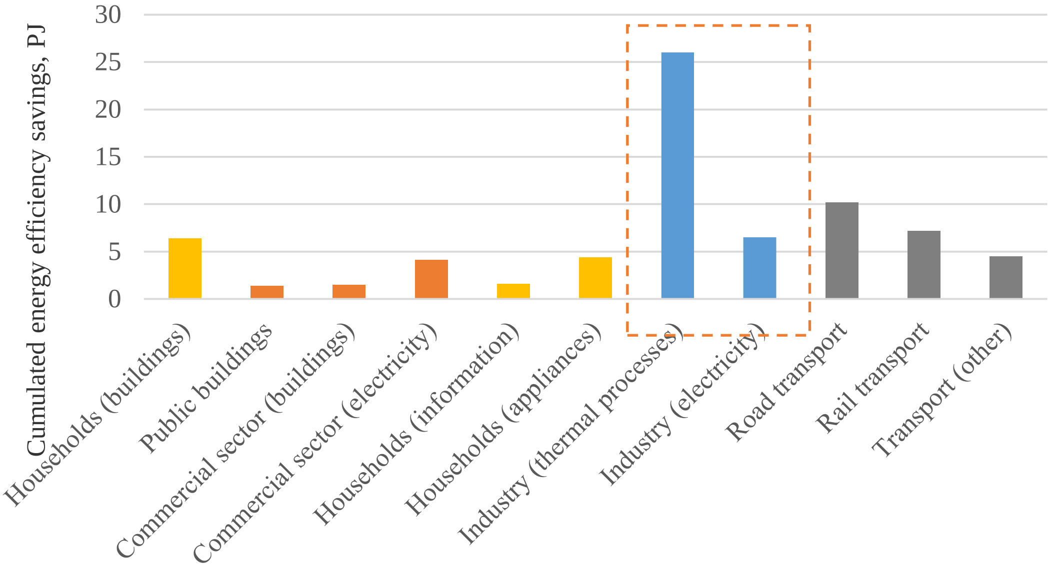


Fig. 1.2. Targeted cumulative energy savings in 2021–2030 (PJ) by sectors and activities.

1.2. Energy Efficiency Obligations on Large Enterprises and Consumers

Although the EED directly imposes requirements for regular energy audits on large enterprises, the Energy Efficiency Act imposes additional obligations to implement at least three energy efficiency improvement measures identified in the energy audit with the highest estimated energy savings or economic returns by 2020 (Saeima, 2016). It is not required to carry out energy audits if company has implemented and maintains a certified energy management system or if it implements and maintains additional energy management in a certified environmental management system and if it covers at least 90 % of the total final energy consumption of company. An obligation to implement at least three recommended energy efficiency improvement measures with the highest calculated energy savings or economic returns remains. In order to involve more industrial consumers, the Energy Efficiency Act imposes similar requirements on large electricity consumers as on large enterprises and imposes to implement at least three energy efficiency improvement measures recommended by an energy audit or energy management system with the highest estimated energy savings or economic returns by 2022 (Saeima, 2016).

If a large company or a large consumer does not fulfil the obligations specified in the Energy Efficiency Law, an energy efficiency fee of 7 % of the annual electricity costs is applicable to it. According to the Energy Efficiency Law, the Ministry of Economics (MoE) is responsible for monitoring compliance with the energy efficiency obligation for large companies and large consumers.

2. PROFILING OF INDUSTRIAL SECTORS OF LATVIA

The profiling of Latvia's manufacturing industry is carried out with the aim to identify the most dominant manufacturing industries in Latvia by energy consumption and GVA. The profiling of industrial sectors has been developed by processing statistics on energy consumption, turnover, energy costs, energy intensity and CO_2 intensity of industrial sectors and by performing cross-sectoral comparative analysis, as well as comparisons with other countries.

2.1. Energy Consumption

The share of manufacturing industries in Latvia's national GDP was 11.9 % in 2018, while the share of final energy consumption was 20.3 % (CSP, 2018). The most dominant industrial sector in Latvia, both in terms of GVA and energy consumption, is the production of wood and wood products. This sector consumed 62 % of all industrial energy consumption and produced 24 % of all industrial GVA in 2017. The three most dominant industries in terms of energy consumption are the production of wood and wood products, the production of non-metallic minerals and the production of food products and beverages, consuming a total of 89 % of all industrial consumption in Latvia (CSP, 2017).

Energy consumption in industries and distribution of energy sources is shown in Fig. 2.1, but the proportion of energy resources in final consumption in Fig. 2.2.

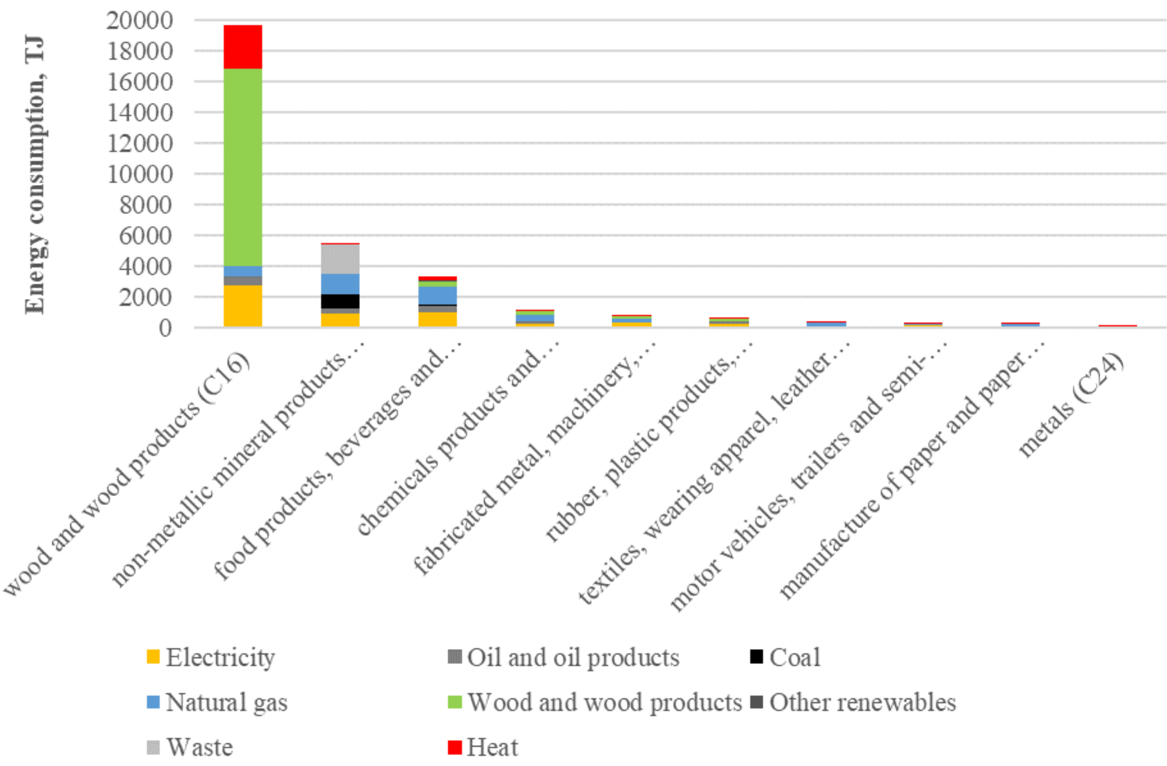


Fig. 2.1. Energy consumption and distribution of energy sources (2017).

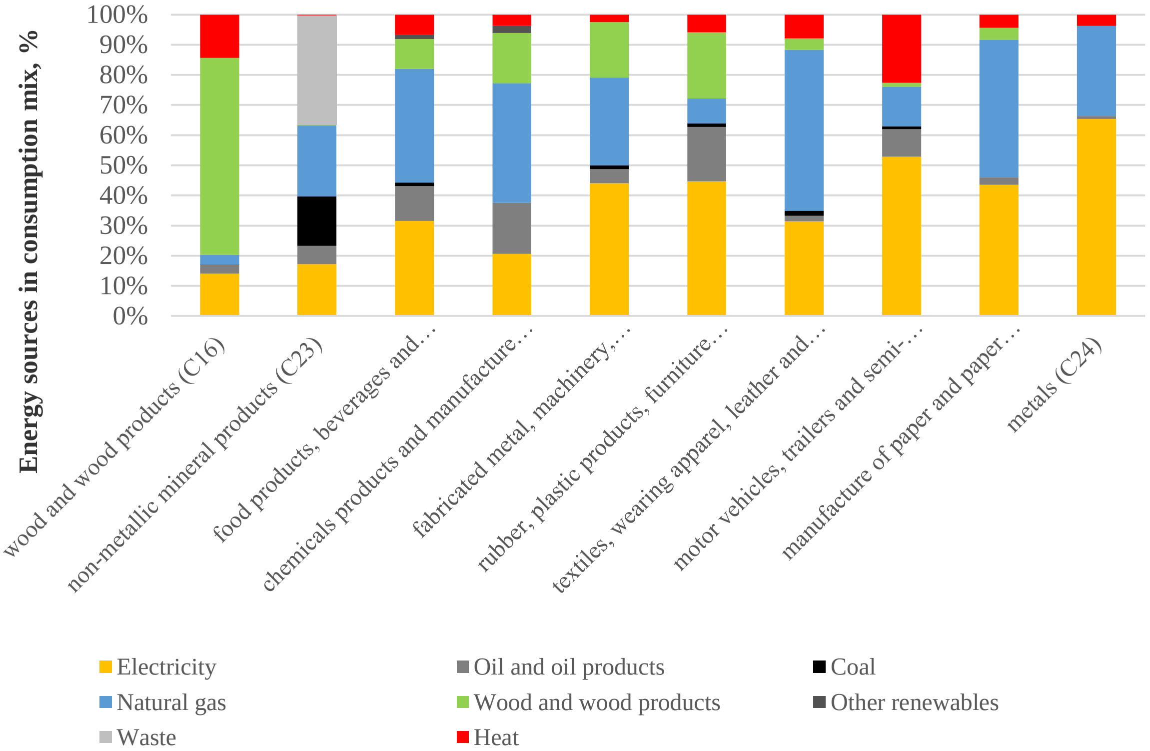


Fig. 2.2. Proportion of energy resources in final consumption (2017).

An important aspect to determine cost-effective energy efficiency measures is the correct assessment of the market value of the energy saved, as different MWh of savings have different market values. It can be concluded from Fig. 2.2 that the most of the energy consumption in largest industries is related to thermal processes (oil products, coal, wood, natural gas, waste), but a relatively smaller share is related to more expensive electricity. It is also important to note the significant wood consumption in the Latvian manufacturing industry, which according to the EU Emissions Trading Scheme (ETS) regulation (EP, 2003) is considered a CO_2-neutral fuel, thus Latvian industry has a much lower CO_2 intensity compared to, for example, the EU average (see Fig. 2.3).

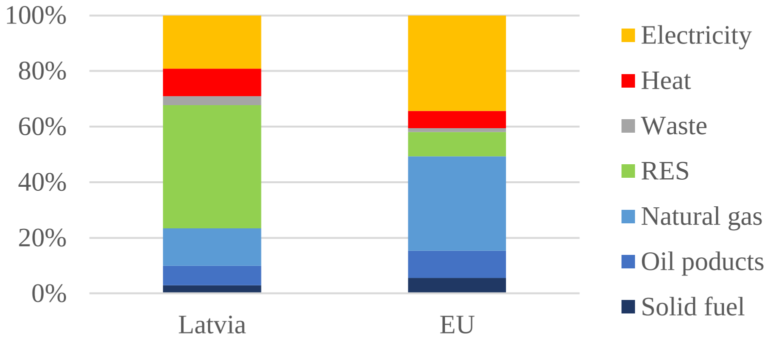


Fig. 2.3. Proportion of energy resources in industrial consumption in Latvia and EU (2017).

2.2. Electricity Price Analysis

Costs of energy transition are passed on to the consumers mostly via electricity bills that have previously raised the energy costs of industries and are creating risks to global competitiveness for EU industry. In a comprehensive study on the electricity prices for energy-intensive industries in the EU and its global competitors, Lutz et al. (2015) confirmed the importance of low electricity costs in maintaining the global competitiveness of energy intensive industries (Lutz et al., 2015).

Energy efficiency is considered to be one of the most cost-effective ways to ensure security of energy supply, reduce carbon emissions and economic competitiveness. Energy efficiency is also mentioned as a solution to rising electricity prices in Latvia and the EU. The comparison of electricity prices for large industrial consumers with annual electricity consumption from 20 000 MWh to 70 000 MWh on average in the EU and Latvia according to Eurostat data (Eurostat, 2019) is summarized in Fig. 2.4.

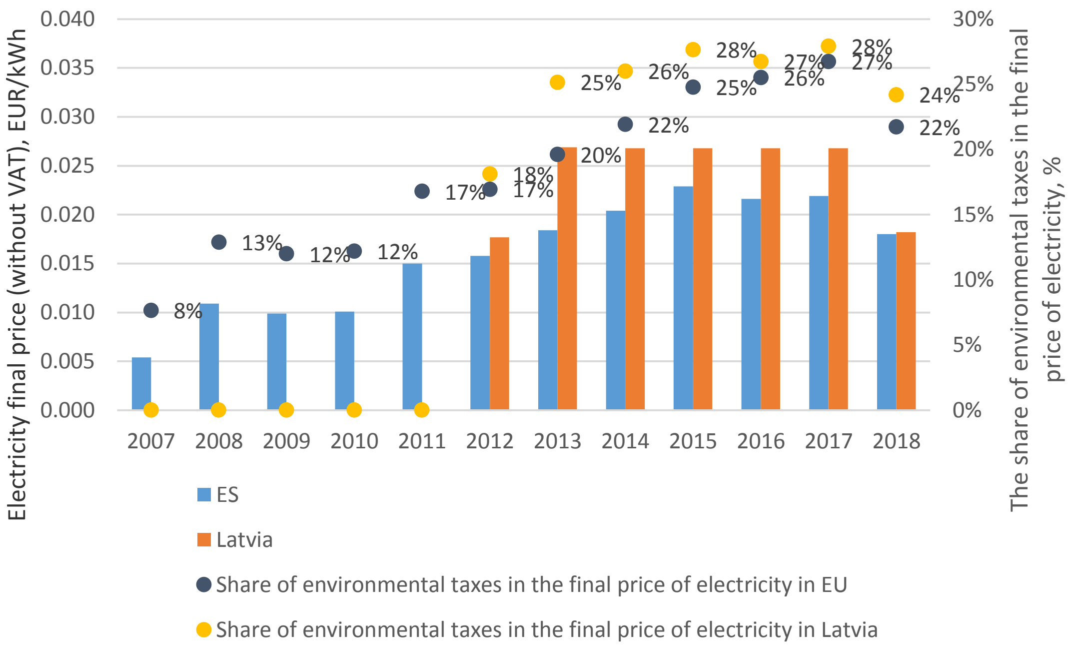


Fig. 2.4. Electricity prices for large industrial consumers with annual electricity consumption from 20 000 MWh to 70 000 MWh on average in the EU and Latvia (left axis) and the share of environmental taxes in the final price of electricity (right axis)

Eurostat data indicate that electricity prices for energy-intensive manufacturing companies in both the EU and Latvia have consistently increased every year, declining significantly in 2018. In the same way consistently the proportion of environmental taxes (in Latvia – OIK) in the final price of electricity has consistently increased over decade and decreased in 2018, showing a close correlation between the proportion of environmental taxes and the total price of electricity. Thus, it can be concluded that one of the reasons for the increase in electricity prices in the EU is the costs related to environmental taxes, and in Latvia their analogue – OIK. The reduction in costs in 2018 is due to the implementation of the EC and Latvian policies, which, in order to reduce the negative impact on energy-intensive companies that are particularly exposed to international competition, ensure that Member States can partially exempt energy-intensive companies from these taxes and fees.

2.3. Energy Intensity Analysis

EU institutions, such as the European Environment Agency, use the ratio of energy consumption to GVA as an indicator to assess energy efficiency at national level. This indicator shows to what extent there is decoupling between energy consumption and economic growth. In environmental context using less energy per unit of economic output equals using energy in a more efficient way, however, the overall climate impacts depend on the total amount of energy consumption, and the fuels and technology used to generate the energy (EEA, 2020).

The energy intensity is calculated according to Equation (2.1)

$$EI_{\mathrm{BPV}} = \frac{E}{I_{\mathrm{BPV}}}, \tag{2.1}$$

where

EI_{BPV} – energy consumption in the GVA of a given industry, GJ per 1000 EUR;

E – energy consumption in a given industry, GJ;

I_{BPV} – GVA in a given industry, 1000 EUR.

The energy intensity of industries in Latvia and a comparison with the EU average is summarized in Table 2.1. The three largest and most significant manufacturing industries in Latvia in terms of energy consumption are wood and wood products (C16), non-metallic mineral products (C23) and food, beverages and tobacco (C10–C12), consuming a total of 89 % of all industrial energy consumption in Latvia, at the same time providing for 53 % of the total industrial GVA. These sectors also show the highest energy intensity indicators (except for metal production, which is currently a very insignificant sector both in terms of consumption and GVA). Among the industrial sectors, the production of finished metal products, machinery, electronic, optical, computer equipment (C25–C28) stands out, which provides 21 % of the GVA of all industry, at the same time consuming only 2 % of energy consumption (see Table 2.1).

Comparing the average energy intensity of industries in Latvia and the EU, it can be seen that the largest and most important sectors in terms of energy consumption and GVA in Latvia also have higher energy intensity compared to the EU average. Such industries as paper, pulp and printing (C17, C18) as it can be seen from Fig. 2.5 have a relatively low energy intensity in Latvia compared to the EU average, which can be explained by significant structural differences in these sectors, representing relatively small, niche companies in Latvia without significant energy consumption (1 % of a total consumption), in contrast to the EU, where these sectors are important energy consumers.

Table 2.1

Industry Sectors. Their Share of Energy Consumption and GVA in Latvia.
Sectoral Energy Intensity in Latvia and EU (2017)

Industrial sector (NACE classificatory)	Share of energy consumption, %	Share of GVA, %	Energy intensity, GJ per 1000 EUR	
			Latvia	EU
Wood and wood products (C16)	62	27	33.3	10.5
Non-metallic mineral products (C23)	17	8	31.9	20.5
food products, beverages and tobacco (C10–C12)	10	18	8.4	5.0
Chemicals products and manufacture of pharmaceutical products (C20, C21)	4	6	8.2	9.1
Fabricated metal, machinery, electronic, optical, computer equipment (C25–C28)	2	21	1.6	1.3
Rubber, plastic products, furniture and other manufacturing (C22, C31, C32)	2	8	3.8	4.1
Textiles, wearing apparel, leather and related products (C13–C15)	1	5	3.2	3.0
Motor vehicles, trailers and semi-trailers and other transport equipment (C29, C30)	1	3	4.3	1.2
Paper and paper products printing and reproduction of recorded media (C17, C18)	1	5	2.2	18.3
Metals (C24)	0	0	14.7	22.8
Total	100	100	14.4	5.4

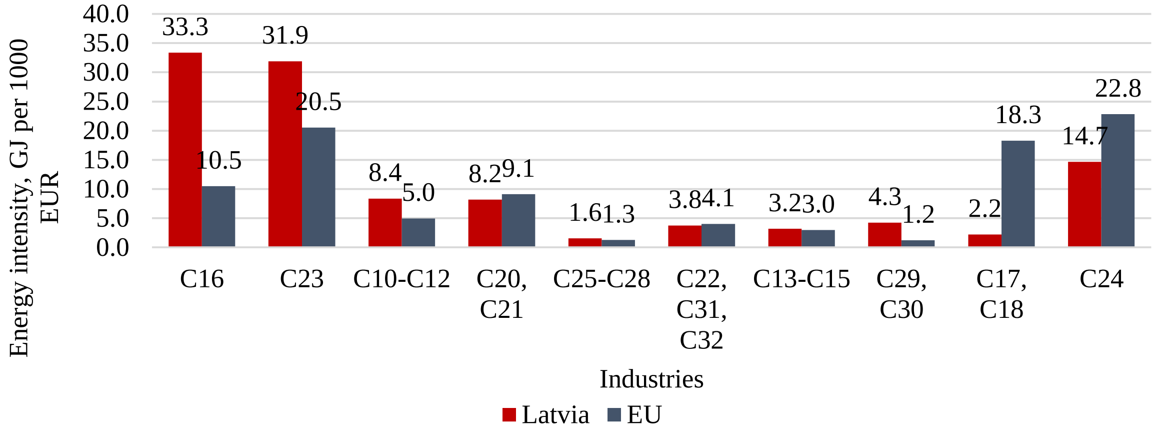


Fig. 2.5. Average energy intensity of industries in Latvia and the EU (2017).

However, Fig. 2.5 and Table 2.1 show only energy intensity of one year (2017). To estimate the energy intensity trend in a longer term, Fig. 2.6 shows the energy intensity of all Latvia's industry over several years (2009–2017) and in comparison with the average indicators of other countries and the EU.

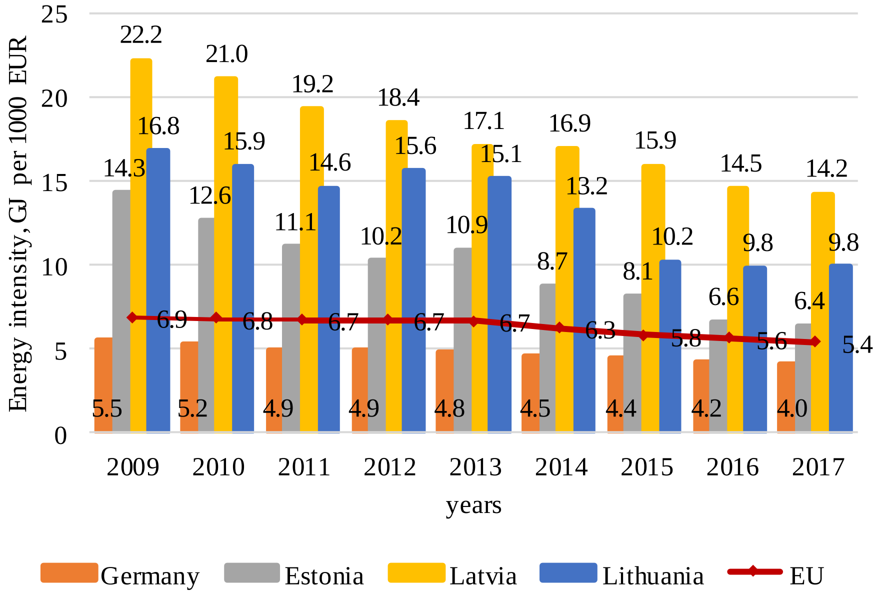


Fig. 2.6. Average industrial energy intensity in Latvia, Lithuania, Estonia, Germany and EU (2009–2017).

It can be seen from Fig. 2.6 that energy intensity of Latvia's manufacturing industry is gradually decreasing, but significantly exceeds an average energy intensity in the EU, Germany and both other Baltic States (Estonia and Lithuania). In 2017, Latvia's industry consumed approximately 2.6 times more energy to produce the same GVA than the EU average. Although industry in Latvia is experiencing a declining trend in energy intensity, it has mainly been achieved due to increasing industrial activity, while energy consumption is still rising, although it has stabilized in recent years.

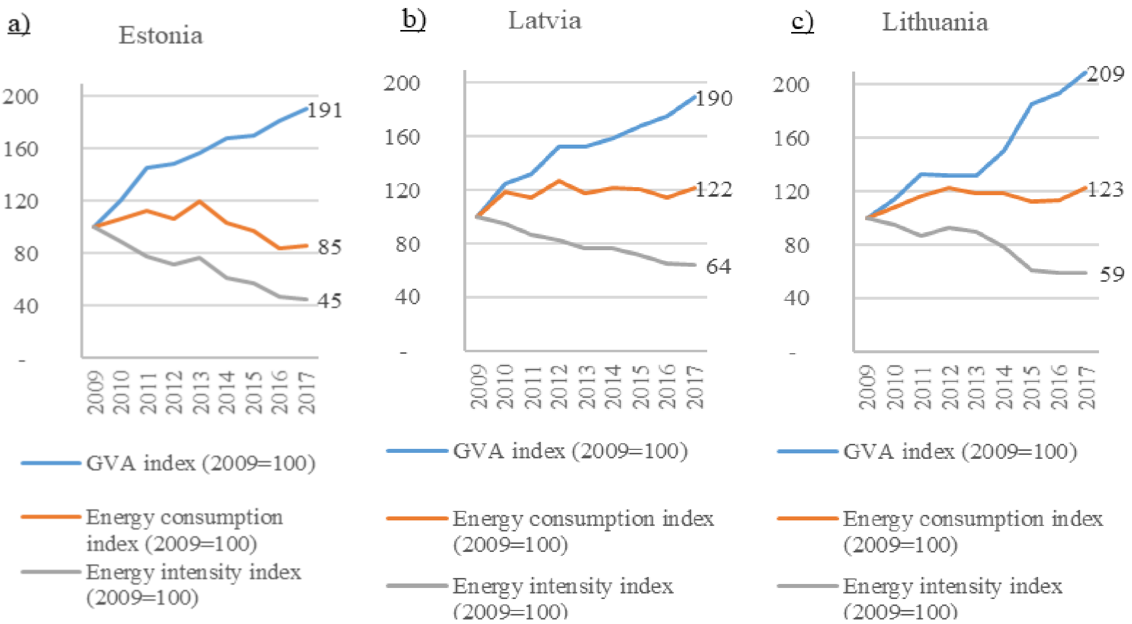


Fig. 2.7. Index (2009=100) of industrial energy consumption, GVA and energy intensity: a) Estonia; b) Latvia; c) Lithuania.

Trends in industrial energy consumption, GVA and energy intensity in Estonia, Latvia and Lithuania compared to 2009 are shown in Fig. 2.7, the results are visualized as index points, where 2009 = 100 points. Latvia shows the highest industrial energy intensity index – 64 points, while Lithuania and Estonia show 59 and 45 points, respectively. In general, the indexes of Latvian and Lithuanian industrial energy consumption, industrial energy intensity and GVA are very similar, however, Estonia stands out from the Baltic States, where industrial consumption has fallen, while ensuring GVA growth.

2.4. Industrial CO_2 Intensity Analysis

To determine the impact of energy efficiency measures in the industrial sector on the reduction of CO_2 emissions, the CO_2 intensity for a given industrial sector shall be calculated according to equation

$$CI = \frac{EI_{\mathrm{BPV}}}{1000} \cdot CF, \qquad (2.2)$$

where

CI is CO_2 emission intensity to produce 1000 EUR of GVA, t per 1000 EUR; and

CF is CO_2 emission factor, t/TJ.

$$CF = \frac{\sum_{i}^{n} \left(CF_i \cdot E_i \right)}{\sum_{i}^{n} E_i}, \qquad (2.3)$$

where

CF_i is CO_2 emission factor for energy source *i*, t/TJ; and

E_i is consumption of energy source *i*, TJ.

The average CO_2 emission factor of Latvian industry is 0.114 t/MWh, while the EU average is 0.234 t/MWh (see Fig. 2.8). The CO_2 emission factor of Latvia's three most dominant manufacturing industries is 0.045 t/MWh in the wood and wood products industry, 0.325 t/MWh in the non-metallic minerals industry, and 0.151 t/MWh in the food and beverage industry.

The comparison of CO_2 intensity between manufacturing industry in Latvia and the EU is shown in Fig. 2.9. The average CO_2 emission intensity in Latvia is 412.7 kg CO_2 per 1000 EUR of GVA, which is 60.4 kg or 17 % more than the EU average.

Fig. 2.8. Industrial CO_2 emission factor on average in the EU, Latvia, and Latvia's three most dominant sectors.

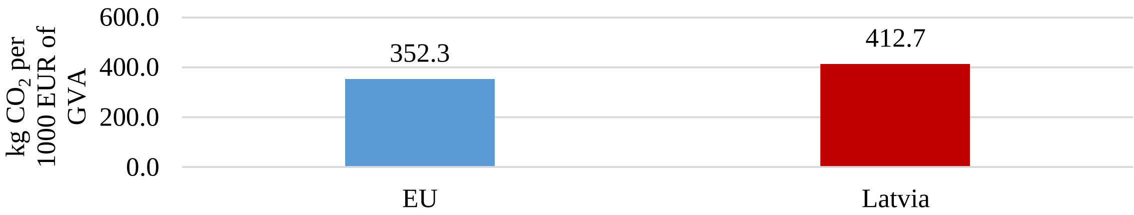


Fig. 2.9. Average industrial CO_2 intensity in EU and Latvia.

2.5. Discussions and Conclusions

At the macroeconomic level, the industry in Latvia has a higher energy intensity compared to the neighbouring countries, Germany and the EU average. Significantly higher energy intensity is in the three most dominant industries of Latvia – wood and wood products, non-metallic minerals and food and beverage production, which account for 89 % of all industrial energy consumption in Latvia. Most of the energy consumption in the three largest industries are related to thermal processes (oil products, coal, wood, natural gas, waste), but a relatively smaller share is related to more expensive electricity.

Considering the significant energy consumption of wood and wood products industry and the correspondingly large share of biomass and other CO_2-neutral energy sources in the energy balance, the CO_2 intensity of industry in Latvia is twice lower than the EU average. Consequently, setting CO_2 prices as one of the policy instruments for stimulating industrial energy efficiency will have twice less impact in Latvia than in the EU.

The industry in Latvia consumes on average 2.6 times more resources to produce the same value added of industrial production compared to the EU average and emits 60 kg more CO_2 per 1000 EUR of GVA. This means that the industry in Latvia has untapped energy efficiency potential, especially in sectors with high consumption and low added value, although increasing energy efficiency will have a relatively small impact on CO_2 emission savings.

3. SUPPORT POLICY FOR ENERGY-INTENSIVE MANUFACTURING COMPANIES AND ITS IMPACT ON ENERGY EFFICIENCY

3.1. System Dynamic Modelling

In Latvia, a regulation has been created that partially rebates OIK payment for energy-intensive companies (MK, 2015). One of the most important preconditions for obtaining the rebate is the relatively high intensity of electricity costs. Electricity costs must exceed 20 % of the company's GVA. At company's level decisions of implementation of energy efficiency measures would be based on the business cases of measures gaining financial benefits from reduced consumption. On the other hand, the company has a financial incentive to keep the energy intensity above the 20 % benchmark as long as it is possible to recover a part of the electricity costs as an energy-intensive company. Consequently, Latvia's energy policy for energy-intensive industries stimulates energy-intensive companies to implement energy efficiency measures, yet maintaining a rather high level of energy intensity, which in fact are mutually contradictory measures.

Taking into account the complexity of company's behaviour, a system dynamic model has been used in this research. System dynamic modelling can simulate the behaviour of energy intensive companies with different input parameters and assess sustainability of this Latvia's energy policy. System dynamic approach also provides the necessary tools to simulate different improvements in the policy.

According to Sterman (2000), system dynamic modelling involves the following steps:

1) articulating the problem to be addressed;
2) formulating a dynamic hypothesis or theory about the causes of the problem;
3) formulating a simulation model to test the dynamic hypothesis;
4) testing the model output to satisfy the purpose;
5) designing and evaluating policies for improvement (Sterman, 2000).

In this study a hypothetical energy-intensive manufacturing company's predictive behavioural model was designed which simulates the company's decision to take or not to take energy efficiency measures on the basis of energy intensity indicator. The modelling period was set for 7 years until 2023, which includes the period during which the energy policy is in place and the period without it.

Articulating the Problem

Energy efficiency measures will reduce the company's power consumption and energy costs, subsequently reducing its energy intensity. If in this case the energy intensity goes below the policy threshold and the increase of electricity costs due to loss of OIK repayments outweighs the efficiency gains, energy intensive companies most likely would sacrifice efficiency measures just to keep intensity above the threshold or even deliberately increase electricity consumption in order to maintain energy intensity above the benchmark. From the energy policy point of view this is an undesirable consequence that should be evaluated and addressed.

Evidently the undesirable consequences of energy policy occur where the energy intensity of a company is close to the benchmark set in the policy and, as a result of changes of various external or internal parameters, energy intensity would cross the benchmark. If energy intensity of a company is well above or below the benchmark, the undesirable policy consequences most likely would not appear. Taking into account this consideration, modelling is focused on cases where there is evidence of potential energy policy failure, namely on cases where initial energy intensity of a company is close to the benchmark and relevant policy improvements are evaluated taking into consideration this aspect.

Formulating a Dynamic Hypothesis

Electricity consumption in manufacturing industry depends on various factors. Casual loop diagram is shown in Fig. 3.1. The stock corresponds to the company's electricity consumption, which increases every year as a result of growth of company's production output, while the outgoing flow of electricity consumption represents energy efficiency measures.

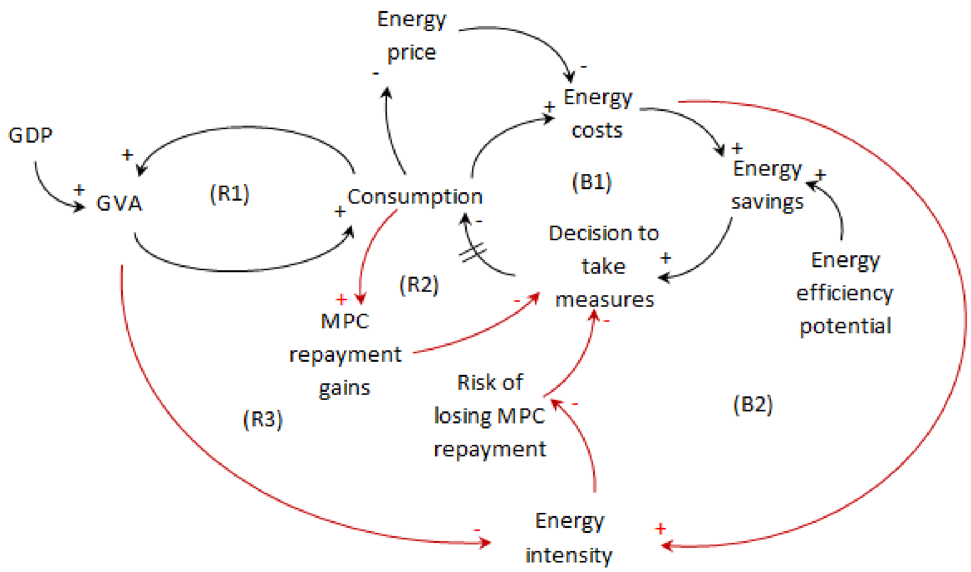


Fig. 3.1. Casual loop diagram of energy-intensive manufacturing company's decisions on energy efficiency.

Normally the model would have two causal loops – reinforcing loop (R1) and balancing loop (B1). The strength of two loops is determined by the consumption growth factor, which largely depends on company's GVA and gross domestic product (GDP) growth, and energy efficiency factor, which depends on company's identified energy efficiency potential.

Since energy efficiency measures balance the consumption growth, but do not affect the growing company's GVA, the company's energy intensity, which is calculated as total electrical energy costs to GVA, is decreasing. The manufacturing company may not be advantageous to reduce its energy intensity below the benchmark of 20 %, in which case it loses the energy-intensive manufacturing company's status and consequently economic benefits of OIK repayment. If the company's savings from energy efficiency is less than the OIK refund, then the company can be expected to adopt a rational decision to stop delivering energy efficiency measures and to keep the energy intensity above benchmark. Consequently, the system dynamic model has an additional reinforcement and balancing loops that essentially weakens the main balancing loop (B1). This system conforms to Senge (1990) "fixes that fail" archetype (Senge, 1990). In particular, energy-intensive manufacturing companies are initially created as incentive (OIK rebates) to implement energy efficiency measures and improve their competitiveness, however, the solution with delay might lead to a situation where energy efficiency measures are no longer implemented (even if they are reasonably cost effective), as to be too effective means not to be energy-intensive.

Formulating a Simulation Model

The main stocks in the system dynamic model are electricity consumption, GVA and accumulated energy efficiency savings. Changes in stocks are functions of the input and output flows, and these flows are dependent on various factors. The electricity consumption in a given year (stock) depends on consumption growth factors and energy efficiency factors; see Eq. (3.1):

$$E = \int_{t=2017}^{t=2023} \left(E_{\mathrm{gr}} - E_{\mathrm{EE}}\right)\mathrm{d}t + E_{\mathrm{ini}}, \tag{3.1}$$

where

E – electricity consumption in a given year, MWh;
E_{gr} – electricity consumption increase, MWh per year;
E_{EE} – energy efficiency measures the company has implemented, MWh per year;
E_{ini} – initial electricity consumption, MWh.

Although energy-intensive manufacturing company's energy consumption in a given year could be used as a factor to evaluate the energy policy outcomes, it is more appropriate to use accumulated new energy efficiency savings as an energy policy evaluation measure. The volume of accumulated new energy efficiency savings is derived from the energy efficiency measures the company has implemented, see Eq. (3.2):

$$E_{\mathrm{AS}} = \int_{t=2017}^{t=2023} E_{\mathrm{EE}}\mathrm{d}t, \tag{3.2}$$

where E_{AS} is accumulated new energy efficiency savings, MWh.

The consumption growth factor in the system dynamics model depends on the input data on GDP growth, its correlation with the company's GVA growth and the corresponding correlation with the electricity consumption growth. The energy efficiency factor in the system dynamics model is variable: it can be static and represent the average energy efficiency potential, or it can be dynamic, thus representing different energy efficiency measures implemented at different times with different potentials.

Energy intensity is calculated as company's full costs of electricity to company's GVA on a yearly basis. Electricity costs are calculated multiplying consumption and electricity price, which are summed from three price components (procurement price, network tariffs and OIK). Electricity price is calculated according to Eq. (3.3):

$$T = T_{\mathrm{E}} + \frac{T_{\mathrm{NC}}C}{E} + T_{\mathrm{NE}} + \frac{T_{\mathrm{MC}}C}{E} + T_{\mathrm{ME}}, \tag{3.3}$$

where

T – electricity final price, EUR/MWh;

T_{E} – electricity procurement price, EUR/MWh;

T_{NC} – capacity component of network tariffs, EUR/kW;

T_{MC} – capacity component of OIK, EUR/kW;

T_{NE} – energy component of network tarifs, EUR/MWh;

T_{ME} – energy component of OIK, EUR/MWh;

C – contracted capapcity, kW;

E – electricity consumption, MWh.

The company's decisions to implement energy efficiency measures (or not) are carried out on the basis of short-term economic benefit. Namely, if there is a risk that energy efficiency measure would result in a loss of status of energy-intensive manufacturing company, the energy efficiency measure is taken only when the short-term financial gains from savings would exceed short-term financial losses from loss of OIK repayment. Otherwise, energy efficiency measures are not implemented or are postponed. The decision-making flowchart is shown in Fig. 3.2.

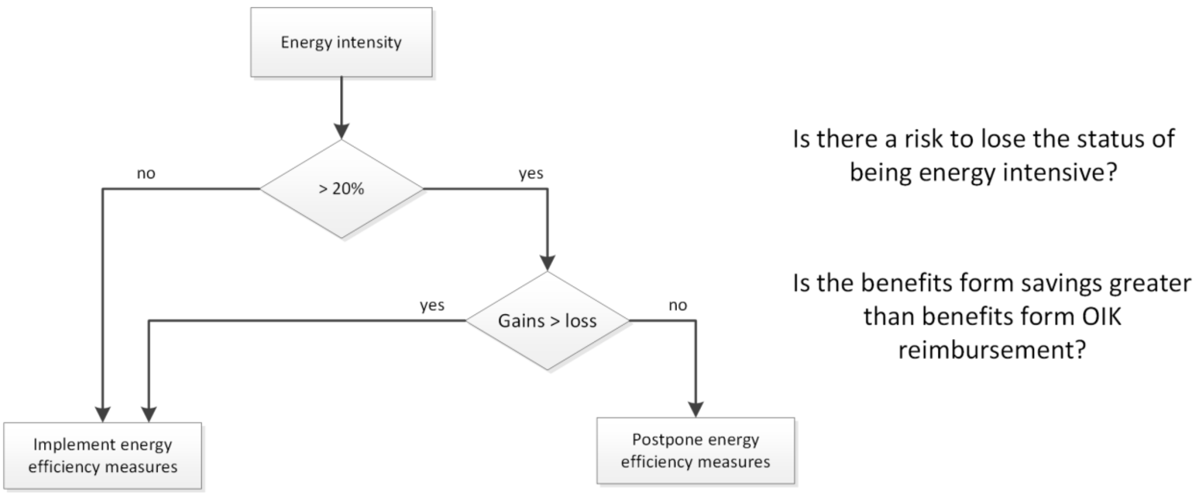


Fig. 3.2. Decision-making flowchart.

Since the decision-making process normally requires time to adjust, the delay functionality similar to the implementation of energy efficiency measures is designed in the system dynamics model.

Model Output

The system dynamics model was created by using Powersim simulation tool. The simulation step was 1 year, the simulation period was 2017–2023 or 7 years.

To evaluate the output of simulation two indicators were used. First – the accumulated new energy efficiency savings (Fig. 3.3b) that indicates the outcome of energy efficiency measures, and second – energy intensity that shows the company's current state of energy intensity (Fig. 3.3a). Results of the simulation show that while company's energy intensity is above the benchmark of 20 % (0.2), the company implements energy efficiency measures and accumulated savings are increasing. When the energy intensity gets close to the benchmark, energy efficiency measures are not implemented and accumulated savings are not increasing. After energy intensity increases above the benchmark, company restarts to implement energy efficiency measures. The behaviour of a company can be explained with a short-term economic benefit the company is gaining from OIK refunding instead of a benefit the company could get from the reduced energy consumption. With that in mind, there might be situations where a company is even incentivized to inefficiently increase consumption just to keep the energy intensity above the benchmark and accumulated savings would even decrease over time, which is highly undesirable from the policy point of view.

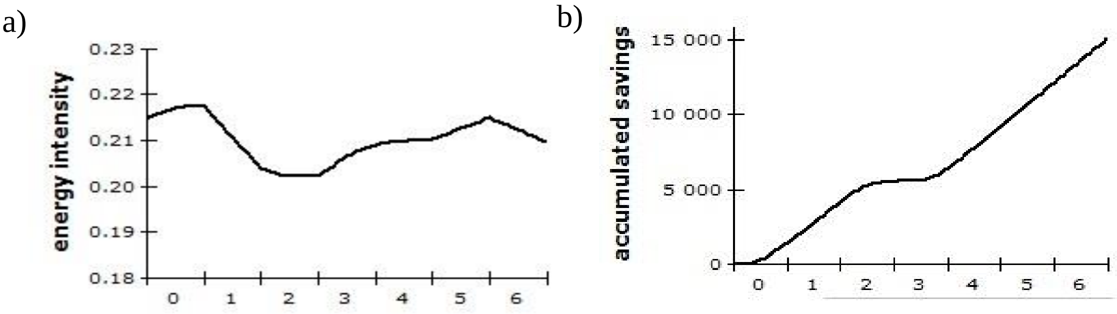


Fig. 3.3. Results of simulation: a) energy intensity; and b) accumulated savings, MWh.

In these simulations, the absolute values of the accumulated energy efficiency savings are not significantly obtained, as they depend on the initial data entered in the system dynamics model, but rather the observation of trends that characterize the policy.

3.2. Quantitative Analysis of Policy and Time Lag Factor

Until July 1, 2019 the MoE has issued 46 decisions on OIK rebate totaling just over 10 million euros for OIK paid until 2017. More than half of OIK rebates are granted to manufacturing of wood industries, where manufacturing of wood pellets (C1629) alone account for 42.59 % of energy tax rebate. Other major manufacturing industries that received tax rebates are manufacturing of cement and manufacture of glass fibres (see Table 3.1).

Table 3.1

OIK Rebates Breakdown by Industrial Sub-Sectors for 2015–2017

Sub-sectors (NACE class)	OIK rebate, EUR	OIK rebate, %
Sawmilling and planing of wood (C1610)	860 018.35	8.57
Veneer sheets and wood-based panels (C1621)	648 433.79	6.46
Other builders' carpentry and joinery (C1623)	284 904.73	2.84
Manufacture of wood pellets (C1629)	4 272 601.65	42.59
Manufacture of plastic packing goods (C2222)	67 814.98	0.68
Manufacture of glass fibres (C2314)	1 024 418.29	10.21
Manufacture of cement (C2351)	2 667 376.12	26.59
Basic iron and steel and of ferro-alloys (C2410)	29 606.61	0.30
Casting of iron (C2451)	90 382.94	0.90
Manufacture of other plastic products (C2229)	85 935.57	0.86
Total	10 031 493.03	100.00

Energy tax rebate is not received immediately at the time of consumption. The time lag between the OIK payment and recovery is rather lengthy. The study shows that on average it takes 554 days (median is 490 days) from OIK payment until recovery provided by positive decisions of MoE, but half of all positive decisions were made with a time gap of one and a half year (see Fig. 3.4).

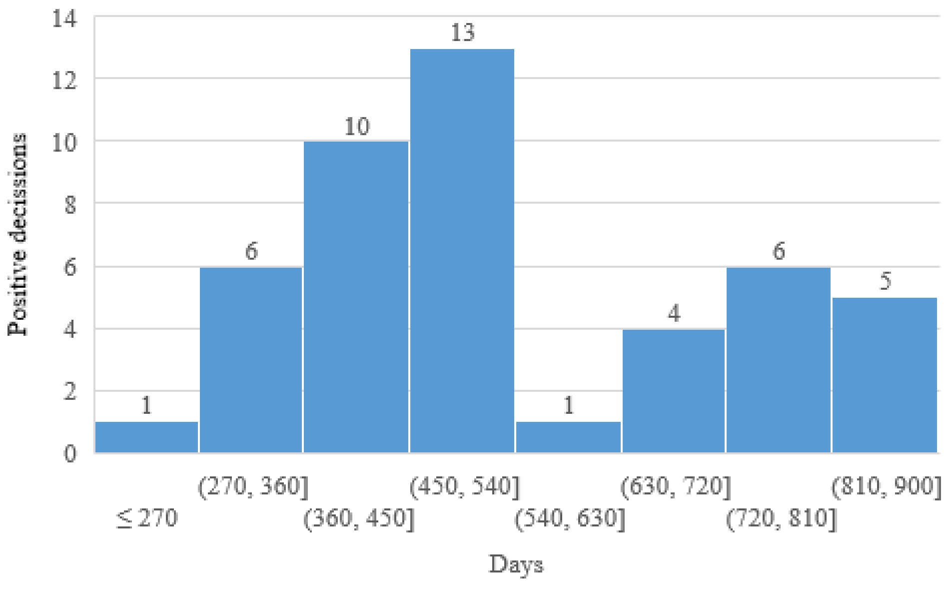


Fig. 3.4. Histogram of the number of decision-making days of the MoE (from the end of the calendar year for which the OIK refund can be received to the date of a positive decision).

The rather lengthy time period that appears to be necessary for the OIK rebate to be effected creates some uncertainty about the sustainability of this policy, which would have an impact on the decision-making process on a company's level, which was not initially considered in the system dynamics model. The incentive to maintain certain energy intensity would disappear if there was no confidence that energy prices are kept at a low level for eligible industries. Even more, the "windfall profit" that energy intensive industries received in the form of OIK rebate might be an alternative source of financing for energy efficiency measures as the only sustainable long-term solution to lower energy costs and to increase competitiveness. However, such a policy should be strengthened in a national regulation by requiring part of this "windfall profit" to be reinvested in energy efficiency measures.

3.3. Discussions and Conclusions

Consequently, Latvia's energy policy for energy-intensive industries stimulates energy-intensive companies to implement energy efficiency measures, yet maintaining rather high level of energy intensity, which is mutually contradictory. At company's level decisions of implementation of energy efficiency measures would be based on the business cases of measures. On the other hand, the company has a financial incentive to keep the energy intensity above the 20 % benchmark as long as it is possible to recover part of the electricity costs as an energy-intensive company. Taking into account the complexity of company's behaviour, a system dynamics model is proposed in this research.

Results of the simulation show that, while company's energy intensity is above the benchmark of 20 %, the company implements energy efficiency measures and accumulated savings are increasing. When the energy intensity closes to the benchmark, energy efficiency measures are not implemented and accumulated savings are not increasing, which can be explained with short-term economic benefit company is gaining from OIK refunding instead of benefit company could get from reduced energy consumption. With that in mind, there might be even situations where company is even incentivized to inefficiently increase consumption just to keep the energy intensity above the benchmark and accumulated savings would even decrease over time.

Until July 1, 2019 the MoE has issued 46 decisions on OIK rebate totaling just over 10 million euros for OIK paid until 2017. More than half of OIK rebates are granted to manufacturing of wood industries, where manufacturing of wood pellets (C1629) alone account for 42.59 % of OIK rebate. Other major manufacturing industries that received OIK rebates are manufacturing of cement (26.59 %) and manufacture of glass fibres (10.21 %), sawmilling and planing of wood (8.57 %) and manufacturing of veneer sheets and wood-based panels (6.46 %).

OIK rebate is not received immediately at the time of consumption. The time lag between the OIK paid and recovery is rather lengthy. Half of all positive decisions were made with a time gap of one and a half years, thus, the rebate of OIK is unlikely to affect operational decisions, but rather to generate "windfall profits" that could be used by energy-intensive companies as a source to fianance energy efficiency measures, the only sustainable long-term solution to reduce energy costs and increase competitiveness.

Consequently, the continuation of such a policy should be directly linked to the condition of investing in energy efficiency measures, also ensuring appropriate control, and changing the conditions for calculating the intensity, such as calculating electricity costs for a certain number of years before energy efficiency measures.

4. BENCHMARKING OF OUTCOMES FROM INDUSTRIAL ENERGY AUDITS AND ASSESSMENT OF ENERGY EFFICIENCY GAP

One of the objectives of this research was to assess the outcomes of Latvia's first industrial energy efficiency program, by analysing the data available in the national energy efficiency monitoring system (NEEMS), and by benchmarking the identified energy efficiency potential of the most significant industrial sectors in Latvia with findings of a similar energy efficiency program in Sweden. Another goal of this study was to examine the feasibility of constructing energy efficiency costs curves (EECC) to determine the technical and economic potential of industrial sector by using bottom-up approach.

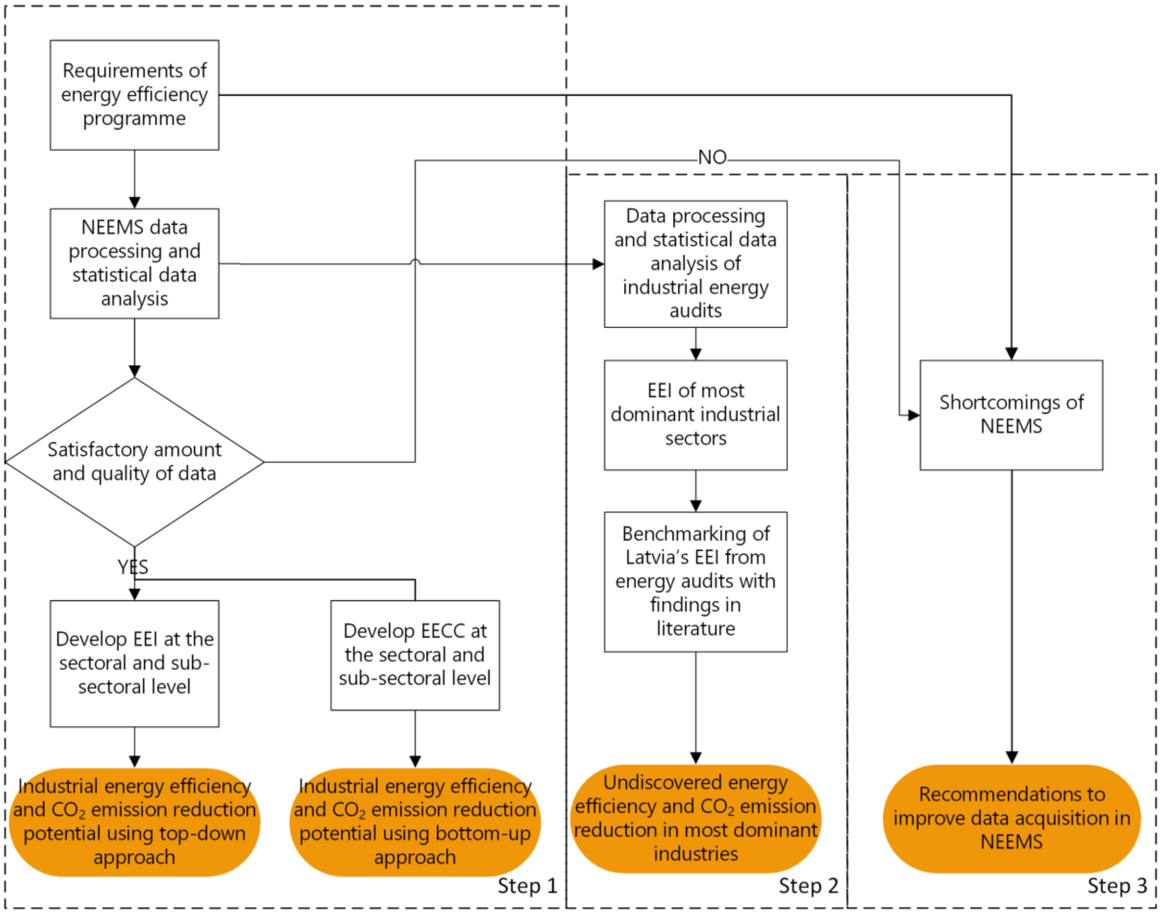


Fig. 4.1. Proposed algorithm of the research

This research was conducted in three steps according to the algorithm shown in Fig. 4.1. In the first step a statistical analysis of information available in NEEMS was performed. The aim of this step was to identify the correlation between the planned energy efficiency savings the program is delivering and the consumption level of the program's participants, so that it could lead to develop energy efficiency indicators (EEI) at sectoral and sub-sectoral levels and estimations of energy efficiency saving potential using a top-down approach. The sub-objective of this step was to examine the feasibility of constructing EECC, which could be further used to identify cost-effective industrial energy efficiency measures available, considering the technological and energy costs, and use them for industrial energy and CO_2 savings estimation by using a bottom-up approach. In the second step, benchmarking method was developed for energy efficiency and CO_2 reduction potential, which is based on the statistical processing of data available from energy efficiency program that allows to compare the energy efficiency potential of different industrial sectors, as well as to compare them between two countries: Latvia and Sweden. Finally, recommendations to improve data acquisition in NEEMS to address the shortcomings of the system were developed.

4.1. Analysis of NEEMS

The regulation created in Latvia envisages the establishment of NEEMS which collects data provided by large enterprises and large comsumers on implementation of energy audits or energy management systems, as well as on those energy efficiency measures and savings identified and on implemented energy efficiency (MK, 2016). The data received from NEEMS contained the following data:

- each company's main activity according to NACE Rev.2.0 division;
- large enterprise/large consumer identification;
- electricity (not energy) consumption for 2016–2018;
- method via which each company fulfilled obligations such as energy audit / certified energy management system (ISO 50001) or supplementary environmental management system (ISO 14001);
- each company's targeted annual energy savings (MWh per year) and its distribution between specific activities (energy efficiency of buildings, lighting, equipment, transport, other);
- each company's already achieved annual energy savings in 2016–2017 (MWh) and their distribution among specific activities (energy efficiency of buildings, lighting, equipment, transport, other);
- copies of performed energy audits, if an energy audit was performed.

The analysis was performed from May 2019 till October 2019. There are in total 1441 entities included in NEEMS, of which approximately 500 are industrial companies, and 111 industrial energy audit reports were available.

The companies' planned energy efficiency savings submitted to NEEMS were related to the only common parameter available in NEEMS – electricity consumption, and the results are summarized in Fig. 4.2. The planned annual energy savings can exceed 100 % of electricity consumption, as energy efficiency savings can be achieved in all types of energy resources, but consumption in NEEMS is indicated only for electricity. The trend shows that companies with higher electricity consumption plan to achieve proportionally lower savings. However, the data set shows weak correlation between annual electricity consumption and targeted or planned energy efficiency savings, hence it is groundless to claim that savings can be derived from electricity consumption alone, and it is crucial that the NEEMS collects all energy consumption data.

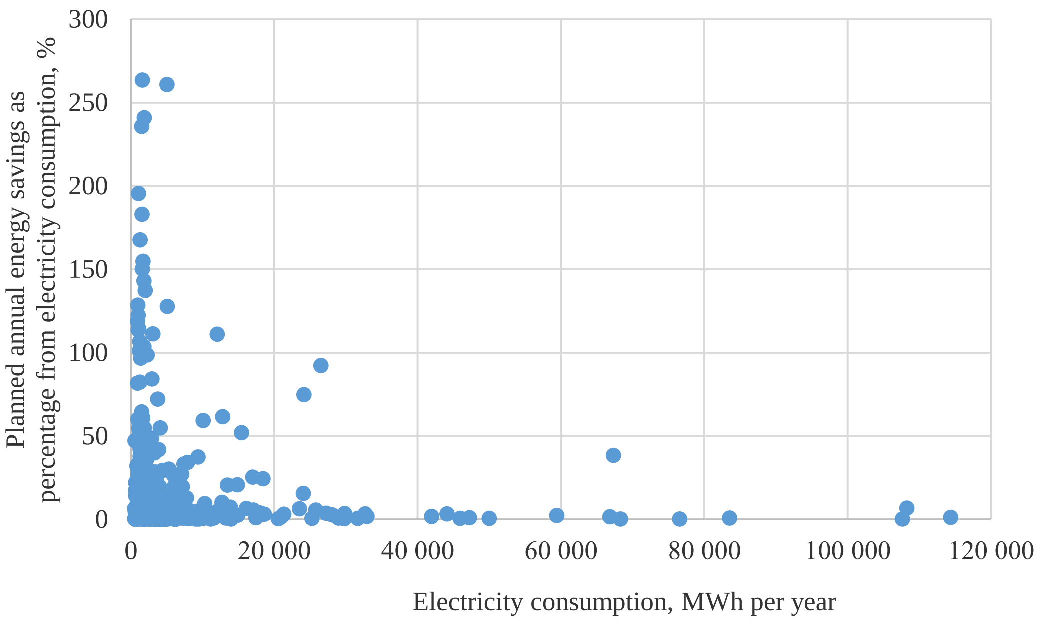


Fig. 4.2. Correlation between annual electricity consumption and planned annual energy savings.

The total projected annual industrial savings indicated in NEEMS to be achieved by 2022 are 190.3 GWh or 1.87 % of current industrial energy consumption in Latvia. Three quarters (142.6 GWh) of the planned annual savings are expected to be achieved in lighting and equipment energy efficiency activities, 12.4 GWh (6.5 %) is planned to be saved in buildings, 0.3 GWh or practically nothing is planned to be saved in transport activities, but a large part or 35 GWh (18 %) is planned to be saved in uncategorized activities (see Fig. 4.3).

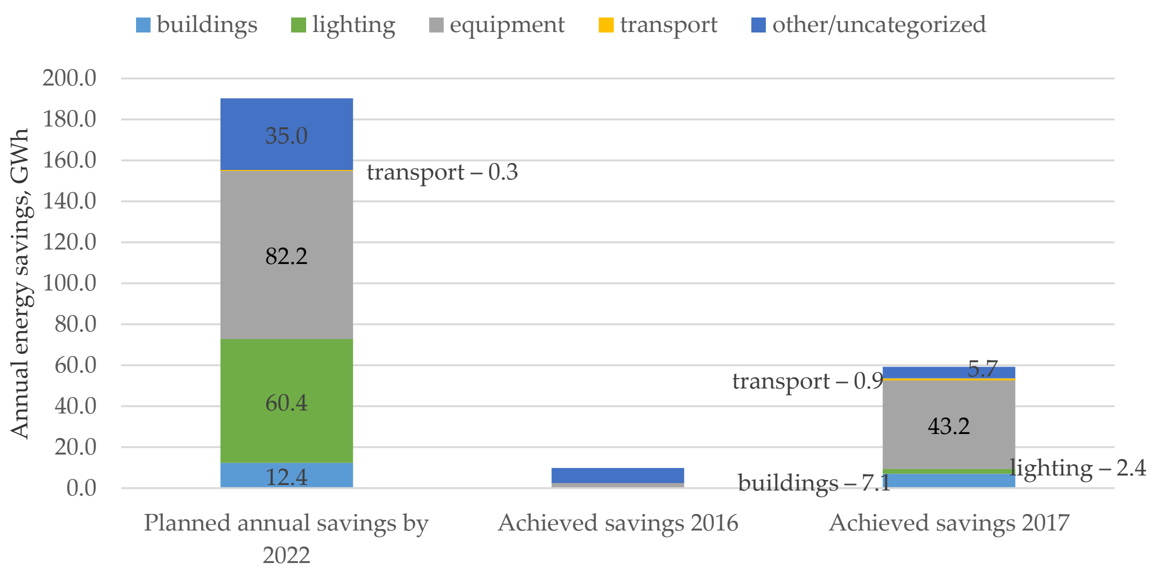


Fig. 4.3. Planned annual savings and achieved savings (2016–2017) by specific activities, GWh.

The already achieved savings in 2016 are 9.9 GWh or 0.10 % and in 2017 – 59.3 GWh or 0.58 % of industrial consumption in Latvia. Such modest initial results might be explained by the ramping-up time of the program. Comparing the annual planned savings by 2022 and achieved savings in 2017 by activities described in NEEMS, it can be seen form Fig. 4.3 that in buildings 57 % and in equipment 53 % of the planned savings have been achieved. Savings in lighting have reached only 4 % of the planned savings, but savings in transport have tripled compared to the originally planned savings, but it is still an insignificant activity for the industry.

The data insufficiency in NEEMS imposes limitations on further usage of the research findings to develop EEI at sectoral and sub-sectoral industrial levels for estimations of energy efficiency saving potential or to develop EECCs.

4.2. Sectoral EEI of Most Energy Consuming Industries in Latvia From Energy Audits

As opposed to the generic data found in the NEEMS, energy audit reports contained more detailed information regarding the energy (not only electricity) consumption levels and proposed energy efficiency measures identified as a result of energy audits. Data available in 111 industrial energy audits covering only a part of the entire industrial energy efficiency program in Latvia were analysed.

Energy efficiency indicators (EEI) obtained from energy audits show a weak correlation with energy consumption levels (see Fig. 4.4). The identified energy efficiency potential in energy audits was in the range from 0.13 % to 40.11 % with an average value of 6.53 % (see Table 4.1).

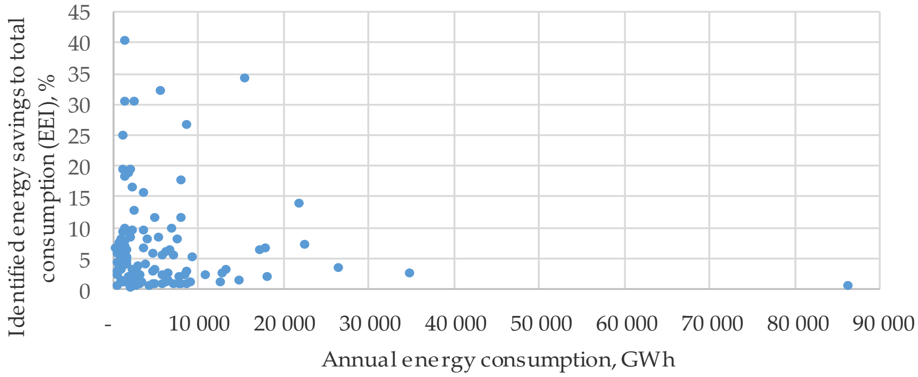


Fig. 4.4. Energy efficiency potential indicated by energy audits depending on annual consumption.

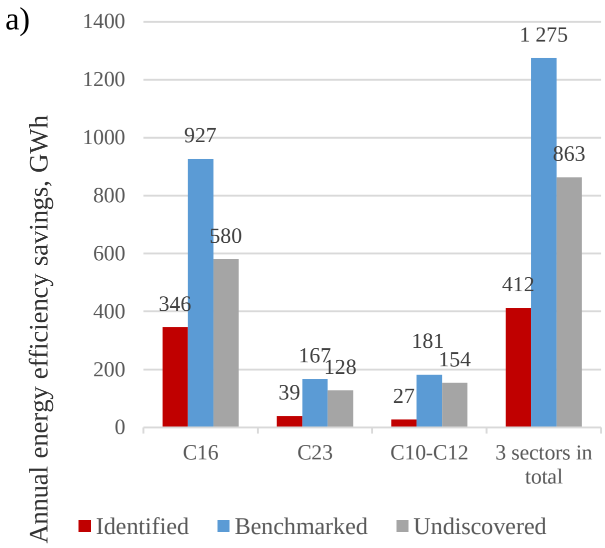
Nevertheless, the average energy efficiency potential indicated in the energy audits is 6.53 % of final energy consumption (see Table 4.1), which is 3.5 times higher than the 1.87 % savings planned in the program. 93 (84 %) of energy audits recorded energy efficiency potential below 10 % and 18 (16 %) reported energy efficiency potential in a range from 10 % to 40 %. A separate analysis was made for the top three energy consuming industries based on energy audits from wood and wood products, from non-metallic mineral products and food products, beverages and tobacco production. The results are summarized in Table 4.1.

Table 4.1

Statistical Analysis of Energy Efficiency Potential Indicated in Energy Audits for Industry and Key Industrial Sectors

Metrics	Industry	Wood and wood products (C16)	Non-metallic minerals (C23)	Food products, beverages (C10, C12)
Average value	6.53	6.68	2.57	3.00
Median	3.60	3.49	1.02	2.33
Standard deviation	7.93	7.37	2.73	2.27
Range of values	39.97	31.98	6.25	7.6
Minimum value	0.13	0.13	0.30	0.62
Maximum value	40.11	32.11	6.55	8.21
Records in sample	111	36	7	22

The average energy efficiency potential of most energy consuming industries in Latvia is 6.68 % in wood and wood products, 3.00 % in food products and beverages, 2.57 % in non-metallic mineral products, whereas according to Paramonova and Thollander's research (Paramonova & Thollander, 2016) a similar program in Sweden reported energy efficiency potential of these sectors as follows: 18 %, 11 % and 20 %, respectively. Applying the energy efficiency potential benchmarks obtained in the study of Paramonova and Thollander to industries in Latvia, the possible undiscovered energy and CO_2 emission reduction potential is obtained, which is summarized in Fig. 4.5.



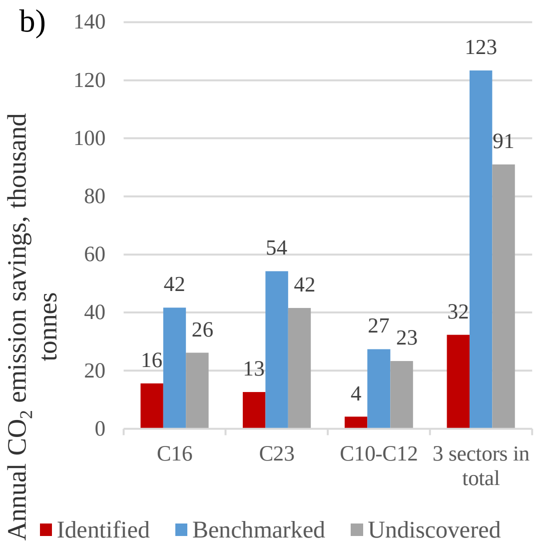


Fig. 4.5. Identified, benchmarked and undiscovered annual saving potential in C16, C23, C10-C12 and in all three sectors: a) energy consumption (GWh); and b) CO_2 emission (thousand tonnes).

Although the average energy efficiency potential found in energy audits from the three largest industrial sectors of Latvia would provide annual energy savings of 412 GWh or 5.2 % of energy consumption of these sectors, a benchmarking analysis with a similar program in Sweden suggests up to 863 GWh of undetected energy efficiency potential. Taking into account the CO_2 intensity of each industrial sector, the undetected potential of CO_2 emissions reduction in the three most dominat industries in Latvia has been assessed up to 91 thousand tons (see Fig. 4.5).

It can be seen from Fig. 4.5 that the largest potential for reducing CO_2 emissions is in the non-metallic mineral production sector, given that this sector has the largest share of CO_2-emitting energy resources. The largest possible undetected reduction in CO_2 emissions is also in the non-metallic mineral production sector, from which it could be concluded that energy efficiency policy should be more closely monitored in companies from these sectors, starting with better energy audits. The wood and wood products industry also has significant CO_2 reduction potential, but here the potential for reducing CO_2 emissions is more limited given the low CO_2 intensity in this sector.

4.3. Discussions and Conclusions

The Energy Efficiency Law requires large companies and large consumers to implement at least three energy efficiency improvement measures recommended by an energy audit or energy management system with the highest estimated energy savings or economic returns by 2020 (large companies) or 2022 (large consumers), however, the mechanism is deficient and does not provide the real potential of energy efficiency.

The data analysis available fom NEEMS shows that the already achieved savings in 2016 are 9.9 GWh or 0.10 % and in 2017 – 59.3 GWh or 0.58 % of industrial consumption in Latvia. Such modest initial results might be explained by the ramping-up time of the program.

The analysis of industrial energy audits performed in accordance with the requirements of the Energy Efficiency Law indicates that the value of the average technical energy efficiency potential is 6.53 % of the final energy consumption. 84 % of the analysed energy audits indicated a technical energy efficiency potential below 10 % of total consumption, which is a low figure compared to studies in other countries.

The developed methodology, which uses the data available from energy audits, allowed to compare the energy efficiency potential of Latvia's three most dominant industrial sectors (wood and wood products, non-metallic minerals, and food and beverage production) with the findings of a similar program in Sweden. In the comparative analysis, using the energy efficiency potentials identified in the Swedish study as benchmarks, the undiscovered energy efficiency potential of these three sectors in Latvia can reach 862.6 GWh of annual energy savings or 11 % of the annual energy consumption of these sectors. But the undiscovered CO_2 emission reduction potential is 91.0 thousand tons per year where approximately 46 % of CO_2 emission savings come from the non-metallic mineral industry (cement, fiberglass and other construction materials).

The data available in NEEMS only summarize the total costs of an energy efficiency measure, but it is not possible to determine exactly what the average costs for specific groups of energy efficiency measures (lighting, appliances, etc.) or individual measures are. It is not possible to derive credible and robust energy efficiency cost curves from NEEMS data. A significant drawback is the fact that NEEMS only collects data on electricity consumption, not covering the energy consumption in its entirety, limiting the possibility to fully assess the potential for energy efficiency.

Manual analysis of energy audits revealed different approaches used by energy auditors and sometimes reluctance to go into industrial processes. Energy auditors in Latvia often recommend energy efficiency measures for support processes rather than production processes. The lack of binding energy efficiency targets has led to a situation where the necessary energy efficiency measures can only be set formally, reporting small energy savings of only a few percent of a company's total energy consumption. Although a number of energy efficiency reports have been identified in energy audit reports, some audit reports contain only three minimum necessary measures, often all of the same type.

The energy efficiency policy for industry could be substantially improved by improving the process of data collection, standardizing reporting forms and introducing mandatory electronic environment for periodical data submissions, as well as introducing an appropriate support, training and control mechanism for the data and reporting quality.

5. BINDING ENERGY EFFICIENCY TARGETS AND PERFORMANCE TRAJECTORIES IN THE CONTEXT OF THE GREEN DEAL

To meet its ambitious energy efficiency targets, the EU has adopted amendments to the EED (EP, 2018) under the Clean Energy for All Europeans initiative (EC, 2019), which impose mandatory energy efficiency targets on Member States, with a special focus on the industrial sector as one of the largest emitters of GHGs. On 11 December 2019, the EC came up with even more ambitious climate goals by publishing the European Green Deal, aiming at EU GHG neutrality by 2050, which cannot be achieved without rapid and significant involvement of industry (EC, 2019).

On 4 March 2020, the EC presented a proposal for a European Climate Law to strengthen the binding objectives of the European Green Deal into EU legislation, namely to achieve net zero GHG emissions across the EU, mainly by reducing emissions, investing in green technologies and protecting natural environment (EC, 2020). European Climate Law includes measures to continuously monitor implementation progress and adjust EU actions accordingly, based on existing systems such as the Member States' national energy and climate plan management process, regular European Environment Agency reports and the latest scientific evidence on climate change and its effects.

To evaluate the ambition level of Latvia's industrial energy efficiency goals for the next decade, actual industrial energy intensity curve was supplemented with targeted energy intensity in 2020 from National Development Plan (Saeima, 2013) and 2030 from NECP (MK, 2020) (see Fig. 5.1), and it can be concluded that the actual reference points and new targets have good correlation and the curve has exponential form with R^2 0.9962 (see Fig. 5.1).

This suggests that the energy efficiency targets set for industry will need to be refined in the context of the European Green Deal with more ambitious targets to close the current energy efficiency gap. This will need to be achieved through both investment in energy efficiency solutions and green technologies, reducing both energy intensity and CO_2 intensity. However, it will not be realistic for industry to reach the EU average energy intensity by 2030, but in order to reach the 2050 targets, the energy consumption in industry needs to decrease much faster, following the green path (see Fig. 5.1).

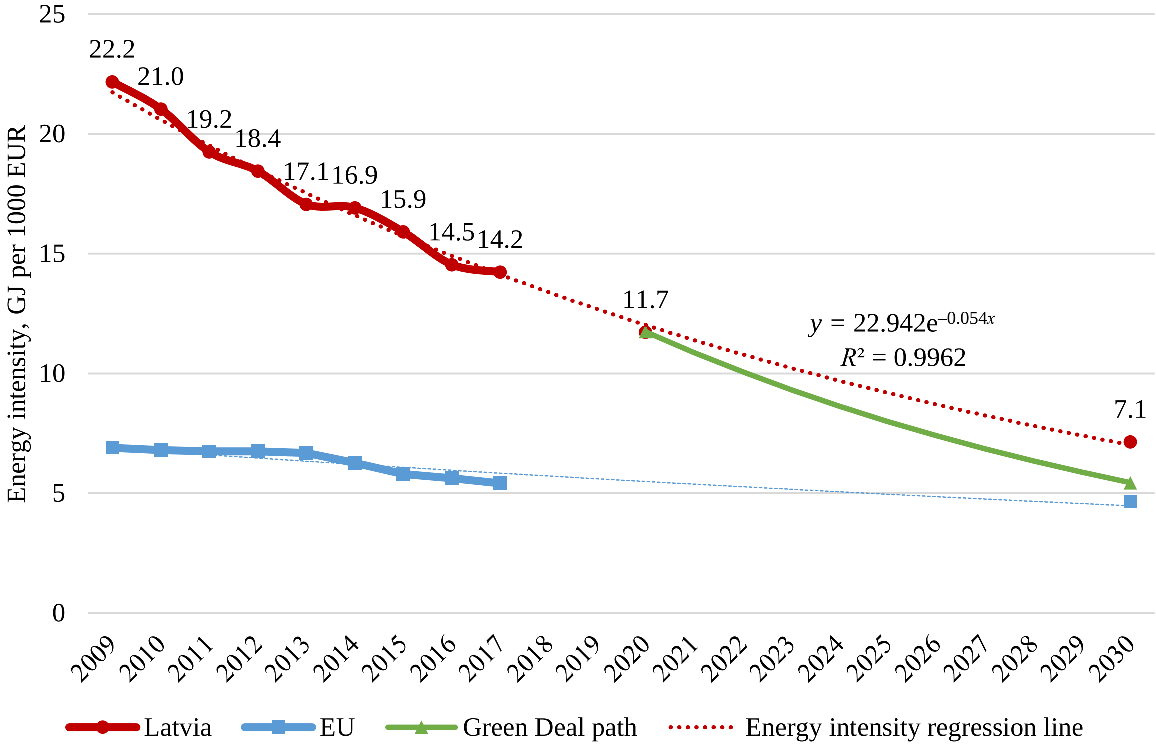


Fig. 5.1. Annual indicators of energy intensity of manufacturing industry of Latvia and EU, goals set in Latvia by 2020 and 2030, and their correlation, as well as the trajectory of the Green Deal path.

CONCLUSIONS AND PROPOSALS

The Doctoral Thesis evaluates Latvia’s energy efficiency policy for the manufacturing industry in the transition to the European Green Deal. A complex methodological approach has been developed for the evaluation of energy efficiency policy in which, using various research methods (statistical, system dynamics, benchmarking), various implications of energy efficiency policy have been analysed and the obtained results integrated into the recommendations for future policy instruments.

The applied methodological approach allows to identify the most dominat industries of Latvia in terms of energy consumption and GVA, determining the differences in their energy and CO_2 intensity, as well as to perform a comparative analysis with other countries. The obtained results allow to identify industrial sectors where energy and CO_2 intensities differ significantly, which allows to develop sector-specific policy improvements to achieve long-term climate neutrality goals. The analysis of energy intensity of industrial sectors shows that Latvia’s industry consumes on average 2.6 times more resources to obtain the same GVA of industrial production compared to the EU average. And although Latvia’s energy intensity is gradually decreasing, reducing the gap with the EU average, the taken pace is insufficient, considering the climate neutrality goals in the future. However, the CO_2 intensity of Latvia’s industry is twice lower than the EU average, so changes in CO_2 emission taxes, as one of the policy instruments for stimulating industrial energy efficiency, will have twice less impact in Latvia comparing to the EU.

Since the adoption of the Energy Efficiency Law in Latvia and the imposition of mandatory energy efficiency obligations on large companies and large consumers, the role of energy efficiency in industry has increased, as evidenced by NEEMS data on already achieved and growing energy efficiency savings in 2016 and 2017. However, the developed benchmarking methodology, which uses available data from Latvian industrial energy audit reports and allows to compare the energy efficiency potential of Latvia’s industries with the results of a similar energy audit program in Sweden, showed significantly lower identified energy efficiency potential in Latvia’s three leading industrial sectors (wood and wood products, non-metallic mineral products, food and beverage production). This undiscovered energy efficiency potential in Latvia’s three most dominant industries was estimated at 863 GWh of annual energy savings, which corresponds to 91 thousand tons of CO_2 emissions per year.

The reasons for the relatively high energy intensity and low energy efficiency indicators of Latvia’s most dominant industries were sought in the analysis of the behaviour of energy-intensive industrial comapnies using system dynamics modelling and the analysis of data available in NEEMS. System dynamics modelling highlighted the contradictory implications of energy policy in Latvia which encouraged energy-intensive industrial companies to maintain a relatively high level of energy intensity by sacrificing energy efficiency measures. In addition, the lack of high-quality energy efficiency monitoring system has led to incomplete collection of energy efficiency data, acceptance of formal reports, and poor-quality energy audits.

These shortcomings of the energy efficiency monitoring system can be remedied by the following:

1) investing to improve the data collection, support and control process, standardizing reporting forms and introducing an electronic environment for periodic data submissions;
2) investing for raising the professional skills of energy auditors and monitoring their activities, improving the availability of high-quality energy audits.

This would allow industrial companies of Latvia to obtain higher quality energy audits and policy makers to make better use of energy efficiency policy performance indicators, as well as to set industry-specific targets, taking into account their energy intensity, CO_2 intensity, energy efficiency potential and benchmarking with peers in other countries. The findings of the Doctoral Thesis on different industries allow to conclude that in the context of the European Green Deal industry needs to set sector-specific targets, addressing separately CO_2-intensive industries such as cement production and low-carbon intensive industries such as wood and wood products. The recomendations are:

3) the energy efficiency and climate neutrality targets for CO_2-intensive industries can be achieved through existing ETS regulation, while assisting companies to adapt through the EU financial instruments offered by the European Green Deal;
4) the continuation of the electricity cost support policy of energy-intensive manufacturing companies, which mainly reaches high energy intensity and low value-added sectors, should be conditional on mandatory investment in energy efficiency measures, ensuring both binding targets and control of their achievement and by changing the intensity calculation conditions, assessing electricity costs in the company at the level before the introduction of energy efficiency measures.

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