European Commission

JRC TECHNICAL REPORTS

Revision of the EU Green Public Procurement Criteria for Transport

Preliminary report (Draft)

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2016

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Preliminary Report - DRAFT

October 2016

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1 INTRODUCTION

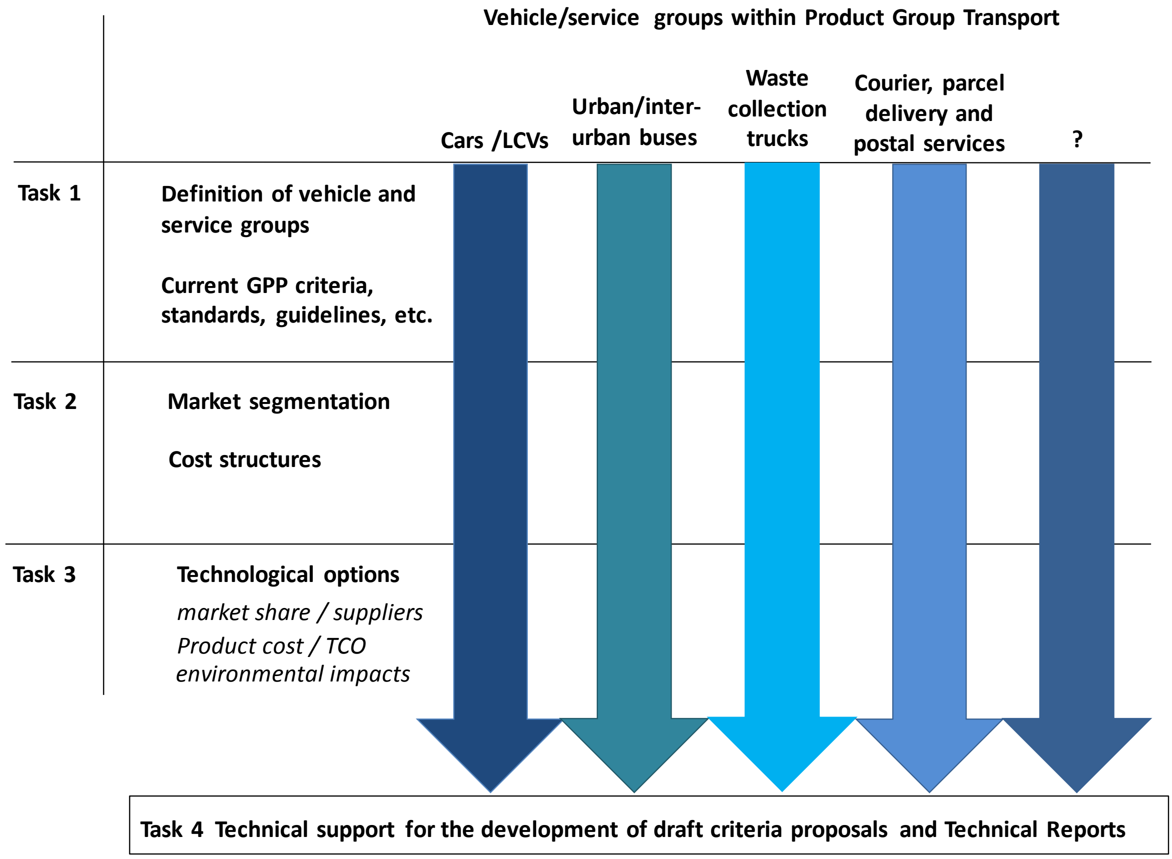
1.1 Background and objective

Green Public Procurement (GPP), in which public authorities procure goods, services and works that have less environmental impact than comparable contracts, has the potential to accelerate the market introduction and market uptake of less environmentally damaging technologies. In order to support GPP, the European Commission has developed a set of common EU GPP criteria for various products and services in order to avoid a distortion of the single market and to reduce administrative burdens. The most recent EU GPP criteria for transport were published in 2012 (European Commission, 2012) and were based on the Technical Background Report published in 2011 (BRE, 2011).

The aim of this study is to revise the current EU GPP criteria for Transport (2012 EU GPP criteria). CE Delft, jointly with Transport and Environmental Policy Research (TEPR), is supporting the JRC in this process[1].

The project has four separate tasks, as shown in Figure 1.

Figure 1: Overview of the project



[1] See the project's website: http://susproc.jrc.ec.europa.eu/Transport/index.html

This report includes the results of Task 1, 2 and 3.

The aim of the revision process is to deliver revised criteria that reflect the latest technological development, while taking into account stakeholder opinions, current legal developments and other GPP initiatives. The criteria need to be ambitious enough to result in the 'greening' of the transport sector, while on the other hand, barriers associated with the level of ambition should not hinder the use of the revised EU GPP criteria.

The scope of the revision includes the product group 'Transport' and is limited to the European transport sector. The main focus of the revision of EU GPP criteria is those that are applied in the EU, although similar GPP initiatives and standards from non-EU countries will be taken into account. Due to the regular update of EU GPP criteria, this project focuses on the market developments in the period 2012-2015 (since the last publication of the EU GPP criteria). For future market developments the scope was limited to the time period 2015-2020, assuming a new revision process to take place before 2020 to determine the criteria required after 2020.

1.2 Methodology for determining the scope and definitions

As part of Task 1, the following work has been undertaken:

- **Overview of existing legislation, standards and criteria.** This includes a review of EU legislation, relevant guidelines and ecolabels at the EU and national levels and relevant standards, guidelines and initiatives used in the private sector. This is presented in Section 2.1.
- **Overview of statistical and technical categories.** The focus of this review was on the categories that can be used to define the vehicles and services that might be covered by EU GPP criteria for transport. This is covered in Section 2.2.
- **Stakeholder survey.** The focus of the survey is to gather the views of relevant stakeholders on the existing EU GPP criteria, particularly the need to update them. The survey asked for views on the categories of transport vehicle and service covered by the criteria, the definitions of these vehicles and services, the scope and definition of the criteria themselves and the uptake of the criteria. Section 2.3 analyses the responses to the survey only in relation to the categories of vehicle and service covered in this report and according to their definition. The analysis of the remaining responses is included in section 2.3 on the various vehicle and service types.
- **Proposals for the revision of the categories covered by the criteria and their definition.** This is presented in Section 2.4 and has the same scope as the analysis of Section 2.3.

1.3 Methodology for market, cost, environmental and technical analysis

1.3.1 Methodology for market analysis

In each chapter, one section is devoted to the analysis of the market. The aim of the market analysis is to gain insight in the economic relevance of the product group 'Transport' and the relevant market segments, and the difference between the overall vehicle fleets and services, and the vehicles and services procured by the public sector.

Based on a review of the literature, each chapter holds a characterization of the overall market by the size of current vehicle fleet or services, sales, production, and import/export. Moreover, the distribution of the current fleet into characteristics such as fuel type, weight, engine size, and age is presented. Finally, the part of the market that pertains to the public sector is discussed.

1.3.2 Methodology for cost analysis

In the cost analysis sections, the Total Cost of Ownership is calculated both for vehicles and for the services. For passenger cars and LCVs, the vehicles are subdivided into two size classes (small and large), and for passenger cars also into petrol and diesel. Furthermore, also various scenarios are used for the annual mileage of the vehicle, as the total cost of ownership of a vehicle is also strongly dependent on this.

Four types of costs are taken into account: acquisition costs, fuel costs, maintenance costs and insurance costs. These costs are calculated with and without taxes. Besides relevant taxes such as excise duty on fuels and car purchase taxes, also Value Added Tax is taken into account. Based on (CE Delft, 2016a), a European Union average Value Added Tax of 22% is used.

The Total Cost of Ownership is calculated as the sum of yearly payments distributed over the entire lifetime of the vehicle. This means that variable or periodic costs are not converted to the net present value and that fixed costs (only acquisition costs) are paid as annuities from a loan with an interest rate of 4% (EC, ongoing). The Cost of Ownership of a vehicle is also calculated per year and per km.

1.3.3 Methodology for the identification of environmental hotspots

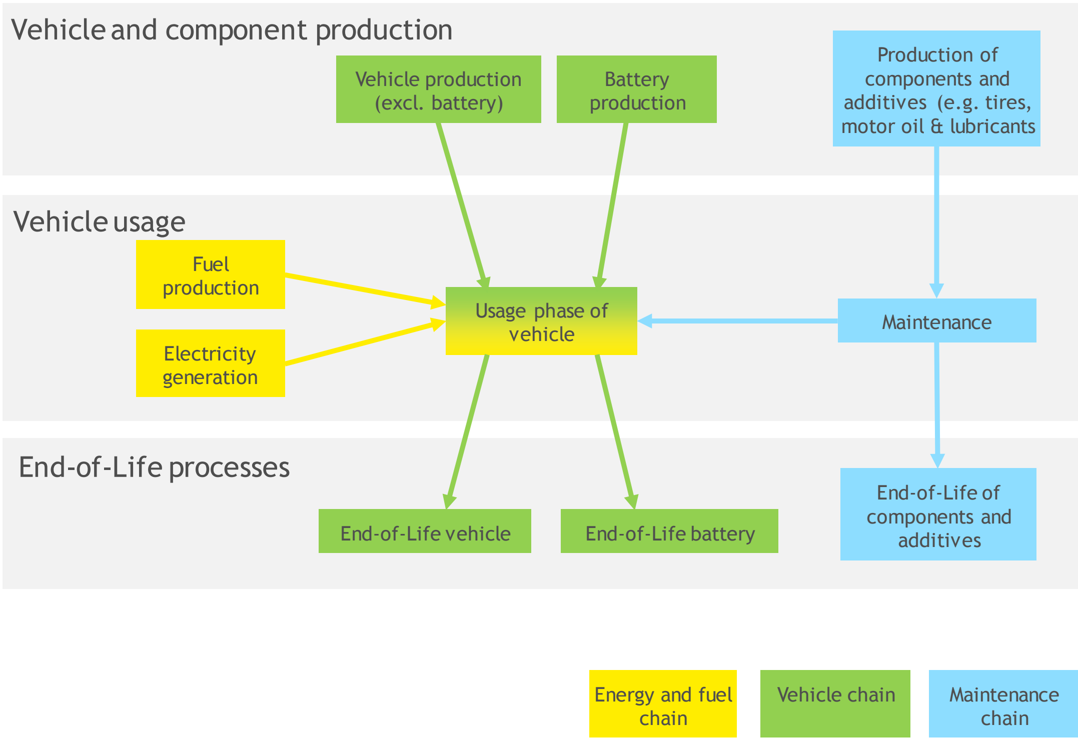
The various impacts occur in different phases of the vehicle life cycle. For considering a comprehensive life cycle of a vehicle, three main components can be distinguished, see also Figure 2:

- vehicle;
- components and additives used for vehicle maintenance;
- energy carriers (electricity and fuel).

In order to define the most relevant life cycle stages and environmental hotspots a variety of scientific LCA-papers have been studied describing the life cycle performance of passenger cars and buses. Based on the conclusions of this LCA review relevant indicators and options are defined to be further studied in the technical analysis.

Outcomes of the LCA review can be found in Annex B 'LCA screening for LDVs' and Annex C 'LCA screening for buses'.

Figure 2: Overview of a comprehensive vehicle life cycle



1.3.4 Methodology for technical analysis

The analysis of the technical aspects of the transport vehicles and services that were selected in Task 1, is done in the following steps in each chapter. The potential for improvement compared to the baseline and the associated costs are described per functional unit (e.g. vehicle or parcel). This is done for the various options that exist for vehicles or services with an environmental performance that is better than the average on the EU market. In cases where a performance indicator exists for the environmental performance of an entire vehicle or service that could be used for defining GPP criteria, these are used to analyse the potential and cost of improvements. An example is the CO_2 type approval value for cars or LCVs. If such an indicator does not exist or is not measured on a consistent, transparent and regular basis, the analysis is focused on individual technological measures for improving the environmental performance. An example of this is a hybrid public transport bus.

2 SCOPE, DEFINITIONS AND LEGISLATION

2.1 Overview of existing legislation, standards and criteria

The aim of this section is to provide an overview of existing legislation, standards and other procurement criteria that are of relevance to road transport vehicles and services. First, an overview of relevant EU legislation is provided, which focuses on those Communications, Regulations and Directives that are important for regulating the performance of road transport vehicles. Second, an overview is provided of relevant labelling and green/sustainable procurement criteria at the national level, including national or transnational ecolabels such as the Blue Angel and Nordic Swan. A brief overview of relevant initiatives in the private sector is then provided, before the section concludes with a synthesis of the analysis.

2.1.1 Overview of EU legislation that regulates the environmental performance of transport

The importance of taking action in the transport sector to reduce its environmental impacts, particularly in relation to its emission of greenhouse gases (GHGs), air pollutants and noise, has been highlighted in various EU strategic documents, including the seventh Environment Action Programme[2]. The broader transport policy framework is set by the 2011 Transport White Paper, which underlines the need for, and a number of initiatives that will contribute to, improving the environmental performance of road transport vehicles and the way that they are used (European Commission, 2011a). Environmental considerations were core to the Transport White Paper, as it took as its starting point the need to reduce transport's GHG reductions by 60% by 2050 (compared to 1990 levels), which was the mid-point in the range of cost effective GHG reductions from transport identified by the Commission's Low Carbon Roadmap (European Commission, 2011b). The importance of decarbonising transport was also underlined in the 2030 climate and energy policy framework (European Commission, 2014a).

The ambient air quality Directive provides the policy framework for air quality as its sets limit values for a range of air pollutants, including nitrogen dioxide and particulate matter (PM), in order to protect human health and the environment[3]. In spite of improvements in air quality in recent years, largely as a result of European emissions legislation, some challenges remain, particularly related to the emissions of the oxides of nitrogen (NO_x) from road vehicles. Noise from road traffic is similarly a persistent problem (EEA, 2015a). Vehicles are also a major waste stream and so need to be designed and treated appropriately at the end of their life in order to be consistent with the emerging circular economy framework (European Commission, 2015a). The remainder of this section sets out the detail of the EU policy framework for improving the environmental performance of road transport vehicles by:

- reducing GHG emissions from vehicles by improving their efficiency and the way in which they are used;
- reducing the air pollutant emissions from vehicles and measures to reduce the impact of these emissions on human health;
- reducing the noise from vehicles; and
- reducing other environmental impacts, such as those relating to the end of life treatment of vehicles.

[2] Decision No 1386/2013/EU on a General Union Environment Action Programme to 2020.

[3] Directive 2008/50/EC on ambient air quality and cleaner air for Europe.

Reducing GHG emissions from vehicles

The main legislation to improve the GHG emissions performance of road transport focuses on reducing carbon dioxide (CO_2) emissions from new cars and light commercial vehicles (LCVs). The passenger car CO_2 Regulation sets a fleet-wide average target of 95 gCO_2/km for 2021 for the new car fleet[4], while the LCV CO_2 Regulation[5] sets a similar target for the new LCV fleet of 147 gCO_2/km for 2020. The Regulations apply to M_1 and N_1 vehicles respectively and both had earlier targets (for cars in 2015 and for LCVs in 2017), which have already been met. In 2014, the average CO_2 emissions of new cars in the EU was 123g/km, which was a 10% drop since 2011, while the equivalent figure for new LCVs was 169 g/km (EEA, 2015b). There is no equivalent legislation for heavy duty vehicles (HDVs), such as buses and waste collection trucks, although a tool to support the measurement of the CO_2 emissions of these vehicles has been developed at the EU level (European Commission, 2014b). In the course of 2016-17, the Commission plans to review the car and LCV CO_2 Regulations with the aim of establishing post-2020 targets for these vehicles, and to establish a monitoring and reporting system for HDVs in order to improve the information provided to potential purchasers (European Commission, 2015b).

In order to reduce CO_2 emissions from their vehicles, manufacturers can include a range of different technologies that have the potential to improve the fuel efficiency of the vehicle. This includes varying degrees of hybridisation in which an increasing amount of energy comes from an electric motor. The use of '**stop and start**' technology, which was included in the 2012 EU GPP criteria for Transport, is part of the increasing hybridisation of vehicles. Its use on new vehicles has been increasing as it turns a vehicle's engine off when the vehicle is standing still, thus reducing emissions particularly in congested conditions or when vehicles are otherwise stationary, e.g. at bus stops. However, 'stop and start' technology is only one of many different types of technology that can reduce CO_2 emissions. This will be covered in more detail in the technical analysis in Task 3.

In order to reduce transport's GHG emissions, it is also important to decarbonise the fuels and energy sources that are used through the increased **use of alternative fuels**, such as biofuels (including biogas), electricity and hydrogen. Vehicles using natural gas also deliver savings in GHG emissions compared to petrol-engined vehicles. Two closely-related Directives set requirements on Member States to increase the amount of renewable fuels used in the transport sector and to reduce the GHG intensity of existing fuels. The aim of the Renewable Energy Directive is to increase the amount of energy produced from renewable sources, including in the transport sector. For transport, it sets a minimum target for 2020 of 10% for the proportion of final energy consumption that must be from renewable sources[6]. The Fuel Quality Directive sets the quality parameters for the petrol and diesel used by road transport, as well as by non-road mobile machinery. A 2009 amendment to the Directive introduced targets for energy suppliers to reduce the life cycle GHG emissions of the fuels that the supplied. This included a mandatory 6% target to be achieved by 2020, which was supplemented by two indicative targets that could take the final target to 10%[7]. More recently, the Alternative Fuels Infrastructure Directive aims to contribute to the development of the necessary

[4] Regulation (EC) No 443/2009 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.

[5] Regulation (EU) No 510/2011 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.

[6] Directive 2009/28/EC on the promotion of the use of energy from renewable sources.

[7] Directive 98/79/EC relating to the quality of petrol and diesel fuels, as amended by Directive 2009/30/EC.

infrastructure for alternative transport fuels, including for natural gas, by requiring Member States to develop appropriate national policy frameworks[8].

Apart from CO_2 emissions from the combustion of fossil fuels, the other important source of GHG emissions from the transport sector relates to the gases used in **air conditioning systems**. Since 2011, the mobile air conditioning Directive[9] has required that the gases used in air conditioning systems that are designed to contain fluorinated greenhouse gases are fitted to new models of cars and small LCVs (i.e. class I LCVs) have a Global Warming Potential (GWP) of 150 or less. From 2017, the use of gases with a GWP higher than 150 is effectively banned in all new cars and small LCVs. While the Directive stated that it would be reviewed, and potential additional legislative proposals made, none has been forthcoming or has been mentioned in future plans, e.g. in the Transport White Paper.

In addition to setting technical standards for vehicles, such as for cars and LCVs, a vehicle's fuel use, and therefore its CO_2 emissions, is also influenced by how the vehicle is driven. Driving at appropriate speeds and with appropriate acceleration, braking and gear changes all influence fuel use. Fuel efficient driving behaviour is often referred to as **'eco-driving'**. This can be facilitated by the provision of information to drivers, e.g. provided with the vehicle, or through a mechanism in the vehicle that monitors driving behaviour and provides feedback. The feedback might be given directly to the driver and/or in reports discussed as part of driver training particularly in the case of vehicle fleets. For these reasons, criteria on the provision of information on eco-driving and fuel consumption displays were included in the 2012 EU GPP criteria for Transport, for the category 'purchasing or leasing of cars and LCVs', as were criteria on driving training and the provision of fuel consumption data for bus and waste collection services.

Two elements of eco-driving for cars - ensuring appropriate tyre pressures and appropriate gear changes - that were included in the 2012 EU GPP criteria - have been facilitated through technical requirements. Since 2014, the General Safety Regulation has required that all new cars registered or sold in the EU are fitted with an accurate **tyre pressure monitoring system (TPMS)** and a **gear shift indicator (GSI)**[10]. In its Transport White Paper, the Commission included a potential future initiative on 'eco-driving and speed limits'[11]. This mentioned that the inclusion of eco-driving requirements might be considered in future revisions of the driving licence Directive, that the deployment of ITS applications in support of eco-driving should be accelerated and that approaches to limit the maximum speed of LCVs would be examined.

The General Safety Regulation[12] also set out safety and environmental requirements for tyres. It requires that **all tyres**, including those provided with new vehicles, must meet specified **rolling resistance and rolling noise requirements**. The requirements apply first to new types of tyre, then tyres fitted to new vehicles, before ultimately preventing tyres that do not meet the specified limits from being sold. New types of tyre have had to meet the rolling noise limits and the first set of rolling resistance limits specified in the Regulation since 2012.

From November 2016 new types of tyre have to comply with a second set of limit values for rolling resistance:

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[8] Directive 2014/94/EU on the deployment of alternative fuels infrastructure.

[9] Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles.

[10] Regulation (EC) No 661/2009 concerning type approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor.

[11] Initiative 30 of European Commission (2011a).

[12] Regulation 661/2009.

- 10.5 kg/tonne for tyres designed primarily for cars, LCVs and their trailers;
- 9 kg/tonne for tyres designed primarily for larger vehicles and their trailers that carry lighter loads; and
- 6.5 kg/tonne for tyres designed primarily for larger vehicles and their trailers that carry heavier loads.

All of these coefficients are measured in accordance with ISO 28580. For snow tyres, the specified limit values are increased by 1 kg/tonne.

Reducing the air pollutant emissions from vehicles

Separate legislation limits the **emissions of air pollutants** from light duty vehicles (LDVs, i.e. cars and LCVs) and from HDVs. Additionally, other legislation sets emission limit values on a range of non-road mobile machinery (NRMM) that is not primarily (or at all) used on roads. The LDV emissions Regulation sets the latest emission limit values for cars and LCVs, known as Euro 6, for various pollutants including NO_x, PM and non-methane hydrocarbons (NMHC). These have been required for all new cars and smaller LCVs since September 2015 and will be required for all new large LCVs from September 2016[13]. One of the reasons for the persistent problem with NO_x emissions from road vehicles mentioned above has been an emerging discrepancy between NO_x emissions measured on the test cycle and those that are emitted in real world conditions. As a result real driving emission (RDE) tests are being developed and introduced for LDVs, which will require real world emissions to be within a fixed range of the test cycle emissions. RDE emissions of 110% above the test cycle emissions will be permitted until 2019, after which the maximum variance allowed will be 50% (European Commission, 2015c).

The HDV emissions Regulation sets the latest emission standards for such vehicles, or specifically their engines. The current Euro VI standards, which cover similar emissions to the LDV emissions Regulation, have applied to all new vehicles and engines since the start of 2014[14]. These replaced, and are more stringent than, the limit values referred to as Euro V and 'EEV' (enhanced environmentally friendly vehicle) that were set by previous legislation. In addition, the NRMM emissions Directive sets emission limit values for a similar range of pollutants for engines installed in a wide range of machinery, from hedge trimmers through construction machinery to rail locomotives and inland waterway vessels. All new machinery covered by the NRMM Directive now have to meet the most recent set of emission limit values that are specified, as the latest emission values have been a requirement since 2014[15]. The Commission proposed to repeal the current NRMM Directive and replace it with a Regulation that would *inter alia* introduce new emission limits in September 2014 (European Commission, 2014c), but this has not yet been adopted.

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[13] Regulation 715/2007 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.

[14] Regulation 595/2009 on type approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and on access to vehicle repair and maintenance information, as amended by Commission Regulation (EU) No 582/2011.

[15] Directive 97/68 on the approximation of the laws of the Member States relating to measures against emission of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery, as amended by Directive 2004/26/EC.

In order to protect human health, reducing people's exposure to air pollutants is important. For this reason, the 2012 EU GPP criteria include a criterion with respect to the location of the exhaust on buses. Specifically, that for buses purchased, or any buses used in contracts that have been procured, the **exhaust pipe** should not be located on the same side as the passenger door.

Air pollutant emissions come not just from the operation of vehicles, but also from their maintenance. The paints Directive sets the maximum content of volatile organic compounds (VOCs) for various products used to refinish vehicles; all relevant products have had to comply with the stated maximum values since 2007[16].

Reducing the noise from vehicles

European legislation also directly regulates the **noise levels** of vehicles and other outdoor machinery. The vehicle noise Regulation[17] sets three phases of declining noise limit values for cars, LCVs, buses and other heavy duty vehicles, starting in 2016 with phase 1. Phase 2 applies to new vehicle types from 2020 and to all registrations from 2022, while phase 3 applies four years later. For each category of vehicle, the emissions limits are summarised in Table 1.

Table 1: Future noise limit values as set out in the vehicle noise Regulation

	Measured in decibels (A) or dB(A)		
	Phase 1 (2016)	Phase 2 (2020 for new vehicle types, 2022 for all registrations)	Phase 3 (2024 for new vehicle types, 2026 for all registrations)
Cars	72 to 75 depending on the vehicle's power to mass ratio	70 to 74 depending on the vehicle's power to mass ratio	68 to 72 depending on the vehicle's power to mass ratio
Small buses (M_2)	72 to 75 depending on the vehicle's mass and rated engine power	70 to 74 depending on the vehicle's mass and rated engine power	69 to 72 depending on the vehicle's mass and rated engine power
Buses (M_3)	76 to 80 depending on the vehicle's mass and rated engine power	74 to 78 depending on the vehicle's mass and rated engine power	73 to 77 depending on the vehicle's mass and rated engine power
LCVs	72 to 74 depending on the vehicle's mass	71 to 73 depending on the vehicle's mass	69 to 71 depending on the vehicle's mass
Heavy commercial vehicles	77 to 82 depending on the vehicle's rated engine power	75 to 81 depending on the vehicle's rated engine power	74 to 79 depending on the vehicle's rated engine power

[16] Directive 2004/42/EC on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain paints and varnishes and vehicle refinishing products.

[17] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

The outdoor equipment noise Directive 2000/14[18] sets limit values for noise from selected outdoor machinery, the last stage of which has applied since 2006. For other outdoor machinery, including waste collection vehicles, the Directive does not set emission limit values, only requiring that this machinery are subject to noise marking.

Reducing other environmental impacts

From an environmental perspective, the materials used in vehicle manufacture, as well as any lubricants used in the course of a vehicle's operation, are also important. Some materials and components of lubricants are potentially more damaging to human health and the environment than others, if they are disposed of inappropriately or, in the case of lubricants, are released accidentally in the course of vehicle operation or repair. Additionally, the use of low viscosity engine lubricants has the potential to improve the efficiency of engines and thus contribute to reducing CO_2 emissions.

Conditions on the **materials used** in cars and LCVs and on their disposal in order to minimise waste are set in the end of life vehicle Directive, which also aims to improve their end-of-life treatment[19]. The Directive sets minimum requirements that apply from 2015, i.e. that a minimum of 95% by weight of end-of-life cars and LCVs should be reused and recovered, and that a minimum of 85% should be reused and recycled. The Directive also prohibits the use of certain substances in cars and LCVs, including lead, mercury, cadmium and hexavalent chromium, other than for a regularly-updated list of exemptions. Manufacturers are also encouraged to increase the use of recycled materials in the vehicles.

There is no specific EU legislation that regulates the environmental performance and use of **lubricants**. Instead there are a number of pieces of legislation that regulate potentially dangerous substances, including the CLP[20] and the REACH[21] Regulations. The ecolabel Regulation[22] sets the framework within which ecolabels are developed and refers to both of the CLP and REACH Regulations, as does the EU's ecolabel on lubricants (see below).

The principles of waste management in the EU are set out in the waste Directive and include that disposal should occur only when re-use, recycling and recovery are not possible and that when disposal does take places, it should not endanger human health or harm the environment[23]. **Waste oils** (including lubricating oils) and **end-of-life tyres** from road transport vehicles are included on the EU's waste list[24]. The waste Directive explicitly notes that waste oils should be collected separately (where technically feasible) and that their disposal should occur only when re-use, recycling and recovery are not possible and that their disposal should not endanger human health or harm the environment. Consequently, where services are procured, procurers can ensure that contractors dispose of waste oils and end of life tyres, and operate their **wash bays**, appropriately.

[18] Directive 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors.

[19] Directive 2000/53/EC on end of life vehicles.

[20] Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures.

[21] Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency.

[22] Regulation (EC) No 66/210 on the EU ecolabel.

[23] Directive 2008/98/EC on waste.

[24] Commission Decision 2000/532/EC establishing a list of wastes.

EU requirements on vehicle procurement and relevant labels

The most relevant piece of EU legislation relating to the green public procurement of transport vehicles is the **Clean Vehicle Directive** (CVD)[25]. This requires national, regional and local authorities, as well as public transport operators over which these authorities have control, to take account of the environmental performance of road transport vehicles in the course of any procurement process for purchases above the EU public procurement thresholds. The environmental impacts to be taken into account must include at least the following:

- energy consumption;
- CO_2 emissions; and
- emissions of NO_x, NMHC and PM.

The Directive specifies different options for including these impacts in the course of the procurement process, i.e. by:

- setting technical specifications for the performance of vehicles in relation to these impacts; or
- including energy and environmental impacts in the purchasing decision by:
  - using the impacts as award criteria; or
  - monetising the impacts, according to a methodology outlined in the Directive.

Other EU legislation sets requirements for the labelling of certain vehicles and components. The **Car Labelling Directive**[26] requires that a label containing information on its fuel efficiency and CO_2 emissions is applied to each new car model at the point of sale, e.g. in car showrooms. Many EU Member States have developed labels that have gone beyond the basic requirements set by the Directive, and some of these include other environmental information (AEA *et al*, 2011). Fuel economy and/or CO_2 labels for new cars also exist in many countries around the world and most focus on fuel economy. However, there are exceptions, as the car label used in Switzerland includes the Euro emissions standard of the new car, in addition to its fuel efficiency and CO_2 emissions (TCS and SuisseEnergie, 2015), while the label used in the United States includes a 'smog rating' (US EPA, 2016).

The **tyre labelling Regulation**[27] requires that all new tyres for cars, LCVs and some tyres for HDVs, including buses, have a label attached that provides information on the tyre's fuel efficiency class and its external rolling noise class, as specified in the Regulation (as well as its wet grip class, where relevant). The format of the label is specified by the Directive and requires a colour-coded A to G rating for fuel efficiency and one of three graphic representations of a tyre to illustrate the external rolling noise class. The fuel efficiency classes are determined on the basis of the tyre's rolling resistance coefficient, which has to be less than 6.5 kg/t to receive the best 'A' rating for tyres of cars and LCVs and less than 5.5 or 4.0 kg/t to receive the best rating for tyres of heavier vehicles. In order to receive the best rating for noise a tyre's external rolling noise must be at least 3 dB less than the respective limit values indicated in the General Safety Regulation[28]. The purchase of the most energy efficient tyres according to the tyre labelling Regulation is also part of the energy efficiency requirements for purchasing

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[25] Directive 2009/33/EC on the promotion of clean and energy efficiency road transport vehicles.

[26] Directive 1999/94/EC relating to the availability of consumer information on fuel economy and CO_2 emissions in respect of the marketing of new passenger cars.

[27] Regulation (EC) No 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters.

[28] Regulation 661/2009.

products, services and buildings by central government set by the Energy Efficiency Directive[29].

There is only one current EU ecolabel that is relevant for transport and that is the **EU ecolabel on lubricants**[30]. The ecolabel contains a number of criteria, including to:

- limit the content of specified hazardous substances and mixtures, with reference to both the CLP and REACH Regulations[31];
- exclude specific substances above a certain minimal limit, with reference to the water framework Directive[32];
- limit the adverse effects on the aquatic environment, with reference to *inter alia* an implementing Regulation of the REACH Regulation[33];
- set requirements for biodegradability and bioaccumulative potential, with reference to the same REACH implementing Regulation;
- set a minimum requirement for the carbon content derived from renewable raw materials; and
- set minimum standards for technical performance.

The criteria set in the lubricants EU ecolabel will be valid until the end of 2018[34].

2.1.2 Overview of relevant national guidelines and labels

Some countries have extensive ecolabel programmes at the national level, particularly the Blue Angel in Germany and the trans-national Nordic Ecolabel, commonly known as the 'Swan'. These are covered in detail in this section, along with some other relevant ecolabels in place. The section also reviews national guidelines that are in place for road transport vehicles and services, with a focus on the EU Member States although there are some references to guidelines elsewhere in the world.

Blue Angel - Germany

The Blue Angel scheme in Germany has numerous ecolabels, covering many different products of which two are relevant for transport (Blue Angel, 2016). The criteria for municipal vehicles and buses (RAL, 2014a) cover road sweepers, waste collection trucks, buses, as well as separate engines in other mobile machinery[35] and cover:

- **Pollutant emissions**. The driving engine of the vehicle has to meet the Euro VI emission standards as specified in the HDV emissions Regulation, while any work machinery with a drive engine that Regulation must meet its Euro V standard. Driving engines of work machinery not covered by the HDV emissions Regulation, as well as separate engines for auxiliary units that fall under the NRMM emissions Directive must meet the Stage IV and Stage III emission standards specified in that Directive[36]. All engines mentioned must also be fitted with a particulate

[29] Directive 2012/27/EU on energy efficiency.

[30] Commission Decision 2011/381/EU on establishing the ecological criteria for the award of the EU ecolabel on lubricants.

[31] Regulation 1272/2008 and Regulation 1907/2006.

[32] Directive 2006/60/EC establishing a framework for Community action in the field of water policy.

[33] Council Regulation (EC) No 440/2008 laying down test methods pursuant to the REACH Regulation.

[34] Commission Decision (EU) 2015/877/EU amending Decisions 2009/568/EC, 2011/333/EU, 2011/381/EU, 2012/448/EU and 2012/481/EU in order to prolong the validity of the ecological criteria for the award of the EU Ecolabel to certain products.

[35] As defined by Directive 97/68/EC.

[36] Regulation 595/2009 and Directive 97/68.

reduction system that reduces particulate matter by at least 99% and the particulate mass by at least 90%.

- **Noise emissions**. Criteria are set to cover driving noise for buses and operating and workplace noise for street sweepers and waste collection trucks. For buses, the criteria are 1 dB(A) less than the legal noise limits set by the noise emissions Regulation for 2016[37]. These were 3 db(A) less than the limit values in force in 2014 when the label was finalised. EU legislation does not set emission limit values for the operating noise of street sweepers and waste collection trucks, only requiring that these vehicles are subject to noise marking[38].
- **Air conditioning**. The refrigerants used in air conditioning systems in buses must have a GWP(referenced to CO_2 and based on a 100-year period) of less than 150. This is consistent with the requirements of the mobile air conditioning Directive, even though the latter only covers cars and small LCVs[39]. From 2018, all refrigerants used on two-axle buses must be halogen-free.
- **Painting and coating**. Coating materials used must be free from paint raw materials that contain lead, chromium VI and cadmium compounds. Solvent emission limits during coating are set of 70 g/m^2 (or 50 g/m^2 for large installations) for waste collection trucks and road sweepers and of 130 g/m^2 for buses. The stated values are much less than the maximum limits allowed in such products by the paints Directive[40].

The Blue Angel criteria for lubricants (RAL, 2014b) are similar in scope to those included in the EU ecolabel on lubricants and similarly make reference to the definitions and classification used in the CLP and REACH Regulations[41]. The Blue Angel criteria require the following:

- restriction of the use of certain substances that have a harmful effect on human health and/or the environment, with reference to the CLP and REACH Regulations;
- requirements as a result of the aquatic toxicity of certain substances;
- requirements relating to the biodegradability and bioaccumulation potential of substances used;
- requirements relating to the disposal of selected lubricants; and
- technical requirements relating to the area in which specific lubricants are used.

Nordic 'Swan' Ecolabel - Denmark, Finland, Iceland, Norway and Sweden

The Nordic Ecolabel covers 63 product groups, of which two are relevant to transport: car (and boat) care products; and vehicle wash installations, including installations for cars, buses and trucks (Nordic Ecolabelling, 2016). Both restrict the products that can be used as a result of their potential to cause harm to human health and/or the environment, or as a result of other properties, such as flammability, with reference to the CLP Regulation. They also both have limitations on the constituent parts of the products used, e.g. on the quantity of VOCs, or their characteristics, such as their biodegradability. Additionally, the criteria for the vehicle wash installations include requirements relating to water consumption and the content of waste water (Nordic Ecolabelling, 2013; 2015).

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[37] Regulation (EU) No 540/2104; the limit values in force in 2014 had been set in Directive 70/157, as amended by Directive 92/97, both of which were repealed by the 2014 noise emissions Regulation.

[38] Directive 2000/14.

[39] Directive 2006/40.

[40] Directive 2004/42.

[41] Commission Decision 2011/381, Regulation 1272/2008 and Regulation 1907/2006.

Other national ecolabels

The Swedish Society for Nature Conservation (Naturskyddsföreningens) has an ecolabel for passenger transport, as part of its **Bra Miljöval** (Good Environmental Choice) programme. The label puts requirements on the passenger transport services to be covered by the ecolabel, as well as on the electricity or fuel used and on the way in which the vehicle is operated. At a general level, maximum levels are set for:

- energy supplied must not exceed 0.18 kWh per passenger kilometre;
- CO_2 emissions associated with energy consumption, as measured over the life cycle, must not exceed 50 gCO_2 per passenger kilometre; and
- NO_x emissions from the operation of transport must not exceed 0.3 gNO_x per passenger kilometre.

Operators must also demonstrate how they are working towards increasing awareness of the origin and environmental performance of the energy carriers that they use. The electricity used must come from renewable sources and at least 50% also has to have the Bra Miljöval label for electricity, which goes beyond a basic requirement to use renewables to include, for example, requirements on energy efficiency. Any fossil fuels used only have to meet legal requirements, as there is no system in place to require more than this. The ecolabelled passenger transport services must have at least one element of their internal operation of the vehicles meeting certain environmental requirements. Options include:

- ecolabelled toilet, general cleaning or vehicle washing products;
- ecolabelled lubricants;
- different bins for different waste streams in order to facilitate recycling; or that
- at least 50% of the range of any food products on sale are organic.

More generally, operators must also demonstrate that they are striving to improve their environmental performance (Naturskyddsföreningens, 2011).

Elsewhere in the world, there are **various 'green' label schemes**, including Green Seal and Ecologo in North America, Good Environmental Choice in Australia and New Zealand and various schemes in Asia, but there are few labels of relevance to transport, particularly for vehicles. There is a US Green Seal for alternatively-fuelled vehicles, but this only applies to vehicles using predominantly CNG or electricity, that are maintained for optimum efficiency and which do not fail emission tests (Green Seal, 2013a). Labels for tyres are more common, e.g. in South Korea (KEITI, nd a), Taiwan (Taiwan EPA, nd) and Singapore (Singapore Green Label, nd), for which requirements for rolling resistance are the most common, with other covering noise, wet grip, requirements for durability and on the substances used, e.g. a maximum content for polycyclic aromatic hydrocarbons in Taiwan. There are also various labels for oils, including a US Green Seal for re-refined oils (Green Seal, 2013b) and ecolabels in South Korea for oils used in different types of engine (such as diesel and petrol) (KEITI, nd b). These include requirements on the proportion of re-refined oil, the use of various toxic materials and various other physical and chemical characteristics, such as viscosity. Only two examples of a label for a transport service were identified, both in Taiwan: for car wash services and car rental services (Taiwan EPA, nd b and c). Both labels included various environmental criteria for the operation of the business more generally. Car rental services also had to include a minimum proportion of low polluting, efficient cars in their fleets and to promote eco-driving, while the label for car wash services had requirements for the content of detergents as a maximum average water consumption per wash and requirements on the proportion of waste water to be recycled and reused.

Labels are used in transport for other purposes, including relating to pollution. Beijing has colour-coded labels to indicate the emissions performance in terms of air pollution of vehicles (ICCT, 2015). A recent project for the European Commission's DG Environment was exploring the possibility of introducing a voluntary EU low emissions standard for cars (Cortvriend, 2014).

National guidelines for green/sustainable public procurement

Within the EU, various Member States have guidelines on GPP for transport vehicles and some for different types of transport service. Many of the criteria for vehicles in particularly draw on the 2012 EU GPP criteria. In some countries, the criteria are not for GPP, but for sustainable public procurement, including social issues. The latter goes beyond the scope of this criteria development process.

One of the more extensive set of criteria is in **Sweden**, which also has various standards for 'green' cars that are applied for different purposes. The national definition is used as the basis of exemptions from vehicle taxes. It estimates the maximum CO_2 emissions that a car can have before it can be considered to be green as a function of its mass in the same way as the EU's passenger car CO_2 Regulation, but in relation to the 2021 target of 95 gCO_2/km (see above)[42]. A car of the same mass using ethanol is allowed to have CO_2 emissions 55 gCO_2/km higher and still be considered to be green, while plug-in cars must have an electric energy consumption of no more than 37 kWh per 100 km to be considered green. A definition of a 'super green' car applies to cars that meet the latest Euro emissions standard, i.e. Euro 6, and have CO_2 emissions of no more than 50 gCO_2/km (Stockolms Stad and Malmö Stad).

There are also various GPP criteria for different vehicles, goods transport services (using heavy and light duty vehicles), tyres and transport fuels in Sweden (see Tables 5, 6 and 7). References to EU standards are made in order to define criteria for air pollutants and noise, while maximum CO_2 values are provided for light duty vehicles, including the possibility to use the 'super green' car definition noted above. For the acquisition of heavy duty vehicles, and goods services using all types of vehicle, criteria also relate to the ability to use alternative fuels and to the rolling resistance of tyres (again with reference to the EU Regulation). The Swedish criteria reflect many of the other elements of the 2012 EU GPP criteria, including the need for a vehicle to be equipped with a TPMS, GSI and a support system for energy-efficiency driving, while some elements go beyond the EU criteria, as vehicles should also be equipped with intelligent speed adaptation. For goods transport services, requirements are also put in place for temperature-controlled transport. The criteria also include the application of the CVD's monetisation methodology as an award criterion, and the application of life cycle costing for light duty vehicles. According to its stated scope, goods services using bicycles are covered by the criteria, but there were no specific criteria for bicycle goods services in the document.

The Swedish criteria for tyres include criteria for the use of various substances in tyres and the tyre's lifespan, as well as the application of life cycle costing. The criteria for fuels cover both fossil and renewable fuels and include criteria on compliance with laws and provisions relating to the conservation of land and water in the country of origin, the traceability of fuels and a prohibition on the use of fossil fuels from more carbon-intensive oil feedstocks. Where there is the potential to supply vehicle washing services alongside the supply of fuel, criteria are set for the substances that can be used in the washing process. In relation to the supply of goods transport services and tyres, there is a criterion for the contractor relating to the existence of an environmental management system.

In **the Netherlands**, PIANOo, the tendering expertise centre for government, maintains a set of environmental criteria to use in sustainable public procurement. There are three guides relating to transport: service cars; transport services; and HDV, mobile machinery and their maintenance. The transport services to which the respective criteria are applicable are listed with reference to specified CPV codes and include courier, postal

[42] Effectively a car with a mass of 1372 kg would be classified a green car if its CO_2 emissions were 95 g or less. If a car uses ethanol, the maximum CO_2 emissions allowed for a car to be considered green are 150 g.

and moving services, but not waste collection services. The criteria used in the guide for service cars draw extensively on the 2012 EU GPP criteria for transport. Most of the criteria are reproduced in full, although the criteria used are all comprehensive criteria, rather than core criteria. The exceptions are the criterion relating to noise emission levels, which is absent, while there are additional criteria. The latter include limits on water and energy used in the course of vehicle cleaning as either a technical specification or an award criterion, and a requirement on contractors to inform the authority where recycled components can be used in the course of the maintenance of the cars as a contract performance clause (see Annex Table A-1). The criteria for HDVs, which also cover mobile machinery, and transport services make fewer references to the EU GP criteria, although similar issues are covered. Additional elements include a longer list of fuel saving options for HDVs (e.g. including aerodynamic features), requirements for tyre maintenance and, for maintenance contracts, a requirement to have an environmental management system in place. For transport services, the main additional element is an award criterion for the 100% compensation of CO_2 emissions through the purchase of credits generated in line with the guidelines of the Clean Development Mechanism. The criteria for service cars and transport services also include a section on 'points of attention/suggestions', which recommends the consideration of alternatives to the procurement of vehicles or services using motorised vehicles (see Tables 6 and 7).

The development of environmental criteria for a range of product groups including transport vehicles and services resulted from the 2010 Action Plan for Sustainable Public Procurement in **Austria** (NABE, 2016). The transport criteria relate to the same categories of vehicles and services as the 2012 EU GPP criteria for Transport, but include fewer of the proposed criteria (see Annex Tables A-1, A-2 and A-3). Most of the criteria used are the same as those in the equivalent section of the EU criteria, with the exception of CO_2 emissions for cars and LCVs, for which the criteria require that the average CO_2 emissions of the fleet of vehicles purchased are less than the respective car and LCV CO_2 targets for 2015 and 2017, respectively, i.e. 130 gCO_2/km and 175 gCO_2/km (see above).

The UK has Government Buying Standards in place for transport that closely follow the EU GPP criteria. There are mandatory criteria that central government departments and related organisations must adhere to; other public sector organisations are encouraged to use these criteria. Additionally, there are best practice standards that are more comprehensive or stricter for organisations that want to go further. While the distribution of criteria between mandatory and 'best practice' do not always reflect the EU criteria's split between core and comprehensive, the criteria draw heavily on the coverage and formulation of the EU criteria. The criteria in relation to recycling are slightly different as they mention 'designing' for recycling, recovery and reparability, while there are also criteria against the use of tyres containing oils in tread rubber that are subject to labelling under Directive 67/548, which was repealed by the CLP Regulation (see Annex Tables A-1, A-2 and A-3). These standards are currently under review.

The **Danish GPP criteria** for transport are based on the recommendations and advice of the Danish Transport Authority's Centre for Green Transport, supplemented with recommendations from the Danish Partnership for Green Public Procurement, which brings together the national environment ministry and various municipalities. The criteria only apply to cars and LCVs. For CO_2 emissions, reference is made to various categories of the Danish fuel economy label, implemented as a result of Directive 1999/94[43]. Other elements are similar to those of the EU GPP criteria, although there was a recommendation that noise levels of vehicles should be 3 dB below those required by

[43] The Danish label goes beyond the Directive's requirements, as the Directive does not require a categorised label.

law. An additional fuel economy option that purchasers were advised to look out for was a speed alarm (see above and Annex Table A-1).

In **Italy** GPP criteria exist for the lease, rental and purchase of light and heavy, passenger and commercial vehicles and cover similar environmental issues to other criteria (see Tables 5 and 6). Criteria are set for the CO_2 emissions of light duty vehicles, whereas heavy duty vehicles have to be fitted with a fuel consumption indicator. Reference is made to the EU emission standards to set criteria for air pollutants and noise, and to the EU GPP criteria and the EU ecolabel to set criteria for lubricants. An additional element that is not common in other criteria is that emissions criteria are set for the purchase of used vehicles, which have to comply with the previous set of Euro emissions standards, i.e. currently Euro 5/V now that Euro 6/VI are applicable. Reference is also made to the monetisation methodology of the EU's CVD to be used as an award criterion.

The **German Action Plan on Sustainability** states that federal authorities and associated institutions should consider using public procurement to continuously improve the energy efficiency of their fleets. It proposes values for the average CO_2 emissions of new cars for both 2018 and 2020, the latter reflecting the EU target of 95 gCO_2/km. The plan also states that priority should be given to procuring vehicles meeting the highest emission standards and having the lowest possible noise emissions. For short business trips, the plan also suggests that authorities provide their employees with the possibility of using official bicycles or electric bicycles (see Annex Table A-1). Some cities in Germany produce similar guidance locally, e.g. Hamburg notes that car sharing, the availability of bicycle fleets and reduced rates on public transport can all be used to reduce the number of official cars (Hamburg, 2016).

However, not all Member States make reference to the EU GPP criteria when setting environmental conditions for the public procurement of transport vehicles. In **Belgium**, a 2009 circular sets out the criteria to be applied when procuring passenger transport vehicles for government services and other public interest bodies. This has subsequently been complemented by the legislation transposing the EU's CVD. The approach is very different to that set out in the EU's GPP criteria. The circular requires that vehicles be bought with reference to the guidelines in the circular, which include a minimum 'ecoscore' (see Box 1) and an upper limit for the price of each vehicle (Monitor Belge, 2009). In a complementary note, it is recommended that the approach of the circular only be used for passenger cars, as these go beyond the requirements of the CVD, while the approach in the CVD should be used for all other types of vehicles (i.e. N_1, N_2, N_3, M_2 and M_3 vehicles; SFPOSPDD, 2011).

Box 1: The Belgian ecoscore sytem

The 'ecoscore' system provides a single score for the environmental performance of a vehicle. It covers GHG emissions, which account for 50% of the total score, air pollutant emissions, which account for 40% and noise, which accounts for the remaining 10%.

The GHG score takes account of three GHGs - CO_2, methane and nitrous oxide - and includes both in-use and fuel cycle emissions. The respective gases are weighted according to their respective GWPs. Air pollutant emissions cover carbon monoxide, hydrocarbons, NO_x, PM and sulphur dioxide. External cost values resulting from the ExternE project are used to weight the air pollutant emissions. All values are taken from a vehicle's certificate of conformity. For noise, the vehicle's engine noise value is used. The minimum ecoscore required for small passenger vehicles is 65, whether the vehicle uses petrol, diesel or gas.

A similar scoring system, EcoTest, has been developed by ADAC and the FIA Foundation.

Source: http://ecoscore.be/how-do-we-calculate-ecoscore; Monitor Belge (2009); http://www.ecotest.eu/index.html

Elsewhere in the world, **Japan** sets criteria for promoting GPP for a number of product groups, including vehicles and transport services, including postal and home delivery services (see Annex Tables A-1, A-2 and A-3). The focus of the criteria for vehicles is on fuel efficiency and, to a lesser extent, emissions of air pollutants. Other factors that might be taken into consideration include many already in the EU GPP criteria, such as the GWP of the air conditioning gases, the use of alternative fuels and stop-start. Considerations that are not explicitly present in the EU GPP criteria include the installation of eco-drive support and a reduction in the amount of lead used (excluding that used in batteries). For transport services, the evaluation criteria focused on the monitoring, promoting and reducing of energy use. Operational matters that might be taken into consideration included modal shift and improvements in the loading capacity of vehicles (GJ, MoE, 2015).

The focus of the GPP guidance for vehicles in both **Norway and New Zealand** is on fuel efficiency and compliance with emissions standards for air pollutants (see Annex Table A-1). Both also have considerations relating to tyres, while New Zealand also has criteria relating to the use of less polluting lubricant and hydraulic oils, the use of alternative fuels and the end-of-life treatment of vehicles, tyres and used oil. In Norway, there was a commitment to explore whether it would be possible to have a CO_2-free or CO_2-neutral requirement for government vehicles by 2020.

UNEP also has guidelines for the procurement of vehicles and for freight forwarding (see Annex Tables A-1, A-2 and A-3). As the criteria are meant to inform public procurement across the world, they tend to be of a more general nature. For vehicles, both fuel efficiency and emissions standards are covered, with the suggestion that additional points be awarded to tenders in which vehicles have a specified fuel efficiency or meet a particular emissions standard. Criteria relating to the recyclability and reusability of the vehicles are also mentioned, including potentially awarding more points to vehicles using a higher proportion of recycled material and the provision by the contractor of a vehicle take back scheme or a vehicle refurbishment programme. Criteria for freight forwarding also focus on fuel efficiency and emissions, but from the perspective of demonstrating that various actions were undertaken. For example, criteria included the existence of fuel-efficient driver training, the monitoring of fuel consumption and tyre pressure and the installation of aerodynamic features on trucks and their trailers. There was also a range of more operational requirements, including the existence of a corporate environmental policy, which was also mentioned in relation to contractors that supply vehicles, the existence of activities to monitor GHG and air pollutant emissions and a description of measures taken to improve overall environmental performance.

Finally, in its sustainable public procurement manual **ICLEI** included criteria that might be used to procure buses. For the direct procurement of buses, proposed criteria made references to respective EU standards for air pollutant and noise emissions and that meters be fitted to monitor fuel usage. Proposed criteria for procuring bus services covered similar issues, but were less ambitious in terms of environmental requirements as they were to be applied to all buses used in carrying out the service. Suggested contract provisions included reporting on the annual km driven by the cleanest buses with a requirement that the proportion must increase by 10% annually and that all bus drivers employed in carrying out the service are trained in environmentally-conscious driving by a recognised institution (ICLEI, 2007).

2.1.3 Overview of relevant standards, guidelines and initiatives used in the private sector

In addition to their involvement in public procurement, private stakeholders can also influence the environmental performance and characteristics of fleets in their own procurement processes. This section describes various initiatives: there are some initiatives, which focus on the procurement itself, but there are more initiatives, which try to stimulate fleet owners to green their fleets by means of various tools and monitoring instruments. This can give fleet owners an advantage when environmental criteria are set in procurement processes. These private stakeholders might also demand higher environmental performances in their own procurement services, however there is not much information available on the procurement processes of individual market actors.

Private procurement initiatives

In 2010, three Dutch companies introduced a sustainable concept for the logistics sector, called **Green Tender** (Connekt, 2010). The idea is that a Green Tender not only involves criteria for ‘performance’, but also sustainable criteria for ‘people’ and the ‘planet’. Using the Green Tender questionnaire, shipping agents and hauliers can assess the sustainability performance of the third parties to whom they subcontract transport. The questions in the questionnaire involve finance, capacity, and service (i.e. performance), safety and security, quality certificates, and corporate communication (people), and Euro-standards, environmentally-friendly fuels, and the number of empty miles (planet). The input of hauliers has been used to establish the questions.

UITP has published UITP recommendations for the structure of tender documents in **UITP Tender Structure (UITP, 2009). In drafting these recommendations a UITP** working groups conducted a review of current rules and observed practices in the EU. The recommendations are meant for the purchase/offering of buses and related services, but can also be applied more broadly. Operators, manufacturers and organising authorities were all involved in the process. The second version of the recommendations dealt with environmental issues, such as environmental award criteria, LCC, eco-driving etc.

Standardisation initiatives

The International Workshop Agreement **IWA 16:2015** (ISO, 2015) defines a framework for a coherent quantification of CO_2eq emissions of freight transport. The framework is defined at three levels:

- cargo, to estimate the emissions of the individual cargo;
- transport chain elements (TCE), where a TCE is seen as an indivisible logistics operation and all TCEs together sum up to the transport chain; and
- network, to be able to optimize the emissions of transport organizations over their entire network.

On these levels, the framework provides a comparative analysis between the starting point and the recommended situation on mode-specific and intermodal levels, including transhipment centres and warehouses.

The European **EN 16258:2012** standard (CEN, 2012) provides a common methodology for the calculation of energy consumption and GHG emissions, related to the transport of freight, passengers or both. The standard specifies general principles, definitions, system boundaries, calculation methods, allocation rules, and data recommendations. It is aimed especially at freight or passenger carriers, carriers subcontracting transport operations, freight forwarders, travel agencies, shippers, and passengers.

The **SORT project** was an initiative of the UITP Bus Committee, which resulted in a co-operation between UITP, VDV, operators and leading EU manufacturers of both vehicles and transmissions. The main aim was to design reproducible test cycles of on-road tests of buses in order to enable the monitoring of fuel consumption and to be able to compare buses. In 2014 a protocol was developed and published on applying diesel SORT testing methodology to hybrid vehicles (SORT-Hy; UITP, 2014).

In the UK, support for the purchase of low emission buses by local authorities is linked to the amount of WTW emissions saved beyond a specified threshold. The methodology used to define a Low Emission Bus (LEB) was developed by the LowCVP, which is a public-private partnership set up to accelerate the shift to low carbon vehicles in the UK. This defines an LEB as a Euro VI vehicle that produces 15% fewer WTW GHG emissions compared to an equivalent Euro V diesel bus. An LEB certificate is awarded to bus models that attain this threshold on the basis of an independent whole vehicle emissions test of the bus and its Euro V diesel equivalent. Bus manufacturers can propose their own WTT GHG factors, supported by relevant documentation, otherwise default factors will be used. Additional funding is available for buses that can demonstrate zero emission capability, i.e. they can travel 2.5 km of a route with no emissions (LowCVP, 2016).

Other market initiatives

The **Fleet Operator Recognition Scheme** (FORS) (FORS, 2016) is a voluntary accreditation scheme in the UK, which takes account of all aspects of safety, fuel efficiency, vehicle emissions and improved operations. FORS is meant for operators of LCVs, trucks, mini-buses, coaches and other vehicles, and companies that subcontract to these operators. The aim of FORS is to help them to measure, monitor, and improve performance on the aforementioned aspects. FORS offers best practice toolkits, of which the Fuel Use Tracker is the most relevant for sustainability, tracking fuel use to improve fuel efficiency and CO_2 emissions.

The British **ECO Stars** scheme (ECO Stars, 2016) provides an assessment of the current operational and environmental performance of a fleet. The members of the scheme (operators of HGVs, buses, coaches, vans, and taxis) are awarded between 1 and 5 stars based on six pillars:

- fleet composition;
- fuel management;
- driver skills development;

- vehicle specification and preventative maintenance;
- IT support systems; and
- performance monitoring and management.

The European Commission project **RECODRIVE** (RECODRIVE, 2010) ended in 2010 and was aimed at merging existing ecodriving initiatives with good fleet management and logistics optimization practices. In the project, policy guidelines were developed for fleet owners to set up recognition and rewarding schemes for drivers, managers, and procurement and maintenance staff.

Lean and Green (Connekt, 2016) is a Dutch public-private network for sustainable mobility (now also extended to other countries). The program aims to stimulate logistics companies to reduce their transport-related emissions. Companies which can prove to have reduced their emissions by 20% in five years receive a 'Lean and Green Star'.

The **Green Freight Europe** (GFE) initiative (GFE, 2016) was started by several multinational companies (both shippers and transport operators) and aims to establish a pan-European system to collect, analyse, and monitor GHG emissions from freight transport by road. The initiative also aims for best-practice sharing, access to verified green technologies and a future certification of green transport service providers.

2.1.4 Synthesis on existing legislation, standards and criteria

It is clear from the review undertaken in this section that the **EU policy framework** supports the improvement of the environmental performance of transport. A clear policy framework exists to reduce the GHG emissions of cars and LCVs by improving their fuel efficiency, while the use of alternative fuels is also promoted by various pieces of legislation. However, technology is developing fast and some technologies that were considered at the cutting edge when the previous EU GPP criteria for transport were being developed are now common place, or even required by legislation.

The focus of policy that aims to reduce air pollutants has shifted from test cycle emissions to real world driving emissions, at least for cars and LCVs. All new HDVs and NRMM have to meet the most recent emission standards, although the Commission has proposed to make the emission standards for the latter more stringent. A set of continuously more stringent noise emission limits values for LDVs and HDVs was adopted in 2014, which sets three phases of emission limit values out to the mid-2020s. EU waste policy also makes sure that the manufacture and disposal of vehicles, lubricants oils and tyres in particular do not damage human health or the environment. The policy framework has clearly developed since the 2011 Technical Report that supported the development of the 2012 EU GPP criteria for transport, and so will inform the development of the revised criteria later in the project.

At the **national level**, a couple of Member States have relevant ecolabels and several have GPP criteria in place for transport. The most extensive set of ecolabels identified were the 'Blue Angel' in Germany and the 'Swan' used across the Nordic countries, while the Good Environmental Choice (Bra Miljöval) labels produced by the Swedish Society for Nature Conservation cover other services of relevance. The most extensive GPP criteria identified were in Sweden and the Netherlands. Many of the ecolabels and GPP criteria closely followed, and made reference to, the EU GPP criteria for transport. Indeed, some countries use the same categories and very similar text for many of their criteria. Hence, national ecolabels and GPP criteria also often refer directly to EU legislation, such as that discussed in Section 2.1.1. In most cases, national ecolabels and GPP criteria covered a subset of the categories and environmental issues covered in the EU criteria, although there were exceptions.

The German Blue Angel ecolabel for 'municipal vehicles and buses' covers the painting and coating of vehicles (with reference to the Paints Directive), while 'municipal vehicles' include road sweepers in addition to waste collection trucks. The Nordic Swan has ecolabels for car care products and for vehicle wash installations (for cars, buses and trucks). In Sweden, the Good Environmental Choice for passenger transport services includes a number of ambitious criteria, including for the energy supplied, and CO_2 and NO_x emissions per passenger kilometre. Elsewhere in the world, ecolabels in Taiwan cover car wash and car rental services.

In Sweden, the national definition of a 'green car' includes a reference to the maximum electric energy consumption of plug-in car above which it does not qualify as being a 'green car'. There are also GPP criteria for goods transport services and fuel supply, which also cover vehicle washing. In the Netherlands, the three sets of criteria refer explicitly to the CPV categories that are covered, which for transport services are broader than the EU criteria including courier, postal and moving services. Criteria for vehicle cleaning are also included in the guidelines for procuring service cars. Both the Swedish and the Dutch criteria make reference to contractors having appropriate environmental management systems in place, while the Dutch criteria for transport services also make reference to the use of 100% compensation of CO_2 emissions through the purchase of CDM credits as an award criterion.

In other Member States, there are few categories or criteria that are not mentioned in the 2012 EU GPP criteria for transport. In Italy, there are GPP criteria to cover the purchase of used vehicles (cars, vans and HDVs), which might be relevant for some other Member States. Elsewhere in the world, in Japan there are criteria for postal and home delivery services, while UNEP has defined criteria that could be used for freight forwarding.

The growth in various **private initiatives** shows that there is growing attention on the environmental performance of private fleets. Most private initiatives are focused on freight transport and aim to improve monitoring and data analysis of fleet performances, mainly on CO_2 and fuel consumption, but also on other indicators. Various instruments, such as toolkits, have been developed to enable this monitoring and to enable continuous improvement. Private actors participating in these schemes have a comparative advantage when participating in public procurement procedures, but might also have an advantage when private actors demand higher environmental performance in their procurement schemes. There is, however, not much information on the individual procurement schemes of private actors, other than the initiatives listed in this chapter.

2.2 Overview of statistical and technical categories

The aim of this section is to provide an overview of existing statistical and technical categories that could be used to define categories of product groups for the revised EU GPP criteria. Hence, this section investigates agreed definitions of potentially relevant transport vehicles and services that could be applied EU-wide for the purpose of defining the EU GPP criteria. This includes passenger as well as freight transport and both vehicles and services.

2.2.1 The need for statistical and technical categories

In the case of public contracts the development of effective competition is desirable and therefore should be ensured. To reach this it is necessary that contract notices are advertised throughout the Community. The information in these contract notices should contain sufficient information for economic operators to be able to determine the relevance of the contracts for their businesses. Several instruments can be used to improve the visibility of relevant contracts, such as the use of standard statistical and technical categories and the Common Procurement Vocabulary (CPV) as the reference nomenclature for public contracts. Another reason to use statistical and technical categories is to be able to monitor and analyse trade and other economic developments on the EU market.

Relevant legislation

There are several classification systems, which are used in practice. The following Directives and Regulation include a classification system or prescribe the use of systems:

- Directive 2007/46/EC establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles;
- Regulation 168/2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles (L-category vehicles);
- Regulation 1370/2007 on public passenger transport services by rail and by road;
- Directive 2014/24/EU on public procurement and repealing Directive 2004/18/EC;
- Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sector and repealing Directive 2004/17/EC; and
- Regulation 213/2008 as regards the revision of the CPV.

Directive 2007/46 regulates the EC type approval of vehicles. The main objective of the legislation is to ensure that new vehicles, components and separate technical units put on the market provide a high level of safety and environmental protection.

Article 3 lays down the following general definitions:

- Motor vehicle: any power-driven vehicle which is moved by its own means, having at least four wheels, being complete, completed or incomplete, with a maximum design speed exceeding 25 km/h.
- Trailer: any non-self-propelled vehicle on wheels which is designed and constructed to be towed by a motor.
- Vehicle: means any motor vehicle or its trailer as defined by the two definitions above.
- Hybrid motor vehicle: a vehicle with at least two different energy converters and two different energy storage systems (on-vehicle) for the purpose of vehicle propulsion.
- Hybrid electric vehicle: a hybrid vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power: a consumable fuel or an electrical energy/power storage device (e.g. battery, capacitor, flywheel/generator, etc.).

Furthermore, Annex II provides more detailed definitions of vehicle categories and vehicle types. With respect to road transport the definitions depicted in Table 2 are included in the Directive.

Table 2: Definitions for road transport of Annex II of Directive 2007/46/EC

M	Motor vehicles with at least for wheels designed and constructed for the carriage of passenger
M_1	Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver’s seat
M_2	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver’s seat, and having a maximum mass not exceeding 5 tonnes.
M_3	Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver’s seat, and having a maximum mass exceeding 5 tonnes.

N	Motor vehicles with at least four wheels designed and constructed for the carriage of goods
N_1	Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3,5 tonnes
N_2	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 3,5 tonnes but not exceeding 12 tonnes
N_3	Vehicles designed and constructed for the carriage of goods and having a maximum mass exceeding 12 tonnes.
O	Trailers (including semi-trailers)
O_1	Trailers with a maximum mass not exceeding 0.75 tonnes
O_2	Trailers with a maximum mass exceeding 0.75 tonnes but not exceeding 3,5 tonnes.
O_3	Trailers with a maximum mass exceeding 3,5 tonnes but not exceeding 10 tonnes.
O_4	Trailers with a maximum mass exceeding 10 tonnes.
Special vehicles	
Motor caravans	
Armoured vehicles	
Ambulances	
Hearses	
Trailer caravans	
Mobile cranes	
Other specials purpose vehicles	
Wheel-chair accessible vehicles	

The current EU GPP criteria for transport have been developed for three main vehicle groups and refer to the above mentioned vehicle categories:

- The 'cars and LCVs' product group encompasses vehicles classified as M_1 (passenger cars, all sizes) and N_1.
- The 'buses' product group encompasses vehicles classified as M_2 and M_3 vehicles (buses of various sizes). And
- The third vehicle group, waste disposal trucks, are not further defined: such specialist vehicles are almost exclusively produced for the public sector and are characterised by different duty cycles in terms of speed, amount of stops and auxiliary load etc.). Therefore these should be treated differently than other heavy duty vehicles. Although criteria have been developed no strict definition has been presented. According to the Technical Background report, size and class considerations also do not apply to buses and waste collection trucks, because their selection is more based on real performance requirements than passenger vehicles.

Regulation 168/2013 regulates the approval of L-category vehicles and applies to all two- or three-wheel vehicles and quadricycles as categorised in Article 4 and Annex I ('L-category vehicles') of the regulation. Below the various categories are depicted. 'L-category' vehicles include the more powerful powered cycles, mopeds and motorcycles, as well as small and larger four-wheeled vehicles that increasing resemble M_1 vehicles the heavier they are (see Table 3). Note that some categories also have subcategories, which further define the vehicles.

Table 3: Classification of L-category vehicles according to Regulation 168/2013

Type of vehicle	**Category**
Light two-wheel powered vehicle	L1e
Three-wheel moped	L2e
Two-wheel motorcycle	L3e
Two-wheel motorcycle with side-car	L4e
Powered tricycle	L5e
Light quadricycle	L6e
Heavy quadricycles	L7e

Regulation 1370/2007 on public passenger transport services by rail and by road lays down 'the conditions under which competent authorities, when imposing or contracting for public service obligations, compensate public service operators for costs incurred and/or grant exclusive rights in return for the discharge of public service obligations'. The Regulation does, however, not provide clear definitions for the various public transport services and is therefore less relevant in the context of this report.

Directive 2004/17 regulates the coordination of the procedures for awarding public procurement in the water, energy, transport and postal services sectors, while **Directive 2004/18** lays down EU rules for awarding contracts for public works, supplies and services. Both Directives address the need to assure the opening of the market, as well as a fair balance in the implementation of the procurement in the respective sectors. They will be replaced by Directive 2014/24 and Directive 2014/25 in 2016, which means that the 2014 Directives will be in place at the time of the new GPP criteria for transport.

The 2014 Directives refer to two product classification systems, namely:

- nomenclature statistique des activités économiques dans la Communauté européenne (NACE); and
- CPV as laid down in Regulation No 2195/2002 on the CPV.

Annex I of these Directives states that in the event of any difference of interpretation between the CPV and the NACE, the CPV nomenclature will apply.

As result of these various classification systems there are not only differences between public and private procurement, but also within public procurement itself as a result of the various schemes overlapping with the CPV, such as CPC and NACE.

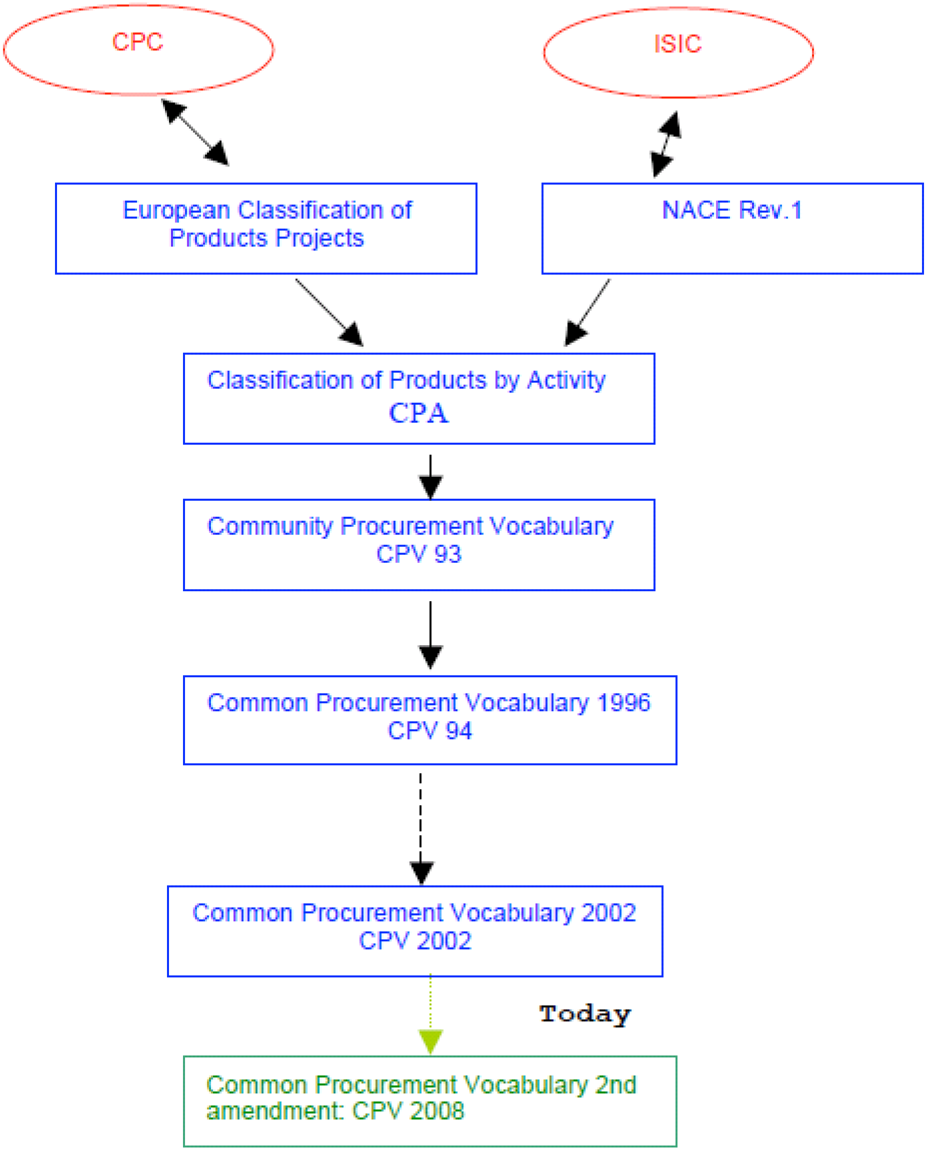
In Figure 3 a schematic overview of the link between the various systems is depicted. It shows that the CPV can be traced back to several international nomenclatures:

- **CPC**, which is an international nomenclature developed by the United Nations in order to monitor world trade.
- **International Standard Industrial Classification (ISIC)** has also been developed by the United Nations as a nomenclature to classify economic activity. The European version of ISIC is **NACE**, which was first published in October 1990

(NACE Rev.1). NACE is more suited to the presentation and monitoring of European economies. And

- **Classification of Products by Activity (CPA)**, which is based on CPC and NACE. The final version of the CPA was produced in August 1992.

Figure 3: Schematic overview of the various classification systems for economic activities and products (European Commission, 2008)



NACE

NACE provides a framework for statistical data on economic activity and works with a four-digit classification. *NACE Rev. 2*, the most recent revision of the classification system, was adopted at the end of 2006[44] and implemented starting from 2007. This means that first compatible statistics are available from 2008 onwards.

The structure of the NACE codes is laid down in the NACE Regulation and is build up as follows:

- sections indicated by an alphabetical code;
- divisions indicated by a two-digit numerical code;
- groups indicated by a three-digit numerical code;
- classes indicated by a four-digit numerical code.

PRODCOM

While NACE determines economic activities, PRODCOM is used to provide statistics on the production of manufactured goods, so on a product level. The abbreviation stands for the French term "PRODuction COMmunautaire" (Community Production) for mining, quarrying and manufacturing: Sections B and C of NACE 2 (Eurostat, 2016). The PRODCOM codes are not only linked to NACE 2, but also to CPA and are structured by means of eight-digit codes in the following way:

XX.XX.YY.ZZ

The first four digits correspond to the NACE 2 classes. The first six digits represent the CPA code and the last two digits represent the classification of a heading within the CPA heading and specify the product in more detail. Most of the PRODCOM codes correspond to one or more of the codes from the Combined Nomenclature, but not all of them.

CPV

The CPV consists of a main vocabulary for defining the subject of a contract, and a supplementary vocabulary for adding further qualitative information. The **main vocabulary** is based on a tree structure comprising codes of up to nine digits associated with a wording that describes the supplies, works or services forming the subject of the contract. There are various levels of classification, as followed:

- divisions identified by the first two digits;
- groups identified by the first three digits;
- classes identified by the first four digits; and
- categories identified by the first five digits.

Each of the last three digits gives a greater degree of precision within each category. A ninth digit serves to verify the previous digits.

The **supplementary vocabulary** may be used to expand the description of the subject of a contract. The items in the supplementary vocabulary are made up of an alphanumeric code with a corresponding wording allowing further details to be added. The alphanumeric code is made up of:

- a letter corresponding to a section (the first level);
- four digits, the first three of which indicate a subdivision, while the fourth is for verification (the second level).

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[44] Regulation (EC) No 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC Regulations on specific statistical domains Text with EEA relevance.

2.2.2 Overview per transport mode

The previous section described the various classification systems and their structure and relation with other classification systems. This section focuses on the relevant statistical definitions for those categories that are currently included in the 2012 EU GPP criteria, or which could potentially be included in the revised EU GPP criteria, i.e.:

- cars and LCVs;
- buses;
- bus services;
- waste collection trucks;
- waste collection services;
- courier and postal services, and;
- other potential categories.

Cars and LCVs

As noted above, **Directive 2007/46** defines cars and LCVs as M_1 and N_1 vehicles, respectively, as follows:

- M_1: Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.
- N_1: Vehicles designed and constructed for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes.

The relevant **CPV-codes** for cars and LCVs are listed in: *Division 34 Transport equipment and auxiliary products to transportation.* Passenger cars fall under 'motor vehicles':

- 341100000 Passenger cars;
- 341150000 Other passenger cars;
    - 34115200: Motor vehicles for the transport of fewer than 10 persons;
    - 34115300: Second-hand transport vehicles.

Electric vehicles have a different individual code under 'motor vehicles'. LCVs (3413500) also fall under 'motor vehicles' and include the following categories of LCV:

- 34136100: Light vans;
- 34136200: Panel vans;
- 34137000: Second-hand goods vehicles;
- 34138999: Road tractor units.

As **NACE** only describes economic activities and not products, there are no relevant definitions for cars and LCVs in NACE. The manufacturing of vehicles falls under *C Manufacturing*, which includes different definitions for motor vehicles, bodies for motor vehicles and part and accessories. However, within public procurement procedures transport related criteria are only likely to define the end characteristics of vehicles and will not cover manufacturing processes.

The **PRODCOM** list uses various technical characteristics to define vehicles, such as the type of combustion and cylinder capacity. The relevant categories are provided in Table 4. Note that the codes for good vehicles only differentiate between the type of combustion and do not include any reference to the size of the goods vehicles.

Table 4: PRODCOM-codes

- 29.10	Manufacture of motor vehicles
+ 29.10.11	Spark-ignition reciprocating internal combustion piston engines for vehicles, of a cylinder capacity ≤ 1000 cm3
+ 29.10.12	Spark-ignition reciprocating internal combustion piston engines for vehicles, of a cylinder capacity > 1000 cm3
+ 29.10.13	Compression-ignition internal combustion piston engines for vehicles
+ 29.10.21	Vehicles with spark-ignition engine of a cylinder capacity ≤ 1500 cm3, new
+ 29.10.22	Vehicles with spark-ignition engine of a cylinder capacity > 1500 cm3, new
+ 29.10.23	Vehicles with compression-ignition internal combustion piston engine (diesel or semi-diesel), new
+ 29.10.24	Other motor vehicles for the transport of persons
+ 29.10.30	Motor vehicles for the transport of 10 or more persons
+ 29.10.41	Goods vehicles, with compression-ignition internal combustion piston engine (diesel or semi-diesel), new
+ 29.10.42	Goods vehicles, with spark-ignition internal combustion piston engine; other goods vehicles, new

Buses

With respect to the vehicle category buses **Directive 2007/46** includes two definitions to define vehicles comprising more than eight seats:

- M_2: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver’s seat, and having a maximum mass not exceeding 5 tonnes.
- M_3: Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver’s seat, and having a maximum mass exceeding 5 tonnes.

As with cars and LCVs the relevant **CPV-codes** can be found in *Division 34 Transport equipment and auxiliary products to transportation* under the general code ‘motor vehicles’ and more specifically under code 34120000- ‘Motor vehicles for the transport of 10 or more persons’:

- 34121100 - Public service buses;
- 34121100 - Articulated buses;
- 34121300 - Double-decker buses;
- 34121400 - Low-floor buses;
- 34121500 - Coaches.

'Motor vehicles' also includes a specific code for electric buses.

As mentioned under ‘cars and LCVs’, **NACE** only covers the manufacturing of vehicles, which are not relevant for the EU GPP criteria for transport, because only the end produce of the manufacturing process is relevant for public authorities. For buses the **PRODCOM**-relevant category is:

- 29.10.30 - Motor vehicles for the transport of 10 or more persons.

Bus services

Directive 2007/46 does not include definitions for services, only for vehicles. Division 60 of the **CPV-system** includes the definitions for *Transport services,* but excludes waste transport. Below the type of transport services under road transport services are listed:

- Group 601: Road transport services:
  - 60112000-6 Public road transport services;
  - 60120000-5 Taxi services;
  - 60130000-8 Special-purpose road passenger-transport services;
  - 60140000-1 Non-scheduled passenger transport;
  - 60170000-0 Hire of passenger transport vehicles with driver:

- including 60170000-7 Hire of passenger cars with driver and 60172000-4: Hire of buses and coaches with driver.

All of these services can also be classified as bus services, although taxi services might be more relevant for cars rather than buses. The group *Road transport services* does not include:

- Sleeping-car services, which are found in class 5526.
- Dining-car services, found in class 5532.
- Hire of passenger transport vehicles without driver, found in group 341 adding the CPV Supplementary Vocabulary code PA01-7 Hire.
- Ambulance services, found in class 8514.
- Hire of goods-transport vehicles without driver, found in class 3413 adding the CPV Supplementary Vocabulary code PA01-7 Hire.

Under **NACE** bus services fall under code 4931 under *H Transportation and storage*: *Urban and suburban passenger land transport, which includes various bus services*. There is a long list of synonyms (CSO, 2014). **PRODCOM** is not relevant for bus services, because it only includes the classification of products, not of services.

Waste collection trucks

Directive 2007/46 does not provide a specific definition for waste collection trucks. Within the **CPV-system** waste collection trucks also fall within *Division 34 Transport equipment and auxiliary products to transportation* and fall under *'vehicles for refuse and sewage'* and more specifically under 34144510: '*vehicles for refuse':*

- 34144511 Refuse-collection vehicles;
- 34144512 Refuse-compaction vehicles;
- 34144520 Sewage tankers;

As indicated earlier **NACE** only describes economic activities and not products and therefore is not relevant for this category. Within **PRODCOM**_29.10.41 and 29.10.42 both represent goods vehicles, but no specific definition of waste collection trucks is included.

Waste collection services

No definitions for services are included in **Directive 2007/46**. Waste collection services are exclusively excluded from 'transport services' of the **CPV-system**, but seem to fall under *Division 90: Sewage-, refuse-, cleaning-, and environmental services*:

- Group 905: Refuse and waste related services:
  - 90511000-2 Refuse collection services;
  - 90512000-9 Refuse transport services;
  - 90514000-3 Refuse recycling services.

There might be some other waste-related services which could also be relevant, but which are more linked to cleaning services, such as the cleaning of public areas. Under **NACE** waste collection services fall under *38 Waste collection, treatment and disposal activities; materials recovery* and covers both *Collection of non-hazardous waste (3811)* and *Collection of hazardous waste (3812).* **PRODCOM** is not relevant for this category, because it only covers the classification of products and not of services.

Courier and postal services

Directive 2007/46 does not provide any definitions for services, only for vehicles. Within the CPV postal and courier services are listed under *Division 64 'Postal and telecommunications services* under *Transport services.* Group 641 'Post and courier services' includes Class 6411: Postal services:

- 64111000-7 postal services related to newspapers and periodicals.
- 64112000-4 postal services related to letters.
- 64113000-1 postal services related to parcels.

- 64114000-8 post office counter services.
- 64115000-5 mailbox rental.
- 64116000-2 post-restante services.

Group 641 also includes Class 6412: Courier services:

- 64121000-1 Multi-modal courier services:
  - 64121100-1 Mail delivery service;
  - 64121200-2 Parcel delivery service.

Mail transport by road is also specifically mentioned under division 60 'Transport services', which also includes parcel services. Note that the Dutch GPP criteria (see Annex Table A-3) for transport in addition also refer to:

- 79570000-0 - Mailing-list compilation and mailing services;
- 79571000-7 - Mailing services.

The Dutch criteria also refer to mail transport by rail, airmail and mail transport over water, but since the EU GPP criteria focused on road transport modes, we do not include these here. Postal and courier activities fall under *H Transportation and storage* of the **NACE-system**. The specific labels and synonyms are depicted in Table 5. **PRODCOM** is not relevant for this category, because it only covers the classification of products and not of services.

Table 5: Classification under NACE

Code	Label	Synonyms
5310	Postal activities under universal service obligation	An Post, An Post Parcel Services, General Post Office (GPO), Mail distribution and delivery, Post activities, Post office, Post office regional headquarters, Post office stores department, Postal headquarters, Postal sorting office, Poste restante, Sub post office, Parcels distribution and delivery
5320	Other postal and courier activities	City messenger, Courier activities, Courier service, Goods taxi service, Letter-post delivery service (not post office), Licensed carriers, Mail handling, Messenger, Messenger (own account), Messenger service, Parcels delivery service (not post office), Unlicensed carriers, Home deliveries service

Other potential categories

Directive 2007/46/EC mentions the following vehicles as special vehicles:

- Motor caravans.
- Armoured vehicles.
- Ambulances.
- Hearses.
- Trailer caravans.
- Mobile cranes.
- Other special purpose vehicles.
- Wheel-chair accessible vehicles.

Some of these vehicles might also be relevant in procurement processes. Under the **CPV** Ambulance services fall under '*Division 85: Health and social work services' - Group 851: Health services:*

- Class 8514: Miscellaneous health services:
  - Ambulance services which consist of general and specialised medical services delivered in the ambulance.

The CPV also has codes for the vehicles itself, but these are less likely to be procured directly. The Dutch GPP criteria (see Annex Table A-3) also refer to moving services and the related codes under the CPV (see Table 6).

Table 6: CPV codes for moving services

Moving services	
Employee relocation services	79613000-4
Cargo handling and storage services	63100000-0
Relocation services	98392000-4

2.2.3 Conclusions

The CPV system seems to be the most appropriate system in combination with the definitions of Directive 2007/46. PRODCOM and NACE seem to be less appropriate because they are limited to services or products. Compared to NACE and CPV, Directive 2007/46 and PRODCOM seem to provide the most technical definitions referring to technical characteristics of the vehicles, while the definitions of CPV are very broad. Overall, the existence of such many classification systems might be a barrier for harmonisation.

2.3 Stakeholder survey

2.3.1 The survey: questionnaire and distribution

As noted above, the aim of the survey was to gather the views of relevant stakeholders on the existing EU GPP criteria, particularly whether there was a need to modify or remove each criterion. The intention was to engage with a range of stakeholders in order to ensure that all relevant views were taken into account in the course of the revision of the criteria.

The questionnaire for the survey was developed with reference to recent surveys for other GPP product groups in order to ensure that good practice elements from these surveys were taken on board. The 2012 GPP criteria for transport are extensive as they cover five categories of vehicle and service, and between nine and 16 different criteria for each category. Consequently, most of the supporting information relating to the definition of each criterion was included in an Annex.

The questionnaire was divided into four separate sections. Section A asked for factual information about the respondent in order to provide context for the remaining answers. The focus of Section B was on the scope of the criteria, i.e. the categories of transport vehicles and services covered by the guidelines. Currently, criteria are set for the purchase or lease of three categories of vehicle: light duty vehicles (i.e. cars and LCVs), buses and waste collection trucks. Two categories of related services are also covered, i.e. bus services and waste collection services. The questionnaire asked whether these categories should be retained, how they should be defined and whether additional categories, such as postal and courier services, should be included.

The criteria themselves were the subject of Section C of the questionnaire. For each criterion in each category, respondents were asked for their views on whether the criterion should remain unchanged, or whether it should be modified or removed. Space was left for respondents to explain the reasoning behind their answer. The section concluded by asking whether there was a need for any additional environmental criteria and also about the relevant criteria that should be included in any additional category proposed by the respondent. Section D focused on identifying the extent to which the criteria were used, and the associated experience of both procurers and suppliers.

The questionnaire was distributed to members of the EU GPP Advisory Group, Member State contact points for the Public Procurement Network[45], as well as to stakeholders of direct relevance to transport. The latter included various industry associations, including manufacturers of vehicles and other automotive products, suppliers and associations representing relevant transport services, as well as to user groups, environmental groups and city networks. The latter in particular were encouraged to circulate the questionnaire to their members.

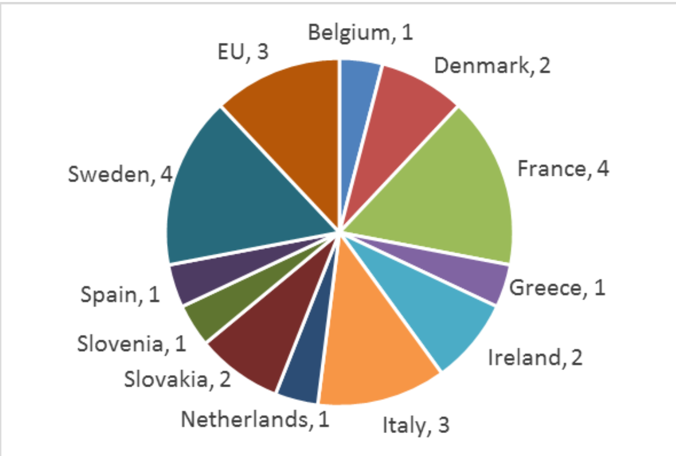
Section 2.3.2 analyses the responses to the survey only in relation to the categories of vehicle and service covered and the definition of these, i.e. Section B of the questionnaire. The analysis of the remaining responses will be undertaken in the Task 3 report.

2.3.2 Analysis of the responses

Overview of respondents

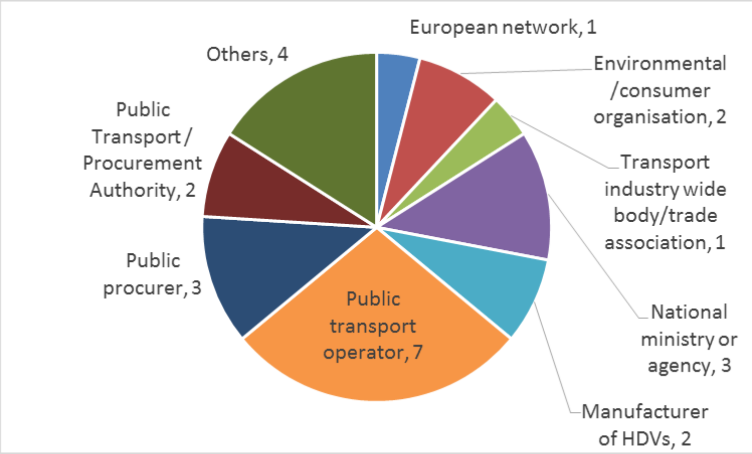
By the 10th March 2016, 25 responses to the stakeholder survey had been received. A couple of additional responses are anticipated, which will be incorporated into later versions of this or other reports. Respondents represented stakeholders from ten different Member States, while three EU level networks or consumer/environmental organisations also submitted a response (see Figure 4). A wide range of stakeholders were also represented, including manufacturers and national ministries. Around half of all of the responses were from public transport operators, public procurers or associated authorities (see Figure 5).

Figure 4: Breakdown of respondents by Member State



[45] http://www.publicprocurementnetwork.org/index.php?option=com_content&view=article&id=69&Itemid=53

Figure 5: Breakdown of respondents by type



Views on the scope and definitions of existing categories

Overall, stakeholders' views were positive on both the categories covered by the criteria and the definition of these. No respondent proposed to remove any of the five categories of transport vehicles and services currently covered by the guidelines. In all cases the majority of respondents with a view were in favour of keeping the requirements, with some supporting some kind of modification. There were more responses with respect to the purchase of buses and bus services, reflecting the number of public transport operators who responded to the survey (see Figure 6). The vast majority of stakeholders that expressed an opinion also agreed with the way in which 'cars and LCVs' and 'buses' are defined in the criteria (see Figure 7).

Figure 6: Stakeholders' views on the scope of the criteria

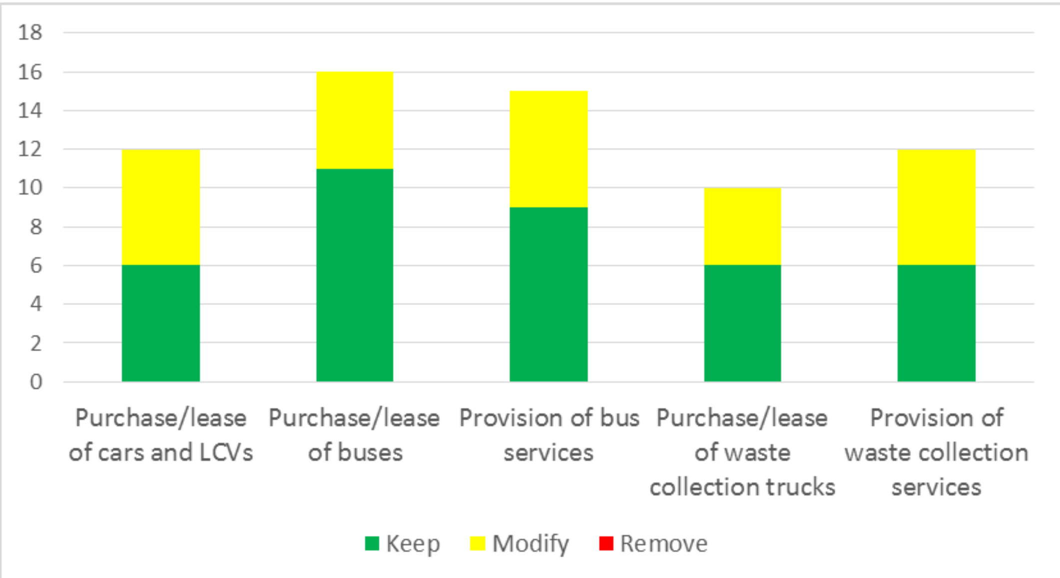
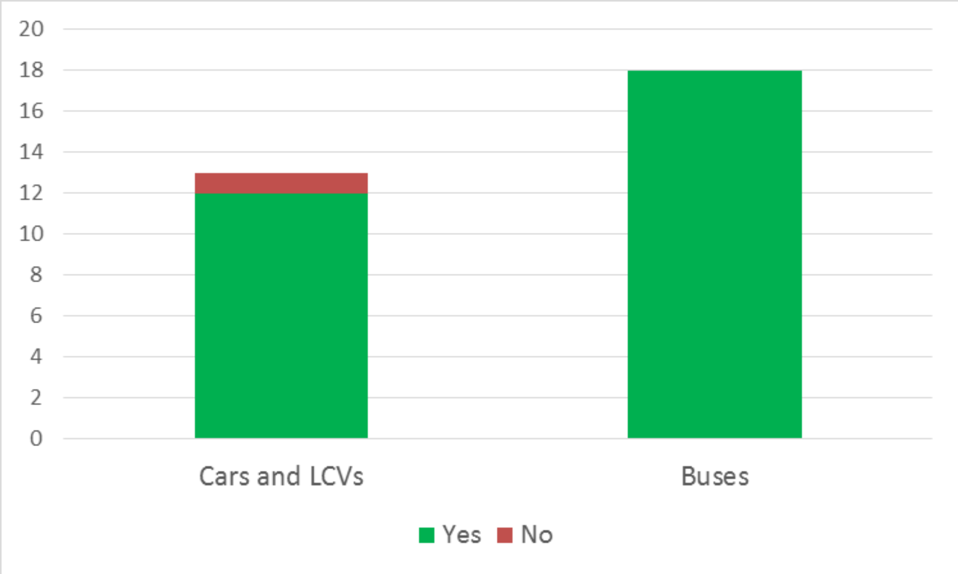


Figure 7: Stakeholders' views when they were asked whether they agreed with the way in which the specified categories were defined



A number of stakeholders considered that some of the definitions of some of the categories were too narrow and so did not reflect the way in which public authorities delivered some of the services, or that they restricted the procurement of more sustainable options. This issue was raised in relation to the definition of 'cars and LCVs' by two stakeholders, including the one that supplied the only negative response in Figure 7. It was argued that the current terminology limits the scope of procurement to cars and LCVs (i.e. M_1 and N_1 vehicles as defined by Directive 2007/46), and so excludes some categories of vehicle, such as 'L-category' vehicles (as defined by Regulation 168/2103), some vehicles excluded from this Regulation[46] and bicycles, that potentially have lower environmental impact for both freight and passenger trips. The vehicles excluded from this Regulation, but which were proposed might be covered by the EU GPP criteria include electric bicycles, 'self-balancing vehicles' and vehicles not equipped with at least one seating position. The inclusion of such vehicles, or the requirement to consider the use of such vehicles, would allow 'the smallest, lightest and least powerful vehicle' to be used to meet the respective mobility needs, which the Technical Background Report supporting the current EU GPP criteria noted should be the general guideline when procuring transport services or vehicles. This could entail modifying the name of the category to "passenger vehicles and light commercial vehicles". Two stakeholders also noted that it is not always trucks that perform waste collection services, as L-category vehicles could also be used, as could ferries; consequently, one stakeholder proposed that the name of the fourth category should be "waste collection vehicle".

One stakeholder also argued that the scope of the 'waste collection services' category was too narrow, as other local services, such as parks and public gardens' services, street cleaning, road/infrastructure works, could also be included. It was argued that expanding the scope in this way would increase the effects of the criteria and would allow public authorities to demonstrate their sustainability policies. It was proposed that

[46] Regulation (EU) No 168/2103 on the approval and market surveillance of two- or three-wheel vehicles and quadricycles.

the category be broadened and renamed "technical public service vehicles". A public transport operator noted that it followed the UITP's document for procuring buses and related services (UITP, 2009).

There were various suggestions relating to how the categories currently without an explicit definition might be defined, including a couple with references to relevant pieces of EU legislation (see Table 7). On the other hand, one stakeholder asked whether it was necessary to define these categories as the procurer knows what they want to procure without the need for a technical definition. Another respondent raised a general point in relation to all of the definitions. This suggested that, for each category, an explicit reference be made to the vehicle category with reference to Directive 2007/46 (as is done for the definition of 'cars and LCVs' and 'buses') and also to the CPV codes covered.

Table 7: Suggestions for definitions for categories currently without an explicit definition

Public transport (bus) services
Services made with a vehicle, for which there is non-discriminatory access for users.
A network including vehicles and routes managed with specific rules (time table, number of vehicles, bus stops, etc.).
A shared passenger road transport vehicle service which is available for use by the general public based on regular operation of vehicles along a route calling at agreed stops according to a published transport timetable.
Definition set within Regulation 1370/2007[47], article 2(a).
Services that are offered to the public with the purpose of allowing transit between different locations. Commuters are able to choose the kind of transport and the time of transportation as they wish.
A service that allows citizens to move without its own vehicle across the whole country, region or city.
Public transport tendered by public authorities, carried out by commercial companies.
Waste collection trucks
A road transport vehicle used for picking up waste and then taking it to landfills or other places where waste materials are managed and treated.
N_2 and N_3 vehicles for urban waste collection and transport[48].
A truck with a specially adapted superstructure for collection and transport of waste.
Waste collection services
An activity provided by local government authorities or by private companies, which includes picking up all kinds of waste from urban and suburban areas and then moving it to landfills or other places where waste materials are managed and treated.
Collection, transport, recovery and disposal of waste.

[47] Regulation (EC) No. 1370/2007 on public passenger transport services by road and rail; the article referred to defines "public passenger transport" as "passenger transport services of general economic interest provided to the public on a non-discriminatory and continuous basis".

[48] N_2 and N_3 vehicles are defined in Directive 2007/46.

Other comments from respondents that called for the modification of the categories related to the definition of the criteria and so will be covered in the Task 3 report. There were also two comments relating to the need to change the approach contained within the CVD (see above).

Views on potentially extending the scope of the criteria

A majority of stakeholders that had a view were supportive of the expansion of the criteria to the 'provision of postal and courier services' (see Figure 8). Comments in favour of the inclusion of these services noted that criteria would be useful for local authorities and the introduction of new technologies, that these service providers have large fleets and so criteria could bring significant environmental improvements, that these services have high visibility amongst the public and that their inclusion would contribute further to enabling public procurement to lead the way towards a low carbon transport system. It was also noted that as the GPP criteria are a voluntary instrument, it would be good to include as many public fleets as possible within them in order to stimulate the production of greener vehicles. The importance of including L-category vehicles and bicycles within the scope of the definition of the category was also highlighted by two stakeholders. A set of definitions was proposed for a new category of 'provision of postal and courier services' (see Table 8), although none made reference to existing EU legislation.

Figure 8: Stakeholders' views on the expansion of the scope of the criteria to cover 'provision of postal and courier services'

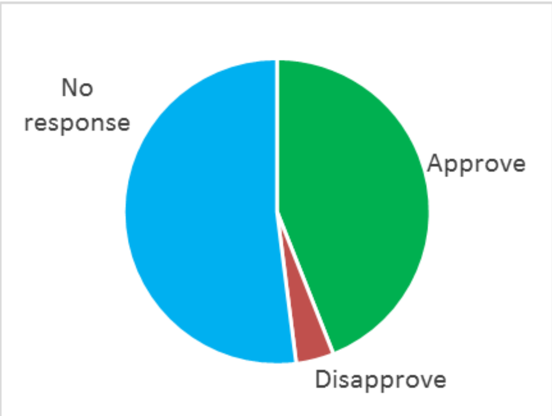


Table 8: Suggestions for a definition for a new category of 'provision of postal and courier services'

Provision of postal and courier services
An activity operates by companies on all scales, from within specific towns or cities, to regional, national and global, which covers the delivery of goods from one place to another using a road transport vehicle. Postal services: letter and parcel services, financial services, other - non-postal services, sale of goods. Courier services: services for fast delivery of documents and goods across the country.

Forty percent of the respondents suggested an additional category of vehicle or service that could be included in a revised set of EU GPP criteria (see Figure 9). The suggestions that were provided are listed in Table **9**. Some of these reflect earlier comments, such as the inclusion of 'L-category' vehicles, which raises the question as to whether these vehicles could be included in an extended definition of passenger vehicles, or as a separate category in their own right.

Other suggestions, such as ferries and trams, are outside of the scope of the EU GPP criteria for transport, as they are not road transport. These vehicles also use different technologies and infrastructures to road transport and so would be more appropriately covered by separate product groups that might comprise the construction and maintenance of the infrastructures associated to those transport modes.

A number of respondents suggested vehicles or services, such as tractors, city distribution and intercity bus operations, that would not generally be considered to be core services provided or procured by public authorities and so which are unlikely to be relevant for many authorities. The proposal to include vehicles not contained within the road vehicle type approval Directive covers vehicles that are more or less by definition outside of the scope of the criteria, e.g. vehicles used in quarries, in airports and by the armed forces. Finally, the proposal to extend the scope to alternative powertrains and fuels is more appropriately addressed through the inclusion of criteria.

Private fleets contracted to do public works, which would potentially include some vehicles covered by the NRMM legislation, was also suggested. However, these activities fall under the tendering processes for public works and other services than transport, such as road construction and maintenance, gardening services, etc., which already have their own EU GPP criteria. Perhaps the most promising for inclusion in the criteria raised in this section relate to contracted public transport, and taxi services and vehicle sharing services.

Figure 9: Stakeholder views on whether there are other categories that could be included in the scope the expansion of the scope of the criteria

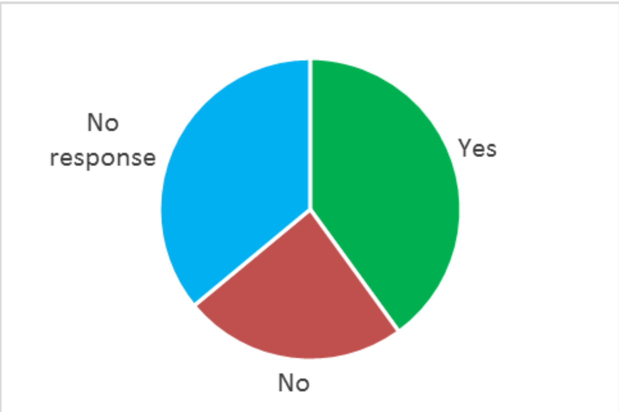


Table 9: Suggestions for additional categories (and proposed definitions where provided) that could be included in the revised GPP criteria

Additional categories (and proposed definitions) that could be included in the revised GPP criteria
Vehicles
'L-category' vehicles (as defined by Regulation 168/2013 and some vehicles excluded from this Regulation (see footnote 46). Tractors ('T-category' vehicles) in the scope of Regulation (EU) No 167/2013[49]. Non-road Mobile Machinery as defined in the extended scope of the Commission's proposal re NRMM (European Commission, 2014c). Vehicles currently falling out of scope of Directive 2007/46, including vehicles principally designed and constructed for use on construction sites or in quarries, port or airport facilities; vehicles designed and constructed for use by the armed services, civil defence, fire services and forces responsible for maintaining public order when travelling on public roads; and self-propelled vehicle designed and constructed to perform work and which is not suitable for carrying passengers or for goods. Ferry boats, boats. Urban Light Rail Vehicles (trams).
Services
Private fleets that are contracted to do public works (e.g. construction / road works). Taxi services. Vehicle sharing services. Public transport service by boats (ferry boats). City distribution. Intercity bus operation. Chartering i.e. delegation of the right to run a bus service to another bus transport company by tender. Contracted public transport (done by taxi companies) i.e. transport carried out for pupils/students who are not able travelling by themselves. Proposed definition: Transport services for people who are not able to travel independent. These transport services are tendered by local authorities and carried out by (commercial) taxi companies.
Others
Alternative powertrains and alternative fuels.

2.3.3 Discussion and summary

The 24 stakeholders from whom responses were received were from a range of different Member States and stakeholder groups. Those procuring or operating the vehicles and services covered were well represented.

No stakeholder proposed that the scope of the criteria be reduced and only one explicitly disagreed with the way in which 'cars and LCVs' or 'buses' were defined in the respective categories. Some comments - and the one stakeholder with a negative view on the current definition of 'cars and LCVs' - argued that some of the categories were too narrow in scope if they were trying to encourage the use of the most environmentally beneficial vehicles in each case. Smaller vehicles than those covered by Directive

[49] Regulation (EU) No 167/2103 on the approval and market surveillance of agricultural and forestry vehicles.

2007/46 could be used instead of cars, LCVs and even waste trucks. In this respect, reference was made to 'L-category' vehicles, which include powered bicycles, mopeds, motorcycles and smaller four-wheeled vehicles, as well as to (non-powered) bicycles. This reflects the suggestion in Dutch procurement guidance to consider alternatives to motorised vehicles and services (see Section 2.1.2).

A majority of those that expressed an opinion supported the extension of the criteria to include the 'provision of postal and courier services', while a couple of stakeholders highlighted the potential role of L-category vehicles and (non-powered) bicycles here as well. There were also suggestions that the service categories be extended to other services procured by public authorities. This might be achieved by extending and redefining the existing 'waste collection services' category' or by introducing new categories. The most promising vehicles/services suggested that might be included in the criteria included vehicles used contracted public transport and taxi services.

A few suggestions were made with respect to how categories currently not explicitly defined in the criteria might be defined, including some references to EU legislation. One respondent supported the explicit inclusion of vehicle definitions with reference to EU Directives and the inclusion of the CPV codes covered by all categories. The latter approach is already taken in Dutch procurement guidelines (see Section 2.1.2).

2.4 Proposals for the revision of the scope and definition of the transport categories

The proposals of the scope and definitions of the categories that might be covered in the revised EU GPP criteria for transport are based on the findings and the survey carried out to develop the Task 1 of the revision process.

2.4.1 Proposed categories to cover in the scope of the revised criteria

The first proposal is that the current five categories - 'cars and LCVs', 'buses', 'bus services', 'waste collection trucks' and 'waste collection services' - should be retained. There is no reason, on the basis of the information presented in this report, to conclude otherwise. No survey respondent called for the removal of any of these five categories. However, there might be scope for widening some of the categories or developing criteria for additional categories.

The first category that could be added is **'Mobility services'**. This product group concerns all kinds of services for mobility of public authorities' staff with vehicles that are (partly) driven by others, including different transport modes, as well as car sharing concessions. This includes for example taxi services but also broader mobility service packages as offered by some more advanced lease companies. Such packages can include access to (leased) cars or LCVs, but also 'L-category' vehicles (i.e. two-, three- and small four-wheeled vehicles), bicycles, as well as access to car-sharing schemes, public transport cards or multi-modal transport cards, etc. One of the differences with the first category (purchase or lease of cars, LCVs and L-category vehicles) is that this new category does not (only) include vehicles driven by public staff or elected representatives, but (also) driven by others. These can be either taxi drivers or users of car sharing schemes. Furthermore, it can also include services with other vehicle types than cars or LCVs (e.g. two-wheelers or public transport vehicles). Another important difference is that the provision of mobility services involves the use of a service fleet.

Table 10 gives an overview of the types of services that are included in this new product group and how it relates to the product group 'Procurement or lease of cars or LCVs'.

Table 10: Overview of types public procurement that involve cars or LCVs

<table>
<tr><th></th><th>Just LDVs (owned by public authority)</th><th>Just LDVs (privately owned)</th><th>Mix of leased LDVs & other vehicle types and public transport services</th></tr>
<tr><td rowspan="2">Driver is public staff or elected representative</td><td>Purchase of cars/LDVs</td><td>Leased cars/LDVs</td><td rowspan="3">Advanced service packages by lease companies</td></tr>
<tr><td colspan="2">Procurement/lease of cars/LCVs</td></tr>
<tr><td rowspan="2">Private driver(s)</td><td>Publicly owned car sharing schemes</td><td>Taxi services,
Car sharing concessions</td></tr>
<tr><td colspan="3">Mobility services involving cars/LCVs</td></tr>
</table>

Other additional service categories that might be considered for inclusion in the revised EU GPP criteria for transport comprise the following ones:

- 'Post and courier services', as this received support from stakeholders and could be developed by drawing on the criteria for transport services in the Netherlands and those for postal and home delivery services in Japan.
- 'Moving services', which are covered by the same criteria as postal and courier services in the Netherlands.

The fact that the Dutch 'transport services' GPP criteria cover a range of transport services, including postal, courier and moving services, but excluding waste collection and goods transport services, suggests that common criteria might be developed for these services. Other vehicles, or services involving the use vehicles or the transport of goods, such as gardening services and road construction and maintenance works that were proposed by stakeholders or are referred to in some national approaches, are covered by EU GPP criteria for those specific product groups. This product-approach enables the development of criteria bespoke to each product group as the subject matter of a public procurement process, and therefore adapted to the different transport demands of each sector.

L-category vehicles could be addressed following a similar approach as for cars and LCVs, even though the legislation regarding air emissions and CO2 labelling are not the same. Therefore, it proposed to be added to the category 'Procurement, lease or rental of cars, LCV.

In summary, the scope proposal comprises the following categories:

1. 'Procurement, lease or rental of cars, LCV and L-category vehicles.
2. 'Mobility services'.
3. 'Buses'.
4. 'Bus services'.
5. 'Waste collection trucks'.
6. 'Waste collection services'.
7. 'Post, courier and moving services'.

2.4.2 Proposed definitions of the categories

As was concluded in Section 2.2.3, the most appropriate way of defining the categories covered by the revised EU GPP criteria for transport seem to be to use the definitions of vehicles from Directive 2007/46, in combination with the CPV categories where appropriate.

Thus the definitions of the categories proposed are the following:

1) 'Procurement, lease or rental of cars, LCV and L-category vehicles.

The information available regarding short term renting services show that these services offer very young vehicles, which are usually below 1 year old. Therefore, renting services are proposed to be part of category 1

- 'Cars and LCVs': M_1 and N_1 vehicles, as defined by Directive 2007/46;
- L-category vehicles as defined by Regulation 168/2013;

2) 'Mobility services'.

As noted in Section 3.4, it is proposed a new service category covering mobility services involving cars or LCVs. As part of these criteria, the following definitions might be applied:

- 'Taxi services' as covered by CPV code 60120000-5.
- 'Cycles': Bicycles (CPV codes 34430000-0 and 34431000-7), cycle trailers, electrically power assisted cycles (CPV code 34420000-7),
- 'Light electric vehicles and self-balancing vehicles' whose specific definitions are under development by CEN/TC 354 /WG 4.

3) 'Buses'

- 'M_2 and M_3 vehicles, as defined by Directive 2007/46.

The definition of the categories 4), 5), 6) and 7) would also make reference to the definitions of categories 1) , 2) and 3), where relevant, but also to CPV categories, as appropriate.

4) 'Bus services'

- 'Bus services' or 'Public transport services': The services should be defined as those covered by CPV codes 60112000-6 (Public road transport services), 60130000-8 (Special-purpose road passenger-transport services) and 60140000-1 (Non-scheduled passenger transport). This should cover the contracted public transport services proposed in Section 2.3. (contracted public transport done by taxi companies, i.e. transport carried out for pupils/students who are not able travelling by themselves). It is worth noting that these three CPV categories refer directly to the definition of public transport services in the public procurement Directives (discussed in Section 0), with the explicit exception of rail public transport services.

5) 'Waste collection vehicles':

- Vehicles of category N_2 and N_3, as defined by Directive 2007/46, that are designed to provide services that fall into the CPV categories of 'Refuse collection services' (CPV code: 90511000-2), 'Refuse transport services' (90512000-9) and 'Refuse recycling services' (90514000-3).

6) 'Waste collection services'

- Services that fall into the CPV categories of ‘Refuse collection services’ (90511000-2), ‘Refuse transport services’ (90512000-9) and ‘Refuse recycling services’ (90514000-3).

7) 'Post, courier and moving services’:

- Services that fall into the CPV categories for various postal, courier and moving services:
    - Group 641 Post and courier services, with the exception of rail, airmail and mail transport over water
    - 79613000-4 Employee relocation services
    - 63100000-0 Cargo handling and storage services
    - 98392000-7 Relocation services

3 PASSENGER CARS, LIGHT COMMERCIAL VEHICLES AND RELATED SERVICES

3.1 Introduction

This chapter describes the overall and public market of passenger cars and Light Commercial Vehicles (LCVs, also known as vans), followed by a cost analysis, the views of stakeholders on the current criteria, and a technical analysis.

This analysis is the core information for the revision of the category 'Procurement or cars and LCVs' and 'Mobility services involving cars or LCVs'. As this category also includes other services (e.g. taxis or multi-modal services for staff), these are also discussed, although in less detail.

3.2 Market analysis

3.2.1 Overall market

Passenger cars

The current passenger car fleet in the European Union consists of 250 million vehicles, with a growth rate of 1.2% from 2012 to 2013. Of the 15 million passenger cars that are produced in the EU, about a third is exported. The produced cars that remain in the EU, combined with 2 million imported passenger cars, add up to 12.5 million new registrations each year.

Yearly, 4.7 trillion passenger-kilometres are driven in the European Union by passenger cars, which leads to an average yearly mileage of 19 000 passenger-km per vehicle. Main data on the EU passenger car market are summarized in Table 11, along with the respective reference.

Table 11: Market data of passenger cars in the European Union

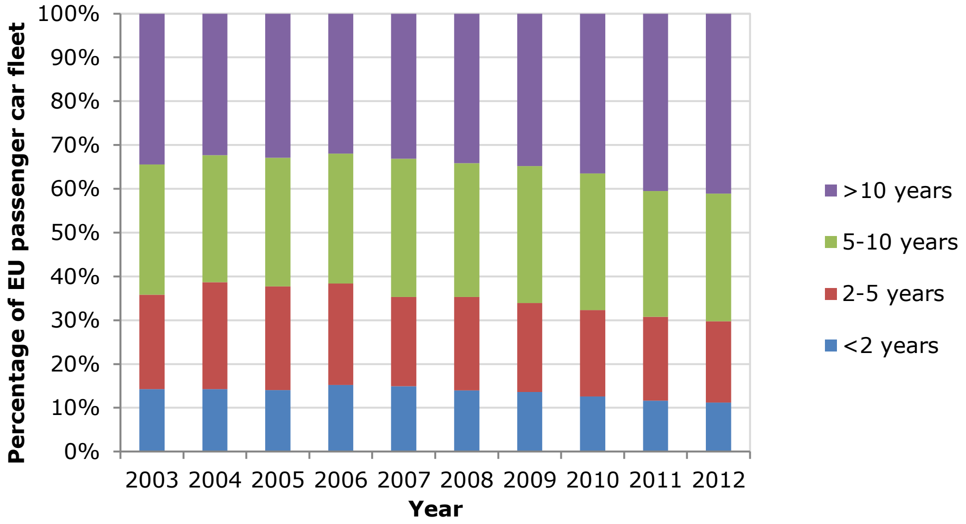
Quantity	Unit	Value	Year	Source
Current size of the fleet	Vehicles	250 000 000	2013	(ACEA, 2016)
Annual growth rate	Vehicles/year	3 000 000 (1.2%)	2013/2012	(ACEA, 2016)
EU production	Vehicles/year	15 000 000	2014	(ACEA, 2016)
EU sales (new registrations)	Vehicles/year	12 550 707	2014	(ACEA, 2016)
Import (into EU)	Vehicles/year	2 043 919	2014	(ACEA, 2016)
Export (out of EU)	Vehicles/year	5 461 083	2014	(ACEA, 2016)

Quantity	Unit	Value	Year	Source
EU performance	Million passenger-km/year	4 672 000	2013	(EC, 2015 d)
EU performance	Million vehicle-km/year	3 034 000	2013/2007	(50)
Average mileage	Passenger-km/vehicle/year	18 688	2013	(calculation)
Average fuel consumption (petrol)	Litres of fuel/vehicle/year	1 458	2013	(ICCT, 2016b) (CE Delft, 2014) (TNO, 2014b)
Average fuel consumption (diesel)	Litres of fuel/vehicle/year	1 259	2013	(ICCT, 2016b) (CE Delft, 2014) (TNO, 2014b)

The European fleet of passenger cars is distributed fairly flat along age, as can be seen in Figure 10. For 2012, each build year up to 17 years (or at least up to 10 years) is shown to contain approximately 6% of the passenger cars. Since 2006, the average age has slowly been increasing. The reason behind this aging of the fleet might be the economic crisis which might have entailed a lower replacement rate.

[50] Calculation based on the EU performance in passenger-km/year and the average occupancy of 1.54 passengers/vehicle (EEA, 2010).

Figure 10: Shares of vehicle age of current passenger car fleet for EU28[51] in 2003-2012 (Eurostat, 2015b)



Although alternative fuels are seeing an increase in the share of the current passenger car fleet, the majority still uses fossil fuels[52]. Alternative fuel vehicles use fuels other than petrol and diesel, and include (but are not limited to) pure electric vehicles, liquefied petroleum gas vehicles (LPGs), natural gas vehicles (NG), ethanol (E85), pure biodiesel (B100) and plug-in hybrid electric vehicles. Figure 11 shows that 41% of the current passenger car fleet uses diesel fuel and 54% petrol, with a small share of 5% for alternative fuels.

[51] EU28 excluding Bulgaria, Greece, Slovakia. Missing data points were replaced by the previous supplied data point for that member state.

[52] Having a small percentage of biofuel blended in diesel or petrol, like B7 or E5/E10.

Figure 11: Shares of fuel type in current passenger car fleet in the European Union in 2014 (ACEA, 2016)

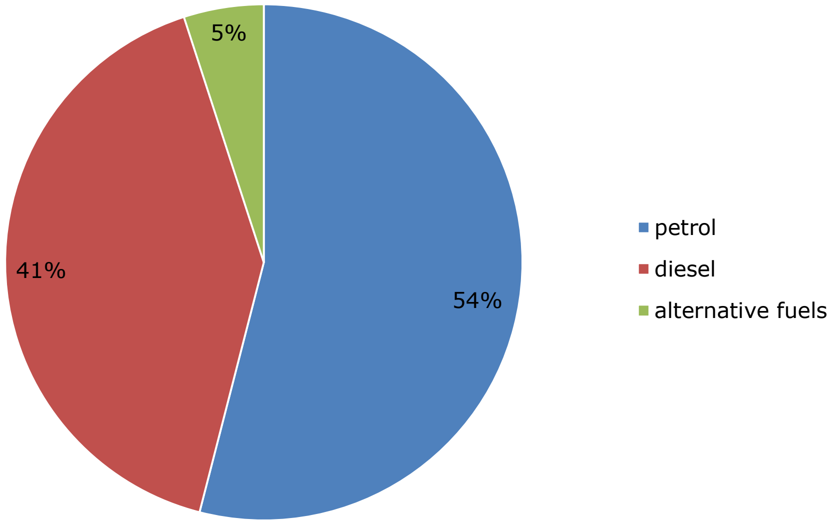
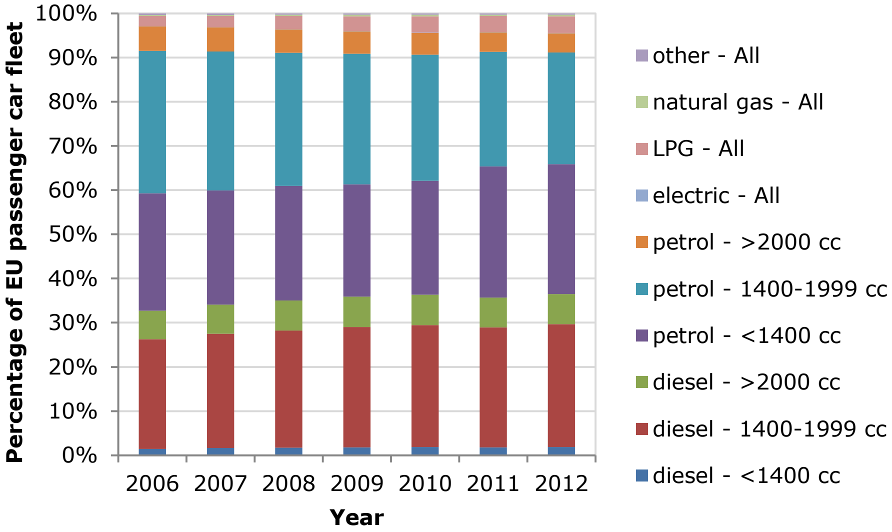


Figure 12 shows the trend in fuel type and engine size between 2006 and 2012. It shows that the share of diesel cars in the fleet increases over time. This is in line with the share of diesel in new car sales in the EU, which was 53% in 2014 (ICCT, 2016b)

Within diesel passenger cars, the majority uses a midsized engine. Petrol passenger cars on average have a smaller engine, being approximately equally divided between small and midsized engines, with a small share for large engines. Between 2006 and 2012, there was a small increase in midsized diesel cars and a small decrease in midsized petrol cars.

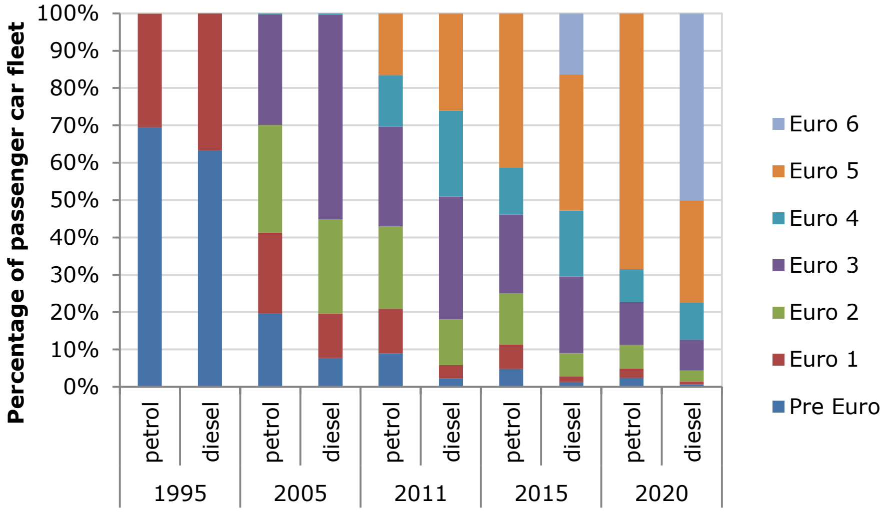
Figure 12: Shares of fuel type and engine size in current passenger car fleet in the European Union[53]



In 2011, 17% of gasoline cars and 26% of diesel cars conformed to the 2009 Euro 5 standard. Of the then-current fleet, 43% of gasoline cars and 18% of diesel cars in the fleet did not meet the Euro 3 standard that had been set ten years earlier. A projection for 2020 shows that 70% of the petrol passenger cars will have a Euro 5 engine (note that for petrol Euro 6 is identical to Euro 5 with the addition of a limit for the number of particles and a change in the requirements of the on-board diagnostics). For diesel, approximately 75% will have a Euro 5 or 6 engine in 2020. The full distribution of Euro-standards among gasoline and diesel passenger cars is shown in Figure 13. Note that no estimations are presented for Euro 6 petrol engines; an explanation for this could be the unchanged emissions requirements for petrol; the limits are still equal to Euro 5.

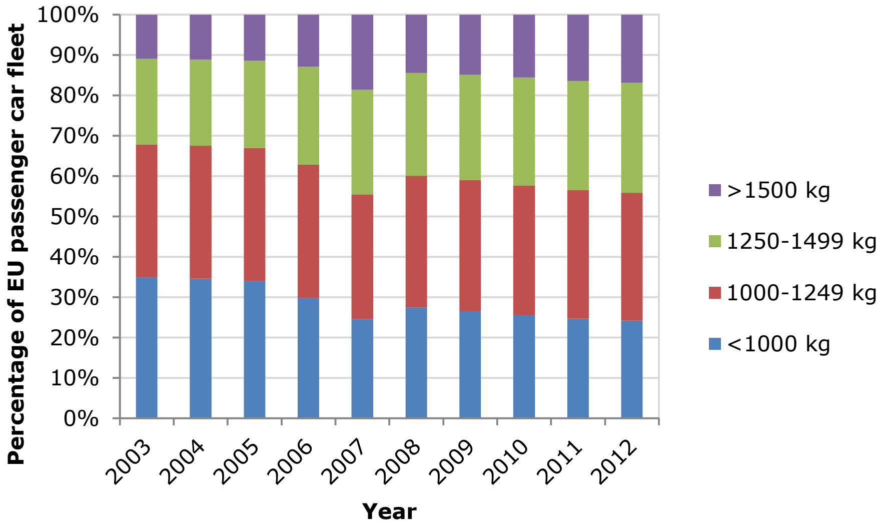
[53] (Eurostat, 2015f) and (Eurostat, 2015g) adapted by interpolating missing data.

Figure 13: Shares of Euro-standards in current and future fleets of gasoline and diesel passenger cars for 30 EEA countries[54]



The vehicle mass of passenger cars in the European Union has risen considerably between 2003 and 2012. Whereas 68% of the passenger cars weighed less than 1,250 kg in 2003, this percentage is only 57% in 2012. Figure 14 shows how the shares of the two lighter weight classes decrease and the shares of the two heavier weight classes increases.

Figure 14: Shares of vehicle weight of passenger cars in the European Union[55]



[54] 1995, 2005, 2011 historical data from (EEA, 2011), 2015, 2020, prognosis by TREMOVE (TML, 2012)).

[55] (Eurostat, 2015h) adapted by interpolating missing data.

Light Commercial Vehicles

The European Union currently has a fleet of 23 million light commercial vehicles (LCVs), which is about one-tenth of the number of passenger cars. Production of LCVs within the EU is 1.7 million per year. Import and export of LCVs (including both new and used LCVs) are fairly balanced at 310 000 and 370 000 respectively. Yearly, 1.5 million LCVs are registered in the EU. The overall market data is summarized in Table 12, along with the respective reference.

Table 12: Market data of light commercial vehicles in the European Union

Quantity	Unit	Value	Year	Source
Current size of the fleet	Vehicles	23 000 000	2015	(ICCT, 2016b)
Annual growth rate	Vehicles/year	n/a		
EU production	Vehicles/year	1 720 000	2014	(ACEA, 2016)
EU sales (new registrations)	Vehicles/year	1 535 125	2014	(ACEA, 2016)
Import (into EU)	Vehicles/year	310 426	2014	(ACEA, 2016)
Export (out of EU)	Vehicles/year	366 656	2014	(ACEA, 2016)
EU performance	Vehicle-km/year			
EU apparent consumption	Litres of fuel/vehicle/year	n/a		

Almost the entire fleet of light commercial vehicles runs on diesel fuel (96.8%). Figure 15 shows that only a small fraction uses petrol/gasoline (2.0%) or alternative fuels (1.2%). The percentage of LCVs running on diesel fuel increased slightly between 2009 and 2014, as shown in Figure 16.

Figure 15: Shares of fuel type in light commercial vehicle sales in the European Union in 2014 **(EEA, 2015b)**

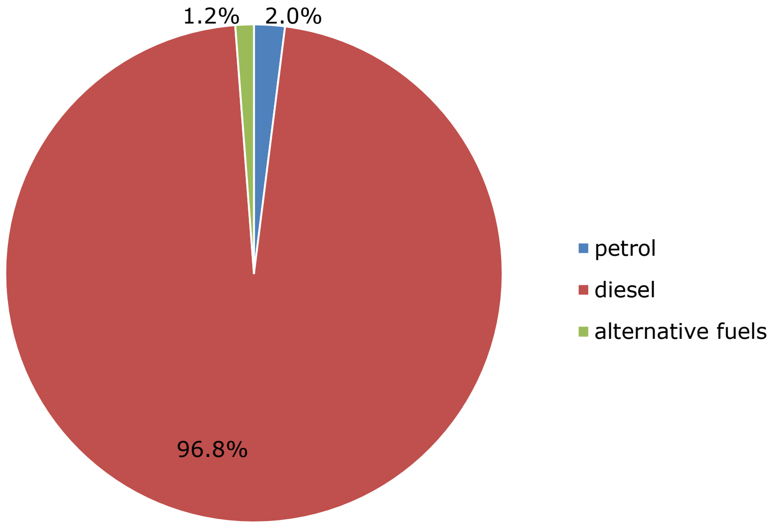
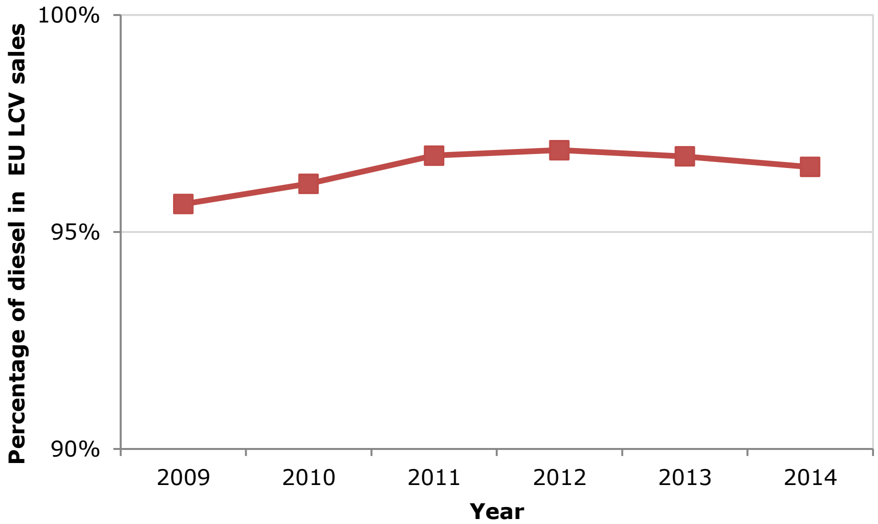
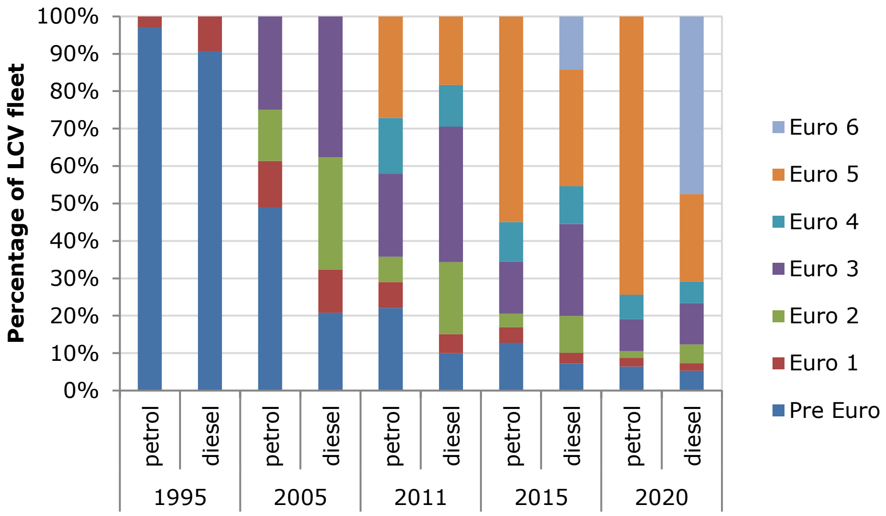


Figure 16: Share of diesel in light commercial vehicle sales in the European Union for 2009-2014 **(ICCT, 2016b)**



In 2011, 27% of the gasoline LCVs and 18% of the diesel LCVs of the then-current fleet conformed to the Euro 5 standard that was implemented in 2009. Approximately one third of the gasoline and diesel LCVs did not meet the 2000 Euro 3 standard. A prognosis for 2020 shows that 75% of the petrol passenger cars will have a Euro 5 engine (note that for petrol Euro 6 is identical to Euro 5 with the addition of a limit for the number of particles and a change in the requirements of the on-board diagnostics). For diesel, approximately 70% will have a Euro 5 or 6 engine in 2020. The complete distribution of Euro emission standards is shown in Figure 17.

Figure 17: Shares of Euro-standards in current fleets of gasoline and diesel light commercial vehicles for 30 EEA countries[56]



L-category vehicles

The market data available refer to powered two-wheelers (PTW) which cover mopeds (L1e) and motorcycles (L3e). For other types of L-category vehicles, market data is quite scarce and scattered. The European Union had a fleet of 35 million of mopeds and motorcycles in 2013. Production of LCVs within the EU is 1.7 million per year. Import and export of PTW is quite unbalanced at EUR 2 300 million and EUR 700 million respectively in 2008. Yearly, 1.14 million pf PTW are registered in the EU. The overall market data is summarized in Table 12, along with the respective reference.

[56] 1995, 2005, 2011 historical data from (EEA, 2011), 2015, 2020, prognosis by TREMOVE (TML, 2012).

Table 13: Market data of PTW in the European Union

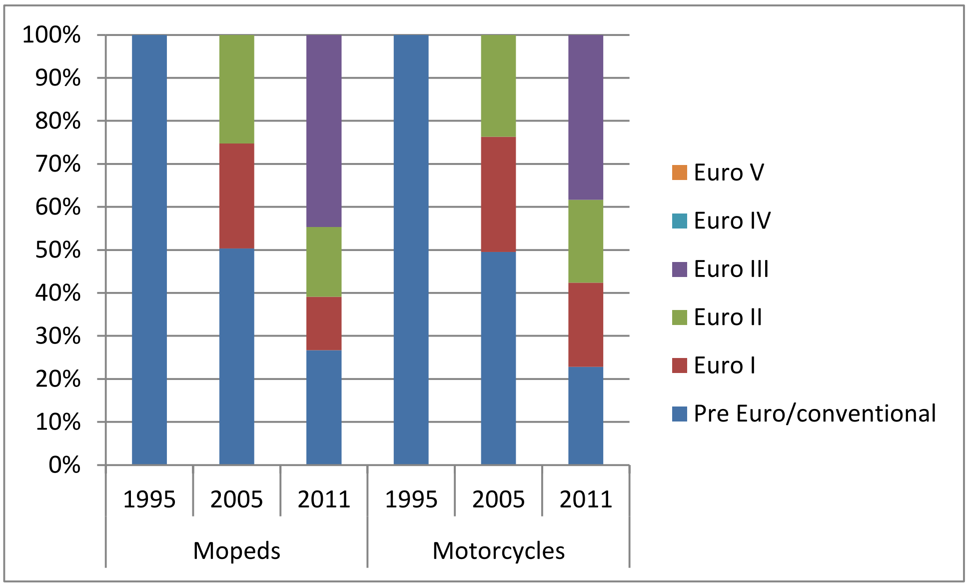
Quantity	Unit	Value	Year	Source
Current size of the fleet	Vehicles	34 581 100	2013	(European Union, 2015)
Annual growth rate	Vehicles/year	n/a		
EU production	Vehicles/year	767 593	2011	(ACEM, 2013)
EU sales (new registrations)	Vehicles/year	1 144 300	2013	(European Union, 2015)
Import (into EU)	Mill EUR/year	2 300	2008	(ACEM, 2010)
Export (out of EU)	Mill EUR/year	700	2008	(ACEM, 2010)
EU performance	Vehicle-km/year			(ACEM, 2010)
EU apparent consumption	Litres of fuel/vehicle/year	n/a		

Electric PTWs still account for only 0.3% of the market; however they experienced a 60% surge in purchases between 2009 and 2010, and a similar growth in 2011 (ACEM, 2013)

With regards to air emissions, Figure **18** shows the share of moped and motorcycles complying with the Euro standards in 1995, 2005 and 2011 (EEA, 2013)[57]

[57] http://www.eea.europa.eu/data-and-maps/figures/allocation-of-heavy-duty-vehicles-1

Figure 18: Share of moped and motorcycles complying with the Euro standards in 1995, 2005 and 2011 (EEA, 2013)



There are also data available from a JRC study (Clairotte, et al., 2015) in the framework of the Regulation 168/2013, which includes stocktaking of representative data of products placed on the EU market based on data available between September 2014 and June 2015. According to this study, less than 1% of mopeds and motorcycles complied with Euro 5, and 63% of mopeds and 8% of motorcycles complied with Euro 4. Note that the enforcement timing of Euro standards for L-category vehicles according to Regulation 168/2013 is the following:

	L-vehicle	New types of vehicles	Existing types of vehicles
Euro 4	L1e, L2e, L6e	1 January 2017	1 January 2018
	L3e, L4e, L5e, L7e	1 January 2016	1 January 2017
Euro 5	L1e-L7e	1 January 2020	1 January 2021

Mobility services

Besides the leasing of cars and LCVs, also other types of services can be provided, as taxi services. Cost impacts will generally be larger than the lease of vehicles, as the total cost also consist of other cost components (like the driver) and vehicle mileages will generally be higher than averages.

Another category of services are multi-modal service packages as an alternative to a leased car for staff or elected representatives. By offering options like multi-modal mobility cards or mobility budgets (with which either a car or multi-modal solutions can be purchased) employees are incentivised to choose alternatives for passenger car transport (e.g. public transport or bicycles). This can have significant benefits in terms of both net cost savings and improved environmental performance. The same is true for incentives for eco-driving (like driver training or feedback to drivers on their fuel efficiency performance) and charging of plug-in hybrid vehicles. Some examples can be found in (CE Delft, 2015). Within the GPP criteria for this service category, some incentives for lease companies or service providers to offer this type of services could be considered.

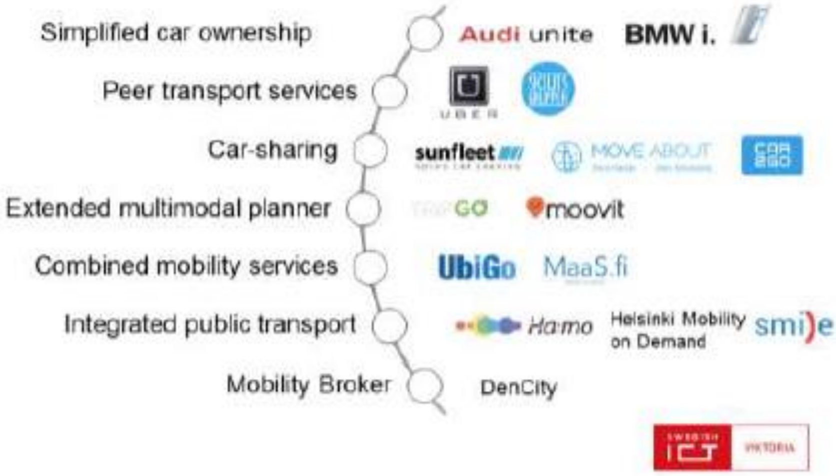
This new category proposed to be included in the scope could fit in the concept *Mobility as a Service (MaaS)* (Kamargianni, et al., 2015), (Holmberg, et al., 2016) however there is not an agreed definition of this concept yet. According to Holmberg et al (2015), the auto-makers are starting to explore the possibilities of this new transport concept, and are launching mobility services such as car-pool, free-floating car-pools and simplified car-owning schemes.

For a better understanding of MaaS concept, (Holmberg, et al., 2016) describe the different levels based on their complexity and innovativeness:

- Simplified car ownership: it offers their customers to share the ownership of a car with other users.
- Peer transport services: it leverages the excess of capacity (empty seats during a trip) and shares it with users. The MaaS provider does not own the vehicles, it only provides the platform for the pairing. The main example is Uber.
- Car sharing: in this category, an organisation owns the vehicles and the platform. It is usually more standardised and reliable than the peer services, and most carmakers have an associated car sharing company.
- Extended multimodal planners: they combine all the available transport options with real time transport data in order to help users plan the most efficient route to their destination. Some services can go beyond just planning by allowing you to purchase the necessary tickets for the suggest route.
- Combined mobility services (CMS); neutral third-party, commercial such as UbiGo and MaaS.fi or otherwise, that offer a wide range of combined mobility options and offer it to users based on subscription and unified invoicing, possibly also with some form of repackaging of the included services. CMS is also supported by some form of digital interface for the customer (app, web based service etc).
- Integrated public transport systems: they aim at designing public transport in a way that it can easily integrate other mobility offers (e.g. car sharing, bike sharing, taxis, etc.). In Austria, the SMILE-project 4 2014-2015, aimed to include public transport, urban mobility services and national railway in the same concept offering planning options and ability to book and obtain tickets in the same app (without subscription or packaging). With of 1000 registered users during the pilot in 2015, the turnover of consumed mobility services were significantly lower than for the 70 households in the UbiGo trials. The SMILE-service was though not offered as a subscription, in the same way as in the UbiGo case. Another example is Ha:mo, the Toyota platform that tries to optimize the use of cars and other personal vehicles in combination with public transportation. Similar to the extended multimodal planner, the idea is that you should be able to purchase the best mobility offer for your specific trip based on real time transport data. The main difference is that the level of integration and complementation required must be overseen by a specific organization in order to maintain the quality required to have mobility as a public good.
- Mobility Broker: this concept also offers mobility subscriptions but these services go one step further in that mobility is offered as part of the house rent. This demands that mobility services be included in the initial planning process of apartment complexes or city areas. The drive for such services is to enable densification of cities without the need of a personal car. There is currently no such offer in Sweden, however the Vinnova financed project "Dencity" aims at delivering a working concept for a Mobility Broker in Frihamnen, Gothenburg.

The different levels of MaaS are depicted in Figure **19**

Figure 19: Different levels of MaaS **(Holmberg, et al., 2016)**



In the Nordic countries, Ubigo was the pioneer project developed in Goteborg during 2014), offering a range of mobility options to users based on subscription and unified invoicing. ((Kamargianni, et al., 2015), (Holmberg, et al., 2016))

At EU level, the MaaS-alliance is supported by European network for ITS deployment, and it was launched in 2015 to stimulate the implementation of MaaS in Europe.

The report *Feasibility Study for "Mobility as a Service" concept in London* (Kamargianni, et al., 2015), is aimed at proposing the design of MaaS concept for London, and assessing its feasibility. For this analysis, the report provides a survey of selected mobility integration projects worldwide, which is summarised in Figure 20:

Figure 20: Summary of Integrated Mobility Services around the World

Name	Place	Integrator	Integration level**						Modes included
			1	2	3	4	5	6	
Communauto + BIXI + Public transport + local Taxi	Canada	Communauto (car sharing)	X						
SBB + Mobilty +Publibike/Quickbike	Switzerland	SBB (rail)	X						
STIB+Cambio	Brussels, Belgium	Cambio (car sharing)	X	X					
Hannovermobil	Hannover, Germany	Üstra (public transport)	X	X	X*	X			
EMMA	Montpellier, France	TAM (public transport)	X*	X	X	X	X*		
Smile	Vienna, Austria			X	X	X			
Moovel	Germany	Moovel (application)		X	X*	X			
SHIFT	Los Angeles, USA	SHIFT (all modes)		X	X	X	X	X	+ Valet
UbiGo	Gothenburg, Sweden	CLOSER, Lindholmen Science Park AB (research)		X	X	X		X	
Helsinki Model	Helsinki, Finland			X	X	X		X	+ on demand transport

* Partial integration
**1:Cooperation only in terms of providing discounts for combined subscriptions
2: Ticketing integration
3: Payment integration
4: ICT integration
5: Institutional integration
6: Mobility packages

Source: (Kamargianni, et al., 2015),

3.2.2 Public procurement

Passenger cars

It is challenging to identify the extent of public procurement of transport vehicles in the EU. The 2015 evaluation of the EU's Clean Vehicle Directive (CVD) was not able to identify an EU-wide database on vehicles - either their stock or new registrations - by vehicle owner (Ricardo Energy & Environment and TEPR, 2015). In order to estimate the number of cars publicly procured annually in the EU, the report used information on public fleets (i.e. vehicle stock) from the four Member States for which this information was available together with information on public registrations from one Member State combined with EU registration data from ACEA (see above). This analysis concluded that - on average - 1.01% of the car stock in these four countries was owned by the public sector (see Table 14). It is worth noting in this respect that the estimates vary significantly by country, which reflects the different procurement practices of the public sector in these countries. It is likely that such differences exist across the other Member States, meaning that the EU average might be around 1.0% of the ***car stock*** owned by the public sector, but this figure would not be representative at national level, because there might be significant variations among countries.

Table 14: Estimate of public sector car stock

	France	Germany	Italy	UK
Estimated public sector car stock	477 000	364 000	627 000	13 000
% of total car stock	1.47%	0.83%	1.69%	0.04%
Average % of total car stock for the four Member States	1.01%			

Source: (Ricardo Energy & Environment ; TEPR, 2015), see Table 9-1 of this report.

Information from Germany suggested that while the public sector accounted for 1.0% of ***new car registrations***, it only owned 0.3% of the total passenger car stock. If it is assumed that this ratio is applicable across the EU, it can be estimated that around 3.4% of new car registrations might be for the public sector (Ricardo Energy & Environment and TEPR, 2015)[58]. Applying this percentage to the new car registrations in 2014 (see Table 11) gives an estimate of 423 000 cars procured by the public sector in the EU that year.

Light Commercial Vehicles (LCVs)

As noted in the previous section, it is not easy to identify the number of vehicles procured by the public sector each year. Information on LCVs is even more difficult to identify than for cars. The report on the evaluation of the CVD identified data for public sector LCV stocks for only two Member States and, on this basis, estimated that on average 3.9% of the LCV stock in the EU is ***owned*** by the public sector (see Table 15). Whereas for cars, data from Germany suggested that the public sector owned a higher proportion of new registrations than of the vehicle stock more generally (see above), for LCVs the opposite was the case. The German data suggested that whereas 2.5% of the LCV stock was owned by the public sector, only 1.8% of new registrations were due to the public sector. Applying this ratio to the average percentage in Table 15 suggests that 2.8% of new LCVs might be registered by the public sector (Ricardo Energy & Environment and TEPR, 2015). Applying this percentage to the annual new registrations in the EU (see Table 12) suggests that annually 43 000 new LCVs might be bought by the public sector in the EU.

[58] The 3.4% is calculated by multiplying the 1.01% from Table 14 by the ratio of proportion of German new car registrations by the public sector (i.e. 1.0%) to the proportion of the car stock owned by the public sector (i.e. 0.3%).

Table 15: Estimate of public sector LCV stock

	Germany	UK
Estimated public sector LCV stock	159 000	37 000
% of total LCV stock	6.8%	1.1%
Average % of total LCV stock for the two Member States	3.9%	

Source: Ricardo Energy & Environment and TEPR (2015), see Table 9-2 of this report.

L-category vehicles

No specific data on public procurement volumes of L-vehicles have been found in the preparation of this report, but it is apparent that main public procurers might be public postal services operated by public entities and police agencies.

Mobility Services

In the preparation of this report, no specific information was found on public procurement criteria that provide incentives for choosing intermodal transport solutions, reduced car-use or eco-driving (e.g. mobility cards, mobility budgets, eco-driving training, etc.). There are some examples of services offered to both private and public organisations, either separately or as part of a package (e.g. with leased cars), as for example Carbon Heroes, Jambusters or Carshare UK (Kamargianni, et al., 2015)

3.3 Cost analysis

Passenger cars

In this section, the Total Cost of Ownership is calculated for passenger cars in four variations: petrol and diesel, both small and large.

Table 16 shows the parameters that are used for this calculation. The average CO_2 emission as determined at the type approval is corrected for the divergence between real world and type approval (based on the NEDC test) CO_2 emissions and then used to calculate the average fuel consumption of a newly purchased reference passenger car.

Table 16: Parameters used for the cost analysis of passenger cars

Parameter	Small petrol	Large petrol	Small diesel	Large diesel	Source
Acquisition costs excl. taxes (€)[59]	16 000	31 000	24 000	39 000	(CE Delft, 2016a)
Lifetime (years)	15	15	15	15	(Ricardo-AEA, 2012b)
CO_2 emission without correction (g CO_2/km)	116	149	99	126	(60)
Correction CO_2 emission (g CO_2/km)	49	60	40	50	(11)
CO_2 emission with correction g CO_2/km)	165	197	149	175	(TNO, 2014b)
CO_2 emission per L (g CO_2/L)	2 269	2 269	2 606	2 606	(CE Delft, 2014)
Fuel consumption (L/km)	0.073	0.087	0.057	0.067	(calc)
Fuel price incl. taxes (€/L)	1.250	1.250	1.040	1.040	(EC, 2016a)
Fuel price excl. taxes (€/L)	0.404	0.404	0.378	0.378	
Maintenance costs incl. taxes (€/km)[61]	0.031	0.036	0.032	0.037	62
Insurance (€/year)	557	557	557	557	(Insurance Europe, 2015)[63]
Circulation taxes (€/year)	136	245	136	245	(64)

[59] An average European registration tax of 4.30% is used.

[60] Calculation based on (TNO, 2011).

[61] Maintenance costs are rough estimates, assuming that maintenance costs of diesel cars are 4% higher than diesel cars (Cambridge Econometrics and Ricardo AEA, 2013), and maintenance costs of large cars are 15% than small cars (Victoria Transport Policy Institute, 2015)

[62] http://www.gewoonovergeld.nl/artikelen/elektrische-auto-vs-benzinewagen/

[63] (Insurance Europe, 2015) provides an average figure of insurance cost in the EU. The report states that it differs significantly between European countries, due to variations in economic development and standards of living and differences in risk exposure and coverage.

[64] Calculation based on (CE Delft, 2016a) and (Zahedi; Cremades;, 2012), assuming that circulation taxes for large cars are 80% higher than for small cars.

For passenger cars, three scenarios are used, based on different annual mileages of 10 000, 20 000, and 30 000 km/year. Based on these numbers and the previously determined fuel consumption, the lifetime fuel consumption is calculated for the three scenarios, as shown in Table 17. It is important to highlight that the third scenario (lifetime 450 000 km) is unlikely for small cars, and not often either for large cars, but not impossible (Ricardo-AEA, 2012b). For the purpose of this report, this scenario is included to analyse the impact of lifetime in the Total Cost of Ownership.

Table 17: Annual mileage assumed for different scenarios and consequent lifetime mileage and fuel consumption

Parameter	**Small petrol**	**Large petrol**	**Small diesel**	**Large diesel**	**Scenario**
Annual mileage (km/year)	10 000	10 000	10 000	10 000	1
Lifetime mileage (km)	150 000	150 000	150 000	150 000	
Lifetime fuel consumption (L)	10 481	11 549	9 618	10 657	
Annual mileage (km/year)	20 000	20 000	20 000	20 000	2
Lifetime mileage (km)	300 000	300 000	300 000	300 000	
Lifetime fuel consumption (L)	20 963	23 098	19 236	21 314	
Annual mileage (km/year)	30 000	30 000	30 000	30 000	3
Lifetime mileage (km)	450 000	450 000	450 000	450 000	
Lifetime fuel consumption (L)	31 444	34 647	28 855	31 971	

Using the values from Table 16 and Table 17, the different contributions to the Total Cost of Ownership are calculated, both with taxes and without, for all three scenarios. Even though an analysis based on taxes-included cost would bring a closer view on the real prices paid by the consumers, these taxes widely vary across Europe. The fuel costs and maintenance costs depend on the annual mileage and are therefore different between the scenarios. The other costs are the same for all three scenarios. Table 18 shows the costs with taxes, whereas Table 19 shows the costs without taxes.

Table 18: Contributions to the Total Cost of Ownership with taxes for the three scenarios

Parameter	Small petrol	Large petrol	Small diesel	Large diesel	Scenario
Acquisition costs incl. Taxes (€)[65]	20 000	39 000	31 000	50 000	All
Fuel costs incl. taxes (€)	14 000	16 000	9 000	10 000	10 000 km
Fuel costs incl. taxes (€)	27 000	32 000	18 000	21 000	20 000 km
Fuel costs incl. taxes (€)	41 000	49 000	27 000	31 000	30 000 km
Maintenance costs incl. taxes (€)	4 700	5 400	4 800	5 600	10 000 km
Maintenance costs incl. taxes (€)	9 300	10 700	9 600	11 100	20 000 km
Maintenance costs incl. taxes (€)	14 000	16 000	14 400	17 700	30 000 km
Insurance incl. taxes (€)	8 000	8 000	8 000	8 000	All
Circulation taxes (€)	2 000	4 000	2 000	4 000	All

Table 19: Contributions to the Total Cost of Ownership without taxes for the three scenarios

Parameter	Small petrol	Large petrol	Small diesel	Large diesel	Scenario
Acquisition costs excl. taxes (€)[66]	16 000	31 000	24 000	39 000	All
Fuel costs excl. taxes (€)	4 000	5 000	3 000	4 000	10 000 km
Fuel costs excl. taxes (€)	9 000	11 000	6 000	8 000	20 000 km
Fuel costs excl. taxes (€)	13 000	16 000	10 000	11 000	30 000 km
Maintenance costs excl. taxes (€)	3 800	4 400	3 900	4 500	10 000 km

[65] Calculation based on (ICCT, 2016b).

[66] Based on (CE Delft, 2016a), an average European registration tax of 4.30% is used.

Maintenance costs excl. taxes (€)	7 600	8 800	7 900	9 100	20 000 km
Maintenance costs excl. taxes (€)	11 400	13 100	11 800	13 700	30 000 km
Insurance excl. taxes (€)	7 000	7 000	7 000	7 000	All

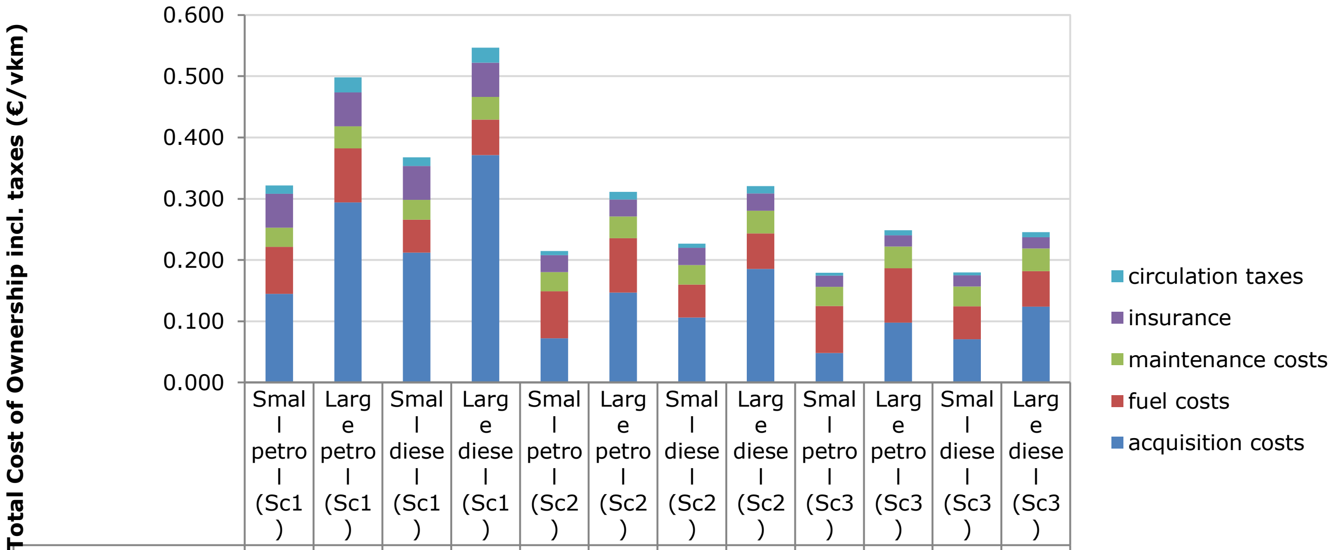
Figure 21 and

Figure **22** show the Total Cost of Ownership for passenger cars per vehicle and km with and without taxes for the four different types and the three scenarios. The first thing that can be deduced from the graphs is that the larger the annual mileage in the scenario, the lower the total cost per km is. This is easily explained by noting that the fixed costs are divided by more kilometres.

Whereas in scenario 1 (10 000 km/year) the acquisition costs are by far the largest portion of the costs, this is no longer the case for scenarios 2 and 3 (20 000 and 30 000 km/year, respectively), where fuel costs can even exceed them. Insurance and circulation taxes are considerable at lower annual mileage, but become less important at higher mileage. Maintenance and fuel costs per km keep constant, since they are proportional to the distance.

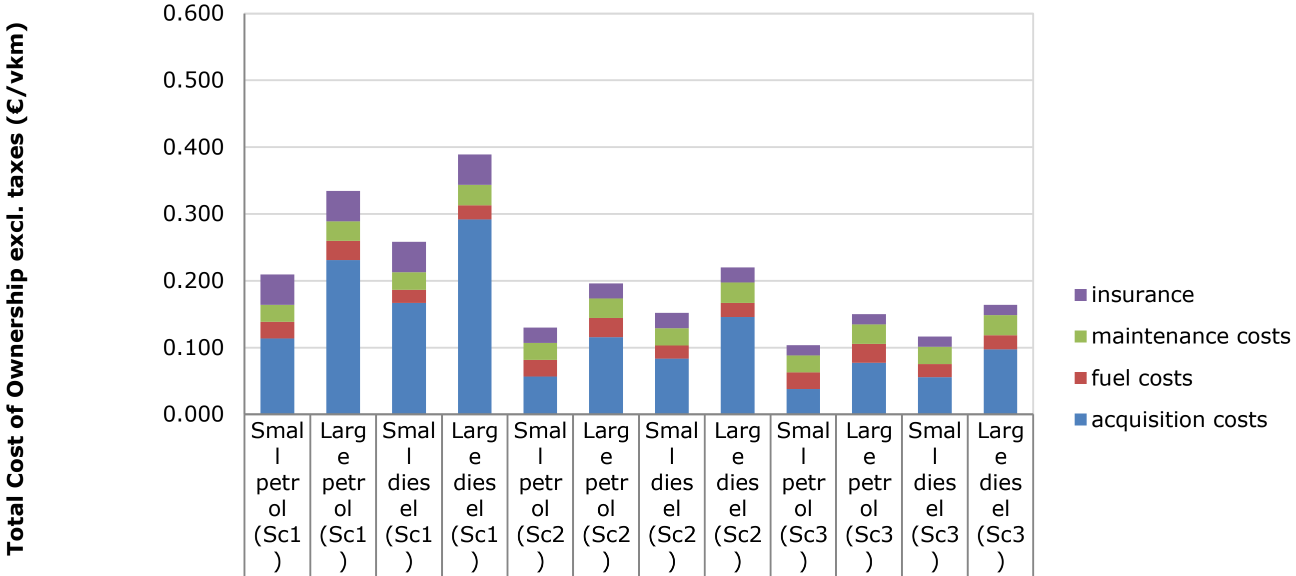
Diesel cars have a higher cost than petrol cars and also larger cars have a higher cost than smaller cars, mainly due to the higher acquisition costs. Only at an annual mileage of 30 000 km in Scenario 3, we see that the costs per km of diesel cars match those of petrol cars. This is however only the case when taxes are taken into account.

Figure 21: Total Cost of Ownership with taxes per vkm for passenger cars



	Small petrol (Sc1)	Large petrol (Sc1)	Small diesel (Sc1)	Large diesel (Sc1)	Small petrol (Sc2)	Large petrol (Sc2)	Small diesel (Sc2)	Large diesel (Sc2)	Small petrol (Sc3)	Large petrol (Sc3)	Small diesel (Sc3)	Large diesel (Sc3)
circulation taxes	0.014	0.024	0.014	0.024	0.007	0.012	0.007	0.012	0.005	0.008	0.005	0.008
insurance	0.056	0.056	0.056	0.056	0.028	0.028	0.028	0.028	0.019	0.019	0.019	0.019
maintenance costs	0.031	0.036	0.032	0.037	0.031	0.036	0.032	0.037	0.031	0.036	0.032	0.037
fuel costs	0.077	0.088	0.054	0.058	0.077	0.088	0.054	0.058	0.077	0.088	0.054	0.058
acquisition costs	0.145	0.294	0.212	0.371	0.072	0.147	0.106	0.186	0.048	0.098	0.071	0.124

Figure 22: Total Cost of Ownership without taxes per vkm for passenger cars



	Small petrol (Sc1)	Large petrol (Sc1)	Small diesel (Sc1)	Large diesel (Sc1)	Small petrol (Sc2)	Large petrol (Sc2)	Small diesel (Sc2)	Large diesel (Sc2)	Small petrol (Sc3)	Large petrol (Sc3)	Small diesel (Sc3)	Large diesel (Sc3)
insurance	0.046	0.046	0.046	0.046	0.023	0.023	0.023	0.023	0.015	0.015	0.015	0.015
maintenance costs	0.025	0.029	0.026	0.030	0.025	0.029	0.026	0.030	0.025	0.029	0.026	0.030
fuel costs	0.025	0.029	0.020	0.021	0.025	0.029	0.020	0.021	0.025	0.029	0.020	0.021
acquisition costs	0.114	0.231	0.167	0.292	0.057	0.116	0.083	0.146	0.038	0.077	0.056	0.097

Table 20 (with taxes) and Table 21 (without taxes) give an overview of the Cost of Ownership of a passenger car, over the lifetime, per year, and per km.

Table 20: Total Cost of Ownership with taxes for passenger cars for the three scenarios

Parameter	**Small petrol**	**Large petrol**	**Small diesel**	**Large diesel**	**Scenario**
Total Costs of Ownership incl. taxes (€/vehicle)	49 000	70 000	55 000	75 000	10 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	3 252	4 684	3 656	5 018	
Per km Cost of Ownership incl. taxes (€/vkm)	0.33	0.47	0.37	0.50	
Total Costs of Ownership incl. taxes (€/vehicle)	67 000	91 000	68 000	90 000	20 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	4 462	6 066	4 551	6 015	
Per km Cost of Ownership incl. taxes (€/vkm)	0.22	0.30	0.23	0.30	
Total Costs of Ownership incl. taxes (€/vehicle)	85 000	112 000	82 000	105 000	30 000 km

Yearly Cost of Ownership incl. taxes (€/year/vehicle)	5 672	7 449	5 446	7 012	
Per km Cost of Ownership incl. taxes (€/vkm)	0.19	0.25	0.18	0.23	

Table 21: Total Cost of Ownership without taxes for passenger cars for the three scenarios

Parameter	**Small petrol**	**Large petrol**	**Small diesel**	**Large diesel**	**Scenario**
Total Costs of Ownership excl. taxes (€/vehicle)	31 000	47 000	38 000	54 000	10 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	2 057	3 103	2 545	3 571	
Per km Cost of Ownership excl. taxes (€/vkm)	0.21	0.31	0.25	0.36	
Total Costs of Ownership incl. taxes (€/vehicle)	39 000	55 000	45 000	61 000	20 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	2 597	3 699	3 007	4 071	
Per km Cost of Ownership incl. taxes (€/vkm)	0.13	0.18	0.15	0.20	
Total Costs of Ownership incl. taxes (€/vehicle)	47 000	64 000	52 000	69 000	30 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	3,138	4,295	3,469	4,570	
Per km Cost of Ownership incl. taxes (€/vkm)	0.10	0.14	0.12	0.15	

Light Commercial Vehicles

In this section, the Total Cost of Ownership is calculated for Light Commercial Vehicles (LCVs) in two variations: small and large.

Table 22 shows the parameters that are used for this calculation. The average CO_2 emission as determined at the type approval is corrected (TNO, 2014b) and then used to calculate the average fuel consumption of a newly purchased reference LCV.

Table 22: Parameters used for the cost analysis of LCVs

Parameter	**Small**	**Large**	**Source**
Acquisition costs incl. taxes (€)	24 000	42 000	(67)
Lifetime (years)	15	15	(Ricardo-AEA, 2012b)
CO_2 emission without correction (g CO_2/km)	123	190	
Correction CO_2 emission (g CO_2/km)	49	46	(TNO, 2014b)
CO_2 emission with correction (g CO_2/km)	172	236	
CO_2 emission per L (g CO_2/L)	2 602	2 602	(CE Delft, 2014)
Fuel consumption (L/km)	0.062	0.085	
Fuel price incl. taxes (€/L)	1.040	1.040	(EC, 2016a)
Fuel price excl. taxes (€/L)	0.378	0.378	
Maintenance costs incl. taxes (€/km)	0.03	0.03	
Insurance (€/year)	557	557	(Insurance Europe, 2015)
Circulation taxes (€/year)	89	89	(68)

For LCVs, three scenarios are used based on different annual mileages of 10 000, 20 000, and 30000 km/year. Based on these numbers and the previously determined fuel consumption, the lifetime fuel consumption is calculated for the three scenarios, as shown in Table 23.

Table 23: Annual mileage assumed for different scenarios and consequent lifetime mileage and fuel consumption

Parameter	**Small**	**Large**	**Scenario**
Annual mileage (km/year)	10 000	10 000	1
Lifetime mileage (km)	150 000	150 000	
Lifetime fuel consumption (l)	9 304	12 755	
Annual mileage (km/year)	20 000	20 000	2
Lifetime mileage (km)	300 000	300 000	

[67] Calculation based on (ANWB, 2015).

[68] Calculation based on (CE Delft, 2016a).

Lifetime fuel consumption (l)	18 609	25 509	
Annual mileage (km/year)	30 000	30 000	3
Lifetime mileage (km)	450 000	450 000	
Lifetime fuel consumption (l)	27 913	38 264	

Using the values from Table 22 and Table 23, the different contributions to the Total Cost of Ownership are calculated, both with taxes and without, for all three scenarios. The fuel costs and maintenance costs depend on the annual mileage and are therefore different between the scenarios. The other costs are the same for all three scenarios. Table 24 shows the costs with taxes, whereas Table 25 shows the costs without taxes.

Table 24: Contributions to the Total Cost of Ownership with taxes for the three scenarios

Parameter	**Small**	**Large**	**Scenario**
Acquisition costs incl. taxes (€)	24 000	42 000	All
Fuel costs incl. taxes (€)	10 000	14 000	10 000 km
Fuel costs incl. taxes (€)	21 000	28 000	20 000 km
Fuel costs incl. taxes (€)	31 000	42 000	30 000 km
Maintenance costs incl. taxes (€)	4 500	4 500	10 000 km
Maintenance costs incl. taxes (€)	9 000	9 000	20 000 km
Maintenance costs incl. taxes (€)	13 500	13 500	30 000 km
Insurance incl. taxes (€)	8 000	8 000	All
Circulation taxes (€)	1 300	1 300	All

Table 25: Contributions to the Total Cost of Ownership without taxes for the three scenarios

Parameter	**Small**	**Large**	**Scenario**
Acquisition costs excl. taxes (€)	19 000	33 000	All
Fuel costs excl. taxes (€)	4 000	5 000	10 000 km
Fuel costs excl. taxes (€)	7 000	10 000	20 000 km
Fuel costs excl. taxes (€)	11 000	15 000	30 000 km
Maintenance costs excl. taxes (€)	4 000	4 000	10 000 km
Maintenance costs excl. taxes (€)	7 000	7 000	20 000 km
Maintenance costs excl. taxes (€)	11 000	11 000	30 000 km
Insurance excl. taxes (€)	7 000	7 000	All

Figure 23 and Figure 24 show the Total Cost of Ownership for LCVs with and without taxes for the four different types and the three scenarios. The first thing that can be deduced from the graphs is that the shorter the annual mileage in the scenario, the larger the total cost per km is. This is easily explained by noting that the fixed costs are divided by more kilometres.

Whereas in scenario 1 the acquisition costs are by far the largest portion of the costs, this is no longer the case for scenarios 2 and 3. Insurance and circulation taxes are considerable at lower annual mileage, but become less important at higher mileage. Maintenance and fuel costs per km keep constant, since they are proportional to the distance.

Larger LCVS have a higher cost than smaller LCVs, mainly due to the higher acquisition costs.

Figure 23: Total Cost of Ownership with taxes per vkm for LCVs

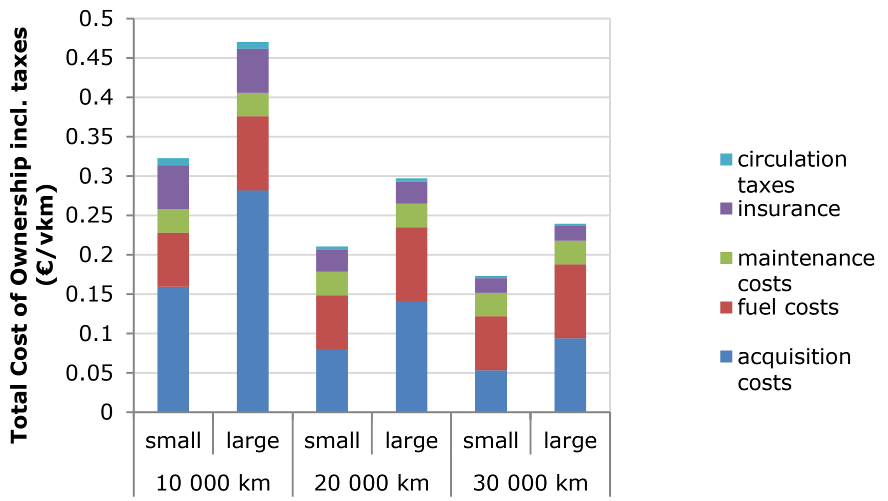


Figure 24: Total Cost of Ownership without taxes per vkm for LCVs

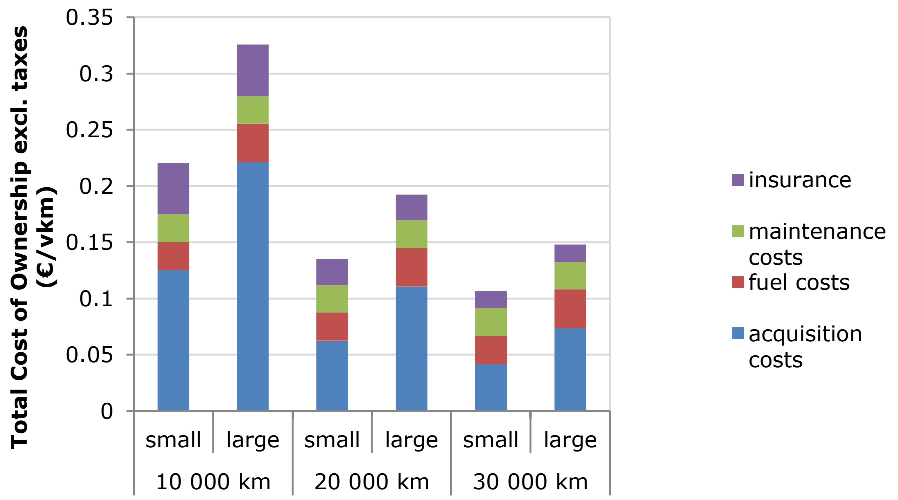


Table 26 (with taxes) and Table 27 (without taxes) give an overview of the Cost of Ownership of an LCV, over the lifetime, per year, and per km.

Table 26: Total Cost of Ownership with taxes for LCVs for the three scenarios

Parameter	**Small**	**Large**	**Scenario**
Total Costs of Ownership incl. taxes (€/vehicle)	48 000	71 000	10 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	3 226	4 702	
Per km Cost of Ownership incl. taxes (€/vkm)	0.32	0.47	
Total Costs of Ownership incl. taxes (€/vehicle)	63 000	89 000	20 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	4 213	5 943	
Per km Cost of Ownership incl. taxes (€/vkm)	0.21	0.30	
Total Costs of Ownership incl. taxes (€/vehicle)	78 000	108 000	30 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	5 200	7 184	
Per km Cost of Ownership incl. taxes (€/vkm)	0.17	0.24	

Table 27: Total Cost of Ownership without taxes for LCVs for the three scenarios

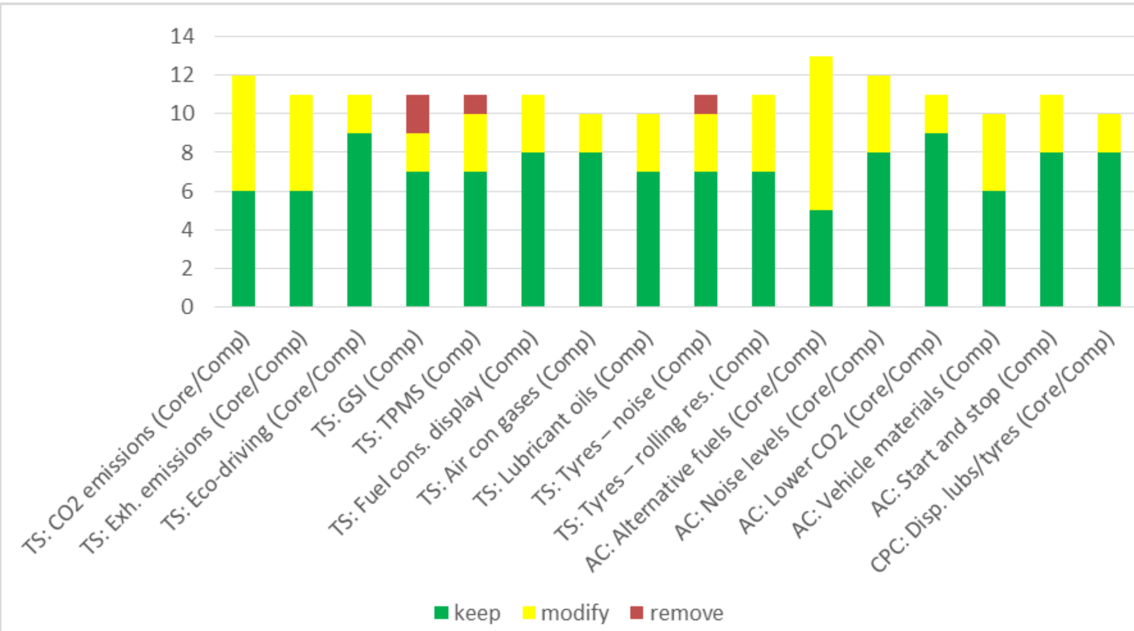
Parameter	Small	Large	Scenario
Total Costs of Ownership excl. taxes (€/vehicle)	33 000	49 000	10 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	2 206	3 259	
Per km Cost of Ownership excl. taxes (€/vkm)	0.22	0.33	
Total Costs of Ownership excl. taxes (€/vehicle)	41 000	58 000	20 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	2 702	3 847	
Per km Cost of Ownership excl. taxes (€/vkm)	0.14	0.19	
Total Costs of Ownership excl. taxes (€/vehicle)	48 000	67 000	30 000 km
Yearly Cost of Ownership excl. taxes	3 198	4 435	

(€/year/vehicle)			
Per km Cost of Ownership excl. taxes (€/vkm)	0.11	0.15	

3.4 Stakeholder views on current criteria (both passenger cars and LCVs)

Only around half of the 26 stakeholders that responded to the survey had views on the existing GPP criteria for the purchase and lease of cars and LCVs (see Figure 25). In most cases, the majority of stakeholders supported keeping the existing criteria, although for all criteria at least two stakeholders were in favour of some form of modification. The criteria on 'CO_2 emissions', 'Exhaust gas emissions' and the 'Use of alternative fuels' were those for which more stakeholders supported their modification. There were only four suggestions to remove a criterion.

Figure 25: Views of the stakeholders on the existing EU GPP criteria for the purchase or lease of cars and LCVs



Key: 'Core/Comp' in brackets means that the criterion was both a core and a comprehensive criterion, while those criteria that only have 'Comp' in brackets were only included as a comprehensive criterion. 'TS' indicates that the criterion was proposed as a 'Technical Specification', while 'AC' means that it was proposed as one of the 'Award criteria' and 'CPC' indicates that it was proposed as a 'contract performance clause'.

The main reason put forward for modifying the 'CO_2 emissions' criterion was that the figures presented in the current EU GPP criteria were out of date as a result of the improvements in CO_2 emissions from new cars and LCVs in the EU. The simplest proposed modification was to make the current set of comprehensive criteria the new core criteria, while others argued for the need for a more regular updating of the standards in order to reflect changes in the values in the respective EU legislation[69,70]. Other stakeholders suggested that a trajectory for future 'procurement years' might be developed to ensure that the criterion remains relevant, or that the values for each segment should represent the respective 'best in class' and be updated as this changes. It was also suggested that the segments included in the table might be more clearly defined, e.g. with reference to EU categories, rather than market segments.

As with the 'CO_2 emissions' criterion, the main reason for modifying the 'Exhaust gas emissions' criterion was that it was out of date, as the Euro 6 emission limit values of the comprehensive criterion are now mandatory for new cars and LCVs[71]. A couple of stakeholders suggested that the criterion be modified to reflect the new real driving emissions (RDE) tests, while another suggested a reference to a future 'Euro 7', so that this was taken into account if it is eventually defined. Others highlighted the need to update the criterion on a regular basis to keep it aligned with EU legislation. One stakeholder proposed that the criterion take the same form as that on CO_2 emissions and have a different emissions value for each pollutant, e.g. NO_x, particulate matter, etc., for each vehicle segment. It was also suggested that, as the category applies to the lease of cars and LCVs, that Euro 5 would be appropriate when leasing.

The two stakeholders that suggested that the 'Eco driving' criterion should be modified both believed that the existing criterion was too vague. It was suggested that a reference could be made to the 'eco-mode' feature that is available on many new cars or more thought be given to what the aim of the criterion should be. The rationale for the removal (or modification) of the criteria relating to 'GSI' and 'TPMS' was that these are now mandatory for new cars[72]. On the other hand, as fuel consumption meters will be mandatory from 2018, the comments on the 'fuel consumption display' criterion suggested that the existence of a fuel consumption meter on a new car should be a core criterion until these are mandated[73].

Those stakeholders that believed the criterion relating to 'air conditioning gases' should be modified all thought that the criterion should be made more ambitious. This could be achieved by making it a core criterion (rather than a comprehensive one) and/or by making a new award criterion for vehicles that use gases that are better than the limits set by the legislation. Another stakeholder noted that the part of the criterion relating to the GWP of the refrigerant gases used will be mandatory from January 2017[74], so proposed a reference to the use of a more environmentally-friendly refrigerant in the criterion, such as a CO_2 air conditioning system (referred to as R744).

Two stakeholders proposed that the 'lubricant oils' criterion should be modified by changing it from a comprehensive into a core criterion. It was also proposed that the minimum carbon content of the lubricant oil used that is derived from renewable raw materials should be increased to more than 50% (from more than 45%, as it is

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[69] Regulation (EC) No 443/2009 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.

[70] Regulation (EU) No 510/2011 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.

[71] Regulation 715/2007 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.

[72] Regulation (EC) No 661/2009 concerning type approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor.

[73] It does not appear that this Regulation has been finalised yet. The European Parliament proposed that Fuel Consumption Meters be mandatory for cars and LCVs in their amendments to COM(2014) 28, which had not originally mentioned such meters.

[74] Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles.

currently). On the other hand, a representative of a national ministry suggested that the criterion had too many details for procurers to consider.

The reasons put forward for modifying the two criteria relating to tyres were that these should make more use of the tyre label[75] and also be more ambitious, which could also include a reference to the tyre's wet grip. It was also suggested that the EU GPP criteria could contain a core and a comprehensive criterion on tyres. One stakeholder argued that compliance with the UN Regulation No 117, revision 3 (which were first issued in 2012) and the latest UNECE requirements on tyre noise and rolling resistance might be used in the definition of the tyre criteria. Another proposal was that other information on tyres be considered for inclusion in the criterion, such as the materials used to make the tyre and the emissions associated with its production.

The 'Use of alternative fuels' was the most criticised of the current EU GPP criteria. Many stakeholders were critical of the lack of differentiation in the treatment of different "fuels", which can have significantly different environmental impacts, and the lack of clarity as to what was supposed to be achieved by the criterion. Some argued that it was important to think through what the aim of this criterion was and then to ensure that it was aligned properly with other criteria, such as those focusing on a vehicle's CO_2 emissions or a vehicle's exhaust gas emissions. A stakeholder quoted the previous Technical Report arguing that the ultimate aim should be that the criterion does not favour one particular type of fuel but should be a crosscutting, performance-based specification that can be used for all different types of vehicles (BRE, 2011).The references to specific fuels and technologies were criticised by some stakeholders, such as the reference to biofuels as not all biofuels are sustainable and to hybrids as their use of electricity, and so overall environmental performance, depends on how the vehicle is used. It was suggested that there should be a core and comprehensive criterion, which should be differentiated. A stakeholder suggested that CNG might also be considered in the revised criterion.

Those in favour of modifying the 'Noise emission levels' criterion argued for a strengthening of the current approach. It was suggested that vehicle noise was too important an issue to only be considered as a comprehensive criterion, and so should be a core criterion as is the case with tyre noise. There were different proposals for how the noise criteria should be set, including that they should be set at 1 or 2 dB below the legal requirement for all vehicle types, that they should be set equivalent to the use of hybrid, electric or hydrogen engines using the common methodology set out under the Environmental Noise Directive[76] or that they be aligned with the vehicle noise Regulation[77].

Both of those stakeholders that called for the modification of the 'Lower CO_2 emissions' criterion called for a more ambitious criterion that ensured that green vehicles were procured. One suggested that the criterion should state that vehicles should have CO_2 emissions of no more than 35 g/km. For the 'Vehicle materials' criterion, there were differing views supporting calls for a modification of the criterion. Two stakeholders argued for an explicit reference to be made to the use of materials that reduce a vehicle's weight in addition to renewable and recycled materials, while another called for both core and comprehensive criteria to set a requirement on the content of recycled

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[75] Regulation (EC) No 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters.

[76] Commission Directive (EU) 2015/996 establishing common nose assessment methods according to Directive 2002/49.

[77] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

material in vehicles. On the other hand, a representative of a national ministry suggested that this criterion was too detailed for a procurer to consider.

In relation to the criterion that the vehicle should be fitted with a 'Start and Stop' system, those calling for a modification noted that such systems were increasingly common, so the criterion should also be core and perhaps even not an award criterion, but a technical specification. The two comments on the 'Disposal of lubricant oils and tyres' argued from opposing perspectives: one stakeholder argued that there should be recycling requirements on the purchase of these products, not just on their disposal; the other, a representative of a national ministry, suggested that the criterion was too detailed.

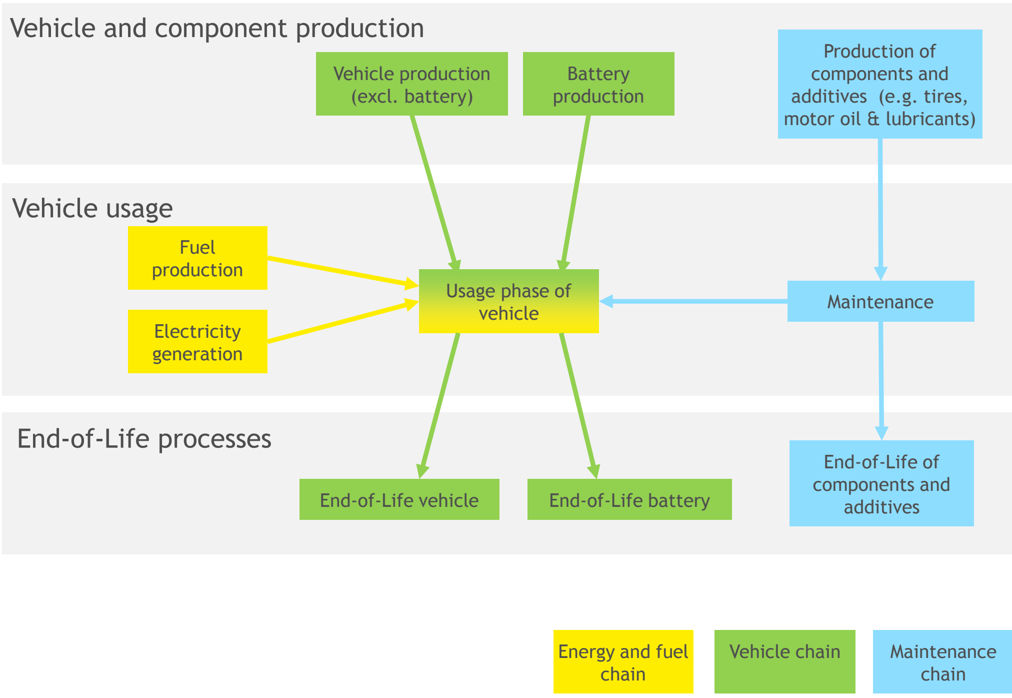
3.5 Technical analysis

3.5.1 Identification of environmental hotspots along the life cycle of cars and LCVs

The methodology for the identification of environmental hotspots has been described in Section 1.3.3. The full LCA review can be found in Annex B and C. This section presents the main findings of the LCA review together with the current environmental performance of road vehicles. An LCA-approach is important, because the various environmental impacts and energy consumption occur differently in different phases of the vehicle life cycle, and the main hotspot should be identified. We distinguish between the vehicle chain, and energy and fuel chain, where both chains overlap in the use phase, as depicted in Figure 2. The maintenance chain is comparable to the vehicle chain, although it is linked to components and additives rather than the vehicle.

Moreover, the LCA is currently used in a lot of manufacturing companies (Mercedes-Benz, 2014; BMW Group, 2015) as assessing and supporting decision-making tool. It is often used at the beginning of development of a new model to assess its own environmental impacts and improving them compared to the old model of the same product line. Sometimes it is also used to assess the electric version of a model and to confirm that a lower environmental impact along the entire life, compared to the correspondent conventional model ((BMW Group, 2014; Nissan Motor , 2016).

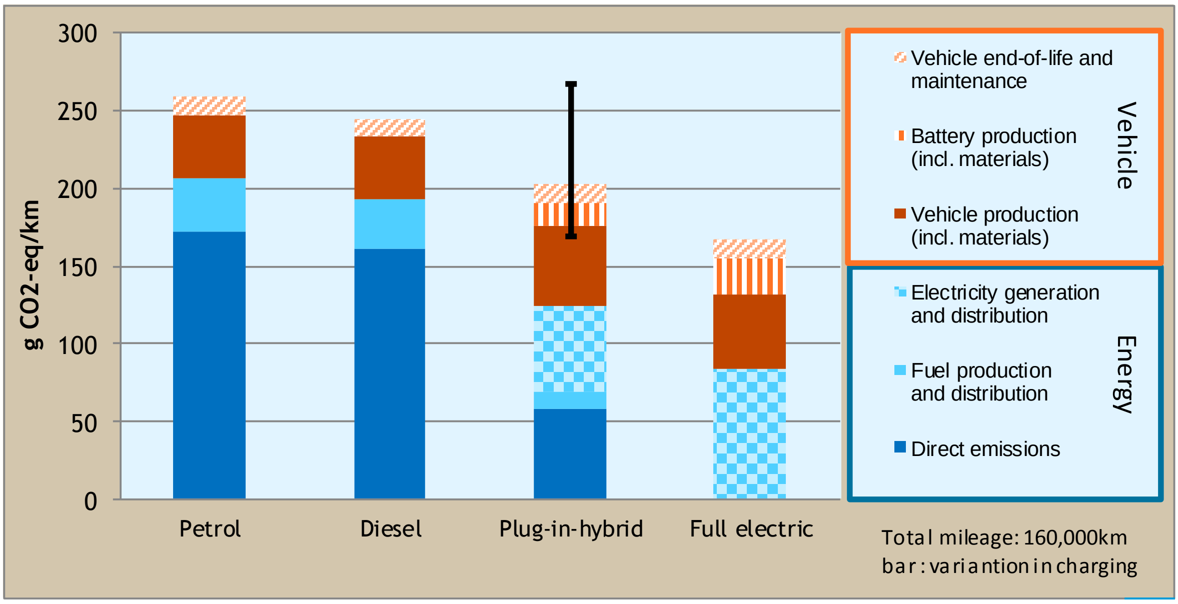
Figure 26: Overview of relevant life cycles



GHG emissions (GWP)

According to the LCA literature review (Annex B: LCA literature review for cars and LDVs), overall total life cycle GHG emissions are dominated by GHG emissions from the use phase as result of the high GHG exhaust emissions. Figure 27 is in line with the overall conclusions of the LCA review in Annex B and C and shows the total GHG emissions of petrol, diesel and (plug-in and full) electric passenger cars (TNO; CE Delft, 2014). The share of the so called upstream emissions from fuel production (including extraction, transport and refining of oil) is for conventional diesel or petrol powered road vehicles about 20% of the tailpipe GHG emissions. Also the share of vehicle production and maintenance is smaller than that of vehicle usage. Altogether about two third of the GHG emissions occur during the use phase. For vehicle with a higher lifetime mileage than assumed in this comparison (which is 160 000 km), the share of the use phase in total GHG emissions is even higher.

Figure 27: GHG emissions of various life cycle phases for passenger cars



In the remainder of this section the main conclusions for the various life cycles are shortly described and the use phase will be zoomed in on more closely.

Upstream/vehicle manufacturing

Based on the LCA review it can be said that the GHG emissions associated with the production of vehicles and upstream processes are limited. Overall, various drivetrains have similar GHG impacts in the production phase except for the production of the fuel cell and battery. The production of FCEV and FEV results in higher GHG emissions than conventional vehicles. Although the use phase currently dominates the life cycle, the vehicle manufacturing phase might become more relevant in case GHG emissions are strongly reduced in the use phase. This could be the case for electric vehicles running solely on power from renewable sources. Further decarbonisation will then rely on measures in the production phase. The relevance of this life cycle phase is also determined by the assumptions made for lifetime mileage and battery lifetime: most studies assume 150 000 km both for the lifetime mileage and battery lifetime. In practice, the actual lifetime of batteries is uncertain and may well considerably exceed this mileage. The longer is the lifetime, the less relevant is the production phase.

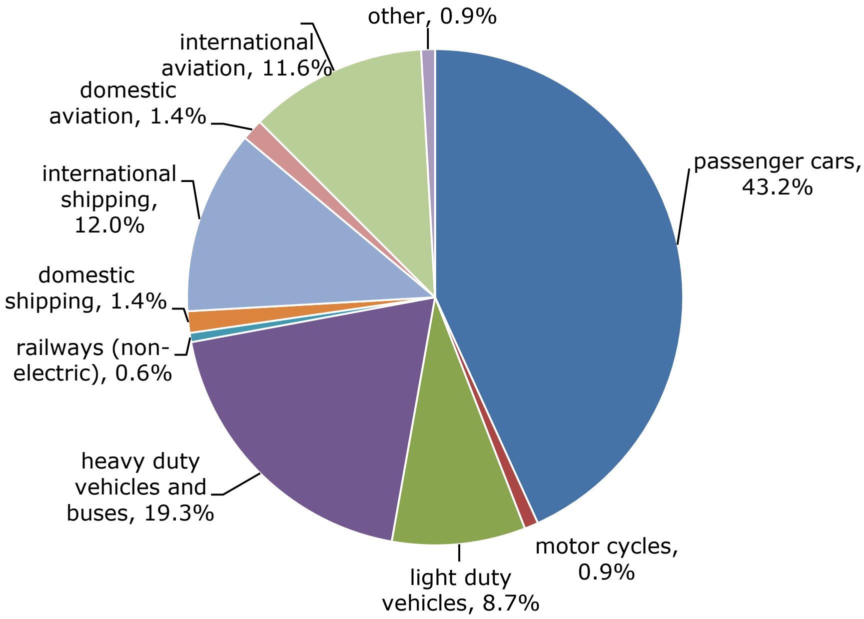
Use phase

The use phase is dominated by GHG emissions from exhaust emissions and fuel supply. In case of EVs the GHG reduction in the use phase depends on the CO_2-intensity of the electricity mix. The emissions in the use phase do also strongly depend on driving style and in the case of EVs on charging behaviour and, for plug-in vehicles also on the share of kilometres driven electrically. This indicates the relevance of technical or operational options aimed at decreasing fuel consumption (like fuel consumption metres or driving training).

The transport sector emits 22.3% of the total GHG emissions in the European Union (data for 2013) (Eurostat, 2016b). Most of the greenhouse gases emitted by transport is carbon dioxide. The contribution of other greenhouse gases, such as methane, nitrous oxide, and fluorinated gases, is relatively small.

Figure 28 illustrates that, of the greenhouse gases emitted by transport in the European Union, the largest share is through road transport (72%), consisting of passenger cars (43%), light duty vehicles (mostly light commercial vehicles, also known as vans, 9%), and heavy duty vehicles and buses (19%) (EEA, 2015a). Other major contributions are due to shipping and aviation (13% each). Passenger cars are responsible for around 12% of total GHG emissions in the EU. As can be seen in Figure 28 passenger cars are responsible for 43% of the GHG emissions from the transport sector.

Figure 28: Contribution of transport modes to EU transport GHG emissions in 2013 **(EEA, 2015a)**



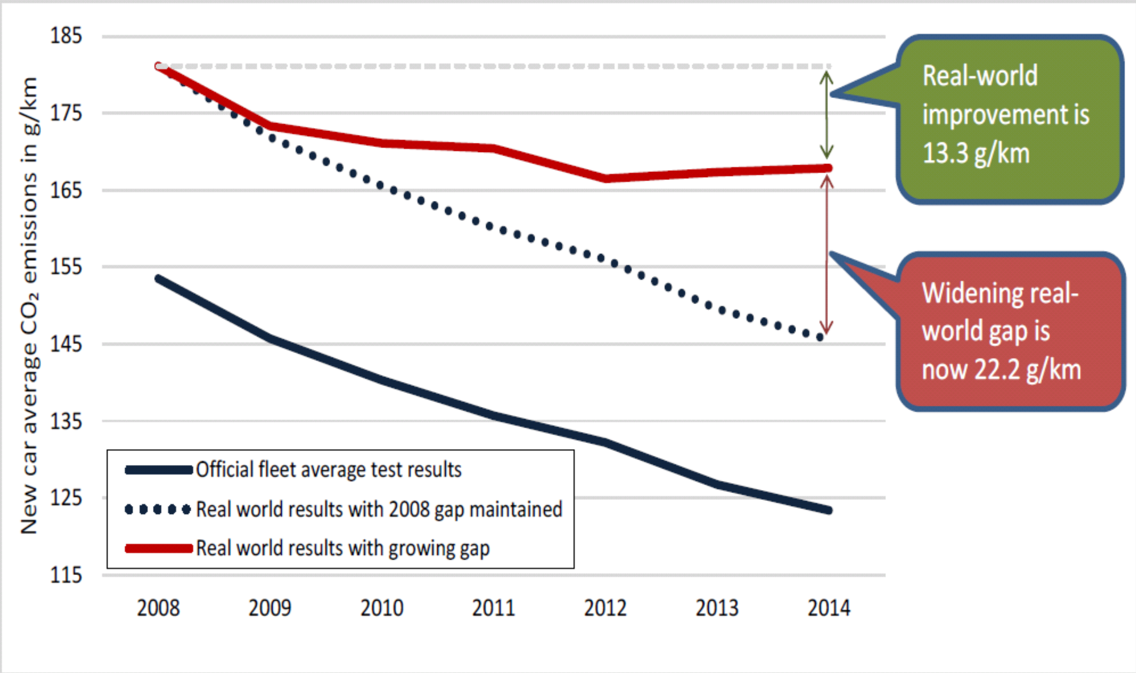
Whereas the other sectors in the European Union have seen a decrease in GHG emissions over the last decade, transport is the only sector in which the GHG emissions have increased. Between 1990 and 2013, transport GHG emissions have increased by 19%, while non-transport GHG emissions decreased.

On the vehicle level, passenger cars emit on average 119.6 g CO_2/km on the NEDC test cycle in 2015, which is 8% below the 130 g/km EU target set for that year. In 2014 the average was 123.3 g/km. Comparison of the 2014 levels to the 2005 ones shows a decrease of 24% GHG emissions per kilometre on the test cycle (and the same improvement rate for the average fuel efficiency. The target value for 2021 has been set at 95 g/km (NEDC test). (EEA, 2015b)

It should be noted that these reductions are in terms of NEDC type approval emissions and deviate from the real world fuel consumptions. Real world improvements are significantly smaller, as manufacturers have used the flexibilities in test procedures to achieve lower CO_2 type approval values at zero or low cost (see Figure 29). Based on 2008 data, real-world improvements of 35.5 g/km would have been expected, while the real world reduction amounts only 13.3 g/km.

For the period up to 2020, a further reduction of 23% is required to meet the EU target of 95 g/km. It is unclear to what extent these reductions will be (partly) absorbed by a further (T&E, 2015a) increase of the gap between real-world and type approval emissions. Note that the WLTP test (Worldwide harmonized Light vehicles Test Procedures) will be introduced in the coming year to better deal with the real-world emissions than the NEDC-cycle.

Figure 29: Official CO_2 test results versus the real-world outcomes in 2014 for private motorists (derived from ICCT, 2015 and EEA official CO_2 data) **(T&E, 2015a)**



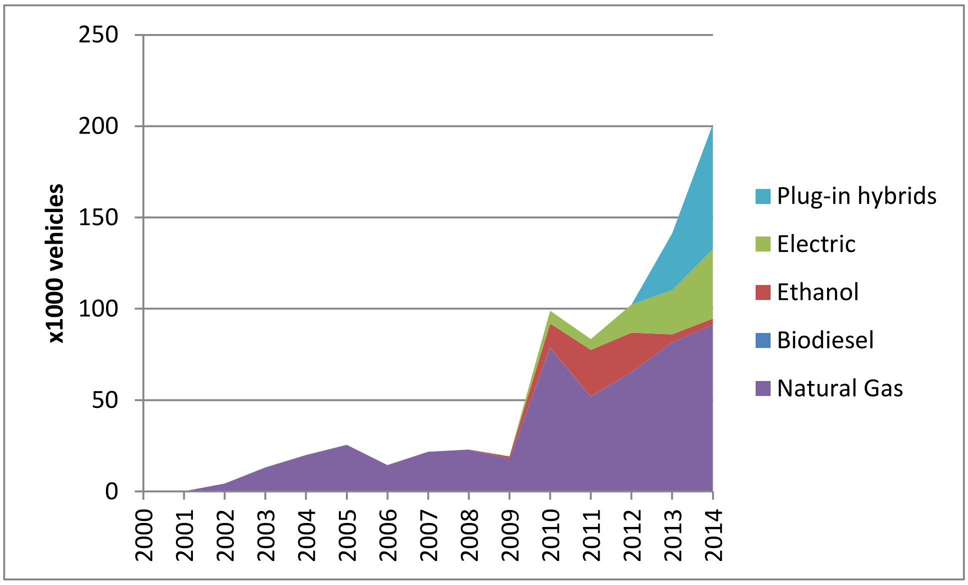
The development of the average CO_2 emissions from diesel and petrol cars is depicted in Table 28 (NEDC test cycle values). Note that the emission factors only represent the TTW emissions (only the tailpipe emissions and not the indirect emissions from electricity production in the electric vehicles).

Table 28: Average CO_2 emissions (gCO_2/km) from new passenger cars by fuel (EU-27 **(EEA, 2015b)**

gCO_2/ km	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010[a]**	**2011[a]**	**2012[a]**	**2013[a]**
All fuels[c]	172.2	169.7	167.2	165.5	163.4	162.4	161.3	158.7	153.6	145.7	140.3	135.7	132.2	126.7
Petrol	177.4	175.3	173.5	171.7	170	168.1	164.9	161.6	156.6	147.6	142.5	137.6	133.7	128.5
Diesel	160.3	159.7	158.1	157.7	156.2	156.5	157.9	156.3	151.2	145.3	139.3	134.5	131.5	126.9
AFV[b]	208	207.4	179.2	164.7	147.9	149.4	151.1	140	137	125.8	126.0	124.7	118.5	98.3

The decrease in the average CO_2 emissions from passenger cars is partly the result of the increase in alternative fuel vehicles (AFVs) over the years, as depicted in Figure 30.

Figure 30: Evolution of total registrations of AFVs over the years (EEA[78])



Similar to passenger cars, new registered light commercial vehicles (vans) also have to comply with CO_2 targets: new LCVs should on average not emit more than 175 gCO_2/km on the NEDC test cycle by 2017, 3% less compared to the average in 2012 of 180.2 g CO_2/km. The target of 175 gCO_2/km corresponds to 6.6 l/100 km of diesel and already has been met in 2013 (four years ahead of schedule). The average van in 2014 emitted 169.2 gCO_2/km (EC, Climate Action, 2016). The target value for 2020 has been set at 147 gCO_2/km (NEDC test).

Like for passenger cars, also for vans part of this reduction on the NEDC test cycle is absorbed by an increasing gap between real world and type approval emission levels.

The LCA literature reviewed reveals different approaches to model the fuel consumption and air emissions of the vehicle during the use stage. Some models use the type approval result based on NEDC test procedures while other ones chose to apply data closer to real driving. The results show that the driver behaviour and the road related conditions are key elements of the fuel consumption of the vehicle.

In this regard, Garbarino et al (Garbarino, et al., 2016) reviewed the different elements of the road that might affect the fuel consumption of a vehicle during the use stage. Congestion was identified as a relevant external condition that increases the vehicle fuel consumption (Taylor P. et al., 2012). The LCA literature review on road construction and maintenance works concluded that congestion is potentially one of main parameters affecting the fuel consumption for high-traffic flows, but its impact diminishes significantly for low traffic flows (i.e. secondary and other roads) (Garbarino, et al., 2016)

Grote et al. (Grote, et al., 2016) gathered a review of literature concerning road traffic data and its use by local government authorities in emissions models. It was widely accepted by the authors reviewed that congestion entails an increase in the number of acceleration and deceleration events resulting in increased fuel consumption. According to several authors, congestion is a relevant parameter when estimating road traffic emissions, together with vehicle-kilometers, vehicle speed and vehicle category. One

[78] http://www.eea.europa.eu/data-and-maps/indicators/proportion-of-vehicle-fleet-meeting-4/assessment

reference quoted by Grote compared CO_2 emissions from cars during steady-state activity (i.e. constant speed) to emissions during real-world activity (i.e. including dynamics due to congestion) having the same average speed. According to results, the increase in emissions at 45 km/h (a typical average speed on urban roads) due to congestion was approximately 40%.

Maintenance and end-of-life

Maintenance and vehicle disposal represent less than 10% of the overall life cycle GHG emissions and therefore do not receive much attention in the LCA-studies investigated.

Other environmental impacts

Although GHG emissions are the main environmental impact, other environmental impacts occur as well. Human toxicity and eutrophication are mainly relevant for the upstream/manufacturing phase of the vehicle supply chain, while acidification, photochemical oxidant formation (POF) and cumulated energy demand are mainly relevant for the use phase (actual use and energy supply chain). A shift from ICEVs to EVs result in some trade-offs: while EVs perform better on GHG emissions in the use phase, EVs have higher impacts for some other environmental aspects. Note that with respect to air pollution, this goes together with a shift from emissions in high density populated areas to less populated areas with high stacks emitting the emissions.

Upstream/vehicle manufacturing

Overall EVs perform better than ICEVs, except for human toxicity and eutrophication. The latter due to the battery manufacturing, which is responsible for 45-47% of overall human toxicity and 31-38% of overall eutrophication of the entire life cycle of EVs. Vehicle production is also responsible for a part of these environmental impacts, which make that battery and vehicle production together dominate these environmental impacts for EVs.

Use phase

The following environmental impacts occur either in the use phase as exhaust emissions or occur during the fuel/energy supply chain.

- **Photochemical Oxidant Formation (POF)** is one of the environmental impacts where all types of vehicles score similar levels, but CNG vehicles and BEVs (in 2030 scenario, which is modelled assuming an increased share of renewable sources in the EU electricity mix) score best. POF is the only impact category where the exhaust emissions of fossil fuelled vehicles (ICEV and HEV) have major contributions.
- **Air acidification, depletion of abiotic resources and cumulated energy demand non-renewable** are mainly caused in the well to tank phase for both EVs and ICEVs (so the energy supply chain), but with the impacts of ICEVs being higher than EVs. Only for air acidification the actual use phase of ICEVs also contributes a little. Any improvements of these environmental impacts should therefore come from actions taken in the fuel supply chain or electricity generation.
- Some environmental impacts, like **human toxicity, acidification and PM formation** might be actually higher as result of the higher real-world NO_x tail-pipe emissions, which have currently been underestimated and have been heavily debated recently.
- **Acidification (ATP) and PM formation (PMF)** of EV will also be higher compared to ICEV in the 2030 scenario. ATP and PMF will lower for BEV as result of the changing electricity mix, but the ATP and PMF impacts of FCV will remain higher than for ICEV in 2030, because FC manufacturing and hydrogen

production (emissions from mining of platinum). ICEVs score also high as result of the emissions from gas and oil production processes. CNG vehicles score lower on these aspects than ICEV vehicles and HEV also due to fuel demand reduction.

The environmental impacts acidification and PM formation are also the result of air polluting emissions.

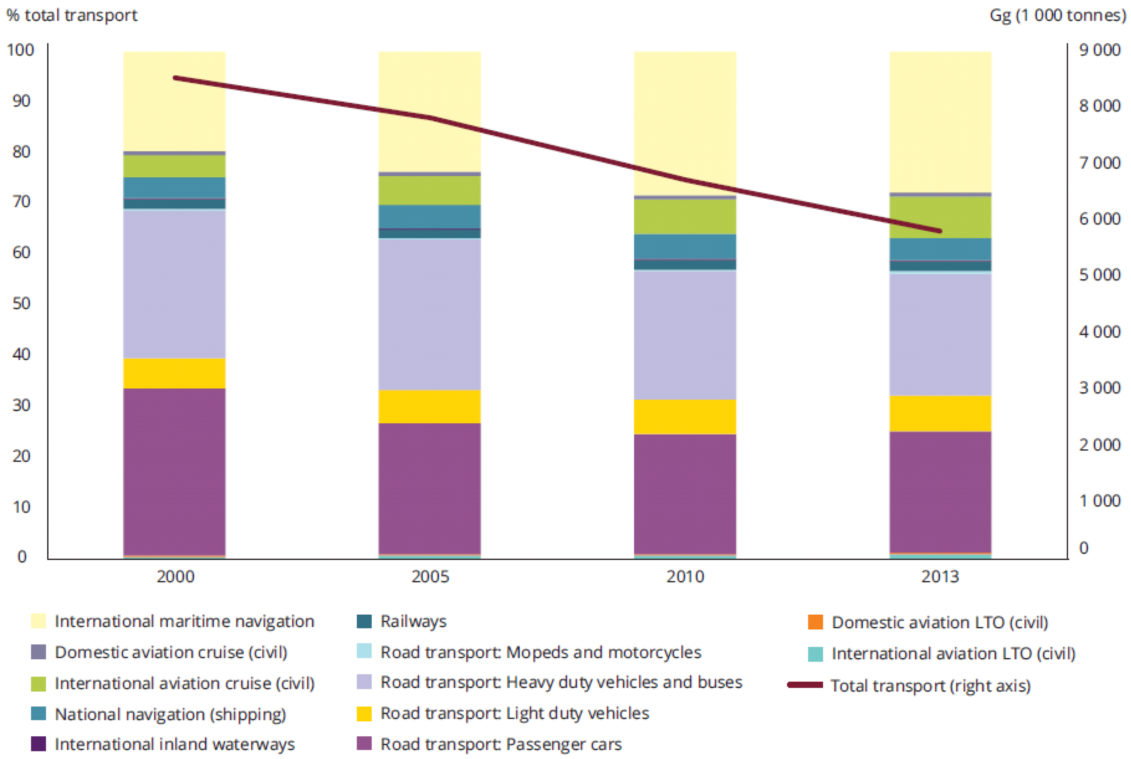
Major air pollutants from transport are nitrogen oxides (NO_x) and particulate matter (PM). Since the regulation of the sulphur content of road fuels, emission of SO_x by road transport has decreased sharply and is therefore not significant anymore and not taken into account.

Nitrogen oxides are produced during combustion in the presence of nitrogen, mainly in high-temperature compression-ignition (diesel) engines. They can, through various reaction products, lead to respiratory and heart diseases, as well as to acid rain. The EU annual air quality limit for NO_2 was widely exceeded in Europe in 2013. Of these exceedances, 93% was near roads.

Particulate matter, usually denoted by PM_{10} and $PM_{2.5}$ according to their maximum diameter in µm, is produced during the combustion of fossil and bio fuels. Due to their small diameter, particulates can penetrate deeply into the lungs and lead to respiratory disease, lung cancer, and heart disease.

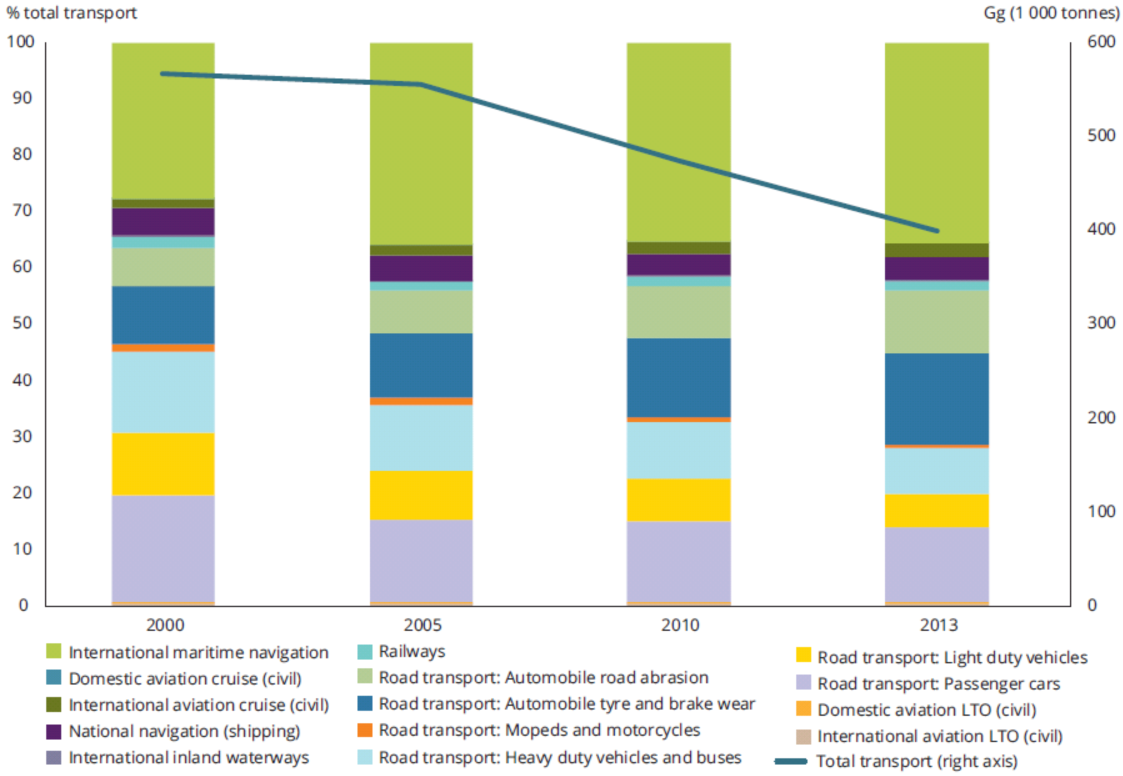
The largest shares in air pollution by the release of NO_x are from road transport by heavy duty vehicles and by passenger cars, and by international shipping. The emission of particulate matter (PM_{10}) is for more than 30% due to international shipping, followed by tyre and break wear in road transport, passenger cars, road abrasion, and heavy and light duty vehicles.

Figure 31: NO_x emissions from the transport sector in the EU28



Source: EEA, TERM 03, based on the European Union emission inventory report 1990–2013 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP).

Figure 32: PM_{10} emissions from the transport sector in the EU28

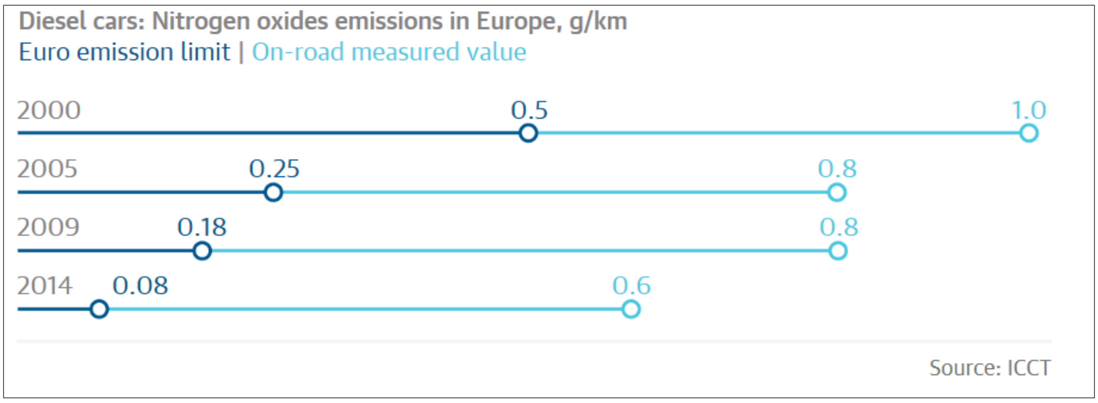


Source: EEA, TERM 03, based on the European Union emission inventory report 1990–2013 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP).

Between 1990 and 2013, the emission of NO_x and PM_{10} by transport has decreased by 35% and 27% respectively. For most types of fuel and emissions, real world emissions are lower than the type approval value. This is in particular the case for PM emissions of both petrol and diesel cars and for NO_x emissions of petrol cars.

An exception is the NO_x emissions of new diesel cars. Real world NO_x emissions are considerably higher than the type approval values and the gap has increased over time, as shown in Figure 33. This increasing gap is partly the result of manufacturers using the flexibilities in vehicle testing. It got particular attention in 2015 with the so-called 'diesel-gate'.

Figure 33: NO_x emission limits and gap between limits and on-road measured values **(The Guardian, 2015)** (2000 = Euro 3, 2005 = Euro 4, 2009 = Euro 5, 2014 = Euro 6)



As a result of this, the European Parliament agreed on requiring real 'Real Driving Emissions' (RDE) tests for all new models by September 2017 (and for new vehicles by September 2019), with a 'conformity factor' of a maximum of 2.1 (110% exceedance of the NEDC limit value). In a next step this discrepancy between the RDE emissions value and the type approval NEDC limit value will be brought down to a factor of 1.5 (50%), taking account of technical margins of error, by January 2020 for all new models (and by January 2021 for all new cars). All this will make that real world emissions of new diesel cars will be further reduced, although it is possible that their real world NO_x emissions will remain exceeding the NEDC type approval value for quite some time.

Noise (CE Delft ; INFRAS ; Fraunhofer-ISI, 2011)**.** Although noise is not part of the LCA methodology, exposure to **noise** has an adverse effect on the quality of life and well-being. The harmful levels of noise are estimated to result in more than 10 000 premature deaths per year in the EU. In the EU, 125 million people are exposed to levels above the Environmental Noise Directive threshold of 55 dB L_{den} ($L_{day/evening/night}$) and 83 million people to harmful levels of nightly noise above 50 dB L_{night}. The vast majority of these people are affected by noise due to road traffic; less than 10% due to railways, airports, and industry.

Noise impacts caused by transport can be expressed in annoyance costs and health costs per person and per dB (A) and are based on noise exposure data and the amount of persons exposed. In Table 28 the total number of people exposed to noise from road for the EU is given.

Table 29: Number of people (in millions) exposed to noise from roads (CE Delft et al. 2011)

	Noise levels Lden in dB (A)					
	55-59	60-64	65-69	70-74	>75	Total
Total EU	60.29	45.14	22.17	8.79	1.62	138.01

End-of-Life

Girardi et al. 2015 estimate that the end-of-life stage (EoL stage) of batteries is responsible for the 7% CML eutrophication by life cycle stage

With respect to dismantling of vehicles at the EoL-stage, Tian and Chen (2013) discuss the concept of design for dismantling, which allows car producers to save costs and as a means to take care of the environmentally dismantling of their products. Tian and Chen (2013) also stress the importance of the use of a single material as an important element of design for dismantling which can increase the material recycling rate strongly.

According to the European Commission, end-of-life vehicles (ELV) generate between 7 and 8 million tonnes of waste in the EU. These waste flows should be managed correctly to minimize environmental impacts. The End-of-Life Directive (Directive 2000/53/EC) for vehicles has the aim to make dismantling and recycling of ELVs more environmental friendly and has set target for reuse, recycling as well as recovery and at the same time pushes car manufacturers to produce cars without hazardous substances. The targets are listed below and are valid for passenger cars and vans.

No later than 1 January 2006:

- reuse and recovery rate: 85%;
- reuse and recycling rate: 80%.

No later than 1 January 2015:

- reuse and recovery rate: 95%;
- reuse and recycling rate: 85%.

The recovery, reuse and recycling rates over the period 2006-2012 are depicted in Table 30.

Table 30: Total recovery and reuse rate and recycling and reuse rate for EU-27 for the period 2006-2012 (in %) **(Eurostat, 2015i) (Eurostat, 2016c)**

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Recovery and reuse	81.3	84.1	85.4	85.07	87.2	88.4	89.4
Recycling and reuse	78.37	82.09	82.66	82.08	83.33	84.05	84.40

Conclusion

The main environmental impacts of cars and LDVs are related to the use phase of the vehicles. The main environmental issues during the use phase are energy consumption, the GHG emissions, air pollutant emissions and noise.

Closely related to the use phase are the environmental impacts related to the production of energy carriers (liquid or gaseous fuels or electricity). The main environmental issues of this are GHG emissions and air polluting emissions.

Other environmental impacts occur during vehicle manufacturing, which become relevant for electric vehicles and whose battery is the most impacting component. The reduction of the environmental impact of electric vehicles during the use phase, however, outweighs the negative environmental impacts of the additional emissions in the production phase.

Life Cycle Assessment as decision supporting tool in the automotive sector

The use of Life cycle assessment as decision supporting tool is quite common in the automotive sector which has been used since early 90's. The LCA methodology is applied mainly internally for improving the environmental performance of a vehicle already at the design phase and for comparing to its previous model if it exists. Some of these reports are published in the website of the car company (Mercedes, 2016), (BMW Group, 2015)

According to the ISO 14040/44 (2006), when a report on the LCA results has to be disclosed to the public, it shall be developed according to guidelines presented in the standards.

Moreover, data and results are often verified by a third party certification body, such as TÜV Süd and the report is reviewed by a critical reviewer to check if it is consistent with the framework given by the ISO 14040/44 (2006).

As it was mentioned before, the LCA is a decision supporting tool that is used along the entire development process of a new car in the manufacturing company. The first LCA is made in the earliest phase of the development of a new model when an approximate shape and the main material composition of the body are known (Traverso, et al., 2015). According to the new innovation and/or new materials that are to be included in the new mode,l more scenarios can be built. Of those scenarios, the material compositions and the relative environmental performances are compared to each other to choose the best one in environmental, performance and economic terms. At this stage, specific targets of environmental performance (e.g. percentage of CO_2 reduction reached by the new model compared to its previous one) and fuel consumption are established. These targets are monitored along the entire development process of the car, for being sure that the right measures are introduced to reach at Start-Of-Production (SOP) the established targets.

The percentage CO_2 reduced in the entire life cycle of the product comparing the new model with the previous one is an example of target. Producing a car with a smaller Carbon Footprint balance than its previous model is only possible by acting on the use phase as well as in the manufacturing one. Examples of measures used at BMW Group to reach a higher environmental performance are: use of more secondary source of materials such as metals and thermoplastics, promotion of less energy intensive materials, components produced with renewable energy sources, and improvement of the recyclability of the car’s components at the end of life (EoL) (Traverso, et al., 2015). For the measures on the metals for example high attention is paid to use as much as possible secondary aluminium instead of primary one. In fact the primary aluminium has an impact of 10 kgCO2e per kg and the secondary one can have 2-3 kgCO2e per kg of metal. Because the secondary aluminium components have not the same resistance of the primary one, it can be used only in the non-crash relevant components. In the crash relevant components a possible measure is to use primary aluminium produced with renewable energy in the electrolyse phase (BMW, 2013).

The percentage of recycled thermoplastic in the car is used as an indicator to measure the reduction of the resource use, and results and monitoring of this indicator can found in different car manufacturing.

Figure 28: Companies using LCA for developing their product, World Steel study Russ Balzer, WorldAutoSteel, LCA in the Automotive Sector.pdf (Accessed by October 2016)

3.5.2 Technical options to reduce GHG emissions

In the following paragraphs the technical improvement options are described. Insight will be given in:

- the option and possible variations;
- the market availability and market penetration of the option;
- the improvement potential for the relevant environmental impacts;
- cost, TCO and GHG abatement costs.

The information will be provided for options on vehicles to reduce CO_2 emissions (Section 3.5.2), alternative fuel options (Section 3.5.3) and options to limit air pollution and noise (Section 0).

All options related to improving the environmental performance of services are presented in Section 3.5.5.

Type approval value

Both for cars and LCVs, there exists a whole range of vehicles with a CO_2 performance that is better than the average of new vehicle sold on the EU market. A very useful indicator for the CO_2 performance of a new cars or LCVs is the type approval CO_2 value. For all new light duty vehicles this value is measured with the same NEDC test cycle. Therefore these values provide a good basis for comparison.

In the future the type approval conformity test will change to the WLTP test cycle. However, as the 2021 CO_2 emission target for cars of 95 g/km and 2020 target for LCVs of 147 g/km are both defined in terms of NEDC emissions, the EU GPP criteria can also for quite some time still be defined in terms of NEDC type approval emissions. At the moment of writing this report, no formally agreed translation form NEDC to WLTP values is available. It is expected that in context of the CO2 regulation of LDVs and vehicle labelling, the European Commission will in the coming years come up with such a set of translation factors. This set could then also be applied to the EU GPP criteria.

As already discussed in Section 3.5.1, the real world CO_2 emissions are significantly higher than the NEDC type approval values and the gap between the two has increased over the past years. At the same time, from data on real world emissions for large number of vehicles (TNO, 2014b). it is clear that within the same year, vehicles performing better on the test cycle usually also have lower emissions in the real world. This makes that, although the type approval values themselves are not representative for real world emissions, they are still a useful indicator for EU GPP criteria.

Very stringent criteria for the CO_2 type approval value could *de facto* result in a requirement for alternative powertrains like (plug-in) electric or hydrogen vehicles. The application of such alternative powertrains itself could also be used as an indicator (see below).

A challenge for setting the GPP criteria is the fact that the CO_2 standards are becoming more stringent over time and vehicle technology and alternative powertrains are rapidly developing. Furthermore, some Member States have announced that they would like to allow only zero emission vehicles in their new car sales from 2025 onwards. (DutchNews, 2016)

Improvement potential

To be meaningful, EU GPP criteria should clearly go beyond the average fleet development. As the latter is very uncertain, particularly after 2021, it is hard to predict what level is appropriate.

Very low emission levels (below 70 g/km and particularly below 50 g/km) can only be achieved by using alternative powertrains such as PHEVs, FEV or FCEV. The cost and impacts of these are discussed separately below.

Levels around 80 - 90 g/km can be achieved by cars using ultra-efficient internal combustion engines, possibly including hybrid drivetrain, although the number of vehicles meeting the threshold depends on the exact emission level and size class. Hybrid vehicles (HV) can be powered by both a combustion engine and an electric motor but cannot be charged from the grid. The electric drivetrain is just used to make the vehicle more fuel efficient. In the remainder of this study, HVs are not considered electric vehicles.

On average the NEDC CO_2 value of passenger cars needs to decrease 21% between 2015 (119.6 g/km) and 2021 (95 g/km). For the update of the EU GPP criteria, a key question is what difference between the best in class vehicles and average vehicles could be assumed. A good indication for the current market situation (2016) can be based on the top 10 of lowest CO_2 emitting new cars available in the Netherlands[79]. This is an overview of the most fuel efficient car types per fuel type and size segment.

The table below lists the *highest* NEDC CO_2 emission in the top-10 lists of most fuel efficient cars/LCVs in the Netherlands (so the CO_2 emissions of the tenth vehicle type on the list). This can be regarded as an ambitious CO_2 emission value that still can be met by a sufficient number of vehicle types (at least 10).

[79] Source ANWB: www.anwb.nl/auto/besparen/top-10-zuinige-autos

In the coming years, the CO_2 emissions of new cars and LCVs will be reduced further in order to meet the 2020 (LCVs) and 2021 (cars) CO_2 emission targets. If we assume that the reduction rates of the best in class vehicles follow the average reduction rate of all new cars, the NEDC CO_2 emissions of the best in class (defined as the tenth on the list) will develop as indicated in Table 31.

Table 31: Improvement potential for new cars and LCVs

Fuel type	Size category	Average NEDC CO_2 emission (2002)	Average NEDC CO_2 emission (2015)	Highest NEDC CO_2 emission in top-10 most fuel efficient cars 2016[80]	CO_2 in 2017-2021 assuming equal reduction rates for best in class and average sales[81]				
		In g/km[82]	In g/km	In g/km	2017	2018	2019	2020	2021
CARS	Average		119.6						
Petrol	Small (segment A, B)	149	119	93	89	85	81	77	74
Petrol	Mid-size (segment C)	189	136	102	97	93	89	85	81
Petrol	Large (all other segments)	264	153	116	111	106	101	96	92
Diesel	Small (segment A, B)	123	102	88	84	80	77	73	70
Diesel	Mid-size (segment C)	157	110	89	85	81	78	74	71
Diesel	Large (all other segments)	213	130	99	95	90	86	82	79
LCVs	Average	181	169.2						
Diesel	Small (N1 class I)	121		109	104	102	99	97	97
Diesel	Mid-size (N1 class II)	161		155	148	144	141	138	138
Diesel	Large (N1 class III)	223		175	167	163	159	156	156

[80] For cars data are for May 2016, for LCVs data are for 2015 (http://www.anwb.nl/auto/besparen/top-10-zuinige-autos/top-10-zuinige-bestelautos-overzicht).

[81] Reduction of 21% between 2016 and 2021 (for cars) and 2.3% (LCVs) 2016-2021 (4.5% per year).

[82] TNO, 2011 Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars Service request #1 for Framework Contract on Vehicle Emissions.

Cost

In the study that supported the impact assessment of the 2021 CO_2 regulation for cars[83] the additional vehicle manufacture costs for meeting the 95 g/km (compared to 130 g/km) were estimated at €1 852 and €1 993 for small and large petrol cars, respectively; and €1 552 and €1 930 for small and large diesel cars, respectively. In these numbers no share of PHEVs or ZEV was assumed. The marginal reduction costs at 95 g/km target were estimated at € 91 per g/km reduction. The cost for the best in class vehicles will however be higher. An indication of these costs has been derived from the cost curves developed for the 2020/2021 CO_2 regulation for cars and LCVs[84] and are included in Table 32. Based on the CO_2 reductions, energy cost savings, change in total cost of ownership (TCO) over the entire vehicle lifetime and the GHG abatement cost has been calculated, assuming a vehicle lifetime of 15 years. The GHG abatement cost is based on the CO_2 emissions savings and energy cost savings over the entire vehicle lifetime and the additional purchase costs (all without taxes); impacts on external costs are not included. The table shows that, in some cases, the GHG abatement cost is lower than zero, meaning that the energy cost savings exceed the higher vehicle purchase prices and so that these can be regarded as no-regret reduction options.

It should be noted that the additional costs of more fuel efficient vehicles depend on many things:

- powertrain technology (regular combustion engine, hybrid, plug-in hybrid, fuel electric, fuel cell, etc.);
- size segment;
- annual mileage;
- tax regime;
- fuel price.

Therefore, the TCO and the GHG abatement cost can vary per car type and application. However, purchasing the relatively most fuel efficient cars (according to the values shown in Table 31), can be expected to be cost effective (meaning negative GHG abatement costs) in almost all cases.

[83] TNO, 2011 Support for the revision of Regulation (EC) No 443/2009 on CO_2 emissions from cars Service request #1 for Framework Contract on Vehicle Emissions.

[84] Recently the cost estimates have been updated as part of the research supporting the preparation the post-2020 CO_2 regulation for cars and LCVs, but this information is not yet publicly available.

Table 32: Cost analysis for fuel efficient passenger cars and LCVs (ICEVs) in 2017 compared to 2015 levels (passenger cars)/2014 levels (LCVs)

Fuel type	Size category	Additional vehicle cost (indicative)[85]	Cumulative energy cost savings (incl. taxes)	Change in TCO in %	GHG abatement cost (€/t CO_2)	Scenario
CARS		Compared to 2015				
Petrol	Small	1 100	2 400	-1.8%	-195	10 000 km
			4 700	-4.8%	-359	20 000 km
			7 100	-6.6%	-414	30 000 km
Petrol	Large	3 700	3 300	2.4%	265	10 000 km
			6 600	-1.8%	-129	20 000 km
			9 900	-4.4%	-261	30 000 km
Diesel	Small	600	1 000	-0.4%	-79	10 000 km
			2 000	-1.8%	-229	20 000 km
			3 100	-2.7%	-279	30 000 km
Diesel	Large	4 300	2 000	5.0%	712	10 000 km
			4 000	2.0%	166	20 000 km
			6 000	-0.2%	-15	30 000 km
LCVs		Compared to 2014				
Diesel	Small	150	500	-0.5%	-189	10 000 km
			1 000	-1.2%	-284	20 000 km
			1 500	-1.7%	-316	30 000 km
	Large	200	1 900	-2.2%	-310	10 000 km
			3 800	-3.8%	-345	20 000 km
			5 600	-4.8%	-357	30 000 km

Tyre-pressure monitoring system

Tyres account for around 20-30% of the fuel consumption of vehicles as result of their rolling resistance. Therefore, a reduction of the rolling resistance of tyres could contribute significantly to the energy efficiency of road transport and thus to the reduction of emissions (Viegand Maagøe A/S, 2015). A tyre-pressure monitoring systems is a monitoring tool informing drivers on the air pressure in tyres enabling drivers to avoid unnecessary rolling resistance as result of too low pressure and thus avoiding unnecessary fuel consumption. There are two types of TPMS available: direct and indirect systems.

[85] The Total Cost of Ownership is calculated as the sum of yearly costs as they occur over the lifetime. This entails that financing costs are added to the additional vehicle costs.

Market availability

TPMSs are currently mandatory for passenger cars: from 2014 onwards all new vehicles should be equipped with a TPMS. The current market share of TPMSs in LCVs is limited to only 1% in N1 vehicles of which the majority is OEM-fitted, where retrofit systems represent a market share between 10 and 40%. The application of TPMS in LCVs is expected to remain low, but will depend on the following factors:

- Competition between direct TPMS and indirect TPMS. Suppliers expect market shares to remain low for direct TPMS (on average 3% in 2018) and far higher for indirect TPMS (30% in 2018).
- The spill-over effect from passenger cars: because TPMS is mandatory for new passenger cars, it has resulted in standardized solutions which can also be applied in LCVs.

There are about 10 suppliers worldwide offering direct control and indirect control systems.

Improvement potential

TPMS results on average in a 1% fuel consumption reduction and thus equal CO_2 savings. In case of a 0.5 bar lower pressure increases fuel consumption by 2-5%. In terms of gCO_2/km too low tyre pressure results in an additional 4.6 gCO_2/km for each passenger car. This can be avoided by correct use of a TPMS. (Mustafic, et al., 2014). Besides CO_2 savings, it is estimated that properly maintained air pressure in the tyres can reduce the number of accidents, caused by the speed and poor condition of the tyres, between 4% and 20%, and the total number of accidents by 0.8% to 4%.

Cost

The cost of these systems depends on the distributors of original TPMS equipment and it ranges in average €220, plus the cost of shipping and installation. In terms of cost the price of a direct TPMS system is several times higher than the cost of the indirect system. Fuel savings are similar to the CO_2 savings.

The CO_2 reduction potential and cost result in a GHG abatement cost of € - 39 and- 64/t CO_2.

Low-resistance tyres

The Tyre Labelling Regulation lays down labelling requirements with respect to fuel efficiency, wet grip and noise levels of tyres. The labelling required is similar to the design of the energy label design (A to G with A being the best performing tyre and G the worst). The Energy Efficiency Directive 2012/27/EU refers to the Tyre Labelling Regulation and lays down requirements for public procurement of tyres: public procurers must purchase the best performing tyres in terms of fuel efficiency. In case of service providers these providers should use the most fuel efficient tyres as well.

Market availability

Low-resistance tyres are widely available on the market since the ‘90s. About 50% of passenger car tyres sold in EU on the replacement market are low-resistance tyres. But for classes, A and B, the market penetration is still very low (0-1% for all tyre types). This is probably the result of low consumer awareness with respect to the benefits.

Improvement potential

There is a 7.5% difference in fuel consumption between an A and G labelled tyre. A reduction of rolling resistance of 1 kg/ton equals a fuel consumption reduction of 1.5% (Blackcircles.com, 2012). On average low-resistance tyres will save about 4-5% fuel.

Cost

According to (TNO, 2014a) there is little evidence that tyre costs and performance are correlated. Therefore cost differences between conventional tyres and low resistance tyres are expected to be low. For the end-user, annual cost savings are expected to amount about €117 for passenger cars, which equals a fuel saving of 67-300 litres annually (in case of triple-A tyres).

Start-stop system

Start-stop technology saves fuel by automatically shutting the engine of when a vehicle is at stop (for example at traffic lights). The engine instantly restarts when the driver accelerates again. Within the EU there are 4 common systems:

- Belt Driven starter generator.
- Enhanced starter.
- Direct Starter.
- Integrated Starter Generator (FEV, 2011)

Market availability

More than 50% of the newly registered vehicles will have start-stop as standard technology after 2013.

Improvement potential

A start-stop system potentially saves 3-12% of CO_2 and polluting emissions.

Cost

Investment costs are in the range of €300 to €600 hundred of euros additional to conventional vehicles. Energy cost savings are equal to the CO_2 emission savings. The abatement costs are estimated to be negative (between- €300 and -€60 per tonne CO_2)

Gear-shift indicators (GSI)

A GSI helps a car driver by visually indicating the optimal gear in case this is different to the selected gear, and propose the action required (shift up or down) to reduce fuel consumption. GSI have already been made mandatory in new passenger cars (M1) according to Regulation No 661/2009, but are not mandatory yet for light commercial vehicles, trucks or buses.

Market availability

GSI are often unavailable (EC, 2014d) or sold as part of options packages; this impedes the widespread use of GSI, although it can be installed at relatively small costs for the vehicle manufacturer.

Improvement potential

The impact of a gear-shift indicator strongly depends on the way of implementation in terms of permanent visibility, instantaneous information etc.). Impacts depend on way of implementation (permanent visibility, no instantaneous information on fuel consumption, etc.). This can be explained by a lack of consumer awareness of the potential fuel cost savings and the tendency of consumers to not fully take into account the future benefits of investments, like a GSI.

Cost

Investment costs are very low (€0-15) and estimated to be even lower on the long term: €0-7 (component cost). Due to the low investment cost the abatement cost is estimated to be negative.

Fuel consumption meter (FCM)

A FCM is a display presenting fuel consumption data to a car driver (when idling or total fuel consumption). In this way a FCM serves as a feedback tool to monitor if any eco-driving measures a driver is taken do actually result in fuel consumption. Feedback to a driver on changes in fuel consumption is especially important to see if any eco-driving measures actually result in fuel consumption reduction.

Market availability

Currently, FCMs are not legally required in any motor vehicle, but are likely to become mandatory on the medium to long term. Like GSI, FCM are often unavailable or sold as part of options packages. The current market share is <5% in small passenger cars and >95% in large passenger cars.

Improvement potential

CO_2 savings from FCM are in the range of 0.3 and 1.1%. This strongly depends on the way of implementation (permanent visibility, non-instantaneous information etc.). When FCM and GSI are combined GHG savings will range between 1.8% and 2.6%.

Cost

Additional costs for manufacturers of the vehicles to install FCM are between €0-10 (EC, 2014d) for large passenger cars, €5-10 for medium passenger cars and up to €20 for small passenger cars. LCV costs are expected to be similar to medium or large passenger cars. The exact height of these cost depend on the need to redesign the dashboard or not. Energy cost savings are similar to the CO_2 savings. Due to the low investment cost the abatement cost is estimated to be negative.

Speed limiter and Intelligent Speed Adaptation

A speed limiter or speed limitation device is an on-board device that automatically limits the speed of a vehicle to a certain maximum speed as set in the device.

Two systems of speed limiters are the most prominent offered for LCV's: separate speed limiters and cruise control with speed limiters. The separate speed limiter is installed by the OEM and generally cannot be adjusted by the driver. For the cruise control with speed limiter, however, the speed limiter is a functionality of the cruise control system which can always be adjusted by the driver.

For Intelligent Speed Adaptation Systems (ISA), three different types can be distinguished:

- **Advisory systems**
  In the advisory or informing system the speed limits are visually presented to the driver (mostly when changes in speed regimes are present). The driver is only informed on the speed limits and there is no warning when the speed exceeds the posted speed limit. The driver is free to adjust his speed. This system is currently being offered as an option in some passenger cars.
- **Voluntary or driver select systems**
- These systems can vary from systems that present a visual or auditory warning when the speed exceeds the limit and more intervening systems where tactile feedback is presented to the driver resulting in higher pressure required for the operation of the accelerator pedal.
- **Intervening or mandatory system** in which the maximum speed of the vehicle is automatically limited to the set speed that is in force on that particular location.

Directive 92/6/EEC required speed limitation devices to be installed on large Heavy Goods Vehicles (HGVs) and buses (N3 and M3 vehicles). In 2002, this "Speed Limitation Directive" was amended by Directive 2002/85/EC, which expanded the obligation to all Heavy Commercial Vehicles (HCVs), so also N2 and M2 vehicles, to be equipped with speed limiters. A speed limiter is not yet mandatory for passenger cars and light commercial vehicles (M1 and N1).

Market availability

Speed limiters are available as option for many new vehicles and can also be installed as a retro-fit system. Intelligent Speed Adaptation Systems (ISA) are currently not yet offered by OEMs but can in some cases be installed as retro-fit system.

Improvement potential

The emission reductions of speed limiters for LCVs are listed in Table 33. For passenger cars, similar reduction rates are to be expected.

Table 33: Emission reductions resulting from various speed limiting devices

Speed limiting device	Road type	Average velocity	Reductions		
			CO_2	NO_x	PM_{10}
ISA (Closed - fixed)	Urban	17	1.7%	3.6%	1.7%
ISA (Closed - fixed)	Rural	80			
ISA (Closed - fixed)	Rural	90			
ISA (Closed - fixed)	Motorway	107			
ISA (Closed - fixed)	Motorway	115			
Speed limiter (110 km/h)	Urban	17	6.4%	17%	6%
Speed limiter (110 km/h)	Rural	80			
Speed limiter (110 km/h)	Rural	90			
Speed limiter (110 km/h)	Motorway	107			
Speed limiter (110 km/h)	Motorway	115			
Speed limiter (120 km/h)	Urban	17	0.9%	2.2%	0.9%
Speed limiter (120 km/h)	Rural	80			
Speed limiter (120 km/h)	Rural	90			
Speed limiter (120 km/h)	Motorway	107			
Speed limiter (120 km/h)	Motorway	115			

Source: (CE Delft, 2016b).

An important co-benefit of speed limiters and ISA-systems is an improvement of road safety. Table 34 summarizes the reduction in road fatalities that were found for various types of speed limiters.

Table 34: Potential safety effect of speed control devices (fatalities)

	Urban	Rural	Motorways
Speed limiter (120 km/h)	0%	0%	-7.7%
Speed limiter (110 km/h)	0%	-2.1%	-19.9%
ISA (half open-fixed)	-30%	-11%	-11%
ISA (closed-fixed)	-31%	-12%	-12%

Source: (CE Delft, 2016b).

Cost

The combination of speed limiter and cruise control is an option in the price range of € 150-347 excluding taxes. For separate speed limiters, the speed limit is set either at the dealer or in the factory; and the driver cannot turn it off. If the speed limiter is set in the factory, it is protected by a factory code and it can only be removed at considerable costs. This type of separate speed limiters (i.e. without cruise control) is installed at the factory for a price in the range of €25-139 excluding taxes.

Currently, ISA systems are not being sold for LCV's in the Netherlands, Germany, or the United Kingdom. Open ISA systems are ubiquitous in current navigation systems. Carsten et al. (2008) expected prices to drop to £60 (€80) for advisory ISA and £160 (€222) for voluntary/mandatory ISA systems if fitted in new vehicles by 2015 (CE Delft, 2016b). The installation of speed limiters is expected to be cost effective (CE Delft, 2010a).

Information systems applied to traffic management by means of connected cars

Information systems are meant to interact with the driver providing pre-trip information services to help drivers avoid congestion and make other journey choices (other modes). The information systems implemented in roads should be accessible to the users on time, and the connected cars can play an important role as conveyor of this information.

Connected cars (Everis, 2015)

The connected car is able to digitally connect and interact with its surroundings, including the infrastructure. The access to information on current traffic conditions on the road enables connected cars to dynamically optimise routes, minimising traffic congestions

There are three options of connectivity in cars: Embedded, Tethered and Integrated. The use of these different connectivity options differ across the various in-car services. These three connectivity solutions can be used simultaneously as appropriate for the proposed applications.

In an embedded system, a complete communication module, which consists of a modem and a Subscriber Identity Module (SIM), is permanently integrated into the car. The application runs on the built-in system and does not require the use of a smartphone

The tethered solution relies on the intelligence of the applications running in the vehicle, while an external SIM is used to enable connectivity. There are basically two ways to enable tethering. Either the vehicle features a built-in modem (with a SIM card slot) or an external modem on a user's mobile device is used, e.g. a smartphone. For safety and security solutions it remains an unreliable solution, given the need for the user to insert their SIM or activate their phone. The main benefits of tethered solutions with external modems are that they require less costly in-vehicle hardware and external modems are more likely to be up-to-date, given the higher replacement rate of mobile devices.

For the integrated approach, the connection is made through a mobile device and all applications and programs also run on the user's mobile device. The car hardware is solely used for displaying and human machine interface.

Intelligent Transport Systems (Grote, et al., 2016)

Intelligent Transport Systems (ITS) could be defined as any application of information and communication technology to transport, which includes several technologies that can serve as sources of road traffic data. Floating car data (probe vehicles) can be provided by a number of different in-vehicle devices, such as Bluetooth, GPS, mobile telephony and Wi-Fi. These devices can provide information on traffic flow, average speeds, delays, travel times, and driving patterns.

(Grote, et al., 2016) describe the different Traffic Congestion Indices (TCIs) available: TomTom produce a Traffic Index for 218 cities worldwide based on GPS data. INRIX also produce global congestion data for urban areas (e.g. the Urban Mobility Scorecard Annual Report), and the Texas A&M Transportation Institute produce similar data for the USA. In the UK, Mott MacDonald produce Strat-e-gis Congestion which provides historic congestion data based on GPS.

The same study describes the Urban Traffic Control (UTC) systems and particularly SCOOT,10 which operates in over 250 cities and towns worldwide. The data used are generated by inductive loop detectors (ILDs) installed under the road surface, which send updates of vehicle presence every 250 ms in the form of 1s and 0s (denoting occupied or unoccupied respectively). Enhanced ILDs are able to identify the different vehicle categories, and can be complemented with axel count data.

Improvement potential

The section 3.5.1 indicates that some authors estimate the increase in emissions at 45 km/h (a typical average speed on urban roads) due to congestion at 40%. Garbarino (Garbarino, et al., 2016) pointed out that congestion is potentially one of main parameters affecting the fuel consumption in the life-cycle of a road with high-traffic flows, but its impact diminishes significantly for low traffic flows (i.e. secondary and other roads). Therefore, the improvement potential of the access to information on current traffic condition is strongly dependent on the specific traffic conditions.

Market availability of connected cars

The car makers are currently offering different options of connectivity, which are summarizes in Table **35**

Table 35: Type of connection offered by commercial brands **(Everis, 2015)**

	Type of connection			
	Embedded	**tethered - embedded modem**	**tethered - external modem**	**integrated**
Audi		x		x
BMW	x		x	x
Mercedes	x		x	x
Ford			x	x

Nissan			x	x
Opel	x			x
Peugeot	x		x	x
Renault	x			x
Toyota			x	x
Volkswagen		x		x

With respect to navigation and traffic information, Audi, BMW and Mercedes offer extensive and highly developed services. In addition to real-time traffic information, Audi and Tesla have embedded "Google Street View" into their navigation system, so the user can get an idea of the destination before arrival.

Mercedes and BMW do not use Google maps for their navigation services. Another interesting navigational feature, which is offered by Audi and Mercedes, is the ability of planning a route at home or on a mobile device and sending it to the car, where it then can be used. Especially for longer trips or journeys with multiple destinations, this can be a helpful application. It can also be used for planning recharge stops for electrical vehicles.

The navigation systems provide detailed information on the traffic status on a specified route, but the navigation system is not used on many daily drives, either because the routes are familiar or because keying in the destination is time-consuming. However, the Volkswagen "CarNet" system notes the regularly driven routes and automatically scans them for traffic problems, even when navigation is inactive.

Routes can be planned on a mobile device or personal computer and sent to the car. This service is offered by Opel, Renault, Toyota and Volkswagen.

Table 36 shows provides an overview of the number of models out of the total models that each brand offers equipped with traffic information, on-line routing and parking information.

Table 36: Number of models out of total with traffic information, online route and parking information **(Everis, 2015)**

	Traffic info	**Online route**	**Parking info**
Audi	13/13	13/13	13/13
BMW	16/16	0/16	16/16
Mercedes	16/16	16/16	0/16; 16/16 planned
Ford	7/10	0/10	0/10; 10/10 planned
Nissan	8/8	8/8	0/8
Opel	9/10	10/10	0/10
Peugeot	9/10	0/10	4/10

Renault	10/11	10/11	10/11
Toyota	10/10	10/10	10/10
Volkswagen	9/14	0/14; 14/14 planned	4/14

** 'planned' means that the manufacturer is planning to include them in next models.*

Costs

The costs of the connected cars consist of the additional cost of the device in those models that do not have them as standard equipment, plus the subscription fees for the applications needed.

The purchase cost of embedded options is sometimes difficult to evaluate since they are usually part of integrated 'packages' or just available in more costly models. For example, the system R- Link of Renault costs €800, but it must be purchased together with the pack Clima (€450). The whole package R-link and Clima is not available in the cheapest model, but in an upper model that costs €1000. Ford offers a the Travel Package comprising the tethered option SYNC2 + USB, together with dual zone automatic climate control, Visibility Package, and Package City, whose price is €1600. In other cases, as Toyota, the connectivity solution can be chosen disaggregated from other packages. Toyota Touch and go consists of a tethered system with external modem, and costs €800.

There are several applications for traffic information and route planning as Inrix, Waze and TomTom traffic, whose annual fees might range between €25 – 50. In other cases, the customer pays the subscription as part of the purchase price, and the car brand acts as intermediary between the final customer and the information service providers.

Mobile Air Conditioning (MAC)

Market availability (Gluckman Consulting, 2014)

Mobile Air Conditioning systems result in additional energy use, GHG emissions and air emissions. Direct GHG emissions result from refrigerant losses (at the rubber hoses and connections, at the servicing level and at EOL). Indirect GHG emission and air polluting emissions are the result of the higher energy use due to the operation of the system. MACs are mostly small systems using HFC 134a as refrigerant. These systems are usually driven via a belt drive to the engine. In larger vehicles, like buses and trains, the MAC can be electrically driven or powered by a dedicated engine.

The use of MACs is affected by the 2014 EU F-Gas Regulation (517/2014) and the 2006 MAC Directive (40/2006). Only cars and light vans fall under the scope of both the MAC Directive and the F-Gas Regulation. Other transport modes are only affected by the F-Gas Regulation. The traditionally used refrigerant in MAC systems, R134a, has a GWP of 1300. The aim of the Directive is to enforce the use of gases with GPW lower than 150. The Directive does, however, not specify any particular refrigerant or system, making the Directive technology neutral.

The ban takes place in two steps:

1. **January 1st, 2013:** The use of HFCs with a GWP above 150 was banned in the MACs of new vehicle types placed on the market in the EU after January 1st 2013. These new vehicle types are required to be "type approved".
2. **January 1st 2017:** The use of HFCs with a GWP above 150 will banned in the MACs of all new vehicles placed on the market in the EU after January 1st 2017.

The F-Gas Regulation affects the use of HFCs as refrigerants by organisations that use, install or maintain MAC equipment using F-Gases. F-Gases must be used with care and efforts are required to avoid unintentional release. This involves trained technician at the various steps of the life cycle.

Improvement potential (EC, JRC, IPTS, 2008)

The use of air conditioning leads to an increase in CO_2 emissions of 7 g CO_2/km on an average European car as result of additional fuel consumption. (EC, JRC, IPTS, 2008) The overall impact of MAC use on fuel consumption is estimated to be 3.3% of annual fuel consumption. Total leakage emissions (at all life cycle stages) were found to be 5g CO_2 eq./km or 70 g HFC-134a/year (in 2003). Note that refrigerant leakages strongly depend on factors, like system design, vehicle age, maintenance practice, model year and operating environment. Total emissions or total equivalent warming impact (TEWI) is estimated to lie between 11-12 g CO_2 eq./km depending on the vehicle type.

Reduction options consist of:

- Reducing the leakages of refrigerants; US manufacturers state that a 50% reduction can be reached in terms of refrigerant leakages.
- Using refrigerants with a lower GWP; it is currently unclear which alternative refrigerants will penetrate the market, but new fluids might reduce emissions by 95-100%. Examples of alternatives are HFC152a or a CO_2 system.
- Improving the energy efficiency of MAC systems.
- Reducing the thermal load of passenger compartments, like by insulation of doors and roof, limitation of window size and use of solar reflective glazing. Ventilated seats can result in fuel consumption reductions of 0.3-0.5% when the AC is on).
- Reducing the cooling demand in the car (non-technical option): by manual use of AC rather than an automatic system or higher set temperatures in case of an automatic system.

Cost (EC, 2007)

The reference cost of a typical European HFC-134a system is estimated to be about €194. (IPCC, 2003) Additional cost for better performing systems are between €43-90 for a CO_2 system and € 43 for an HFC-152a system.

An impact assessment of the European Commission on reduction measures for passenger cars has shown that a shift to more fuel efficient MACs will result in a GHG abatement cost of - €30/t CO_2 (Well To Wheel). However, there are no agreed measure procedures for the fuel efficiency of MACs yet.

Lubricants/low viscosity lubricants (LVL)

Lubricants (motor oils) are liquids used for lubrication of various combustion engines. Their main function is to lubricate moving parts of the engine, but on the other hand, also improves engine performance in other ways, Lubricants can consist of hydrocarbons and can be mineral (oil-based) or synthetic. Mineral lubricants only meet minimum standard, but synthetic oils (low-viscosity lubricants (LVL)) have far better product characteristics. Compared to mineral lubricants LVLs have a high viscosity at a broad range of temperatures, which results in significant reduction of fuel consumption. Other advantages are:

- improved flow properties at low temperatures;
- low friction during cold starts of the engine;
- low wear and tear due to fast lubrication of the engine;
- the lubricant film is not cut in case of high temperatures;
- reduction of oil consumption due to higher vapour point;
- reduction of deposits in the motor.

Market availability (WIP; Q1, 2008)

It is possible to switch from conventional to synthetic lubricants without difficulties, but this will require complete oil change. Synthetic lubricants are widely available and can be bought in any shop selling motor oils. Many of the vehicle manufacturers claim minimum requirements of the lubricant efficiency. These details and recommendations are mostly included in the user manual of the vehicle.

Improvement potential

The reduction potential can be compared to the potential of low resistance tyres and tyre pressure monitoring systems. (Sharpe, 2009). According to various energy agencies up to 2-6% fuel savings can be achieved with innovative lubricants. The reduction potential is, however, different for different road types:

- in town 4-6%
- out of town 2-4%
- highway 2%

However, the awareness of the GHG reduction potential of improved lubricants among consumers is very low. More important drivers for the purchase of LVLs are approval by the car manufacturer, quality and price, but the interrelationship between CO_2 and improved lubricants is hard to understand for consumers.

Cost (WIP; Q1, 2008)

Cost savings are the result of fuel savings: one major manufacturer guarantees a fuel cost saving of at least 4% in case of making use of the latest LVLs. According to the Deutsche Energie Agentur, on average €70 per year can be saved. This saving can outweigh the increased lubricant costs, which are double or triple price of conventional lubricants.The use of synthetic lubricants is a cost effective option even for older vehicles, but only if oil consumption is less than 0.3 l per 1 000 km. (WIP; Q1, 2008)

3.5.3 Improvement options for alternative powertrains and fuels

In the following section, technical options for alternative powertrains and fuels are analysed. Wherever possible along this study, a Well-to-Wheel approach has been used to evaluate the improvement options analysed in this report. (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014) The term 'Well-to-Wheel' (WTW) distinguishes between:

- Well to Tank (WTT): it accounts for the energy expended and the associated GHG emitted in the steps required to deliver the finished fuel into the on-board tank of a vehicle. They cover the stages of the energy supply chain to transform the primary energy into final energy and its distribution for vehicles refuelling: extracting/growing, transporting, manufacturing and distributing.
- Tank to Wheels (TTW): it accounts for the energy expended and the associated GHG emitted due to the fuel/energy carrier consumed by the vehicle at its use stage.

Electric vehicles

Different types of electric vehicles can be distinguished:

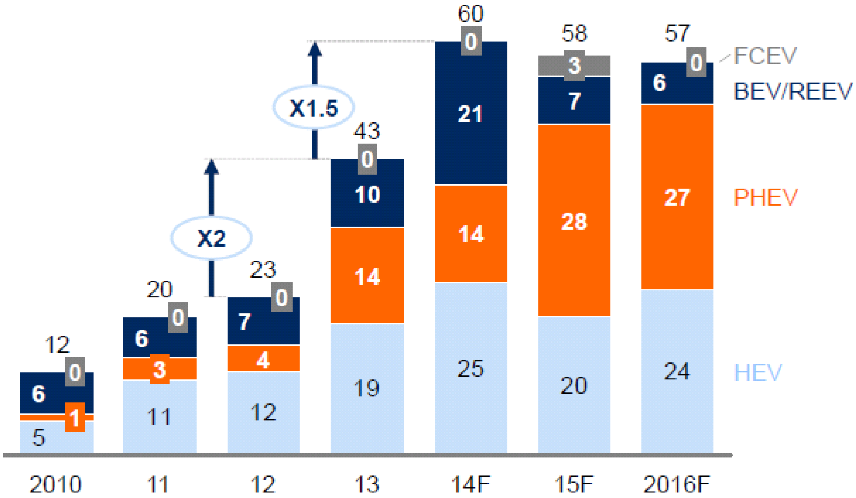
- Battery or full electric vehicles (BEV or FEV) which can just be powered by the electric motor.
- Plug-in hybrid vehicles (PHEV) and Range extender vehicles (REEV) which can be powered by both a combustion engine and an electric motor and that can be charged from the grid.

Market availability

In most EU countries the share of electric vehicles (EVs) in car sales does not exceed 1%. Two exceptions are Norway and the Netherlands, where the growth in electric vehicles on the market have been the result of taxation in favour of electric vehicles.

In Figure 34 the trend in EV model launches per type of EV is depicted. The number of models launched is about 5 times higher than compared to 2010.

Figure 34: Number of EV model launches in the period 2010-2016 **(McKinsey & Company, 2014)** (number of models with start of production in the respective year)



Limitations for further market penetration pf PHEVs and FEVs are the driving range, weight of the battery and required energy capacity (usually expressed in kWh) to be installed.

Improvement potential

The improvement potential in terms of potential GHG emission reduction in comparison to a conventional diesel car is depicted in

Table **37**. Electric vehicles result in a strong increase of WTT emissions, but a strong reduction in the TTW phase. The net impact is a significant reduction of CO_2 emissions. When also taking account of the higher GHG emissions in vehicle production for EVs, the net impact is still a significant emission reduction. This is line with the conclusions of the LCA review which is included in Annex B and C. As the CO_2 intensity of the EU28 electricity mix is expected to decrease significantly over the coming years, the CO_2 advantage of EVs is expected to increase.

Table 37: CO_2 impacts of electric passenger cars and LCVs **(EC, 2015)**

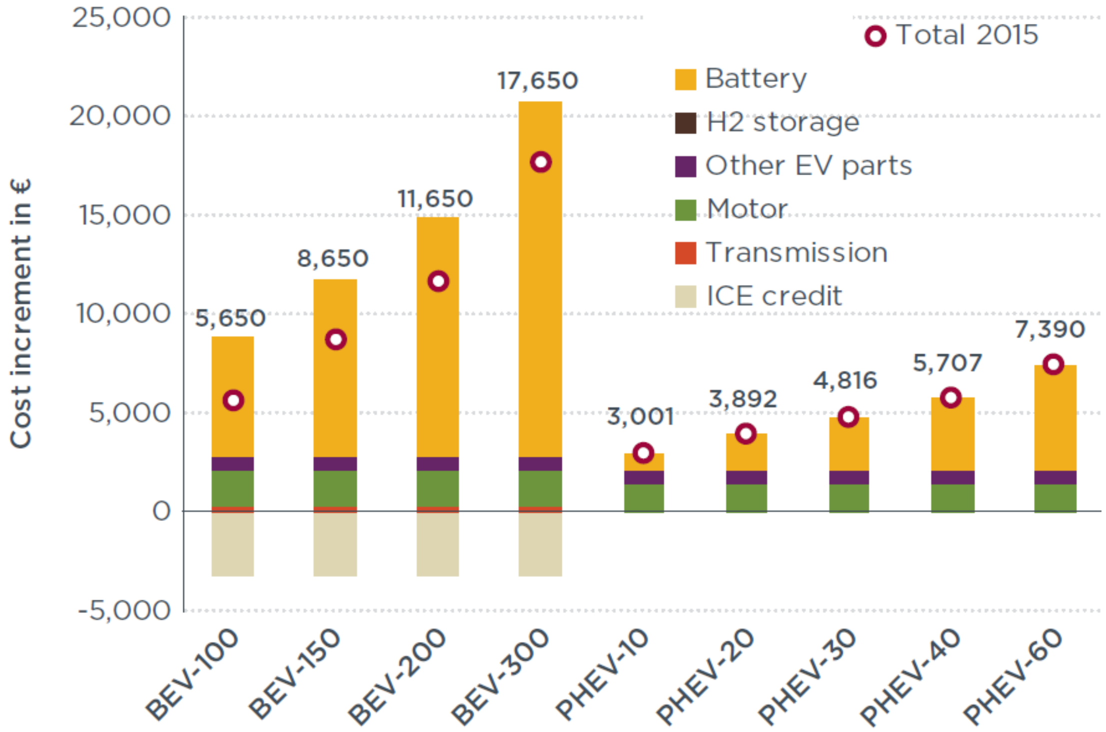
	WTT	TTW	WTW
	gCO_2/km	gCO_2/km	gCO_2/km
Electric passenger cars (electricity mix EU28 2010 based on (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014)			
PHEV gasoline	36 (+44%)	75 (-37%)	111 (-23%)
PHEV diesel	36 (+44%)	68 (-43%)	105 (-28%)
Full electric vehicles	78 (+212%)	0 (-100%)	78 (-46%)
Conventional fuels			
Conventional gasoline	29 (+16%)	156 (+30%)	185 (+28%)
Conventional diesel (baseline)	25	120	145

Electric vehicles can contribute to air quality improvement; especially in urban areas since they don't produce any tailpipe emissions, include NO_x emissions or particles (PM) while running in electric drive mode. Regulation (EU) No 540/2014 set requirements on the minimum noise ('Approaching Vehicle Audible Systems') of electric and hybrid electric vehicles, because these are so quiet and can be a safety risk.

Cost

The cost of EV technology is decreasing much faster than previously expected. According to AVERE, BEVs will be cost competitive within 5 to 10 years. In some situations BEVs are already cost competitive thanks to incentive given by government ((The Guardian, 2016). According to McKinsey this will be 10 years. (McKinsey, 2010). A recent comparison made for a regular and full electric Volkswagen Golf (which is one of the only car models that is available both as an ICEV and a full electric vehicle) shows that without tax, the electric Golf has about €0.2 per kilometre higher TCO than the petrol Golf, assuming 17 000 kilometre per year (SER, 2015). Cost competitiveness will also largely depend on taxations in the various Member States. Also the range of EVs is improving with several 300 km+ range models entering the market. These models will come on the market in 2016 and 2017 at prices around €31 000 ($ 35 000).
ICCT (ICCT, 2016a) provides a breakdown of the additional costs for different EV and PHEV models, based on a literature review (Figure 35):

Figure 35: Cost breakdown of different electric power trains for a 2015 lower medium car. Assumed battery production volume is in the mid-ten thousand units **(ICCT, 2016a)**



As an average, the ICCT literature review shows that some authors estimate that the battery pack determines about 75% of the current cost increments of BEV, with 24.9 kWh battery at €375 per kWh. It also indicates that the costs associated with Li-ion batteries are expected to drop: they are expected to cost €205 per kWh for PHEVs and €160 per kWh for BEVs in 2030 in the optimistic scenario, or €250 and €200 per kWh in the midrange scenario. This cost reduction would be derived from the replacement of high-cost materials and economies of scale, improvements to the cell and electrode structure design, and high-volume production processes with reduced wastage.

Cost estimates for charging infrastructure vary strongly and on the other hand, are also heavily subsidized by governments in order to promote electric transport. According to McKinsey, 2014 one slow two-plug charging station costs about €2 000 in hardware alone, while COWI (2015) states that a wall mounted charging solution that can fully charge a BEV in 1.5-2.5 hours, costs approximately €500 to 1 500.

Electricity production is becoming increasingly low-carbon, with a growing increase in renewable energy sources. According to the European Commission (2013), under current trends and adopted policies, the share of electricity generation from renewable energy sources (RES-E indicator) would go up from 20% in 2010 to about 35% by 2020, 43% by 2030 and 50% by 2050. Below projections for the average electricity price in the next decades are given.

Table 38: Average electricity price (source: I3M-Lab et al (2013)) **(EC, 2015)**

€$_{2010}$/MWh	**2010**	**2020**	**2030**	**2050**
Average price of electricity (after tax)	131	172	172	169

Overall, the electrification of passenger cars will result in lower energy cost as result of the greater efficiency and no use of oil. Other operational cost are also lower, because of the lower maintenance cost due to fewer moving parts, absence of catalyst and other emission control systems.

From the above we conclude that BEVs and PHEVs can already have a TCO equivalent to ICE vehicles if intensively used and the TCO for BEV is expected to converge with ICE after 2025. The GHG abatement cost of electric cars varies widely, depending on many assumptions. For the Volkswagen Golf mentioned above, the €0.2 per km additional cost and about 100 g/km lower CO_2 emissions result in a cost of €200 per tonne of CO_2 reduced.

FCEV

FCEV stands for fuel cell electric vehicle. These vehicles use a fuel cell in combination with a battery to power the electric motor. Electricity is generated by using oxygen and (compressed) hydrogen. A vehicle running on hydrogen only emits water and heat.

Market availability

Only two car manufacturers have already FCEVs on the market for individual consumers. Other car manufacturers have announced market introduction in the next years.

ICCT (ICCT, 2016a) indicates that current fuel cell production is considerably lower than EV battery production: Toyota produced 700 fuel cell vehicles in 2015, whereas most BEV manufacturers produced more than 25 000 units in the same year.

The infrastructure for hydrogen as fuel is in an early build-up phase, which constitutes a key obstacle to market development.

Improvement potential

The improvement potential of hydrogen vehicles strongly depend on the sources used to produce the hydrogen in the WTT phase. Fossil fuel sources, like natural gas and coal gasification result in substantially higher WTT emissions and in case of natural gas these higher emissions therefore also result in an increase in WTW emissions compared to a conventional diesel. All options of using hydrogen produced through electrolysis result in overall WTW savings. In terms of TTW emissions FCEVs do not have result in any exhaust emissions other than water and heat. Therefore GHG TTW emissions are 0, like air polluting emissions (from the engine) are 0 as well.

Table 39: CO_2 impacts of fuel cell passenger cars and LCVs **(EC, 2015)**

	WTT	**TTW**	**WTW**
	gCO_2/km	**gCO_2/km**	**gCO_2/km**
Hydrogen			
Hydrogen thermal			
Natural gas EU-mix	62 (+148%)	0 (-100%)	62 (57%)
Coal gasification EU-mix	128 (+412%)	0 (-100%)	128 (-12%)
Wood gasification	9 (-64%)	0 (-100%)	9 (-94%)
Hydrogen electrolysis			
Electricity mix	125 (+400%)	0 (-100%)	125 (-14%)
Coal EU gasification	68 (+172%)	0 (-100%)	68 (-53%)
Wood gasification	12 (-52%)	0 (-100%)	12 (-17%)
Wind	7 (-72%)	0 (-100%)	7 (-95%)
Conventional fuels			
Conventional gasoline	29 (+16%)	156 (+30%)	185 (+28%)
Conventional diesel	25	120	145

Cost

The current cost of hydrogen vehicles depends on the country and model and could vary between €55 000 and 80 000. The only EU manufacturer Daimler is expected to propose a hydrogen model in 2017, but the price is not yet known yet. The ix35FCEV model of Hyundai is placed on the on the Dutch, Norwegian and Danish market at a price of €66 000.

Other references also suggest similar additional costs. The additional manufacturing costs of HFCEVs are estimated over a 2013 conventional ICEV at about €52 270, assuming a production volume in the low thousands, according to the ICCT review (ICCT, 2016a). The authors assumed fuel cell costs at €600 per kW (fuel cell size is not specified), and a 1.4 kWh battery at about €1 500 per kWh. One of the authors reviewed assumed fuel cell costs to be about 85% of the power train. Fuel cell costs are expected to drop due to the increase of the production rate and the scaling effects, and ICCT literature review mentions that some authors estimated costs of €28 - 32 per kW at an assumed production volume of 300 000 in 2020, while other ones estimated €225 per kW at 1 000 produced units and €83 per kW at 10 000 units..

Cost for a hydrogen refuelling station range between €330 000 to €5 million and depend on size and performance (ICCT, 2016a). Per vehicle the costs of hydrogen retail and distribution are estimated to be between €700 and €1 500 over the entire lifetime (that is assumed to be 15 years). This includes distribution from the production site to the retail station including both operational and capital costs for the retail station.

Currently, hydrogen is produced mainly from natural gas reforming, but there are other pathways mentioned in Table 39. It still needs significant efforts to set up the necessary hydrogen refuelling station infrastructure. Different hydrogen production methods show a wide range of costs between €1.9 and 10.3/kg.

The TCO of FCEVs is still much higher than that of ICEVs, resulting in relatively high cost per tonne of CO_2 (no estimates available yet).

Biofuels

Because biofuels can be brought on the market in low blends without any vehicle modifications, the market share of biofuels is relatively high compared to other alternative fuels (4.3% of all energy consumed in transport in 2013 (Eur'Observer, 2014). According to the Fuel Quality Directive biofuels are allowed up to 7% in regular diesel and up to 10% in regular petrol. Drop-in biofuels can be used without limitations. In 2020, about 95% of the passenger cars and vans will be compatible with E10, and all diesel vehicles (since model year 2000) are compatible with B7. In 2020, about 95% of the passenger cars and vans will be compatible with E10, and all diesel vehicles (since model year 2000) are compatible with B7.

Vehicles capable of running on higher blends, like E85, are estimated at 250 000, so less than 0.1% of the fleet (with nearly 4 500 refuelling stations available). Vehicles and infrastructures are not available on a significant scale except for E85 in Sweden, France, Germany and the Netherlands. The number of vehicles running with other blends, such as B100, B30, ED95 (95% ethanol, 5% cetane improver) is limited. These fuels are mainly used in dedicated public fleets, e.g. the Stockholm buses by Scania.

Sustainability risks require a shift towards advanced biofuels, while most current production capacity produces first generation biofuels and not advanced biofuels.

Improvement potential

The GHG reduction potential of biofuels strongly relies on the feedstock used to produce the biofuels and on the energy share of biofuel in the fuel blend. Where TTW emissions are mostly fully reduced in case of electric drivetrains, biofuels only slightly reduce or increase GHG emissions. This because the biogenic carbon content of biofuels is similar to fossil fuels in combination with the reliance on the conventional ICE as drivetrain. Due to the biogenic content of the carbon significant reductions of GHG emissions can be reached in the WTT phase only with biofuels produced from waste and residues or advanced feedstocks. (Note that according JEC methodology (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014) biogenic CO2 that is emitted in the use phase is deducted from the WTT CO2 emissions, since it is considered to have been previously fixed by plants during the agricultural stage).

However, biofuels from land based biofuels, like rapeseed, can result in significant higher emissions compared to conventional diesel. This is the result of direct and indirect land use change impacts. Sustainability criteria as laid down in the Renewable Energy Directive (2009/28/EC) and in the Fuel Quality Directive (2009/30/EC) prevent the direct displacement of carbon natural storages, but indirect displacement is harder to control and is often referred to as indirect land use change. In addition to this, biofuels from energy crops can result in competition between energy crops and food crops causing an increase of food prices. In response to this concern, the Directive (EU) 2015/1513 limits the amount of biofuels and bioliquids produced from cereal and other starch-rich crops, sugars and oil crops and from crops grown as main crops primarily for energy purposes on agricultural land that can be counted towards targets set out in Directive 2009/28/EC (maximum 7% of the final consumption of energy in transport)

For these two reasons, it is recommended to shift away from food/land based biofuels towards biofuels from waste and residues, like used cooking oil, and advanced biofuels, like cellulosic ethanol and biofuels derived from algae (IEEP, 2010) (Edwards, et al., 2010). Because there is no agreement yet on how to calculate ILUC emissions within

WTW calculations, Table 24 still presents the WTT and WTW emissions without ILUC impacts. These numbers should therefore be seen as optimistic estimates. More recent studies, like the GLOBIOM study (Ecofys, 2015), have shown that the emissions of for example, biodiesel could also be higher than conventional diesel.

Table 40: WTT, TTW and WTW emissions for biofuels (biodiesel options compared to conv. diesel and bioethanol options compared to conv. gasoline) - excluding ILUC impacts **(EC, 2015)**

	WTT	**TTW**	**WTW**
	gCO_2/km	**gCO_2/km**	**gCO_2/km**
Biofuels			
Biodiesel (neat fuel eq.)	-101 to -22 (-500% to -188%)	125 (+4%)	44-103 (-70% to -29%)
B7	14-19 (-44% to -24%)	120 (+0%)	137-140 (-5% to -3%)
Ethanol (neat fuel equivalent)	-127 to 30 (-538% to +3%)	146 (-6%)	19-176 (-90% to -5%)
E10	17-28 (-41% to -3%)	150 (-4%)	166-178 (-10% to -4%)
E20	6-28 (-76% to -3%)	148 (-5,2%)	154-176 (-17% to +5%)
E85	-82 to 29 (-383% to 0%)	143 (-8%)	61-171 (-67% to +12%)
Conventional fuels			
Conventional gasoline	29	156	185
Conventional diesel	25	120	145

Bioethanol blends reduce significantly NO_x emissions, however FAME blends can reduce PM, but increase other pollutants. Biofuels without complying with specific sustainability criteria can harm biodiversity and can result in negative impacts on soil and water quality. The Renewable Energy Directive has laid down sustainability criteria to prevent these negative eco-system impacts and to ensure a minimum GHG reduction: biofuels that count towards the targets should all comply with these criteria. It is recommended to use the same sustainability requirements for biofuels being used under green public procurement contracts.

Cost

At the vehicle level there are no significant additional cost compared to a conventional vehicle, except for E85 vehicles. Higher levels of FAME and bioethanol might require adaptations for higher blends above the blending limits as set by the Fuel Quality Directive, but these costs are relatively low compared to electric drivetrains. An increase in fungible biofuels leads to biofuels of 'drop-in' quality, which are so similar to the characteristics of diesel that these can be blended without limitations. The cost of adaptation of a conventional pump station into a biofuel station is between € 5 000-20 000. A new pump costs between € 15 000-30 000, without the storage enlargement being included.

The increased cost of biofuel mainly come from higher fuels cost as result of feedstock prices. In the future feedstock prices might even increase as result of limited availability of biomass and thus scarcity on the market. Price projections for current biofuels made from food crops as well as advanced ethanol and biodiesel (like waste derived biofuels) show that both biodiesel and ethanol can become cost-competitive in the future, despite the necessary shift to more advanced technologies, because of the ILUC risks associated with land-based biofuels. Although this conclusion was derived from a study focusing on the US market, similar trends can be expected for the EU market, although this depends on future RES-T policy and the development of the advanced biofuel sector in the EU. Due to the higher premium price for feedstocks, no competitive TCO exists: however, note that fuel suppliers obliged to bring a certain share of their fuel sales as biofuel on the market, try to reach their target by lowering the price of higher blends of biofuels. The premium price for biofuels is therefore also shared by road users driving on lower blends of biofuels and those one not using biofuels at all.

Compressed Natural Gas (CNG)

CNG is derived by compressing natural gas, which is mainly composed of methane. After compression the CNG only takes up 1% of the volume of non-compressed gas. It is stored and distributed under pressure as well. CNG can be applied in dedicated vehicles (which are only able to run on CNG), or dual-fuel or bi-fuel system, which represent systems running on two fuels.

Market availability

Compressed Natural Gas (CNG) is mature and fully OEM-developed with more than 30 LDV models on the market. 0.7% of the vehicle fleet of the EU27 and Switzerland consists of CNG-vehicles (1.2 million vehicles) of which 75% driving in Italy. Refuelling infrastructure consists of over 3 000 refuelling stations, which is mostly situated in Italy and Germany and is still limited, but growing.

The CNG vehicle offer includes more than 30 passenger cars and light commercial vehicles (by Fiat, Lancia, Mercedes, Iveco, VW, Audi, Seat, Skoda and Opel and Volvo), and keeps expanding.

Improvement potential

The improvement potential of CNG depends on the type of gas used as fuel. From a WTW perspective natural gas (EU mix) scores in between conventional gasoline and conventional diesel. However, natural gas also offers the potential to reach a higher share of renewable gas, like biogas (other options are for example Power-To-Gas). Biogas can result in negative WTT emissions, because biogas production also avoids methane emissions in case of biogas from manure.

Table 41: WTT, TTW and WTW emissions of CNG and biogas compared to conventional diesel **(EC, 2015)**

	WTT	TTW	WTW
	gCO_2/km	gCO_2/km	gCO_2/km
Natural gas			
CNG, EU mix	30 (+20%)	132 (+10%)	163 (+12%)
Biogas	-290 to -33 (EC, 2015) (-1260% to -232%)	132 (+10%)	-158 to 99 (-208% to -32%)
Conventional fuels			
Conventional gasoline	29 (+16%)	156 (+30%)	185 (+28%)
Conventional diesel	25	120	145

The use of natural gas and biogas has low pollutant emission levels (mainly NO_x), almost zero sulphur emissions, and particulate matter emissions close to zero. The reduced noise is another advantage compared to diesel, although this is more significant for HDVs than it is for LDVs.

Cost

CNG passenger cars are between € 1 000 and 3 000 more expensive compared to petrol cars, which is mainly caused by the required storage capacity. Sometimes CNG vehicles are already cheaper than a diesel version.

CNG-infrastructure can make use of the existing natural gas grid by installing a compressor being able to reach a final pressure of 200 bars and dispensers. The total cost of this are estimated to be between €200 000 and €300 000 (depending on the compression capacity of the installation). In case the natural gas grid is not nearby, a natural gas pipeline is required, which costs about €300-600 per metre.

Total biogas costs today are between €6-10 cent per kWh compared to an expected CNG price between €4 and 6 cent per kWh.

The TCO of CNG vehicles is currently competitive with diesel and petrol in the current German tax framework. Without energy tax benefits in this country the TCO will be higher.

The GHG abatement cost of CNG in passenger cars is about €260 per tonne CO_2 for CNG, about €230 per tonne CO_2 for bio-CNG from co-digestion and slightly negative per tonne CO_2 for bio-CNG sourced from landfill gas (CE Delft, 2010b) (Dittrich, et al., 2015)

3.5.4 Technical options to reduce air polluting emissions and noise

The following options have been identified as relevant options to reduce pollutant emissions from transport:

- Euro standard and RDE;
- Fuel type;
- Speed limiter;
- Intelligent Speed Adaption (ISA);
- Alternative powertrains and fuels:
    - EV;

- FCEV;
- Biofuels;
  - CNG.

The following options have been identified as relevant to reduce noise:

- noise level;
- low noise tyres;
- speed limiter;
- intelligent Speed Adaption (ISA);
- alternative powertrains and fuels:
  - EV;
  - FCEV.

Due to the overlap between options for noise and pollutant emissions and GHG reduction options, many of these measures have already been discussed in Section 3.5.2 and Section 3.5.3. Therefore only the Euro standard and RDE, noise level and low noise tyres will be described below.

Euro standards and RDE

From September 2015 onwards all new LDVs (M1, M2, N1 class I, II and III, and N2) have to comply with Euro 6. Therefore Euro 6 should also be the minimum standard required by public procurement bodies. In the next years Real Driving Emission (RDE) testing procedures will be introduced, see Section 3.5.1. As soon as the RDE tests become mandatory for all new vehicles from September 2019 onwards, vehicles exceeding the NEDC value on the RDE test with a lower percentage than the conformity factor of 110% have a better air pollutant emission performance than the average. The market availability and cost of vehicles meeting a lower exceedance rate (e.g. 50% that needs to be met by all vehicles from January 2021 onwards; or even 0%) are not yet clear. Note that some stakeholders are also working on the so-called EULES standard, which will be a standard to distinguish the cleanest vehicles in terms of nitrogen oxides (NO_x) emissions. These vehicles will emit lower real-world emissions than the existing standards (EMISIA S.A.,; Open Evidence; IIASA, ICCT, 2016).

Noise level (Dittrich, et al., 2015)

Regulation 540/2014 has introduced new limits for vehicle noise (engine noise). The regulation will phase in new limits in three steps:

- by July 1, 2016 the first phase will only apply to new vehicle types;
- by July 1, 2020, the second phase will introduce lower dB limits not only to new vehicle types, but to all new vehicles being produced two years after the start of phase 2 (2022);
- by July 1, 2024, the third phase will introduce lower dB limits to all new vehicles produced two years after the start of phase 3 (2024).

At the end of these three phases, the limit for standard cars will be reduced to 68 dB in 12 years, while the current level is 74 dB (Environment News Service, 2014) It is recommended to include an overall performance indicator for vehicle noise in the new set of EU GPP criteria and to at least align the maximum level with above mentioned regulation or to set stricter limits to move the market forward.

Low noise tyres

In addition to taking into account Regulation 540/2014 low noise tyres can be stimulated to reduce tyre noise. As indicator the classification of the EU Tyre Label Directive (EC regulation No 1222/2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters) can be used. This Directive came into force on 1 November 2012. The label for tyre noise is expressed in dB and black waves: one black wave indicated the best noise level (3dB below legal limit) and three black waves indicate the weakest performance.

Market availability

The best-performing tyres in terms of noise are widely available at no additional cost. In Figure 36 the development in market averages in the period 2013-2015 is depicted, which shows an increase rather than a decrease in dB over these three years.

Figure 36: External rolling noise (measured dB) shown as market averages **(Viegand Maagøe A/S, 2015)**

Tyre	**2013**	**2014**	**2015**
C1	70.67	70.86	70.80
C2	71.98	72.07	72.03
C3	72.19	72.05	71.71

Improvement potential

In Table 42 the reduction potential of low noise tyres compared to the average rolling noise emissions per tyre class is presented.

Table 42: Estimated reduction of rolling noise emissions per vehicle based on the difference between the average tyre and best performing low noise tyre

Tyre class	**Vehicle category**	**Limit value in Reg (EC) 661/2009 (dB)**	**Average rolling noise emission of subcategory (dB)**	**Best performing low noise sample of subcategory (dB)**	**Estimated reduction of rolling noise emissions (dB)**
Weighted average/sum C1	Passenger cars	71.2	69.9	66.2	-3.7
Weighted average/sum C2	LCVs	72.7	71.6	68.6	-3
Weighted average/sum C3	Trucks/ lorries	73.8	71.9	66.1	-5.8

Cost

Low noise tyres do not require additional investment cost. For end-users annual cost savings are about €117 for passenger cars (€2 418 for long-haul vehicles). In terms of environmental and social issues, replacing the current tyres by best-performing tyres will result in fuel reduction (and CO_2 reduction consequently), less traffic accidents and less people highly annoyed by road traffic noise and less people being highly sleep disturbed.

3.5.5 Improvement options for services

In the case of purchasing services, the various types of measures exist for improving the environmental performance. First of all, all vehicle-related measures as presented in the previous section can also be requested when purchasing services.

In addition, measures targeting driving behaviour can also contribute. So-called '**eco-driving**' can involve several driving techniques that drivers can use to improve the fuel economy of their car such as using a higher gear and limiting fast acceleration, apply an anticipating driving style, minimising unnecessary braking, minimising idling and maintaining tyre pressure at specified levels. Most estimates available in literature indicate that eco-driving techniques result in an average emission reduction of 10 to 15% (CE Delft, 2012).

The starting point for encouraging employees to adopt this eco-driving style is often to implement a driving course, which immediately results in significant fuel. However, these savings reduce rapidly if driving courses are not regularly repeated and/or if no follow-up measures are taken by the company to motivate employees. With follow-up measures, significant CO_2 reduction potential can be sustained. Such measures include monitoring the performance of individual drivers and offering feedback, internal eco-driving competitions.

The cost of applying a full eco-driving package like outlined above includes:

- The trainer fee for the driving course and loss in man hours when employees are in training. TNO et al. (2006) estimated the costs of the driving course at €50-100, which does not cover the loss in man hours. FLEAT (2010) does include this loss of man hours, which results in costs of €300 to 1 000 per driver.
- Setting up a monitoring and feedback system, and the FTEs spend on the actual execution the system. Costs are highly dependent on the complexity of the monitoring and feedback, wages, etc.

Besides fuel cost savings, eco-driving also has various types of co-benefits like fewer accidents and lower maintenance costs. Although only fuel cost savings are taken into account, most studies estimate that eco-driving has negative GHG abatement cost (i.e. higher benefits in terms of fuel savings than costs), with abatement costs ranging from -€315 to €15 per tonne ((CE Delft, 2008), cited in (CE Delft ; TNO, 2012); TNO et al., 2006; (FLEAT, 2010). Finally, eco-driving can result in other positive impacts, such as reducing traffic noise and improving road safety (which in turn positively impacts congestion, reduces medical costs and improves health) (CE Delft, 2012).

Another category of measures that is relevant when purchasing services, are **measures targeting mobility services**. In this regard, Holmberg et al. (Holmberg, et al., 2016) highlight that the environmental improvement that might be derived from the mobility services relies on the assumption that the primary customer group is the car-user, and not the public transport everyday user. The intermodality, referring to the seamless use of several different modes in one trip chain, is therefore a key element to ensure the environmental improvement from mobility services. Holmberg et al also reported that Ubigo trial analysis supported that the net-effect was positive, but some users had changed their habits into more car usage (taxi, car sharing).

A particular type of modal shift is that from cars to light electric vehicles (LEVs). Particular for short to medium distance trips, LEVs can be an alternative for car travel. Another option in that segment is using electric bicycles.

The impacts on the mobility costs of measures aimed at modal shift are very case specific; no quantitative evidence is available on the overall cost savings that could be realised. Holmberg et al recommend the analysis of more initiatives and point out the absence of methods to measure the environmental effects.

4 PUBLIC TRANSPORT BUSES AND BUS SERVICES

4.1 Introduction

This chapter describes the overall and public market of public transport buses and bus services, followed by a cost analysis, the views of stakeholders on the current criteria, and a technical analysis.

4.2 Market analysis

4.2.1 Overall market

Currently, there are slightly less than 600 000 buses in the European fleet, growing by 4,500 vehicles per year.

Table 43: Market data of public transport buses in the European Union

Quantity	Unit	Value	Year	Source
Current size of the fleet[86]	Vehicles	574 003	2013	(EC, 2015 d)
Annual growth rate[87]	Vehicles/year	0.5%	2013/2012	(EC, 2015 d)
EU production	Vehicles/year	n/a		
EU sales (new registrations)	Vehicles/year	24 000		(Ricardo Energy & Environment ; TEPR, 2015)
Import (into EU)	Vehicles/year	n/a		
Export (out of EU)	Vehicles/year	n/a		
EU performance[86][88]	Passenger-km/year	263 517 000 000	2013	(EC, 2015 d)
EU performance	Vehicle-km/year	n/a		
EU apparent consumption	Passenger-km/vehicle/year	n/a		
EU apparent consumption	Litres of fuel/vehicle/year	n/a		
Number of journeys	Journeys	31 700 000 000	2012	(UITP, 2015)

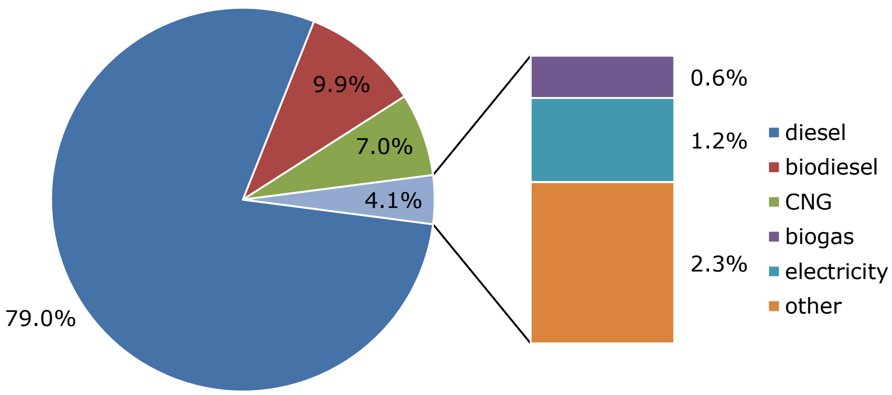
[86] 822 900 buses and coaches (EC, 2015 d) minus 248 897 coaches (Steer Davies Gleave, 2009).

[87] Buses and coaches.

[88] 526 500 000 000 passenger-km/year by buses and coaches (EC, 2015 d) minus 262 983000 000 passenger-km/year by coaches (Steer Davies Gleave, 2009).

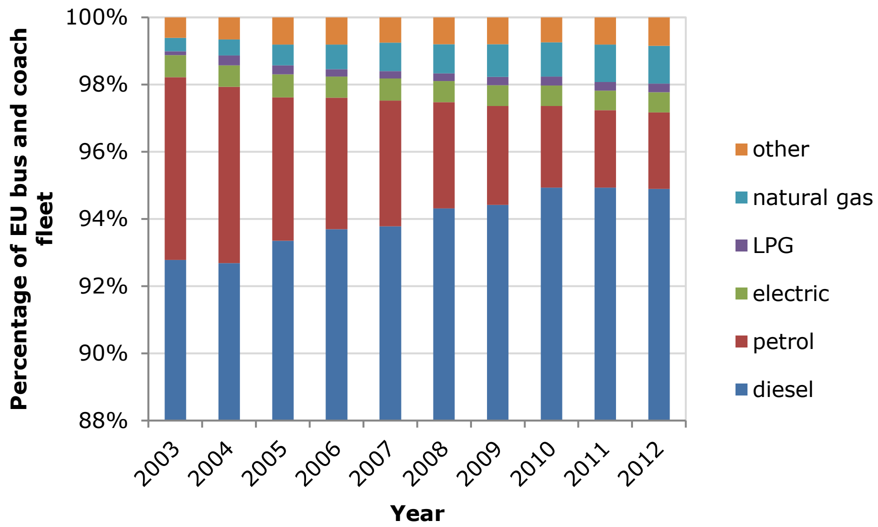
A survey in 2013 for 70 bus stakeholders in 24 countries resulted in the majority of buses for public transport in Europe driving on diesel (79%) or biodiesel (10%), as shown in Figure 37. The remaining buses use biogas (0.6%), electricity (1.2%, including trolley buses), or other means (2.3%). However, 40% of the bus stakeholders want to change towards more electric transport, mainly by means of more hybrids and more FEV, but significant increases of CNG, biodiesel and biogas can also be expected based on the survey outcomes.

Figure 37: Shares of fuel type in current public transport bus fleet in the European Union **(3iBS, 2013)**



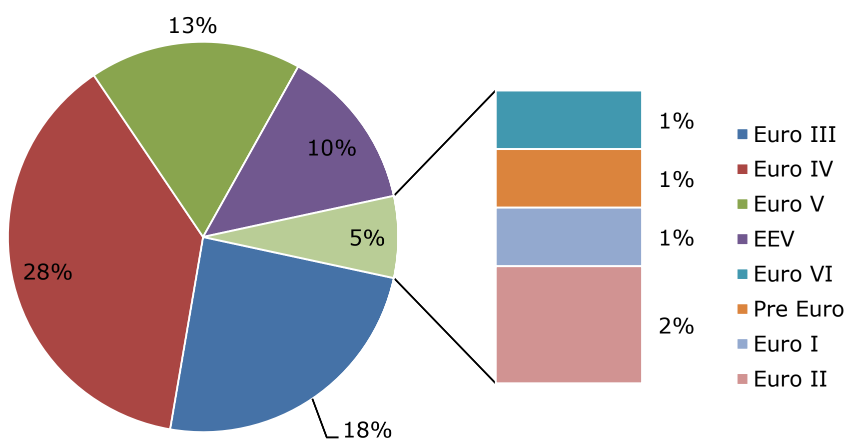
Statistical data from 2003 to 2012 illustrated (Figure 38) that a vast majority of the bus and coach fleet drive on diesel, increasing by approximately 2 percentage point to 95%. The share of alternative fuels increased by 1 percentage point, also at the expense of petrol. Discrepancies between Figure 37 and Figure 38 may arise from a different fuel type distribution among coaches than among buses, or from a bias in the survey.

Figure 38: Shares of fuel type in current bus and coach fleet in the European Union **(Eurostat, 2015e)** (Note: vertical axis starts at 88%)



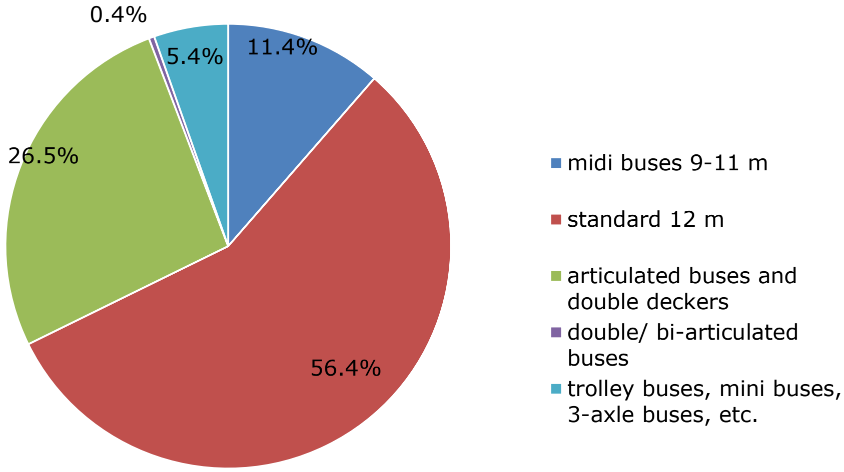
More than half of the current bus fleet using diesel is still equipped with Euro III (implemented in 2000) or Euro IV (in 2005) engines. About a quarter has Euro V or EEV engines and only 1% conforms to the latest Euro VI standard. A small fraction (4%) does not even meet the Euro III standard. Figure 39 summarizes the shares of the different Euro standards in the current European public transport bus fleet.

Figure 39: Shares of Euro-standards in current public transport bus fleet in the European Union **(UITP, 2015)**



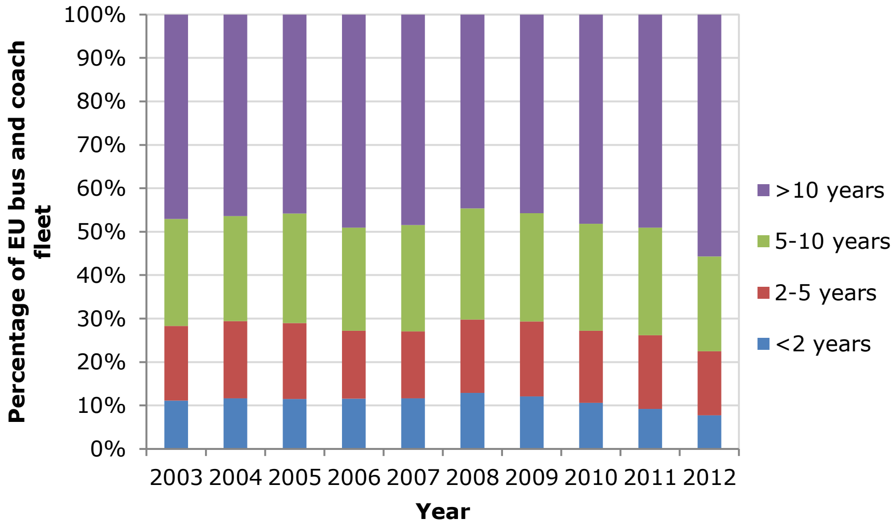
Standard buses (56.4%) and articulated buses and double-deckers (26.5%) are the most common buses in the current European fleet, as can be seen in Figure 40. Smaller fractions are taken up by midi buses (11.4%), double/bi-articulated buses (0.4%), and trolley/mini/3-axle buses (5.4%).

Figure 40: Shares of sizes in current public transport bus fleet in the European Union **(3iBS, 2013)**



About half of the buses and coaches in the European Union is older than 10 years, as shown in Figure 41. The other half is distributed evenly with age. Since 2008, the average age of the bus and coach fleet is increasing slowly. The reason behind this aging of the fleet might be the economic crisis which might have entailed a lower replacement rate.

Figure 41: Shares of vehicle age in current bus and coach fleet in the European Union **(Eurostat, 2015e)**



4.2.2 Public procurement

For buses, the 2015 CVD evaluation was not able to find comprehensive data for any Member State that would enable the estimation of the number of buses procured by the public sector in the EU. Instead the report brought together data from various sources to break down the total number of annual bus and coach registrations according to ACEA (see Table 44). Using this approach the report estimated that 18 000 buses were procured by contracting authorities or by transport operators performing public service obligations each year (see Table 44).

Table 44: Estimate of the number of buses that are procured annually by/for the public sector

	Estimates
Total annual registrations of buses and coaches	31 000
Estimated proportion of these which are buses	76%
Total annual registrations of buses	24 000
Estimated proportion of buses procured by the public sector or for performing public service obligations (PSOs)	75%
Total number of buses procured by contracting authorities or transport operators performing PSOs each year	18 000

Source: Ricardo Energy & Environment and TEPR (2015), see Table 9-5 of this report.

The public procurement of buses and buses services is usually carried out under the framework of the following public transport regimes (Velde, et al., 2008):

- **In-house operation:**

In-house operators or publicly owned operators are quite common in urban public transport in Europe. However this regime has evolved towards the corporatisation of the passenger transport unit of the authority into an 'in-house' operator; and the introduction of a contractual relationship between the owner and/or transport authority and the in-house operator.

- **Route contracting under competition:**

In this case, the authority organises the contracting out of the routes and services planned. It can be observed in the Copenhagen, Stockholm or London area. In such areas, one or several regional and local governments co-operate to form a transport authority which has its own planning body which itself mostly results from the split-up of the former regional transport company into a planning division and a bus division. Route-by-route competitive tendering is very common in Denmark and Sweden.

- **Network contracting under competition:**

The contracting authority organises the tendering of all services, area-wise or for the whole urban network. These services are regulated by standards services which determine the 'public service obligations'. This organisational form is mainly used in France. It is also a practice in public transport in the Netherlands and in Germany. This regime allows operators to make use of some of the service design freedoms inherent in deregulated operators.

- **Deregulated regimes (free market initiative with additional contracting):**

This regime is most clearly visible in the British bus sector (outside London), where it was introduced in 1986. In this organisational form, the service stems from a market process, even though some subsidies may be involved. These are aimed at compensating public service obligations (for example, special fare for target groups). Some regulation may be needed, such as published fares and timetables, service coordination, integrated information and ticketing, accessibility, minimum frequencies, etc.. For this reason, the British regime has evolved towards a new balance between competition and coordination. The Transport Act 2000 created the possibility for Statutory Quality Bus Partnerships, Quality Contracts (i.e. effectively creating the possibility to abolish deregulation and replace it by competitive tendering). The Local

Transport Act (LTA) 2008 set a Quality Bus Partnerships covering also fares and services, and with easier to implement Quality contracts.

4.3 Cost analysis buses

In this section, the Total Cost of Ownership is calculated for public transport buses. Only one type of bus is assessed. No different variations are taken into account as with passenger cars and LCVs; no ranges have been assumed for the various values. Table **45** shows the parameters that are used for this calculation.

Table 45: Parameters used for the cost analysis of public transport buses

Parameter	**Value**	**Source**
Acquisition costs incl. Taxes (€)	265 000	(CE Delft, 2007)
Lifetime (years)	14	(TIAX, 2011)
Fuel consumption (L/km)	0.360	(AEA, 2011)
Fuel price incl. Taxes (€/l)	1.040	(EC, 2016a)
Fuel price excl. Taxes (€/l)	0.378	
Maintenance costs incl. Taxes (€/km)	0.155	(CE Delft, 2007)
Insurance (€/year)	2 117	(89)
Circulation taxes (€/year)	517	(90)

For public transport buses, three scenarios are used based on different annual mileages of 50 000, 60 000, and 70 000 km/year. Based on these numbers and the previously determined fuel consumption, the lifetime fuel consumption is calculated for the three scenarios, as shown in Table **46**.

Table 46: Annual mileage assumed for different scenarios and consequent lifetime mileage and fuel consumption

Parameter	**Value**	**Scenario**
Annual mileage (km/year)	50 000	1
Lifetime mileage (km)	700 000	
Lifetime fuel consumption (l)	252 000	
Annual mileage (km/year)	60 000	2

[89] Same proportion to circulation taxes as for passenger cars.

[90] Calculation based on (CE Delft, 2016a).

Lifetime mileage (km)	840 000	
Lifetime fuel consumption (l)	302 400	
Annual mileage (km/year)	70 000	3
Lifetime mileage (km)	980 000	
Lifetime fuel consumption (l)	352 800	

Using the values from Table 45 and Table 46, the different contributions to the Total Cost of Ownership are calculated, both with taxes and without, for all three scenarios. The fuel costs and maintenance costs depend on the annual mileage and are therefore different between the scenarios. The other costs are the same for all three scenarios. Table 47 shows the costs with taxes, whereas Table 48 shows the costs without taxes.

Table 47: Contributions to the Total Cost of Ownership with taxes for the three scenarios

Parameter	**Value**	**Scenario**
Acquisition costs incl. taxes (€)	265 000	All
Fuel costs incl. taxes (€)	262 000	50 000 km
Fuel costs incl. taxes (€)	314 000	60 000 km
Fuel costs incl. taxes (€)	367 000	70 000 km
Maintenance costs incl. taxes (€)	109 000	50 000 km
Maintenance costs incl. taxes (€)	130 000	60 000 km
Maintenance costs incl. taxes (€)	152 000	70 000 km
Insurance incl. taxes (€)	30 000	All
Circulation taxes (€)	7 000	All

Table 48: Contributions to the Total Cost of Ownership without taxes for the three scenarios

Parameter	**Value**	**Scenario**
Acquisition costs excl. Taxes (€)	208 000	All
Fuel costs excl. Taxes (€)	95 000	50 000 km
Fuel costs excl. Taxes (€)	114 000	60 000 km
Fuel costs excl. Taxes (€)	133 000	70 000 km
Maintenance costs excl. Taxes (€)	89 000	50 000 km
Maintenance costs excl. Taxes (€)	107 000	60 000 km
Maintenance costs excl. Taxes (€)	125 000	70 000 km
Insurance excl. Taxes (€)	24 000	All

Figure 42 and Figure 43 show the Total Cost of Ownership for public transport buses with and without taxes for the three scenarios. The first thing that can be deduced from the graphs is that the shorter the annual mileage in the scenario, the larger the total cost per km is. This is easily explained by noting that the fixed costs are divided by more kilometres.

With taxes, the acquisition costs match the fuel costs in scenario 1 and become slightly less important in scenarios 2 and 3. Insurance and circulation taxes are small at all annual mileages. Maintenance and fuel costs per km keep constant, since they are proportional to the distance.

Figure 42: Total Cost of Ownership with taxes per vkm for public transport buses

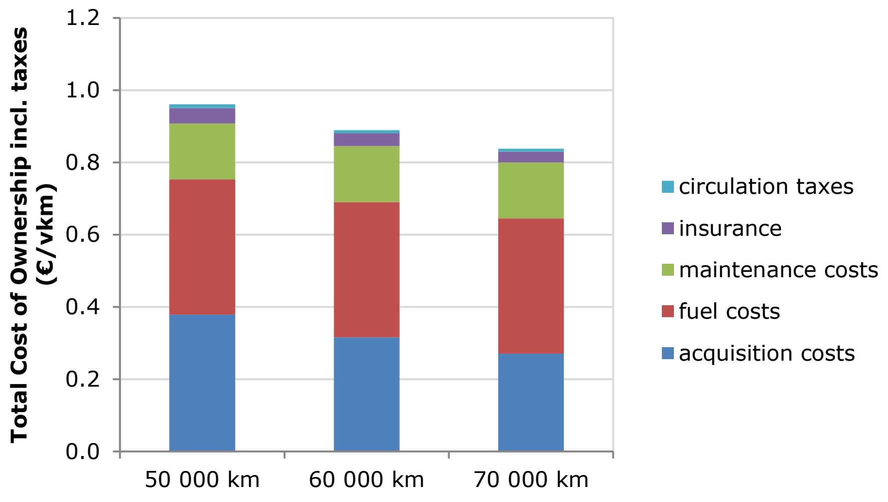


Figure 43: Total Cost of Ownership without taxes per vkm for public transport buses

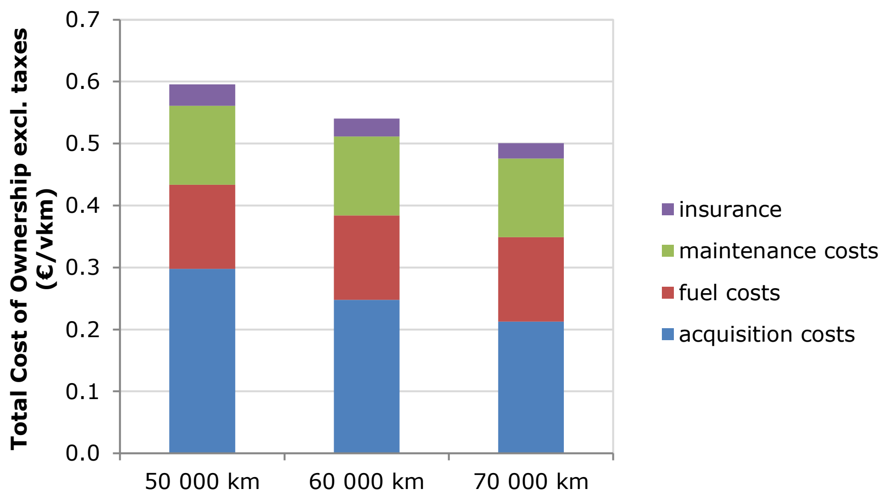


Table 49 (with taxes) and Table 50 (without taxes) give an overview of the Cost of Ownership of a public transport bus, over the lifetime, per year, and per km.

Table 49: Total Cost of Ownership with taxes for public transport buses for the three scenarios

Parameter	**Value**	**Scenario**
Total Costs of Ownership incl. taxes (€/vehicle)	672 000	50 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	48 000	

Per km Cost of Ownership incl. taxes (€/vkm)	0.96	
Total Costs of Ownership incl. taxes (€/vehicle)	747 000	60 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	53 000	
Per km Cost of Ownership incl. taxes (€/vkm)	0.89	
Total Costs of Ownership incl. taxes (€/vehicle)	821 000	70 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	59 000	
Per km Cost of Ownership incl. taxes (€/vkm)	0.84	

Table 50: Total Cost of Ownership without taxes for public transport buses for the three scenarios

Parameter	Value	Scenario
Total Costs of Ownership excl. taxes (€/vehicle)	417 000	50 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	30 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.60	
Total Costs of Ownership excl. taxes (€/vehicle)	454 000	60 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	32 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.54	
Total Costs of Ownership excl. taxes (€/vehicle)	491 000	70 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	35 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.50	

4.4 Cost analysis bus services

The cost structure of bus services consists of cost for labour, depreciation and financing the vehicles, fuel cost, maintenance, repair and components and costs related to running the organisation, like the cost for renting an office and IT facilities. In Table 51 a rough indication of the cost breakdown is given and shows that above mentioned TCO of the vehicles (depreciation costs and financing fuel costs and maintenance, repair and components) compromise about 33% of the total cost of a public transport service. Cost will differ per country and transport service, because factors like the transport service area (rural/urban) and size of the fleet also impact the cost structure. However, no more detailed information could be found.

Table 51: Indicative cost structure of a public transport company

Category	Relative share of cost
Labour (bus drivers and office staff)	60%
Depreciation costs and financing	15%
Fuel costs	10%
Maintenance, repair and components	8%
Organisation (renting offices, IT etc.)	7%
	100%

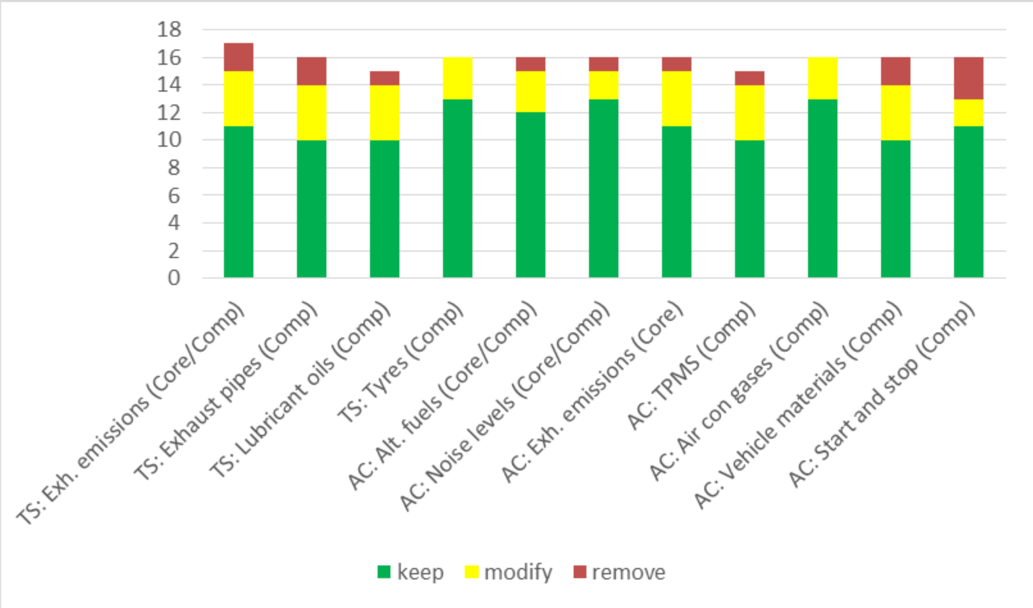
Source: (ING, 2009).

4.5 Stakeholder views on current criteria

4.5.1 Purchase or lease of buses

Of the 26 different stakeholders that responded to the survey around two thirds had views on the various criteria relating to the purchase or lease of buses (see Figure 44). In all cases, the majority of stakeholders supported keeping the existing criteria, although a minority called for a modification in each case and, for most criteria, at least one stakeholder called for its removal.

Figure 44: Views of the stakeholders on the existing EU GPP criteria for the purchase or lease of buses



Key: 'Core/Comp' in brackets means that the criterion was both a core and a comprehensive criterion, while those criteria that only have 'Comp' in brackets were only included as a comprehensive criterion. 'TS' indicates that the criterion was proposed as a 'Technical Specification', while 'AC' means that it was proposed as one of the 'Award criteria' and 'CPC' indicates that it was proposed as a 'contract performance clause'.

Comments calling for the modification and removal of the 'Exhaust gas emissions' criterion from the technical specifications were based on the same reason as for the purchase or lease of cars and LCVs (see Section 3.4): that the criteria were now out of date as all new vehicles met the Euro VI standard of the comprehensive criterion. For some, this suggested that the criterion should be modified; others argued that this suggested that they should be removed. Of those supporting modification, one stakeholder called for the current comprehensive criterion to be made a core criterion, whereas another called for the change to promote "state-of-the art conventional buses" using CNG or hydrogen, or even retrofitting. Others argued for changes to wider legislation, including a change in the way in which air pollutants are measured by changing these to g/km in order to encourage reductions in the size and power of buses or legislation to regulate CO_2 emissions of buses.

Two of the comments supporting a modification to the criterion on the location of 'Exhaust pipes' argued that this criterion should be a core, rather than a comprehensive, criterion, while another argued that it should be modified to ensure that the exhaust pipe was directed upwards. An operator noted that there was a lack of clarity, as it was not clear whether the criterion also applied to the exhaust pipes from additional heaters, which were often on the passenger side of the vehicle.

The three stakeholders arguing for a modification of the 'Lubricant oils' criterion all called for the current comprehensive criterion to be made a core criterion, which was also the position of one stakeholder in relation to the 'Tyres' criterion. Other proposed modifications to the latter included basing it on UN Regulation No 117, revision 3 and the latest UNECE requirements on tyre noise and rolling resistance or adapting it to take account of the tyre label categories[91].

Two of the stakeholders in favour of a modification of the 'Use of alternative fuels' criterion argued that it should not focus on particular fuels, but rather on the CO_2 emissions reductions that should be delivered. Other stakeholders suggested that the criterion be used to promote vehicles using CNG and hydrogen and that it should be a technical specification rather than an award criterion. The stakeholder that called for the removal of the criterion argued that the use of alternative fuels was not a consideration made in the course of purchasing, but was part of a public transport authority's wider strategy.

With respect to the 'Noise emission levels' criterion, those in favour of modification argued that it should be made a technical specification rather than an award criterion or that it should be aligned with the vehicle noise Regulation[92]. The stakeholder that called for the removal of the criterion stated that noise emission levels should be kept at the levels required by law.

Similar arguments were made in relation to the 'Exhaust gas emissions' award criterion, as were made in relation to the 'Exhaust gas emissions' technical specification criterion (see above), as the award criterion was also considered to be out of date. Stakeholders commented that, as a result, the criterion should be made a core criterion rather than a comprehensive one or that the fact that some buses have lower emissions than required by the Euro VI standard should be reflected in the criterion. The fact that all buses meet the Euro VI standard was also the justification provided by the stakeholder that called for the removal of this criterion, while another argued for a shift to a bus's CO_2 emissions as there were no further air pollutant emissions standards in place.

The majority of those supporting a modification of the 'Tyre Pressure Monitoring System' criterion called for it to be made a core, rather than a comprehensive, criterion. On the other hand, a couple of stakeholders, including the one that argued for the removal of the criterion argued that a focus on TPMS does not necessarily lead to an optimal solution when the vehicle is considered as a whole. Those supporting the modification of the 'Air conditioning gases' criterion also wanted it to become a core criterion.

With respect to the 'Vehicle materials' criterion, two stakeholders were in favour of a stronger criterion, e.g. for it to incentivise mass reduction or to include a reference to the content of recycled materials used as both a core and a comprehensive criterion. On the other hand, another argued that it was important to modify the criterion, as it was difficult to compare the environmental performance of different vehicles. The stakeholder supporting the removal of this criterion argued that price was still the most important selection factor in a tender, so requirements on vehicle materials would be better as a direct legal requirement on bus manufacturers.

[91] Regulation (EC) No 1222/2009.

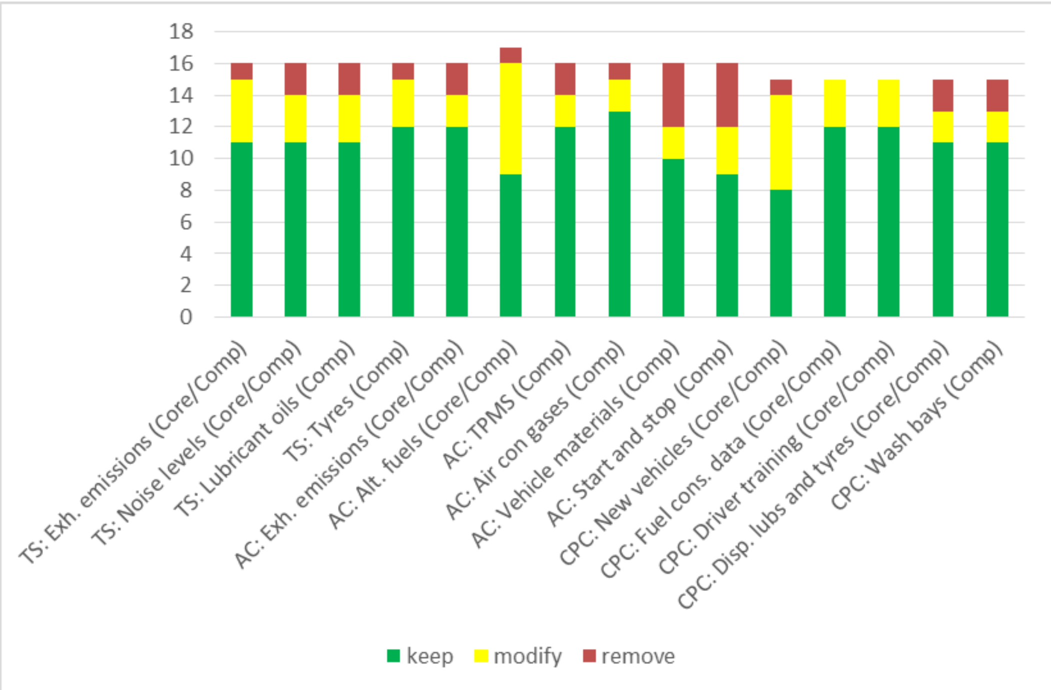
[92] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

Three stakeholders called for the removal of the criterion relating to the fitting of a 'Start and stop' system to a bus, arguing that such systems made no sense for buses using conventional engines or that it risked sub-optimising the energy efficiency system of these vehicle (even though it was an obvious system to include on electric buses). Other stakeholders argued that the criterion should be core, not comprehensive, or that a light version of a stop-and-start system be included that includes an 'Idle Shutdown' function, which means that the bus shuts down the engine if it idle for a few minutes.

4.5.2 Provision of bus services

As with the purchase or lease of bus services (see above), around two thirds of the respondents to the survey provided views on the criteria relating to the provision of bus services (see Figure 45). A majority of stakeholders were in favour of all of the criteria being kept, although a significant proportion of stakeholders called for the modification of some criteria, such as the 'Use of alternative fuels' and 'New vehicles'. There was at least one stakeholder who called for the removal all but two of the criteria.

Figure 45: Views of the stakeholders on the existing EU GPP criteria for the provision of bus services



Key: 'Core/Comp' in brackets means that the criterion was both a core and a comprehensive criterion, while those criteria that only have 'Comp' in brackets were only included as a comprehensive criterion. 'TS' indicates that the criterion was proposed as a 'Technical Specification', while 'AC' means that it was proposed as one of the 'Award criteria' and 'CPC' indicates that it was proposed as a 'contract performance clause'.

A number of stakeholders called for the modification of the 'Exhaust gas emissions' criterion for the same reason as for the purchase or lease of bus services: that Euro VI was now mandatory for all new buses, so the criteria were out of date. A proposed modification included requiring Euro VI engines under both the core and comprehensive criteria. On the other hand, one stakeholder thought that Euro IV was too strict to have as a core technical specification.

The stakeholders in favour of modifying the 'Noise emissions' criterion argued for a stricter standard, including aligning it with the vehicle noise Regulation[93]. Those supporting the criterion's removal proposed that the criterion should only be a core criterion not a comprehensive one, while another stated that noise emission levels should be kept at the levels required by law. The stakeholder that called for a modification of the 'Lubricant oils' criterion called for it to be a core criterion as well as a comprehensive one, whereas the stakeholder that called for its removal argued that such products are best regulated elsewhere, e.g. in chemicals legislation.

All of the stakeholders in favour of the modification of the 'Tyres' criterion called for it to be stricter. Suggestions included requiring compliance with UN Regulation No 117 (revision 3) and the latest UNECE requirements on tyre noise and rolling resistance, making the criterion core as well as comprehensive, and requiring that only tyres with label category A are used[94].

Most of the comments made in relation to the 'Exhaust gas emissions' award criterion reflected those made in relation to these emissions used as a technical specification (see above). The one exception suggested that the criterion be merged with that relating to the 'Use of alternative fuels' and be used to reward hybrid, electric and hydrogen buses. Some of the comments directly relating to the alternative fuels reflected comments made in relation to this criterion in previous vehicle categories, calling for more clarity as to what this criteria was ultimately trying to achieve, or that the focus should be on reducing CO_2 emissions rather than promoting particular types of fuel. On the other hand, one stakeholder called for it to be only a comprehensive, not a core, criterion, while the stakeholder calling for its removal argued that it was better to let public transport authorities promote such fuels if they wished.

Only one of the comments supporting a modification of the 'Tyre Pressure Monitoring Systems' criterion called for it to be stronger, arguing that all vehicles should have such a system, rather than operators being rewarded for the proportion of their fleets fitted with a TPMS. On the other hand, others argued that focusing on TPMS risked sub-optimising the wider system or it missed actions that were potentially more environmentally beneficial. A representative of a public transport authority noted that they encouraged operators to find the best solutions to reduce fuel consumptions and CO_2 emissions on their own, rather than setting requirements.

A stakeholder also called for the 'Air conditioning gases' criterion to be applied to an operator's entire fleet, rather than an operator being rewarded for the proportion of its vehicles that had air conditioning systems that met the conditions. Another stakeholder called for the addition of another condition, i.e. for the maximum ΔC° from external temperature for the in-use phase to be indicated. The stakeholder that called for the removal of this criterion argued that there were already enough environmental criteria and so this one was not needed.

One quarter of those that expressed a view, called for the 'Vehicle materials' criterion to be removed. Reasons for this included that the requirement risked sub-optimising the energy performance of the vehicle, that material use was best addressed through legislation, that it was too strict, or that it was unnecessary as there were already enough environmental criteria. The one comment in support of modifying the criterion reiterated support for mass reduction generally.

The removal of the 'Start and stop' criterion was also called for by one quarter of those that expressed a view. The associated comments reflected those made in relation to the

[93] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

[94] Regulation (EC) No 1222/2009.

purchase of buses, including that the requirement did not make sense for buses with combustion engines and that the inclusion of such a system risked sub-optimising the energy efficiency of the vehicle. Another stakeholder felt that it was another unnecessary environmental criterion. Of those in favour of modifying the criterion, one believed that it was too strict, while another believed that it should be a core criterion, rather than a comprehensive one. Another stakeholder argued, as with the purchase of buses, for the inclusion of an 'Idle Shutdown' function (see Section 4.5.1).

The many comments calling for a modification of the 'New vehicles' criterion reflected the fact that the criterion is broad as it covers the Euro emissions standards of the vehicles, requires the fitting of a TPMS and that the exhaust pipe is located on the side opposite to the passenger door. One stakeholder called for either the removal of the requirements relating to TPMS or those relating to the location of the exhaust pipe. Others argued for the criteria to be strengthened, including adding noise emissions or requiring that all vehicles under both the core and comprehensive criteria meet Euro VI standards. One stakeholder made a similar comment for this as for previous criteria: that this was another unnecessary environmental criterion.

A comment to support the modification of the 'Fuel consumption data' criterion underlined that real consumption data is better than estimated or simulated data, while another questioned the need for the criterion in its current form as operators already take account of such costs in their quote, arguing instead for a CO_2-based criterion. Another stakeholder believed that the criteria should only be comprehensive, not core. There was a similar comment in relation to the 'Training of drivers', i.e. that it should only be a comprehensive criterion, while an operator noted that they had installed eco-driving systems in buses as training alone was not sufficient.

There was one comment with respect to the modification of the 'Disposal of lubricant oils and tyres' criterion, which was that as operators needed to follow the laws in their respective countries regarding disposal, the current criterion should be replaced by a requirement that operators have an environmental reporting system. The two stakeholders that argued for this criterion to be removed argued that rules for the disposal of waste were too dependent on national law to be included, while another reiterated that this was another unnecessary environmental criterion.

Similar comments were made with respect to the 'Wash bays' criterion, i.e. that it might be better as part of an environmental reporting system or that it was another unnecessary environmental criterion. On the other hand, one stakeholder argued that this should be a core, as well as a comprehensive, criterion.

4.6 Technical analysis

4.6.1 Identification of environmental hotspots along the life cycle of buses

For the identification of environmental hotspots of buses the same approach has been used as for passenger cars and LCVs. Fewer LCA-studies are available for buses, but the focus of available studies is similar to passenger cars and LCVs: most of the studies focus on the comparison between ICEV and EVs, while other drivetrains receive less attention. In contrast to passenger cars, natural gas deserves more attention. End-of-life has not been discussed in the studies investigated and will therefore be not further discussed below. The LCA review can be found in Annex C: LCA literature review for buses.

GHG emissions

Overall

Like for passenger cars, GHG emissions are the dominating type of emissions and mainly the result of the use phase. Due to the variety in this market segment, studies on buses focus on slightly different subjects. For example, electric buses know a wider variety in electric drivetrain configurations and charging options. Some studies therefore focus on these differences, for example between plug-in buses and wireless charging. Over the entire life cycle, wireless charging consumes slightly less energy (0.3% less energy and 0.5% less GHG) compared to plug-in buses. This is because of the trade-off between higher GHG and energy burdens for the wireless charging infrastructure and the battery size, which can be downsized to some extent. The electricity consumption in the use phase dominates the energy demand and GHG emissions and accounts for about 97-98% of CED and GWP.

Upstream processes/vehicle manufacturing

The conclusions drawn for LDVs on the impact of the upstream processes and vehicle manufacturing are also valid for buses. Battery production also results in the biggest impact in this phase. Therefore increasing the energy density of batteries or extending the lifetime of batteries can result in significant reduction in total life cycle emissions: according to Cooney, et al., 2013 a 25% increase in energy density of Li-on batteries will result in a reduction of 1.1% GWP. Doubling the lifetime of a battery halves the required battery replacement over the lifetime of a bus and results in 2% reduction in GWP.

Use and maintenance

Like for passenger car the use phase is dominated by the energy supply chain and exhaust emissions of the vehicles. The CO_2-intensity of the electricity mix strongly determines the GHG emissions in the use phase and determines to what extent emissions are reduced or not. A study on buses in various US states have found that electric buses only result in emission reductions (compared to conventional buses) in 8 states. These states have for example higher shares of hydropower in their energy mix. With the lower GHG intensity of electric power in most EU countries than in the US, electric buses have in most cases significantly lower GHG emissions over the entire life cycle, compared to conventional buses. As an example, with the average power mix in the Netherlands the reduction for electric buses is about 30% compared to new diesel buses (TNO & CE Delft, 2014).

At the EU level, HGVs and buses are responsible for 19.3% of GHG emissions from transport according to 3.5.1, in which HGVs are likely to be the dominant vehicle type. According to Umwelt Bundesamt (Ifeu - Institut für Energie- und Umweltforschung Heidelberg gGmbH, 2015) city buses, including rigid and articulated buses, represent 4.4% of CO_2 emissions. This may seem small, but as the share of buses purchased by public institutions is relatively high, also potential impacts of GPP criteria for buses can be significant.

Further insight in WTW and TTW GHG emissions will be provided in Section 4.6.3.

Other environmental impacts

When comparing air pollutant emissions over the entire life cycle, conventional buses have higher CO, NO_x and PM emissions, while electric buses are responsible for higher SO_x emissions, as result of electricity production (but generally emitted further away from people). (see the Annex for the various sources)

Upstream processes/vehicle manufacturing

When zooming in on the battery production process, battery production turns out to be an important factor in several environmental impact categories. Conventional buses score better on ozone depletion potential, carcinogens and eco-toxicity (as result of cobalt production). Like for GHG emissions, further improvement of battery production also results in less environmental impacts: a 25% increase in energy density of Li-on batteries will result in a reduction of 1.7% reduction in particulate matter and 16% reduction in ozone depletion. Doubling the lifetime of a battery halves the required battery replacement over the lifetime of a bus and results in 4.5% reduction in PM, 39% reduction in ozone depletion potential.

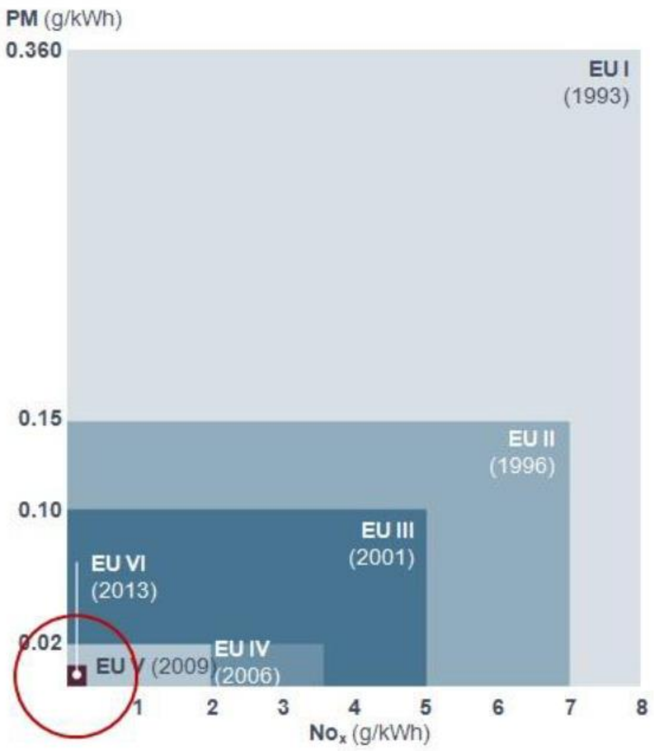
Use phase

The use phase is dominated by the air polluting emissions in the exhaust emissions. Improving the efficiency of the electric drive train, which is part of the use phase, results in a reduction of overall life cycle emissions for GWP, PM and ozone depletion: an increase in efficiency of the electric drive train from 75% to 80% will result in 11% reduction of GWP, 12% reduction in PM and 9% reduction in ozone depletion.

The share of buses (T&E, 2015b) in air polluting emissions has already been provided in Section 3.5.1 the share of different Euro standards in the EU bus fleet is depicted in Figure 39. The differences in g/kWh between the various Euro standards are depicted in Figure 46.

The environmental impacts related to the bus maintenance operations for the conventional buses, electric buses and the charging infrastructure are far less compared to the environmental impacts from other processes and therefore are not deemed to be relevant.

Figure 46: Pollutants by Euro VI standards in comparison with previous Euro standards



4.6.2 Technical options to reduce GHG emissions

The information on the improvement potential and cost of options for buses is provided below, distinguishing technical options to reduce CO_2 emissions, alternative powertrains and fuels and technical options to limit air pollution and noise.

Indicators and improvement options for CO_2 emissions (EC, 2016b)

While there are CO_2 emission standards in place for new cars and vans leading to CO_2 emissions being successfully reduced under recent EU legislation, no limits are in place for HGVs and buses. In May 2014, the EU adopted the HDV strategy, which can be seen as the first initiative to tackle emissions from these vehicle groups.

The Commission has developed the computer simulation tool, VECTO, to measure CO_2 emissions from new vehicles. Based on this tool, the Commission is likely to propose legislation for new HDVs on the short term, which will require CO_2 emissions to be certified, reported and monitored.

Because there are currently no uniform CO_2 emission values available for trucks, buses and coaches, it is, at this moment in time, not possible to define an overall performance based indicator for CO_2 emissions to be included in the GPP criteria.

This is also valid for the UITP standard: the SORT-test cycle, which has been especially designed for buses. SORT (Clean Fleets, 2014) stands for Standardised on-road text cycles and has been designed by UITP to measure fuel consumption in buses in a comparable way and therefore can be used in a call for tender to compare different buses. It is a real-life test with a full-size bus on a test track and aims to realise a sector-wide single-approach. Nowadays it has been widely recognised and accepted industry and therefore many bus manufacturers test their vehicles according to the SORT test. This makes the data easily available for procurers. According to the data provided by UITP (UITP personal communication 2016), 50% of their members use SORT in tenders, and in the future, it is expected to reach 80%. The Swedish, German and Italian national public transport associations have incorporated a SORT link in their national reference documents.

Because there is no legal framework yet the reduction of CO_2 emissions from public transport, alternatively, buses may rely on criteria, which require technical measures to be applied or which require a certain share of alternative fuels and powertrains.

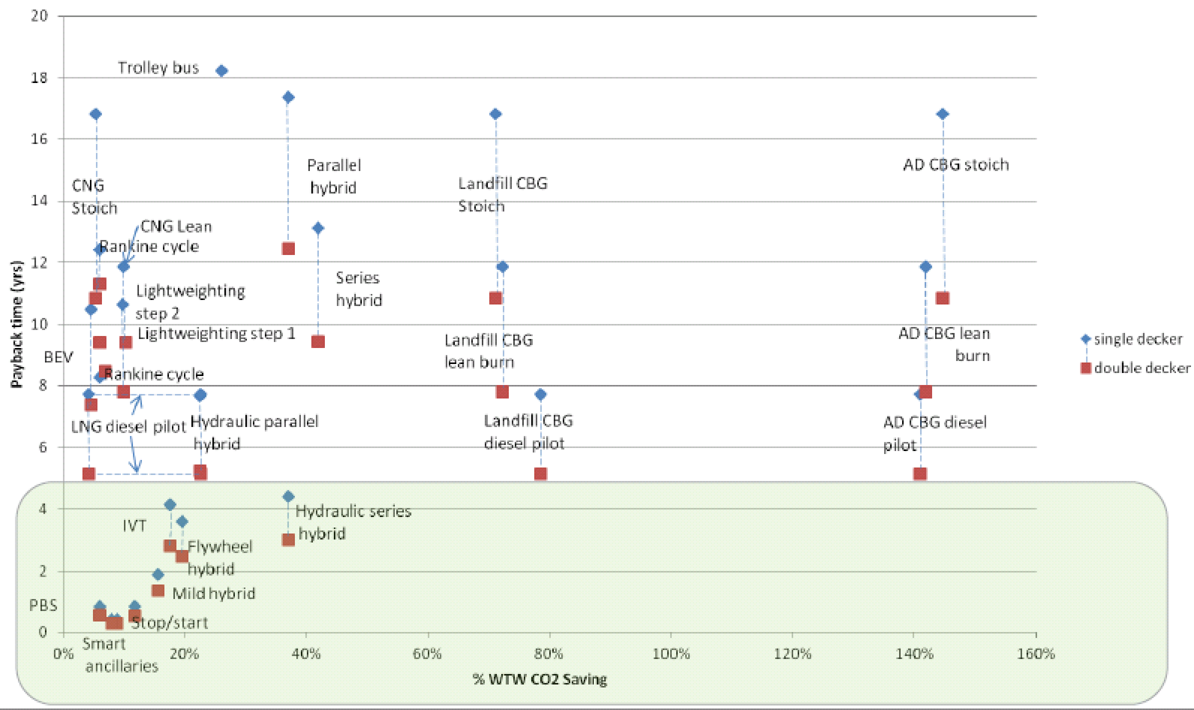
Hybridisation (Ricardo, 2013)

There are various options of hybridisation of buses. Ricardo-AEA (Ricardo, 2013) has identified various packages of different types of hybridization:

- stop start, pneumatic booster systems and smart ancillaries;
- mild hybrid and smart ancillaries;
- flywheel hybrid and stop start;
- series hybrid with diesel pilot and biogas engine.

There are, however, more options for hybridization, as can be seen in Figure 47, but most of the other options have a longer payback time. The assumptions behind are: 40 000 miles (64 374 km) per year both singledeck (SD) and doubledeck (DD); fuel consumption 8mpg (35 L/100 km) SD, 6mpg (47 L/100 km) DD; base diesel fuel price 50 ppL (€58 cents/L); base CNG, CBG price 60.3p/kg (€70 cents/kg) (prices do not include duty and Bus Service Operators Grant BSOG); electricity 8.5ppkWh (€10 cents/kWh).

Figure 47: Payback time versus CO_2 savings **(Ricardo, 2013)**



Market availability

The hybrid technologies of the packages are all commercially available and should be seen as a first stage of electrification of the EU fleet. No data could be found for the current application of these technologies in the current fleet other than the figures already presented in Section 4.2.

Improvement potential

The reduction potential of the four different hybridization packages as identified by Ricardo AEA is depicted in Table 52. Air polluting emissions are still caused by the conventional engine, but will significantly be reduced in case of the heavier forms of hybridization. Within the Ricardo AEA project baseline bus specifications were developed from manufacturers specifications for the four best-selling single and double deck buses in 2011 (both on diesel and Euro V/ EEV).

Table 52: Potential WTW savings for different packages of hybridisation

	WTW savings (%)
Stop start, pneumatic booster systems and smart ancillaries	18
Mild hybrid and smart ancillaries	22
Flywheel hybrid and stop start	24
Series hybrid with diesel pilot and biogas engine	125

According to CIVITAS WIKI Consortium (TNO (CIVITAS WIKI), 2013) noise emission are reduced by about 14% (standing) to 5% (passing by).

Cost

Below cost estimates are presented for the different packages as defined by Ricardo-AEA, but also cost estimates of CIVITAS WIKI (TNO (CIVITAS WIKI), 2013) for a serial hybrid bus. Both sources present cost in different units and therefore both sources are presented in Table 52 and Table 54.

Table 53: Investment cost, payback time and potential WTW savings for different packages of hybridization (Ricardo, 2013)

	Investment cost (€)	Payback time (years)
Stop start, pneumatic booster systems and smart ancillaries	3 000	0.2-0.3
Mild hybrid and smart ancillaries	7 100-7 500	0.5-0.7
Flywheel hybrid and stop start	16 400	1.0-1.5
Series hybrid with diesel pilot and biogas engine	120 000-135 000	7.0-9.8

Table 54: Cost of a serial hybrid bus compared to Euro VI diesel (TNO (CIVITAS WIKI), 2013)

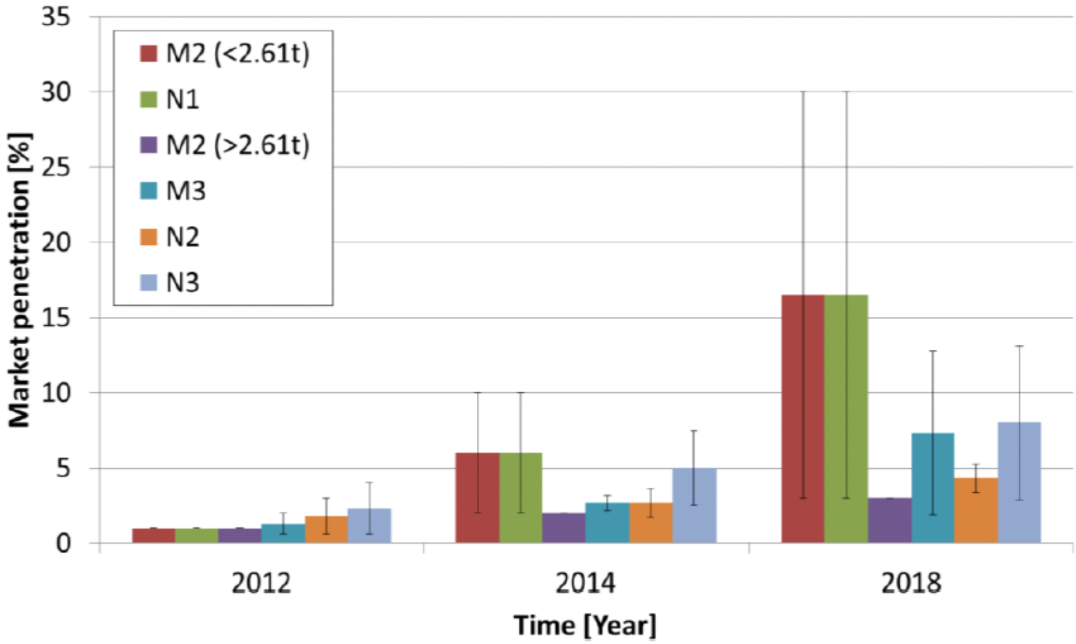
	Investment cost	Additional infrastructure investment	TCO		GHG abatement costs, well-to-wheel
	1 000 €	1 000 €	€/km 2012	€/km 2030	€/kg CO_2 eq.
Euro VI diesel	220	-	2.1	2.5	-
Serial hybrid electricity/ diesel	270 (+23%)	-	2.4 (14%)	2.7 (+8%)	0.4-0.5

Tyre Pressure Monitoring System (TPMS) (TNO, 2013)

Market availability

Like for LCVs, TPMS is a technically and economically mature product to be applied in HDVs, including buses. TPMSs are sufficiently available by various suppliers. The market penetration for HDVs is estimated to be on average between 3 and 8% in 2018: however, more autonomous growth is expected for N3 and M3 (buses) (TNO, 2013) vehicles, because the highest savings can be achieved within these vehicle categories

Figure 48: Current and projected market penetration of TPMS on new vehicles: (different colours indicate different vehicle categories, M2 and M3 relevant for buses) (TNO, 2013)



Improvement potential

For city buses TPMS has the lowest impact as shown in Table 55.

Table 55: TMPS impact on CO_2 emissions per vehicle category

		Lowest savings potential	**Highest savings potential**
M2	Minibus	-0.19%	-0.37%
M3	City Class I	-0.04%	-0.08%
M3	Interurban Class II	-0.09%	-0.17%
M3	Coach Class III	-0.14%	-0.27%
M3	Average	-0.08%	-0.15%

In addition to the CO_2 impacts, it is estimated that properly maintaining the tyre inflation pressure can reduce the number of speed and tyre related accidents by 4% to 20%, and the total number of accidents by 0.8% up to 4% (TNO, 2013).

Cost

The investment cost of TPMS for buses and coaches are listed in Table 56. Retrofitted systems are more expensive due to the higher installation efforts.

Table 56: Current and optimistic estimates of TPMS investment cost (TNO, 2013)

	OEM-fitted		Retrofitted	
	€ excl. VAT (optimistic)	**€ excl. VAT (current)**	**€ excl. VAT (optimistic)**	**€ excl. VAT (current)**
Bus	50	174	80	327
coach	52	209	80	378

TPMS can result in reductions in operating costs and societal costs for several reasons:

- fuel cost savings;
- reduced maintenance costs due to:
  - extended lifetime of tyres;
  - optimized inflation frequency.
- decrease in service disruptions;
- reduced roadside tyre breakdown;
- reduction of external costs due to:
  - reduced amount of accidents (fatalities, injuries and congestion)
  - reduced amount of emissions

In the scenarios of TNO, OEM-fitted TPMS is cost-effective for all vehicle segments at all diesel prices. Retrofitted systems are also cost-effective for buses and coaches. The different cost elements are presented in Table 57.

Table 57: Cost of TPMS (TNO, 2013)

Vehicle segment	OEM investment cost (ex VAT) [€]	Annuity [€]	Fuel savings (ex VAT) [€]	Extended lifetime of tyres [€]	Change in check frequency [€]	Reduced break-down [€]
Bus	174	29	-19	-37	+12	-12
Coach	209	35	-28	-38	+12	-12

Low rolling resistance tyres

Market availability

Category C3 of the Tyre Regulation Directive is for tyres for buses and lorries, with class D being the average score on rolling resistance, while A and B classes still have a very low market share of 0-1%. The shift towards low rolling resistance tyres has been mainly from label E to B/C.

Improvement potential

About one-third of fuel consumption stems from the rolling resistance of tyres. The study 'EU Transport GHG: Routes to 2050' has assessed the technical options for heavy duty vehicles and concluded that the reduction potential of a shift to low rolling resistance tyres can result in GHG emission savings of about 6% (AEA; TNO, n.d.).

There does not have to be a trade-off between safety and rolling resistance: low rolling resistance tyres can also perform excellent on other performance characteristics.

Cost

Like for passenger cars, cost differences between low rolling resistance tyres and regular tyres can expected to be low, because there seems to be no correlation between tyre costs and performance (TNO, 2014a).

Aerodynamics (EECA, 2015)

According to the study 'EU GHG: Routes to 2050', improved aerodynamic properties can reduce GHG emissions of HGVs by approximately 6%. This is probably not valid for city buses, because vehicles that mainly operate in 50 km/h speed zones will not benefit from aerodynamic devices installed on the vehicle, but might even face an increase of fuel consumption by 1%. Low-cost measures that can be taken for these low speed operating vehicles are placing of the load near the headboard whenever possible and covering empty tipper bodies (AEA; TNO, n.d.). Cost information is not available and will depend too much on the specific vehicle and the duty cycle of the vehicle to provide an average number here.

Air-conditioning improvement

A large share of the bus fleet is probably equipped with air-conditioning systems (MAC): in Germany 70% of new city buses are air-conditioned.

Buses and coaches (Honeywell, 2013) are excluded from the MAC Directive (2006/40/EC) which provides a gradual phase-out of refrigerant HFC-134a from mobile air conditioners in passenger cars and light commercial vehicles, although refrigerant R134a is the main refrigerant for buses (some buses use R407C).

About 13-15% of the refrigerant is released as leakages and the additional fuel consumption of MACs is about 4 l/km (this is also valid for ancillary heating).

The various cost factors for two alternatives for R134a are given in Table 58 and show a wide variation in cost and environmental impacts.

Table 58: Comparison of R744, R134a and R1234yf (DU, 2013)

	R744 (CO_2)	R134a	R1234yf
Ecological characteristics			
ODP (R12=1)	0	0	0
GWP (100 years)	1 (0)	1430	4
Environmental effects	Known	Partly known	Unknown
Economic characteristics[3]			
Life Cycle Costing (LCC)	Good	Medium	Poor
Filling of a city bus	20 €	150 €	700 to 1,500 €
Station for service and disposal	1,000 to 2,000 €	5,000 to 10,000 €	8,000 to 10,000 €
Dryer	No	No	Yes
Maintenance cost/year	1. year: 150 € / 2. year: 100 €	450 €	1,000 to 2,000 €
Additional fuel consumption for AC (city bus)	3 l/100km	4 l/100km	4.4 l/100km
Recycling required	No	Yes	Yes

Stop-start systems

According to (CENEX, 2015) new technologies, such as stop-start, mild hybrid and flywheel hybrid systems, which offer relatively rapid (<5 year) payback period will appear in increasing numbers in city buses.

Improvements in the fuel efficiency of ICE vehicles is likely to dominate the main advances to 2020 such as stop-start, mild-hybrid, smart alternator, light weighting, variable transmission (IVT) etc. producing CO_2 savings of between 5-15%. Of these options the smart alternator and stop-start have both a relative short payback period of <5 yr and are available from at least one manufacturer. This is also valid for flywheel energy storage. Other options are still in development.

Gearshift indicators

Nowadays most buses are equipped with automatic transmission, especially buses operating in urban areas with many stops. Therefore gearshift indicators are not relevant. In case of manual gearboxes a gearshift indicators will likely result in impacts comparable to the reduction of gearshift indicators in passenger cars.

Speed limiters and Intelligent Speed Adaptation (ISA) (TML; TNO; CE Delft; TRT, 2013)

According to the Speed Limitation Directive vehicles included in categories M3 and M2 should be equipped with a speed limitation device set in such a way that their speed cannot exceed 100 km/h. With respect to city buses operating in urban areas it can be questioned to what extent speed limitation devices have a large potential due to their specific duty cycle. Because these devices are obligatory for buses GPP Criteria will also not provide any additional incentive.

ISA systems could have potential benefits, just like for LDVs, but are not yet widely available (just as a retro-fit system).

4.6.3 Improvement options for alternative powertrains and fuels

Electric vehicles

Like for LDVs, we can distinguish different types of electric buses: plug-in hybrid and full electric buses, with different types of electricity supply (opportunity charging, overnight charging or trolley).

A full electric bus is driven by a purely electric motor powered by batteries charged with electricity. The vehicle has no other power source other than the battery. In case of opportunity charging system an electric bus recharges multiple times a day and each time for a short recharging time of 5 to 10 minutes. In case overnight charging electric buses recharge at the end of each day with a very long recharging time of more than 3 hours. Due to these different charging routines opportunity-charging buses have a short free range and limited route flexibility compared to overnight-charging buses. On the other hand, overnight-charging buses are more expensive per km due to the higher battery capacity required. Charging is possible via a plug-in system or induction. By mean of real time data of the price and share of renewable electricity opportunity charging can be optimized. Trolley buses require an overhead wiring network for power supply and are therefore only able to operate within the network (TNO (CIVITAS WIKI), 2013).

Limitations with respect to the deployment of electric buses are:

- limited route flexibility;
- need to recharge multiple times;
- recharging time;
- heavier battery in case of overnight charging;
- required charging infrastructure en route (in case of opportunity e-buses).

Market availability

Electric buses are expected to reach market maturity soon. A differentiation can be made between opportunity charging (en route) and overnight charging. This requires different technical specifications in terms of battery capacity. In 2012 1.2% of the EU bus fleet consisted of EV buses. (UITP, n.d.) Electric buses demonstrations are being developed at least in eight European cities (Barcelona, Bonn, Cagliari, Glasgow, London, Münster, Plzen and Stockholm). One of the most relevant projects is ZeEUS, whose scope is *testing electrification solutions at the heart of the urban bus system network through live urban demonstrations and facilitating the market uptake of electric buses in Europe*[95]*.*

Long haul and coach fleet will probably not be electrified on the short term, although PHEV might be a solution (COWI, 2015).

Improvement potential

Table 59 shows the improvement potential for three types of electric bus configurations based on (TNO (CIVITAS WIKI), 2013). Note that this study only report the WTW emissions and assesses the current situation. Therefore it is likely that the current EU electricity mix has been used (but prove could not be found in the report). In terms of CO_2 emissions full electric buses can save 40-100% of CO_2 emissions, depending on the electricity mix. Some opportunity charging systems also incorporate real time data of the price and share of renewable sources of the electricity mix along the day, so the bus can be charged during the peaks of renewable share (seen in Münster, March 2016).

Exhaust emissions are completely reduced, because full electric vehicles do not result in tailpipe emissions.

[95] http://zeeus.eu/about-zeeus/objectives-below-titles

Table 59: GHG and exhaust emissions reduction potential of various electric bus configurations compared to Euro VI diesel[96]

	GHG emissions (WTW)		**Exhaust emissions**			
	CO_2eq g/km	**Difference compared to Euro VI**	**NO_x g/km**	**Difference compared to Euro VI**	**PM_{10} (g/km)**	**Difference compared to Euro VI**
Conventional						
Euro VI diesel	834	-	1.1	-	0.03	-
CNG	1 000 800 – 850 (2020 prospects)	+20% -4% - +1%	1.4-4.5 0.88 (2020 prospects)	+ 27 to 309% -20% (2020 prospects)	0.005-0.03 0.024 (2020 prospects)	-83 to 0% -20% (2020 prospects)
Electric						
Opportunity	0-500	-40 to -100%	0	100%	0	100%
Overnight charging	0-500	-40 to-100%	0	-100%	0	-100%
Trolley bus	0-500	-40 to -100%	0	-100%	0	-100%

The noise reduction in terms of dB for the bus standing still and passing by are not available for opportunity and overnight charging, but is likely to be significant, because the noise reduction of trolley buses and serial hybrids are already between -13.8 and -22.5% for standing still and between -5.3 and -6.5% for passing by. Note: a reduction of 10 dB indicates a 50% reduction of noise perception.

[96] As this report is based on literature study no own calculations have been made. Therefore there are some differences in assumptions behind the figures for buses and passenger cars.

Table 60: Noise impacts of alternative fuels and powertrains (EC, 2015)

	Noise standing (dB)		Noise passing by (dB)	
Fossil				
Euro VI diesel	80		77	
Electric				
Opportunity	n/a	n/a	n/a	n/a
Overnight charging	n/a	n/a	n/a	n/a
Trolley bus	62	-22.5%	72	-6.5%

Cost

Although electricity costs per kilometre are lower than costs of fossil fuels, electric buses are still relatively expensive compared to conventional buses. This is mainly the result of the higher investment cost and required charging infrastructure, but significant cost reductions are foreseen before 2030, as is also depicted in Table 61. TCO estimations include purchase, financing, running, infrastructure and emission costs and are based on TNO and McKinsey data (TNO (CIVITAS WIKI), 2014).

Table 61: Cost analysis alternative fuel and powertrains for public transport buses

	Investment cost	**Additional infrastructure investment**	**TCO**		**GHG abatement costs, well-to-wheel**
	1 000 €	**1 000 €**	**€/km 2012**	**€/km 2030**	**€/kg CO_2 eq.**
Fossil fuel					
Euro VI diesel	220	-	2.1	2.5	-
CNG	250 (+14%)	500-1 000 per fuelling station	2.1	2.6 (+4%)	No GHG abatement costs due to increase in emissions
Electricity					
Opportunity	400 (+82%)	10 per bus per station	3.2 (+52%)	2.9 (+16%)	0.2-0.3
Overnight charging	350-500 (+59% to +127%)	100 per bus per station*	5.5 (+162%)	3.8 (+52%)	0.7-1.0
Trolley bus	300 (+36%)	1 000 euro/km	3.1 (+48%)	3.4 (+36%)	0.7

The difference in infrastructure cost between overnight charging and opportunity is probably due to the fact that an opportunity charging point can be used by more buses due to the short recharging time or due to the fact that opportunity charging points are only used to charge relative small batteries compared to overnight charging, which require more power.

Hydrogen

Hydrogen buses drive on electricity produced by fuel cells which convert the chemical energy of hydrogen into electricity to power the vehicle. Hydrogen can be produced by steam reforming in industry, through conventionally or renewably powered electrolysis or by means of conversion of methanol.

Market availability

The technology as such is mature, safe and ready for deployment. The commercialisation process has begun within some specific market segments, including buses, which makes that three types of bus technologies are already available on the market:

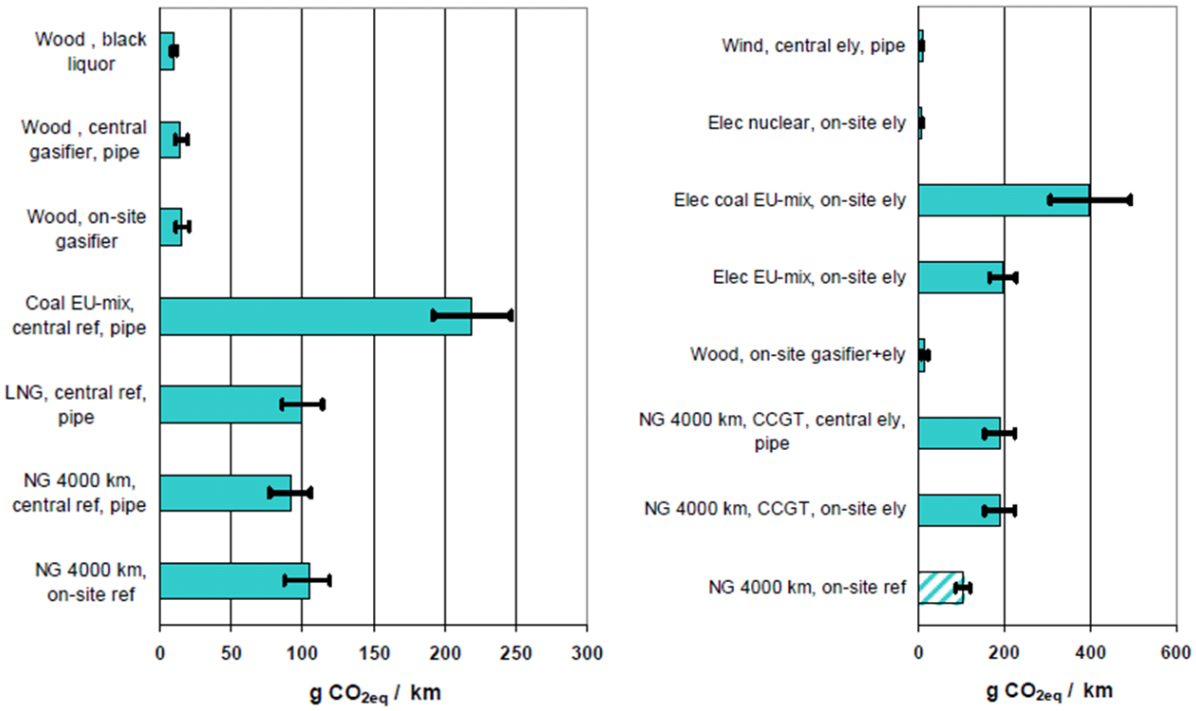
- fuel cell engine without battery;
- hydrogen internal combustion engine; and
- combined hydrogen with electric battery.

The hybrid bus configuration of a fuel cell system and electric drive is currently the most promising option with respect to hydrogen buses. At the same time, this option is still in an experimental stage and not yet in widespread use. The operation of fleets of fuel cell buses for public transport has already started in London, Hamburg, Cologne, Milan, Oslo and other cities. Currently, 45 public transport authorities and bus operators representing 35 cities and regions from 12 European countries are participating in the EU FC coalition aimed at 300 to 400 FC buses in Europe by 2020 (Roland Berger, 2015).

Improvement potential

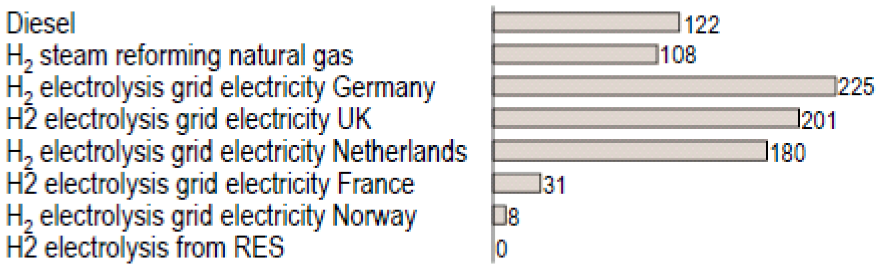
Because hydrogen is still mainly sourced from fossil sources hydrogen results in a significant increase of GHG emissions. This current situation is depicted in Table 62. However, Figure 49 also shows less CO_2-intensive production pathways.

Figure 49: WTW GHG emissions (direct hydrogen production on the left, electrolysis on the right) **(JRC, 2011)**



A study of Roland Berger (Roland Berger, 2015) also provides insight in the different WTW savings and especially the relation between the energy mix in a Member State and the WTW saving potential of the electrolysis pathway. (Figure 50).

Figure 50 CO_2 emissions of bus fuel (well-to-wheel) in 2015 (kg/100km) (Roland Berger, 2015)



Like electric buses, hydrogen buses do not cause any tailpipe emissions and thus fully reduce NO_x and PM_{10} emissions.

Table 62: Environmental impacts of a hydrogen bus ((TNO (CIVITAS WIKI), 2013)

	GHG emissions (WTW)		**Exhaust emissions**			
	CO_2eq g/km	**Difference compared to Euro VI**	**NO_x g/km**	**Difference compared to Euro VI**	**PM_{10} (g/km)**	**Difference compared to Euro VI**
Conventional						
Euro VI diesel	834	-	1.1	-	0.03	-
CNG	1 000 800 – 850 (2020 prospects)	+20% -4% - +1%	1.4-4.5 0.88 (2020 prospects)	+ 27 to 309% -20% (2020 prospects)	0.005-0.03 0.024 (2020 prospects)	-83 to 0% -20% (2020 prospects)
Hydrogen						
Hybrid hydrogen/ electric	1 500	+80%	0	-100%	0	-100%

Hydrogen buses also significantly reduce noise impacts compared to a Euro VI diesel bus: -21.3% for a standing bus and -10.4% for a bus passing by. Hybrid hydrogen/electric buses can result in a reduction of dB between 10 and 21% as result of the electric drivetrain.

Table 63: Noise impacts of alternative fuels and powertrains (EC, 2015)

	Noise standing (dB)		**Noise passing by (dB)**	
Fossil				
Euro VI diesel	80		77	
Hydrogen				
Hybrid hydrogen/electric	63	-21.3%	69	-10.4%

Cost

There are also similarities between electric buses and hydrogen buses in terms of cost structure: hydrogen buses also have far higher investment costs and therefore a far higher total cost of ownership. In addition to this are high investments required in the refuelling infrastructure. However, by 2030 the TCO of hydrogen buses will only be 9% higher compared to a Euro VI diesel bus according to (TNO (CIVITAS WIKI), 2013)) (see Table 64), but no further details of that projection are given

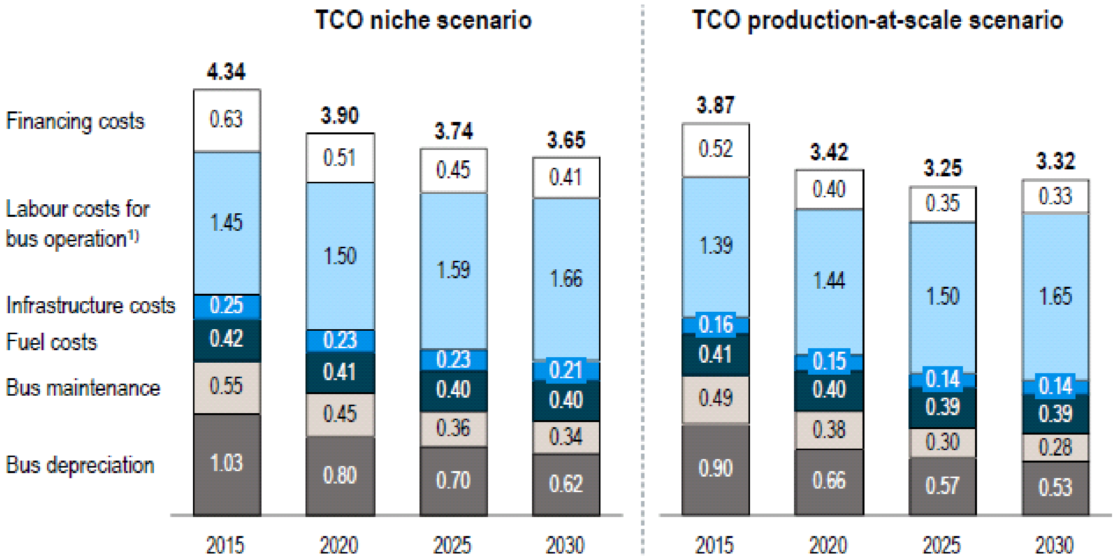
Table 64: Cost analysis alternative fuel and powertrains for public transport buses (TNO (CIVITAS WIKI), 2013)

	Investment cost	**Additional infrastructure investment**	**TCO**	
	1 000 €	**1 000 €**	**€/km 2012**	**€/km 2030**
Fossil fuel				
Euro VI diesel	220	-	2.1	2.5
CNG	250 (+14%)	500-1 000 per fuelling station	2.1	2.6 (+4%)
Hydrogen				
Hybrid hydrogen/ electric	800 (+264%)	100 per bus per station*	4.6 (+119%)	2.72 (+9%)

* Note that additional infrastructure investments are given per fuelling station for CNG and per bus per station of hydrogen.

The GHG abatement cost strongly depends on the production pathway and the WTW emission savings. No estimations have been provided by (TNO (CIVITAS WIKI), 2013): in fact, the hydrogen mix assumed by (TNO (CIVITAS WIKI), 2013) results in an increase of GHG emissions and can therefore not be seen as a GHG abatement measure. Roland Berger has provided both estimations for the developments in TCO as the reduction potential of various routes (see Figure 50). The TCO estimations are presented in Figure 51, including a breakdown of the various components for standard fuel cell buses. The "niche scenario" and the "production-at-scale scenario" represent the variance of potential costs depending on efficiencies and economies of scale achieved with varying market sizes and the related overall technological progress in the framework of the heavy-duty technology pathway. For the niche scenario to materialise, a cumulative number of 1 200-1 800 FC buses needs to be deployed on Europe's roads in total until 2025. For the production-at-scale scenario, a total cumulative volume of 8 000-10 000 FC buses is required until 2025.

Figure 51 TCO split by components for standard FC buses according to different scenarios in the heavy-duty pathway (€/km) (Roland Berger, 2015)



If we take estimations for the future based on this study the GHG abatement costs can be calculated using the data depicted in the table below.

Table 65 Calculation of GHG abatement costs for the current situation and for 2030 based on **(Roland Berger, 2015)**

	TCO current (€/100km)	**TCO 2030 (scale scenario) (€/100km)**	**WTW CO_2 (steam reforming) (kgCO2/100km)**	**WTW CO_2 (fully RES) (kgCO2/100km)**	**GHG abatement cost WTW (€/kg CO_2 eq.)**
Diesel	210	210	122	122	Scale scenario – fully RES (2030): €1 Niche scenario – Steam reforming (2015): €16
Hydrogen	434	332	108	0	
Delta	224	122	-14	-122	

Biofuels

Like passenger cars, buses can also run on biofuel blends. Where passenger cars mostly run on low blends that does not require vehicle adjustments, buses are a better option for higher blends, like E85 (85% ethanol) or B100 (100% biodiesel). Because buses operate in fleets and bus operators mostly have their own fuel supply infrastructure higher blends are more easily realised in such dedicated fleets.

Market availability

The technology required to drive on biofuels is a more mature technology compared to the technology required for electric driving and FCEV. Conventional buses can be modified to enable buses to drive on higher blends of biofuels.

The number of vehicles running on higher blends, such as biodiesel-B100, biodiesel B30, ED95 (95% ethanol, 5% cetane improver) is limited. These fuels are mainly used in dedicated public fleets, e.g. the Stockholm buses by Scania. A disadvantage is the specific motor modifications required for each particular blend, although there are also dual-fuel systems on the market.

Improvement potential

Like for passenger cars the feedstocks used to produce the biofuels largely determine the reduction potential. Within specific contracts with suppliers public operators can guarantee a certain level of sustainability of biofuels, like a minimum level of GHG reduction. In terms of air polluting emissions the biofuel options depicted below result in strong increases of PM_{10} and NO_x emissions. This is because the biofuel blends are applied in EURO V vehicles and are being compared with a EURO VI diesel. Because the technology is still based on the conventional internal combustion engine no large differences should be expected.

According to (TNO (CIVITAS WIKI), 2014), 1st generation biodiesel (Fatty Acid Methyl Ester, or FAME) is one of the most used 1st generation biofuels to power the buses. The production of 2nd generation biofuels is not yet widespread. Research, development and implementation today focus on 2nd generation biofuels and in particular on HVO (Hydrotreating vegetable oil: advanced biodiesel made by treating vegetable oil or animal fat with hydrogen). FAME biodiesel is limited to maximum 7% by the EN 590 standard in order to avoid technical problems in engines and vehicles. Higher blends of FAME are not supported by OEMs due to concerns over fuel quality and stability.

(TNO (CIVITAS WIKI), 2014) also reports that very limited current supply of HVO: current HVO global production equates to only 1% of European diesel demand (produced by Nestle Oil in Finland, the Netherlands and Singapore).

Regarding bioethanol, bioethanol is primarily sourced from sugarcane, grain/corn/straw or forestry waste. Buses have to operate on 100% bioethanol, since it cannot be blended with another type of fuel.

Table 66: GHG and air polluting emission reduction potential of biofuels in buses (TNO (CIVITAS WIKI), 2014)

	GHG emissions (WTW)		Air polluting emissions			
	CO_2/eq g/km	**Difference compared to Euro VI**	**NO_x g/km**	**Difference compared to Euro VI**	**PM_{10} (g/km)**	**Difference compared to Euro VI**
Conventional						
EURO VI diesel	834	-	1.1	-	0.03	-
CNG	1 000 800 – 850 (2020 prospects)	+20% -4% - +1%	1.4-4.5 0.88 (2020 prospects)	+ 27 to 309% -20% (2020 prospects)	0.005-0.03 0.024 (2020 prospects)	-83 to 0% -20% (2020 prospects)
Biofuels						
EURO V FAME B100	up to 500	Max. -40%	4.39	+299%	0.04	+33%
EURO V HVO B100	>500	Max.-40%	3.16	+187	0.08	+167%
EURO V Bioethanol	400-600	-28 to -52%	3.51	+219	0.10	+233%

Emissions from biofuel buses depend on the feed stock used to produce the biofuel and on the biofuel blend used. For lower blends, emission benefits will be proportionally less.

The noise improvement potential of buses running on biofuels is zero compared to conventional buses, because the internal combustion engine is not replaced (EC, 2015).

Cost

Because minor vehicle adjustments are required additional investment cost is zero or relatively low compared to investments in electric or hydrogen buses. Also the additional infrastructure investments are limited, because the fuel infrastructure for conventional diesel and petrol can partly be used. TCO is 6 to 20% higher, which can be explained by the higher feedstock prices.

Table 67: Cost of biofuels applied in buses

	Investment cost	Additional infrastructure investment	TCO	
	1 000 €	1 000 €	€/km 2012	€/km 2030
Fossil fuel				
Euro VI diesel	220	-	2.1	2.5
CNG	250 (+14%)	500-1 000 per fuelling station	2.1	2.6 (+4%)
Biofuels				
FAME B100	220 (+0%)	50	2.22 (+6%)	n/a
HVO B100	220 (+0%)	50	2.35 (+12%)	n/a
Bioethanol	250 (+14%)	200 per fuelling station	2.52 (+20%)	n/a

The GHG abatement cost strongly depends on the production pathway and the WTW emission savings. No estimations have been provided by CIVITAS. If we assume 334 gCO_2/km reduction compared to diesel and a difference in TCO of 0.25 €/km GHG abatement costs are 0.75 €/kg CO_2.

CNG

Market availability

The technology is very mature and a range of EURO VI/6 cars, vans, buses and trucks exists. All major bus and truck providers offer CNG solutions. EUR VI CNG buses are offered by Iveco, Scania, MAN, Mercedes (in 2015) and several smaller manufacturers.

In 2012 there were 13 168 natural gas buses, which is 1.76% (OIES, 2014) of the EU bus fleet. New technologies and emissions pathways to be taken into account include CNG-hybrids: the first successful examples of CNG-hybrid buses in operation already exist in Spain and Sweden.

Improvement potential

CNG are not likely to reduce CO_2 emissions with the current natural gas mix and might even increase CO_2 emissions, but can significantly reduce PM_{10} emissions.

The CO_2 emissions are 13-20% higher based on Civitas (TNO (CIVITAS WIKI), 2014) and (EC, 2015). Note that this is based on the EU NG mix. The study 'Natural gas in transport (CE Delft, TNO and ECN, 2013) assessing different natural gas routes in the Netherlands report a WTW CO_2 reduction between 0-20%, probably due to a less carbon intensive natural gas mix as result of a higher share of renewable sources in the mix. According to (European Biogas Association, 2013), in 2030 18-20 billion m^3 of biomethane could be produced in Europe with the necessary measures, what will correspond to about 3% of the present natural gas consumption of the European Union.

(TNO (CIVITAS WIKI), 2014) provides two estimations of GHG emissions of CNG buses: 1000 g CO_2eq/km in 2013 and 800 – 850 g CO_2eq/km expected by 2020.

Table 68: GHG emissions and air polluting emissions of CNG buses

	GHG emissions (WTW)		Exhaust emissions			
	CO_2eq g/km	**Difference compared to Euro VI**	**NO_x g/km**	**Difference compared to Euro VI**	**PM_{10} (g/km)**	**Difference compared to Euro VI**
Conventional						
Euro VI diesel	834	-	1.1	-	0.03	-
CNG	1 000 800 – 850 (2020 prospects)	+20% -4% - +1%	1.4-4.5 0.88 (2020 prospects)	+ 27 to 309% -20% (2020 prospects)	0.005-0.03 0.024 (2020 prospects)	-83 to 0% -20% (2020 prospects)

The noise emission levels of CNG are comparable to Euro VI diesel busses: standing still CNG results in 2.5% less dB, while passing by results in an increase of 1.3% dB.

Table 69: Noise emission levels of CNG buses compared to Euro VI diesel buses (CIVITAS, 2014)

	Noise standing (dB)		**Noise passing by (dB)**	
Fossil				
Euro VI diesel	80		77	
CNG	78	-2.5%	78	1.3%

The additional cost compared to Euro VI buses are presented in Table 70. In terms of investment cost CNG buses are approximately 14% more expensive. The required additional CNG-infrastructure ranges from € 500-1 000 per fuelling station. TCO per km are equal for the year 2012, but the TCO of CNG is expected to be 4% more expensive in 2030 compared to Euro VI diesel. (TNO (CIVITAS WIKI), 2013) mentions both an expected increase of operational cost for both diesel and CNG, with CNG prices increasing slightly more.

Table 70: Additional cost for CNG buses compared to Euro VI buses (TNO (CIVITAS WIKI), 2013)

	Investment cost	**Additional infrastructure investment**	**TCO**		**GHG abatement costs (WTW)**
	1 000 €	**1 000 €**	**€/km 2012**	**€/km 2030**	**€/kg CO_2eq**
Fossil fuel					
Euro VI diesel	220	-	2.1	2.5	-
CNG	250 (+14%)	500-1 000 per fuelling station	2.1	2.6 (+4%)	Not evaluated

LNG

Market availability

Natural gas and biogas could be also used in the form of Liquefied Natural Gas (LNG) for fuelling combustion engines in buses and trucks and in maritime and inland shipping. LNG is natural gas cooled to and stored at a temperature of -162°Celcius and requires 3 times less volume than CNG at 200 bar. For this reason, LNG vehicles often have a higher range compared to CNG vehicles. LNG can also be replaced by biogas, which is called liquefied biogas (LBG).

The market mainly consists of dual fuel systems (engines burning together diesel and methane), but mono fuel systems with an EU type approval are also being introduced more regularly. (EC, 2015) At least 35 Solbus LNG articulated buses are in service in Warsaw, but overall LNG seems to be more preferred for long-distance HDV.

Improvement potential

According to JEC report (JEC - Joint Research Centre-EUCAR-CONCAWE collaboration, 2014), the WTT GHG emissions of the LNG (natural gas liquefied at source, sea transport, distribution by road and use liquefied in the vehicle) is estimated to be 50% higher than the EU mix of CNG. This is due to the GHG emissions associated to energy needed for the liquefaction and the road distribution.

Cost

(Le-Fevre, 2014) refers to a statement of the European Expert Group on Future Transport fuel that CNG and LNG stations investment requirements are at least five times higher than for conventional diesel and petrol and that it will take up to 15 years to develop the necessary infrastructure.

In terms of fuel costs LNG has in general higher retail costs, but lower taxes (excise + VAT), making LNG cheaper compared to conventional diesel. LBG prices will, like biofuels, strongly depend on the sources used to produce the biogas.

Overall

In terms of energy cost (which are also included in the TCO figures), two factors are important: the efficiency of the various drivetrains and the price of the fuel itself. Table 71 shows that almost all alternative fuel options (except CNG) are more energy efficient compared to Euro VI buses, especially the electric powertrains on a WTW basis. This efficiency will have a positive impact on energy costs. Lower energy cost and higher efficiencies are major benefits of alternative fuels, but the higher investment costs hinder a more competitive TCO.

Table 71: Efficiency of the various fuel options for 2012 and 2030 (TNO (CIVITAS WIKI), 2013)

	2012 kWh/km	**2030 kWh/km**
Euro VI	4.13	3.89
CNG	5.21	5
Electricity - opportunity	1.8	1.58
Electricity - overnight charging	1.91	1.68
Electricity - trolley	1.8	1.71
Serial-hybrid	3.34	3.17
Hydrogen	3.2	2.72
FAME/HVO	4.13	3.89
Bioethanol	4.13	3.89

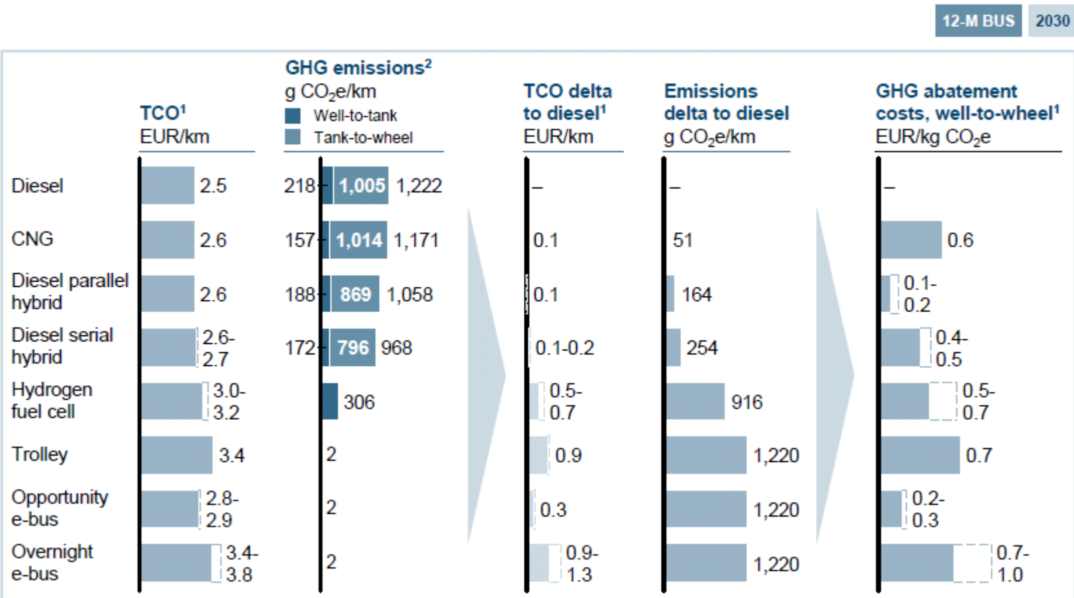
In Figure 52 the emissions factors in gCO_2/km and TCO figures in €/km are combined to express the GHG abatement costs (WTW) in €/kgCO_2e. The data depicted in Figure 52 are projections for 2030. Different scenarios were developed to simulate different bus production volume levels:

- Niche scenario: no major breakthrough occurs; only up to 120 buses per powertrain per manufacturer are produced each year from 2020 to 2030
- Production-at-scale scenario: diesel hybrids, hydrogen fuel cell buses and/or e-buses capture a significant market share, resulting in production volumes of 1 500 buses per powertrain per manufacturer each year from 2020 to 2030
- Cross-industry scenario: as the alternative powertrain market takes off for cars and other applications, more than 100 000 fuel cell systems and batteries for the automotive sector are produced each year from 2020, resulting in additional economies of scale for urban buses.

The estimations are based on a balanced mix scenario for hydrogen production and fully renewable electricity.

From a GHG-perspective option a diesel parallel hybrid and opportunity e-bus will deliver the highest CO_2 reduction per euro spent. CNG buses and trolley buses seem to be less favourable buses, probably because GHG reduction is limited in case of CNG and because of the high infrastructure costs for trolley buses.

Figure 52: GHG abatement costs of individual powertrains (McKinsey & Company, 2012)



Lower numbers correspond to 'cross-industry' scenario, higher numbers to 'production-at-scale' scenario.

4.6.4 Technical options to reduce and air pollutant emissions and noise

Due to the overlap between options for noise and pollutant emissions and GHG reduction options, many of these measures have already been discussed in Section Technical options to reduce GHG emissions

4.6.2 and Section 4.6.3. Therefore only the Euro standard, noise level and low noise tyres will be described below.

Euro standard

The best indicator to limit air polluting emissions from public transport buses are most likely the Euro standards. All new buses need to comply with the Euro VI emissions standard (including RDE conformity tests). Euro V standard applies as of October 2008 for the new types of vehicles sold in the EU market and one year later it became mandatory for all new registrations. EURO VI was required to all new vehicles registration in January 2014, and some specific parts of it in 2017. Therefore, for new buses reduction no additional requirements with regard to Euro Standards can be set.

In the case of bus services, the range of Euro standards is usually much larger and the share of Euro VI is limited.

Market availability

In 2015 the share of Euro VI buses in the EU fleet was limited to 1%, but there is no problem with respect to market availability: Euro VI is commercially available and higher shares of Euro VI will probably enter bus fleets at the start of new concession periods.

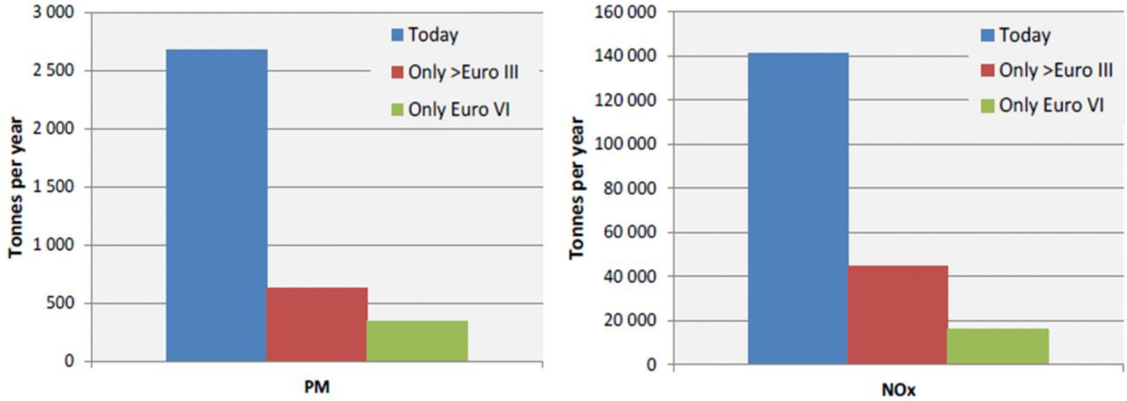
Improvement potential

EURO VI reduces 67% the PM emissions limit compared to EURO IV and V, and includes a PN limit. It also decreases the NOx emissions limit 77% relative to EURO V. The standard also replaces the European Stationary Cycle and Transient Cycle used for testing by the World harmonized Transient cycle, which covers cold and hot start, and in general stricter testing conditions (load, idle time). EURO VI introduces in-service conformity testing using Portable Emission Measurement System, the first one to be carried out within 18 months of the approval and then every 2 years. Other changes are a new limit for ammonia emissions due to the selective catalytic reduction systems using urea and stricter limits for methane on CNG and LPG vehicles (ICCT, 2015).

Assuming a bus fleet renewal of 8% a year it can take 12.5 years to replace an entire fleet. Accelerating this renewal rate by replacing the oldest buses by Euro VI buses and or buses running on alternative fuels would result in a direct reduction of CO_2 and air polluting emissions. The graphs in Figure 53 shows the impact on air polluting emissions of having a fleet consisting of only >Euro III buses or only Euro VI buses.

Compared to the current average fleet PM and NO_x emissions can be reduced by about 85% (Figure 53).

Figure 53: Estimated reduction in local pollutants with new buses (Source: UITP Europe based on VOLVO Bus Corporation, based on data from the 3iBS project, 2015) (UITP, 2015)



Cost

The cost difference between different Euro standards seems to be limited. According to COWI (2015) and Euro V and Euro VI bus costs the same.

Noise level (EC, 2014e)

Regulation 540/2014 has introduced also new limits for vehicle noise (engine noise) of M3 vehicles, like for passenger cars.

The regulation will phase in new limits in three steps:

- by July 1, 2016 the first phase will only apply to new vehicle types;
- by July 1, 2020, the second phase will introduce lower dB limits not only to new vehicle types, but to all new vehicles being produced two years after the start of phase 2 (2022);
- by July 1, 2024, the third phase will introduce lower dB limits to all new vehicles produced two years after the start of phase 3 (2024).

At the end of these three phases, the limit for M3 vehicles will be reduced to 67-68 dB in 12 years, while the current level is 78-80 dB.

Low noise tyres

In Section 3.5.4 low noise tyres are discussed including category of tyres (C3) used for buses.

4.6.5 Improvement options for bus services

In the case of purchasing services, various types of measures exist for improving the environmental performance. Like for LDVs, also for buses, all vehicle related measures can also be requested when purchasing services

Furthermore also measures targeting driving behaviour (**eco-driving**) has significant reduction potential. Again, the impact of just offering driving courses is limited, but a more complete package including monitoring and feedback and/or incentives for drivers can have large impacts. In an interesting case in the Netherlands, Connexion granted drivers in total €1 million of incentives for applying a fuel efficient driving style, resulting in €4.3 million of fuel cost savings[97].

For buses (and other HDVs) regularly **alignment of tyres and axles** is also measure that cab save fuel and cost. Various market suppliers in the maintenance of HDV (and thus buses) offer wheel alignment as part of their services. A proper wheel alignment (Stuarts Truck And Bus , 2012) can cut fuel consumption by 2.5-5%. Having the right tyres, tyre pressure and wheel alignment can all together save CO_2 emissions by up to 15%.

Buses with a correct wheel alignment can reach fuel cost savings up to 10%. Other cost advantages are the result of the increase in tyre life by up to 25 (HAWEKA, 2016)%. Cost for alignment are estimated to be a few hundred euros, which is compensated by above mentioned cost savings.

Other relevant measures when purchasing bus services are related to **local contamination and waste disposal**. Requirements with respect to disposal of lubricant oils and washing bays can reduce local pollution. No specific data has been found on impacts and cost of such requirements.

Last but not least, the environmental performance of public transport bus concessions can be also improved by **logistic optimizations**. This can include measures to increase occupancy rates, to reduce empty runs or to use smaller buses for connections with a low number of passengers.

[97] https://www.ovmagazine.nl/2016/01/connexxion-beloont-rustige-chauffeurs-1217/

5 WASTE COLLECTION VEHICLES AND SERVICES

5.1 Introduction

This chapter describes the overall and public market of waste collection vehicles and services, followed by a cost analysis, the views of stakeholders on the current criteria, and a technical analysis.

5.2 Market analysis

5.2.1 Overall market

Data on the market of waste collection vehicles is scarce. (Tekes, 2003) reports a market of approximately € 900 million per year for European manufacturers of waste collection vehicles, amounting to some 6 000 trucks per year. In 2003, of the 6 000 trucks, 700 were side-loading and 5,300 were rear-loading trucks. The order of magnitude for the 2003 numbers corresponds quite well with the number estimated in the next section. Yearly, 213 million tonne of garbage is collected from households in the EU (Eurostat, 2015e).

Quantity	**Unit**	**Value**	**Year**	**Source**
Current size of the fleet	Vehicles	n/a		
Annual growth rate	Vehicles/year	n/a		
EU production	Vehicles/year	6 000	2003	(Tekes, 2003)
EU sales (new registrations)	Vehicles/year	4 500 (indicative)		See Section 5.2.2
Import (into EU)	Vehicles/year	n/a		
Export (out of EU)	Vehicles/year	n/a		
EU performance	Passenger-km/year	n/a		
EU performance	Vehicle-km/year	n/a		
EU apparent consumption	Passenger-km/vehicle/year	n/a		
EU apparent consumption	Litres of fuel/vehicle/year	n/a		
Waste collected from households	Tonne	213 410 000	2012	(Eurostat, 2015e)
Revenue of vehicle manufacturers	€	900 million	2013	(Tekes, 2003)

5.2.2 Public procurement

The report that evaluated the CVD estimated the number of rigid trucks procured by the public sector, rather than the number of waste collection vehicles. Data on the number of new registrations of waste collection vehicles is available for Germany for 2013, which can be related to ACEA figures for total truck registrations in Germany to estimate that in 2013, 1.47% of new truck registrations in Germany were waste collection vehicles (see Table 72). If we assume that this proportion can be applied across the EU, using ACEA data for total EU registrations of medium and heavy trucks suggests that, in 2013, 4,500 new waste collection vehicles were registered. It is likely that the vast majority of these will either be used directly by the public sector or on contracts for the public sector.

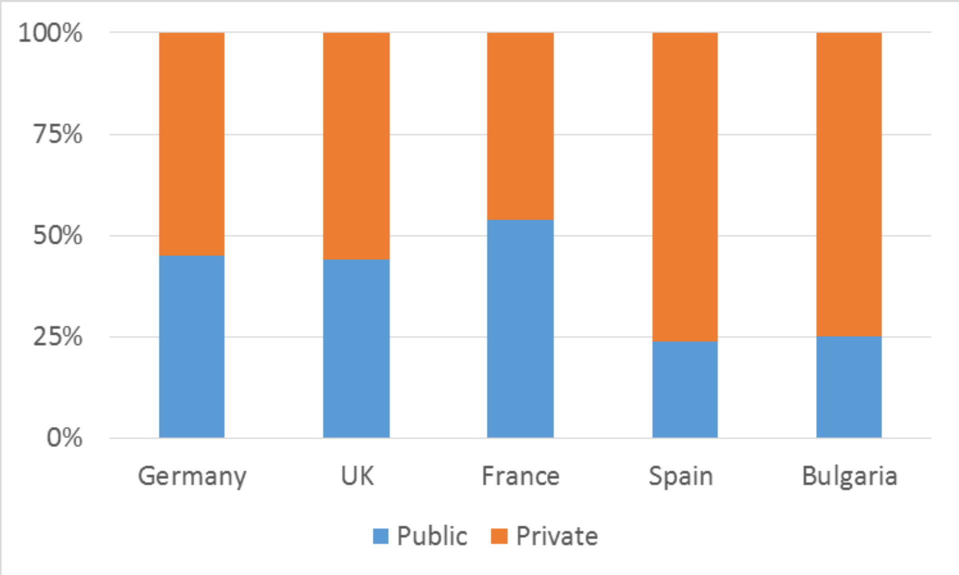
Table 72: Estimate of proportion of German new medium and heavy truck registrations that were waste collection vehicles

	Germany, 2013
Total new registrations of medium and heavy trucks (over 3.5 tonnes)	86 632
Total new registrations of waste collection vehicles	1 270
% of total that were waste collection vehicles	1.47%

Source: Analysis based on data from (ACEA, 2014) and (KBA, 2014) .

It might be argued that the municipal waste industry is by definition operated for, if not by, the public sector. However, municipal waste collection services can either be delivered directly by public authorities or contracted out to the private sector. Estimates suggest that between 25% and 50% of the employment in EU's municipal waste collection is in the public sector (Hall, 2013) see Figure 54). It might be considered that these proportions could also be applied to the share of municipal waste collection services delivered by the public sector, as Hall (2013) considered that there was no difference in efficiency between public and private sector delivery. However, the municipal waste collection part of the waste industry is a relatively small share of the total waste industry, as households only generate 8% of the total waste generated in the EU (Eurostat, 2015d).

Figure 54: Proportion of employees in municipal waste collection employed in the private and public sectors



Source: Hall (2013).

5.3 Cost analysis waste collection vehicles

In this section, the Total Cost of Ownership is calculated for waste collection trucks. No vehicle variations are taken into account. Table 73 shows the parameters that are used for this calculation.

Table 73: Parameters used for the cost analysis of waste collection trucks

Parameter	Waste collection truck	Source
Acquisition costs incl. Taxes (€)	307 000	(CE Delft, 2006)
Lifetime (years)	17	(TIAX, 2011)
Fuel consumption (L/km)	0.552	(AEA, 2011)
Fuel price incl. Taxes (€/l)	1.040	(EC, 2016a)
Fuel price excl. Taxes (€/l)	0.378	
Maintenance costs incl. Taxes (€/km)	0.155	(Duinn, 2009)[98]
Insurance (€/year)	2 117	(99)
Circulation taxes (€/year)	517	(100)

[98] Same maintenance costs assumed as public transport bus.

[99] Insurance costs based on same proportionality to circulation taxes as passenger cars.

[100] Calculation based on (CE Delft, 2016a).

For waste collection trucks, three scenarios are used based on different annual mileages of 25 000, 40 000, and 50 000 km/year. Based on these numbers and the previously determined fuel consumption, the lifetime fuel consumption is calculated for the three scenarios, as shown in Table 74.

Table 74: Annual mileage assumed for different scenarios and consequent lifetime mileage and fuel consumption

Parameter	Waste collection truck	Scenario
Annual mileage (km/year)	25 000	1
Lifetime mileage (km)	425 000	
Lifetime fuel consumption (L)	234 600	
Annual mileage (km/year)	40 000	2
Lifetime mileage (km)	680 000	
Lifetime fuel consumption (L)	375 360	
Annual mileage (km/year)	50 000	3
Lifetime mileage (km)	850 000	
Lifetime fuel consumption (L)	469 200	

Using the values from Table 73 and Table 74, the different contributions to the Total Cost of Ownership are calculated, both with taxes and without, for all three scenarios. The fuel costs and maintenance costs depend on the annual mileage and are therefore different between the scenarios. The other costs are the same for all three scenarios. Table 75 shows the costs with taxes, whereas Table 76 shows the costs without taxes.

Table 75: Contributions to the Total Cost of Ownership with taxes for the three scenarios

Parameter	Waste collection truck	Scenario
Acquisition costs incl. Taxes (€)	307 000	All
Fuel costs incl. Taxes (€)	244 000	25 000 km
Fuel costs incl. Taxes (€)	390 000	40 000 km
Fuel costs incl. Taxes (€)	488 000	50 000 km
Maintenance costs incl. Taxes (€)	66 000	25 000 km
Maintenance costs incl. Taxes (€)	105 000	40 000 km
Maintenance costs incl. Taxes (€)	132 000	50 000 km
Insurance incl. Taxes (€)	36 000	All
Circulation taxes (€)	9 000	All

Table 76: Contributions to the Total Cost of Ownership without taxes for the three scenarios

Parameter	Waste collection truck	Scenario
Acquisition costs excl. taxes (€)	242 000	All
Fuel costs excl. taxes (€)	89 000	25 000 km
Fuel costs excl. taxes (€)	142 000	40 000 km
Fuel costs excl. taxes (€)	178 000	50 000 km
Maintenance costs excl. taxes (€)	54 000	25 000 km
Maintenance costs excl. taxes (€)	86 000	40 000 km
Maintenance costs excl. taxes (€)	108 000	50 000 km
Insurance excl. taxes (€)	30 000	All

Figure 55 and Figure 56 show the Total Cost of Ownership for waste collection trucks with and without taxes for the three scenarios. The first thing that can be deduced from the graphs is that the shorter the annual mileage in the scenario, the larger the total cost per km is. This is easily explained by noting that the fixed costs are divided by more kilometres.

With taxes, the acquisition costs match the fuel costs in scenario 1 and become slightly less important in scenarios 2 and 3. Insurance and circulation taxes are small at all annual mileages. Maintenance costs per km keep constant, since they increase due the aging of the vehicle.

Figure 55: Total Cost of Ownership with taxes per vkm for waste collection trucks

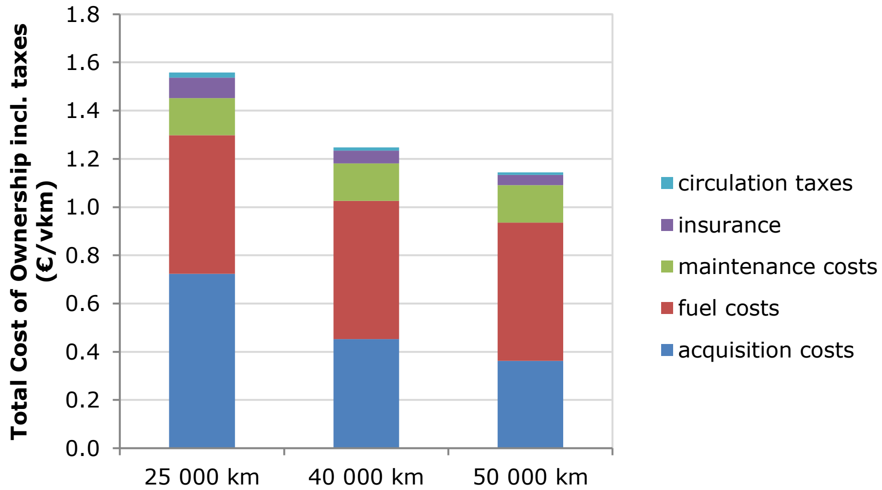


Figure 56: Total Cost of Ownership without taxes per vkm for waste collection trucks

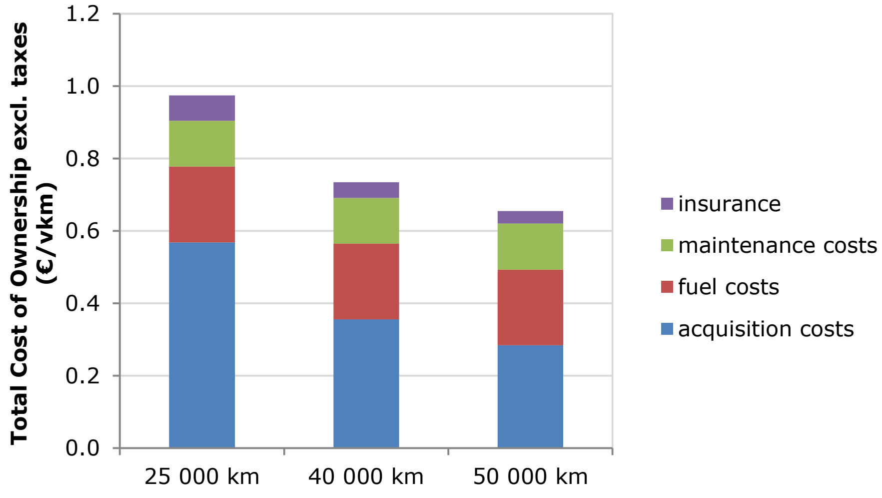


Table 77 (with taxes) and Table 78 (without taxes) give an overview of the Cost of Ownership of a waste collection truck, over the lifetime, per year, and per km.

Table 77: Total Cost of Ownership with taxes for waste collection trucks for the three scenarios

Parameter	**Waste collection truck**	**Scenario**
Total Costs of Ownership incl. taxes (€/vehicle)	662 000	25 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	39 000	
Per km Cost of Ownership incl. taxes (€/vkm)	1.56	
Total Costs of Ownership incl. taxes (€/vehicle)	848 000	40 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	50 000	
Per km Cost of Ownership incl. taxes (€/vkm)	1.25	
Total Costs of Ownership incl. taxes (€/vehicle)	972 000	50 000 km
Yearly Cost of Ownership incl. taxes (€/year/vehicle)	57 000	
Per km Cost of Ownership incl. taxes (€/vkm)	1.14	

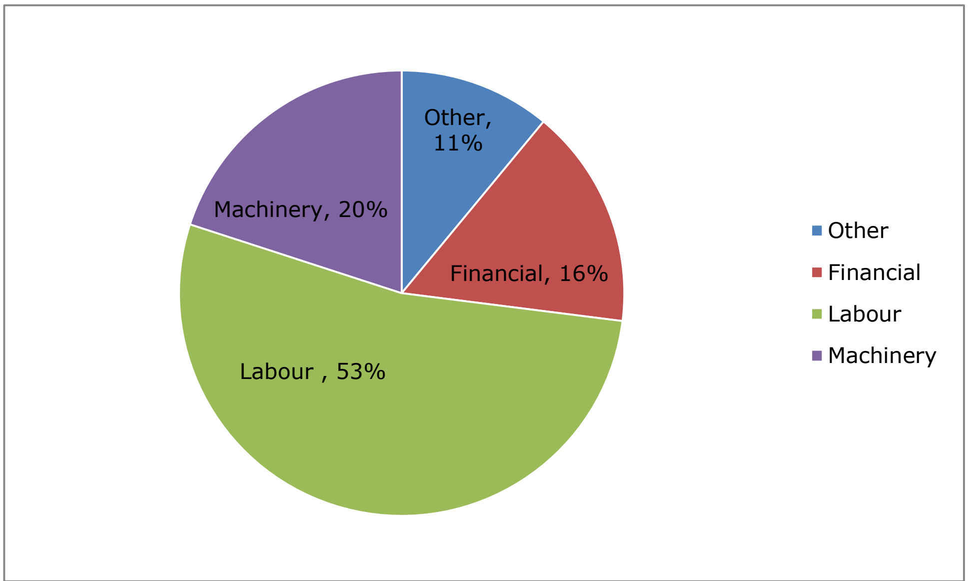
Table 78: Total Cost of Ownership without taxes for waste collection trucks for the three scenarios

Parameter	**Waste collection truck**	**Scenario**
Total Costs of Ownership excl. taxes (€/vehicle)	414 000	25 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	24 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.97	
Total Costs of Ownership excl. taxes (€/vehicle)	500 000	40 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	29 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.73	
Total Costs of Ownership excl. taxes (€/vehicle)	557 000	50 000 km
Yearly Cost of Ownership excl. taxes (€/year/vehicle)	33 000	
Per km Cost of Ownership excl. taxes (€/vkm)	0.65	

5.4 Cost analysis waste collection services

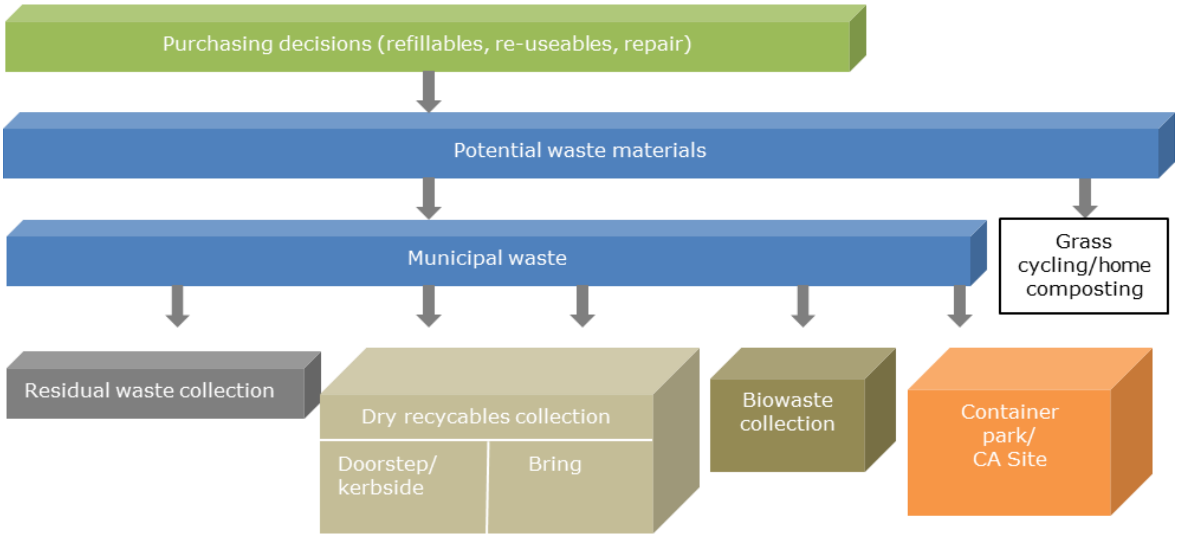
Like for bus services, information is also available on the estimated cost of waste collection services. Similar to bus services, labour cost compromise the largest share of cost, followed by the cost for machinery (20%), financial cost (16%) and other cost (11%). No details are provided for the cost included in the categories.

Figure 57: Estimated cost of waste collection services (Hall, 2013)



Cost might vary depending on the type of waste collection services. In Figure 58 a schematic overview of a representative waste collection system is depicted.

Figure 58: Schematic overview of representative collection system (Eunomia, 2001)



Other cost data are often presented in different units, because waste collection management operations are mostly seen as systems of both collection and treatment together and the costs have been mostly reported in terms of a per tonne cost for residual waste (or other types of waste materials).

Factors having a significant impact on the cost structure of waste collection are:

- the collection approach (bring or doorstep/curbside collection);
- the degree to which vehicle choice is matched to the relative bulk;
- the densities of different materials;
- the frequency of collection;
- the degree to which one can capitalise on the cost-optimising;
- the possibilities afforded by diversification of vehicle fleets (Eunomia, 2001).

In addition to this, the cost figures depicted in Table 59 also show that the type of area in which the waste is being collected impacts costs significantly: on average the cost of residual waste collection in rural areas are significantly higher (about 1.5 times) compared to urban areas.

Table 59: Comparative Costs of Residual Waste Collection in Different Member States (€/tonne and €/household) (Eunomia, 2001)

		Costs (€/tonne)			Costs (€/household)		
		Low	**High**	**Best Est.**	**Low**	**High**	**Best Est.**
AU				70			
BE	F	58	92	75	14	22	18
	Br			56			
DK				126			62
FI		15 (urb)	32 (rur)		17 (urb)	37 (rur)	
FR		54 (urb) 63 (rur)	65 (urb) 74 (rur)	60 (urb) 70 (urb)			
GE		39 (urb)	81 (urb)	67 (urb)			30 (urb)
		48 (urb)	91 (rur)	71 (rur)			40 (rur)
GR		25 (urb)	36 (urb)	30 (urb)			32 (urb)
		40 (rur)	67 (rur)	55 (rur)			57 (rur)
IR		60	70	65	70	80	75
IT		48	255	75	15	45	25
LUX		85	104	85			
NL		75	123	100			
PO				45*			
SP		19	91	60	10	43	25
SW		59	80	65			
UK		32 (urb)	50 (urb)	42(urb)	24 (urb)	38 (urb)	31 (urb)
		50 (rur)	80 (rur)	60 (rur)	38 (rur)	60 (rur)	45 (rur)

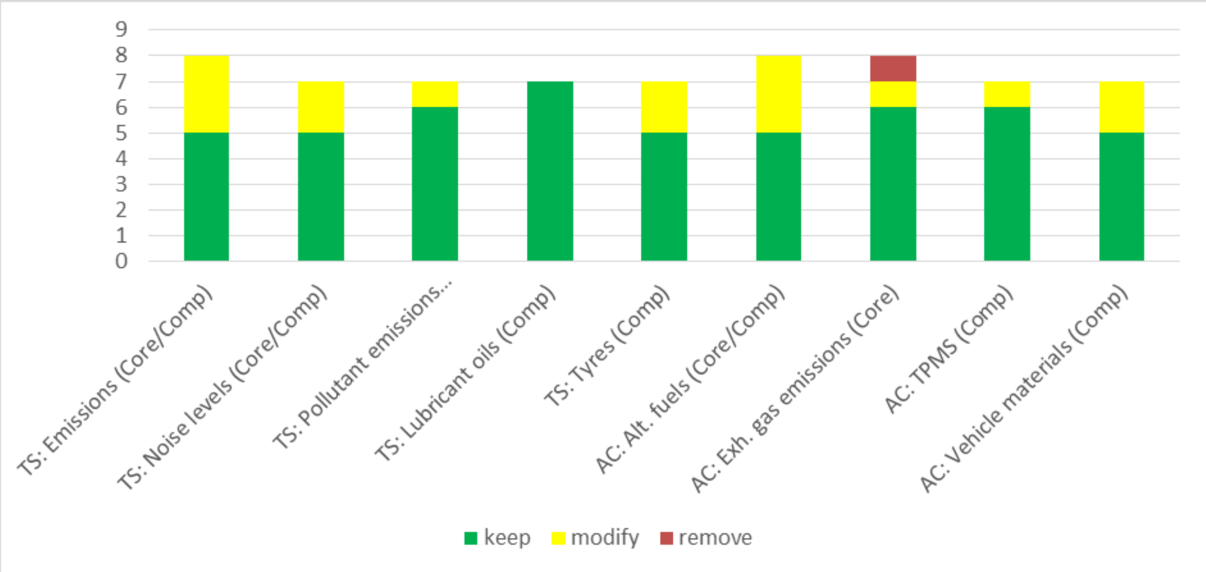
* Estimate.

5.5 Stakeholder views on current criteria

5.5.1 Purchase or lease of waste collection trucks

One third of the survey respondents had views on the criteria relating to the purchase or lease of waste collection trucks (see Figure 60). As with the previous categories, the majority of those with an opinion supported keeping all of the criteria, although a minority of stakeholders in all but one case believed that a modification would be appropriate. There was only one suggestion to remove a criterion.

Figure 60: Views of the stakeholders on the existing EU GPP criteria for the purchase or lease of waste collection trucks



Key: 'Core/Comp' in brackets means that the criterion was both a core and a comprehensive criterion, while those criteria that only have 'Comp' in brackets were only included as a comprehensive criterion. 'TS' indicates that the criterion was proposed as a 'Technical Specification', while 'AC' means that it was proposed as one of the 'Award criteria' and 'CPC' indicates that it was proposed as a 'contract performance clause'.

Those who argued for a modification of the 'Exhaust gas emissions', 'Noise emissions levels' and 'Pollutant emissions' criteria all called for a strengthening of the criteria. Suggestions relating to exhaust gases included making the current comprehensive criterion the core criterion, as well as inserting a new comprehensive criterion requiring "(partially) electrically fuelled" or one that promoted the use of CNG or hydrogen trucks. Comments relating to noise included aligning the criterion with those of the vehicle noise Regulation[101], while it was also noted that the Environmental Noise Directive[102] was

[101] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

[102] Commission Directive (EU) 2015/996 establishing common nose assessment methods according to Directive 2002/49.

currently under review, which could have implications for transport. The only comment relating to the pollutant emissions criterion, which focuses on mobile machinery rather than road vehicles, called for the criteria to be set at the most stringent stage of the Commission's current proposal to amend the non-road mobile machinery Directive[103].

The only comment proposing a modification to the 'Lubricant oils' criterion was to use the Ecolabel in setting the criterion. Those supporting a modification to the 'Tyres' category reflected comments made in relation to this criterion in other categories, i.e. that compliance with UN Regulation No 117 (revision 3) and the latest UNECE requirements on tyre noise and rolling resistance should be required or setting the criterion as the best category on the tyre label[104].

The comments in relation to the 'Use of alternative fuels' criterion also reflected those made in relation to this criterion in previous categories. One reiterated that different types of alternative fuel have different environmental impacts, so that the criterion should be amended to become performance-based that could be used for all different types of vehicles. Others argued for the criterion to be changed to promote CNG and hydrogen vehicles, or hybrid, electric and hydrogen vehicles.

With respect to the 'Exhaust gas emissions' criterion, one stakeholder supporting its modification argued that it needed to be updated regularly in order to be consistent with relevant EU policy, while the stakeholder calling for its removal suggested that it be merged with the 'Use of alternative fuels' criterion if that was amended in the way proposed.

The only comments supporting the modification of the 'Tyre Pressure Monitoring Systems' and 'Vehicle materials' criteria argued that the former should become a core, rather than a comprehensive criterion, while support was given to the use of the latter for mass reduction.

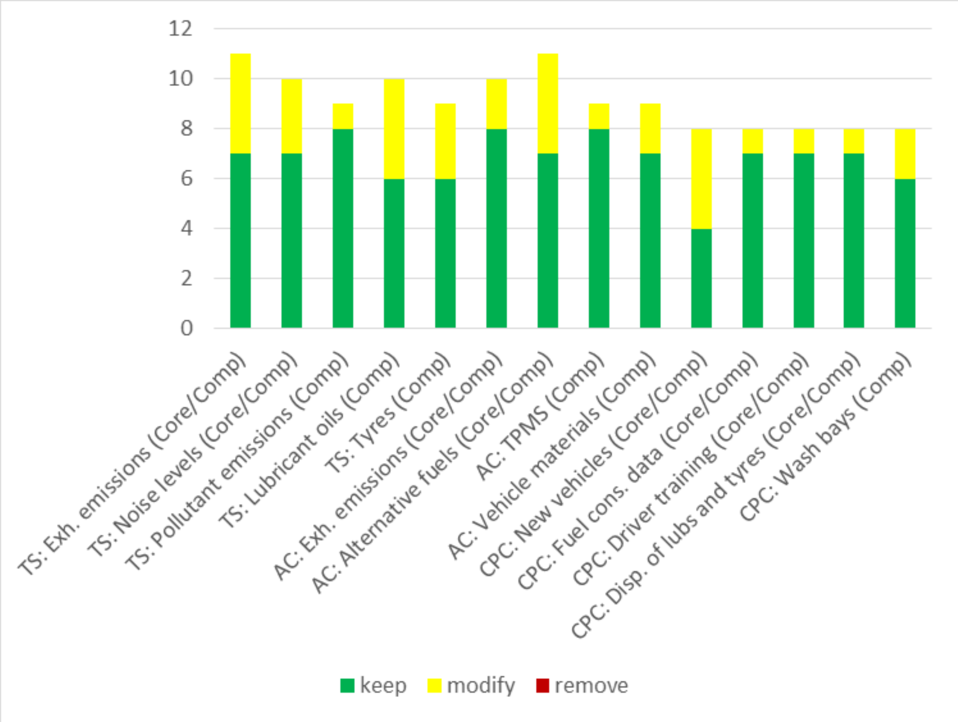
5.5.2 Provision of waste collection services

Forty per cent of stakeholders that responded to the survey had views on the criteria relating to the provision of waste collection services (see Figure 61). No stakeholder proposed that any of the criteria be removed, with the vast majority in most cases happy to keep the criteria in their current form. At least one stakeholder supported the modification of each criterion, while half of those that expressed an opinion on the 'New vehicles' criterion called for its modification.

[103] Proposal for a Regulation on requirements relating to emission limits and type approval for internal combustion engines for non-road mobile machinery, COM(2014) 581.

[104] Regulation (EC) No 1222/2009.

Figure 61: Views of the stakeholders on the existing EU GPP criteria for the provision of waste collection services



Key: 'Core/Comp' in brackets means that the criterion was both a core and a comprehensive criterion, while those criteria that only have 'Comp' in brackets were only included as a comprehensive criterion. 'TS' indicates that the criterion was proposed as a 'Technical Specification', while 'AC' means that it was proposed as one of the 'Award criteria' and 'CPC' indicates that it was proposed as a 'contract performance clause'.

Many of the comments from those in favour of modifying the various criteria were similar to those mentioned in relation to the equivalent criteria for other categories, although there were fewer comments overall, with no opinion being expressed on some of the criteria.

Comments relating to the two 'Exhaust gas emissions' criteria, i.e. the ones to be used as a technical specification and the other as an award criterion, all reflected the fact that Euro VI vehicles were now mandatory, and so at the minimum Euro VI should be the core criterion. Others argued that the criterion should now focus on the promotion of alternatively-fuelled vehicles, with one proposing CNG and hydrogen vehicles, while another suggested electric vehicles or vehicles using renewable fuels.

The comments in support of modifying the 'Noise emissions' and 'Pollutant emissions' categories also called for these to be updated in line with, respectively, the vehicle noise Regulation[105] and the Commission's proposed amendment to the non-road mobile machinery Directive[106]. For noise, it was also suggested that vehicles used should be required not to exceed the noise levels of new vehicles, while another noted that the

[105] Regulation (EU) No 540/2014 on the sound level of motor vehicles and of replacement silencing systems.

[106] Proposal for a Regulation on requirements relating to emission limits and type approval for internal combustion engines for non-road mobile machinery, COM(2014) 581.

Environmental Noise Directive[107] was currently under review, which could have implications for transport.

With respect to the 'Lubricant oils' criterion, one stakeholder suggested that this should also be included as a core criterion, while others argued its modification as the current criterion was complicated or that the criterion should reflect the Ecolabel. Comments in relation to the 'Tyres' criterion were similar to those made for the equivalent criterion in previous categories. These included that the criterion should require compliance with UN Regulation No 117 (revision 3) and the latest UNECE requirements on tyre noise and rolling resistance, that the criterion should be core as well as comprehensive, and that the criterion should reflect the tyre category label categories and possibly only require that tyres with the best label category are used[108].

More clarity was one of the requests in relation to the 'Use of alternative fuels' category, while others reiterated comments made with respect to the equivalent criterion under other categories. These included that the criterion should be amended to become performance-based and usable for all different types of vehicles or that it should promote CNG and hydrogen vehicles, or hybrid, electric and hydrogen vehicles.

Those who argued for a modification of the 'Tyre Pressure Monitoring Systems' category called for it to become a core criterion, while the comment relating to the modification of the 'Vehicle materials' category supported its use to reduce the mass of vehicles.

The 'New vehicles' criterion received more calls for its modification than other criteria, which was probably due to the fact that it has a number of different elements. Comments suggested that Euro VI should now be required for the core, as well as the comprehensive, criterion, that mention should be made of electric vehicles and that the reference to the location of the exhaust pipe to be removed, as this was not relevant to waste collection trucks.

The only comment relating to 'Fuel consumption data' was that this information could also include the tonnes of waste transported and the distance driven, while the only comment relating to the 'Training of drivers' noted that this was already mandatory in some countries. The only comment on the 'Wash bays' criterion was that it should be a core criterion.

5.6 Technical analysis

5.6.1 Identification of environmental hotspots along the life cycle of trucks

Very scarce information is available on LCA of trucks and in particular on waste collection trucks. A study was made by Chalmers on Comparative LCA of Electrified Heavy Vehicles in Urban Use (Soriano & Laudon, 2012). It confirms that the main environmental impact is for the energy consumption during the use phase (named 'well-to-wheel phase') including when the heavy vehicle are electrified.

Particular attention is paid by the study to the electrified heavy vehicle and to the environmental impacts saved with them compare to conventional ones. GWP is considered the most relevant impact category also in this vehicles category.

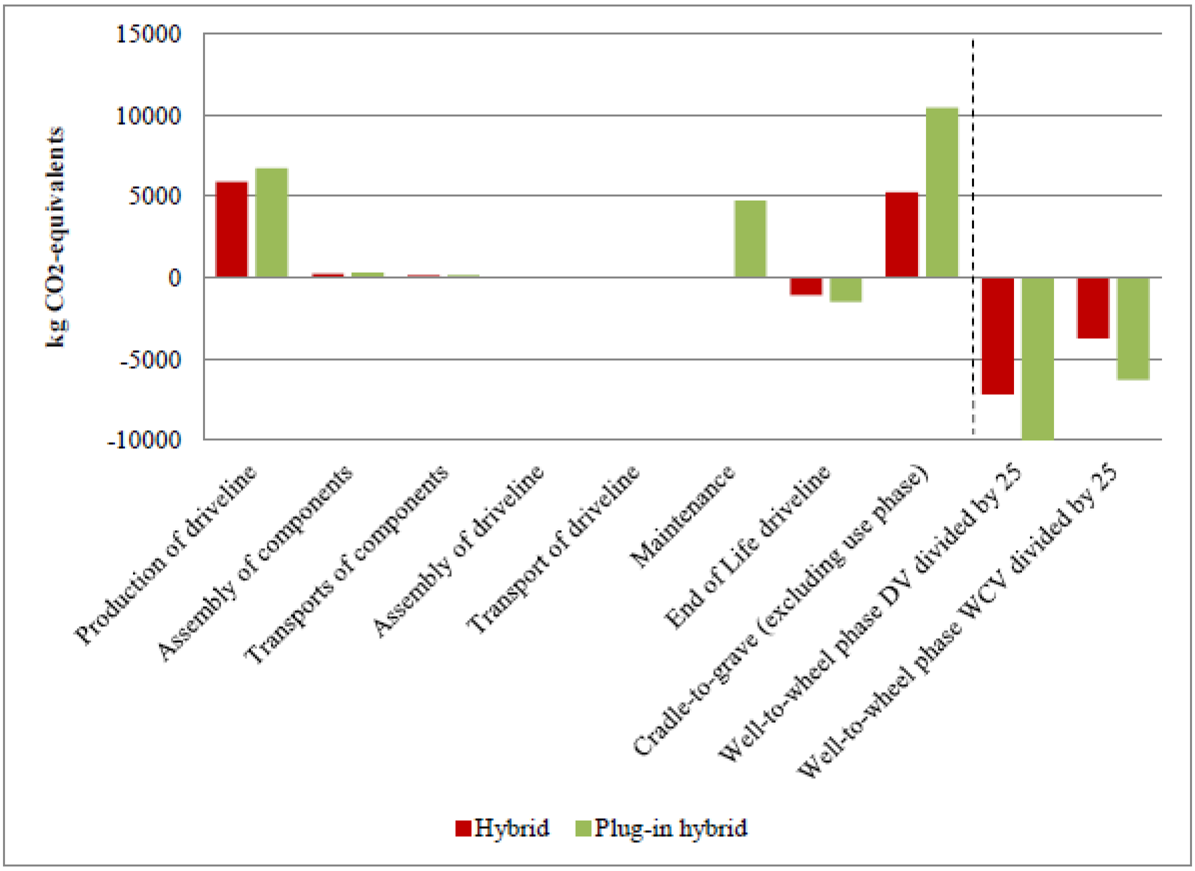
The first graph, Figure 55, shows the GWP100 for the different life cycle stages of the drivetrain and the emissions saved in the well-to-wheel phase. Well-to-wheel phase

[107] Commission Directive (EU) 2015/996 establishing common nose assessment methods according to Directive 2002/49.

[108] Regulation (EC) No 1222/2009.

values include both distribution (DV) and waste collection vehicle (WCV) driving patterns. These values have been scaled down 25 times, to simplify a comparison with the other stages. In the Production of drivetrain bar, the avoided emissions for not using a lead-acid battery are included.

Figure 62: GWP in CO_2-eq for the different life cycle stages with the conventional vehicles as a baseline



The saved emissions from the well-to-wheel phase are divided by a factor of 25. The avoided emissions from the lead-acid battery are also included in the Production of drivetrain. Data left of the dashed line represents cradle-to-grave processes, excluding the use phase and data to the right of the dashed line represents well-to-wheel processes.

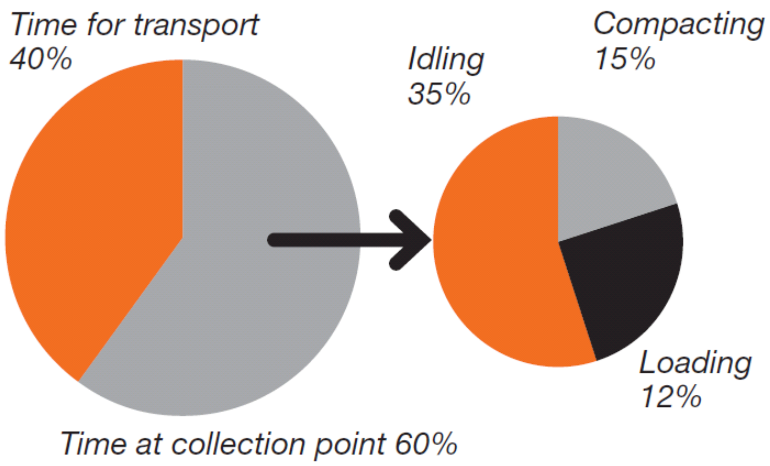
The savings in the well-to-wheel phase are much bigger than the emissions from the other stages, since diesel combustion is avoided during the life time of the trucks. The Maintenance bar consists solely of one Li-ion battery change and is only applied to the plug-in hybrid version. When this battery change is compared to the Production of drivetrain bar, the battery is responsible for more than half of the emissions for all components in the hybrid and plug-in hybrid drivetrain. It is also obvious that the assembly and transport stages are very small compared to the other stages, which means that most of the environmental burden from the production comes from the material extraction and transformation (included in the Production of drivetrain category).

5.6.2 Improvement options for waste collection vehicles

Waste collection vehicles are designed to collect and transport domestic and bulky waste and can be loaded via containers or by hand (Ricardo-AEA, 2012a). In addition a compaction mechanism and/or a container lifting device can be installed. The vehicles operate in urban areas and have other driving cycle characteristics compared to other transport modes. Due to the waste collection activities, the duty cycle of a waste collection vehicle has many stops, is partly operated at low vehicle speed and in general drives to and from a central base point. For the UK it has been estimated that municipal delivery duty cycles contribute 4% to overall CO_2 emissions.

The time in operation in waste collection vehicles can be divided into time for transport (40%) and time at collection point (60%). Of the time at a collection point the time can be divided into idling (35%), loading (12%) and compacting (15%). This suggests that the energy consumption of waste collection vehicles is not only determined by the kilometres driven.

Figure 63: Phases in the work cycle for waste collection vehicles in the urban environment (Renova, 2006).



Collection vehicles work most often in densely populated urban areas that maintain strict criteria for emissions and environmental norms. In addition, minimising the health impacts of exhaust emissions is highly relevant for the workers who operate the waste collection trucks. A quiet, zero-emission waste collection vehicle will be able to meet all the needs of municipalities, local citizens and waste collection services. Because waste collection trucks also require energy to ride, lift, tilt and compress, the range will be limited to 200 kilometres if only batteries are used. As part of the project Waterstofregio Vlaanderen-Zuid-Nederland (Hydrogen Region for Flanders and the southern Netherlands) E-trucks Europe has experimented with extending an electrical powertrain with a fuel cell running on hydrogen, which increases the range up to 360 kilometres instead of 200 kilometres.

Table 79 lists the potential powertrain technologies for five different duty cycles. The municipal utility is representative for the drive cycle of waste collection trucks and shows that all powertrain could be potentially applied to waste collection trucks.

Table 79: Powertrain technologies considered for municipal utility duty cycles, like driven by waste collection trucks (Ricardo-AEA, 2012a).

Type	Technology	Mapping compatibility to duty cycles				
		Urban delivery	Regional delivery	Long haul	Municipal utility	Constr-uction
Powertrain	Diesel ICE	✓	✓	✓	✓	✓
	Diesel Flywheel Hybrid Vehicle	✓	✓	✓	✓	✓
	Diesel Hydraulic Hybrid Vehicle	✓	✓	✓	✓	✓
	Diesel Hybrid Electric Vehicle	✓	✓	✓	✓	✓
	Pure Electric Vehicle	✓	No	No	✓	No
	Hydrogen Fuel Cell Vehicle	✓	✓	✓	✓	✓
	Dual-fuel (diesel-natural gas)	✓	✓	✓	✓	✓
	Dedicated natural gas	✓	✓	✓	✓	✓
Powertrain enhance-ments	Mechanical turbo-compound	✓	✓	✓	✓	✓
	Electrical turbo-compound	✓	✓	✓	✓	✓
	Heat recovery (bottoming cycles)	✓	✓	✓	✓	✓
	Controllable air compressor	✓	✓	✓	✓	✓
	Automated Transmission	✓	✓	✓	✓	✓
	Stop / start system	✓	✓	✓	✓	✓
	Pneumatic booster – air hybrid	✓	✓	✓	✓	✓

Table 80 shows the potential of fuel saving measures. Predictive and advanced predictive cruise controls are not an option, because these vehicles do not operate at a constant speed. Aerodynamics, which are not listed in the table also do not have not much potential (Ricardo-AEA, 2012a).

Table 80: Vehicle technologies considered (Ricardo-AEA, 2012a).

Type	Technology	Mapping compatibility to duty cycles				
		Urban delivery	Regional delivery	Long haul	Municipal utility	Constr-uction
Rolling Resistance	Low rolling resistance tyres	✓	✓	✓	✓	✓
	Single wide tyres	✓	✓	✓	✓	✓
	Automatic tyre pressure adjustment	✓	✓	✓	✓	✓
Weight	Light weighting	✓	✓	✓	✓	✓
Others	Predictive cruise control	No	✓	✓	No	✓
	Smart alternator, battery sensor & AGM battery	✓	✓	✓	✓	✓
	Alternative fuel bodies (for refuse collection vehicle / refrigeration / tipper)	11 %	23 %	16 %	76 %	79 %
	Advanced predictive cruise control	No	✓	✓	No	✓

A further analysis of Ricardo-AEA per duty cycle has resulted in recommendations for waste collection trucks. As can be seen in Table 81 these recommendations focus on the hybridization and electrification of waste collection vehicles, including electrically powered bodies. Natural gas, including biogas can also result in WTW emission savings of 5-18% for CNG and 61-65% for biogas. The other environmental impacts are described qualitatively and indicate air quality benefits and noise reduction in addition to the WTW CO_2-eq savings.

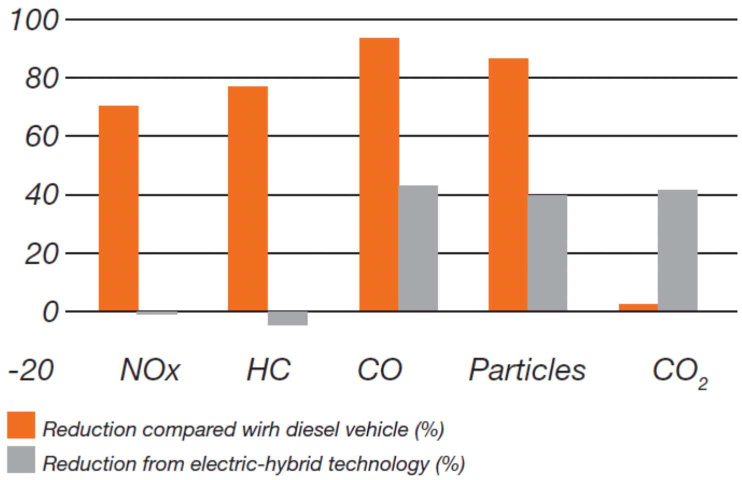
Table 81: Technology recommendations for municipal utility duty cycle

Municipal utility – technology recommendations				
	Technology / fuel	**WTW CO_2e saving**	**Payback range***	**Additional considerations**
1	Stop / Start and idle shut-off	5 %	<1-2½ years	Small air quality and noise reduction benefits in congested urban areas. Marginal increase in lifecycle impact due to additional components.
2=	Hybrid electric / hydraulic hybrid vehicles	15-25 % (15 % expected for hydraulic hybrids)	4-16 years	Air quality and noise reduction benefits particularly if able to run in electric only mode. Lifecycle impacts of batteries need to be considered.
2=	Dedicated natural gas vehicles	5-16 % (CNG) 61-65 % (biomethane)	6-18 years	Significant particulate emission & noise reduction benefits; requires additional refuelling infrastructure. Substantially larger CO_2e reduction benefits with biomethane.
3	Alternatively fuelled bodies	10-12 %	9 years plus	Electrically powered refuse truck bodies can reduce noise and air pollution.

* Based on current technology marginal capital costs fuel cost savings and low-high mileage sensitivities.

The city of Gothenburg has focused on the use of electric-hybrid technology during the stationary phases of operation in addition to natural gas as fuel. This implies the internal combustion engine does not have to run unnecessarily. Figure 64 provides insight in the reduction potential for the reduction potential compared to diesel vehicles of the CNG + hybrid technology, but also for the hybrid technology alone. Compared to conventional diesel vehicles (not equipped with a particle filter), the reduction potential of the electric-hybrid vehicle is about 70-94% for nitrogen oxides, hydrocarbons, carbon monoxide and particles. For carbon dioxide, the reduction is limited to a few percent. Fuel consumption reduction is about 20-40%.

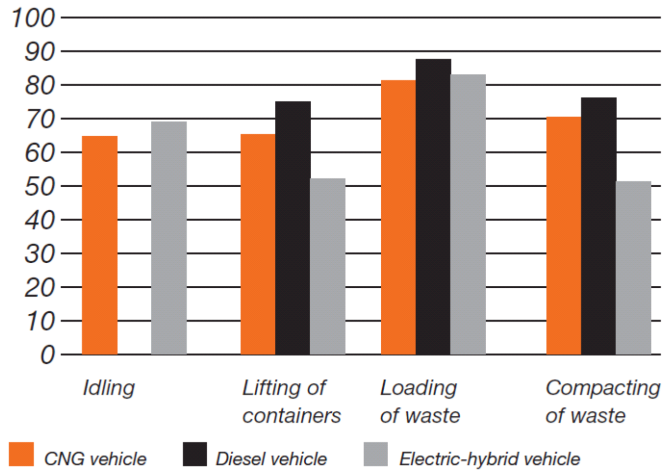
Figure 64: Results of emissions measurements (Renova, 2006)



Also the noise impacts can be compared and are presented in Figure 65.

It is important to note that a reduction in noise level of 3 dB is equivalent to a reduction of 50 percent in the noise level as experienced.

Figure 65: Noise levels (in dB) (Renova, 2006)



In order to get insight in the various cost components of various drivetrains has expressed the cost of conventional CNG and diesel waste collection trucks as share of an electric-hybrid vehicle. Capital costs are lower for CNG and diesel vehicles (below 100%), while fuels are 25% more expensive compared to charging electric waste collection trucks.

Table 82: Cost of a conventional CNG and diesel vehicle in relation to an electric-hybrid vehicle (Renova, 2006).

Cost categori	Conventional CNG vehicle (%)	Conventional diesel vehicle (%)
Financial depreciation and capital costs	81	64
Personnel	100	100
Service and repairs	94	78
Fuel	125	125
Electricity	0	0
Other costs	100	107
Total	97	93

5.6.3 Improvement options for waste collection services

In terms of services many of the aspects described under LDVs and buses is also valid for waste collection services. All vehicle related measures can also be requested when purchasing services.

In addition to technical measures, operational measures can be required which have a positive impact on fuel consumptions, like **eco-driving.** The more complete the package in terms of feedback to the driver and incentives the larger the impact could be.

Other operational measures, which can be part of a maintenance scheme, are for example the **alignment of tyres and axles**. Reductions equal to buses (2.5-5%) can be expected.

Together technical and operational measures can reduce fuel consumption, but waste collection operators also can impact the kilometres driven by **logistics optimizations**. Where passenger transport can focus on occupancy rates waste collection services can focus on route optimization. Factors related to the logistical optimizations are for example frequency of collection, type of collection systems in terms of waste streams (like the number of separated waste streams) and collection points (for example, if people bring their waste to collective containers). New innovative and smart technologies can also help with indicating the need for and best way of collection. The optimal situation will also depend on local circumstances, for example, climate conditions might influence the frequency required to collect bio-waste to prevent smell and hygiene issues. Measurable indicators can be used, such as the kgCO2/tonne of waste or km. Requiring management plans describing and evaluating measures that will be taken to reach continuous improvements in terms of environmental impacts could also be a good step to stimulate reduction of environmental impacts.

According to the Background Report on Best Environmental Management Practice in the Waste Management Sector (Zeschmar-Lahl, et al., 2016), commercially available software tools incorporating Computerised Vehicle Routing and Scheduling (CVRS) technology could improve the modelling and optimisation of collection operations. This report also describes some examples of collection optimisation, where CVRS were able to reduce the fuel consumption from 5% to 15%.

(Zeschmar-Lahl, et al., 2016) cites a report from WRAP (2010) which selected a set of parameters to feed in the models that provide the basis for re-designing and optimising collection rounds using CVRS technology: household locations, collection day requirements, waste volumes, unloading locations and vehicle turnaround times / congestion

It also suggests that data generated by Pay-As-You-Throw (PAYT) systems can provide a powerful basis for logistics optimisation. Contrary to PAYT systems, whose main objective is reducing the waste disposal, there are dedicated systems to provide data for route optimisation. (Zeschmar-Lahl, et al., 2016) describes a case study of collaboration between PROMEDIO and Wellness Telecom in Badajoz, Spain, where micro-chip sensors were used in bins to monitor bin fullness at the point of collection in order to inform optimisation of collection frequency and public collection point siting. Wellness Telecom and PROMEDIO implemented a project in the Spanish province of Badajoz to monitor 50 bins for 12 months, using electronic sensors to record bin weight at collection. The study was part of the EU LIFE-funded "Ewas" project, and revealed the following:

- Only 20 % of bins have a fill rate high enough to require weekly collections
- 18-20 % of bins are collected with content below 40 % to 50 %.
- 75 to 80 % of bins are collected at least once per year with content below 40-50 %
- From these findings, Wellness Telecom proposed the following measures to PROMEDIO:
- Identify a list of bins that need to be collected weekly due to a higher service demand. Reorganise collection site locations and enhance service availability, with additional bins in nearby locations, to allow for collection every 15 days.
- The rest of the bins should be collected every two weeks.

This will provide a basis from which to further optimise collection routes and frequency, saving in fuel and human resources. Continued monitoring of bin fill level through use of a simple electronic tool ("e-Garbage") is proposed to identify full bins requiring earlier collection. Expected savings in fuel are ca. 5 000 litres per year, whilst workforce savings are in estimated to be 40-50 %, switching from weekly to biweekly collection.

Another system to collect historic data of waste collection to feed in predictive models is recording the weight of waste collected in each bin, which is measured by a weighing system installed in the waste collection truck (MOBA, n.d.).. This system was implemented in the municipality of Sant Cugat allowing up to 25% fuel consumption reduction (Municipality of Sant Cugat, personal interview 2016)

There are also systems providing real time data of the bin fill level. In 2006, a study carried out in Sweden (Johansson, 2016) analysed 3 300 recycling containers that had been equipped with level sensors and wireless communication equipment, thereby giving waste collection operators access to real-time information on the status of each container. Malmo case study resulted in a reduction of the collection and hauling distances by 17%, the number of stops to collect containers is decreased by 14% and the operational cost (fuel consumption) reduced by 15%.

This technology is currently mature and available but the market penetration still remains low: around 30 municipalities across EU have this system implemented (SmartBin, personal interview 2016). The system is usually composed by two main elements:

- The level sensors, which consist of an ultrasonic sensor technology equipped with an internal antenna and a SIM On Chip card that communicates with the waste collection data server through GPRS over GSM.
- The waste collection data server, which gathers and analysed the data enabling the route optimisation of the waste collection fleet

The communication with the drivers is also made by means of GSM through a mobile phone or tablet (SmartBin, n.d.), or by means of an embedded system that needs to be installed in the truck ((MOBA, n.d.)).

6 POSTAL AND COURIER SERVICES AND MOVING SERVICES

6.1 Introduction

This section gives a description of the objectives and taken approach of the market analysis of postal and courier services and moving services.

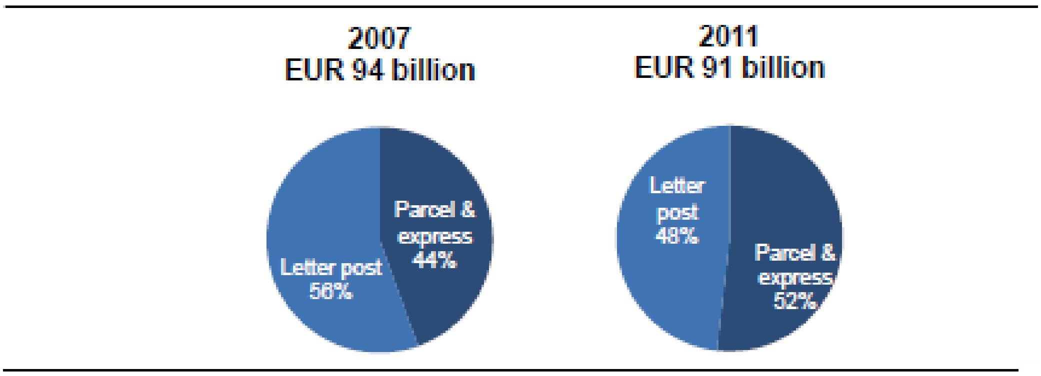
6.2 Market analysis

6.2.1 Overall market

Postal and courier services

According to (ITA Consulting and WIK Consult, 2009) the EU postal sector, including letter post, parcel and express services, represented a total revenue of about € 94 billion in 2007, which is approximately 0.7% of EU-27 GDP. Within the postal sector letter post is responsible for 56% of the revenues and the parcel and express market 44%. However, according to (WIK-Consult, 2013), between 2007 and 2011 the size of the European postal sector has reduced from €94 billion to 91 billion accounting for 0.72% of EU-28 GDP. While revenues in the parcel & express sector have grown, demand for letter post services has declined. For this reason the structure of the European postal sector has changed: now parcel & express revenues account for more than half of total sector revenues (see Figure 66). This is the result of the growing e-commerce business.

Figure 66: The European postal sector 2011



As depicted in Figure 67 six Member States represent 79% of total letter post volume, including the UK, Germany, France, Spain, Italy and the Netherlands. For the parcel and express market Germany, UK, France, Spain and Italy represent 77% of the market.

Figure 67: EU-27: The size of the national letter post markets (in terms of letter post volume) (WIK-Consult, 2013)

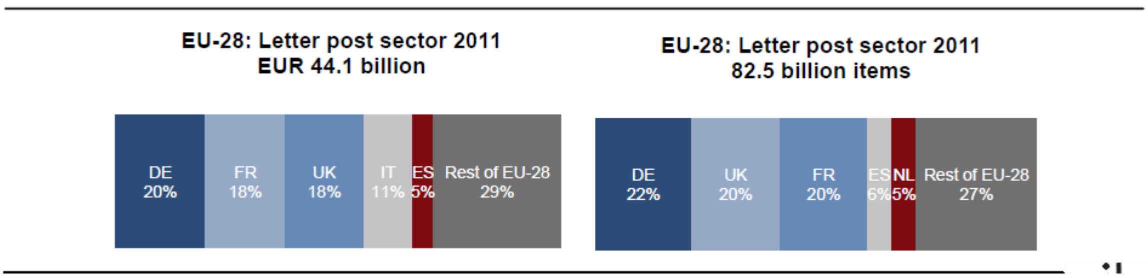


Figure 68: EU-27: Parcel & express market by country

On average, the demand for postal services varies across the EU depending on economic development. Table 83 summarises the annual average amount of postal items received per capita.

Table 83: Average amount of letters and parcels per capita per year (2011) (WIK-Consult, 2013)

		Letters	Parcels
Wester Member States	AT, BE, DE, DK, FR, FI, IE, LU, NL, SE, UK, IS, LI, NO, CH	252	20
Southern Member States	CY, EL, ES, IT, MT, PT	82	5
Eastern Member States	BG, CZ, EE, HR, HU, LT, LV, PL, RO, SI, SK	50	2
EU average		163	13

In terms of product segment the letter post in the EU consists for 60% of correspondence, 28% of direct mail and 12% of publications. 88% of the letters are sent by businesses (B2X) and 12% by consumers. In 2008 the division between parcel and express has been 65% parcel and 35% express, being 80% B2B, 15%, B2C, C2C 5%.

Moving services

No market data on moving services in the EU could be found. As result of this lack of data, moving services should get special attention during upcoming stakeholder interaction. There are, however, statistics available on the HDV market.

For the category moving services rigid trucks are most relevant. The market shares of rigid trucks and tractor trucks went down in 2008 and 2009 as result of the economic crisis, but are increasing again and are almost similar in size. Buses, pickup/vans and other HDV-vehicles are the other categories under this market segment, but a lot smaller. The impacts of the economic crisis is even more reflected in the figures on annual sales (see Figure **70**)

Figure 69 HDV market share by vehicle type in the EU **(ICCT, 2016b)**

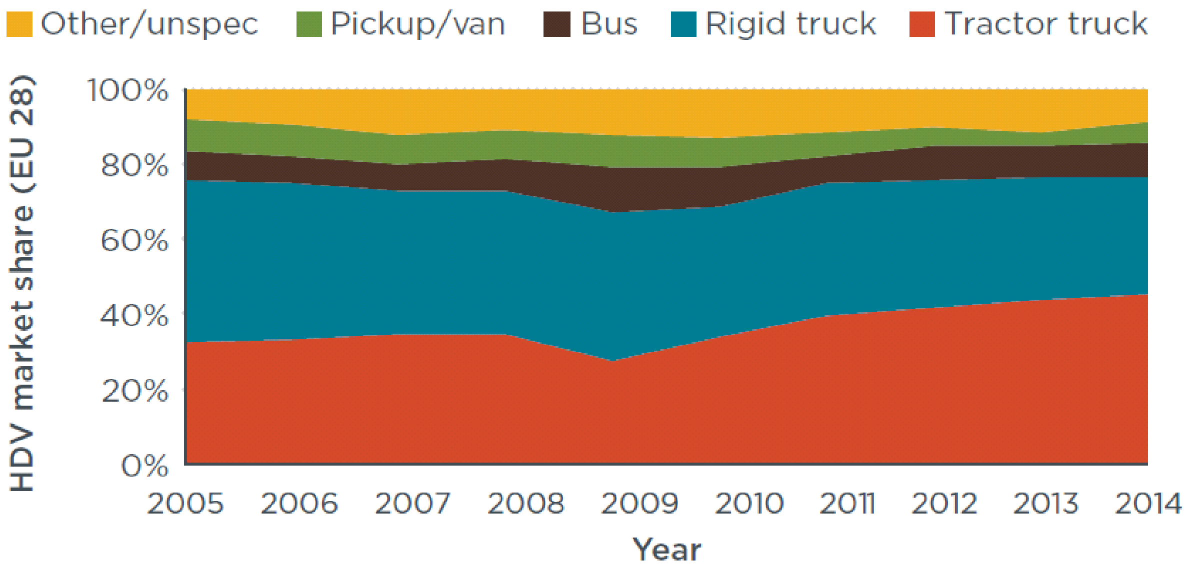
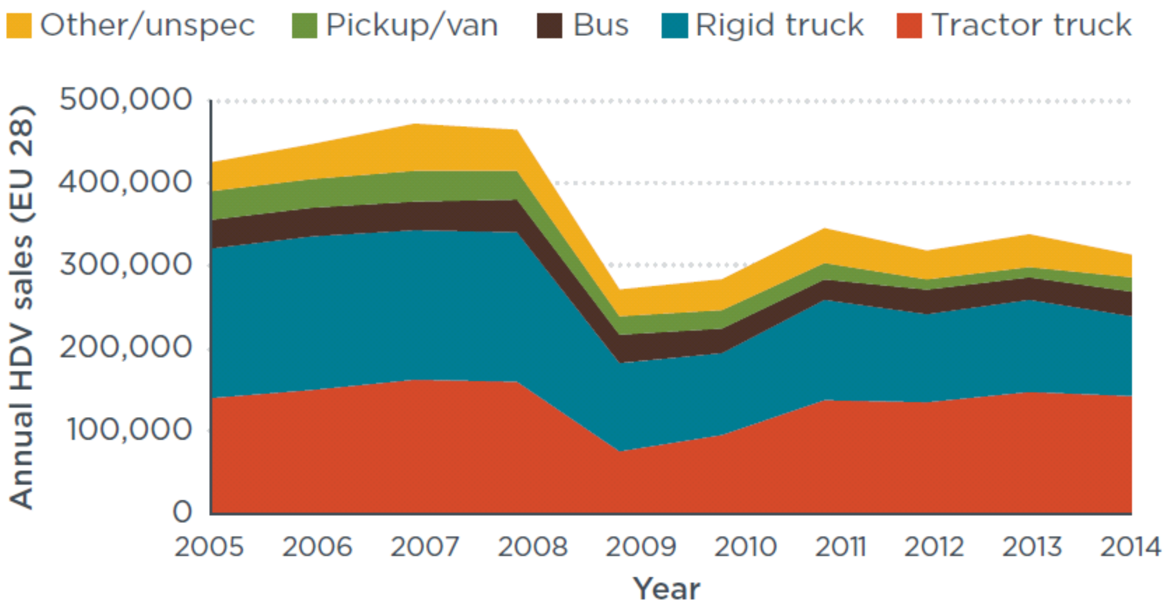
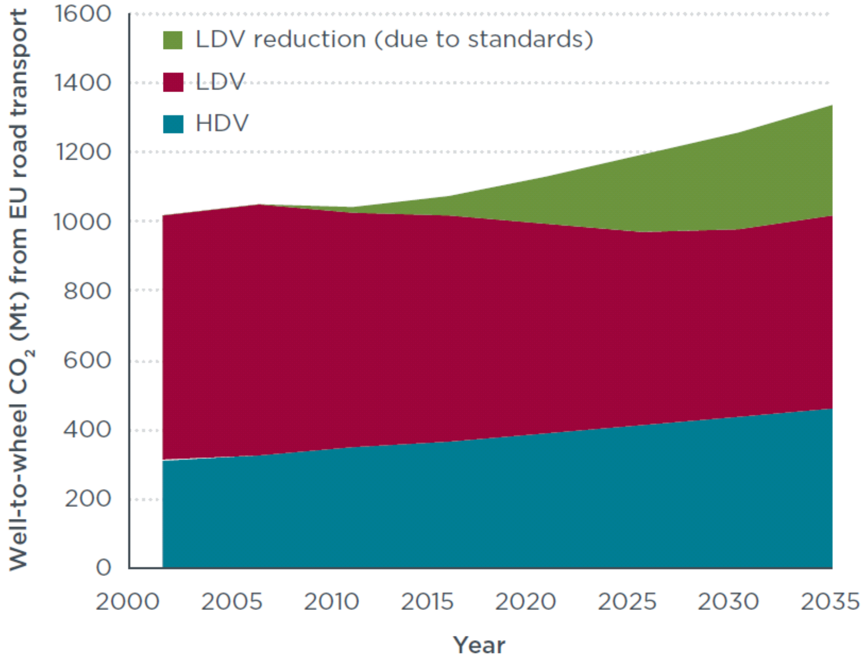


Figure 70 HDV annual sales by vehicle type in the EU **(ICCT, 2016b)**



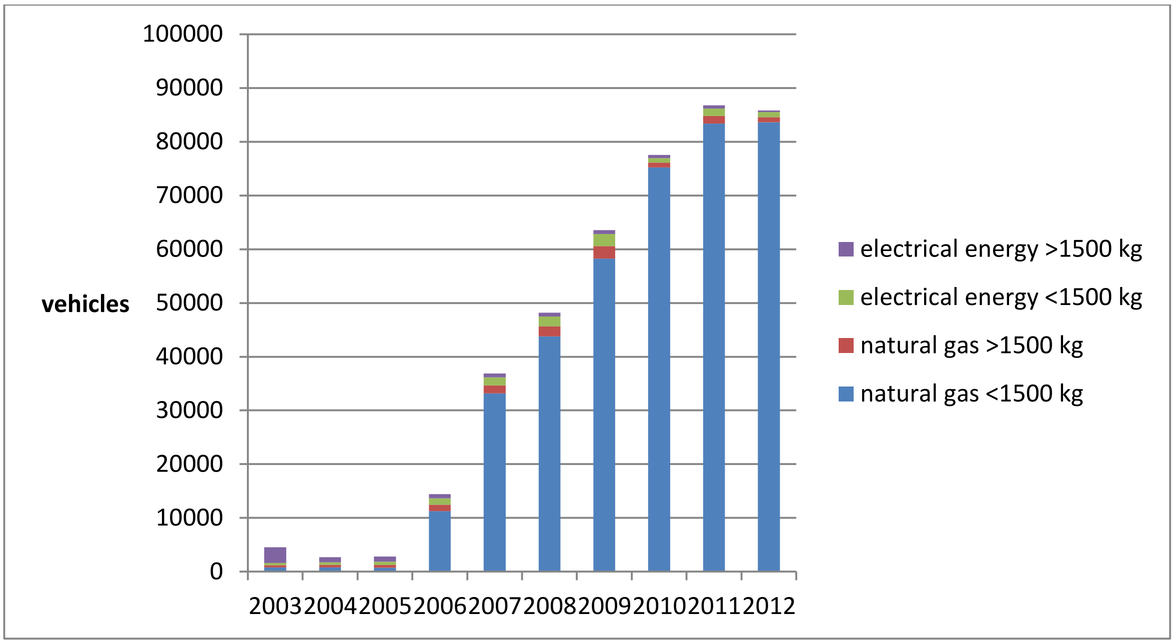
According to ICCT (2015) heavy-duty vehicles (HDVs) represent only 4% of the on-road fleet in the EU but are responsible for about 30% of on-road CO_2 emissions. CO_2 emissions from LDV show a decreasing trend as result of the existing standards. Due to the lack of standards for HDVs emissions are still increasing for this market segment.

Figure 71 Road transport CO_2 emissions in the EU between 2000 and 2035 **(ICCT, 2016b)**



In terms of alternative fuels Eurostat statistics show that the share of electrical energy in trucks is still very limited and the biggest growth is caused by the application of natural gas in vehicles with a load capacity <1500 kg. Natural gas in vehicles >1500 kg are also limited. The category 'other products' is also used by Eurostat, but because it was not clear what type of alternative energy is included in that specific category this category is not included in the figure below.

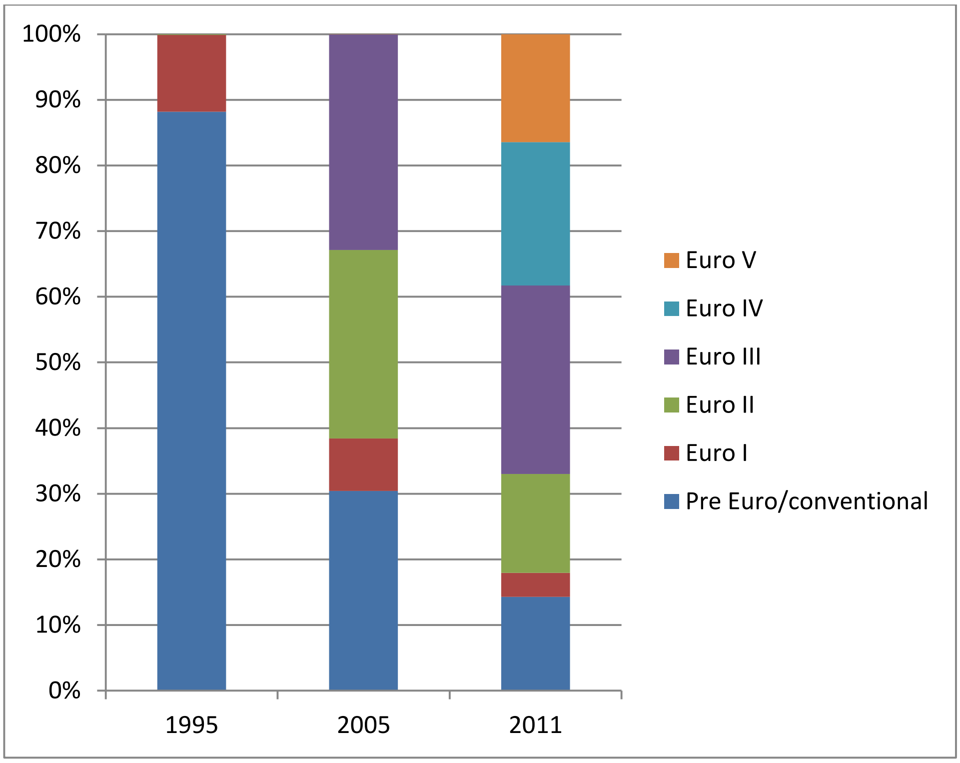
Figure 72 Lorries, by type of alternative motor energy and load capacity (Eurostat, 2015[109])



With respect to the Euro standards regulating the air polluting emissions the development in the different shares of Euro classes is depicted in Figure **73**.

[109] http://ec.europa.eu/eurostat/web/products-datasets/-/road_eqs_loralt

Figure 73 Share of Euro classes in heavy duty vehicles in 1995, 2005, 2011 (EEA, 2013[110])



6.2.2 Public procurement

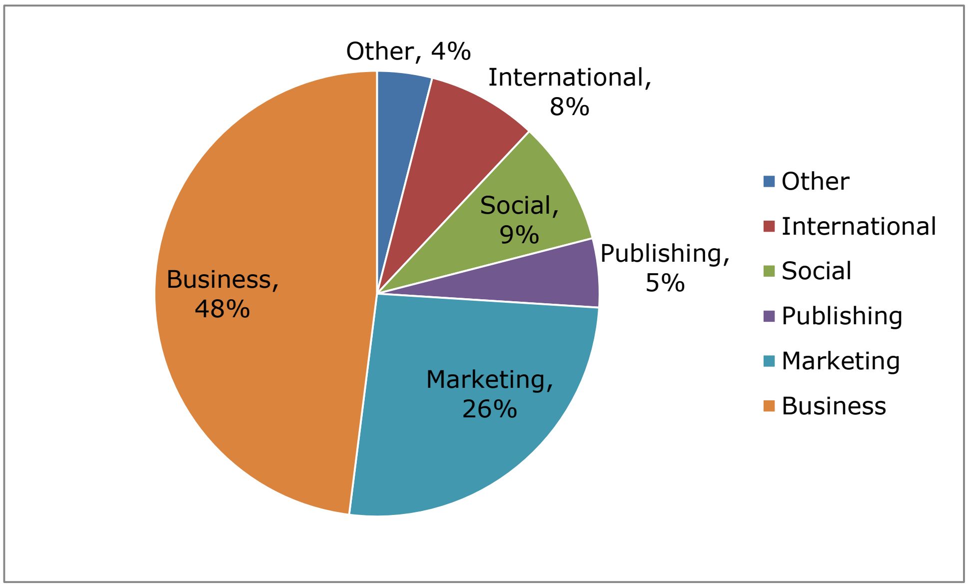
Postal and courier services

While there are various surveys available of the EU postal market in the public domain, it was not possible to identify a survey that explicitly specified the role of the public sector in this market. However, a sense of the extent to which the public sector uses postal service is provided by looking at data from the UK. The UK postal regulator Ofcom used data for the Royal Mail, which had 95% of the UK postal market, to estimate that around 48% of the revenue from letters in the UK was related to 'business' or 'transactional' letters, which were primarily bills and statements (Ofcom, 2015); see Figure 74). Given the other categories of letter type, it is likely that the 'business' category of letter includes letters generally sent by the public sector. However, such letters could also come from a range of other types of organisation, including companies involved in financial services, insurance, telecommunications, electricity, gas and water, as well as government organisations. These organisations are considered to be 'larger mailers', along with the likes of retail companies, the leisure industry, the health and education sectors and charities, along with various business to business services. In addition, there will be a large number of smaller business users (Postcomm, 2010).

[110] http://www.eea.europa.eu/data-and-maps/figures/allocation-of-heavy-duty-vehicles-1

Consequently, it appears likely that the proportion of the postal market in the UK that is due to the public sector is no more than a few percent of the total given the number of other types of industry using this service. In other Member States where the public sector is larger, it is possible that this proportion might be larger, but is unlikely to be much higher, say no more than 5%, in the EU on average.

Figure 74: Breakdown of revenue by type of letter (UK)



Source: (Ofcom, 2015).

Given the nature of the public sector, it is likely that its share of the postal market will be larger than its share of the courier market, which could be less than 1%. For example, in the UK, Royal Mail considers that one quarter of its domestic parcel revenue is generated by large and medium-sized companies, while three quarters is generated by individual consumers and small businesses; there is no mention of the public sector (Royal Mail, 2014).

Moving services

As stated above, there is little publicly available information on the moving (or removal) industry. However, it is possible to obtain a sense of the extent to which the public sector is a client of the moving industry by identifying the extent of the potential moving market. Essentially, moving services might be needed by households, businesses or public sector organisations, the numbers of which in the EU are presented in the second column of Table 84. Households make up around 91% of the total number of potential clients for the moving industry, while public authorities make up around 0.1%.

However, many businesses and local authorities will be larger, and therefore potentially more lucrative for the moving industry, than households. Consequently, it is unlikely that households will contribute 91% to the business of the moving industry, and so is important to increase the number of businesses and local authorities by some factor to lessen the potential contribution of households to the business of the moving industry. In order to do this, assumptions have to be made. If it can be assumed that the potential contribution to the revenue of the moving industry of a business or a local authority is linked to their size, the size of different businesses and local authorities can be used to estimate the number of 'household equivalents' for each business or local authority. In this respect, it might be assumed that micro-businesses are twice as large as households, as these businesses have between 0 and 9 employees, whereas the average household size in the EU is 2.3 (Eurostat, 2015 a). In a similar manner it might be considered that small and medium sized businesses (and local authorities) are 50 times as large as a household, while large businesses and regional and central public authorities might be 250 times as large. Clearly, these assumptions are estimates, but they only raise the potential share of the moving market that might be attributable to public authorities to 2% of the total. Consequently, it is unlikely that the public sector contributes more than a few percent to the market of the moving industry.

Of course, these assumptions imply that households, businesses and local authorities are as likely to move as each other. Data from the UK suggests that around 10% households move each year (ONS, 2011), but it was not possible to identify equivalent figures for businesses or local authorities.

Table 84: The numbers of households, businesses and local authorities in the EU

	Millions	**Millions 'household equivalents'**	**% of total 'household equivalents'**
Households	**216.13**	**216.13**	**61%**
Businesses			37%
Micro businesses (less than 9 employees)	20.71	41.43	
Small/medium businesses (10 to 249 employees)	1.59	79.32	
Large businesses (250 or more employees)	0.04	11.17	
Public authorities			2%
Local authorities	0.09	4.67	
Regional authorities	0.002	0.42	
Central authorities	0.001	0.35	
Totals	238.57	353.47	

Sources: (Eurostat, 2015 a) for household numbers; (Eurostat, 2015c) for business numbers; (CCRE/CEMR, 2016) for local and regional authority numbers; own estimates for central authority numbers (assuming 50 ministries and agencies per Member State).

6.3 Cost analysis

6.3.1 Postal and courier services

The cost for post items (per unit) are depicted in Table 85 for various Member States and show a range between €0.31-1.30 per unit.

Table 85: Unit costs for Universal Service Providers in Purchasing power parity (Nera, 2004)

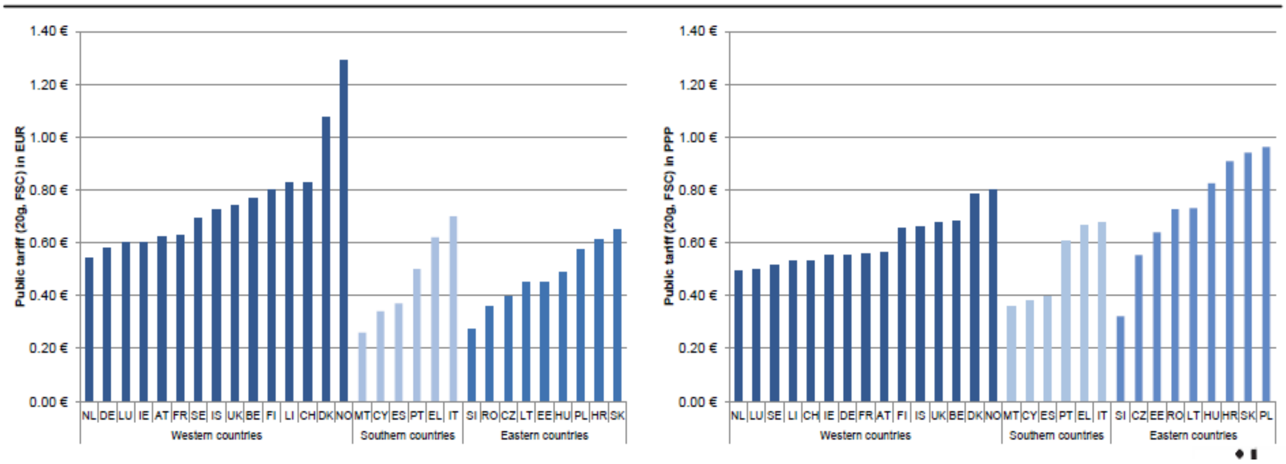
	1998 (€)	1999 (€)	2000 (€)	2001 (€)	2002 (€)	2003 (€)
Austria	0.57	0.60	0.51	0.37	0.33	
Belgium	0.49					
Denmark	0.41	0.41	0.41	0.40	0.40	0.39
Estonia	1.50	1.29	1.28	0.68	0.53	0.50
Finland	1.12	1.07	1.05	1.07	1.12	1.10
France		0.81	0.87	0.93		
Germany	0.51	0.50	0.43	0.43	0.46	0.44
Greece		0.66	0.67	0.71	0.76	
Hungary	1.50	1.10	1.10	1.11	1.18	1.30
Ireland	0.78	0.78	0.76	0.77	0.81	
Italy		1.25	1.25	1.23	1.31	
Latvia		1.61	0.72	0.65	0.68	1.25
Lithuania	2.21	2.21	2.25	2.21	1.94	2.02
Luxembourg				0.33		
Netherlands		0.43	0.43	0.43	0.46	
Malta				0.44	0.45	0.38
Portugal			0.52	0.53	0.58	
Slovakia			1.04	0.99	1.34	
Slovenia	0.51	0.48	0.43	0.41	0.37	0.31
Spain				0.37	0.35	0.34
Sweden	0.40	0.43	0.43	0.41	0.42	0.44
United Kingdom	0.54	0.58	0.70	0.69		

Source: Total cost data from Table 5.1 divided by traffic data from country reports.

Notes: Countries missing: Cyprus, Czech Republic, and Poland.

More recent data on tariffs are available from (WIK Consult, 2013), as shown in Figure **75**:

Figure 75: Domestic public tariffs in Euro and in Purchasing Power Parity (PPP), (20g FSC, May 2013) **(WIK Consult, 2013)**,



On average, labour cost represent about 63% of total costs, while the depreciation/amortisation costs only represent about 5%. Cost figures are also provided for costs splits by activity for universal service providers[111] (see Table 86). On average 50% of the cost can be attributed to the delivery phase, followed by sorting 16%. Transport has the lowest share with only 7% on average. Delivery is a very labour intensive phase, which can explain its large share on the total costs. However, (Nera, 2004) suggests that geographical factors (transport costs) as well as mail volumes are also parameters influencing the delivery costs.

[111] According to Eurostat a universal service provider can be defined as 'a public or private entity providing a universal service or parts thereof within a country, not specifying whether required by license, authorization or another legal instrument'. A universal service is 'the practice or legal obligation of providing a baseline level of service to every resident of a country. It is mostly used in the context of regulated industries, considered by authorities as providing vital services (for example postal services, telecommunication, public transport, ...).

Table 86: Cost Splits by Activity in Letter Mail for Universal Service Providers (Nera, 2004)

Country	Year	Collection (%)	Transport (%)	Sorting (%)	Delivery (%)	Overheads (%)	Retail (%)	Total (%)
Austria	*pre 1998*	22	2	22	54	0		100
Czech Republic	*2003*	17	9	12	39	23		100
Denmark	*pre 1998*	5	5	9	43	38		100
Estonia	*2003*	17	10	12	32	5		76
Finland	*pre 1998*	13	10	20	50	7		100
France	*2001*	8	5	15	46	21	5	100
Germany	*1998*	13.2		17.4	69.4			100
Greece	*2002*	21.4	2.9	14.3	50.7	10.7		100
Hungary	*2003*	13	9	4	54	20		100
Ireland	*pre 1998*	12	7	24	57	0		100
Italy	*pre 1998*	17.7	9	26.3	47	0		100
Luxembourg	*2001*	9.3	7	20.8	51.4	11.5		100
Slovakia	*2002*	8.1	9.4	11.2	27.4	43.9		100
Slovenia	*2003*	1.4	4.5	4.5	77	12.6		100
Spain	*2003*	9.1	5.9	14.3	52.2	18.5		100
United Kingdom	*circa 2000*	5	14	26	43	12		100
Unweighted average		*12.0*	*7.3*	*15.8*	*49.6*	*14.9*		100

Moving services

No data on cost of moving services could be found within this task. As result of this lack of data, moving services should get special attention during upcoming stakeholder interaction.

6.4 Technical analysis

6.4.1 Improvement options for Postal and courier services

The environmental impact of vehicle fleet of operators will strongly depend on the age of the fleet and the renewal rate. Many of the technical requirements could be similar to those for passenger cars and LCVs. And like for all services, operational measures, like eco-driving or alternative fuels can be applied to reduce fuel consumption of operation

Low emission vehicles

The LaMiLo (last mile logistics) project deliverable Public sector influence on last mile logistics (LaMilo, 2014) includes the use of low emission vehicles as a policy measure to improve the air quality of urban areas. Some case studies are described in this report, as summarized below:

- *UPS is testing and analysing the use of a fleet of electric vehicles in urban traffic systems to reduce CO2 emissions, noise and particulate emissions in Karlsruhe (Germany) and London (UK). The vehicles being used are conventional diesel vehicles that have been modified into electric vehicles. These electric vehicles are being used mainly in inner city areas and on trips shorter than 80km. The vehicles return to the depot with about 20% residual charge and are then recharged at a specific loading facility by the responsible person. All vehicles are charged through the night.*
- *As part of the IKONE project, about 50 Mercedes-Benz Vito E-CELL transporters powered by electricity are used by selected partners and the large German parcel*

logistics service provider DPD in the Stuttgart region. Their field of application involves various commercial activities and delivery tasks. The Stuttgart region has a very difficult topography (situated in a basin) and the filed test focused on the analysis of the vehicle use in these specific conditions. The logistics provider had to change their business model to accommodate electric vehicles (EVs) by splitting the delivery of B2B and B2C parcels, and delivering the generally smaller B2C parcel with EV.

- *The Green Link (TGL) is a company making parcels deliveries in central Paris with an entire fleet of battery electric vehicles (EVs). TGL started operations in 2009 and is now using 3 urban hubs in Paris and trying to develop in other French cities and other countries. At the end of 2013, the volume of parcels distributed was 2 500 per day, and the business was expected to grow to a volume of about 5 000 parcels per day in 2014. The scale of growth is limited by the size of the current urban hubs.*

Cycle logistics

Because delivery of parcels and letters will largely take place in urban areas modal shift options are also an option to reduce the environmental impact. The **bike** can potentially play a much bigger role in delivery, especially because the potential has increased since the introduction of electric bikes on the market. The term of cycle logistics is often mentioned in relation to urban delivery, but this is also valid for electrified vehicles (like L-category vehicles).

According to CIVITAS 42% of all motorized trips in urban areas could be shifted to logistics by bicycle (this corresponds to 25% of all trips). (EPOMM, 2012) Also a deliverable within the project Cyclelogistics ahead (Chiffi & Galli, 2014a) indicates a high potential for municipal document delivery, like small documents, internal mail and consultation documents to residents, to shift to cargo bikes. The study also showed that cargo bikes are differently defined by the various participating countries. Cargo bikes without electric motor can reach capacities up to 250 kg and with an electric motor this could even up to 400 kg. The shows the characteristics of the most common freight cycle types used by cyclelogistics companies in Europe. An electric micro van and a CNG van are included for comparison.

Figure 76: Comparison of different freight cycle types used by cyclogistics companies in Europe **(Chiffi & Galli, 2014a)**

	8freight	iBullit	Lovelo	CycleMaximus	Vrachtfiets Cargo	Alke‘ ATX 210E	Fiat Doblò Cargo
Type	cargo bike	cargo e-bike	cargo e-trike	cargo e-trike	cargo e-quadricycle	micro e-van	CNG Van
Wheels	2	2	3	3	4	4	4
Weight (Kg)	20-25	35-40	90-100		95	995	1600-2000
Lenght (mm)	2000	2430	2600	2500	2700	3520	4400-4700
Width (mm)	510	500-680	1040		1050	1270	1832-1872
Height (mm)	1000	1027	2000		1900	1850	1845-2010
Cargobox dimensions (mm)	650x570x510	780x680x540	1250x730x1540	1210x1210x950	1000x2000x1000	1250x1800x1100	1310x1714x3000
Cargobox volume (m3)	0,2-0,5	0,2-0,3	1,4-1,5	1,4-1,6	2	2,5	3,4-5,4
Net Payload (up to) Kg	60-80	100-150	180	200	200	500	700-1000
Net price	from € 2,000	€ 3,700 - € 5,300	€ 7,500	€ 9,500	€ 7,500	from € 20,000	from € 14,000

Overall, the capital and operational cost of bicycles are lot less than motorized transport and cargo bikes are not subject to parking and congestion charging. A disadvantage of cargobikes is the higher number of staff that is required and consequently higher cost.

Besides, it needs to be supported by specific urban measures, such as access restrictions, urban consolidation centres, cycling infrastructures and special loading and unloading bays.

In this regard, the deliverable *State of the Art of existing Cyclelogistics measures and services in partner cities* also from the project Cyclelogistics ahead (Chiffi & Galli, 2014b) *provides an* overview of the situation and planned interventions in the demonstration cities that participate in the project: Berlin, Budapest, Cambridge, Donostia-San Sebastian, Graz, Mechelen, Milan and Prague. The report summarised the state as follows:

- *All cities have implemented access restrictions for motorised traffic using schemes like environmental areas, speed limit (30km/h) areas, road charging (Milan) and several time windows restrictions including freight vehicles (e.g. between 3.5 and 7.5 ton).*
- *Pedestrian areas are present in all the partner cities with variable extension: they are generally open to bicycle traffic (and thus cargo bikes) with some exceptions (i.e. some downtown areas in Budapest).*
- *Cycling infrastructures are well developed in almost every city. Two aspects seems here to be the most critical: the lack or inadequacy of bike parking facilities and above all the irregularity of surfaces or uphill of roads which can be an obstacle to cyclelogistics diffusion.*
- *In general there is at least one cyclelogistics operator per city (*Figure **77***) with the highest number of cycle-based delivery company being concentrated in Milan. On average, cyclelogistics operators have a fleet of 2 to 5 cargo bikes. More details are gathered in table….*
- *Locker systems (on-street or home pick-up points) are located in most of the cities with a massive presence in Berlin (50) and in Mechelen (100). DHL is the most relevant player with its Packstations but several other providers are also present.*
- *It was extremely difficult to identify the number of Urban Consolidation Centres, being such information typically not available with numerous (especially private) warehouses disseminated in the outskirt of every city.*

Figure 77: Cyclelogistic operators per city **(Chiffi & Galli, 2014b)**

CYCLE-LOGISTICS OPERATORS	Cyclelogistics operators	Fleet
Berlin	Urban-e and GO! Express and logistics	2 cargo bikes (electric)
	Messenger	20 cargo bikes
	Twister	5-10 cargo bikes
Budapest	Ökocickli	2 special cargo tricycles
	Mol-Bubi (BKK)	n.a.
	Kantaa	3 cargo bikes
	Hajtás Pajtás	2 cargo bikes 6 motorized vehicles
Cambridge	Outspoken Delivery	7 cargo bikes 4 cargo trikes n.a. standard bicycles
Donostia San Sebastian	Txita	10 cargo trikes 2 cargo bikes 9 taxi-bikes
Graz, Austrian cities	Pink Pedals Heavy Pedals Veloblitz Hermes Spinning Cyclee Veloteam Green Pedals	n.a.
Mechelen	BubblePost Mediamrkt Apasionata Soeper Group Intro	n.a.
Milan	DHL express Triclò Milanbike Ecomilano Ubm Ponyzero Fastexpress	n.a.
Prague	Messenger Prague Cargo Bike	4 cargo bikes (1 electrically assisted) 25 bikes 34 motorcycle 146 cars and vans

Within urban deliveries, bikes are very suitable to be used in postal and courier services due to the volume and weight of letters and parcels. Some case studies are summarized below:

E-bikes Croatian Post (Eltis, 2015).

In July 2014 the EU-funded Pro-E-Bike project helped Croatia's national postal service Hrvatska pošta (Croatian Post) to test electric bikes as a way for it to deliver letters and small packages using cleaner and more energy-efficient vehicles.

The test phase started with two e-bicycles: one e-tricycle and one e-scooter for six months and was more successful than the project anticipated: the evaluation showed a reduction in CO2 emissions, financial savings and positive feedback from postmen and good logistics indicators. Croatian Post thinks the e-bikes are better than the scooters: they have a similar range of 25-40 km, but the e-bikes can still be used when battery power is low. Consequently Croatian Post decided to purchase 180 e-bikes to replace its petrol-powered mopeds, which came into service in October 2015.

Coventry's zero-emission postal service (UK) (Eltis, 2015).

Coventry, a city in central England, has a bicycle-based postal delivery service. Yellow Jersey Delivery made its first deliveries in 2009 and initially delivered around 400 letters a month. Three years later, the company delivers 40 000 to 45 000 letters a month

Public procurement of postal and courier services in UK (European Cyclists' Federation, n.d.)

Cambridge City Council outsourced their internal mail delivery to the local cyclelogistic operator Outspoken Delivery. Brighton and Hove City Council also contracted deliveries to the cycle courier company The Bike's the Business.

Optimization of logistics by consolidation solutions

Urban consolidation solutions are coming back to the urban planning responding to the increasing last mile issues due to the growing e-commerce (LaMiLo, 2015). As mentioned above, it is a key element to increase the electrification of the delivery fleet and to implement cyclelogistic solutions.

Urban consolidation is not a new concept: urban consolidation centres (UCC) or urban hubs were a popular measure in city logistics 25 years ago. In Europe 150 UCC projects were started, but only 5 projects survived (Vahrenkamp, 2013). One of the main reasons was that the additional transhipment often prevented them of being cost-effective. In addition, urban retailers were reluctant to use the service provided by the UCC, since the added value was not apparent for them (Verlinde, et al., 2012).

The LaMiLo (last mile logistics) project deliverable *Public sector influence on last mile logistics* (LaMiLo, 2015) includes the consolidation solutions as a policy measure to reduce the number of delivery vehicles in the urban area and therefore the issues derived from congestion.

LaMiLo report has also collected several examples of consolidations solutions, which are summarized below:

- *CityPorto is an UCC in Padua (Italy) operating since 2004. It performs more than 100 000 deliveries per year (2012) for 65 customers which are most of the couriers of the city.*
- *The London Borough of Camden together with partners Enfield and Waltham Forest, set up a consolidation centre trial for use by local authorities' suppliers of cleaning products and stationary. The consolidation centre logistics operator consolidates the goods running two trucks from the centre to 300 local authority buildings across the three boroughs. The trial expanded to include Islington Council, so the area covered by the consolidation centre is 157km2 or 10% of London's geography. When Camden's new building in Pancras Square came into use, restricted with only one loading bay to handle approximately 100 deliveries per week, an additional 44 suppliers started using the centre, with an increased range of product categories. Camden has required its trial suppliers to use the consolidation centre, through their procurement processes*
- *The Freigth Circle Binnenstadservice, Eco2City is undertaking a B2C (business to consumer) pilot in two cities in the Netherlands. Customers who order goods*

online can select a hub in the city as the delivery address. Operators transport the goods to the hub by bike. At the hub goods are consolidated before delivered at the end user. The bike couriers are also responsible for taking back waste for resource recovery at the same time. Due to the current limited scale no quantitative impacts are known yet.

- *Brussels Consolidation Centre: In order to tackle increasing and scattered freight movement within the city centre, Brussels Mobility promoted the trial of an urban consolidation centre in favour of logistics service providers and local retailers. In close collaboration with CityDepot, the operator of the consolidation centre, value added services have been tested in addition to last mile deliveries and were supported by a stakeholder group. From September 2014 - May 2015 seven logistics operators / transporters have signed up to deliver all of their goods for central Brussels through the consolidation centre. In order to persuade transporters to change their behaviour and use the consolidation centre, it was important to identify that the service would not be more expensive for them to use, compared to them making the 'last mile' of the delivery themselves. As part of this process it became clear that many transporters did not know how much the last mile cost them.*

As an alternative to conventional UCC, (Verlinde, et al., 2012) suggest to downscale the scope of the consolidation to a particular delivery area. The paper describes several case studies where the concept of Nearby Delivery Area was implemented in France (Bordeaux, Paris, Dijon, Rouen and Lyon). A specific area is dedicated to goods vehicles for the loading and unloading of goods for the nearby shops (often an underground car park). Goods are unloaded from the incoming freight vehicles and then loaded onto electric tricycles for the final distribution leg. That way, both freight vehicle kilometres and the global time for delivery are reduced as goods destined for this particular district are unloaded at once. And more importantly, loading and unloading operations are facilitated without modifying current transport contracts, freight vehicle drivers have dedicated spaces at their disposal and the road occupancy of freight vehicles is reduced drastically. This concept is quite similar to the traditional UCC, but deviates from it because it is completely privately operated and serves a particular (small scale) area

The European project CITYLOG developed a solution to reduce the number of vehicles in the city centre and at the same time improve the urban delivery of goods, also applying Nearby Delivery Area (Eltis, 2015). The project, called BentoBox, focuses on 'smart packaging', Drop-off points are used where customers can pick up their deliveries or where cleaner 'last-mile' vehicles can take over to deliver the goods to their final destination. The BentoBox itself is a type of container composed of a fixed docking station with a user-interface (touchscreen) and a control unit and a chassis subdivided into six modules. The system in the container allows information notices to be sent to receivers on arrival time etc.

In 2011 one of the first tests took place in Berlin aiming at the following three goals:

- Limit the number of trucks in downtown during peak hour and participate in decongesting the cities;
- Provide flexibility for recipients who can collect their packages when they like;
- Contribute to a better logistics organisation of malls and decongest delivery areas.'

The field test in Berlin took place between November 2011 and January 2012. The system proved to be reliable (also later on in other cities) and 85% of the conventional light commercial vehicles' routes in the test area could be replaced by cargo bikes.

Also the SMILE-project (SMILE, n.d.) (SMart green Innovative urban Logistics for Energy Efficient Mediterranean cities) has delivered some good examples of improvement options. The project will be implementing nine pilot projects in six MED cities and includes Barcelona, Bologna, Montpellier, Piraeus, Rijeka and Valencia in order to promote sustainable transport, ICT and transport operations optimisation, with a specific focus on waste and green labelling for businesses. In Valencia a project has been implemented on electric mobility: two electrically assisted tricycles deliver parcels within the historical city centre. The tricycles are a silent, flexible and green alternative to traditional vans. The tricycles are combined with the use of a micro-distribution platform located in the parking of a train station outside the city centre, which manages the interchange of goods. Logistic operators (ASM, DHL, SEUR and TNT) deliver the goods and parcels early in the morning. After that another company responsible for the last-mile delivery transfers the goods and parcels to the tricycles for delivery.

6.4.2 Improvement options for Moving services

Moving services are to be executed by small to medium sized trucks due to more freight. For this reason a shift to alternative powertrains is more likely than a shift to non-motorized or electric small vehicles.

For short distance transport, the battery electric technology is a feasible option for delivery trucks, because of the generally lower daily driving distances, and recharging can occur at scheduled downtimes, like overnight. Nowadays, around 1 000 battery electric distribution trucks are operated worldwide. Significant improvements are expected within the next five years, especially when it comes down to the costs and durability of battery technologies that would increase the potential of electric distribution trucks (CE Delft & DLR, 2013). Fuel cell vehicles might be an option as well.

The study ´Natural Gas in Transport (CE Delft, TNO and ECN, 2013) provides insight in the TTW and WTW emissions and cost of various options for rigid trucks. The TTW and WTW emissions are depicted in Figure 78. The cost per km for the same routes are depicted in Figure 79.

Figure 78: WTW GHG emissions for different NG-based energy carriers – rigid trucks (CE Delft, TNO and ECN, 2013)

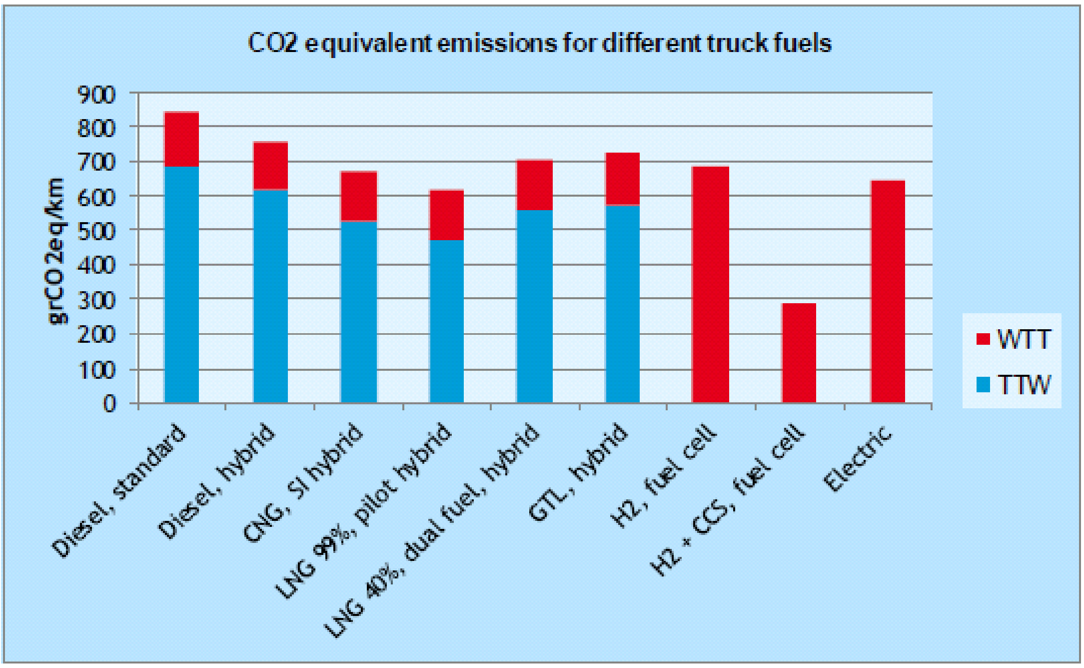
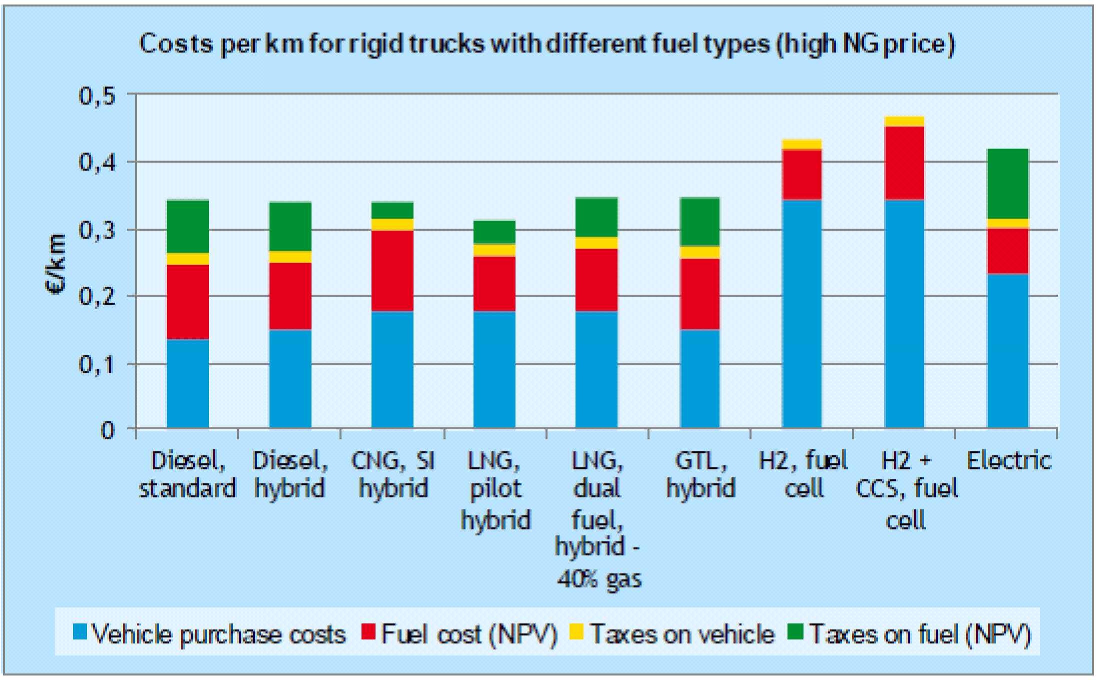
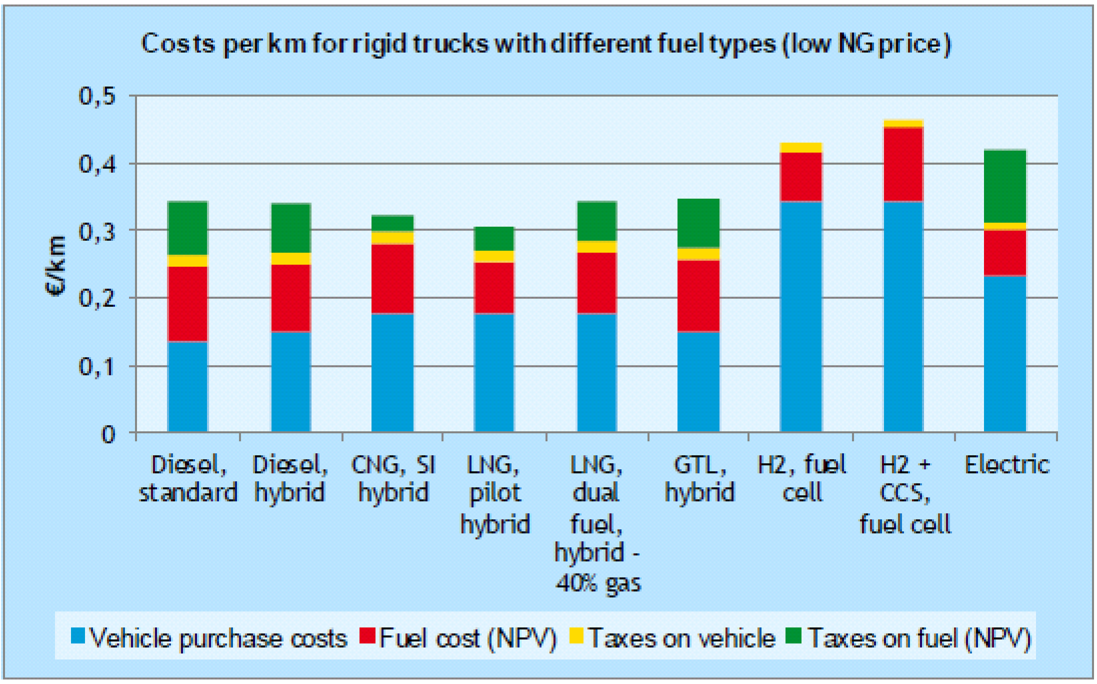


Figure 79 Cost for different NG-based energy carriers – trucks, high and low NG price **(CE Delft, TNO and ECN, 2013)**





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List of abbreviations

CLP - Classification, labelling and packaging

CNG - Compressed Natural Gas

CO_2 - Carbon dioxide

CPA - Classification of Products by Activity

CPC - Central Product Classification

CPV - Common Procurement Vocabulary

CVD - Clean Vehicle Directive

dB - decibels

DG - Directorate General

EEV - Enhanced environmentally friendly vehicle

EU - European Union

GHG - GHG

GPP - Green Public Procurement

GSI - Gear Shift Indicator

GWP - Global Warming Potential

HDV - Heavy duty vehicle

ISIC - International Standard Industrial Classification

ITS - Intelligent Transport System

LCV - Light commercial vehicle

LDV - Light duty vehicle, i.e. a car or an LCV

M_1 - Cars

M_2 - Small buses

M_3 - Large buses

NACE - Nomenclature statistique des activités économiques dans la Communauté européenne

N_1 - LCVs

N_2 - Heavier commercial vehicles

N_3 - Heavy commercial vehicles

NMHC - non-methane hydrocarbons

NO_x - Oxides of nitrogen

NRMM - Non-road mobile machinery

PM - Particulate matter

PRODCOM - PRODuction COMmunautaire

REACH - Registration, Evaluation, Authorisation and Restriction of Chemicals

RDE - Real driving emission

TCE - Transport chain elements

TPMS - Tyre Pressure Monitoring System

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Annex A: National GPP criteria

Table A-1.: Summary of national GPP criteria for light duty vehicles, i.e. cars and LCVs (noting similarities to and differences from respective EU GPP criteria)

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
Austria (definition: not specified; as categories follow EU GPP criteria, assume M_1 and N_1 vehicles)	***Technical specifications***: The CO_2 emissions from fleets of new cars should not exceed an average of 130 gCO_2/km; for LCVs the equivalent figure is 175 gCO_2/km.	None	***Award criteria***: Additional points awarded for vehicles with noise emissions lower than those required by legislation.	
Denmark (cars and LCVs)	Cars that can carry up to 5 people should have a fuel efficiency label of 'A+'; larger cars (built for 6 or 7 people; or 8 to 9 people) must have a B- or E- label at the minimum[112]; for LCVs, minimum label categories are set according to LCV's weight. ***Purchasers also advised*** to look out for TPMS, the provision of fuel consumption displays, GSI and a speed alarm. ***Additional recommendations***: Vehicle should have start-stop, be accompanied by information on eco-driving training and have CO_2 emissions 10% below the required label category.	Vehicles should comply with Euro 6 standards	***Additional recommendation***: Vehicles should have noise levels 3 dB less than required.	
Germany (cars, vehicles)	Consideration should be given to requiring that the energy efficiency of vehicle fleets be improved by purchasing new cars with average	Priority should be given to the procurement of vehicles with the highest emissions standards.	Priority should be given to the procurement of vehicles with the lowest possible noise emissions.	

[112] According to the label implemented in Denmark, as a result of Directive 1999/94; the Danish label goes beyond the Directive's requirements.

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	emissions of no more than 110 gCO_2/km by 2018 and 95 gCO_2/km by 2020, the proportion of new cars purchased or rented with emissions of less than 50 gCO_2/km should be increased beyond 10%, the energy efficiency of the remaining vehicles should be improved continuously taking account of the possibilities of alternative drivetrains.			
Italy (purchase, lease and rental of cars and LCVs; purchase of second hand vehicles)	***Technical specifications:*** Vehicles should have CO_2 emissions not exceeding specified limits, i.e. 175 gCO_2/km for off-road vehicles, 150 g/km for class 1 LCVs, 130 g/km for other cars, 225 g/km for other LCVs.	***Technical specifications:*** Vehicles should comply with the current Euro standard (i.e. Euro 5 in 2012, but Euro 6 when that came into force); second hand vehicles should comply with the previous Euro standard ***Optional award criteria:*** Pollutant emissions 30% lower than those required (i.e. Euro 6)		***Optional award criteria:*** An estimation of the energy and environmental operational costs (in line with the methodology set out in the EU's CVD) ***Contract clauses (rental, where maintenance included):*** Lubricants should be low viscosity corresponding to SAE grade number 0W30 or 5W30 or equivalent or regenerated lubricants should meet the requirements of the EU ecolabel (Decision 2011/381)
Netherlands (definition: stated CPV codes, so includes cars and LCVs, as well as fleet maintenance and management)	***Technical specifications***: Sets maximum CO_2 values per type of vehicle in line with EU GPP comprehensive criteria, requires vehicles to be equipped with GSI, TPMS and fuel consumption display, sets criteria for air conditioning gases and tyre rolling resistance in line with EU GPP comprehensive criteria ***Award criteria***: Criteria are set for alternative fuels, lower CO_2 emissions and start-and-stop in line with EU GPP comprehensive criteria. ***Suggestions (for consideration):*** Encourage eco-driving, maximise electric kms when using plug-in	***Technical specifications***: Vehicle's must comply with Euro 6 standards (also includes a reference to Euro VI to cover the case where an LCV was type approved as an HDV)	***Technical specifications***: Sets criteria for tyre noise in line with EU GPP comprehensive criteria Note: Comprehensive award criteria re noise emissions levels NOT used.	***Technical specifications***: Sets criteria for lubricants in line with EU GPP comprehensive criteria ***(where cleaning is part of a service contract):*** Net fresh water consumption must not exceed 105 litres per vehicle; energy use no more than 25 MJ for whole process (15MJ for roll over for each wash) ***Award criteria***: Criteria are set for vehicle materials in line with EU GPP comprehensive criteria ***(where cleaning is part of a service contract):*** Less fresh water and energy use than for technical specification

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	vehicles			***Contract provision***: Contractor to indicate where recycled components can be used in the course of any repair for decision of contracting authority ***Suggestions (for consideration):*** Consider alternatives to the procurement of vehicles, select the right cars, limit acquisition of 4x4s
Sweden (cars, maximum of 6 seats; purchase or leasing)	***Technical specification[113]:*** ***(spearhead)*** Car must emit a maximum of 50 gCO_2/km, ***(advanced)*** manual vehicles must be equipped with a GSI ***Special contract terms: (advanced)*** Vehicle supplied with a TPMS, equipped with a support system for energy-efficient driving and intelligent speed adaptation	***Award criteria:*** ***(advanced)*** Car complies with Euro 6 criteria	***Technical specification:*** ***(advanced)*** Vehicle's noise levels must not exceed 72 dB regardless of fuel type	***Award criteria: (basic)*** Apply cost calculation in accordance with CVD, apply life cycle costing ***Criteria relating to tyres include (covering both purchase and procurement of services):*** Environmental management system, servicing and follow-up, the use of various chemicals, lifespan, life cycle cost and whether tyres are studded ***Technical specification: (basic)*** Fuel must comply with specified environmental class of fuel ***Special contract terms relating to fuel (fossil and renewable):*** Compliance with conservation laws and provisions (in country of origin) for land and water, prohibition of fuel from more carbon-intensive feedstocks, raw materials should be at least 97% traceable, commitment to continually reduce associated GHG emissions; demands re fuel properties to protect sensitive environments.
Sweden (minibuses, maximum of 9 seats; purchase or leasing)	***Technical specification:*** ***(advanced)*** Manual vehicles must be equipped with a GSI ***Award criteria: (spearhead)*** Vehicles must emit no more than 185 gCO_2/km (fossil fuels) or 310 gCO_2/km (biofuels), ***Special contract terms: (advanced)*** Vehicle supplied with a TPMS, equipped with a support system for energy-efficient driving and intelligent speed adaptation	***Award criteria:*** ***(advanced)*** Vehicle complies with Euro 6 criteria	***Technical specification:*** ***(advanced)*** Vehicle's noise levels must not exceed 72 dB regardless of fuel type	

[113] Sweden has 'basic', 'advanced' and 'spearhead' standards.

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
Sweden (light duty trucks; purchase or leasing)	***Technical specification***[114]***:*** ***(spearhead)*** Vehicle must emit no more than 175 gCO_2/km or run on alternative fuels, ***(advanced)*** manual vehicles must be equipped with a GSI ***Special contract terms: (advanced)*** Vehicle supplied with a TPMS, equipped with a support system for energy-efficient driving and intelligent speed adaptation	***Award criteria:*** ***(advanced)*** Vehicle complies with Euro 6 criteria	***Technical specification:*** ***(advanced)*** Vehicle's noise levels must not exceed 72 dB regardless of fuel type	
UK (car and LCV)	***Minimum mandatory***: Fleet average CO2 emissions for new cars should not exceed 130 gCO_2/km; the equivalent figure for LCVs is 175 gCO_2/km. ***Additional 'best practice' criteria*** : Fleet average CO_2 emissions lower than the minimum required ***Minimum award criteria***: Capability to use fuel from renewable resources ***Best practice award criteria***: Vehicle capable of using renewable energy, equipped with GSI and TPMS, have air conditioning systems with a GWP of less than 150, commitment to use low rolling resistance tyres	***Best practice***: Vehicles comply with Euro 5 standard	***Minimum award criteria***: Noise emissions lower than required by national law ***Best practice award criteria***: Vehicle equipped with tyres with noise emissions below those required by national law	***Minimum award criteria***: Use of recycled content, inclusion of bio-content/materials, design to maximise opportunities to recycle or recover parts at the end of the vehicle's life, design to enhance reparability and availability of more frequently used spares ***Best practice contract performance criteria***: Contractor must selectively collect used lubricants and tyres and have a contract with a relevant waste management organisation. ***Best practice award criteria***: Low viscosity lubricants (and minimum requirements re regenerated oil base), commitment to use tyres that do not contain oils subject to labelling in accordance with Directive 67/548 in tread rubber
Norway (vehicles)	Vehicles should have low emissions of GHGs, when purchasing or leasing cars guideline maximum limit should be 120 to 140 gCO_2/km (which could be	Vehicles should have low emissions of NO_x and PM, diesel vehicles must have particulate traps fitted	Tyres should be low noise	Tyres should be stud-free

[114] Sweden has 'basic', 'advanced' and 'spearhead' standards.

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	tightened later), being investigated whether all government vehicles could be CO_2 free or CO_2 neutral by 2020, tyres should be "easy roll"			
Japan (cars and LCVs, defined by weight)	***Evaluation criteria:*** Categories of vehicles with less environmental impact are defined, including those using electricity, natural gas, fuel cells and hydrogen, along with hybrids and plug-in hybrids. Fuel efficiency standards are set in terms of minimum km/litre according to a vehicle's weight for cars and LCVs. Tyres used for cars must have rolling resistance of 9 or less, as measured on a specified testing methodology. ***Factors for consideration***: GWP of air conditioning gases less than 150, is designed with stop-start, has and eco-drive support installed.	***Evaluation criteria:*** For cars and LCVs using petrol and LPG, emissions limit values are set for various air pollutants.		Factors for consideration: ***For cars and LCVs:*** The amount of lead used is reduced as much as possible (excluding that used in the battery), vehicle is designed for long-term use and designed to facilitate re-use (particularly of rare metals), and vehicle contains as much recycled material as possible. ***For tyres***: Lifetime of tyre, its noise reduction, its packaging and storage and a collection for reuse and recycling of the packaging.
New Zealand	Tenderers required to submit fuel economy information, fuel economy should be a criterion in tender evaluations, suppliers invited to include options for the use of renewable fuels	Tenderers required to state emission standards for the vehicle(s) proposed, vehicles purchased, leased or hired must comply with at least Euro 4 (or equivalent)		For LDVs longer life and less polluting lubricating and hydraulic oils should be specified, suppliers of maintenance services should comply with standards for tyre and used oil disposal, requirements re ecolabels should be included (when these are ratified), specifications re recycling and disposal
UNEP (vehicles)	***Requirement definition:*** Bidders should provide information on fuel efficiency (expressed in km/litre or litres/100km) ***Award/evaluation criteria***: Additional points awarded for vehicles delivering specified fuel efficiency ***Contract management (systems contracts only):*** Contractor should report annually on CO_2 emissions and efforts to reduce these	***Requirement definition:*** Bidders should state the emission control technology pre-fitted and the national emission standards that the vehicle meets, requirements relating to emission standards could be set ***Award/evaluation criteria***: Additional points awarded for using certain		***Requirement definition:*** Total weight of recycled material should be provided as a percentage of total weight, vehicles and their parts should be recyclable and reusable, minimum percentages (e.g. 25%, 75%) could be set for the proportion of the aluminium and /or steel used that was recycled ***Sourcing:*** Bidder (manufacturer and companies in the supply chain) required to have a written corporate environmental

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
		emission control technologies or meeting specified emission standards		policy ***Award/evaluation criteria***: Points awarded according to percentage of recycled content, provision of end-of-life take back or used vehicle refurbishment programme

Table A-2.: Summary of national GPP criteria for heavy duty vehicles, i.e. trucks and buses (noting similarities to and differences from respective EU GPP criteria)*

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
Austria (buses)	None	***Technical specifications***: Engines must comply with Euro V standard[115]. Award criteria: Additional points will be awarded for vehicles that meet EEV or Euro VI standard.	***Award criteria***: Additional points awarded for vehicles with noise emissions lower than those required by legislation.	
Austria (waste collection vehicles)	None	***Technical specifications***: The vehicle must comply with Euro V standard[116]. Award criteria: Additional points will be awarded for vehicles that meet EEV or Euro VI standard.	***Award criteria***: Additional points awarded for vehicles with noise emissions levels below 102 dB(A) in accordance with Directive 2000/14.	
Italy (bus purchase, lease or rental, explicitly M_2 and M_3)	***Technical specifications:*** Vehicles must be fitted with a fuel consumption indicator (except for those using CNG)	***Technical specifications:*** Vehicles should comply with Euro VI standards, second hand vehicles should comply with Euro V emission standards, the exhaust pipe of the vehicle should not be on the same side of the vehicle as	***Award criteria:*** Score awarded should relate to extent to which the noise emissions are lower than those required	***Award criteria:*** An estimation of the energy and environmental operational costs (in line with the methodology set out in the EU's CVD)

[115] The criteria refer to Directive 2055/55/EC in this respect, but this Directive was replaced and repealed by Regulation 595/2009 (see above).

[116] The criteria refer to Directive 2055/55/EC in this respect, but this Directive was replaced and repealed by Regulation 595/2009 (see above).

National GPP	**CO_2 emissions**	**Pollutant emissions**	**Noise emissions**	**Other environmental criteria**
		the passenger door		
Italy (Heavy goods vehicle purchase, lease or rental, explicitly N_2 and N_3)	***Technical specifications:*** Vehicles must be fitted with a fuel consumption indicator (except for those using CNG)	***Technical specifications:*** Vehicles should comply with Euro VI standards, second hand vehicles should comply with Euro V emission standards	***Award criteria:*** Score awarded should relate to extent to which the noise emissions are lower than those required	***Award criteria:*** An estimation of the energy and environmental operational costs (in line with the methodology set out in the EU's CVD)
Netherlands (HDVs, and specified mobile equipment (ME) and maintenance services, with reference to CPV codes)	***Technical specifications***: ***ME:*** Protocol supplied to regarding energy efficient use Award criteria: ***HDVs***: Inclusion of fuel saving options (fuel consumption indicator, GSI, TPMS, lightweight construction, aerodynamic features, cruise control, start-stop), designed for alternative fuels (reference to EU GPP criteria) ***ME:*** Inclusion of fuel saving options (backstop system, load sensing technology); designed for alternative drives or sustainable fuels	Technical specifications: ***HDVs:*** Vehicles must comply with Euro VI standard ***ME***: Must be compliant with specified stage standards set by the NRMM Directive 2004/26[117]	***Award criteria (ME):*** Quiet mobile equipment (with reference to a national list)	***Selection criteria (maintenance contracts only):*** Environmental management system in place (with reference to EMAS) ***Technical specifications***: HDVS: Retreaded tyres and tread regrooving used in maintenance of M_3, N_2 and N_3 vehicles ***ME***: Lubricants oils (requirements set with reference to EU GPP criteria) ***Contract provision***: Contractor to indicate where recycled components can be used in the course of any repair for decision of contracting authority
Sweden (heavy duty trucks; purchase or leasing)	***Award criteria: (advanced)*** Vehicle type-approved for biofuels, hybrid technologies or	***Award criteria: (advanced)*** Vehicle complies with Euro VI criteria		***Award criteria: (basic)*** Apply cost calculation in accordance with CVD ***Criteria relating to tyres***

[117] Directive 2005/13/EC is also mentioned here; this Directive relates to agricultural and forestry tractors.

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	electricity. ***Special contract terms: (advanced)*** Vehicle supplied with a TPMS, equipped with a support system for energy-efficient driving and intelligent speed adaptation			***include (covering both purchase and procurement of services):*** Environmental management system, servicing and follow-up, the use of various chemicals, lifespan, life cycle cost and whether tyres are studded. ***Technical specification: (basic)*** Fuel must comply with specified environmental class of fuel ***Special contract terms relating to fuel (fossil and renewable):*** Land and water use (in country of origin), prohibition of fuel from more carbon-intensive feedstocks, raw materials should be at least 97% traceable, commitment to continually reduce associated GHG emissions; demands re fuel properties to protect sensitive environments
UK (buses)	***Additional 'best practice' criteria***: Vehicle equipped with GSI, TPMS and an air conditioning system using fluorinated gas with a GWP of less than 2,500 ***Minimum award criteria***: Capability to use fuel from renewable resources	***Mandatory criteria***: Vehicle engines must be certified as meeting Euro V standards. Additional 'good practice' criteria: Vehicles' exhaust pipes should not be on the same side as the passenger door. ***Minimum award criteria***: Vehicle engines must be certified as meeting Euro VI standards.	***Minimum award criteria***: Noise emissions lower than required by national law	***Minimum award criteria***: Use of recycled content, inclusion of bio-content/materials, design to maximise opportunities to recycle or recover parts at the end of the vehicle's life, design to enhance reparability and availability of more frequently used spares
UK (waste collection	***Minimum award criteria***: Capability to use fuel from	***Mandatory criteria***: Vehicle engines must be certified as meeting Euro V	***Minimum award criteria***: Average noise emissions lower	

National GPP	**CO_2 emissions**	**Pollutant emissions**	**Noise emissions**	**Other environmental criteria**
trucks)	renewable resources Best practice award criteria: Vehicle equipped with TPMS	standards. ***Minimum award criteria***: Vehicle engines must be certified as meeting Euro VI standards. ***Best practice award criteria:*** Emissions from auxiliary units meet specified limits in NRMM Directive	than 102 dB(A), measured according to Directive 2000/14	
Japan (different types of HDV, including buses)	***Evaluation criteria:*** Categories of vehicles with less environmental impact are defined, including those using electricity, natural gas, fuel cells and hydrogen, along with hybrids and plug-in hybrids. Fuel efficiency standards are set in terms of minimum km/litre according to a vehicle's type, means of transmission, structure and weight. ***Factors for consideration***: GWP of air conditioning gases less than 150, is designed with stop-start, has and eco-drive support installed.			***Factors for consideration***: The amount of lead used is reduced as much as possible (excluding that used in the battery), vehicle is designed for long-term use and designed to facilitate re-use (particularly of rare metals), vehicle contains as much recycled material as possible,

Note: The table includes criteria for heavy duty vehicles where these were explicitly separate from criteria for light duty vehicles. Any criteria that were applicable to 'vehicles' generally are covered in Table A-1.

Table A-3.: Summary of national GPP criteria for transport services

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
Austria (bus services)	***Contract performance clause***: Each year the contractor shall submit a report on the fuel used in delivering the services and the resulting CO_2 emissions.	***Technical specifications***: All vehicles used to provide the service must be equipped with engines that comply with Euro IV standard[118]. If this standard has been achieved through retrofitting, this should be documented. ***Award criteria***: Additional points will be awarded for the proportion of vehicles used to meet the service that meet stricter Euro standards.	***Award criteria***: Additional points awarded for vehicles with noise emissions lower than those required by legislation.	***Contract performance clause***: All vehicles purchased during the contract period and used to deliver the service must comply with the Euro V standard, be equipped with a gear shift indicator (vehicles without automatic transmission) and a tyre pressure monitoring system. The exhaust pipe must not be on the same side as the passenger entry door.
Netherlands (transport services, as indicated by CPV codes; includes courier, postal and moving services, but not waste services)	***Award criteria***: Use of alternative fuels (with reference to EU GPP criteria); 100% compensation of transport CO_2 (using credits generated in line with Clean Development Mechanism guidelines) ***Contract provision***: Requirement to report annually on fuel used ***Suggestions (for consideration):*** Choose low CO_2 vehicles (for LDVs),	***Technical specifications***: Vehicle used in performance of contract, must comply with Euro 5 (for LDVs) or Euro V (for HDVs) ***Award criteria***: Higher rating can be assigned the more vehicles used in performance of contract meet Euro 6 (for LDVs) or EEV or Euro VI (for HDVs) with a minimum proportion of 50%	***Suggestions (for consideration)***: Use low noise emissions tyres (with reference to EU GPP criteria)	***Suggestions (for consideration):*** Consider alternatives to motorised transport, use environmentally friendly lubricants (with reference to EU GPP criteria), ask tenderers for environmental management system, use retreaded tyres and inspect these

[118] The criteria refer to Directive 2055/55/EC in this respect, but this Directive was replaced and repealed by Regulation 595/2009 (see above).

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	use low rolling resistance tyres, use coolants with low GWP, (all with reference to EU GPP criteria), encourage efficient driving			
Sweden (goods transport services by heavy duty vehicles)	***Special contract terms: (basic)*** Rolling resistance of tyres acquired for assignment shall comply with specified energy efficiency labelling classes, a stated proportion of the fuel used must be renewable CNG or electricity, procedures for checking tyre pressures shall have been established, report on climate impact, ***(advanced)*** temperature-controlled transport shall comply with industry guidelines and supplier shall establish relevant emission reduction goals during the contract	***Special contract terms: (advanced)*** All vehicles shall comply with Euro III, a stated proportion must comply with Euro V (or retrofitted Euro IV) and all new vehicles acquired to be used should at least comply with Euro VI.		***Qualification requirement: (basic)*** Appropriate environmental management systems in place ***Special contract terms: (basic)*** Limit placed on the proportion of certain substances in tread rubber, ***(spearhead)*** Fuel must comply with specified environmental class of fuel

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
Sweden (goods transport services by light duty trucks, private cars and bicycles[119])	Special contract terms: ***(basic)*** Rolling resistance of tyres acquired for assignment shall comply with specified energy efficiency labelling classes, a stated proportion of the fuel used must be renewable CNG or electricity, procedures for checking tyre pressures shall have been established, ***(advanced)*** temperature-controlled transport shall comply with industry guidelines and supplier shall establish relevant emission reduction goals during the contract, ***(spearhead)*** A stated proportion of vehicles must release no more than 120 gCO_2/km or being type approved to run on biofuels or electricity	***Award criteria: (spearhead)*** All vehicles shall comply with Euro 6.		***Qualification requirement: (basic)*** Appropriate environmental management systems in place ***Special contract terms: (basic)*** Stud-free tyres shall be used (with minor exceptions), ***(spearhead)*** Fuel must comply with specified environmental class of fuel
Sweden (car washes)				***Technical specifications (if included in a contract):*** Certain substances must be biodegradable, substances must not be used if they are marked as an environmental hazard, health risk or as being bioaccumulative

[119] The document explicitly mentions that it covers bicycles, but there are no specific criteria for bicycle goods services.

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
				(according to CLP Regulation), while limitations are placed on the use of other substances
UK (bus services)	***Minimum contract performance clauses***: All new vehicles purchased after award of contract and to be used in carrying out the service must have a GSI and TPMS. Contractor must supply annual report on fuel used and associated CO_2 emissions. ***Best practice contract performance criteria:*** Commitment to use low rolling resistance tyres, all drivers must be trained on environmentally-conscious driving in a recognised institution ***Best practice award criteria:*** Capability to use fuel from renewable resources, proportion of vehicles with GSI, TPMS and air condition with gases with a GWP of less than 2,500	***Mandatory criteria***: All vehicles used in carrying out the service must have engines meeting Euro IV standards. Where vehicles meet this standard as a result of technical after-treatment, the relevant documentation should be provided. ***Minimum award criteria***: Proportion of vehicles to be used in carrying out the service complying with stricter Euro standards (Euro V or VI) ***Minimum contract performance clauses***: All new vehicles purchased after award of contract and to be used in carrying out the service must comply with Euro VI standard, the vehicle's exhaust pipe must not be on the same side as the passing door	***Minimum award criteria***: Noise emissions lower than required by national law	***Minimum award criteria***: Use of recycled content, inclusion of bio-content/materials, design to maximise opportunities to recycle or recover parts at the end of the vehicle's life, design to enhance reparability and availability of more frequently used spares. ***Best practice contract performance criteria:*** Use of low viscosity lubricant, with a minimum of 25% regenerated oil base in vehicle maintenance ***Best practice contract performance criteria:*** commitment to use tyres that do not contain oils subject to labelling in accordance with Directive 67/548 in tread rubber
UK (waste collection services)	***Minimum award criteria***: Capability to use fuel from renewable resources ***Minimum contract performance clauses***: All new vehicles purchased after award of contract and to be used in carrying out	***Mandatory criteria***: All vehicles used in carrying out the service must have engines meeting Euro IV standards. Where vehicles meet this standard as a result of technical after-treatment, the relevant documentation should be provided. ***Minimum award criteria***: Proportion	***Minimum award criteria***: Average noise emissions lower than 102 dB(A), measured according to Directive 2000/14	***Minimum award criteria***: Use of recycled content, inclusion of bio-content/materials, design to maximise opportunities to recycle or recover parts at the end of the vehicle's life, design to enhance reparability and availability

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	the service must have a GSI and TPMS. Contractor must supply annual report on fuel used and associated CO_2 emissions, all drivers must be trained on environmentally-conscious driving in a recognised institution. ***Best practice contract performance criteria:*** Commitment to use low rolling resistance tyres ***Best practice award criteria:*** Proportion of vehicles with TPMS	of vehicles to be used in carrying out the service complying with stricter Euro standards (Euro V or VI) ***Minimum contract performance clauses***: All new vehicles purchased after award of contract and to be used in carrying out the service must comply with Euro VI standard, the vehicle's exhaust pipe must not be on the same side as the passing door ***Best practice award criteria:*** Emissions from auxiliary units meet specified limits in NRMM Directive		of more frequently used spares. ***Best practice contract performance criteria:*** Use of low viscosity lubricant, with a minimum of 25% regenerated oil base in vehicle maintenance
Japan (postal and other home delivery services, passenger transportation (cars))	***Evaluation criteria:*** Energy use (and actions to reduce it) are reviewed periodically, eco-driving is promoted, and measures are in place to improve efficiency of service. ***Measures for consideration:*** Measures to manage demand for electricity, and promotion of fuel efficient vehicles.	***Evaluation criteria:*** Inspection and maintenance to ensure vehicles perform as they should from an environmental perspective.		***Evaluation criteria:*** Modal shift is in place, information on environmental criteria is published ***Measures for consideration:*** Improvements on carrying capacity and cooperation to reduce number of vehicles, recycling of packaging, energy use of related buildings.
UNEP (freight forwarding, only those relating to road transport mentioned here)	***Requirement definition:*** There should be fuel efficient driver training for new and current drivers, fuel consumption monitoring of drivers, idling time monitoring, tyre pressure monitoring procedures and technologies, aerodynamic	***Requirement definition:*** Technological measures to reduce NO_x and PM should be implemented, the average age of the truck fleet should be less than seven years		***Requirement definition:*** Bidder has to demonstrate existence of a publicly-available written corporate environmental policy, perform monitoring of GHG and air pollutant emissions to international standards, describe measures to improve

National GPP	CO_2 emissions	Pollutant emissions	Noise emissions	Other environmental criteria
	features installed on trucks and trailers			environmental performance and reduce fuel consumption ***Sourcing:*** Bidder should be compliant with environmental legislation

Sources:

- For Austria, documents downloaded from http://www.nachhaltigebeschaffung.at/ausschreibungen-fahrzeuge
- For Denmark: http://www.gronneindkob.dk/indkoebsmaal/transport/
- For France: http://www.developpement-durable.gouv.fr/Transport-vehicules.html
- For Germany: http://www.bundesregierung.de/Content/DE/_Anlagen/2015/03/2015-03-30-massnahmenprogramm-nachhaltigkeit.pdf;jsessionid=1E6247024EB74208CC949C39E1BB831D.s2t2?__blob=publicationFile&v=2
- For Italy: Official Gazette of the Italian Republic (2012), "Piano d'azione per la sostenibilità ambientale dei consume net settore della Pubblica Amministrazione ovvero Piano d'Azione Nazionale sul Green Public Procurement (PANGPP)"; http://www.minambiente.it/sites/default/files/archivio/allegati/GPP/gu_128_all.pdf
- For the Netherlands, 2016 documents supplied by PIANOo; documents will be downloadable from https://www.pianoo.nl/about-pianoo/sustainable-public-procurement/environmental-criteria-for-sustainable-public-procurement
- For Sweden: http://www.upphandlingsmyndigheten.se/en/sustainable-public-procurement/sustainable-procurement-criteria/vehicles-and-transport/
- For the UK: https://www.gov.uk/government/collections/sustainable-procurement-the-government-buying-standards-gbs
- For Norway: https://www.regjeringen.no/globalassets/upload/FAD/Vedlegg/Konkurransepolitikk/T-1467_eng.pdf
- For Japan: http://www.env.go.jp/en/laws/policy/green/
- For New Zealand: https://www.business.govt.nz/procurement/pdf-library/agencies/Category_reviews.pdf
- For UNEP: http://www.unep.org/resourceefficiency/Home/Society/SustainableUN/ReducingtheUNsImpact/Procurement/Guidelines/tabid/101228/Default.aspx

Annex B: LCA literature review for cars and LDVs

In order to identify the main environmental hotspots along the life cycle of vehicles various LCA papers have been studied for the vehicle category passenger cars/LCVs. Information of each LCA paper is gathered in the following table.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Environmental impacts assessed	Main assumptions/ Sensitivity analysis	Findings of the study
LCA papers						
Bauer et al. (2015) The environmental performance of current and future passenger vehicles: Life cycle assessment based on a novel scenario analysis framework. Applied Energy 157 (2015) 871-883*	Comparative LCA of: - ICEV gasoline/diesel - HEV gasoline/diesel - NG - BEV - FCV	All life cycle phases	2012, 2030, EU	- GHG emissions - Particulate matter formation (PMF) - Human toxicity potential (HTP) - Photochemical oxidant formation (POF) - Terrestrial acidification potential (TAP)	lifetime mileage of 240 000 km ; battery lifetime 150 000 km; 2030 electricity mix projections EU	BEV/FCEV cause substantially less life cycle GHG emissions ICEVs, if and only if they use non-fossil energy sources. Reduction potential of 80%, but also an increase in GHG emissions is possible (+30% for FCEV coal gasification). CNG is the best fossil fuelled ICEV: max reduction potential of 50%. BEV (in some cases) and FCEV perform worse on acidification, particulate matter formation, and toxicity compared to ICEV.
Egede et al. (2015) Life Cycle Assessment of Electric Vehicles - A Framework to Consider Influencing Factors. Procedia CIRP 29 (2015) 233-238*	Influencing factors (driving behaviour, desired temperature, topography, type of road) for the environmental assessment of EVs and Impact of light-weighting	Use phase	Case study: Germany, Brazil and Spain, current situation	- GWP	Lifetime mileage of: - 100 000 km - 15 000 km - 200 000 km	Lightweight aluminium construction becomes more and more relevant if the vehicle is used over a longer period time (higher lifetime mileage). . Favourable switch to other material does not only depend on electricity mix, but also on the energy consumption in the use phase. Country analysis shows variation in pay-off of material use. Considering average values can therefore be misleading. This study might be relevant in case of a discussion on material use, but does not affect the overall conclusions on overall life cycle performance.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Environmental impacts assessed	Main assumptions/ Sensitivity analysis	Findings of the study
Faria et al. (2013) Impact of the electricity mix and use profile in the life cycle assessment of electric vehicles. Renewable and Sustainable Energy Reviews 24 (2013) 271-287	ICEV and EVs; Primary energy source in use phase and GHG emissions.	Vehicle manufacturing phase, use phase (WTW)	EU market EU mix for 2011	GHG emissions; TCO impacts	Polish, Portuguese and French electricity mix Sensitivity analysis for: vehicle charging profile; driving profile. ICEV (d & g) = Volkswagen Golf, PHEV/BEV = Chevrolet Volt and Nissan Leaf and for urban Smart ED and Peugot iOn	30-50% of vehicle production emissions (GHG) of PHEVs and BEVs can be contributed to battery production Use phase dominant in total GHG emissions: 85-90% of total life cycle emissions for an ICEV, and 50% (nuclear or renewable electricity) to >75% (fossil electricity of total life cycle GHG emissions for an EV.
Girardi et al. (2015) A comparative LCA of an electric vehicle and an internal combustion engine vehicle using the appropriate power mix: the Italian case study. Int J Life Cycle Assess (2015) 20:1127-1142 DOI 10.1007/s11367-015-0903-x	Comparison of two passenger cars: EV and ICEV paying particular attention to the production of electricity that will charge the EV	Vehicle manu-facturing and EoL phase, use phase (WTW),, road construction and road maintenance	Italy, EV 2013 and 2030 compared to ICE 2013 and 2030, also variations for 36% and 50% renewable electricity from solar PV	GHG emissions, cumulative energy demand non-renewable, air acidification, photochemical oxidant formation, greenhouse effects, eutrophication, human toxicity, resource depletion, particulate matter formation potential	Lifetime mileage of 150 000 for vehicle and battery Italian electricity mix 100 years of road life	Lower impacts EV for: If electricity is still produced from fossil fuels, EVs still score better on GHG and primary energy consumption and also on air acidification, photochemical oxidant formation, particulate matter formation potential. Pollutant emissions are emitted far from high density populated areas and by high stacks, resulting in lower environmental and health damages than pollutants emissions from ICEVs. Higher impacts for EVs for: Eutrophication and human toxicity (linked to battery production), but human toxicity is not the only impact affecting human health. Other environmental impacts also affect human health.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Environmental impacts assessed	Main assumptions/ Sensitivity analysis	Findings of the study
						Currently, a shift to other batteries still results in the same outcomes. Note that until 2030 a technological evolution in battery production might occur which can reduce those impacts beyond expectations.
Hawkins et al. (2012) Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles. Journal of Industrial Ecology (2012) Volume 17, Number 1	Comparison of conventional and EV cars	Vehicle manu-facturing and EoL phase, use phase (WTW)	Current situation in EU	GWP, toxicity impacts metal depletion	Lifetime mileage of 150 000 km (vehicle and battery) EU average conditions	For all scenarios: HTP, MDP and FETP mainly caused by vehicle manufacturing; GWP, TETP and FDP dominated by use phase; EoL only marginal impacts. EV production impacts more env. intensive for all impacts categories except for TAP. EVs powered by the present EU electricity mix: - 10% to - 24% in GWP compared to ICEV g or d (150 000 km), but potential increase in toxicity, freshwater eco-toxicity, eutrophication and metal depletion impacts from the vehicle supply chain. for 200 000km lifetime: GWP benefits are 27-29%relative to gasoline vehicles, 17-20% relative to diesel. 100 000km lifetime reduction potential 9-14% compared to gasoline and indistinguishable compared to diesel vehicles.
Helmers et al. (2015) Electric car life cycle assessment based on real-world mileage and the electric	Conversion of an ICEV Smart to EV Smart after 100 000 km driven. Comparison of new Smart,	Vehicle manu-facturing and EoL phase, use phase (WTW)	2012-2014, Germany	GWP, ozone depletion, acidification, eutrophication, eutrophication, human toxicity, photochemical oxidant formation, particulate matter	Lifetime mileage: 100 000 km, mixed versus urban driving conditions (based on EU average)	Electric conversion of ICEV can save additional of 16% CO_2 eq or 19% (single score endpoints) of env. impacts over a lifetime, respectively when compared with the new BEV. Advantages BEV over ICEV (current DE

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Environmental impacts assessed	Main assumptions/ Sensitivity analysis	Findings of the study
conversion scenario. Int J Life Cycle Assess DOI 10.1007/s11367-015-0934-3	converted Smart and mew electric Smart under real-world conditions			formation, eco-toxicity, ionising radiation, agricultural land occupation, urban land occupation, natural land transformation, water depletion, resource depletion		e.mix) Climate change (CC), terrestrial acidification (TA), photochemical oxidant formation (POF), fossil resource depletion (FD), natural land transformation (NLT) and,ozone depletion (OD). Particulate matter formation (PMF) is favourable over the ICEV only if the BEV is operated with wind electricity. Disadvantages BEV over ICE freshwater eutrophication (FE), freshwater ecotoxicity (FET), mineral resource depletion depletion (MRD), human toxicity (HT), marine ecotoxicity (MET), urban land occupation (ULO).
Hill, 2012 (EU GHG 2050)	Embedded emissions	Vehicle manu-facturing and EoL phase, use phase (WTW), energy infrastructuredevelopment	EU	No specific LCA study	Vehicle lifetime 238 000 km Fuel WTW emissions from JEC 2008 Real world driving	GHG emissions are anticipated to reduce by between 30% and 55% from 2010 to 2050, depending on the material (when sourced in the EU). GHG emissions of vehicle manufacturing are for 60% the result of material use and is higher for battery and fuel cell vehicles.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Environmental impacts assessed	Main assumptions/ Sensitivity analysis	Findings of the study
Tian and Chen (2014) Sustainable design for automotive products: Dismantling and recycling of end-of-life vehicles. Waste Management 34 (2014) 458-467	End of life of the car. Design for dismantling. Case study with dashboard dismantling	Dismantling	2009-2010, case study China	Cost, time required to dismantle, combustible gases, recycling rate	No specific assumptions	Design for dismantling can help to save cost and to dismantle cars in an environmental sound way. Recommendation is to use a single material. This study might be relevant in case of a discussion on material use, but does not affect the overall conclusions on overall life cycle performance.
TNO and CE Delft, 2014	Direct and indirect GHG emissions from EVs and conventional vehicles	Vehicle manu-facturing and EoL phase, use phase (WTW)	Current situation in the NL	GHG emissions	Lifetime mileage : of 160 000 (both vehicle and battery), average electricity mix NL (467 g/kWh), average use. Sensitivity analysis for: - lifetime mileages of 100 000 (small car, mainly urban use) and 240 000 km (large car, mainly motorway use) - charging frequency of PHEVs - electricity mix: 200 g/kWh (large share RE), 935 g/kWh (coal).	Overall GHG emission reduction of FEVs over the entire life cycle is 35% compared to ICEV on average. With coal powered electricity the reduction is 3%; with large share of renewables it is 54%. For a large BEV with high mileage, GHG reduction is higher: 48%. For PHEV the reduction depends also on the kilometres driven electrically and charging behaviour: 20% (one charge a day), 35% (2 charges a day), 3% (when only 10% of kilometres driven on electricity).

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Thiel et al. (2014) and Singh et al. (2015) have been left out of the analysis, because these studies are more focused on what role EVs can play in the realisation of policy targets rather than being LCA-studies.

Analysis of environmental impacts along the life cycle

Of all LCA studies investigated to determine the environmental hotspots, most studies focus on the comparison between ICEV and EVs. Other alternative powertrains get far less attention in the comparisons. In terms of environmental impacts, the main focus is on GHG emissions (or GWP) in the use phase. All studies include emissions from electricity generation and mostly also emissions from fuel production and extraction and refinement.

Most studies provide an overall overview of the life cycle, without zooming in on a specific life cycle phase, but with most attention being paid to the trade-offs between the manufacturing and usage phase, especially in the light of EVs.

On average the studies assume 150 000 km for the vehicle and battery lifetime of EVs and various assumptions have been made for the electricity mix. In the following paragraphs the main conclusions per environmental impact are described.

GHG emissions/GWP

Total GHG emissions over the entire vehicle and energy life cycle

Overall, GHG emissions are dominated by the use phase (exhaust emissions + fuel production/electricity mix). Bauer et al. (2015) has studied a broader range of alternative powertrains and fuels (ICEV and HEV fuelled with gasoline, diesel and CNG, a BEV on the average EU mix and FCV using hydrogen from NG SMR) both for 2012 and 2030. The CNG and diesel hybrids and BEV on EU mix result among the current technologies in the lowest life cycle GHG emissions (in the order of 210 gCO_2/km). The highest emissions in the range of 300 gCO_2/km are caused by gasoline vehicles. BEV is assumed to score best in 2030 with an expected reduction of life cycle GHG emissions of 50% between 2012 and 2030.

The FCV vehicle on hydrogen from NG SMR scores only slightly under a gasoline vehicle (in 2012 and 2030 as well). The comparison between the various fuels is depicted in Figure 80 and Figure 81.

Figure 80: Life cycle GHG emissions of selected mid-size passenger vehicles with different drivetrains and fuels (Bauer et al., 2015)

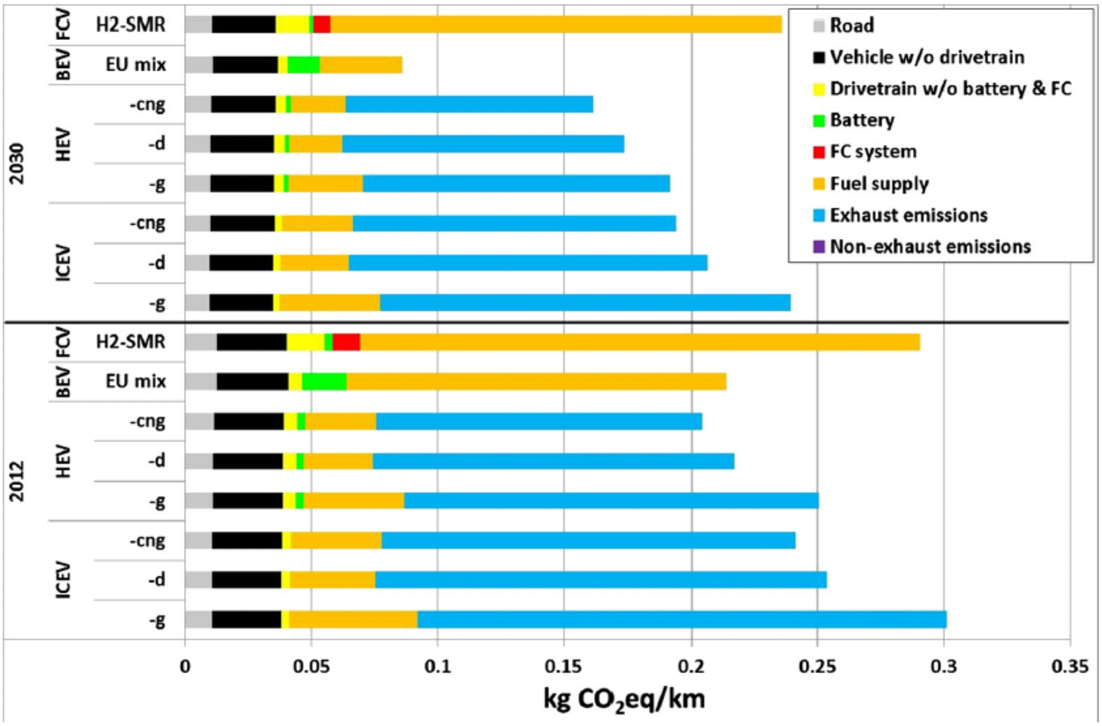
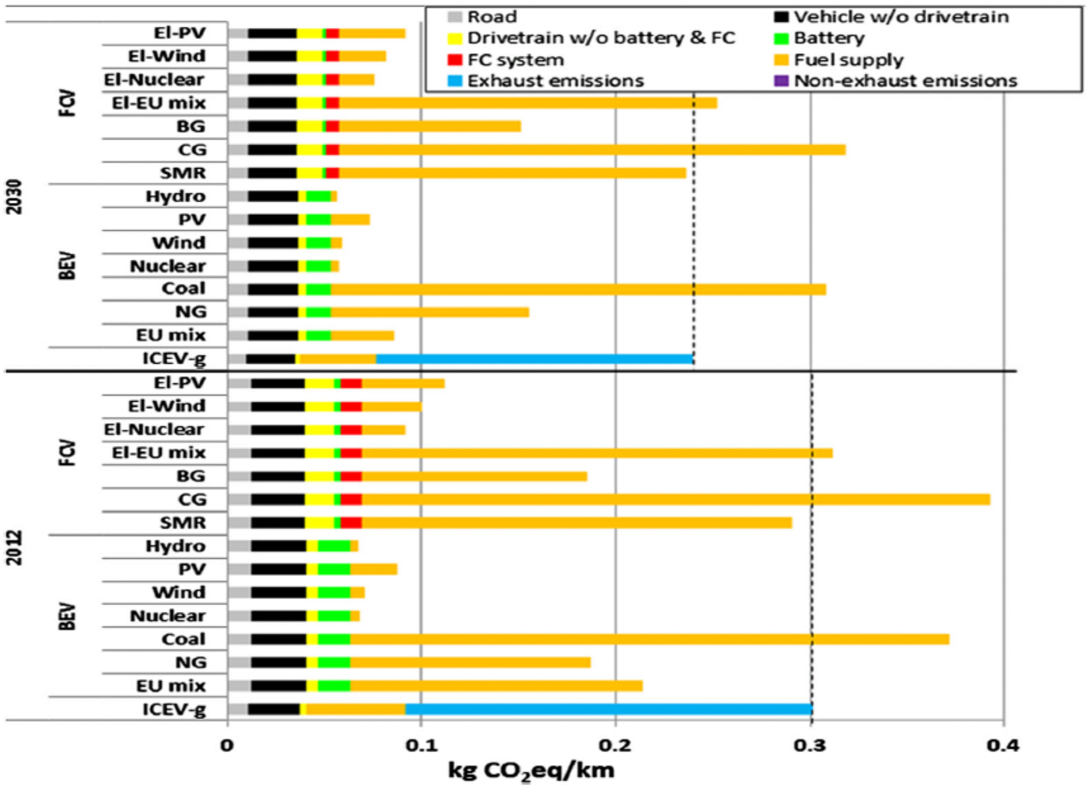


Figure 81: Life cycle GHG emissions of BEV and FCV operated with electricity and hydrogen from different sources, compared to reference gasoline ICEV (Bauer et al., 2015)

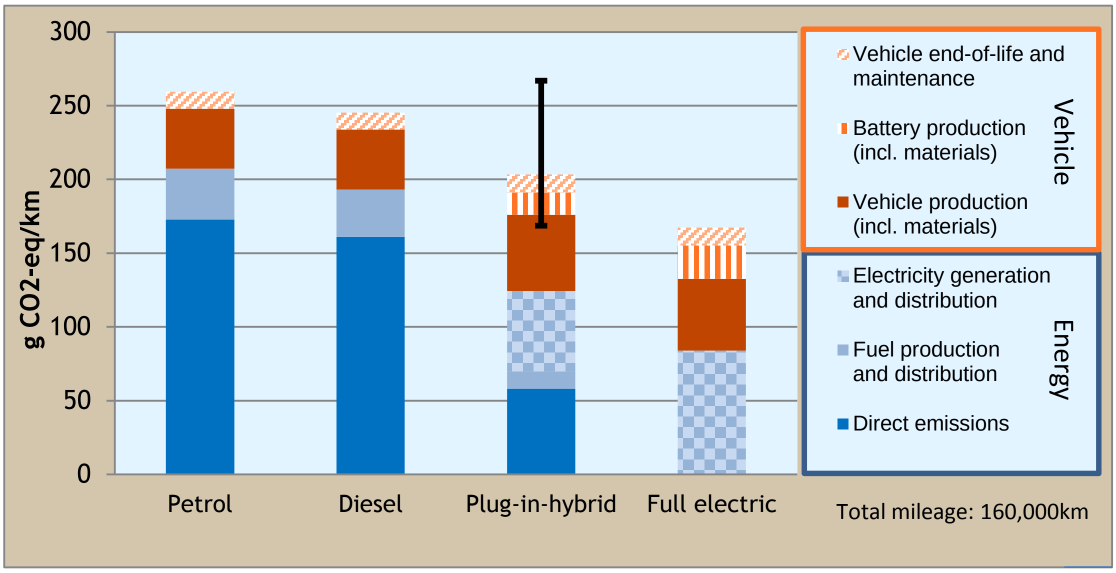


Both figures also show the dominance of fuel supply and exhaust emissions (both part of the use phase) and the limited variation in GHG emissions from road and vehicle drive train for the various options and the higher share of GHG emissions required for the battery and FC drivetrain, although this is compensated by the reduction in exhaust emissions. With natural gas steam methane reforming being the dominant source for hydrogen production, the reduction potential of FCEV seems to be limited compared to gasoline.

According to TNO and CE Delft (2014) a BEV saves on average 35% of GHG emissions over the entire life cycle (NL electricity mix) (see Figure 82). This seems to be in line with the EU mix in 2012 (see Figure 81). This study has also investigated lifetime mileage impacts: for a large BEV with high mileage, GHG reduction is higher than the average: 48% instead of 35%.

For PHEV the reduction depends also on the kilometres driven electrically and charging behaviour: 20% (one charge a day), 35% (2 charges a day), 3% (when only 10% of kilometres driven on electricity).

Figure 82: GHG emissions per life cycle phase for ICEV and PHEV and BEV (TNO and CE Delft, 2014)



Hawkins et al. (2012) also provides insight in this relationship between lifetime mileage assumptions and the higher environmental impact of EV production by calculating the GWP savings for 200 000 km and 100 000 km lifetime mileage compared to an average lifetime mileage of 150 000 km. For 150 000 km the GWP savings are between 10-24% compared to conventional diesel and gasoline vehicles. For 200 000 km the GWP savings are 27-29% relative to gasoline vehicles and 17-20% relative to diesel, while for 100 000 km these savings are limited to 9-14% compared to gasoline and no significant savings compared to diesel.

Upstream processes and manufacturing

GHG emissions of upstream processes and manufacturing are limited compared to the use phase. BEV and FC production requires double the GHG emissions in the production phase compared to ICEV. GHG emissions from this phase might become more relevant in case the use phase becomes less dominant.

Note that the upstream processes referred to here are related to the vehicle supply chain and battery production, but not to the upstream processes linked to the fuel chain (electricity mix and transport fuels).

According to Hill et al. (2012) the GHG emissions of production/disposal is an estimated 10-16% of total GHG emissions for conventional ICE. Current production emissions for electric and fuel cell cars have been estimated to be up to double those of conventional vehicles.

This is also confirmed by to TNO and CE Delft (2014) and Bauer et al. (2015). The latter study states that emissions during the production phase are similar for all vehicle types, except for battery and FC production. During the vehicle production, the battery used in PHEVs and BEVs is the most critical component in terms of GHG emissions contributing 30-50% of total emissions, mainly due to the materials and quantities required for the battery production. The GHG emissions/GWP of vehicle manufacturing becomes more relevant in case of low GHG emissions in the use phase, like in case of a low CO_2 intensive electricity mix.

In Egede et al. (2015) a case study on the overall GWP reduction potential of light weighting (aluminium versus steel) has been performed. Because light weighting results in higher environmental impacts during the manufacturing phase it was questioned to what extent this was corrected for in the use phase. With a weight reduction of 67% aluminium does not seem to be the preferred material in all cases. To what extent aluminium is preferred also depends on the lifetime, electricity mix and energy consumption in the use phase. The selected case study countries Germany, Spain and Brazil show that the variety in preferences for aluminium over steel, but that aluminium not necessarily pays off. On the long term it does, but for example, for low energy consumption and low driving distance (100 000 km) steel is the preferred option.

Use phase

With respect to the use phase the GHG emissions associated with the electricity mix used to drive EVs has been the most widely discussed environmental aspect.

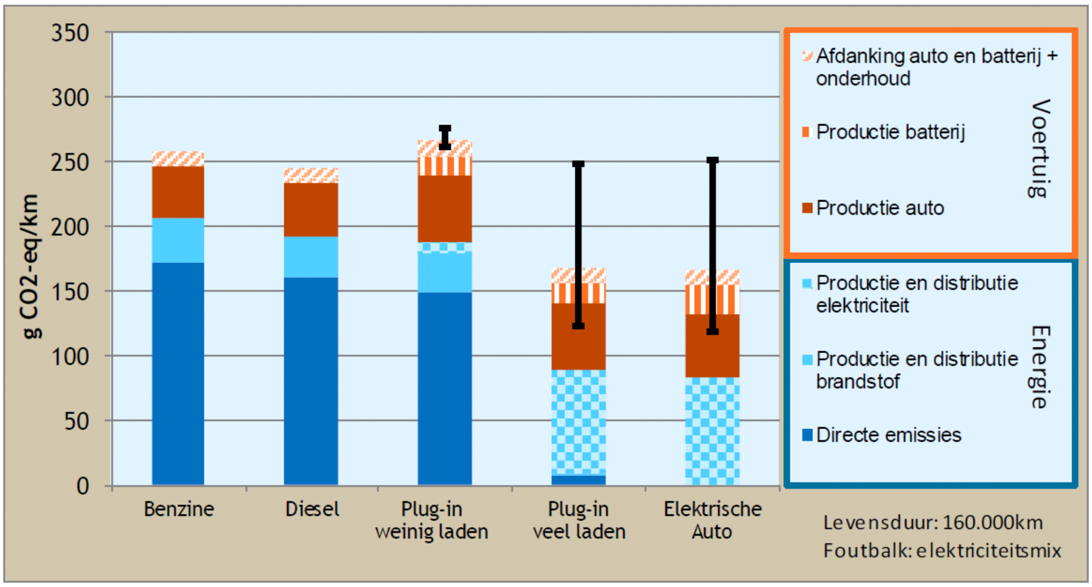
Another aspect, which is point of discussion is the impact of driving and charging behaviour on the overall environmental performance of vehicles. Faria et al. (2013) have investigated the impact of a driving profile (aggressive, normal and ECO) and climate control settings (on cooling, on heating or off) on the estimated GHG emissions per km travelled of a Nissan Leaf. The electricity mixes assumed for 2011 have been 979 gCO_2/kW for Poland, 376 gCO_2/kW for Portugal and 103 gCO_2/kW for France. The outcomes show that the differences in emissions as result of differences in driving style are limited for a relative low CO_2-intensive electricity mix, like in France, while significant differences occur in case of a more carbon intensive electricity mix, like in Poland, making driving behaviour more relevant for overall life cycle emissions

Table 87: Relation between driving style and air-conditioning use and GHG emissions per km driven (Faria et al., 2013)

Driving style	AC OFF			AC ON Cool.			AC ON Heat.		
	PL Mix	PT Mix	FR Mix	PL Mix	PT Mix	FR Mix	PL Mix	PT Mix	FR Mix
Aggressive	177	68	19	202	78	21	243	93	26
Normal	149	57	16	172	66	18	208	80	22
ECO	119	46	13	147	56	15	190	73	20

For the relative GHG savings TNO and CE Delft, 2014 has found a range of 16-53% for a PHEV (charging 2 times a day, 240 000 km) and between 17-65% for a BEV (also 240 000 km). The lower end of the range represents coal based electricity of 935 gCO_2/kWh and 200 gCO_2/kWh for the upper end representing a large share of renewables. The error bars in the figure below represent this range.

Figure 83 : GHG emissions entire life cycle including various assumptions for the electricity mix (black error bars) for an average car (TNO and CE Delft, 2014)



Maintenance makes up to 40-50% of production emissions *(Hill et al. 2012).*

With respect to maintenance Faria et al. (2013) state that GHG from emissions from maintenance and vehicle disposal represent less than 10% of the overall emissions. EVs have less maintenance compared to conventional vehicles, but since EVs have lower emissions the relative share of emissions related to maintenance is higher.

End-of-life

According to Hill et al. (2012) the GHG emissions of production/disposal is an estimated 10-16% of total GHG emissions for conventional ICE and this share is likely to be more caused by production rather than disposal, because in the same study Hill et al. 2012 provides an explanation for this: in terms of emissions from the recycling process, these are only a very small component of the vehicle life cycle (0.2%).

Faria et al. mentioned that the GHG emissions from maintenance and vehicle disposal represent less than 10% of overall emissions. On the disposal of the battery, Faria et al. mention that the additional emissions should be taken into account as well, although, it should be noted that batteries still retain some capacity at the end-of-life and thus can be reused on other applications, such as static energy storage, where the requirements are more flexible. This suggests that a part of the manufacturing emissions should be ascribed to the second-life application, which consequently lowers overall GHG emissions of an EV.

Other environmental impacts

Overall

Regarding other environmental impacts, we can make a distinction between environmental impacts being mainly relevant for the upstream/manufacturing phase of the vehicle supply chain:

- human toxicity;
- euthrophication.

Or being mainly relevant for the use phase (actual use and energy supply chain):

- acidification;
- photochemical Oxidant Formation (POF);
- cumulated energy demand.

Overall human toxicity and eutrophication are the main other environmental impacts being discussed by the authors of the various LCA studies. Human toxicity is linked to the vehicle supply chain, but also to the fuel supply chain (the electricity mix).

Note that the trade-offs between EVs and ICEVs also result in a shift of emissions: EVs score higher for some environmental aspects, but on the other hand also result in a shift from emissions emitted in high density populated areas to less populated areas with high stacks emitting the emissions.

Upstream processes and manufacturing

Girardi et al. (2015) mentions that EVs perform better than ICEVs except for human toxicity and eutrophication. EV battery manufacturing is responsible for 45-47% of overall human toxicity and 31-38% of overall eutrophication of the entire life cycle. Besides battery manufacturing the manufacturing of the car also has a large impact. So together battery and vehicle production dominate these environmental impacts for EVs.

Figure 84: CML human toxicity by life cycle stage for ICEV and EV (2013 scenario) (Girardi et al, 2015)

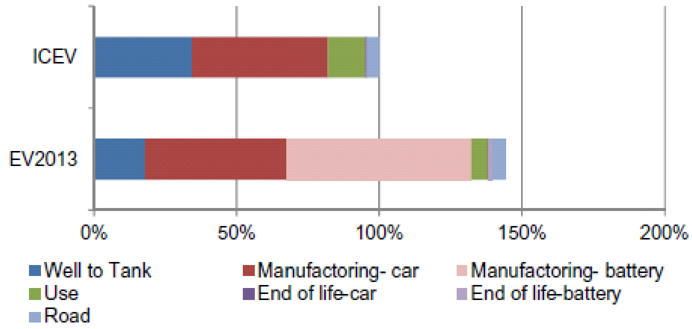


Figure 85: Human toxicity potential (Bauer et al. 2015)

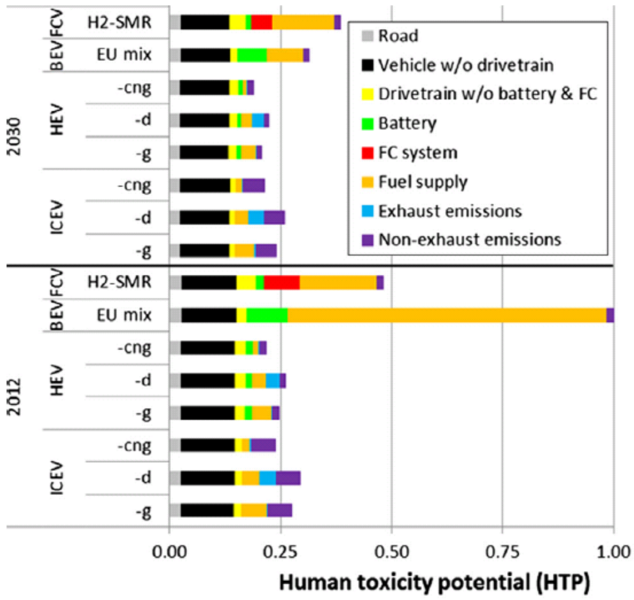
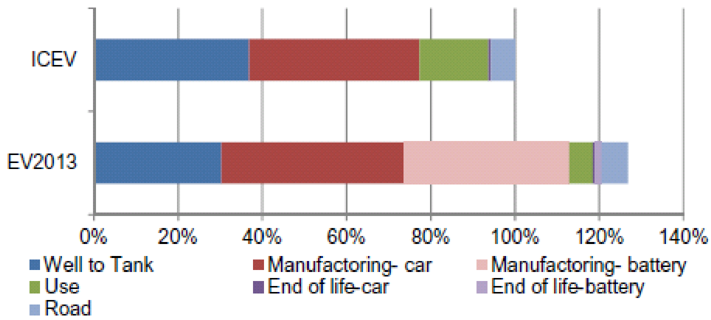


Figure 86: CML eutrophication by life cycle stage for ICEV and EV (2013 scenario) (Girardi et al. 2015)

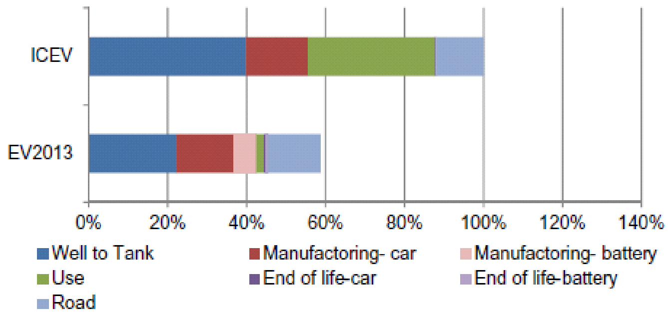


Bauer et al (2015) also state that BEV has the largest human toxicity potential (HTP) as result of the current EU electricity mix: the toxic substances responsible for this are mainly released by coal mining and metal mining activities (nickel, copper, platinum and aluminium) and are related to the vehicle glider, FC and battery manufacturing, hydrogen production, but also power transmission and distribution grid. He seems to refer to the well-to-tank, manufacturing-car and manufacturing-battery phases of the Girardi figures above. HTP for BEV and FCV will still be higher compared to ICEV in 2030.

Use phase

According to Bauer et al. (2015) Photochemical Oxidant Formation (POF) is one of the environmental impacts where all type of vehicles score similar levels, but CNG vehicles and 2030 BEVs score best. POF is the only impact category where the exhaust emissions of fossil fuelled vehicles (ICEV and HEV) have major contributions. This is also confirmed by Girardi et al. (2015) (see figure below).

Figure 87: ReCiPe photochemical oxidant formation potential by life cycle stage of ICEV and EV (2013 scenario) (Girardi et al. 2015)



Note that the impacts human toxicity, acidification and PM formation might be actually higher as result of the higher real-world NO_x tail-pipe emissions, which have currently been underestimated and have been heavily debated recently.

According to Girardi et al. (2015) air acidification, depletion of abiotic resources and cumulated energy demand non-renewable are mainly caused in the well to tank phase for both EVs and ICEVs (so the energy supply chain), but with the impacts of ICEVs being higher than EVs. Only for air acidification the actual use phase of ICEVs also contributes a little. Any improvements of these environmental impacts should therefore come from actions taken in the fuel supply chain or electricity generation.

Figure 88: CML air acidification by life cycle stage for ICEV and EV (2013 scenario)

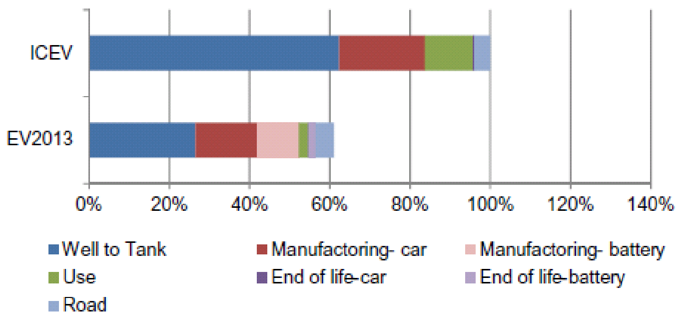


Figure 89: CML depletion of abiotic resources by life cycle stage for ICEV and EV (2013 scenario) (Girardi et al. 2015)

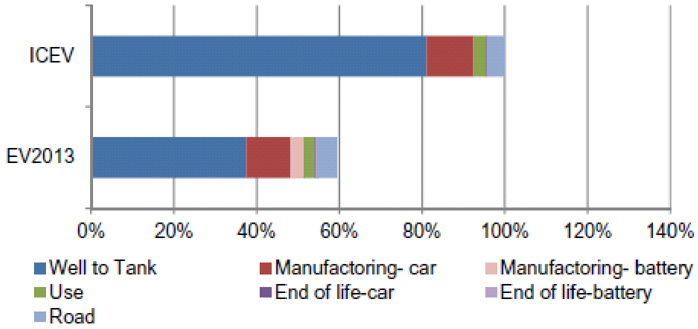
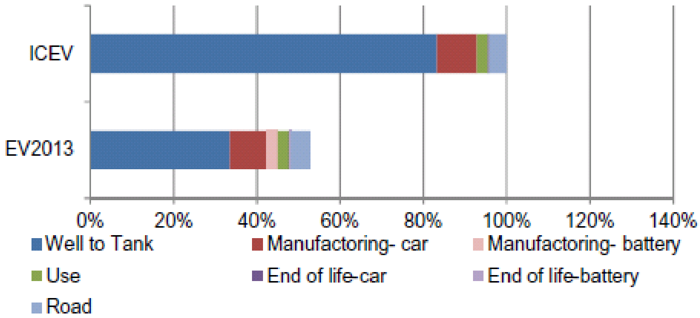
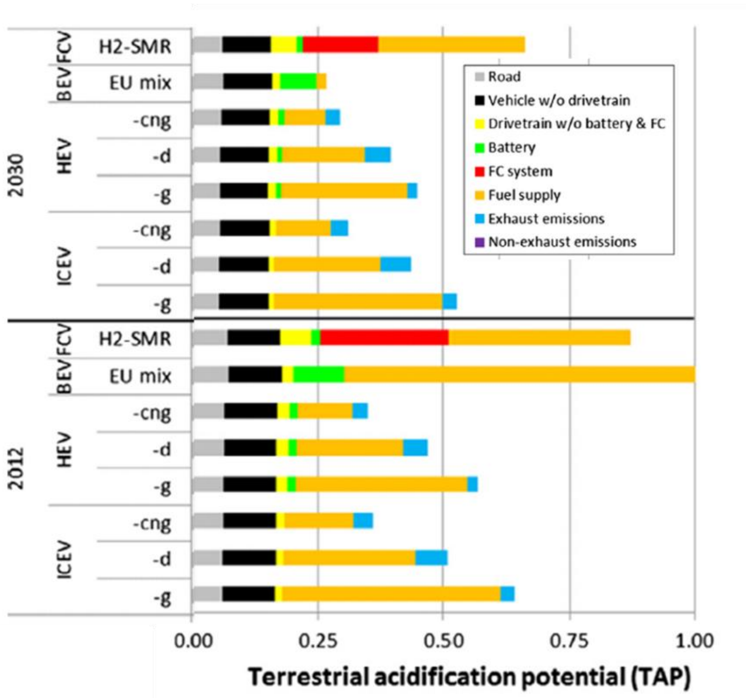


Figure 90: Cumulated energy demand (fossil) by life cycle stage for ICEV and EV (2013 scenario) (Girardi et al, 2015)



According to Bauer et al. (2015) acidification (ATP) and PM formation (PMF) of EV will also be higher compared to ICEV in 2030. ATP and PMF will lower for BEV as result of the changing electricity mix, but the ATP and PMF impacts of FCV will remain higher than for ICEV in 2030, because FC manufacturing and hydrogen production (emissions from mining of platinum). ICEVs score also high as result of the emissions from gas and oil production processes. CNG vehicles score lower on these aspects than ICEV vehicles and HEV also due to fuel demand reduction.

Figure 91: Terrestrial acidification potential (Bauer et al. 2015)



End-of-life

End-of-life is not discussed very often. With respect to dismantling of vehicles at the EoL-stage, Tian and Chen (2013) discuss the concept of design for dismantling, which allows car producers to save costs and as a means to take care of the environmentally dismantling of their products. Tian and Chen (2013) also stress the importance of the use of a single material as an important element of design for dismantling which can increase the material recycling rate strongly.

Annex C: LCA literature review for buses

In order to identify the main environmental hotspots along the life cycle of vehicles various LCA papers have been studied for buses. Information of each LCA paper is gathered in the following table.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Env. impact assessed	Main assumptions/ Sensitivity analysis	Findings of the study
LCA papers						
Bi et al. (2015) Plug-in vs. wireless charging: Life cycle energy and GHG emissions for an electric bus system. Applied Energy 146 (2015) 11-19	Lifecycle energy yand GHG comparison of plug-in vs wireless charging for Electric buses	each stage of the life cycle except EoL	Ann Arbor and Ypsilanti area for 12 years with 67 buses	CED, GWP	Impacts per km, assuming a 12-year lifetime.	There is not much difference found comparing the plug-in and wireless charging systems from the perspectives of CED and GWP. Wireless charging system consumes 0.3% less energy and emits 0.5% less GHGs than plug-in charging
(Cooney, et al., 2013) Life Cycle Assessment of Diesel and Electric Public Transportation Buses. Journal of Industrial Ecology DOI: 10.1111/jiec.12024	LCA diesel bus vs electric bus in USA	Upstream processes, manufacturing, use phase Excluded: EOL	12-years lifetime of bus, current situation, USA	GWP, ozone, depletion, particulate matter formation, eco-toxicity, acidification	Sensitivity analysis for the electricity grid impact and further battery improvements	Use phase dominates most impact categories; however, the effects of battery production are significant for global warming, carcinogens, ozone depletion, and eco-toxicity. Strong connection between the mix of power-generation technologies and the preference for the diesel or electric bus. With the existing U.S. average grid, there is a strong preference for the conventional diesel bus over the electric bus when considering global warming impacts alone.

Reference	Subject of the study	Life cycle phases covered	Coverage (time and geographical)	Env. impact assessed	Main assumptions/ Sensitivity analysis	Findings of the study
Kliucininkas et al. (2012) The life cycle assessment of alternative fuel chains for urban buses and trolleybuses/ Journal of Environmental Management 99 (2012) 98e103	Biogas, electricity and diesel in midi urban bus and a similar type of trolleybus.	All life cycle phases, except road construction and vehicle production	Current situation, Lithuania	WTP and PTW: human health - ecosystems and resources - energy consumption/fuel consumption (end points)	impacts per km for a city bus or trolleybus in urban conditions Local biogas production	Biogas The weighted damage caused by the Biogas CNG fuel chain was 45.7 mPt, which was the lowest damage value for all the fuel chains assessed. 90% of the overall damage caused by the Biogas CNG fuel chain occurred during the "well-to-pump"(WTP) stage. Trolley WTW-reduction Trolley natural gas fuel chain compared to Trolley Heavy Fuel Oil chain -23%.
(Tong, et al., 2015) Comparison of Life Cycle GHGes from Natural Gas Pathways for Medium and Heavy-Duty Vehicles. Environ. Sci. Technol. 2015, 49, 7123-7133	Natural gas pathways	Manu-facturing Use phase ((incl. upstream processes natural gas extraction))	Current situation, US	GWP: CO_2, H_4 and N2O	Functional unit: a pathway as a way to use natural gas for road transportation Vehicle distance travelled (gCO_2 eq/km) and freight distance moved (gCO_2/eq/km/metric ton) Shale gas (the question is to what extent this is also valid for the EU) Timeframe of GWP	Of all natural gas pathways Battery electric vehicles (BEVs) powered with natural gas-produced electricity are the only fuel-technology combination that achieves emission reductions for Class 8 transit buses (31% reduction compared to the petroleum-fueled vehicles).

Analysis of environmental impacts along the life cycle

The focus of the studies on buses is similar to passenger cars: most of the studies focus on the comparison between ICEV and EVs, while other drivetrains receive less attention. However, natural gas is also a part of a few studies. Another similarity is that most studies provide an overall overview of the life cycle, without zooming in on a specific life cycle stage. In the following paragraphs the main conclusions per life cycle phase are described. End-of-life has not been discussed in the studies investigated and will therefore be not further discussed below.

GWP

Overall

Bi et al. (2015) compared plug-in buses versus wireless charging over the entire life cycle on the impacts on CED and GWP. In terms of energy consumption there is not much difference between plug-in and wireless charging. Wireless charging consumes slightly less energy (0.3% less energy and 0.5% less GHG). This can be explained by the trade-off between the higher GHG and energy burdens for the wireless charging infrastructure and the battery size, which can be downsized to some extent. The use phase electricity consumption dominates energy demand and GHG emissions and accounts for about 97-98% of CED and GWI.

Upstream processes and manufacturing

Like for passenger cars, studies do not make a clear distinction between the manufacturing phase and upstream processes. Therefore we discuss all aspects under manufacturing'.Cooney, et al., 2013 also has given estimations for further improvement of battery production a 25% increase in energy density of Li-on batteries will result in a reduction of 1.1% global warming impacts. Doubling the lifetime of a battery halves the required battery replacement over the lifetime of a bus and results in 2% reduction in GWP.

Use and maintenance

Also for buses, the use phase is the dominant life cycle. Kliucininkas et al. (2012) has summarised the main type of emissions in the use phase (PTW) for 4 buses, including buses on natural gas. Note that these numbers are valid for the selected study area in Lithuania. It found that the use of natural gas to power buses is 1.9 less efficient than using natural gas to produce electricity for urban trolleybuses.

Table 88: Estimated fuel consumption and fuel emissions per 1 km of travel (PTW stage) (Kliucininkas, 2012)

	Fuel consumption, g/km	Emissions, g/km				
		CO_2	CO	NO_x	SO_2	PM
Diesel bus (B_D)	319.6	1010	3.13	11.00	$6.39*10^{-3}$	0.75
Trolleybus (heavy fuel oil) (T_{HFO})	247.6	773.2	0.95	1.12	1.42	0.17
Trolleybus (natural gas) (T_{NG})	215.7	485	0.73	1.17	$32.4*10^{-6}$	$2.11*10^{-3}$
Compressed natural gas bus (B_{CB})	409.5	1130.4	0.90	2.25	$2.46*10^{-3}$	0.11
Compressed biogas bus (B_{CNG})	852.4	1591	0.90	2.25	0.29	0.11

Cooney, et al., 2013 provided insight in the impact of the electricity grid in various US states. As result of the variations in the CO_2-intensity of the electricity mix in the investigated states EB would only result in emission reduction in 8 states over ICEB, for examples in the states with a high share of hydropower in the mix.

According to this same study, an increase in efficiency of the electric drive train from 75% to 80% will result in 11% reduction of GWP, 12% reduction in PM and 9% reduction in ozone depletion.

Tong, et al., 2015 has investigated various natural gas pathways and use in various MHVD, also for so-called Class 8-transit buses. This study concludes that BEVs with natural gas electricity emit the lowest GHG emissions (31% reduction compared to a diesel bus). BEV with the US average electricity mix can reduce 8% GHG emissions as result of the higher efficiency. Other natural gas pathways increase GHG emissions 6-43% on average compared to diesel.

Other environmental impacts

Overall

When comparing air pollutant emissions of an ICEB and EB Cooney et al. (2013) takes into account the emissions resulting from electricity generation and Li-ion battery production for EB and diesel production and combustion emissions for the ICEB. The results show that ICEB has higher CO, NO_x and PM emissions, while EB has higher SO_x emissions, which are caused by electricity production.

Upstream processes and manufacturing

According to Cooney et al. (2013) battery production is an important factor in several environmental impacts categories. ICEB is preferable with respect to the environmental impacts ozone depletion potential, carcinogens and eco-toxicity. This last category is uncertain due to the environmental impact of cobalt. The release of cobalt is a by-product caused by the production of the positive electrode of the battery containing a mixture of heavy metals. The study also has given estimations for further improvement of battery production a 25% increase in energy density of Li-on batteries will result in a reduction of 1.7% reduction in particulate matter and 16% reduction in ozone depletion. Doubling the lifetime of a battery halves the required battery replacement over the lifetime of a bus and results in 4.5% reduction in PM, 39% reduction in ozone depletion potential.

Use phase

When comparing air pollutant emissions of an ICEB and EB Cooney et al. (2013) takes into account the emissions resulting from electricity generation and Li-ion battery production for EB and diesel production and combustion emissions for the ICEB. The results show that ICEB has higher CO, NO_x and PM emissions, while EB has higher SO_x emissions, which are caused by electricity production.

According to this same study, an increase in efficiency of the electric drive train from 75 to 80% will result in 11% reduction of GWP, 12% reduction in PM and 9% reduction in ozone depletion.

According to Cooney, et al., 2013 the environmental impacts related to the bus maintenance operations for the ICEB and EB and the charging infrastructure are dominated by the environmental impacts from other processes and therefore are not deemed to be relevant.