All Sciences Proceedings

3rd International Conference on Innovative Academic Studies

September 26-28, 2023 : Konya, Turkey

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The Distribution and Trends of Greenhouse Gas Emissions in Türkiye

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Abstract **–** Global climate change is driven by increasing greenhouse gas emissions in the atmosphere such as CO_2, O_3, CH_4 and N_2O. Global warming heats nights faster than days, and that climate change causes seven million deaths per year and will cause 250,000 more by 2030. It affects different regions, mental health, species distribution, and biodiversity loss. Efforts have been made to reduce emissions by various actors. In this study in greenhouse gas emissions between 2015-2021 from different sectors in Türkiye has been examined. The data is fetched from Climate TRACE website. According to the results, Türkiye's CO_2 emissions have increased significantly from 2015 to 2021, with manufacturing and power sectors accounting for 55 % and 58 % of total emissions respectively. Agriculture emissions have decreased by 75 %, indicating a decline in production. Türkiye's total CH_4 emissions increased from 3.25 M tons in 2015 to 3.5 M tons in 2021, with the waste production causing the highest emissions. Population growth and increasing wealth are the main reasons for waste generation. Agriculture and fossil fuels also contribute to CH_4 emissions. N_2O emissions are mainly from agriculture and manufacturing and increasing every year. Türkiye's economic and population growth is triggering emissions. Increased greenhouse gas emissions in Türkiye could lead to air pollution, health issues, and economic and social disruptions, necessitating state control and evaluation of sectors for sustainability.

Keywords – Climate Trace, Global Climate Change, Greenhouse Gases, Emissions, Sectoral Analysis.

I. INTRODUCTION

Significant, long-term changes in the statistical distribution of weather patterns spanning timescales ranging from decades to millions of years are referred to as climate change [1]. Human activities in energy production, industrial manufacturing, and automobile emissions have led to a considerable rise in global greenhouse gas emissions since the industrial revolution, which has led to changes in the climate and environment [2]. The main gases that are known as greenhouse gases (GHG) are ozone (O_3), carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) [3]. The core physics of the greenhouse effect has to do with the wavelength-dependent selective transmission and absorption of energy [4]. The atypical weather of torrential rains, droughts, and the acceleration of desertification are also a result of global climate change, and they pose a danger to ecosystems, water resources, biodiversity, and the stability and resilience of ecosystems [2]. In recent decades, global warming has warmed nights more quickly than days, compared to the last 2000 years [5]. Global climate change (GCC) has now evolved into a multi-disciplinary research field, encompassing a wide range of disciplines ranging from water resources to engineering, ecology, physical geography, geology, and so on, and has become one of the global issues that people all over the world are concerned about [6]. Under the scenario of a global climate change, ecological and environmental changes have emerged as an urgent global concern for both the public and the scientific groups. Global climate change has gained more and more attention worldwide since the 1980s as a new, integrated concern [2].

Due to things like air pollution, severe weather, and infectious illnesses, this phenomenon causes seven million fatalities per year throughout the world. By 2030, it is predicted that climate change will be a factor in an additional 250,000 fatalities yearly [1]. Depending on a number of variables, different parts of the world will experience global climate change in various ways [7]. Heat and other extreme weather conditions are climate change stressors that have been related to several detrimental effects on mental health, including higher rates of suicide and psychological distress, exacerbated symptoms of psychiatric diseases, and increased mortality among those who have mental health issues [8]. Additionally, the geographical distribution of species is permanently altered by climate change, as are size-structure adjustments [9]. Besides, the greatest issues that both the current and future generations must overcome are still climate change and environmental degradation, especially biodiversity loss [10]. In today's world, more investors, non-governmental organizations and governments from developed, developing and emerging economies are working to reduce global greenhouse gas emissions by supporting and endorsing environmentally friendly energy production, business initiatives, transport sectors and the entertainment industry [11].

All countries of the world - developed, developing and underdeveloped - have a greater or lesser impact on global climate change. Türkiye is not an exception. Since 1990, Türkiye has achieved significant development gains. Income per capita quadrupled due to rapid economic expansion, reaching a peak of $12,000 in 2015, making Türkiye the 19th biggest economy in the world. This rapid economic growth has also led to an increase in greenhouse gas emissions. Despite the fact that Türkiye's GHG emissions have grown more slowly than its economy and that its per-capita emissions are lower than those of the OECD or the EU, there is a compelling case for a vigorous mitigation strategy in Türkiye. As a country that confronts high susceptibility to the consequences of climate change, Türkiye has undertaken aggressive climate change promises, ratified the Paris Agreement in October 2021 and pledged to net zero emissions by 2053 [12].

This study examines the annual changes (2015-2021) in greenhouse gas emissions from different sectors in Türkiye's and discusses their reasons and possible impacts.

II. Materials and Method

The data used in the study downloaded from Climate Trace website [13]. Climate TRACE is a non-profit alliance of groups working to provide a rapid, transparent, and accessible inventory of where greenhouse gas emissions originate. Climate TRACE was developed to deliver this knowledge on a global scale across all nations, significant polluting industries, and large individual sources of emissions, ushering in a new era of radical transparency that will aid in the implementation of actual climate action. Climate TRACE uses artificial intelligence (AI) and machine learning (ML) to analyse over 59 trillion bytes of data from more than 300 satellites, 11,100 sensors, and countless other sources of emissions data from across the world [14]. The dataset includes the carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) GHG emissions from different sectors such as power, waste, agriculture, fossil fuel, manufacturing, mineral extraction, transportation, buildings, forestry and land use, and fluorinated gases from the year 2015 to 2021. Power depicts emissions of greenhouse gases from energy generating. Waste originated emissions of greenhouse gases are from land-based solid waste disposal, wastewater, waste incineration, and any other waste management activity. Agricultural GHG emissions are from agricultural and livestock production for food and raw materials for non-food use. Fossil fuel means emissions of greenhouse gases from oil and gas production, refining, and coal mining. Manufacturing include GHG from cement, aluminium, steel, and other manufacturing processes. Mineral extraction GHG originated from mineral and ore mining and quarrying. Transportation indicates greenhouse gas emissions from automobiles, aircraft, ships, trains, and other forms of transportation. Building originated GHG include gases caused by onsite fuel burning in residential, commercial, and institutional buildings. Forestry and land use GHG emissions and removals from change in living biomass due to clearing, degradation and fires in forests, grasslands and wetlands and fluorinated gases depicts emissions of greenhouse gases from the discharge of fluorinated gases used in refrigeration, air conditioning, transportation, and industrial. The

total amount of CO_2, CH_4 and N_2O emitted by all sectors worldwide between 2015-2021 is 280.12 B tons, 2.70 B tons and 53.2 M tons, respectively [14].

III. RESULTS

Results should be clear and concise. The most important features and trends in the results should be described but should not interpreted in detail. The principal carbon source for life on Earth is atmospheric CO_2 which is a vital part of the carbon cycle. The main anthropogenic sources of CO_2 emissions are the burning of fossil fuels, deforestation, and some agricultural and industrial practices. Fig. 1 indicates the annual CO_2 emission from different sources in Türkiye.

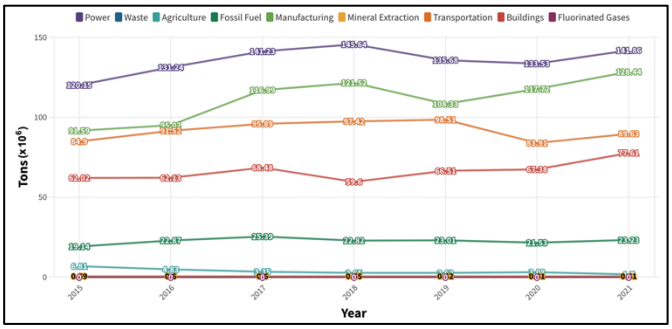

Fig. 1 Yearly CO_2 emissions of different sectors in Türkiye

Methane (CH_4) is an important gaseous fuel. CH_4 is found naturally below ground and beneath the seafloor, and it is created by both geological and biological processes. Landfills, oil and natural gas networks, agricultural operations, coal mining, stationary and mobile combustion, wastewater treatment, and some industrial processes can all emit methane into the atmosphere. The variations of methane over years by sectors in Türkiye can be seen in Fig. 2.

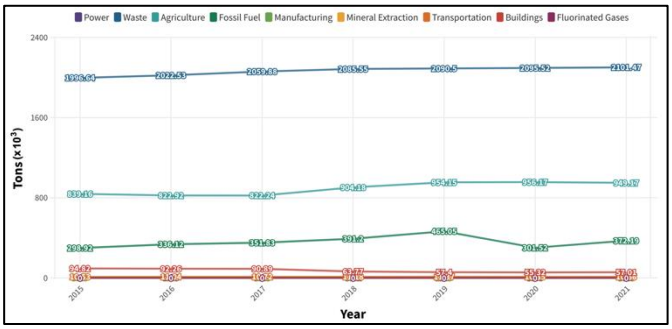

Fig. 2 Yearly CH_4 emissions of different sectors in Türkiye

Nitrous Oxide (N_2O) is a colorless non-flammable gas. Upland soils with natural vegetation, coastal waterways, estuaries, oceans, rivers, etc. are the principal natural sources of nitrous oxide. The anthropogenic sources can be agriculture, fossil fuel combustion, savage and biomass burning. The annual change in N_2O emissions by sector in Türkiye is given in Fig. 3.

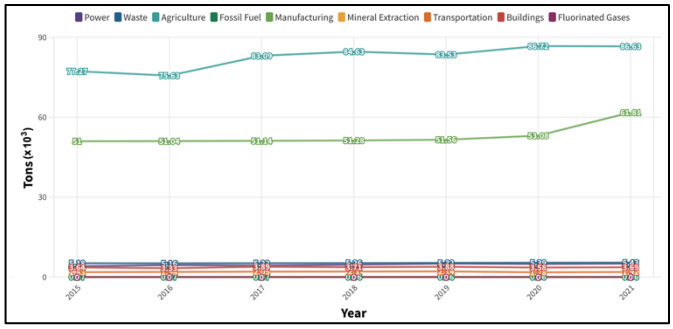

Fig. 3 Yearly N_2O emissions of different sectors in Türkiye

IV. DISCUSSION

As can be seen in Fig. 1 the total amount of CO_2 emissions of Türkiye increased from 2015 to 2021. In 2015, total emissions were 385 M tons, while in 2021 they are 463 M tons. Total CO_2 emissions in this 7-year period exceeded 3 B tons. Most of the emissions come from the Manufacturing and Power sectors. These two sectors accounted for 55 % of total emissions in 2015 and 58 % in 2021. Emissions in the Agriculture sector decrease significantly from 2015 to 2021. Emissions from this sector fall from 6.8 M tons in 2015 to 1.7 M tons in 2021. This corresponds to a 75 % reduction. The decline in agricultural-based CO_2 emissions over the years also points to a decline in agricultural production. The Fluorinated Gases column has a value of zero in the dataset. This value shows that Türkiye has limited or not reported its use of fluorinated gases. Emissions in the Power sector increased from 2015 to 2018 but decreased from 2019 onwards. This indicates an increased use of renewable energy sources in power production of Türkiye. Emission fluctuations in most of the sectors are observable. Waste, mine extraction and agricultural applications originated CO_2 emissions are very low when compared to other sectors. When the trends of sector-based CO_2 emissions in Türkiye are analysed as a whole, the increase in CO_2 emissions from Power, Manufacturing and Building clearly reveals that Türkiye's industry, development and

population are increasing. The ways to reduce the carbon dioxide emissions in a country is common which are to encourage public transportation by improving transportation infrastructure, to increase energy efficiency (thermal insulation in buildings, central heating systems, etc.), to promote green energy instead of fossil fuels, to increase the volume of green spaces (planting trees, building parks in cities, etc.). The increase in CO_2 emissions could trigger air pollution and can have negative impacts in health, biodiversity, and on economic and social structures in Türkiye. It is essential for Türkiye to take these considerations into account as it increases its industrial development.

As with CO_2 emissions, Türkiye's total CH_4 emissions (Fig. 2) also increased from 2015 to 2021. Emissions increased from 3.25 M tons in 2015 to 3.5 M tons in 2021. The total CH_4 emissions between 2015-2021 is 23.86 M tons. The source causing the highest CH_4 emissions has been the waste sector every year. Waste sector emissions increased from 2 M tons in 2015 to 2.1 M tons in 2021. The population of Türkiye is increasing every year. This population growth is positively correlated with waste generation. There is also a correlation between waste generation and CH_4 emission. This relation is caused by the decomposition of organic waste in landfills or open fields. In this process, CH_4 gas is produced by bacteria in anaerobic conditions. CH_4 gas is the most potent greenhouse gas and contributes to global warming. Therefore, reducing waste generation and improving waste management will also reduce CH_4 emissions. To reduce waste generation, methods such as reducing consumption, recycling and composting can be used. To improve waste management, methods such as converting landfills into closed systems, biogas production and energy recovery can be used. Agriculture is the sector with the second largest impact on CH_4 emissions. Agricultural activities caused the production of 6.25 M tons of methane in the 7-year period measured. Livestock farming, wetland rice cultivation and biomass burning are the main sources of methane emissions from agricultural activities. Some measures can be taken to reduce CH_4 emissions in agriculture. For example, optimizing manure management, improving animal nutrition, improving water management in wetland rice farming, and replacing biomass burning with alternative methods. Türkiye can go a long way in reducing methane emissions by implementing these practices. The total amount of CH_4 emissions from fossil fuel is 2.52 M tons. Methane is released into the atmosphere during the production, transportation, and combustion of fossil fuels. Therefore, taking necessary precautions in these processes will limit CH_4 emissions. It is clear that the remaining sectors do not contribute much to Türkiye's methane gas emissions. Moreover, the contribution of mineral extraction and fluorinated gases to methane emissions is zero.

As can be seen from Fig. 3, there are 2 important sources of N_2O gas emissions to the atmosphere in Türkiye: agriculture and manufacturing. The contribution of the remaining sources can be ignored. Besides, the contribution of mineral extraction and fluorinated gases to N_2O emissions is zero. Nitrous oxide emissions from agricultural processes are increasing every year. 77.3 T tons of emissions in 2015 increased to 86.6 T tons in 2021, representing an increase of 12 %. Fertilization is the main cause of N_2O gas emissions in agriculture. Applying organic or chemical fertilizers to the soil causes bacteria in the soil to convert nitrogen into N_2O. It is therefore of great importance that fertilization processes are optimized by the competent authorities in Türkiye. N_2O emissions from manufacturing did not change much between 2015 and 2020 but increased by 16 % to 61.81 tons in 2021. Fuels used in the manufacturing sector and some chemical and biological substances produced or used contain nitrogen. The combustion, reaction and fermentation of such ingredients are the main causes of N_2O emissions from manufacturing. It is important that Türkiye enacts and enforces the necessary laws to prevent the release of excess nitrogen oxides into the air.

The increase in greenhouse gas emissions in the atmosphere could trigger air pollution and can have negative impacts in health, biodiversity, and on economic and social structures in Türkiye. These effects can cause irreversible negative consequences. Therefore, the necessary industries (sectors) need to be controlled by state mechanisms in Türkiye and evaluated in terms of economic development, social welfare, and environmental protection within the framework of sustainability.

V. CONCLUSION

Climate change refers to long-term changes in weather patterns caused by human activities such as energy production, industrial manufacturing, and automobile emissions. These emissions, including O_3, CO_2, N_2O, and CH_4, have led to a rise in global greenhouse gas emissions. Greenhouse gas emissions pose threats to ecosystems, water resources, biodiversity, and the stability of ecosystems. Countries like Türkiye, which has experienced rapid economic growth since 1990, are working to reduce greenhouse gas emissions and implement mitigation strategies. This study examines the annual changes (2015-2021) in greenhouse gas emissions (CO_2, N_2O, and CH_4) from different sectors (power, waste, agriculture, fossil fuel, manufacturing, mineral extraction, transportation, buildings, forestry and land use, and fluorinated gases) in Türkiye downloaded from Climate Trace Organization website and discusses their reasons and possible impacts. Türkiye's CO_2 emissions have increased significantly from 2015 to 2021, with manufacturing and power sectors accounting for 55 % and 58 % of total emissions respectively. Agriculture emissions have decreased by 75 %, indicating a decline in agricultural production. The power sector's emissions increased from 2015 to 2018 but decreased from 2019 onwards, indicating increased use of renewable energy sources. Emission fluctuations are observable across sectors, with waste, mine extraction, and agricultural emissions being low. The increase in CO_2 emissions from power, manufacturing, and building sectors indicates an increase in industry, development, and population. Türkiye's total CH_4 emissions increased from 3.25 M tons in 2015 to 3.5 M tons in 2021, reaching 23.86 M tons. The waste production is the primary source of CH_4 emissions, with a correlation between population growth and waste generation. Agriculture, with 6.25 M tons of methane produced in 7 years. Fossil fuel production and combustion contribute to 2.52 M tons of CH_4 emissions. Mineral extraction and fluorinated gases contribute to zero methane emissions. In Türkiye, N_2O emissions from agriculture and manufacturing are increasing. Manufacturing emissions also increased, with 61.81 tons in 2021. The increase in greenhouse gas emissions could negatively impact health, biodiversity, and economic and social structures. Therefore, state mechanisms in Türkiye should control industries and evaluate their economic development, social welfare, and environmental protection within the sustainability framework.

ACKNOWLEDGMENT

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