The Contribution of Passenger Vehicles to Global CO2 Emissions

Executive Summary

Passenger vehicles, encompassing cars, light-duty trucks, sport utility vehicles (SUVs), and minivans, represent a significant and growing source of global carbon dioxide (CO2) emissions. In 2023, these "usual cars" were responsible for approximately 3.8 gigatonnes (Gt) of CO2, constituting over 60% of road transport emissions and roughly 10% of total global energy-related CO2 emissions. This substantial contribution is driven by a complex interplay of factors, including increasing vehicle miles travelled, the rising global vehicle fleet, and a notable consumer shift towards larger, less fuel-efficient vehicles like SUVs. While technological advancements, particularly the rapid adoption of electric vehicles (EVs), offer considerable potential for emissions reduction, their full impact is contingent upon ongoing grid decarbonization and effective policy frameworks that address both vehicle efficiency and consumer behavior. Achieving ambitious global climate targets necessitates a comprehensive approach that integrates technological innovation with demand-side management and sustainable urban planning.

1. Introduction

The escalating challenge of climate change underscores the urgent need to understand and mitigate anthropogenic greenhouse gas (GHG) emissions, with carbon dioxide (CO2) being the most prominent contributor. A detailed examination of sectoral contributions to CO2 emissions is crucial for developing effective policy interventions and targeted mitigation strategies. This report aims to quantify and analyse the specific contribution of "usual cars"—defined broadly as passenger vehicles, including cars, light-duty trucks, SUVs, and minivans—to global CO2 emissions. The analysis will delve into their share within the broader global emissions landscape and the transportation sector, identify key influencing factors, and discuss recent trends and ongoing mitigation efforts to provide a comprehensive understanding of this critical environmental issue.

2. Global CO2 Emissions Landscape

The global CO2 emissions landscape continues to present a formidable challenge to climate stabilization efforts. In 2024, total energy-related CO2 emissions reached an unprecedented high of 37.8 Gt CO2, representing a 0.8% increase from the previous year. This rise contributed to record atmospheric CO2 concentrations, which stood at 422.5 parts per million (ppm) in 2024, approximately 3 ppm higher than in 2023 and 50% above pre-industrial levels.[1] The primary drivers of this increase were CO2 emissions from fuel combustion, which grew by about 1% (357 Mt CO2) in 2024, while emissions from industrial processes saw a decline.[1]

The surge in emissions was largely propelled by increased consumption of natural gas and coal, particularly in rapidly developing economies such as China, India, and the Middle East, as well as continued growth in natural gas use in the United States.[1] This trend highlights a significant global dichotomy in climate action. While advanced economies, including the European Union and the United States, demonstrated a decrease in energy-related CO2 emissions in 2024 (1.1% and 0.5% respectively), primarily due to the accelerated deployment of low-emissions energy sources like renewables and nuclear power, these gains were largely counterbalanced by rising energy demand and continued reliance on fossil fuels in emerging markets.[1] This dynamic suggests that despite progress in decarbonization efforts in some regions, the overall global increase in emissions persists, underscoring the complex, multifaceted nature of achieving worldwide emission reductions. It implies a need for differentiated strategies and international cooperation to support developing nations in transitioning to cleaner energy pathways.

Globally, fossil fuel use and industrial processes remain the predominant sources of CO2 emissions. The Intergovernmental Panel on Climate Change (IPCC) reported that global net anthropogenic greenhouse gas (GHG) emissions reached 59 ± 6.6 GtCO2-eq in 2019, with CO2 from fossil fuel and industry (FFI) having grown by 67% since 1990.[2] Agriculture, deforestation, and other land-use changes constitute the second-largest contributors to overall greenhouse gas emissions.[3]

The following table provides a snapshot of the global energy-related CO_2 emissions and the contributions from major sectors based on the latest available data.

Table 1: Global Energy-Related CO2 Emissions and Major Sectoral Contributions (2024/Latest Available)

Category	Value (Gt CO2)	Percentage of Global Energy-Related CO2	Source Year
Total Global Energy-Related CO2	**37.8**	**100%**	**2024**
Fuel Combustion Emissions	35.7 (est.)	~94.4%	2024
Industrial Process Emissions	2.1 (est.)	~5.6%	2024
Transport Sector	~8.7 (GHG) / ~7.9 (CO2)	21-24% (of CO2) / 23% (of GHG)	2018-2019
Agriculture, Forestry, Other Land Use	~12 (GHG)	~21% (of total GHG)	2019

Note: Percentages for sectors may not sum to 100% as they represent different reporting years and sometimes include broader GHG emissions (CO2 equivalent) rather than just CO2. Fuel combustion and industrial process figures are estimated based on reported changes from 2023 to 2024.

3. The Transportation Sector's Contribution to Global CO2 Emissions

The transportation sector stands as a substantial contributor to global CO2 emissions. It accounts for approximately 21% to 24% of global carbon dioxide emissions, with the International Energy

Agency (IEA) reporting that transport was responsible for 24% of energy-related CO2 emissions in 2018.[4] Similarly, the IPCC's 2019 data indicates that the transport sector contributed 23% of global energy-related CO2 emissions.[5] While some sources may cite higher figures, these often encompass a broader range of greenhouse gases (CO2 equivalent) or different methodological scopes. For the purposes of this report, the focus remains on CO2 emissions directly linked to energy consumption within the transport sector.

Within the transportation sector, road transport is overwhelmingly the dominant sub-sector, responsible for approximately 70% to 75% of direct transport emissions.[4] This includes emissions from passenger vehicles (cars and buses) as well as trucks carrying freight. Other modes of transportation contribute smaller, though still significant, shares. Aviation accounts for 11% to 12% of transport emissions, translating to roughly 2.5% of total global CO2 emissions. International maritime shipping contributes a similar amount, at 10.6% to 11% of transport emissions, or approximately 2.9% of total global CO2. In contrast, rail travel and freight emit a comparatively small 1% of transport emissions.[4]

The disproportionate share of road transport within the sector, combined with projections of increasing vehicle ownership and travel distances, signifies that road transport is not merely the largest current contributor but also a critical area for future emission growth. Global transport demand is anticipated to double by 2070, with car ownership rates projected to increase by 60%.[4] The rising demand for greater travel distances and the increasing size and weight of vehicles are identified as key factors driving greenhouse gas emissions from this sector.[3] This trend underscores the urgent necessity of concentrating mitigation efforts specifically on road vehicles, particularly passenger cars, to achieve meaningful global CO2 reductions. Without targeted interventions, the growth in demand could easily negate advancements in vehicle efficiency.

The following table illustrates the breakdown of global transportation sector CO2 emissions by mode, providing a clear picture of the relative impact of each category.

Table 2: Global Transportation Sector CO2 Emissions Breakdown by Mode (2018-2019 Data)

Mode of Transport	Percentage of Total Transport Emissions	Estimated Percentage of Global CO2 Emissions	Primary Source
Road Transport	70% - 75%	15% - 18%	4
Passenger Vehicles (Cars & Buses)	45.1% (of transport)	9.5% - 10.8%	4

Mode of Transport	Percentage of Total Transport Emissions	Estimated Percentage of Global CO2 Emissions	Primary Source
Trucks (Freight)	29.4% (of transport)	6.2% - 7.1%	4
Aviation	11% - 12%	~2.5%	5
Maritime Shipping	10.6% - 11%	~2.9%	4
Rail	1%	<0.5%	4
Other Transport	2.2%	<0.5%	4
Total Transport	**~100%**	**21% - 24%**	4

4. Passenger Vehicles: Quantifying Emissions from "Usual Cars"

Focusing specifically on "usual cars," which primarily comprise passenger cars and vans, their contribution to global CO2 emissions is substantial. In 2023, total CO2 emissions from cars and vans reached 3.8 Gt, representing more than 60% of the emissions generated by the road transport sector.[7] This figure also translates to approximately 10% of overall global energy-related CO2 emissions in the same year.[7] For context, in 2020, passenger cars worldwide were estimated to have produced 3 Gt of CO2 emissions [8], indicating a notable increase and a rapid rebound to, and beyond, pre-pandemic levels by 2023.

A significant portion of these emissions stems from sport utility vehicles (SUVs). The 360 million SUVs currently on the road globally are estimated to emit about 1 Gt of CO2 annually.[7] This highlights a growing trend where consumer preference for larger vehicles directly impacts overall emissions.

At an individual level, a typical passenger vehicle emits approximately 4.6 metric tons of carbon dioxide per year.[9] This annual figure can vary depending on several factors, including the vehicle's fuel type, its fuel economy, and the total number of miles driven annually. On average, a passenger vehicle emits about 400 grams of CO2 for every mile traveled.[9] The combustion of one gallon of gasoline releases approximately 8,887 grams of CO_2, while a gallon of diesel produces about 10,180 grams of CO_2.[9] It is important to note that the significant weight increase from the liquid fuel to the gaseous CO_2 is primarily due to the oxygen from the air combining with carbon during the combustion process.[9] While CO_2 constitutes the vast majority (94-95%) of total greenhouse gas emissions from passenger vehicles, other GHGs such as methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs) account for the remainder.[9]

The individual contribution of 4.6 metric tons of CO_2 per typical passenger vehicle per year, while seemingly modest, aggregates to a substantial portion of global CO_2 when considering the sheer volume of "usual cars" worldwide, as evidenced by the 3.8 Gt total in 2023. The rapid growth and high emissions from SUVs, contributing 1 Gt from 360 million vehicles, further emphasize a critical trend: consumer preference for larger, heavier vehicles is actively undermining efforts to reduce emissions through technological efficiency gains. This suggests that shifts in consumer behaviour and market trends are as crucial as technological advancements in determining overall emissions outcomes. Effective mitigation strategies must therefore consider both the supply-side (e.g., stricter efficiency standards) and the demand-side (e.g., incentives for smaller or electric vehicles) of the automotive market.

The following tables provide a detailed quantification of passenger vehicle emissions.

Table 3: Passenger Vehicle Contribution to Global and Road Transport CO_2 Emissions (2023 Data)

Category	Value (Gt CO_2)	Percentage of Global Energy-Related CO_2	Percentage of Road Transport CO_2
Total Global Energy-Related CO_2 (2024)	37.8	100%	-
Total Transportation Sector CO_2 (approx.)	~8.7	~23%	-
Road Transport CO_2 (approx.)	~6.5	~17%	100%
Passenger Vehicle CO_2 (Cars & Vans)	**3.8**	**~10%**	**>60%**

SUV CO_2 (subset of passenger vehicles)	1.0	~2.6%	~15%

Note: Percentages are approximate based on available data and calculations.

Table 4: Typical Passenger Vehicle CO_2 Emission Metrics

Metric	Value	Source
Average Annual CO_2 Emissions	4.6 metric tons/year	[9]
Average CO_2 Emissions per Mile	400 grams CO_2/mile	[9]
CO_2 Emissions per Gallon of Gasoline	8,887 grams CO_2/gallon	[9]
CO_2 Emissions per Gallon of Diesel	10,180 grams CO_2/gallon	[9]
Average Fuel Economy (Gasoline Vehicle)	22.2 miles per gallon	[9]
Average Annual Miles Driven	11,500 miles/year	[9]
CO_2 as % of total GHG from passenger vehicles	94-95%	[10]

5. Factors Influencing Passenger Vehicle CO_2 Emissions

Several interconnected factors influence the volume of CO_2 emissions generated by passenger vehicles, ranging from intrinsic vehicle characteristics to broader socio-economic trends and individual behaviours.

Fuel Type and Fuel Economy

The type of fuel consumed by a vehicle directly impacts its CO_2 emissions. Diesel, for instance, produces more CO_2 per gallon (10,180 grams) than gasoline (8,887 grams).[9] Beyond fuel type, a vehicle's fuel economy, typically measured in miles per gallon (mpg), is a primary determinant of its CO_2 emissions per mile. Enhancing fuel efficiency can reduce CO_2 emissions from vehicles by up to 20%.[6] This underscores the importance of technological advancements in engine design and vehicle aerodynamics.

Vehicle Size and Weight

A critical factor counteracting improvements in fuel efficiency is the increasing size and weight of passenger vehicles. This trend is particularly evident in the rapid growth of Sport Utility Vehicle (SUV) sales. In 2023, SUVs accounted for approximately 50% of global car sales, and their combustion-related CO_2 emissions alone increased by nearly 100 million tonnes in that year.[7] Between 2015 and 2019, improvements in specific fuel consumption slowed considerably, to just 0.8% per year, largely because technical advancements were offset by a significant increase in vehicle power and weight, driven by the proliferation of SUVs.[7] This phenomenon illustrates a "rebound effect," where efficiency gains are negated by increased consumption or a shift towards less efficient, yet more desired, products. It highlights that technological solutions alone are insufficient; consumer behaviour and market preferences, often influenced by cultural perceptions and utility, play a crucial role in determining actual environmental outcomes. Consequently, policy interventions must consider both supply-side measures, such as stringent efficiency standards, and demand-side factors, like incentives for smaller or electric vehicles, to effectively steer the market towards lower emissions.

Driving Patterns and Behaviour

Beyond vehicle characteristics, the way a vehicle is driven significantly affects its emissions. Individual driving patterns and behaviours, such as acceleration, braking, and average speed, directly influence fuel consumption and tailpipe emissions.[11] Aggressive driving, characterized by rapid acceleration and hard braking, typically leads to higher fuel consumption and, consequently, greater CO_2 emissions compared to smoother, more consistent driving.

Population Growth and Increasing Travel Demand

At a macroeconomic level, global population growth and rising incomes are fundamental drivers of increasing travel demand and, subsequently, higher greenhouse gas emissions from the transport sector.[3] In 2023, the growing populations and rising incomes, particularly in emerging economies like China, India, and Southeast Asia, led to an increase of 20 million vehicles in the global light-duty vehicle fleet. This contributed to a more than 2% increase in CO2 emissions for the second consecutive year.[7] Over the last decade (2010-2019), gross domestic product (GDP) per capita and population growth remained the strongest drivers of CO2 emissions from fossil fuel combustion, outpacing any reductions achieved through improvements in energy intensity.[2] This indicates that the fundamental drivers of passenger vehicle emissions are deeply intertwined with global socio-economic development. While advanced economies may show some reductions due to decarbonization efforts, the sheer scale of development and increasing affluence in populous emerging markets presents a formidable challenge. This dynamic implies a pressing need for sustainable development pathways that decouple economic growth from emissions, potentially through leapfrogging traditional fossil-fuel-dependent transportation models in favour of electrified or public transport solutions.

6. Trends and Mitigation Efforts

The trajectory of CO2 emissions from passenger vehicles over the past decade reveals a complex interplay of growth, temporary dips, and the emerging impact of mitigation strategies.

Recent Trends in Passenger Vehicle CO2 Emissions (2015-2024)

Overall, global CO2 emissions from passenger cars have shown an increasing trend compared to 1990 levels, with only intermittent reductions observed during significant economic downturns, such as the COVID-19 pandemic in 2020.[2] The pandemic indeed led to a sharp drop in CO2 emissions from fossil fuel and industry (approximately 5.8%) in 2020, but a rapid global rebound occurred by the end of that year.[2] By 2023, CO2 emissions from cars and vans had not only recovered but returned to pre-pandemic levels, largely propelled by population growth and rising incomes in regions like China, India, and Southeast Asia.[7]

Between 2015 and 2019, the rate of improvement in specific fuel consumption for vehicles slowed to a mere 0.8% per year. This deceleration was primarily due to the fact that technical advancements were being offset by a rapid increase in vehicle power and weight, exacerbated by the rising sales shares of SUVs.[7] However, a notable shift occurred between 2019 and 2022, when rapid electrification began to outpace the effects of increasing car size, leading to a 10% decrease in the fuel economy of new light-duty vehicle sales globally compared to 2019 levels.[7]

A deeper examination of these trends reveals a significant disconnect between regulatory intent and real-world outcomes for internal combustion engine (ICE) vehicles. While CO2 emissions from new passenger cars began to drop significantly from 2020, this was predominantly attributed to the substantial uptake of electric vehicles.[12] Critically, real-world CO2 emissions from cars with combustion engines themselves have not shown a corresponding decrease. Furthermore, from 2009 to 2019, the average real-world emissions of new vehicles remained stagnant, as manufacturers often focused on optimizing vehicles for laboratory tests rather than for on-road performance.[12] This pattern indicates a fundamental gap between regulatory testing protocols and actual operational emissions. Policies that rely solely on laboratory-based efficiency metrics may not translate into tangible real-world emission reductions if manufacturers prioritize test cycles or if consumer behaviour (e.g., driving larger vehicles, or not consistently charging plug-in hybrids) negates theoretical gains. This suggests that future regulations must prioritize real-world emissions performance, potentially through more stringent on-road testing and clearer consumer information regarding actual fuel consumption. It also underscores that the primary driver of recent emission reductions in the passenger car fleet is a compositional shift towards electric vehicles, rather than a significant improvement in the efficiency of conventional vehicles.

The Role of Electric and Hybrid Vehicles

The accelerating transition to electric vehicles (EVs) and hybrid vehicles (HEVs) is a cornerstone strategy for reducing transportation emissions. Electric vehicles, particularly Battery Electric Vehicles (BEVs), produce zero tailpipe emissions.[6] BEVs demonstrate substantial life-cycle greenhouse gas emission reductions; for instance, model year 2024 BEV sedans in the U.S. have 66% to 70% lower life-cycle GHG emissions compared to conventional gasoline vehicles, with BEV SUVs showing even greater reductions of 71% to 74%.[13] These savings extend beyond tailpipe emissions, encompassing the entire life cycle, including fuel or electricity production, vehicle manufacturing, and battery production.[13] Although BEVs typically have higher production emissions due to battery manufacturing, these additional emissions are largely offset after approximately 17,000 km of use.[14]

Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) also offer emission reductions, with HEVs reducing emissions by 20% and PHEVs by 30% compared to gasoline ICEVs.[14] However, a critical challenge for PHEVs is the discrepancy between their laboratory-tested emissions and real-world performance. Studies have found that real-world CO2 emissions from PHEVs are, on average, 3.5 times higher than laboratory values, primarily because these vehicles are often not charged and driven in full electric mode as frequently as assumed.[14]

The environmental benefits of electric vehicles are not solely dependent on the vehicle technology itself but are profoundly influenced by the energy source used to charge them. Power grid decarbonization is crucial for maximizing the environmental benefit of BEVs.[15] For instance, a battery electric car sold in 2023 is projected to emit half as much as its conventional equivalent over its lifetime, with further reductions expected as grids become cleaner.[15] This highlights that a rapid transition to renewable energy sources in electricity grids amplifies the positive climate impact of EV adoption. It implies a strong need for integrated energy and transport policies, where grid decarbonization is recognized as a co-requisite for realizing the full emissions reduction potential of vehicle electrification.

Impact of Fuel Efficiency Standards and Regulations

Regulatory frameworks play a pivotal role in driving the shift towards cleaner vehicles. Agencies like the U.S. Environmental Protection Agency (EPA) and the Department of Transportation (DOT) have established stringent GHG emission and fuel economy standards for both light-duty and heavy-duty vehicles.[16] New light-duty GHG regulations for model years 2027-2032 are projected to cut 7 billion metric tons of GHG emissions over the lifetimes of the vehicles sold.[16] The EPA anticipates that these standards will lead to 68% of new light-duty vehicles sold in 2032 being plug-in electric.[13]

Globally, governments are increasingly aligning towards achieving 100% Zero-Emission Vehicle (ZEV) sales for new light-duty vehicles by 2035.[17] These ambitious regulations are expected to lead to significant emission reductions, particularly in major economies such as the United States, the European Union, and China, where projected reductions are anticipated to offset emissions growth in other countries.[17]

Table 5: Key Trends in Global Passenger Vehicle CO2 Emissions (2015-2024)

Year	Annual Global CO2 from Passenger Vehicles (Gt)	Annual Change (%)	Key Influencing Factors
2015-2019	Growing	+0.8% (fuel consumption improvement slowdown)	Increased vehicle power/weight, rising SUV sales [7]

Year	Annual Global CO2 from Passenger Vehicles (Gt)	Annual Change (%)	Key Influencing Factors
2020	~3.0	Significant drop (COVID-19 pandemic)	Economic downturn, reduced travel [2]
2021	Rebound	Significant increase	Post-pandemic recovery, increased travel [2]
2022	Rebound	Significant increase	Post-pandemic recovery, increased travel [7]
2023	3.8	>+2% (for 2nd consecutive year)	Return to pre-pandemic levels, growing population/income in emerging economies, continued SUV growth [7]
2024	Continued growth (implied)	+0.3% (oil-related emissions globally)	Continued reliance on fossil fuels, aviation recovery [1]

7. Conclusion

Passenger vehicles, often referred to as "usual cars," are a substantial and persistent contributor to global CO2 emissions. In 2023, these vehicles were responsible for approximately 3.8 Gt of CO2, representing over 60% of road transport emissions and roughly 10% of total global energy-related CO2 emissions. This significant share underscores their critical role in the broader climate change challenge.

The analysis reveals a complex interplay of factors driving these emissions. While technological advancements, particularly in electric vehicle (EV) development, offer substantial mitigation potential, their impact is frequently challenged by increasing demand for travel, population and economic growth in developing regions, and persistent consumer preferences for larger, less efficient vehicles like SUVs. The observed "rebound effect," where efficiency gains are offset by increased consumption or a shift towards heavier vehicles, highlights that technological solutions alone are insufficient; behavioral shifts and market dynamics are equally crucial. Furthermore, the discrepancy between laboratory-tested and real-world emissions for internal combustion engine vehicles points to the need for more robust regulatory frameworks that ensure actual on-road performance.

The transition to electric vehicles, while promising, is not a standalone solution. The full environmental benefits of EVs are profoundly influenced by the decarbonization of electricity grids. This necessitates an integrated policy approach where investments in renewable energy infrastructure go hand-in-hand with the promotion of EV adoption. The global target of a 59% reduction in transport-related CO2 emissions by 2050, necessary to limit warming to 1.5°C, underscores the immense scale of transformation required.[5]

Achieving meaningful reductions in passenger vehicle CO2 emissions will require accelerated and comprehensive mitigation efforts. This includes not only continued promotion of EV adoption and rapid grid decarbonization but also addressing demand-side factors through sustainable urban planning that reduces reliance on private vehicles, fostering public transportation, and implementing regulatory frameworks that effectively drive real-world emission reductions across the entire vehicle fleet. The path forward demands a holistic strategy that integrates technological innovation, policy incentives, and shifts in consumer behaviour to decouple economic development from carbon emissions.

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