Global and Regional (Baltics) Carbon Dioxide Emissions

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Carbon dioxide (CO2) is one of the major greenhouse gasses (GHGs), which, if released into the atmosphere, is reflecting infrared radiation back to the Earth's surface and traps the radiant heat. Therefore, excessive CO2 emissions are of global concern as they are amongst the main contributors to climate change.

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1. Introduction

Carbon dioxide (CO_2) is one of the major greenhouse gasses (GHGs), which, if released into the atmosphere, is reflecting infrared radiation back to the Earth's surface and traps the radiant heat. Therefore, excessive CO_2 emissions are of global concern as they are amongst the main contributors to climate change. Furthermore, global trends of CO_2 emissions show annual growth, which is then naturally followed by an annual increase in the average temperature. Recent data indicate that in October 2021, the increase of CO_2 concentration was 2.46 ± 0.26 ppm y^{-1}, but according to the National Oceanic and Atmospheric Administration (NOAA) 2020 annual climate report, the temperature (land and ocean combined) has increased at an average rate of 0.08 °C per decade since 1980 [1][2]. The consequences thereof are gradual warming and drying of the climate that, among other threats, is causing major and devastating wildfires worldwide, which in fact release massive amounts of CO_2 to the atmosphere themselves and make carbon emissions into even a larger issue [3]. In reality, an ever-increasing CO_2 concentration in the atmosphere has a number of other secondary effects on the environment, such as changes in the hydrogeological cycle, increased occurrence of various extreme climate events, sea-level rise, species migration, harvest loses, increased occurrence of infectious diseases, and others [4][5][6][7][8].

The evidence suggests that the atmospheric CO_2 concentration has increased from the pre-industrialization level (1750) of 280 ppm to 413.3 ppm in 2021 [9][10]. Furthermore, the rate of CO_2 growth currently is rapidly speeding up and, according to the future predictions, CO_2 concentration will continue to increase and can reach 670 ppm by year 2100 if no action is taken as soon as possible [9]. Essentially, far-reaching measures are required to deal with this growing climate change emergency. It is crucial that forward-looking measures to reduce the impact of climate change caused by increasing CO_2 concentration include alternative, green, and sustainable energy sources. In addition, incentives to increase energy efficiency are required as indicated in recent political declarations of the European Union (EU), United Nations (UN), and other international organisations [11][12][13].

Given that the replacement of energy sources is a slow, gradual, and yet expensive process, measures to absorb industrially produced CO_2 emissions are amidst current primary tasks. At the same time, actions for energy source transition must also be implemented immediately, in parallel with emission reduction. The most sustainable strategies to limit these CO_2 emissions is carbon capture and storage (CCS) and, where it is possible, the subsequent CO_2 utilization [14].

2. Global and Regional Carbon Dioxide Emissions

Global CO_2 emissions are the primary driver of climate change. It is universally recognized that to avoid irreversible damage to the climate, the civilization immediately needs to reduce GHG emissions. If no action is taken as soon as possible, climate change will fundamentally reshape the society and geopolitical relations; in perspective, it will destroy economies and health care systems. This is a global and comprehensive issue, which everyone must be involved in tackling. Unfortunately, due to a lack of public and political support for specific pro-environmental policies, it has been an endless point of contention in international discussions with strong resistance against immediate action [15][16][17].

The majority of anthropogenic CO_2 emissions are produced in urban areas, which therefore is a challenge for a sustainable development. It was expected that during the COVID-19 pandemic in 2020 and 2021, with continuation in 2022, when due to worldwide lockdowns the industry was significantly less active, CO_2 emissions would decrease [18]. However, the decrease did not stand out from any natural CO_2 variations observed before and the average growth rate kept increasing (**Table 1**) [19]. In addition, global wildfires that seem to increase annually by the extent of area they occupy were producing perhaps similar if not higher CO_2 emissions than any possible decrease resulting from this pandemic.

Table 1. Mean annual CO_2 growth rates (ppm y^{-1}) for Mauna Loa for the last decade from 2011 through 2021 [10].

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Growth (ppm)	1.92	2.65	1.99	2.22	2.90	3.03	1.92	2.86	2.48	2.31	2.46 [1]

[1] Data for October 2021.

Most of the anthropogenic CO_2 emissions on the planet are produced in the Northern Hemisphere, with the largest emitters being Eastern Asia, Western Europe, and the Northeast of North America, where GHG is a major by-product of industrial activities. In general, five global economic sectors with the highest produced CO_2 emissions are:

- Transportation (predominantly non-commercial motor vehicles);
- Electricity production (fossil fuel burning);
- Industry (manufacturing, processing, etc.);
- Residential (heating, cooking, etc.);
- Agriculture (farm equipment, agricultural machinery, etc.).

Although these sectors have varied in correlative sequence depending on the given state economy, emissions within these sectors fundamentally reside in fossil fuel burning. Even though the agriculture is commonly seen as a non-fuel contributor of CO_2 emissions, the agricultural machinery, such as harvesters, tractors, and other technologies are clearly a significant contributor of fossil fuel CO_2 emissions, especially in top agricultural producing countries. In view of this, the largest producers of fossil fuel CO_2 emissions worldwide in 2019 were China, United States (US), India, and Russia [20]. Even though statistics for 2020 at the time of this review had not yet been compiled, predictable trends were similar to those before.

Trends of the annual atmospheric CO_2 emissions typically are measured at the Mauna Loa observatory. Mauna Loa is an island of Hawaii, isolated in the middle of the Pacific Ocean at over 3 km above sea level. The CO_2 measurements are performed at the upper north face of Mauna Loa volcano, where there is no impact from any industrial objects or forests that may cause increase or decrease in CO_2 concentration within their vicinity. The CO_2 sensors are positioned so they can sample an incoming breeze directly from the ocean, unaffected by any factors on the island [21]. Recent measures indicated that the monthly average Mauna Loa atmospheric CO_2 in September 2021 was 413.30 ppm, which was nearly 2 ppm increase from the year before, when in September 2020 it was 411.52 ppm [10]. Even the worldwide suspension of industry in 2020 due to COVID-19 did not yield any significant reduction in CO_2 emissions and trends keep showing annual increase, which therefore requires an immediate action to slow down this trend. In 2020, global CO_2 emissions declined by 5.8%, which

is the largest decline ever recorded; however, global energy-related CO_2 emissions remained high and contributed to CO_2 emissions reaching their highest ever average concentration in the atmosphere at 412.5 ppm at the end of the year, followed by yet another increase in 2021 [22]. The only option to slow down climate change is to halt the annual increase of CO_2 emissions, which requires the implementation of carbon neutrality policies, prudent use of fossil resources, and transition to environmentally friendly energy sources. The future of the Earth requires creating and sustaining an effective strategic dialogue among governments, industries, and societies worldwide.

Even though the carbon emissions vary greatly from country to country, reducing these emissions must be a global effort. As for the CO_2 emission level in the Baltic States, it is determined by the range of energy sources of the region. The range, however, differs significantly among the three Baltic States (**Table 2**) and thus the emissions there are also contrasting. Nevertheless, all three countries are gradually making greater use of renewable resources, especially in electricity production, where such energy sources as solar, wind, hydropower, biomass, and others are put into practice, and Latvia in this respect is the leader with 61.11% share of low-carbon sources in the electricity production.

Table 2. Share of electricity production (%) in the Baltic States in 2020. Fossil fuel, low-carbon sources (solar, wind, hydropower, biomass, waste, geothermal, wave, tidal) [23].

Share	Estonia	Latvia	Lithuania
Fossil fuel	64.79	38.89	42.46
Low-carbon sources (renewables)	35.21	61.11	57.54

Furthermore, the Baltic States have ratified the Paris Climate Agreement and have defined their strategic climate targets for emission reduction; this among all includes majorly reducing the use of fossil resources (oil, coal, and gas) in energy production (**Table 3**) [23][24].

Table 3. Energy consumption by source (TWh) in the Baltic States in 2019 [23].

Share	Estonia	Latvia	Lithuania
Oil	18	22	38
Coal	39	<1	2
Gas	4	13	22
Hydropower	<1	5	<1
Wind	2	<1	4
Solar	<1	0	<1
Other renewables	3	2	1

While the share of energy sources differs amongst the Baltic States (**Table 3**), all three countries are highly dependent on energy imports. In this regard, Estonia has the lowest share of imports due to its access to domestic oil shale resources [24]. In comparison, in Latvia a major part of the total primary energy supply comes from firewood, but in Lithuania until 2009, more than 70% of primary supply was provided by nuclear energy (zero emission energy). The last Lithuanian nuclear power plant (Ignalina), however, was decommissioned in 2009, due to its similarities to the Chernobyl power plant [24]. Differences in the

use of energy sources are reflected in distinct CO_2 emissions amongst Baltic countries. For instance, according to Eurostat (last update on 17 August 2021), in 2019 the Estonian energy sector produced 11,975.96 tCO_2, Latvia 6975.52 tCO_2, but Lithuania caused the release of 11,240.45 tCO_2 into the atmosphere [25].

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