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Review

The Baltic States' Move toward a Sustainable Energy Future

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Abstract: In respect to CO_2 emissions, the post-Soviet states are a scientifically interesting object of research, as each of the countries has developed via different paths since reclaiming independence from the Soviet Union. Given that each country has a different approach to the use of fossil resources, it is essential to assess their input to global carbon footprint individually. Such assessment then allows to find certain actions in the development of legislation and to apply focused techniques to reduce carbon emissions. The aim of this study was to evaluate the fossil CO_2 emissions produced in the Baltic States from 1991 onward, describing challenges relating to sustainability and socio-economic, scientific, and integrated approaches to sustainable development, including clean and efficient use of energy, and thus addressing climate challenges. This paper reports on data on CO_2 emissions in the Baltic States. The results show that the transition of the Baltic States from the specificities of the Soviet Union's economy to an economy integrated into global markets has led to a significant reduction in CO_2 emissions. However, the development and implementation of national policies for sustainable development are still crucial for mitigation of the climate crisis. Further actions must include the implementation and monitoring of policies for sustainable development, changing of the consumption and production patterns, education and awareness of sustainability, and adaptation to global climate change, while also addressing sustainability challenges.

Keywords: climate change; CO_2 emissions; net zero emissions; sustainability; sustainable energy; Baltic States

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1. Introduction

Establishing a sustainable energy future, together with tackling climate change and undoing loss of natural values, is not something any one country can achieve alone. This endeavor demands decent decision-making and a commitment to solving complex social, economic, and environmental challenges. Therefore, partnering of governments, businesses, organizations, and communities is crucial for a sustainable future of the world. Consequently, the United Nations (UN) have agreed on 17 sustainable development goals, which among many things also focus on mitigating climate change and transitioning to net zero emissions, while also improving the quality of life [1]. In this respect, Goal 13 (climate action) is especially devoted to taking urgent action to combat climate change and its impacts. Essentially, the goal is to trigger long-term systemic shifts that will change the trajectory of CO_2 levels in the atmosphere [1].

The vast majority of climate scientists agree that climate change is a human-caused phenomenon [2–5]. At the same time, there is also a consensus that it is facilitated by processes in nature, such as volcanic eruptions, oceanic current changes, solar radiation variability, and other natural processes [6,7]. There is also a widespread consensus that the primary source of CO_2 emissions, which is the main driver of climate change, is the use of fossil fuels [8–10]. However, it must be borne in mind that high CO_2 emissions can also be released into the atmosphere due to other factors and activities, such as deforestation, agriculture, degradation of soils, and other direct human-induced impacts on the environment [11–13]. Simultaneously, the sustainable use of fossil resources, introduction of alternative clean and efficient energy sources, and practical and meaningful use of land and water can reduce the increasingly negative environmental impact of the economic and other human activities at substantial levels [14,15]. Although climate neutrality currently receives an exceptional awareness globally, it still demands more attention, and an actual future-oriented action is essential in order to achieve any long-lasting effects [16–18]. Furthermore, the net zero economy can only be realized through global collaboration, as it requires a profound transformation of the global energy system. Moreover, the market needs to be more transparent regarding carbon targets, and the set net zero targets have to be developed into carbon-negative targets as quickly as possible. Unfortunately, progress in this direction is still very slow and faces opposition.

Historically, various predicaments, both humanitarian and economic, have shown to have a remarkable impact on CO_2 emissions (Table 1). For instance, World Wars I and II drastically reduced the annual CO_2 emissions, whereas in times of peace, they have grown considerably [19,20]. Furthermore, other global disasters, such as the oil crisis in 1973, the banking crisis in 2008, or even the recent worldwide pandemic in 2019 have also to a noticeable extent reduced the global CO_2 emissions, which are equivalent to or even higher than those caused by the poverty and devastation of the war [20–22]. All these examples show that the amount of CO_2 emissions is intricately linked to the economic situation. However, nowadays, more alternative energy resources have become available, and humanity's needs can be met without consuming immense amounts of fossil resources and increasing CO_2 emissions [14,23–25]. At the same time, it must be understood that unforeseen circumstances may arise in a region or particular country, making certain fossil resources the only available option. Therefore, this issue requires urgent and collaborative solution.

Table 1. Change in global CO_2 emissions from energy combustion and industrial processes due to global humanitarian and economic predicaments. Based on International Energy Agency data [26].

Crisis	Reduction below the Baseline	Rebound above the Baseline
World War I	−0.47 $GtCO_2$ in 1919	+0.48 $GtCO_2$ in 1920
World War II	−0.86 $GtCO_2$ in 1945	+0.41 $GtCO_2$ in 1946
1973 Oil Crisis	−0.03 $GtCO_2$ in 1974	+0.82 $GtCO_2$ in 1976
2008 Banking Crisis	−0.41 $GtCO_2$ in 2009	+1.89 $GtCO_2$ in 2010
COVID-19	−1.86 $GtCO_2$ in 2020	+2.04 $GtCO_2$ in 2021

The baseline is 0 $GtCO_2$.

Recent experience with the 2019 pandemic shows that it is possible to reduce the global atmospheric CO_2 content rather swiftly (Table 1) if the fossil fuel-consuming industry stops operation [20,27,28]. However, it is clear that such a solution is not realistic until the cost-effectiveness ratio of the alternative green and clean energy sources becomes equivalent to or higher than that of the fossil resources. Moreover, resumption of the industry shows that the emissions can return to the pre-pandemic levels just as quickly [20,26–28]. Therefore, at this moment, more attention should be given to technologies for carbon capture and storage (CCS) that would temporarily allow us to trap this greenhouse gas (GHG). This measure then should be followed by recycling and usage of the captured CO_2. Unfortunately, such technologies do not solve the problem of emissions from the transport infrastructure, which would require entirely different approaches, for instance, transition to a non-fossil fuel or other types of fuel. At the same time, the captured CO_2 could be processed into methanol that can be used as an alternative biofuel for internal combustion engines. In this context, in the present day, electrification of the transport industry is gaining vast recognition. However, this approach is still leading to climate change, as the necessary electricity still has to be generated, and presently the power generation using fossil resources is responsible for the major CO_2 emissions worldwide [29]. Thus, prior to full electrification of the transportation infrastructure, it is essential to make electricity generation climate neutral. In this context, wider use of nuclear power should be considered. Nuclear power plants produce no GHG emissions during operation, but nuclear reactors in their life cycle produce approximately the same amount of CO_2 emissions per unit of electricity as wind and one-third of the emissions per unit of electricity compared to solar energy. At the same time, nuclear waste management has to be thoughtfully planned beforehand. Most of the nuclear waste can be recycled, and by doing so will also produce more energy, so that the possible risks can be efficiently mitigated. Moreover, new methods for recycling car batteries and for recapturing rare earth elements inside batteries must also be addressed [30,31]. On the positive side, all these issues can be solved if global effort is undertaken. In this matter, in summer 2022, the European Union (EU) Parliament approved a ban on new petroleum and diesel cars beginning in 2035. Yet, several EU member states (Italy, Portugal, Slovakia, Bulgaria, and Romania) are opposing the ban and demand delaying the deadline to at least 2040 [32]. Moreover, Lithuania, Poland, and Latvia are seeking a larger share of EU funds to shield their citizens from the policy's costs and inevitable increase of energy expenses. The developing situation in the world (energy prices, Ukrainian–Russian war, etc.) will determine how everything turns out in this regard.

In the context of the fossil CO_2 emissions, the post-Soviet states are a scientifically attractive object of study, as these countries have developed by diverse means since regaining their independence from the Soviet Union (SU). The post-Soviet states are now 15 sovereign countries (Table 2). The Baltic States were first to declare their independence from the SU in 1991. The command economy and industrial activities of the SU have caused elevated levels of CO_2 emissions for decades, but, following the collapse of the communist regime and the change from the state ownership of virtually all sectors into the free market economy, the emissions in the independent countries decreased drastically, while further development varied depending on the capabilities and laws of each country [33,34]. For example, CO_2 emissions in Turkmenistan recently (2020) far exceeded the emissions produced during Soviet times [26]. Many similar post-Soviet states are still under high influence from Russia and do not follow any European policies toward a sustainable future. Among the Baltic States, Latvia stands out with considerably lower total CO_2 emissions. Today, the lowest CO_2 emissions are produced by Tajikistan, and this can be explained by a very high poverty rate and dominance of hydroelectric power in electricity generation [26]. The share of the impact of different sectors on the total CO_2 emissions varied and still varies significantly among all post-Soviet states. For instance, the CO_2 emissions from waste in Latvia are higher than in other Baltic States. Unfortunately, this is due to waste management problems, as waste is better managed in Estonia and Lithuania [26,35].

Table 2. CO_2 emissions (per capita) in the post-Soviet states. 1991 vs. 2020. Based on International Energy Agency data [26].

Country	International Organization	1991 tCO_2	2020 tCO_2	Change
Armenia	CIS member	2.08	1.99	−4%
Azerbaijan	CIS member	6.80	3.72	−45%
Belarus	CIS member	9.52	6.08	−36%
Estonia	EU member	21.85	7.88	−64%
Georgia	Potential EU candidate	2.95	2.50	−15%
Kazakhstan	CIS member	16.59	15.52	−6%
Kyrgyzstan	CIS member	3.62	1.76	−51%
Latvia	EU member	6.76	3.59	−47%
Lithuania	EU member	10.24	5.07	−50%
Moldova	EU candidate	6.77	1.28	−81%
Russia	CIS member	16.19	10.81	−33%
Tajikistan	CIS member	1.81	0.99	−45%
Turkmenistan	CIS associate	8.63	12.49	+45%
Ukraine	EU candidate	12.29	4.89	−60%
Uzbekistan	CIS member	4.93	3.37	−32%

CIS, the Commonwealth of Independent States; EU, the European Union.

In this study, we have analyzed the CO_2 emissions produced over the last 30 years of the independence of the Baltic States. Although this group of countries—Estonia (EE), Latvia (LV), and Lithuania (LT)—occupies a relatively small territory in northeastern Europe, each of them has a distinct CO_2 emission profile, which would consequently require a rather distinct approach to climate change mitigation [26,35], all the more so because the dominant emission sources differ. To deal with climate change, in December 2015, the Baltic States participated in the signing of the Paris Agreement (PA). This is a fundamental agreement for global collaboration, whereby the members of the pact vouch for decreasing their total GHG emissions and seek to limit the Earth's temperature increase by 1.5 °C by 2050 [36]. All UN Framework Convention on Climate Change (UNFCC) members have signed the PA, and 189 have become parties thereto. The only signatories that are not yet parties are Angola, Eritrea, Iran, Iraq, Libya, South Sudan, and Turkey [36]. From said countries, the highest CO_2 emitters are Iran, Turkey, and Iraq, with 745.04 million t, 392.79 million t, and 210.83 million t of produced CO_2eq emissions in 2020 [26,35], respectively. Following the PA, the Baltic States released key legislative acts (e.g., strategies to achieve climate neutrality) to reduce the GHG emissions by 100% by 2050, considering as reference the GHG levels of 1990 [37–42]. Furthermore, in 2015, green targets were set to be achieved by 2030 and designed to be a proposal for a more sustainable future [43]. It should be noted that these strategies/targets are regularly improved and refined, with a 100% reduction target by 2050 as the main goal. In fact, a significant CO_2 drop below 1990 levels was already seen almost immediately after regaining the independence in 1991, and, if the path is continued, then the set green goals might be largely achieved in due time [26,29,44]. However, to secure a sustainable future, it is not advisable to wait until the very last moment to act on the crisis.

Given that each country has a different approach to the use of fossil resources, it is necessary to assess their contribution to the global carbon footprint separately. Such an assessment then allows us to name specific actions in the development of legislation and to apply focused techniques to reduce certain emissions. Furthermore, the evaluation of the CO_2 emissions in the post-Soviet states is important for the representation of the impact of modern activities on environmental and climate sustainability in the region in the context of climate change. This approach makes it possible to find critical sectors for investment in the development toward climate neutrality. In this context, the main aim of this study was to evaluate/review the fossil CO_2 emissions produced in the Baltic States from 1991 onward, describing challenges relating to sustainability and socio-economic, scientific, and integrated approaches to sustainable development, and thus communicating the climate crisis. The research hypothesis was that the transition to an open, transparent market economy and industry with regulations oriented toward environmental protection has significantly improved the situation in the Baltic States.

A principal conclusion of this study is that the recovery of the Baltic States from the situation of 50 years of the SU's economy has led to more sustainable patterns of production and consumption, improved national and regional sustainability and stability, mitigated degradation of ecosystems and contaminant risks to human well-being, all of which is consistent with a significant reduction in CO_2 emissions. At the same time, to fill the gaps in the knowledge of sustainable energy and to further mitigate climate change, the industrial development, energy crisis, and waste management are still issues that require a solution. The development, implementation, and continuous improvement of national strategies for sustainable development are critical for mitigation of the climate crisis; therefore, forthcoming actions must include the implementation and monitoring of policies for sustainable development and adjustment of the consumption and production patterns, including transition to clean and efficient energy sources.

2. Calculation of Carbon Dioxide Emissions

The chronological fossil fuel CO_2 emissions can be reconstructed back to the Industrial Revolution in 1751. The reconstruction generally describes the production numbers of various types of fossil fuels, which, when combined with trade data, allow for national-level reconstruction of fossil fuel production and the resultant CO_2 emissions [45]. The latest energy statistics are obtained from the UN Statistical Office, which lists data from official national statistical publications and annual reports [45,46].

Historical fossil CO_2 emissions are usually analyzed in depth by evaluating various essential factors, yet only approximate estimates can be obtained. For instance, to conclude about the CO_2 emissions in 1830, the industrial data on how much fossil resources were extracted in the relevant year are gathered. To obtain an estimate of the net consumption in the particular year, the data on imported fossil fuel is added while the exported fuel is subtracted from the domestic production. Resulting produced energy is then converted to the CO_2 emissions. Each type of fossil fuel has its own emission factor and multiplying this factor by the quantity of fossil fuel makes it is possible to estimate the CO_2 emissions in the particular year (Equation (1)) [45]:

$$\text{Annual } CO_2 \text{ emissions} = EF \times (O_{FF} + I_{FF} - E_{FF}) \tag{1}$$

EF—emission factor; O_{FF}—obtained fossil fuel; I_{FF}—imported fossil fuel; E_{FF}—exported fossil fuel.

The emission factor is a characteristic value that relates the quantity of a GHG released in the atmosphere with activities associated with the release of that GHG. The emission factor is generally expressed as the weight of GHG divided by a unit weight, volume, distance, or duration of the activity emitting the GHG. The emission factor facilitates estimation of emissions from various sources of GHGs. The emission factor is an average of all available data of acceptable quality and is assumed to be representative of long-term average for all facilities in the source category.

The assessment of the CO_2 emissions requires consistent and broad coverage on domestic and imported/exported energy, but, unfortunately, the long-term/historical reconstructions lack the precision. Nevertheless, the international framework and monitoring has substantially advanced through the history and the knowledge of emissions in the late 20th and 21st centuries and so this assessment is seen as reliable [45,47,48]. The modern-day estimates are calculated in accordance with the methodologies provided by the Intergovernmental Panel on Climate Change (IPCC), but even so uncertainties can still arise, such as those regarding the coverage of energy consumption and the assumption of emission factors used for fuel burning [47–49]. Furthermore, the size of the country and the level of uncertainty in the CO_2 emission calculations have a considerable impact on the inaccuracy of the global emission numbers, which can lead to a considerable emission overestimation and thus also to unjustified emission limits [47–49]. This uncertainty should be taken into account when evaluating climate change and technology implementation, as the exact CO_2 emissions may be either overstated or understated.

3. The Historical Variations of Carbon Dioxide Emissions

Throughout history, variations in the CO_2 emissions in the Baltic States have been related to global worldwide events and a complex of the local issues. Since the 19th century, EE, LV, and LT have more or less been affected by the same events—World Wars I and II, the Soviet occupation, accession to the EU and Eurozone, worldwide economic and financial crises, and the 2019 pandemic, to name a few. These events have had an incredibly significant impact on the production, thus either contributing to or reducing the fossil CO_2 emissions [20–22]. It is clear that the devastation of two world wars led to poverty and decline in industrial activities in most countries of the world, which resulted in a considerable CO_2 emission drop. One of the exceptions were the United States (US), which benefited from World War II, as it accelerated income tax and urbanization and helped make the country into the lead economic and military power. In peacetime, the industrial development of most countries depended on the political regime. For instance, during the Soviet occupation, various global economic or financial crises have had a lesser impact on the Baltic States due to the isolation of the Soviet Union from the world around it. This, in combination with the specificities of the Soviet economy, resulted in a rapid unrestrained increase in the CO_2 emissions from 1940 to late 1980s [26,33–35]. In comparison, nowadays, the open market makes the economy of the Baltic States sensitive to various developments in the world [20–22]. Thus, is it crucial that the Baltic States work diligently on the energy self-sufficiency and also continues on the path to climate neutrality. For instance, although in LV it is allowed to capture the CO_2 emissions, it is still prohibited by the national laws to store this GHG in geological structures. Similar restrictions are also considered in LT, but there is a good reason to believe that these laws should be amended to support climate neutrality [50].

The first noteworthy records on CO_2 emissions in EE date from 1830, when the estimated carbon emissions were around 184 tCO_2eq. The emissions continued to increase annually, including during World War I, until 1916, when they reached 1.09 million tCO_2eq. In the postwar period (1916–1920), the carbon emissions considerably decreased to 0.31 million tCO_2eq. However, when after World War I the industry was resumed, the emissions began to rise again, and in 1940 reached up to 4.90 million tCO_2eq. An exceptionally rapid increase in the carbon emissions occurred during the Soviet occupation (1940–1991), when, close to its collapse, the annual CO_2 emissions reached an unprecedented 38.87 million tCO_2eq (1989). After the collapse of the SU, the annual carbon emissions significantly decreased. Notably, the decline was especially pronounced in 1991, when the estimated annual CO_2 emissions reduced to 15.91 million tCO_2eq. From 2000 onward, the annual carbon emissions sharply fluctuated in the range between 10 and 20 million tCO_2eq, with EE being the largest CO_2 emitter among the Baltic States [26,35].

Just like in EE, the first distinguished records on the CO_2 emissions from the burning of fossil fuel in LV are from year 1830 (Figure 1). The estimated carbon emissions in that year were 122 tCO_2eq, showing less active industrial activity than in EE. The emissions kept rising until 1916, when they reached 0.72 million tCO_2eq, which was still significantly less than in EE at that time. World War I affected the existing industry a great deal, and in the post-war period between 1916 and 1920 the annual CO_2 emissions declined to 0.21 million tCO_2eq. Furthermore, after resuming the industry, LV still did not reach the emissions of EE, and in 1940 the estimated CO_2 emissions were around 3.23 million tCO_2eq. The Soviet occupation, just like in EE, however, marked a rapid increase in the emissions, where the peak was reached in 1985, when the estimated CO_2 emissions were 25.69 million tCO_2eq. From this point onward, the CO_2 emissions rapidly decreased and stabilized at around 7 million tCO_2eq annually, making LV the smallest CO_2 emitter among the Baltic States [26,35]. At present day, the CO_2 emissions in LV are similar to those in late 1950s.

As in EE and LV, the first noteworthy records on CO_2 emissions in LT date back to 1830. The estimated CO_2 emissions in this year were 190 tCO_2eq, showing more active industry than in LV and similar to that in EE. The emissions continued to rise until 1916, when they reached 1.13 million tCO_2eq. The period between 1916 and 1920, like in EE and LV, can be described as a decline, as the CO_2 emissions at that time reduced to 0.32 million tCO_2eq. Due to the recovery from the war and resumption of the industrial activities, carbon emissions began to rise again and reached 5.01 million tCO_2eq in 1940. During 1940–1942, the emissions declined again (2.41 million tCO_2eq), while for the duration of the Soviet occupation, the emissions drastically increased and reached 40.31 million tCO_2eq—the highest value ever recorded in the Baltic States. Fortunately, after the collapse of the SU, the emissions decreased significantly and reached 11.88 million tCO_2eq in 2000. From 2000 until now, the CO_2 emissions have been fluctuating in the range between 11 and 16 million tCO_2eq, but without a definite direction, with LT being the second among the Baltic States in terms of the CO_2 emissions [26,35].

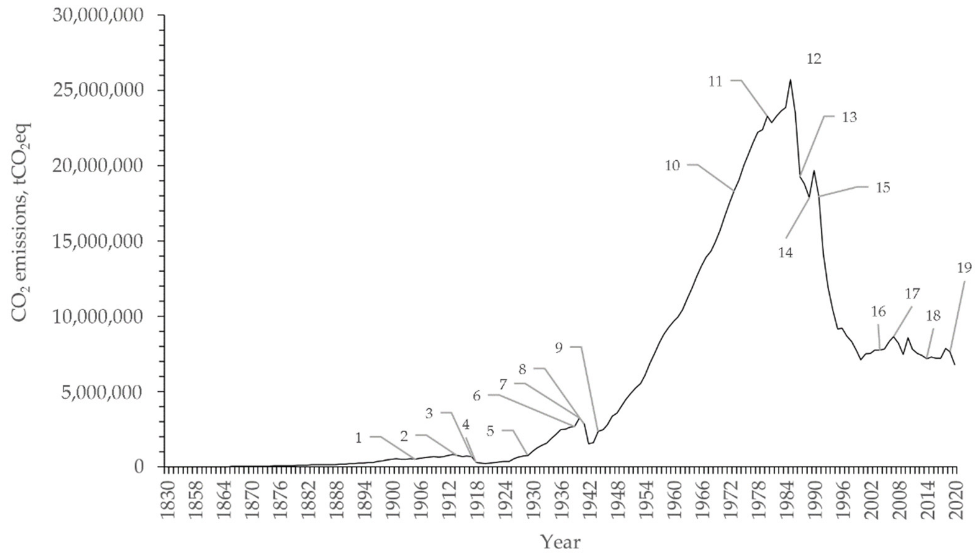

Figure 1. Variations in the CO_2 emissions in Latvia in connection with global and national events from 1830 to 2020. 1: The 1905 Revolution; 2: World War I; 3: The Russian Revolution; 4: The Declaration of Independence; 5: The Great Depression; 6: World War II; 7: The Soviet Occupation; 8: The Nazi Occupation; 9: The Soviet Re-occupation; 10: The Energy Crisis; 11: The Early 1980s Recession; 12: 'Perestroika'; 13: The Third Awakening; 14: The Declaration of Sovereignty; 15: The Restoration of Independence; 16: Accession to the European Union; 17: The Global Financial Crisis; 18: Accession to the Eurozone; 19: COVID-19 [35].

The Baltic States regained their independence from the SU in 1991. Changes in the state structures led to massive changes for the CO_2 emissions produced (Figure 2). In this context, EE produced the highest CO_2 emissions from 1992 to 2018, while in recent years (2019 onward) the EE emissions have significantly dropped below the emissions produced, for instance, by LT [26,35]. In addition, the CO_2 emissions in EE have been varying from year to year to a considerable extent. Simultaneously, LV has been producing similar annual CO_2 emissions since 1994, and they are the smallest among the Baltic States [26,35].

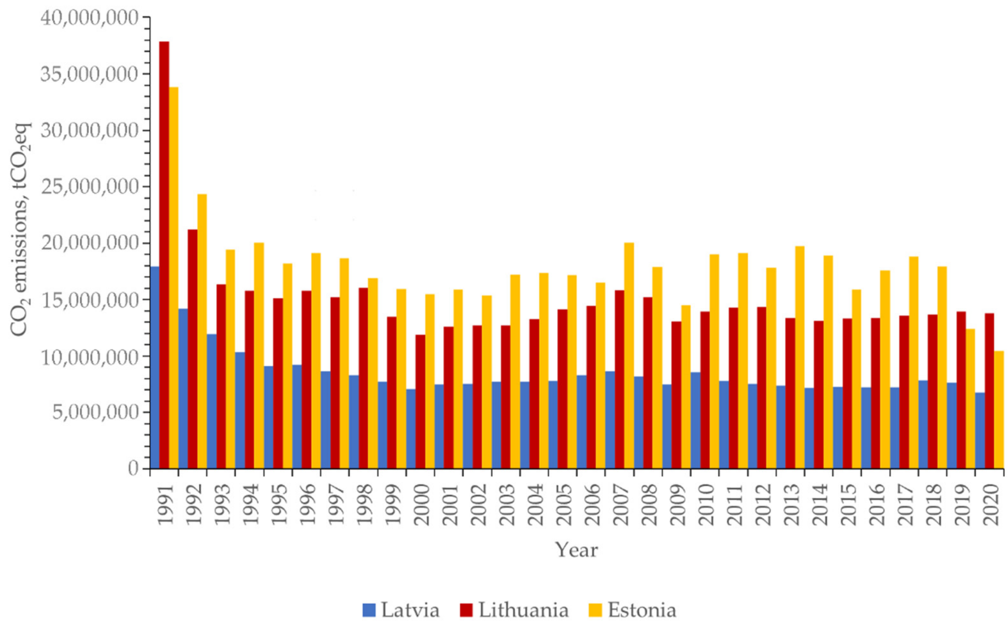

Figure 2. The CO_2 emissions in the Baltic States since the restoration of independence in 1991 [35].

The emissions in each country are related to the industrial activities, transportation, and waste management, which differ among the Baltic States, although the overall pattern is similar. In EE, the total CO_2 emissions decreased from 33.93 million tCO_2eq in 1991 to 12.59 million tCO_2eq in 2019. At the same time, the overall annual emissions increased after joining the EU in 2004 (in comparison with the period from 1991 to 2004) [26,35]. In LV, in turn, the total CO_2 emissions decreased from 18.26 million tCO_2eq in 1991 to 8.14 million tCO_2eq in 2019. Overall annual emissions in LV kept the tendency to gradually decrease after joining the EU in 2004 (in comparison with the period from 1991 to 2004) [26,35]. In LT, the total CO_2 emissions decreased from 38.33 million tCO_2eq in 1991 to 14.29 million tCO_2eq in 2019. The overall annual emissions declined slightly after joining the EU in 2004 (in comparison with the period from 1991 to 2004) [26,35].

The future CO_2 emissions in the Baltic States and in the world in general depends substantially on the direction of the political and military situation in the world (e.g., global energy crisis, invasion of Ukraine). To replace Russian gas, the EU is planning to ship liquefied natural gas (LNG) from Qatar, Egypt, and the US. Regrettably, these countries extract most of their gas by fracking, which can cause many different environmental and climate problems, including toxic pollution.

4. The Carbon Dioxide Emissions from the Energy Sector

The energy sector in the Baltic States uses various energy resources in different amounts. Hence, there is a contrast energy mix (Table 3) with varied emission factors.

Table 3. The energy mix (%) of the Baltic States (2021) [51–53].

Energy Source	Estonia	Latvia	Lithuania
Gas	28.01	48.86	32.77
Oil	7.99	29.25	3.30
Coal	56.11	0.94	0
Hydropower	0.13	17.91	10.18
Wind	3.19	0.92	35.98
Solar	1.08	0.03	3.27
Other renewables	3.48	2.07	14.63

In all three Baltic countries, major CO_2 emissions come from the energy sector (Figure 3). In EE, the energy sector produces more than 90% of the total CO_2 emissions [35]. By comparison, in LV, since 2001, the energy-related CO_2 emissions have been between 90% and 75% [35], whereas in LT, the emissions produced by the energy sector take a similar percentage from total emissions to LV [35]. The energy sector in EE emits the highest CO_2 emissions annually, but in comparison to 1991 (32.85 million tCO_2eq) they are still substantially lower. For instance, in 2019, the energy-related CO_2 emissions in EE accounted for 11.98 million tCO_2eq. By comparison, the energy sector in LV has had the least CO_2 emissions amongst the Baltic States since 1991 (17.11 million tCO_2eq). The lowest energy-related emissions in LV (6.54 million tCO_2eq) were produced in 2014, but in recent years there has been a slight increase—the CO_2 emissions in LV now range from 6 to 8 million tCO_2eq annually. The energy sector in LT produces similar amounts of CO_2 emissions annually since 1999 (around 11 million tCO_2eq).

In EE, the majority of the energy-related emissions goes to fuel combustion in energy industries (78% on average) [35]. In 1993, the electricity and heat production accounted for 83% of the energy-related CO_2 emissions in EE. By comparison, in 2019, fuel combustion in public electricity and heat production in EE accounted for 55% of the energy-related CO_2 emissions [35]. In LV, fuel combustion in energy industries takes only around 30% of the energy-related CO_2 emissions, and the percentage keeps decreasing [35]. In LV, fuel combustion in public electricity and heat production plays a minor role in regard to energy-related CO_2 emissions [35]. The highest percentage was reached in 1996 and 1997, when electricity and heat production accounted for 38% of the energy-related emissions. In comparison, the lowest percentage was reached in 2017, when it was just 22% of the energy-related CO_2 emissions [35]. A plain decrease in fuel combustion in energy industries can also be noticed in LT, where since 2014 it is below 30% of the energy-related CO_2 emissions [35]. Nearly all of fuel combustion in the energy industries in EE is related to public electricity and heat production; however, the percentage is gradually decreasing. In fact, in LV, fuel combustion in public electricity and heat production takes a comparatively larger share of fuel combustion in energy industries, and there is no clear decrease or increase of this share. Fuel combustion in public electricity and heat production in LT takes the least share of fuel combustion in energy industries. In recent years, the share has been below 50% of fuel combustion in energy industries, and it keeps decreasing. LT's fuel combustion in public electricity and heat production has in recent years been the most effective among the Baltic States. In 2019, it accounted for just 8% of energy-related CO_2 emissions. In fact, these emissions have been showing a downward trend since 1991.

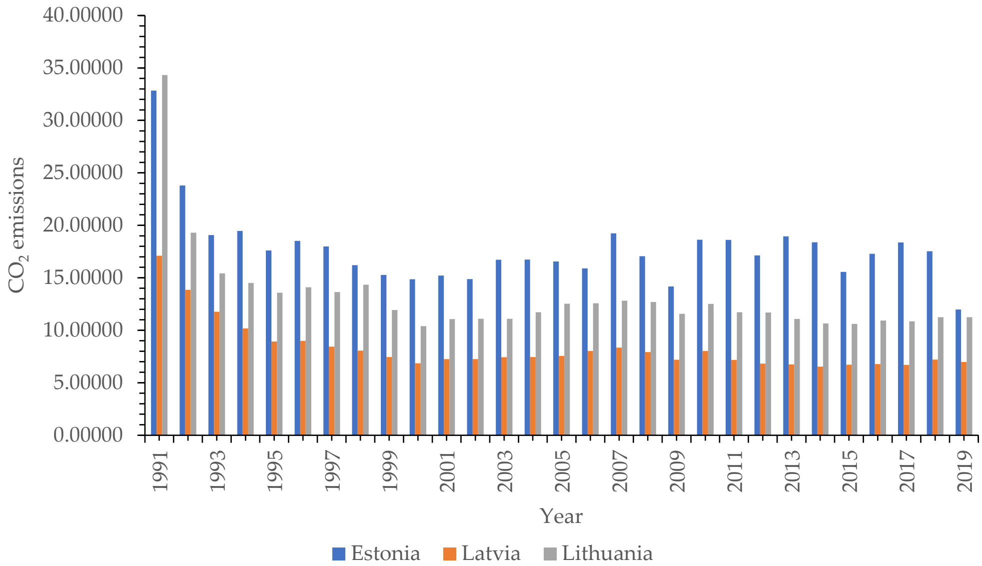

Figure 3. The energy-related CO_2 emissions in the Baltic States since the restoration of independence in 1991 [35].

5. The Carbon Dioxide Emissions from the Transport Sector

The CO_2 emissions from the transport sector are a major contributor to climate change. In the individual Baltic States, these emissions have different shares of the total emissions, and they are still substantial. A great deal of attention needs to be paid to measures for reducing them. The share of the given emissions has been increasing from year to year, and immediate restrictive measures should be considered all over the world [35].

In EE, the CO_2 emissions from the transport sector have increased from 2.19 million tCO_2eq to 2.36 million tCO_2eq in 2019. In LV, these emissions have increased from 2.75 million tCO_2eq to 3.28 million tCO_2eq over the same period. By comparison, in LT, the given emissions have increased from 4.13 million tCO_2eq in 1992 to 6.21 million tCO_2eq in 2019. It is noteworthy that in LT in 1991, the transport-related emissions were even higher than today—6.25 million tCO_2eq, respectively, whereas the following year (1992) began with a substantial decline [35]. In any case, a substantial difference among transport-related CO_2 emissions in the Baltic States is evident.

At present, all three countries show a major increase in transport-related CO_2 emissions, especially when they are viewed as a part of the total emissions. In EE, the share of transport-related emissions has increased from 6% in 1991 to 19% in 2019 (from the total CO_2 emissions) [35]. By comparison, the situation with the CO_2 emissions from the transport sector in LV and LT is much harsher. In LV, the given emissions have increased from 15% of the total CO_2 emissions in 1991 to 43% in 2019. Simultaneously, in LT, the share of the given emissions has grown from 17% in 1991 to 45% in 2019 [35]. Hence, if no restrictive measures are taken now, the CO_2 emissions from the transport sector will be the main contributor to climate change coming from the Baltic States.

The CO_2 emissions from the transport sector in the Baltic States are generally related to the fuel combustion in road transport and railways, whereas aviation (national) emissions are negligible [35]. On a positive note, the share of railways in producing the given emissions has been gradually decreasing. In EE, the given share (railways) decreased from 7% in 1991 to 1% in 2019, but in LT from 6% to 3%, over the same period. However, between 1992 and 1994, the share increased from 9% to 15% [35]. By comparison, the fuel combustion in railways in LV accounts for a comparatively larger share in the CO_2 emissions from the transport sector among the Baltic States. That is, the share has decreased from 19% in 1991 to 4% in 2019 [35]. Starting from 2022 for an indefinite period, rail freight from Russia to and through the Baltic States is expected to drop substantially due to the sanctions against Russia and Belarus, and this situation is expected to reduce the emissions from fuel combustion in railways even further [35]. Nevertheless, the main focus should be on road transportation, which accounts for the majority of CO_2 emissions from the transport sector in the Baltic States [35]. Even though new car purchases have declined in recent years (Table 4), this cannot be explained by people's turning to a green lifestyle. The most likely reason for this is a decrease in purchasing power, because consumers lose purchasing power when prices rise, and numerous crises (e.g., security, economical, resource, energy crises) of the last years have significantly contributed to this.

Table 4. New registered passenger cars (new and used) in the Baltic States by type of motor energy, years 2018, 2019, and 2020. Based on Eurostat database [54].

Country	Year	Diesel	Petrol	Electric *	Total
Estonia	2018	6527	19,686	86	26,299
	2019	6414	20,510	655	27,579
	2020	5123	13,164	1008	19,295
Latvia	2018	6807	10,240	138	17,185
	2019	6893	11,393	251	18,537
	2020	4870	8363	492	13,725
Lithuania	2018	110,072	55,574	3497	169,143
	2019	94,151	66,641	3133	163,925
	2020	7042	32,922	914	40,870

* Including plug-in hybrid electric vehicles.

Road transportation in the Baltic States can be classified into four main groups:

- cars;
- light duty trucks;
- heavy duty trucks and buses; and
- motorcycles.

The CO_2 emission share of each of these groups vary from country to country. However, a major increase in fuel combustion in cars is characteristic to all three states. Even though in last years the popularity of electric cars has been on the rise (Table 3), overall, the most popular cars are with petroleum engines, as they are comparatively less expensive. At the same time, diesel cars are more fuel-efficient and more economical. In theory, the electric cars are the most energy efficient, yet the inconvenience of their use, their current price, and increasing electricity prices cannot at this moment justify the replacement of the car fleet with such vehicles. LT has one of the lowest excise taxes on petroleum and diesel in the OECD and a much lower tax rate on diesel compared to petroleum. To promote the sales of electric vehicles, the tax rates for both types of fuel should be increased.

In EE, the share of fuel combustion in cars has increased from 56% in 1991 to 67% in 2019 of the total emissions from the transport sector [35]. In LV, the growth is not so significant, but it is still present. There the share has increased from 51% to 58%, respectively [35]. By comparison, in LT, fuel combustion in cars accounted from 51% to 56% of the CO_2 emissions produced by the transport sector in 1991 in 2019, respectively [35]. Hence, in the Baltic States, fuel combustion in private motor vehicles (Table 3) accounts for more than half of the transportation-related emissions and their impact is expanding.

A comparatively smaller share in the transport-related CO_2 emissions comprises the emissions produced by light duty trucks, although these emissions vary among the Baltic States. In EE, the CO_2 emissions from fuel combustion in light duty trucks have increased from 8% in 1991 to 12% in 2019 [35]. In turn, in LV, the relevant emissions have decreased from 10% in 1991 to 7% in 2011, but from 2012 onward the given emissions have been showing an increasing trend and in 2019 accounted for 9% of the transport-related CO_2 emissions [35]. By comparison, in LT, the CO_2 emissions from fuel combustion in light duty trucks have increased from 3% in 1991 to 5% in 2019 [35].

Against the background of other types of vehicles, the share of CO_2 emissions from fuel combustion in heavy trucks and buses has been gradually declining in all three countries, but with varied rates. In EE, it has decreased from 35% in 1991 to 20% in 2019 [35]. In LV, it has reduced from 39% to 32% [35]. By comparison, in LT, it declined from 45% to 39% over the same period [35].

Interestingly, in recent years, the CO_2 emissions from motorcycles, although negligibly, but have also been gradually increasing in all three countries. For instance, in EE, fuel combustion in motorcycles from 1991 to 1993 accounted for up to 3% of the transportation-related CO_2 emissions, following a substantial drop in 1994 (0.04%), but from 1996 to 2019 the given emissions have increased from 0.1 to 0.4% of the transportation-related emissions [35]. To a lesser extent, the CO_2 emissions from fuel combustion in motorcycles have also been increasing in LV and LT [35]. Hence, an attention must be paid to ensure that these emissions do not make a sharp jump. Moreover, studies indicate that motorcycles emit more particulate matter and polycyclic aromatic hydrocarbons and have stronger polyaromatic hydrocarbon-related carcinogenicity and indirect-acting mutagenicity than automobiles, which is another aspect to consider when assessing purchase of a motorcycle [55].

6. The Carbon Dioxide Emissions from Waste

Waste is the fourth-largest source sector of GHG emissions (CH_4 and CO_2) in the world [56,57]. As mentioned above, solar cells, wind turbines, and other green technologies contain materials that cannot be recycled, and thus they can substantially increase the global waste problem, if an unreasonable, rapid transition to such technologies is in place [56,57]. Moreover, global waste generation has already greatly expanded all over the world, and there are no signs of it slowing down. This is due to a number of factors, such as population increase, urbanization, economic growth, and consumer shopping habits, to name a few [56,57]. The quantity of GHG emissions from waste depends on how the waste is treated. Less than 20% of waste is recycled every year globally, with huge quantities sent to landfill sites (Table 5) [56,57]. We know that if waste is landfilled the organic material in the waste decomposes and produces GHGs. In fact, waste already is a massive contributor to global GHG emissions and climate change. However, there is a known solution to this issue. The reduction in GHG emissions from waste disposal can follow from an increase in the recovery of landfill gas and a reduction in the amount of landfilling [58]. This can be achieved through active and thoughtful recycling, which would mitigate the need for landfilling or waste incineration [59]. At the same time, all new materials need to be developed with the idea in mind that it will be possible to recycle them after use.

Waste can be divided into two main groups: municipal waste and industrial waste. Even though municipal waste makes just a small share of total waste, industrial waste contains relatively little organic and fossil carbon material, and thus the majority of GHG emissions are essentially related to municipal waste, a large part of which consists of organic material. A natural byproduct of the decomposition of organic material in landfills is landfill gas [58]. The major components of landfill gas are CH_4 and CO_2, and the emissions of the former may be higher than of the latter. For instance, in the US, municipal solid waste landfills are the third-largest source of human-related CH_4 emissions [58].

Table 5. Operational landfills for non-hazardous municipal waste and generation of non-hazardous municipal waste (kg per capita) in 2020 [60–63].

Country	Landfill Sites	Generation of Waste (kg/Capita)
Estonia	5	10,974
Latvia	10	1427
Lithuania	11	2384

In regard to waste management, EE focuses on modern product design, clean, resource-saving production, and the recycling of already produced materials. Waste management in EE is based on minimizing the effect on the environment. The top solution is considered as avoiding the production of waste, whereas recycling is considered as a lower-priority option. Recycling methods involve reuse, recycling of materials, and energy production. Landfill disposal is considered to be the last choice. In fact, the waste amount being landfilled in EE has been decreasing due to the requirement to collect waste separately and due to the threshold to landfilling biological waste, as well as due to the steady increase of the pollution tax and the intensive expansion of new recovery methods [59].

LV has a relatively comprehensive policy and legal framework for waste management, supported with measurable targets and economic instruments. Strategic objectives for waste management in LV are essentially defined by the EU law and policies and specified in line with the international commitments and OECD Council Decisions. LV employs a series of policy instruments to promote waste recovery and recycling. They embrace separate collection requirements and mandatory targets for recoverable materials, economic instruments, a deposit-refund system for glass bottles, and extended producer responsibility and take-back systems for selected products [64–66]. A similar system also exists in EE. The Greater Riga ecological landfill complex Getlini treats 40% of all municipal waste generated in LV. It has developed from a traditional landfill to a modern waste treatment and recovery complex. Following sorting, recyclable materials are sent to further processing. Biodegradable materials are stored together with biological waste and are assimilated in an anaerobic environment with accelerated biogas production. The biogas is then utilized in a power station to produce electricity that is supplied to the power grid. The produced heat is used locally for heating of the office, water heating, effluent treatment and the production of vegetables, berries, and flowers in a greenhouse compound. The estimated CO_2 savings of the Getlini complex are about 16,000 t per year [66].

LT has moved from landfilling almost all of its waste to recycling and composting. LT has one of the highest recycling rates in Europe. In addition, the government is investing money into waste incineration and heat-producing power plants [67,68].

Waste management in the Baltic States over the years has reduced the total GHG emissions coming from waste. Furthermore, these emissions keep decreasing every year. For instance, in EE the relevant emissions are the lowest amongst the Baltic States and in 2019 accounted for just around 0.31 million tCO_2eq. In LV, these emissions do not exceed one million tCO_2eq and gradually keep decreasing—from 0.76 million tCO_2eq in 1991 to 0.58 million tCO_2eq in 2019. By comparison, in LT these emissions are the highest, but still keep a downward direction. In LT, from 1991 to 2004, the emissions from waste management were around 1.50 million tCO_2eq annually, but since 2004 they have been decreasing and in 2019 declined to 0.82 million tCO_2eq [35].

The majority of waste management in all three states takes place at solid waste disposal sites. Unfortunately, in addition to managed waste disposal sites, there are also unmanaged ones, and in LV the emissions from such sites are higher than from the managed sites. Long-term storage of carbon in waste disposal sites in the Baltic States accounts for substantial CO_2 emissions, which tend to increase year by year. For instance, in EE the relevant emissions have increased from 1.76 million tCO_2eq in 1991 to 3.62 million tCO_2eq in 2018, although there is a minor decrease observed in recent years. A similar trend can be noticed in LT, where emissions have grown from 2.24 million tCO_2eq in 1991 to 3.90 million tCO_2eq in 2019. Therefore, these emissions are close to those produced by the transport sector and require an immediate attention. Instead of allowing landfill gases escaping into the atmosphere, it is recommended to capture them, convert, and use as a renewable energy resource [35]. Other waste-related activities in the Baltic States that cause GHG emissions into the atmosphere, CO_2 emissions in particular, are biological treatment of solid waste, waste composting, waste incineration, wastewater treatment and discharge, domestic wastewater, anaerobic digestion at biogas facilities in LT (since 1999 and LV since 2010), and open burning of waste in EE [35].

7. The Reduction of Carbon Dioxide Emissions through Land Use, Land Use Change, and Forestry

On July 14, 2021, the European Commission (EC) approved a series of governmental proposals establishing how it is intended to succeed in climate neutrality in the EU by 2050, including the transitional goal of an at least 55% net reduction in GHG emissions by 2030 [69,70]. The proposal intends to revise EU climate legislation, emission trading system (ETS), effort sharing regulation (ESR), and transport and land use legislation to reach climate targets under the European Green Deal [69,70]. In this regard, EU Member States have to guarantee that reported GHG emissions from land use, land use change, and forestry (LULUCF) are balanced by at least an equivalent accounted removal of CO_2 from the atmosphere from 2021 to 2030 [69,70].

Since 1991, LULUCF in the Baltic States have led to substantial CO_2 removal from the atmosphere [35]. Historically, the remarkably positive impact of the activities within this sector was seen in LV. The most pronounced positive effect was in 1994, when an estimated 17 million tCO_2eq were removed from the atmosphere [35]. By comparison, the highest estimated values for the other two countries were 5.28 million tCO_2eq for EE (2003) and 10.73 million tCO_2eq for LT (2011) [35]. These data show and prove that a prudent and sustainable use of land can lead toward a sustainable net zero future. Unfortunately, the positive outcome of this GHG inventory sector diminishes over time. This is especially true in LV since 2004, where the reduction in the positive impact is particularly pronounced [35]. For instance, in 2014, instead of GHG removal, this sector contributed to the CO_2 emissions (0.27 million tCO_2eq). In fact, currently, LULUCF in LT contributes to a much larger CO_2 removal from the atmosphere than in LV or EE. This is partly due to land transformation to grasslands and due to sustainable forestry. If land conversion to grasslands in EE and LV produces negligible CO_2 emissions, then in LT there is a noteworthy reduction in these emissions due to such conversion. For instance, in 2001, this approach removed estimated 1.97 million tCO_2eq from the atmosphere. Unfortunately, the positive effect diminished over the years and, for example, in 2019, the CO_2 absorption was reduced to 0.91 million tCO_2eq. Still, LV and EE in regard to LULUCF share the last place, although in the 1990s LV was in the lead in this sector [35]. In fact, for a while, the capacity of the CO_2 absorption exceeded the produced CO_2 emissions, and LV can be considered as a carbon-negative country. Now and in the future, significant attention needs to be paid to this sector, as it is clear that the positive effects have been diminishing and will soon be fully suppressed by rapidly increasing fossil CO_2 emissions.

Forests are considered to be carbon sinks as they can attract much more CO_2 than they produce [71]. The Baltic States are no exception in this regard, where forest land has helped substantially to reduce the CO_2 content in the atmosphere. In fact, the forest land (Table 6) has absorbed more CO_2 than land use and land use change jointly. For instance, in LV (1994), forest land accounted for a reduction of 20.31 million tCO_2eq [35]. By comparison, in EE (2011) it was 5.78 million tCO_2eq, but in LT (2011) it was 10.20 million tCO_2eq [35]. Nowadays, the forestry sector is an important part of the national economies of the Baltic States. Consequently, deforestation has led to a significant reduction in the positive effects, especially in LV, where in 2014 carbon removal decreased to 1.11 million tCO_2eq [35]. The situation was worse in LT (1996), where the sector produced CO_2 emissions in the amount of around 0.54 million tons. At the same time, since 2009, LT forests have absorbed considerably more CO_2 than LV or EE forests. For instance, in 2019, forest land in LT absorbed an estimated 6.68 million tCO_2eq, whereas in LV it was approximately 4.83 million tCO_2eq, but in EE it was approximately 2.13 million tCO_2eq [35].

Table 6. Net annual change of the forest land in the Baltic States (mln ha). 1990 vs. 2020. Based on Food and Agriculture Organization data [72].

Country	Forest Area		Net Annual Change (%)		
	1990	2020	1990–2000	2000–2010	2010–2020
Estonia	2.206	2.438	+0.15	+0.43	+0.43
Latvia	3.173	3.411	+0.21	+0.40	+0.11
Lithuania	1.945	2.201	+0.38	+0.72	+0.14

The logging industries plant new forests, but young stands evidently are not able to provide the same CO_2 absorption efficiency as forests that have developed over decades and hundreds of years. Moreover, herbivorous mammals eat the bark of young plantation trees. The damage inflicted can vary from minor scarring to serious deformation of the trunk to death of the tree. Hence, not all young stands may be viable. Although young forests (~10 to 15 years) can absorb more CO_2 overall, because trees can be crowded together when they are small, the CO_2 absorption rate accelerates with the age of the tree. Simultaneously, very mature forests do not absorb CO_2 anymore due to the tree age. Among the Baltic States, the most significant effect of young tree stands has been seen in LT since 1991, where they account for absorption of more than 0.80 million tCO_2eq annually; moreover, since 2016 it exceeds 1.00 million tCO_2eq [35]. In LV and EE, the impact of planting young tree stands is negligible, but over the years it does gradually increase. In LV, the peak (0.24 million tCO_2eq) was reached in 2015, and in EE, it was achieved in 2009 (0.46 million tCO_2eq) [35]. Hence, strategies to reduce deforestation should be considered. Furthermore, a sustainable management also is a crucial factor, as increasing climate change puts forests at considerable risk of wildfire, which can lead not only to devastating ecosystem damage but also to enormous CO_2 emissions.

8. The Concerns about Carbon Offsetting

In general terms, carbon offsetting is all the actions of counterbalancing for CO_2 emissions rising from human activities, by contributing to policies designed to make equal reductions of CO_2 in the atmosphere. Although this sounds like a promising idea, in its current form it does not work in practice, as trading off harm in one location with good intentions elsewhere cannot preserve the sustainability of nature, as each habitat is unique and is not replaceable. Moreover, offsetting currently produced emissions would not solve the climate change; it would only keep emissions at their current rates, which are already too high. The current manifestation of carbon offsetting is more like "greenwashing" than an actual solution. A quality offset has to result in a permanent reduction of GHGs, in which current options do not really succeed. At this moment, the carbon offsetting market is dominated by temporary biological capture of carbon (generally by planting trees) and funding renewable energy [73]. At the same time, recent studies show that if no urgent action is taken right now and we keep relying just on carbon offsetting in hope for advanced technologies in the future, then warming might increase by up to 1.4 °C [73,74]. Moreover, said offsetting may increase food prices in the world even further, as afforestation for the offsetting market would reduce available lands for food production. In addition, although trees capture copious amounts of CO_2, they need to grow for a long period time to be effective CO_2 storage units. Furthermore, different tree species have varied growing speeds and lifespans, which substantially affect CO_2 absorption capacity. Trees that grow faster absorb CO_2 faster, but trees that grow slower but live longer absorb more CO_2 in their lifecycle, respectively. It is difficult to estimate which tree species absorb the most CO_2, but it is clear that same species cannot be planted in all climatic zones, and for the highest CO_2 absorption efficiency planting, mixed forests should be favored. Hence, it can be concluded that because carbon offsetting via afforestation cannot be used as the main option to mitigate climate change, the only alternative is to cut existing CO_2 emissions, and it is strongly suggested that the set ambitions for carbon offsetting be discarded and shifted to carbon neutral technologies as soon as possible. In addition, carbon offsetting cannot be justified, as economically developed countries keep producing high emissions, whereas developing countries, often on the other side of the world, are paid to offset this carbon.

Financial instruments that represent one tCO_2 removed or reduced from the atmosphere are carbon credits (Table 7). Up until 2020, carbon credits were generated through the clean development mechanism (CDM) and joint implementation (JI). The CDM allows industrialized countries to invest in projects that reduce emissions in developing countries. In turn, the JI allows industrialized countries to meet part of their required cuts in GHG emissions by paying for projects that reduce emissions in other industrialized countries. Fortunately, the Paris Agreement sets up a new market mechanism to replace the CDM and JI after 2020. This involves setting up new accounting rules and new mitigation mechanisms. The new conditions require parties to apply vigorous accounting frameworks to approaches that involve the use of internationally transferred mitigation outcomes toward nationally determined contributions. Simultaneously, new mitigation mechanisms must provide for certification of emission reductions for use toward nationally determined contributions. At the current date, carbon credits must be exchanged for emission allowances [75,76].

Table 7. Credits exchanged by 30 April 2021, in the Baltic States. Carbon price April 2021, Eur 48.84 per credit (in September 2022 it has increased to Eur 71.85 per credit) [75,76].

Country	Carbon Credits	Estimated Value (Eur)
Estonia	25,688	1,254,602
Latvia	8850	432,234
Lithuania	3,539,188	172,853,942

In the case of carbon offsetting by other means, the Baltic States are viewing peatlands as potential sites for CO_2 mitigation projects. In addition to this, in EU communications peatlands are distinguished as one of the key carbon farming mechanisms. The idea here is based on rewetting the drained peatlands for CO_2 mitigation.

9. The Baltic Strategies for Climate Neutrality by 2050

The relevant strategies are long-term policy planning documents that are designed to increase the growth of the economy in the Baltic States while regulating and easing climate change and also increasing the Baltic economy's competitiveness and ensuring a safe living environment for the population of the Baltic States. In the context of international politics, these strategies are designed to promote monitoring of the actual and projected progress on GHG emission reduction and meeting GHG emission reduction commitments under the PA in a cost-effective manner (Table 8).

Table 8. The Baltic GHG emission reduction targets from the 1990 levels [37–41].

Country	1990 Levels (tCO_2eq)	2030	2040	2050
Estonia	37,028.96	−70%	−72%	−80%
Latvia	19,992.95	−65%	−85%	−100%
Lithuania	36,166.64	−40%	−70%	−80%

The EE low carbon strategy is a concept document that establishes the long-term GHG emission reduction goal and policy strategies for adapting to the impact of climate change and ensuring the readiness and flexibility to react to the impact of climate change [38,41]. In EE, switching to a low-carbon economy has been evolving into a global trend. The target of EE is to reduce the emission of GHGs in three phases—by 70% by 2030, by 72% through 2040, and by 80% by 2050 in comparison with the 1990 emission levels [38,41].

The common sectoral guidelines and standards of green policies for EE include [38,41]

- an effective interface of the system when designing energy application facilities and other production functions;
- enabling the use of machineries with a low CO_2 emission factor and cost-effective use of supplies in the industrial activities;
- seeing the economy and energy efficiency of the system as a unified structure when renovating the existing buildings and planning and building new structures and buildings;
- evaluating the economy and energy efficiency when designing, developing, managing, and modernizing networks inside the energy systems;
- moving toward improving the energy value and the manufacture of commodities with greater added value to reduce the GHG emissions in the oil shale treatment processes;
- directing major participants in the energy and industry sectors to move toward productive and cost-efficient reduction of GHG emissions, while preserving the use of market-based mechanisms;
- safeguarding the energy security and supply security with a gradual wider exploitation of domestic renewable energy sources;
- supporting a well-functioning transportation system and reducing traffic load through the incorporation of the settlement designing, transportation and the strategy and execution of mobility strategies;
- encouraging acquisitions of fuel-efficient vehicles and viable alternative fuels over assets and tax policies of the public sector;
- prioritizing the advancement of public transport, non-motorized vehicles and energy-effective distribution of supplies;
- boosting and preserving carbon stock in soil, and improving carbon stock in land areas;
- promoting cost-effective and natural use of rural territories;
- enhancing the application of plant nutrients and finding substitutes to inorganic fertilizers, and developing green soil conditioners;
- increasing the amount of bioenergy production and use of bioenergy in energy-intensive production processes;
- increasing the yield of cultivation with an emphasis on environmentally friendly fertilizer management for regulating ammonia emissions and exposure to N_2O;
- increasing forest growth and the carbon sequestration ability through productive and sustainable forest management;
- consistently improving timber use and increasing the carbon stock in timber products and buildings;
- enabling conservation of forests, while supporting practices for increasing carbon sequestration and emission savings;
- preventing continuous water drainage from peatlands and reestablishing near-natural water systems in drained peatlands;
- providing a cut in waste production and making the waste disposal more efficient; and
- enabling research, advances, and modernization that can support the development of cost-effective energy technologies, renewable energy production technologies, sustainable transport and mobility, sustainable agriculture, carbon sequestration in forestry, and discovering alternative applications for lumber.

In LV, there are two strategic goals to reduce GHG emissions in all economic sectors and increase CO_2 sequestration. For instance, in the following decades a major reduction in GHG emissions is planned (excluding LULUCF) vs. 1990 as the base year. The set target is to be met in three GHG reduction phases (decades)—2030 (–65%), 2040 (–85%), and 2050 (–100%), respectively [37]. At the same time, if the LULUCF sector is included, then the emission-reduction steps are rather different. In this case, by 2030 it is planned to reduce the emissions by 38%, through 2040 by 76%, and before 2050 by 100% in comparison to the

1990 emissions, and the target is considered to be met if the deviation is within 5% [37]. However, targets for 2030 and 2040 in the LV strategy are subject to change if a more applicable trajectory for attaining the climate neutrality target in 2050 is found.

In LV, the corresponding gradation toward climate neutrality in 2050 is determined according to the Bass diffusion model, which mathematically describes how new innovations are adapted to the interaction of existing and potential users [37]. Indicators of the trend, either it is approaching or moving away from the climate neutrality target, play a vital role in assessing the progress of the strategy. The LV strategy offers four major indicators [37]:

- intensity of GHG emissions;
- intensity of GHG emissions from energy sector (GHG emissions per total primary energy consumption);
- changes in GHG emissions from the previous year by sector; and
- total balance of emissions and removals from land use, land use change, and forestry.

The LV strategy addresses two basic approaches to achieve climate neutrality, which are technological solutions and lifestyle change [37]. The technological solutions focus primarily on direct GHG-emission reduction. Major investments are needed to execute direct GHG emission reduction (energy, transportation, agriculture, waste management, industrial processes, etc.), and the development and commercialization of green innovations, which in the optimal scenario would also provide an opportunity for the export of innovative technologies [37]. In turn, the lifestyle change incorporates solutions that focus on extensive public information and education measures to ensure that every citizen understands and is interested in moving toward climate neutrality. Improvement of the tax system by adapting the entire tax system, so that both citizens and businesses can be sure of a clear overall long-term direction of the country (i.e., that tax policy does not send conflicting signals), and creation of economic incentives for everyone to choose more environmentally friendly habits and technologies, are in order [37].

Workable solutions to ensure low carbon development in LV include [37]:

- research and innovation in low-carbon technologies;
- comprehensive energy efficiency;
- sustainable energy;
- resource-efficient and environmentally friendly transport;
- sustainable land management and agriculture;
- sustainable consumption and production; and
- sustainable municipalities and urban environments.

Research and innovation in low-carbon technologies offers the integration of low-carbon development principles in all publicly funded research. Moreover, investments can be successfully attracted for the development of research and innovation, development of new and improved technologies and processes. In addition, a prominent level of commercialization and competitiveness of research results can potentially be achieved. Furthermore, the improvement in resource efficiency provides an opportunity for growth through eco-innovation and green jobs that lead to well-developed research human capital, infrastructure sharing, and cooperation culture. As a result, a broad, easily accessible and practical knowledge base can be created that contributes to reducing GHG emissions and ensuring the sequestration of CO_2 emissions [37,77].

Comprehensive energy efficiency is one of the main factors of sustainable energy in LV. To meet this target, construction of all new buildings in LV has to meet the requirements of zero-energy buildings, and renovation and conversion of all buildings have to meet the requirements of zero or near-zero energy buildings. Moreover, comprehensive energy efficiency is possible if only energy-efficient and resource-efficient products and equipment are available to the public and all production processes are energy efficient. Sustainability of energy in LV is planned to be improved by the use of renewable energy sources in energy generation and by creating a fully connected and freely accessible energy market for everyone [37].

Resource-efficient and environmentally friendly transport is among the biggest challenges in LV. This is possible if road transport is mainly electrified, and the charging infrastructure is widely available. In this context, the rail transport also has to be electrified and/or use other alternative low- or non-carbon fuels. Moreover, aviation has to use modern biofuel efficiently, and energy-efficient solutions also have to be integrated directly into aircraft and airports. In addition, waterborne transportation should use alternative fuels and energy-efficient solutions to reduce fuel consumption. In addition to changing fuels and improving their efficiency, it is also necessary to ensure the sustainable and environmentally friendly mobility of the population, such as via a well-thought-out public transportation network. In the case of transportation networks, freight transportation must be carried out by using an interconnected, efficient, and intelligent transportation system, as well as multimodal transportation. This in turn requires improvements in road infrastructure, which must keep pace with the latest transportation trends through the integration of intelligent transportation systems. The development of the road network must be planned in a sustainable way, considering transportation developments, including the safety of vulnerable road users and reducing the environmental and climate impact of road construction.

A sustainable land management policy has already been developed and successfully implemented in LV. A sustainable balance has been reached between different land uses, considering climate, nature, economic, and social aspects. The majority of forests in LV are sustainably managed. At the same time, agriculture and forestry must continue to make a significant contribution to bioenergy without compromising food security and CO_2 sequestration. With no municipal initiatives and active action to mitigate climate change at the regional level, the achievement of LV national goals is at considerable risk. Cities and municipalities have to contribute to climate change mitigation, recognizing their actual impact on climate change, as well as their crucial role in meeting the national GHG emission targets. Municipalities have to participate in domestic and international initiatives, recognizing their potential in mitigating climate change, as well as setting GHG targets and sharing experiences to achieve them [37].

According to LT strategic guidelines, it is planned to achieve 100% national renewable energy-based electricity generation by 2050, with key targets set for reducing imports. To reach this target, investments in energy infrastructure, including energy storage, is essential. Furthermore, LT sets out a vision to become an energy technology exporter [39,40]. To increase the share of renewables, LT is planning to build wind farms in the Baltic Sea and in renewable energy communities [39,40]. In addition to renewable energy-based electricity generation, it is also crucial to deliver substantial energy savings. To do so, the digitization and modernization of industry are among the main measures that have to be implemented. This includes the improvement of energy efficiency of buildings. In LT, the National Energy Independence Strategy (adopted in June 2018), the National Air Pollution Reduction Plan (approved in April 2019), and the National Strategy for the Climate Change Management (adopted in 2012, updated in 2019) are the main legal documents integrated into the national energy plan [39,40].

The objectives that are relevant to the national energy and climate action in LT are [39,40]:

- safeguarding good environmental quality and the sustainability of the use of natural resources, mitigating LT's impact on climate change and increasing LT's climate resilience;
- improving the competitiveness of the energy sector;
- incorporating the LT natural gas market into the single EU gas market;
- linking the LT power system with the continental EU power system for synchronous operation;
- guaranteeing the adequacy of the LT electricity market and power system and increasing the share of local electricity generation;
- lessening the energy poverty of the population;

- expanding the utilization of renewable and unconventional fuels in the transport sector and strengthening sustainable intramodality;
- increasing the share of renewable energy sources in national energy production and gross final energy use, and reducing contamination risks in the energy sector;
- improving the energy efficiency and use of energy from renewable sources in residential and essential public facilities; and
- shutting down the Ignalina Nuclear Power Plant and disposing of the produced radioactive waste.

LT's concept for 2050 is energy production that uses advanced technologies, low-GHG technologies, and clean energy sources, which are resistant to cyberthreats and climate change, and provide energy reliably at a reasonable price. In accordance with the strategy, LT's energy sector by 2050 will produce 80% of its energy from clean sources. LT employs the GHG emission reduction on the basis of the National Strategy for the Climate Change Management Policy, which, similarly to LV legislation, sets out emission reduction in three steps (decades). The set target is to be met in three GHG reduction phases—2030 (−40%), 2040 (−70%), and 2050 (−80%), respectively [39,40].

10. Challenges Relating to Sustainable Net Zero Future

Benin, Bhutan, Tuvalu, Gabon, Guinea-Bissau, Guyana, Cambodia, Liberia, Madagascar, and Suriname already have achieved carbon neutrality [70]. However, all these countries can be considered as poor and are without a developed industry that could generate any significant emissions to begin with. For instance, Bhutan is primarily covered by forest and agricultural land, whereas Suriname is covered by tropical rainforests. At the same time, Gabon is one of the largest oil producers in Africa. As to the European countries, none have reached carbon neutrality yet, but numerous countries engage in processes and practices that minimize harm to ecosystems and the environment. In this regard, Denmark is implementing some of the world's most efficient policies to reduce GHG emissions and prevent climate change. To calculate the combined environmental impact of all policies and legislations of a country, the Environmental Performance Index (EPI) is typically used. The EPI score reflects the efficiency of environmental trends and progress of a country (Table 9).

Table 9. The environmental performance indexes (x out of 100) of the Baltic States, 2022 [78].

Country	Environmental Performance Index	Ecosystem Vitality	Environmental Health	Climate Change Policy Objective
Estonia	61.4	65.0	71.8	52.0
Latvia	61.1	65.4	56.9	58.6
Lithuania	55.9	61.0	61.8	77.1

The EPI score generally provides a foundation from which governments can implement more effective environmental policies. In 2022, Denmark has the highest EPI score in the world—77.9, respectively. In comparison, the Baltic States are far behind Denmark. EE is in 14th place with an EPI of 61.4, LV is in 15th place with an EPI score of 61.1, and LT is in 31st place with an EPI score of 55.9. In regard to climate change policy objectives and climate change mitigation, LV is in 25th place with a score of 58.6, EE is in 42nd place with a score of 52.0, and LT is in 61st place (out of 180) with a score of 47.1. Simultaneously, the Baltic States have thoughtful policies on preserving, protecting, and enhancing ecosystems and the services they provide—LV is in ninth place in the world, EE in 11th place, and LT is in 22nd place. In regard to actions toward retaining natural ecosystems and protecting biodiversity, EE is in seventh place in the world, but LT and LV are in the 13th and 14th place, respectively [78]. Regarding climate change policy objectives (Table 8), LT scores the highest amongst the Baltic States (77.1) due to the considerably lower growth rate of CH_4 emissions.

There are eight key challenges relating to sustainability [77]:

- zero waste;
- regenerative nature;
- dematerialization;
- resource efficiency;
- a fair society;
- a secure society;
- zero emissions; and
- adaptation and resilience.

All these challenges need to be considered in regard to the reduction of the CO_2 emissions within the Baltic States and worldwide.

In theory, the CO_2 emissions from the energy sector, including the electricity, heat, and industrial segments in the Baltic States could be halted by 2030 when the set green goals would be partially achieved. However, this would exclude the transport sector that requires a different approach. The carbon neutrality in the energy sector can be achieved by phasing out fossil energy, even without using CCS technologies. This can be done through energy efficiency and renewable resources, such as wind, water, and solar power. The EU has intended to completely phase out of nuclear, coal, oil, and waste power and to significantly reduce the consumption of natural gas by 2030. This shortfall is expected to be offset by increased use of solar and wind energy (Table 10), by biofuels and, where possible, by developing geothermal and ocean/wave energy use [70].

Table 10. 2030 plans for the wind energy in the Baltic States [79–81].

Country	Current Capacity (MW)	Planned Capacity (MW)
Estonia	320	800
Latvia	80	1000
Lithuania	671	2000

When estimating the sustainable future of the Baltics, it must be considered that not all of the abovementioned approaches will be feasible. For example, geothermal and ocean/wave energy applications would not be possible in this region due to the geological conditions and geographical location. In contrast, hydropower, wind energy, and biofuels have a rather high potential, evidently higher than solar energy. Hydropower can be considered as a renewable resource, and to a large degree it is also adaptable and dispatchable. Hydropower can match supply to demand by adjusting the power, meaning less production when less energy is needed, thus allowing high energy efficiency. Although hydropower has many advantages, there is a strong interannual variability between drier and wetter years, the variability whereof, in fact, affects climate change. Wind energy is fairly inexpensive, yet wind turbines occupy large areas. Moreover, a number of environmentally friendly strategies meet opposition [82,83]. A reasonable strategy would be to combine various options without completely relying just on one. For instance, in windy weather, hydropower could be used less, which would raise water levels, but in windless weather, consequently, more water could run through the turbines and generate electricity. Another option would be the use of biofuels. Biofuels vary from timber used in construction to slaughterhouse waste, straw, the biogenic fraction of household waste, wood chips, and wood pellets, to name a few. In general, biofuels are considered as carbon neutral, and power is only a small part of potential biofuel use. Notably, it has a tactical role in stabilizing the energy system. Although wind and solar power are sporadic, biopower is both stable and dispatchable. At the same time, solar energy is one of the cheapest sources of electricity globally. It can produce substantial amounts of power; it is consistent and predictable over the course of a year [84]. However, the efficiency of solar energy panels is negligible in midwinter; they make a valuable contribution to the energy grid only in spring and summer. In the Baltic States, the most economically justifiable type of solar panels would be the photovoltaic solar cells. The traditional technology used is crystalline silicon with fixed tilt on roofs, or solar parks [84].

11. The Impact of the Ukraine Conflict on Global Energy Sector

Global resource markets are staggering from the impacts of Russia's invasion in Ukraine, because the two countries are major suppliers of energy. For instance, Ukraine produces coal, natural gas, petroleum and other liquids, nuclear energy, and renewables [85–87]. Moreover, the EU up until now relied on Russia for nearly half of their imported natural gas [86]. For instance, in August 2022, Russia was wasting large volumes (more than 4.3 million m^3 per day or more than € 1000 per hour) of natural gas just by burning it in the atmosphere at a compressor site for Nord Stream 1 gas pipeline near the border with Finland. This action substantially harms the environment and climate, especially for the North Pole area, but negotiations on compromise seem impossible for now. In addition, in September 2022, the Nord Stream pipelines in the Baltic Sea were sabotaged. The pipe rupture caused by the explosion is likely to have led to the biggest single release of CH_4 ever recorded. CH_4 oxidizes to CO_2, which dissolves in seawater, making it more acidic, which has consequences for marine life. Moreover, CH_4 is more efficient at trapping heat than CO_2.

Supply interruption and the rapid imposition, in response to the crisis, of unprecedented economic sanctions to Russia, trade restrictions and policy interventions have triggered market prices to rise [87,88]. Prior to the war, the need for global resources already surpassed available quantities and pushed prices up as world economies regained strength in economic output after the COVID-19 pandemic. This event led to a global cost-of-living crisis, expressed by the rising price of energy. Existing conditions are likely to grow into a harsher state as a result of the war in Ukraine and present a threat to human security, especially among low-income and vulnerable people. The EU should invest into the flexibility of the society and economies to meet these long-term challenges. Alleviating challenges to sustainable development are is a matter of primary importance for legislators, but a failure to maintain long-term goals, e.g., climate change mitigation, can lead to outcomes that further aggravate the prevailing weaknesses in economic and social systems.

Russia, up until the war, was in control of about 10% of global energy production and was a major exporter of all fossil fuels, accounting for around 15% of global coal trade, 10% of global oil trade, and 8% of global gas trade in 2020. In that year, decreasing prices led the total value of its fossil fuel exports to fall. The EU imports 90% of its gas consumption, with Russia providing 41.1% of the EU's imports of natural gas (and 35% of total EU consumption), as well as 26.9% of imported oil (25% of consumption), and 46.7% of coal (20% of consumption). Russia is by far the EU's largest source of imported energy; the EU imports 60% of its total energy needs. Simultaneously, the UK is relatively independent of Russian energy exports, with only 4% of its gas consumption and 8% of oil consumption imported from Russia [89]. The Inčukalns underground gas storage in LV is the only functional storage in the Baltic States that safeguards the stability of regional gas supply (Table 11).

Table 11. The Inčukalns underground gas storage data, 20 September 2022 [90].

Gas in Storage (TWh)	Consumption (TWh)	Injection (GWh/d)	Withdrawal (GWh/d)	Working Gas Volume (TWh)	Injection Capacity (GWh/d)	Withdrawal Capacity (GWh/d)
12.5465	12.3417	26.38	0	24.074	157	74

Prices in the energy sector have oscillated substantially since early 2020, primarily as a consequence of the restrictions on movement and economic activity that many governments passed to limit the public health impacts of the COVID-19 pandemic. As far less people traveled to work and limitations were placed on international travel, demand for transport fuel fell, as did the price of oil. In early 2022, as concerns grew over the Russian conflict with Ukraine, the oil price rose dramatically. By February 24 it surpassed $100 per barrel, and two weeks into the conflict, on March 9, it peaked at $128 per barrel. Prices for other fossil fuels (e.g., natural gas and coal) followed analogous paths at the beginning of the pandemic-caused global economic decline, because the demand from factories was negligible. Said prices went up again at the beginning of 2022 because of sanctions applied to Russia. As disagreements between Russia and Ukraine intensified, the situation only worsened. For instance, the International Energy Agency (IEA) reported that Gazprom's exports to Europe in the last quarter of 2021 plummeted by 25% when compared to the same period of 2020 [91].

Prior to the invasion of Ukraine, governments were preparing to respond to higher energy prices, which were having a serious impact on household income and rendering energy increasingly unaffordable for a growing percentage of the population—even in the relatively wealthy member countries of the Organization of Economic Cooperation and Development (OECD) (Table 12). At the end of 2021, the World Bank noted that "the surge in energy prices poses significant near-term risks to global inflation and, if sustained, could also weigh on growth in energy-importing countries" [92,93].

Table 12. Average monthly electricity prices (including taxes) for household consumers in the Baltic States (Eur per MWh) [94].

Country	August 2021	August 2022
Estonia	87.03	361.35
Latvia	87.32	467.75
Lithuania	87.74	480.39

To deal with the energy crisis, net importers will need to find reasonable ways to transform into more sustainable economies while avoiding the social risks of more expensive energy. The EU has been vocal in its dedication to the energy transition; however, over the years, it has increased its dependence on Russian energy, as domestic production has declined and investment in renewable energy continued to be insufficient. Given that the substantial transition away from fossil fuels requires adherence to the Paris-aligned pathways, European dependence on Russia's resources is potentially temporary, but currently Russia is still amongst the main providers. Due to the self-initiated conflict, Russia's income from the trade in fossil resources has decreased significantly. The Russian regime will certainly try to find solutions to maintain its economic and political power, and seeing the regime's actions, any means to achieve the goal cannot be ruled out, even if it means complete isolation of Russia from the surrounding world.

To stabilize the energy sector, the Baltic States examine the possibilities of installation of units for generation of electricity from nuclear power. In this respect, EE is a step ahead of the other Baltic States, as Fermi Energia (EE) intends to collaborate with Fortum (Finland) and Tractebel (Belgium) to research the SMR development potential with a vision to employ the technology in the 2030s [95]. Fermi Energia is a privately owned SMR deployment company, seeking the first SMR deployment in the EU. It wants to build the plant in EE, arguing that it offers both carbon neutrality and security of power supply to EE, LV, and LT. The Baltic SMR is seen to become a necessity to secure electricity for the region because EE, LV, and LT can desynchronize from the Russian electricity grid as soon as by the end of 2025. SMRs constitute a very important element in achieving reliable low-carbon power supplies for the Baltic countries. Simultaneously, the use of nuclear energy results in the production of toxic radioactive waste, the disposal and management of which is a global concern. Therefore, even if nuclear power plants can considerably mitigate CO_2 emissions, the potential risks of operating them may not be worth it. The United States (US) and LV in a joint statement on 4 April 2022, announced a new partnership under the Foundational Infrastructure for Responsible Use of SMR Technology program [96]. The cooperation will focus on the transfer of knowledge from public institutions, industries, scientific institutes, and academia. This knowledge will be used to develop a strategy and conduct technical discussions focused on developing the working environment, engaging entrepreneurs, drafting legislation, and presenting SMRs. This cooperation can promote the energy autonomy, energy security, and implementation of the current climate priorities in LV.

12. Discussion

The Baltic States historically have gone through economic prosperity and various crises, of both a global and a local character. For instance, in more recent past, the Baltic States were arguably among the countries most relentlessly affected by the global financial crisis in 2008, but in late 2019 they were faced with yet another hit—the COVID-19 pandemic, when a significant cut in production happened [20–22]. Despite that, meaningful political and economic decisions, attracting foreign funding, and participation in numerous international cooperation projects contributed to the economic growth a great deal. Unfortunately, more intensive economic activity strongly correlates with higher energy use and consumption of natural resources and hence also with higher CO_2 emissions. As a matter of fact, both the economic growth and downturn are clearly reflected in the annual CO_2 emissions throughout the recorded history of the Baltic States.

Although the Baltic States occupy a rather small area in northeastern Europe, the annual CO_2 emissions vary significantly among EE, LV, and LT. LV stands out in this regard, as the CO_2 emissions there have been much lower from the offset since the emissions are being measured. Admittedly, the reliability of the Soviet-era data might be dubious, as the communist regime tended to falsify and withhold information, and thus the data on the actual impact on the climate may not be accurate. In this context, a scientifically interesting topic is to assess the CO_2 emissions in the Baltic States from 1991 onward and describe modern challenges relating to the sustainability and socio-economic, scientific, and integrated approaches to sustainable development. As a matter of fact, the CO_2 emissions have significantly reduced since the SU times. Simultaneously, communicating the climate crisis is still high on schedule, and the expansion of green and clean sectorial approaches to sustainable development are believed to be inevitable for preserving the climate.

The introduction and development of innovative technologies for energy production are essential, especially now (2022), when the use of fossil resources is known to be not only unsustainable but also increasingly expensive [2,92,97]. Achieving energy independence is crucial, because fossil resources can rapidly become unavailable not only because of their depletion but also due to various global or regional political or military conflicts. In this respect, clean and practical energy plays a key role in ensuring a sustainable future without compromising the capabilities of future generations to meet their demands [25]. One such option that the Baltic States should consider is SMRs with a power capacity of up to 300 MW(e) per unit. These modular reactors are much safer than traditional nuclear reactors, as they are cooled by natural convection and gravity coolant feed. This feature guarantees that the reactor will remain safe even under severe accident conditions. Moreover, SMRs can be integrated with wind turbines for power generation, ensuring stability of the energy supply [98]. However, to implement this option, a strict and thoughtful nuclear waste management policy must be developed and followed. It would be most advisable to recycle nuclear waste, thereby obtaining additional energy resources.

Even though climate change is now irreversible, the transition to new environmental conditions can still be made easier for humanity if reckless consumption of fossil resources is kept to a minimum and nations look for environmentally friendly alternatives. The Baltic States take this issue very seriously and are developing and introducing technologies based on renewable resources, including the installation of wind farms and solar panel systems [23,78,83,99]. Despite the fact that these technologies are considered as sustainable, we believe that critical attention should be paid to the origin of such environmentally friendly energy sources, and the technology has to be constantly improved. This is because the components currently used in wind turbines and solar panels contain materials that cannot be recycled and therefore greatly contribute to the global waste problem, but zero waste is known to be one of the challenges to sustainability [82,100]. Moreover, solar technologies also hold rare earth elements, the mining of which itself has an enormously negative environmental impact [84,101–103]. Unfortunately, there is no clear solution to this problem yet. At this moment, the only reasonable choice would be to use resources more wisely, efficiently, and sustainably. This, however, would require a major change in the lifestyle of a modern person, but this necessitates the overcoming of barriers to clean and renewable energy first, which unfortunately transpires very slowly and is subject to backlash from parties involved in the fossil energy sectors [24]. Moreover, less developed countries cannot even afford to strand their assets toward alternative carbon-neutral energy resources; hence, global support and cooperation in this matter is essential.

Part of an immediate temporary solution to carbon emissions in the Baltic States and in Europe as a whole could be the widespread introduction of CCS technologies where possible. This requires substantial support, including financial aid, or else the companies involved in CO_2 emission production would just move their businesses outside the EU and circumvent the legislation. Unfortunately, even this suggestion elicits vast criticism, and its further development is being hampered. Nevertheless, the introduction of CCS technologies in the Baltic States is entirely possible. For instance, due to the geological structure of LV, there are numerous fitting underground structures that could easily be used as CO_2 storage facilities, and enterprises would only have to choose the most justifiable approach for the CO_2 capture and for the delivery system to these reservoirs [50,104]. However, the current national legislation in LV allows only CO_2 capture, and its storage is prohibited by Cabinet regulations due to uncertainties about safe storage conditions. We believe that this legislation has to be reviewed by including the latest research results on the safety of storage and the restriction has to be lifted.

As mentioned above, since the beginning of recorded history of CO_2 emissions in the Baltics, the annual CO_2 emissions in LV have been lower than in EE and LT [35]. At the same time, EE and LT produced similar amounts of carbon emissions until 1991, when, after regaining the independence, it was possible to start independent industrial activities. In general, all decreases and increases in CO_2 emissions followed the same pattern over the same periods in all three Baltic States, which leads to a reasonable conclusion that EE, LV, and LT have been affected by the same large-scale events, such as war, occupation, Soviet five-year plans, poverty, and prosperity, to name a few. The highest impact from the Baltic States on the climate change was during the Soviet occupation, when tens of millions of metric tons of CO_2 were released into the atmosphere. Even though the CO_2 emissions to this day remain on an upward trajectory, the membership in the EU has certainly made it possible to balance and normalize these emissions in the Baltic States, but further decreasing of these emissions is still essential. The Baltic States are already investing in renewable energy, which is a step in the right direction [99]. However, the growing climate crisis demands a much faster decrease in the CO_2 emissions, making technologies that can capture and store away these generated gases an immediate priority.

Two main contributors to the CO_2 emissions within the Baltic States are the energy sector and transport infrastructure, whereas the main support for reducing the given emissions is LULUCF [35]. The largest contributor to the CO_2 emissions in the Baltic States clearly is the energy sector. In detail, this includes electricity and heat generation, manufacture, and construction segments [35]. There are also considerable differences between EE, LV, and LT. In this regard, LV emits the least CO_2 annually, whereas EE emits the most. Furthermore, the CO_2 emissions from the LT energy sector are close to those of EE, making LV the most sustainable among the Baltic States in regard to fossil fuel combustion [26,35]. In EE, the given emissions seem to change considerably from year to year with no clear direction toward an increase or decrease. Most of the energy-related emissions in EE are directly related to the fuel combustion in public electricity and heat production; however, over the years the percentage has considerably declined [35]. As mentioned above, the energy sector in LV emits the least CO_2 emissions amongst the Baltic States, and this is due to the use of alternative energy sources for electricity and heat generation. By comparison, the energy sector in LT has been producing a similar amount of CO_2 emissions annually since 1999, and as in LV, the given emissions appear stable with no marked downward or upward trend [35]. At the same time, the fuel combustion in public electricity and heat generation in LT in recent years is the most effective among the Baltic States. In 2019, it accounted for just 8% of the energy-related CO_2 emissions. In fact, these emissions have been showing a downward trend since 1991 [35]. However, considering the current global state of fossil resources and the increase in electricity production price, these emissions will most likely increase again.

Another critical topic is the transportation-related CO_2 emissions. Fuel combustion in transportation produces an enormous amount of CO_2 emissions annually, and this volume is on the rise worldwide. However, in the context of these emissions, major differences can be discerned amongst the Baltic States. The size of the car fleet has grown substantially since 1991 in all three countries, but so has the quality of cars. Thus, the number or motor vehicles does not directly correlate with the produced CO_2 emissions, all the more so nowadays when the transition to electric cars is taking place [35]. For instance, in EE, the transportation-related emissions account for approximately 4 to 7% of the total emissions. Furthermore, in recent years, no upward trend in these emissions can be noticed, thus evidencing possibly effective and sustainable policies regarding motor vehicles. There was, however, an upward trend for the transportation-related emissions up until 2007. The transportation-related emissions in EE at the current date are the lowest among the Baltic States [35]. By comparison, in LV, the transportation-related CO_2 emissions are considerably higher. The maximum of the given emissions was reached in 2008 (3.59 million tCO_2eq), when they accounted for 19% of the total emissions produced by the country. In fact, in LV, transportation-related emissions account for the highest percentage of the total emissions among the Baltic States. Moreover, an upward trend for these emissions can be noticed [35]. Therefore, the transport sector and the related environmental and climate impacts in LV should be reviewed without delay. The critical evaluation of the transport infrastructure and quick adoption of new and sustainable policies are even more crucial for LT. In LT, the transportation-related CO_2 emissions are the highest amongst the Baltic States and still keep increasing. For example, in 2019, transport-related emissions accounted for 6.2 million tCO_2eq (16% of the total CO_2 emissions), almost doubling the peak amount of LV in 2008 and nearly approaching the total annual emissions of LV [35]. A significant part of the CO_2 emissions coming from fuel combustion in transport is directly related to heavy duty trucks (freight transport), and hence their immediate reduction is unlikely. However, in the future, freight transport may be diverted to electric or battery-electric freight trains, which can substantially reduce the given emissions and significantly contribute to reduction of the transport-related emissions. The International Energy Agency (IEA) proposes that, beginning in 2035, all new cars and half of all trucks have to be equipped with an electric motor. To meet the European Green Deal emission targets, the incentives for zero- and low-emission cars in the EU will be phased out in 2030. The EU management argues that electric engines will no longer be competing with petrol and diesel engines. Therefore, the demand for government aid will no longer be relevant. The Baltic States, being the part of EU, will follow these initiatives. For instance, LV has set a sharp cut in vehicle CO_2 emissions. The guidelines developed by the Ministry of Transport show that the transportation-related emissions must be reduced by 18% by 2023 and by 23% by 2027 [105]. Unfortunately, the attainability of such a reduction is questionable in such a brief time. Furthermore, there is no clear vision of how to achieve this target. However, it is clear that it would require radical changes in road transportation policies. One of the most effective and extreme measures would be the replacement of the car fleet. But the car fleet in LV is on average 15 years old, and it is improbable to replace it with electric cars on such short notice. Moreover, the road infrastructure in LV at current date is not yet suitable for electric cars.

The amount of GHG emissions in waste management is determined for four types of waste management, which are the following: solid waste disposal, biological recycling of solid waste, incineration at plants and open incineration of waste, and wastewater treatment and discharge. In EE, the GHG emissions from the waste management sector are gradually declining. The lowest CO_2 emissions occurred in connection to a decreasing amount of waste deposited in landfills. In addition, low CO_2 emissions might be related to decreased paper and sludge disposal. Simultaneously, the highest CO_2 emissions are related to solid waste disposal [59].

LULUCF is a GHG inventory sector that encompasses emissions and removal of GHGs arising from direct human-caused land use, such as settlements and commercial uses, land use change, and forestry activities [83]. This GHG inventory sector has a substantial impact on the global carbon cycle, and activities within this sector can either add or remove CO_2 from the atmosphere, changing the climate [106]. Furthermore, LULUCF is of critical importance for biodiversity [107]. Transformation of forests into agricultural lands not only delimits biodiversity but also contributes to global climate change [108]. However, the emissions from fossil fuel combustion clearly contribute much more, and reducing them must be a priority [109]. Summarizing the data collected, however, it can be concluded that LULUCF has made a significant contribution to reducing the carbon footprint of the Baltic States. This even allowed LV to be a carbon-neutral country for several years (1992–2003), if adding up all emissions and removals of CO_2 [35]. Unfortunately, the impact on the reduction of CO_2 emissions is declining. Hence, development and implementation of sustainable strategies have to be considered as soon as possible.

The recovery of the Baltic States from the idiosyncrasies of 50 years of the SU's economy led to more sustainable patterns of production and consumption, improved national and regional sustainability and stability, mitigated degradation of ecosystems and contaminant risks to human well-being, all of which is consistent with the significant reduction of CO_2 emissions. At the same time, industrial development and energy crises are still an issue that requires a solution. Moreover, development and implementation of national policies for sustainable development are crucial for mitigation of the climate crisis. Future actions must include the implementation and monitoring of policies for sustainable development, changing of consumption and production patterns, education and awareness of sustainability and effects of global climate change on development and sustainability [89].

The Baltic States are members of the EU since 2004, and hence it is important to measure how the membership has changed the carbon footprint. Each of the Baltic States, during the 50 years of the Soviet occupation, generated tens of millions of metric tons of CO_2 emissions annually. In fact, the Soviet industry had the greatest negative impact on environmental and climate sustainability in the recorded history in the region, especially as it approached its collapse in 1991. Nowadays, the EU is working to reduce its carbon footprint and support environmental sustainability through a variety of legal measures. No matter what, climate change is an all-encompassing global issue, and no union can solve it on its own. The preservation of the planet requires the unity of the world's economies for a common future. In this perspective, the EU, US, and China are strengthening cooperation on climate and environment with varying degrees of success. One of the ultimate solutions to the climate crisis could be the development of a degrowth economy. However, this cannot be accomplished immediately, nor even within the next decade. Such economy also requires a complete lifestyle change and a change in human thinking. To concede, contemporary people do not seem to be ready for that, even in the event of an extreme and inevitable disaster. Such a change of the world is possible only for new generations. Meanwhile, however, we are the ones who have to develop the mechanisms to get there.

13. Conclusions

It is generally acknowledged that the collapse of the SU significantly reduced the negative environmental and climate impact of fossil fuel consumption in the Baltic States.

However, with the restoration of national independence in 1991, each country developed an independent energy and industrial policy as well as national policies in respect to the use of fossil resources, resulting in major reduction in CO_2 emissions among the post-Soviet states. At the beginning of the 21st century, further curbing of the CO_2 emissions took place in view of joining to the EU and thus adhering to international regulations and policies. In this context, future policies should include specialized provisions that consider the specificities of national economies.

The collapse of the SU has significantly reduced the carbon footprint of the Baltic States, whereas the membership in the EU has made it possible to balance and normalize the CO_2 emissions. However, to mitigate climate change, further reduction of emissions is essential. To recover the nature and climate from the reckless use of fossil resources for many decades, the implementation of well-thought-out and sustainable policies is crucial.

The transition of the Baltic States from the centrally planned Soviet economy led to more sustainable patterns of production and consumption, improved national and regional sustainability and stability. The change is also reflected in the recovery of ecosystems and reduced contaminant risks to human well-being. However, this does not mean that the climate crisis has been adequately addressed. In fact, the industrial development and energy crisis need constant attention, especially at present when the fossil resource situation is very precarious. In this regard, the development and implementation of national policies for sustainable development are crucial not only for the climate change mitigation but also for the sustainability of the national economy. Future legal actions must include further implementation and monitoring of policies for sustainable development and changing the consumption and production patterns. If all these measures are affected considerately, then the adaption to the forthcoming environmental changes can be made without endangering human existence. Moreover, we believe that special attention also has to be paid to the education and awareness of sustainability and effects of global climate change on development and sustainability. The EU leadership must take critical decisions on GHG emissions while climate change has still not gone too far. The measures may be costly to implement and without any real support from the industry or society, but they will certainly pay off eventually, and this has to be clarified and proven by factual information made available to the public. By the same token, those who implement reforms must really want to preserve the future of the planet, not to just make profit from alternative energy sources while they are fashionable. This paper calls for global cooperation between scientists and industries involved in the CO_2 emission reduction. By learning from success stories and improving them with transferrable aspects, a high degree of sustainability and climate neutrality can be reached.

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