ANALYSIS OF CO_2 EMISSIONS FROM NEW PASSENGER CARS IN THE EUROPEAN UNION

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Gödöllő
2024

HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

SZENT ISTVÁN CAMPUS

BSC IN ENVIRONMENTAL ENGINEERING

ANALYSIS OF CO_2 EMISSIONS FROM NEW PASSENGER CARS IN THE EUROPEAN UNION

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GÖDÖLLŐ
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INTRODUCTION

In this thesis work I will analyse the issue of CO_2 emissions from new passenger cars in the European Union's automotive industry. The automotive industry is one of the biggest and most dynamic sectors of the global economy, it serves to drive technological development and at the same time is one of the largest contributors to greenhouse gases, especially carbon dioxide (CO_2) emitted.

Apart from that, another big issue is balancing economic growth with ecological sustainability. Among important public debates on how to mitigate the effects of climate change, the reduction of CO_2 emissions from passenger car vehicles has been highlithed in the past years. In this regard, the EU has implemented various stringent policies and regulations aiming reduction or even neutrality of CO_2 emissions from passenger cars. This encourages me to research this emission numbers over the years comparing to the effectiveness of such measures, together with the response of the sector over time.

Starting with voluntary agreements in 1995, the EU initially aimed to reduce emissions by working collaboratively with car manufacturers. The 2007 strategy introduced a goal of 120 g/km by 2012 (EC 2007[1]), later formalized by Regulation No. 443/2009, which set a 130 g/km target for 2015 (EC 2009). Subsequent regulations (EU No. 333/2014 and 2019/631[2]), progressively reduced these targets, EU 2023/851[3] aiming zero emissions by 2035 and neutrality by 2050 as in the European Green Deal[4].

The main focus of my research will be directed to the automotive industry, which accounts for nearly a quarter of Europe's total green house gas emissions, with 76% of these coming from road transport.

My study on CO_2 emissions includes new passenger cars in Europe covers a period between 2000 and 2023, where the European Environment Agency (EEA) dataset will be analized. This is an essential database for this research because it will help to establish what effects some of the environmental policies in EU have on CO2 emission trends and how the automotive industry will respond to those changes. The data set would therefore be extremely useful not just for emissions trends assessment but accessing the impacts of economic crisis and other external variables.

[1]*European Commission. Regulation (EC) No 443/2009. Official Journal (OJ) of the European Union, L 140/1.*
[2]*European Commission. Regulation (EU) No 333/2014. OJ, L 103/15 and European Commission. Regulation (EU) 2019/631. OJ, L 111/13.*
[3] *European Commission. Regulation (EU) 2023/851. OJ, L 111/13.*
[4] *European Commission. The European Green Deal. COM (2019) 640 final.*

I also plan to access the transition from Internal Combustion Engines (ICE) to Battery Electric Vehicles (BEV) as an essential part of the EU's efforts to reduce carbon emissions. Also, I will look for information about the obstacles to shift to low-emission vehicle in the European member states such as charging infrastructure, consumer acceptance and current new automotive technologies for passenger cars.

Such challenges show the difficulty of reducing CO2 emission in the transport sector and reinforce the need for supportive structures and consumers awareness in terms of emission reduction plan. As a result, my study will examine how national policies in the 27 EU member states differ from one another and how these factors, together with consumer preferences and the infrastructure that is currently in place, have affected the advancement of CO2 reduction targets over time.

The main obstacles to the adoption of low-emission vehicles, regulatory efficacy, and technological innovation will be highlighted in this examination of CO2 emissions trends from passenger cars in the European Union. I therefore aim to support several areas by offering an analysis that may be pertinent to decision-makers.

2. LITERATURE REVIEW

The concentration of greenhouse gases (GHGs) in the atmosphere is increasing significatly, composed by CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorinated gases, among others, GHGs are responsible for trapping the heat in the atmosphere and leading the climate change globally (IPCC, 2021).

Based on Kyoto Protocol, CO_2 is the greenhouse gas that significantly causes global warming. According to Penney et al. (2010), carbon dioxide (CO_2), a naturally occurring gas, being primarily released through fossil fuel combustion and deforestation.

Effective management of CO_2 and other GHGs emissions in the atmosphere, not only supports global climate goals but also promotes sustainable development and public health by reducing air pollution. Martin (2023), highlights that unchecked emissions can lead to catastrophic environmental consequences, including rising sea levels, extreme weather events, and biodiversity loss. On this chapter I will examine the existing regulations targeting climate change and CO_2 emissions in the automotive industry.

2.1 Historical Policies and Context

The EU is a political and economic union of 27 countries that have chosen to work together for shared goals and mutual benefits. The EU fosters cooperation among its member states in various areas, including trade, security, and environmental policy. There are 24 official languages in the EU, reflecting its diverse cultural heritage and ensuring that citizens can communicate with EU institutions in their native tongues (European Union, n.d.).

The European Comissions, as the executive body of the EU, plays a crucial role in proposing legislation, implementing decisions, and upholding the EU treaties. Its importance lies in its ability to drive policy initiatives, manage budgets, and represent the EU on the global stage, thereby facilitating collaboration and addressing challenges that transcend national borders, such as climate change, economic instability, and migration (European Union, n.d.). The EC directives progressively established targets for CO_2 emissions from new and existing passenger cars over the years across the EU.

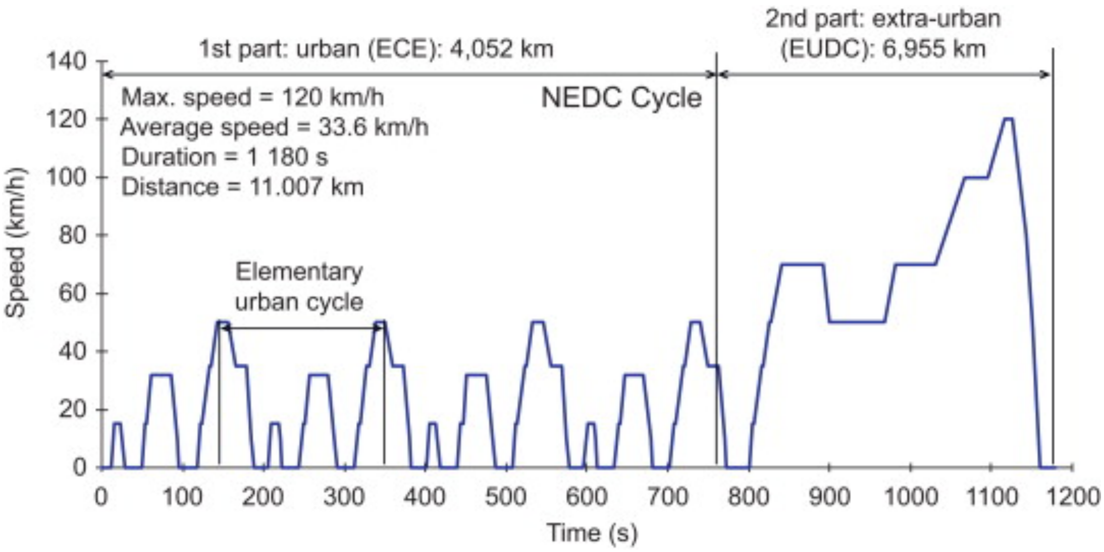
Table 1: European Commission Directives for Reducing CO_2 Emissions in the Automotive Sector

Directives/Policies	Year	Target
Voluntary Agreement	1995	140 g/km by 2008
Regulation (EC) No 443/2009	2009	130 g/km by 2015
Regulation (EU) No 333/2014	2014	95 g/km by 2021
Regulation (EU) 2019/631	2019	37.5% reduction from 2021 levels for cars by 2030
European Green Deal	2019	Climate neutrality by 2050
Fit for 55 Package	2021	55% reduction by 2030 (vs. 1990 levels)
Regulation (EU) 2023/851	2023	Zero emissions for new cars and vans by 2035

Source: Own editing based on data from European Commission regulations and directives (2024)

These targets are measured based on the New European Driving Cycle (NEDC), which is the official driving cycle in EU according to European directive 70/220/EEC. The total distance of NEDC is 11 km from which 4 km simulate urban driving conditions (UDC) and 7 km extra urban ones (EUDC). The total driving time is about 20 min; the highest speed is 120 km/h, while the average speed is 33.6 km/h. It must be noticed that NEDC is just a regulatory driving cycle and real CO_2 emissions per kilometer can be different. Real exhaust CO_2 emissions per kilometer depend on the driving profile, annual mileage, and other factors (Bampatsou, C. and Zervas, E. 2011).

Figure 1: New European Driving Cycle (NEDC)



Source: Bampatsou, C. and Zervas, E. (2011)

Even with the ambitious EU directives aiming the reduction of CO_2 emissions, various experts have presented several deficiencies and challenges associated with this regulatory approach. The major concern is the effectiveness of the targets themselves. According to Miller, J. (2016), theres a gap between intended regulatory outcomes and actual emissions, and the need for more effective strategies to meet climate goals.

Another critique focuses on the impact of market trends. According to the European Federation for Transport and Environment (T&E, 2020) the growing preference for SUVs challenges emissions reductions for passenger car market due to their lower fuel efficiency compared to smaller cars. Over 70% of electric car sales in 2023 were for SUVs, or large or more luxurious models, compared to less than 60% for ICE cars (Trends in Electric Cars – Global EV Outlook 2024 – Analysis - IEA, n.d.).

On technical solution issues, Muratori et al. (2020) argues that while promoting electric vehicles is essential, the lack of comprehensive charging infrastructure poses a significant barrier to achieving the EU's emission reduction targets. In the other hand, the long-term viability of these policies in the face of economic crisis and fluctuations have also been emphasized.

2.2 Impact of EU Climate Policies on CO_2 Emissions Trends

2.2.1 European Passenger Cars Classification System

Table 2: Segments of the EU Passenger Car Market, Average Weight (2023), and Representative Models (1995–2023)

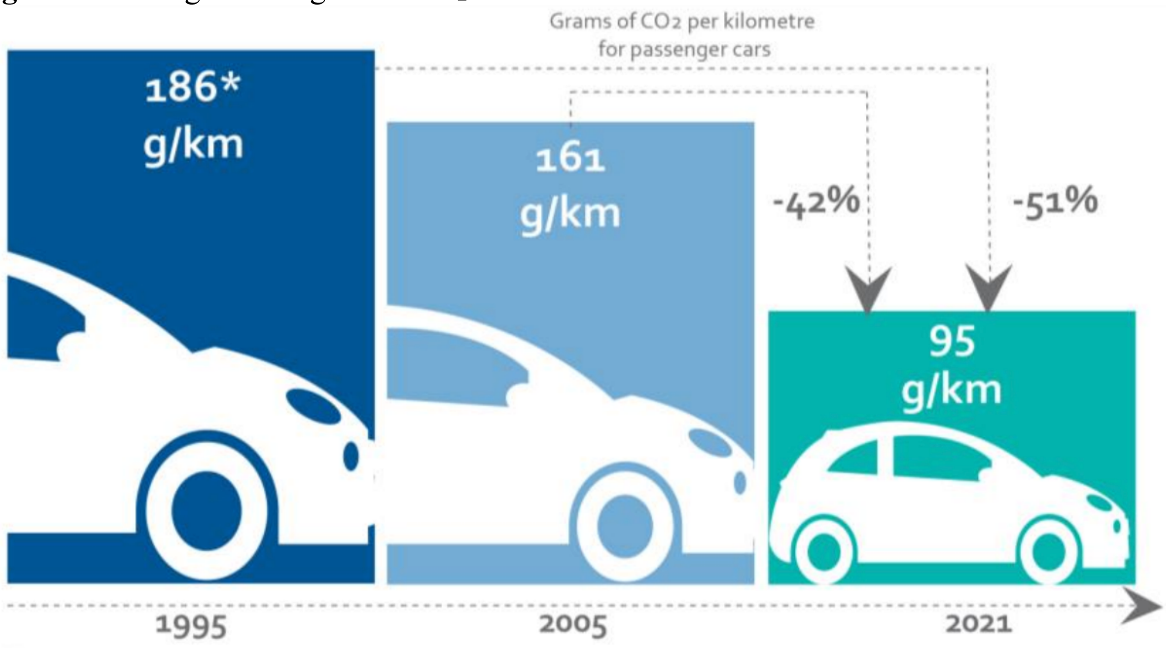
Segments	Gasoline (kg)	Diesel (kg)	Models (1995–2023)
A - Mini	900–1,100	1,000–1,200	Fiat 500, Renault Twingo, VW Up!
B - Small	1,000–1,200	1,100–1,300	Ford Fiesta, VW Polo, Peugeot 208
C - Compact	1,200–1,400	1,300–1,500	VW Golf, Ford Focus, Audi A3
D - Mid-size	1,400–1,600	1,500–1,700	BMW 3 Series, Mercedes C-Class, Audi A4
E - Executive	1,600–1,800	1,700–1,900	BMW 5 Series, Mercedes E-Class, Audi A6
F - Luxury	1,800–2,000	1,900–2,200	BMW 7 Series, Mercedes S-Class, Audi A8
M - Multi-purpose	1,300–1,500	1,400–1,600	Renault Scénic, VW Touran, Ford S-Max
J - SUV	1,500–1,800	1,600–2,000	BMW X5, Audi Q5, VW Tiguan
4x4	1,700–2,000	1,800–2,200	Land Rover Defender, Jeep Wrangler, Toyota Land Cruiser

Source: ACEA (2023)

To meet the rigorous CO_2 emission targets required by EUregulations, manufacturers have been actively engaged not only in the design and development of vehicles and fuel efficiency improvements but also in exploring new technologies across various segments of the passenger car (PC) market.

Trying to address this matter, the automobile industry in Europe has invested heavily in innovations designed to bring down significantly the CO_2 emissions from each kilometre cars are driven (ACEA, 2021). Advances to vehicle engine technology have been supplemented with efforts to reduce the weight of vehicles. As a result, it was expected that the average new car on the road in 2021 would produce 42% less CO_2 per kilometer than the new car bought in 2005 (ACEA, 2016).

Figure 2: Average Passenger Car CO_2 Emissions Reduction Rates



Source: ACEA (2015)

Additionally, despite the CO_2 reductions delivered by manufacturers for new vehicles, progress in reducing the overall road transport emissions has been slow. It is clear that going further in terms of carbon dioxide emissions from individual vehicles presents car manufacturers with a real challenge. There are limits to the extent to which the internal combustion engine can be further refined whilst keeping cars affordable. Significant innovations in vehicle technology have been delivered, which have involved considerable investment in time and resources.

ACEA (2015) contends that car manufacturers can reduce the amount of CO_2 emissions from each kilometre driven, but they cannot influence how those kilometres are driven, nor how many kilometres are driven.

Also according to The Automobile Industry Pocket Guide 2024/2025 (ACEA, 2024), the average new car in the EU emits 2% less CO_2/km than in 2022 and almost a quarter of new cars emit 95g CO_2/km or less.

However, this modest reduction suggests the need for accelerated action to meet the EU's ambitious long-term targets. Additionally, the fact that a significant proportion of new cars still exceed the 95 g CO_2/km threshold could impede efforts to achieve the broader 2030 and 2035 targets set by subsequent regulations and the Fit for 55 Package.

2.3 Comparative Analysis of National Environemental Policies within the EU

Table 3: Countries with National Policies Targeting Climate Change

No.	Country	National Policy	National Policy Target	Year	Source
1	Germany	Climate Action Plan 2050	Aims for an 80-95% reduction in GHG emissions by 2050 compared to 1990 levels.	2016	EEA
2	Hungary	National Energy Strategy	Focuses on energy efficiency and renewable energy, but lacks specific CO_2 targets.	2014	EEA
3	Ireland	Climate Action Plan	Aims for a 51% reduction in GHG emissions by 2030 compared to 2018 levels.	2019	EEA
4	Latvia	National Development Plan	Sets goals for reducing GHG emissions as part of EU commitments.	2021	EEA
5	Sweden	Climate Act	Aims for net-zero emissions by 2045 with interim targets for reductions.	2017	EEA
6	Denmark	Climate Act	Aims for a 70% reduction in GHG emissions by 2030 compared to 1990 levels.	2019	IEA
7	France	National Low Carbon Strategy	Targets a 40% reduction in GHG emissions by 2030 compared to 1990 levels.	2015	IEA
8	Netherlands	Climate Agreement	Aims for a 49% reduction in CO_2 emissions by 2030 compared to 1990 levels.	2019	IEA
9	Slovenia	Climate Change Adaptation Strategy	Aims for a 15% reduction in emissions by 2030 compared to 2005 levels.	2016	IEA

10	Austria	Climate and Energy Strategy	Aims for climate neutrality by 2040 with specific sector targets.	2018	NECP
11	Belgium	Federal Climate Policy	Sets GHG reduction targets for 2030 and outlines sectoral measures.	2021	NECP
12	Croatia	National Energy and Climate Plan	Targets a 36% reduction in GHG emissions by 2030 compared to 1990 levels.	2020	NECP
13	Czech Republic	National Climate Change Adaptation Strategy	Focuses on reducing emissions and enhancing resilience by 2030.	2017	NECP
14	Estonia	National Energy and Climate Plan	Aims for a 70% reduction in emissions by 2030 compared to 1990 levels.	2017	NECP
15	Finland	Climate Change Act	Aims for carbon neutrality by 2035 with specific sector targets.	2015	NECP
16	Greece	National Energy and Climate Plan	Sets a target for a 55% reduction in emissions by 2030 compared to 1990 levels.	2021	NECP
17	Italy	National Energy and Climate Plan	Aims for a 33% reduction in CO_2 emissions by 2030 compared to 2005 levels.	2020	NECP
18	Lithuania	National Energy Independence Strategy	Aims for a 40% reduction in emissions by 2030 compared to 2005 levels.	2018	NECP
19	Poland	National Energy and Climate Plan	Focuses on energy transition but has less stringent CO_2 reduction targets.	2021	NECP
20	Portugal	National Energy and Climate Plan	Targets a 55% reduction in emissions by 2030 compared to 2005 levels.	2020	NECP
21	Slovakia	National Energy and Climate Plan	Aims for a 25% reduction in GHG emissions by 2030 compared to 1990 levels.	2021	NECP
22	Spain	Climate Change and Energy Transition Law	Targets a 23% reduction in GHG emissions by 2030 compared to 1990 levels.	2021	NECP

Sources: Own editing based on European Commission National Energy and Climate Plans (NECPs, 2021), European Environment Agency (EEA, 2023) and International Energy Agency (IEA, 2021)

According to the same sources, countries like Bulgaria, Cyprus, Luxembourg, Malta, and Romania do not have comprehensive national policies specifically targeting CO_2 emissions. According to Table 3 and compared to Table 1, countries such as Austria, Belgium, and Portugal demonstrate a strong commitment to harmonizing their national policies with EU directives, reflecting a proactive approach to environmental sustainability.

However, nations like Germany and France exhibit varied levels of compliance; some pursue more ambitious targets while others lag behind, indicating a fragmented approach to emission reduction within the European Union.

Table 4: Difference between National Environmental Policy Targets and EU Regulations

No.	Country	National Policy Target	Difference Summary
1	Germany	80-95% emissions reduction by 2050	Less stringent (range allows flexibility vs. EU's definitive target)
2	Denmark	70% emissions reduction by 2030	More ambitious (exceeds EU's 37.5% for cars and 55% overall by 2030)
3	France	40% emissions reduction by 2030	Less ambitious (compared to EU's 55% reduction by 2030)
4	Netherlands	49% emissions reduction by 2030	Slightly less ambitious (EU target is 55% by 2030)
5	Ireland	51% emissions reduction by 2030	Slightly less ambitious (different baseline year: 2018 vs. EU’s 1990)
6	Sweden	Net-zero by 2045	More ambitious (target is five years earlier than EU’s 2050 goal)

Source: Own editing based on data from European Commission National Energy and Climate Plans (NECPs, 2021), European Environment Agency (EEA, 2023), and International Energy Agency (IEA, 2021)

This divergence in policy alignment highlights the challenges faced by the automotive sector as it navigates differing regulatory frameworks while while aiming to achieve the EU's overall emissions targets.

According to the European Environment Agency (2023), the effectiveness of national policies is critical not only for achieving collective climate goals but also for fostering innovation within the automotive industry. The emphasis on technological advancements and fuel efficiency improvements is vital for manufacturers aiming to comply with stringent EU standards.

Table 5: Overall Findings on National Environmental Policies within the EU

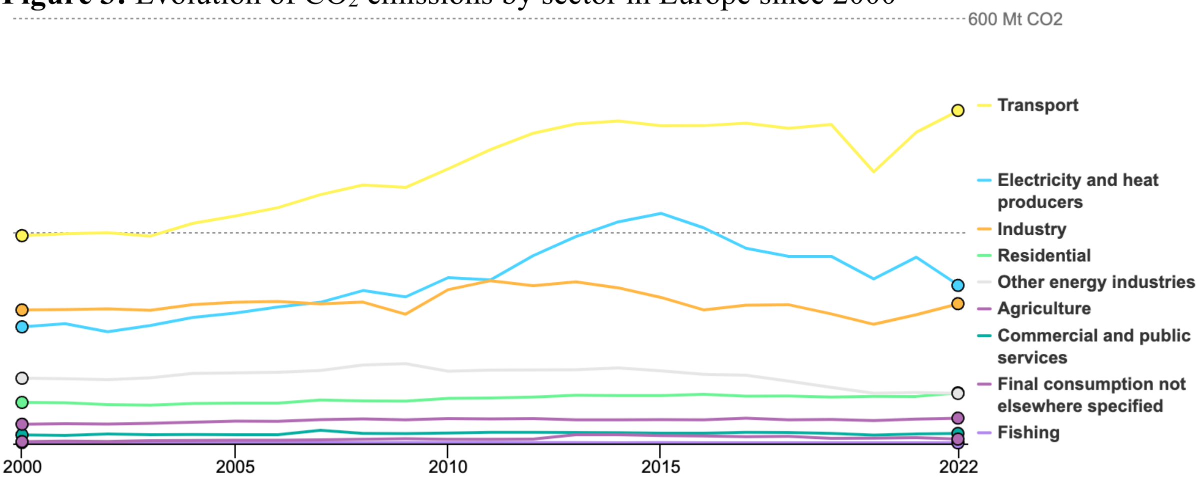
Category	Countries
EU Countries with National Environmental Policies	Austria, Belgium, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden
Countries with National Environmental Policies Targeting the Automotive Sector	Denmark, Germany, France, Netherlands, Ireland, Sweden, Austria, Finland, Spain, Portugal
Countries Without National Environmental Policies	Bulgaria, Cyprus, Luxembourg, Malta and Romania

Source: Own editing based on data from European Commission National Energy and Climate Plans (NECPs, 2021), European Environment Agency (EEA, 2023), and International Energy Agency (IEA, 2021)

2.4 Consumer Preferences and their Influence on Vehicle Emissions

According to the IEA (2022), most of the carbon dioxide emissions in Europe's energy sector in 2022, results from the combustion of fossil fuels used for power generation and to operate vehicles and machinery. Oil accounts for 65.8% of these emissions, followed by natural gas at 24%, and coal at 10.2%.

Figure 3: Evolution of CO_2 emissions by sector in Europe since 2000



Source: IEA (2022)

In 2022, the transport sector was the largest emitter, contributing with 43% of total CO_2 emissions. This was followed by electricity and heat producers at 20.5%, industry at 18.1%, and residential buildings at 6.6%, with other sectors making up the remainder. In the transport sector, most emissions in most countries came from cars, which, despite the rapid growth of electric vehicles, remain heavily dependent on oil-based fuels (IEA, 2022).

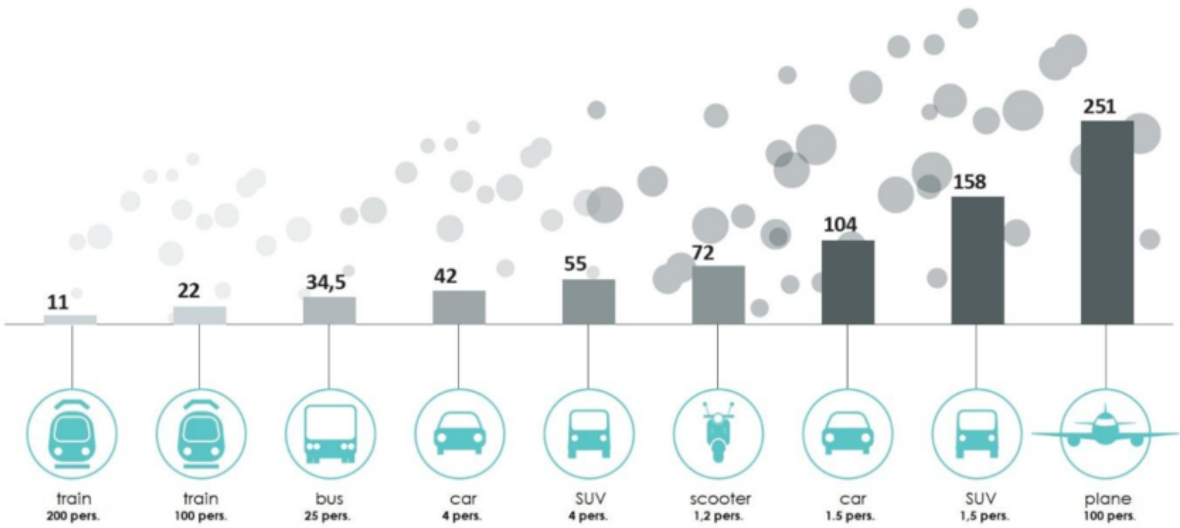
According to Eurostat data from 2022, passenger cars and light commercial vehicles are responsible for the largest share of emissions within the transport sector, contributing approximately 60% of the total emissions from road transport (Destatis, 2024) and responsible for around 19% of total EU emissions of carbon dioxide. This substantial contribution highlights the critical role of passenger cars in overall transport-related greenhouse gas emissions.

Figure 4: Carbon dioxide emissions by road transport

Source: Statistisches Bundesamt (Destatis, 2024)

The continuous rise in motorization and road traffic, which has persisted for decades in most of the countries, has significantly transformed travel patterns and urban mobility. Similarly, the decline of public transport has intensified car dependency according to Bertolini, L., & le Clercq, F. (2003).

Figure 5: *CO_2* emission per passenger per km and type of transport



Source: ProKolej Foundation, Rail for the Climate, Summary Report (2021)

For instance, the increasing demand for environmentally friendly vehicles has driven manufacturers to prioritize the development of low-emission and electric vehicles (ACEA -

Pocket Guide 2024/2025). This shift can relate to a growing awareness among consumers regarding the environmental impact of their choices, as noted by (Groening et al., 2014), who emphasize that consumers are increasingly familiar with the term "carbon footprint" through extended news coverage of climate change, multi-national treaties, and green investment.

According to the IPCC guidelines (2006) Carbon Footprint (CF) is defined as "a representation of the effect on climate in terms of the total amount of greenhouse gases that are produced, measured in units of CO_2 as a result of the activities of an organization". Carbon footprint is a blanket term that refers to the emissions of greenhouse gasses generated by human activities, and to carbon dioxide emissions, including the life cycle of a product (Karaś, 2023).

Environmental concerns are not the only influence consumer preferences. According to Greene et al. (2018), the incorporation of technologies to reduce emissions may not only increase vehicle costs but may also compromises in other vehicle features important to consumers such as safety, comfort, or performance.

ACEA (2024) supports this notion, revealing that the market for Battery Electric Vehicles (BEV) has surged, driven by consumer interest in sustainable options. This trend aligns with the findings of Hulshof & Mulder (2020) which considers that providing consumers with trustworthy information of emission reductions in passenger car transport can be considered as a key policy tool for achieving this aim.

The IEA (2022) argues that BEVs are currently the most promising technology to replace Internal Combustion Engines (ICE) vehicles, however, charging infrastructure needs to expand substantially to meet projected growth in demand.

As reported by ACEA - Automotive Insights (2024), there were around 632 thousand public charging points available across the EU by the end of 2023, with around 153,000 new public charging stations installed that year. However, the association warns that to meet the EU's 55% CO_2 reduction target[5] for passenger cars, nearly 2.9 million public charging points would need to be installed over the next seven years. Representing 410,000 new charging points per year, or about 7,900 per week.

Also, according to the same report from ACEA (2024), consumer preferences are strongly linked to the availability of infrastructure for the BEV ecosystem. The association argues that battery electric vehicle sales have significantly outpaced the growth of public charging stations, with electric car sales increasing over 18 times between 2017 and 2023, while the number of public chargers in the EU increased only six times during the same period.

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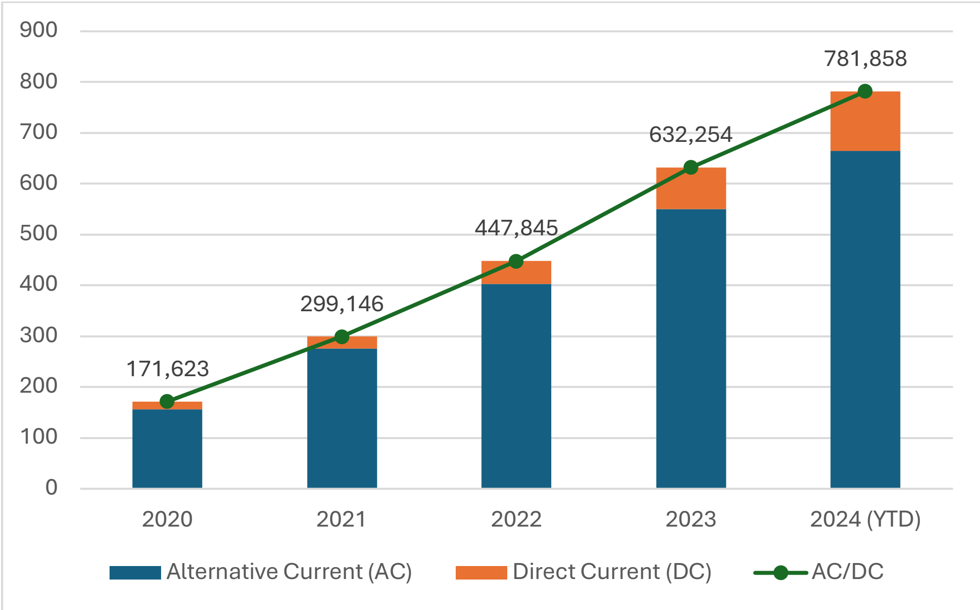
[5] Fit for 55 Package - https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55/

Figure 6: Year to Date (YTD) - Recharging Points in the European Union (EU27)



Source: Infrastructure - European Alternative Fuels Observatory, n.d. (September 28th, 2024)

The European Automobile Manufacturers Association also argues that there is a strong link between BEV sales in 2023 and the availability of charging infrastructure. Despite ranking 4th for available infrastructure, Belgium is not among the top five countries for BEV sales. Additionally, 61% of all EU charging points are concentrated in just three countries: the Netherlands (23%), Germany (19%), and France (19%).

Figure 7: Other BEV Indicators

BEV cars on the road (% share, 2022)		**New BEV cars sold** (% share, 2023)		**Charging points per 1,000 inhabitants** (2023)		**Charging points per 10 km of road** (2023)	
EU	**1.2%**	**EU**	**14.6%**	**EU**	**1.4**	**EU average**	**1.3**
TOP FIVE COUNTRIES							
1 Denmark	4.0%	1 Sweden	38.7%	1 Netherlands	8.2	1 Luxembourg	8.0
2 Sweden	4.0%	2 Denmark	36.3%	2 Denmark	3.9	2 Netherlands	7.7
3 Netherlands	3.7%	3 Finland	33.8%	3 Belgium	3.8	3 Portugal	5.1
4 Luxembourg	3.1%	4 Netherlands	30.8%	4 Luxembourg	3.6	4 Denmark	3.1
5 Austria	2.1%	5 Luxembourg	22.5%	5 Sweden	3.6	5 Belgium	2.9
BOTTOM FIVE COUNTRIES							
1 Czechia	0.2%	1 Italy	4.2%	1 Croatia	0.3	1 Latvia	0.1
2 Slovakia	0.2%	2 Poland	3.6%	2 Bulgaria	0.2	2 Estonia	0.1
3 Poland	0.2%	3 Czechia	3.0%	3 Malta	0.2	3 Poland	0.1
4 Cyprus	0.1%	4 Croatia	2.8%	4 Poland	0.2	4 Hungary	0.2
5 Greece	0.1%	5 Slovakia	2.7%	5 Romania	0.1	5 Lithuania	0.2

Source: ACEA – Automotive Insights (2024)

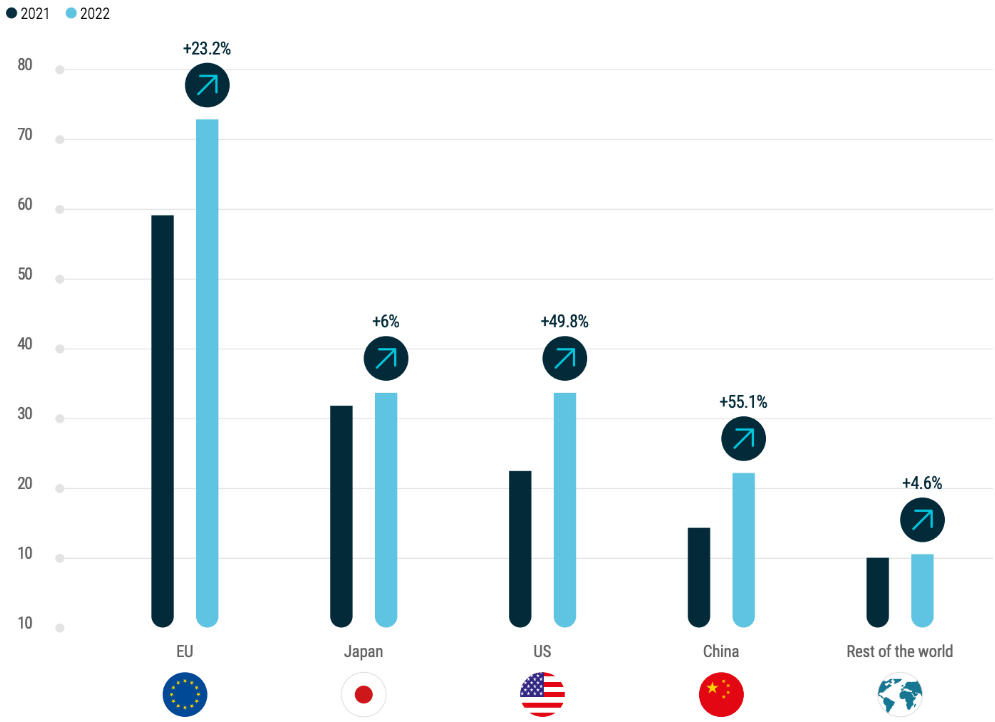
2.5 Technological Innovations in the Automotive Sector

The automotive sector is undergoing a significant transformation, aiming to increase the energy efficiency and driven by increasing regulations targeting carbon emissions reduction due the effects of climate change, manufactures are challenged to innovate and adopt alternative fuel technologies to the traditional Internal Combustion Engines (ICE) vehicles.

According to ACEA (2024) The Automobile Industry: Pocket Guide 2024/2025, automotive companies lead EU investments in a diversified scenario, the sector invests around €73 billion annually in Research and Development (R&D), about twice the amount as the pharmaceutical and biotech sector.

Many of these investments are directed to find out substitutes for the traditional transport vehicles which uses Internal Combustion Engines (ICE). Those are powered by gasoline or diesel fuel, which are non-renewable sources of energy extracted from fossil fuels, meaning that will eventually run out or will not be replaced rapidly enough as noted by Bukhari et al. (2023).

Figure 8: Automotive R&D Investment Comparission Across the World



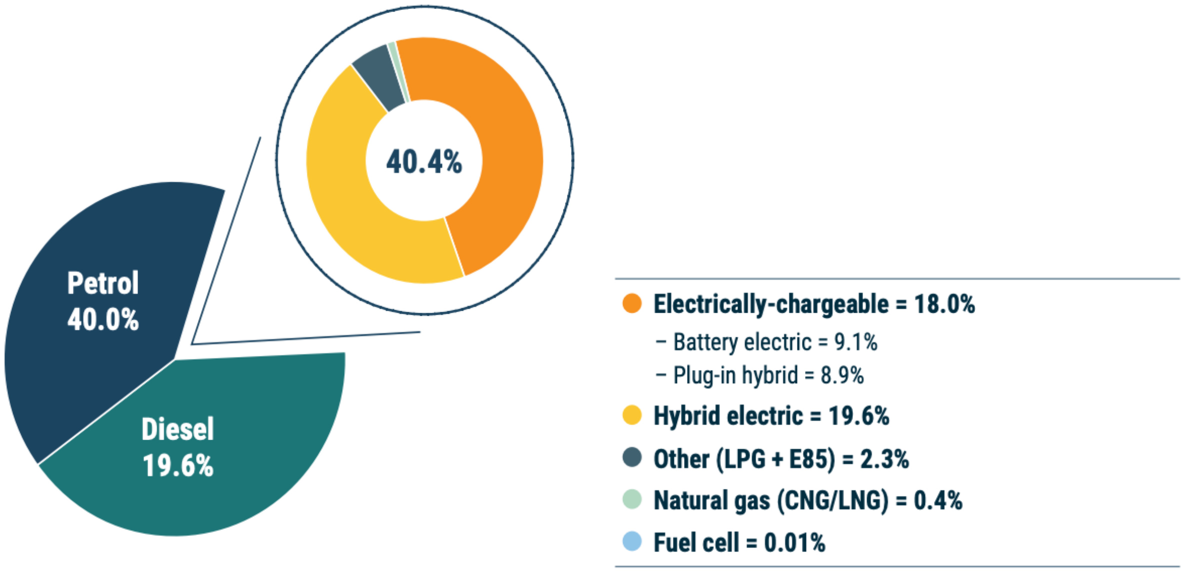
Source: ACEA (2024) The Automobile Industry: Pocket Guide 2024/2025

Trying to address correctly the changes on this transition, the European Union decides to classify passenger transport cars up to eight passengers as M1 and light commercial vehicles up to 3.5 tons as N1 (Vehicle Categories, n.d.).

2.5.1 Electric Vehicles (EVs)

EVs include electrically chargeable vehicles (ECVs) and fuel cell electric vehicles (FCEVs). ACEA (2022) notes that ECVs, comprising battery electric and plug-in hybrids, accounted for 18% of all new car sales in the European Union in 2021, as highlighted in the 2022 Progress Report on Making the Transition to Zero-Emission Mobility.

Figure 9: New Cars sales in the EU by Fuel Type (2021)



Source: ACEA (2022) - Making the Transition to Zero-Emission Mobility

2.5.1.1 ECVs: Battery Electric Vehicle (BEV) and Plug-in Hybrid Electric Vehicle (PHEV)

BEV is a type of Electric Vehicles that is powered entirely by electricity stored in an onboard battery, with no internal combustion engine. The electric motor is driven by the battery, which is recharged via external power sources like charging stations or home chargers. BEVs produce zero tailpipe emissions, making them a key component in the shift towards sustainable, zero-emission mobility (ACEA - Making the transition to zero-emission mobility: 2022 Progress Report). According to Pautasso et al. (2019) an increase in the number of EVs results in less air pollution and, therefore, minor public health expenditure.

PHEV combines convectional ICE motor with an electric propulsion system, allowing limited electric-only operation. Rassaei et al. (2014) notes that PHEV are becoming popular, not only because are they much more environmentally friendly than conventional ICE vehicles, but their fuel can also be catered from diverse energy sources and resources.

Despite these advantages, the expected growth in EV and PHEV depends heavily on the battery costs, even if these costs are successfully lowered, electric vehicles can potentially still cost significantly more than vehicles with internal combustion engines, where not enough customers are willing to pay the difference, at least in a traditional purchase (Bernhart et al., 2010).

The academic literature also highlights the importance of policy interventions to reduce the total cost of ownership of ECVs compared to conventional vehicles, which would accelerate consumer adoption (Boulanger et al., 2011).

Economic factors play, therefore, significant influence on consumer decisions regarding electric vehicle purchases, as highlighted by ACEA which stablishes a correlation between uptake of electric cars and Gross Domestic Product (GDP) per capita, which (ACEA - Interactive Map - 2021).

The Global EV Outlook 2022 from IEA emphasizes that while the initial purchase price of ECVs can be higher than traditional vehicles, the total cost of ownership, including fuel savings and maintenance, can make ECVs more affordable over time. However, the financial burden of the upfront costs can deter buyers in lower-income countries.

Figure 10: Relation between Income and ECVs in 2021

Top 5: Countries with the LOWEST ECV market share

1. Bulgaria – 1.7% (GDP of €9,850)
2. Cyprus – 1.7% (GDP of €26,030)
3. Estonia – 2.9 % (GDP of €23,060)
4. Slovakia – 3.0% (GDP of €17,820)
5. Czech Republic – 3.2% (GDP of €22,320)

Top 5: Countries with the HIGHEST ECV market share

1. Sweden – 45.0% (GDP of €50,910)
2. Denmark – 35.3% (GDP of €57,350)
3. Finland – 30.8% (GDP of €45,620)
4. Netherlands – 29.5% ECVs (GDP of €49,090)
5. Germany – 26.0% ECVs (GDP of €42,920)

Source: ACEA (2022) - Making the Transition to Zero-Emission Mobility

2.5.1.2 Fuel Cell Electric Vehicles (FCEVs)

Fuel Cell Electric Vehicles use hydrogen to generate electricity through a reaction in a fuel cell, powering an electric motor and emitting only water vapor, making them a zero-emission alternative. Hydrogen is stored in high-pressure tanks and can be refuelled in 3-5 minutes, like gasoline cars.

According to Kumar et al., 2009, hydrogen-powered vehicles offer ranges comparable to gasoline-powered cars, with some models capable of reaching over 300 miles on a single tank of hydrogen. This makes them a promising solution for long-distance travel without contributing to carbon emissions.

However, the adoption of FCEVs faces significant challenges, primarily due to the lack of a widespread hydrogen refuelling infrastructure. This limitation significantly affects consumer confidence and the practicality of using FCEVs for daily transportation. The availability of hydrogen refuelling stations is currently sparse, which makes long-distance travel difficult and restricts potential buyers to regions with sufficient infrastructure. As noted by the Hydrogen Mobility Europe project, the slow pace of infrastructure development remains one of the biggest obstacles to wider adoption of FCEVs (Hydrogen Mobility Europe. n.d.).

2.5.2 Hybrid Electric Vehicles (HEVs)

Hybrid Electric Vehicles combine a traditional internal combustion engine with an electric motor, utilising both power sources to improve fuel efficiency and reduce emissions. Unlike plug-in hybrids, HEVs cannot be charged from an external power source; instead, they rely on regenerative braking and the internal engine to recharge their battery.

The hybrid drivetrain in HEVs offers several advantages over conventional vehicles. Wright & Pinkelman, (2007) argues that the electric motor enables the engine to operate at its most efficient load most of the time, utilising the batteries to smooth out spikes in power demand. Additionally, the presence of an electric motor provides designers the flexibility to select a smaller and more fuel-efficient engine, without sacrificing vehicle performance (Shiau et al., 2010).

However, noise and vibration suppression are a critical challenge for HEV manufacturers. Compared to conventional vehicles, HEVs have fundamentally different power sources and powertrain systems, leading to unique noise and vibration properties (Qin et al., 2020). Addressing these NVH issues is crucial for providing a comfortable driving experience for both drivers and passengers.

Hybrid vehicle designs can be broadly categorised into series and parallel configurations. In a series HEV, the electric motor is the sole source of motive power, while the internal combustion engine is coupled to a generator to charge the batteries when needed (Duoba et al., 1996). Conversely, in a parallel HEV, both the engine and the electric motor provide power to the wheels (Duoba et al., 1996). These different configurations offer unique advantages and compensates in terms of efficiency, performance, and cost.

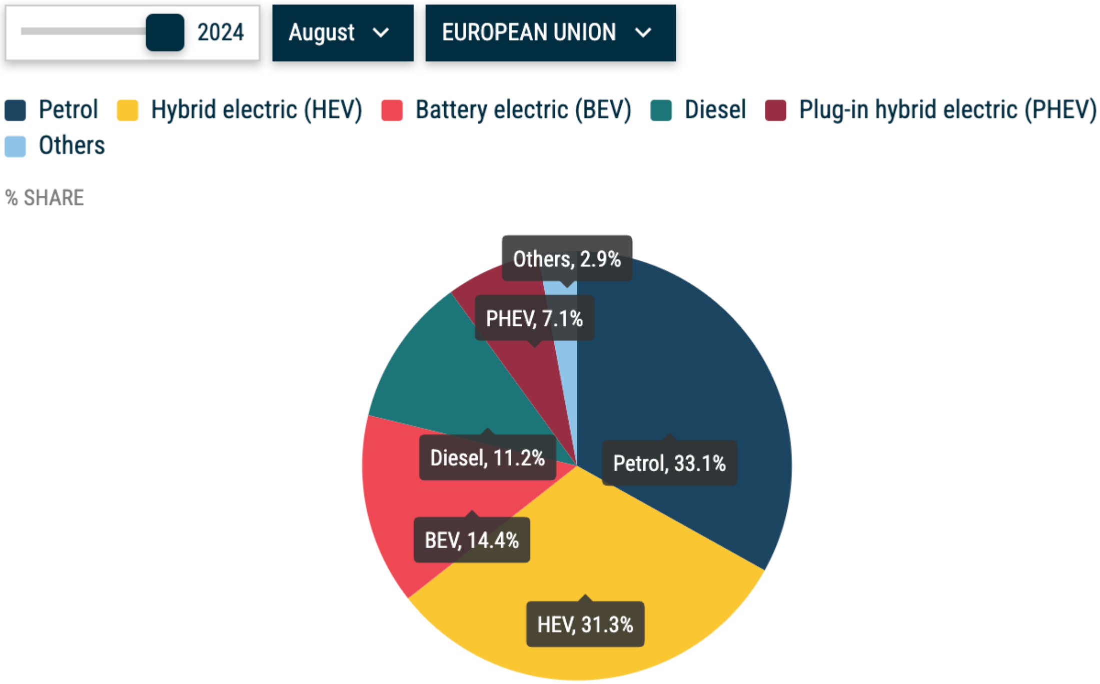
The HEVs engines were 31,3% of total EU new passenger cars registrations by power source in August of 2024 (ACEA, 2024).

2.5.3 Natural Gas Vehicles (NGV)

Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), and Liquefied Natural Gas (LNG) are increasingly viable alternatives to diesel in heavy transportation, offering emissions reductions and operational efficiency. LPG significantly lowers carbon emissions and is cost-effective for fleets and buses (Özcan & Söylemez, 2005). CNG and LNG have also gained traction, with major advances in natural gas engine technology enabling lower greenhouse gas, criteria pollutant, and toxic emissions than contemporary diesel vehicles (Boretti, 2013). The emissions benefits of natural gas vehicles, particularly in urban environments, make them an attractive option for cities and municipalities seeking to improve air quality.

However, the capital expenditure and infrastructure requirements for natural gas vehicles have presented barriers to widespread adoption. Nonetheless, as natural gas reserves continue to grow globally, these fuels are poised to play a greater role in decarbonizing the heavy transportation sector.

Figure 11: New EU car registrations by Power Source in August 2024



Source: ACEA (2024) - New car registrations Report

2.6 Barriers to Adoption of Low-Emission Vehicles

As global efforts to reduce greenhouse gas emissions intensify, the adoption of low-emission vehicles (LEVs) is seen as a crucial step toward achieving sustainability in the transportation sector.

However, despite advancements in technology and growing public awareness, several barriers continue to hinder the widespread adoption of low-emission vehicles across different regions, particularly in Europe.

These barriers can be grouped into three main categories: cost and affordability, infrastructure challenges, and policy-related obstacles. This section will explore these barriers, incorporating direct references from research and reports, with a specific focus on the role of tax incentives and the infrastructure for recharging points, using data from the European Automobile Manufacturers Association.

2.6.1 Affordability of Low-Emission Vehicles (LEVs)

One of the most significant barriers to the adoption of LEVs is their higher upfront cost compared to traditional ICE vehicles. Lebeau et al. (2019), argues that the higher price tag is mainly due to the cost of the battery pack, which can account for up to 50% of the total vehicle cost. However, the operating costs of LEVs are generally lower due to their energy efficiency and lower maintenance requirements, which can partially offset the higher initial investment. (Boulanger et al., 2011)

Various policies and incentives have been implemented in different countries to address the affordability challenge and promote the adoption of LEVs. These include purchase subsidies, tax exemptions, and other financial incentives to reduce the total cost of ownership of LEVs.

Elsewhere in Europe, electric cars remain typically much more expensive than ICE equivalents. In Poland, for example, just a few electric car models could be found at prices competitive with ICE cars in 2023, under the PLN 150 000 (Polish zloty) (EUR 35 000) mark. (Trends in Electric Cars – Global EV Outlook 2024 – Analysis - IEA, n.d.).

For instance, in Eastern Europe, where average disposable income is lower, the adoption rate of LEVs is significantly slower compared to wealthier Northern and Western European countries. Even so, studies from Knez et al. (2020) indicates that in Slovenia, the interest in zero-emission vehicles could increase significantly if the prices of electric cars decline and fuel costs rise. Additionally, preferences regarding car pricing show that 40% of consumers in Slovenia and Poland would be inclined to consider purchasing an electric vehicle if prices were to drop by 25%, a sentiment echoed by as much as 85% of Spanish consumers.

This study also highlights that women across Slovenia, Poland, and Spain display a greater inclination toward zero-emission vehicles compared to their male counterparts. In terms of policy implications, the findings suggest a need for different strategies in Poland, where interest in zero-emission vehicles is comparatively lower than in Slovenia and Spain.

2.6.2 Infrastructure

A major barrier to the adoption of LEVs is the lack of adequate infrastructure, particularly for electric vehicles, which rely on an extensive network of recharging points. According to ACEA - Interactive Map – Correlation Between Electric Car Sales and Charging Point Availability (2023 Data) (2024) there is significant disparities in the availability of charging stations among European countries.

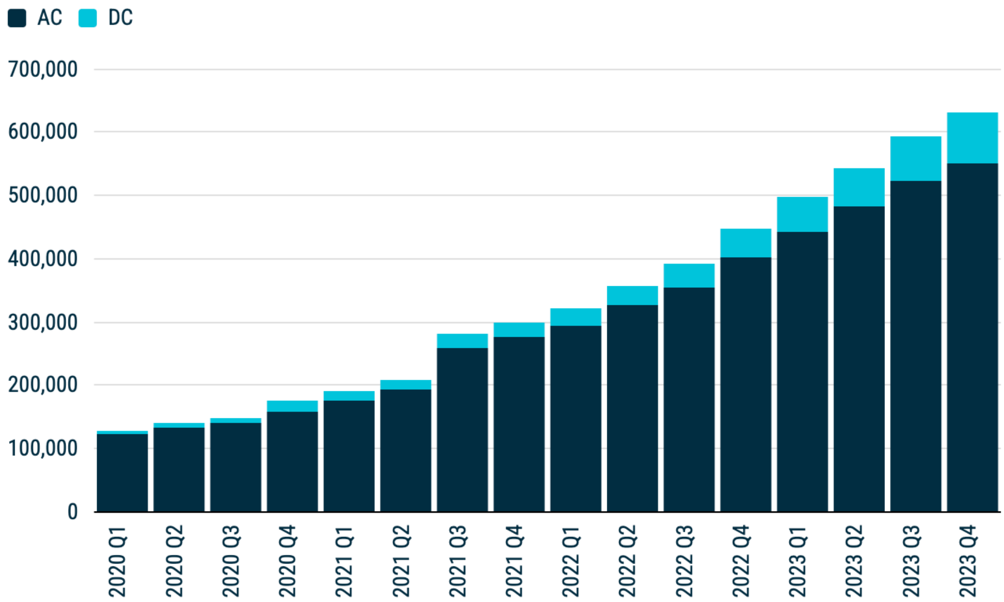
In the same report we can visualize how Western European countries, such as the Netherlands, Germany, and France, have made substantial investments in electric vehicle infrastructure. The Netherlands, for example, has the highest number of public charging points in Europe, with over 140 thousands stations in 2023. By contrast, countries in Eastern Europe, such as Poland and Bulgaria, and Northern Europe, such as Latvia and Estonia, lacks significantly public charging points availability (ACEA, 2024).

The uneven distribution of charging infrastructure is a major hurdle for consumers considering electric vehicles. Sayed et al. (2021) note that Range anxiety and unavailability of sufficient charging infrastructure in some areas have led to reluctance in the acceptance of EVs by some users. Without a reliable and widespread charging network, many consumers are hesitant to switch from traditional gasoline or diesel vehicles to electric ones.

Therefore an attractive solution is to place the charging facilities at the drivers' home, workplace or other places where they are likely to stay for an extensive period of time (Ghamami et al., 2015).

ACEA data from 2022 indicates that while there are approximately 400,000 charging points across the European Union, only about 10% of them are fast chargers. This presents a significant challenge, especially for long-distance travelers who may not have the time to wait for several hours for a full charge (ACEA - Around One out of Every Eight EU Public Chargers is a Fast Charger (2024)).

Figure 12: Public charging points in the EU by type (AC/DC)



Source: ACEA - Around One out of Every Eight EU Public Chargers is a Fast Charger (2024)

Alternating Current (AC) chargers are predominantly used for slower charging applications, making them ideal for homes, workplaces, and public areas like supermarkets and leisure facilities. Direct Current (DC) chargers are tailored for fast charging, often found along motorways and main highways, providing quick recharge options for drivers on long journeys (ACEA, 2024).

2.6.3 Policy-Related Barriers and Tax Benefits and Incentives

While some European countries have implemented strong policy frameworks to encourage the adoption of low-emission vehicles, there are considerable disparities in tax incentives and other financial support measures across the continent. According to ACEA's 2023 report, countries such as The Netherlands and Germany offer generous tax incentives for electric vehicle buyers, which have contributed to higher adoption rates in these regions (ACEA - Tax Benefits and Incentives for Electric Cars (2024)).

Still checking the same report, by contrast, countries like Poland and Hungary provide little to no financial incentives for electric vehicle buyers, resulting in significantly lower adoption rates. ACEA data shows that in 2023, electric vehicles accounted for less than 3% of new car sales in Poland, compared to 12% in the EU overall. In these countries, the lack of tax incentives means that the cost barrier remains particularly high for consumers.

Table 6: Tax Benefits and Incentives for Electric Cars 27 EU Member States

Country	Tax Benefits	Incentives
Austria	VAT deduction for zero-emission cars based on purchase price Exemption from ownership and pollution tax for zero-emission cars	Tax investment incentive of 15% for purchase of zero-emission cars Bonus for new fully electric cars and charging infrastructure until the end of 2024
Belgium	Minimum tax rates for BEVs and FCEVs 6% VAT for electricity consumption 100% deductibility of company car expenses	€5,000 premium for new zero-emission cars Municipal purchase subsidies for charging infrastructure
Bulgaria	Tax exemption for electric vehicles	None
Croatia	No excise duties for electric vehicles Exemption from special environmental tax	Incentive scheme: €9,000 for BEVs, €5,000 for PHEVs until December 31, 2024
Cyprus	Exemption for vehicles emitting ≤ 120g CO_2/km	Up to €12,000 to scrap and replace a vehicle emitting < 50g CO_2/km Up to €19,000 for BEVs
Czechia	Exempt from registration fees for BEVs and FCEVs Reduced depreciation period for charging stations	Purchase incentives for low- and zero-emission vehicles for state and local government bodies
Denmark	Reduced registration tax for zero-emission and low-emission vehicles	Minimum semi-annual tax rate based on CO_2 emissions
Estonia	€5,000 for individuals, €4,000 for legal persons for new BEVs and FCEVs	None
Finland	Exempt from registration taxes for zero-emission passenger cars	Tax deduction of €170 per month from taxable value (income tax) for BEVs (2021-2025), and €85 per month for cars with 1-100g CO_2/km (2022-2025). Electric vehicle charging at the workplace is exempt from income tax (2021-2025).
France	Exemption for alternatively powered vehicles and low CO_2-emission vehicles	Bonus for new BEVs and scrappage scheme for second-hand vehicles
Germany	10-year exemption for BEVs and FCEVs registered until December 31, 2025	Funding applications for electric vehicle incentives no longer accepted since December 31, 2023

Greece	Reduced registration tax for PHEVs and exemptions for low-emission vehicles	Cashback of up to €17,500 for battery-electric taxis
Hungary	Exemption for BEVs and PHEVs	€7,350 for electric cars with a gross price of up to €32,000
Ireland	€5,000 relief for BEVs up to €40,000	Purchase incentives of up to €5,000 for BEVs and PHEVs
Italy	Five-year exemption from the date of first registration for BEVs	Various incentives based on CO_2 emissions and selling price
Latvia	Exemption from registration costs for BEVs	Minimum rate (€10) for BEVs
Lithuania	Exempt from registration tax for BEVs	Purchase incentives for individuals and legal persons up to €5,000 for new BEVs
Luxembourg	50% reduction in administrative tax for zero-emission vehicles	Purchase incentives for private infrastructures ranging from €750 to €1,650
Malta	Minimum rate for vehicles emitting ≤ 100g CO_2/km	Up to €11,000 for individuals and €20,000 for companies for BEVs
Netherlands	Exemption for zero-emission cars	Subsidy scheme for individuals to buy/lease BEVs
Poland	Exemption for BEVs and FCEVs	Purchase incentives from PLN 18,750 to PLN 27,000 for BEVs and FCEVs
Portugal	Complete exemption for BEVs; 75% reduction for PHEVs	€3,000 for individuals to buy a new BEV with a maximum price of €62,500
Romania	Exemption for BEVs	Renewal scheme (RABLA) with bonuses for PHEVs and BEVs
Slovakia	Maximum charge of €33 for BEVs, 50% reduction for PHEVs in registration fees	Accelerated depreciation for BEVs and PHEVs from four to two years
Slovenia	Minimum additional tax rate (0.5%) for BEVs	Incentive scheme up to €4,500 for BEVs
Spain	Exemption from special tax for vehicles emitting ≤ 120g CO_2/km	15% personal income tax deduction on acquisition costs for private use vehicles in 2023-2024. Offers funding, based on size and charging point power, of up to 70% for self-employed individuals and local communities, with companies receiving between 30% and 55%. Higher amounts apply in municipalities with fewer than 5,000 residents.
Sweden	None for acquisition, but low annual road tax (SEK 360) for zero-	Offers a 50% tax deduction on labor and material costs for households installing electric vehicle charging boxes at home and a grant

	emission vehicles and PHEVs ownership.	funding for up to 50% of the installation costs for charging stations in apartment buildings and workplaces.

Source: Own editing based on data from ACEA - Tax Benefits Incentives (2024)

2.6.4 Market Fragmentation and Consumer Awareness

Electric Vehicles (EV) market fragmentation often manifests as variations of consumer engagement across different European Union member states. This fragmentation in the EV sector is primarily the result of inconsistent policies across EU member states. While the EU sets overarching goals for reducing carbon emissions, the implementation of specific policies is left to individual countries, leading to a patchwork of incentives, taxation policies, and infrastructure investment.

Notably, recent data indicates that after a steady decline in average CO_2 emissions from new passenger cars in the European Union between 2010 and 2016, these emissions increased in 2017 (Sokorai et al., 2018). This reversal underscores the challenges in transitioning the passenger vehicle fleet to lower emission technologies, despite policy support and consumer interest in some markets.

Countries like Bulgaria and Estonia provide much fewer financial incentives, limiting the attractiveness of electric vehicles to consumers in those regions as we can see in the Table 6: Tax Benefits and Incentives for Electric Cars 27 EU Member States. This results in significantly different rates of EV adoption within EU countries, where potentially Eastern Europe countries are behind.

In terms of charging stations accessibility, the European Union is also still not well diffuse. Northern and Western European countries, where EV adoption rates are high, have developed extensive networks of fast-charging stations, while countries in Southern and Eastern Europe often have sparse or poorly maintained infrastructure (Matanov & Zahov, 2020). Overcoming this geographic imbalance in EV infrastructure is critical for achieving widespread EV adoption in Europe (Schnee et al., 2020).

Also, according to Table 6, in countries where government campaigns and incentives have been robust, consumers can be generally more informed about the positive environmental impact of EVs and the available purchasing subsidies.

However, in other regions where public outreach has been limited, consumers may still be unclear about the extent to which EVs can reduce carbon emissions and other pollutants. This lack of understanding can act as a deterrent to adoption, particularly in regions where the environmental rationale for EV ownership has not been effectively communicated.

2.7 Future Projections and Policy Recommendations for CO_2 Emission Reductions

As the EU aims to reduce its carbon footprint, the electrification of the transport sector is expected to play a pivotal role. The European Automobile Manufacturers Association predicts that the adoption of electric vehicles will significantly increase in the coming decade, driven by both regulatory pressure and consumer demand. However, achieving these targets requires substantial changes in both vehicle technology and energy infrastructure.

In terms of future projections, sales of BEV and plug-in hybrid electric vehicles are expected to continue growing, with BEVs making up nearly 60% of all new car sales by 2030 (IEA, 2022). This growth will be supported by improvements in battery technology, which are expected to lower the cost of EVs, and by the expansion of charging infrastructure across Europe. The continued development of hydrogen fuel cell vehicles also has the potential to contribute to emissions reductions, particularly in the heavy-duty vehicle segment.

However, despite these optimistic projections, there are still significant challenges to be addressed. The structural limitations of highly dense urban cities, which have larger proportions of on-street and large-commercial-garage parking, are the catalysts for increased public-charging demand. In the near term, low levels of public charging should therefore not significantly hinder EV adoption in the European Union and United States (Engel et al., 2018).

3. MATERIALS AND METHODS

In this thesis, I looked at emissions of CO_2 from new passenger cars in the EU and how countries impact the European Green Deal to be climate neutral by 2050. The closest target was to explore how countries are advancing towards these goals on the example of the average emissions of CO_2 per kilometre for new passenger cars within the range of 2000 to 2023. I focused on using datasets provided by the European Environment Agency (EEA) to observe the patterns of emissions throughout the EU.

The data, which was collected from the EEA' website, was in a CSV format and then imported into Google Colab to enable manipulation of data. In addition, I utilized mainly Python with the crucial libraries, for example, the Pandas to deal with the data while using the NumPy for computations and the Matplotlib for depicting the graphs. In the data cleaning phase, I handled missing or incomplete data, irregularity in the data time-series, and made necessary amendments to the data to suit the analysis.

For the analysis, I grouped the EU member states into regions: There are current and historical data on Northern, Southern, Eastern, Western, and Central European countries, which facilitates direct emissions comparison. The numerical analysis included the means, medians, and standard deviations, which made it easier to reveal general trends and differences in the level of CO_2 emissions between countries within specific regions and compare them to indicate which regions had the highest or the lowest levels of CO_2 emissions.

Besides these, simple statistics, I had used time series analysis in order to see how emissions changed throughout the 23 years. This enabled the detection of emission skewness, and highlighted areas that had high or low emission levels. To the connected outliers, I relate it to facets found in the literature review as to the plausible explanations like innovation in car manufacturing processes, existing policies, or consumer behavior.

I also used bar chart to support my findings on the trends in emissions and their distribution by region. These charts were essential in demonstrating important patterns, such as emissions decreasing in some regions while remaining constant or even increasing in others.

4. RESULTS AND DISCUSSION

The data for my analysis has been obtained from the EEA Datahub: Eurostat SDG_13_31, which tracks new passenger cars CO_2 emissions from 2000 to 2023. I observed some gaps in the dataset; all the country data is missing for the year 2017, some data for 2018 and 2019 were estimated, and the data for 2023 was provisionally estimated. To stress these inequalities, these changes should be demonstrated to produce a more appropriate interpretation of the outcomes that follow.

To balance the distribution and make comparisons easier, I divided the EU27 countries into five regions, as shown in Table 7: Distribution of the aggregate sum of EU27 Member States. Within this regional division, all the EU member states are represented more or less equally, which makes the analysis of the tendencies of CO_2 emissions across different regions of Europe more effective.

Table 7: Division of EU27 Member States

EU Regions	Countries	Total Countries
EU Countries	EU27 member states	27
Western Europe	Belgium, France, Luxembourg, Netherlands, Ireland	5
Eastern Europe	Bulgaria, Hungary, Romania, Slovenia, Slovakia	5
Southern Europe	Cyprus, Greece, Spain, Croatia, Italy, Malta, Portugal	7
Northern Europe	Denmark, Estonia, Finland, Lithuania, Latvia, Sweden	6
Central Europe	Austria, Germany, Czech Republic, Poland	4

Source: Own editing based on Easy to Read – About the EU | European Union, n.d. (2024)

I performed descriptive statistics to calculate the mean, median, and Standard Deviation (SD), as shown in Table 8. Such measures are crucial in providing a summary of emissions with regards to the central tendencies and variability across the regions and the continent.

Table 8: Descriptive Statistics by Region

Region	Mean	Median	SD
EU Countries	132,30	132,00	15,23

Region	Mean	Median	StdDev
Central	146,38	149,00	17,14
Eastern	142,88	144,60	12,90
Northern	148,58	147,85	29,45
Southern	135,83	135,35	19,46
Western	138,42	137,60	24,04

Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

The analysis of CO_2 emissions from new passenger cars across various regions in the EU shows notable regional differences, as outlined in Table 8: Descriptive Statistics by Region. Currently the EU countries have an average CO_2 emission rate of 132.30 g/km, the median is 132.00 g/km, and the standard deviation is 15.23 g/km. This suggests that there is still much similarity in the emission levels of the countries within the member states. But it is significant to consider that the tracking of emissions in some of these countries has correlation with their membership in the EU27.

Especially, some of the countries of the Central Region started calculating their emission data from 2000 or 2002, which corresponds to crucial steps in the process of EU membership. The timing likely shifts the mean, median and standard deviation of emissions since it is conceivable that, for example, records of emissions today are different due to the varying regulatory environment in these countries. To illustrate this, I organized the countries and their respective start dates for emissions tracking in Table 9: Region Distribution by Country and Start Date. This layout helps to understand emission tracking in connection with accession to EU27 and potential impact on emission of CO_2, if any.

Table 9: Region Distribution by Country and Start Date

Region and Country	Mean	Median	StdDev	Start Year
Central	**146,38**	**149,00**	**17,14**	
Austria (AT)	144,11	147,70	19,23	2000
Czech Republic (CZ)	144,62	146,90	10,68	2002
Germany (DE)	151,03	154,10	23,01	2000
Poland (PL)	145,29	146,10	10,19	2002
Eastern	**142,88**	**144,60**	**12,90**	
Bulgaria (BG)	148,50	149,20	14,83	2005
Hungary (HU)	144,08	144,50	11,40	2002
Romania (RO)	138,06	139,00	13,55	2005
Slovenia (SI)	139,94	142,05	13,44	2002
Slovakia (SK)	143,98	144,90	9,96	2004
Northern	**148,58**	**147,85**	**29,45**	
Denmark (DK)	133,12	131,30	29,75	2000
Estonia (EE)	157,42	157,30	16,97	2002
Finland (FI)	144,73	143,65	32,81	2000
Lithuania (LT)	151,95	148,55	18,50	2002
Latvia (LV)	157,45	154,70	19,94	2002
Sweden (SE)	150,33	148,15	41,43	2000
Southern	**135,83**	**135,35**	**19,46**	
Cyprus (CY)	148,38	149,75	18,85	2003
Greece (EL)	141,17	137,55	24,55	2000

Spain (ES)	139,18	140,80	15,43	2000
Croatia (HR)	127,85	127,30	10,97	2013
Italy (IT)	136,25	136,80	14,50	2000
Malta (MT)	126,39	129,30	17,72	2003
Western	**138,42**	**137,60**	**24,04**	
Portugal (PT)	127,45	127,20	19,79	2000
Belgium (BE)	137,30	141,30	20,60	2000
France (FR)	132,74	133,65	19,55	2000
Ireland (IE)	138,51	136,30	23,16	2000
Luxembourg (LU)	149,67	153,20	20,82	2000
Netherlands (NL)	133,88	129,60	32,01	2000

Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

In this case, I was able to identify that the Central Region had higher emissions relatively higher that the overall EU descriptive statistics with a mean of 146.38 g/km, median of 149.00 g/km, and standard deviation that was slightly above 17.00 g/km. This means average fluctuation and signs of high emission rates starting soon.

The Eastern Region almost brings the tally of average emission means behind it with a mean of 142.88 g / km, median at 144.60 g / km, and standard deviation of 12.90 g / km. While the averages mentioned above are higher than the European Union mean values, the smaller standard deviation indicates there would be less variation in emissions in the countries of this area.

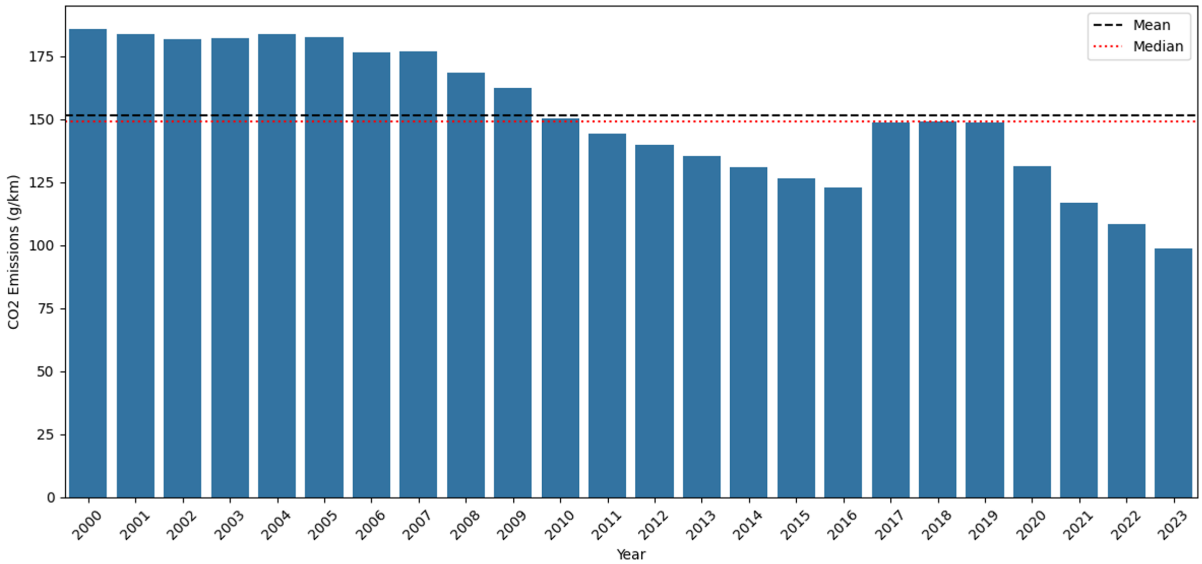
The maximum and minimum average emissions observed are in the Northern Region with a mean of 148.58 g/km and median of 147.85 g/km and with the highest standard deviation of 29.45 g/km. This reveals fairly large differences in emissions within its countries. In the Southern Region, the mean emission was 135.83 g/km and median 135.35 g/km, and standard derivation 19.46 g/km which suggests performance that is more or less average as compared to total EU average.

As for the countries that have first recorded their emissions, it is possible to divide them into two groups: those which have first made it in 2000, namely Greece (EL) and Italy (IT), while Croatia (HR) first did it in 2013.

The means emissions of the Western Region were 138.42 g/km the median emissions were 137.60 g/km, while the standard deviation was 24.04 g/km which indicated moderate emissions with some dispersion. But it occurred to me that to gain better understanding of emissions fluctuations over regions and countries, then it was necessary to consider not only the starting year in recording of emissions but a few other factors as well.

Therefore, analysing CO_2 emissions trends over the years for each region was essential in determining whether emissions were reducing or stabilizing over time. By plotting these trends, I was able to visualize the trajectory of emissions across different regions and compare their progress.

Figure 13: CO_2 Emissions from Passenger Cars in the Northern Region Over Time



Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

Figure 13 above shows the trend of CO_2 emission from new passenger cars in the Northern Region for the period between 2000 and 2022. Firstly, I found out that the emissions are still higher echoing about 172 g/km in the year 2000 to 2005 showing that Northern Region's CO_2 emissions were comparatively high during early part of this decade. Despite that, the graph presents a decrease in emissions starting 2006, although gradual, there is a more significant decrease in emissions around the year 2010.

Thus, with the help of the Judaism state's promotion of significantly increasing fuel consumption, emissions were below 125 g/km by 2020. It is believable to attribute this decline to the increased implementation of the emission rules that came with the inauguration of the European Green deal in 2019 the development of vehicles technology and increase of the flow of electric and hybrid cars and increases in the high GDP income nations.

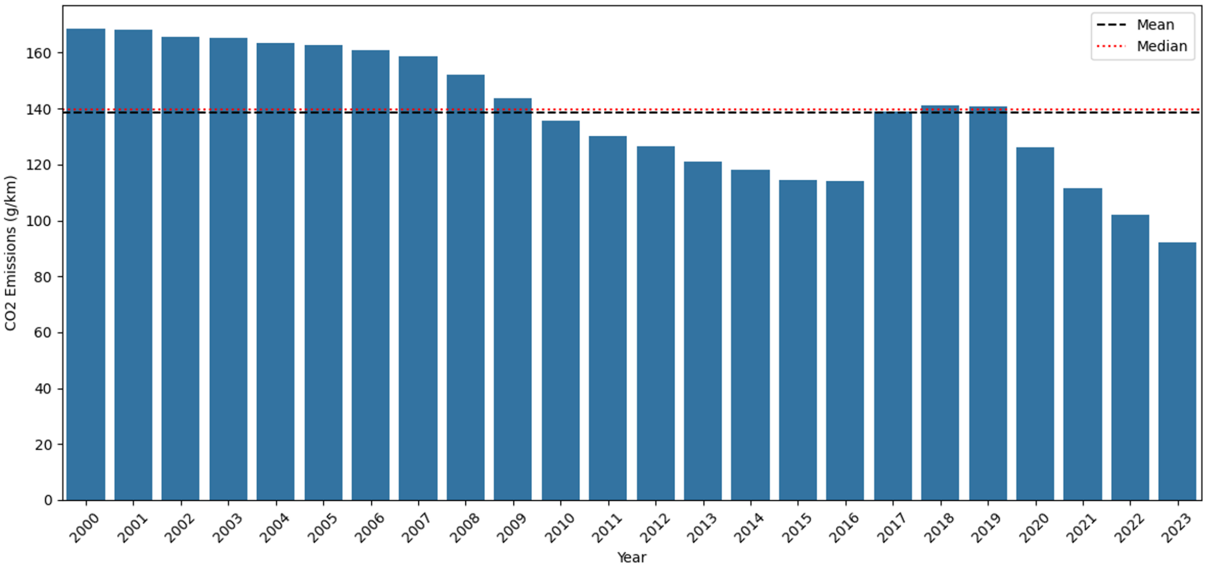
The Northern Region's high standard deviation of 29.45 g/km, as presented in Table 9: Region Distribution by Country and Start Date also illustrated the variation of emissions of CO_2 in countries of the region. For example, Denmark (DK) is characterized by relatively high Standard Deviation of 29.75 g/km, which means that its emissions are not very stable although their mean is 133.12 g/km, moreover, Sweden (SE) is even higher, equal to 41.43 g/km that may be explained by early adoption of measures to maintain sustainable economic growth and cut the emission level.

Such countries as Estonia (EE), Lithuania (LT), Latvia (LV) have the coefficient of variability below 20, what illustrates relative emission stability when their values were monitored in 2002+ years having standard deviations within the range 16.97 ÷ 19.94 g/km. Finland (FI), with a standard deviation of 32.81 g/km, falls in between, further contributing to the overall regional variability.

Despite the overall downward trend presented in Figure 13, I noticed fluctuations between 2015 and 2018, where emissions slightly increased. This could be due to economic changes, shifts in consumer behaviour, or adjustments in the energy mix. The most dramatic decrease occurred in 2020 and 2021, coinciding with the COVID-19 pandemic. Reduced vehicle usage, production disruptions, and global lockdowns likely played a significant role in this sharp decline.

Overall, I see while the Northern Region has made considerable progress in reducing emissions, the fluctuations in the mid-2010s and the unique drop during the pandemic suggest that further analysis will be necessary to determine whether the recent reductions will persist in the long term.

Figure 14: CO_2 Emissions from Passenger Cars in the Western Region Over the Years



Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

As illustrated in the Figure 14 the emissions have reduced progressively from the year 2000 to the year 2022. It shows a fairly stable picture between 2000-2009 with average carbon dioxide emission of around 140 g/km with occasional up and down movements. From 2010, however, I discerned a fall until 2017, with CO_2 emissions declining year on year. In the year 2022 emissions had progressively reduced to about 110 g/km clearly showing great improvement in emission control in this continent in the given period of years.

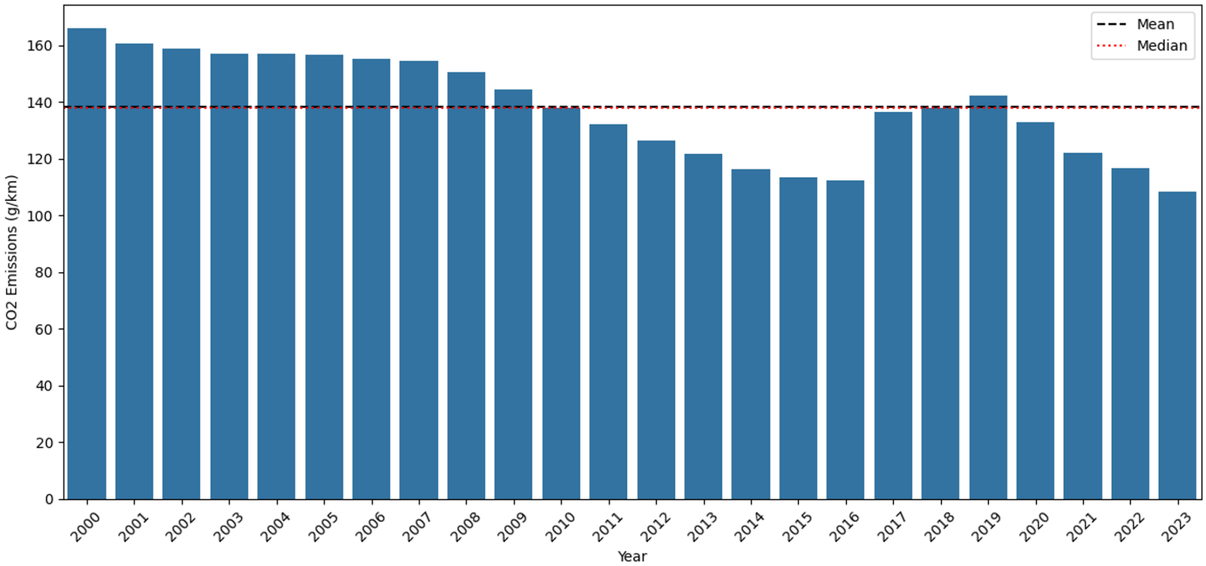
The second largest standard deviation, depicted in Table 9, shows the fluctuation of emissions in Western Region concerning other regions in the European Union. I highlighted that with the average CO_2 emissions in Luxembourg standing at 149.67 g/km, followed by Belgium and Ireland at 137.30 g/km, and 138.51 g/km respectively.

Compared to these averages, figures of Portugal and the Netherlands, for instance, were much lower, at 127.45 g/km and 133.88 CO_2 g/km accordingly. Equally importantly, the range here again revealed that the Netherlands itself had the highest standard deviation, which is equal to 32.01 g/km. The mentioned intra-country variability, combined with the rest of the regional standard deviation equalling 24.04 g/km, demonstrates that the countries of the Western Region face quite different challenges on the way to achieve comparable reductions of emissions.

The high SD of the Western Region means the variability of the results achieved by the countries in the reduction of their emissions. Since the region would include some countries with excellent emission status, and others with poor status, I realize the value of establishing factors that could be behind these variations.

These factors should be addressed to formulate specific measures that would assist all countries in the region to move towards the European Green Deal and its very high CO_2 neutrality targets. Thus, the variation I saw necessitated region-specific measures toward enhancing more uniform coverage in controlling emissions across the western states.

Figure 15: CO_2 Emissions from Passenger Cars in the Southern Region Over the Years



Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

The specific graph in Figure 15 is CO_2 emissions from passenger cars located in the Southern Region and as I observed there are reducing in the future. Again, initially emissions were relatively high, at around 140 g/km but I observed that it began declining, or at least stabilising from somewhere around 2010. It got to just about 120 g/km by 2022.

When I analyse the results of by Figure 15 with the results of the Table 9, I observed Cyprus (CY) occupies the top position with average emissions of 149.75 g/km which is more than the average emissions of the Southern region 135.83 g/km. This again places Cyprus above the regional trend depicted in the graph suggesting that this is contributing towards the higher emissions registered during the earlier years.

Greece (EL) has moderate average of 137.55 g/km and relatively high coefficient of variation of 24.55. This is the reason why there is some fluctuation in the graph for the Southern Region as shown by me in years past. Nevertheless, it shows that some countries face issues in the pursuit of continued declines in the index in the region, though the overall trend is negative.

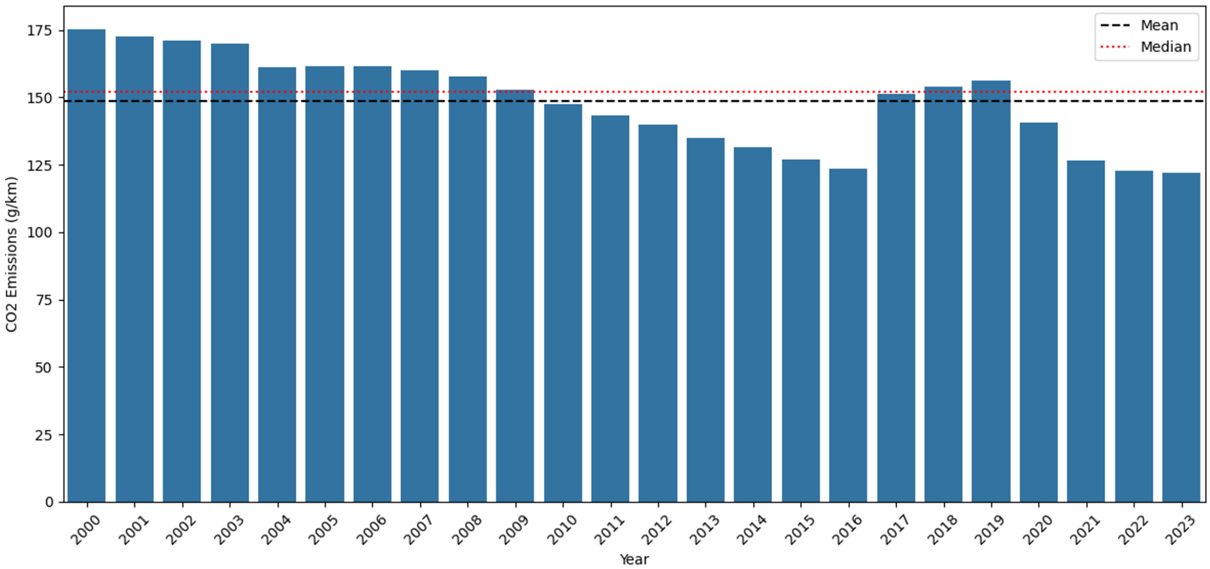
On the other hand, the selected countries that reflect the moderate Southern regional mean emission values include Spain (ES) at 140,80g/km and Italy (IT) at 136,80g/km. What I realized is that both countries emissions are on a declining trend, which corresponds to the declining trend depicted in the graph. Nevertheless, they improve the overall regional rate, but they remain above the regional average.

The corresponding indicators reflect the average emission level: 322,87 g/km, Malta (MT) – 129,30 g/km, Croatia (HR) – 127,30 g/km. I identified that these values are lower than the mean of the region and they correspond to the curve on the graph, where emissions in the later years, allowing for the year 2022, are considerably lower. The lower standard deviations of these countries, especially in Croatia (10.97 g/km) imply more stable emissions performance that offsets the Southern Region's averages.

Despite the general decline in CO_2 emissions for the Southern Region as illustrated in Figure 15, I understand that Table 9 presents sharp differences between the countries of the region. The top-ranked country groups spatial distribution can be described by the following remarks: Cyprus and Greece are the most evident outliers, revealing higher average emissions and higher variability, While Malta and Croatia demonstrate lower average emissions and nearly no variability, which means that these two countries play a positive role in achieving the aim of reducing emissions in the region.

I realize that those with higher emissions and higher variation, might require extra measures and extra resources to address certain problems. On the other hand, countries with lower initial emissions could continue business as usual, which also would allow them to participate in regional cooperation and thus to contribute to higher collective overall rate of progress. Comparing the progress achieved in the Southern Region one can see a clear example of how the overall objectives are met while at the same time finding significant disparities in how the countries manage to decrease emissions.

Figure 16: CO_2 Emissions from Passenger Cars in the Central Region Over the Years



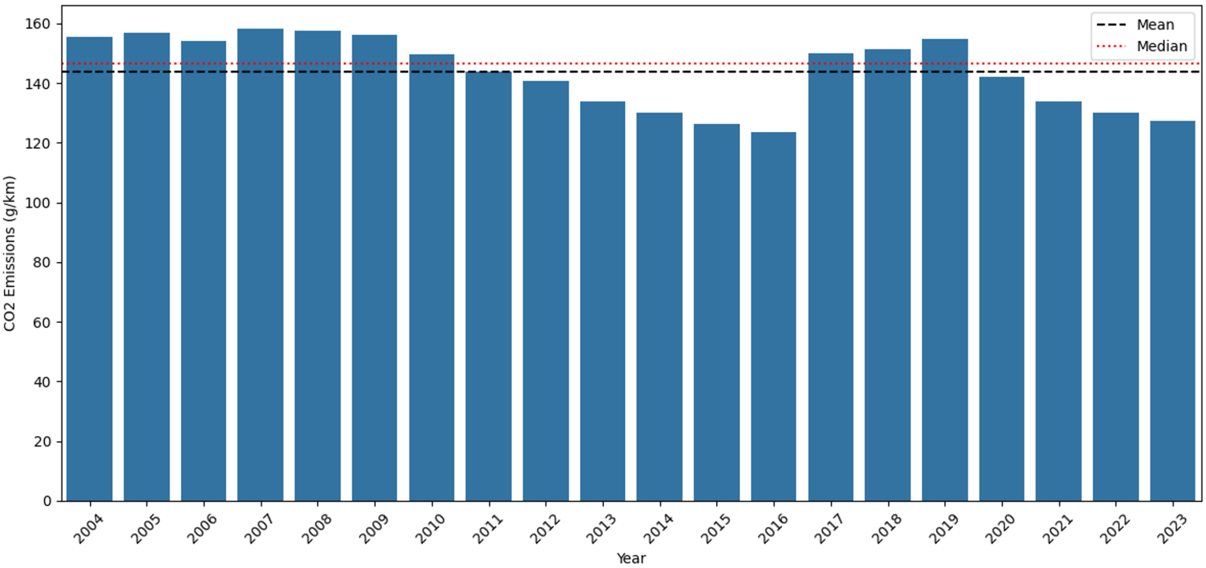
Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

The Central Region transport emissions of CO_2 from passenger cars are presented in the form of a graph in Figure 16 for the years between 2000 and 2023. Analysing emissions data, I found that while in the early 2000s emissions started quite high and were above 170 g/km, they have been decreasing year after year.

Further substantial decline was observed after 2006 where emissions reduced to below 160 g/km. However, this has been declining over the years up to about 2016 when we saw emissions slightly going up then drop again and go below the 150 g/km threshold. I noticed two other breaks on the graph displaying the mean and median CO_2 emissions in the analysed period. Focusing on the central tendencies of the data, mean and median are both nearby 150 g/km.

This indicates that emissions are relatively well dispersed around the mean since the difference between the mean and median is comparatively small and not skewed by some enormously high or low values. In general, this trend demonstrates that the Central Region has been fairly aligned on CO_2 emissions over time. I only observed some variations, and the quantity informs me that with time the plan has been providing a gradual decrease in emissions especially from the year 2019. As for the recent, rather dramatic decline I think I can identify progress in automotive engineering, due the increasing pressure from the ecological legislation, and changing perception of the importance of the topic in the region.

Figure 17: CO_2 Emissions from Passenger Cars in the Eastern Region Over the Years



Source: Data analysis by the author based on "CO_2 Emissions from New Passenger Cars" dataset, European Environment Agency (EEA), 2000–2023

Figure 17 shows the trend of CO_2 emission from passenger cars in the Eastern Region ranging from 2000 to 2023. I also realized that it stayed constant in the early 2000s at roughly 150 g/km. A drop was observed from approximately 2010 when the emission standards reduced to slightly round about 140g/km and has been viscously dropping in the next following years.

The one for the Eastern Region indicates mean and median emissions, the similar and almost equal, approximately 143 – 145 g/ km. CO_2 emission has relatively low variability in this region as shown by the standard deviation of 12.90, this is because most countries are close proximities.

From this low variability I deduce that although emissions have been declining, the cuts aren't sharp and have not cut emissions dramatically. For the key influencers, if I look at the countries, for example, the Slovakia (SK) observed low standard deviation of 9.96 that shows that have been doing similar in terms of emission level with little or no fluctuations since 2004. Hungary (HU) and Romania (RO) portrays the stable trends and low volatility.

On the other hand, Bulgaria (BG) was slightly higher and more variable after 2005, but this did not markedly alter the regional trends. I infer low standard deviation in the Eastern Region as meaning that the region has hardly or least progressed to decrease CO_2 emission. This constant trend could suggest passive measures or moderate polices for deep cuts are not being pursued as levels with greater fluctuations could represent reactive actions to policies or shifts in the economy of the car technology.

CONCLUSIONS

My findings of the trends and patterns of CO_2 emissions from new passenger cars in the European Union: 2000-2023 indicate a mixed picture of the region's journey towards environmental sustainability. Looking at the same period, I have noted increased efforts in emission reductions evidenced by different policies and technological advancements. Still, there are differences between individual EU member states, so while some countries demonstrate rather fast progress, others still experience challenges that prevent them from moving forward as fast as they would like to. These differences show how relevant is to work in cooperation to achieve CO_2 neutrality emissions throughout the entire EU by 2050, as outlined in the European Green Deal.

Especially in Northern and Western Europe the change towards greener automotive technologies and stricter environmental controls has proven most effective. Some of the countries which I consider as leaders in the fight against CO_2 emissions from passenger cars include Denmark, Sweden and the Netherlands. One of the major considerations which has boosted their success is the technology of electric vehicles (EVs) and hybrids at an earlier time. I regard this transition to new technologies as a part of the general shift toward innovation and such concerns as sustainability, backed up by a combination of governmental and consumers initiatives.

For example, when trying to analyse Sweden and Denmark's governments and their actions to promote electric and low emission cars, I have observed the use of taxes and subsidies as centre financial pull levers. These endeavours have not only been useful in bringing down the average CO_2 emission level below the general EU figure of 132.30 g/km. These countries besides offering direct incentives to the consumer for purchasing inexpensive EVs also have also spent a lot of money on undertaking the social costs to build the necessary supporting infrastructure for large scale acceptance of electric vehicles like widespread charging stations.

Another factor that supports the decrease of emissions in Northern and Western Europe is the demand for environmentally friendly public transport and urban mobility. Modern metropolises such as Amsterdam or Copenhagen have developed well-coordinated systems of transport that include not only cycling paths and pedestrian crossings but also quite efficient and predominantly eco-friendly public transport with minimal presence of cars for private use.

However, I appreciate the fact that these regions aren't left behind in their undertakings even as they face some challenges. Hence, I agree with this solution suggesting that even though emissions have reduced over the years, more can still be done in terms of ensuring that consumers adopt the use of electric or hybrid cars as well as the improvement of vehicle technology to reduce emissions even further. It is not just, what more should be done to continue achieving this speed but, how much more should be done to make all cars on the road contribute positively towards the EU long term environmental vision.

One of the biggest problems that I can identify in Central and Eastern Europe is the financial constraint which challenges governments and consumers from purchasing cleaner solutions. Some examples include electric cars and hybrid cars, which are usually more expensive than the conventional internal combustion engine cars. Apart from that, consumers in these regions cannot afford often to spend a lot of money on the initial prices of EVs, even though in the long run, they may have to spend less on refuels and most importantly repairs.

Also, it is important to understand that despite the increased rate adoption of new technologies in the mentioned areas, the infrastructure concerning certain innovations, for example charging terminals for electric cars, is practically non-existent. Currently, the problem of available charging stations is still a disputably alarming one, as several barriers, including the inconvenience of charging or the potential of the battery's depletion while on the road, still discourages consumers from buying electric cars. Growing this infrastructure shall, however, demand a huge capital investment, in this case from both the government and private sector to make electric vehicles a feasible aspiration.

Another one of the major reasons for the higher emissions in Central and Eastern Europe (CEE) is that more old-fashioned vehicles are employed. Sometimes, I notice that such countries have lower emission standards than other countries, thus more CO_2 emitting older models with outmoded technologies are used for longer durations. While in Northern and Western Europe governments are pushing for removal of old and highly polluting vehicles and replacing them with cleaner models, a variety of countries in CEE still boast large pools of very polluting vehicles.

However, I also understand that such regions are not a total write off in terms of development. This implies that those governments in Central and Eastern Europe are slowly waking up to the realization that reduction of emissions is necessary and are slowly adopting policies that will promote cleaner technologies. For instance, I have noticed that some are slowly stepping up their standards on emissions and proposing bonuses that can encourage clients to move towards purchasing green automobiles. These endeavours remain comparatively nascent compared with those that have occurred in Northern and Western Europe, but nevertheless remain a welcome development.

Southern Europe, too, presents a mixed picture. While the region has made some headway in reducing CO_2 emissions from new passenger cars, I see that there are still outliers presenting challenges. Countries such as Cyprus and Greece, for instance, continue to report higher-than-average emissions compared to their regional counterparts. These outliers highlight the difficulty of achieving uniform progress across the EU, as each country faces unique circumstances that influence its ability to reduce emissions effectively.

Thus, observing Southern European countries, I also found that financial or economic considerations are the main factors that prevent the dissemination of electric automobiles. Further, the dependence on own automobiles for trip in the areas where public transportation is scarce is only aggravated the situation. That said, I believe that there is going to be some form of development in this part of the world. For instance, Spain and Portugal have adopted quite recent assertive measures regarding the emission reduction with boosting investments into public transportation as well as charging infrastructure and providing residents with bonuses for EVs buying. These policies are gradually lowing emissions, more slowly than in other parts of the EU in as far as the speed of change is concerned.

Although one of the most ambitious legislative initiatives so far dealing with CO_2 emissions has already delivered its first positive results, I understand that the path towards achieving CO_2 neutrality in the EU by 2050 is still a distant and challenging one. Such less consistent results across the various territories suggest that there should be a more integrated system that easier meets the diverse needs the member states should face.

The countries of Northern and Western Europe, especially, have set an encouraging example of what can be done through targeted governmental measures, appeal to the conscience of consumers and producers, and the application of new technologies. Still, I understand that the gaps in Central, Eastern, and Southern Europe's electrification pathways make me realize that the path to CO_2 neutrality cannot and will not be without further work, capital, and cooperation.

On this, as for the future development of the EU, I think that along with emerging technological opportunities it will be critical to pay attention to technology accessibility in all EU countries. In this manner, the EU can handle properly some of its grand environment goals and aspirations and help bring change to regions where barriers make the progress harder.

SUMMARY

Analysis of CO_2 Emissions from New Passenger Cars in The European Union

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This thesis analysed new passenger car CO_2 emissions in the EU from 2000 to 2023 using datasets from the European Environment Agency (EEA). The data manipulation was performed in Google Colab using Python, focusing on statistical analysis and visualisations to reveal regional trends and differences in emissions across EU member states. While some countries managed to reduce their level of emissions, others still face some issues achieving the goal of climate neutrality by the year 2050 as set in the European Green Deal. Denmark, Sweden, and the Netherlands are some of the most successful in Northern and Western Europe. These countries relied on shifting to cleaner automotive technology, offering tax subsidies and incentives on electric vehicles, driving the reduction of CO_2 emissions below the EU average of 132.30 g/km. The study found that this decrease reflects a shared interest between the community and the government in countries with high Gross Domestic Product (GDP). However, countries like Hungary, Bulgaria, Romania, Slovenia, Slovakia, Poland, and the Czech Republic still prioritised individual affordability over general environmental impact. Consequently, challenges on reducing CO_2 emissions from passenger cars towards the years were observed. The study also identified that this is likely due to the population's willingness to afford and invest in solutions such as electric and hybrid vehicles, influenced by lower income levels and barriers to establishing the charging infrastructure. Despite the recent partial improvement in the European Union, supporting investments and policies are required for those countries that have not progressed well, contributing to the long-term EU climate objectives.

Keywords: emission of carbon dioxide (CO_2), passenger cars, climate change.

REFERENCES

1. ACEA (2024). *The Automobile Industry Pocket Guide* 2024/2025. https://www.acea.auto/publication/the-automobile-industry-pocket-guide-2024-2025
2. ACEA. (2015). *Backgrounder: reducing* CO_2 *emissions from cars and vans. (2021).* https://www.acea.auto/publication/background-reducing-CO2-emissions-from-cars-and-vans/
3. ACEA. (2015). *Reducing* CO_2 *emissions from cars and vans. In Tackling Road Transport* CO_2 *Emissions: an Overview*. https://www.acea.auto/files/06052015_ACEA_Tackling_Road_Transport_CO2_Emissions_paper_cm.pdf
4. ACEA. (2016). *Joining forces to tackle the road transport* CO_2 *challenge*. https://www.acea.auto/publications/report-joining-forces-to-tackle-the-road-transport-CO2-challenge/
5. ACEA. (2021). *Interactive Map - Correlation between uptake of electric cars and GDP in the EU.* https://www.acea.auto/figure/interactive-map-correlation-between-uptake-of-electric-cars-and-gdp-in-the-eu/.
6. ACEA. (2022). *Making the transition to zero-emission mobility: 2022 progress report*. https://www.acea.auto/files/ACEA_progress_report-2022.pdf.
7. ACEA. (2023). *Segments of the EU Passenger Car Market, Average Weight* (2023). https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2023.pdf
8. ACEA. (2024). *Around one out of every eight EU public chargers is a fast charger*. https://www.acea.auto/figure/around-one-out-of-every-eight-eu-public-chargers-is-a-fast-charger/.
9. ACEA. (2024). *Automotive Insights. Charging ahead: accelerating the roll-out of EU electric vehicle charging infrastructure*. https://alternative-fuels-observatory.ec.europa.eu/sites/default/files/document-files/2024-05/Charging_ahead_Accelerating_the_roll-out_of_EU_electric_vehicle_charging_infrastructure.pdf
10. ACEA. (2024). *Interactive Map – Correlation between electric car sales and charging point availability* (2023 data). https://www.acea.auto/figure/interactive-map-correlation-between-electric-car-sales-and-charging-point-availability-2023-data/
11. ACEA. (2024). *New car registrations: -18.3% in August 2024; BEV market share down by almost one third*. https://www.acea.auto/pc-registrations/new-car-registrations-18-3-in-august-2024-bev-market-share-down-by-almost-one-third/.
12. ACEA. (2024). *Tax Benefits and Incentives, Electric cars, 27 EU member states [Report]*. https://www.acea.auto/files/Electric-cars-Tax-benefits-purchase-incentives_2024.pdf.pdf.
13. Bampatsou, C., & Zervas, E. (2011). *Critique of the regulatory limitations of exhaust* CO_2 *emissions from passenger cars in European union. Energy Policy*, 39(12), 7794–7802. https://www.sciencedirect.com/science/article/abs/pii/S0301421511007130?via%3Dihub.
14. Bernhart, Wolfgang & Zhang, Junyi & Wagenleitner, Juri. (2011). *EV/PHEV - changing revenue & profit pools in the automotive value chain require new business models.* World Electric Vehicle Journal. 4. 104-109. https://10.3390/wevj4010104.
15. Bertolini, L., & le Clercq, F. (2003). "*Urban Development without more Mobility by Car? Lessons from Amsterdam, a Multimodal Urban Region*". https://journals.sagepub.com/doi/10.1068/a3592.
16. Boretti, A. (2013). *Conversion of a heavy duty truck diesel engine with an innovative power turbine connected to the crankshaft through a continuously variable transmission to operate compression ignition dual fuel diesel-LPG. Fuel Processing Technology*, 113, 97–108. https://doi.org/10.1016/j.fuproc.2013.03.018.
17. Boulanger, A. G., Chu, A. C., Maxx, S., & Waltz, D. L. (2011b). *Vehicle Electrification: Status and Issues. Proceedings of the IEEE,* 99(6), 1116–1138. https://doi.org/10.1109/jproc.2011.2112750.
18. Boulanger, Albert & Chu, Andrew & Maxx, S. & Waltz, David. (2011). Vehicle Electrification: Status and Issues. Proceedings of the IEEE. 99. 1116 - 1138. https://10.1109/JPROC.2011.2112750.
19. Bukhari, J., Somanagoudar, A. G., Hou, L., Herrera, O., & Mérida, W. (2023). *Zero-Emission Delivery for Logistics and Transportation.* In Springer eBooks (pp. 1729–1749). https://doi.org/10.1007/978-3-031-01949-4_107.
20. Destatis. (2024). *Road transport: EU-wide carbon dioxide emissions have increased by 21% since 1990.* https://www.destatis.de/Europa/EN/Topic/Environment-energy/CarbonDioxideRoadTransport.html.
21. Duoba, M., Larsen, R., & LeBlanc, N. (1996). *Design Diversity of HEVs with Example Vehicles from HEV Competitions. SAE Technical Papers on CD-ROM/SAE Technical Paper Series*. https://doi.org/10.4271/960736.
22. EEA. (2023). *Various reports and documents detailing country-specific climate action plans and targets.* https://www.eea.europa.eu/themes/climate
23. EIA. (2022). *By 2030 EVs represent more than 60% of vehicles sold globally, and require an adequate surge in chargers installed in buildings – Analysis*. https://www.iea.org/reports/by-2030-evs-represent-more-than-60-of-vehicles-sold-globally-and-require-an-adequate-surge-in-chargers-installed-in-buildings.

24. Engel, H., Hensley, R., Knupfer, S., & Sahdev, S. (2018, August 8). *Charging ahead: Electric-vehicle infrastructure demand. McKinsey & Company.* https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand.
25. European Alternative Fuels Observatory. (n.d.). Infrastructure https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27/infrastructure.
26. European Commission. (2009). *Regulation - 443/2009 - EN - EUR-Lex*. (n.d.). https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32009R0443.
27. European Commission. (2009). Regulation (EC) No 443/2009. *OJ, L 140/1*.
28. European Commission. (2014). *Regulation - 333/2014 - EN - EUR-Lex*. (n.d.). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2014.103.01.0015.01.ENG
29. European Commission. (2019). *Regulation - 2019/631 - EN - EUR-Lex*. (n.d.). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0631
30. European Commission. (2019). The European Green Deal. *COM (2019) 640 final*. EUR-Lex. (n.d.). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN
31. European Commission. (2021). *National energy and climate plans (NECPs).* https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en.
32. European Commission. (2023). *Regulation - 2023/851 - EN - EUR-Lex*. (n.d.). https://eur-lex.europa.eu/eli/reg/2023/851
33. European Federation for Transport and Environment (T&E). (2020). *SUVs: The second largest cause of rising CO_2 emissions in Europe. Transport and Environment.* https://www.transportenvironment.org/articles/rising-CO_2-emissions-problem-carmakers-own-making-they-push-suvs-hold-back-electric-cars.
34. European Union, n.d.. Your gateway to the European Union. https://european-union.europa.eu/index_en.
35. European Union. 2024. *Easy to read – about the EU | European Union*. (n.d.). https://european-union.europa.eu/easy-read_en.
36. Eurostat (2022). *Transport Emissions in the EU: Statistics and Trends.* https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Transport_emissions
37. Ghamami, M., Nie, Y., & Zockaie, A. (2015). *Planning charging infrastructure for plug-in electric vehicles in city centers. International Journal of Sustainable Transportation,* 10(4), 343–353. https://doi.org/10.1080/15568318.2014.937840.
38. Greene, D., Hossain, A., Hofmann, J., Helfand, G., & Beach, R. (2018). *Consumer willingness to pay for vehicle attributes: What do we Know? Transportation Research Part a Policy and Practice*, 118, 258–279. https://doi.org/10.1016/j.tra.2018.09.013.
39. Groening, Christopher & Inman, J. & Jr, William. (2014). *Carbon Footprints in the Sand: Marketing in the Age of Sustainability. Customer Needs and Solutions*. 1. 40-51. https://10.1007/s40547-013-0005-5.
40. Hulshof, D., & Mulder, M. (2020). Willingness to Pay for CO_2 Emission Reductions in Passenger Car Transport. Environmental and Resource Economics, 75(4), 899–929. https://doi.org/10.1007/s10640-020-00411-6.
41. Hydrogen Mobility Europe. (n.d.). *Hydrogen Refuelling Infrastructure*. https://h2me.eu/about/hydrogen-refuelling-infrastructure/
42. IEA. (2021). *Various reports related to climate policies and targets of member countries*. https://www.iea.org/
43. IEA. (2022). *Global CO_2 emissions in 2022*. https://www.iea.org/reports/CO_2-emissions-in-2022.
44. IEA. (2022). *Global EV Outlook 2022 – Analysis* - https://www.iea.org/reports/global-ev-outlook-2022.
45. IEA. (2024). *Trends in electric cars – Global EV Outlook 2024 – Analysis* - (n.d.). https://www.iea.org/reports/global-ev-outlook-2024/trends-in-electric-cars
46. Inter governmental Panel on Climate Change (IPCC). (2021). *Climate Change 2021: The Physical Science Basis*. (n.d.). IPCC. https://www.ipcc.ch/report/ar6/wg1/
47. IPCC (2006). "*IPCC Guidelines for National Greenhouse Gas Inventories.*" https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.
48. Karaś, Adrianna. (2023). *An Analysis of The Carbon Footprint In Maritime Transport: Challenges And Opportunities For Reducing Greenhouse Gas Emissions*. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation. 17. 199-203. https://doi:10.12716/1001.17.01.22.
49. Knez, M., Jereb, B., Gago, E. J., Rosak-Szyrocka, J., & Obrecht, M. (2020). *Features influencing policy recommendations for the promotion of zero-emission vehicles in Slovenia, Spain, and Poland*. Clean Technologies and Environmental Policy, 23(3), 749–764. https://doi.org/10.1007/s10098-020-01909-9.
50. Kumar, P., Britter, R., and Gupta, N. (February 25, 2009). *Hydrogen Fuel: Opportunities and Barriers.* ASME. J. Fuel Cell Sci. Technol. May 2009; 6(2): 021009. https://doi.org/10.1115/1.3005384.
51. Kyoto Protocol to the United Nations Framework Convention on Climate Change. (2018). In *Cambridge University Press eBooks* (pp. 491–508). https://doi.org/10.1017/9781316577226.067.

52. Lebeau, P., Macharis, C., & Van Mierlo, J. (2019). *How to Improve the Total Cost of Ownership of Electric Vehicles: An Analysis of the Light Commercial Vehicle Segment. World Electric Vehicle Journal*, 10(4), 90. https://doi.org/10.3390/wevj10040090.
53. Martin. (2023). Climate Change - *United Nations Sustainable Development. United Nations Sustainable Development.* https://www.un.org/sustainabledevelopment/climate-change/
54. Matanov, Nikolay & Zahov, Atanas. (2020). *Developments and Challenges for Electric Vehicle Charging Infrastructure.* 1-5. http://10.1109/BulEF51036.2020.9326080.
55. Miller, J. (2016) *Reducing* CO_2 *emissions from road transport in the European Union: An evaluation of policy options. International Council on Clean Transportation.* https://theicct.org/publication/reducing-CO_2-emissions-from-road-transport-in-the-european-union-an-evaluation-of-policy-options/.
56. Muratori, M., Greene, D., Kontou, E., & Dong, J. (2020). *The role of infrastructure to enable and support electric drive vehicles: A Transportation Research Part D special issue. Transportation Research Part D: Transport and Environment,* 89, 102609. https://www.osti.gov/servlets/purl/1726082.
57. Özcan, H., & Söylemez, M. S. (2005). *Experimental Investigation of the Effects of Water Addition on the Exhaust Emissions of a Naturally Aspirated, Liquefied-Petroleum-Gas-Fueled Engine.* Energy & Fuels, 19(4), 1468–1472. https://doi.org/10.1021/ef049850g.
58. Pautasso, Elisa & Osella, Michele & Caroleo, Brunella. (2019). *Addressing the Sustainability Issue in Smart Cities: A Comprehensive Model for Evaluating the Impacts of Electric Vehicle Diffusion.* Systems. 7. 29. https://10.3390/systems7020029.
59. Penney D, Benignus V, Kephalopoulos. *Carbon monoxide. In: WHO Guidelines for Indoor Air Quality: Selected Pollutants. Geneva: World Health Organization; 2010*. 2. Available from: https://www.ncbi.nlm.nih.gov/books/NBK138710/
60. ProKolej (2021). Kolej dla Klimatu, klimat dla kolei – raport podsumowujący. [*Rail for Climate, Climate for Rail - Summary Report*]. https://www.prokolej.org/sites/default/files/raport_kolej_dla_klimatu_0.pdf.
61. Qin, Y., Tang, X., Jia, T., Duan, Z., Zhang, J., Li, Y., & Zheng, L. (2020). *Noise and vibration suppression in hybrid electric vehicles: State of the art and challenges. Renewable and Sustainable Energy Reviews*, 124, 109782. https://doi.org/10.1016/j.rser.2020.109782.
62. Rassaei, F., Soh, W., & Chua, K. (2014, July 7). *A Statistical Modelling and Analysis of PHEVs' Power Demand in Smart Grids*. https://arxiv.org/abs/1407.1576.
63. Sayed, M. A., Atallah, R., Assi, C., & Debbabi, M. (2021). *Electric vehicle attack impact on power grid operation. International Journal of Electrical Power & Energy Systems*, 137, 107784. https://doi.org/10.1016/j.ijepes.2021.107784.
64. Schnee, Rudolf & Chrenko, Daniela & Rodet-Kroichvili, Nathalie & Neugebauer, Peter. (2020). *Examination of Charging Infrastructure for Electric Vehicles Based on Components of Sustainable Business Models*. 1-6. https://10.1109/VPPC49601.2020.9330892.
65. Shiau, Norman & Peterson, Scott & Michalek, Jeremy. (2010). *Optimal Plug-In Hybrid Vehicle Design and Allocation for Minimum Life Cycle Cost, Petroleum Consumption and Greenhouse Gas Emissions*. Proceedings of the ASME Design Engineering Technical Conference. 4. https://10.1115/DETC2010-28198.
66. Sokorai, P., Fleischhacker, A., Lettner, G., & Auer, H. (2018). *Stochastic Modeling of the Charging Behavior of Electromobility.* World Electric Vehicle Journal, 9(3), 44. https://doi.org/10.3390/wevj9030044.
67. Steffen, B., Egli, F., Pahle, M., & Schmidt, T. S. (2020). *Navigating the Clean Energy Transition in the COVID-19 Crisis*. Joule, 4(6), 1137–1141. https://doi.org/10.1016/j.joule.2020.04.011.
68. Vehicle categories. (n.d.). *Internal Market, Industry, Entrepreneurship and SMEs*. https://single-market-economy.ec.europa.eu/sectors/automotive-industry/vehicle-categories_en.
69. Wright, S. & Pinkelman, A. (2008). *Natural gas internal combustion engine hybrid passenger vehicle*. International Journal of Energy Research. 32. 612 - 622. https://10.1002/er.1369.

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