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Research Paper

Fuel Consumption and Greenhouse Gas Emission Trends in Road Transportation in Türkiye

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ABSTRACT: *Air pollution, which is one of the main causes of global warming, is one of the priority problems of the whole world waiting to be solved. As in all countries of the world, water, solid waste, and air pollution are considered as the most important problems in Türkiye. Air pollution, in general industrial production centers, agricultural activities and internal combustion motor vehicles used in transportation, public institutions and domestic heating activities consist of emission sources in Türkiye. The transportation sector is one of the most important sectors in terms of its contribution to the Turkish economy, leading different sectors and offering alternatives. At the same time, the transportation sector is one of the sectors that cause an increase in greenhouse gases. In this study, vehicle types that are actively used in the transportation sector in Türkiye are classified and their greenhouse gas effects are explained. Suggestions that can be made are presented, considering the practices, expectations, and actions to be taken for future greenhouse gas control, based on standards that restrict vehicle-borne pollutant exhaust emissions.*

KEYWORDS: *Fuel consumption, Transportation, Air pollution, Greenhouse gases, Emissions.*

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I. INTRODUCTION

Emissions from transportation continue to increase around the world. Global transport emissions increased by less than 0.5% in 2019 (compared to 1.9% annually since 2000) due to efficiency improvements, electrification, and greater use of biofuels. However, 24% of direct CO_2 emissions from fuel combustion come from transport activities. Road vehicles (cars, trucks, buses, and two/three-wheeled vehicles) are responsible for about three-quarters of CO_2 emissions in transport. Similarly, emissions from aviation and shipping continue to increase. It highlights the need for more international policy on the part of governments focusing on these sub-sectors that are difficult to control emissions [1]. Historically in the background, the majority of greenhouse gas emissions have come from developed countries, but climate change is expected to have the largest impacts on developing countries. Clearly forward, it is estimated that CO_2 emissions from non-OECD countries will double by 2030, with approximately 73% of the total increase by 2030 being produced by these countries [2]. The share of greenhouse gas emissions from transportation activities of non-OECD countries is 36% and is expected to be 46% in 2030 if current trends continue. In addition to the increase in CO_2, transportation activities create a negative process in terms of emissions, traffic congestion, air and water pollution in urban areas and sustainability effects in terms of human health, travel time, quality, and costs [3]. China, Mexico, South Korea and 131 other developing nations are completely exempt from these new restrictions on industrialized countries. The reduction in potential welfare loss in energy-exporting countries is offset by the impact on energy-importing countries such as Brazil, China and India, where welfare gains are declining. This effect on energy-importing countries derives from the terms of trade, with lower prices for energy commodities such as crude oil or petroleum products being forfeited. Nevertheless, welfare changes associated with carbon trading are positive for most developing countries, including when the D5 mitigates, unless the United States does not participate in the market. In this case, both Brazil and Mexico have fewer comparative advantages than China and India might experience some welfare losses [4] and [5]. While developing nations have been reluctant to accept binding emissions targets, asking that richer nations take action first, many are undertaking efforts that have significantly reduced the growth of their own greenhouse gas emissions. In most cases, climate mitigation is not the goal, but rather an outgrowth of efforts driven by economic, security, or local environmental concerns. In the context of

the international agreement against the problem of climate change, the Kyoto Protocol has imposed obligations on countries such as China and India in Asia and Mexico and Brazil in Latin America accordance with the United Nations Framework Convention On the basis of this obligation, pressure was made on these countries to achieve a commitment to reduce greenhouse gas emissions. This regulation is also necessary to analyze the energy consumption trends, to look into a low-carbon future, energy security, reduce other environmental impacts, improve the quality of life, and meet goals such as sustainable development [3] and [6] and [7].

Although international environmental agreements have been on the agenda for over a century, environmental protection activities covering various issues such as loss of biodiversity on a global scale, pollution of the atmosphere, degradation of the oceans and degradation of forests have greatly increased in recent years. In May 2004, Türkiye became a party to the United Nations Framework Convention on Climate Change. In February 2009, at a time when the first commitment period of the Protocol expired, Türkiye also became a party to the Kyoto Protocol. For Türkiye, which signed the Kyoto Protocol on February 05.2009, this protocol has both political and economic importance [8]. In addition, Türkiye is not rich in fossil energy resources, it has a high potential in terms of renewable energy resources. On the other hand, it has a geopolitical position that acts as a bridge between producer and consumer countries in terms of fossil energy resource transportation corridor. Türkiye occupies a unique position between the continents of Asia and Europe, which has played a critical role for centuries. It is home to various oil and gas pipeline projects currently in use and ongoing. Türkiye should eliminate foreign dependency in energy for various reasons such as surviving in the energy sector, increasing its power in the energy field, and regional dominance [9]. Türkiye is a major economy that connects Europe and Asia. It ranks 20th in greenhouse gas (GHG) production in the world. Despite being a middle-income country with low historical emissions, it is also among the generally developed countries club that makes up the OECD (Organization for Economic Cooperation and Development). Türkiye's its per capita GHG emission in 2012 at 5.9 tonnes CO_2 (tCO_2e) per person are "much lower than the EU and OECD average". Different emissions counting from database shows lower emissions of 5.4t CO_2 per person in 2015. However, assuming that Türkiye 's population will increase by 10 million by 2030 and adhere to the Paris commitment, emissions per capita are predicted to nearly double to 10.5 tCO_2 by 2030, the UN says. This value would be well above today's world average of 6.8 tCO_2 per capita. On the other hand, it is estimated that EU emissions per capita will decrease to around 6.4 tCO_2 by 2030 [10].

The global transportation sector produced approximately 7.3 billion metric tons of CO_2 emissions in 2020, a major pollutant in terms of greenhouse gas production. Within the transportation sector, Passenger cars are the largest source of emissions, accounting for 41 percent of global transportation emissions. Global CO_2 emissions from passenger cars in recent years reached 3.2 billion metric tons in 2019. It was observed that vehicle emissions decreased in 2020 compared to 2019 due to the COVID-19 pandemic. Medium and heavy trucks are the second largest polluters, accounting for 22 percent of transportation emissions. Although there are significantly fewer trucks on the roads than passenger cars, half of the emissions produced by passenger cars, 22%, were produced by trucks. In 2020, heavy-duty truck CO_2 emissions totaled nearly two billion metric tons. These two values indicate that global road transport is the highest pollutant. COVID-19 has impacted transport emissions in other countries of the world, reducing it to about 300 million metric tons in 2020 [11]. Figure 1. shows distribution of CO_2 emissions by the transportation subsector worldwide in 2020.

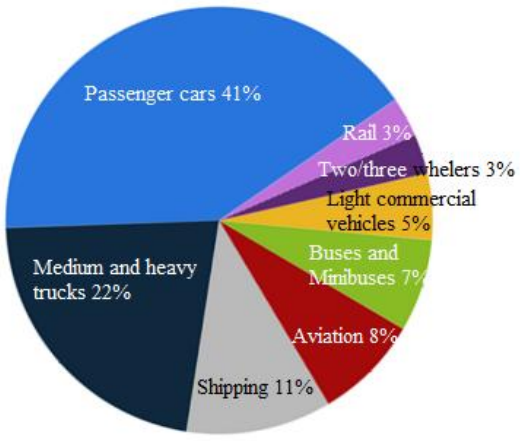

Figure 1. Distribution of CO_2 emissions by the transportation subsector worldwide in 2020

II. INTERNAL COMBUSTION MOTOR VEHICLE EMISSIONS AND CHARACTERISTICS

Air pollution is the biggest problem of our age due to its impact on society and individual health as well as climate change. Air pollution caused by motor vehicle emissions is one of the most important problems of today and constitutes a large part of environmental pollution. Air pollution caused by transportation causes smog and a decrease in air quality, and air pollution has negative effects on the environment, human well-being and health. Among them, Particulate Matter (PM), particles of variable but very small diameter, penetrate the respiratory system via breathing-in, causing respiratory and cardiovascular diseases, reproductive and central nervous system dysfunctions, and cancer. Furthermore, nitrogen oxide, sulphur dioxide, Volatile Organic Compounds (VOCs), dioxins, and polycyclic aromatic hydrocarbons (PAHs) are all considered air pollutants that are harmful to humans. Carbon monoxide can even provoke direct poisoning when breathed in at high levels. Heavy metals such as lead, when absorbed into the human body, can lead to direct poisoning or chronic intoxication, depending on exposure. Vehicles of powered by internal combustion engines, emit various air pollutants including volatile organic compounds (VOCs), nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO) and sulphur oxides (SO_x). Both nitrogen oxides (NO_x) and volatile organic compounds (VOCs) are involved in a series of complex reactions that result in the formation of ground-level ozone, which is a respiratory irritant and one of the major components of smog. Engine vehicles account for a considerable proportion of the total transportation emissions including, approximately 21% of nitrogen oxide (NO_x) emissions, approximately 51% of volatile organic compound (VOC) emissions and approximately 4% of fine particulate matter (PM) emissions. Pollutants that contribute to poor air quality include Carbon monoxide (CO), hydrocarbon (HC) particulate matter (PM), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) and Carbon dioxide (CO_2). That is why, to minimize the air pollution resulting from vehicle emissions governments make periodic emission measurements compulsory. After completed combustion, harmless CO_2 and H_2O occur and without combustion reaction inert N_2 comes out exhaust pipe. Because of engine configurations, wrong engine adjustments and engine subsystems, unfortunately completed combustion is not possible with compression ignition engines. As a result of uncompleted combustion, a high ratio of CO, HC, $NO_{x,}$ and PM harmful emissions such as come into atmosphere. Carbon monoxide (CO) is a deadly, colourless, odourless, poisonous gas. Thermal combustion process is the most common source for carbon monoxide, and it is produced by the incomplete burning of various fuels, including coal, wood, charcoal, oil, kerosene, propane, and natural gas. At low levels, CO can exacerbate cardiovascular disease. At high levels, it can damage the central nervous system. At extremely high levels, CO is poisonous and can cause death. NO_x and PM were produced in a high degree by diesel fuel engines especially in high speed and high compression ratio. NOX emission is whose inhalation of air with a volumetric concentration of can cancer. NO form NO_2 which is a reddish brown, smelling and poisonous gas comes into air that has a great effect on inhalation systems. HC is formed because of uncompleted combustion or evaporated fuel from fuel tank. Some hydrocarbons are carcinogenic. Normally, nitrogen is an inert gas; however, reacts with combustion process in high compression ratio and high temperature and forms NO_2. In exhaust gases PM which can be both in solid and liquid state is a partial matter which increases with engine wearing [12] and [13] and [14].

III. OVERVIEW OF COMPOSITION AND EFFECTS OF GREENHOUSE GASES

Greenhouse gases trap heat in the atmosphere and make the planet warmer. As a result of human activities, there has been a rapid increase in greenhouse gases in the atmosphere in the last 150 years, all of which are responsible for humans. According to EPA's 2014 data, 14% of global greenhouse gas emissions are produced by the transportation sector. Greenhouse gas emissions from the transport sector are primarily emitted from fossil fuels burned for road, rail, air and sea transport. Almost all of the world's transport energy (95%) comes from petroleum-based fuels, largely gasoline, diesel, and LPG. Other pollutants originating from motor vehicles are greenhouse gases defined "global pollutants" and these gases that trap heat in the atmosphere are called greenhouse gases. Vehicle-derived greenhouse gases include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Greenhouse gases originating from combustion systems are affected by the characteristics of the fuel used and the amount of fuel consumption [14] and[15]. **Carbon dioxide (CO_2);** enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and other biological materials, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle. **Methane (CH_4);** is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices, land use and by the decay of organic waste in municipal solid waste landfills. **Nitrous oxide(N_2O);** is emitted during agricultural, land use, industrial activities, combustion of fossil fuels and solid waste, as well as during treatment of wastewater. **Fluorinated gases;** hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are

sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases"). Tetrafluoromethane, also known as carbon tetrafluoride or R-14, is the simplest perfluorocarbon (CF_4). Tetrafluoromethane is a useful refrigerant but also a potent greenhouse gas. Fluorinated gases (F-gases) are man-made gases that can stay in the atmosphere for centuries and contribute to a global greenhouse effect. There are four types: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). F-gases are a subgroup of the halogenated gases, the majority of which are halocarbons that include fluorine, but do not include chlorine, bromine, or iodine. Sulfur hexafluoride (SF_6) or sulphur hexafluoride is an extremely potent and persistent greenhouse gas that is primarily utilized as an electrical insulator and arc suppressant [14]. It is inorganic, colorless, odorless, non-flammable, and non-toxic. Types of greenhouse gases are given in Table 1.

Table 1. Greenhouse gas types, technical and specific properties [14]

Main Greenhouse Gases					
Greenhouse Gas	Anthropogenic sources(examples)	Atmospheric Concentration		Atmospheric lifetime years	GWP 100 Year Time Horizon
		Pre-industrial (1000-1750)	Recent (1998)		
Carbondioxide (CO_2)	Fossil fuel, combustion, deforestion, cement production	280 ppm	365 ppm	50-200	1
Methane(CH_4)	Fossil fuels, landfills, animal husbandry	0.7 ppm	1.745 ppm	12	23
Nitrousoxide (N_2O)	Fertilizer, fossil fuel combustion	0.270 ppm	0.314 ppm	114	296
Perfluoro-methane(CF_4)	Refrigerant process	40 ppt	80 ppt	>50,000	5700
Sulfur hexafluride (SF_6)	Electric energy sector	0	4.2ppt	3200	22,200
Fluorinated Gases(various)	Industrial processes	various	various	various	various
ppm: parts per million ppt: parts per trillion					
Source: U.S. Environmental Protection Agency					

IV. CHANGES OF MOTOR VEHICLES IN TÜRKİYE BY FUEL TYPES

The most important problem of Türkiye, as in all countries of the world, is wastewater, solid waste, and air pollution, which tend to increase gradually. The known air pollution in Türkiye is generally caused by domestic heating and vehicles, and in industrial centers, pollution from industry emissions is added to these sources. In this study, Türkiye's road vehicle profiles and the current and future estimated potential of vehicle-centered greenhouse gases (especially CO_2) were examined and their negative effects on the environment were tried to be defined. In Türkiye, the total number of motor vehicles registered to traffic reached 25,188,967 million, according to the end of November 2021 data. By the end of November 2021, 54.3% of the total registered motor land vehicles were automobiles, 16.3% pickup trucks, 14.8% motorcycles, 8.0% tractors, 3.5% trucks, 2.0% minibuses, 0.8% buses and 0.3% special purpose vehicles. Gasoline engine and diesel engine (representative) most of the internal combustion engines are used for automobiles and the use of LPG as an alternative fuel has been increasing in the last 30 years. Different types of diesel engines were widely used for trucks, lorries, city buses, intercity buses, and others. Today, gasoline and diesel, LPG continue to be the main fuels of the transportation sector in Türkiye and the demand for such fuels is showing an increasing trend in the coming years. Table 2 show that distribution of vehicles registered to the traffic according to fuel type for 2016-2021 in Türkiye [16].

Table 2. Distribution of vehicles for registered according to fuel type, 2016-2021 in Türkiye [16].

Type of vehicle	Number of highway motor vehicles by year					
	2016	2017	2018	2019	2020	2021(1)
Car	11 317 998	12 035 978	12 398 190	12 503 049	12 503 049	13 676 615
Minibus	463 933	478 618	487 527	493 373	493 395	485 575
Bus	220 361	221 885	218 523	213 358	212 407	209 271
Small truck	3 442 483	3 642 625	3 755 580	3 796 919	3 938 732	4 103 192
Truck	825 334	838 718	845 462	844 481	859 670	884 403
Motorcycle	3 003 733	3 102 800	3 211 328	3 331 326	3 512 576	3 733 409
Special vehicles	50 818	60 099	63 359	65 470	70 309	77 923
Tractor	1 765 764	1 838 222	1 885 952	1 908 999	1 958 727	2 018 579
Total	**21 090 424**	**22 218 945**	**22 865 921**	**23 156 975**	**24 144 857**	**25 188 967**
Source: Republic of Türkiye General Directorate of Public Security (1) Data is by the end of November.						

The gasoline and the diesel engines using most of the internal combustion engines for the automobile and as an alternative fuel using LPG is increasing in the last year. The different type of diesel engines was commonly using for the lorries, trucks, city bus, intercity bus, and others. Today, the gasoline and the diesel fuel, LPG are still the main fuels for transportation sector in Türkiye and the demand for these types of fuel have been tend increased over the next years. In the other hand, reducing emissions will require some action on the part of the government. The transportation sector has increasing to a great of pollution problems, including air pollution, climate changes, greenhouse effect, healthy, dependence on foreign oil and for solve the pollution problems the need for compulsory choices oil production or protection of environmental security. In Türkiye, in terms of emissions and pollution, it is very important to increase the efficiency of energy use as well as the diversity of the energy consumption of the transportation sector. As of the end of September 2021, 37.8% of the 13 million 591 thousand 103 cars registered to the traffic are diesel fuel, 36.1% LPG, 25.3% gasoline, 0.6% are electric or hybrid. The ratio of cars whose fuel type is unknown is 0.3% [17].

V. TÜRKIYE'S FOSSIL FUEL CONSUMPTION

Since 2016, market reform and energy security remain the guiding principles of Turkish energy policy. Rapid economic growth and population growth over the past two decades have not only led to strong growth in energy demand, but also to an increase in import dependency. With its developing economy, Türkiye is among the world's largest energy consumers. Türkiye is a foreign-dependent country in terms of energy and oil constitutes a significant part of this energy import. The determinations to strengthen the energy security of the Turkish transportation sector should be evaluated in terms of the potential costs of liquid-gas fossil fuel policies and the emission of exhaust gases. According to 2020 data, Türkiye pays more than 70 billion dollars for the energy resources it purchases, primarily crude oil and natural gas. Vehicles used in the transportation sector are commonly produced to use crude oil products and LPG (liquid petroleum gas) fuels. 99% of petroleum products are used in the transportation sector and 49.37% of diesel fuel is used in vehicles with diesel engines. Despite this, there are many old vehicles used in the Turkish transportation sector. It is estimated that the demand for alternative fuels in transportation in Türkiye will increase rapidly in the coming years. According to the foreign trade data of the Turkish Statistical Institute (TUIK) and the Ministry of Trade, crude oil imports decreased by 5.5% in 2020 compared to the previous year and amounted to 29 million 368 thousand 757 tons. According to the National Energy Balance Table, Türkiye's primary oil equivalent (tpe) in 2019 was 144.2 million tons. While 33.5 million tpe in energy supply was used in the conversion sector, the total final energy consumption was 110.6 million tpe. Coal ranked first in total primary energy supply with 29.1%, followed by oil with a small margin of 28.6% and natural gas with 25.7%. According to the December 2020 Natural Gas Market Report published by the Energy Market Regulatory Authority (EPDK), Türkiye's natural gas imports increased by 6.45% compared to the previous year and amounted to 48 billion 125 million cubic meters. Türkiye imported 45.2 billion m3 of natural gas in 2019 and its dependence on natural gas imports in 2020 increased by 6.45% compared to the previous year and became 99.1%. When the vehicle park in Türkiye is evaluated, it is seen that 44% of the total vehicles are 15 years or older. The motor vehicle tax levied on vehicles in Türkiye decreases as the vehicle ages, which means that the tax system encourages the use of elderly vehicles. Compared to new generation vehicles, old vehicles consume 40% more fuel on average, so this can be explained as producing more emissions. For this reason, the use of worn-out diesel-engine buses, which are used for long-term intercity transportation, especially in big cities with a dense population and number of vehicles, should be stopped as a service or public transportation vehicle in urban traffic [20].

Diesel consumption increased regularly until 2017 and decreased in 2018 and 2019. Total diesel consumption in 2020 increased by 0.5% compared to 2019 and reached 27.69 million m^3. In order to meet the quality and performance expectations of consumers in a competitive environment, fuel distribution companies offered special/additive differentiated diesel and gasoline variants. Gasoline consumption has increased in recent years, but with the effect of the global pandemic, total gasoline consumption in 2020 decreased by 2.5% compared to 2019 and amounted to approximately 3.1 million m^3. In total gasoline consumption, 95 octane gasoline is the most consumed fuel type with approximately 92% among gasoline types. LPG (autogas) consumption, which was 6.0 million cubic meters in 2019, decreased by 8.6% to 5.5 million cubic meters in 2020. While the share of bulk and bottled LPG in total LPG products contracted by around 0.1% and expanded by 1.2%, respectively, the share of LPG (autogas) shrank at the same rate. As can be expected, the most important reason for the decrease in LPG (autogas) consumption is due to the global pandemic. Total automotive fuel consumption in 2020 decreased by 1.2% compared to the previous year and became approximately 36.3 million m^3. While the share of diesel among automotive fuels decreased, the share of gasoline types and LPG (autogas) increased. Although LPG (autogas) consumption has increased its share in automotive fuels, it is approximately twice the volume of gasoline and constitutes 15.1% of the total automotive fuels market by volume 67% of imported petroleum products produced in refineries in Türkiye are used in the transportation sector, and 70% of this is diesel fuels in road transportation. In other words, the diesel need in

road transport constitutes 18% of Türkiye's final energy consumption. The diesel fuel consumed in road transport is more than the sum of the energy consumed in the basic metal industry and the manufacture of non-metallic products in Türkiye [14] and [18] and [19] and [21] and [22]. Figure 2. shows Distribution of Energy Consumption in Transportation by Sector Types in Türkiye.

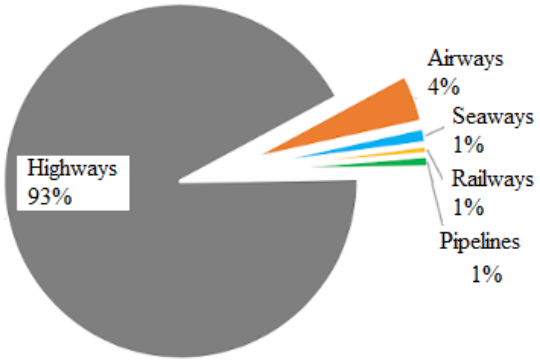

Figure 2. Distribution of Energy Consumption in Transportation by Sector Types in Türkiye [21]

VI. TRANSPORTATION SECTOR GREENHOUSE GAS EMISSION IN TÜRKİYE

The first CO_2 emission limitation studies among vehicle manufacturers in the world were carried out in 1988/89 in cooperation with the European Automobile Manufacturers Association (ACEA), Japanese Automobile Manufacturers Association (JAMA) and Korean Automobile Manufacturers Association (KAMA). With this agreement, CO_2 emissions were targeted as 140g/km average for 2008/09 and this commission made it mandatory to develop CO_2 emission reduction programs for the coming years. Vehicles with pre-1994 technologies produce a significant amount of carbon dioxide gas and there are 2.5 million vehicles in Türkiye that are not subject to any emission standards. These values are It is estimated that they are 60-70% higher than the emission values in their countries and they emit 270 gr CO_2/km carbon dioxide, which is higher than the new generation gasoline vehicles**.** In Türkiye, exhaust emission standards can only be achieved with a delay of 4-5 years compared to European Union countries. In Türkiye, an improvement in the amount of CO_2 production has started with the implementation of Euro 4 standards since 2008, with the increase in the production of quality fuel and the use of new generation diesel vehicles. In the European Union countries, the regulation of CO_2 emissions in the automotive industry by years is planned as follows. While it was reduced from 186 gCO_2/km in 1995 to 164 gCO_2/km in 2003, the voluntary target of 140 gCO_2/km for 2008 has not yet been reached. A reduction of approximately 10% greenhouse gas emissions was achieved in vehicles manufactured in the European Union countries between 1995 and 2003, and it was aimed to decrease the greenhouse gas value from 186 gCO_2/km to 164 gCO_2/km. At the end of 2005, carbon dioxide emissions in most EU countries decreased to 160 $grCO_2$/km. It is estimated that there will be a gradual downward trend in carbon dioxide emissions after 2008 as a result of the improvement of fuel quality and the introduction of new standards in vehicles with new engine systems that will take their place in the transportation sector in Türkiye [23]. It was stated that the CO_2 emission of the cars that will enter the market in 2015 was targeted as 120 $grCO_2$/km, and 95 $grCO_2$/km in 2020, and it should not exceed the limit value of 70 $grCO_2$/km in 2025. According to 2020 data, cars used in European Union countries, including Türkiye, release an average of 163 gCO_2/km into the atmosphere [24].

High level of carbon dioxide emission engine vehicles aged 16 and over should be replaced by vehicles that consume less fuel with a planning. As a result of this planning, with the inclusion of new vehicles in transportation, there will be significant reductions in carbon dioxide emissions, while the amount of foreign currency paid for oil will tend to decrease. It should also be noted that older vehicles consume a lot of fuel, emit high levels of CO_2, and have high operating costs. When a vehicle that consumes 4-6 liters of fuel is used instead of a vehicle that consumes 10-12 liters of fuel at a distance of 100 km the fuel consumption cost of the vehicle will be less 50% the equivalent usage distance per year. While only diesel and gasoline were used in road transport until 1997, LPG also started to be used as of 1998. While the use of diesel and LPG used in the transportation sector increased after 1998, the use of gasoline began to decrease and the transition from gasoline vehicles to vehicles using diesel and LPG (autogas) began to increase. While the share of LPG among the collected fuels used in transportation was only 4% in 1998, this value increased with the continuation of the transition from gasoline to auto LPG, reaching 12% in 2000 and 29.4% in 2008 [24]. According to the 2019 data of the European Statistical Office (Eurostat), in Türkiye, the country with the highest rate of LPG cars in Europe, 38 cars out of every 100 runs on LPG. There are at least 4 million 661 thousand LPG cars in Türkiye. Due to the fact that LPG is cheaper than gasoline and diesel in Türkiye, the number of vehicles with LPG

continues to rise in recent years. The rate of LPG vehicles in the country is 37.4%. The ratio of diesel fueled vehicles is 38.2% and the ratio of gasoline vehicles is 24.3% 2019 data [25].

The greenhouse gas inventory results revealed that overall greenhouse gas (GHG) emissions as CO_2 equivalent for the year 2019 compared to the previous year decreased by 3.1% to 506.1 million tons, the Turkish Statistical Institute said in a statement. Total GHG emissions per capita was 4 tons CO_2 equivalent in 1990 while it was calculated at 6.4 tonnes CO_2 equivalent per capita for 2018 and 6.1 tones CO_2 equivalent per capita for 2019 according to the statement. The biggest share in CO_2 emissions was observed in the energy sector. The energy sector ranks first in emission amounts by sectors. In 2019, the energy sector had the largest share of total GHG emissions with 72%. The energy sector was followed by the agriculture sector with 13.4%, the industrial processes and product use with 11.2%, and waste with 3.4%. 87.4% of CO_2 emissions originated from the energy sector when 34.6% of total CO_2 emissions originated from electricity and heat production which is a sub-category of the energy sector. The remaining 12.3% of CO_2 emissions originated from the industrial processes and product use sector and 0.3% from the agriculture and waste sectors in 2019. 62.4% of CH_4 emissions originated from agriculture, 19.5% from energy, 18.1% from waste, and 0.03% from the industrial processes and product use sector, while 72.5% of N_2O emissions originated from the agriculture sector, 15.7% from waste, 8.8% from energy and 3% from the industrial processes and product use sector. As a result of the global lockdown measures due to the Covid-19 crisis, mobility and global oil demand declined on an unprecedented scale of 57% in early 2020. Global average road transport activities decreased by approximately 50% in 2020 compared to 2019, with road transport falling between 50% and 75% in regions where restrictions apply. Greenhouse gas emissions in Türkiye are lower than in other countries, and according to 2019 data, total greenhouse gas emissions were calculated as 506.1 million tons (Mt) of CO_2 equivalent. According to 2020 data, the distribution of carbon dioxide emissions by sectors in Türkiye; energy sector is defined as 41%, industry sector 31%, transportation sector 17% and residences 11%. The share of the transportation sector in CO_2 emissions in Türkiye is in the range of 18-20% and it is estimated that it will tend to increase in the coming years. According to 2020 data, road transport has a share of 94% in the transport sector in Türkiye and 29% of CO_2 emissions originate from the transport sector. The results showed that in 2020, CO_2 emissions were caused by 32.6% private gasoline powered vehicles, 25% gasoline light commercial vehicles, 11.3% diesel intercity and city buses and 12% diesel heavy goods vehicles [26]. Figure 3 shows greenhouse gases from motor vehicles in Türkiye.

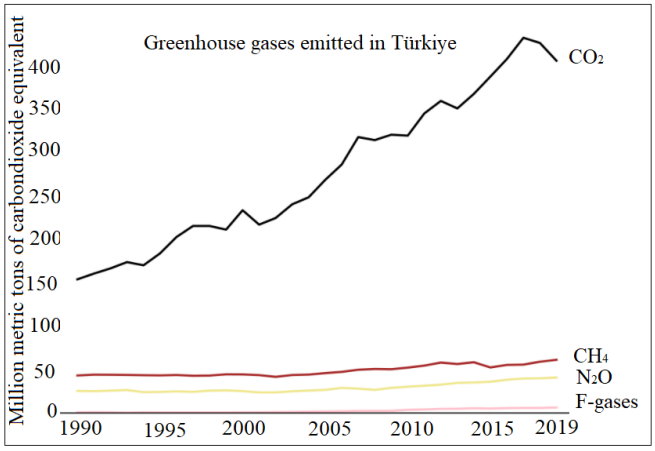

Figure 3. Greenhouse gases from motor vehicles in Türkiye [21]

Fuel consumption of vehicles can be reduced as a result of improvements in vehicle and engine designs (light vehicle and small engine displacement) and production technologies. Less fuel consumption will be contributed by the use of light materials, reduction in vehicle dimensions, reduction of engine cylinder volumes and the use of quality fuel, the use of small engines with equivalent performance, reduction of vehicle mass and improvement of vehicle aerodynamics. Reducing fuel consumption of vehicles will reduce vehicle-related emissions. In cities where the number of vehicles tends to increase, small automobile production should be aimed to be used in transportation. This application will also help solve the parking problem of vehicles. The creation of such small cars from hybrid vehicles and encouraging the use of such vehicles will produce benefits in terms of combating greenhouse gases. On the other hand, it is necessary to accelerate the replacement of old vehicles, which are still widely used in Türkiye, with new generation vehicles. The faster this process is, the sooner the vehicle-borne emissions control process will take place [23].

VII. RESULTS AND DISCUSSIONS

Due to the economic growth and development, increase in the number of motor vehicles and changes in consumption habits in Türkiye, greenhouse gas emissions are expected to increase in the transportation sector in the coming years. In this study, fuel consumption and greenhouse gas emissions, especially CO_2, used in road passenger and freight transportation in Türkiye are taken as basis. As clean air acts are becoming more and more serious, car manufacturers pay attention to produce cars that have lower emission and that are good for environment. Today, environmental disasters caused by global warming are seen as the biggest threat to our world and it is evaluated that this threat will continue to increase in the coming years. The factor that has the biggest share in the emergence of global warming is greenhouse gas emissions. Currently, many international agreements have been signed to reduce greenhouse gas emissions from fossil fuel use. In line with these agreements, searches continue to reduce the effect of motor vehicles, which play an important role in greenhouse gas emissions.

-To reduce greenhouse gas emissions; by reducing the use of private vehicles, policies that will encourage fuel consumption in gasoline vehicles, fuel efficiency standards and quality fuel use, public transportation and logistics operations and light freight transportation should be taken into consideration.
-Reducing greenhouse gas emissions, based on policies aimed at reducing fuel consumption of gasoline vehicles, such as with fuel efficiency standards, but public transport and logistics operations for light freight transport, the use of private vehicles should also be reduced.
-Carbureted vehicles in Türkiye consume more fuel per unit distance and their withdrawal from the market should be accelerated. Such vehicle owners prefer to use LPG fuel, which has a lower fuel price, by having LPG conversion in their vehicles.
-It should be ensured that the most appropriate vehicle speeds in terms of fuel consumption and emissions are applied in the regulation of traffic flow planning in cities and planning of new urbanization zones. Stops and traffic lights should be built to ensure that traffic flow rates are used in the 60-70 km/h vehicle speed range. This will both reduce fuel consumption and contribute to the lowest level of emissions, especially CO_2, into the atmosphere.

Suggestions for activities to bring CO_2 emissions produced by vehicles, especially road transport, to the level of European Union standards and to reduce them are given under the following headings.
- Encouraging the use of new generation vehicles with low fuel consumption,
- Encouraging the withdrawal of old vehicles with high fuel consumption from traffic,
- Support for the use of alternative fuels that produce low greenhouse gasses,
- Arranging traffic flow plans in cities,
- Planning of traffic flow in new urbanization areas,
-The implementation of low-emission alternative options in public transportation should be carried out.

Finally, climate change resulting from environmental pollution affects the geographical distribution of many infectious diseases, as do natural disasters. The only way to tackle this problem is through public awareness coupled with a multidisciplinary approach by scientific experts. National and international organizations must address the emergence of this threat and propose sustainable solutions.

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