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Sustainability and EU Road Transport Carbon Emissions from Consumption of Diesel and Gasoline in 2000 and 2018 †

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† The data, analysis and conclusions expressed in the text are those of the authors and do not reflect the views of the University of Granada.

Abstract: To accomplish the 1.5 °C and 2 °C climate change targets, the European Union (EU) has set up several policy initiatives. Within the EU, the carbon emissions of the road transport sector from the consumption of diesel and gasoline are constantly rising. (1) Background: due to road transport policies, diesel and gasoline use within the EU is increasing the amount of carbon in the atmosphere and adding to climate risks. (2) Methods: sustainability analysis used was based on the method recommended by the Intergovernmental Panel on Climate Change. (3) Results: to meet its road transport requirements, the EU produces an estimated 0.237–0.245 billion tonnes of carbon per year from its total consumption of diesel and gasoline. (4) Conclusion: if there is no significant reduction in diesel and gasoline carbon emissions, there is a real risk that the EU's carbon budget commitment could lapse and that climate change targets will not be met. Sustainability analysis of energy consumption in road transport sector shows the optimum solution is the direct electrification of road transport.

Keywords: climate change; Paris Agreement; CO_2; emissions; carbon budget; sustainability; European Union

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1. Introduction

Decarbonisation of road transport in response to the climate change challenge is a complex political, economic and technological challenge for all stakeholders in the European Union (EU). To address this challenge, a sustainability study that estimates the greenhouse gas (GHG) emissions and energy consumption from diesel and gasoline consumption within the EU is needed. This paper presents a clear picture of the scale of the challenge and unpacks the complexity associated with the challenge of decarbonisation. Emissions from road transport consumption of diesel and gasoline are classified as downstream emissions. A new conceptual model of sustainability is needed to develop a coherent decarbonisation policy in road transport.

1.1. Background

The EU has traditionally been at the forefront of the world's energy and climate politics and has a bespoke programme to decarbonise its energy and transport sectors. It adopted the Paris Agreement, which aims to limit the increase in global temperature to less than 2 °C [1]. To accomplish the EU's political goals and market requirements, the European Commission adopted the concept of the Energy Union in 2015 [2]. To maintain momentum regarding the Paris Agreement, the EU pledged a 40% reduction in domestic GHG emissions by 2030 compared to the 1990 baseline [3]; emission reductions in the transport sector are part of this pledge.

Road transport GHG emissions are formed of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) gas emissions. CO_2 is the most predominant GHG, and the

International Energy Agency's (IEA) report on CO_2 emissions from fuel combustion [4] revealed that road transport accounted for 24% (=7.75 $GtCO_2$) of the world's CO_2 emissions in 2015. Similarly, the European Environment Agency (EEA) report [5] stated that road transportation accounts for 24% of Europe's CO_2 emissions.

The Paris Agreement targets are based on the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (FAR), which stated that the remaining cumulative CO_2 emissions (i.e., the carbon budget) must not exceed 1000 $GtCO_2$ if global warming is to be limited to 2 °C. It also stated that the increase in global surface temperature is likely to exceed 1.5 °C by the end of the 21st century [6].

The Sixth Assessment Report (SAR) [7], released in August 2021, stated that a total of 2390 $GtCO_2$ had been emitted between 1850 and 2019. As of January 2020, the remaining carbon budget was estimated to be 500 $GtCO_2$, 850 $GtCO_2$ or 1350 $GtCO_2$ to limit global warming to 1.5 °C, 1.7 °C or 2 °C, respectively. These estimates were based on climate models that measured climate change and the associated transient climate response to cumulative CO_2 emissions (TCRE).

1.2. Goals and Scope

The methodology used in the current paper estimates or measures GHG emissions in all EU member states and revealed the sustainability implications of the EU's road transport policy. Vital points relevant to long-term sustainability implications are taxes for fuel, technology transfer, and fiscal and regulatory areas. Road transport GHG emissions are projected to increase rapidly, and this rise has big implications for climate change and the EU's political ambitions. For example, road transport emissions could consume the entire carbon budget allocated to the EU [8]. The practical goal is to integrate road transport policy with the EU's carbon budget and identify opportunities that could limit global warming to 1.5 °C or 2 °C.

It is necessary to estimate or measure downstream GHG emissions to fully understand the mechanics of road transport sustainability. Road transport sustainability pivots on the input and output of energy and emissions throughout the life cycle of vehicles. To accomplish the transition to low carbon or zero carbon transport, it is important to highlight the significance of downstream GHG emissions. The transition to low or zero carbon would also deliver sustainable development goals in urban infrastructure within the EU. Transition to sustainable transport requires a clear and accurate understanding of the complete life-cycle emissions that take place in the road transport sector.

This paper looks at the energy input from diesel and gasoline, the emissions output of EU road transport and the new sustainability requirements. The sustainability approach identifies the prevailing political and domestic economic opportunities and the future trajectories in EU road transport. Future road transport policy goals within and outside the EU will eventually integrate road transport sustainability with the TCRE and carbon budget requirements. This approach will be unique to the EU.

The EU has already announced major sustainability and decarbonisation initiatives in road transport policy, e.g., the Green Deal [9] and the fleet-wide CO_2 emission targets for 2020 and 2024 announced by the European Commission [10]. These targets are 95 gCO_2/km for cars and 147 gCO_2/km for vans.

2. Literature Review

There is diverse scientific and policy literature looking at the road transport sector; for example, some of the literature looks at methods of GHG emission estimation and policy analysis within and outside the EU.

2.1. Paper Review

Hao, Geng and Sarkis [11] looked at the carbon footprint of global passenger cars and found that regulating the fuel economy of cars is the most effective method for reducing CO_2 emissions in passenger cars. They also predicted that diesel and gasoline would be the predominant sources of CO_2 emissions and could account for 83% of total CO_2 emissions by 2050.

It is important to highlight that the EU's Green Deal aims to reduce GHG emissions by carrying out a modal shift from road freight transport to inland waterways. Li, Fan and Wu [12] conducted a time-series analysis of CO_2 emissions in the transport sector and found that waterway and road transportation led to a significant increase in transport-based CO_2 emissions in China. As a result, they predicted that China's future transport-based CO_2 emissions would be similar to the transport-based emissions of the USA and the EU. Meanwhile, Perez–Martinez and Miranda [13] estimated the energy consumption and CO_2 emissions from toll highways in Spain and found that the energy intensity of buses was significantly higher than that of cars and that the energy intensity of cars was lower than that of motorcycles. To highlight the role of fuel substitution in the sustainability of road transport, Perez and associates [14] used a life-cycle assessment (LCA) to estimate the carbon footprint of waste collection vehicles in Madrid. They found that the carbon footprint increased by 18.5% if diesel was replaced by compressed natural gas (CNG) and decreased by 92% if CNG was substituted with biogas.

Moro and Lonza [15] conducted a well-to-wheels analysis to show the GHG emissions produced by electric vehicles (EV). They found that, in Sweden, battery-powered EVs only produced 7–9 gCO_2eq/km, while in Latvia, these vehicles emitted 169–234 gCO_2eq/km. In contrast, the EU average was 65–89 gCO_2eq/km. Enzman and Ringel [16] pointed out that the share of road transport emissions had increased, while Drummond [17] highlighted that urban spatial variation and the tiered political decision-making system will make the transition to low carbon transport challenging.

A sustainability analysis of gasoline and diesel consumption within the EU transport sector is needed for several important reasons. According to the IEA, the transport consumption of energy in Europe increased between 1990 and 2018. The literature review shows that the world's diesel consumption has increased significantly due to demand from China and the USA. Diesel and gasoline play a vital role in sustaining economic growth but are also the cause of GHG emissions in the road transport sector. These emissions increase the likelihood of breaching the carbon budgets.

2.2. Policy Review

To give the road transport policy an optimal trajectory, the European Commission devised the Sustainable and Smart Mobility Strategy (SSMS) [18]. The main aim of the SSMS is to progress to zero-emission mobility by significantly reducing dependence on fossil fuels and internalising external costs. To understand the energy input implications of zero-emission mobility, a decarbonisation study was carried out [19]. This study pointed out that in a business-as-usual (BAU) scenario, the EU would need approximately 2800 TWh/y of renewable energy to decarbonise road transport. It also highlighted the use of electrofuels, such as hydrogen and ammonia, to accomplish transport decarbonisation. Within the EU's free market boundaries, it is Germany, Norway, the United Kingdom, France and the Netherlands that are dominant players in the electrification of road transport [20].

The move towards zero-carbon road transport is present in a position paper by Fuels Europe [21]. The main point of this paper is that the Renewable Energy Directive target should be expressed in terms of GHG emissions. This change could enable the introduction of emission trading and reform the Fuel Quality Directive. In the long term, the paper envisages a transport fuels emission trading system. The objective is to accomplish a uniform carbon price or social cost of carbon across the EU.

3. Methodology and Data

The IPCC mobile source methodology is widely used to estimate GHG emissions caused by the consumption of diesel and motor gasoline by automobiles, light trucks, heavy duty vehicles, buses and motorcycles. It is the best choice for estimating GHG emissions based on the amount of fuel consumed and/or sold [22] and has been used in similar studies [23,24]. The method is based on Equations (1) and (2), which are based on the IPCC Tier-1 approach.

$$\text{Energy consumption (TJ)}_{\text{gasoline, diesel,}} = \{(\text{Amount of fuel [kt]}) \times (\text{NCV of fossil fuel [TJ/kt]})\} \quad (1)$$

$$CO_2, N_2O \text{ and } CH_4 \text{ emissions}_{\text{gasoline, diesel}} = \{(\text{Energy consumption [TJ]}) \times (CO_2\ N_2\ O \text{ and } CH_4 \text{ emission factor [kg/TJ]})\} \quad (2)$$

$$\text{Emission change}_{\text{year 2018/year 2000}} = (CO_2, N_2O \text{ and } CH_4 \text{ emissions}_{\text{gasoline, diesel}})_{\text{year 2018}} - (CO_2, N_2O \text{ and } CH_4 \text{ emissions}_{\text{gasoline, diesel}})_{\text{year 2000}} \quad (3)$$

$$\text{Emitted Carbon}_{\text{year 2000/year 2018}} = (CO_2 * \text{GWP of } CO_2 + N_2O * \text{GWP of } N_2O + CH_4 * \text{GWP of } CH_4) \quad (4)$$

where CO_2, N_2O and CH_4 emissions $_{\text{gasoline, diesel}}$ is the GHG emissions from diesel and gasoline; NCV is the net calorific value of fuel for carbon in diesel and gasoline (TJ/Gg); emission factor is the carbon emission factor for CO_2, N_2O and CH_4 emissions (kg/TJ) from diesel and gasoline; and GWP is the global warming potential of a specific GHG.

The IPCC methodology provides a default CO_2 emission factor [22] and net calorific value (NCV) [25] of diesel and motor gasoline. It is important to note that the CO_2 emission factor takes into account all the carbon in the fuel that is emitted by the process of combustion. This approach was used by Moro and Lonza [15]. The data for motor gasoline and diesel consumption were acquired from the IEA data services [26] for 2000 and 2018. The data for 2018 are the most recent dataset available from the IEA. The IPCC method and sustainability analysis approach is illustrated in Figure 1.

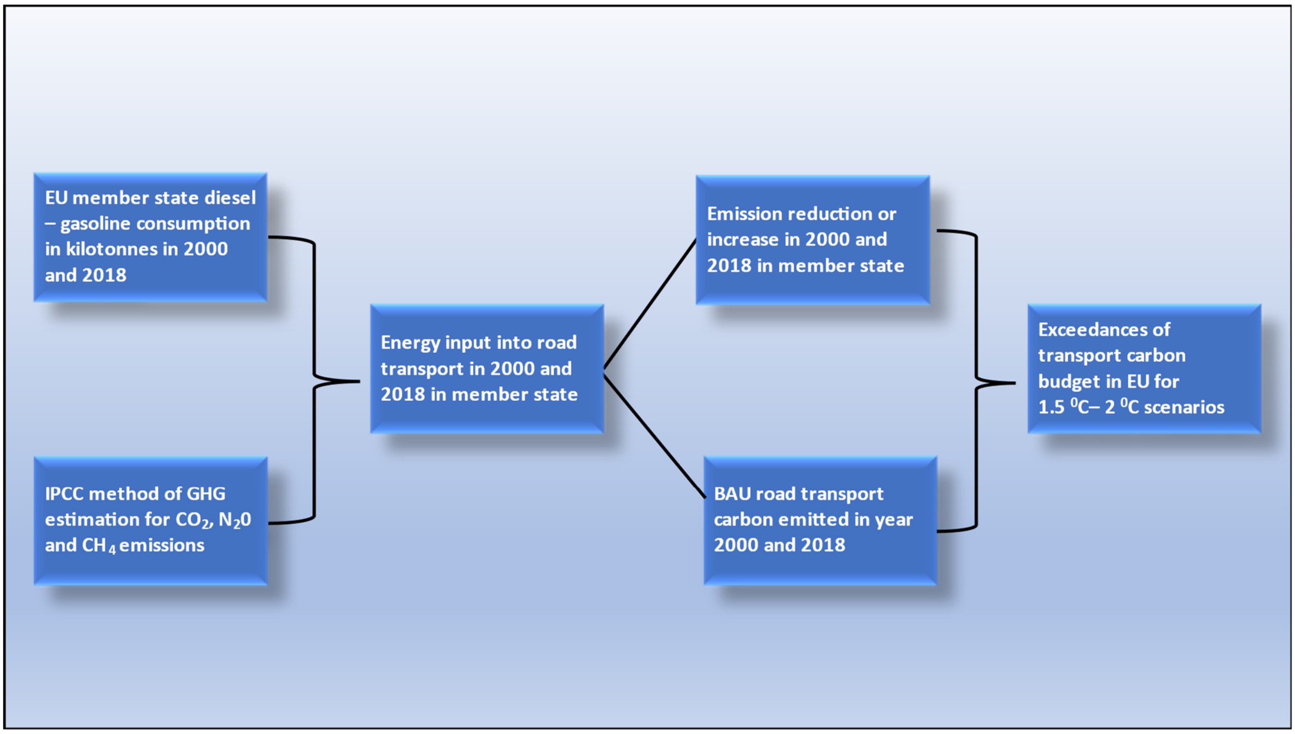

Figure 1. Flow chart of the methodology.

4. Results of GHG and Carbon Emission Estimation

The results are provided in Table 1 and Figure 2 below. The complete dataset is given in the Appendix A. The majority of member states exhibited a consistent pattern of diesel GHG emissions increasing and gasoline GHG emissions decreasing between 2000 and 2018. The total GHG emissions from diesel were highest in Poland, the United Kingdom, Germany, Spain and France and lowest in Cyprus, the Netherlands, Malta, Estonia and Greece. The GHG emissions from gasoline were highest in Germany, the United Kingdom, Italy, France and Spain and lowest in Malta, Hungary, Estonia, Romania and the Slovak Republic. The Netherlands was an exceptional case as its diesel and gasoline road transport emissions remained constant between 2000 and 2018.

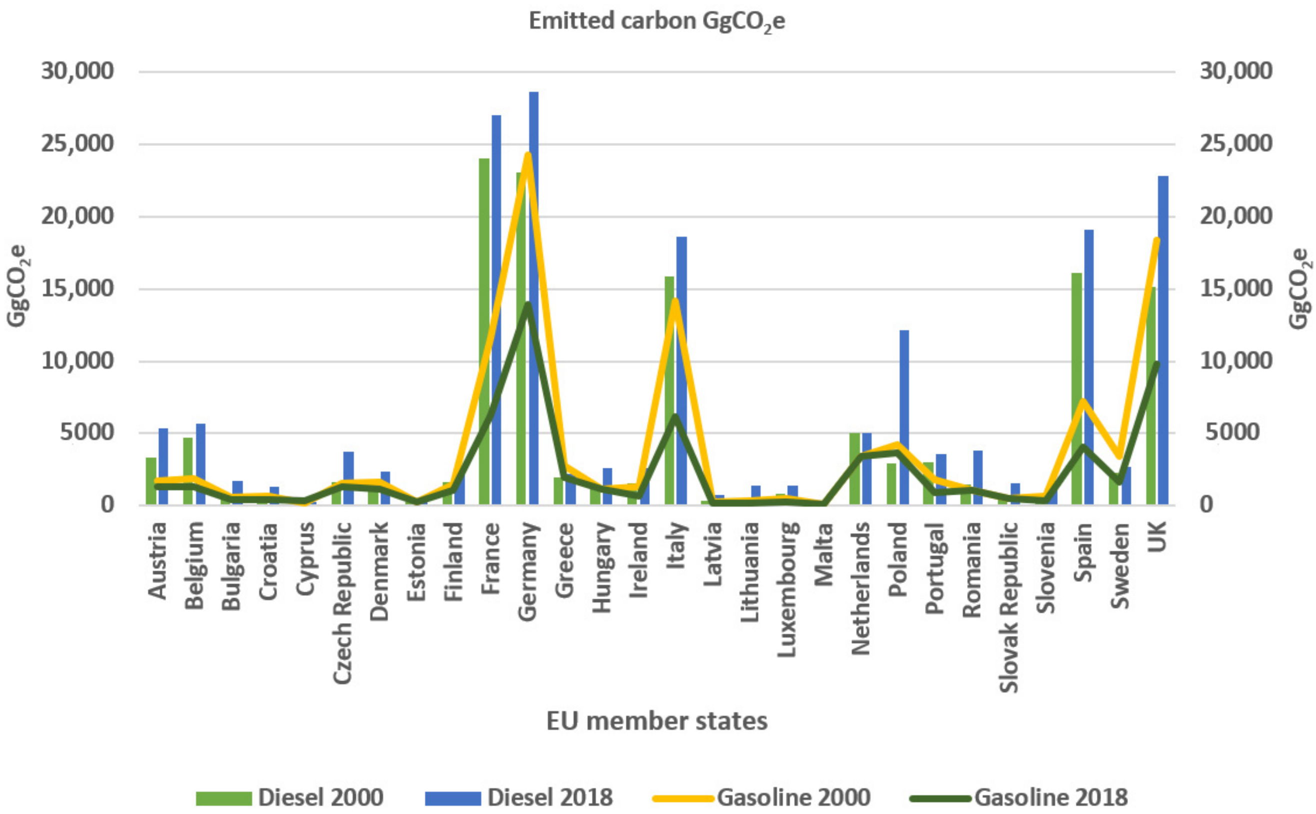

Figure 2. Emitted carbon from diesel and gasoline use by EU member states in 2000 and 2018.

Table 1. Diesel and Gasoline carbon emissions in EU 28 (2000 and 2018).

Diesel CO_2e Gg 2000	Gasoline CO_2e Gg 2000	Diesel CO_2e Gg 2018	Gasoline CO_2e Gg 2018
130,957	106,829	180,133	63,429
Total CO_2e Gg in 2000 and 2018	237,786	243,562	
Net addition of carbon to atmosphere in GtC	0.237	0.243	

Overall, transport carbon emissions increased between 2000 and 2018, with the EU's Road transport sector adding 0.23–0.24 Gt of carbon to the atmosphere each year. The approach taken was based on real fuel consumption of diesel and gasoline within the EU. These results show that transport emissions are not necessarily related to the size of the economy and are actually a result of national transport policy. The net amount of diesel- and gasoline-based energy consumed by the EU's road transport sector was 3335 TWh in 2000 and 3377 TWh in 2018. It is profoundly challenging to permanently substitute these energy requirements with low carbon options, and these results suggest that the total EV charging capacity for Europe needs to exceed 3000 TWh per year if a net zero in road transport is to be accomplished.

These results indicate that over an 18-year period, the energy input in road transport increased by 42 TWh, which is an increase of 2.33 TWh per year. As mentioned previously, the decarbonisation base case study [19] estimated the EU energy input requirement to be 2800 TWh per year.

5. Critical Analysis of Results and the Sustainability Approach

As mentioned previously, the decarbonisation of transport is a major economic, societal and political challenge for the EU. The underlying cause of the constant increase in diesel consumption is the nature of the fuel market and the fuel taxation system in the EU. As we have seen, gasoline consumption decreased in all member states (expect one) and diesel emissions increased. High duty on gasoline and lower duty on diesel has contributed to a market-based shift in favour of diesel road transport vehicles. Customers choose diesel vehicles as they are considered better value for money in the long term.

This belief in the economy of diesel has led to an increase in diesel emissions. The EU's fuel duty policy is influenced by the long-term goal of obtaining more mileage from diesel fuel and thereby maximising the purchasers' advantage in the oil import market. The fuel excise policy is skewed even though diesel has a higher CO_2 emissions factor than gasoline: 74,100 $KgCO_2/TJ$ for diesel and 69,300 $KgCO_2/TJ$ for gasoline. The carbon content of diesel is also higher than that of gasoline, while the net calorific values of diesel and gasoline are similar. The EU does not gain any substantial advantage by consuming more diesel nor does it have any particular incentive to do so.

The results do not take into account the number of diesel and gasoline cars in each EU member state, the number of miles travelled by the cars and the specific economic drivers that lead to the emission of GHGs. The methodology estimates the total amount of energy and emissions to measure GHG emissions. To overcome the climate change challenge, the EU must avoid these emissions, and the prevailing sustainability policy falls short when addressing the climate sustainability challenge. According to the Global Carbon Budget [27], a reduction of 1–2 $GtCO_2$ is needed to achieve the goals of the Paris Agreement.

At present, there is a real risk that road transport GHG emissions will consume the majority of the EU's carbon budget [8]. One study calculated the EU's carbon budget for 2010 to 2100 as being 83 Gt and 116 Gt for the 1.5 °C and 2 °C scenarios, respectively [28]. Another study calculated the EU's carbon transport budget as being between 10.2 and 12.1 $GtCO_2e$, which included aviation, rail and navigation emissions [29]. The results in Table 1 and the Appendix A show that the total carbon emissions for road transport in the EU in 2000 and 2018 were 0.23 $GtCO_2e$ and 0.24 $GtCO_2e$, respectively. These totals do not include aviation, shipping and navigation emissions. This indicates that BAU annual road transport emissions in the EU are in the range of 0.23–0.24 $GtCO_2e$. It should be noted that these emissions will decrease as the United Kingdom is no longer an EU member state.

The BAU trajectory of road transport carbon emissions in the EU is outlined in Table 2. There are limitations to the BAU scenario, however, as it assumes that long-term carbon emissions will remain at 0.23 or 0.24 $GtCO_2e$ per year. In addition, the results shown in Tables 1 and 2 may vary as default emission factors were used to calculate the CH_4 and N_2O emissions. If the rate of carbon emissions does not decrease, the EU will have used up its allocated carbon transport budget by the early 2060s. Road transport emissions will consume a significant part of EU's total carbon budget.

Table 2. BAU road transport emissions and the EU carbon budget for 1.5 °C and 2 °C scenario.

EU Total Carbon Budget from 2010–2100 in Ecologic Study [28]	**EU Transport Carbon Budget 2010–2100 in Fraunhofer Study [29], Includes Aviation, Shipping and Navigation**	**EU Diesel and Gasoline Road Transport Carbon Emissions in 2000 and 2018 Respectively,**
83–116 $GtCO_2e$	10.2–12.1 $GtCO_2e$	0.23 and 0.24 $GtCO_2e$
Carbon emissions in BAU trajectory: excluding aviation, shipping and navigation 0.23 $GtCO_2e$ and 0.24 $GtCO_2e$ per year if diesel and gasoline BAU emissions continue for 11 years, 31 years and 81 years from 2019 to 2100		
2019–2030	2019–2050	2019–2100
2.53–2.64 $GtCO_2e$	7.13–7.44 $GtCO_2e$	18.63–19.44 $GtCO_2e$
EU transport carbon budget in a BAU scenario of 0.23 or 0.24 $GtCO_2e$ per year could be completely consumed in 2060s. Road transport emissions could consume 16–22% of EU total carbon budget in 2100		

6. Critical Analysis of EU Road Transport Policy and Sustainability

The results revealed a conundrum for EU policy makers: if the EU reduces gasoline GHG emissions, it will have to use more diesel as its main road transport fuel. The results showed a net increase in GHG emissions between 2000 and 2018, and there is evidence to suggest that this was caused by the fuel excise duty of member states. The move from gasoline to diesel was caused by the EU's policy on fuel excise duty as excise duty on gasoline is higher than that on diesel. To successfully achieve net zero or even a reduction in emissions, a new paradigm is required to reduce transport-based carbon emissions. Europe's prevalent 'command and control' regulatory emission reduction mechanism will lead to a breach of the emission reduction target.

6.1. EU Market Dimensions in Road Transport Policy and Sustainability

The automotive sector contributes 4% to Europe's GDP [30], and 12 million people work in this industry. It also contributes 388 billion euros in tax to the EU. Car availability in the EU has increased due to competitive pricing, growth in the second-hand market and the financial relationship between the manufacturers, their dealers and finance companies [31]. The average engine power in kilowatts (kW) in the EU (here EU refers to the EU-15 and EFTA) increased from 72 to 93 kW between 2000 and 2015. Cars in Luxembourg, Sweden and Germany have an average power of 112 kW, 106 kW and 102 kW, respectively [32]. The highest percentage of 4×4s in the EU is in Luxembourg (23%) [33].

Engine displacement and its distribution in the passenger transport fleet also play important roles in determining the emissions of a country. For example, Li et al. [34] looked at the CO_2 emission factors for gasoline cars in Beijing and found that an engine displacement increase of one level led to an emission factor increase of 56.79 gCO_2/km.

Changes in motorisation patterns can also increase carbon emissions [35]. Luxembourg has the highest rate of motorisation in the EU, while the largest increases in motorisation between 1980 and 2014 were seen in Romania, Poland, Estonia, Greece, Lithuania and Latvia. In contrast, France showed the smallest increase.

Controlling and managing the complex passenger car market and all the supply chains is challenging as the stakeholders, their finance companies and car retail dealers are important political stakeholders in the EU. For example, 2012 data on the fiscal income from motor vehicles revealed it was 80 billion euros for Germany and 64.8 billion euros for the UK [36]. Similarly, an income of 71 billion euros each for Italy and France was reported for 2014. The EU's fuel excise duty is higher for gasoline and lower for diesel in all EU member states except in the United Kingdom [36].

The most recent White Paper report on CO_2 emissions from passenger cars in the EU, From Laboratory to Road [37], claimed that the CO_2 emission values of new European passenger cars increased from approximately 9% in 2001 to 42% in 2016.

The European Commission produced major initiatives for road transport sustainability in two White Papers in 2001 and 2011. These White Papers focused on promoting an integrated environmental and transport system across the EU [38]. Recently, the European Commission [39] announced its plan to reach a 55% reduction in carbon emissions. This will mean that half of the cars sold in the EU in 2030 will be electric. A road transport emission trading scheme was also announced. These proposals aim to introduce new economic and investment drivers within the EU market. For example, the 2021 Tax Guide [40] of the European Automobile Manufacturer Association stated that the EU's annual fiscal income from the motor vehicles industry was 398.4 billion euros.

6.2. Sustainability in Road Transport Emissions for 1.5 °C and 2 °C Scenarios

Decarbonisation will build resilient road transport infrastructure and is an important action for combatting climate change and its impact. Policies to decarbonise transport by improving vehicle efficiency and developing technologies such as hybrid, plug-in hybrid and battery electric vehicles (BEVs) will help achieve the carbon targets of the EU and help meet goals 9 and 13 of the Sustainable Development Goals [41].

The carbon emissions produced by the consumption of diesel and gasoline could also be temporarily reduced through changes in fuel excise levies. To further reduce emissions, the EU could restrict the engine sizes of vehicles and leverage the fuel tax and engine power of vehicles. It could also promote competition between internal combustion engine (ICE) manufacturers and the BEV car industry. BEVs and adequate renewable charging infrastructure are an effective path to road transport sustainability. It is important to state that studies have shown that the electrofuel supply chain also emits a significant amount of GHGs. For example, a recent paper indicated that blue hydrogen can create 60% more GHG emissions than burning diesel for heating or combustion [42].

The EU has a fiscal incentive to make the decarbonisation of downstream emissions the main pillar of sustainability. Exposure to international competition from BEV manufacturers will make EU car manufacturers more dependent on financial support from the European Commission. The prevailing fuel excise duty gap between diesel and gasoline will gradually diminish and emission trading will open EU member states to new market influences. The shift to low carbon or net-zero road transport could readily take place within an urban-demographic environment (e.g., in Berlin, Madrid, Paris, Warsaw, Rome and London). In the long-term, the EU could abolish the use of diesel and gasoline ICEs and provide a renewable energy-powered EV or BEV infrastructure.

7. Discussion on Future Policy Paths

The path to decarbonisation will need reorientation and a strategic change in road transport policy. The new policy structures will calibrate the limits of carbon budgets, temperature changes, new economic requirements and demand–supply constraints within and outside the EU. This policy is illustrated in Figure 3 and the following sections.

7.1. Energy and Emissions Path for the 1.5 °C and 2 °C Scenarios

The challenge is to resolve the logjam between the transport needs of the EU and the GHG emissions created by the dependence on diesel and gasoline. The results in Tables 1 and 2 suggest there is a need to create accurate milestones and precision targets for 2030, 2050 and 2100. The challenge is to substitute the present cycle of diesel/gasoline use, fuel taxes and downstream GHG emissions. The suitable policy paths need to deliver the sustainable electrification of transport supported by renewables, carbon pricing and emission trading and develop creative policies to accomplish intermodal change between road freight and passenger transport.

The electrification of road transport through the deployment of BEVs and other technologies is an effective policy for EU. Targets that need to be met are the reduction of the annual addition of 0.23–0.24 $GtCO_2e$ to the atmosphere. Electrification through BEVs and other deployments could reduce and even stop the constant increase in the energy needs of road transport within the EU. This could be initiated by 2030 and stabilised by 2050 and would create market space within the EU for emission trading, mileage allowance trading and road transport carbon pricing. A new economic reality would allow the creation of market-based allowances for consumers, passengers, hauliers, transport companies and manufacturers. Each EU member state could have a separate road transport allowance ceiling for road freight and passengers according to the carbon price or social cost of carbon. The carbon price or social cost of carbon could be set by the European Central Bank (ECB), that fits with the fiscal and monetary policy of the European Commission.

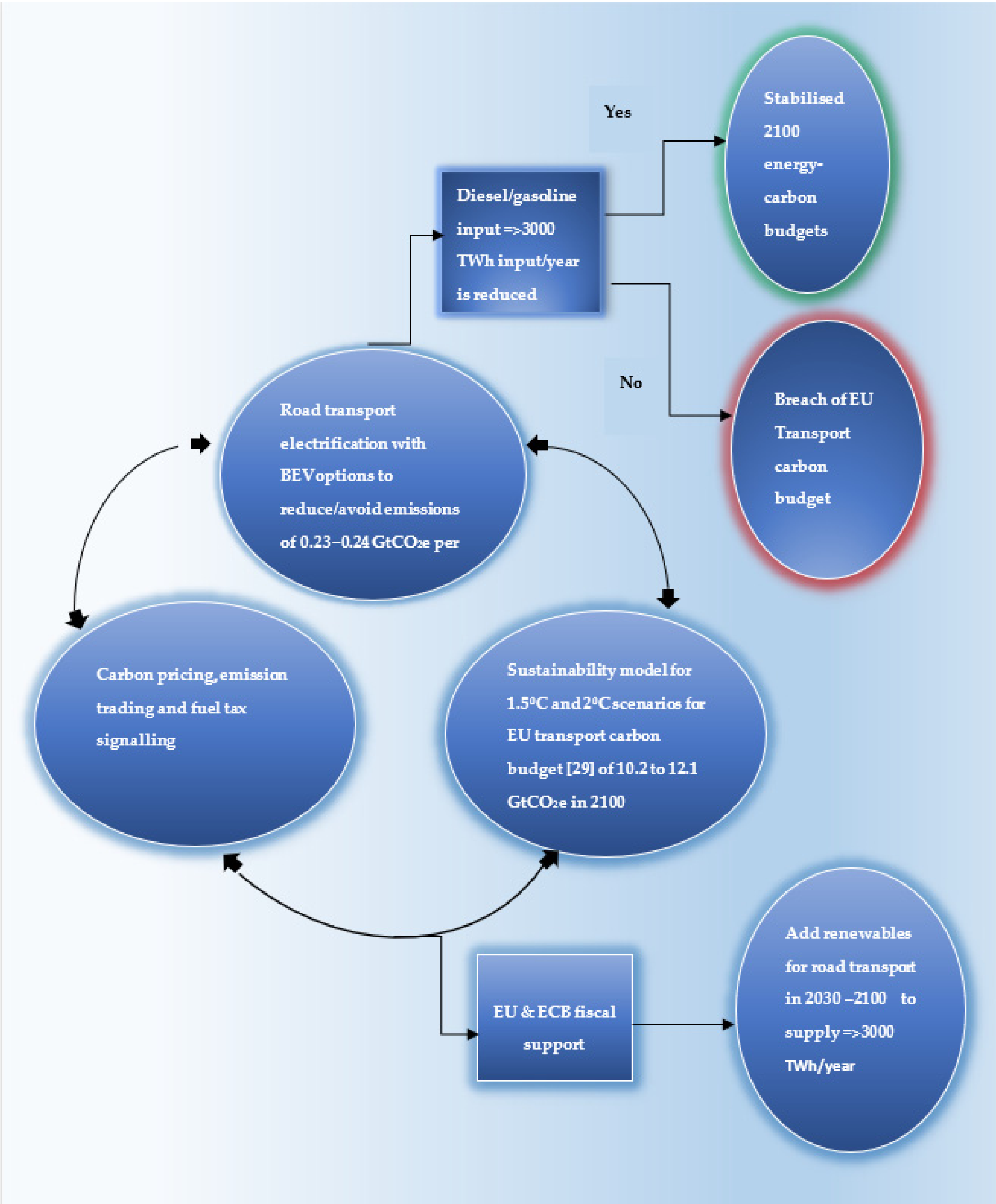

Figure 3. Future policy paths.

These proposals could lead to an effective change in favour of decarbonisation and stakeholders. For example, the proposals could reduce the rate of motorisation, motorway mileage and the rate of 4 × 4 registration across EU member states. In the long term, these changes would lead to the restructuring of urban transport systems and decarbonise metropolitan–urban travel within the EU.

There is also scope for innovative policies. For example, introducing carbon pricing and an allowance exchange in an inter- or multi-modal transport allowance system. Electrification could be supported by allowance trading between aviation, road freight, road hauliers and shipping companies. This would be relevant for both freight and passenger modes. An inter- or multi-modal allowance trade would diversify risks, reduce costs, unlock investment and generate incentives for irreversible decarbonisation of road transport.

7.2. Future Sustainability Path for the 1.5 °C and 2 °C Scenarios

To support EU-wide road transport decarbonisation, a tailored road transport sustainability model is required that delivers sustainability for EU institutions, member states and market stakeholders. When responding to climate, financial and technological challenges, the sustainability model must accommodate EU carbon budget ceilings for the 1.5 °C and 2 °C scenarios, the temperature changes taking place and the requirements of the TCRE as they apply to the EU carbon budget. A strategic change in the typology and taxonomy of vehicles, as well as changes to the fuel tax system, value added taxes and public transport capacity, is justified on the grounds of the climate risks.

8. Conclusions

The EU automotive industry creates GHG emissions but also contributes significantly to the fiscal income of the EU. Road transport carbon emissions increased between 2000 and 2018, with fuel excise duty potentially leading to a reduction in gasoline consumption. The sustainability analysis highlights a need to harmonise fuel excise duty across member states. In the short term, the fuel excise duty could be leveraged to initiate emission reductions in the EU. The results suggest that giving a fiscal advantage to EV users could reduce emissions but also lead to lower tax revenue.

At this stage, the optimum solution is the direct electrification of road transport through the use of BEVs and other low carbon options. The most suitable sustainability option involves updating the approach to sustainability by using the constraints of the carbon budget within the EU.

A new set of measures needs to be put in place to give road transport policy a clear direction. The main barrier to carbon emission reduction is the absence of a market that can accelerate change towards a low carbon or a net-zero transport system. At this stage, the EU is making progress but is still heavily dependent on diesel and gasoline. Although Germany, the Netherlands and France are well positioned to reduce road transport carbon emissions, to meet the challenges of the climate change scenarios, the European Commission needs to modernise road transport policy, outperform the BEV competition and overcome the technological barriers in the ICE and EV market within the next decade.

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Appendix A

Diesel, gasoline and GHG estimation is available in the Supplementary Materials.

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