Used vehicle trade and fleet composition in Europe

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Final report

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Information about the contract

This document is the final report of the project “Used vehicle trade and fleet composition in Europe” carried out by Ecologic Institute and Fraunhofer ISI from August 2019 to February 2020 on behalf of the European Environment Agency (EEA) within the framework service contract EEA/ACC/18/001/LOT1 with a funding of 49,900.00 €.

Executive summary

Road transport constitutes a major challenge for European countries as road vehicles' air pollutant and CO_2 emissions significantly contribute to local air pollution and to the climate crisis. The characteristics of a vehicle such as age, engine type, size, and power, and the mass have a strong impact on its CO_2 and air pollutant emissions. However, we know relatively little about the characteristics of used vehicles that make up the current vehicle stock and trade between European countries. Only newly registered vehicles are subject to monitoring and environmental regulation with respect to air pollutant and CO_2 emissions. There is no framework (beyond the road-worthiness testing and Regulation 715/2007 requiring manufacturers to check in-service conformity for a period of up to five years or 100,000 km) to limit environmental impacts of used vehicles when re-registered after purchase by another owner as well as imported and exported vehicles.

This report estimates the environmental impact of used vehicles in Europe and those that are traded within Europe focusing on air pollutants and CO_2 emissions. It covers the European Union (EU) Member States, the additional EEA member countries which are Iceland, Lichtenstein, Norway, Switzerland and Turkey as well as the cooperating countries Albania, Bosnia and Herzegovina, Montenegro, North Macedonia and Serbia as well as Kosovo under UN Security Council Resolution 1244/99.[1] The report also covers the United Kingdom, as the data used predates its withdrawal from the European Union. Data collection focussed on publically available Europe-wide central data sources as well as on national data sources containing information about the characteristics of vehicle stocks and used vehicle trade for the time period from 2000 to latest available data.

Key findings

Overall improvement of the environmental performance of used vehicles

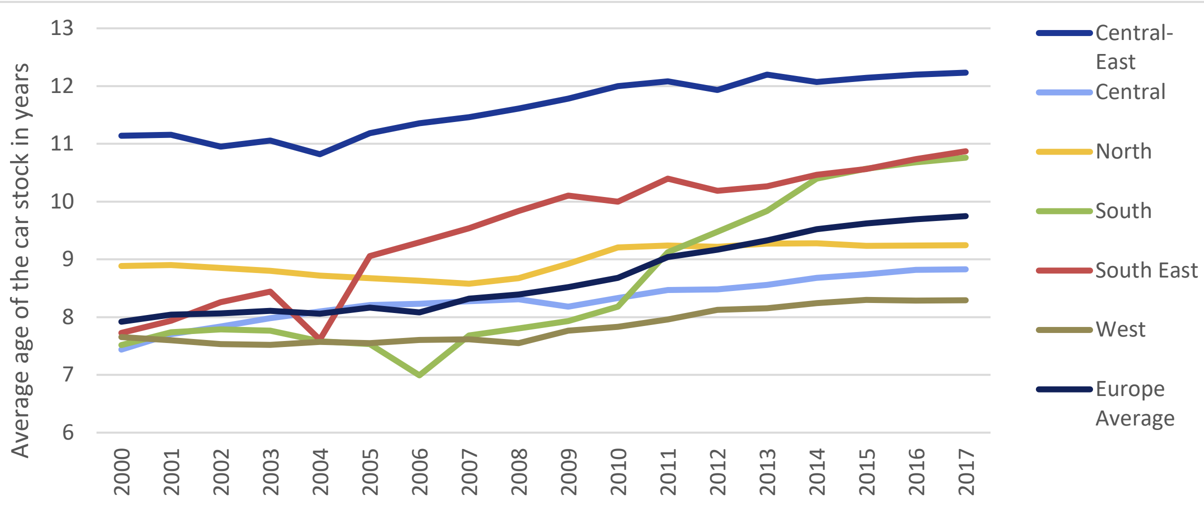
Since 2000, the vehicle stocks of all European countries increased in size as well as the used vehicle trade within Europe increased in terms of numbers and value. In countries with a rapid economic growth like Poland, Czechia and Estonia, the increase of stocks was especially pronounced. Although the average age of the vehicle stocks increased overall, the environmental performance of the vehicles in the stocks and traded used vehicles improved with respect to air pollutants and CO_2 emissions. This can be traced back to EU regulations and in most countries also national regulatory frameworks including taxation which favour environmental friendly vehicles over environmental harmful vehicles as well as to a technological progress reducing the specific energy consumption as well as air pollutants and CO_2 emissions. For instance, more than half of the analysed countries consider the air pollutants and/or CO_2 emissions in the calculation method of their registration tax. In addition, some countries such as Bosnia and Herzegovina, Finland, Hungary, Serbia and Turkey also introduced import bans for old vehicles or for vehicles with particularly high air pollutants.

[1] This designation is without prejudice to positions on status, and is in line with UNSCR 1244/99 and the ICJ Opinion on the Kosovo Declaration of Independence.

Regional differences remain in the stocks and used vehicle trade

Besides the overall progress, regional differences of the environmental performance of vehicles in the stocks and in the trade flows of used vehicles remain with high income countries having on average relatively new vehicles with comparably lower air pollutants and CO_2 emissions and low income countries having rather old vehicles with comparably higher air pollutants and CO_2 emissions (see Figure 1). This is also reflected in the trade flows with high income countries exporting more used vehicles than they import while at the same time importing rather environmental friendly vehicles and exporting vehicles with rather high air pollutants and CO_2 emissions (see Figure 2).

Figure 1: Age of the car stocks



Source: own calculations based on Eurostat, 2019a.

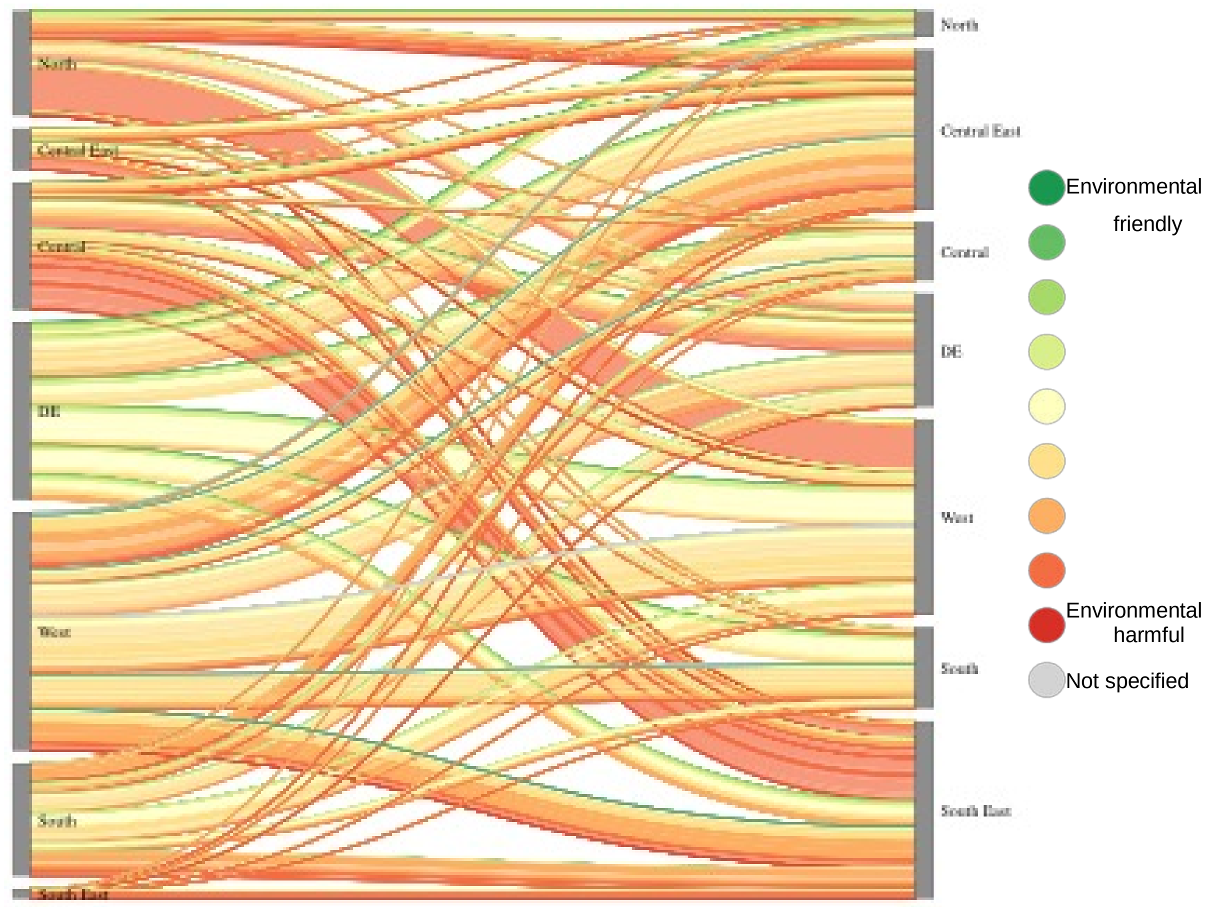
The **Northern, Central and Western country groups**[2] have the most environmental friendly vehicle stocks, with vehicles having on average the lowest air pollutants and CO_2 emissions. The countries have a much higher share of new vehicles and have a comparably younger vehicle stock when compared to the European average. In these countries, the impact of regulations for new vehicles have a much stronger and direct impact on the vehicle fleet. One exemption is Finland as the country has one of the oldest vehicle stocks with an average of 11.5 years. Imports of used vehicles play a crucial role in that country as it imported the most significant number of used cars when compared to the stock.

The relatively high share of new vehicles also results in the fact that the Northern and Central country group exported much more used vehicles than they imported (for trade flows in 2017 see Figure 2); the trade surplus was less pronounced for the Western country group. All three country groups exported lower-value vehicles classified with a low environmental performance while they imported higher-value vehicles with a relatively good environmental performance. The vehicles exported by the Northern country group with particularly high CO_2 emissions were sold to the

[2] The Northern country group consists of Denmark, Finland, Norway, Sweden and Iceland.
The Western country group consists of Belgium, France, Ireland, the Netherlands and UK.
The Central country group consists of Austria, Germany, Liechtenstein, Luxembourg, Slovenia and Switzerland.

Central Eastern country group[3] while vehicles with particularly high air pollutants (i.e. diesel vehicles with a very low value) went to the Western country group. The Central country group exported mainly large diesel passenger cars with a low average trade value and therefore with particularly high air pollutants to the South-Eastern group. The Western country group exported its used vehicles basically to all country groups while it imported rather environmental friendly used vehicles, in particular in terms of CO_2 emissions. The vehicles came mainly from within its group followed by Germany and the Northern country group. For instance, Germany exported a large share of diesel vehicles with a medium engine capacity and an average trade value between EUR 15,001 and EUR 20,000 while a large share of low-value diesel vehicles came from the Northern country group with particular high air pollutants.

Figure 2: Amount and environmental performance of traded used vehicles in Europe in 2017



Source: own calculations based on Eurostat Comext (2019). The figure shows the trade flow from exporting to importing country groups. The width of arrows reflects the amount of traded used vehicles; the colours reflect the environmental performance as an average for CO_2 emissions and air pollutants; green lines indicate the trade of electric vehicles which have no direct air pollutants and CO_2 emissions while on contrast red lines indicate the trade of vehicles with high air pollutant and CO_2 emissions i.e. low-value diesel or petrol vehicles with a large engine.

[3] The Central Eastern country group consists of Czechia, Hungary, Poland and Slovakia as well as of the Baltic countries Estonia, Latvia and Lithuania.

Vehicles in the **South-Eastern, Central-Eastern and Southern**[4] country groups have particularly high air pollutants and CO_2 emissions when compared to the other country groups. Their vehicle stocks consists of vehicles with an average age of above 11 years and the share of new vehicles is particularly low. The means that in 2017, most of the vehicles originated from years before significant improvements of EU regulation for limiting air pollutants and CO_2 emissions from new vehicles.

The South-Eastern and Central-Eastern country groups imported much more vehicles than they exported – the vehicles mainly from the Western and Central (incl. Germany) country groups. For instance, a large amount of more environmental friendly vehicles is imported from Germany. The vehicles imported to the South-Eastern country group have a very low environmental performance while the vehicles imported to the Central Eastern country group perform better in terms of air pollutants and CO_2 emissions. Some of the countries in the South-Eastern country group addressed the problem of imports of vehicles with particularly high air pollutants by introducing a ban on imports of old vehicles and vehicles with low European emission standard for air pollutants such as Bosnia-Herzegovina, Serbia or Turkey.

Factors influencing the environmental performance of used vehicles in stocks and trade

One of the key factors for the differences in the stocks and trade of used vehicles is the available household income which differs significantly between the country groups but which determines what a household is able to pay for a vehicle. In addition, national regulations and taxation schemes can influence the purchasing decision e.g. when the registration tax rapidly increases as a function of rising air pollutants and/or CO_2 emissions, thus somewhat closing the financial gap between a low-value but environmental harmful vehicle and a higher-priced vehicle with better environmental performance.

Import bans on old or on vehicles with low European emission standard (i.e. high air pollutants), however, did not lead to the import of higher-value vehicles in Serbia, Bosnia-Herzegovina or Hungary. It might be the case that for those countries the underlying assumption that low-value vehicles have high emissions is not valid but that these countries in particular import vehicles having a low price but still a medium emission intensity (e.g. because of high kilometre driven or other drawbacks of a vehicles reducing its price). However, further research is required to better understand the influences of the import ban on the vehicle stock.

A new important driver is also the introduction of electric vehicles which do not directly emit air pollutants nor CO_2. Although the market for electric vehicles is relatively new and hence, the share of used electric vehicles is still small, the increasing share of electric vehicles in the sales of new cars since 2010 also improves the environmental performance of the vehicle stocks. In addition, these vehicles also enter the used vehicle market and trade statistics show that the electric vehicles are also traded amongst the country groups with a somewhat rising share over the past five years. In 2017, these vehicles were traded amongst all country groups without clear direction. The stock as well as the trade of electric vehicles is likely to increase as a result of the European CO_2 targets for new vehicles and national plans to ban the sale of new internal combustion engine cars in e.g. Norway, the Netherlands, Ireland, Slovenia, France and the UK (see e.g. Velten et al. 2019). The

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[4] The South-Eastern country group consists of Albania, Bosnia and Herzegovina, Bulgaria, Cyprus, Greece, Montenegro, North Macedonia, Romania, Serbia, Turkey and Kosovo under UN Security Council Resolution 1244/99
The Southern country group consists of Croatia, Italy, Malta, Portugal and Spain

increase of new zero-emission vehicles in the market will also result in the increased availability of these vehicles to used vehicle buyers. This also means that country groups with a high share of used vehicle imports also start to import zero-emission vehicles. This means that irrespectively of the vehicle age, the countries can improve the environmental performance of their vehicle stocks.

Data gaps

The available statistics from Eurostat as well as from national sources are partly incomplete, inconsistent and not sufficient to allow an in-depth and detailed analysis of the environmental compatibility of used vehicles in the different European countries over the defined timeframe. This was partly unexpected as the transport sector, and particularly road transport are at the heart of current discussions to mitigate the climate crisis and local air pollution.

In particular, our data collection showed that there is no comprehensive data available from Eurostat and from national sources on the environmental characteristics of vehicles. Data on air and CO_2 emissions of the vehicle stock or of traded vehicles is only available for a few countries. A drawback is also that Eurostat provides characteristics largely independent from each other e.g. no combination of engine type and age structure. The databases include breaks in reporting and a range of countries does not report regularly for all (sub)indicators, and report data that is not consistent over the time period covered. Finally, the trade statistics (Eurostat Comext) do not include all vehicle imports and exports as reporting countries can exempt small- and medium enterprises (SMEs) from the reporting. The data compilation included a synthesis of available data sources where possible to close data gaps and reduce inconsistencies over the timeframe. Any further missing data for specific years in a time series were closed by linear interpolation over a related time frame. We also corrected obvious inconsistencies such as the reporting of full numbers instead of thousand. We could, however, not fill in gaps related to a whole characteristic, such as the age structure.

Due to missing data, we had to derive the environmental characteristic (i.e. air and CO_2 emissions) of the stock and trade of used vehicles based on the available characteristics. For the stock, we used the engine type and capacity as well as the age structure; for trade, we used the engine type and capacity as well as the average value of the traded vehicles in any given subcategory. For the stock, we thus also had to combine available age structures and engine types (including capacity where available). The classification of a vehicle in terms of its air pollutant and CO_2 emissions is based on a 10 scale, ranking the vehicles from 1 (no emissions) to 10 (very high emissions) based on specific characteristics of the vehicle such as engine type, age, average trade value and engine size.

Due to the data gaps and the applied methodology to derive the emission classification, the results are to be considered as rough estimates and are used for showing the general trends and order of magnitude. A more comprehensive database would facilitate the analysis of policy interventions that should have an effect on motorised road vehicles.

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1 Introduction

Road transport poses a major challenge for European countries as road vehicles' air pollutants and CO_2 emissions significantly contribute to local air pollution and to the acceleration of the climate crisis.

Age, engine type, capacity and power, and the mass of a vehicle have a strong impact on its CO_2 emissions and air pollutants (see e.g. EEA, 2019a). The age seems particularly important as EU regulations got stricter over the past decade setting targets for CO_2 emissions and maximum levels of air pollutants for new vehicles (see also Chapter 2.1.6). As these regulations only apply to new vehicles, they do not have an immediate impact on already used and the registration of used vehicles. In countries with a low share of new vehicle registrations each year, the current EU legislation can therefore only have a very limited or delayed impact.

In this context, previous studies[5] demonstrated that there are several EU Member States where imported used vehicles from other EU Member States far exceeded the number of new vehicles sales. However, there are no EU-wide criteria regarding the environmental performance of imported or exported used vehicles. Some European countries, however, have introduced specific legislation (see Chapter 4.1.3).

In order to achieve European and national climate targets and to reduce air pollution in the EU, it is thus crucial to understand a) the composition of the vehicle stock as well as b) the scale, directions and what types of vehicles are traded between European countries. This includes most importantly also the environmental friendliness of the vehicle stock and of the traded vehicles e.g. in terms of average air pollutants and CO_2 emissions per km driven. At present, there is however no EU-wide regulation or framework on the monitoring of existing or used vehicles environmental characteristics in the stock or trade. A monitoring procedure has been set up only for the registrations of new vehicles[6] and Eurostat[7] only collects more general vehicle characteristics.

In this context, this project aims at a better understanding of the environmental impact of the stock and trade of used vehicles in Europe with a focus on air pollutants and CO_2 emissions based on existing statistics for vehicle stocks and trade. Thus, a key part was the collection and compilation of respective available information from central and national sources (see Chapter 2). However, the data availability was limited so that the environmental characteristics of used vehicles had to be derived from available characteristics (see Chapter 3). The results are presented in Chapter 4 starting with a presentation of the regulatory background followed by the analysis for the stock and trade of used vehicles. We conclude with our findings in Chapter 5 focussing on options to reduce the emission intensity of the vehicle stocks.

[5] Öko-Institut et al. 2011; GFK and CE 2016

[6] For cars and vans: Regulation (EU) 2019/631 repealing Regulations (EC) No 443/2009 and Regulation (EU) No 510/2011; for busses and lorries: Regulation (EU) 2018/956

[7] The main role of Eurostat is the compilation, harmonisation and publication of European statistics which are collected and handed over by the European countries based on the Regulation (EC) No 223/2009 of the European Parliament and of the Council of 11 March 2009 on European statistics.

2 Data collection and compilation

Data collection focussed on vehicle characteristics such as age, engine type and capacity, mass, air pollutants and CO_2 emissions for Europe based on Europe-wide central data sources as well as on national data sources containing information about used vehicle stocks and trade.

2.1 Indicators to describe vehicle characteristics

The compilation and summary of data was carried out along the following indicators:

2.1.1 Countries

This indicator describes the respective countries where the corresponding vehicle stock is registered as well as the exporting and importing country for trade flows. The report covers the European Union (EU) Member States, the additional EEA 32 member countries which are Iceland, Lichtenstein, Norway, Switzerland and Turkey as well as the cooperating countries Albania, Bosnia and Herzegovina, Kosovo under UN Security Council Resolution 1244/99, Montenegro, North Macedonia and Serbia. The report also covers the United Kingdom, as the data used predates its withdrawal from the European Union. In the following, we refer to these countries as 'Europe'.

In order to give a better overview, the countries are merged into the following country groups:

Table 1: Overview on regions and countries and their abbreviation code covered by this report

Abb.	Name	Abb.	Name	Abb.	Name
Region: Central		***Region: Central-East***		***Region: North***	
AT	Austria	CZ	Czechia	DK	Denmark
CH	Switzerland	EE	Estonia	FI	Finland
DE	Germany	HU	Hungary	IS	Iceland
LI	Liechtenstein	LV	Latvia	NO	Norway
LU	Luxembourg	LT	Lithuania	SE	Sweden
SI	Slovenia	PL	Poland		
		SK	Slovakia		
Region: South		***Region: South-East***		***Region: West***	
ES	Spain	AL	Albania	BE	Belgium
HR	Croatia	BA	Bosnia and Herzegovina	FR	France
IT	Italy	BG	Bulgaria	IE	Ireland
MT	Malta	CY	Cyprus	NL	Netherlands
PT	Portugal	EL	Greece	UK	United Kingdom
		ME	Montenegro		
		MK	North Macedonia		
		RO	Romania		
		RS	Serbia		
		TR	Turkey		
		XK	Kosovo under UN Security Council Resolution 1244/99		

Source: own compilation of country groups; country abbreviations based on EEA (2020).

2.1.2 Year

This indicator describes the respective year for which the stock or trade is given. The report covers the period from 2000 to 2017 for the stock (for some also 2018/2019) and 2000 to 2018 for trade.

2.1.3 Vehicle class

This indicator describes the type of vehicle for which additional indicators are given. We use four categories which are passenger cars (i.e. M1-type vehicles) and busses (M2+M3) as well as vans (N1) and lorries and road tractors (N2+N3).

Table 2: Overview of vehicle classes covered by this report

Abb.	Full meaning
M1	Passenger car for the transport of maximum 8 persons in addition to the driver’s seat
M2+3	Passenger vehicle for the transport of at least 9 persons in addition to the driver's seat
N1	Goods vehicle with a mass of below 3.5 tons
N2+3	Goods vehicle with a weight of more than 3.5 tons

Source: Annex II of Directive 2007/46/EC on the definition of vehicle categories and vehicle types

As passenger cars (M1) represent the majority of motorised vehicles, the analysis in Chapter 4 focusses on this vehicle group. Nevertheless, busses and cargo vehicles also constitute an important lever for emission reduction because of their high mass and annual mileage.

In the report, we use the following wording for the different vehicles classes:

- vehicle: all vehicles of the classes M1 - M3 and N1 - N3
- car: only vehicles of class M1
- bus: only vehicles of classes M2 + M3
- van: only vehicles of class N1
- lorry (including road tractors): only vehicles of classes N2 - N3

2.1.4 Engine type

This indicator describes the respective engine type given as standard fuel type. We use five categories for the engine type including “Diesel”, “Petrol”, “Gas fuels”, “Electric” and “Other”. The categories “diesel” and “petrol” include also hybrids thereof. The category “Gas fuels” includes compressed natural gas (CNG), liquefied natural gas (LNG) and liquefied petrol gas (LPG; also called autogas). This category is determined by LPG-fuelled vehicles: in 2016, there were roughly 60 times more LPG-fuelled cars when compared to CNG/LNG; for vans and lorries, LPG is used roughly 3 and 2 times more, respectively. The category “Other” covers a variety of fuel types including for example not specified fuel types, hydrogen, bifuel and alternative.

2.1.5 Engine capacity

This indicator describes the respective cylinder capacity given in cubic centimetre (cc). We use here the same categories as Eurostat. The following table shows the categories for the different engine types:

Table 3: Overview of vehicle classes and related cylinder capacity

Vehicle class	Stock database Engine type [as fuel type] and capacity [in cc]	Trade database Engine type [as fuel type] and capacity [in cc]
M1	Diesel/Petrol: <1400; 1400 - <2000; >2000 Gas fuels/Electric/Other: n/a	Diesel: ≤1500; >1500 - ≤2500; >2500 Petrol: ≤1000; >1000 - ≤1500; >1500 - ≤3000; >3000 Other: n/a
M2+3	n/a	Diesel: ≤2500; >2500 Petrol: ≤2800; >2800
N1	n/a	Diesel: ≤2500; >2500 Petrol: ≤2800; >2800
N2+3	n/a	n/a

Source: Own compilation based on Eurostat (2019) and Eurostat Comext (2019).

2.1.6 Air pollutants and CO_2 emissions

These two indicators describe the environmental performance of the vehicles.

For air pollutants, vehicles are classified according to the European emission standard. For cars and vans, the standard defines the maximum amount of air pollutants per km for new approvals and new registrations for cars and vans (Regulation (EC) No 715/2007); for busses and lorries, the standard defines maximum values for the engine energy output (Regulation (EC) No 595/2009).

The EU introduced the first European emission standard in 1992 for cars and vans (generally referred to as Euro 1) as well as for busses and lorries (generally referred to as Euro I). Euro 1 for cars and vans required e.g. the complete switch to unleaded petrol and that all new cars have catalytic converters. Since 1992, the EU has added new air pollutants and tightened the maximum values. Important developments included the introduction of maximum values for particle numbers besides particulate mass with Euro 5b in 2011 for new approvals and 2013 for all new registrations and a significant reduction of the maximum values for nitrogen oxides (NO_x) from diesel cars and vans with Euro 6b in 2014 / 2015. For busses and lorries, a maximum value for particle number and a significant reduction of NO_x emissions was introduced with Euro VI in 2012 / 2013 (see e.g. AECC, 2019).

The current Euro 6d for cars and vans and Euro VI for busses and lorries includes maximum values for carbon monoxide (CO), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), nitrogen oxides (NO_x), particulate mass (PM) and particle number (PN). It does not include GHG emissions from vehicles.

The CO_2 emissions of vehicles are measured in grams CO_2 per km. The EU introduced a CO_2 target for new registered vehicles by setting targets for the car fleet of each car manufacturer (Regulation 443/2009) as well as for vans (Regulation (EU) No 510/2011); Regulation (EU) 2019/631 replaces both regulations setting new targets for the post-2020 period while also requiring a new testing method. Regulation (EU) 2019/1242 addresses new registered lorries and busses also setting an average CO_2 performance standard for the fleet of a manufacturer (see DG CLIMA, 2020). In this context, car manufacturers report on the newly registered vehicle's CO_2 emissions in each Member State since 2010 (see EEA, 2019b,c).

2.2 Data sources

Central and national data sources provide information about the characteristics of vehicles in a country's vehicle stock and in trade; however, information about environmental characteristics are largely missing. An overview is given in the following.

2.2.1 Stock data

The main **central source** of information for European countries is Eurostat.[8] For vehicle stock, Eurostat provides a range of databases covering a range of vehicles' characteristics (see Table 4) for the EU Member States, the additional EEA member countries and partly also for the cooperating countries. The databases, however, include breaks in reporting and a range of countries do not report regularly for all (sub)indicators or report data that is not consistent over the time period covered. In addition, data for most indicators is not connected so that there is, for example, no combination of engine type and age structure available. Finally, most important indicators to assess the environmental impact of the vehicle stock (i.e. air pollutants and CO_2 emissions) are not available at all.

Table 4: Eurostat data coverage for the stock of vehicles

Eurostat databases	Vehicle class	Characteristics	Time period
road_eqs_carmot	M1	Engine type (only diesel and petrol) and engine capacity	Up to 2017
road_eqs_caralt	M1	Engine type	Up to 2012
road_eqs_carpda	M1	Engine type	2013 - 2017
road_eqs_carage	M1	Age classes	Up to 2017
road_eqs_unlweig	M1	Mass	Up to 2017
road_eqs_busmot_h	M2-3	Engine type	Up to 2012
road_eqs_busmot	M2-3	Engine type	2013 - 2017
road_eqs_busage	M2-3	Age classes	Up to 2017
road_eqs_lormot_h and road_eqs_roaene_h	N1-3	Engine type	Up to 2012
road_eqs_lormot and road_eqs_roaene	N1, N2-3	Engine	2013 - 2017
road_eqs_lorroa_h	N1-3	Age classes	Up to 2012
road_eqs_lorroa	N1, N2-3	Age classes	2013 - 2017
road_eqs_lornum	N1-N3	Mass	2013 - 2017

Source: Own compilation based Eurostat (2019) on available data in November 2019

In addition, **national sources** provide statistics on the stock of vehicles in the given country. However, most of the sources provide the same data as also reported to Eurostat (or less) and sources that have additional data provide these only for the most recent year(s).

[8] Other central sources for vehicle's characteristics include the European Automobile Manufacturers' Association (ACEA) and the International Council of Clean Transportation (ICCT). However, both do not provide additional online information beyond Eurostat on the stock or trade of vehicles.

Only four countries (Germany, Spain, Finland and Italy) report on the combination of age class and engine type. For the combination of age and mass, data could only be found for Spain. The combination of age and engine capacity was available from Spain and Liechtenstein. Germany provides the data for a range of years, Spain only for 2017 and 2018, Finland only for 2019, Italy for cars in selected years, and Liechtenstein since 2013 but also only for passenger cars.

The reporting on air pollutants and/or CO_2 emissions is particularly limited. Only five countries provide information about vehicle's air pollutants for at least one year. Germany, Italy, Norway and Slovakia provide the number of vehicles in each air pollution category in combination with the engine type for each vehicle class; however, Germany provides no data for busses and Italy only for cars. Germany, Italy and Norway provide the data for various years, Slovakia only for the last two years. Spain provides only emission category for cars in the years 2017 and 2018. The data about the CO_2 emissions of the vehicle stock is even thinner. There are three countries (Ireland, Liechtenstein and UK) providing at least some information on passenger cars while there is no data on the other types of vehicles. Ireland provides data for CO_2 emission categories in combination with the engine capacity for the years 2010-2019 but not for the engine type. Liechtenstein has information about the CO_2 emission categories in combination with the age structure for 2015 and UK provides only the CO_2 emission categories for 2015. We did not consider data on CO_2 emissions of new registered cars and vans which is available since 2010 (see EEA, 2019b,c) as new registrations make up only a small share of the overall vehicle stocks and the data is only available since 2010 which means that it could only provide information for the younger age classes for the latest years. In addition, to determine the influence of new registered vehicles on the vehicle stock in a country would require some sort of "stock modelling" including all in- and outgoing vehicles such as from imports, exports and scrapping and such an exercise was not subject to this project.

2.2.2 Trade data

The main **central source** for the trade of vehicles is Eurostat Comext. The database provides the total amount, total value and total mass of the traded used vehicles for a given year and for the specific engine types in combination with the engine capacity (see also Table 5). Notably, the statistics do not include all engine types as given above but only include petrol, diesel and plug-in hybrids as well as electric vehicles. CNG, LPG and LNG as well as other engine types are not defined in the combined nomenclature (CN) (see Commission Implementing Regulation (EU) 2019/1776). The database provide no information about the age or the environmental characteristics of the traded vehicles.

Table 5: Eurostat data coverage for the trade of vehicles

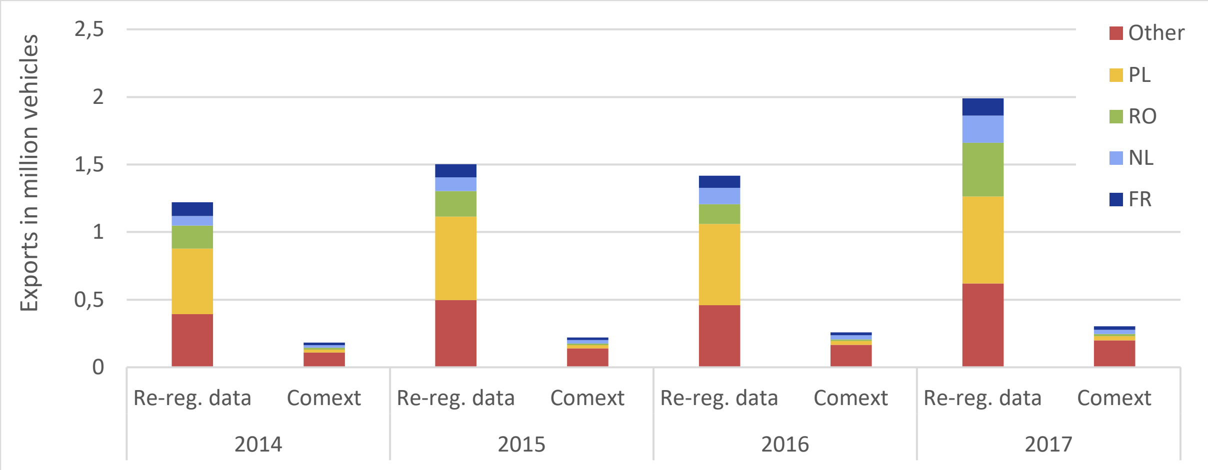
Eurostat databases	Vehicle class	Characteristics	Time period
Comext	M1, M2+3, N1, N2, N3	Engine type; engine capacity for M1; amount; total mass; value	Up to 2018

Source: Own compilation based Eurostat Comext (2019) on available data in December 2019

Most importantly, the trade statistics do not include all vehicle imports and exports as reporting countries can exempt small- and medium enterprises (SMEs) from the reporting to reduce the administrative burden for them as long as at least 97 % of their total intra-EU exports and 93 % of total intra-EU import is covered. For example, in Germany, the exemption threshold related to a company's turn-over was EUR 800,000 for intra-EU imports and EUR 500,000 for intra-EU exports in 2016 (see Eurostat, 2019b and further explanation also in Öko-Institut et al., 2011). Small sellers importing or exporting used vehicles are thus not included in the foreign trade statistics.

In Germany, more complete data on used vehicle exports are provided by the KBA's working statistics on re-registrations of used vehicles in other countries. According to BMU (2019), the number of exported vehicles from the re-registration statistics exceeds the export figures reported in Comext six times. In 2017, the used vehicles re-registered in another EU country amount to roughly 1.9 million vehicles (BMU, 2019: Tab.7) while the foreign trade statistics report an amount of roughly 300 thousand vehicles (Eurostat Comext, 2019) (see Figure 3).

Figure 3: Differences in the exports from Germany to the EU according to trade and re-registration statistics



Source: own compilation based on Eurostat Comext (2019) and BMU (2019).

The KBA' statistics on re-registration in other countries were not taken into account for this project as these only provide the total number of exported used vehicles to other countries without providing any information about vehicle characteristics and are not available online nor free of charge. In addition, we could not find similar data for the other European countries.[9]

Under the assumption that the coverage of Comext compared to the data given in the re-registration statistics look similar for other countries, the Comext trade statistics reflect roughly 1/6 of all trade volumes. This does not constitute a drawback per se. We consider that the trade statistics can be used to assess the changes in the trade flows when compared over several years as well as that the statistics can provide an indication on the environmental friendliness of the traded vehicles.

The re-registration statistics, however, constitute a suitable source of information for further research – in particular if the KBA and other authorities would also provide the related characteristics for the re-registered vehicles.

National sources mainly present the same (or even less) data as reported to Eurostat. In fact, only for Finland, Ireland and Poland additional information is available from a national governmental agency (the Finnish Transport and Communications Agency) or from the Irish and Polish automotive industry associations. The dataset on Finland includes the imports from all European countries with the respective amount given for a combination of vehicle class, engine types and age structure. The data on Ireland shows the total imports of passenger cars in the different CO_2

[9] Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles stipulates a data exchange only for internal use of the competent authorities and do not request the official publishing of such data in a suitable way e.g. as sums so as not to allow for misuse or disclosure of confidential information.

emission classes for various years. The data on Poland includes passenger car imports in various years in the different age classes. For 2018, there is also data on air pollutant categories which is, however, not combined with the age structure given in the other dataset.

2.3 Data gaps and inconsistencies

Previous studies and reports about characteristics and trade flows of used cars already highlighted problems about lacking data in many European countries (e.g. Öko-Institut et al. 2011; GFK and CE 2016). The data analysis in this study confirms this for passenger cars as well as for the other vehicle classes.

For the Eurostat databases, data gaps and inconsistencies vary among and within the datasets with some of these gaps and inconsistencies being less relevant than others. To give some examples: there is a lack of data only for single years in a times series; sometimes there is no data of a country for a whole dataset or subcategories are not reported. Inconsistencies include reporting errors such as typos (i.e. adding two times a number in the sequence of a number), unit errors (i.e. reporting of full number although the unit is given in thousand vehicles), definition difficulties (e.g. definition of a lorry, heavy-duty vehicle and a road tractor and respective vehicle class N1 to N3), definition errors (i.e. reporting of road tractors under lorries) and changes in the definition of a (sub)category.

The national online available databases cannot compensate for Eurostat data gaps and inconsistencies as these generally contain the same figures or even less information.

Due to the strong variety of data gaps, there is no common methodology appropriate to fill all of them. In general, the first step consists in the synthesis of available data sources but as mentioned, national datasets generally reflect the shortcomings of central databases. Missing data for specific years in a time series were closed by linear interpolation over the missing time frame. For example, data on the stock of passenger cars (M1) differentiated by age structure for France is missing for the years 2008 and 2009 in Eurostat. Reporting from France cannot be used as it is provided in another format (i.e. other split of age structure). In this case, a linear interpolation differentiated by age structure between 2007 and 2010 is used to fill the respective gap. In the case of not specified engine size of passenger cars, we assumed that these vehicles belong to the medium size category which by far contains the largest share of cars. We also corrected obvious inconsistencies such as the reporting of full numbers instead of thousand. We could, however, not fill-in gaps related to a whole category, such as the age structure which is the case for Greece or Bulgaria.

3 Derivation of environmental characteristics

The limited availability of data on the environmental characteristics of used vehicles in the stock and trade in almost all of the European countries makes the assessment of them dependent on further assumptions beyond pure inter- or extrapolation.

For this study, the chosen approach focusses on deriving environmental characteristic (i.e. air and CO_2 emissions) based on a combination of available vehicle characteristics:

- for the stock, the environmental characteristics are derived from the engine type and capacity as well as from the age structure;
- for trade, the environmental characteristics are derived from the engine type and capacity as well as from the average value of the traded vehicles.

The decision to use the engine capacity instead of the engine power, which seems more useful in accordance with EEA (2019a), is a result of the missing data on engine power. For the **stock**, we also faced a limited availability of the combination of single characteristics (such as engine type, engine capacity, and age structure) which was deemed necessary to derive a classification of vehicles in terms of air pollutants and CO_2 emissions. As a work-around, we chose to combine available age structures and engine types (including engine capacity where available) based on an equal distribution in the respective year. This approach has its drawbacks in particular in terms of varying diesel and petrol shares of new registrations over the years; however, it provides enough clarity if data is compared over a longer timeframe and seems accurate enough to use it as a starting point for the evaluation of likely air and CO_2 emissions of the vehicle stocks. We checked this approach for some countries and found little divergence.

Figure 4: Assumptions for classification of used vehicles in terms of air pollutants and CO_2 emissions

		Fuel Type		Engine size [in cc]		Year of registration	Average value [in EUR]
Emissions	**Scores**	**Air**	**CO_2**	**Stock**	**Trade**		
Very high	10	Diesel	Petrol	> 2,000	> 3000	1985	< 1,000
	9	Petrol, Gas fuels	Gas fuels		> 2800		1,000 - 2,500
	8		Diesel		> 2500		2,501 - 5,000
	7				≤ 2800		5,001 - 7,500
	6				≤ 2500		7,501 - 10,000
	5			1,400 - 2,000	1500 - 3000		10,001 - 15,000
	4				1500 - 2500		15,001 - 20,000
	3				1000 - 1500		20,001 - 25,000
	2				≤ 1500		25,001 - 30,000
Low	1	Electric	Electric	< 1,400	≤ 1000	2016	> 30,000

Source: own representation based on EEA (2019) and ICCT (2018), ICCT (2012), Wietschel et al. (2019), Synák et al. (2019) and Heidt et al. (2013) as well as on online vehicle sales platforms.

The classification of a vehicle in terms of its air and CO_2 emissions is based on a 10 scale, ranking the vehicles from 1 (no emissions) to 10 (very high emissions) for air pollutants and for CO_2

emissions.[10] The classification is calculated based on the following valuation of each characteristic (see Figure 4) and their weighting depending on the relative importance (see Formula 1 to Formula 4).

The four different **fuel types** analysed are diesel, petrol, gas fuels and electric. Vehicles categorized as "Other" are not included in this analysis, due to the diverse composition and as it contains vehicles that are not specified which means that no robust assignment to environmental characteristics is possible. The fuel category "Gas fuels" includes both natural gas and liquefied propane gas (LPG), in some countries commonly called autogas. Those two fuels differ significantly in terms of chemical composition and environmental impact. As the category is numerally dominated by LPG cars (see Chapter 2.1.4) the assessment of this fuel type is based on the environmental characteristics of LPG.

The environmental performance of diesel, petrol, gas fuels and electric vehicles in relation to both CO_2 emissions and air pollutants is expressed by different scores as reflected in Figure 4. Electric vehicles have no direct air pollutants and CO_2 emissions and therefore get the best rating (1 point).

In terms of CO_2 emissions, petrol vehicles have the highest CO_2 emissions (10 points), followed by LPG (9 points) and diesel (8 points) vehicles (see Table 6).

Table 6: CO_2 emissions classification

CO_2 Emissions Classification	Petrol	Diesel	LPG
CO_2 emission factors	2.34 kgCO_2/l	2.68 kgCO_2/l	Emission data for vehicles with gaseous fuels are not available as standardised as for diesel and petrol cars. Publications on the topic do not give clear numbers but correspondently indicate that LPG emits more CO_2 per km than diesel, but less than petrol
Average CO_2 emissions for compact cars	5.1 l/100km → 120 g/km	4.1 l/100km → 110 g/km	
Average CO_2 emissions for luxury cars	7.5 l/100km → 175 g/km	6.0 l/100km → 160 g/km	

Source: own compilation based on ICCT (2012) for CO_2 emission factors; Wietschel et al. (2019) for average CO_2 emissions for compact and luxury vehicles; Synák et al. (2019) and Heidt et al. (2013) for evaluation of LPG.

In terms of air pollutants, diesel vehicles have the highest emissions followed by petrol and LPG vehicles. From the introduction in 1992, the European emissions standards for petrol vehicles were stricter than those for diesel vehicles. Even though the emission standards for diesel were adjusted over the years, still a large quantity of vehicles with lower emission standards are on the road and in road test diesel vehicles emit more NO_X and PM than petrol vehicles (see Chapter 2.1.6 and Bernard et al. 2018). Therefor a score of 10 was assigned to vehicles with diesel engine and a score of 9 to vehicles with petrol engine. It is discussed controversially if LPG is cleaner in terms of air pollutants as petrol cars. The used publications reached no coherent conclusion. As vehicles fuelled with LPG are subject to the same European Emission standards as petrol vehicles, gas fuels are assigned the same score (9 points) (see e.g. Bielaczyc et al. 2016; Ristovski et al. 2005).

The **engine capacity** directly influences the environmental performance of a petrol and diesel vehicle in terms of its CO_2 emissions while it is less important for air pollutants as all cars, irrespectively of their engine size have to comply with the European emission etandards (see

[10] These are direct air pollutants and CO_2 emissions arising from internal combustion and do not take into account particle emissions from tyre and brake wear, embedded emissions or emissions from electricity generation for electric vehicles.

Chapter 2.1.6). Electric vehicles and vehicles running on gas fuels are not evaluated within this subcategory since the engine capacity is not available or applicable here. For the stocks, no engine capacity was available for busses, vans and lorries.

The evaluation in terms of the engine capacity is based on the fact that vehicles with a smaller engine capacity (but the same type of fuel) emit less CO_2 emissions when compared to a vehicles with a large engine capacity (see e.g. EEA, 2019 and ICCT, 2018). The smallest engine capacity (evaluated with 1 point) in the stock database is smaller than 1,400 cc while it is smaller than 1,000 cc in the trade database. The biggest engine capacity category (evaluated with 10 points) is the category of larger than 2,000 cc in the stock and larger than 3,000 cc in the trade database. The other categories in between are distributed accordingly.

The **age structure** is only given for vehicle stocks. It is categorised as younger than two years, two to five years, five to ten years, and older than ten years. In order to obtain a stable value over the years, we have allocated a registration year to each vehicle by taking the average value from one age category (i.e. a vehicle within the category two to five years was classified as a three and half year old vehicle; vehicles older than ten years are assumed to be on average 15 years old). This means that the oldest vehicle is registered in 1985 as it is in the category of “older than ten years” in the year 2000 (evaluated with 10 points). A data entry of a vehicle in 2017 within the age structure of “younger than two” is assumed to be registered in 2016 and is therefore the youngest vehicle in the data set (evaluated with 1 point) (see Figure 4). The other registration dates in between are distributed accordingly.

The **average values of a vehicle** is used to evaluate the environmental performance of traded used vehicles as data on age structure is missing. It is based on the assumption that lower-value vehicles emit more than high-value vehicles which can be justified when checking e.g. online vehicle sales platforms. However, there are other vehicle characteristics (besides the age and environmental performance) that influence the value of a vehicle, in particular the brand, the interior, and most importantly the driven kilometres. Thus, the given evaluation (see Chapter 4.3) can only serve as a rough estimate of the environmental performance of traded vehicles. In addition, when compared to the stock database, the use of different characteristics (age vs. average value) can lead to disparities in the emissions outcomes between both databases, i.e. that vehicles in the trade database might occur as emission intensive vehicles, because they were traded for a small price but are rather new and have a good emission performance. In the stock database, the same car would occur as a rather well performing vehicle in terms of its emission intensity. Besides these drawbacks, we consider the average value as a good mean to evaluate the traded vehicles in terms of their environmental performance – at least for Ireland results are similar to the data provided for the CO_2 emission classification of its imports (see Box 4).

We defined ten categories ranking the average value from less than EUR 1,000 (10 points) to an average value larger than EUR 30,000 (1 point) (see Figure 4 for intermediate steps).

For the final scoring, **each characteristic is weighted** depending on the relative importance. For the **stock**, the classification system for air pollutants addresses age structure and engine type with the weights being 0.7 for age and 0.3 for the engine type; to evaluate the CO_2 emissions, the weights are 0.5 for age, 0.3 for the engine type and 0.2 for the cylinder capacity.

The following equations summarise the evaluations scheme for the vehicle stocks for air pollutants and CO_2 emissions:

for air pollutants: $$EP = ET * 0.2 + RD * 0.8$$ **Formula 1**

for CO_2 emissions: $$EP = ET * 0.3 + RD * 0.5 + EC * 0.2$$ **Formula 2**

with EP = evaluation points
ET = engine type
RD = registration date
EC = engine capacity

This classification gives a maximum of ten points in terms of air pollutants to a diesel vehicle which was first registered in 1985 and a maximum of ten points in terms of CO_2 emissions to a petrol vehicle first registered in 1985 with an engine capacity of more than 2,000 cc. Electric vehicles are assumed to be the top-performer with an overall scoring of 1 point.

For **trade**, the classification is based on the engine type and average value of the traded used vehicle to derive the classification of air pollutants as well as on the engine capacity for CO_2 emissions. Notably, there is no category for gas fuelled vehicles in the trade statistics. The following equations summarise the evaluations scheme for the traded vehicle in terms of their air pollutants and CO_2 emissions:

for air pollutants: $$EP = ET * 0.5 + AV * 0.5$$ **Formula 3**

for CO_2 emissions: $$EP = ET * 0.3 + AV * 0.5 + EC * 0.2$$ **Formula 4**

with EP = evaluation points
ET = engine type
AV = average value
EC = engine capacity

This classification gives a maximum of ten points in terms of air pollutants to a diesel vehicle with an average trade value below EUR 1,000 and a maximum of ten points in terms of CO_2 emissions to a petrol vehicle with an average trade value below EUR 1,000 and an engine capacity of more than 3,000 cc. Electric vehicles are assumed to be the top-performer with an overall scoring of 1 point.

Due to the data gaps and the methodology to derive the air pollutants and CO_2 emission classification of vehicle stocks and used vehicle trade within the analysed statistics, **the results are to be considered as rough estimates** and are used for showing the general trends and order of magnitude.

4 Environmental characteristics of used vehicles

The estimates of the environmental performance of used vehicles in the stock and trade of European countries are presented in the following. As the regulatory framework may impact purchasing decisions, we give an overview of relevant European and national regulations and taxes for the trade as well as for the registration of used vehicles which also fed into the analysis.

In principle, we cover all European countries in this chapter beside some countries which do not provide sufficient information with respect to their vehicle stock. For trade, every European country participated in the trade of used vehicles with varying intensity and direction. The focus year is 2017 as for the vehicle stocks no comprehensive data was available for 2018.

4.1 Regulatory background of vehicle stocks and trade

This section gives an overview of the applicable regulations and taxation when registering a vehicle to be used on public roads as well as regulations and taxation when vehicles are traded. This mainly serves as background information to better understand differences in the stock and trade of used vehicles beyond other indicators such as economic activity or average household income.

4.1.1 Regulations for registering a vehicle

Directive 2014/45/EU regulates the registration and roadworthiness of motor vehicles in the EU and European Economic Area) countries. The primary objective of the roadworthiness testing is to ensure that vehicles are safe during their use. Thus, each vehicle in the EU has to undergo a regular mandatory check-up according to EU and national technical, safety and environmental requirements. The Directive’s preamble states that a periodic testing of roadworthiness contributes to improving the environment by maintaining vehicles in good condition; however, this does not mean that the Directive and its national implementations ban old vehicles with high emissions from public roads. It basically requires the vehicle to work properly according to its original conditions.

In addition, for vehicles registered in 2006 or later, the Directive 2014/45/EU allows to perform the emission test by checking only the on-board diagnostics (OBD). This means if the OBD reports no malfunction of the exhaust-system, the emissions test is deemed to be passed without any physical test (e.g. Schröder et al. 2015). However, test series show that a significant share, especially of older vehicles, pass this test procedure that would not have passed a tailpipe test (Supnithadnaporn et al. 2011). In this regard, e.g. Germany introduced a tailpipe test for all vehicles in 2018 and considers to introduce a particle emissions test starting in 2021 (ADAC 2019).

4.1.2 Taxation for incentivising efficient and low-emission vehicle stocks

Fees and taxes are widely used policy instruments, especially in environment-related fields. By internalising external costs, individual and institutional market participants can be pushed towards a more desirable behaviour without any hard prohibitions. As the composition of national vehicle fleets in regards to motorisation and emissions has a direct impact on air quality and the achievement of climate mitigation goals, fees and taxes aim to motivate vehicle buyers to choose a smaller, fuel efficient and low-emission vehicle. Of course, governments can also use taxes and fees to influence a vehicle buyer's decision, whether he or she buys an old or new car.

Taxes and fees are linked to a range of different activities: acquisition, registration, ownership, refilling and road use. In addition, in some countries bonuses or tax reimbursements are paid for scrappage or export of used cars. Even though all of these presumably have an influence on car buyer's purchase decisions, in this study the focus is on fees and taxes that are to be paid for acquisition and registration as these have the most immediate impact.

The tax level and method of setting the registration tax can have a substantial impact on purchase decisions. However, so far not all governments use the registration tax to incentivise the purchasing of environmental friendly vehicles but some countries even indirectly incentivise environmental harmful vehicles above environmental friendly vehicles through their tax method (see e.g. below examples of taxation favouring older vehicles). Table 7 gives an overview on the relevance of the registration tax in the countries highlighting:

- Which vehicle characteristics determine the tax rate and in which direction,
  i.e. if the tax favours environmental harmful vehicles it is marked with “-“ while those favouring environmental friendly vehicles are marked with ”+”, “++” and “+++” with “+” meaning that the tax rate does not increase in the same order as the characteristic, “++” means a proportional increase and “+++” means that the tax rate increases much more than the increase of characteristic.

- Which relevance the tax has based on the amount of the tax,
  i.e. if it plays a marginal role of below of EUR 50 or if the tax rate can amount to more than EUR 5,000 which then can have an impact on the purchase decision.

Table 7 shows that most countries combine different characteristics of a vehicle to define the tax level. The already most common vehicle characteristic for the determination of taxes and fees are the **CO_2 emissions [g/km]** measured during the WLTC (Worldwide Harmonized Light Vehicles Test Cycle), which replaced the formerly used NEDC (New European Driving Cycle) in September 2017. In many countries e.g. Austria, Belgium, France, Italy, the Netherlands, Norway, Portugal and Spain a bonus-malus-system exists, which grants tax reductions for vehicles with low CO_2 emissions and increasing taxes and fees for higher CO_2 emissions - often even exponentially. In all of those countries the tax can rise to more than EUR 5,000 (except Italy, where they still can amount up to more than EUR 2,500). The **emission standard [EURO 1-6]** is another common factor for taxes and fees on acquisition and registration such as in Czechia. There exist penalty taxes for vehicles with low emission standards which should motivate vehicle buyers to choose a newer, cleaner model. Norway provides the best example for incentivising the purchasing of environmental friendly vehicles with its progressive registration tax that increases disproportionately with rising air pollutants and CO_2 emissions to much more than EUR 5,000 (Norwegian Tax Administration, 2019). As such, Norway has a high share of electric vehicles and other clean vehicles in its stock and hardly any vehicles with very high air pollutant or CO_2 emissions (see also Box 1).

Table 7: Taxes and fees for the registration of a vehicle in Europe

		Relevance of characteristics							Relevance of tax						
Country	**Vehicle type**	Age	CO_2	Euro-standard	Purchase price	Engine capacity	Engine power	Mass	≤50 EUR	>50 EUR	>250 EUR	>500 EUR	>1k EUR	>2.5k EUR	>5k EUR
AT	M1		+++		++						x	x	x	x	x
BE	M1	-	+++	++		++	+++				x	x	x	x	x
BG	M1-M3, N1-N3								x						
CH	M1-M3, N1-N3										x	x	x	x	
CY	M1		+++								x	x	x	x	x
	M2					++					x	x			
CZ	M1, N1			+					x	x	x				
	M2-M3, N2-N3								x						
DE	M1-M3, N1-N3								x						
DK	M1		+		+++								x	x	x
EE	M1-M3, N1-N3										x				
EL	N1		+	++	+++							x	x	x	x
ES	M1		+++		++					x	x	x	x	x	x
FI	N1		++		++			-			x	x	x	x	x
FR	N1		+++				++		x	x	x	x	x	x	x
HR	M1-M3, N1-N3		+++		+++					x	x	x	x	x	x
HU	M1, N1	-		+++		+++	+++				x	x	x	x	x
IE	N1		+		++					x	x	x	x	x	x

		Relevance of characteristics							Relevance of tax						
Country	**Vehicle type**	Age	CO_2	EURO standard	Purchase price	Engine capacity	Engine power	Mass	≤50 EUR	>50 EUR	>250 EUR	>500 EUR	>1k EUR	>2.5k EUR	>5k EUR
IS	M1-M3, N1-N3														
IT	M1-M3, N1-N3		++				++				x	x	x	x	
LT	M1-M3, N1-N3									x					
LU	M1-M3, N1-N3									x					
LV	M1-M3, N1-N3									x					
MT	M1-M3, N1-N3		+	+	++								x	x	x
NL	M1-M3, N1-N3		+++									x	x	x	x
NO	M1-M3		+++	+++			+	+					x	x	x
PL	M1				++	+++					x	x	x	x	x
PT	M1, N1		+++			+++					x	x	x	x	x
RO	M1-M3, N1-N3								x						
SE	M1, N1		+												
SI	M1-M3, N1-N3		++	+	++	+				x	x	x	x	x	x
SK	M1-M3, N1-N3	-					++		x	x	x	x	x	x	x
TR	M1; N1-N3				++	+++						x	x	x	x
	M2, M3, N2-3				++							x	x		
UK	M1-M3, N1-N3									x					

Source: own illustration based on ACEA (2019) and complemented and corrected where necessary with COM (2019a), Norwegian Tax Administration (2019), Automobile (2018), PWC (2016) and Iberley (2016). No information included about Albania, Bosnia-Herzegovina, Kosovo, Liechtenstein, Montenegro, North Macedonia, and Serbia.
The tax methods favours environmental harmful ("-") or friendly vehicles: "+, ++, +++" with tax rate change below, same, higher than change of characteristic.

In some countries, vehicles with powerful engines are subject to higher taxes and fees than smaller ones. In this case, two different figures can be used for the calculation: the **cylinder capacity [cm^3]** or the **engine power [kW]**. Even though both are interdependent, modern efficiency and downsizing technologies allow higher engine power with lower cylinder capacities. On that account, taxation of cylinder capacity favours new cars with smaller but stronger engines, while taxation of engine power might favour the acquisition of older and thus used cars.

There are also some countries that have tax calculation methods discouraging the purchasing of low-emission vehicles but rather incentivising purchases of old, inefficient and/or large, heavy ones. For example, in three European countries (Belgium, Hungary and Slovakia) the registration tax decreases with increasing **vehicle age**. This is clearly an incentive to buy an old i.e. used car. In other countries fees or taxes are based on the vehicle's **purchase price**. As used vehicles tend to be cheaper than new ones (apart from vintage cars), this is an incentive in the same direction. In Finland the tax depend on the **vehicle mass** and decreases with increasing mass favouring heavy vehicles over light vehicles.

Finally, some countries (e.g. Bulgaria, Germany, the Baltic states and Switzerland) apply a **flat registration fee** of less than EUR 50 for all vehicles. This means that there is no immediate incentive for the purchasing of low-emission vehicles.

4.1.3 Regulation and taxation during the trade of vehicles

In the EU' single market goods can be traded freely without customs duties or quantitative restrictions. The EU single market includes the EU Member States as well as Iceland, Liechtenstein and Norway forming the European Economic Area. Switzerland is partly integrated in the EU's single market on the basis of bilateral agreements. The underlying rules for the European Economic Area aim to enable free movement of labour, goods, services, and capital within the single market. The 'free movement of goods' also applies to all vehicles. The EU is in customs union with Monaco and, until 31 December 2020, with the United Kingdom and some associated territories Further, the EU is in customs unions with Andorra, San Marino and Turkey (with the exception of certain goods) through separate bilateral agreements (see e.g. COM 2019b). Furthermore, all countries of the Western Balkans have a European perspective (COM, 2019c). This European perspective is integrated into the Stabilisation and Association Process. Since the launch of this process, the EU has progressively concluded bilateral Free Trade Agreements – referred to as "Stabilisation and Association Agreements" (SAAs) with each of the Western Balkan countries: Albania (2009), North Macedonia (2004), Montenegro (2010), Serbia (2013), Bosnia and Herzegovina (2015) and Kosovo (2016). Thus, new and used vehicles can be traded without customs duties or limits on quantities.

Besides this general trade framework, European countries request a certificate of roadworthiness, VAT payments and payment of the registration tax (as well as insurance and payment of other taxes such as an annual vehicles road tax). In addition, certain European countries have additional regulations and taxes in place for the import of used vehicles (see Table 8). Some Western Balkan countries prohibit the import of passenger vehicles not having at least Euro 3 standard and light duty vehicles not having at least Euro 5 standard and Turkey has a ban on the import of all used vehicles. In the EU, Finland bans the import of cars without catalytic converters and Hungary of passenger vehicles older than 4 years and commercial vehicles older than 6 years.

Table 8: National regulations and taxes for the import of used vehicles

Country	National regulation for or tax on imported used vehicles
Bosnia and Herzegovina	Import ban on passenger vehicles below Euro 3 standard and light commercial vehicles below Euro 5.
Finland	Import ban on cars without catalytic converters
Hungary	Import ban on used passenger vehicles older than four years and commercial vehicles older than six years. Exemption for specialized older vehicles after passing a special technical test.
Netherlands	Exemption of import duties and reduced VAT of 6% for vehicles older than 20 years
Norway	Taxes on imported vehicles: scrap deposit tax of NOK 2,400 (~EUR 250) plus the GHG tax on air-conditioning systems depending on gas used by the system and weight of the gas in the vehicle. VAT of 25% applies to the customs value (purchase price, freight costs and insurance costs).
Serbia	Import ban on passenger vehicles below Euro 3 standard and light commercial vehicles below Euro 5. The government currently considers to ban the import of cars with Euro 3 and 4 standard as well as cars which are older than 10 years.
Turkey	Import ban on used vehicles

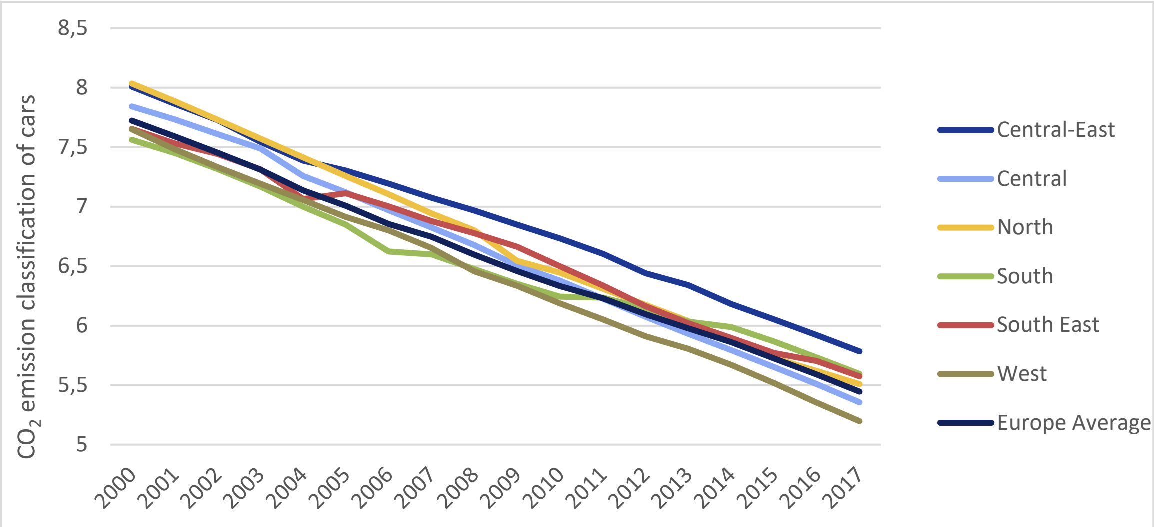
Source: US ITA 2015; Norwegian Tax Administration 2019; Bjelotomic 2019; UNEP and UNECE 2017, TCC 2019

4.2 Characteristics of European countries' vehicle stocks

The total vehicle stock in the countries covered by the study increased significantly since the year 2000. In the 29 countries, for which data is available over the given timeframe, the number of passenger cars rose from 210 million to 272 million; the number of buses increased from 1.2 million to 1.6 million, and the number of lorries and road tractors also increased considerably from 25 million to 41 million. In countries with a rapid economic growth like Poland, Czechia and Estonia, this increase was especially pronounced. In Poland, the number of motorised vehicles more than doubled over the given period. The slowest growth can be observed in the case of Germany where during the financial crisis the number of registered cars sank by about half a million. Although passenger cars represent the majority of motorized vehicles, busses and cargo vehicles also constitute an important lever for emission reduction because of their high mass and annual mileage.

As the numbers of vehicles is growing, so are engine power, size and weight of each vehicle (see e.g. Transport & Environment 2018). As these characteristics still determine the environmental performance of vehicles in terms of air pollutants and CO_2 emissions, this directly contradicts the society's interest of reducing the environmental impact of individual vehicles.

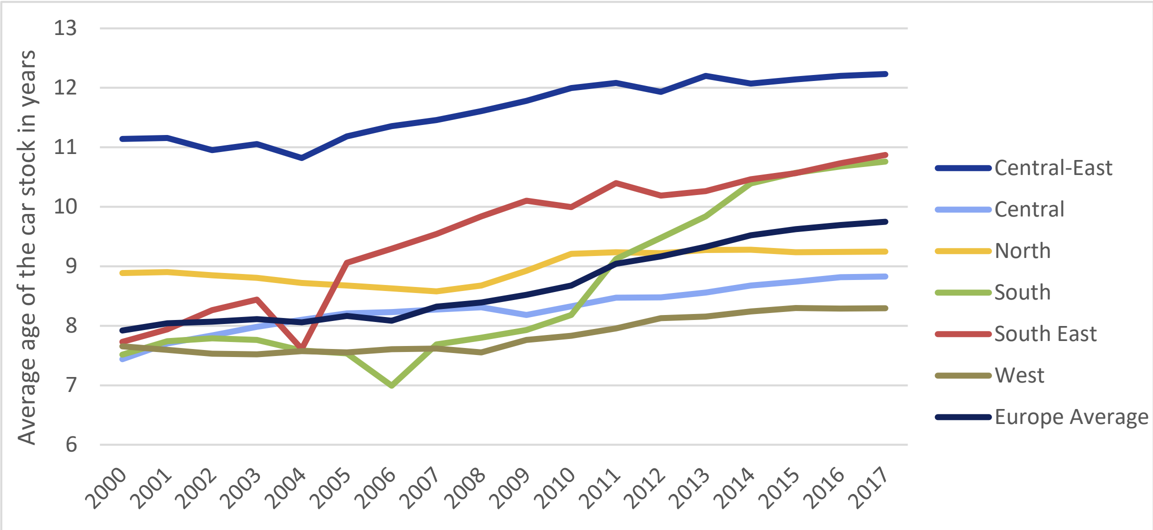
Figure 5: Advances of the CO_2 emission classification of the car stocks



Source: own calculations based on Eurostat, 2019a.

The environmental impact of a country's vehicle stock results from the individual composition of the vehicle stock in this country. In Europe, the CO_2 emission intensity of used vehicles constantly decreased since 2000. Figure 5 shows this for passenger cars for the different country groups. While the country groups are on different levels in terms of the CO_2 emissions of their cars, all of them show a constant improvement. However, the dynamic of this improvement varies between the groups. For instance, in 2001, the average CO_2 emissions of a car in the stocks of the North and Central-Eastern groups are almost on the same level. While the Central-Eastern group improved in a similar pace as the European average, the car stock of the Northern country group improved its average CO_2 emissions much faster. This can be explained by the fact that the trend towards a higher age of the car stock in the Northern group is not as pronounced as in other countries. In Denmark and Sweden the average age of passenger cars was even lower in 2017 than in 2000. In Norway the average age of passenger cars sank by more than 0.3 years since 2009.

Figure 6: Average age of a car in the vehicle stocks



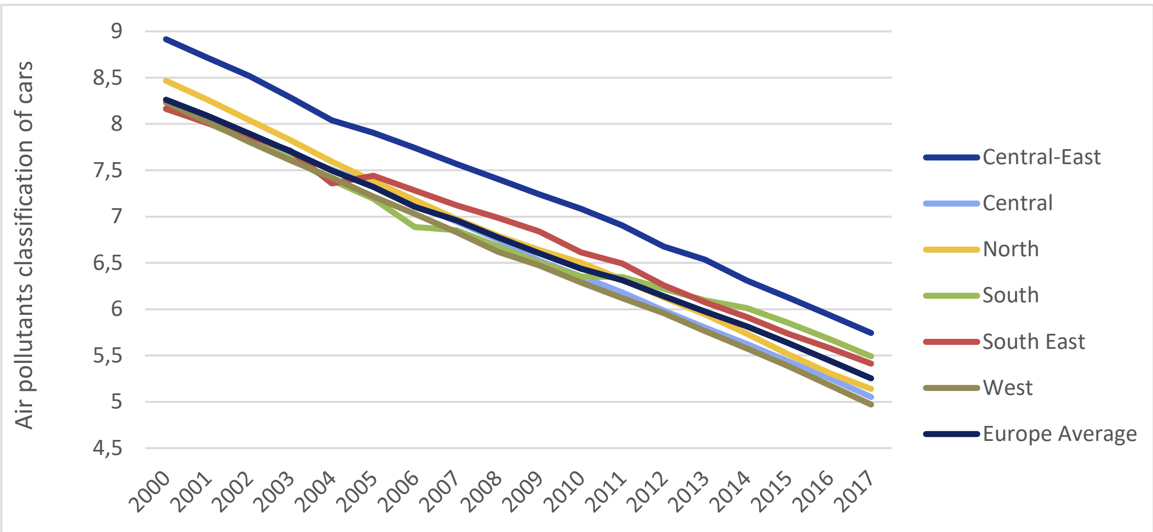
Source: own calculations based on Eurostat, 2019a.

While both, the Northern and the Central-Eastern group are among the three country groups with the lowest share of diesel cars, the countries of the Northern group, especially Norway, had a very high share of electric cars in 2017. This is a direct result of the high taxes imposed on cars with high CO_2 emissions and air pollutants (see e.g. Haugneland et al., 2017).

Finland is a special case in the Northern country group with its ageing car stock and low share of electric cars, so are the Baltic States in the Central-East group where the (still very old) car stock is being rejuvenated and the share of electric cars is rising. The latter also applies to the Polish car stock. Poland also has a significant share of LPG cars.

The high age of the car stock of the Central-Eastern group also has an impact on the air pollutant emissions. It is by far the car stock with the highest air pollutant emissions. In general the curves which represent the air pollutant emissions fall much more sharply than those of CO_2 emissions. This is a result of both improved efficiency and increasingly strict emission standards (as represented though our derivation methodology introduced in chapter 3).

Figure 7: Advances in terms of air pollutant emission classification of the car stocks

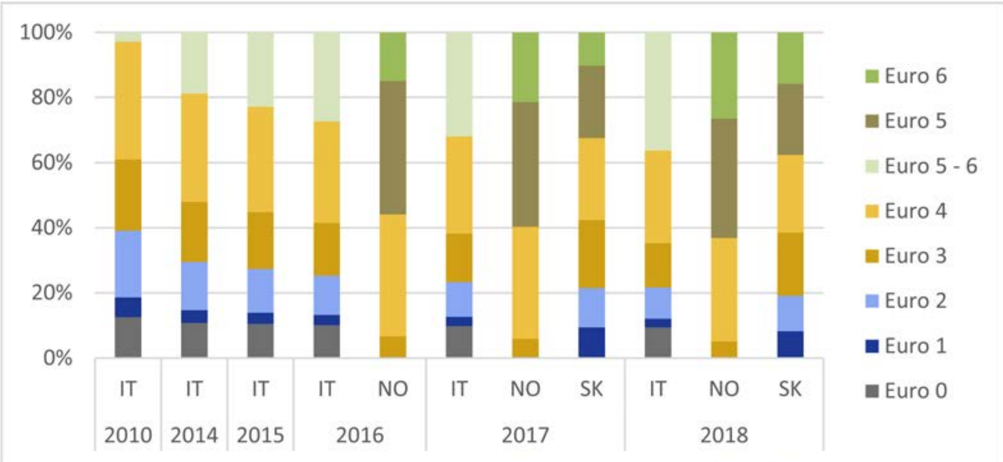


Source: own calculations based on Eurostat, 2019a.

Box 1: Euro standards of the car stocks in Italy, Norway and Slovakia

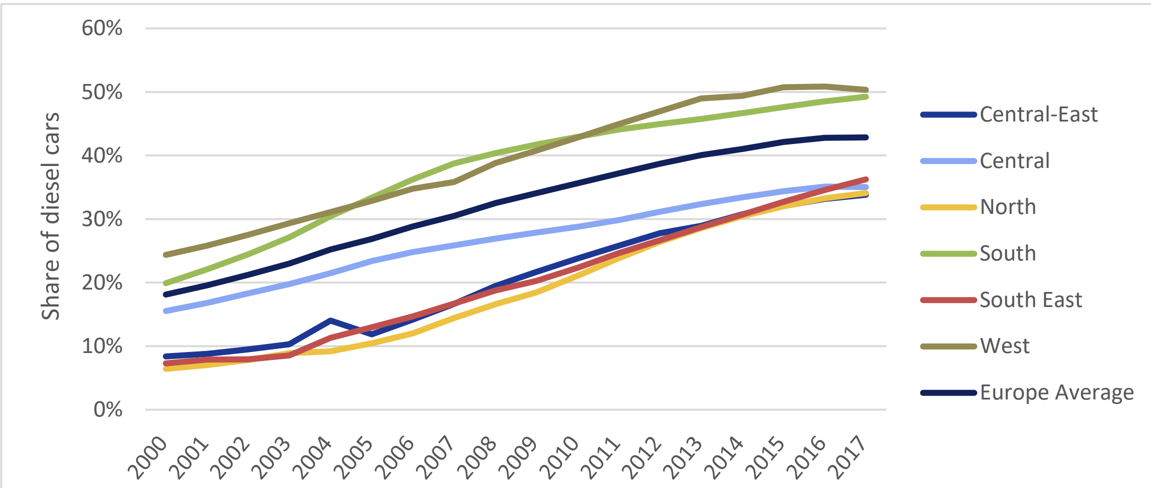
Italy, Norway and Slovakia report on the air emission standards of their car stocks with Italy providing data since 2010, Norway since 2016 and Slovakia for the last two years. While Italy's car stock consist of vehicles with relatively high emissions, the majority of cars in Norway have comparably low air pollutants which is also a result of the progressive taxation (see Chapter 4.1). In Norway, the introduction of Euro 6 cars also happened quite fast as these cars had a share of 15 % already in 2016 – one year after its introduction for all new registered cars. Slovakia's stock consists mainly of cars with Euro 3-5. In all three countries, the share of Euro 5 and 6 cars increased over the past years.

Figure 8: Air pollutant classification of the vehicle stocks in Italy, Norway and Slovakia



Source: Automobile Club d'Italia (2019), Statistik sentralbyrå (2019), Statistical Office of the Slovak Republic (2019)

Figure 9: Diesel share of the car stocks



Source: own calculations based on Eurostat, 2019a.

In all country groups, a rising share of diesel cars is visible in Figure 9. This trend starts early in the West, South and central country groups, and slows down between 2006 and 2008 in the Central and Southern country groups. In the meanwhile, the diesel trend accelerated in the North, Central-Eastern and South-Eastern country groups. For the latter two it seems plausible, that this is at least partly a delayed effect of the diesel trends in the countries which are net exporters of used vehicles, as the diesel share in the used vehicle trade also increased.

Box 2: Air pollutants and CO_2 emissions of passenger cars in Germany

Germany was the only country reporting both air pollutants and CO_2 emission classifications for its car stock. The air pollutants classification is available for the last 9 years; the CO_2 emission classification is only available for the year 2018. The left graph shows that the share of used cars with relatively high air pollutants constantly decreased while the share of cars with low air pollutants i.e. high Euro standard increased. In 2019, for instance, used cars with Euro 1 standards almost completely disappeared in the German stock, whereas Euro 6 standard vehicle's share increased significantly. The graph on the right-hand side displays CO_2 emission categories (g/km) in 2018 reflecting that most of the used cars are classified as medium CO_2 emitting vehicles. Zero to low-emission cars (below 50g CO_2/km) are hardly used in Germany – they account for just 0.3 % of the entire car fleet in 2018.

Figure 10: Share of Euro Standards

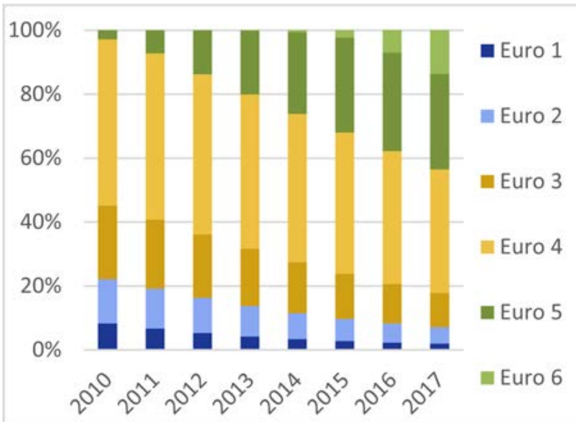
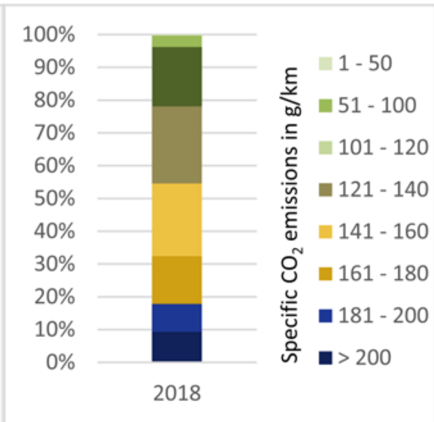


Figure 11: CO_2 emission classification in 2018



Source: own presentation based on KBA (2019a, b)

The stocks of busses, vans and lorries are dominated by vehicles running on diesel. As no data for engine capacity was given for these vehicle classes, the decisive factor for both, air pollutants and CO_2 emissions is the age of the respective stock.

The oldest bus stock with high air pollutants and CO_2 emissions can be found in the South-Eastern group, followed by the Central-Eastern group. The age and resulting air pollutants and CO_2 emissions of the Central, Northern, and Western country groups are the lowest and almost identical. The curves are rather parallel, only the bus stock of the South group improved its emissions slower than the average.

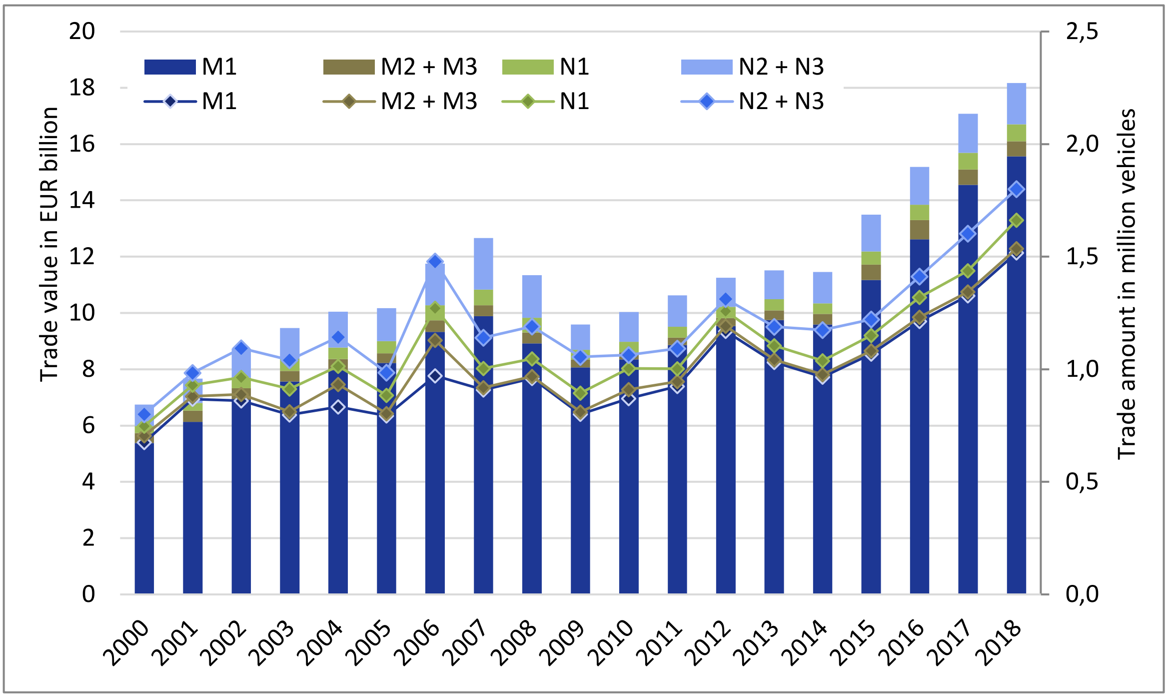
The Southern and Central-Eastern vans have the worst environmental performance, with the latter improving rapidly, leaving the former behind as the van stock with the highest CO_2 and air pollutant emissions. The van stock of the South-East group is the one with the slowest improvement. In 2013, its emissions were approximately the same as those of the North group's. In 2017 however, they were much higher. The environmental performance of the lorry stocks give a very different picture. In this case, the environmental performance of the lorries in the South-Eastern group increased the fastest, almost reaching the same level as the lorry stocks of the Northern and Western group. The lorry stock of the Central-Eastern group is the one with the highest air pollutants and CO_2 emissions. The van and lorry stocks of the Central country group is the cleanest in terms of air pollutants and CO_2 emissions.

4.3 Characteristics of European countries' used vehicle trade

Like the total stocks, the trade volume of used vehicles increased over the period from 2000 to 2017 and also to 2018 in terms of value and amounts based on available trade statistics. The trade value rose from almost EUR 7 billion in 2000 to around EUR 18 billion in 2018 with most of the trade happening for used passenger cars. A similar trend can be identified for the number of traded vehicles which rose form roughly 800 thousand to 1.8 million vehicles over the same period of time (see Figure 12). The average value of a traded vehicle thus remained relatively stable varying around EUR 9,500.

Over the covered time period, the growth of the trade volume stagnated in the aftermath of the global financial crisis in 2007/2008, afterwards the volume decreased in the years 2007 to 2009. Only in recent years, from 2015 to 2018, trade volumes of used vehicles began to increase again. Passenger cars contributed the biggest share of the overall trade volume and were also responsible for the positive development in recent years. The share of heavy duty vehicles increased again after 2015 since it was lower in the years of the financial crisis.

Figure 12: Trade volume of used vehicles in Europe



Source: Eurostat Comext (2019). Bars represent the trade value and lines the traded number of vehicles.

In 2017[11] the biggest exporters were Germany, Belgium, France, Italy and the Netherlands with high exports both in terms of value and in terms of the amount. In addition, Spain and Austria were among the largest exporters in terms of value and Denmark and Slovenia in terms of amounts (see Figure 13). On average, a vehicle was exported for around EUR 11,000 in that year. The biggest exporters showed varying values for an exported vehicle with Germany having exported mainly passenger cars at an average value of EUR 19,500 while Denmark

[11] Here we refer to 2017 to be able to compare the datasets for stock and trade. In 2018, similar countries are key exporters (Germany, Belgium, France) and importers (Germany, France and Poland).

exported a large amount of heavy-duty vehicles for a rather low EUR 700. Both France and Italy exported used vehicles with an average value of around EUR 7,000 while Belgium exported used vehicles with an average value close to the European average. In comparison, Turkey exported vehicles with a value of more than EUR 38,000 on average due to a relatively high share of exported busses. Ireland exported a relatively high share of lorries which resulted in an average value of almost EUR 25,000 for its exported used vehicles.

Figure 13: Top exporters by value (above) and amount (below) in 2017

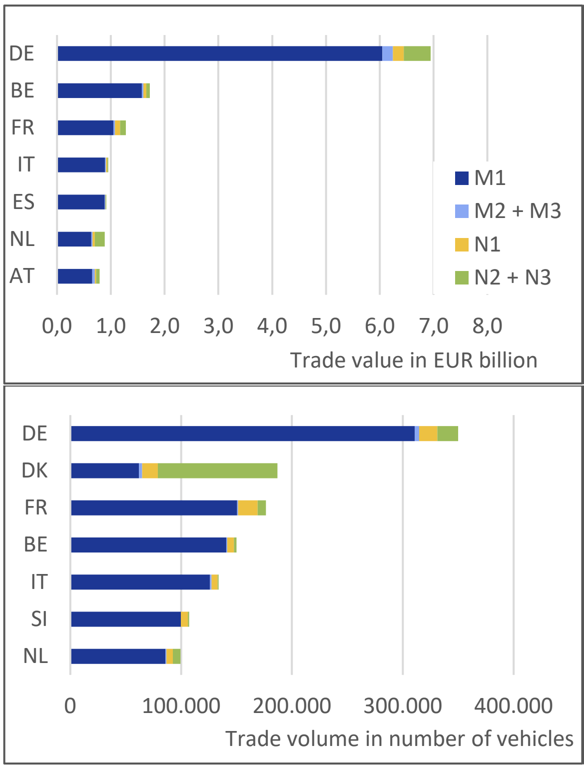
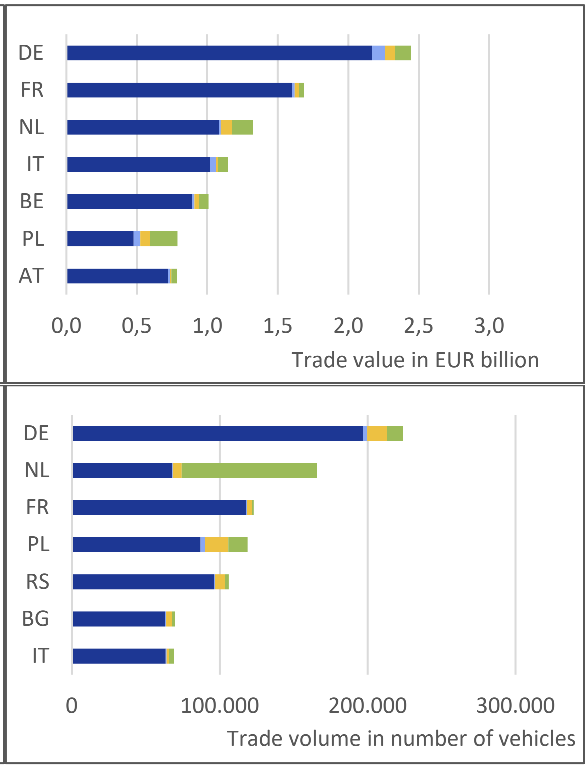


Figure 14: Top importers by value (above) and amount (below) in 2017



Source: Eurostat Comext (2019)

The seven biggest importers (see Figure 14) included again Germany, France, the Netherlands and Italy in terms of value and amount with an average value of a vehicle which varied around the European mean value for im- or exported vehicles. The numbers show that Germany was by far the biggest exporter and importer in Europe: the country exported used vehicles with a value of around EUR 6.9 billion, while it imported a value of around EUR 2.4 billion translating into a substantial trade surplus in 2017. However, Germany exported vehicles with an average value of almost EUR 27,000 while it imported lower value vehicles. This distribution is also valid in 2018.

Poland was also a large importer in terms of value and amount while Austria and Belgium were large importers in terms of value and Serbia and Bulgaria in terms of the amount. Vehicles imported to Bulgaria and Poland showed an average value of roughly EUR 6,000 and EUR 7,000, respectively. Serbia imported vehicles for less than EUR 3,000 on average - mainly medium-size diesel and petrol cars - which was the lowest value in Europe. It is possible that vehicles were sold for a low price although these vehicles were relatively new and had relatively high emission standards. This is somewhat supported by the fact that Serbia ban imports of passenger vehicles below Euro 3 standard and light commercial vehicles below Euro 5 (see Chapter 4.1.3). Also most of the other cooperating countries imported low-value used passenger cars having ranged from EUR 3,500 (Bosnia and Herzegovina), around EUR 4,000-6,000 (Montenegro, North Macedonia, Albania) and almost EUR 9,000 (Kosovo).

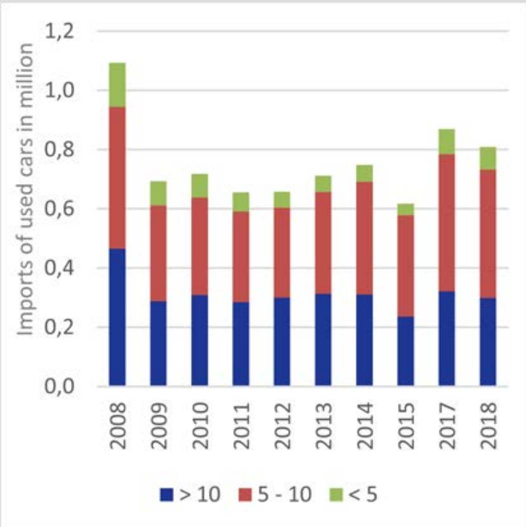
As the trade of passenger cars dominates the overall figures (see also Figure 12), one reason for the differences can be found in the economic situation of households in the respective countries. In Serbia, for example, the mean yearly income of a household amounted to just EUR 2,500 and in Poland to EUR 6,600 in 2017 (Eurostat, 2019c). Countries having imported high-value vehicles also had a comparably high household income: for example, Switzerland, Norway and Denmark imported vehicles with an average value between EUR 37,000 and EUR 26,000 while the median yearly income ranged from almost EUR 44,000 to EUR 29,000 in that year (Eurostat, 2019c). Interestingly, the level of income seems to be of about the same order of magnitude as the value of imported passenger cars for most of the European countries.

Box 3: Age structure of Poland's passenger car imports and related stock

Over the past decade, Poland imported rather old passenger cars with only 10 % being younger than 5 years and more than 50 % being older than 10 years (PZPM, 2019). This is also reflected in the average value of the imported used cars which ranged from roughly EUR 7,000 to 9,000 seeing a slight upward trend over the past decade.

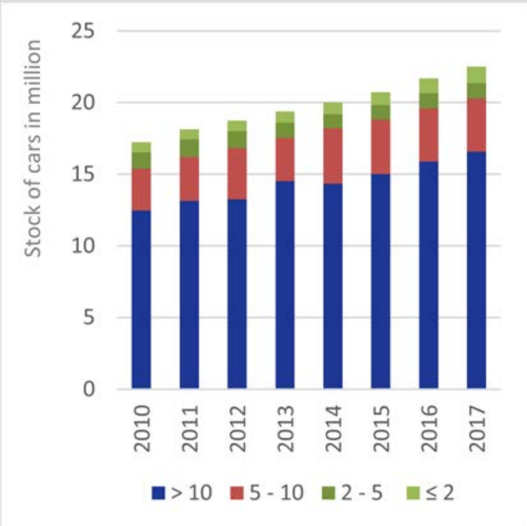
The imports also impacted Poland's stock of passenger cars: over the past decade, the share of cars older than 10 years remained almost constant at 70 % of the overall stock and cars younger than 5 amounted to only 10 %.

Figure 15: Age structure of car imports



Source: PZPM (2019)

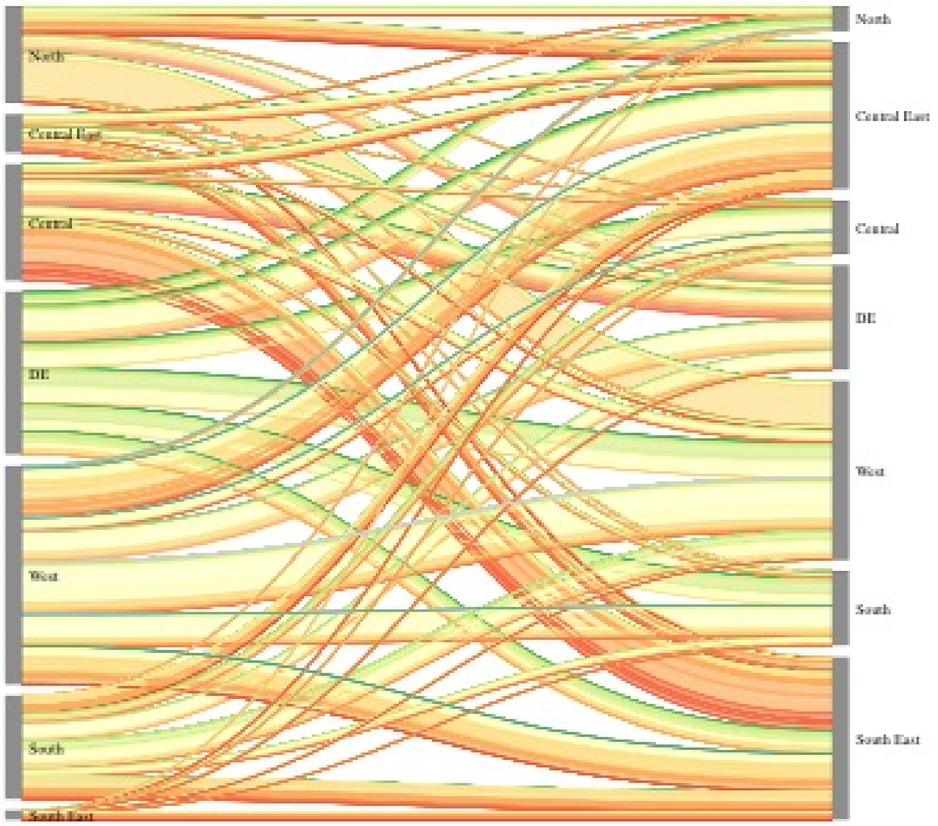
Figure 16: Age structure of the car stock

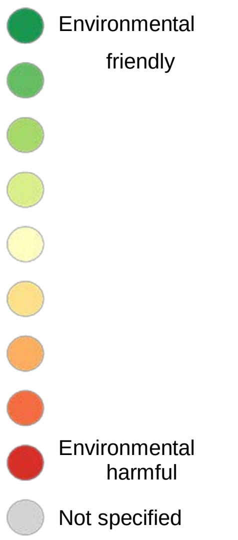


Source: Eurostat (2019a)

The environmental performance of traded vehicles varied as it also did in the stock of vehicles. Figure 17 and Figure 18 display the trade flow in terms of numbers of used vehicles between the analysed countries in 2017 which is given in the width of lines. The colours indicate the environmental performance of the trade flow with Figure 17 reflecting the CO_2 emission classification of traded vehicles in the colour code and Figure 18 reflecting the air pollutant classification. Red lines are traded vehicles with particularly high air pollutants or CO_2 emissions while green lines reflect the trade of electric vehicles which do not have any direct emissions. When compared over the past five years, the 2017 figures show similar results although, in particular, more electric vehicles were traded in 2017 than over the past 5 year.

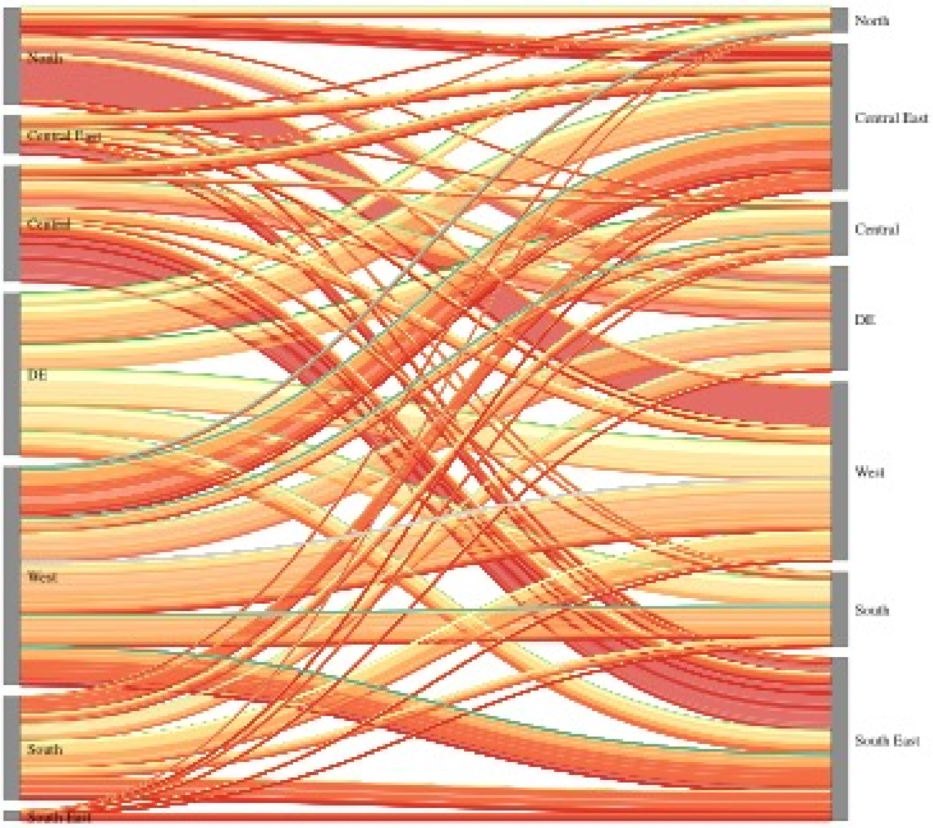
Figure 17: Used vehicle trade and corresponding CO_2 emission intensity in 2017





Source: own calculations based on Eurostat Comext (2019)

Figure 18: Used vehicle trade and corresponding air pollutant intensity in 2017



The figure shows the trade flow from exporting to importing countries/country groups. The width of lines reflects the amount of traded used vehicles; the colours reflect the environmental performance in terms of CO_2 emissions and air pollutants; green lines indicate the trade of electric vehicles which have no direct air pollutants and CO_2 emissions while in contrast red lines indicate the trade of vehicles with high air pollutant and CO_2 emissions i.e. low-value diesel or petrol vehicles with a large engine.

It can be seen from both figures that traded vehicles showed a rather low environmental performance as orange and red dominate in both figures. The somewhat better performance in term of CO_2 emissions than in terms of air pollutants can be directly linked to the weighting which includes the engine capacity in the evaluation of CO_2 emissions. As most vehicles belonged to a medium-size category, the evaluation results in a better scoring. For the evaluation of air pollutants, the engine capacity was not considered (see Chapter 3).

Most of the European countries with high income levels exported more used vehicles than they imported; as the overall stock of these countries remained fairly stable or even increased over the past years, the difference between exports and imports of used vehicles is covered by new vehicles and to a limited extent by trade from other countries outside of Europe.

The Northern country group, consisting of Denmark, Finland, Norway, Sweden and Iceland, exported more than twice as much as it imported. Most of the exported vehicles had a rather low environmental performance. Thus, the Northern country group improved their vehicle stock by having exported CO_2 and air pollutant intensive vehicles while having imported low emission vehicles and new vehicles (with the latter not being displayed here). Main recipient of the vehicles with high CO_2 emissions (red lines in Figure 17) was the Central-Eastern country group, i.e. Czechia, Hungary, Poland and Slovakia as well as the Baltics (Estonia, Latvia, Lithuania), followed by – to a lesser extent – Germany. At the same time, the vehicles in this export flow also had high air pollutants (see Figure 18). The low environmental performance was a result of the low values of vehicles traded between these regions. The majority of the Northern group's air pollutant intensive used vehicles (which were diesel-fuelled vehicles traded with an average value below EUR 1,000) went to the countries of the Western country group, i.e. Belgium, France, Ireland, the Netherlands and UK. As these vehicles were mainly diesel-fuelled vehicles with a medium-size engine capacity, their performance was much better in terms of CO_2 emissions (yellow line in the Figure 18).

Similarly, the Central country group exported more used vehicles than it imported. Exports consisted of mainly vehicles with high air pollutants and CO_2 emission while imported vehicles had a medium environmental performance, thus having improved the own vehicle stock. The main destination countries of air pollutant and CO_2 emission intensive vehicles were countries of the South-Eastern group. The majority of traded vehicles were large diesel passenger cars with a low average trade value. Hence, these cars were relatively CO_2 emission intensive and are in the highest classification in terms of air pollutants.

As the biggest trader in Europe, Germany exported used vehicles to all of the country groups. Germany exported rather environmental friendly used vehicles, while the country imported used vehicles with rather high air pollutants and CO_2 emissions – mainly from the Northern and Central country group. Not only is Germany in short distance to both of these two country blocks but also had the lowest mean household income among them, although income differences were not as significant as they were between the Northern and the Eastern or South-Eastern country group (Eurostat, 2019c). In addition, Germany had the highest share of vehicles with rather high air pollutants and CO_2 emissions in its vehicle stock among the stronger economies in Europe. The biggest share of good performing used vehicles originated from the Western country group, followed by the Southern group. Overall, these trade flows were in line with a fairly balanced vehicle stock with a majority of these vehicles categorized as medium emission intensive.

The Central-Eastern country group was a key importing region of vehicles with low environmental performance and limited exports. Within the group, Poland was the biggest importer of used vehicles with high CO_2 emissions and air pollutants, which resulted in a vehicle stock that consisted of a relatively large share of vehicles with low environmental performance.

The biggest share of vehicles imported to the Central-Eastern country group came from the Western country group; a large amount of more environmental friendly vehicles was imported from Germany.

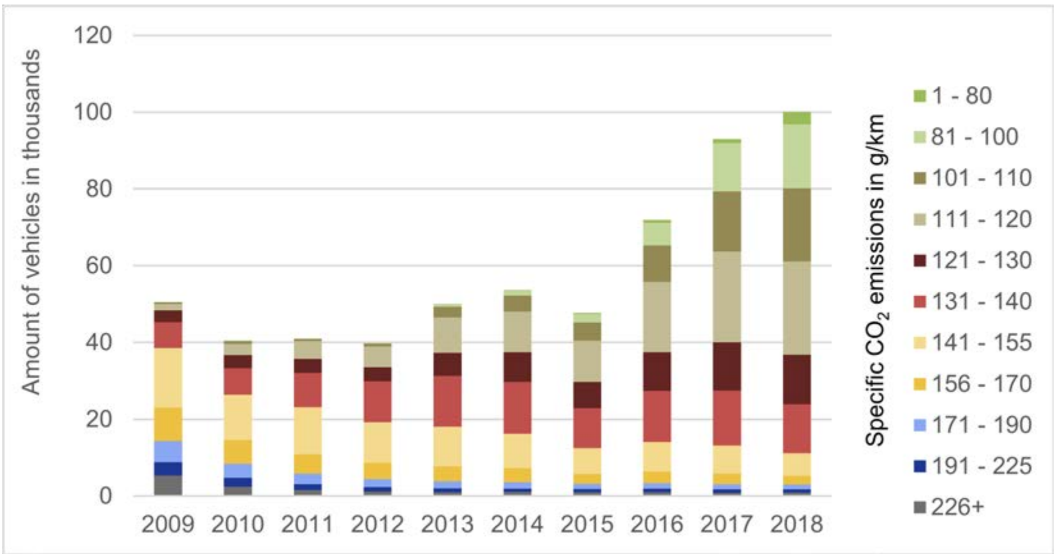
The biggest importing block was the Western country group consisting of Belgium, France, Ireland, the Netherlands and the UK. The Western country group imported rather environmental friendly used vehicles, in particular in terms of CO_2 emissions as also most of these countries had a comparably high mean household income. For example, Ireland imported only a limited number of vehicles with average CO_2 emissions of more than 155g CO_2/km in 2017 (see Box 4).[12] The biggest amount of imported vehicles to the Western country group originated from within the group followed by Germany and the Northern group. For instance, Germany exported a large share of diesel vehicles with a medium engine capacity and an average trade value between EUR 15,001 and EUR 20,000 while a large share of low-value diesel vehicles came from the Northern country group with particular high air pollutants.

Box 4: CO_2 intensity of imported cars to Ireland

Ireland is one of the few countries reporting on the CO_2 emissions of imported vehicles throughout the last decade. However, the figures include intra- and extra-EU trade and also includes new cars.

The total imports of cars significantly increased from 2016 onwards. The imports of vehicles with relatively low CO_2 emissions per kilometre driven has increased notably in the last years – not only in total numbers but also relative to the overall amount. On the contrary, vehicles with high values of CO_2 emissions constantly decreased in both relative and total numbers.

Figure 19: Imports of cars to Ireland according to their specific CO_2 emissions



Source: SIMI (2019)

[12] New passenger cars emit on average 120 gCO_2 /km in the EU in 2018

Similar to the Central-Eastern country group, the South-Eastern group was a main recipient of used vehicles with medium to high CO_2 emission and air pollutant intensity. These vehicles mainly came from the Central country group, which consists of Austria, Switzerland, Liechtenstein as well as Luxembourg and Slovenia. While the Central-Eastern country group exported vehicles with high CO_2 emissions to the South-Eastern group, vehicles with high air pollutants originated from the Western and the Southern country group (Italy, Malta, Portugal and Spain). As indicated above, the majority of households in the South-Eastern country group had a comparably low household income in Europe which may explain the low value of the imported vehicles. As some countries ban imports of old vehicles and vehicles with low European emission standard for air pollutants such as Bosnia-Herzegovina, Serbia or Turkey (see also Chapter 4.1), it could be the case that vehicles have been traded for a relatively small price although these vehicles are relatively new and have a relatively good environmental performance.

5 Conclusions

There was considerable progress in the environmental performance of vehicles in the stocks and also of the traded used vehicles in Europe:

Since 2000, progress has been achieved in the environmental performance of vehicle stocks and in the trade of used vehicles in terms of air pollutant and CO_2 emissions. The progress in the vehicle stocks was stronger for passenger cars than for busses, vans and lorries while it was comparable for all country groups. This can be traced back to EU regulations and in most countries also national regulatory frameworks including taxation which favour environmental friendly vehicles over environmental harmful vehicles as well as to technological progress reducing the specific energy consumption as well as air pollutants and CO_2 emissions (see Table 7).

This also includes the introduction of electric vehicles which do not directly emit air pollutants nor CO_2. Although the market for electric vehicles is relatively new and hence, the share of used electric vehicles is still small, the increasing share of electric vehicles in the sales of new cars since 2010 also improved the environmental performance of the vehicle stocks. In addition, these vehicles also enter the used vehicle market and trade statistics show that the electric vehicles are also traded amongst the country groups with a somewhat rising share over the past five years. So far, these vehicles are traded amongst all country groups without clear direction. The stock as well as the trade of electric vehicles is likely to increase as a result of the European CO_2 targets for new vehicles and national plans to ban the sale of new internal combustion engine cars in e.g. Norway, the Netherlands, Ireland, Slovenia, France and the UK (see Velten et al. 2019). The increase of new zero-emission vehicles in the market will also result in the increased availability of these vehicles to second hand vehicle buyers, thus substituting vehicles with higher air pollutants CO_2 emissions on the secondary market.

There are regional differences of the environmental performance of vehicles in the vehicle stocks and trade flows:

The Northern, Central and Western country groups have the most environmental friendly vehicle stocks, with vehicles having on average the lowest air pollutants and CO_2 emissions. Vehicles in the South-Eastern, Central-Eastern and Southern country groups have particularly high air pollutants and CO_2 emissions when compared to the other country groups. The trade flows also show differences for these country groups. For instance, the Northern and Central country group export much more used vehicles than they import. As the overall number of vehicles increased over the past years, the difference is covered by new vehicles (and to a limited extent by extra-EU trade). In these countries, the impact of regulations for new vehicles have a stronger and direct impact on the vehicle fleet. The South-Eastern and Central-Eastern country groups are key importers while exports to the other country groups are particularly low. In addition, these two country groups import vehicles with relatively high air pollutants and CO_2 emissions.

One of the key factors for the differences is the available household income which differs significantly between these country groups but which determines what a household is able to pay for a vehicle. In addition, national regulations and taxation schemes can influence the purchasing decision e.g. when the registration tax rapidly increases as a function of rising air pollutants and/or CO_2 emissions, thus somewhat closing the financial gap between a low-value but environmental harmful vehicle and a higher-priced vehicle with better environmental performance.

Import bans on old vehicles or vehicles with low European emission standard (i.e. high air pollutants), however, did not lead to the import of higher-value vehicles in Serbia, Bosnia-Herzegovina or Hungary. It might be the case that for those countries the underlying assumption that low-value vehicles have high emissions is not valid but that these countries in particular import vehicles having a low price but still a medium emission intensity (e.g. because of high kilometre driven or other drawbacks of a vehicles reducing its price). However, further research is required to better understand the influences of the import ban on the vehicle stock.

Necessity for better data: The analysis of stock and trade data shows that the current available data on used vehicle stocks and trade is limited and provides little options for analysis. This was partly unexpected as the transport sector, and particularly road transport are at the heart of current discussions to mitigate the climate crisis and local air pollution. As a consequence, it was a challenge to draw conclusions on reasons for low or high emission vehicle stocks and trade flows and related options to improve the environmental sustainability, for example with regard to the effects of individual policy measures.

Some countries already provide some good reporting on their vehicle stock and/or trade. For example, for the vehicle stock, Slovakia and Norway provide the engine type and Euro standard over at least the last decade; UK and Lichtenstein provide a CO_2 classification of their passenger cars. For vehicle trade, Ireland publishes the CO_2 classification of imported vehicles.

However, in the light of the global climate crisis and local air pollution problems, a suitable European database is urgently needed. Such database should include the age structure, engine type and capacity or power as well as the air and CO_2 emissions for the stock and trade of vehicles in Europe. The data on stock is available at the countries' responsible authority for registering a vehicle. For trade, a key source for this information seems to be the re-registration information which Member States share according to Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles. The shared information includes basically all relevant characteristics provided by the vehicle registration documents. These statistics are, however, not publically available and thus, only some countries provide statistics on the environmental performance of their stock based on these statistics.

Such statistics would facilitate the analysis of influencing factors such as household incomes, corporate activities and most importantly policy interventions that should have an effect on motorised road vehicles.

6 Indexes

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Abbreviations

M	Passenger vehicle
M1	Passenger car for the transport of maximum 8 persons in addition to the driver’s seat
M2	Passenger vehicle for the transport of at least 9 persons in addition to the driver's seat and with a maximum mass not exceeding 5 tons.
M3	Passenger vehicle for the transport of at least 9 persons in addition to the driver's seat and with a maximum mass exceeding 5 tons.
N	Goods vehicle
N1	Goods vehicle with a mass of below 3.5 tons
N2	Goods vehicle with a mass of 3.5 to 12 tons
N3	Goods vehicle with a mass of more than 12 tons

7 Literature

ACEA (European Automobile Manufacturers Association) (2019). ACEA Tax Guide 2019. Online available at: https://www.acea.be/publications/article/acea-tax-guide (accessed: 26.09.2019).

ADAC (2019): HU und AU: Alles Wissenswerte zum „TÜV". Website of the ADAC. Online available at: https://www.adac.de/rund-ums-fahrzeug/reparatur-pflege-wartung/hu-und-au/ (accessed: 03.10.2019).

AECC (Assocaition for Emissions Control by Catalyst) (2019): Legislation: Light-duty vehicles / Heavy-duty vehicles. Online available at: https://www.aecc.eu/legislation/ (accessed: 11.12.2019)

Automobile (2018): Cos'è l'IPT auto: quanto costa e come si calcola. 25 May 2018. Online available at: https://www.automobile.it/magazine/burocrazia/ipt-auto-5342 (accessed: 21.10.2019)

Automobile Club d'Italia (2019): Annuario statistico 2019. Online available at: http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/annuario-statistico/annuario-statistico-2019.html (accessed on 25. Nov 2019).

Bernard, Yoann; Tietge, Uwe; German, John; Muncrief, Rachel (2018): Determination of real-world emissions from passenger vehicles using remote sensing data. ICCT. London. Online available at: https://theicct.org/sites/default/files/publications/TRUE_Remote_sensing_data_20180604.pdf (assessed: 20.02.2020)

Bielaczyc, P.; Szczotka, A.; Woodburn, J. (2016): A comparison of exhaust emissions from vehicles fuelled with petrol, LPG and CNG. In: IOP Conf. Ser.: Mater. Sci. Eng. 148, S. 12060. DOI: 10.1088/1757-899X/148/1/012060.

Bjelotomic, Snezana (2019): Serbia to ban import of cars that are excessive pollutants. Published by Serbian Monitor. Online available at: https://www.serbianmonitor.com/en/serbia-to-ban-import-of-cars-that-are-excessive-pollutants (accessed: 02.10.2019)

BMU (2019): Description of the data submitted according to Commission Decision 2005/293/EC on the monitoring of the reuse/recovery and re-use/recycling targets on ELVs. . Available at: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/jahresbericht_altfahrzeug_2017_bf.pdf (accessed on 27. Nov 2019).

COM (European Commission) (2019a): Taxes in Europe Database v3. Online available at: http://ec.europa.eu/taxation_customs/tedb/splSearchForm.html (accessed: 21.10.2019).

COM (2019b): European Commission Trade Market Access Database. Online available at: https://madb.europa.eu/madb/euTariffs.htm (accessed: 25.09.2019).

COM (2019c): Trade – Policy – Countries and regions: Western Balkan. Online available at: https://ec.europa.eu/trade/policy/countries-and-regions/regions/western-balkans (accessed: 25.09.2019).

DG CLIMA (2020): Road transport: Reducing CO_2 emissions from vehicles. Online available at: https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en (accessed: 07.01.2020).

EAFO (European Alternative Fuels Observatory) (2019): Could driving with LPG be key to reducing air pollution? Online available at: https://www.eafo.eu/news/23775/Could%2520driving%2520with%2520LPG%2520be%2520key%2520to%2520reducing%2520air%2520pollution%253F (accessed on 29.01.2020).

EEA (European Environment Agency) (2019a): Monitoring CO_2 emissions from new passenger cars and vans in 2017. Online available at: (accessed on 11.12.2019).

EEA (2019b): Monitoring of CO_2 emissions from passenger cars – Regulation (EC) No 443/2009. Online available at: https://www.eea.europa.eu/data-and-maps/data/co2-cars-emission-16 (accessed on 11.12.2019).

EEA (2019c): Monitoring of CO_2 emissions from vans – Regulation 510/2011. Online available at: https://www.eea.europa.eu/data-and-maps/data/vans-12 (accessed on 11.12.2019).

EEA (2020): EEA writing manual.

Eurostat (2019a): Transport database - road transport (road). Online available at: https://ec.europa.eu/eurostat/web/transport/data/database (accessed on 27. Nov 2019).

Eurostat (2019b): Quality report on European statistics on international trade in goods: 2013-2016 data – 2019 edition. Online available at: https://ec.europa.eu/eurostat/documents/7870049/9568307/KS-FT-19-002-EN-N.pdf/856f28e5-e9f6-4669-8be0-2a7aa5b1ee67 (accessed on 27. Nov 2019).

Eurostat (2019c): Mean and median income by household type - EU-SILC and ECHP surveys [ilc_di04]. Available at: https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do (accessed on 21. Jan 2019).

Eurostat Comext (2019): International trade – EU trade since 1988 by CN 8 (DS-016890). Available at: http://epp.eurostat.ec.europa.eu/newxtweb (accessed on 02. Dec 2019).

GFK and CE (2016): Data gathering and analysis to improve the understanding of 2nd hand car and LDV markets and implications for the cost effectiveness and social equity of LDV CO_2 regulations. A report for DG CLIMA.

Haugneland, P., Lorentzen, E., Bu, C., Hauge, E., 2017. EVS30 Symposium. Put a price on carbon to fund EV incentives –Norwegian EV policy success. Stuttgart

Heidt, C.; Lambrecht, U.; Hardinghaus, M.; Knitschky, G.; Schmidt, P.; Weindorf, W. et al. (2013): On the road to sustainable energy supply in road transport. potentials of CNG and LPG as transportation fuels. Federal Ministry for Transport, Building and Urban Development (BMVBS). Heidelberg, Berlin, Munich, Leipzig. Online available at: https://www.bmvi.de/SharedDocs/EN/Documents/MKS/mfs-short-study-cng-lpg.pdf?__blob=publicationFile (assessed: 20.02.2020).

Iberley (2016): Impuesto Especial sobre Determinados Medios de Transporte: Regulado en la Ley 38/1992, de 28 de diciembre de Impuestos Especiales, artículos 65 a 74. Online available at: https://www.iberley.es/temas/impuesto-especial-sobre-determinados-medios-transporte-iedmt-19741 (accessed: 21.10.2019).

ICCT (2012): One Table to Rule them all. Online available at: https://theicct.org/sites/default/files/info-tools/One%20table%20to%20rule%20them%20all%20v1.pdf (assessed: 20.02.2020).

ICCT (2018): CO_2 emissions from cars: the facts. Available at: https://www.transportenvironment.org/sites/te/files/publications/2018_04_CO2_emissions_cars_The_facts_report_final_0_0.pdf (accessed on 11.12.2019).

Kraftfahrt-Bundesamt (KBA) (2019a): Bestand an Kraftfahrzeugen und Kraftfahrzeuganhängern nach Bundesländern, Fahrzeugklassen und ausgewählten Merkmalen am 1. Januar 2019. Online available at: https://www.kba.de/DE/Statistik/Nachrichten/2019/Statistik/fz_27_012019.html (accessed on 25. Nov 2019).

Kraftfahrt-Bundesamt (KBA) (2019b): Bestand nach Umwelt-Merkmalen. Online available at: https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz13_b_uebersicht.html (accessed on 25. Nov 2019).

Merkisz, Jerzy; Gallas, Dawid; Siedlecki, Maciej; Szymlet, Natalia; Sokolnicka, Barbara (2019): Exhaust emissions of an LPG powered vehicle in real operating conditions. In: E3S Web Conf. 100, S. 53. DOI: 10.1051/e3sconf/201910000053.

Norwegian Tax Administration (2019): Duties: Cars and other vehicles. Website of the Norwegian Tax Administration. Online available at: https://www.skatteetaten.no/en/person/duties/cars-and-other-vehicles/importing/ (accessed: 02.10.2019).

Online vehicle sales platforms: e.g. https://www.mobile.de/, https://www.automobile.de/, https://www.automobile.it/

Öko-Institut, TML, COWI (2011): European second-hand car market analysis. Contract Number No. 07.0307/2009/549021/SER/C5 European Commission - DG Climate Action.

PWC (2016): Global automotive tax guide. Online available at: https://www.pwc.de/de/automobilindustrie/pwc-global-automotive-tax-guide-2016.pdf (accessed: 21.10.2019).

PZPM (Polish Association of the Automotive Industry) (2019): First Registrations of Used PC imported to Poland. Available at: https://www.pzpm.org.pl/en/Automotive-market/Used-Passenger-Car-Import-to-Poland/First-Registrations-of-Used-PC-imported-to-Poland (accessed on 19.11.2019).

Ristovski, Z. D.; Jayaratne, E. R.; Morawska, L.; Ayoko, G. A.; Lim, M. (2005): Particle and carbon dioxide emissions from passenger vehicles operating on unleaded petrol and LPG fuel. In: The Science of the total environment 345 (1-3), S. 93–98. DOI: 10.1016/j.scitotenv.2004.10.021

Schröder, Ralph; Steickert, Markus; Walther, Dirk; Ranftl, Ralf-Peter (Hg.) (2015): Ermittlung des Umfangs von Abweichungen bei Durchführung der Abgasuntersuchung zwischen Messung am Auspuff und Abfrage des On-Board-Diagnosesystems. Wirtschaftsverlag N.W. Verlag für Neue Wissenschaft; Bundesanstalt für Straßenwesen (Berichte der Bundesanstalt für Straßenwesen Fahrzeugtechnik F, Heft 109). Online available at: https://edocs.tib.eu/files/e01fn16/868030988.pdf (accessed: 03.10.2019).

SIMI (the Society of the Irish Motor Industry) (2019): National Vehicle Statistics. Online available at: https://www.simi.ie/en/motorstats/national-vehicle-statistics (accessed on 25. Nov 2019).

Statistical Office of the Slovak Republic (2019): Registered vehicles. Online available at: https://slovak.statistics.sk/wps/portal/ext/Databases/STATdat/ (accessed on 25. Nov 2019).

Statistik sentralbyrå (2019): Registered vehicles. Online available at: https://www.ssb.no/en/statbank/table/11823 (accessed on 25. Nov 2019).

Supnithadnaporn, Anupit; Noonan, Douglas S.; Samoylov, Alexander; Rodgers, Michael O. (2011): Estimated validity and reliability of on-board diagnostics for older vehicles. Comparison with remote sensing observations. In: Journal of the Air & Waste Management Association (1995) 61 (10), S. 996–1004. DOI: 10.1080/10473289.2011.596738.

Synák, František; Čulík, Kristián; Rievaj, Vladimír; Gaňa, Ján (2019): Liquefied petroleum gas as an alternative fuel. In: Transportation Research Procedia 40, S. 527–534. DOI: 10.1016/j.trpro.2019.07.076.

TCC (Turkey Customs Consultancy) (2019): FAQ. Online available at: https://www.turkeycustoms.net/en/faq (accessed: 03.10.2019).

Transport & Environment (2018): CO2 EMISSIONS FROM CARS:the facts. Hg. v. William Todts. European Federation for Transport and Environment AISBL. Bruxeles. Online available at: https://www.transportenvironment.org/sites/te/files/publications/2018_04_CO2_emissions_cars_The_facts_report_final_0_0.pdf (accessed: 25.02.2020).

UNEP and UNECE (United Nations Environment Programme and United Nations Economic Commission for Europe) (2017): Used vehicles – A global overview. Online available at: https://www.unece.org/fileadmin/DAM/trans/doc/2017/itc/UNEP-ITC_Background_Paper-Used_Vehicle_Global_Overview.pdf (assessed: 29.09.2019).

US ITA (United States Department of Commerce, International Trade Administration, Office of Transportation and Machinery) (2015): Compilation of Foreign Motor Vehicle Import Requirements.

Vedlugaitė, Diana (2017): Monitoring CO2 emissions from new passenger cars and vans in 2016. Luxembourg: Publications Office of the European Union (EEA report, No 19/2017).

Velten, Eike Karola, Stoll, Theresa; Meinecke, Lisa (2019): Measures for the promotion of electric vehicles. Ecologic Institute, Berlin. Commissioned by Greenpeace e. V.

Wietschel, Martin; Moll, Cornelius; Oberle, Stella; Lux, Benjamin; Timmerberg, Sebastian; Neuling, Ulf et al. (2019): Klimabilanz, Kosten und Potenziale verschiedener Kraftstoffarten und Antriebssysteme für Pkw und Lkw Endbericht. Fraunhofer ISI, technische Universität Hamburg, IREES GmbH. Karlsruhe. Online available at: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2019/klimabilanz-kosten-potenziale-antriebe-pkw-lkw.pdf (assessed: 20.02.2020).

EU Directives and Regulations

Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles.

Commission Implementing Regulation (EU) 2019/1776 of 9 October 2019 amending Annex I to Council Regulation (EEC) No 2658/87 on the tariff and statistical nomenclature and on the Common Customs Tariff

Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive).

Regulation (EU) 2018/858 of the European Parliament and of the Council on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC.

Regulation (EU) 2018/956 of the European Parliament and of the Council of 28 June 2018 on the monitoring and reporting of CO_2 emissions from and fuel consumption of new heavy-duty vehicles.

Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles, and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011.

Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC.

Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO_2 emissions from light-duty vehicles.

Regulation (EU) No 510/2011 of the European Parliament and of the Council of 11 May 2011 setting emission performance standards for new light commercial vehicles as part of the Union's integrated approach to reduce CO_2 emissions from light-duty vehicles.

Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information

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