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Key Determinants of Energy Intensity and Greenhouse Gas Emission Savings in Commercial and Public Services in the Baltic States

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Abstract: The improvement of energy efficiency (EE) and growing consumption of renewable energy sources (RES) in the commercial and public services sector are playing important roles in seeking to pursue sustainable development in the Baltic States and contributing to the transition to a low-carbon economy. This paper provides findings from a detailed analysis of energy intensity trends in economic sectors from 2005 to 2022 in three countries, considering the role of transformations in the energy and climate framework of the European Union (EU). Based on the Fisher Ideal Index application, the different contributions from improving EE and structural changes are revealed. The dominant role of EE improvements in energy savings is identified in Estonia and Lithuania, and structural changes are dominant in Latvia. Changes in energy-related greenhouse gas (GHG) emissions in the commercial and public services sector and the main determinants of their reduction are examined. Based on applying the Kaya identity and the logarithmic mean Divisia index (LMDI) method, decreasing energy intensity is the most important determinant in all three countries. Due to the different extents of RES deployment, their role was very important in Estonia and Latia but was less effective in Lithuania. Reduction in emission intensity has the largest impact in Latvia. The GHG emissions decreased by 34.1% in Estonia, 17.5% in Latvia, and 16.7% in Lithuania. The results confirm the need for new policies, implementation of relevant EE measures, and the growing contribution from RES in Latvia and Lithuania.

Keywords: Baltic States; value-added; energy intensity; GHG emissions; decomposition analysis

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1. Introduction

Climate change, which is mainly caused by the extensive activities of the world's population and the increasing amount of GHG emitted into the atmosphere, is leading to more and more torrential rains, disastrous floods, storms, hurricanes, droughts, forest fires, tropical cyclones, and other extreme meteorological events. The rise in global temperatures threatens the planet's ecosystems and exacerbates problems in many parts of the world. Climate-related hazards pose many threats to the energy and food security of the planet and other important areas such as ecosystems, infrastructure, and human health. Considering the first European Climate Risk Assessment, many of the 36 identified risks have reached a critical level [1]. Thus, urgent and decisive action is required, and all 27 Member States of the EU are responsible for their contribution to climate change mitigation.

The EU has ambitious climate targets, including GHG emission reduction targets across a broad range of sectors, turning the EU into the first climate-neutral economy by 2050, necessary regulatory and financing framework, economic growth decoupled from resource use, etc. [2]. The need to transition from fossil fuels to RES in the energy systems agreed by nearly 200 countries was the main outcome of the United Nations (UN) Climate Change Conference (COP28) [3]. Thus, to achieve net zero emissions by 2050, acceleration of efforts and actions in all countries and all sectors is very important.

Estonia, Latvia, and Lithuania received from their Soviet past energy-intensive industries, very intensive agriculture, inefficient energy transformation and supply systems, energy systems developed to meet the needs of a large region of the Former Soviet Union, high dependence on imports of primary energy resources from Russia, buildings with poor thermal insulation, unclear prospects for economic development, and other problems of former centralised governance. Due to historical circumstances, the Baltic countries' natural gas and electricity systems have been closely linked to Russian gas and electricity systems. The Russian military invasion in Ukraine led to crucial decisions to develop energy sectors independent from Russian fossil fuels. Moreover, the national electricity transmission system operators in Estonia, Latvia, Lithuania, and Poland have assessed scenarios for disconnection of the Baltic power system from the Russian-controlled electricity system. The detailed analysis confirmed that the planned synchronisation with the Continental European network in February 2025 is safe and technically feasible [4,5].

Twenty years ago, the Baltic States joined the EU as the new Member States with ambitious goals for integration into the Western economy. All three countries had specific commitments to contribute to implementing the EU directives, the UN Framework Convention on Climate Change and other international environmental conventions, and to meet the EU's strategic environmental objectives. In December 2020, the European Council endorsed a more ambitious climate and energy policy target to reduce GHG emissions by at least 55% by 2030 (previously 40%). This decision obliged all the Member States to develop updated national adaptation plans and strategies. Estonia, Latvia, and Lithuania submitted updated National Energy and Climate Plans (NECPs) to the European Commission (EC), setting out long-term objectives and measures for climate change management and motivating the development of a climate-neutral economy by 2050 [6–8].

The draft NECPs have been updated and supplemented, considering recommendations and specific commitments of the EC in line with the new, more ambitious energy and climate objectives for the period by 2030. The Baltic countries have committed to accelerating GHG emission reduction, EE improvements, and RES deployment, contributing to the EU's overall climate mitigation objectives. In their NECPs, the countries have envisaged policies and measures covering the five key dimensions of the European Energy Union: (1) decarbonisation, (2) EE, (3) energy security, (4) internal energy market, and (5) research, innovation, and competitiveness. Achieving some of the objectives in these plans, such as a significant reduction in GHG emissions in the transport sector and an indicative reduction in final energy consumption by 2030, is challenging and will require additional policy measures and actions due to their socio-economic sensitivity.

Thus, the scientific innovation in this paper is multi-layered. It is found in the stages of economic sector selection for research and its regional coverage, historical data collection and processing, selecting and applying research methods, a developed tool, and specific knowledge creation, respectively. The literature review revealed that commercial and public services rarely investigated their energy and climate policy indicators. Even if so, this research was carried out by countries or regions without significant historical transformations in their economic systems. In the regions that have undergone significant transformations in economic systems and have considerable deficiencies but are "catching up," there is a knowledge gap in this area. Therefore, innovation is the knowledge developed concerning developments in key energy and climate policy indicators (energy intensity, GHG emissions, and their determinants) in commercial and public services in the Baltic States. However, knowledge acquisition is a complicated task, as it requires the collection of national data sets and tailoring them to the methods' structures. During the data collection and processing, a time-consuming harmonisation of national data was carried out and tailored to the structure of the comparative-historic research methods. We used the Fisher Ideal Index to reveal the effect of EE and structural changes in economic activities leading to a reduction in energy intensity in economic sectors. We applied an extended Kaya identity and the LMDI method to assess the impact of employees, growth in economic activities, reduced energy intensity, deployment of RES, and variation in emission intensity on the reduction in GHG emissions in the commercial and public sectors of Estonia, Latvia, and Lithuania. The application was carried out in Excel. The developed tool allows us to create knowledge about the historical trends in final energy intensity, final energy savings by the effect of EE and structural changes, and GHG emissions by their key determinants. The constructed Excel-based tool is relevant for modelling the long-term development of energy and climate policy indicators. The methodology enables an in-depth analysis of quantitative and qualitative changes in EE in economic sectors and the impact of the determinants on reducing GHG emissions in the commercial and public services sectors. This study identifies the specific features of EE improvements and GHG emission reductions in Estonia, Latvia, and Lithuania. Thus, this research contributes to the existing scientific literature by providing an integrated analysis of EE, structural changes in economic sector activities, deployment of RES, and the reduction in GHG emissions from fossil fuel combustion in the commercial and public services sector in the Baltic States.

Research tasks are the following:

- to analyse the trends of final energy intensity in economic sectors of the Baltic States from 2005 to 2022;
- to study the effects of EE and structural activity on energy savings in economic sectors of the Baltic States;
- to assess the effects of changes in employees, economic activity, energy intensity, RES deployment, and emission intensity on the developments concerning GHG emissions in the Baltic countries' commercial and public services sector.

This paper is organised as follows: in Section 2, we review relevant literature; in Section 3, we present the methodology used to perform research and current sources of information; in Section 4, we show the results of a comparative analysis of energy intensity trends in economic sectors; in Section 5, we study changes in energy-related GHG emissions in the services sector and the impact of key determinants; and in Section 6, we provide our conclusions.

2. Literature Review

Rising global temperatures are causing concern in many countries due to increased extreme weather events and concerns about meeting the fundamental Paris Agreement targets. Energy economists and policymakers are analysing trends in GHG emissions, the determinants that significantly influence their growth, and the opportunities for reducing them. Many experts and researchers are studying the changes in GHG emissions in individual sectors, the determinants driving changes in energy intensity, the integration of RES, and the development of new energy sources.

Based on the application of the extended Kaya identity and the LMDI decomposition method, trends of carbon emissions in China from 2005 to 2016 and their influencing determinants were examined in [9]. An increase in economic output was identified as the most significant determinant promoting the growth of CO_2 emissions. Reduction in energy intensity, structural changes in the industry, and implementation of relevant economic policy measures are key determinants that will influence the future decrease in these emissions in China. The LMDI approach was employed to identify determinants that impact the reduction in energy-related CO_2 emissions in Europe [10]. Despite differences in changes in individual countries, switching to cleaner fuels for end-users and reducing fossil fuels for energy generation resulted in significant improvements in reducing emissions. A decomposition analysis of energy-related CO_2 emissions in 33 countries from 1995 to 2007 was carried out in [11]. Economic growth was the most significant determinant of the increase in energy-related CO_2 emissions. Improvements in EE have been the main determinant contributing to the reduction in CO_2 emissions. After applying the Kaya identity and the LMDI method, the CO_2 emissions in China from 1996 to 2016 were decomposed in [12]. Economic activity was identified as the main determinant promoting the growth of carbon emissions, and the decrease in energy intensity was the most significant contributor to their reduction. The dynamic analysis of CO_2 emissions in Central and Eastern European countries was performed in [13]. The improvement in EE and energy innovations is leading to reduced emissions. Still, faster economic growth than average in the EU is followed by increased energy demand, which can contribute to increased CO_2 emissions. The LMDI decomposition method was employed in [14] for the analysis of carbon emissions in Iran from 2003 to 2014. Increased combustion of fossil fuels was highlighted as the main determinant of growing emissions in the industrial sector and electricity generation. Improvements in the energy mix, in particular in the transport sector, were identified as the measure compensating for this growth. The LMDI was applied to study the carbon emissions in key transport CO_2 emitter countries from 2000 to 2015 in [15]. The carbon intensity effect was identified as the main contributor to CO_2 emission reductions. Electricity structure and economic output effects were key determinants of CO_2 emission increases. The LMDI and the Fisher Ideal Index were applied to decompose GHG emissions and compute the efficiency index in Australia's economic sectors from 1990 to 2015 [16]. Scientists concluded that seeing as economic sectors were efficient, and GHG emissions were reduced continuously in Australia, the country has to invest more in efficient technologies. Input–output structural decomposition analysis was performed to understand key determinants of GHG emissions in China's city Chongqing from 2002 to 2012 by [17]. The results revealed that the change in energy intensity was a key determinant for GHG emissions reduction and the expansion of final demand impacts GHG emission growth. The LMDI method was adapted to examine the key determinants that impacted development of GHG emissions in the cement industry from 2005 to 2009 in China [18]. The effects of cement production activity and clinker production activity were identified as significant determinants. In [19], structural decomposition analysis was conducted to identify the determinants of change in CO_2 emissions in the Baltic States from 1995 to 2009. The final demand was the main determinant for increasing emissions. In Latvia and Lithuania, the increase was compensated by reducing the economy's emission intensity. In Estonia, a shift in consumption patterns and economic structure was the main balancing determinant. The Geographically and Temporally Weighted Regression model was applied to assess several determinants of energy use and GHG emissions in buildings by [20]. Buildings with a large floor area had a positive impact on energy use intensity and GHG intensity, but the impact of the population under poverty and the number of floors was found to be negative.

Two principal ways to reduce energy-related GHG emissions are increasing EE and using RES [21]. Therefore, the literature in this area is worth discussing. Regression analysis was carried out by [22] to set the relationship between GHG emissions per capita, Gross Domestic Product (GDP), energy consumption, and RES consumption for a panel of EU-28 countries from 1990 to 2016. In the long run, the increase in energy consumption caused increased GHG emissions. However, an increase in RES consumption contributed to reduced GHG emissions. In [23], RES technological innovation was recognised as a significant determinant contributing to reductions in CO_2 emissions from 2000 to 2015 in China. In [24], the EMF27 scenarios were applied to assess the importance of RES in climate change mitigation. RES are the most relevant option for electricity supply in many scenarios. Bioenergy is an important and versatile energy carrier. Climate policy is irrelevant to the competitiveness of wind energy. The ambitiousness of climate policy impacted the prospects of solar photovoltaics (PVs). Research findings [25] revealed that solar energy is crucial when meeting GHG emission reduction targets in the electricity sector. Findings in [26] suggested that to implement nearly zero-energy buildings, advanced RES technologies, energy storage systems, and intelligent energy management systems should be implemented.

Further, a review of the literature was performed by [27] to understand key determinants of energy intensity. Researchers found that energy intensity changes due to technological innovations, well-designed infrastructure, urbanisation, accessibility, diversity of energy sources, regulations on EE, economic activity and structural changes in the economy, financial development, foreign direct investment, trade, and energy prices. In [28], the LMDI method was tailored to study developments in energy intensity and determinants in 40 countries. Technological change was found to be a relevant determinant of improvements in EE. Structural changes were found to be less significant in the majority of countries. The Index Decomposition Analysis and the Production Decomposition Analysis methods were used to fully decompose the changes in energy intensity in the metallurgical industry in China by [29]. Results showed that energy intensity decreased due to technological progress. The energy intensity did not decrease as intended due to the labour–energy substitution. In [30], the relationship between industrial intellectualisation and energy intensity from 2006 to 2018 in China was studied. The lag effect can be observed when improving EE and restraining energy intensity through industrial intellectualisation. The Data Envelopment Analysis, the Malmquist–Luenberger index, and the Generalised Method of Moment regression analysis were used to explore the total factor energy efficiency and to assess the impact of technological innovation on it in China from 2001 to 2013 in [31]. Technological innovations increase EE. In [32], a Hybrid Electric Vehicles (HEV) case was simulated to assess their fuel and emissions-saving potential. The analysis of different EV configurations showed that HEVs had fuel efficiency and vehicle emission advantage. Empirical analysis by utilising data from the prefecture level and cities from 2010 to 2019 was performed by [33] to examine the impact of industrial robot applications on urban green total factor energy efficiency. Results demonstrated that robots optimise production processes and reduce energy consumption. They increase labour productivity in regions. A fixed-effects model was applied to determine the relationships between industrial robots, carbon emissions, and the energy rebound effect in China by [34]. Industrial robots reduce carbon emissions but lead to the energy rebound effect. Therefore, to satisfy the increasing need for robot deployment while reducing GHG emissions, fossil fuels should be replaced by clean energy. In [35,36], solutions for improving EE were studied. Ref. [35] proved that building energy management systems using logic control in air conditioning and refrigeration systems reduces energy consumption, while ref. [36] justified the significance of building–plant system retrofit solutions, including PV panel installation and high-quality LED, to reduce energy consumption and CO_2 emissions. In [37], an expert systems approach aimed at improving EE in the industry with a focus on manufacturing was systematically reviewed. In [38], measures for reducing GHG intensity were studied. The authors of [38] argued that tax deductions, a National Clean Energy Fund, preferential financing, and the creation of a carbon market should be used to support technology adoption. In [39], solutions to decarbonise industrial heat generation were proposed.

Thus, the literature review demonstrated that various aspects of GHG emissions are covered by global scientific literature. However, the service sector is rarely investigated separately, and studies for the Baltic States are even rarer. Therefore, issues of energy intensity and GHG emissions in the region are worth further investigation.

3. Methodology

This methodology was prepared to understand the importance of energy intensity changes in increasing energy-related GHG emission savings in the commercial and public services sector in the context of a growing and "catching up" economy. It corresponds to the one developed and applied by the authors to study the impact of key determinants on energy intensity and GHG emissions in the manufacturing sector, presented in [40]. In the present research, the methodology focuses on carrying out three tasks: quantitative assessment of final energy intensity and its historical developments in the national economic sectors by emphasising the commercial and public services sector; assessment and establishment of historical trends in energy savings by effect of sector-specific EE and economic activity; and estimation of historical GHG emission savings by key determinants, including energy intensity, in the commercial and public services sector (Figure 1).

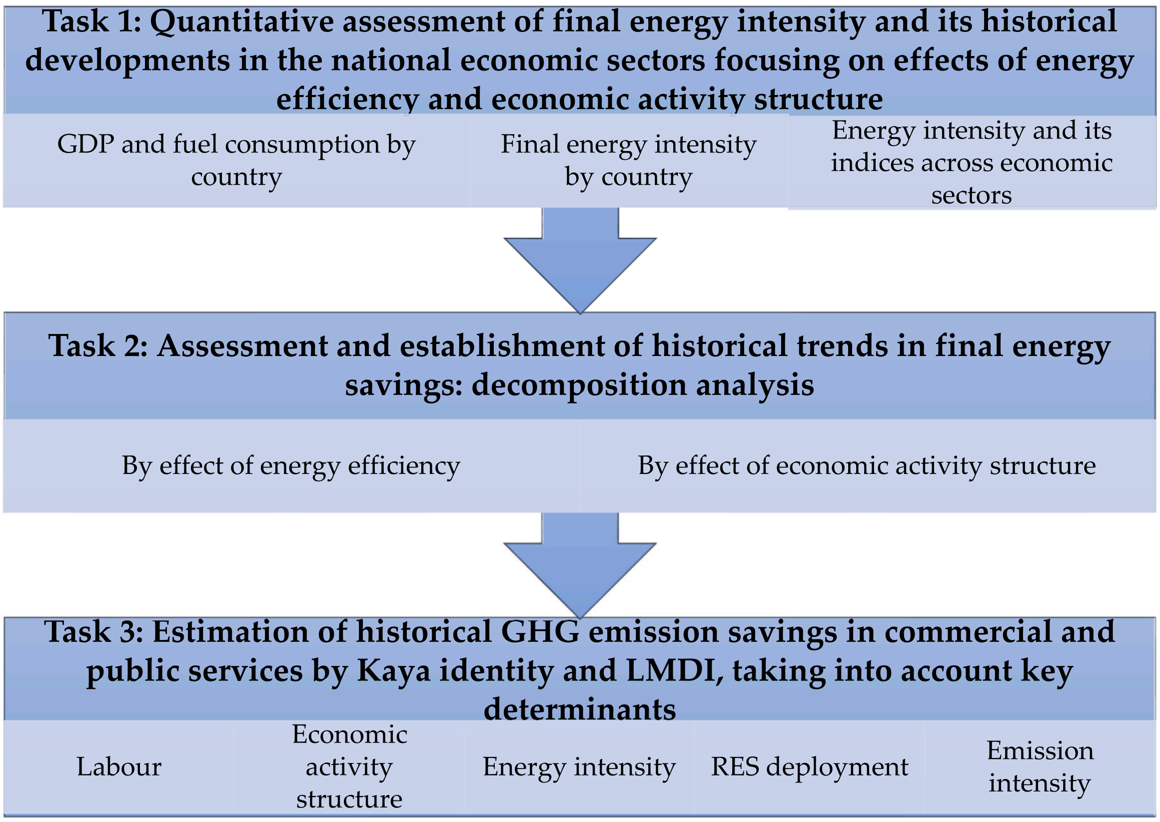


Figure 1. The logical research scheme (made by the authors).

As shown in Figure 1, the research was initiated bearing in mind that after joining the EU, Lithuania, Latvia, and Estonia sought to "catch up" to the economic level of developed economies by reducing the amounts of fuel and energy used and emitting less GHG emissions, which is defined as decoupling. Therefore, firstly, we show the rates of economic development and fuel consumption in the country, between the countries, and in the context of the EU to justify the presence of that aspiration and the feature of a "catching up" economy. For this purpose, we apply the GDP index and the indicator of energy intensity, which implies final energy consumption per unit of value-added (VA) created in the national economy in time *t*. While the GDP index is calculated from the indicator of VA at a chain-linked volume, considering in the base year 2005 it is 100%, the energy intensity is computed by Equation (1):

$$ENI_t = \frac{FEC_t}{VA_t} \tag{1}$$

where ENI_t is the energy intensity in the national economy in time t, FEC_t is the final energy consumption in the national economy, and VA_t is the VA created in the national economy in time t. The definition indicates that the final energy consumption is calculated only for those sectors that generate value-added. To this end, households are not included.

In agreement with [41], an extended approach towards energy intensity is applied to reveal its links with sector-specific EE and economic activity in the sector by Equation (2):

$$ENI_t = \sum_i \frac{FEC_{i;t}}{VA_{i;t}} \times \frac{VA_{i;t}}{VA_t} = \sum_i e_{i;t} \times s_{i;t} \tag{2}$$

where $FEC_{i;t}$ is the final energy consumption in sector i in time t, $VA_{i;t}$ is the value-added created in sector i in time t, $e_{i;t}$ is the sector-specific EE in time t, and $s_{i;t}$ is the share of value-added generated in sector i of the value-added created by the national economy in time t.

The energy intensity index ($I_{ENI;t}$) in the country is computed by dividing energy intensity in year t (ENI_t) by energy intensity in the base year (ENI_o) by Equation (3):

$$I_{ENI;\,t} = \frac{ENI_t}{ENI_o} = \frac{\sum_i e_{i;t} \times s_{i;t}}{\sum_i e_{i;o} \times s_{i;o}} \tag{3}$$

The decomposition of the energy intensity index ($I_{ENI;t}$) is carried out into two components, which are the EE index ($I_{efficiency}$) and the activity structural change index ($I_{activity}$).

The Laspeyres and Paasche indexes are applied correspondingly for this purpose by Equations (4) and (5):

$$L_{efficiency} = \frac{\sum_i e_{i;t} \times s_{i;0}}{\sum_i e_{i;0} \times s_{i;0}}, \quad L_{activity} = \frac{\sum_i e_{i;0} \times s_{i;t}}{\sum_i e_{i;0} \times s_{i;0}} \tag{4}$$

$$P_{efficiency} = \frac{\sum_i e_{i;t} \times s_{i;t}}{\sum_i e_{i;0} \times s_{i;t}}, \quad P_{activity} = \frac{\sum_i e_{i;t} \times s_{i;t}}{\sum_i e_{i;t} \times s_{i;0}} \tag{5}$$

The Fisher Ideal Index is used to assess the main determinants that underlie crucial changes [42]. It is applied to correctly decompose the energy intensity index ($I_{ENI;t}$) into indexes of EE ($I_{efficiency}$) and activity ($I_{activity}$). The geometric averages of the Laspeyres index and the Paasche index are computed by Equation (6):

$$I_{efficiency} = \sqrt{L_{efficiency} \times P_{efficiency}} \text{ and } I_{activity} = \sqrt{L_{activity} \times P_{activity}} \tag{6}$$

The energy intensity index ($I_{ENI;\,t}$) is composed of EE and activity indexes as in Equation (7):

$$I_{ENI;t} = I_{efficiency;t} \times I_{activity;t} \quad (7)$$

After justification that the economies of the Baltic countries have the feature of "catching up", as the economies grow and approach the EU level, when fuel is consumed less and less and fuel intensity in economic sectors is decreased, further research aims to find out how much fuel and energy has been saved due to improvements in EE and structural changes in activities. The indicator of total energy savings in time t ($E_{savings;t}$) is calculated. It is calculated as the difference of final energy that would have been consumed in each economic sector if EE had remained the same as in the base year 0 and the actual energy consumption in time t considering the Equation (8):

$$E_{savings;t} = \sum_i ((e_{i;o} \times VA_{i;t}) - FEC_{i;t}) \quad (8)$$

Total energy savings ($E_{savings;t}$) are decomposed into components of energy savings from EE improvements ($E_{efficiency;t}$) and structural changes in activities ($E_{activity;t}$) by Equation (9):

$$E_{savings;t} = E_{efficiency;t} + E_{activity;t} = E_{savings;t} \times \frac{\ln\left(I_{eff;t}\right)}{\ln(I_{ENI;t})} + E_{savings;t} \times \frac{\ln(I_{act;t})}{\ln(I_{ENI;t})} \quad (9)$$

Finally, we estimate energy-related GHG emissions and their savings, focusing on a targeted sector, which is the commercial and public services, and key determinants, including energy intensity. The Kaya identity [43] is applied to assess the developments in GHG emissions due to a number of determinants. An extended form to common identity is applied in the present research to describe energy-related GHG emissions and their changes in the commercial and public services sector. It considers that GHG emissions are influenced by five relevant determinants. These are number of employees, VA, energy intensity, consumption of fossil fuels, and carbon emissions intensities. The determinants in the GHG emissions model are related as presented by Equation (10):

$$GHG_t = L_t \times \frac{VA_t}{L_t} \times \frac{FEC_t}{VA_t} \times \frac{FFC_t}{FEC_t} \times \frac{GHG_t}{FFC_t} \quad (10)$$

and simplified by Equation (11):

$$GHG_t = L_t \times LP_t \times ENI_t \times FF_t \times GHGI_t \quad (11)$$

where GHG_t is the energy-related GHG emissions in the commercial and public services sector in time t, L_t is the number of employees, VA_t is the value-added created in the commercial and public services sector, FEC_t is the final energy consumption in this sector, FFC_t is the total consumption of fossil fuels, LP_t expressed as VA_t per employee is an indicator of labour productivity, ENI_t expressed as final energy per VA_t is the determinant of energy intensity, FF_t shows the share of fossil fuels in the total final energy consumption and is the determinant of fossil fuels, and $GHGI_t$ is the total GHG emissions per unit of fossil fuels and is the determinant of emission intensity.

We employed the LMDI method, which was used in many energy studies [44–46] to evaluate GHG emission determinants. In detail, an additive decomposition technique is used to analyse changes in GHG emissions between a base year 0 and the end of the period in time t. Absolute change of energy-related GHG emissions is calculated by Equation (12):

$$\Delta GHG = GHG_t - GHG_0 = \Delta L_t + \Delta LP_t + \Delta ENI_t + \Delta FF_t + \Delta GHGI_t \quad (12)$$

where ΔL_t shows the labour effect, ΔLP_t shows the effect of activity (labour productivity) growth in the commercial and public services sector, ΔENI_t shows the energy intensity effect, ΔFF_t shows the effect of reduced consumption of fossil fuels due to their substitution with RES, and $\Delta GHGI_t$ shows the effect of GHG emission intensity.

The effects associated with each determinant are calculated by Equations (13)–(17):

$$\Delta L_t = \frac{GHG_t - GHG_0}{lnGHG_t - lnGHG_0} \times \ln\left(\frac{L_t}{L_0}\right) \tag{13}$$

$$\Delta LP_t = \frac{GHG_t - GHG_0}{lnGHG_t - lnGHG_0} \times \ln\left(\frac{LP_t}{LP_0}\right) \tag{14}$$

$$\Delta ENI_t = \frac{GHG_t - GHG_0}{lnGHG_t - lnGHG_0} \times \ln\left(\frac{ENI_t}{ENI_0}\right) \tag{15}$$

$$\Delta FF_t = \frac{GHG_t - GHG_0}{lnGHG_t - lnGHG_0} \times \ln\left(\frac{FF_t}{FF_0}\right) \tag{16}$$

$$\Delta GHGI_t = \frac{GHG_t - GHG_0}{lnGHG_t - lnGHG_0} \times \ln\left(\frac{GHGI_t}{GHGI_0}\right) \tag{17}$$

The data requested to carry out this analysis were collected from the official databases of national statistics in Lithuania [47–49], Latvia [50–52], Estonia [53–55], and Eurostat [56,57]. Energy-related GHG emission data were collected from the National Inventory Submissions 2023 [58] and the Eurostat database [59].

The analysis period is from 2005 to 2022, and it includes the latest available data. In the present research, the base year is 2005.

4. Comparative Analysis of Energy Intensity Trends in Sectors of the National Economies

4.1. Trends of Final Energy Intensity

Despite many challenges in transitioning from command planning to a free market economy, the accession period was quite successful, and the Baltic States joined the EU on 1 May 2004. Estonia, Latvia, and Lithuania became new members of the enlarged EU with ambitious aspirations to consistently "catch up" with the economic level of developed European countries and contribute to the common goals and objectives of sustainable energy development.

The economies in the Baltic States grew rapidly during the accession period, but all three countries had to survive the complex impacts of the global financial crisis from 2007 to 2008. In 2009, GDP decreased by 14.3% in Latvia, 14.6% in Estonia, and 14.8% in Lithuania. With a 4.3% reduction in economic growth on average in the EU-27, the impact of the crisis on economic development in the Baltic States was painful. Nevertheless, membership in the EU community opened many new opportunities for fast economic growth in all three countries. As one can see from Figure 2, economic growth in the Baltic countries from 2005 to 2022 was much faster than on average in the EU-27 countries—overall GDP in the community was growing by 1.3% per annum: by 1.8% in Latvia, by 2.1% in Estonia, and by 3.0% in Lithuania [56].

In 2005, GDP per capita in purchasing power standards (PPSs) was 51.6% in Latvia of the average in the EU-27 and was equal to 53.8% in Lithuania and 61.5% in Estonia. Due to being the fastest developing economic sector by almost twofold, the differences between this indicator in the Baltic countries and the average in the EU-27 were reduced substantially. In 2022, GDP per capita in PPSs increased to 88.0% in Lithuania, 84.7% in Estonia, and 66.4% in Latvia [57].

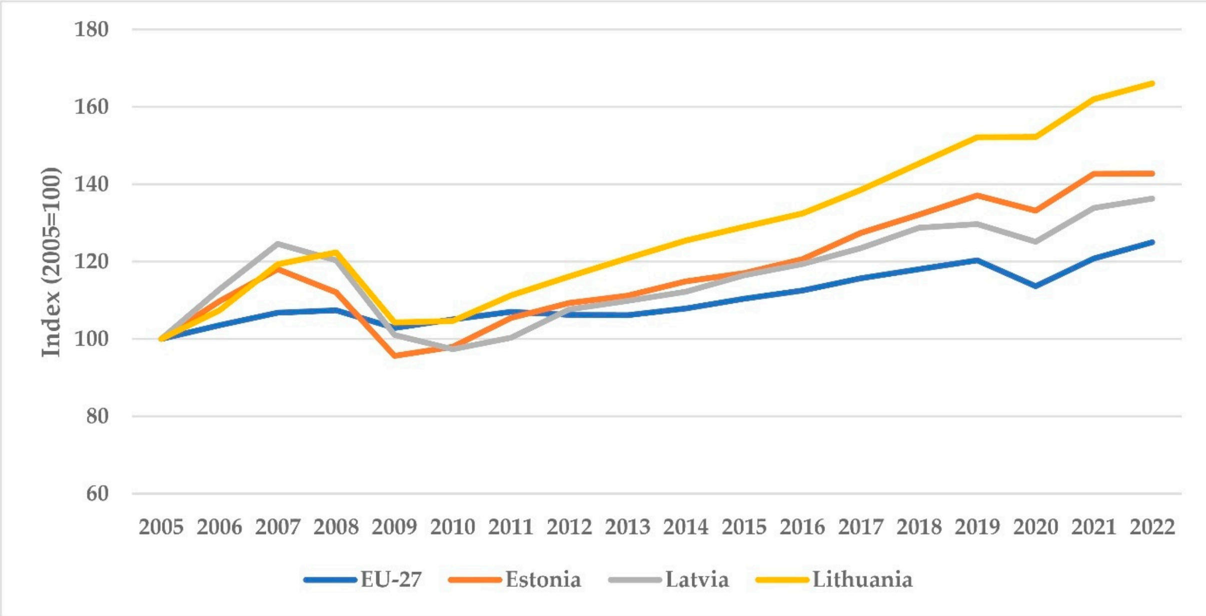


Figure 2. Index of GDP growth in the EU-27 and in the Baltic States [56].

Despite certain fluctuations, the trend of energy intensity reduction is observed in each country (Figure 3), but the reduction rate is quite different. From 2005 to 2022, final energy consumption per unit of VA decreased by 37.1% in Estonia, 23.3% in Lithuania, and 15.8% in Latvia.

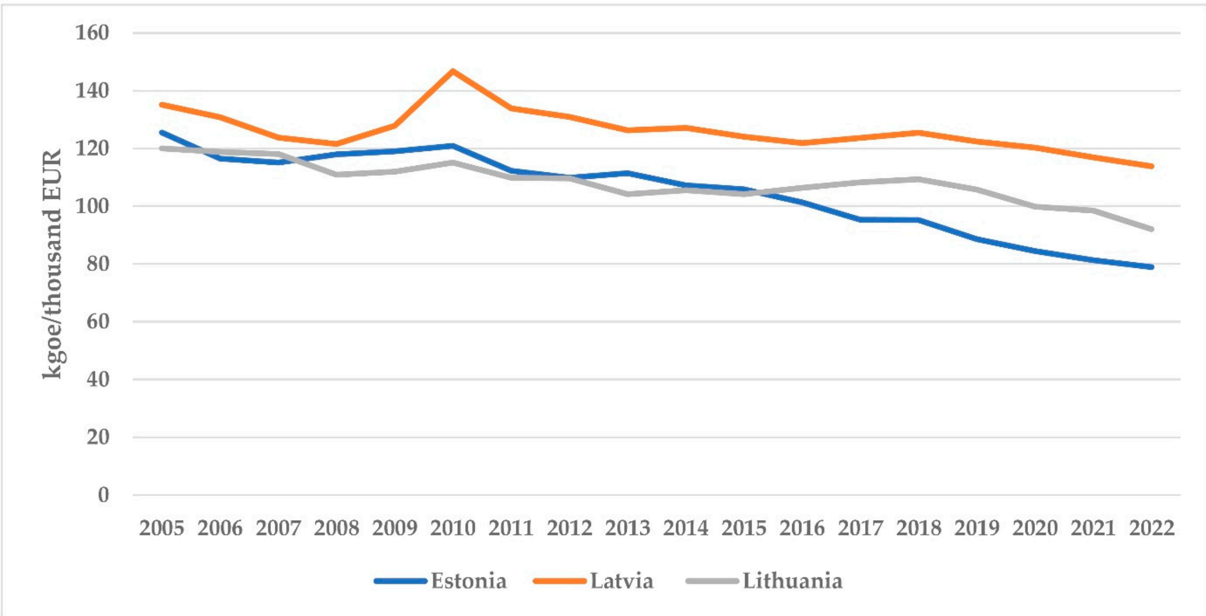


Figure 3. Changes in final energy intensity in economic sectors (own estimations).

A summand of energy consumption in economic sectors is significant in the energy balances of the Baltic States. Presently, it amounts to a total final energy consumption of 64.7% in Estonia, 71.5% in Lithuania, and 71.9% in Latvia. Thus, the share of households in the structure of final energy consumption amounts to 35.3% in Estonia, 28.5% in Lithuania, and 28.1% in Latvia. Changes in the structure of separate economic sectors and implementation of EE measures strongly impact future final energy consumption trends in each country. To correctly compare EE trends in these three countries, we have examined detailed energy consumption indicators per unit of VA created in the same five sectors, i.e., industry, construction, transport, agriculture, and commercial and public services. The importance of separate economic sectors measured by their shares in the final energy consumption and by the share of VA created in the national economies in 2022 is shown in Table 1.

Table 1. Comparative indicators by economic sectors (in %) in 2022 (own estimations).

	Estonia		Latvia		Lithuania	
	Final Energy	**Value-Added**	**Final Energy**	**Value-Added**	**Final Energy**	**Value-Added**
Industry	18.0	19.1	30.7	16.7	23.5	23.4
Construction	2.2	8.0	1.0	4.6	1.1	7.0
Transport sector	48.5	9.8	41.1	8.0	56.5	11.2
Agriculture	5.5	1.5	7.1	4.2	3.3	3.1
Services	25.8	61.6	20.1	66.5	15.6	55.3

Economic activities in the commercial and public services sector account for the largest share of VA and significantly impact economic growth in all three Baltic countries, with a share of 61.6% in Estonia, 66.5% in Latvia, and 55.3% in Lithuania. From 2005 to 2022, VA created in this sector increased at an average annual rate of 2.4% in Estonia, 2.5% in Latvia, and 2.7% in Lithuania. Energy consumption in this sector grew slowly in Estonia and Lithuania—by an average of 1.0% and 0.5%, respectively. In contrast, despite certain volatility, energy consumption in Latvia's commercial and public services sector decreased by 3.8%. The analysis showed different trends regarding VA creation and energy consumption in other sectors.

The industrial sector has traditionally been very important in the Baltic States, generating the most significant number of jobs, producing a wide range of products for the domestic market and goods for export, and consuming a large share of energy resources. From 2005 to 2022, the VA in this sector grew at an average annual rate of 3.2% in Lithuania, 2.1% in Estonia, and 1.0% in Latvia. This growth in economic activities has been followed by changes in final energy consumption, which grew by an average of 1.6% in Latvia, but declined in Estonia and Lithuania by 3.9% and 0.5% per year, respectively. The contribution of this sector to the VA varied between 19.1% and 21.7% in Estonia, 15.1% and 18.1% in Latvia, and 21.0% and 23.4% in Lithuania.

Transport and storage activities consume the largest share of final energy consumption. Due to the growing volumes of goods and passengers transported and the increasing mobility of the population, energy consumption grew in all three countries at an average annual rate of 2.6% in Lithuania, 1.1% in Estonia, and 0.6% in Latvia. In 2022, the share of this sector in the structure of final energy consumption was 56.5% in Lithuania, 48.5% in Estonia, and 41.1% in Latvia. The contribution of transport and storage activities to VA ranged from 8.4% to 10.1% in Estonia, from 8.0% to 10.6% in Latvia, and from 9.6% to 13.6% in Lithuania.

From 2005 to 2022, the VA in the construction sector grew at an average rate of 2.8% in Estonia and 2.2% in Lithuania but declined by 1.5% per year in Latvia. The share of this sector in the VA structure is currently 8.0% in Estonia, 7.0% in Lithuania, and 4.6% in Latvia. Changes in economic activities have been followed by declining energy consumption in all three countries—by 0.7% in Estonia, 1.0% in Latvia, and 0.8% in Lithuania.

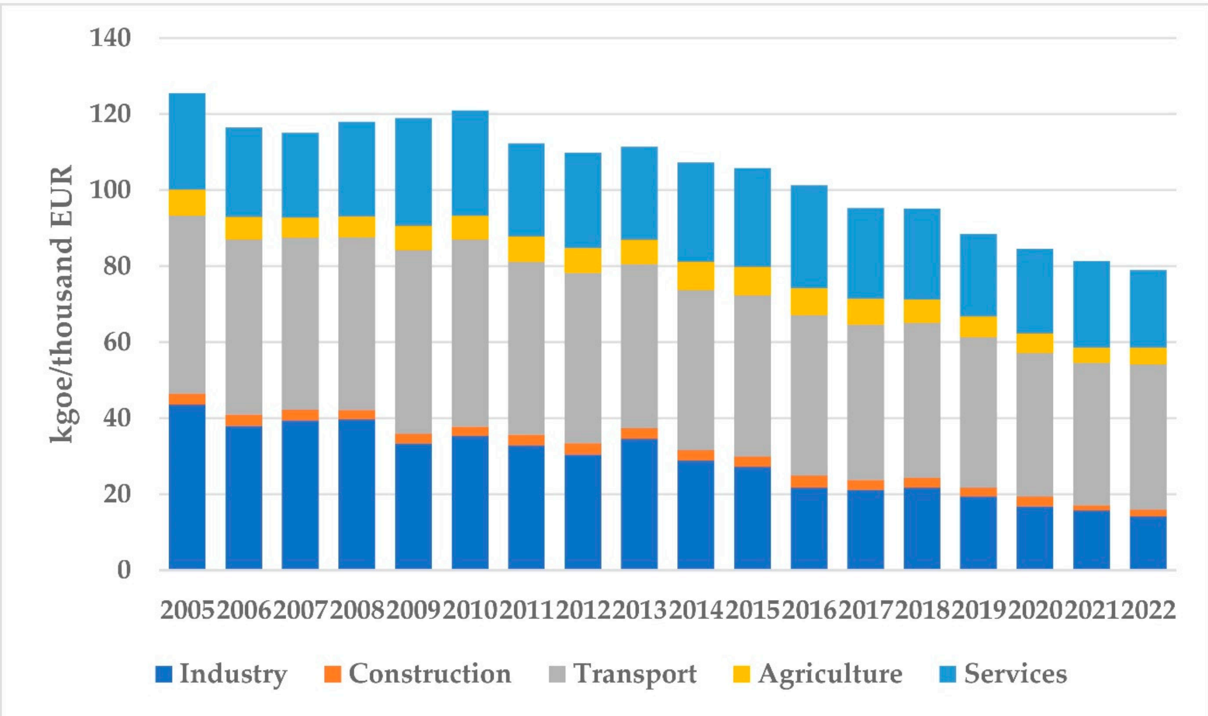
The contribution of agriculture to the national economies in the Baltic States is higher than the average in the EU countries. Still, it has fluctuated due to climatic conditions, changes in the food production industry, as well as social and other factors between 1.5% and 3.3% in Estonia, 3.1% and 4.2% in Latvia, and 2.9% and 4.0% in Lithuania. From 2005 to 2022, final energy consumption in this sector grew at an average rate of 1.6% per year in Latvia and 1.1% in Lithuania. Energy consumption in Estonian agriculture grew by 2.1% per year from 2005 to 2017 but has fallen by 27% in the last 5 years.

It is very important to underline that, due to different changes in the structure of economic activities, the growth in VA was achieved with different trends in energy consumption. In 2022, total final energy consumption in Estonian economic sectors was 7.9% lower, but in Latvia, it was 13.2% higher, and in Lithuania, it was 24.0% higher compared to the 2005 level.

The detailed analysis has revealed very different changes in energy intensity across economic sectors and countries (Figure 4).

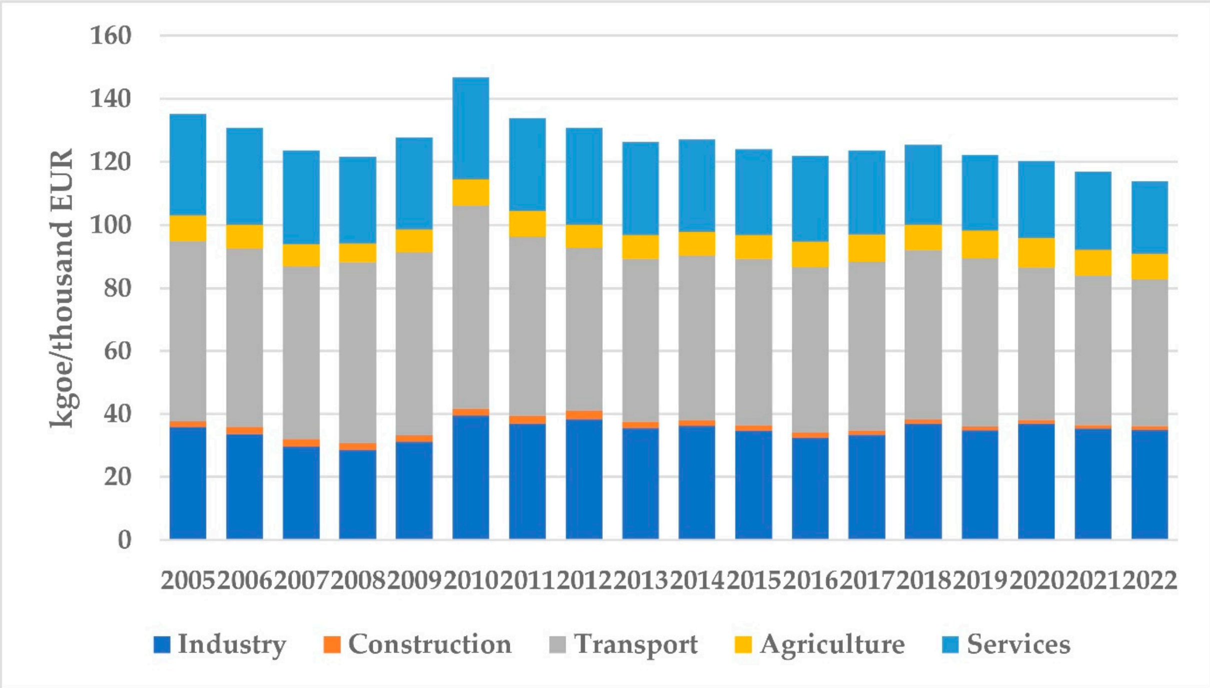
As shown in Figure 4, Estonia's most considerable reduction in energy intensity from 2005 to 2022 was fixed in the industrial sector at 66.7%. In the construction sector, the reduction was 45.3%; in the transport sector, 16.2%; and in the commercial and public services sector, 21.1%. Although the energy intensity in agriculture increased by 8.7%, the overall increase of EE resulted in the most significant reduction in total energy intensity in the economic sectors of the Baltic States with 37.1%.

In 2022, the energy intensity in Latvia's industrial sector was by 9.9%, the construction sector by 9.5%, and the transport sector by 8.2%, higher than the 2005 level. The most significant decrease in energy intensity was recorded in the commercial and public services sector, at 36.7%. The decrease in Latvia's agriculture sector was 12.3%. Thus, the overall decrease in energy intensity in Latvia's economic sectors from 2005 to 2022 was the smallest in the Baltic region, at 15.8%.

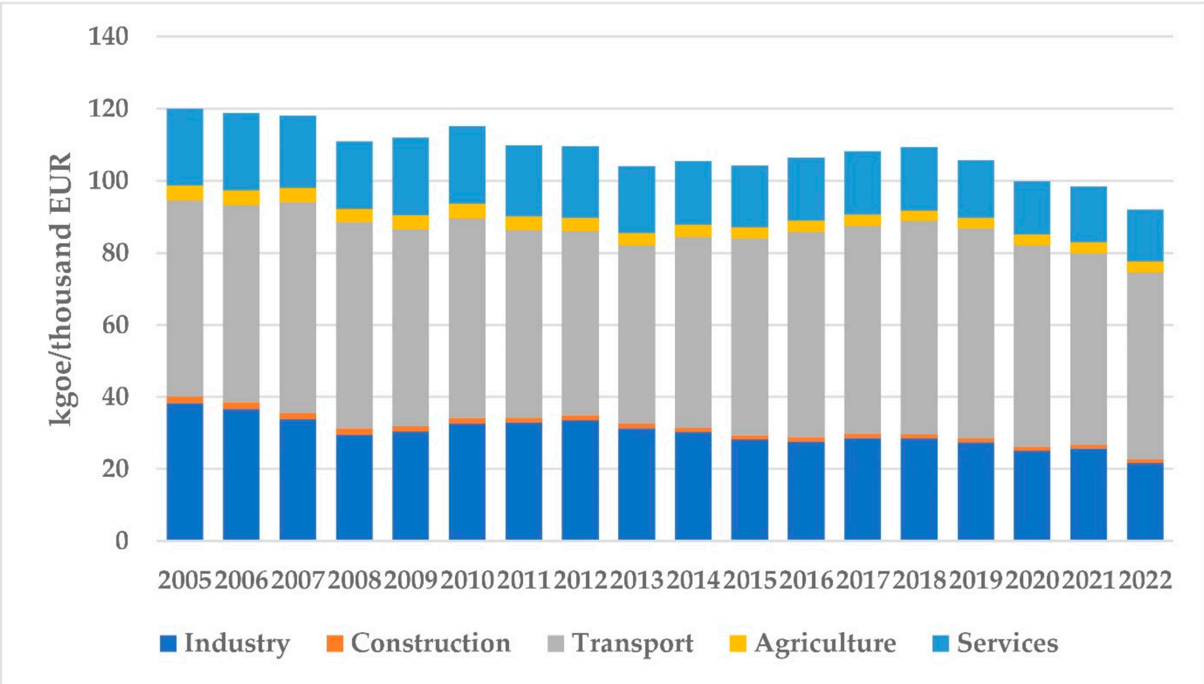


Estonia

Figure 4. *Cont.*



Latvia



Lithuania

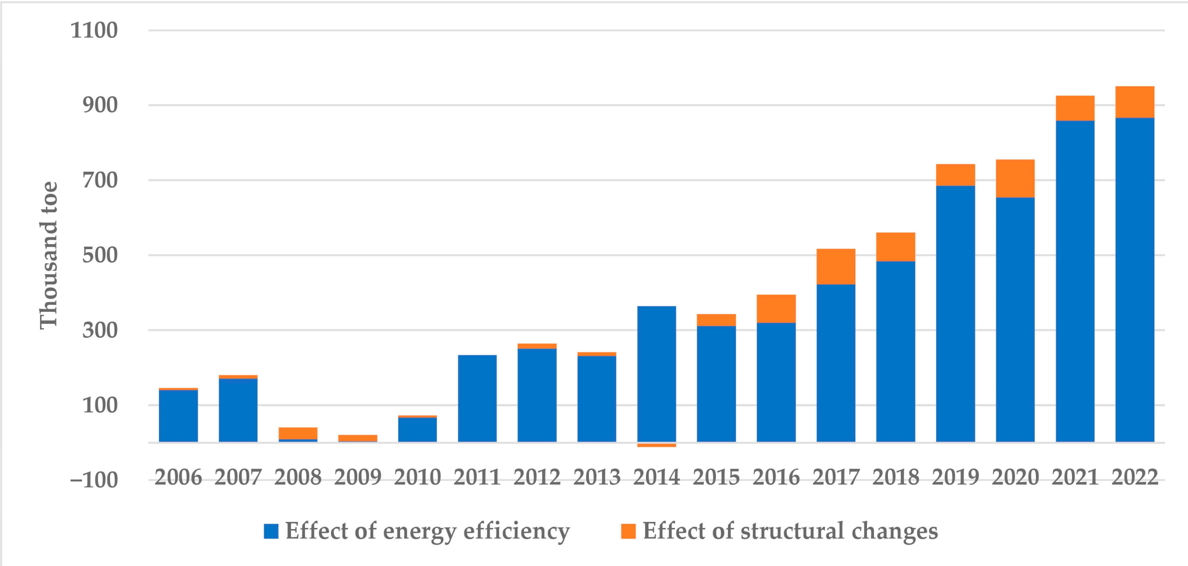
Figure 4. Changes in final energy intensity in sectors of economies (own estimations).

Lithuania's most considerable reduction in energy intensity was fixed in the industrial sector, at 46.0%. In 2022, the construction sector had decreased its energy intensity by 39.7%, the transport sector by 18.9%, the commercial and public services sector by 31.2%, and agriculture by 3.7% compared to the 2005 level. Transport and storage activities consume the most energy resources per unit of VA. In addition, this sector is also the largest consumer of energy resources in Lithuania. Considering these factors, one can explain why the overall reduction in energy intensity in the Lithuanian economic sectors was moderate, 23.3% only.

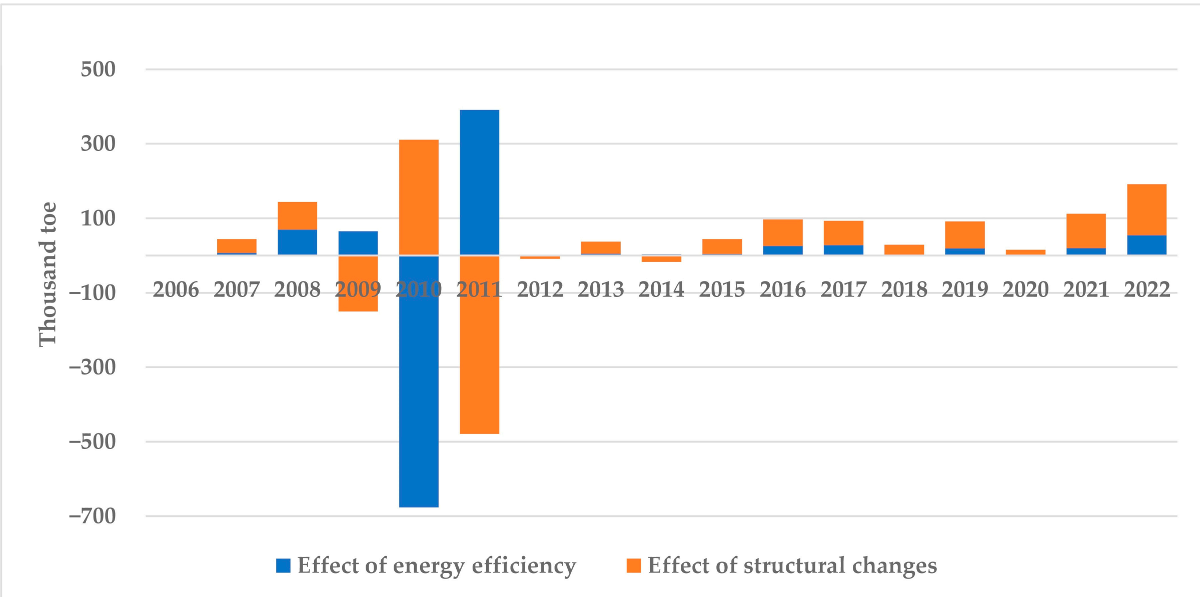
4.2. Results of Decomposition Analysis

The decomposition analysis results are illustrated in Figure 5.

From 2005 to 2022, improvement in EE was the dominant determinant for saving final energy in economic sectors in Estonia. The effect of increased EE accounted for 90.2%, and the effect of structural changes was 9.8% in Estonia. The share of final energy consumption in the three most energy-intensive sectors—industry, transport, and agriculture—in total final energy consumption decreased from 77.5% in 2005 to 72.0% in 2022, while the contribution of these sectors into VA decreased slightly, i.e., from 32.1% to 30.4%. The share of energy consumption in the two sectors with the least energy intensity indicators—construction and services—increased in the country's final energy from 22.5% in 2005 to 28.0% in 2022. However, the share of VA in these sectors also increased significantly, i.e., from 67.9% to 69.6%.

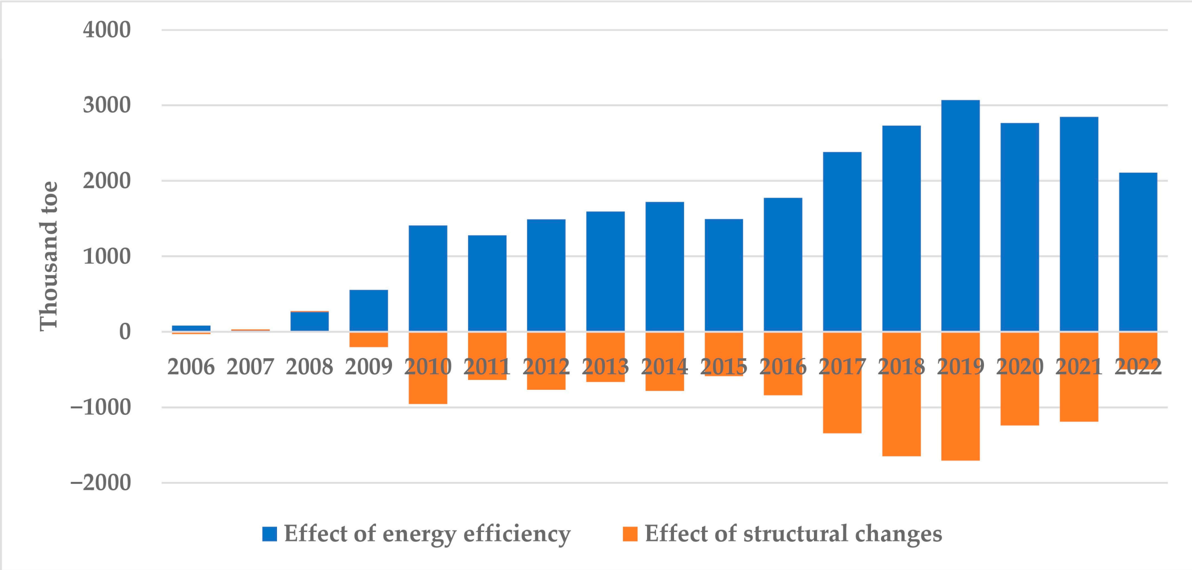


Estonia



Latvia

Figure 5. *Cont.*



Lithuania

Figure 5. Saving of final energy use in sectors of national economies (own estimations).

Due to global economic crises, VA creation in the Latvian industry sector decreased by 14.9%, and in the transport sector, it decreased by 22.7% in 2009. The increase in energy intensity indicators in these sectors stipulated significant changes in energy savings from 2010 to 2011, as fixed in Figure 5. Though the share of VA created by industry, transport, and agriculture decreased from 33.2% in 2005 to 28.9% in 2022, the share of energy consumption in the three sectors increased from 74.9% to 78.8% due to high energy intensity indicators. Vice versa, the share of VA created in construction and services increased from 66.8% in 2005 to 71.1% in 2022, with a reduced share of energy consumption from 25.1% to 21.2%. Thus, the total energy-saving effect due to increased EE in Latvia from 2005 to 2022 accounted for 5.6% only, and the effect of structural changes was 94.4%.

The share of final energy consumption in Lithuania's three most energy-intensive sectors increased from 80.6% in 2005 to 83.2% in 2022, while the share of these sectors in VA increased from 35.8% to 37.7%. The share of VA created in the sectors of services and construction, which had the lowest energy intensity indicators, decreased from 64.2% to 62.3%. The share of energy consumed for activities in these two sectors decreased from 19.4% in 2005 to 16.8% in 2022. In 2007 and 2008, energy savings were fixed due to increased EE and structural changes. However, the total effect of structural activity changes from 2005 to 2022 was negative, accounting for −89.8%. Thus, increasing EE in all economic sectors was the main determinant in saving final energy in Lithuania.

Table 2 summarises the results of changes in energy intensity indicators and of decreases in final energy consumption in separate sectors of the national economies of Estonia, Latvia, and Lithuania.

From 2005 to 2022, the final energy intensity decreased by 37.1% in Estonia, 23.3% in Lithuania, and 15.8% in Latvia. If the structure of activities in sectors of economies over this period had remained the same, energy intensity would have declined by 34.0% in Estonia, 3.2% in Latvia, and 29.5% in Lithuania. If EE had remained the same as in 2005, the decline of final energy intensity would amount to 3.3% in Estonia and 10.1% in Latvia. In this case, Lithuania's final energy use intensity at the end of this period would be 8.2% higher than in the base year due to the increased share of energy-intensive sectors. Thus, the analysis revealed differences in the relative reduction in energy intensity indicators in separate sectors of the national economies and the final energy consumption of the Baltic States.

Table 2. Energy intensity indicators and intensity indexes in the Baltic States (own estimations).

	Energy Intensity, kgoe/Thousand EUR		Intensity Index	Efficiency Index	Activity Index
	2005	2022	2022	2022	2022
		Estonia			
Industry	223	74	0.33	0.33	0.98
Construction	40	22	0.60	0.55	1.10
Transport	466	391	0.82	0.84	0.97
Agriculture	264	287	0.64	1.09	0.59
Commercial and public services	42	33	0.80	0.79	1.02
Final energy use	125	79	0363	0.66	0.96
		Latvia			
Industry	190	209	0.98	1.10	0.89
Construction	23	25	0.63	1.09	0.57
Transport	539	583	0.82	1.08	0.76
Agriculture	219	192	0.98	0.88	1.12
Commercial and public services	54	34	0.72	0.63	1.13
Final energy use	135	114	0.84	0.95	0.88
		Lithuania			
Industry	171	92	0.57	0.54	1.05
Construction	24	15	0.54	0.60	0.90
Transport	570	463	0.95	0.81	1.17
Agriculture	101	97	0.75	0.96	0.78
Commercial and public services	38	26	0.67	0.69	0.98
Final energy use	120	92	0.77	0.71	1.09

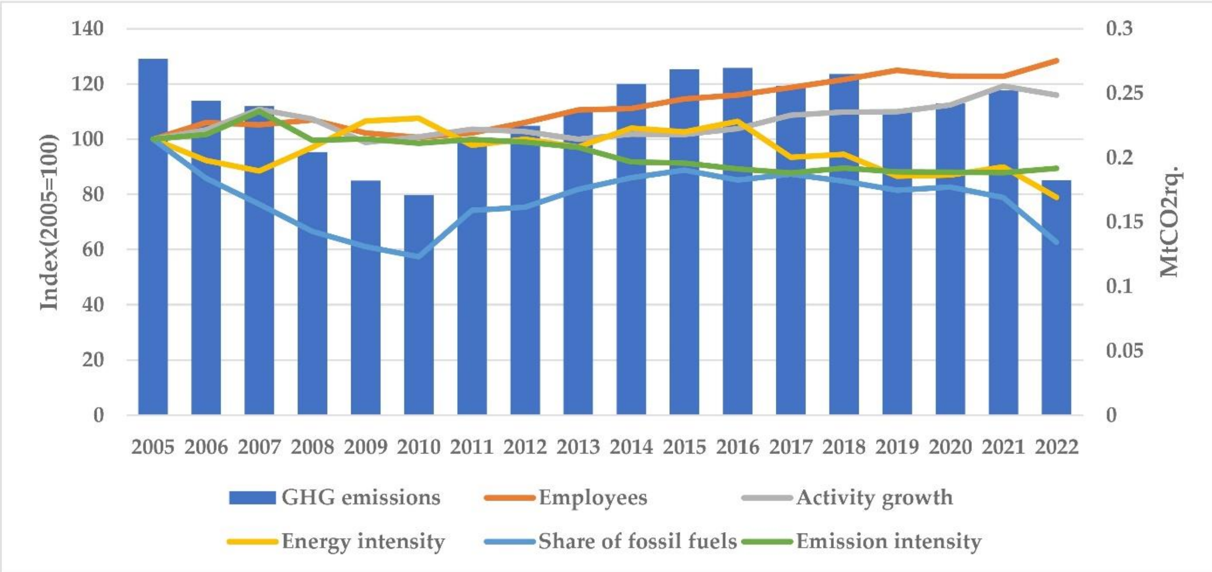
5. Changes in Energy-Related GHG Emissions in the Services Sector and the Impact of Determinants

5.1. Trends in GHG Emissions and Determinants

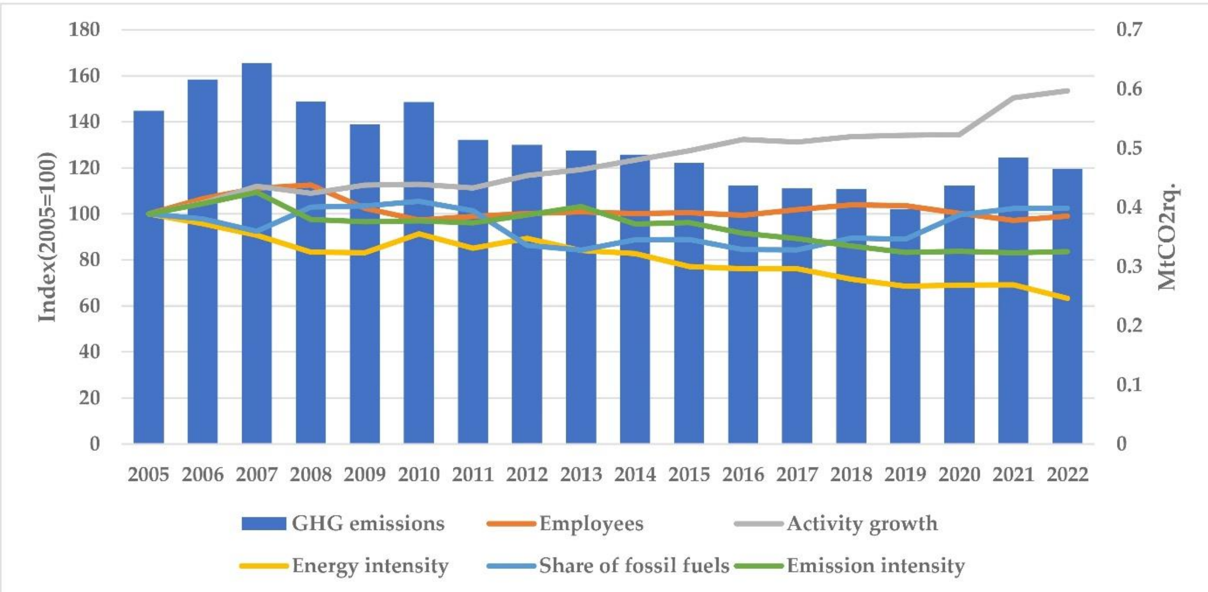
In 2022, due to substituting fossil fuels with RES, GHG emissions from fuel combustion decreased by 37.4% in Estonia, 13.7% in Latvia, and 7.70% in Lithuania, compared with the 2005 level [58]. However, changes in GHG emissions were different in separate sectors and countries. A moderate increase in energy-related GHG emissions in commercial and public services from 2005 to 2010 was evident in Lithuania at 6.2% and Latvia at 2.6%, while an impressive emissions reduction of 38.3% was fixed in Estonia. GHG emissions reduction in this sector from 2005 to 2022 was different also, i.e., in Estonia by 34.1%, in Latvia by 17.5%, and in Lithuania by 16.7% [59]. It is important to stress the significant decrease of GHG emissions in this sector since 2018 in Estonia by 31.2% and Lithuania by 20.7%. Variations of GHG emissions and the five determinants considered are shown in Figure 6.

Significant VA growth in the commercial and public services sector is common in all three countries. From 2005 to 2022, this indicator increased by 48.9% in Estonia, 52.0% in Latvia, and 58.5% in Lithuania. It is important to stress that a significant decline in energy intensity was another common feature. This indicator decreased by 21.1% in Estonia, 36.7% in Latvia, and 31.2% in Lithuania. The growing integration of renewable technologies stipulated a significant decline in the share of fossil fuels in the final energy consumption in Estonia at 37.3%. This indicator decreased in Lithuania by 12.7% but increased in Latvia by 2.5%. Due to the decline in contribution from fossil fuels, emission intensity decreased in all three countries—Estonia by 10.6%, Latvia by 16.3%, and Lithuania by 12.5%. The increase in employees had a certain impact on the trend of GHG emissions. From 2005 to 2022, the total number of employees increased by 28.4% in Estonia and by 15.1% in Lithuania but decreased by 1.0% in Latvia. Thus, the impact of this determinant was conditionally important in Estonia and Lithuania.

Table 3 summarises changes in GHG emissions in the commercial and public services and rates of determinants from 2005 to 2022 in the Baltic States.

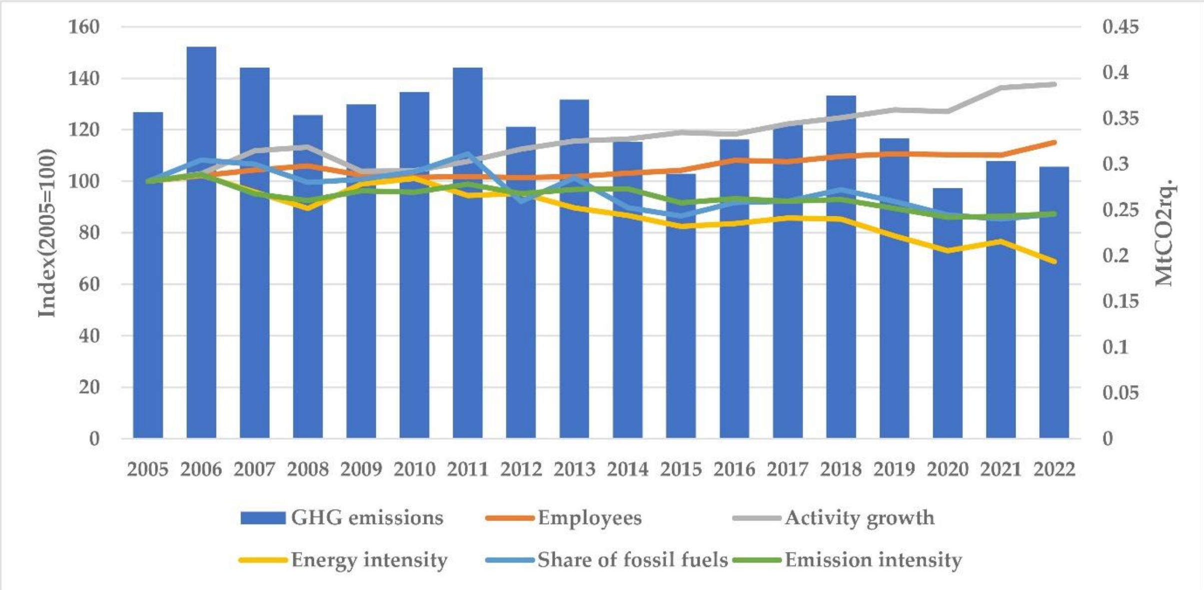


Estonia



Latvia

Figure 6. *Cont*.



Lithuania

Figure 6. Changes in energy-related GHG emissions in the commercial and public services sector and their determinants in the Baltic States (own estimations).

Table 3. Changes in GHG emissions and determinants (in %) in the services sector from 2005 to 2022 (own estimation).

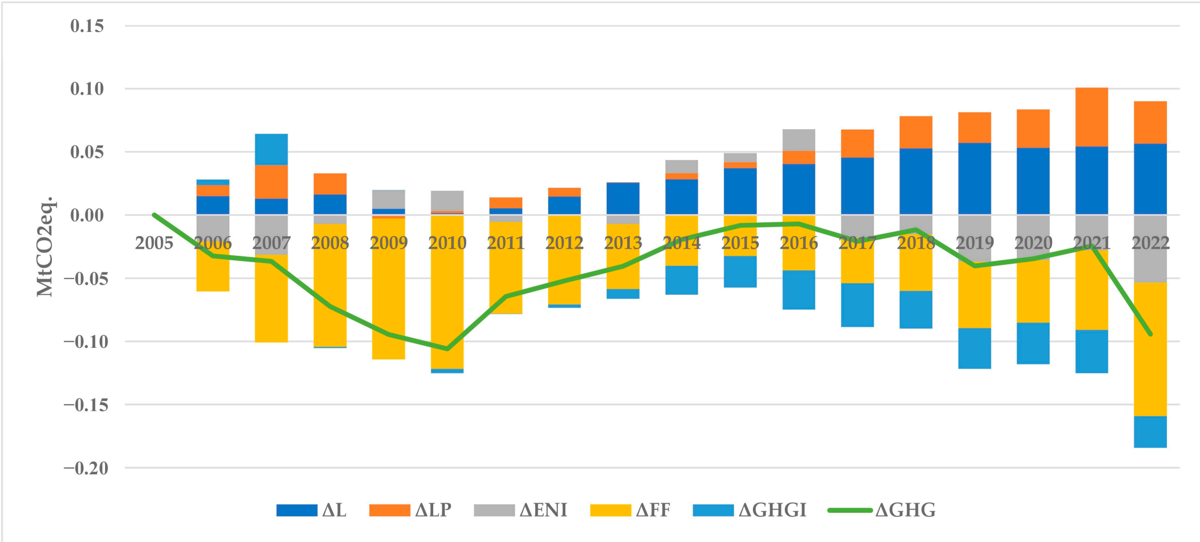
	GHG Emissions	Number of Employees	Labour Productivity	Energy Intensity	Share of Fossil Fuels	Emission Intensity
Estonia	−2.42	1.48	2.37	−1.38	−2.71	−0.66
Latvia	−1.12	−0.06	2.49	−2.64	0.15	−1.04
Lithuania	−1.07	0.83	2.75	−2.17	−0.80	−0.78

As shown in Table 3, GHG emissions decreased faster in Lithuania than in Latvia and Estonia. This is despite the VA created in this sector growing comparatively fast. Thus, GHG emissions in commercial and public services were decoupled from the growth of economic activity from 2005 to 2022 despite certain variations of other determinants.

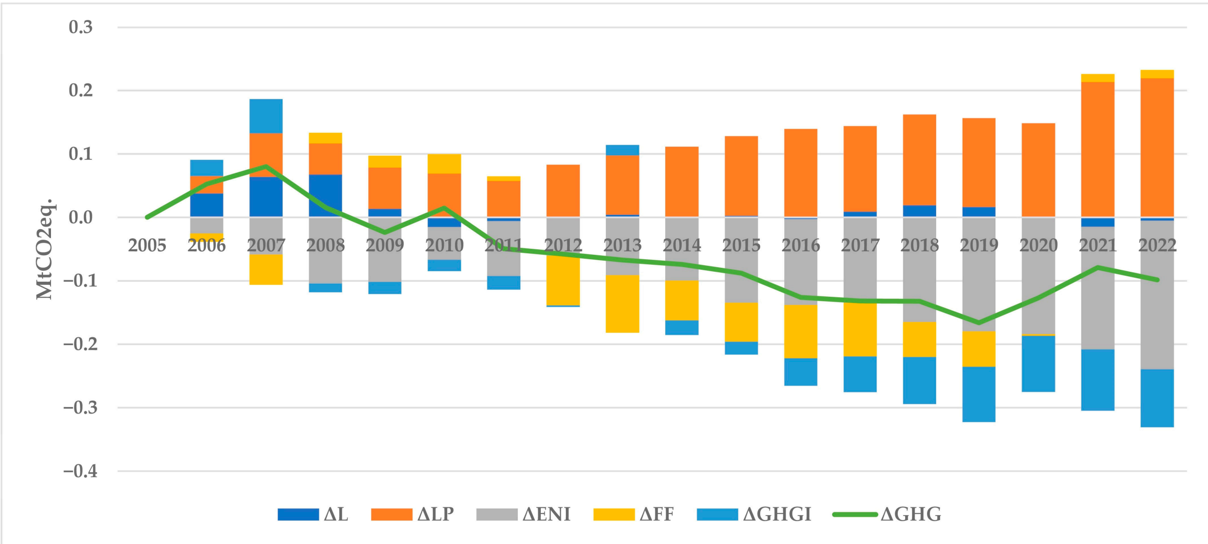
Variations of determinants were different. The number of employees in Estonia and Lithuania increased at similar rates, but in Latvia, it decreased slightly. Activity growth rates in the Baltic States were similar in all three countries. One can distinguish faster energy intensity reduction in Latvia with 2.64% and Lithuania with 2.17%, compared with 1.38% per year in Estonia. Total consumption of fossil fuels was decreasing in all three countries. However, due to the slow integration rates of RES into commercial and public services in Latvia, the share of fossil fuels in the final energy consumption increased by 0.15% per year. This indicator decreased by 2.71% per year in Estonia and 0.80% per year in Lithuania. The indicator of emission intensity was decreasing in all three countries as follows: 0.66% per year in Estonia, 1.04% per year in Latvia, and 0.78% per year in Lithuania.

5.2. Decomposition Analysis

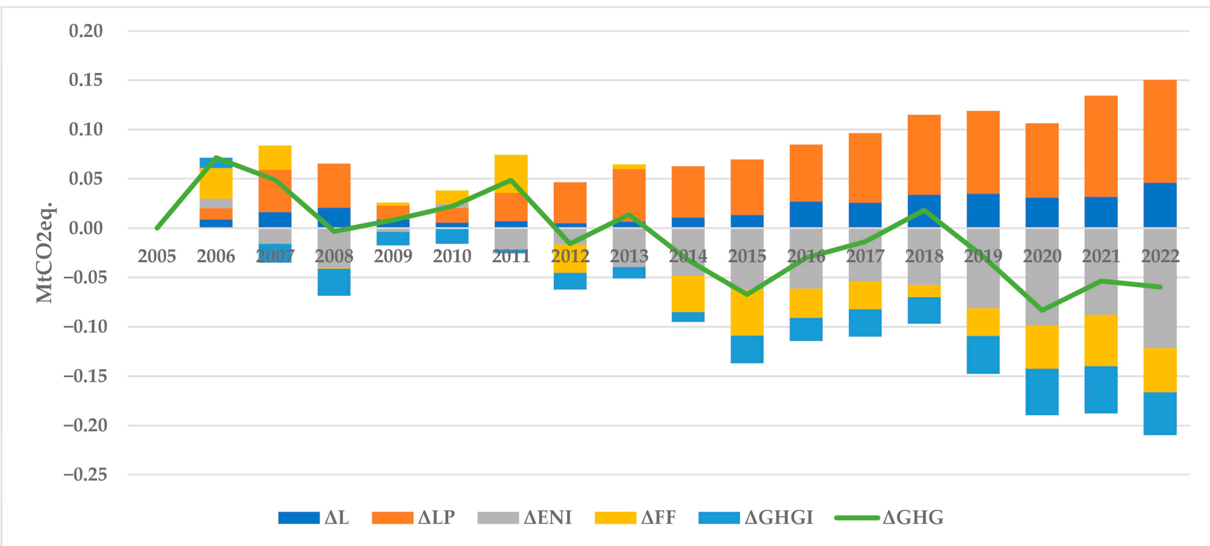
We decomposed the absolute yearly change in GHG emissions (ΔGHG) to examine the impact of determinants on changes in energy-related GHG emissions. Results are presented in Figure 7.



Estonia



Latvia



Lithuania

Figure 7. Decomposition dynamics and changes in GHG emissions in the commercial and public services sector of the Baltic States (own estimation).

The decomposition analysis showed that despite certain variations of activity growth and energy intensity indicators, these two determinants had the largest impact on the change in GHG emissions in all three countries. However, the effect of these two determinants from 2005 to 2022 was different. The growth of activities and the number of employees in the commercial and public services sector stipulated increased GHG emissions. The decreasing energy intensity, integration of RES technologies, and reduction in emission intensity stimulated reduced GHG emissions in the Baltic States. The impact of these determinants was diverse—the growth of economic activities contributed to an increase in GHG emissions by 33.9% in Estonia, by 73.7% in Lithuania, and by 90.7% in Latvia. Changes in the number of employees in Estonia contributed 66.1%, Lithuania 26.3%, and Latvia 9.3%.

The largest impact of increased EE on reducing GHG emissions was fixed in Latvia, at 65.1%. A similar impact of this determinant was observed in Lithuania, at 55.9%, and a low contribution was found in Estonia, at 12.6%. The most considerable determinant affecting GHG emission reduction in Estonia was the integration of RES technologies, at 71.0%. The importance of this determinant was similar in Latvia, at 17.1%, and Lithuania, at 16.5%. The relative contribution of reduced emission intensity leading to a decrease in GHG emissions was similar in all three countries: Estonia at 16.4%, Latvia at 17.9%, and Lithuania at 27.6%.

The combined impact of all determinants on annual changes in GHG emissions varied considerably from country to country. GHG emissions declined rapidly between 2005 and 2010 in Estonia, owing to the deployment of RES and increased EE. Subsequently, the expansion of economic activities and the increase in the number of employees, together with the reduced contribution of RES, led to an increase in GHG emissions from 2011 to 2018. However, the accelerated integration of RES technologies between 2019 and 2022 has been the most important determinant of the downward emission trend.

Due to the expansion of economic activities, the growth in the number of people employed, and the slow deployment of RES, GHG emissions in Latvia's services sector increased slightly between 2005 and 2010. Increasing EE, RES deployment, and emission intensity reduction led to a significant decrease in emissions between 2011 and 2019. Due to the reduced contribution of RES, GHG emissions increased at the end of the period but were 17.5% below the level in the base year.

The trend in GHG emission reductions has been most pronounced in Lithuania, with waves of emission increases followed by waves of emission reductions. The combined cumulative effect of the determinants that reduced these emissions (deployment of RES, increasing EE, and decreasing emission intensity) from 2005 to 2022 was only 12.4% higher than the effect of the determinants that increased them, such as the expansion of economic activities and the growth in the number of employees. However, waves of emission reductions from 2013 to 2015 and from 2018 to 2020 resulted in GHG emissions in Lithuania being 16.7% lower at the end of the period than in the base year.

Table 4 summarises the changes in GHG emissions in the Baltic States and the impact of each determinant from 2005 to 2022 to compare the decomposition analysis results correctly.

Table 4. Change of GHG emissions in commercial and public services and impact of determinants, $tCO_{2eq.}$ per employee in 2022 (own estimation).

	ΔGHG per Employee	Employee Effect	Economic Activity	Energy Intensity	Effect of RES	Emission Intensity
Estonia	−1.82	1.28	0.64	−0.47	−2.63	−0.61
Latvia	−2.09	0.38	3.72	−4.02	−1.06	−1.10
Lithuania	−0.20	0.42	1.18	−1.01	−0.30	−0.50

Results presented in Table 4 show the cumulative decrease or increase in GHG emissions due to changes in each determinant over this period. Latvia recorded the highest GHG emission reduction per employee, with 2.09 tCO_{2eq}. This indicator was slightly lower in Estonia, with 1.82 tCO_{2eq}. Lithuania has the lowest reduction in GHG emissions, with 0.2 $tCO_{2eq.}$ per employee only.

We can emphasise that the increase in GHG emissions per employee in Latvia and Lithuania was mainly driven by the growth in economic activities and, to a lesser extent, the growth in the number of employees. Vice versa, the growth in the number of employees in Estonia had a more significant impact, and the growth in economic activities had a smaller impact. Decreasing energy intensity was the most important determinant in reducing GHG emissions in Latvia and Lithuania but less significant in Estonia. Replacement of fossil fuels with RES was a significant determinant in Estonia, less important in Latvia, and had a small impact in Lithuania. Reduction in emission intensity had the largest impact on emission reductions in Latvia but was less important in Estonia and Lithuania.

Figure 8 illustrates the change in GHG emissions per employee in commercial and public services in 2022 compared to the base year (2005).

As shown in Figure 8, a comparative indicator decreased by 48.7% in Estonia, 16.7% in Latvia, and 27.6% in Lithuania. In 2022, in Latvia, GHG emissions per employee amounted to 0.92 $tCO_{2eq.}$; in Estonia, to 0.44 $tCO_{2eq.}$; and in Lithuania, to 0.38 tCO_{2eq}. Thus, comparative indicators of emissions per employee in this sector in Estonia and Lithuania currently are quite similar and two times less than in Latvia. However, it is important to emphasise that the data based on the period-wise analysis presented in Table 4 are more accurate in characterising the overall change in GHG emissions per employee and the influence of the determinants.

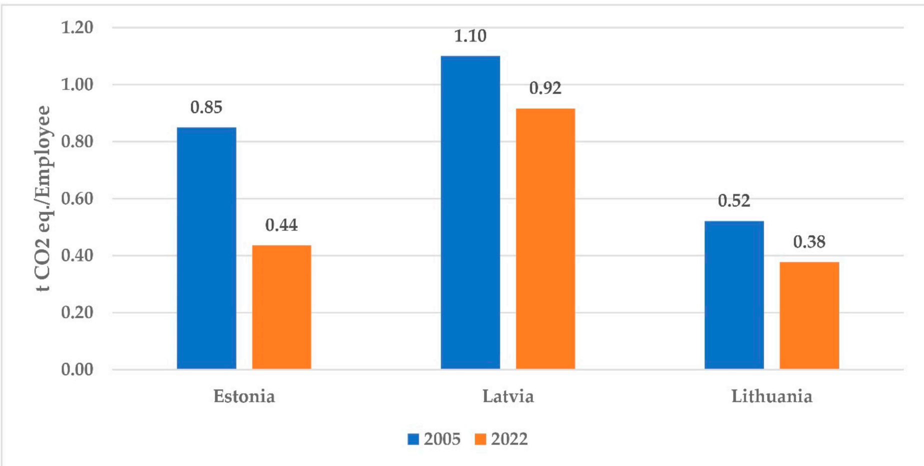


Figure 8. Changes in GHG emissions per employee in the commercial and public services sector (own estimation).

6. Conclusions and Recommendations

This paper conducted an in-depth analysis of energy intensity improvements in five economic sectors and GHG trends in the Baltic States, focusing on the commercial and public services sector from 2005 to 2022.

The integrated analysis of the five economic sectors that create VA and the methodology applied characterise the scientific contribution of this research. The methodology has enabled us to perform a quantitative and qualitative analysis of the commercial and public services sector development over 20 years. It has revealed the role of this sector in trends in final energy consumption and VA created at the national and regional levels. To ensure the comparability of data and investigation results across the three countries, the statistical data have been harmonised, thus avoiding the differences in their compilation and publication in databases. This research methodology allowed for a correct assessment of energy intensity trends by economic sectors and across countries. Analysing changes in GHG emissions from the commercial and public services sector revealed differences and preferences for integrating EE measures and RES technologies in the Baltic countries.

To have a correct comparison of changes in energy intensity by sectors, a detailed analysis of final energy consumption by fuels was performed in the study, and data from national statistics were harmonised due to still existing differences in attribution of non-energy use. Rather different energy intensity changes were observed in each country and separate sectors. The most considerable overall reduction in energy intensity across economic sectors was fixed in Estonia, at 37.1%, compared to 23.3% in Lithuania and only 15.8% in Latvia. These results were driven by changes in energy consumption and VA created in the industry, transport, and commercial and public services sectors. A very impressive reduction in energy intensity was recorded in the Estonian industry sector at 66.7%, while in Lithuania, it fell by 46.0%, and in Latvia, increased by 9.9%. Energy intensity in the Estonian transport sector decreased by 16.2% and in the commercial and public services by 21.1%. In 2022, energy intensity in the Latvian transport sector increased by 8.2% but decreased by 36.7% in the commercial and public services sector, compared with the 2005 levels. Thus, the combined decline of energy intensity in the five economic sectors of Latvia was the smallest in the Baltic region. Energy intensity in the Lithuanian transport sector decreased by 18.9% and in the commercial and public services sector by 31.2%. Transport and storage activities consume the most energy resources per unit of VA created. In addition, this sector is the largest consumer of energy resources in Lithuania. These determinants explain the moderate overall decline in energy intensity in Lithuanian economic sectors. It is very important to underline that the growth in VA was achieved with different trends in energy consumption. In 2022, total final energy consumption in Estonian economic sectors was 7.9% lower, but in Latvia, it was 13.2%, and in Lithuania, it was 24.0% higher compared to the 2005 level. Thus, the goal of significant reduction in final energy consumption by 2030, particularly in the Lithuanian transport sector, is challenging, and new policies and essential measures are required.

The results of decomposition analysis of energy savings explaining the contributions of EE and structural changes to reductions in energy intensity demonstrated that the improvement in EE was the dominant determinant for energy savings in Estonia and Lithuania from 2005 to 2022. In Estonia, improvement in EE led to 90.2% of energy savings; improvement in the structural changes in activity, to 9.8%. In Lithuania, the total effect of structural changes was unfavourable and equal to −89.8% because the three most energy-intensive sectors increased their share of energy consumption from 80.6% to 83.2%. Thus, the improvement in EE in all economic sectors was the main determinant for energy savings. The total energy saving effect due to increased EE in Latvia from 2005 to 2022 accounted for 5.6% only, and the effect of structural changes accounted for 94.4%.

The results of changes in energy-related GHG emissions in the services sector and the impact of determinants revealed that these emissions fell in all three Baltic States. At the same time, the VA created grew rapidly—by 2.4% annually in Estonia, by 2.5% in Latvia, and by 2.7% in Lithuania. Thus, the results showed the GHG emissions in this sector were absolutely decoupled from the growth of economic activities, considering certain impact variations from other determinants. It was found that the reduction in energy intensity and the substitution of fossil fuels with RES were the crucial determinants of reduced GHG emissions in all three countries. The RES deployment and decreased emission intensity also contributed to reduced GHG emissions. The growth of economic activities and the number of employees resulted in increased GHG emissions. Though the GHG emissions per capita in the commercial and public services sector currently are comparatively low in Estonia (0.14 $tCO_{2eq.}$) and Lithuania (0.11 $tCO_{2eq.}$), in comparison to the average EU-27 (0.24 $tCO_{2eq.}$) and in Latvia (0.25 $tCO_{2eq.}$), additional appropriate measures are required to reduce GHG emissions in this sector in all three countries.

Further studies of energy intensity in the commercial and public services sector could focus on analysing energy consumption based on the main economic activities. Comparable data from three countries should be collected to assess the impact of structural changes in activities in this sector. Further research could also focus on a detailed analysis of changes in GHG emissions and energy intensity in the transport sector, particularly considering that the role of transit transport in the three countries is different and comparable data are required.

This research has value on national and regional levels, considering the importance of revealed peculiarities in EE, RES deployment, and GHG emission reduction trends in the commercial and public services sector. The results are important for policymakers to compare changes in the three Baltic countries with average indicators in the EU-27 and targets established by the EC.

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Abbreviations

EE	energy efficiency
EU	European Union
EC	European Commission
Eurostat	Statistical Bureau of the European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
LEI	Lithuanian Energy Institute
LMDI	Logarithmic Mean Divisia Index
NECPs	National Energy and Climate Plans
RES	Renewable Energy Sources
VA	Value-added
UN	United Nations

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