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Comparison of Greenhouse Gas Emissions in North Macedonia over the last Three Decades

Monika Lutovska[a], Vladimir Mijakovski[b] and Nikola Rendevski[c]

[a]Faculty of Technical Sciences, University „Mother Teresa", Skopje, MK, monika.lutovska@unt.edu.mk
[b]Faculty of Technical Sciences, University „St. Kliment Ohridski", Bitola, MK, vladimir.mijakovski@tfb.uklo.edu.mk
[c]Faculty of Information and Communication Technologies, University „St. Kliment Ohridski", Bitola, MK, nikola.rendevski@fikt.edu.mk

Abstract: Greenhouse gases (GHGs), as the most significant driver of observed climate change are attributable primarily to human activities. Worldwide, net emissions of GHGs increased by 35% in the last three decades. In order to identify the major sources and removals/sinks of GHGs, North Macedonia has conducted a National Inventory of anthropogenic emissions. In this study, a comparison between the current emission trends of the main pollutants PM10, SO_2 and NOx, and their concentrations measured in 1990, is made. PM10 emissions are continuously decreasing, reaching a level of 13.4 kt in 2020, or a decrease of 72% compared to 1990. Since then, NOx emissions have decreased by 56% and in 2020 reached a level of around 20 kt. The main emission source of SO_2 in 2020, is as expected energy industries, contributed with 92% in 1990, and with 95% of the national total SO_2 emissions in 2020. These emissions have not reached values below the defined emission ceiling provided by the Gothenburg protocol, because the expected implementation of a desulfurization unit in the REK Bitola Power Plant, according to the oldest sulfur protocol, has not yet been realized. Additionally, the declared crisis situation in the Energy, and the predicted increased use of coal and fuel oil for electricity and heat production in 2022, will further increase SO_2 concentrations.

Keywords: greenhouse gases/ pollutants/ PM10, NOx, SO_2 emissions.

1. Introduction

The natural greenhouse effect is a phenomenon that maintains the warmth of our planet, which, through the normal functioning of the physiological functions of all living organisms, enables life on Earth [1]. In the last three decades, net emissions of greenhouse gases (GHGs) increased by 35%, worldwide [2]. This is the most significant driver of observed climate change that is a serious threat to the environment and people's health, wellbeing and quality of life, reducing natural resources and harming the economy and infrastructure [3]. The international action to address climate change is provided by the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, as an international agreement that sets binding targets for 37 industrialized countries and the European Community for reducing greenhouse gas emissions for six gases: CO2, CH4, N2O, HFCs, PFCs и SF6 [4].

Due to developing and publishing the national emission inventories of GHGs, as a key element for assessing progress towards meeting commitments and targets, developed countries have specific commitments to reduce total emissions compared to emissions from 1990 [4]. So, for tackling climate change, individual countries need to estimate how much emissions they emit and how much they are likely to emit in the future [4]. In order to identify the major sources and removals/sinks of GHGs, North Macedonia has conducted a National Inventory of anthropogenic emissions [5]. Climate change issues are incorporated into the Law on Environment, including details on the preparation of GHG emissions Inventory as well as an Action plan on measures to reduce the increase of GHG emissions and to mitigate the adverse impacts of climate change [5]. On the other hand, the obligation to report on emissions inventory, that North Macedonia has to the Convention on Transboundary Air Pollution and its eight protocols as well as the European Environment Agency (EEA), requires annual reporting on the emissions of main air pollutants covered by the Convention. Limit values of air pollution levels, according to EU legislation, are the strictest rules.

2. Main air pollutants

It has been shown that, although in traces, the presence of harmful substances has a significant harmful effect on human health, the biosphere and other material goods. There are substances in the air, such as: nitrogen oxides (NOx), sulfur dioxide (SO_2), ammonia (NH_3), carbon monoxide, particulate matters, heavy metals, hard degradable organic compounds, etc., that have a direct or indirect negative impact if their presence is in concentrations higher than normal.

Carbon dioxide (CO_2) is naturally present in the atmosphere as part of the Earth's carbon cycle - the natural circulation among the atmosphere, oceans, soil, plants and animals. It is the primary greenhouse gas emitted through human activities that alter the carbon cycle in two ways; by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are exclusively responsible for the increase that has occurred in the atmosphere since the industrial revolution. Fossil fuel use is the primary source of CO_2 [7]. About three-quarters of these emissions are due to fossil fuel burning [6]. It can also be emitted from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing for agriculture and degradation of soils [7].

Suspended particles (PM), as one of the most common pollutants in the air is a mixture of solid and liquid particles, suspended in the air with wide range of sizes and chemical structure. They can originate from anthropogenic sources (industrial processes, combustion of fossil and biofuels - vehicles, power plants and households, transport and waste incineration), or natural sources (sea salt, desert areas dust, wildfires, volcanic ash pollen). According to the inventory of suspended particles, domestic heating accounts for 51% (PM2.5) and 35% (PM10) of particle emissions, especially due to incomplete combustion of wood in old stoves. Mainly, heat and electricity production processes, which account for about 25% (PM2.5) and 22% (PM10), as well as production processes in metallurgy, are key sources of suspended PM emissions [8].

Sulfur dioxide (SO_2), is a colorless, toxic gas with sharp and irritant odor, and acidic properties. Its toxic impact on humans occurs at mass concentration in the air of about 6 mg/m^3 or more, causing serious health problems. Today, SO_2, is considered as one of the main pollutants in the atmosphere from anthropogenic sources, and thus intensive measures are taken to reduce its emissions. Considering that electricity production is the main source for SO_2 emissions, its emissions trends vary and depend highly on coal consumption. There are many industries that emit significant quantities of SO_2 in the ambient air: the oil industry emits SO_2 or H_2S during refining of petroleum products, electricity production plants that use coal with high concentrations of sulfur, sulphide smelters, installations for production of paper and pulp. [8].

Nitrogen monoxide (NO) and **nitrogen dioxide (NO_2),** or general NO_x, are the most important nitrogen oxides, that occur as an air pollutant. NO_2 reactive gas is formed by oxidation of nitrogen monoxide (NO). A major source of NO and NO_2 is high temperature combustion process (processes that are carried out in motor vehicles and power plants). The amount of NO_x is increased in winter due to intensive use of fossil fuels. The largest amounts of nitrogen oxide emissions in North Macedonia are emitted during the production of electricity and thermal energy (48%), due to the dominant electricity production with coal as a fuel. Traffic emissions, also, have large share (38%) of total emissions of this pollutant [8].

3. Global greenhouse gas emissions trends

GHGs and especially CO_2 concentrations in the atmosphere have increased since the beginning of the industrial era [4]. The majority of the world's emissions result from industry, electricity generation, transportation, and other forms of energy production and use [2]. The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. Certain industrial processes and land-use changes also emit CO_2 [9].

Given that тhe European Union's inventory is based on the inventories supplied by Member States, the total estimate of the EU GHG emissions should accurately reflect the sum of Member States' national greenhouse gas inventories. Member States are responsible for choosing activity data, emission factors, correct application of methodologies provided in the 2006 IPCC Guidelines, but also for establishing quality assurance/quality control (QA/QC) programmes for their inventories. In 2019, total GHG emissions were 28.3 % (-1 602 million

tonnes CO_2 equivalents) below 1990 levels. Emissions decreased by 3.9% or 166 million tonnes CO_2 equivalent) between 2018 and 2019 (Fig. 1).

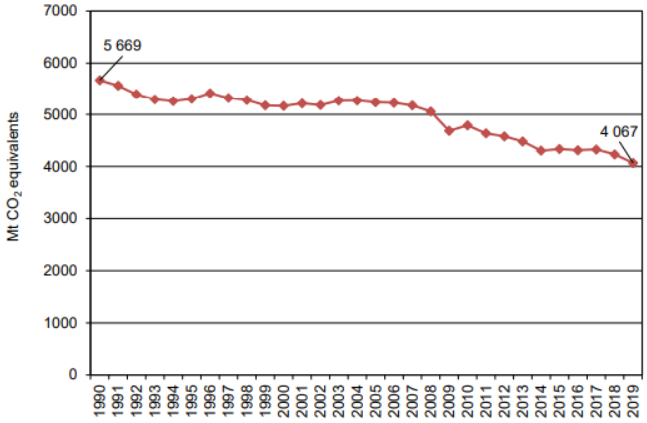

Figure 1. EU-27, Iceland and the UK (EU-KP) GHG emissions (excl. LULUCF)(1990-2019) [Source: EU NIR May 2021]

Total GHG emissions (excluding Land use, land-use change, and forestry (LULUCF) and excluding international aviation) decreased by 1602 Mt CO_2 eq. since 1990 (or 28.3 %) reaching their lowest level during this period in 2019 (4067 Mt CO_2 eq.). There has been a progressive decoupling of gross domestic product (GDP) and GHG emissions compared to 1990, with an increase in GDP above 64 % alongside a decrease in emissions of about 28 % over the period (-26 %, when including international aviation). The reduction in GHG emissions over the 29-year period was due to a variety of factors, including the growing share in the use of renewables, the use of less carbon intensive fossil fuels and improvements in energy efficiency, as well as to structural changes in the economy. These have resulted in a lower energy intensity of the economy and in a lower carbon intensity of energy production and consumption in 2019 compared to 1990. Demand for energy to heat households has also been lower, as Europe on average has experienced milder winters since 1990, which has also helped reduce emissions [10].

4. North Macedonia national emissions

The requirement for the preparation of national emissions projections derives from the obligation of the Gothenburg Protocol (North Macedonia is a party to the protocol starting in 2014). The emissions projections were to be submitted by March 2017, and every two years thereafter, according to the NEC directive 2016/2284/EU, a National Air Pollution Control Program should be prepared.

Figure 2. State automatic ambient air quality monitoring system

The Ministry of Environment and Physical Planning in North Macedonia manages the State automatic monitoring system for ambient air quality, which consists of 17 fixed and 1 mobile monitoring station throughout the country, located on following places: 5 measuring stations in Skopje, 2 measuring stations in Bitola, and one measuring station in Veles, Municipality of Ilinden, Kichevo, Kumanovo, Kochani, Tetovo, Kavadarci, Gostivar, Strumica and in the village of Lazaropole, Figure 2, [11].

Towards the Convention on transboundary air pollution and its eight protocols as well as the European Environmental Agency (EEA), our country is required to annually report data on emissions of the main air pollutants covered by the Convention. Considering that limit values of air pollution levels are the strictest rules, in a case of exceeding the limit values, measures to reduce the levels of pollutant concentrations must be defined and enforced by the authorities. In addition, for the protection of human health and vegetation, critical levels have been defined, Table 1, [10].

Table 1. Limit values of air pollutants

Pollutant	Averaging period	Limit values	Allowed number of exceedances in a year
Sulfur dioxide, SO_2	1 hour	350 µg/m^3	24
	24 hours	125 µg/m^3	3
Nitrogen dioxide NO_2	1 hour	200 µg/m^3	18
	1 year	40 µg/m^3	-
PM10 suspended particles	24 hours	50 µg/m^3	35
	1 year	40 µg/m^3	-

4.1. PM10 emissions

In 1990, emission trend for national total PM10 emissions amounted to 48 kt. Since then, the emissions are continuously decreasing, reaching a level of 13.4 kt in 2020 or a decrease of 72% compared to 1990. The main reason for the decrease is declining emissions from Industrial Processes (Ferroalloys Production), but also decreased use of solid fuels since 2013. Namely the deep presented in the period 2001-2002 is due to limited operation of Ferroalloys production industry, Figure 3.

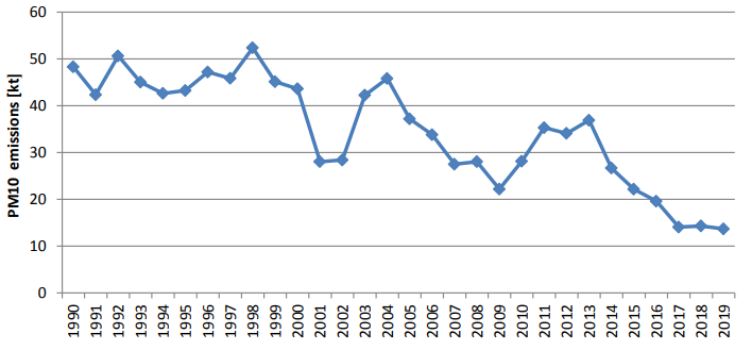

Figure 3. National total PM10 emissions 1990-2019

The Ferroalloys production has decreased because of a limited capacity of an installation producing ferrosilicon, between the end of 2014 and during 2015. This installation did not fulfill the obligation regulated in the IPPC license for installation of a filter for reduction of dust emissions. Additionally, this installation has been closed in November 2016 due to non-compliance with the activities for air quality protection set down in the IPPC permit referring to installation of dust filter (Fig.3), [12].

4.2. SO_2 emissions

The national total SO_2 emissions in 1990, amounted to 112 kt. In the period 2011–2020 there was a decrease of emissions due to the decrease of coal consumption and lower capacity of work of the second largest (by capacity) power plant REK Oslomej, attributed to limited amounts of coal. In 2019 there is a sharp increase due to increased use of coal with higher sulfur content and higher production of electricity compared to 2018. But in 2020 the emissions are again decrease due to lower consumption of coal and heavy fuels, but not on the

level of 2018. Compared to 2020, emissions have decreased by 18%, and compared to 1990, emissions have decreased by 16%. (Fig.4) [12].

Concerning sulfur, North Macedonia is a party to the three protocols under LRTAP convention. The emissions of SO_2 in 2020 are below the base year 1990 emissions and the respective ceiling in 2010, which reflects compliance with the 1994 Protocol on further reduction on sulfur and the Gothenburg protocol.

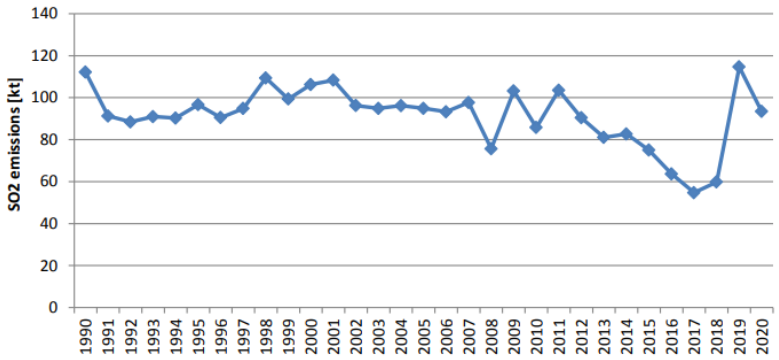

Figure 4. Total national SO_2 emissions 1990-2020

The country is still in non-compliance with the 1985 Protocol on reduction of sulfur emissions or their trans-boundary transmission by at least 30 percent, because the emissions have not been reduced by the designated percentage between 1980 and now. Because the major source of this pollutant is power production, compliance with the oldest protocol on sulfur is expected to be achieved with installation of a desulfurization unit in the Power plant REK Bitola. According to the agreement with the Energy community, the compliance with SOx emission limit values, which will also mean compliance with the protocol, should be reached with implementation of a desulfurization unit, that should be implemented in accordance with the time dynamics set in the revised National Plan for reduction of emissions from large combustion plants approved by the Government in April 2017. In 2020, SOx emissions have not reached values below the defined emission ceiling, since desulfurization unit is still not implemented. [12].

4.3. NOx emissions

In 1990, national total NOx emissions amounted to around 45 kt. Since then, the emissions decreased by 56%. In 2020 emissions were on the level of about 20 kt. The reasons for the decrease are essentially to be found in the significantly declining emissions from the energy sector (electricity and heat production) and manufacturing industries. The sharp fall of emissions between 2012 and 2015 is owned to the lower consumption of coal in the major power plants and the modernization of boilers in the power plant REK Bitola. In the period 2016–2018, the emissions are stable. Compared to 2020, emissions in 2019 are lower for 13% due to lower fuel consumption in REK Bitola and lower consumption of low quality coal. [Fig.5].

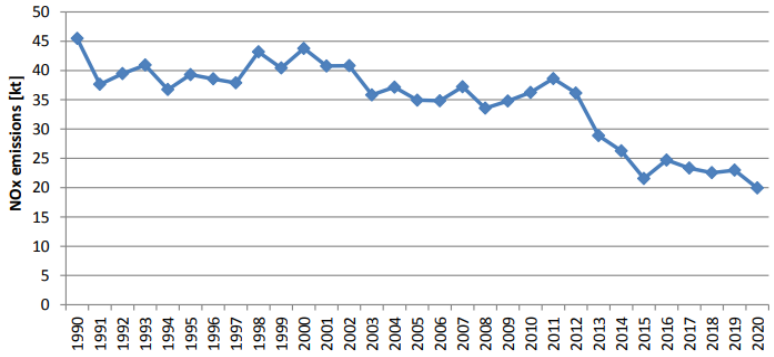

Figure 5. Total national NO_x emissions 1990-2020

The target value for NOx according to the Gothenburg Protocol for the year 2010 is 39 kt. Since 2014, North Macedonia as a part of the protocol regularly meets that target value and the emissions trend is stable. The country is also in compliance with the Protocol in controlling the nitrogen oxides or their trans-boundary fluxes, meaning that NOx emissions in 2020 are less than the NOx emissions reported for 1987. [12].

5. Main sector of pollutant emissions

5.1. PM10 emission sources

The main emission sources for PM10 in 2020 are sectors for residential and administrative heating, with a share of 45% in total PM10 emissions (25% in 1990). Industrial processes and product use (mainly ferroalloys production) share with 6% (48% in 1990), while energy industries share with 19.6% (18% in 1990). The sector Agriculture, with a share of 17% in 2020 (6% in 1990), is also contributing to the total PM10 emissions.

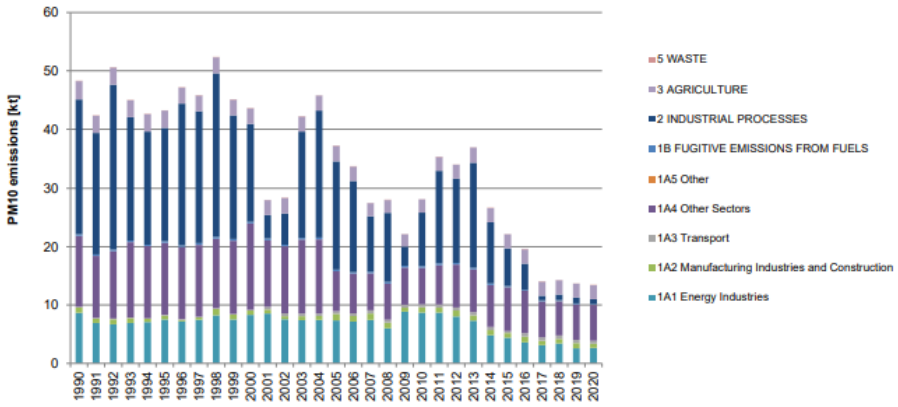

Figure 6. PM10 emissions in North Macedonia 1990–2020 by sectors

As a result, a conclusion can be drawn that while in the past the major source for PM10 was the industry sector, mainly ferroalloys production, in the latest years that the major contributor is combustion of fuels in residential sector and administrative capacities. Transport sector is contributing with 3.6% in PM10 on national level but has higher impact on local emissions. Fugitive emissions and Waste are minor sources of PM10 emissions.

5.2. SO_2 emission sources

Almost all SO_2 emissions are resulting from Energy sector. Consequently, the main emission source in 2020 is as expected Energy industries (Public electricity and heat production), contributed with 92% in 1990, and with 95% in 2020 of the national total SO_2 emissions. About 5% in both 1990 and 3.6% in 2020 of the total emissions are stemming from Manufacturing industries. Other sectors produce minor SO_2 emissions.

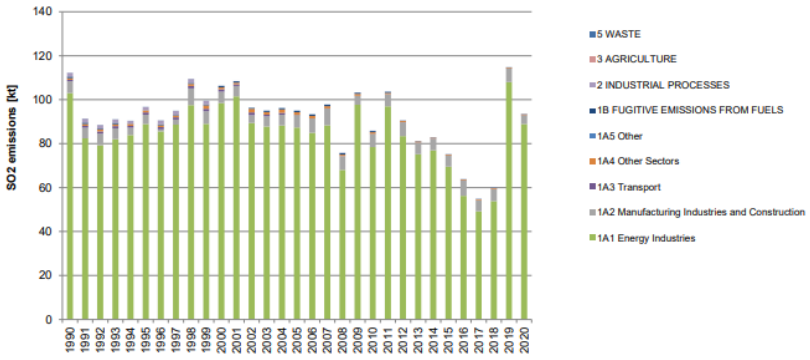

Figure 7. SO_2 emissions in North Macedonia 1990–2020 by sectors

Because the major source of this pollutant is power production, compliance with the oldest protocol on sulfur is expected to be achieved with installation of a desulfurization unit in the Power plant REK Bitola.

According to the agreement with the Energy community, the compliance with SOx emission limit values, which will also mean compliance with the protocol, should be reached with implementation of a desulfurization unit, that should be implemented in accordance with the time dynamics set in the revised National Plan for reduction of emissions from large combustion plants. [12].

5.3. NOx emission sources

Almost all NOx emissions are coming from the sector Energy, and the main emission sources in the national total NOx emissions in 2020 are Transport which contributed with 40% (21% in 1990), Energy and manufacturing industries with 22% (53% in 1990) and Construction with 27% (20% in 1990), respectively. As opposed to 1990, when the Energy sector and heat production were the largest source of emissions, in 2020 the primary source of emissions is found to be transportation, due to the increase of the number of vehicles during the reporting period and the lower consumption of coal and heavy fuel oil. (Fig. 8).

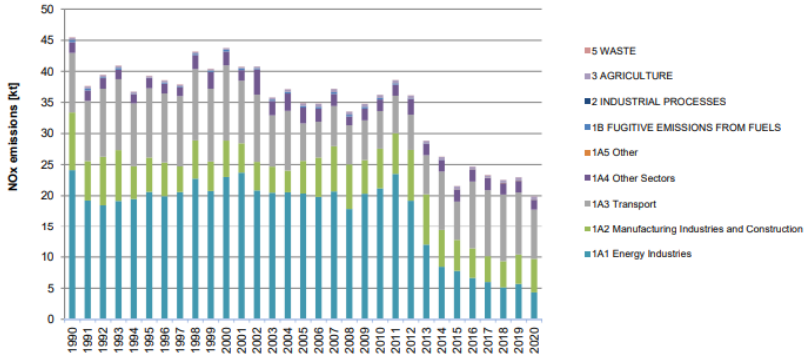

Figure 8. NOx emissions in North Macedonia 1990–2020 by sectors

The Contribution of Manufacturing industries is 27%, and has not changed significantly in comparison to the value of 20% in 1990, [12]. Other sectors and agriculture contribute with 8% and 3% respectively while fugitive emissions, Industrial processes and product use, and the waste are minor sources of NOx emissions.

Overall, emissions can be represented as carbon dioxide equivalents (CO_{2eq}). This means non-CO_2 gases are weighted by the amount of warming they cause over a 100-year timescale. Emissions from land use change – which can be positive or negative – are considered, [13].

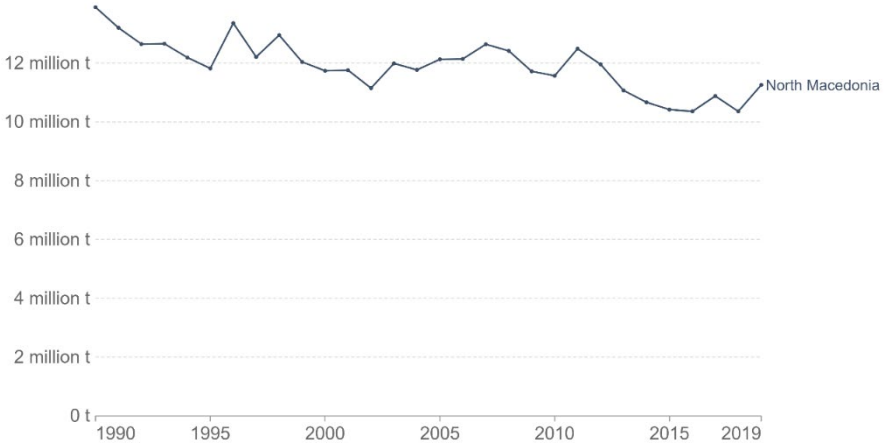

Figure 9. Comparison of CO2eq emissions in North Macedonia for the period 1990-2019 (in million tons)

6. Conclusion

Having in mind that the Earth is becoming an urban planet and more than 60% of the global population now lives in cities, it is expected that most people will suffer the most severe consequences from pollution in urban areas. Increasing the share of renewable energy sources in total energy consumption has led to reduction of pollutants emission. In this regard, activities listed in adjustment permits with operational plans of heat production installations are implemented. It be drawn that while in the past the major source for one of the main pollutants - PM10 was the industry sector, mainly ferroalloys production, in the latest years that the major contributor is combustion of fuels in residential sector and administrative capacities. Transport sector is contributing with 3.6% in PM10 on national level but has higher impact on local emissions. Due to the increase in the number of vehicles during the reporting period and the lower consumption of coal and fuel oil, in 2020, transportation has been determined as the primary source of NOx emissions. Also, the main source of SO_2

emissions is expected to be energy industries (electricity and heat production), which accounted for 92% in 1990 and 95% in 2020 of the national total SO_2 emissions.

Except for SO_2, for the other analyzed pollutants, it can be noted that compared to the emissions in 1990, there is a decrease in concentrations in 2019/2020. In regard to SO_2 emissions, in 2019 there is a sharp increase due to increased use of coal with higher sulfur content and higher production of electricity compared to 2018. Despite the decrease in 2020 due to lower consumption of coal and heavy fuels, that is not on the level of 2018, these concentrations continue to reach almost the same, even higher level of SO_2 compared to 1990. And it seems that the main problem that SOx emissions have not reached values below the defined emission ceiling provided by the Gothenburg protocol, is that the expected implementation of a desulfurization unit in the REK Bitola Power Plant, according to the oldest sulfur protocol, has not yet been realized.

The situation becomes even more complicated due to the declared crisis situation in the energy sector in North Macedonia and the predicted increased use of coal and fuel oil for the production of electricity and heat in the current year 2022, so a further increase in SO_2 concentrations in the air is expected.

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