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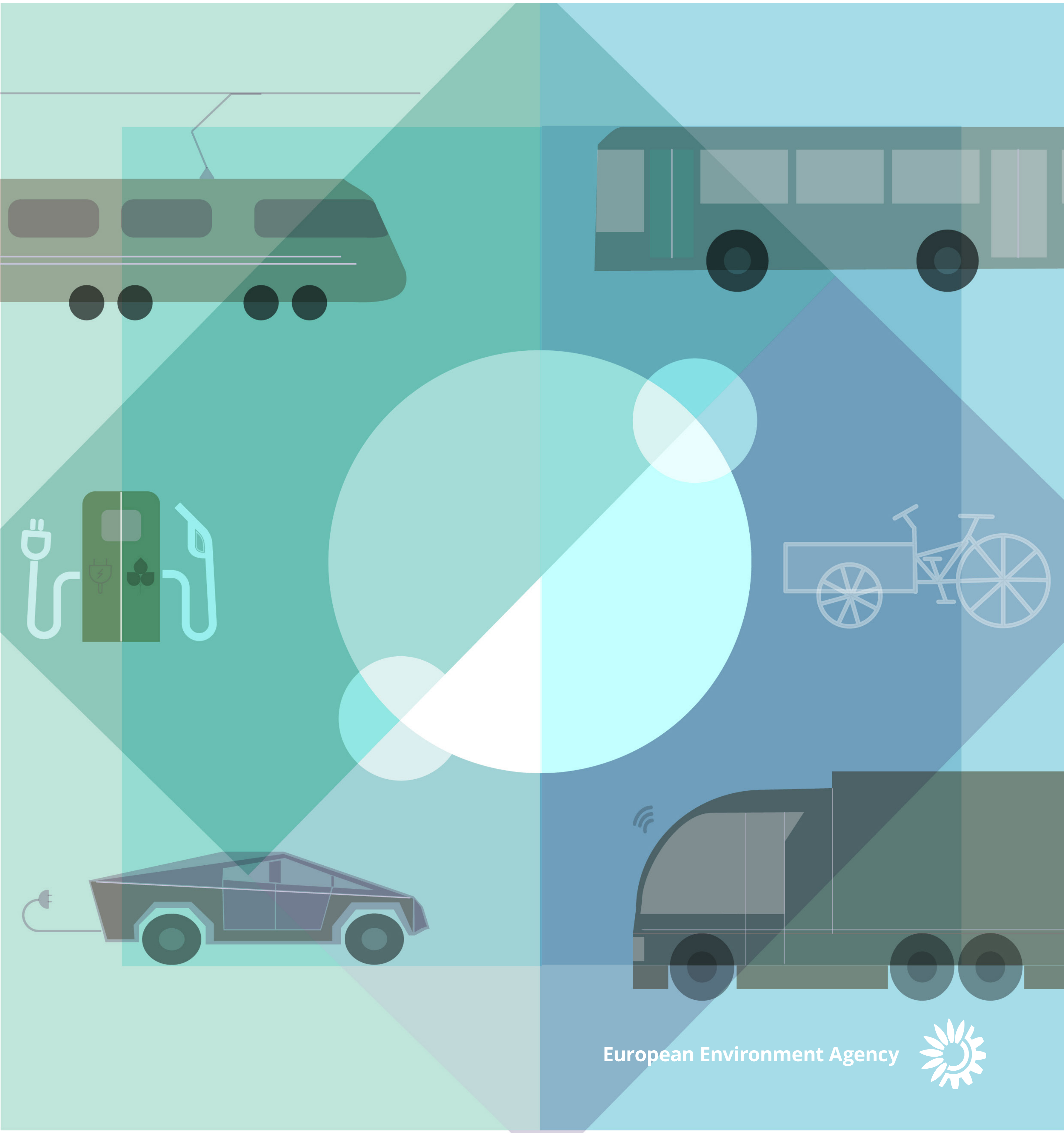
Transport and environment report 2021

Decarbonising road transport — the role of vehicles, fuels and transport demand



European Environment Agency

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Decarbonising road transport — the role of vehicles, fuels and transport demand

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Executive summary

Road transport greenhouse gas emissions increased between 1990 and 2019. Current policies are projected to reverse this trend, but not sufficiently to reach the EU's 2050 climate neutrality target.

Transport is responsible for a quarter of the EU's greenhouse gas emissions, with road transport representing the greatest share (72% in 2019). Climate and energy policies in the EU have contributed to significant reductions in greenhouse gas emissions in all sectors, except transport: total transport greenhouse gas emissions increased by more than 33% between 1990 and 2019 and road transport emissions by almost 28%. According to the European Commission, taking into account all existing policy measures, transport carbon dioxide (CO_2) emissions are projected to be 3.5% higher in 2030 than in 1990 and to fall by only 22% by 2050 compared to 1990 levels. This is a long way from the 90 % reduction by 2050 that is needed from transport to achieve the overall 2050 climate neutrality target. Road transport specifically is projected to perform slightly better, with emissions decreasing by 4% by 2030 and 35% by 2050, compared with 1990.

Road transport emissions remain primarily driven by an increasing demand for transport

This report presents a decomposition analysis for the period 2000-2019, which explores the driving factors behind the trend in CO_2 emissions from passenger cars and heavy goods vehicles.

CO_2 emissions from **passenger cars** in the 27 EU Member States (EU-27) increased by 5.8% between 2000 and 2019. The main driving factor contributing to this increase was the 16.6% growth in passenger transport volumes, combined with a dominant and slightly increasing share of car transport among land-based transport modes. This effect was partly offset by improved energy efficiency, i.e., a reduction in the energy consumption per passenger-kilometre, and by the use of biofuels.

For **heavy goods vehicles**, CO_2 emissions rose by 5.5% between 2000 and 2019. As for passenger cars, the growth in transport activity was the most important factor driving emissions upwards. Inland freight transport activity (i.e. transport by road, rail, inland waterways and oil pipelines) increased by 22% between 2000 and 2019, with fluctuations that are closely related to the general trends in economic activity. The impact of this growth on emissions was reinforced by road transport's dominant and rising share. The most important factor partly compensating for the effect of transport activity was the improvement in energy efficiency (reduction in the energy consumption per tonne-kilometre).

Until 2019, the electrification of the vehicle fleet did not yet play a significant role in reducing CO_2 emissions from road transport. However, it is expected to become more important in the coming years.

The potential of modal shift has not been realised so far

The climate impacts of a passenger-kilometre travelled by car are currently substantially higher than those of buses and trains and active travel modes (walking and cycling). Similarly, the climate impacts of a tonne-kilometre transported by trucks currently exceed those of rail and inland navigation. The modal share of cars in land-based passenger transport and the modal share of trucks in inland freight transport have grown, thus increasing the climate impacts of the transport sector. Importantly, the impact is dependent on the occupancy rate and the load factor.

EU standards have improved the CO_2 performance of new cars and vans, but larger-scale changes in fleet electrification and charging infrastructure development remain necessary

Over the past 10 years, CO_2 performance standards for new cars and vans have been gradually tightened in the EU. For new trucks, the first standards were adopted in 2019. The approach taken in the regulations enables manufacturers to choose the most efficient way to comply. The impact of the standards is visible in the trend in the CO_2 performance of new cars and vans sold in the EU, especially at key target milestone years.

Sales of electric vehicles (battery electric vehicles and plug-in hybrid electric vehicles) have surged since 2017, tripling in 2020 when new targets started to apply. The number of new electric vehicles sold differs significantly across EU Member States. Up until now, the highest sales volumes were recorded in countries with a relatively high gross domestic product per capita. Among Member States with similar income levels, the differences in electric vehicle uptake are partly explained by the variation in national and local policy measures.

The CO_2 efficiency of the entire vehicle stock has also improved, for both cars and heavy goods vehicles. For the latter, this is partly explained by improvements in fuel efficiency and in operational efficiency.

To reach the 2030 and 2050 climate targets, an increase in the share of electric vehicles in the vehicle stock will be necessary. Bottlenecks that could hamper future electrification are the provision of a charging infrastructure and the need to accommodate the electricity demand of electric vehicles and the supply of raw materials for batteries. Emerging innovative solutions, as well as existing and proposed legislation, could help to deal with these bottlenecks.

Road transport fuels remain very carbon intensive, particularly considering the indirect land-use change to grow feedstocks for biofuels

Two key pieces of EU legislation have an impact on the greenhouse gas emission intensity of road transport fuels: the recast Renewable Energy Directive (RED II) and the Fuel Quality Directive. The reduction in the greenhouse gas emission intensity of the road transport fuel mix has been mainly due to the higher share of biofuels (a target for which is set in RED II). In 2020, the average share of energy from renewable fuels in transport in the EU-27 was 10.2%: most of this share is biofuels.

Considering the broader scope of emissions (well-to-wheel, life cycle analysis), the contrast between the greenhouse gas emission performance of biofuels and fossil fuels is even greater than for the scope of only exhaust emissions. However, the feedstock used to produce biofuels is decisive, as potential indirect land-use change from growing crops for biofuels can diminish these benefits.

As the share of electric vehicles increases, the carbon intensity of electricity production will become increasingly relevant to the assessment of the full climate impact of road transport.

Future outlook: all factors need to be harnessed to ensure decarbonisation

With the current policy framework, it is projected that CO_2 emissions from road transport in the EU will decrease by 35% by 2050 (compared with 1990). The decrease will be largely driven by increased efficiency of vehicles, including a shift to electric vehicles. Transport demand is projected to increase, and modal shift to have a limited effect on emissions.

However, the projected driving factors of future reductions in emissions by themselves will not have the same effect on other impacts on the environment, such as noise and non-exhaust air pollutants, congestion, biodiversity loss and resource use. To ensure that greenhouse gas emissions from road transport are significantly reduced, and other impacts are also minimised, factors that have so far driven greenhouse gas emissions upwards (demand and modal shares) could be harnessed to reduce the GHG impact of the road transport sector.

Acknowledgements

The preparation of this report was led by Rasa Narkevičiūtė and Andreas Unterstaller (EEA). The report is based on a draft by the European Topic Centre on Air Pollution, Transport, Noise and Industrial Pollution (ETC/ATNI), written by Sebastiaan Boschmans, Inge Mayeres and Sara Ochelen (Transport & Mobility Leuven).

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1
Introduction

Over the last three decades, the EU climate and energy policy framework has resulted in greenhouse gas (GHG) emission reductions in all sectors except transport. The European Green Deal states that achieving climate neutrality by 2050 requires a 90% reduction by 2050 in all transport GHG emissions compared with 1990. Road transport plays a crucial role in achieving this target, as it accounts for more than 70% of the EU's transport GHG emissions.

The environmental externalities related to road transport, including GHG emissions, can be curbed by a combination of 'avoid, shift and improve' (ASI) strategies (based on Dalkmann and Brannigan (2007)):

- 'Avoid' strategies are directed towards reducing the number of trips or trip length.
- 'Shift' strategies aim for a modal shift towards more environmentally friendly transport modes. Together with the avoid strategies, they address transport demand as a determinant of GHG emissions.
- 'Improve' strategies are about improving vehicle and fuel technologies to be more environmentally friendly.

This report analyses the main driving factors underlying the trend in GHG emissions from road transport in the EU, namely the characteristics of the vehicles that are driven, the type of energy they consume, the level of transport activity and the shares of the different transport modes, that are linked to the avoid, shift and improve strategies.

The **key questions** addressed are:

- How does the EU road transport sector perform in terms of the specific goals for vehicles and the energy they use?
- How is this sector currently contributing to achieving the overarching GHG reduction goals and how will they be reached in the future?
- What are the main policy levers, challenges, obstacles and prospects?

1.1 Scope of the report

The GHG emissions of road transport are the focus of this report. They consist of almost 99% carbon dioxide (CO_2) emissions. Some of the vehicle-related EU regulations address CO_2 emissions specifically. Therefore, some chapters of the report focus on CO_2 emissions.

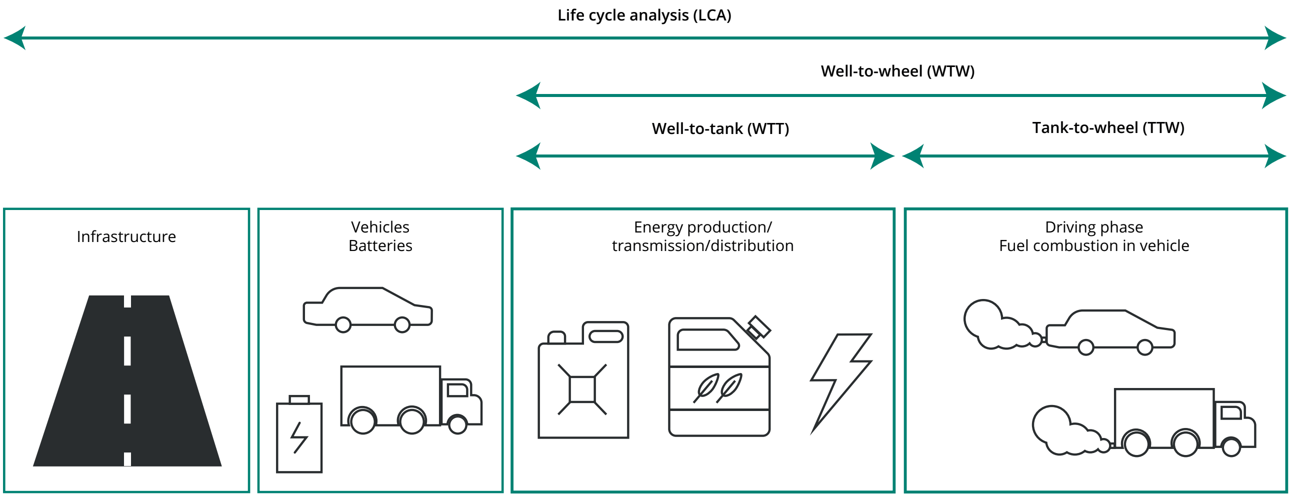
Depending on the driving factor underlying the GHG emissions, the report considers tank-to-wheel (TTW) emissions or well-to-tank (WTT) emissions and emissions related to indirect land use change:

- The TTW emissions, also called exhaust emissions, are caused by fuel combustion during the driving phase. These depend on the characteristics of both the fuel and the vehicle that is driven.
- The WTT emissions, also called upstream emissions, take place during the upstream process of producing, transporting, manufacturing and distributing transport fuels and electricity.
- The emissions related to indirect land use change (ILUC), are defined as follows in the Renewable Energy Directive (recast) (EU, 2018b): 'Indirect land-use change occurs when the cultivation of crops for biofuels, bioliquids and biomass fuels displaces traditional production of crops for food and feed purposes. Such additional demand increases the pressure on land and can lead to the extension of agricultural land into areas with high-carbon stock, such as forests, wetlands and peatland, causing additional greenhouse gas emissions.'

A life cycle analysis (LCA) has a still broader scope as it also considers the energy and emissions involved in the construction and maintenance of the infrastructure and in the manufacturing of the vehicles and the end-of-life stage.

Figure 1.1 presents an overview of the scope of these concepts.

Figure 1.1 Different scopes of GHG emission calculations



Sources: EEA compilation.

Road transport in the report covers both passenger and freight transport, with a focus on cars, vans and heavy goods vehicles. However, as fewer data are available for heavy goods vehicles, the coverage of these vehicles is less detailed.

Unless noted otherwise, the geographical scope of this report is the 27 Member States of the EU (EU-27).

Box 1.1 Country groupings

Throughout the report, abbreviations are used to refer to specific country groupings. The following definitions are used:

- EU-27: the 27 EU Member States as of 1 February 2020;
- European Economic Area: EU-27 Member States plus Iceland, Norway and Liechtenstein. The European Economic Area status of the United Kingdom applied until 31 December 2020.

1.2 Structure of the report

Chapter 2 provides an overview of the climate context and policy framework. It presents the current share of road transport in EU GHG emissions, past trends and the outlook for the trends in these emissions with current policies. The European energy climate policy framework is described, as well as the way it affects road transport GHG emissions. The proposals released by the European Commission to revise the legislation are also introduced.

Chapter 3 presents the analysis of the driving factors behind the trends in the EU's road transport GHG emissions since 2000. This is explored for GHG emissions from passenger cars and heavy goods vehicles. To understand what is behind these trends in emissions, six factors are considered in a decomposition analysis:

- the evolution of total passenger/freight transport activity;
- the modal share of road transport;
- the energy efficiency of road transport;

- the share of electricity in energy consumption by road transport, as a result of the electrification of vehicles;
- the share of biofuels in the demand for non-electric energy for road transport;
- the GHG emission intensity of the fossil fuels.

The next chapters provide more details about each of the driving factors in the decomposition analysis. Each chapter presents the relevant legislation targeting those factors, the past trends and the future outlook:

- Chapter 4 gives more information on the dominant driving factor behind the past trends in road transport GHG emissions, namely the growth of passenger and freight transport activity and the increased modal share of road transport. The chapter briefly goes into the determinants of these trends and assesses the difference in climate effects of the transport modes.
- Chapter 5 presents a deeper analysis of the improved efficiency of vehicles. The trends in the CO_2 emission performance of new vehicles are presented, before assessing how the evolution of these new vehicles affects the vehicle stock. In addition, Chapter 5 takes a closer look at one of the main ways to improve the CO_2 performance of vehicles: the electrification of road transport vehicles.
- Chapter 6 is dedicated to the GHG emission intensity of road transport fuels. This chapter takes a closer look at the status and outlook with respect to the use of both renewable energy, including biofuels, and fossil fuels.

Lastly, Chapter 7 provides a brief future outlook, considering all the aspects analysed.

Figure 1.2 Structure of the report

	Chapter 1: Introduction			
	Chapter 2: Climate context and policy framework			
	Chapter 3: The factors driving road transport greenhouse gas emissions	Chapter 4: Transport activity and modal shares	Chapter 5: The CO_2 performance of cars, vans and heavy goods vehicles in the EU	Chapter 6: The greenhouse gas emissions intensity of road transport energy
ASI-framework	Avoid, shift, improve	Avoid, shift	Improve	Improve
Strategies		- passenger and freight transport activity - modal shares	- fuel efficiency of vehicles - electrification of vehicles	- carbon intensity of fossil fuels, biofuels and electricity - share of biofuels - share of electricity
Scope of GHG emissions	Tank-to-wheel	Well-to-tank Tank-to-wheel Life-cycle analysis	Tank-to-wheel	Indirect land-use change Well-to-tank Tank-to-wheel
	Chapter 7: Looking to the future			

Source: EEA compilation.

2
Climate context and policy framework

Key messages

- **In contrast to other sectors, transport sector greenhouse gas emissions have increased in the past three decades. Emissions from transport increased by 33.5% between 1990 and 2019.**
- **In 2019, transport was responsible for about a quarter of the EU's greenhouse gas emissions. Road transport accounted for 72% of EU transport emissions. With existing policy measures, transport emissions are projected to decrease by only 22% in 2050 compared with 1990. This is a long way from the 90% reduction for transport sought by the European Green Deal by 2050.**

2.1 Introduction

This chapter provides a general overview of the climate context, the general climate and energy policy framework in the EU and the role of road transport in the EU's greenhouse gas (GHG) emissions. The first section sketches the climate challenge and targets. It presents the general European policy framework, highlighting the most important elements affecting road transport GHG emissions and the proposals to reinforce them. The second section presents the share of transport and road transport in current European GHG emissions and the trends in these emissions and the EU emission projections, comparing them with the targets.

2.2 The EU climate-energy policy framework relevant for road transport greenhouse gas emissions

2.2.1 The climate challenge and the global and EU climate targets

Global GHG concentrations in the atmosphere have already reached levels that the Intergovernmental Panel on Climate Change (IPCC) states should not be exceeded in order to limit the global temperature increase to 1.5°C above pre-industrial levels by 2100. The recent assessment by the IPCC indicates that, without significant emission reductions, global warming of 1.5°C and 2°C will be exceeded (IPCC, 2021).

In December 2015 the **Paris Agreement** was signed by 197 countries. They committed to substantially reduce global GHG emissions to limit the global temperature increase in this century to 2°C while pursuing means to limit the increase even further, to 1.5°C (UN, 2021b). The already observed 1°C global temperature rise makes this target very challenging. According to the United Nations, limiting warming to 1.5°C is not impossible yet requires unprecedented changes in all aspects of society, with the next 10 years being critical. By 2030, global carbon dioxide (CO_2) emissions would need to fall by about 45% compared with 2010 levels and reach net zero emissions by around 2050 (UN, 2021a).

EU climate targets

At the core of the **European Green Deal** (EC, 2019a) the European Commission proposed in September 2020 to raise the 2030 GHG emission reduction target to at least 55% compared with 1990. This stepping up of the 2030 target was endorsed by the European Council in December 2020 (EU, 2020). The long-term target is for the EU to become climate neutral by 2050. The **European Climate Law** (EU (2021c)), adopted in June 2021, sets into law the objective of a **climate-neutral EU by 2050** and a collective, net, GHG emission reduction target (emissions after deduction of removals) of at least **55 % in 2030 compared with 1990**. Climate neutrality means that by 2050, the EU aims to achieve net zero GHG emissions. This means that, although some GHG emissions will remain, these should be offset by carbon capture, e.g. by soils and forests.

Although there are no corresponding legally enshrined **sector-specific** reduction targets in the climate law, it envisages sectoral roadmaps towards climate neutrality. The European Green Deal states that **a 90% reduction in GHG emissions from transport by 2050,** with respect to 1990, will be needed to achieve climate neutrality for the economy as a whole. The Sustainable and Smart Mobility Strategy (EC, 2020d) sets out a roadmap to attain smart and sustainable mobility and identifies policy levers that can deliver this 90 % reduction in the transport sector's emissions by 2050.

In July 2021, the European Commission published a set of detailed legislative proposals, called the 'Fit for 55' package or 'Delivering the European Green Deal' package, to achieve the targets agreed in the European Climate Law (EC, 2021b).

2.2.2 The European policy framework

There is a broad framework of legislation to support the EU's aims to achieve its climate goals, including a reduction in the GHG emissions of road transport. Table 2.1 presents an overview of the legislation that plays a role in road transport GHG reductions. General legislation setting targets and incentives with a potential impact on transport emissions is presented here; legislation targeting vehicles and fuels directly is presented in more detail in dedicated chapters.

The Fit for 55 package contains new legislative proposals, as well as proposals to update existing EU legislation. Revisions are proposed for most of the legislation that affects road transport emissions and, if the proposals are accepted, they will have crucial implications for road transport.

The three headline policies for reducing GHG emissions are the Emissions Trading System (ETS), the Effort Sharing legislation and the Land Use, Land Use Change and Forestry (LULUCF) Regulation. **The EU ETS** covers GHG emissions from power plants, large industrial plants and aviation, the latter for flights within the European Economic Area. **The Effort Sharing legislation** sets 2030 targets at EU and Member State levels and covers the remaining domestic GHG emissions from the sectors not covered by the EU ETS: transport, buildings, agriculture, small industrial installations and waste. **The LULUCF Regulation** sets a climate target concerning the carbon stock contained in soils and biomass, stating that there should be no net loss. This is the so-called no-debit rule, which each Member State must respect.

In addition, **the Energy Efficiency Directive** and **the Energy Taxation Directive** also have an impact on the road transport sector. For example, historically, it has been demonstrated that high taxes have contributed to more fuel-efficient cars and thus to lower average CO_2 emissions per vehicle-kilometre of the car stock in the EU than the car stock in the United States, which has lower prevailing fuel taxes (Eberhard et al., 2000).

This set of directives and regulations, their targets for 2030, their relevance for road transport and proposed changes in the Fit for 55 package are summarised in Table 2.2.

The EU has adopted rules to ensure **monitoring of progress** towards its 2030 climate and energy targets, under the **Governance Regulation.** In accordance with these rules, all Member States have developed a National Energy and Climate Plan for the period 2021-2030, which, among other things, describes the existing and planned policies and measures to achieve their GHG reduction targets (EC, 2021i). Member States must also outline in their National Energy and Climate Plans how much they will contribute to the overall energy efficiency target and how they will achieve this.

Table 2.1 Main EU directives and regulations relevant for reducing road transport GHG emissions

Target of legislation	Title	Proposal for revision in Fit for 55 package	Chapter in this report
General	Effort Sharing legislation	Yes	2
	EU Emissions Trading System	Yes	
	Energy Efficiency Directive	Yes	
	Land Use, Land Use Change and Forestry (LULUCF) Regulation	Yes	
	Energy Taxation Directive	Yes	
Vehicles	CO_2 emission standards for new vehicles	Yes	5
	Car Labelling Directive	No	
	Alternative Fuel Infrastructure Directive	Yes	
Fuels	Fuel Quality Directive (FQD)	(Yes)	6
	Renewable Energy Directive (recast) (RED II)	Yes	

Note: (Yes) – The Fit for 55 package does not include a revised FQD. However, the proposed RED II revision includes amendments to the FQD.

Table 2.2 General EU directives and regulations currently in place with relevance for road transport GHG emissions

Legislation	2030 target and key elements	Relevance for road transport	Proposed key changes in Fit for 55 package
Effort Sharing legislation Regulation (EU) 2018/842, EU (2018d)	EU target: **30% GHG emission reduction** with respect to 2005 (non-ETS sectors). Binding non-ETS GHG reduction targets per EU Member State. Covers all GHG emissions that are not covered by the EU ETS or the LULUCF Regulation.	Road transport is one of the sectors covered by the Effort Sharing legislation, without a specific sub-target.	**Transport** and buildings sector continue to be covered under the Effort Sharing. ([a]) It is proposed to increase the EU target for **GHG reduction in the non-ETS sectors to 40%**, and to update the targets for the Member States accordingly.
EU Emissions Trading System Directive 2003/87/EC	**43% GHG emission reduction** with respect to 2005 (ETS sectors). Covers GHG emissions from power stations, manufacturing installations in energy-intensive industries, and airlines operating between countries of the European Economic Area. The EU ETS is a 'cap and trade' system: it sets a total cap on emissions, allocates the emission rights and lets emitters receive or buy emission allowances. An emission allowance grants the right to emit one tonne of CO_2e. Companies can choose to reduce emissions or trade allowances with one another, to achieve reductions at least cost. The price of emission allowances is determined on the market. The EU ETS cap on emissions decreases each year according to a linear path (EC, 2021d).	The EU ETS addresses part of the **well-to-tank CO_2 emissions of road transport**: • from electricity generation (electric vehicles) • from fuel production by refineries regulated by the EU ETS. With greater uptake of electric vehicles expected in the future, a larger part of road transport will (indirectly) fall within the scope of the EU ETS, even with its current set-up.	Separate EU ETS for road transport covering CO_2 emissions from fuel combustion (EC, 2021k): • It is conceived as an upstream system that will regulate fuel suppliers rather than households and vehicle drivers. • It is intended to provide additional financial incentives to use energy-efficient and low-carbon fuels and vehicles, as well as to make more sustainable mobility choices. • The financial incentive is given via the ETS carbon price, which will be reflected in the fuel prices depending on the CO_2 intensity of the fuels. The new ETS for road transport is expected to increase the attractiveness of energy-efficient and low-carbon fuels and vehicles.
LULUCF Regulation Regulation (EU) 2018/841	**No-debit rule:** emissions from land use must be compensated by the equivalent removal of CO_2 from the atmosphere.	Some ILUC emissions of road transport are included in the LULUCF sector (such as carbon released as a result of deforestation to give space for biofuel crops in the EU).	The proposal increases the EU net removal target ([b]).

Table 2.2 General EU directives and regulations currently in place with relevance for road transport GHG emissions (cont.)

Legislation	2030 target and key elements	Relevance for road transport	Proposed key changes in Fit for 55 package
Energy Efficiency Directive Directive 2012/27/EU, amended by Directive (EU)2018/2002 (EU, 2018c)	**At least 32.5% energy efficiency improvement** (compared with projections of the expected energy use in 2030), at EU level. Energy savings of final energy consumption, of 0.8% each year, for the period 2021-2030.	Energy consumption of road transport is part of the overall energy use. No sub-target. Concerning the energy efficiency in end use obligation, Member States can choose whether or not to take into account energy use by transport to achieve their obligation.	New targets have been proposed (EC, 2021m). A further reduction in energy consumption of at least 9% by 2030 (compared with the reference scenario projections). This is a new method of calculating EU energy efficiency that corresponds to a **36% saving in final energy consumption** and a 39% saving in primary energy consumption by 2030. The proposal also includes updates to the upper limit on final and primary energy consumption, which are about 4.7% and 9.3% lower than in the 2018 Energy Efficiency Directive, respectively.
Energy Taxation Directive Directive 2003/96/EC	Establishes the EU rules and the minimum excise duty rates that Member States must apply to energy products for fuel and transport and for electricity. Most Member States apply motor fuel tariffs that are well above these minima. With the current national tax levels, the EU-27 unweighted average of implicit carbon tax rates amounts to around EUR 240/tonne CO_2 for petrol and around EUR 160/tonne CO_2 for diesel (EC, 2020a).	EU rules and minimum excise duty rates that Member States must apply to energy products for fuel and transport, and electricity.	The proposed recast of the Energy Taxation Directive (EC, 2021j) includes: • new structure of tax rates, based on the energy content and environmental performance of fuels and electricity (highest tax rates for the most polluting fuels) • broadening of the taxable base by including more products in the scope and by removing some of the existing exemptions and reductions.

Note: CO_2e, carbon dioxide equivalent; EU-27, 27 Member States of the EU; ILUC, indirect land use change.
([a]) COM (2021) 555, Commission Proposal: Revision of the Effort Sharing Regulation.
([b]) COM (2021) 554, Commission Proposal: Revision of the Land Use, Forestry and Agriculture Regulation.

Source: EEA compilation.

2.3 Road transport greenhouse gas emissions: trends and outlook

In this wider context of policy and targets, the role of road transport in reducing overall GHG emissions has so far been limited.

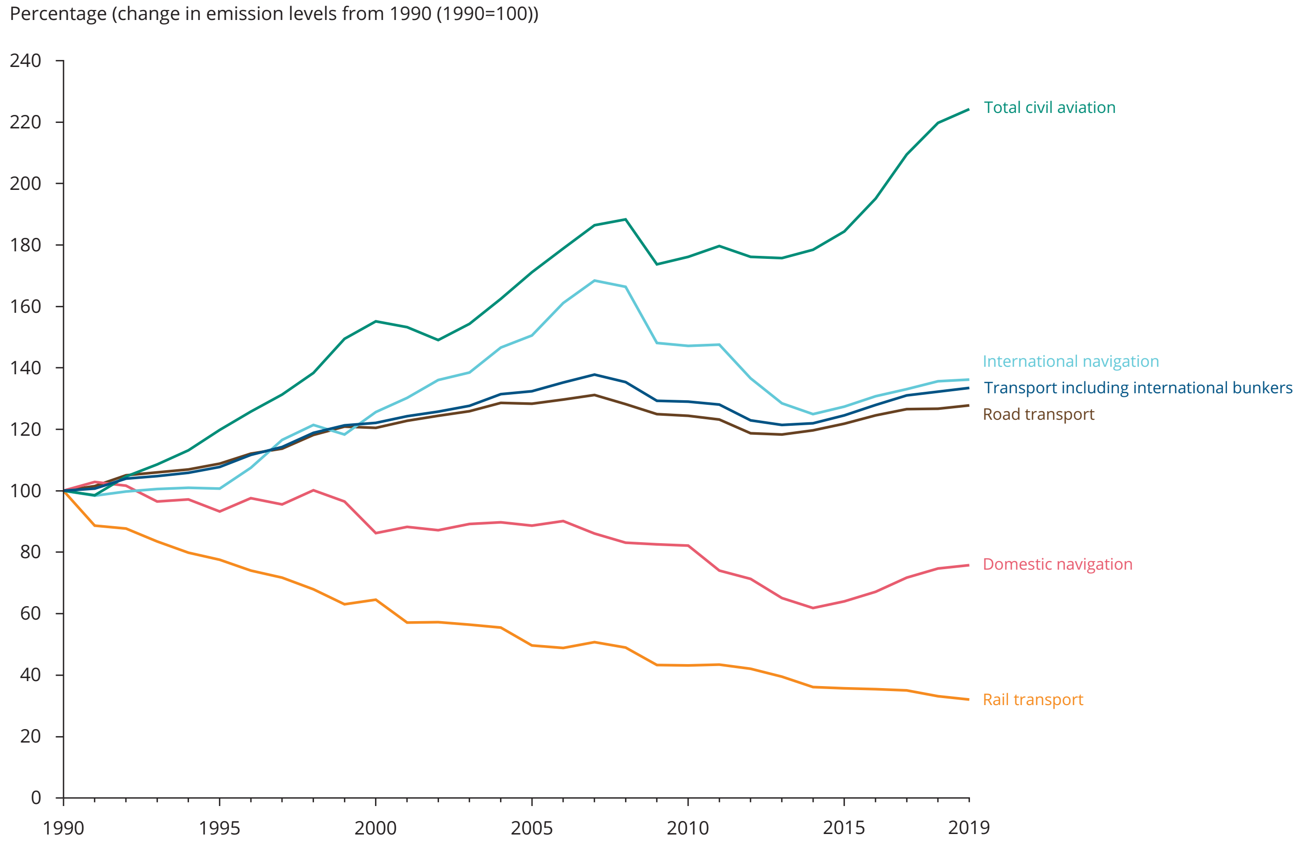
In contrast to other sectors, transport sector GHG emissions have increased in the past three decades. Following a brief drop after the 2008-2009 economic crisis, emissions started increasing again (see Figure 2.1). Preliminary data show that in 2020, as a result of the COVID-19 crisis, emissions decreased (EEA, 2021a).

The GHG emissions from transport (including international aviation and maritime transport) in the 27 Member States of the EU (EU-27) were 33.5% higher in 2019 than in 1990. Road transport emissions increased by 27.8%. Despite a drop in 2020 due to the COVID-19 crisis, it is expected that emissions will rebound.

In 2019, road transport accounted for 71.7% of the EU-27 transport sector emissions (Figure 2.2).

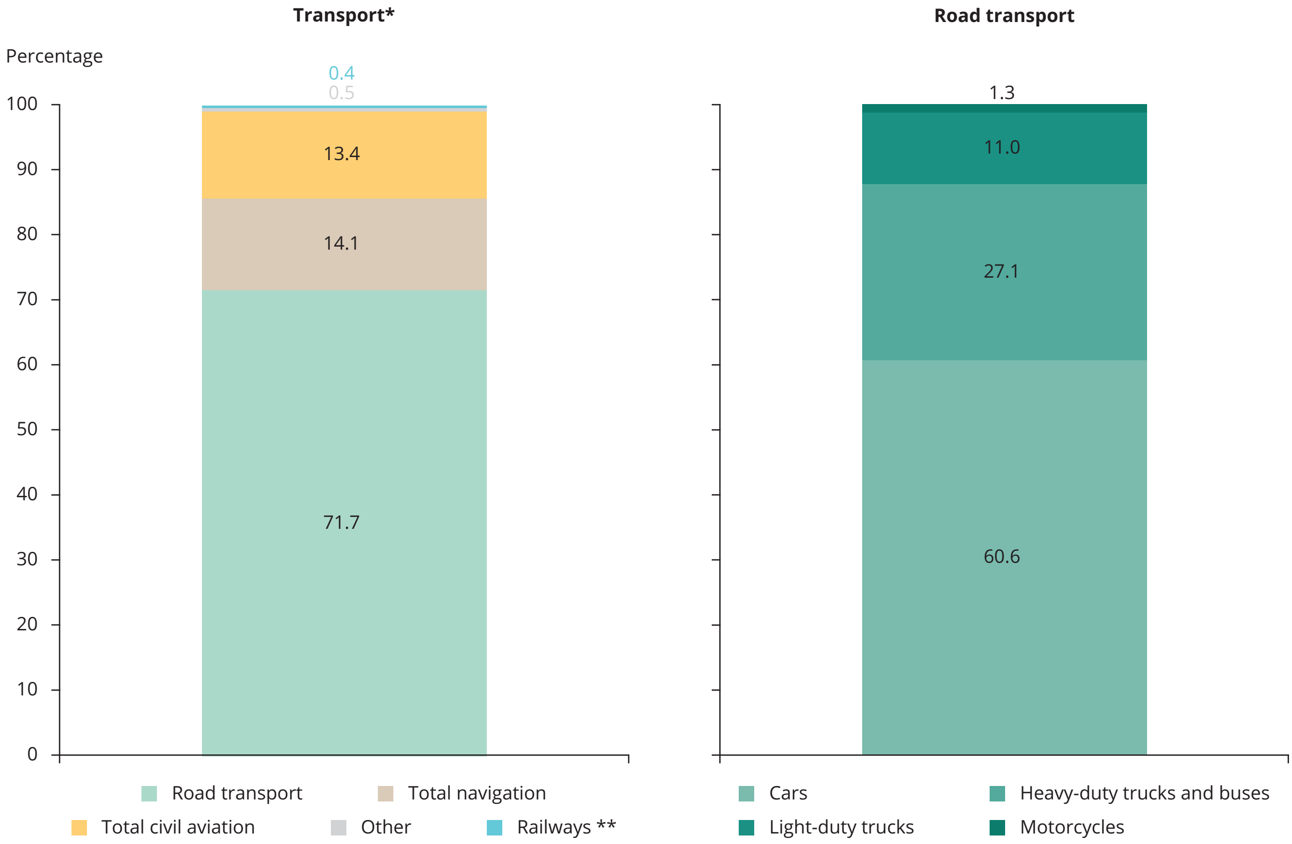
Among the road transport modes, cars have a dominant role, accounting for 60.6% of emissions, followed by heavy-duty trucks and buses, which together represent 27.1% of the road transport emissions in 2019.

Figure 2.1 Trends in GHG emissions by transport mode in the EU-27, 1990-2019 (1990=100%)



Source: EEA compilation based on EEA (2021d).

Figure 2.2 Road transport emissions as a share of EU transport GHG emissions and share of road transport emissions by mode in the EU-27, 2019



Note: *Including international bunkers (international aviation and international maritime transport.
**Excluding indirect emissions from electricity consumption.

Source: EEA compilation based on EEA (2021d).

Box 2.1 Climate accounting rules and implications for reporting the GHG emissions of road transport

The European climate targets are consistent with the way greenhouse gas (GHG) emissions are accounted for in EU and national GHG emissions inventories. Detailed rules are set up to ensure transparent, consistent, comparable, complete and accurate reporting (EC, 2016), in line with the guidelines of the Intergovernmental Panel on Climate Change. The basic principle is that GHG emissions are accounted for at the place and the moment they are released.

For transport, only the tank-to-wheel (TTW) emissions are reported, that is, the emissions that are released when burning fuel to propel the vehicles. The GHG emissions for electricity generation, refining of fossil fuels or cultivation of feedstocks and processing of biofuels take place in other sectors. These are the well-to-tank (WTT) emissions and are included in the EU inventory (and thus in the EU targets) if this production takes place on EU territory. They are not included in the transport emissions in Figure 2.1 and Figure 2.2.

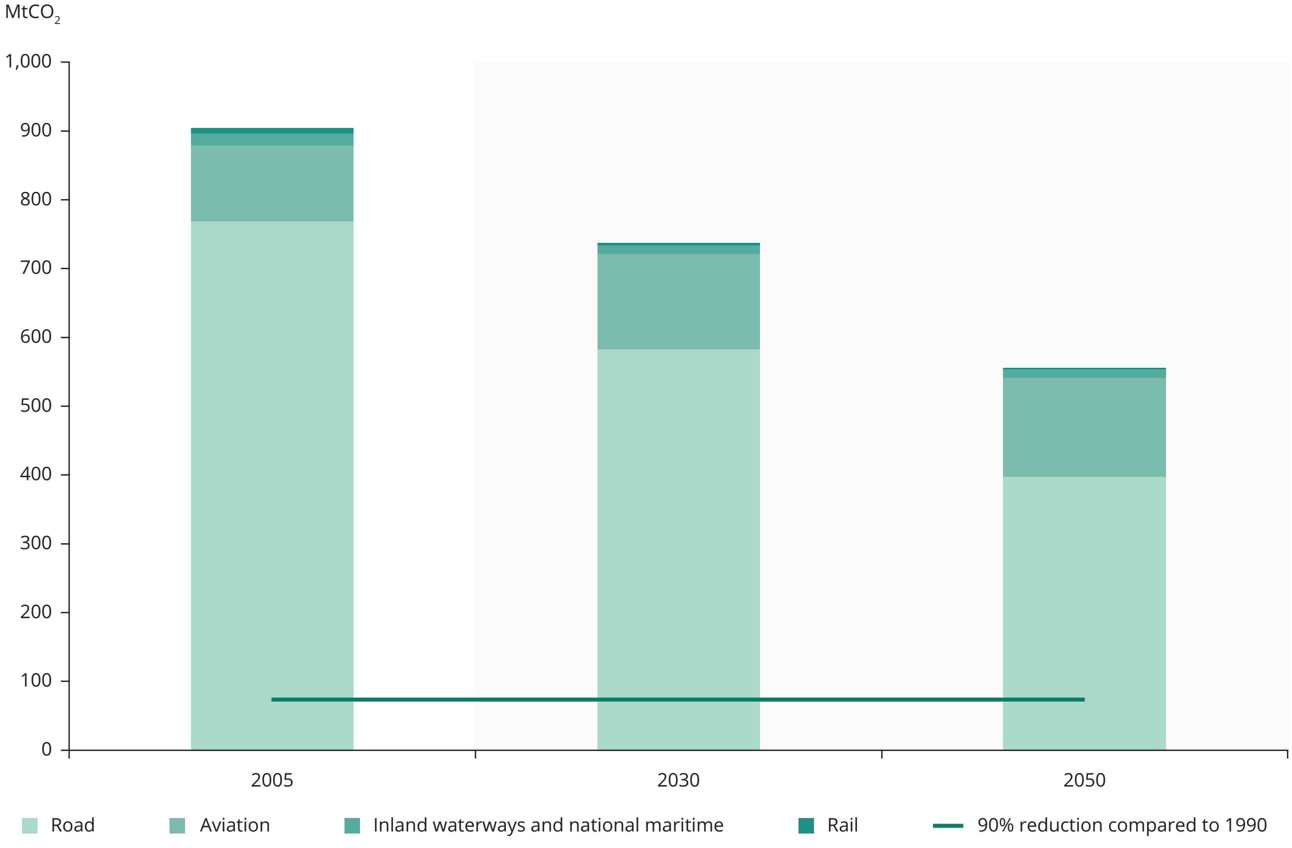
According to the *EU Reference Scenario 2020* (EC, 2021e), transport sector emissions are projected to decrease, and road transport is expected to contribute a large part of this reduction (Figure 2.3). Within road transport, most emission reductions are projected to come from passenger cars (Figure 2.4).

Total transport emissions in the reference scenario are expected to be 3.5% higher in 2030 than in 1990 and to decrease by 22% in 2050, relative to 1990. Compared with the historical transport emission trends, this reduction is substantial; however, there is a significant distance to reach the economy-wide EU target of a 55% reduction by 2030 and a 90% reduction by 2050.

In 2020, passenger transport was severely affected by a system shock in the form of the COVID-19 pandemic. The *EU Reference Scenario 2020* (EC, 2021e) estimates that in 2020 intra-EU passenger transport decreased by 24% compared with 2019. About two thirds of this reduction would have been due to a fall in travel by passenger cars, public road transport and two-wheelers. Travel by rail, inland shipping and intra-EU aviation is estimated to have halved.

For freight transport, the impact of the COVID-19 pandemic in the EU-27 is considered to be smaller than that on passenger transport: a reduction of approximately 7%. For international maritime freight transport the impact is more substantial, with an estimated reduction of 30% (EC, 2021e).

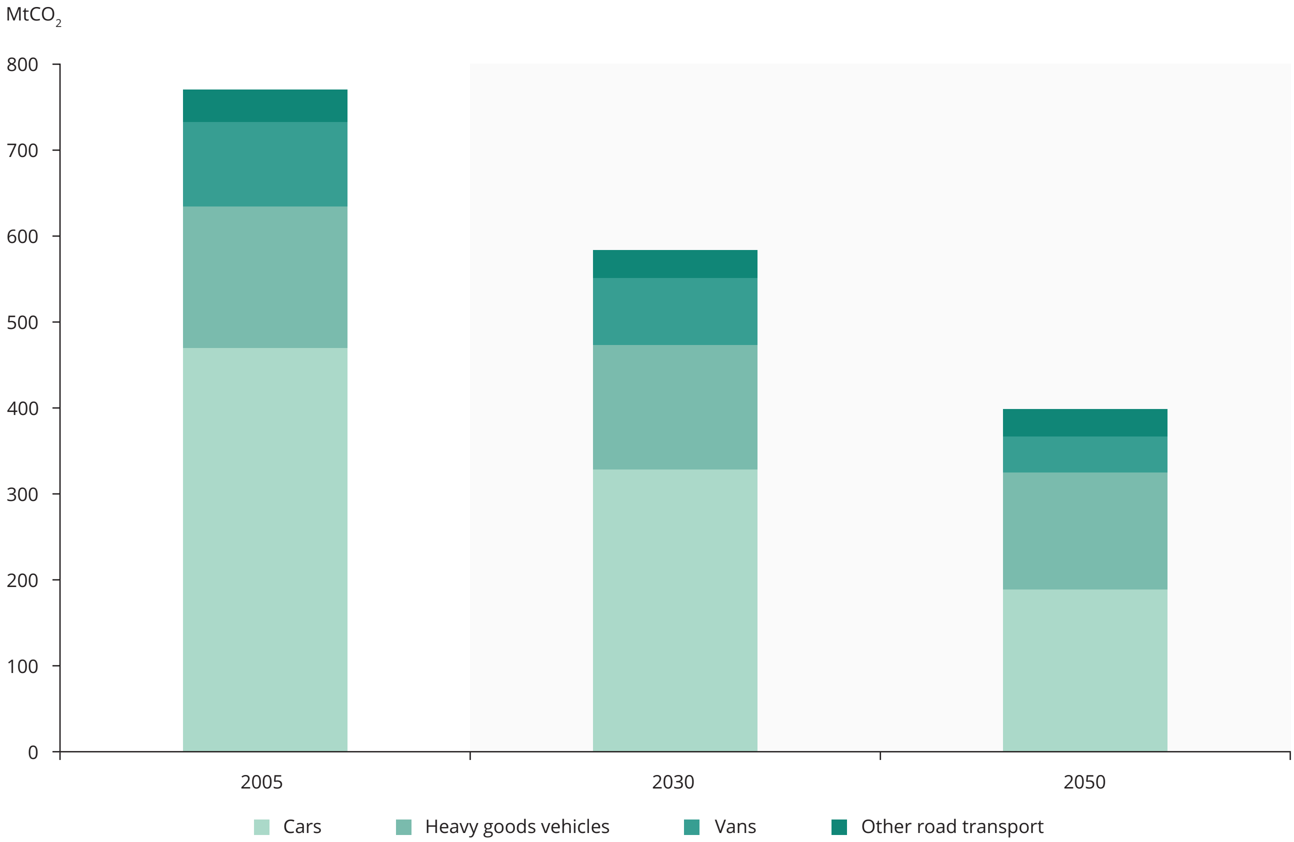
Figure 2.3 CO_2 emissions for transport (including international aviation but excluding international maritime) in the EU Reference Scenario 2020 in the EU-27 ($MtCO_2$)



Note: The *EU Reference Scenario 2020* includes Member State and EU policies adopted up to the end of 2019.

Source: EC (2021e).

Figure 2.4 **CO_2 emissions from road transport in the *EU Reference Scenario 2020* in the EU-27 ($MtCO_2$)**



Note: The *EU Reference Scenario 2020* includes Member State and EU policies adopted up to the end of 2019.

Source: EC (2021e).

Box 2.2 **EU Reference Scenario 2020**

The EU Reference Scenario is the baseline for the impact assessments for the Fit for 55 package. It presents an outlook for the future evolution of CO_2 emissions from transport, based on PRIMES-TREMOVE modelling. The scenario includes a vast array of existing policies: the post-2020 CO_2-standards for new light-duty and heavy-duty vehicles, the Directive on the deployment of alternative fuels infrastructure, the Renewable Energy Directive, the Fuel Quality Directive and the Directive on the deployment of alternative fuels infrastructure, the Trans-European Transport Network Regulation supported by Connecting Europe Facility funding and so on. The scenario takes into account the impacts of the COVID-19 pandemic.

3 The factors driving road transport greenhouse gas emissions

Key messages

- **Carbon dioxide emissions from passenger cars in the 27 EU Member States increased by 5.8% between 2000 and 2019. The main factor contributing to this increase was the 16% growth in passenger transport volumes, combined with a dominant and slightly increasing share of car transport among land-based transport modes. This effect was partly offset by improved energy efficiency, i.e., a reduction in the energy consumption per passenger-kilometre, and by the use of biofuels.**
- **For heavy goods vehicles, carbon dioxide emissions rose by 5.5% between 2000 and 2019, primarily driven by the growth in freight transport activity. This was reinforced by a rising share of road transport among land-based transport modes. The most important factor compensating the increase in emissions was an improvement in energy efficiency, which was more significant than for passenger cars.**

3.1 Introduction

As shown in Chapter 2, greenhouse gas (GHG) emissions in the road transport sector in the EU have increased over the last three decades, in contrast to the developments in other sectors. To explore the factors driving the evolution of these GHG emissions over time, a decomposition analysis was conducted for passenger cars and for heavy goods vehicles in the 27 EU Member States (EU-27). This chapter presents the approach and the results of this analysis.

3.2 Premise and approach

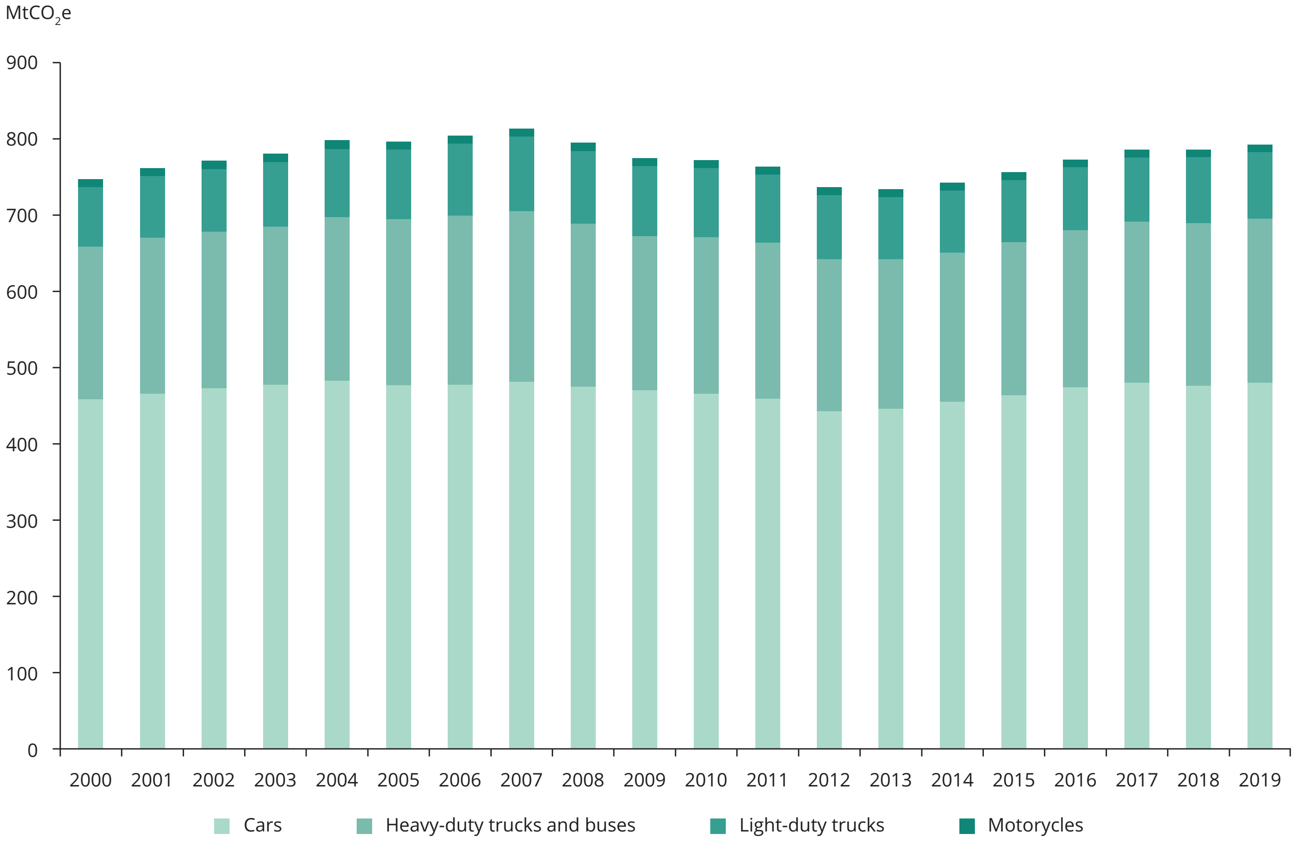
Cars and heavy-duty vehicles (which include buses, coaches and trucks) are responsible for most of the road transport emissions, as illustrated in Figure 3.1. Together they accounted for almost 88% of road transport GHG emissions in 2019. Among the heavy-duty vehicles, heavy goods vehicles used for transporting freight are the category with the greatest emissions (EC, 2021e).

To explore the drivers behind the trends in GHG emissions of the most emitting road transport categories, a decomposition analysis was conducted (see Box 3.1).

Two separate analyses were conducted for each transport category: one for carbon dioxide (CO_2) emissions, which make up approximately 99% of the GHG emissions from road transport, and the second for emissions of methane (CH_4) and nitrous oxide (N_2O). The scope of the analysis is the tank-to-wheel (TTW) emissions, accounted for in the GHG emissions inventories.

The approach chosen was aligned with previous EEA analyses (EEA 2015, 2019a), to allow comparability. The decomposition analysis was conducted for the period 2000-2019. The factors have been selected according to two criteria: (1) previous analyses have shown that they are relevant, and (2) data availability. In contrast to previous EEA analyses, to investigate the role of electrification in the car market a distinction is now made between electric and non-electric energy consumption by passenger cars.

Figure 3.1 GHG emissions from road transport in the EU-27, 2000-2019



Source: Compilation based on EEA (2021d).

Box 3.1 What is a decomposition analysis?

Decomposition analysis is a technique used to illustrate and compare the respective contributions of selected explanatory factors to emissions of greenhouse gases over time.

First, an equation linking the observed emissions to the selected factors is specified. These factors are typically chosen as those likely to have had a significant impact on emissions over the period considered, and for which data are available. The decomposition analysis assumes that each of the different explanatory factors is independent, i.e., no interaction or synergy between different factors is assumed. The number of factors should be limited (usually four to six), as the change in emissions is effectively 'decomposed' and distributed according to which factor is most important in terms of its impacts on emissions across the period chosen; therefore, selecting many factors can complicate the result. Furthermore, as the results are dependent on the explanatory factors chosen, they should not be considered an exhaustive assessment of the contributory factors responsible for past changes in emissions (EEA, 2015).

The figures presenting the decomposition analysis results in this report show the relative contributions made by each factor to changes in emissions over time, i.e. those responsible for either increasing or decreasing emissions, compared with the year 2000. Together, the sum of the different factors in each year is the same as the observed change in emissions.

The decomposition analysis for the emissions of passenger cars and heavy goods vehicles (HGVs) of >3.5 tonnes used the same methodology, with driving factors adapted to passenger/ freight transport, respectively. The following six potential driving factors behind emission trends were considered:

1. Passenger/freight transport activity. For cars: the number of passenger-kilometres travelled by land-based passenger transport modes, namely passenger cars, powered two-wheelers, buses and coaches, railways, trams and metros. For HGVs: the number of tonne-kilometres ([1]) carried by inland waterways, railways and road transport.

2. Modal share. The share of passenger-kilometres travelled by car in overall passenger transport activity/the share of tonne-kilometres delivered by HGVs in overall freight transport activity.

3. Energy efficiency. The energy consumed per passenger-kilometre by passenger cars/energy consumed per tonne-kilometre by HGVs. This includes the energy consumption of fossil fuels, biofuels and electricity.

4. Effect of electrification. Approximated as the share of non-electric energy (fuels) in the energy consumption by cars. This factor is not used for HGV analysis.

5. Biofuel effect. Measured using the share of fossil fuels in non-electric energy consumption by passenger cars/HGVs. Biofuels are attributed a CO_2 emission factor of zero in the climate accounting ([2])

6. Carbon intensity of fossil fuels. Defined as the CO_2 emissions per unit of fossil fuel consumed (by cars/HGVs). This carbon intensity factor is a weighted average of the CO_2 emission factors for the fossil fuels included in the GHG emission inventory.

The first driving factor can be influenced by 'avoid' strategies, the second factor by 'shift' strategies and factors three to six by 'improve' strategies.

For the decomposition analysis for emissions of methane (CH_4) and nitrous oxide (N_2O), no separate factor is considered for the biofuel effect. The analysis of CH_4 and N_2O emissions considered their values weighted by their global warming potential ([3]).

Annex 1 provides more information on the methodology and the data sources.

3.3 Factors behind trends in greenhouse gas emissions from passenger cars

3.3.1 Results of the decomposition analysis for the CO_2 emissions

Figure 3.2 presents the evolution of the driving factors since 2000. The overall CO_2 emissions from passenger cars in the EU-27 increased by 5.8% between 2000 and 2019.

Figure 3.3 provides the results of the decomposition analysis. It presents an overview of how much each driving factor contributed to this change in emissions, given the changes presented in Figure 3.2.

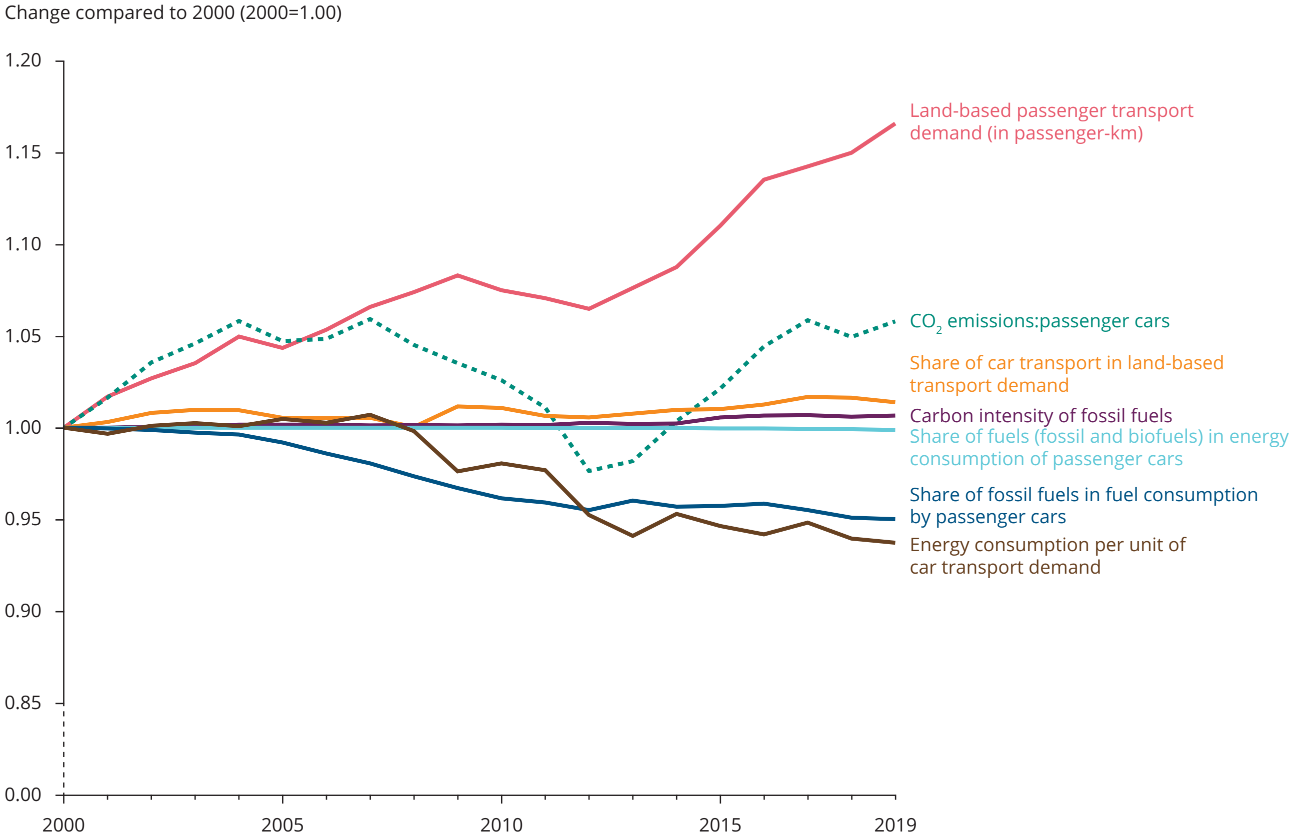
The main driving factor has been the growth in passenger transport volumes. Between 2000 and 2019, passenger transport demand (road and rail) grew by 16.6%, with a dip between 2009 and 2012, following the financial/economic crisis. This driving factor has determined the main pattern in the trends in CO_2 emissions from car transport: in most years, when passenger transport demand grew, CO_2 emissions followed, and vice versa.

([1]) Freight amount is measured in terms of mass of the load carried and distance over which the load travels. A unit of freight amount is thus expressed in terms of, for example, tonne-kilometres. A tonne-kilometre corresponds to the activity of carrying 1 tonne of freight over 1 kilometre.

([2]) The CO_2 emissions that take place during the combustion of biofuels are reported under the GHG emission inventory heading 'transport' and for the different transport modes, but they are not accounted for in total transport emissions. Instead, they are included under the memo items (reported emission sources not included in the aggregation of the national totals). Biofuels are therefore attributed a CO_2 emission factor of zero in the climate accounting for transport. The emission factor of biofuels for CH_4 and N_2O, the other two GHGs included in the GHG inventory, is not zero.

([3]) Over 100 years, CH_4 and N_2O have a global warming potential of 25 and 298, respectively, compared with CO_2 (EEA (2020a) based on UNFCCC (2013)). The global warming potential allows comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 tonne of a gas will absorb over a given period of time, relative to the emissions of 1 tonne of CO_2.

Figure 3.2 Changes in the driving factors considered in the decomposition analysis — passenger cars in the EU-27, 2000-2019 (2000=1)



Source: EEA compilation based on the data sources summarised in Annex 1.

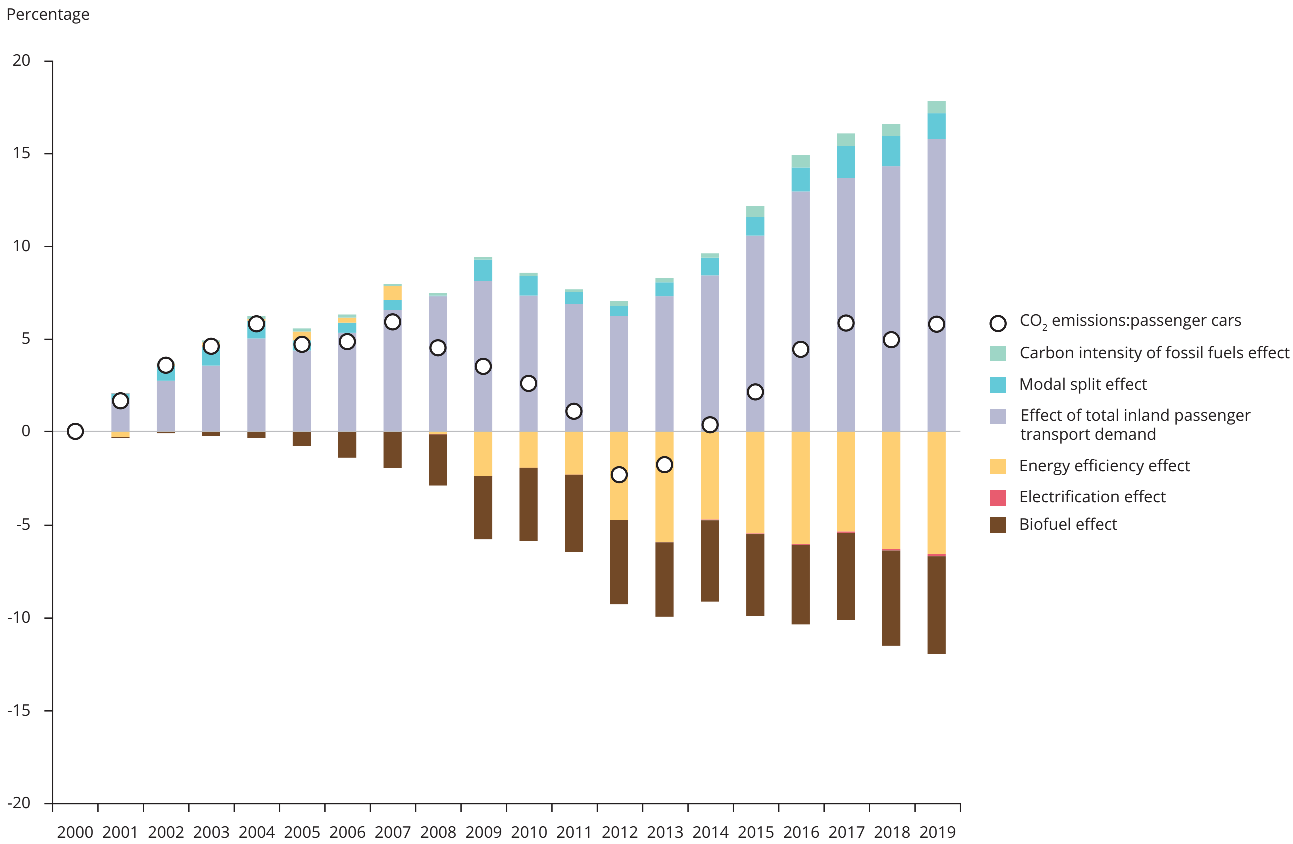
Two of the other factors were also found to contribute to a rise in emissions. First, the growth in the modal share of car transport, which increased from 78.5% to 79.6% between 2000 and 2019. Second, especially in recent years, the carbon intensity of the fossil fuels consumed by passenger cars has increased, though modestly.

The two main factors counteracting the effects of transport activity and contributing to lower CO_2 emissions are the higher energy efficiency of passenger cars (the energy consumption per passenger-kilometre decreased by just over 6%) and the higher share of biofuels. The energy efficiency improvements have had an effect since 2009 when mandatory emission reduction targets for new cars sold in the EU were adopted. As the indicator for energy efficiency considers all energy sources consumed by road transport, including electricity, this energy efficiency effect is also linked to the uptake of electric vehicles in the later years of the analysis.

Finally, the results show that in the period considered (2000-2019) the electrification of passenger cars has not yet played a significant role in reducing emissions.

These factors are further explored in Chapters 4 (transport demand and modal shift), 5 (energy efficiency of vehicles) and 6 (carbon intensity of fuels and the effect of biofuels).

Figure 3.3 Decomposition analysis of the CO_2 emissions from passenger cars in the EU-27, 2000-2019 — percentage contribution



Note: CO_2e emissions: percentage change compared to the year 2000.
Driving factors: Percentage contribution of driving factors to percentage change in CO_2 emissions from passenger cars.

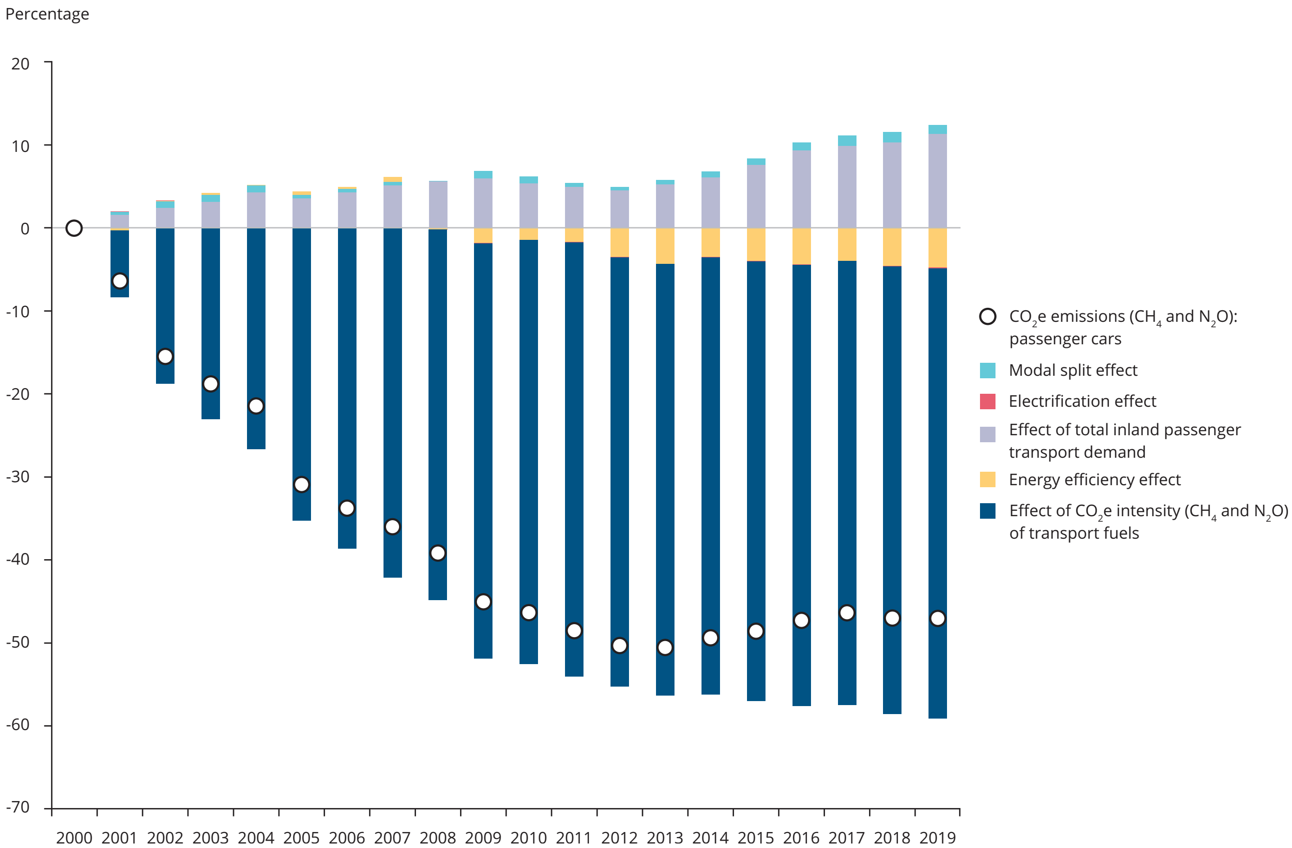
Source: EEA compilation.

3.3.2 Results of the decomposition analysis for CH_4 and N_2O emissions

The decomposition analysis was also conducted for the CH_4 and N_2O emissions from passenger cars, weighted by their global warming potential. In 2019, these two substances made up about 1% of the GHG emissions from passenger cars.

The CO_2e (CO_2 equivalent) emissions from passenger cars related to CH_4 and N_2O nearly halved during the period 2000-2019 (Figure 3.4), predominantly driven by reductions in the average emission intensity of transport fuels.

Figure 3.4 **Decomposition analysis of the CO_2e emissions from passenger cars related to CH_4 and N_2O in the EU-27, 2000-2019 — percentage contribution**



Note: CO_2e emissions: percentage change compared to the year 2000.
Driving factors: Percentage contribution of driving factors to percentage change in CO_2e emissions from passenger cars, related to the N_2O and CH_4 emissions.

Source: EEA compilation.

3.4 Factors behind trends in greenhouse gas emissions from heavy goods vehicles

3.4.1 Results of the decomposition analysis for CO_2 emissions

Figure 3.5 presents the trend in CO_2 emissions from HGVs and the underlying driving factors analysed. Figure 3.6 presents the relative importance of the different driving factors contributing to the total CO_2 emissions from HGVs.

The CO_2 emissions from HGVs were 5.5% higher in 2019 than in 2000. A period of growth until 2007 was followed by annual reductions until 2014, after which emissions started increasing. Freight demand has been a key factor contributing to these trends. The reduction in freight transport demand after the economic crisis played a role in the decrease in emissions between 2008 and 2014. Then, as demand started rising again in 2014, so did the emissions.

Total demand for inland freight transport increased by almost 25% in the period 2000-2019.

The modal share of HGVs in terms of load carried over distance (tonne-kilometres) also increased. More specifically, the number of tonne-kilometres transported in the EU-27 by inland waterways and railways increased by 5% between 2000 and 2019, whereas HGV transport rose by 31%. The share of HGV transport has also increased, from 72% in 2000 to 76.4% in 2019, which also contributes to increased HGV emissions during this period.

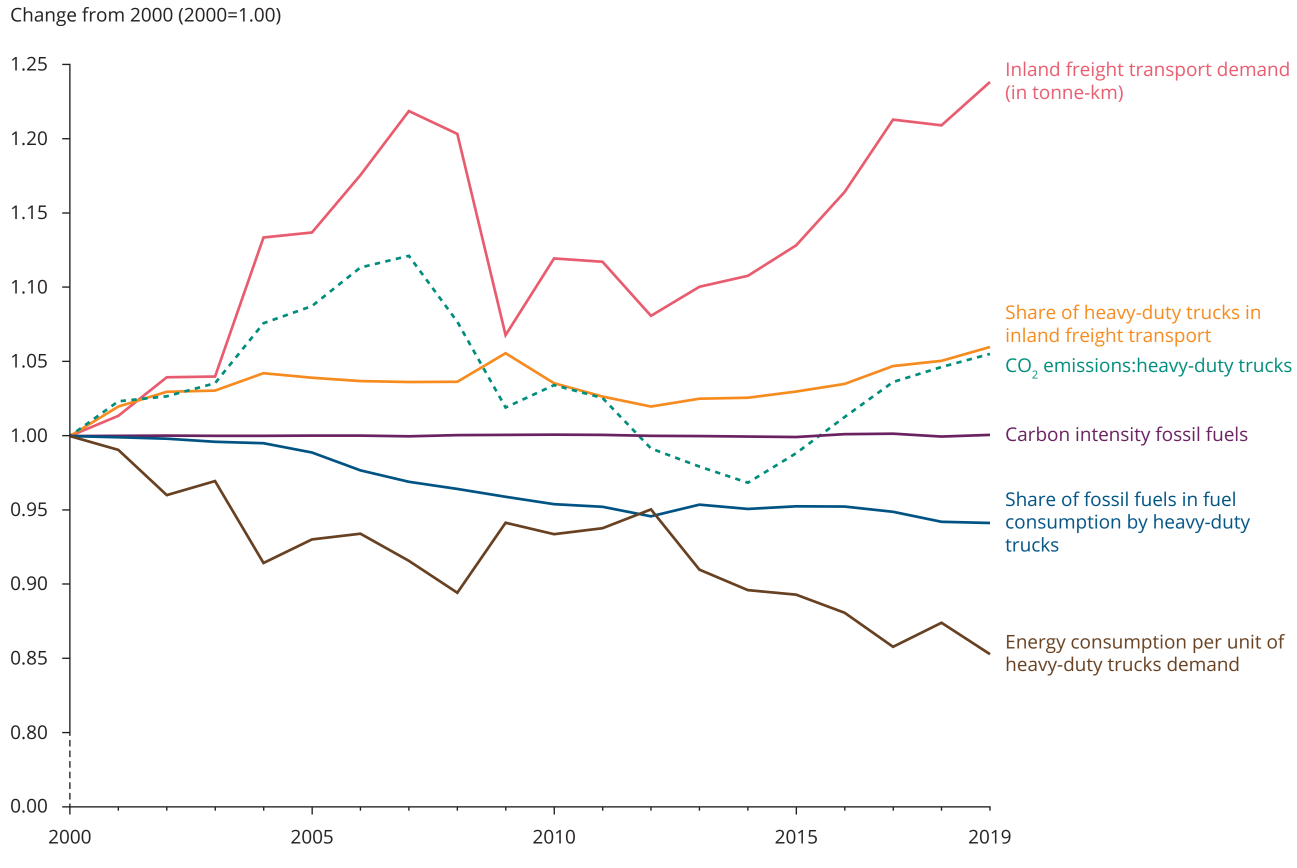
However, improvements in energy efficiency have been the main factor contributing to limiting the increase in emissions during the periods of growth in demand. Energy consumption per tonne-kilometre transported decreased by almost 15% between 2000 and 2019, a more significant reduction than that for passenger cars.

Another factor that appears to have contributed to limiting increases in CO_2 emissions is the broader adoption of biomass fuels, which are considered to be carbon neutral in the GHG emissions inventory. The share of biofuels was 0.6% in 2000 and 6.4% in 2019.

Changes in the CO_2 intensity of fossil fuels used by HGVs played a negligible role, as diesel remained the dominant fossil fuel. The diesel share in fossil fuels was 99.5% in 2000 and 98.9% in 2019.

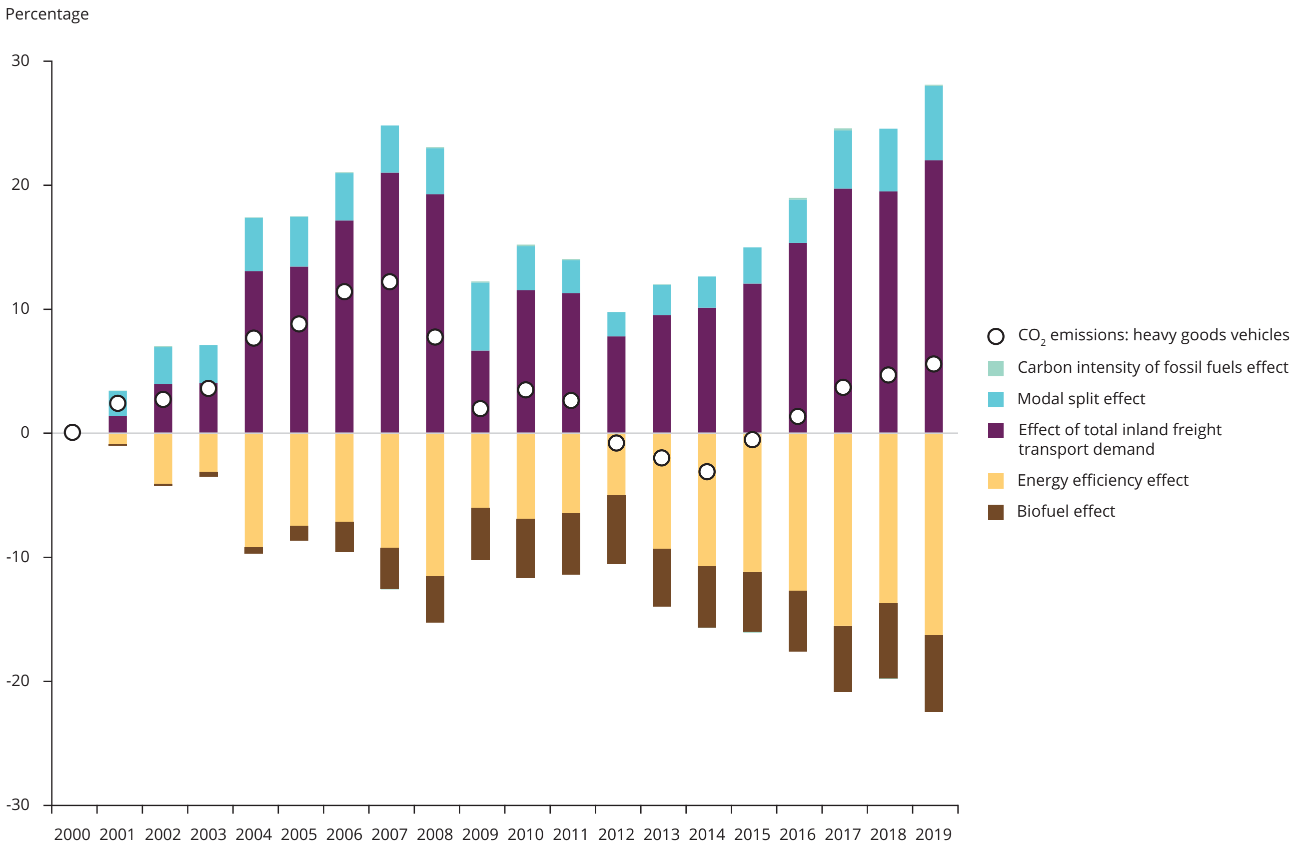
These factors are further explored in Chapters 4 (transport demand and modal shift), 5 (energy efficiency of vehicles) and 6 (carbon intensity of fuels and biofuel effect).

Figure 3.5 Change of the driving factors considered in the decomposition analysis — heavy goods vehicles in the EU-27, 2000-2019 (2000=1)



Source: EEA compilation based on the data sources summarised in Annex 1.

Figure 3.6 **Decomposition analysis of the CO_2 emissions of heavy goods vehicles in the EU-27, 2000-2019 — percentage contribution**



Note: CO_2 emissions: percentage change compared to the year 2000.
Driving factors: Percentage contribution of driving factors to percentage change in CO_2 emissions from HGVs.

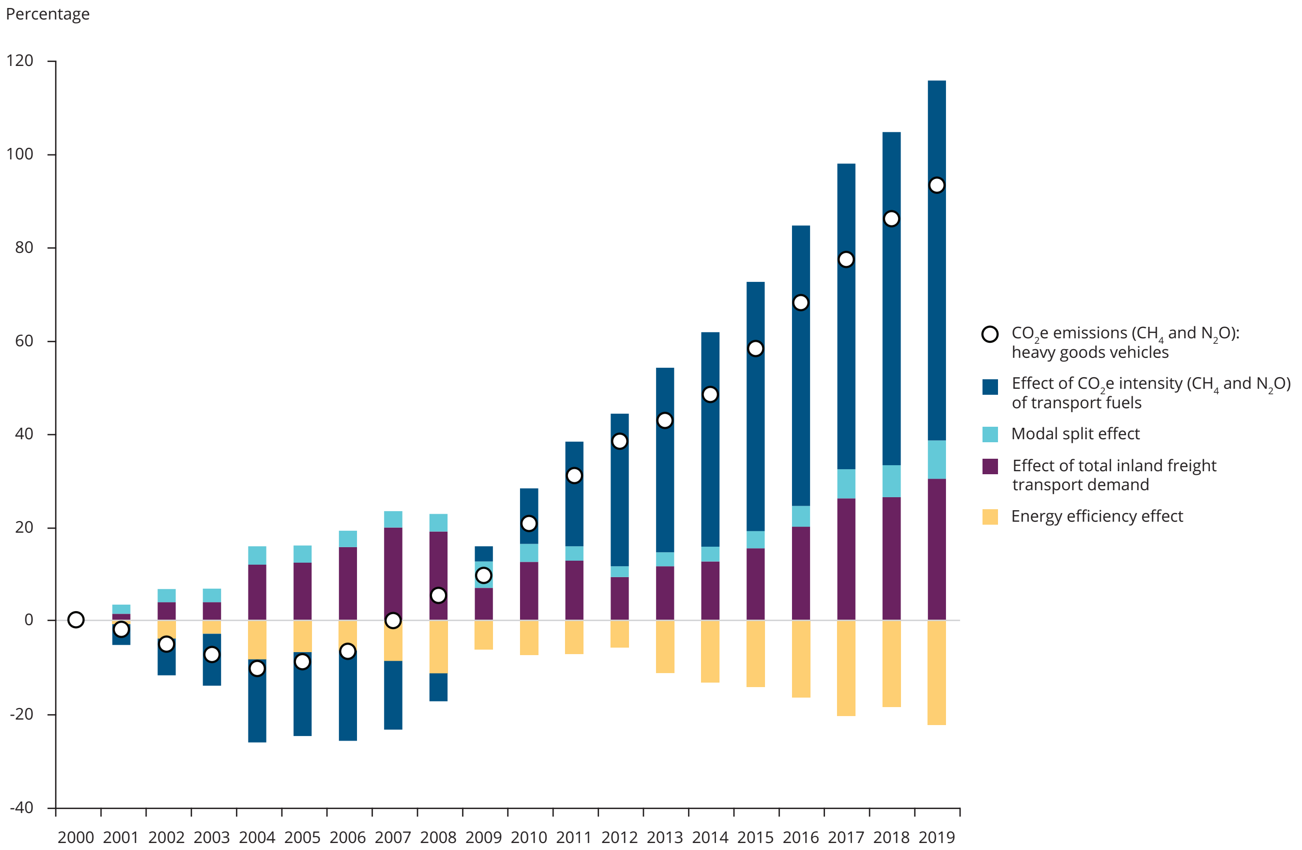
Source: EEA compilation.

3.4.2 Results of the decomposition analysis for CH_4 and N_2O emissions

Between 2000 and 2004, exhaust CO_2e emissions from HGVs related to CH_4 and N_2O decreased (Figure 3.7), thanks to a combination of the energy efficiency effect, which was reinforced by reductions in the emission intensity of the fuels. These factors outweighed the growth of road freight transport. After 2004, the emission reductions became smaller, and emissions started to increase. This was partly because of the growth in road freight transport, but mainly due to the higher emission intensity of the fuels used by HGVs since 2009.

The main factors explaining the past and projected trends in the GHG emissions from road transport will be explored further in the next chapters: the evolution of road transport demand and modal shift in Chapter 4, the energy efficiency of the vehicles and the role of the electrification of the vehicle stock in Chapter 5 and the carbon intensity of transport energy in Chapter 6.

Figure 3.7 **Decomposition analysis of the CO_2e emissions from heavy goods vehicles related to CH_4 and N_2O in the EU-27, 2000-2019 — percentage contribution**



Note: CO_2e emissions: percentage change compared to the year 2000.
Driving factors: Percentage contribution of driving factors to percentage change in CO_2e emissions from HGVs, related to the N_2O and CH_4 emissions.

Source: EEA compilation.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4
Transport activity and modal shares

Key messages

- **Land-based passenger transport increased by 16.6% between 2000 and 2019. This is a key factor in driving emissions upwards during this period.**
- **Inland freight transport activity (i.e. freight by road, rail, inland waterways and oil pipelines) increased more than passenger transport, by 22% between 2000 and 2019. Freight volumes are closely related to the economic situation and are an important factor in greenhouse gas emission trends.**
- **The climate impacts of a passenger-kilometre travelled by car are currently substantially higher than those of both public transport and active travel modes (walking and cycling). Similarly, the climate impacts of a tonne-kilometre transported by road currently exceed those of rail and inland navigation. The modal share of cars in land-based passenger transport and the modal share of trucks in inland freight transport has grown, thus increasing the impacts of the transport sector on climate. Importantly, the impact is dependent on the occupancy rate and the load factor.**

4.1 Introduction

In the decomposition analysis in Chapter 3, transport volumes were the dominant factor driving past trends in road transport greenhouse gas (GHG) emissions. This chapter further explores the developments in transport activity, for both passenger and freight transport. It also looks at the modal shares and compares the different transport modes with respect to their average GHG emissions.

4.2 Policy framework

The Sustainable and Smart Mobility Strategy of the European Commission (EC, 2020d) indicates that in order to reach the climate targets '**all policy levers must be pulled**: (1) measures to significantly reduce the current dependence on fossil fuels (by replacing existing fleets with low and zero-emission vehicles and boosting the use of renewable and low-carbon fuels); (2) decisive action to shift more activity towards more sustainable transport modes (notably increasing the number of passengers travelling by rail and commuting by public transport and active modes, as well as shifting a substantial amount of freight onto rail, inland waterways, and short sea shipping); and (3) internalisation of external costs (by implementing the 'polluter pays' and 'user pays' principles, in particular through carbon pricing and infrastructure charging mechanisms).'

The first policy lever is discussed in Chapters 5 (vehicles) and 6 (fuels) of this report. Concerning the second policy lever, modal shift, the Sustainable and Smart Mobility Strategy contains the following targets:

- doubling of high-speed rail traffic by 2030 and tripling by 2050 (compared with 2015);
- doubling of rail freight traffic by 2050 (compared with 2015);
- increase in transport by inland waterways and short sea shipping of 25% by 2030 and of 50% by 2050 (compared with 2015).

Concerning the internalisation of external costs, the Strategy sets two milestones:

- Rail and waterborne-based intermodal transport will be able to compete on an equal footing with road-only transport in the EU by 2030 (in terms of the share of external costs internalised).
- All external costs of transport within the EU will be covered by the transport users by 2050 at the latest.

To optimise transport demand and to promote a modal shift towards sustainable modes, a broad set of policies is used, at EU level, as well as at national, regional and local levels. Table 4.1 gives examples ([4]) of 'avoid' and 'shift' strategies at EU level.

Table 4.1 Examples of 'avoid' and 'shift' strategies at EU level

Avoid	Shift	Selection of approaches	Examples
		Confronting all modes with their external costs	• Eurovignette Directive 1999/62/EC (and proposed revision) • EU Emissions Trading System (existing scheme via energy costs of road and electric vehicles; proposed scheme has separate systems for transport and buildings) • Energy Taxation Directive (and proposed revision)
		Financial support to sustainable modes via dedicated programmes	• Trans-European Transport Network Regulation supported by Connecting Europe Facility funding • European structural and investment funds • Loans and guarantees from the European Investment Bank • Research and innovation programmes
		Removing administrative and technical barriers	• Successive railway packages • European Rail Traffic Management System (ERTMS) European deployment plan • Transport policy frameworks for inland waterways and short sea shipping
		Supporting digital solutions	• Legislative and non-legislative digitalisation initiatives in all transport modes • Policies related to the development/enhancement of digital skills and the improvement of connectivity and broadband coverage • Research and innovation programmes
		Combination of approaches targeted at urban mobility	Initiatives and funding programmes to stimulate sustainable urban mobility approaches and innovative solutions. For example: Urban Mobility Package (2013); Urban Agenda for the EU (2016); Urban Mobility Partnership Action Plan (2018); CIVITAS and the European Local Transport Information Service (ELTIS)

Source: EEA compilation based on EC (2020d), EU (no date), Pastori et al. (2018) and EEA (2019d).

Note: Shading indicates if the approaches listed support 'avoid', 'shift' strategies (or both).

([4]) It is a non-exhaustive overview. A more complete overview is given in EC (2020d), EU (forthcoming), Pastori et al. (2018) and EEA (2019d).

For 'avoid' and 'shift' GHG reduction strategies, national and local level policies have a key role. Member States may use a range of policies and measures, to achieve the binding national Effort Sharing legislation targets, as stated in their National Energy and Climate Plans (EC, 2021l). Table 4.2 gives an overview of policies and measures that can be put in place to avoid unnecessary trips, reduce trip length, and promote the use of multimodal solutions and sustainable transport modes. These cover a wide range of approaches, for example economic instruments, the provision of transport infrastructure and the supply of sustainable transport services, various regulatory measures in transport and spatial planning.

Table 4.2 Examples of shift and avoid policy instruments at local, regional and national levels

Approach	Avoid	Shift	Examples	Typical level of government		
				Local	Regional	National
Economic instruments to provide the right price signal reflecting all external costs			Congestion pricing schemes, distance-based charging			
			Fuel taxation and removal of tax exemptions			
			Car taxation			
			Parking prices			
			Tax treatment of company cars			
			Tax treatment of commuting costs			
			Car scrapping fees			
			Public transport pricing			
Transport infrastructure and supply of sustainable transport services			Public transit services: improving the coverage, frequency, comfort, information provision and payment systems			
			Reallocating road space			
			Traffic management and control			
			Infrastructure for multimodal freight transport			
			Providing sharing platforms for bikes, e-bikes, cargo-bikes, etc.			
			Improving the quality and coverage of infrastructure for walking, cycling and light electric vehicles, such as safe bike lanes, pavements, priority pedestrian crossings			
Spatial planning			Planning to increase urban densities, to foster the mixed use of land, to improve connectivity and accessibility			
Regulatory measures in transport			Environmental zones, car bans, pedestrian zones, other access regulations			
			Speed limits and other traffic rules			
			Parking regulations			
Other policy measures			Multimodal transport information, management and payment			
			Marketing and rewarding			
			Awareness campaigns			
			Legislation on teleworking			
			Site-based travel plans			

Source: Based on Vanherle et al. (2021), International Transport Forum (2021) and Bartle et al. (2016).

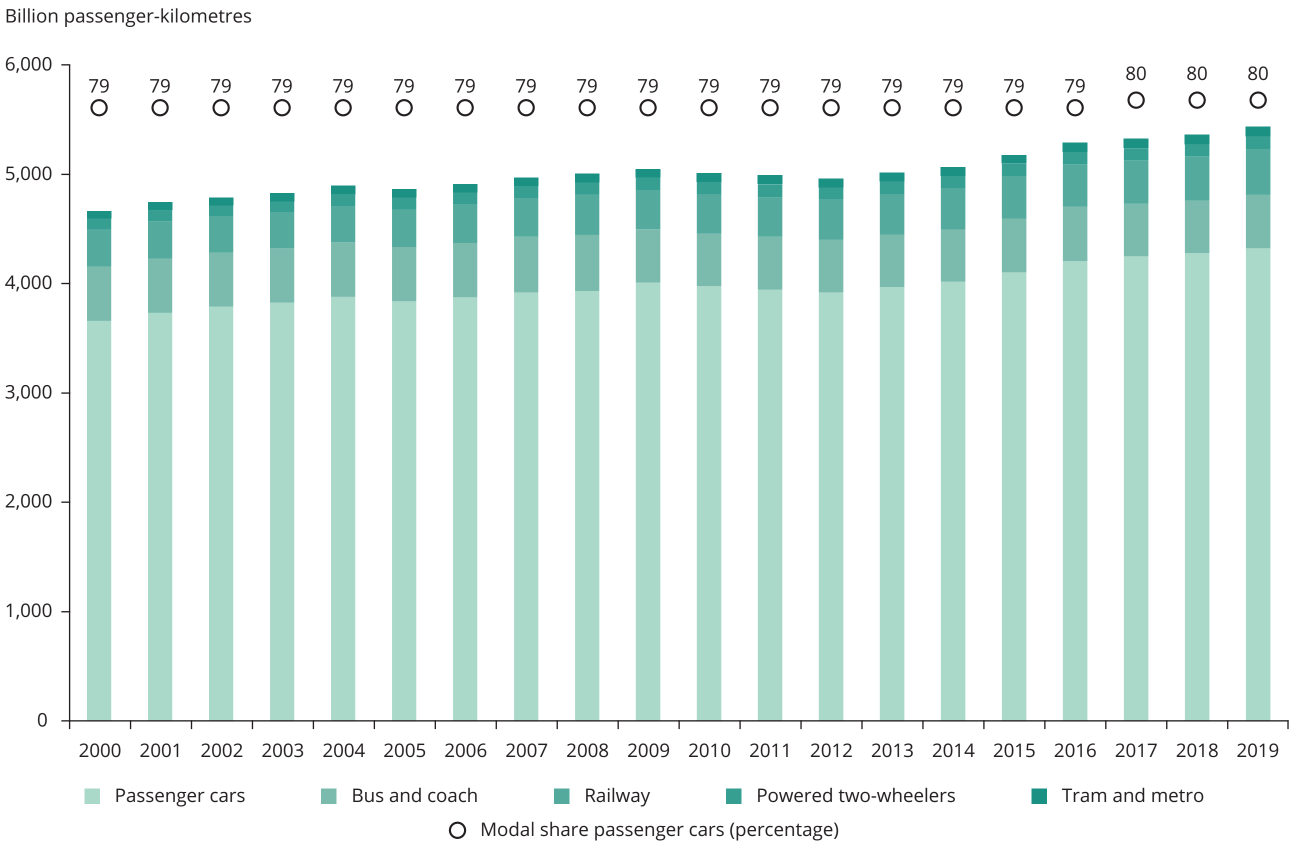
A wider policy context is essential to ensure these transport measures are effective and are not undermined. In urban and metropolitan areas, the Sustainable Urban Mobility Plans contribute to this principle (EC, 2021r). An important related policy domain is **land use policy**. For example, the International Transport Forum (ITF, 2021) advises that the street space and urban land allocated to cars should be reviewed. A well-planned reduction in road capacity for cars can lead to 'disappearing traffic', instead of adding to congestion. Developing compact urban areas and mixed-use neighbourhoods can contribute to reducing demand for private vehicle use by shortening the distances required to access amenities. In addition to this, **building policy** (e.g. abolishing the requirements for minimum parking, which tend to increase car dependency), as well as policies that stimulate the development and uptake of **digitalisation** and **fiscal policy** (e.g. related to the fiscal treatment of company cars) can contribute to sustainable road transport (International Transport Forum, 2021).

4.3 Road transport demand and modal shift

4.3.1 Passenger transport trends

In 2019, more than 5.4 trillion passenger-kilometres were travelled in the 27 Member States of the EU (EU-27) by road and rail (Figure 4.1). This number represents an increase of 16.6% compared with 2000 (EC, 2020e). Car passenger transport is the dominant mode. Moreover, its share increased from 78.5% to 79.6% between 2000 and 2019.

Figure 4.1 Passenger transport by road/rail modes in billion passenger-kilometres and car share in the EU-27, 2000-2019



Source: EC (2021f).

Important **general determinants** of passenger transport activity and modal choice are demographic trends (size and composition of the population), economic development, land use patterns and other general trends such as digitalisation, and changes in consumer preferences or habits (EEA, 2016). Transport activity is the result of the interplay between these general determinants and the **characteristics of the transport system** (in terms of capacity, coverage, user costs, speed, etc.). **Policies** at EU level and a national, regional and local levels influence these general determinants as well as the transport system.

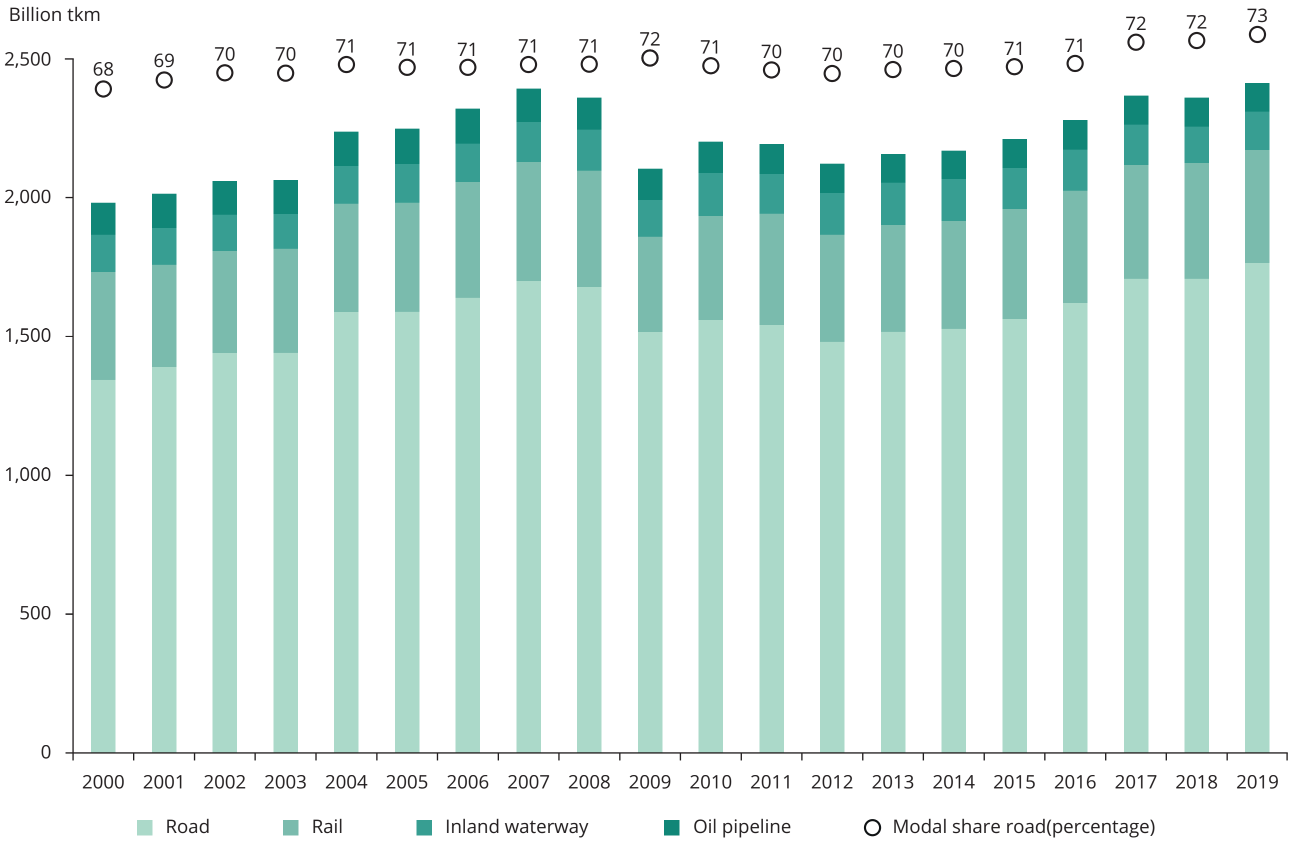
For future years, with existing policies, the *EU Reference Scenario 2020* (EC, 2021e) projects a rebound in passenger transport demand after the COVID-19 pandemic and a reduction in the share of car transport. The three core policy scenarios that are used across the impact assessments supporting the Fit for 55 package indicate that, with varying combinations of transport policy measures and carbon pricing, the shares of the more sustainable transport modes can be increased further.

The way in which the transport system is organised might **change drastically in the future**, for instance via the increased availability of shared transport services or, even more fundamentally, when vehicle automation of a high degree becomes a reality. In that case, the impacts on the level of transport demand could be substantial.

4.3.2 Freight transport trends

The total demand for inland freight transport (i.e. by road, rail, inland waterways and oil pipelines) increased by 22% between 2000 and 2019, although it fluctuated over this time (Figure 4.2). In 2019, 2,411 billion tonne-kilometre were transported by these modes. The share of road transport in this demand grew from 68% in 2000 to 73% in 2019.

Figure 4.2 Inland freight transport by mode in billion tonne-kilometres and road transport share in the EU-27, 2000-2019



Note: tkm: tonne-kilometre.

Source: EC (2021f).

Important **general determinants** of freight transport demand are economic growth and the development of international trade. For example, the impacts of the financial/economic crisis of 2008 are clearly visible in the freight transport volumes (Figure 4.2). Freight transport choices form part of a broader **logistical system**. The set-up of this broader system and the transport choices within it depends on various factors: e.g., the costs and other attributes of the different components, including transport costs, warehousing costs, and reliability considerations. These factors can in turn be influenced by **policies**.

The *EU Reference Scenario 2020* (EC, 2021e) projects that, with existing policies, there will be an increase in the modal share of rail at the expense of other modes. The three core policy scenarios that are used as the basis for the impact assessments of the Fit for 55 package project a further increase in the share of the more sustainable modes, thanks to varying combinations of transport policies and carbon pricing.

The COVID-19 pandemic has given rise to concerns about the functioning of global value chains. This has led to an increased interest in bringing production activities closer to where the goods are consumed. Analysis of the economic and political pros and cons of such developments is ongoing, e.g. Raza et al. (2021). The necessity for a transition to a more circular economy also fuels interest in local production-consumption chains, shorter supply chains, reuse, and digital manufacturing. If such changes take place at a large scale, they could have fundamental implications for freight transport volumes (ITF, 2019).

4.3.3 The potential of a modal shift to reduce greenhouse gas emissions

One of the means to reduce GHG emissions from transport is to **shift to the least GHG-emitting transport modes** and to non-motorised modes such as cycling and walking. Figure 4.3 and Figure 4.4 compare the well-to-wheel (WTW) GHG emissions of different motorised passenger and freight transport modes. Passenger cars have among the highest WTW GHG emissions per passenger-kilometre, together with aviation. Thus, shifting to other modes can help to reduce GHG emissions from passenger transport. For freight transport, the differences between the modes are much larger: carrying cargo by road (using heavy goods vehicles) emits significantly less GHG than air cargo. However, it emits significantly more than transporting goods by either rail or ship.

For both passenger and freight transport the GHG savings that can be obtained by a modal shift depend on the occupancy rate/load factor of the vehicles, as well as the vehicle technologies that are being compared. The comparison below is based on technologies that were used in the period considered, and on average occupancy rates and load factors. The occupancy rates of the passenger modes can vary widely as a function of the time of day or the route taken, and for freight transport also of the load factor.

An analysis of WTW emissions provides only part of the picture. In a life cycle analysis (LCA) all sources of emissions in the product life cycle are considered: those associated with the production, maintenance and disposal of vehicles, and those caused by the construction, maintenance and operation of the transport infrastructure. This broader view can help ensure that reducing one GHG source does not create another problem elsewhere.

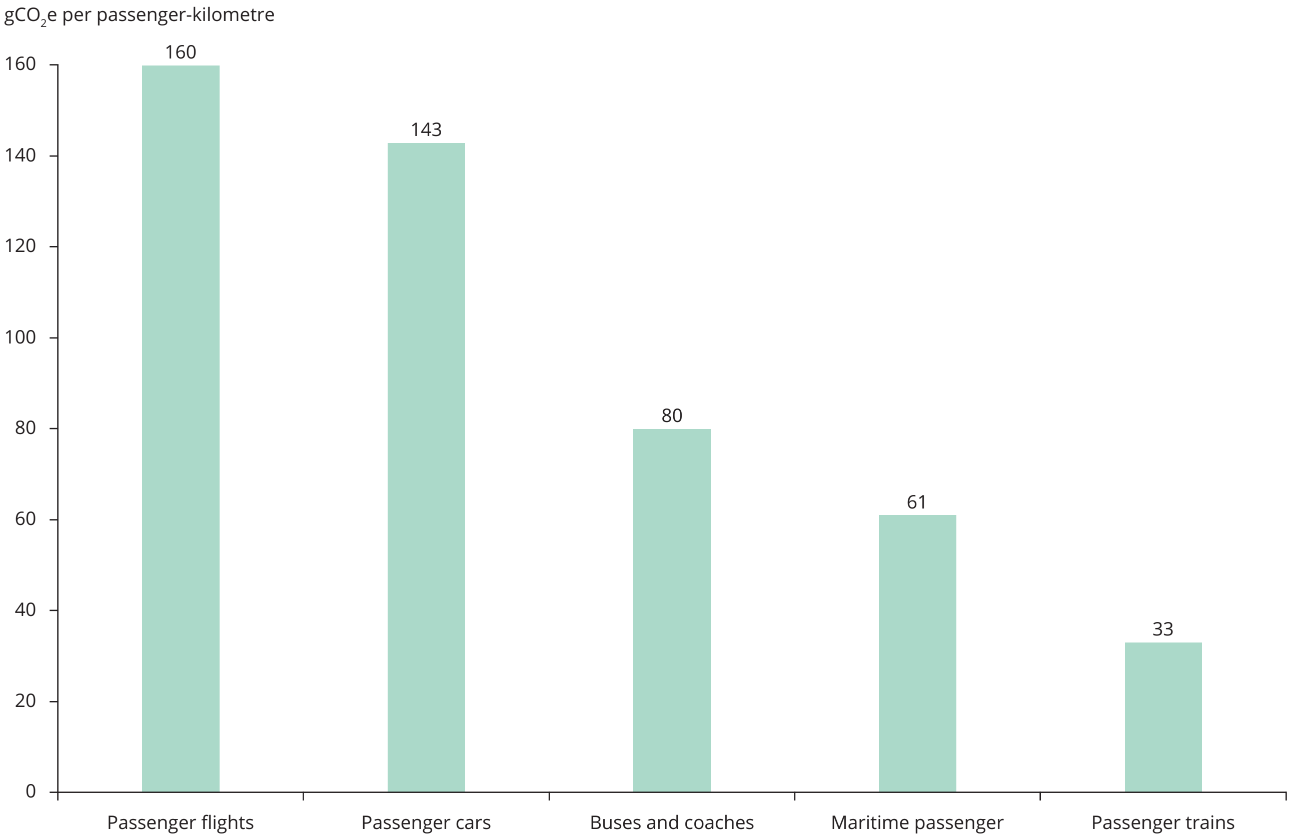
An LCA for regional and long-distance passenger transport modes in Germany (Allekotte et al., 2020) showed that the ranking between modes does not change by taking the LCA perspective rather than the WTW perspective. The infrastructure-and vehicle-related climate impacts per passenger-kilometre are the highest for passenger cars. For bicycles, the vehicle-related impacts are the most important impact category, but their climate impact remains small. For the rail modes, the climate impacts related to the infrastructure are higher than those related to the vehicles, while the opposite is the case for the road modes and aviation. The CO_2 embedded in the rail infrastructure construction will be higher for railway lines with a lot of tunnels and bridges than for others, and will therefore be country specific (IEA, 2019b).

Regarding freight transport, the life cycle climate impact per tonne-kilometre is the highest for aviation, followed by road freight transport. The overall impact is the smallest for inland waterways and rail transport. WTW emissions constitute the bulk of the impact; thus, conducting a full LCA does not change the ranking between modes obtained with the WTW analysis. Rail has the highest relative impact of emissions related to infrastructure.

GHG emissions are an important element in the sustainability analysis of the different transport modes. Transport has other impacts, both on the environment and on human health: air pollution, noise, accidents, habitat damage. When these broader environment- and accident-related externality costs of the main transport modes are also considered, cars have a higher additional impact than bus and rail, per passenger-kilometre. For freight transport, heavy goods vehicles have a higher overall impact than rail and inland waterways (EC, 2019b).

As well as the motorised modes of transport, non-motorised modes, such as cycling and walking, can play a role. These active travel modes offer the potential to significantly reduce GHG emissions, particularly in urban areas (Brand et al., 2021). During the COVID-19 pandemic, many cities took initiatives to improve the conditions for walking and cycling, which may form the basis of more permanent strategies (Nikitas et al., 2021).

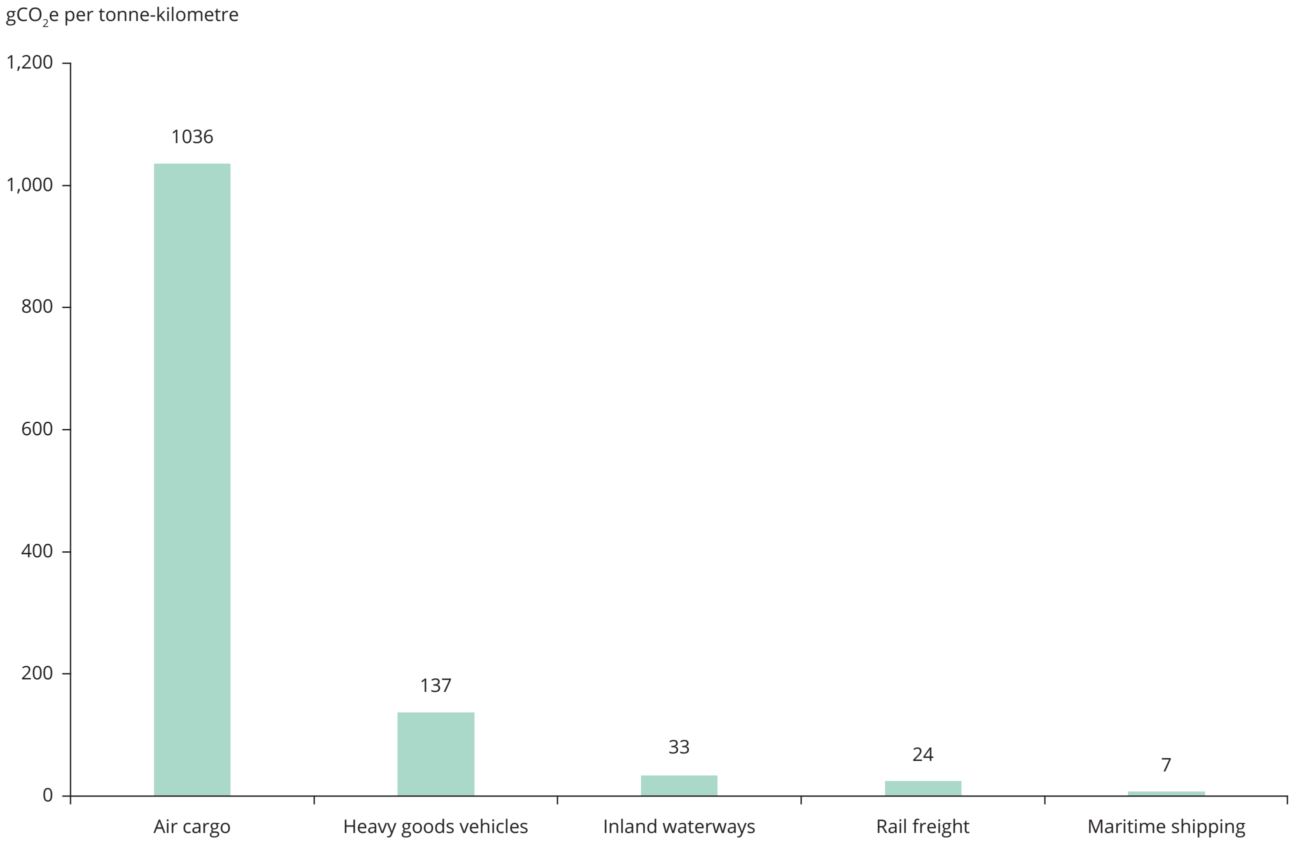
Figure 4.3 Average GHG emissions (gCO_2e per passenger-km), well-to-wheel, for passenger transport in the EU-27, 2018



Note: Implied car occupancy rate: 1.6.

Source: EEA (2021h).

Figure 4.4 Average GHG emissions (gCO_2e per tonne-km), well-to-wheel, for freight transport in the EU-27, 2018



Source: EEA (2021h).

5 The CO_2 performance of cars, vans and heavy goods vehicles in the EU

Key messages

- Since 2009, the carbon dioxide emission performance standards for new cars and vans have gradually been tightened in the EU. For new trucks, the first standards were adopted in 2019. The approach taken in the regulations enables manufacturers to choose the most efficient way to comply. The impact of the standards is visible in the trends in the carbon dioxide emission performance of new cars and vans sold in the EU, especially at key target milestone years.
- Sales of electric vehicles (battery electric vehicles and plug-in hybrid electric vehicles) have surged since 2017, tripling in 2020 when new targets started to apply. The number of new electric vehicles sold differs significantly across EU Member States. Up until now, the highest sales volumes had been recorded in countries with a relatively high gross domestic product per capita. Among Member States with similar income levels, the differences in electric vehicle uptake are partly explained by variation in national and local policy measures.
- The carbon dioxide efficiency of the entire vehicle stock has also improved, for both cars and heavy goods vehicles. For the latter, this is partly explained by improvements in fuel efficiency and in operational efficiency.
- To reach the 2030 and 2050 climate targets, an increase in the share of electric vehicles in the vehicle stock will be necessary. Bottlenecks that could hamper future electrification are the provision of a charging infrastructure, the need to accommodate the electricity demand of electric vehicles and the supply of raw materials for batteries. Emerging innovative solutions, as well as existing and proposed legislation, could help to deal with these bottlenecks.

5.1 Introduction

The decomposition analysis showed that improved vehicle energy efficiency (energy consumed per kilometre), is one of the main factors limiting the increase in road transport greenhouse gas (GHG) emissions. Vehicle efficiency improvements can be achieved by developing new vehicle technologies and increasing the uptake of existing technologies, in which policies play an important role. This chapter looks in more detail at EU policy aimed specifically at improving vehicle efficiency, in particular the EU carbon dioxide (CO_2) emission performance standards for new vehicles. It analyses the trends in emission performance of both new vehicles and the vehicle stock, and the underlying determinants.

The decomposition analysis also included the electrification factor (the share of electricity in road transport energy use) to capture the growing share of zero and low emission vehicles (ZLEVs). This has not yet had a substantial impact on emissions but is expected to increase rapidly in the coming years. This chapter therefore also discusses recent developments in the electrification of road vehicles. The scope in this chapter is limited to the exhaust CO_2 emissions of vehicles. The upstream emissions of electricity production are discussed in Chapter 6.

5.2 Policy framework

5.2.1 Vehicle CO_2 standards in the EU

In 1998 the European Commission and the European Automobile Manufacturers' Association (ACEA) signed a **voluntary agreement** in which ACEA committed to achieving an emissions objective of 140 g CO_2/km for new passenger cars by 2008. Voluntary commitments from Japanese and Korean manufacturers included reaching the same target by 2009.

However, in 2008 the average emission rate of new cars was 154 g CO_2/km, significantly above the target (EEA, 2010). The lack of progress motivated the introduction of a regulation (EU, 2009b), which aimed to control the average **emissions of new cars** registered in the EU by setting **mandatory** EU fleet-wide targets for new cars, which were gradually tightened: from 130 g CO_2/km in 2015 (with a phase-in from 2012) to **95 g CO_2/km in 2021** (with a phase-in from 2020). In 2011, a similar regulation was adopted for new **light commercial vehicles (vans)** (EU, 2011), setting an EU fleet-wide target for the average CO_2 emissions of new vans at 175 g CO_2/km in 2017 (with a phase-in from 2014), reducing to 147 g CO_2/km in 2020 (see Figure 5.1).

In January 2020, these two regulations were replaced by **a new standards regulation** (EU, 2019c), which covers both **new passenger cars and new light commercial vehicles** (Figure 5.1). This regulation maintains the 2020 targets set out in the previous regulations and introduces new EU fleet-wide targets for 2025 and 2030, which are defined as a percentage reduction of the 2021 starting point:

- for new passenger cars — a 15% reduction from 2025 onwards and a 37.5% reduction from 2030 onwards;
- for new light commercial vehicles — a 15% reduction from 2025 onwards and a 31% reduction from 2030 onwards.

The binding CO_2 targets set in the regulation for new cars and vans apply for the **EU fleet-wide average** emissions of each manufacturer's newly registered vehicles, not for each individual new vehicle. This regulation also includes sales benchmarks for ZLEVs. From 2025 onwards, the specific CO_2 emission target of a manufacturer will be relaxed if its share of ZLEVs registered exceeds the benchmarks.

For **heavy-duty vehicles** (HDVs) a regulation setting the first EU CO_2 emission standards (EU, 2019d) was adopted in 2019 (Figure 5.1). As a first step, it covers large trucks, which account for 65-70% of all CO_2 emissions from HDVs. The regulation sets EU fleet-wide targets for reducing the average CO_2 emissions from such new trucks:

- from 2025, a reduction of 15% compared with the reference period (1 July 2019 to 30 June 2020);
- from 2030 onwards, a 30% reduction compared with the same reference period.

The European Commission will assess extending the scope to other vehicle types such as smaller trucks, buses, coaches and trailers as part of its review envisaged for 2022.

The regulation for **HDVs** sets targets following the same principles as the legislation for cars and vans. The targets concern the fleet-wide average of manufacturers' new trucks. The regulation also includes an incentive mechanism for ZLEVs (EC, 2021p).

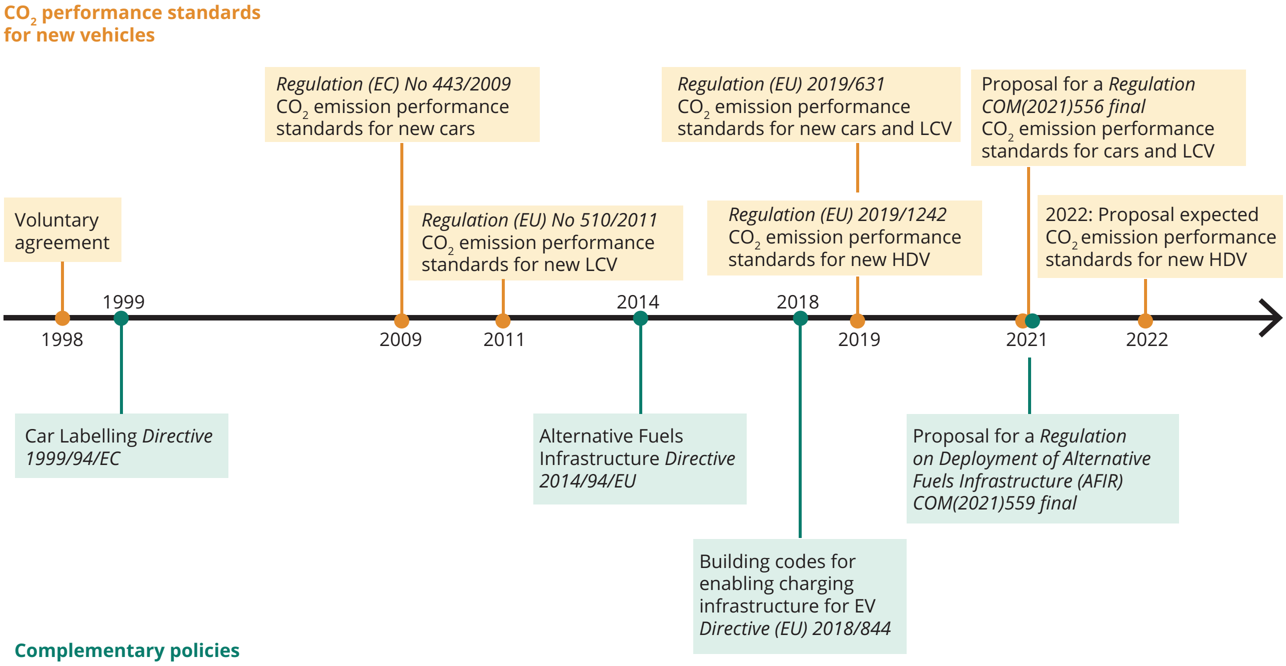
To monitor the performance of new vehicles, Member States collect data each year on newly registered passenger cars and vans, including their CO_2 emissions, and submit them to the European Commission. Data on new HDVs are collected and reported by both vehicle manufacturers and Member States.

There are **no CO_2 standards for light vehicles such a mopeds, motorbikes and quad bikes.**

In the Fit for 55 package, the European Commission proposes a **revision of the CO_2 standards for cars and vans,** with a view to ensuring a clear pathway towards zero emission mobility. The proposal encompasses a revised 2030 EU fleet-wide CO_2 target of -55% for new cars and -50% for new vans. From 2035 onwards, the proposed target for both new cars and vans is 0 g/km (EC, 2021n).

Compared with other regions in the world, the targets set in the EU are already the most ambitious. The EU, Japan and South Korea have set mandatory new car CO_2 emission targets up to the year 2030 (Table 5.1), with the EU having the most ambitious targets in place for that year (ICCT, 2021). All manufacturers selling cars in the EU must comply with the EU standard. This creates a potential spill-over effect to the rest of the world. As the research and development (R&D) undertaken for the EU market lowers the costs of abatement technologies, this may also have beneficial effects for those costs in other world regions (Barla and Proost, 2012).

Figure 5.1 Timeline showing the introduction of CO_2 standards and complementary regulation



Note: CO_2 performance standards for new vehicles (orange boxes) and the complementary policies (green boxes). HDV, heavy-duty vehicle, LCV, light commercial vehicle.

Source: EEA compilation.

Table 5.1 Comparison of global CO_2 emission targets for new passenger cars, normalised to the New European Driving Cycle

World region	Target year	Target CO_2 value (g/km)
EU	2030	59
Japan	2030	74
South Korea	2030	65
United States	2026	108
Canada	2025	99
China	2025	93
Brazil	2022	128
India	2022	113
Saudi Arabia	2020	142
Mexico	2018	145

Note: Regulatory targets are converted to values achieved under the New European DrivingCycle test cycle to make them comparable with those of the EU.

Source: Based on ICCT (2021).

5.2.2 Implementation mechanisms for the CO_2 emission standards

The system envisaged in the CO_2 emission standard regulations provides flexibility (see Box 5.1) for manufacturers to decide how to comply and thus **enhance the cost-efficiency** of achieving the standards (Littlejohn and Proost, 2019; KU Leuven, 2020). The manufacturers can decide how much to invest in R&D to improve internal combustion engine vehicle efficiency and/or to invest in innovation to make electric vehicles cheaper and/or better performing than at present.

An analysis of manufacturers' strategies shows that the actual reductions in CO_2 emissions that took place in the EU car market between 1998 and 2011 were achieved mainly by adopting technologies that improve the fuel efficiency of the vehicle fleet (Reynaert, 2021). During that period, other strategies available to manufacturers, such as a shift in the sales mix towards vehicles with CO_2 emissions below the target or an increase in the share of smaller and more fuel-efficient vehicles, were less important.

CO_2 emissions subject to targets are determined in laboratory testing (see Box 5.2). In the past, it has been observed that manufacturers have achieved their targets partly by optimising their vehicle emissions under the test cycle, rather than aiming to reduce on-road emissions. That is why a new testing procedure, the World Harmonised Light Vehicle Test Procedure (WLTP), has been developed (Lin and Linn, 2019). For cars and vans, the officially reported CO_2 emissions up to 2020 are based on measurements using the New European Driving Cycle (**NEDC**), but since 2018 countries have also started to report CO_2 emissions based on the **WLTP**, which better represents real-world driving conditions. From 2021 onwards, compliance assessment will be fully based on the WLTP data.

To prevent an increasing gap between tested and real-world emissions, from 2022 the European Commission will regularly collect data on real-world CO_2 emissions and energy consumption, using on-board fuel consumption monitoring devices. A new implementing regulation sets out the rules for data gathering via manufacturers and national authorities (EU, 2021b).

Box 5.1 Implementation modalities for manufacturers — CO_2 standards for cars and vans

- Several manufacturers may form a pool and will then be considered a single manufacturer with one common target, calculated on the basis of the whole fleet of the pool registered that year.
- For each manufacturer or pool, the specific CO_2 emission target for a given year depends on the average mass of its fleet of vehicles newly registered in that year. For manufacturers/pools with a higher average mass, the target will be higher (i.e. more lenient) and for those with a lower average mass, the target will be more stringent.
- Manufacturers can claim eco-innovation credits for using certain innovative technologies that produce CO_2 emission savings on the road, but not during the test (such as light-emitting diode (LED) headlamps which are switched off during the test procedure).
- The regulation provides for the allocation of supercredits for new passenger cars with CO_2 emissions lower than 50 g CO_2/km. Until 2022, these vehicles are given a greater weight when calculating the average specific emissions of a manufacturer. However, over the period 2020-2022, the use of super-credits is subject to a cap of 7.5 g CO_2/km for each manufacturer. Most manufacturers had already exhausted these credits in 2020. For vans, no supercredit scheme has existed since 2018.
- Manufacturers selling fewer than 10 000 cars/year or fewer than 22 000 vans/year can apply for a derogation and be granted a specific target consistent with their economic and technological potential.

Box 5.2 Laboratory test emissions and real-world emissions

The **New European Driving Cycle (NEDC)** is a test cycle that has been used since the 1990s to determine the fuel consumption and carbon dioxide (CO_2) emissions of new cars in Europe. It defines the laboratory testing conditions, such as the speed trace, tyre pressure and ambient temperature, to ensure a high level of reproducibility of the test results. However, research demonstrated that the real-world fuel consumption and CO_2 emissions are significantly higher than the NEDC levels, and that this **gap increased over time**, from 8% in 2001 to 39% by 2017. This means that the average real-world CO_2 emissions in 2017 were 39% higher than the official NEDC value (Dornoff et al., 2020).

The EU recognised this problem and in 2017 introduced the **World Harmonised Light Vehicle Test Procedure (WLTP)** driving cycle, as developed by the United Nations. The WLTP driving cycle is more representative of real-world conditions because it includes a greater range of driving situations, more dynamic and representative accelerations and decelerations, more realistic driving behaviour, more realistic vehicle test mass, and stricter test conditions that better represent real-world driving conditions (EEA, 2020b). Based on preliminary data for 2020 the International Council on Clean Transportation found that WLTP-measured CO_2 emissions are on average 21% higher than their respective NEDC values (Tietge et al., 2021). WLTP-tested and real-world emission levels reported by drivers show that there is still a gap (Dornoff et al., 2020), although it is smaller than with the NEDC test cycle.

For **plug-in hybrid vehicles** (PHEVs) the divergence between real-world and officially tested emissions largely depends on the share of kilometres driven on electricity. It has been found that average PHEV fuel consumption and CO_2 emissions are **two to four times higher in real-world driving** than in the NEDC test (Dornoff et al., 2020).

5.2.3 Complementary legislation concerning vehicles and alternative fuel infrastructure

Complementary to the CO_2 emission standards, the **Car Labelling Directive** (EU, 1999) requires Member States to ensure that relevant information on cars' fuel efficiency and CO_2 emissions is provided to consumers.

Electric vehicles require a **charging infrastructure** and not all EU citizens have access to a recharging point at home. More charging stations increase the attractiveness of an electric vehicle (EV), and if there are more EVs, it is more profitable to supply charging stations. The EU is taking initiatives to increase the extent of the charging infrastructure. The **Alternative Fuel Infrastructure Directive (AFID)** (EU, 2014) required Member States to put in place development plans for alternative fuels infrastructures. The optimal number of publicly accessible recharging points depends on location-specific factors such as travel patterns, the number of battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), the number of EV owners with a dedicated private recharging point and with access to recharging points at the workplace. The AFID indicatively mentioned that one public recharging point was needed for every 10 EVs.

A recent European Commission report indicates that there is some progress in the implementation of the AFID (EC, 2021q), but concludes that there is not yet a comprehensive and complete network of alternative fuels infrastructures. An evaluation by the European Court of Auditors published in 2021 found that despite successes (such as promoting a common EU plug standard) important **obstacles** remain: the availability of charging stations varies widely between countries, payment systems are not harmonised with minimum requirements, there is inadequate information for users and the available EU funds are not directed to where they are most needed. It concludes that the EU is still a long way off the 2019 European Green Deal target of 1 million recharging points by 2025 (ECA, 2021). According to the European Alternative Fuels Observatory (EAFO), in 2020 the number of public recharging points was around 224 200 in the EU, of which 11% were fast chargers (≥22 kW) (EAFO, 2021a). However, their geographical distribution is uneven, a problem that is likely to remain and may even increase (EC, 2021g). Moreover, the EAFO data point to an increasing number of EVs per public recharging point over time, as the number of EV registrations has grown more rapidly than the number of public recharging points (EC, 2021q).

New legislative proposals that were released in the Fit for 55 package step up the ambition. A review of the AFID is proposed, shifting the legal tool to a regulation. It adds specific fleet-based targets for charging power for EVs, requires the installation of charging and fuelling points at regular intervals on major roads, mandates targets for the hydrogen as well as liquefied/compressed natural gas infrastructure, and reinforces the governance for progress monitoring (EC, 2021o). The review of the AFID is also relevant for the initiative to revise the regulation on the guidelines for the Trans-European Transport Network (EC, 2021g).

Other policies that can contribute to removing the barriers to EV development are **building codes for installing charging infrastructure.** The 2018 revision of the EU Directive on the energy performance of buildings or EPBD (EU, 2018a) includes measures to ensure that buildings' car parks will be progressively equipped with recharging points for EVs.

The EPBD includes provisions to equip new or renovated buildings with the dedicated infrastructure (power line ducting) suitable for the subsequent installation of recharging points. It also asks Member States to lay down requirements for the installation of a minimum number of recharging points, for all non-residential buildings with more than 20 parking spaces (by 1 January 2025) and to simplify the deployment of recharging points in buildings, e.g. in relation to permitting and approval procedures. The ongoing revision of the EPBD is looking at reinforcing that buildings should be suitable for EVs, including smart charging requirements (EC, 2021c).

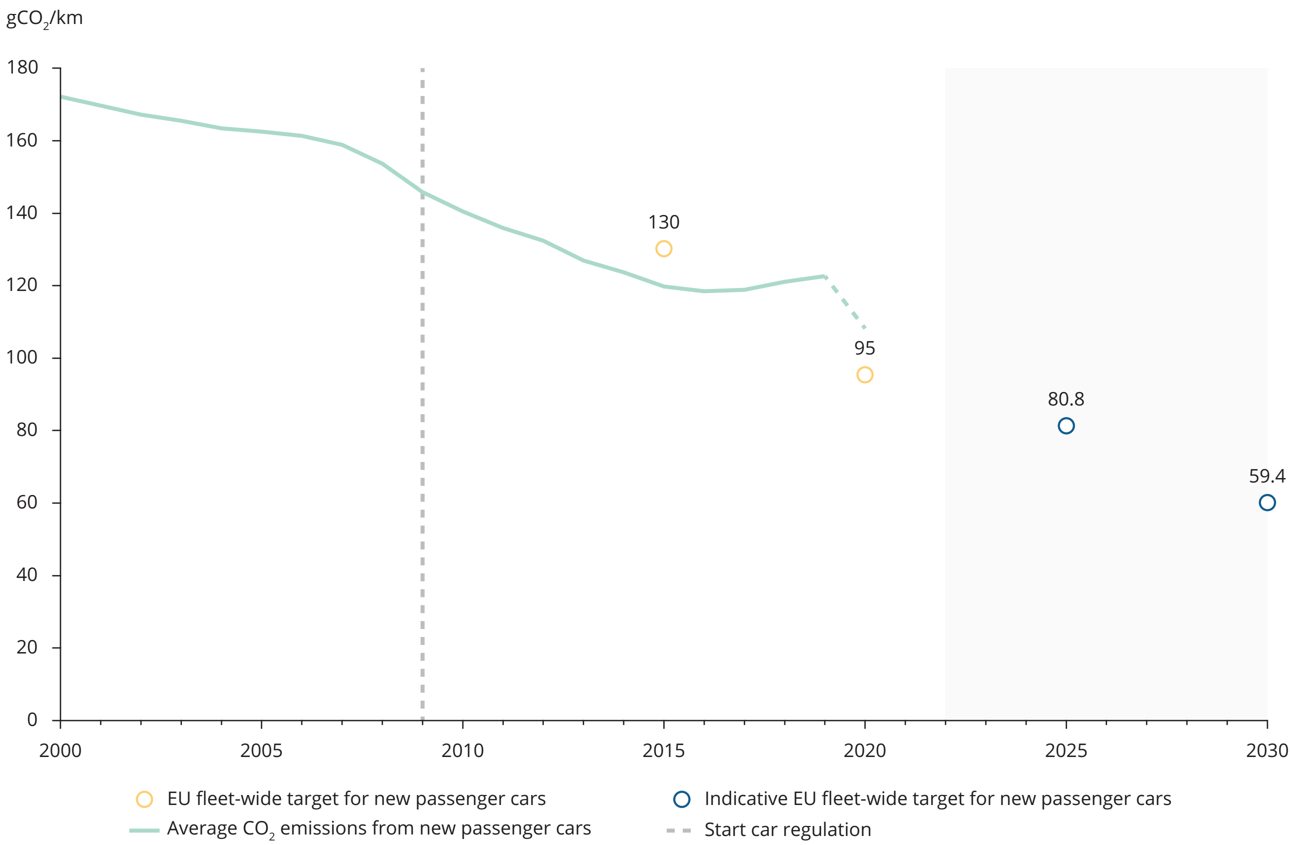
Lastly, public procurement can be a relevant complementary policy. The **Clean Vehicles Directive** (as revised in 2019) promotes clean mobility solutions in public procurement tenders (EU, 2019b). This has the double benefit of demonstrating the technology to the public (leading by example) and allowing the industry to produce and deliver bulk orders to initiate economies of scale. The revised Clean Vehicles Directive aims to accelerate the adoption of electric buses (and other publicly procured vehicles) in EU countries, setting specific targets for 2025 and 2030.

5.3 Trends in the CO_2 performance of new vehicles

The CO_2 emissions from vehicles have been monitored for the longest time for passenger cars, hence most information on trends and manufacturer approaches is available for this segment.

As shown in Figure 5.2, in the early 2000s the CO_2 emissions of new passenger cars fell slowly. In anticipation of the adoption of the 2009 regulation and afterwards, emissions started decreasing more rapidly. However, once the 2015 target had been reached, the average emissions of new cars started increasing again, reaching 122.3 g CO_2/km in 2019. In 2019, almost all car manufacturers achieved their specific emission targets, either individually or as part of a pool or because of derogations (EEA, 2021c). In 2020, the **average emissions of new passenger cars decreased sharply to 107.8 g CO_2/km** (EEA, 2021i).

Figure 5.2 Average CO_2 emissions per kilometre (NEDC) for new passenger cars, 2000-2020



Note: Provisional data for 2020. Coverage: Exhaust emissions; European Union, Iceland, Norway, and the UK.

Source: EEA (2021c, 2021i).

The increase in emissions between 2017 and 2019 was mostly due to the **increase in the share of sport utility vehicles** (SUVs) and other larger and heavier cars. In 2007, SUVs had a market share of 8% of all new passenger cars. This increased to 26% in 2016 and 38% in 2019 (EEA, 2020b, 2021c). In 2019, a newly registered petrol SUV emitted about **13 g CO_2/km more** than the average new non-SUV petrol car. In the period 2017-2019 the trend towards SUVs and other larger and heavier cars more than compensated for the reduction in CO_2 emissions obtained through the efficiency gains in conventional petrol and diesel cars and the modest uptake of electric cars. In 2019 BEVs and PHEVs together represented only 3.5% of new registrations.

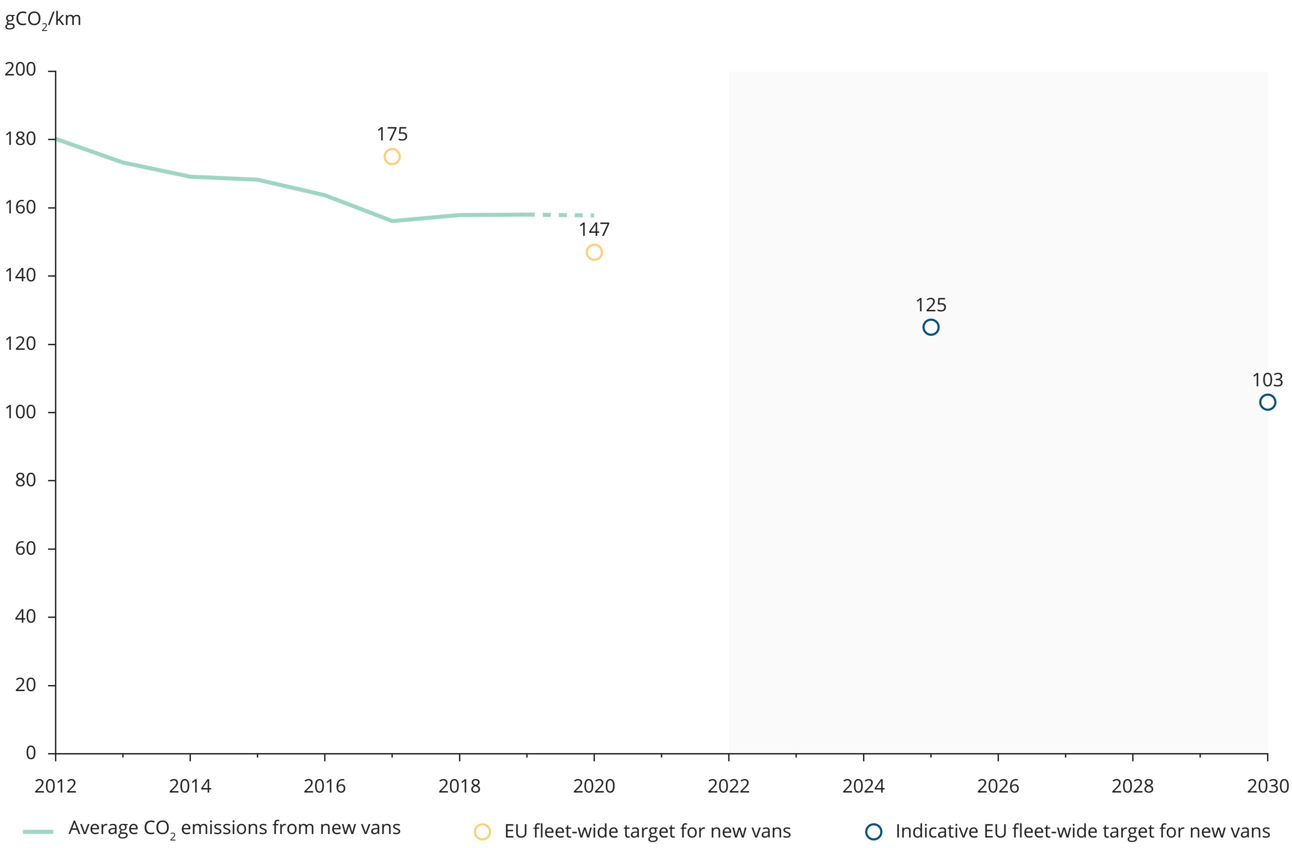
The trend reversal in 2020 can be explained by the surge in the share of electric cars in new car registrations, which tripled in 1 year to reach around 11%, as the new stricter targets were phased in. Moreover, country-specific policies to promote ZLEVs, including those linked to the post-COVID-19 recovery plans, are considered to have had a significant impact.

The trend in the CO_2 emission performance of new vans (Figure 5.3), is similar to that of cars, showing a **decreasing trend after the introduction of the target** to reach the interim target set for 2017. After declining until 2017, the averages increased slightly in 2018-2019 due to an increase in the average mass, engine capacity and size of the vans (EEA, 2021g). Based on provisional data, **the trend reversed in 2020** and the average emissions of new vans decreased to **157.7 g CO_2/km** (EEA, 2021i). In 2020, the share of electric vans in sales of new vans increased to 2.3%, from 1.4% in 2019.

These trends indicate that the CO_2 emission standards regulations contributed to the decrease in the average CO_2 emissions of new cars and vans.

The CO_2 performance of HDVs has been monitored since mid-2019 (EEA, 2021f)buses and trailers registered in their territory. Manufacturers report trucks of specific types that are subject to certification requirements. The reporting periods are annual and run from 1st July to 30 June the following year. One exception was the first reporting which covered 1st January 2019 to 30 June 2020. In addition, the dataset covers the United Kingdom and Norway who reported data in line with the Regulation (EU. The average specific CO_2 emissions of all new HDVs registered in the EU from 2019 to mid-2020 was 52.75 g CO_2/tonne-kilometre (EU, 2021a). This will serve as the baseline for the 2025 and 2030 targets.

Figure 5.3 Average CO_2 emissions per kilometre (NEDC) for new vans in the EU, 2012-2020



Note: Provisional data for 2020. Coverage: Exhaust emissions; European Union, Iceland, Norway,and the UK.

Source: EEA (2021g, 2021i).

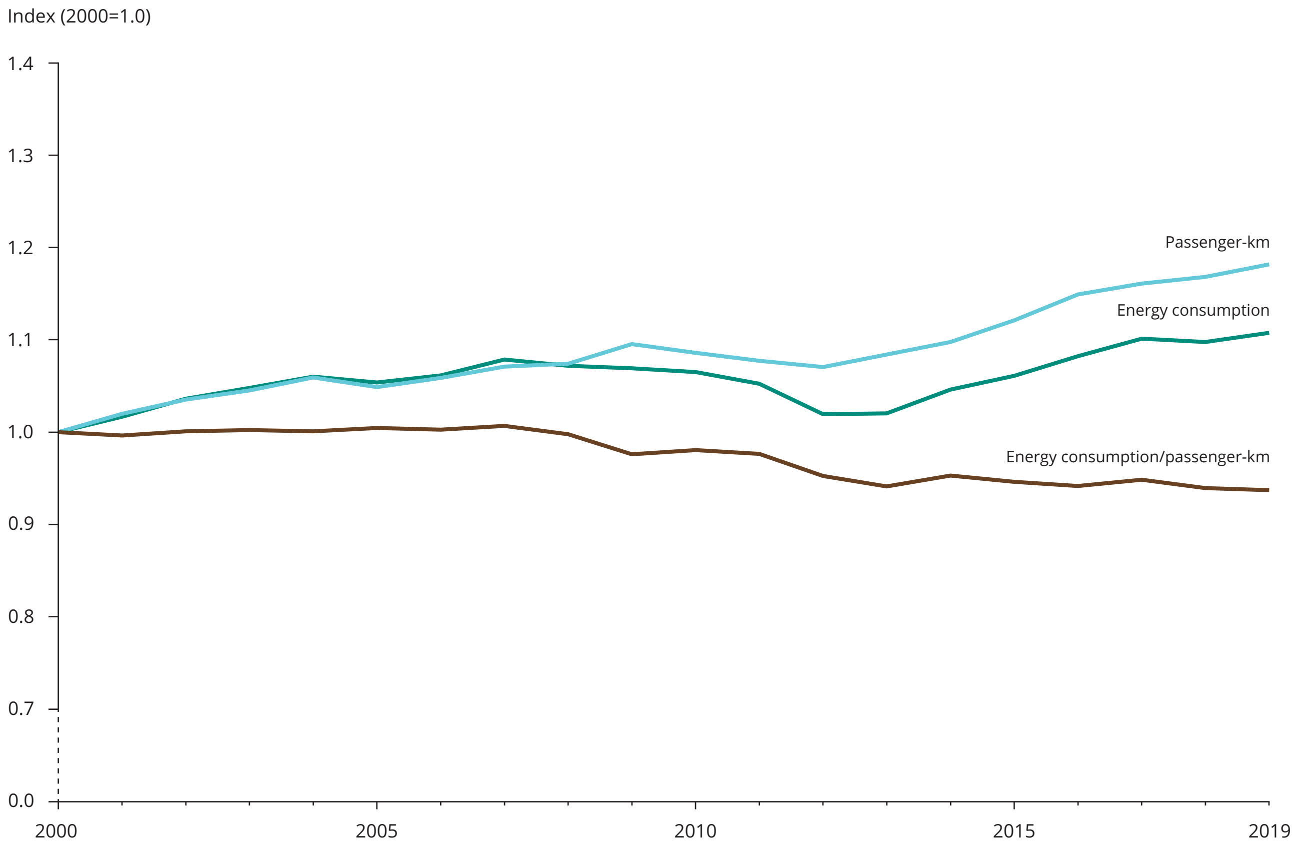
5.4 Trends in the CO_2 emission performance of the vehicle stock

The EU CO_2 emission standards apply to **new vehicles only**. However, the CO_2 emission standards for new cars have an impact on the cars that will be traded on the second-hand market in later years. The **CO_2 emission performance of the vehicle stock** depends on the performance of the individual vehicles comprising the vehicle stock. In each year, the vehicle stock changes as some vehicles are scrapped or exported, and new vehicles and imported second-hand vehicles are added (to replace vehicles or as additional vehicles). Given the gradually improving CO_2 emission performance of new vehicles, the annual renewal and scrappage rates have a strong influence on the performance of the stock.

An indication of the performance of the EU vehicle stock is the evolution of the energy efficiency of the vehicle stock, a factor that was considered in the decomposition analysis presented in Chapter 3. As shown in Figure 5.4, until 2008 the energy consumption of passenger cars grew at approximately the same rate as the passenger-kilometres travelled, and consequently energy efficiency remained almost constant. Since 2008, when the CO_2 emission standards for new cars were introduced, the energy consumption per car passenger-kilometre decreased and in 2019 it was 6.3% lower than in 2000.

Comparing the evolution of energy consumption and the tonne-kilometres transported by road freight ([5]), energy efficiency had also increased in 2019 compared with 2000, with fluctuations over time (Figure 5.5). Energy consumption per tonne-kilometre in 2019 was 15% lower than in 2000.

Figure 5.4 Trend in energy efficiency of passenger car transport in the EU-27, 2000-2019

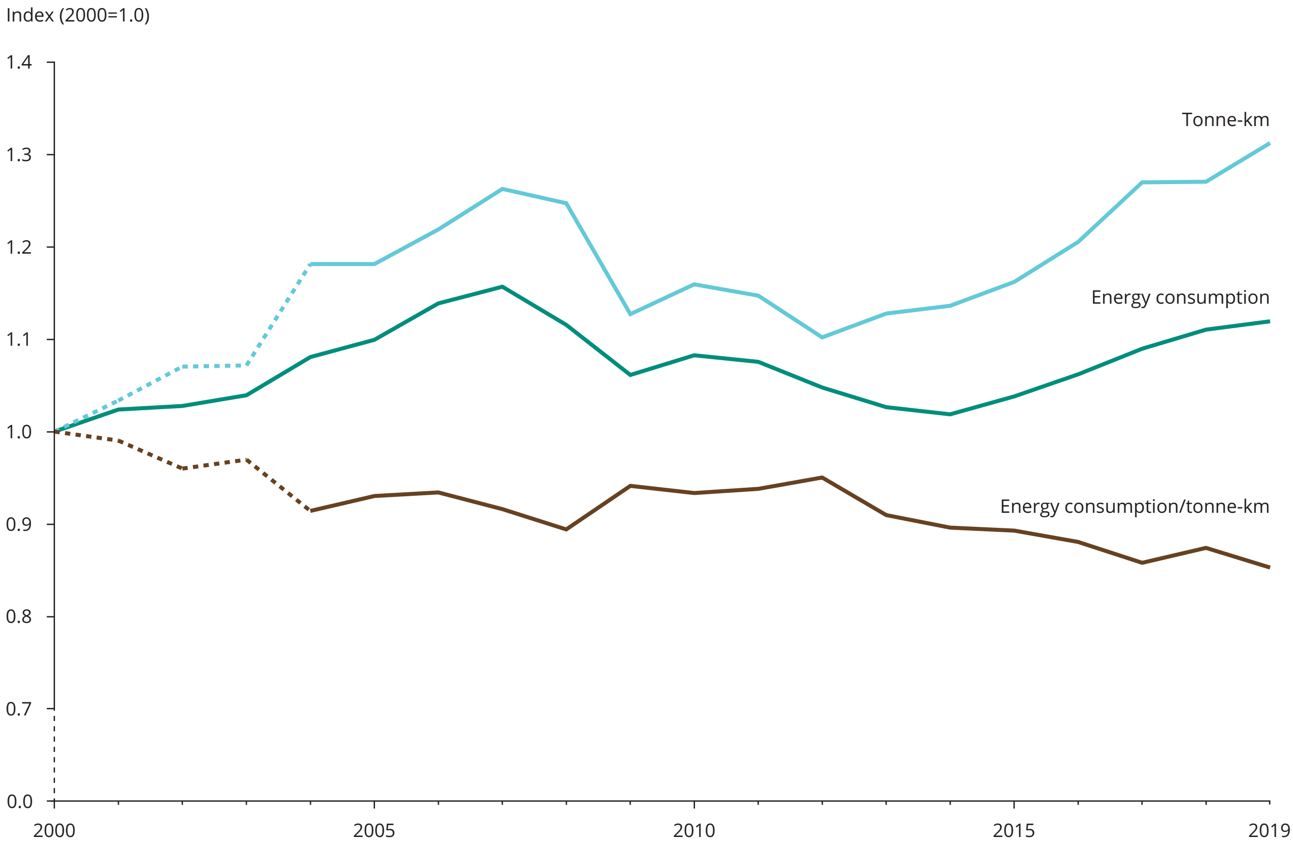


Note: The energy consumption covers fossil fuels, biofuels and electricity.

Source: EEA compilation based on greenhouse gas emissions inventory and energy balances for the EU-27 (EEA, 2021; Eurostat, 2021, EC, 2021f).

([5]) The values for HGVs have more uncertainty than those for passenger cars. The share of HGVs in the energy consumption reported in the GHG emissions inventory for heavy-duty trucks and buses is based on the historical data underpinning the EU Reference Scenario 2020.

Figure 5.5 Trend in energy efficiency of transport by heavy goods vehicles in the EU-27, 2000-2019



Note: Road tonne-kilometre: national and international haulage by vehicles registered in the EU-27 until 2004. From 2005 onwards, it refers to activity undertaken by European drivers within the EU territory.

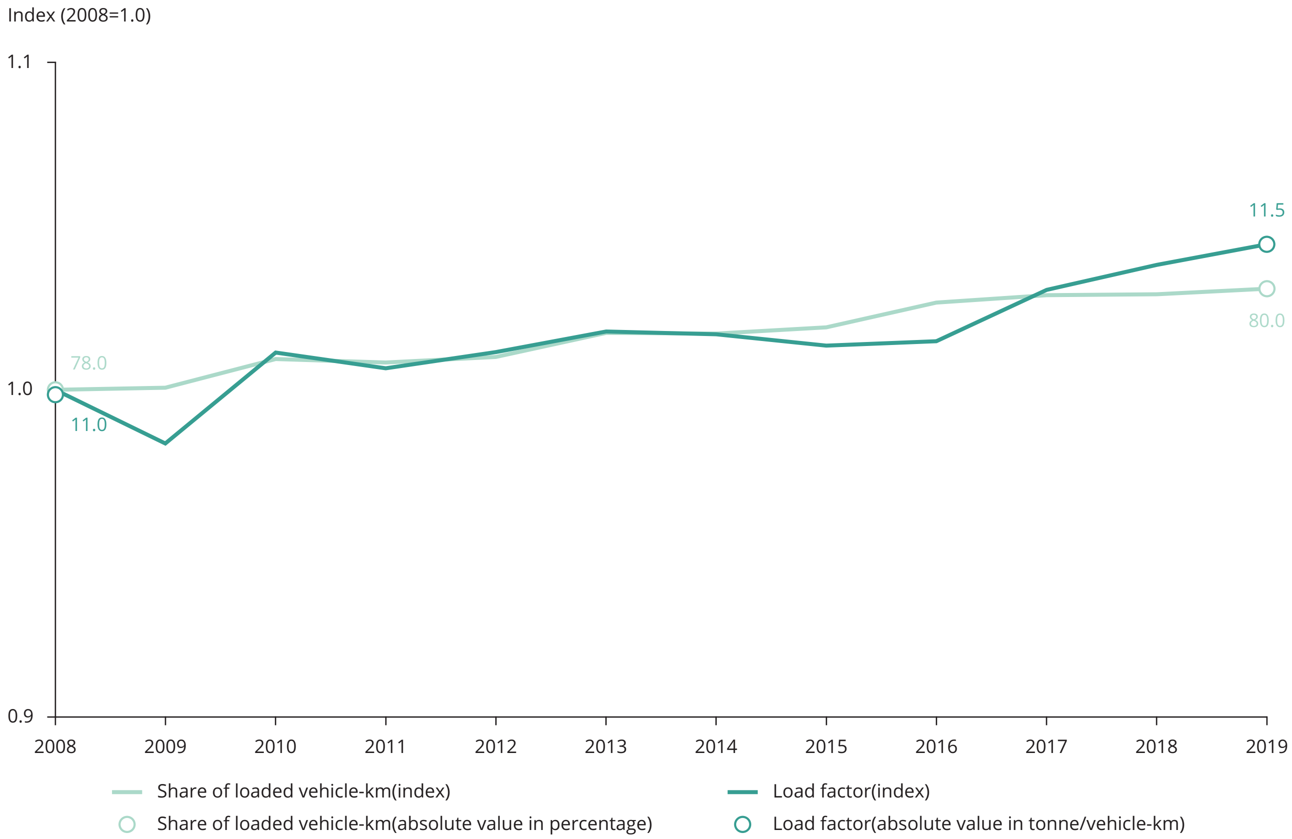
Source: EEA compilation based on greenhouse gas emissions inventory for the EU-27 (EEA and EC DG Climate Action, 2021; EC, 2021e, 2021f).

Improved efficiency of individual vehicles is likely to play a role in this development. International trucks drive large distances, and the fuel cost is a significant part of the total cost. Therefore, firms have a strong incentive to improve fuel efficiency. In addition, some of the reduced fuel consumption per tonne-kilometre can be explained by the improvement in the efficiency of transport by trucks.

Between 2008 and 2019, the average load factor increased from 11 to 11.5 tonne/vehicle-kilometre and the share of loaded kilometres increased from 77.7% to 80. % (Figure 5.6).

For freight transport, it is not yet known what impact the CO_2 emission standards will have.

Figure 5.6 Trend in the load factor in road freight transport and the share of loaded vehicle kilometres in the EU-27, 2008-2019



Note: Data for total road freight transport: national + international transport; load factor calculated as the ratio between tonne-kilometres and vehicle-kilometres.

Source: EEA compilation based on Eurostat, 2021b (indicator road_go_ta_tott).

5.5 The electrification of road transport and its importance for future trends in greenhouse gas emissions

The contribution of road transport electrification to decarbonisation was limited until 2019, but EU ambitions are high. This is reflected in the stronger CO_2 emissions standards for cars and vans that are proposed in the Fit for 55 package. According to the Commission proposal, all new cars and vans registered from 2035 would have to have zero emissions. In addition, the proposal for the revised Alternative Fuels Infrastructure Regulation requires Member States to expand charging capacity and to install charging and fuelling points at regular intervals on major roads (EC, 2021n, 2021o).

Box 5.3 Electric vehicle types

Several types of vehicles may be referred to as 'electric vehicles' or Evs:

- Battery electric vehicle (BEV): powered solely by an electric motor, using electricity stored in an on-board battery which has to be charged, typically by plugging the vehicle in to a recharging point connected to the local electricity grid.
- Plug-in hybrid electric vehicle (PHEV): powered by an electric motor and an internal combustion engine designed to work either together or separately. The on-board battery can be charged from the grid, and the combustion engine supports the electric motor when more operating power is required or when the battery's charge is low.
- Fuel cell electric vehicle (FCEV): entirely propelled by electricity, which is generated on board by a fuel cell stack that uses hydrogen, which has to be carried in a tank.

In this context, vehicles that combine an internal combustion engine and an electric motor assisting the conventional engine, but that cannot be charged from the grid, are not regarded as electric vehicles.

FCEVs can provide longer ranges than BEVs and the time it takes to refuel is similar to that of internal combustion engine vehicles. The drawbacks are the high costs, mainly due to the expensive fuel cells, and their lower efficiency than BEVs. Currently, few FCEVs are offered for sale on the EU market and the refuelling infrastructure is less developed than that for electric cars (JRC and DG Mobility and Transport, 2020).

5.5.1 Trends in the sales and the stock of electric vehicles

In the EU, new registrations of electric cars have been increasing steadily in recent years, with an acceleration in 2020, when the share of electric vehicles among new EU registrations tripled compared with 2019 (Figure 5.7).

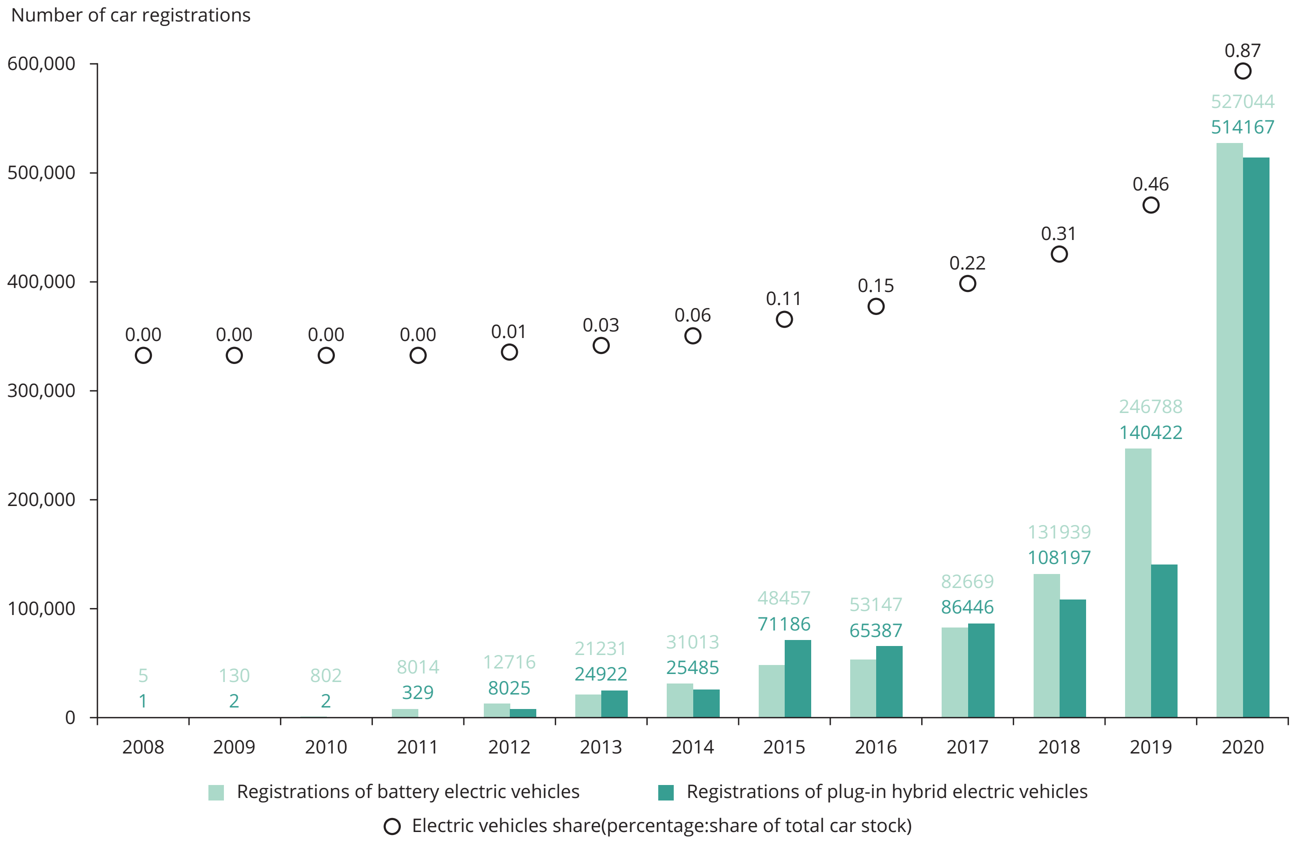
As a share of the total car stock, however, they remain at under 1%. In 2020 BEVs and PHEVs together represented 0.87% of the EU car stock (EAFO, 2021b).

Among vans and HDVs, the electrification rate of new vehicles is increasing but remains moderate compared with that of passenger cars. Among the **HDVs**, **electrification** is most widespread in buses. In this segment the share of electrically chargeable vehicles in the total sales of new vehicles is significant, at 6% in 2020; however, this share is far lower for vans and trucks (Figure 5.8).

Electrification of **heavy trucks** is difficult, because of the challenge of competing with the long range of diesel trucks. Recent literature (Carroll, 2021; Nykvist and Olsson, 2021) suggests that electrification might also become an economically feasible option for heavy trucks soon. For this to happen, the rapid fall in the cost of batteries and increase in their lifetime needs to continue. The second condition would be a dense network of fast charging infrastructure, which would allow charging on average every 4.5 hours, in line with EU regulations on mandatory rests for drivers, and smaller batteries could be used. Detailed vehicle simulations by the International Council on Clean Transport show that, with a 700-kWh battery energy capacity, a 500-km driving range can be obtained in future, which should suffice for a large share of operations. The loss of load capacity due to the presence of a battery is estimated to be small and expected to disappear in future (Basma et al., 2021).

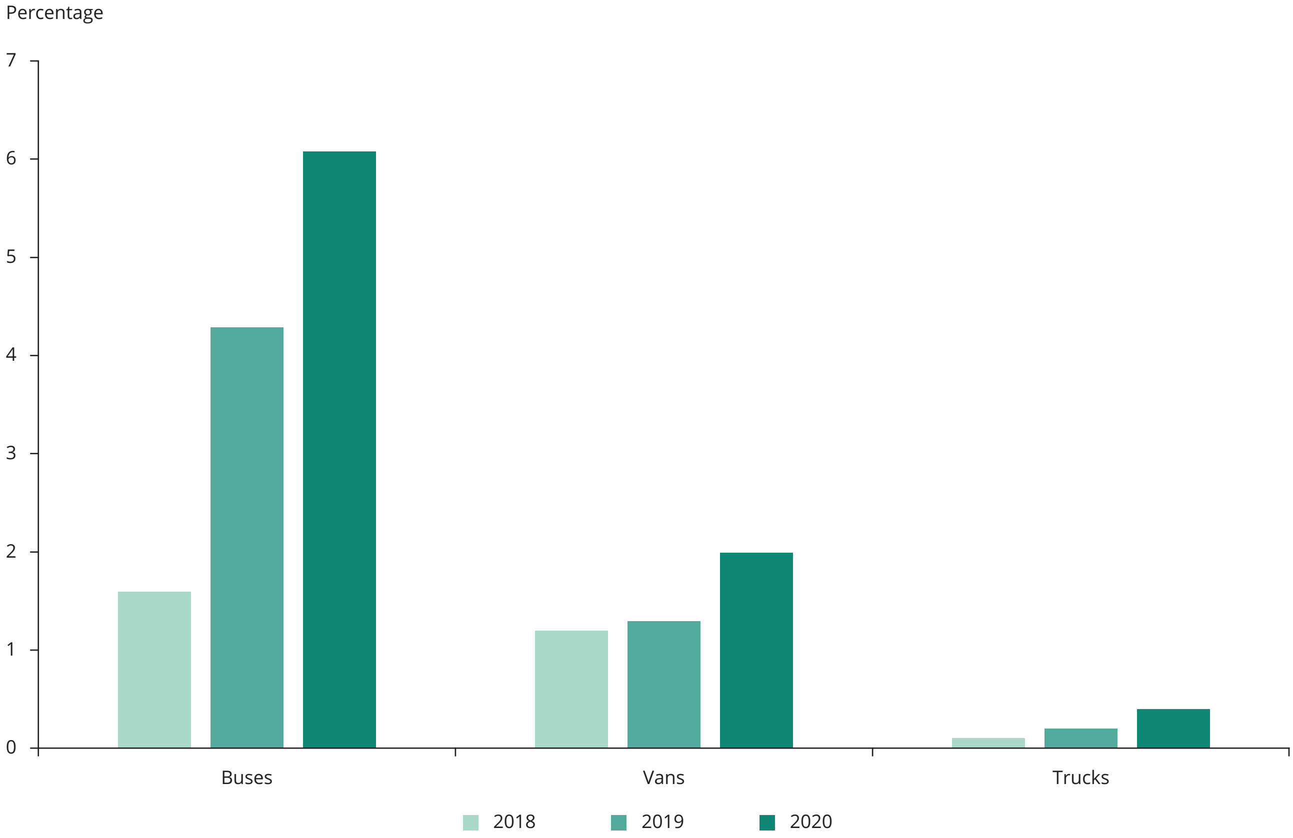
Another option for long-haul freight is a system of overhead catenary wires on main roads, supplying trucks with electricity. Intelligent pantographs are being used in European demonstration projects, for example the eHighways project, with tests in Sweden and Germany (JRC and DG Mobility and Transport, 2020).

Figure 5.7 Electric car registrations (left axis) and share of electric cars in the total car stock (right axis) in the EU-27, 2008-2020



Source: EEA compilation based on EAFO (2021b).

Figure 5.8 Share of electrically chargeable vans, buses and trucks in new vehicle sales in the EU-27, 2018-2020



Source: ACEA (2021b).

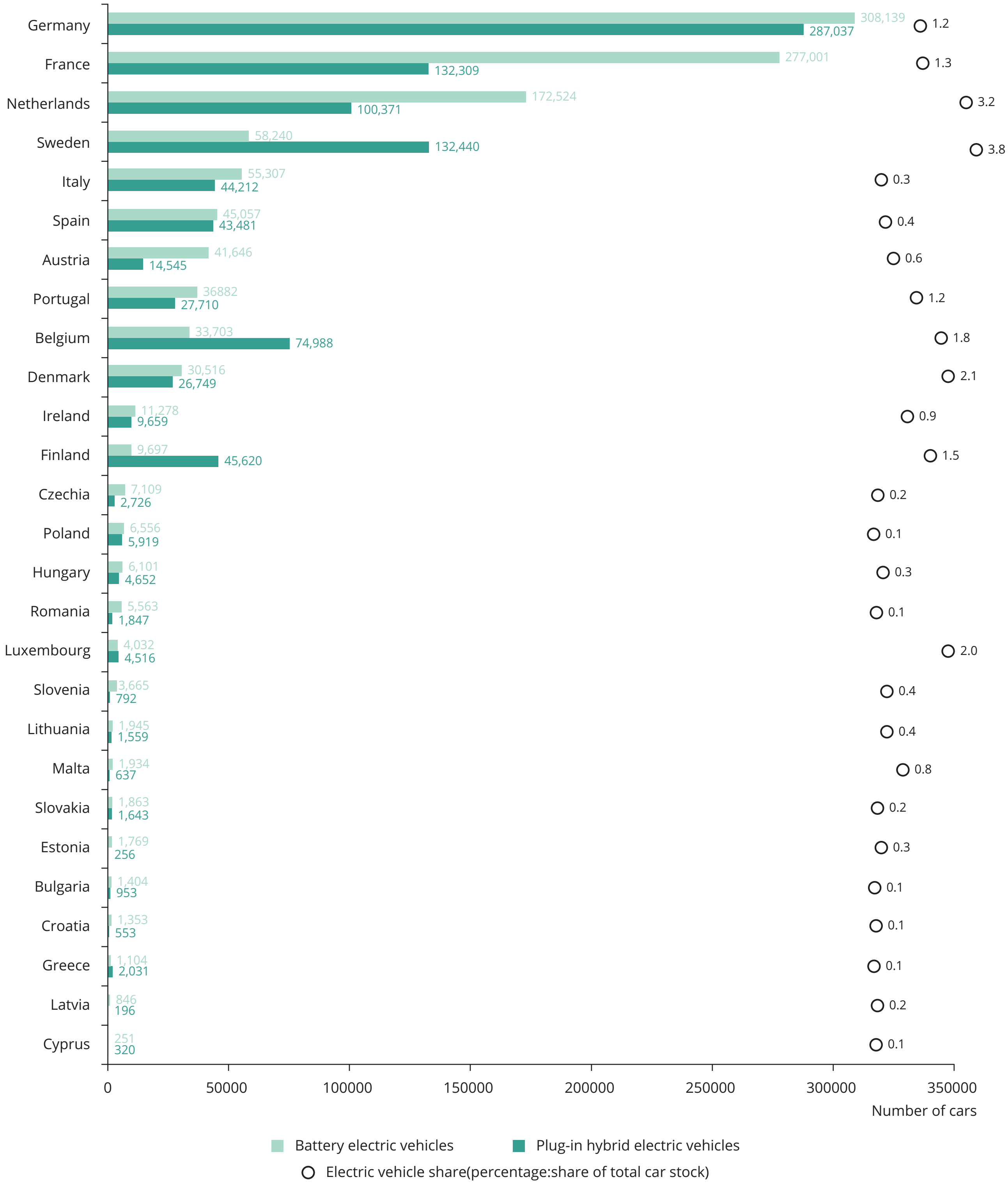
5.5.2 Impact of policies on the uptake of electric vehicles

The recent development of the European EV market is strongly influenced by the EU **CO_2 emission performance standards** (Wappelhorst, 2021a). The fleet-wide target of 95 g CO_2/km for new cars has applied since 2020 (the target until 2019 was 130 g CO_2/km). As only a few vehicles with internal combustion engines have emissions below 95 g CO_2/km, the target is very hard to meet without a significant share of Evs ([6]). Next to the EU standards, in 2020/2021 COVID-19 recovery measures have also been important in incentivising investments in electric mobility. This is one of the reasons why the EV segment was less severely hit by the pandemic than the overall automotive sector (de Vet et al., 2021).

The uptake of Evs in the EU-27 is **concentrated in a small number of countries** (Figure 5.9). In 2020, five EU countries with the highest number of electric cars, together accounted for 75% of the electric car stock (EAFO, 2021b): Germany, France, the Netherlands, Sweden and Belgium. In terms of the EV **share** in the car stock the five countries with the highest share are Sweden (3.7%), the Netherlands (3.2%), Denmark (2.1%), Luxembourg (2.0%) and Belgium (1.8%). In recent years, sales of Evs have mainly been concentrated in European countries with a relatively high GDP per capita (ACEA, 2021a), where more people can afford to buy an electric car given the existing policies. Among countries with similar income levels, variation in national and local measures also explains part of the difference in EV uptake (Wappelhorst, 2021a, 2021b).

([6]) The phase-in provision permitted only the 95% best-performing cars of each manufacturer (or pool) to be considered for the target in 2020; for cars registered in 2021, 100% of the new cars will be considered.

Figure 5.9 **Total and share of electric passenger car stock in the EU-27 by December 2020**



Source: EEA compilation based on EAFO (2021b).

Everything else being equal, car manufacturers will focus on the markets with EV-friendly policies in their supply side decisions. As the EU CO_2 emission targets apply for the EU fleet-wide average emissions of each manufacturer's newly registered vehicles, such national and local EV policies will affect the distribution of the Evs that are required to meet the target across individual Member States. As long as the targets can be met by a combination of Evs and vehicles with an internal combustion engine (ICEVs), national and local policies might have less effect on the total number of EVs In the EU (KU Leuven, 2020). Table 5.2 lists examples of national policies that support Evs or the charging infrastructure in EU countries with high EV sales.

There is little evidence of policies specifically directed at the electrification of vans and HDVs, as those policies are only starting to be introduced.

Table 5.2 Examples of national and local EV policies

Country	Measures to support EV uptake	Measures to supply recharging infrastructure
Germany	• Financial benefits: purchase bonus (also for used, second-hand Evs), exemption from ownership tax, lower taxable amount for electric company cars than ICEVs, tax benefits related to charging. • Electric mobility law: framework for municipalities to grant privileges to Evs such as preferential parking, lower parking fees, driving in restricted areas.	• National and local grants for private charging infrastructure. • Funding for public recharging infrastructure. • Masterplan recharging infrastructure with ambitious targets.
France	• Financial benefits: CO_2 emission-based bonus-malus measures on car purchase, CO_2 emission-based ownership tax, one-time grant for the purchase of a used EV, scrappage scheme, local grants. • Procurement of Evs in public fleets.	• Subsidies for companies and public entities for installing public recharging points.
Sweden	• Financial benefits: bonus-malus system, preferential taxes for electric company cars, free parking in some public places, subsidies for private charging stations. • Free access to high-occupancy vehicle and bus lanes in some areas.	• Funding for public recharging infrastructure.
The Netherlands	• Financial benefits: purchase bonus (also for used Evs), exemption/reduction of ownership tax and registration tax, disincentives for ICEVs, benefits for electric company cars.	• Public recharging points on request for EV owners with no home or workplace recharging access (in some municipalities). • Free public charging in some cities.

Source: Based on Wappelhorst et al. (2020) and Wappelhorst (2021b, 2021c).

5.5.3 Outlook and possible bottlenecks

Among the factors in the decomposition analysis presented in Chapter 3, the electrification of the vehicle stock is the factor that is expected to evolve the most in the coming decades, thereby contributing to a fall in GHG emissions from road transport. The uptake of Evs is forecast to increase strongly under the influence of the CO_2 standards for cars, vans and HDVs, supported by the rolling-out of the recharging infrastructure.

In the *EU Reference Scenario 2020* (EC, 2021e), the European Commission projects that the EV share in the stock of light-duty vehicles (including battery electric, fuel cell vehicles and plug-in hybrids) would reach 16% by 2030 and 53% by 2050. The electrification of HDVs is projected to stay limited, reaching only about 4% of vehicle stock by 2050, with current policies. Among buses and coaches, the uptake of electric buses is expected to accelerate, driven by the implementation of the Clean Vehicles Directive and air quality concerns in many cities resulting in the banning of combustion engine buses.

The scenarios ([7]) analysed by the Commission (EC, 2020b) describe developments with different types of additional policies. In these policy scenarios, the share of Evs in the car stock would increase to 20% in 2030 and to 88-99% in 2050. For vans, a similar evolution in the policy scenarios is projected, with an acceleration in the share of low and zero emission vehicles after 2030, reaching 87-97% in 2050. Buses are also projected to have almost completely zero emissions by 2050 in the policy scenarios. Only HGVs would not have a dominant share of zero or low emission vehicles by 2050. Around one quarter of the trucks in 2050 would be fuel cell vehicles and around 14-20% BEVs. The remaining HGVs would be hybrid or ICEVs, which would require low and zero carbon fuels to achieve climate neutrality.

A recent analysis (Bloomberg New Energy Finance, 2021; Transport & Environment, 2021a) expects that electric vans and cars will achieve **price parity with equivalent ICEVs between 2025 and 2027**, meaning that they would have the same upfront cost as equivalent ICEVs. Falling battery prices and the switch to dedicated BEV manufacturing platforms would be the main drivers of the cost reductions. As well as policies and innovations in Europe, the growth of the global vehicle and automotive battery markets will help to expand the production capacity and achieve economies of scale, resulting in cost reductions (IEA, 2020). There is, however, uncertainty about whether cost reductions will be reflected quickly in the retail prices, or there will be a time lag, which would mean that price parity would be achieved later. Even with such price parity, there is a risk that Evs will not be affordable for all consumers (EC, 2021h). In the Fit for 55 package, the Commission proposes a new Social Climate Fund to achieve a socially fair transition (EC, 2021b).

To achieve a large breakthrough for Evs several **bottlenecks** must still be overcome. The first is the provision of **charging infrastructure**. The proposed revision of the Alternative Fuels Infrastructure Regulation (see Section 5.2.3) is seen as a key instrument to address this issue (EC, 2021h). Next to the policies and measures undertaken at EU, national and local levels, innovation might solve this bottleneck. Innovative solutions include battery swapping, induction-based wireless charging stations or mobile recharging points providing on-demand, portable recharging services to solve emergency situations (JRC and DG Mobility and Transport, 2020).

A second bottleneck is the concern that (peak) electricity demand for recharging Evs could put **pressure on the electricity grid and require expensive grid reinforcement**. Modelling of the electricity market, e.g. with the METIS tool (Klettke et al., 2018), has demonstrated that the increasing penetration of Evs could lead to a substantial increase in total electricity demand (e.g. total electricity demand would increase by 10% in a scenario in which 34% of the energy demand for cars would be for electricity). In combination with uncoordinated charging this would lead to high peak demand, e.g. in the morning and early evening hours, implying high prices and the risk that the energy supply will be insufficient. Innovative solutions are being developed to mitigate this, in the form of **smart grids and smart meters**. This technology enables EV batteries to act as flexible loads and decentralised storage resources. Demand-side management and real-time pricing can provide incentives to charge Evs when the demand is low or there is a large supply of renewable electricity. With bidirectional charging, Evs could bring even greater flexibility to the system by supplying power back to the grid (called vehicle-to-grid) or to the home (vehicle-to-building).

In 2020, the European Commission proposed an EU Strategy for Energy System Integration (EC, 2020c) to optimise the energy system through better links between both the various energy carriers and the end-use sectors. This strategy expects that, by 2050, Evs could provide **up to 20% of the flexibility** required daily. This would diminish the need for costly investments in

([7]) The regulatory-based measures scenario (REG), the carbon-pricing based scenario (CPRICE), the combined approach scenario (MIX) and the most ambitious scenario in which the scope is extended to all aviation and maritime emissions (ALLBNK) all reach an economy-wide -55% GHG reduction in 2030. Only the MIX-50 scenario relaxes this 2030 target to -50%.

grid capacity. At a local level, however, the full electrification of cars will require upgrades to the local grid infrastructure.

The large-scale battery production required is a third bottleneck: will there be **sufficient raw materials** for the batteries required for e-mobility? There are supply risks related to geopolitical stability in the producing countries (e.g. cobalt mining in the Democratic Republic of the Congo). Another risk is that unstable markets with strong price peaks may affect business stability and long-term investments in mining and refining capacities. This may have impacts on the supply of nickel, cobalt and to a lesser extent graphite and lithium. A third risk is related to the concentration of refining capacity in China and the lack of capacity in Europe (JRC and DG Mobility and Transport, 2020). Despite these risks, it is expected that the supply of raw materials needed for battery production will increase, as there are many new mining and refining projects in the pipeline. In addition to the risks associated with the availability of the raw materials required, care must be taken to ensure that the batteries are socially and environmentally sustainable from a life cycle perspective. Reuse and recycling can have a significant mitigating effect on future material needs. A recent study by Transport & Environment (2021b) estimates that by 2035, one fifth of the lithium and nickel and 65% of the cobalt needed could come from recycling. A new EU Batteries Regulation has been proposed to ensure that batteries placed on the EU market are sustainable and safe throughout their life cycle (EC, 2021a).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6
The greenhouse gas emissions intensity of road transport energy

Key messages

- **Two key pieces of EU legislation have an impact on the greenhouse gas (GHG) emission intensity of road transport fuels: the recast Renewable Energy Directive (RED II) and the Fuel Quality Directive. The reduction in the GHG emissions intensity of the road transport fuel mix has been mainly due to the higher share of biofuels (a target for which is set in RED II). In 2020, the average share of energy from renewable fuels in transport in the 27 EU Member States was 10.2%: most of this share is biofuels.**
- **Considering the broader scope of emissions (well-to-wheel, life cycle analysis), the contrast between the GHG emissions performance of biofuels and fossil fuels is even greater than for the scope of only the exhaust emissions. However, the feedstock used to produce biofuels is decisive, as potential indirect land use change from growing crops for biofuels can diminish these benefits.**
- **As the share of electric vehicles increases, the carbon intensity of electricity production will become increasingly relevant to the assessment of the full climate impact of road transport.**

6.1 Introduction

The decomposition analysis presented in Chapter 3 indicated that the share of biofuels has been an important factor in the tank-to-wheel (TTW) GHG emissions from road transport, while the greenhouse gas (GHG) emission intensity of fossil fuels has played a smaller role. This chapter further explores the GHG emission intensity of road transport energy. In addition to the TTW emissions that were examined in the decomposition analysis, the chapter also discusses the well-to-tank (WTT) emissions, as well as potential emissions arising from indirect land-use change (ILUC), to broaden the perspective of the GHG emissions performance of transport fuels.

6.2 Policy framework

EU legislation that has an impact on the GHG emission intensity of road transport fuels includes legislation introducing renewable energy targets and that encouraging the improvement of fossil fuels (Table 6.1). Two pieces of legislation are key: the Renewable Energy Directive (and its update) and the Fuel Quality Directive. The Indirect Land Use Change (ILUC) Directive complements these by regulating the feedstocks from which the biofuels are produced.

Table 6.1 EU legislation that influences the GHG emission intensity of transport fuels

Legislation	Key targets and elements relevant for road transport	Proposed key changes in the Fit for 55 package	Link to the decomposition analysis
Renewable Energy Directive (RED) (2009/28/EC) and RED II (2018/2001)	For 2020, in each Member State the share of energy from renewable sources in all forms of transport is at least 10% of the final consumption of energy in transport. For 2030, in each Member State energy from renewable sources in road and rail is at least 14% of the final consumption of energy in transport. Sustainability criteria for biofuels.	New approach to target setting: 13% GHG emission intensity reduction target in 2030, compared with a liquid fossil fuel baseline. GHG emission intensity target applies to all energy consumed by transport. Gradually increasing shares of advanced biofuels.	Share of electricity and fuels in energy consumed by road transport. Share of fossil fuels and biofuels in fuel consumption by road transport. Energy efficiency (via electricity production for electric vehicles).
Fuel Quality Directive (FQD) (2009/30/EC)	Reduction by a minimum of 6% by 2020 compared with 2010 of life cycle GHG emissions per unit of energy. Sustainability criteria to define eligibility of fuels counting towards the target, aligned with the RED. Applies to petrol, diesel and biofuels in road transport and gasoil for non-road mobile machinery.	GHG emission intensity target of road transport fuels is deleted (in the proposed RED II revision). All related articles in the FQD are also removed.	Carbon intensity of fossil fuels consumed by road transport. Share of fossil fuels, biofuels and electricity in energy consumed by road transport.

6.2.1 Renewable Energy Directive

The Renewable Energy Directive (RED) came into force in 2009, setting renewable energy targets for 2020. The updated Renewable Energy Directive (RED II) (EU, 2018b), entered into force in December 2018, setting targets for 2030.

Both directives include a transport sub-target. For 2020, for each Member State, a target for the share of energy from renewable sources in all forms of transport of at least 10% of the final consumption of energy in transport was set. By 2030, a minimum of 14% of the energy consumed in road and rail transport should be renewable in each Member State. Within this target a specific target applies for advanced biofuels, which is gradually increasing up to 3.5% in 2030. The RED II also defines a series of sustainability and GHG emission criteria that should be met by bioliquids used in transport so that they count towards the overall 14% target and are eligible for financial support by public authorities. The RED II sets limits on high-ILUC-risk biofuels, bioliquids and biomass fuels that would entail a significant expansion of cultivation on land with high carbon stocks, and imposes a gradual phase-out of these fuels between 2023 and 2030. In addition, the share of fuels based on a number of feedstocks that can be processed with mature technologies (including used cooking oils and animal fats), cannot exceed 1.7%.

The RED II is supplemented by Commission Delegated Regulation (EU) 2019/807 (EU, 2019a). The regulation includes criteria for identifying feedstock with high ILUC risk and general criteria for the certification of biofuels with a low ILUC risk. It proposes criteria for improvements in agricultural practices (additionality measures) allowing the yield of food and feed crops on land that is already used for this purpose to be increased or the cultivation of such crops on unused or abandoned land.

In the Fit for 55 package of July 2021 the European Commission published a **proposal for the revision of the Renewable Energy Directive** (EC, 2021l), as achieving at least a 55% net reduction in GHG emissions in 2030 compared with 1990 will require an accelerated transition towards renewable energy.

The proposed revision sets a target share of at least 40%, rather than 32%, of energy from renewable sources in the European Community's gross final consumption of energy. For transport, an important change in approach is proposed: the replacement of the 14% RED II target for renewable energy in transport with a 13% GHG emission intensity reduction target in 2030, compared with a liquid fossil fuel baseline GHG emission intensity. While the RED II target applied to energy consumed by road and rail, the proposed target applies to all energy consumed by transport. Also new is that renewable fuels and renewable electricity count towards the 13% GHG emission reduction target on the basis of their GHG emission savings. The proposed RED II revision includes gradually increasing minimum shares for advanced biofuels and renewable fuels of non-biological origin to 2.2% and 2.6%, respectively, in 2030. The proposal also includes a credit system for the supply of renewable electricity to the transport sector via public charging stations.

6.2.2 Fuel Quality Directive

In addition to the Renewable Energy Directive, the GHG emission intensity of road transport fuels is regulated by the **Fuel Quality Directive** (FQD) (EU, 2009a). The FQD applies to petrol, diesel and biofuels used in road transport and gasoil used in non-road mobile machinery. It establishes an obligation for the suppliers to report annually on the GHG emission intensity of fuels and energy supplied within each Member State. Member States had to require suppliers to reduce GHG emissions per unit of energy from fuel and energy supplied by a minimum of 6% by 2020 compared with the 2010 baseline of 94.1 g CO_2e/MJ. The GHG emission intensity of fuels is calculated on a life cycle basis, covering emissions from extraction, processing and distribution. Furthermore, Member States must ensure that suppliers respect the target of 6% after the year 2020.

Possible strategies to attain the 6% reduction target include:

- using biofuels, electricity, less carbon-intensive fossil fuels, and renewable fuels of non-biological origin (such as electrofuels (e-fuels);
- reducing upstream emissions (such as flaring and venting) during the extraction stage of fossil feedstocks.

For biofuels to count towards the GHG emission reduction targets, they must meet certain sustainability criteria and give consideration to ILUC.

The Fit for 55 package does not include a revised FQD. However, in the proposed RED II revision, the target set in the FQD for the GHG emission intensity of road transport fuels has been deleted, together with all related articles in the FQD and the corresponding Council Directive on the calculation methods and reporting requirements.

6.2.3 Indirect Land Use Change Directive

The growth of feedstocks to produce biofuels might indirectly lead to the extension of agricultural land to previously uncultivated areas (ILUC). This process can give rise to negative impacts on biodiversity, as well as on carbon stocks, in cases where such expansions extend to forests, wetlands and peatlands because the subsequent release of carbon dioxide (CO_2) stored in trees and soil may exceed the GHG emission savings that result from using the biofuels.

Because of these concerns the **ILUC Directive** (Directive 2015/1513, (EU, 2015)) introduced the additional constraint that the share of energy from biofuels produced from crops grown on agricultural land is not to exceed 7% of the final consumption of energy in transport in the Member States in 2020. Moreover, a list of feedstocks was added, including algae and wastes or residues, which do not count towards the 7% limit, and their contribution towards the 10% target (in the RED) was considered to be twice their energy content.

6.2.4 Implementation of directives at Member State level

EU Member States can choose how they meet the RED targets for renewables in transport and the target for the reduction of the GHG emission intensity of fuels under the FQD. As reported in the National Energy and Climate Plans, some Member States set an overall biofuels incorporation target, some set separate targets for biofuels in petrol or diesel or both and others rely solely on targets for reducing the carbon intensity of fuels. Apart from such support measures for biofuels, in recent years Member States are increasingly promoting electric mobility (EC, 2020f). Measures by Member States also include strategic measures, for example regarding the circular economy or the management of urban and agricultural waste, or support for research and development (R&D).

All EU Member States apply taxes on fuels for passenger and freight transport, complying with the minima set in the Energy Taxation Directive and often well above these minima (which have remained constant over time). A number of countries give tax incentives for biofuels or blends (Table 6.2). In Germany a separate emissions trading system has applied since the beginning of 2021, covering road transport and buildings (Wettengel, 2021).

Table 6.2 Overview of tax incentives for biofuels/blends in the EU-27, July 2020

Tax incentive	Member State
None	Belgium, Bulgaria, Cyprus, Estonia, Germany, Greece, Hungary, Italy, Malta, Netherlands, Poland, Romania, Spain
Lower tax for low biofuel blends	Austria, Denmark, France, Slovakia, Sweden
Lower tax for high biofuel blends	Czechia, Denmark, France, Latvia, Lithuania, Sweden
Taxation based on the energy/CO_2 content	Finland
No excise duty/exemption from certain taxes (components)	Croatia, Ireland, Latvia, Luxembourg, Portugal, Slovenia

Source: ePURE (2020).

6.3 The tank-to-wheel greenhouse gas emission intensity of the fuel mix

6.3.1 Greenhouse gas emission intensity of road transport fuels

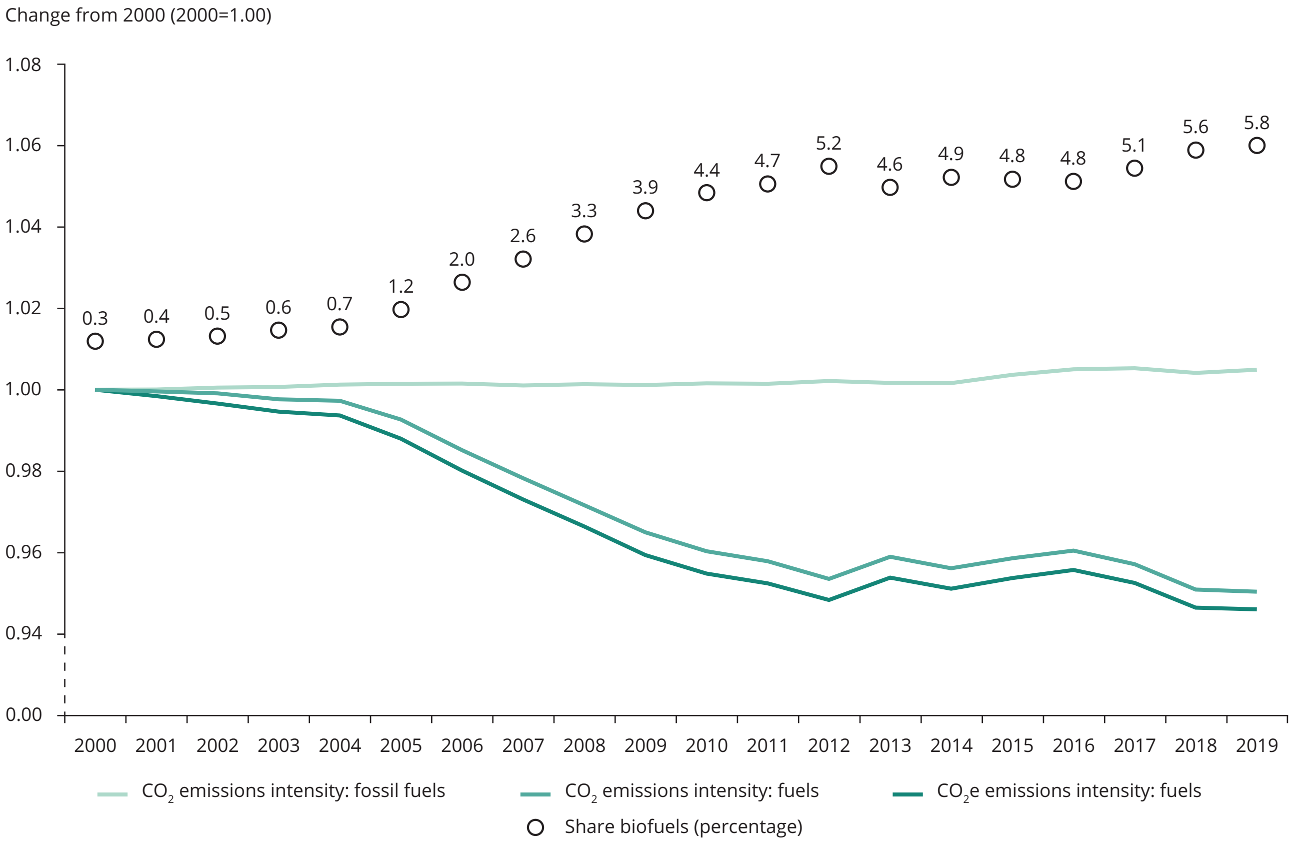
Figure 6.1 presents the trend in the TTW CO_2 emission intensity of fossil fuels (as used in the decomposition analysis) and all road transport fuels for the period between 2000 and 2019. The development of the TTW GHG emission intensity of road transport fuels depends on two factors: the emission factors per fuel type and changes in the fuel mix. For fossil fuels the intensity increases a little during the period. The reduction in the CO_2 emission intensity of all transport fuels is therefore related to the increased share of biofuels.

The CO_2 emissions per unit of energy are the highest for diesel, followed by petrol, liquefied petroleum gas (LPG) and gaseous fuels. For biofuels, as the CO_2 released during fuel combustion is taken to be equal to the CO_2 captured during the growth of the feedstock, the net CO_2 emission is considered to be zero (Table 6.3).

The increase in fossil fuel CO_2 emission intensity can be explained by the increased share of diesel in the overall fuel consumption and by diesel having a higher rate of emissions than petrol. This is partly compensated for by the increased share (measured in terms of energy content) of LPG and gaseous fuels in the fossil fuel mix. Considering all GHGs (in carbon dioxide equivalent (CO_2e)), the carbon intensity of fossil fuels has remained stable. In 2019, the CO_2e emissions per energy unit were higher for diesel than petrol. This is related to the nitrogen oxides (NO_x) abatement technologies for diesel vehicles, which result in an increase in nitrous oxide (N_2O) emissions (EEA and EMEP, 2019). On the other hand, reduced methane emissions from petrol and LPG has contributed to a minor decrease in the overall GHG emission intensity of fossil fuels.

These results suggest that the increased share of biofuels has had a positive impact on the overall intensity of the fuel mix.

Figure 6.1 Tank-to-wheel CO_2 and GHG emission intensity of road transport fuels in the EU-27, 2000-2019 (2000=1) and share of biofuels (%)



Note: Electricity consumption by road transport is not considered in this figure. Fuels=fossil and biofuels.

CO_2e, carbon dioxide equivalent.

Source: EEA compilation based on GHG emission inventory (EEA and EC DG Climate Action, 2021).

Table 6.3 Overview of tax incentives for biofuels/blends in the EU-27, July 2020

	2000					2019				
	Share in fuel consuption	CO_2 t/TJ	CH_4 kg/TJ	N_2O kg/TJ	CO_2e t/TJ	Share in fuel consuption	CO_2 t/TJ	CH_4 kg/TJ	N_2O kg/TJ	CO_2e t/TJ
Petrol	44.8%	72.7	23.7	4.8	74.7	24.3%	73.3	11.2	0.9	73.8
Diesel oil	53.1%	73.9	3.7	1.4	74.5	66.8%	74.1	1.0	3.0	75.0
LPG	1.5%	65.5	14.9	1.1	66.2	2.2%	65.3	9.6	0.4	65.6
Gaseous fuels	0.1%	56.3	43.9	0.7	57.6	0.7%	56.9	36.3	5.0	59.3
Biomass	0.3%	0.0	7.7	1.9	0.8	5.8%	0.0	3.2	2.3	0.8
Other fuels	0.1%					0.2%				
Weighted average		73.0	12.90	2.94	74.2		69.4	4.07	2.40	70.2
Weighted average fossil fuels		73.2	12.92	2.95	74.4		73.6	4.13	2.41	74.4

Note: Electricity consumption by road transport is not considered in this table The carbon dioxide equivalent (CO_2e) emissions per MJ also take the emissions of methane (CH_4) and nitrous oxide (N_2O), weighted by their respective global warming potential, into account. The colours in the table indicate the relative magnitude of the emission intensity per pollutant in the 2 years.

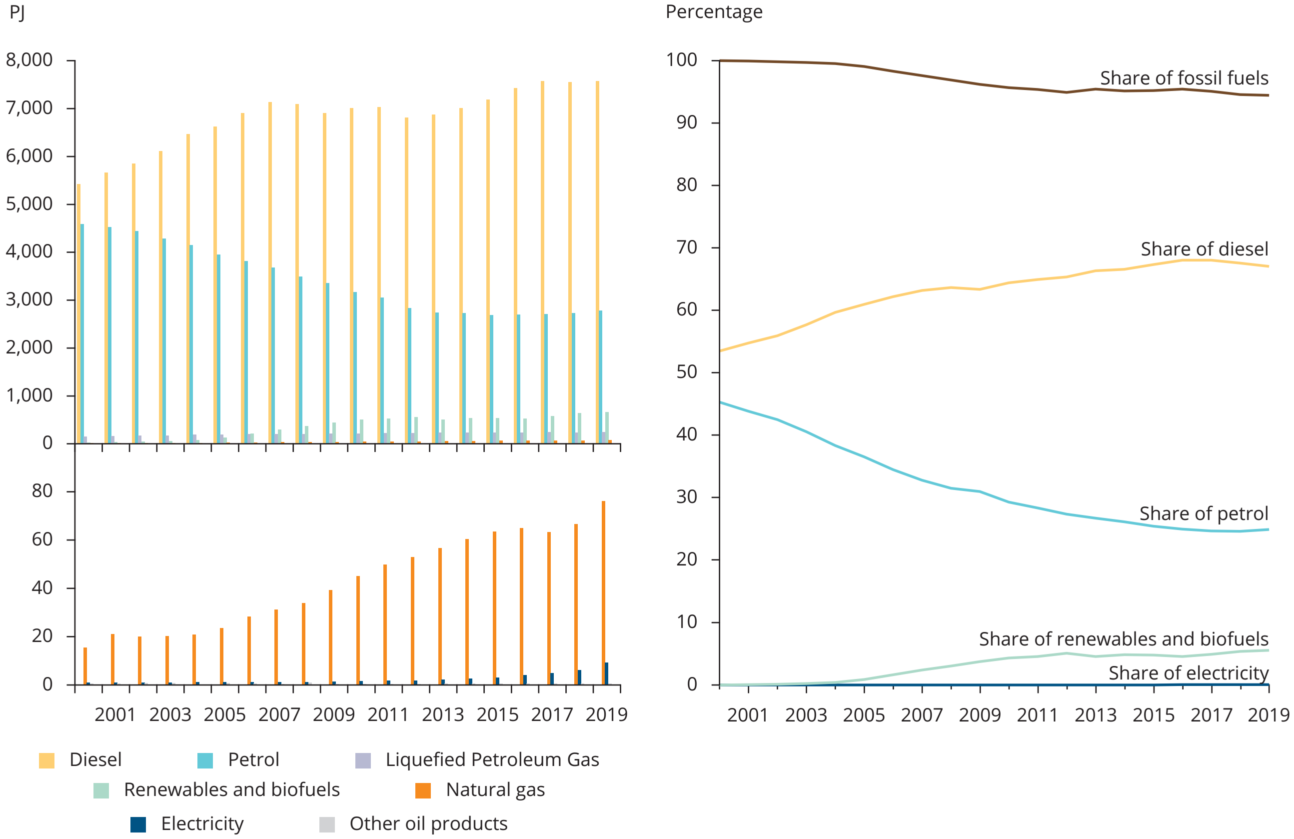
Source: EEA compilation based on GHG emission inventory (EEA and EC DG Climate Action, 2021).

6.3.2 *Road transport energy consumption and the share of renewable fuels*

Figure 6.2 presents the trend in the final energy consumption by road transport in the 27 EU Member States (EU-27) between 2000 and 2019 by category and by the share of the largest categories. In 2019, total final energy consumption in road transport was 11.2% higher than in 2000, despite fluctuations following the economic crisis.

Throughout this period, fossil fuels were dominant, although their share fell from almost 100% in 2000 to 94.2% in 2019, being replaced by renewables and biofuels. The share of electricity was minor, at 0.08% in 2019. The dominant fossil fuels were petrol and diesel (Figures 6.2 and 6.3).

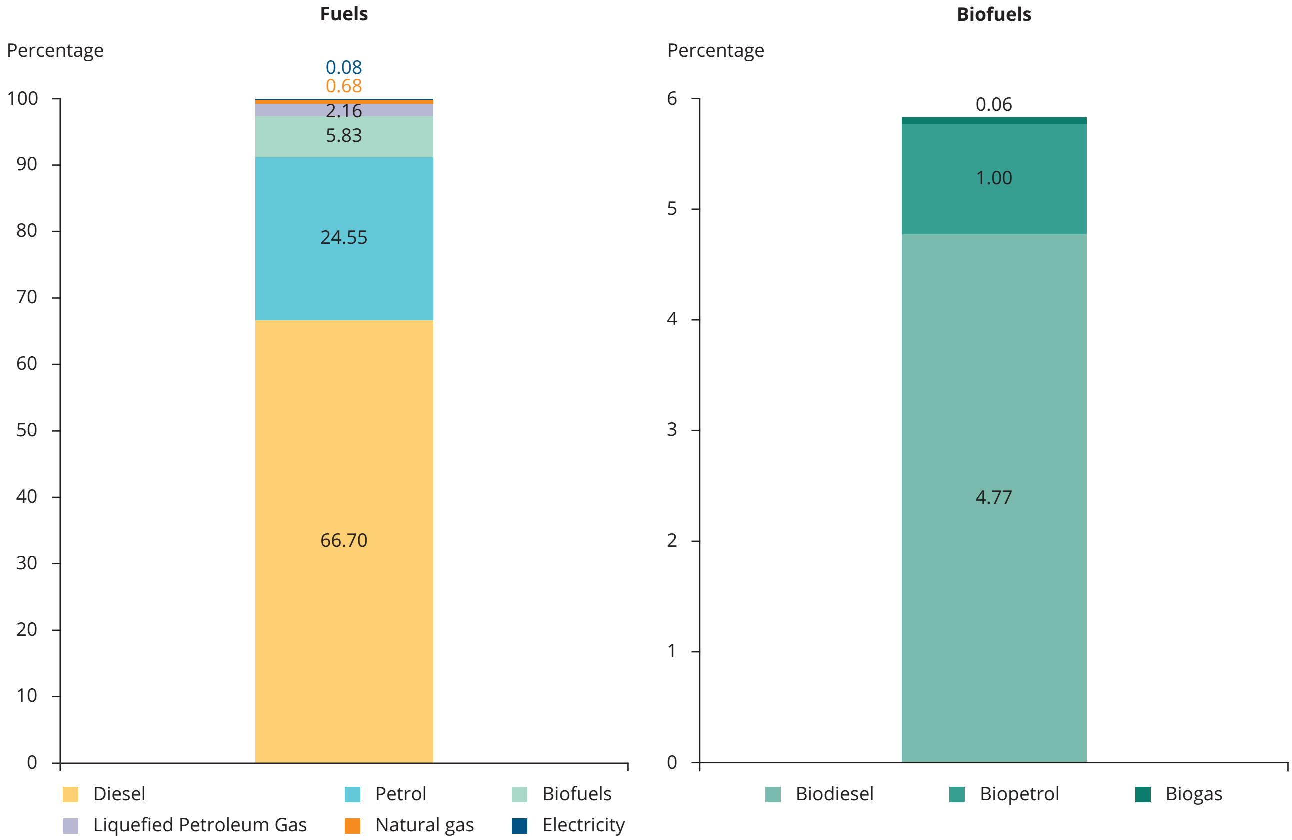
Figure 6.2 Final energy consumption by road transport (left axis) and share of energy categories (right axis) in the EU-27, 2000-2019



Note: PJ - Petajoules.

Source: EEA compilation based on Eurostat (2021).

Figure 6.3 Final energy consumption by road transport by energy type in the EU-27 in 2019

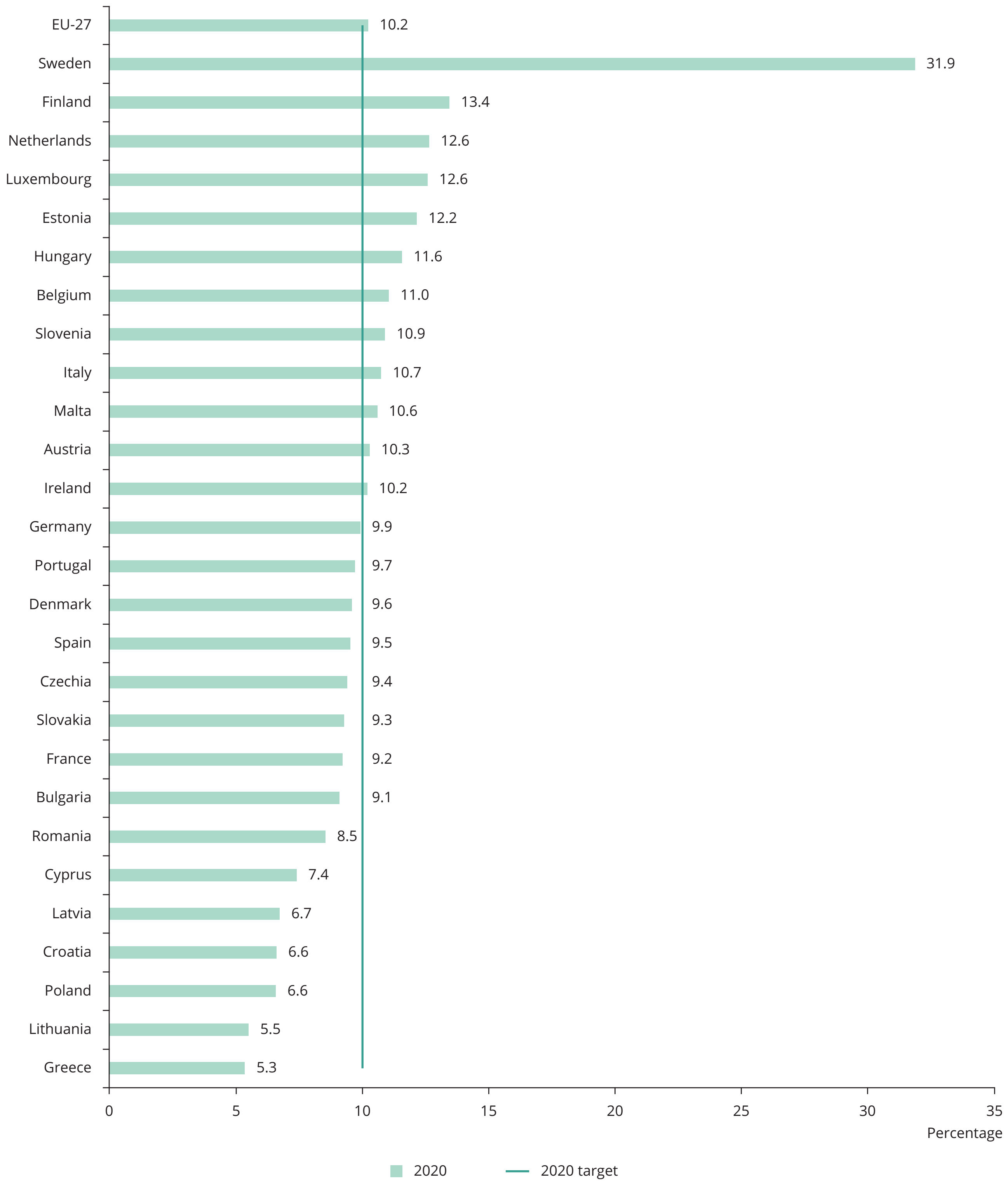


Source: EEA compilation based on Eurostat (2021).

The average share of energy from renewable sources in transport in the EU-27, calculated using the methodology prescribed by the RED, increased from 1.6% in 2004 to 10.2% in 2020 (Figure 6.4). In this way, the 2020 target of 10% has been met. However, this is driven by a small number of Member States that have high shares of renewables, while less than half of the Member States have reached the target individually. Biofuels were the most prevalent type of renewable energy used in transport during this period.

The TTW emissions examined in the decomposition analysis are only one part of the overall impact of GHG emissions from road transport. The WTT emissions (those taking place during the production, transport and distribution of fuels) also play a role and are relevant for all types of energy used in road transport: fossil fuels, biofuels and electricity.

Figure 6.4 **Share of energy from renewable sources in transport in the EU-27 in 2020**



Source: EEA compilation based on Eurostat (2021).

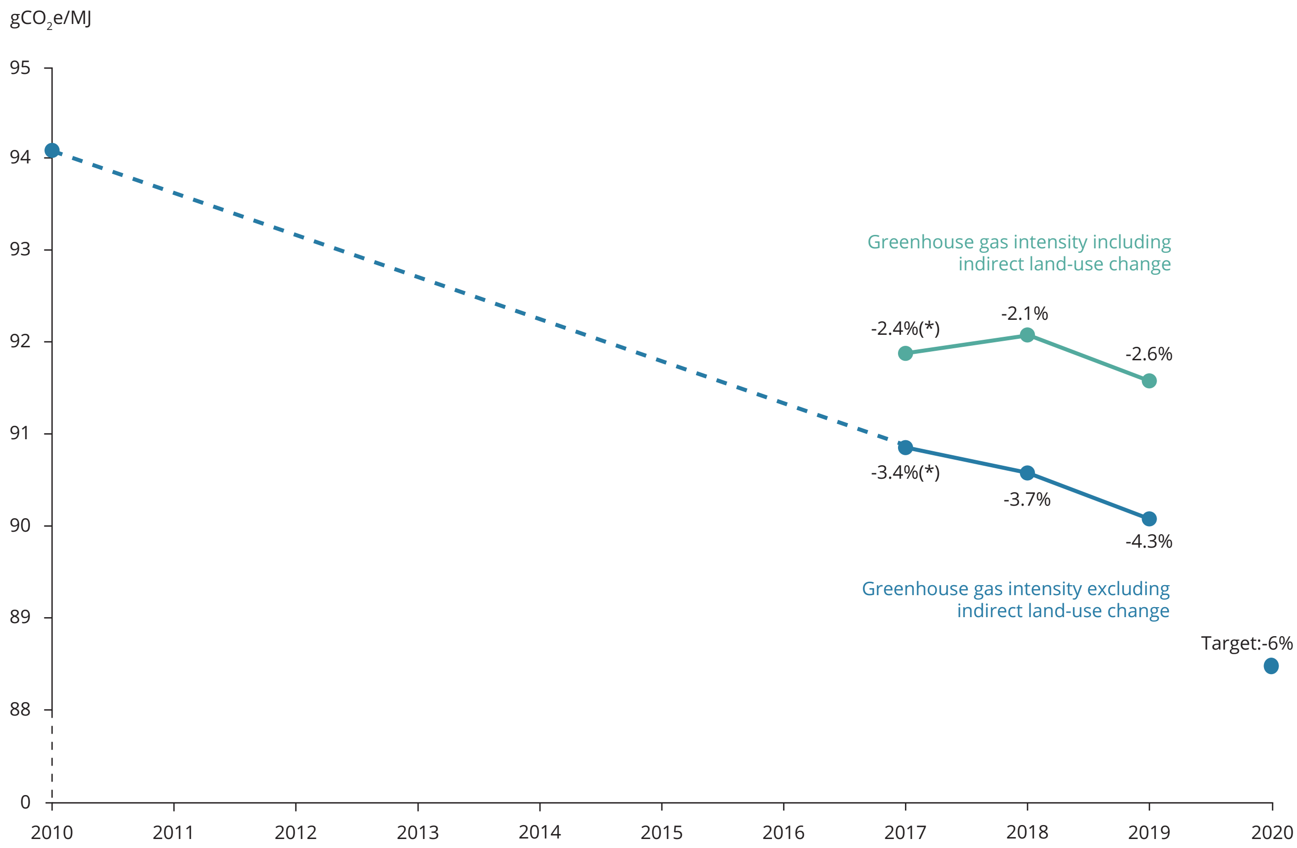
6.4 The well-to-wheel and indirect land use change greenhouse gas emissions of the current energy mix in road transport

6.4.1 Well-to-wheel and indirect land use change impacts of biofuels

In addition to emissions occurring during combustion, GHGs are emitted when producing, transporting and pre-treating the feedstock for fossil fuels and biofuels, as well as during fuel production and distribution. For biofuels, these emissions are highly dependent on the type of feedstock from which they are produced.

In 2019, the average GHG intensity of the fuels supplied in the EU-27 and the UK was 90.1 g CO_2e/MJ, excluding ILUC impacts (EEA, 2021b) (Figure 6.5). This is equivalent to a 4.3% reduction compared with 2010, while the FQD set a target reduction of 6% by 2020. The ILUC emissions are not taken into account for assessing compliance with this target. However, if the emissions related to ILUC are also considered, the value is 91.6 g CO_2e/MJ and the reduction would be 2.6% compared with 2010. Considering ILUC, the GHG intensity of fuels increased in 2018, due to a higher share of oil crop-based biofuels, and decreased again in 2019 as a result of a limited change in feedstocks away from oil crops to sugars.

Figure 6.5 Average GHG intensity of road transport fuels in the EU, 2010-2019



Note: Average EU values (including and excluding ILUC from biofuels production) calculated using 22 Member States' submissions for 2017 (all except Estonia, Lithuania, Poland, Portugal, Romania and Spain) and 28 submissions for 2018 and 2019.

Source: EEA (2021b).

The WTW emission intensity is substantially lower for biofuels than conventional fuels: GHG emissions per unit of energy are estimated to be 42% lower for bioethanol than conventional petrol and 57.7% lower for biodiesel than conventional (fossil) diesel. It has been estimated that using hydrotreated vegetable oil (HVO) leads to a 67.4% reduction compared with diesel (Prussi et al., 2020a).

However, the ILUC effect can diminish these benefits. The feedstock is important when assessing the GHG reduction potential of biofuels, especially when including the ILUC effect. Assessing the magnitude of ILUC is difficult, as it is impossible to measure ILUC directly, even *ex post*, since this requires determining what would have happened without the introduction of biofuels.

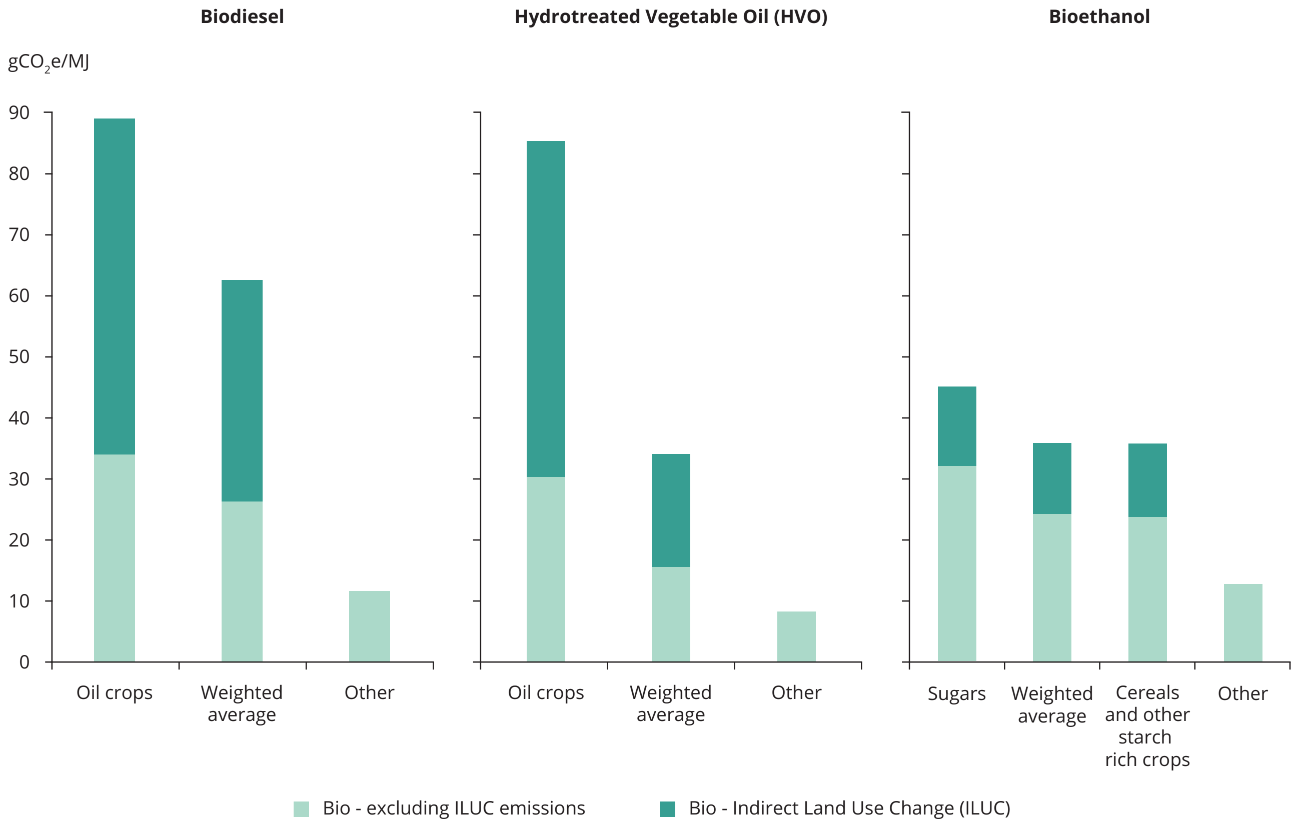
Biofuels produced from oil crops are only marginally better than their fossil fuel equivalent when considering ILUC.

Biodiesel and HVO produced from 'other feedstocks' (such as used cooking oil and animal fats) have a relatively low GHG emission intensity and no ILUC impact. The emission intensity of bioethanol produced from cereals and other starch-rich crops and sugars remains lower than that of fossil petrol, even when including ILUC.

Data reported under the FQD can be used to estimate the impacts of biofuels for each main feedstock and a weighted average over all feedstocks per fuel (Figure 6.6).

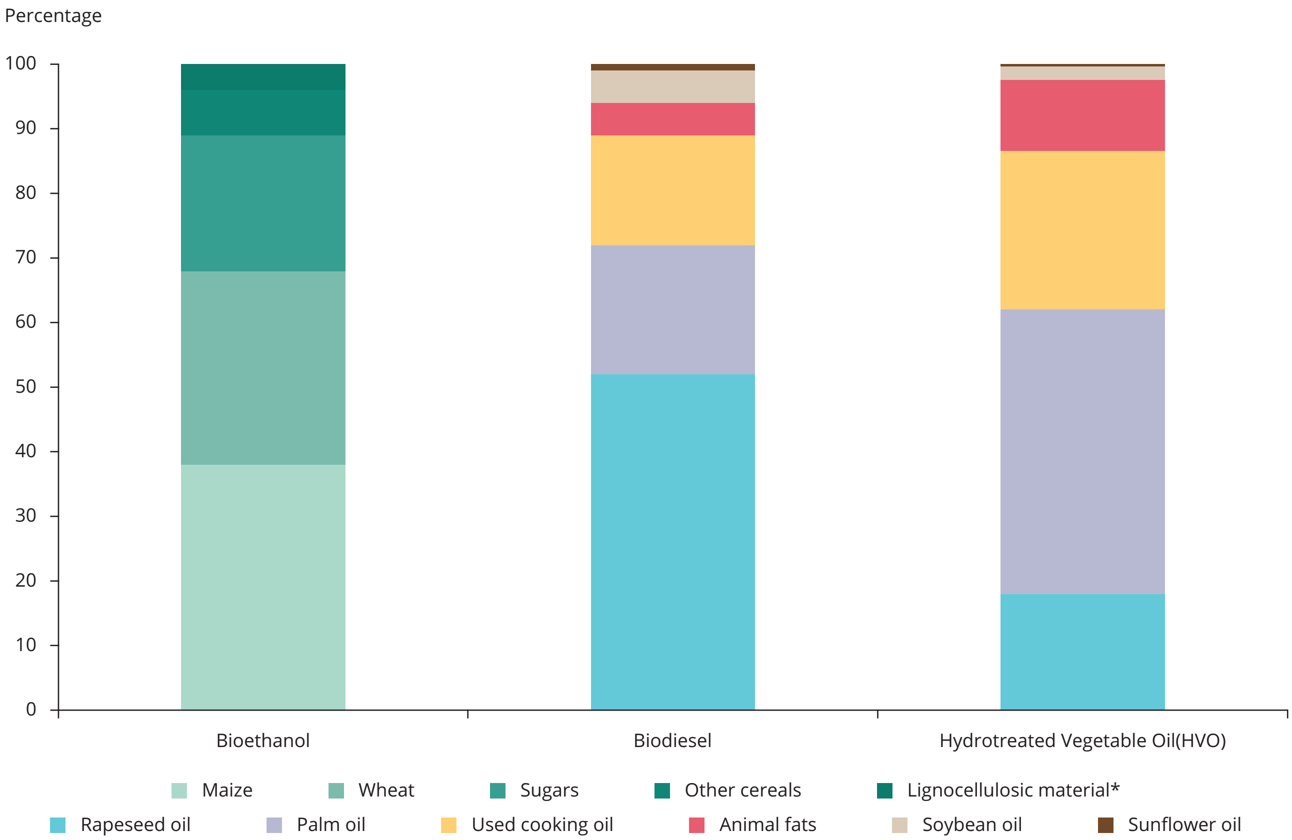
For the most prevalent type of biofuel, biodiesel, the most common feedstocks are rapeseed oil, used cooking oil and palm oil, which together account for almost 90% of the feedstocks (Prussi et al., 2020a). For bioethanol production, mainly wheat, maize and sugars are used (Figure 6.7).

Figure 6.6 GHG emissions from the use of biofuels, based on data collected under the Fuel Quality Directive in the EU-27 + UK, 2018



Source: EEA compilation based on Table 6.2 in Mellios and Gouliarou (2020).

Figure 6.7 Share of feedstocks in 2017 for bioethanol, biodiesel and HVO in the EU-27 and the UK



Note: *or other feedstocks listed in RED II.

Source: EEA compilation based on Appendix 2 in Prussi et al. (2020a).

The RED II incentivises a larger role for waste — and residue — based fuels. In addition, so-called synthetic fuels or e-fuels, which are produced using (renewable) energy, water and $CO_{2,}$ have received attention recently. Such fuels have the potential to decrease the GHG intensity of fuels used in road transport, considering WTW emissions. Depending on the feedstock and production process, these alternative fuels can have significant advantages over fossil fuels. When coal is used as primary energy input to produce synthetic diesel or hydrogen, there is no advantage in producing e-fuels. However, considerable improvements in GHG emission intensity can be achieved if residues and wastes are used as feedstock or if carbon capture and storage is employed in the case of synthetic fuels (Prussi et al., 2020b).

The potential for the future scaling up of these options faces challenges in the form of the availability of feedstocks and the control of ILUC impacts. The production of synthetic fuels is highly energy and capital intensive, and there is a need for further R&D. A large uptake of such fuels or hydrogen would require a substantial expansion in electricity generation (JRC and DG Mobility and Transport, 2020).

Considering the broader scope of emissions (well-to-wheel, life cycle analysis) the contrast between the GHG emission performance of biofuels and fossil fuels is even higher than for the scope of only exhaust emissions. However, the feedstock used to produce biofuels is decisive, since potential ILUC from growing crops for biofuels can diminish these benefits.

6.4.2 The well-to-tank emissions related to electricity production

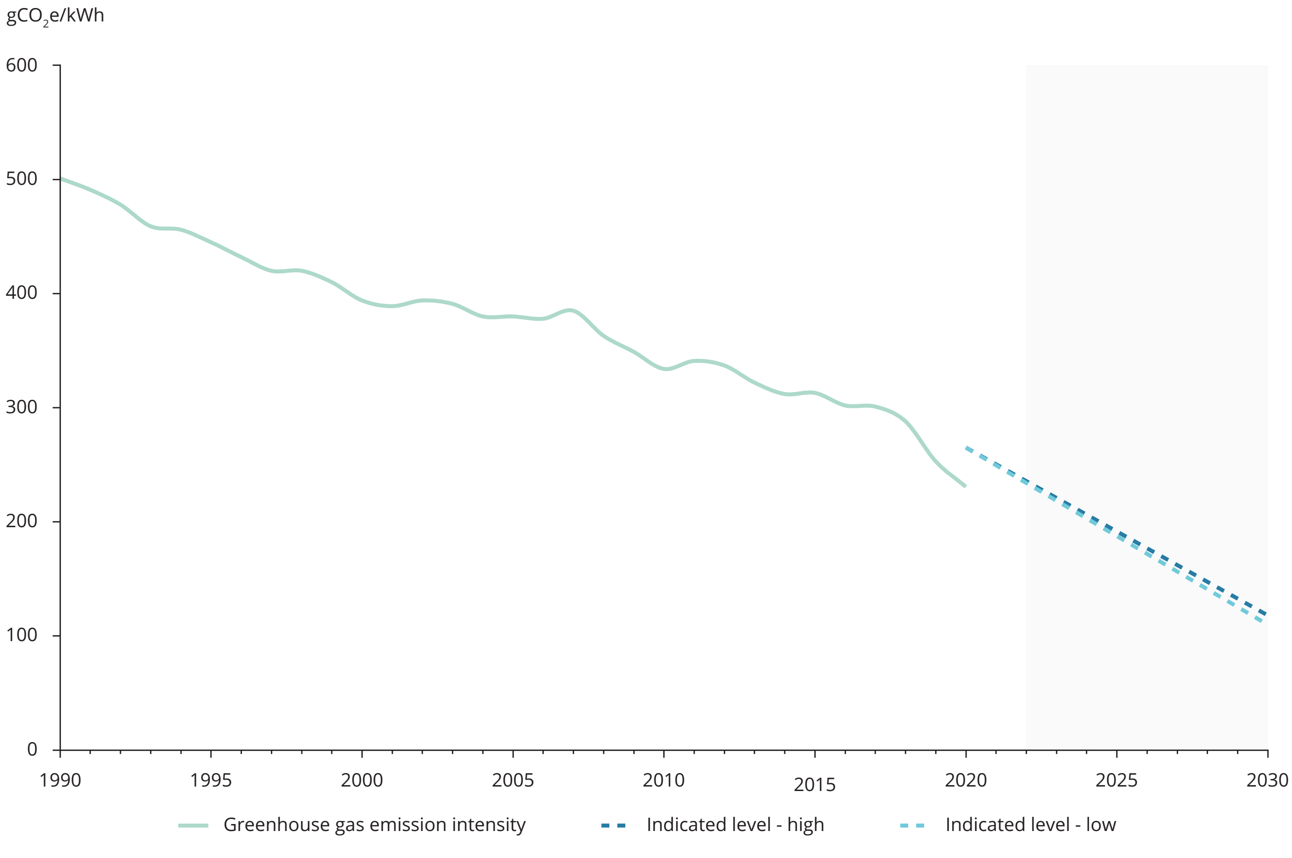
The GHG emission intensity of electricity generation at EU level can be used to assess the GHG intensity of electricity used in road transport. This electricity is used by electric vehicles, and thus constitutes WTT emissions related to those vehicles.

According to EEA (2021e) the GHG emission intensity of total electricity generation in the EU-27 was 231 g CO_2e/kWh in 2020, which is about half the intensity in 1990 (501 g CO_2e/kWh).

Since 2010, the transition from fossil fuels to renewable fuels in electricity generation has been the main factor behind this positive development. For the EU to achieve a net 55% reduction in GHG emissions by 2030, compared with 1990, the emission intensity of electricity generation should be in the indicative range of between 110 and 118 g CO_2e/kWh (Figure 6.8).

As the share of electric vehicles increases in the future, the carbon intensity of electricity generation will also become increasingly relevant to the assessment of the full climate impact of road transport.

Figure 6.8 GHG emission intensity of electricity generation in the EU-27



Note: Indicative values for 2030 consistent with scenario ranges in the Staff Working Document accompanying the Fit for 55 policy package.

Source: EEA (2021e).

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7
Looking to the future

Key messages

- **With the current policy framework, it is projected that carbon dioxide emissions from road transport in the EU will decrease by 35% by 2050 (compared with 1990). The decrease will be largely driven by the increased efficiency of vehicles, including a shift to electric vehicles. Transport demand is projected to increase, and modal shift to have a limited effect on emissions.**
- **However, the projected driving factors of future reductions in emissions by themselves will not have the same effect on other impacts on the environment, such as noise and non-exhaust air pollutants, congestion, biodiversity loss and resource use.**
- **To ensure that greenhouse gas (GHG) emissions from road transport are significantly reduced and other impacts are also minimised, factors that have so far driven GHG emissions upwards could be harnessed to reduce the GHG impact of the road transport sector.**

7.1 Future development of CO_2 emissions

The *EU Reference Scenario 2020* (EC, 2021e) projects a decrease in carbon dioxide (CO_2) emissions from road transport of 35% by 2050 compared with 1990. What underlies this projected change and how does this relate to the driving factors explored in the decomposition analysis?

7.1.1 Transport demand will continue increasing

In 2020, passenger and freight transport volumes dropped as a result of the pandemic. In the period after 2020 the *EU Reference Scenario 2020* projects a rebound in passenger and freight transport volumes by 2025 and a further increase afterwards. Compared with 2015, the number of passenger-kilometres travelled by road/rail is forecast to be about 13% higher in 2030, and **27.4% higher in 2050**. For inland freight transport, the scenario forecasts a rise of 31% by 2030 compared with 2015, and an **increase of 55% by 2050**, in terms of tonne-kilometres.

Overall transport activity will continue increasing; hence, other factors will be needed to reduce emissions. CO_2 emissions are projected to fall by 2050, as the upwards surge in road transport activity is expected to be more than compensated by counteracting factors.

Modal shift will have a limited impact. The passenger car transport share in road/rail transport is projected to fall to **78.1% in 2050** (compared with 78.8% in 2005)**,** mainly to the benefit of rail, the share of which would increase to 11.3% by 2050 (compared with 6.5% in 2015). This is the consequence of higher costs for road transport (both monetary costs and congestion costs), in combination with improved rail services.

In terms of the heavy goods vehicle (HGV) share in freight transport, the rail share is projected to grow (20% in 2050 compared with 17% in 2015) and that of the other inland transport modes to fall. While rail, inland navigation and national maritime transport are all set to benefit from the completion of the Trans-European Transport Network core and comprehensive networks, rail is projected to benefit the most.

Energy efficiency will be a key factor in reducing emissions**.** Vehicle energy efficiency is projected to increase, driven by vehicle efficiency standards. This is projected to lead to a reduction in road transport energy use of 15% by 2030 and 33% by 2050, compared with 2005. The higher energy efficiency is realised by improvements in vehicles with an internal combustion engine (ICEVs) and also by the electrification of vehicles, which is expected to grow faster in the coming decade.

Electrification will have an increasing effect. With existing policies, the share of electricity in road transport is projected to reach 2.7% in 2030 and 11.5 % in 2050. In terms of vehicle stock, the scenario projects that the electric vehicle (EV) share in the stock of light-duty vehicles would reach 16% by 2030 and 53% by 2050. The electrification of heavy-duty vehicles is expected to remain limited, reaching only about 4% of vehicle stock in 2050.

Biofuels are projected to have a limited impact. The *EU Reference Scenario 2020* projects that biofuels and biomethane would constitute 6.8% of all transport fuels (excluding hydrogen and electricity) in 2030 and in 2050 (EC, 2021e) ([8]).

Together these counteracting factors are expected to lead to a reduction in CO_2 emissions by 2050, despite the increase in transport demand.

7.2 Future of sustainable road transport

7.2.1 Impact of vehicle efficiency improvements on other environmental aspects of transport

The projected electrification of the road vehicle stock, together with the increasing role of renewable fuels and electricity are expected to play an important role in the future decarbonisation of road transport. Using 'improve' strategies has some co-benefits for other environmental aspects aside from decarbonisation, but some important environmental impacts remain. Therefore, while the expected switch to EVs and more efficient ICEVs will significantly reduce the CO_2 emissions of road transport, it will not have the same effect on other environmental impacts. Major environmental externalities related to road transport include air pollution, noise, congestion, land uptake and biodiversity loss, as well as resource use.

For air pollution and noise, electrification provides a partial solution. **Exhaust emissions of air pollutants** will be reduced significantly with the expected electrification of the EU vehicle stock in the coming decades. Battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs) eliminate all exhaust emissions, and plug-in hybrid electric vehicles (PHEVs) eliminate emissions during their electric driving phase. Still, **non-exhaust emissions** remain an issue. Tyre, brake and road surface wear and tear cause particulate matter (PM) emissions that are harmful to human health and are an important source of heavy metals and microplastics in the environment. These non-exhaust PM emissions are steadily increasing on a par with increasing transport demand and have already overtaken exhaust PM emissions in importance.

Road traffic is the most important source of **noise pollution** (EEA, 2019c). Noise pollution affects quality of life and can lead to major health problems. The projected increase in road transport volumes might thus also increase the impacts of noise pollution. More efficient ICEVs do not address this issue. Although at low speeds EVs are almost silent, at speeds above 25 km/h they do produce noise through tyre/road interaction (Umweltbundesamt, 2013). By 2050, the increased share of EVs could lead to a limited reduction in road traffic noise (EC, 2020b).

Other environmental impacts relate to the **road transport infrastructure**. The land taken for roads and parking places leads to **fragmentation of ecosystems and biodiversity loss**. It also puts the quality of life in urban areas under pressure. Half of European inner-city land is devoted to roads and parking (Ellen MacArthur Foundation, 2019). This reduces the opportunities for cities to become more resilient to climate change by limiting the space available for more green areas and blue networks. Impacts related to land uptake and biodiversity loss are not expected to benefit from the electrification and improved efficiency of vehicles, as they require the same road and parking infrastructure.

In terms of congestion, the focus on 'improve' strategies alone will not lead to an improvement. In both the *EU Reference Scenario 2020* with existing policies and the policy scenarios developed by the European Commission (EC, 2021e), road transport volumes and related **congestion costs are expected to increase**. This problem is not mitigated by EVs (or more efficient ICEVs) and, depending on the impact of the electrification on the driving costs, could even be exacerbated by them.

Finally, there are **environmental impacts related to the life cycle of vehicles**, from mining, refining and manufacturing to waste disposal. Life cycle analysis studies indicate that BEVs have a smaller climate impact than ICEVs and that this advantage increases with the share of renewable electricity (Del Pero et al., 2018; EEA, 2018; IEA, 2019a; Bieker, 2021)light duty vehicles are responsible for roughly 10% of total energy use and air emissions. As a consequence, the need for higher fuel/energy efficiency in both conventional and electric cars has become urgent and the efforts across industrial and research players have proposed a range of innovative solutions with great potential. This study presents a comparative Life Cycle Assessment of Internal Combustion Engine (ICE. However, other environmental impacts may be higher for BEVs than for ICEVs. Research on these impacts is less extensive than for the climate impacts. However, it cannot be taken for granted that BEVs perform better than ICEVs for all non-climate impacts

([8]) Excel spreadsheets accompanying the EU Reference Scenario 2020 report.

(EEA, 2018). For example, the life cycle analysis study by Del Pero et al. (2018) light duty vehicles are responsible for roughly 10% of total energy use and air emissions. As a consequence, the need for higher fuel/energy efficiency in both conventional and electric cars has become urgent and the efforts across industrial and research players have proposed a range of innovative solutions with great potential. This study presents a comparative Life Cycle Assessment of Internal Combustion Engine (ICE points out that impacts such as resource depletion, acidification, human toxicity or air pollution may be higher for BEVs than ICEVs, mainly because of the environmental impacts occurring during vehicle manufacture. These impacts can be mitigated, as decarbonisation and other environmental policies also affect manufacturing processes, encouraging more environmentally friendly practices.

In addition, **rebound effects** are a challenge for 'improve' policies in transport, as for any policy promoting efficiency, both material and energy efficiency (IRP, 2020). For instance, enhancing logistic efficiency will reduce the cost of freight transport and hence increase the demand for it. Subsidies for more efficient cars and the greater fuel efficiency of cars will reduce the cost per vehicle-kilometre and hence increase travel distances. The rebound effect can also work via income: the money saved as a result of greater efficiency is spent on other forms of consumption, including trips. There is also a location effect: people might choose to live in a more remote location, further from their place of employment. Finally, the latent demand contributes to rebound effects in road transport: people scared off by high levels of congestion will again travel by car if congestion levels are reduced.

7.2.2 Comprehensive approach to road transport decarbonisation

Making the vehicle fleet electric and more efficient is an effective way to contribute to decarbonisation and has some co-benefits for other environmental aspects of road transport. However, challenges with rebound effects and other environmental impacts mean that the extent of their contribution to other aspects of sustainable road transport is limited. Important contributions to reductions in greenhouse gas (GHG) emissions could also come from changes in transport demand and modal shifts, which would also reduce the other environmental impacts of road transport.

For example, emissions could be limited by a reduction in the number and/or length of passenger trips, by improving load factors, or by a modal shift to less polluting transport modes. From the point of view of material use, individual car transport is not efficient. On average, a European car has a utilisation rate of only 2%. This value is obtained considering that 92% of the time it is parked, standing still in traffic jams or searching for parking spots, and is used by only 1.5 passengers on average (SYSTEMIQ and The Club of Rome, 2020). Circular strategies can contribute to improving this. The United Nations Environment Programme International Resource Panel (IRP, 2020) found that, of all circular strategies, the largest reductions in life cycle GHG emissions can be attained by improving material efficiency on the consumption side through car- and ride-sharing and a shift towards smaller vehicle sizes. Shared vehicle fleets allow people to consider alternative means of transport (such as electric bikes (e-bikes) or e-cargobikes) and to choose trip-appropriate vehicle sizes. Shared rides mean increasing the occupancy rate of vehicles, thus reducing the number of vehicles on the road.

In the future it will be important to manage transport demand so that it does not make decarbonising transport difficult. For example, in the case of automated transport, without additional policies the ease of travelling could lead to a large increase in transport demand (Franckx, 2021). This would have implications for the amount of renewable electricity that is needed for transport and therefore also for the electricity market as a whole. On the other hand, a larger uptake of shared vehicles could make it easier to manage the problem of finding enough raw materials for EV batteries if it leads to fewer cars per capita (Harris et al., 2021).

It can be concluded that, in addition to more efficient vehicles and fuels, **other measures contributing to sustainable road transport are needed**. The whole avoid-shift-improve framework needs to be harnessed. As stated in *The European environment — state and outlook 2020* (EEA, 2019c): 'the fundamental issue is not how to create a more sustainable car, but rather how to meet society's need for point-to-point mobility and, perhaps more fundamentally, for social interaction and access to goods and services. Transition for sustainable mobility will require innovations and changes in social norms, values and lifestyles.' International institutions such as the Organisation for Economic Co-operation and Development (OECD, 2020) and the International Resource Panel (IRP, 2020) recommend combining efficiency policies with policies that optimise demand, such as taxes, road pricing or cap-and-trade programmes to avoid strong rebound effects. Considering all road transport externalities, the OECD promotes a broader approach, with optimising the vehicle-kilometres travelled a key component of the transport policy mix, especially in urban areas.

The combined move towards clean vehicles and fuels, together with other policy measures, will not only contribute to faster reductions in GHG emissions and external costs of road transport but also to a better quality of life in cities and neighbourhoods, with low-traffic streets enhancing social cohesion, more accessible transport for all and strengthened local economies.

Abbreviations, symbols and units

ACEA	European Automobile Manufacturers' Association
AFID	Alternative Fuel Infrastructure Directive
ASI	Avoid, shift, improve
BEV	Battery electric vehicle
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COVID-19	Coronavirus disease 2019
EEA	European Environment Agency
EAFO	European Alternative Fuels Observatory
EPBD	Energy Performance of Buildings Directive
ETS	Emissions Trading System
EU-27	27 Member States of the European Union
EV	Electric vehicle
FCEV	Fuel cell electric vehicle
FQD	Fuel Quality Directive
GHG	Greenhouse gas
HDV	Heavy-duty vehicle
HGV	Heavy goods vehicle
HVO	Hydrotreated vegetable oil
ICEV	Internal combustion engine vehicle
ILUC	Indirect land use change
kW	Kilowatt
kWh	Kilowatt hour
LCA	Life cycle analysis
LPG	Liquefied petroleum gas
LULUCF	Land Use, Land-Use Change and Forestry
MJ	Megajoule
Mt	Million tonnes
N_2O	Nitrous oxide
NECP	National Energy and Climate Plan

NEDC	New European Driving Cycle
NO_x	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
PHEV	Plug-in hybrid electric vehicle
PJ	Petajoule
PM	Particulate matter
R&D	Research and Development
RED	Renewable Energy Directive
SUV	Sport utility vehicle
TTW	Tank-to-wheel
WLTP	World Harmonised Light Vehicle Test Procedure
WTT	Well-to-tank
WTW	Well-to-wheel
ZLEV	Zero and low emission vehicle

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Annex 1
Approach used for the decomposition analysis

General methodology used for the decomposition analysis

The decomposition analysis presented in Chapter 3 uses the logarithmic mean Divisia index (LMDI) method, as used in previous analyses (EEA, 2015, 2019a). More details on the approach can be found in Ang (2004, 2005).

For the analysis for CO_2 emissions from passenger cars, the LDMI is based on the following equation:

$$CO_{2,cars} = Pkm_{all} \cdot \frac{Pkm_{cars}}{Pkm_{all}} \cdot \frac{Energy_{Car\ transport}}{Pkm_{all}} \cdot \frac{Energy_{Fuels,cars}}{Energy_{Car\ transport}} \cdot \frac{Energy_{FF,cars}}{Energy_{Fuels,cars}} \cdot \frac{CO_{2,cars}}{Energy_{FF,cars}}$$

Parameter description:

- $CO_{2,cars}$ — the CO_2 emissions from car transport.
- Pkm_{all} — passenger transport activity — the number of passenger-kilometres travelled by the following passenger transport modes: passenger cars, powered two-wheelers, bus and coach, railway, tram and metro. While the last three modes do not have exhaust emissions, they are included, as this allows the evolution of the modal shares in the decomposition analysis to be taken into account.
- Pkm_{cars}/Pkm_{all} — modal share — the share of passenger-kilometres travelled by car in overall passenger transport activity.
- $Energy_{Car\ transport}/Pkm_{cars}$ — energy efficiency — the energy consumption per car passenger-kilometre, i.e. energy efficiency.
- $Energy_{Fuels,cars}/Energy_{Car\ transport}$ — effect of electrification — the share of non-electric energy (fuels) in the energy consumption of car transport. The Eurostat data set reports total electricity consumption by road transport and does not make a distinction between different vehicle types. Therefore, the effect of electrification is estimated by assuming that all electricity for road transport, as reported by Eurostat in the energy balances, is used by passenger cars. This is an over-estimation, as it does not consider the energy used by electric buses and other road vehicles.
- $Energy_{FF,cars}/Energy_{Fuels,cars}$ — biofuel effect — expressed as the fossil fuel share. Biofuels are taken to be carbon neutral.
- $CO_{2,cars}/Energy_{FF,cars}$ — carbon intensity of fossil fuels — the CO_2 emissions per unit of fossil fuel used by passenger cars. This carbon intensity factor is a weighted average of the emission factors of the different fossil fuels included in the greenhouse gas (GHG) emission inventory. The weights are the share in the fossil fuel consumption of the following fuels: petrol, diesel oil, liquefied petroleum gas, gaseous fuels and other fossil fuels.

For the decomposition analysis of the CO_2 emissions by heavy goods vehicles (HGVs) a similar equation is used:

$$CO_{2,HGV} = Tkm_{all} \cdot \frac{Tkm_{HGV}}{Tkm_{all}} \cdot \frac{Energy_{HGV\ transport}}{Tkm_{HGV}} \cdot \frac{Energy_{Fuels,HGV}}{Energy_{HGV\ transport}} \cdot \frac{Energy_{FF,HGV}}{Energy_{Fuels,HGV}} \cdot \frac{CO_{2,HGV}}{Energy_{FF,HGV}}$$

with the following parameters:

- $CO_{2,HGV}$ — the CO_2 emissions of heavy goods vehicles.
- Tkm_{all} — freight transport activity — the number of tonne-kilometres travelled by the following freight transport modes: inland waterway, railway and road transport. In comparison with the decomposition analysis in EEA (2015) light-duty trucks (<3.5 tonnes) were not considered in the total demand because insufficient data were available.
- Tkm_{HGV}/Tkm_{all} — the modal share — the modal share of HGVs (>3.5 tonnes).
- $Energy_{HGV\ Transport}/Tkm_{HGV}$ — energy efficiency — energy consumed per freight transport tonne-kilometre by HGVs.
- $Energy_{FF,HGV}/Energy_{HGV\ transport}$ — biofuel effect — the share of fossil fuels in the energy consumption of HGVs. Biofuels are assumed to be climate neutral.
- $CO_{2,HGV}/Energy_{FF,HGV}$ — carbon intensity of fossil fuels — the CO_2 emissions per unit of fossil fuel used by HGVs.

In the period 2000-2019 the number of electric HGVs was still very small. Therefore, this factor was not considered in the decomposition analysis for HGVs.

In the GHG emissions inventory, emissions of heavy-duty trucks are reported together with the emissions of buses and coaches (collectively attributed to entry 'heavy-duty vehicles'). Historical data for the years 2005, 2010 and 2015, which underpin the *EU Reference Scenario 2020* (EC, 2021e), were used to determine the share of HGVs in the energy consumption and emissions of HDVs. For the intermediate years, the shares were interpolated. For the period before 2005, the share is taken to be the same as in 2005, and for the period after 2015 the share of 2015 is applied. Because of these assumptions, the analysis for HGV is subject to more uncertainty than that for passenger cars.

For both passenger cars and heavy goods vehicles, the decomposition analysis was also conducted for emissions of methane (CH_4) and nitrous oxide (N_2O), weighted by their global warming potential: 25 for CH_4 and 298 for N_2O. The analysis used a similar methodology as used in the case of the CO_2 emissions. However, the biofuel share was not considered as a factor because the GHG emissions inventory also takes into account the CH_4 and N_2O emissions related to biomass in the GHG emissions from road transport.

Data sources

The decomposition analysis was carried out for the period 2000-2019, for the 27 Member States of the EU. Table A1.1 gives an overview of the data sources that were used for the decomposition analysis.

Table A1.1 Data sources for the decomposition analyses

Parameter	Symbol	Data source
Decomposition analysis: passenger cars		
GHG emissions from passenger cars (CO_2, CH_4 and N_2O)		Greenhouse gas emissions inventory (EEA, 2021d)
Total inland passenger-kilometres	Pkm_{all}	Statistical pocket book 2021 (EC, 2021f)
Total car passenger-kilometres	Pkm_{cars}	Statistical pocket book 2021 (EC, 2021f)
Energy consumption by passenger cars	$Energy_{Car\ transport}$	Eurostat, complete energy balances (Eurostat, 2021)
Non-electric energy consumption (fuels) by passenger cars	$Energy_{Fuels,cars}$	Greenhouse gas emissions inventory (EEA, 2021d)
The consumption of fossil fuels by passenger cars	$Energy_{FF,cars}$	Greenhouse gas emissions inventory (EEA, 2021d)

Table A1.1 Data sources for the decomposition analyses (cont.)

Decomposition analysis: heavy goods vehicles		
GHG emissions from heavy goods vehicles (CO_2, CH_4 and N_2O)		Greenhouse gas emissions inventory (EEA, 2021d) ([a])
Total inland freight transport (tonne-km)	Tkm_{all}	Statistical pocket book 2021 (EC, 2021f)
Total tonne-km transported by heavy goods vehicles	Tkm_{HGV}	Statistical pocket book 2021 (EC, 2021f)
Energy consumption by heavy goods vehicles	$Energy_{HGV}$	Greenhouse gas emissions inventory (EEA, 2021d) ([a])
The consumption of fossil fuels by heavy goods vehicles	EnergyFF,HGV	Greenhouse gas emissions inventory (EEA, 2021d) ([a])

([a]) The share of emissions and energy consumption by HGVs in the emissions and energy consumption of the category heavy-duty trucks/ buses in the GHG emission inventory is based on EC (2021e).

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