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Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy

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Executive Summary

Introduction

There is an urgent need to reduce emissions of Greenhouse Gases (GHG) from all sectors of the global economy in order to avoid dangerous climate change. A number of international and national policies and commitments have been put in place over recent years to ensure that emissions from particular sectors of the economy start to reduce, and across the EU, overall emissions of greenhouse gases are on a declining trend. However, emissions from the transport sector continue to increase and there is now a need to take urgent action to control emissions from this part of the economy. Regulatory measures have already been proposed and approved that will ensure that emissions from passenger cars start to reduce. The European Commission also already has well-advanced plans to introduce similar CO_2 targets for new light goods vehicles (vans).

Emissions of CO_2 from the European heavy duty vehicle (HDV) fleet currently account for a significant proportion of total road transport emissions, and consequently it is appropriate to examine the need, scope and potential benefit for introducing measures to reduce emissions from these types of vehicles. However, the reduction of CO_2 from the road freight transport sector is especially challenging due to close links with economic development. This project is an initial step in the process of informing possible policy actions, and as such, it has a particular focus on building up a comprehensive picture of:

I. The heavy duty vehicle market and fleet;

II. Technological options that could help to control CO_2 emissions from heavy duty vehicles;

III. Current and likely future fuel use and CO_2 emissions from heavy duty vehicles; and

IV. Policies and other measures that could be used as a means of controlling emissions from these types of vehicles.

It is important to note that the scope of the study did **not** include analysing the possible impacts of operational efficiency or demand based measures. In addition, biofuels were also excluded from scope of the analysis presented in this study, other than their contribution to the attainment of existing targets in reducing lifecycle emissions from road transport fuels as required under the Fuel Quality Directive and the requirements for the use of biofuels under the Renewable Energy Directive.

Vehicle Market and Fleet

The project team has collected and reviewed readily available information/data in order to characterise the existing European vehicle market and fleet and the current state of legislation in the EU (and the rest of the world) that influences the fleet energy efficiency. The collection of this information was often quite challenging, despite the cooperation of key stakeholders (such as ACEA, the IRU and T&E)[1]. The statistical information sought from and available for different countries was found to be highly variable in detail and quality, and in some cases not available or identifiable at all. Also in many cases European datasets obtained required significant data processing in order to produce consistent information for the EU27.

A review of readily available literature on policy and legislation has revealed that the majority of EU countries have policies to improve the efficiency of heavy duty road transport, promote

[1] ACEA = European Automobile Manufacturers' Association - www.acea.be; IRU = International Road Transport Union - www.iru.org; T&E = Transport & Environment - http://www.transportenvironment.org

low emissions vehicles and control emissions. The use of fiscal measures, driver training and regulation are also common practice to improve the performance of heavy duty road transport inside the EU. However, a number of countries in the EU and beyond have indicated that a lack of a standardised method for measuring and reporting fuel consumption on new vehicles makes it difficult to regulate CO_2 emissions from HDV. Outside of Europe, Japan is already regulating for the future efficiency of HDVs and proposals have recently been put forward in the US for future regulation. However, it is important to take into account regional differences when considering the applicability of experiences in other regions to Europe. For example, the European HDV market is already more significantly focused on improving fuel efficiency due to high fuel prices compared to the rest of the world. As a result, the European manufacturers of HDVs are at the forefront of efficient HDVs.

The EU HDV market is dominated by the seven major European manufacturers (accounting for 93% of EU registrations), which also account for an estimated 40% of worldwide HDV production. In the buses and coaches sub-sector there are also a significant number of smaller manufacturers /bodybuilders accounting for ~25% of all new vehicle registrations. In contrast to the vehicle manufacturers, the trailer and body-builder sector is highly diverse with thousands of organisations, most of which operate only in local markets. However, there are significant players, with top seven trailer manufacturers account for over 50% of new trailer registrations. When compared to light duty vehicles, the HDV market is highly complicated, with the major OEMs for the most part not responsible for the final vehicle configuration (at least for rigid trucks) other than the powertrain, chassis and cab. In addition, in general the final heavy duty vehicles are highly adapted to specific customer requirements and for particular mission profiles. A range of auxiliary equipment is also utilised in HDVs which adds to energy consumption. All this leads to a high level of diversity in HDV performance creating significant challenges in both adequately characterising the sector and the potential for designing suitable potential policy measures.

Data characterising the number and distribution of HDV operators across Europe are not collected in any standard format, and are very difficult to locate, with more data available for freight vehicles than for other HDV categories. In general a higher proportion (60%) of the freight tonne km in the EU is associated with longer distance trips. The majority of freight operators are small in size, with 85% of operators having fewer than ten vehicles. Of these, hire or reward (HoR) operations account for 85% of tonne km and travel longer distances on journeys compared to own account (OA) operations.

The EU bus industry tends to be dominated by large national/international companies, while the coach sector is made up of a considerable number of much smaller operators. New registrations of coaches account for around 24% of all bus and coach registrations for ACEA members in the period from 2007-2009., This is in contrast to total fleet estimates, where coaches account for between 37% to 48% of the total bus and coach fleet.

There are clear differences in the distribution of vehicles by age between trucks and buses/coaches and statistics show that newer vehicles account for a higher percentage of total km compared to their numbers. There is also significant variation between Member States and in general between the Northern, Southern and Eastern European countries.

Alternative fuel powertrains are not significantly used in heavy trucks, except in a few countries. However, there is more widespread use of alternatively powered buses across a number of countries. Little information is available on the second hand vehicle markets for HDVs. However, the available information suggests movements of older used HDVs from the major EU economies to southern Europe and also the newer EU Member States.

Technology

A review of the technology currently used and under development for heavy duty vehicles has been conducted and highlights that across the developed countries, technologies currently employed by HDVs are similar, although trucks in general have a greater number of technology options than buses and coaches. There are a large number of different technologies which can be applied and are being developed to reduce greenhouse gas emissions targeting powertrain efficiency improvement, reduction of vehicle losses and improvement in driver behaviour. Technologies targeting powertrain efficiency improvement have the potential for the largest reduction in GHG emissions.

The large variation in vehicle duty cycle also has an impact on the benefit any one technology will have, with different technologies providing benefits over different duty cycles. Many powertrain technologies have greatest benefit over urban cycles with a high degree of stop start operation whilst technologies aimed at reducing vehicle drag losses give greatest benefit to those operating over long distances at constant high speeds. Maximum benefits which technologies can bring are 20 – 30% for urban operation and ~10% for long haul operations.

Fuel Use and GHG Emissions

The project has developed estimates to quantify the level and contribution of HDVs to European energy consumption and greenhouse gas emissions from road transport. It has also developed estimates of how these are split between different HDV applications and scenarios on how this might develop in the future to 2030. Heavy duty vehicles are estimated to account for around 26% of all CO_2 emissions from road transport in the EU. HDVs consume ~3200 PJ of (predominantly diesel) fuel and generate direct emissions of ~240 Mt CO_2. Of this, over 85% is due to trucks, with the remainder due to buses and coaches.

Estimates for the breakdown of fuel consumption and emissions from European HDVs between different applications were developed for eight mission categories based on information provided by ACEA: Service/Delivery (≤7.5t), Urban Delivery/Collection, Municipal Utility, Regional Delivery/Collection, Long Haul, Construction, Buses, and Coaches. This analysis highlighted the importance of long-haul and regional distribution activity in total energy consumption and emissions, which account for around 37% and 14% of all HDV fuel consumption respectively. Fuel consumption and CO_2 emissions from the vocational use categories - municipal utility and construction – together currently account for around 17.7% of the total for all HDVs. The energy consumption and CO_2 emissions from service/delivery and urban delivery vehicles are relatively low versus their numbers and together account for 16.5% of all HDV emissions. Buses and coaches account for 15% of all HDV emissions currently, with buses accounting for a higher proportion than coaches particularly compared to their vehicle numbers and vkm.

A baseline Business as Usual (BAU) scenario was developed to estimate the potential evolution of fuel consumption and greenhouse gas emissions of HDVs to 2030. BAU assumptions include natural development of powertrain and vehicle based efficiency improvements. The BAU scenario results showed that overall energy consumption and direct CO_2 emissions might increase by almost 15% by 2030 (+21% for trucks, -21% for buses and coaches) without further actions. The increase for lifecycle GHG emissions is estimated to be lower (8%) due to the impact of the Fuel Quality Directive requirements and existing biofuel commitments. In terms of the breakdown by category, the proportion of energy consumption/direct CO_2 emissions due to trucks increases to almost 90% by 2030. This change is principally due to a decrease in stock / activity for buses and coaches and an increase in stock / activity for trucks. The contribution of long-haul trucks to the share of the total for trucks decreases in comparison to other categories. This is principally due to an anticipated reduction in fuel consumption greater than all other HDV categories (at over 10% by 2030), mainly a result of additional vehicle based measures (e.g. aerodynamic bodies).

To understand the overall impact that such technologies can have on the European Heavy Duty vehicle fleet two technology scenarios have been proposed, in addition to a Business as Usual (BAU) scenario, which provide an overview of the level of technology required to have a significant impact on fleet emissions and the rate at which technology uptake may be possible. The BAU scenario provides a baseline of expected improvements in vehicle efficiency without any legislative stimulus. The Cost Effective and Challenging scenarios are proposed technology uptake rates incentivised by some means. The Cost Effective scenario proposes uptake rates of technology applicable for each of the eight different vehicle mission profiles for technologies which have a payback period for the operator of around two to three years, along with rates for the uptake of more costly (but more effective) technologies by early adopters. The Challenging scenario proposes uptake rates of all technologies expected to be commercialised between 2010 and 2030 by vehicle mission profile regardless of the length of time required to achieve technology payback. Uptake rates of technology are aggressive and represent a likely maximum benefit.

Results from this analysis show that only the Challenging scenario can reduce direct CO_2 emissions from the European Heavy Duty vehicle fleet below 2010 levels by 2030. The analysis shows that this scenario would give a reduction in emissions of 2% by 2030 against 2010 levels. While the Cost Effective scenario would reduce emissions over the period 2010 to 2020 due to forecast changes in the vehicle fleet, by 2030 the direct CO_2 emissions are estimated to be 7.5% higher than 2010 levels.

Policy Assessment

The policy assessment identified that there are several policy instruments that appear to have the potential to reduce CO_2 emissions from heavy duty vehicles, at least when taking into account first order effects. However, an assessment of the cost-effectiveness and GHG reduction potential of all of these instruments depends on the detail of the instrument, particularly the level of ambition and design, which was beyond the scope of the assessment undertaken within this project. Instead, a high level policy assessment was undertaken, which followed the Commission's Impact Assessment Guidelines where appropriate.

There are some instruments – such as driver training and best practice dissemination programmes – that appear to have CO_2 reduction benefits, at least in the short-term, from relatively small financial outlays. The introduction of performance requirements for vehicles, vehicle components and vehicle combinations, has potential benefits in addressing the inconsistency of market signals by requiring the uptake of technologies with longer payback periods than would be introduced under prevailing market conditions. However, applying such requirements to whole vehicles or vehicle combinations is not straightforward and requires an agreement on measuring methodologies and metrics that would incentivise the introduction of CO_2 efficient technologies. The first order impacts of speed reduction and allowing larger and heavier vehicles both appear to be positive, but for both there are potential second order effects – linked to the effective impact of each instrument on the capacity of the transport system – that need to be better understood. Fiscal instruments, such as fuel taxation differentiated by the carbon content of the fuel or emissions trading, have the potential to be the most economically efficient instrument and potentially have similar effects. However, the effectiveness of an ETS would only be as effective as the design of the system, and the fact that the EU ETS covers non-transport sectors might limit the potential ambition of this instrument if it also covered HDVs.

Given that the different instruments provide incentives to different stakeholders, there is the possibility of using instruments together in order to complement each other, to overcome the problem of split incentives and to counteract any rebound effects that might occur. Labelling and differentiated vehicle taxes/incentives might be particularly useful as complementary instruments to be used, for example, with performance requirements.

Overall Conclusions and Recommendations

Overall it is clear that tackling the ongoing trend in the increase of fuel consumption and GHG emissions from HDVs will be difficult in comparison to light duty vehicles (LDVs). The HDV market is complex with significant diversity in final vehicle specification and performance/use. The future energy/GHG reduction potential of specific power train and vehicle technologies is extremely dependent on the vehicle type, application and duty cycle. From the work carried out for this (LOT 1) report, it would appear that the most meaningful metric of fuel efficiency or GHG emissions for HDVs will be in relation to the work performed, such as fuel consumption per unit payload carried (i.e. weight in tonnes, volume in m^3 or passengers). The policy assessment work carried out suggests that any possible standards would also best take into account specific duty cycles for different applications or classes of HDV. However, this subject is being investigated in greater detail in LOT 2 of the work, which will be able to provide firmer conclusions and recommendations in this area.

The analysis carried out for this project showed that even under ambitious technology uptake levels starting immediately, GHG emissions from HDVs may only reduce to levels slightly below today's levels by 2030. Should there be significant delay to the stimulation of the HDV market to accelerate the improvement of technical efficiency, the potential future GHG emissions could be significantly higher. However, there are also a number of important elements/areas that have not been covered in this project, or at least not specifically modelled in the estimation of potential future energy and greenhouse gas emissions savings. These would also need to be taken into account when considering the design of future policy and regulation to reduce greenhouse gas emissions and include some of the following:

- Fuel measures, such as uptake and savings from the use of biofuels and infrastructure considerations for alternative fuels;
- Regulations on vehicle dimensions and weight – e.g. longer and heavier vehicle (LHV) combinations may have a beneficial role to play as they are more efficient in transporting freight than smaller vehicles. However, this improvement will be counteracted to an extent depending on the degree to which LHVs divert traffic from less greenhouse gas emitting modes of transport and the size of rebound effects due to reduction in transport operating costs. Their introduction, even on dedicated routes, may require major infrastructure expenditure and raises potential safety concerns;
- Possible impacts of speed controls or reductions on heavy duty vehicle fleet fuel consumption;
- Road infrastructure measures, such as measures improving capacity, reducing inclines and bottlenecks;
- Operational measures and intelligent transport systems (ITS) for:
  - Fleet management and logistics, such as driver training, efficient routing, vehicle tracking and remote diagnostics; and
  - Traffic management and control, such as for reducing congestion, managing dedicated lanes, access control and dynamic speed limits.

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1 Introduction

1.1 Background

There is an urgent need to reduce emissions of Greenhouse Gases (GHG) from all sectors of the global economy in order to avoid dangerous climate change. A number of international and national policies and commitments have been put in place over recent years to ensure that emissions from particular sectors of the economy start to reduce, and across the EU, overall emissions of greenhouse gases are on a declining trend. However, emissions from the transport sector continue to increase and there is now a need to take urgent action to control emissions from this part of the economy. Regulatory measures have already been proposed and approved that will ensure that emissions from passenger cars start to reduce; in April 2009 Regulation 443/2009 (EC) which sets targets for the fleet-weighted average CO_2 performance of new passenger cars was approved. In the near future (from 2012 to 2015), car manufacturers will need to ensure that their new vehicle fleets are capable of complying with the fleet-weighted target of 130 gCO_2/km. Beyond the cars and CO_2 legislation, the European Commission already has well-advanced plans to introduce similar CO_2 targets for new light goods vehicles (vans).

Emissions of CO_2 from the European heavy duty vehicle (HDV) fleet currently account for a significant proportion of total road transport emissions. Consequently there is now a need to examine the scope for introducing measures to reduce emissions from these types of vehicles. However, the reduction of CO_2 from the road freight transport sector is especially challenging due to close links with economic development. This project is an initial step in the process of informing possible policy actions, and as such, it has a particular focus on building up a comprehensive picture of:

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It is important to note that the scope of the study did **not** include analysing the possible impacts of operational efficiency or demand based measures. In addition, biofuels were also excluded from scope of the analysis presented in this study, other than their contribution to the attainment of existing targets in reducing lifecycle emissions from road transport fuels as required under the Fuel Quality Directive and the requirements for the use of biofuels under the Renewable Energy Directive.

1.2 Report Structure

The following provides a summary of the report layout, and the relationship to specific project tasks:

- **Section 2: Vehicle Market and Fleet *(Task 1)***
  - Summarising legislation and planned policies *(Sub-task 1.1)*;
  - Characterisation of vehicle manufacturers *(Sub-task 1.2)*;
  - Number and distribution of vehicle users, by Member State *(Sub-task 1.3)*;
  - New vehicle market size and structure *(Sub-task 1.4)*;
  - Existing fleet size and structure *(Sub-task 1.5)*;
  - Energy consumption from on board equipment and vehicle adaptation to different mission profiles *(Sub-task 1.6)*;
- **Section 3: Technology *(Task 3)***
  - Survey of existing state of the art technology *(Sub-task 3.1)*;
  - Survey of new and emerging technology *(Sub-task 3.2)*;
  - Survey of technical and management solutions *(Sub-task 3.3)*;
  - Effect of vehicle speed on fuel consumption *(Sub-task 3.4)*;
- **Section 4: Fuel Use and GHG Emissions *(Task 2)***
  - Fuel use and GHG emitted by the existing EU fleet *(Sub-task 2.)*;
  - Fuel consumption and GHG emissions for new HDVs *(Sub-task 2.)*;
  - Baseline future development of fuel use and GHG emissions *(Sub-task 2.3)*;
  - Scenario assessment of possible future reduction in total EU HDV fuel consumption and GHG emissions *(Sub-tasks 3.5 and 3.6)*;
- **Section 5: Policy Assessment *(Task 4)***
  - Collation and assessment of existing reports and information *(Sub-task 4.1)*;
  - Development of a long list of policy instruments *(Sub-task 4.2)*;
  - Assessment of the impact of policy instruments *(Sub-task 4.3)*;
  - Prioritisation of policy instruments *(Sub-task 4.4)*;
- **Section 6: Summary of Principal Findings, Conclusions and Recommendations**

2 Vehicle Market and Fleet

Objectives:

- To assess the existing HDV legislative and policy landscape and to identify and assess the vehicle markets and fleets in Europe

Outputs:
Summary of information and data on :

- Existing European and international policy and legislation;
- Characterisation of HDV manufacturers;
- Number and distribution of vehicle users;
- New vehicle market size and structure;
- Existing fleet size and structure; and
- Energy consumption of onboard equipment.

Task Lead: AEA

2.1 Context

The primary aim of this first task (Task 1) was to identify and assess the HDV vehicle and fleet markets in Europe. Six specific aspects of this cover legislation, HDV manufacturers, the number and distribution of vehicle users, the new vehicle market size and structure, the existing fleet size and its structure, and onboard equipment. These are considered, in turn, below.

Sub-task 1.1: Legislation and policy

The Commission is interested in understanding the current state of regulatory activities, legislation and policy actions within the EU, but also worldwide, that have a bearing on fuel efficiency and CO_2 emissions of HDVs. With this in mind, it was necessary for Task 1 to include a review of measures that have been introduced or that are planned for introduction in selected countries around the world. A detailed nation-by-nation review for a large number of countries was not possible given the resource and timescales under which this project had to be carried out. However, it was necessary to include details of activities in selected major economies around the world, including the EU, the USA, and Japan.

Sub-task 1.2: HDV Manufacturers

The specification for this project set out a requirement to gather detailed information on HDV manufacturers, including the main OEMs, body builders and trailer manufacturers. This was important as any future proposed legislation is likely to affect these actors. It is for this reason that the Commission needed to have a detailed understanding of the role of each of these types of organisations, the sales volumes of each company, and how these factors vary according to market segment.

Sub-task 1.3: Number and distribution of vehicle users

Information on the number and distribution of vehicle users was important for understanding the potential future costs and benefits to businesses of any future legislative actions that target heavy duty vehicles. It was possible that some measures could lead to a requirement to fit new low carbon technologies to these types of vehicles, and this could lead to changes (increases or decreases) in whole-life vehicle costs. By understanding the numbers and types of operators that could be affected by any future legislation, it may in the future be possible to estimate the costs and benefits of any future action to control, CO_2 emissions from heavy duty vehicles.

Sub-task 1.4: New vehicle market size and structure

Future legislation targeting emissions from heavy duty vehicles may be focussed on the new vehicle fleet (in the same way as Regulation 443/2009 (EC) only targets CO_2 emissions from new passenger cars). With this in mind, it was important that this study was able to provide the Commission with detailed and accurate data on the size and structure of the new HDV market. Such data can eventually be used in any future Impact Assessment that could be carried out on possible future legislation in this area.

Sub-task 1.5: Existing fleet size and structure

Whilst any future legislation on vehicle emission targets is likely to be focussed on new vehicles, there are a number of actions that can be taken to control emissions from the existing fleet, including eco-driving techniques, provision of information on fuel saving measures, and the use of aerodynamic trailers, etc. Hence, there was a need to understand the size of the existing fleet in order that the abatement potential from these vehicles due to the application of these types of measures could be quantified in the future. Only by having access to accurate information on the structure and composition of the existing fleet was it possible for the Commission to build up a comprehensive picture of the total abatement potential available from the heavy duty vehicle sector.

Sub-task 1.6: Onboard equipment

Finally, the type of equipment that is onboard HDVs and the associated energy usage; and a description of the degree of adaptation of vehicles carried out by the vehicle manufacturers to support different mission profiles was needed. Running auxiliary equipment off the main HDV engine, such as cab heater and air conditioners used when the vehicle is stationary, results in efficiency losses. Although the overall absolute impacts of efficiency improvements in auxiliary system is lower than for other systems (~7% of overall potential efficiency improvements according to the US Department of Energy DOE), the relative improvement potential could be quite high (up to a 50% improvement). Besides air conditioners and cab heaters, other typical systems that contribute to the auxiliary load include air compressors, air control units, water and steering pumps, and fans and other embarked electronic engines. For some industries the attachment of cranes and other lifting mechanisms contribute significantly to the fuel usage as these equipments slave their power from the vehicle engine. In addition, refrigeration units can add very significantly to the overall energy consumption in refrigerated vehicles.

2.2 Collection of information and data

The review carried out for Task 1 was restricted to readily available information collected through a combination of methods including a general literature review, internet searches, consultation with key stakeholder organisations and questionnaires sent to all 27 EU Member States. Key information was collected from a number of freely available sources and datasets such as the: EU wide general statistics from Eurostat, National Agencies and a Transport Ministries of each Member State (which were also contacted directly in many cases). In addition the project had a budget to purchase key data where freely public information sources were unavailable. This was utilised to purchase a number of datasets, including key data on trailers from CLEAR International Consulting on and information on urban buses from UITP. AEA also contacted all of the major data European data providers (such as JATO, POLK, Global Insight, Datamonitor, etc) to establish what they held. The response was in general that whilst the light duty vehicle market is quite well covered, very little or no information was held by these organisations. The exception was POLK, who indicated they may have information on the second hand HDV markets. However, we were unable to source this information within the resources and time available for this project.

This information collection and assessment activity was supported by valuable discussion/consultation and information obtained from a variety of specific expert and stakeholder sources including the European Automobile Manufacturers' Association (ACEA), the International Road Union (IRU), the International Union for Passenger Transport (UITP) and Transport & Environment (T&E) to name a few.

Important note on datasets:

In many cases the European datasets used in the analysis for the following sub-sections were incomplete in a number of different ways, and to greater or lesser extent (i.e. some data series had only relatively few/minor gaps). These data gaps were filled using a variety of estimation techniques in order to present a consistent overall picture for the EU27 over time. Examples of the types of data gaps occurring and how they were filled is summarised in the following Table 2.1, listed in order of the approximate increasing uncertainty of the estimation method.

Table 2.1: Summary of gap-filling methodology for datasets

Data gap description	Estimation method for gap-filling
Data series contains breaks	Interpolate between data points
Data series only has category totals, not more disaggregated breakdown (e.g. vehicle registrations split by own-account and hire or reward operation)	Estimate for related dataset for the country (e.g. if rigid vehicle breakdown missing, estimate on basis of road tractor breakdown), relative to trend in 'similar' country, or the EU average for non-gap-filled dataset, or.
Data series incomplete at either end of timeseries	Extrapolate relative to trend in 'similar' country, EU average for non-gap-filled dataset, or temporal trend for country.
Data series entirely missing for country	Estimate relative to trend in 'similar' country and related dataset where both countries have data.

A summary of the principal European datasets from Eurostat that were utilised for this work and an indication of the degree to which these were gap-filled is also provided in Table 2.2.

Table 2.2: Summary of gap-filling for the principal Eurostat data series for EU27 countries utilised in this report

Data series Name	Data series description	Completeness of data series and gap-filling
road_eqr_bum	New registrations of motor coaches, buses and trolley buses by type of motor energy and engine size	Dataset complete for most countries, with some limited interpolation and extrapolation in historical series (mostly 1-3 years). More significant extrapolation (5-6 years data) to 2008 was necessary for Greece, Italy, Portugal and Malta.
road_eqr_lrstn	New registrations of lorries, road tractors, semi-trailers and trailers, by kind of transport (number)	Total numbers complete for vast majority of countries for recent years, some limited back-extrapolation for earlier years in timeseries. Limited amount of data interpolation due to gaps in timeseries. Significant gap-filling split between OA and HOR operations - mix of extrapolation of trends and estimation based on 'similar' countries/ regions *.
road_eqr_semitn	New registrations of semi-trailers, by load capacity (number)	19 Countries with complete data for 2008, or with totals present and data split extrapolated from recent historical figures. Split of data for other countries (notably Italy) estimated based on 'similar' countries / regions. UK dataset entirely absent.
road_eqr_trailn	New registrations of trailers, by load capacity (number)	16 Countries with complete data for 2008, or with totals present and data split extrapolated from recent historical figures. Split of data for other countries (notably Italy) estimated based on 'similar' countries / regions *. UK dataset entirely absent.
road_eqs_busage	Motor coaches, buses and trolley buses, by age class	Vast majority of countries have data for at least 2007 and 2008. Age class extrapolated to 2008 for most of the other countries. For the 3 countries without a split by age in the whole timeseries, the split was estimated based on similar countries for purposes of calculating EU12, EU15 and EU27 averages.
road_eqs_busalt	Motor coaches, buses and trolley buses, by alternative motor energy	Dataset complete for majority of countries. Some very limited interpolation. No data available/apparent data gaps in split by alternative fuel type for some countries (the only large country missing this data was Spain).
road_eqs_loralt	Lorries, by type of alternative motor energy and load capacity	Dataset largely complete, though data appears to be missing for some countries. No gap-filling carried out/possible due to nature of dataset.
road_eqs_lorroa	Lorries and road tractors, by age (number)	Dataset for 2008 mostly complete - for a limited number of countries only the total was available (sometimes from another dataset), but split was extrapolated based on historic data with the split for majority of these.
road_eqs_lrstn	Lorries, road tractors, semi-trailers and trailers, by kind of transport (number)	Total numbers complete for vast majority of countries for recent years, some limited back-extrapolation for earlier years in timeseries. Limited amount of data interpolation due to gaps in timeseries. Significant gap-filling split between OA and HOR operations - mix of extrapolation of trends and estimation based on similar countries.
road_eqs_semitn	Semi-trailers, by load capacity (number)	19 Countries with complete data for 2008, or with totals present and data split extrapolated from recent historical figures. Split of data for other countries (notably Italy) estimated based on 'similar' countries / regions. UK dataset entirely absent from 2009.

Data series Name	Data series description	Completeness of data series and gap-filling
road_eqs_trailn	Trailers, by load capacity (number)	18 Countries with complete data for 2008, or with totals present and data split extrapolated from recent historical figures. Split of data for other countries (notably Italy) estimated based on 'similar' countries / regions. UK dataset entirely absent.
road_go_ta_agev	Annual road freight transport, by age of vehicle (Mio Tkm, Mio Veh-km, 1000 Jrnys)	Low level of gap-filling. Dataset for recent years essentially complete. Dataset for EU12 mostly absent prior to 2003.
road_go_ta_axle	Annual road freight transport by axle configuration (Mio TKM, Mio Veh-km, 1000 Jrnys)	Most recent years complete for all countries. Interpolation of occasional gaps in timeseries and more significant extrapolating gap-filling for some countries (mostly for EU12 countries - many with no data prior to 2003 and some with no data prior to 2006).
road_go_ta_dc	Annual road freight transport, by distance class (1000 T, Mio Tkm, Mio Veh-km, 1000 BTO)	Most recent 5 years complete for vast majority countries (minor gap filling for remainder). Interpolation of occasional gaps in timeseries and more significant extrapolating gap-filling for some countries (mostly for EU12 countries - many with no data prior to 2003 and some with no data prior to 2006).
road_go_ta_mplw	Annual road freight transport by maximum permissible laden weight of vehicle (Mio Tkm, Mio Veh-km, 1000 Jrnys)	Most recent years complete for almost all countries. Interpolation of occasional gaps in timeseries and more significant extrapolating gap-filling for some countries (mostly for EU12 countries - many with no data prior to 2003 and some with no data prior to 2006).
road_go_ca_c	Road cabotage transport by country in which cabotage takes place (1000 TKM) - as from 1999 (Regulation (EC) 1172/98)	Complete dataset, no gap-filling.

Notes: All data series are available for download from the Eurostat data portal at: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

* For the purposes of gap-filling the following general country and regional associations were assumed, with actual associations varying depending on the specific gaps needing to be filled:
Large Northern Europe = DE, FR, UK, (NL); *Large Southern Europe* = ES, PT, IT, (GR);
Scandinavia = DK, FI, SE; *Southern Europe Islands*: CY, MT, (GR); *Benelux* = BE, LU, NL;
Other associations = AT / DE, UK / IE, CZ / SI / SK, BG / RO, EE / LV / LT, PL / HU.

2.3 Summarising legislation and planned policies

Objectives:

The purpose of this sub-task was to:

"Summarise the current state of regulatory activities and policy actions in the EU and worldwide that have a bearing on fuel efficiency and CO_2 emissions of HDV."

Summary of Main Findings

⇒ The majority of EU countries have policies to improve the efficiencies of heavy duty road transport, promoted low emissions vehicles and control emissions;

⇒ Taxation, driver training and regulation are common practice inside the EU;

⇒ The Swedish Transport Administration acknowledges that a lack of a standardised method for measuring and reporting fuel consumption on new vehicles makes it difficult to regulate CO_2 emissions from HDV (as it impacts the possibility to enforce and verify compliance). Furthermore, there is an urgent need for an international standard for measuring and reporting CO_2 and fuel consumption on new vehicles;

⇒ In the UK, the Government has recently consulted on options to increase the uptake of eco-driving training among drivers of HDVs, including whether it should become compulsory. The conclusion was that it should remain voluntary;

⇒ Outside the EU, the SmartWay best practice program in the US aims for a saving of 33-66 million tonne of CO_2 per annum by 2012; The US has also just announced the forthcoming introduction of CO_2/fuel efficiency standards for medium and heavy duty vehicles. (In the EU, the Climate TransAct initiative in Europe has recently been dubbed 'EU SmartWay'.)

⇒ In Hong Kong, a 30-100% reduction in registration tax is applied to vehicles that meet Euro V standards;

⇒ Australia has developed a test facility to measure HDV emissions to facilitate the engagement of the Australian Government;

⇒ The Japanese Government has set vehicle emission standards for HDVs, which requires an average 12% improvement in fuel efficiency relative to 2002 across multiple HDV classes by 2015. However, this mainly involves smaller distribution trucks and is supported by strong incentive programs for hybrid solutions.

The Commission is not only interested in understanding the current state of regulatory activities, legislation and policy actions within the EU, but also worldwide, that have a bearing on fuel efficiency and CO_2 emissions of HDVs. With this in mind, it was necessary for Task 1 to include a review of measures that have been introduced or that are planned for introduction in selected countries around the world. A detailed nation-by-nation review for a large number of countries was not possible given the resource and timescales under which this project had to be carried out. However, it was necessary to include details of activities in selected major economies around the world, including the EU, the USA, and Japan. To assist this review AEA prepared a questionnaire which was sent to each of the 27 member states asking them for further details on their own legislation and planning policies. The questionnaire also sought to gather information to assist with the entirety of Task 1.

Since the slow uptake of higher cost but more fuel efficient HDV technologies due to cost-effectiveness issues is a concern, both regulation and other policy instruments are being used / considered to address the situation. The types of policy interventions addressed in this review and asked in the questionnaire included:

- Statutory regulation
- Fiscal incentives
- State funding and procurement
- Information, training and behaviour change programmes

The remainder of this section provides a summary of the legislation and planned policies relating to HDVs found from the literature review. The review of activity within individual EU member states is supplemented by information gathered through the questionnaires that were sent to all 27 EU member states. This information has been summarised into the three categories below. Within each of these sections, a summary table of the main policies found and further discussion of these within the context of the task is provided:

- Legislation and planned policies at the EU level (Section 2.3.1);
- Legislation and planned policies at the EU Member State level (Section 2.3.1.6);
- Legislation and planned policies outside of the EU (Section 2.3.3).

2.3.1 Summary of identified legislation and planned policies at the EU level

Policy name	Country	Start Year	Status	Type of policy	HDV (/CO_2) Relevance
Directive 1999/96/EC European emission regulations for new heavy-duty diesel engines	EU	1999	In force	Regulatory	HDV specific (-ve impact)
Regulation (EC) No 484/2002 for the purposes of establishing a driver attestation	EU	2002	In force	Regulatory	Mention of HDV (+ve impact)
Directive 2003/59/EC Initial Qualification and Periodic Training for Drivers of Road Vehicles for the Carriage of Goods or Passengers.	EU	2003	In force	Regulatory	Mention of HDV (indirect +ve impact)
Directive 2005/78/EC and Directive 2005/55/EC: Twin Directives on Heavy-Duty Vehicle Emissions	EU	2005	In force	Regulatory	HDV specific (-ve impact)
Regulation 595/2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI)	EU	2009	In force	Regulatory	HDV specific (-ve impact)
Directive 2006/38 Eurovignette Directive: Charging of heavy-duty vehicles for the use of road infrastructure	EU	2006	Implemented	Regulatory	HDV specific (indirect +ve impact)
Directive 2009/33 on the promotion of clean and energy-efficient road transport vehicles	EU	2010	Apply from December 2010	Regulatory	Mention of HDV (+ve impact)
Directive Of The European Parliament And Of The Council on labelling of tyres with respect to fuel efficiency and other essential parameters	EU	2012	Planned	Regulatory	Mention of HDV (+ve impact)

Policy name	Country	Start Year	Status	Type of policy	HDV (/CO_2) Relevance
Directive 96/53/EC on vehicle dimensions and weights.	EU	1996	In force	Regulatory	HDV specific (-/+ve impact)

The primary EU approach to control of emissions from HDVs has been to directly regulate emissions standards for new vehicles (focusing on the engine in terms of limit values expressed in mg/kWh). A series of progressively strict emissions standards have been introduced since 1999, moving from 'Euro III' through to 'Euro VI' which will become mandatory for manufacturers in 2013.

However, these Euro standards only regulate emissions that affect air quality, not CO_2 or other GHGs (although CO_2 emissions have been measured since Euro V). In practice, many of the engine modifications required to limit the regulated emissions have also decreased the fuel efficiency of the engines and therefore led to an increase in CO_2 emissions. CO_2 emissions cannot as easily be addressed through limits on vehicle emissions and legislation has been developed to address CO_2 emissions from cars and vans, but not yet for heavier commercial vehicles.

In addition to the Euro emissions standards, the EU has introduced directives on driver training, government procurement and road user charging, all of which have an influence on HDV emissions. The EU's Intelligent Energy Europe programme has run an information and behaviour change programme called 'STEER' since 2005.

2.3.1.1 European directive on driver training

In 2003 the EU enacted a directive requiring all professional drivers to undergo regular accredited training relating to their work. Directive 2003/59/EC introduced the 'Driver Certificate of Professional Competence' (Driver CPC), which all professional drivers of goods vehicles, buses, coaches and minibuses will eventually be required to hold.

Although the Driver CPC does not relate directly to GHG emissions of HDVs, in practice it may serve to promote 'eco-driving' techniques in many member states. In each member state, a variety of training courses have been accredited to the Driver CPC, including such topics as legal requirements on drivers, safe loading of vehicles etc, and in many cases some form of eco-driving training (the 'Safe And Fuel Efficient Driving' course in the UK for example). Eco-driving training can improve safety, reduce driver stress, and increase fuel efficiency by 5-20%, making it attractive to both drivers and employers.

There is also legislation on speed limitation and weights and measures plus we have the EU cabotage legislation which currently acts as a barrier to reducing HGVs' CO_2 emissions. These are examined in Task 4.

2.3.1.2 'Eurovignette' directive on road user charging

In 2006, the directive 2006/38 extended the discretionary powers of member states to charge HDVs for the use of the road network. Existing provisions allowing vehicles over 12 tonnes to be charged were extended to cover all vehicles over 3.5 tonnes, and member states were also granted the power to assign charges which include the 'externalities' of transport – e.g. noise, congestion, emissions, landscape impacts.

A further proposal for the revision of the Directive was implemented on 15th October 2010, which paved the way to the 'polluter pays' principle for road transport. Members States will be allowed to charge tolls on heavy-duty vehicles (12 tonnes and over) to cover the external costs associated with the road transport of goods, including air pollution and noise. These 'external costs tolls' will be in addition to the existing transport infrastructure charges that are allowed under the current Eurovignette Directive. It is encouraged that revenue generated from the additional charges imposed on heavy lorries (covering the costs of environmental impacts) will be used to finance investments into making transport more sustainable, such as research and development into clean vehicle technologies, construction of alternative transport infrastructure, and efforts to reduce pollution at source.

2.3.1.3 Directive on the promotion of clean and energy efficient road transport vehicles

The Directive 2009/33 on the promotion of clean and energy-efficient road transport vehicles will apply from 4 December 2010 and require that energy and environmental impacts linked to the operation of vehicles over their lifetime are taken into account in purchase decisions. The Directive applies only to the public tender purchase of road transport vehicles (including heavy-duty vehicles), and includes at least energy consumption, CO_2 emissions and emissions of the regulated pollutants of NO_X, NMHC and particulate matter. This Directive (along with the new EU energy strategy), has a strong CO_2 component which will impact heavy-duty vehicles as a part of road transport. The two options that are offered to meet the requirements of the Directive are setting technical specifications for energy and environmental performance, or including environmental impacts as award criteria in the purchasing procedure. It is expected to result in the wider deployment of clean and energy efficient vehicles in the longer term. However, a limitation of this directive is that it does not include a recommended methodology to be used to evaluate vehicles with respect to their 'green' credentials.

2.3.1.4 Directive on labelling of tyres with respect to fuel efficiency and other essential parameters

The objective of the Directive on the labelling of tyres is to promote the market transformation towards fuel-efficient tyres, also called low rolling-resistance tyres (LRRTs). The labelling proposal will come into force during 2012 and will ensure that standardised information is supplied on fuel efficiency (as well as on wet grip and external rolling noise), so that consumers and end-users can make an informed choice about picking tyres that will reduce fuel use and subsequently CO_2 emissions.

2.3.1.5 STEER programme

In place since 2005, the projects in the STEER programme promote the more sustainable use of energy in transport. This includes increased energy efficiency, new and renewable fuel sources, and the take-up of alternatively propelled vehicles. The specific focus is on alternative vehicle propulsion, policy measures for the more efficient use of energy in transport, and strengthening the knowledge of local management agencies in the transport field. STEER is funded through Intelligent Energy Europe.

The directives outlined above have been implemented in different ways by different member states. Member states have also introduced a range of additional, country-specific programmes which in some way affect GHG emissions from HDVs.

2.3.1.6 Directive on vehicle dimensions and weights

Directive 96/53/EC sets out the maximum authorised dimensions for road vehicles that are intended to carry goods (weighing more than 3.5 tonnes) or passengers (with more than 9 seats) within the EC, and maximum authorised weights/certain other characteristics for international vehicles that are mentioned in Annex 1 of the Directive. Member States are responsible for ensuring that vehicles are provided with one of three proofs of compliance with the Directive. The Directive has subsequently been amended to permit larger, heavier vehicles on the EC's roads. A summary of the permitted weights is summarised in the following Table 2.3.

Table 2.3: Maximum Gross Vehicle Weight (GVW) limits by EU Member State

	Weight per bearing axle	Weight per drive axle	Lorries		Road train		Articulated vehicles
			2 axles	3 axles	4 axles	≥ 5 axles	≥ 5 axles
AT	10	11.5	18	26	36	40	40
BE	10	12	19	26	39	44	44 (2)
BG	10	11.5	18	26 (1)	36	40	40
CY							
CZ	10	11.5	18	26 (1)	36	44 (1)	42 - 48
DE	10	11.5	18	26 (1)	36	40	40
DK	10	10 / 11.5 (3)	18	24 / 26 (1) (3)	38	42 - 48	42 - 48
EE	10	11.5	18	26 (1)	36	40	40
EL	7 / 10	13	19	26	33	40	40
ES	10	11.5	18	26	36	40	42 - 44
FI	10	11.5	18	26 (1)	36	44 - 60 (4)	42 - 48
FR	13	13	19	26	38	40	40
HU	10	11.5	18	25	30	40	40 (6)
IE	10	11.5 (7)	18	26 (1)	36	44 (1)	44 (1)
IT	12	12	18	26 (1)	40	44	44
LT	10	11.5	18	26 (1)	36	40	40 - 44 (8)
LU	10	12 (9)	19	26	44	44	44
LV	10	11.5	18	26 (1)	40	40	40
MT	10	11.5	18	25	36	40	40 (6)
NL	10	11.5	21.5	33	40	50, 60 (11)	50, 60 (11)
PL	10	11.5	18	26 (1)	36	40	40
PT	10	12	19	26	37 (10)	40	40
RO	10	11.5	18	26 (1)	36	40	40
SE	10	11.5	18	26 (1)	38	48 - 60 (5)	48 - 60 (5)
SI	10	11.5	18	26 (1)	36	40	40
SK	10	11.5	18	26 (1)	36	40	40
UK	10	11.5	18	26 (1)	36	40	40 - 44 (8)

Source: Statistical Pocketbook 2010 (EC DG Mobility & Transport, 2010)

Notes: An articulated vehicle consists of a road tractor coupled to a semi-trailer. A road train is a goods road motor vehicle coupled to one or more trailers.

(1) For axles equipped with air suspension or equivalent
(2) 2 axles tractor + 3 axles semi-trailer: mechanical suspension = 43t, pneumatic suspension = 44t
(3) national traffic / international traffic
(4) 5 axles = 44t; 6 axles = 56t; 7 axles = 60t
(5) 5 axles = 48t; 6 axles = 58t; 7 axles = 60t
(6) 44t for 40 feet long ISO containers
(7) 10.5t for vehicles with mechanical suspension in national traffic
(8) higher value for vehicles engaged in combined transport
(9) 11.5 t if mechanical suspension
(10) 35 t for 3-axle tractor + 1-axle trailer
(11) Up to 60 tonnes is permitted for Europe Module System (EMS) combinations

2.3.2 Summary of identified legislation and planned policies at the EU Member State level

Legislation or policy name	Country	Start Year	Status	Type of policy	HDV (/CO_2) Relevance
The Joint Ministerial Decision 90364. Incentives for the replacement of old middle weight and heavy vehicles (over 3.5 t and over 10 years old)	Greece	2002	Planned	Information Regulatory Fiscal Economic	Mention of HDV (+ve impact)
Redistribution of Highway toll for heavy duty vehicles	Germany	2005	Adopted	Fiscal	HDV specific (+ve impact)
Improving freight transport efficiency	Belgium		Implemented	Regulatory planning	Mention of HDV (+ve impact)
Regulation 715/2007 EC. Realisation of investments aimed at the manufacturing of more environmental friendly products.	Spain	2009	Implemented	State aid scheme	Mention of HDV (+ve impact)
Eco fee for heavy transport	France	2011	Adopted	Fiscal	HDV specific (+ve impact)
Enlargement of the fleet of vehicles powered by natural gas of CARRIS and of the STCP	Portugal		Implemented	Economic	Mention of HDV (-/+ve impact)
Increasing fuel efficiency of heavy duty road transport	Finland				HDV specific (+ve impact)

2.3.2.1 Denmark

Driver training concerning HDVs is regulated by the EU directive 2003/59/EC which is implemented in national regulation. Denmark will fulfil EU directive 2009/28/EU by implementing 5.75 % (by energy) biofuel gradually from 2010 to 2012. Hence 7 % (by volume) biodiesel will be obligatory from Jan 2012. The Danish Government has granted 200m DKK (approx. 26.5m Euro) for demonstrating new technologies and alternative fuels for energy efficient road transport. The funding is primarily aimed at HDVs. The Danish Government has also granted 42m DKK (approx. 5.5m Euro) for fitting HDVs with aerodynamic kits.

Private and public enterprises have the opportunity to be certified by the Road Safety and Transport Agency, Danish Ministry of Transport. The certification process is a commitment to address transport energy efficiency and CO_2 reduction in their business.

In February 2007 a majority of the Danish Parliament passed a change of the national Road Traffic Act, authorising the Minister for Transport to permit Modular Vehicle Combinations (MVCs) in Denmark on a specifically selected road network as of March 1, 2007. The three-year trial was launched in November 2008. In the latest agreement on future Danish traffic investments from January 2009, ‘A Green Transport Policy’, the national Parliament agreed to lengthen the MVC trial beyond 2011.

2.3.2.2 Finland

At the moment the only existing national HDV regulation regarding driver training and eco-driving is based on the directive on the initial qualification and periodic training of drivers of certain road vehicles. The periodic training (35 hours every five years) based on the Directive 2003/59/EC shall have at least 7 hours of proactive driver training, which contains both traffic safety and eco-driving elements. Moreover, the energy efficiency agreements (EEA) of transport sector (public transports; freight transport and logistics) encourage the transport companies to implement measures aiming at improving energy efficiency. These voluntary agreements are a Finnish way of implementing Energy Services Directive (ESD). Eco-driving training may be one of the measures.

Since 2002, the VTT Technical Research Centre of Finland has regularly monitored fuel efficiency and emissions of HD vehicles. Testing is done with complete vehicles in a chassis dynamometer, and the results are reported in distance based units as called for in the Directive 2009/33/EC. The most representative vehicle types and brands in Finland have been covered. The results are reported publicly. The database contains fuel consumption and emission data for more that 120 buses and some 100 HD trucks. Results can be found at www.rastu.fi . Energy efficiency and renewable energy in transport is now covered in a new research integrate called TransEco (2009 – 2013), covering vehicle and fuel research, demonstrations as well as the development of monitoring and reporting systems.

Some 100 buses in greater Helsinki run on natural gas. A pilot project with 7 HD CNG trucks has just been completed. Pilot projects for hybrid as well as full-electric buses are under development. www.transeco.fi aims to find solutions for CO_2 lowering and EU biofuel targets and www.rastu.fi has similar objectives. The World's largest 2nd generation biodiesel (NExBTL) field test with some 300 city busses using high-concentration paraffinic renewable biofuel is underway

The taxation of transportation fuels will be renewed from the beginning of 2011. Taxation will be divided into an energy component and a carbon dioxide component. Fuel reducing local pollution (methane, paraffinic diesel fuel) will receive a tax relief. The objective is to create a transparent system that accounts for energy, carbon dioxide emissions and local pollution.

The Finnish Transport and Logistics SKAL organises the "Litre a day" campaign with a club membership and training programme in order to raise awareness off economic driving. http://www.litrapaivassa.fi/. The voluntary target of 1 litre/day/vehicle of SKAL members means 1 % yearly savings in fuel consumption. The programme is set for nine years.

2.3.2.3 Hungary

Evaluation and modification of Regulation 60/1992. (IV. 1.) "Fuel and lubricant consumption rates for vehicles, agricultural, forestry and fishing engines" – affects all vehicle categories in Hungary, enabling drivers to lower their fuel consumption. In connection with this regulation the Institute for Transport Sciences (Budapest) made an impact assessment to evaluate the impact both on fuel efficiency and CO_2 emissions.

For monitoring and reporting emissions caused by road transport the Institute for Transport Sciences is collecting and evaluating the yearly changes in all categories of HDV fleets (type of vehicles, fuel types, etc.). The Regulation 60/1992 (modified in 2010) has financial incentives for more efficient driving for all categories of HDVs (and LDVs). The Association of Hungarian Highways Freighters (MKFE) plans to impose such training on drivers for fuel efficient driving.

2.3.2.4 Poland

There is no law in Poland regarding emissions of GHG (including CO_2) from vehicles. The EU EURO standards regulation is already implemented. However, the Environmental Protection Law is in place which specifies a charge on environmental impact. According to this regulation the Minister of Environment specifies each year the charge for the emissions of gas pollution and particulates to air from vehicles depending on the different fuel type used.

2.3.2.5 Sweden

Fuel efficient driving is mandatory in driving training and theory for all vehicle classes to get a driving licence. The tax on fuels can be divided into energy and CO_2 tax. Biofuels are exempted from CO_2 tax.

The Swedish Transport Administration acknowledges that a lack of a standardised method for measuring and reporting fuel consumption on new vehicles makes it difficult to regulate CO_2 emissions from HDV. Fuel efficient driving is one of many measures that Swedish Transport Administration uses when they cooperate with government organisations and companies to reduce CO_2 emissions.

Sweden acknowledges that they need (1) an international standard for measuring and reporting CO_2 and fuel consumption on new vehicles. This must include whole vehicle life cycle (2) more useful information so that they can introduce legislation to push for more fuel efficient vehicles and lower CO_2; (3) some kind of EU based requirements. However incentives or requirements on HDV are much more difficult than on passenger cars. In particular **vehicle load capacity has to be taken into account**, i.e. incentives or requirements should be based on emissions or fuel consumption per tonne kilometre or passenger kilometre. It is important to utilise such metrics which reflect the ‘work done’ when evaluating the performance of HDVs, in order to avoid the possibility of undesirable distortions. For example, a shift to smaller capacity vehicles would resulting in using less fuel per vehicle km, but transport freight or passengers less efficiently and require more vehicles.

Swedish Transport Administration (earlier Swedish Road Administration) have together with AVL-MTC Sweden investigated possible methods for measuring and calculating emissions and fuel consumption for whole heavy duty vehicles. AVL-MTC is a part of the Lot 2 of the project ’Reduction and Testing of Greenhouse Gas Emissions from Heavy Duty Vehicles (HDVs)”.

2.3.2.6 United Kingdom

Although not currently compulsory, the UK Government encouraged bus and coach drivers in England to take up fuel efficiency training by funding a Safe and Fuel Efficient Driving (SAFED) demonstration scheme and publishing case studies. The UK Government recently consulted on options to increase the uptake of such training among drivers of HDVs, including whether it should become a compulsory part of a bus driver’s Certificate of Professional Competence (CPC).

Preliminary analysis showed that if 90 per cent of HGV drivers were eco-driving trained and continued to drive in that manner, up to 3 million tonnes of CO_2 could be saved over a five year carbon budgetary period and £300 million in fuel costs could be saved for the industry per year. The eco-driving consultation sought views on three options for achieving a 90 per cent uptake of eco-driving courses for HDV drivers: no change on the current approach, where eco-driving training continued to be undertaken on a voluntary basis; a non-regulatory approach aiming to increase the promotion of the benefits of eco-driving training, through increased marketing or improved best practice; or regulatory change, where eco-driving training became a mandatory part of the Driver CPC. Because the Driver CPC applies to both HGVs and PCVs, the consultation also considers the possibility and implications of making the eco-driving training a mandatory part of the Driver CPC for both categories of driver. The result has been not to make eco-driving training compulsory, but to review the voluntary take up of this training in 2012.

The Low Carbon Vehicle Partnership (supported by UK Govt.) is considering the possibility of development of a whole vehicle test cycle that might be used as the basis for any measures to encourage greater use of lower carbon HGV technologies. This includes consideration of those technologies with greatest potential for saving CO_2 emissions.

Fuel Duty for vehicles is levied on a pence per litre basis, which means it increases proportionately with the number of miles driven. Budget 2010 confirmed planned increases of fuel duty by 1 penny per litre above the retail price index each year from 2010 to 2014.

Of the Department for Transport's best practice programmes aimed at helping operators in England to reduce costs and carbon emissions through operational efficiency and to improve safety, one is aimed at HGVs. The Freight Best Practice programme provides a wide range of guides, case studies and software tools for freight operators in the road, rail and water sectors. All materials are free to all operators and several products are specifically designed for small operators of HGVs. The Freight Best Practice programme has been shown to achieve significant savings in the HGV sector. An impact assessment (2007) reported savings of 120,000 tonnes of CO_2 and over £40 million achieved by the industry per year, directly through use of Freight Best Practice. www.freightbestpractice.org.uk

2.3.3 Summary of identified legislation and planned policies outside the EU

Policy name	Country	Start Year	Status	Type of policy	HDV (/CO_2) Relevance
Heavy duty vehicle emissions test facility	Australia	2008	In force	Funding	HDV specific (+ve impact)
Long Combination Vehicle (LCV) Programme	Canada	2009	In force	Pilot scheme	HDV specific (+ve impact)
Hong Kong - Tax Incentives for Environmentally Friendly Commercial Vehicles	China (Hong Kong)	2008	In force	Tax incentive	Mention of HDV (+ve impact)
Top Runner Programme: Fuel efficiency standards for Heavy duty vehicles	Japan	2006	In force	Regulatory	HDV specific (+ve impact)
Green Taxation and Subsidies for Automobiles	Japan	2001	In force	Taxation	Mention of HDV (+ve impact)
Heavy-Duty Vehicle Idling Emission Reduction Program	United States	2005	In force	Regulatory	HDV specific (+ve impact)
Heavy Vehicles Fee	Switzerland	2001	In force	Vehicle Fee	HDV specific (-/+ve impact)
SmartWay Transport Partnership	US	2004	Implemented	Training	HDV specific (+ve impact)
FleetSmart – Natural Resources Canada	Canada	1997	Implemented	Training	HDV specific (+ve impact)
CARB Zero Emission Bus Programme	US	2007	In place	Regulation	HDV specific (+ve impact)
California Hybrid Truck and Bus Voucher Incentive Project	US				HDV specific (+ve impact)
US EPA and DOT proposal on GHG Emission Standards and Fuel Efficiency Standards for medium and Heavy Duty Engines and Vehicles	US	2010	Proposed	Regulatory	HDV specific (+ve impact)

Worldwide, similar measures have been introduced to those implemented within the EU. Japan and the United States (specifically California) have been particularly active on the issue of HDV efficiency. However, it is important to highlight here that important differences exist between the different regions, which needs to be understood in considering the applicability and effects of different measures.

Japan has a totally different fleet of HDVs with a focus on smaller vehicles for pick-up and delivery operations with lower annual km activity and therefore have not be in focus so much with respect to fuel efficiency. Long-haul trucks that are responsible for an important part of European truck fuel consumption are almost nonexistent in Japan (ACEA, 2010).

The situation in the US has more in common with Europe where long-haul trucks are in focus with respect to the EPA/NHTSA proposed rulemaking (discussed in section 2.3.3.3). However there are still major important differences. The most noticeable is the relatively low price of fuels in the US, which has had an impact on the cost-effectiveness and the attractiveness of fuel saving measures. There are also differences in the regulated size of vehicle combinations and in the weight regulations, which in Europe result in further efficiency improvements.

2.3.3.1 Japan

Japan introduced the world's first Fuel Efficiency Standard for HDV in April 2006. Introducing these standards involved addressing the challenge of measuring a wide variety of HDVs without placing too great a burden on manufacturers. This issue was addressed through the introduction of a new test procedure, which utilises state of the art computer simulation methods. The standards require an average fuel efficiency improvement of about 12% from the 2002 level.

The standards affect commercial trucks with a gross vehicle weight in excess of 3.5 metric tons and all buses with a carrying capacity of more than 11 passengers. Table 2.4 summarises the improvement target under the Japanese heavy-duty vehicle fuel economy regulation.

Table 2.4: Improvement targets under the Japanese Heavy-Duty Vehicle fuel economy regulation.

Vehicle Type	Vehicle Class	Fuel Economy (Km/L)		Improvement (%)
		2002 Baseline	2015 Target	
Truck	Tractor	2.67	2.93	9.7
	Other truck	6.56	7.36	12.2
	Total	6.32	7.09	12.2
Bus	Urban	4.51	5.01	11.1
	Other bus	6.19	6.98	12.8
	Total	5.62	6.30	12.1

2.3.3.2 China

In Hong Kong, a Tax Incentives for Environmentally Friendly Commercial Vehicles was introduced in 2008 on heavy-duty and light-duty diesel vehicles which met Euro V emission standards. Under this First Registration Tax incentive, goods vehicles receive a 50% tax reduction. Vehicles are sold with an "Environment-Friendly Commercial Vehicle Certificate" in order to qualify for the tax waiver, with four models of Toyota vans and three Mercedes-Benz trucks currently qualifying.

2.3.3.3 United States

In October 2010, the US's EPA and NHTSA proposed the first ever programme to reduce GHG emissions and improve fuel efficiency of medium- and heavy-duty vehicles through the setting of standards in the States[2]. Standards being set are for CO_2 and fuel consumption, and standards for N_2O, CH_4 and HFC.

[2] US EPA (2010) "EPA and NHTSA propose first ever program to reduce greenhouse gas emissions and improve fuel efficiency of medium and heavy-duty vehicles: Regulatory announcement. http://www.epa.gov/otaq/climate/regulations/420f10901.htm

It is anticipated that the setting of standards for the heavy duty sector will improve the State's energy security, increase fuel savings, reduce GHG emissions and provide regulatory certainty for manufacturers. It has been estimated that the combined proposed standards have the potential to reduce GHG emissions by nearly 250 million metric tonnes and save approximately 500 million barrels of oil over the life of vehicles sold between 2014 and 2018. The combined standards would reduce CO_2 emissions from the US heavy vehicle fleet by approximately 72m metric tonnes of CO_2 equivalent by 2030. Other benefits include an estimated $35 billion in net benefits to truckers, or $41 billion when societal benefits are included.

CO_2 and fuel consumption standards are to apply to three main vehicle categories; combination tractors, heavy-duty pickup trucks and vans, and vocational vehicles, and covers all on-road vehicles at or above 8,500 pounds. The joint proposed standards cover both the engine and the complete vehicle. Two types of standard metrics will be proposed:

- Payload-dependant gram per mile (and gallon per mile) standards proposed for pickups and trucks; and
- Gram per tonne-mile (and gallon per 1,000 tonne-mile) standards proposed for vocational vehicles and combination tractors.

This accounts for the fact that work to move heavier loads burns more fuel, and emits more CO_2 than in moving lighter loads.

The agencies involved in developing the proposed standards have drawn from the SmartWay Transport Partnership Program experience in order to identify technologies as well as operational approaches that fleet owners, drivers and freight customers can incorporate. It is anticipated that the operational measures promoted by SmartWay could compliment the proposed standards, providing benefits for the existing heavy-duty fleet.

Differentiated standards for nine subcategories of combination tractors are being proposed by the agencies based on three attributes: weight class, cab type and roof height. The standards would phase in to the 2017 levels shown in Table 2.5 below. These proposed standards would achieve from 7% to 20% reduction in emissions and fuel consumption from affected tractors over the 2010 baselines.

For heavy duty pickup trucks, the agencies are proposing to set corporate average standards, similar to the approach taken for light-duty vehicles. Each manufacturer's standard for a model year would depend on its sales mix, with higher capacity vehicles (payload and towing) having numerically less stringent target levels, and with an added adjustment for 4-wheel drive vehicles. EPA is proposing to establish standards for this segment in the form of a set of target standard curves, based on a "work factor" that combines a vehicle's payload, towing capabilities, and whether or not it has 4-wheel drive. The EPA standards proposed for 2018 (including a separate standard to control air conditioning system leakage) represent an average per-vehicle reduction in GHG emissions of 17% for diesel vehicles and 12% for gasoline vehicles, compared to a common baseline. NHTSA is proposing to set corporate average standards for fuel consumption that are equivalent to EPA's proposal (though not including EPA's proposed air conditioning leakage standard). The proposed NHTSA standards represent an average per-vehicle improvement in fuel consumption of 15% for diesel vehicles and 10% for gasoline vehicles, compared to a common baseline. To satisfy lead time requirements under EISA, NHTSA standards would be voluntary in 2014 and 2015. Both agencies are proposing to provide manufacturers with two alternative phase-in approaches that get equivalent overall reductions.

The agencies are proposing to divide the vocational truck segment into three regulatory subcategories - Light Heavy (Class 2b through 5), Medium Heavy (Class 6 and 7), and Heavy Heavy (Class 8), which is consistent with the engine classification. After engines, tyres are the second largest contributor to energy losses of vocational vehicles. The proposed programme for vocational vehicles for this phase of regulatory standards is limited to tyre technologies and hybrid powertrains (along with the separate engine standards). The proposed standards depicted in Table 2.5 represent emission reductions from 7% to 10%, from a 2010 baseline.

Table 2.5: Proposed Emission and Fuel Consumption standards for Heavy-Duty Vehicles

	EPA Emission Standards (g CO_2/tone-mile			NHTSA Fuel Consumption Standards (gal/1,000 tonne-mile)		
Proposed MY 2017 Combination Tractor Standards						
	Low roof	**Mid roof**	**High roof**	**Low roof**	**Mid roof**	**High roof**
Day Cab Class 7	1.3	1.3	116	10.1	10.1	11.4
Day Cab Class 8	78	78	86	7.7	7.7	8.5
Sleeper Cab Class 8	64	69	71	6.3	6.8	7.0
Proposed MY 2017 Vocational Vehicle Standards						
Light Heavy Class 3-5	344			33.8		
Medium Heavy Class 6-7	204			20		
Heavy Heavy Class 8	107			10.5		

The proposed HD national Program provide flexibilities to manufacturers in terms of how they are able to comply with the new standards, ensuring the sufficient lead time for manufacturers is available to ensure that the necessary technological improvements can be made and the overall cost of the program is reduced, without compromising environmental and fuel consumption objectives. These include an engine averaging, banking and trading (ABT) program and a vehicle ABT program. Secondly, they propose to allow engine manufacturers the added option of using CO_2 credits to offset CH4 or N2O emissions that exceed the applicable emission standard based on the relative global warming potentials of these emissions.

In the United States, Vehicle Miles Travelled (VMT) has grown more quickly for commercial vehicles than other vehicles, resulting in an increasing share of transportation-related greenhouse gas emissions. However, there is currently no regulation for fuel consumption of medium- and heavy-duty vehicles in the US. The Energy Independence and Security Act (EISA) of 2007 required the US Secretary of Transportation to consult with the Secretary of Energy and the Administrator of the Environmental Protection Agency in prescribing new average fuel economy standards for work trucks and medium- and heavy-duty on-highway vehicles (defined as vehicles with a gross vehicle weight rating of 10,000 pounds or more). The legislation required that these new fuel economy regulations be based on a study, to be completed by the National Academy of Sciences, and that rulemaking for the fuel economy standards would be complete not less than 24 months following completion of the study. The legislation stipulated that the study would evaluate the following:

(1) an assessment of technologies and costs to evaluate fuel economy for medium-duty and heavy-duty trucks;

(2) an analysis of existing and potential technologies that may be used practically to improve medium-duty and heavy-duty truck fuel economy;

(3) an analysis of how such technologies may be practically integrated into the medium-duty and heavy-duty truck manufacturing process;

(4) an assessment of how such technologies may be used to meet fuel economy standards to be prescribed under EISA; and

(5) associated costs and other impacts on the operation of medium-duty and heavy-duty trucks, including congestion.

The National Academy of Sciences, through the National Research Council, established a committee to undertake the study and released the resulting report in March, 2010. Key findings of the study include:

- Advanced diesel engines in tractor-trailers could lower fuel consumption by up to 20 percent by 2020, and improved aerodynamics could yield an 11 percent reduction
- Hybrid powertrains could lower the fuel consumption of vehicles that stop frequently, such as garbage trucks and transit buses, by as much 35 percent by 2020
- Many of the suites of technologies examined would pay for themselves, even at today's energy prices
- A combination of technologies implemented on tractor-trailers could cut fuel use by about 50 percent by 2020 and cost about $84,600 per truck, which represents the best cost-benefit ratio for any vehicle type over ten years, provided gas prices are at least $1.10 per gallon. [Note: this includes a reduction by the use of longer-heavier vehicles – i.e. related to the European Modular System (EMS)]
- The fuel use of motor coaches could be lowered by 32 percent for an estimated $36,350 per bus, which would be cost-effective if the price of fuel is $1.70 per gallon or higher
- Nontechnical methods that could be used to lower fuel consumption include training vehicle operators in efficient driving techniques, which was estimated to result in fuel savings of anywhere from 2 percent to 17 percent

The report recommends that regulators implement a fuel economy standard that accounts for the amount of freight or passengers carried by these vehicles. The metric should reflect the efficiency with which a vehicle moves goods or passengers, such as gallons per ton-mile.

In addition to the evolving regulatory landscape, the federal government also operates a number of incentive programs. Congress authorized funding for clean diesel activities in the Diesel Emissions Reduction Act as part of the 2005 Energy Policy Act and the 2009 American Recovery and Reinvestment Act. By far the most well-established federal heavy duty vehicle incentive program is SmartWay, run by the US Environmental Protection Agency (EPA).

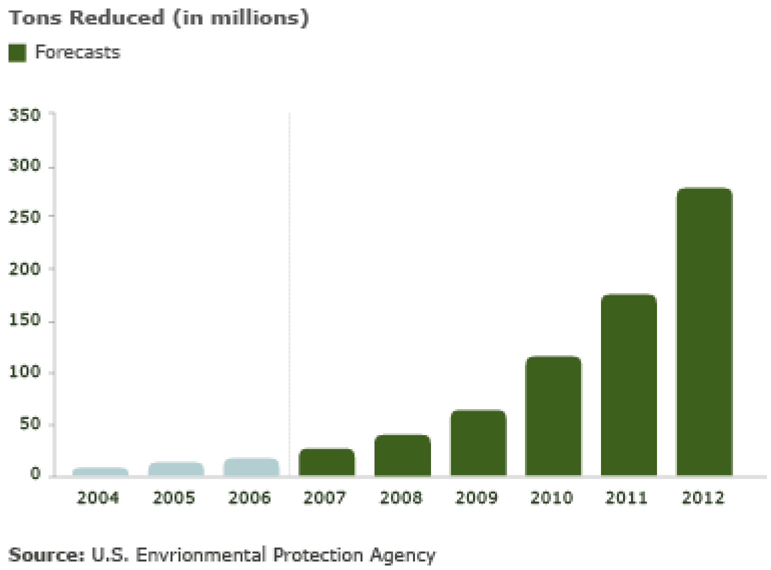
SmartWay

EPA launched the SmartWay program in 2004. As described by EPA, SmartWay is a "brand" that identifies products and services that reduce transportation-related emissions.

The SmartWay Transport Partnership is a voluntary public-private initiative designed to improve the environmental performance of the freight delivery system in the United States through money saving, market-based approaches. SmartWay Transport Partners are progressive corporations and organizations that recognize they can improve their business and the environment at the same time. Companies that provide and hire freight delivery services become SmartWay Transport Partners by committing to improve the environmental performance of their freight delivery operations. SmartWay Transport Carriers commit to integrate innovative cost saving strategies into their fleet operations. SmartWay Transport Shippers commit to ship the majority of their goods with SmartWay Transport carriers. Companies that meet SmartWay Transport Partnership requirements will benefit from reduced operating costs and enhanced visibility. Partners that demonstrate superior performance will earn the right to display the SmartWay Transport logo.

In 2006, SmartWay saved 2.5 million tons of CO_2 and over 220 million gallons of diesel. Projections of cumulative savings for future years are shown in Figure 2–1 below.

Figure 2–1: CO_2 Emission Reductions Achieved from Freight Industry under U.S. EPA's SmartWay Transport Partnership Programme



California

The State of California is the only state in the US to have implemented heavy-duty vehicle regulations specifically relating to GHGs. The California Air Resources Board (CARB) adopted a regulation in December 2008 that aims to accelerate adoption of technologies that reduce GHGs from heavy-duty trucks. The measure requires that:

- Beginning January 2010, with the 2011 model year, all sleeper cab tractors that pull 53-ft. or longer box van trailers must be SmartWay certified
- Day cab tractors must have SmartWay-approved low rolling resistant tires
- In model year 2011 and beyond, all 53-ft. or longer van trailers must be SmartWay certified
- Older trailers must be retrofitted with SmartWay-approved technologies, phased-in for larger fleets from 2010 to 2015 and for smaller fleets from 2013 to 2016
- By January 1, 2023, all vehicles must have a 2010 model year engine or equivalent.

The regulation applies to all on-road heavy-duty diesel fuelled vehicles with a gross vehicle weight rating (GVWR) greater than 14,000 pounds, agricultural yard trucks with off-road certified engines, and certain diesel fuelled shuttle vehicles of any GVWR. Out-of-state trucks and buses that operate in California are also subject to the regulation.

In addition to the SmartWay requirements, California had also previously implemented idle reduction legislation. In 2005, CARB approved a regulatory measure that limits idling of diesel trucks. The regulation requires 2008 and newer model year heavy-duty diesel engines to be equipped with an automatic engine shutdown system that kicks in after five minutes of idling. Further, the regulation requires operators of older sleeper berth equipped trucks to manually shut down their engine when idling for more than five minutes at any location within California, beginning in 2008.

CARB has a voucher program for the purchase of medium and heavy-duty hybrid vehicles called the California Hybrid Truck and Bus Voucher Incentive Project (HVIP). The programme offers $10,000 to $45,000 towards the incremental cost of a new hybrid vehicle to help overcome the high incremental cost of these vehicles in the early market years when production volumes are still low.

About 63 vehicle models are currently eligible. Hybrid trucks and buses have been shown in testing to reduce both greenhouse gases and fuel use by 20-50 percent, depending on the vehicle and its application. Under the Air Quality Improvement Program (AQIP) Funding Plan, the HVIP accounts for about 60 percent of the $34.6 million budget for 2010.

In California, the Zero emission Bus (ZBus) regulation is designed to encourage the operation and use of zero emission buses in urban bus fleets. As part of the ZBus program, during the 2006-2007, the CARB directed staff to review the technology and report to the Board on the status of the technology and the feasibility of implementing the purchase requirements as currently required. (http://www.arb.ca.gov/msprog/bus/zeb/zeb.htm).

2.3.3.4 Other State Initiatives

Many other initiatives are underway in the United States that will help reduce greenhouse gas emissions from heavy duty vehicles. A number of states have implemented “Weigh-in-Motion” systems, allowing the monitoring of vehicle weight and collection of freight taxes without the need for trucks to line up at weigh stations, idling their engines. States are exploring truck stop electrification, reducing the need for idling that would otherwise be done to power truck cabs and trailer refrigeration units. Some states have set lower speed limits in an effort to conserve fuel from all types of vehicles, while also improving safety. Other states support raising commercial vehicle size and/or weight restrictions to 97,000 pounds, or above, for six-axle trailers, since research suggests these trucks are able to achieve increased efficiencies in terms of gallons per ton-mile. However, it is worth noting that there may be an increase in pavement wear from these vehicles, requiring more frequenting paving maintenance with the resulting carbon impacts.

2.3.3.5 Private companies

Beyond governmental regulations and incentive programs, many private companies in the US have begun implementing programs to reduce fuel consumption, with resulting impacts to GHG emissions. While the primary aim of these programs is often to reduce operating expenses, the public relations benefit of greener shipping is not lost, and some firms are strengthening their brands by emphasizing these programs. Particular companies to note include Wal-Mart, UPS, FedEx, DHL, Coca-Cola, Kraft Foods, and Con-Way.

2.3.3.6 Canada

The ‘ecoEnergy for Fleets’ program offered by Natural Resources Canada introduces fleets to energy-efficient practices that can reduce fuel consumption and emissions. FleetSmart is a component of this program offering free practical advice on how energy-efficient vehicles and business practices can reduce fleet operating costs, improve productivity and increase competitiveness. The scheme is run by Natural Resources Canada and offers tailor advice for trucks, coaches and buses in partnership with the US SmartWay initiative.

In the Canadian state of Ontario, a three year pilot programme has been in place since 2009 allowing long combination vehicles operate across the state. These turnpike-double vehicles are a single truck tractor hauling two regular 53-foot trailers and are being piloted in Ontario because of their perceived efficiency for hauling low-density freight. LCVs have been estimated by the Ontario Ministry of Transportation to be able to save shippers and consumers up to $320 million a year through a reduced fuel consumption of up to 70 million litres a year (equating to a greenhouse gas emissions saving of 200,000 tonnes a year).

2.4 Characterisation of vehicle manufacturers

Objectives:

The purpose of this sub-task was to:

"Characterise the manufacturers of HDV in the EU including OEMs, body builders, and trailer builders, their sales volumes and market shares in different vehicle segments."

Summary of Main Findings

⇒ The EU HDV market is dominated by 7 major manufacturers (accounting for 93% of EU registrations), which also account for an estimated 40% of worldwide HDV production.

⇒ In the buses and coaches sub-sector there are also a significant number of smaller manufacturers /bodybuilders accounting for ~25% of all new vehicle registrations.

⇒ The HDV market is highly complicated when compared to light duty vehicles, with the major OEMs for the most part not responsible for the final vehicle configuration (at least for rigid trucks) other than the powertrain, chassis and cab.

⇒ In contrast to the vehicle manufacturers, the trailer and body-builder sector is highly diverse with thousands of organisations (Daimler alone has over 5000 in its database), most of which operate only in local markets. Consequently very little information available on the EU market as a whole. However, there are a number of larger players with the top 7 trailer manufacturers accounting for over 50% of new trailer registrations.

2.4.1 Vehicle Manufacturers

2.4.1.1 General Characteristics

The European heavy duty vehicle (HDV) market is dominated by 7 major original equipment manufacturer (OEM) groups, which account for over 93% of all new EU registrations and include the organisations in bold in the following Table 2.6 (with major European HDV sub-brands bulleted).

Table 2.6: Summary of the major European heavy-duty vehicle manufacturers and bus builders

Name	Brands and HDV Types Covered	Head Office
DAF Trucks	- DAF Trucks	Eindhoven (Netherlands)
VDL Group	- VDL Bus and Coach	Valkenswaard (Netherlands)
Daimler AG	- Mercedes-Benz Trucks - Evobus (Mercedes-Benz, Setra)	Stuttgart (Germany)
Ford*	- Ford trucks (large vans), minibuses	Köln (Germany)
BMC	- BMC trucks and buses/coaches	Izmir (Turkey)
M.A.N.	- MAN trucks and buses/coaches. Neoplan coaches.	München (Germany)
Renault Trucks	- The Renault Truck and Bus business has been owned by Volvo since 2001	Saint-Priest (France)

Name	Brands and HDV Types Covered	Head Office
Scania	- Scania trucks, buses/coaches	Södertälje (Sweden)
Volkswagen*	- VW trucks (large vans), minibuses	Wolfsburg (Germany)
Volvo Trucks	- Volvo Trucks and Volvo buses/coaches - (also Renault trucks, buses – see above)	Göteborg (Sweden)
Iveco (Fiat)	- Iveco (trucks) - Iveco Irisbus (buses/coaches). - Iveco Magirus (fire fighting and civil protection vehicles)	Turin (Italy)
Mitsubishi Fuso	- Trucks (3.5-7.5-t segment)	Stuttgart (Germany)
Alexander Dennis	- Bus and coach chassis and bodies, also includes Plaxton coaches	Edinburgh (UK)
Wright Group	- Bus bodies (built on Volvo and Scania chassis)	Northern Ireland (UK)
Optare	- Bus and coach chassis	Lancashire (UK)
Van Hool	- Manufacturer of buses, coaches, trolleybuses, and trailers	Koningshooikt (Belgium)
Solaris	- bus, coach and trolleybus manufacturer	Bolechowo-Osiedle and Środa Wielkopolska (Poland)
SOR	- Manufacturer of buses, coaches and trolleybuses	Libchavy (Czech Republic)

Notes: Major manufacturer groups accounting for over 93% EU HDV registrations highlighted in bold. The major manufacturers also supply engines and chassis to the vehicle builders like VDL. * Ford and Volkswagen produce only large vans and minibuses that fall in the 3.5-7.5 tonne GVW sub-category.

The other major European vehicle manufacturers (Volkswagen and PSA) contribute to less than 1% of total new registrations of HDVs.

Although there are a relatively small number of major manufacturers, the HDV market is highly complicated when compared to light duty vehicles. The OEMs are for the most part not responsible for the final vehicle configuration (at least for rigid vehicles) other than the powertrain, chassis and cab. Essentially all rigid trucks will go through (sometimes several) bodybuilders to provide the additional body/superstructure and any additional auxiliaries (e.g. tail lifts, cranes, cement mixers, refuse collection systems, etc) for most cases specific customer requirements. Road tractors in contrast are essentially finished products although there may be some additional modifications (e.g. for alternative layout of fuel tanks/capacity, cooking facilities for overnight cabs, etc). In addition, the end performance /characteristics of the full articulated vehicle (= road tractor + semi-trailer) will be highly dependant on the characteristics of the semi-trailer type pulled by the tractor unit.

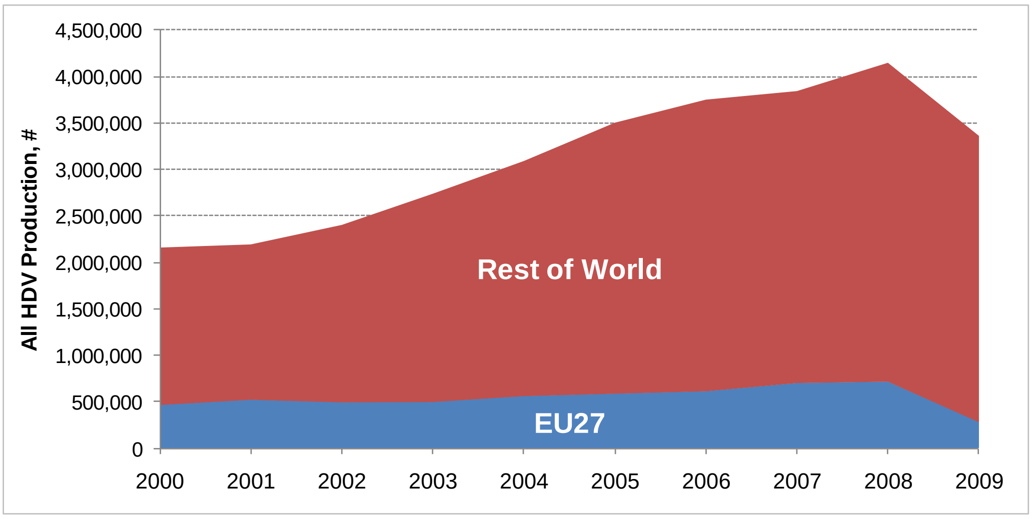
Engine manufacturers (beyond the major manufacturers) only have a very limited role to play in the EU HDV market, as the vast majority of the engines used in EU HDVs are produced by the major manufacturers.

The following section provides an overview of the worldwide production and EU registrations of new HDVs over time and the relative significance of different EU manufacturers.

2.4.1.2 Production and Registrations / Sales

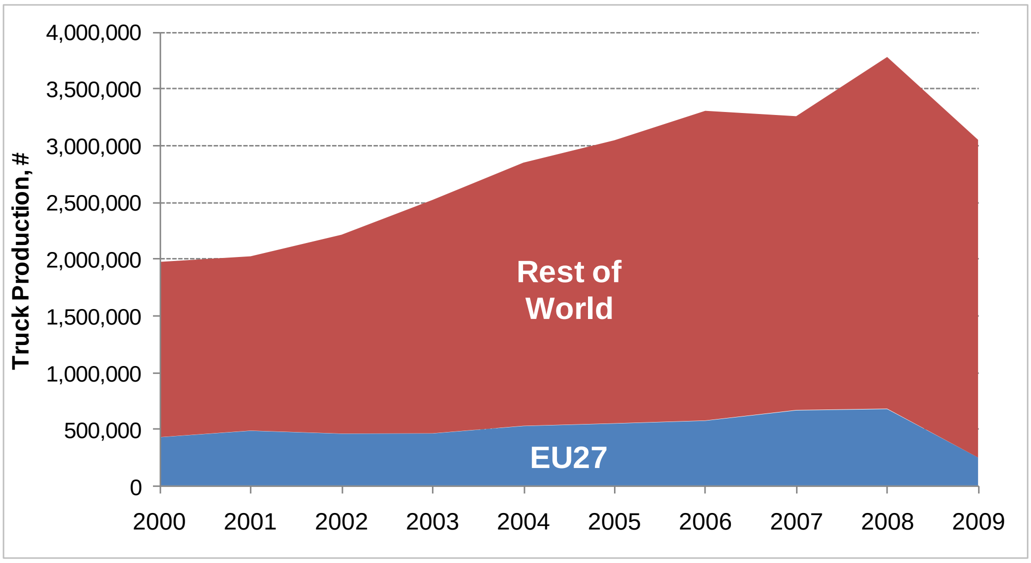
The following Figure 2–2 based on OICA (2010)[3] statistics illustrates that the production of HDVs worldwide increased by over 90% between 2000 and 2008, before a sharp 19% fall in 2009 due to the global recession. Production in the EU has increased by just over 50% in the same 2000-2008 period and accounted for 17.5% of all HDV production in 2008 before dropping by over 60% in 2009. In contrast the proportion of production outside of the EU has risen significantly since 2000 (more doubling in production to 2008) and had a more modest fall in production (at -10%) in 2009. Total HDV production is dominated by trucks, which account for almost 91% of all HDVs manufactured worldwide (and over 94% in the EU). Truck production therefore dominates the overall picture, with separate trends in production for the truck and bus/coach segments provided separately in Figure 2–3 and Figure 2–4, respectively. The reduction in production in the bus and coach markets between 2008 and 2009 was slightly lower (at -15%) with EU production fairing slightly better (at -12%) compared with production in the rest of the world.

Figure 2–2: Worldwide production of all HDVs by region, 2000-2009



Source: OICA, 2010.

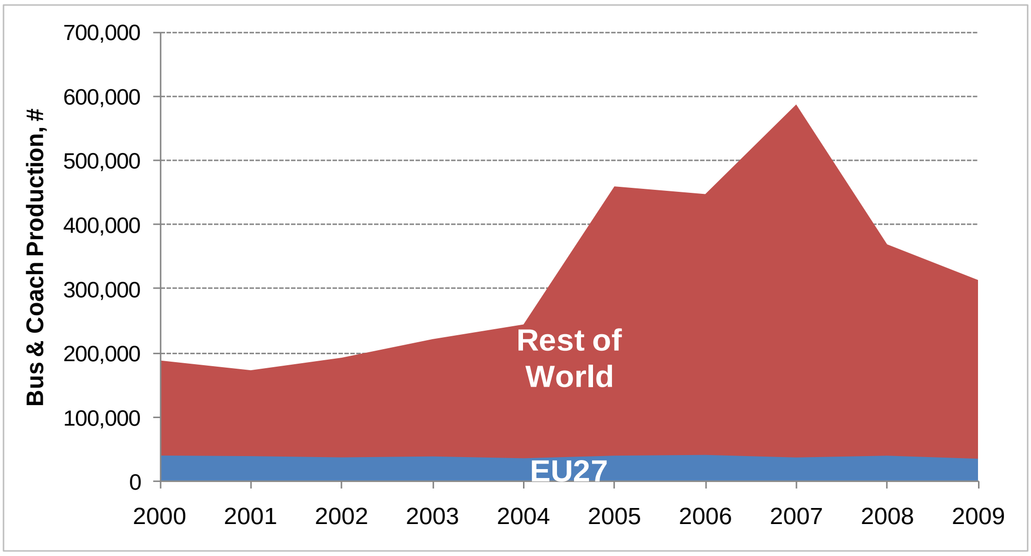
Figure 2–3: Worldwide production of Trucks by region, 2000-2009



Source: OICA, 2010.

[3] OICA (Organisation Internationale des Constructeurs d'Automobiles), is the International Organization of Motor Vehicle Manufacturers. Compiled vehicle production data is available from OICA's website at: http://oica.net/category/production-statistics/

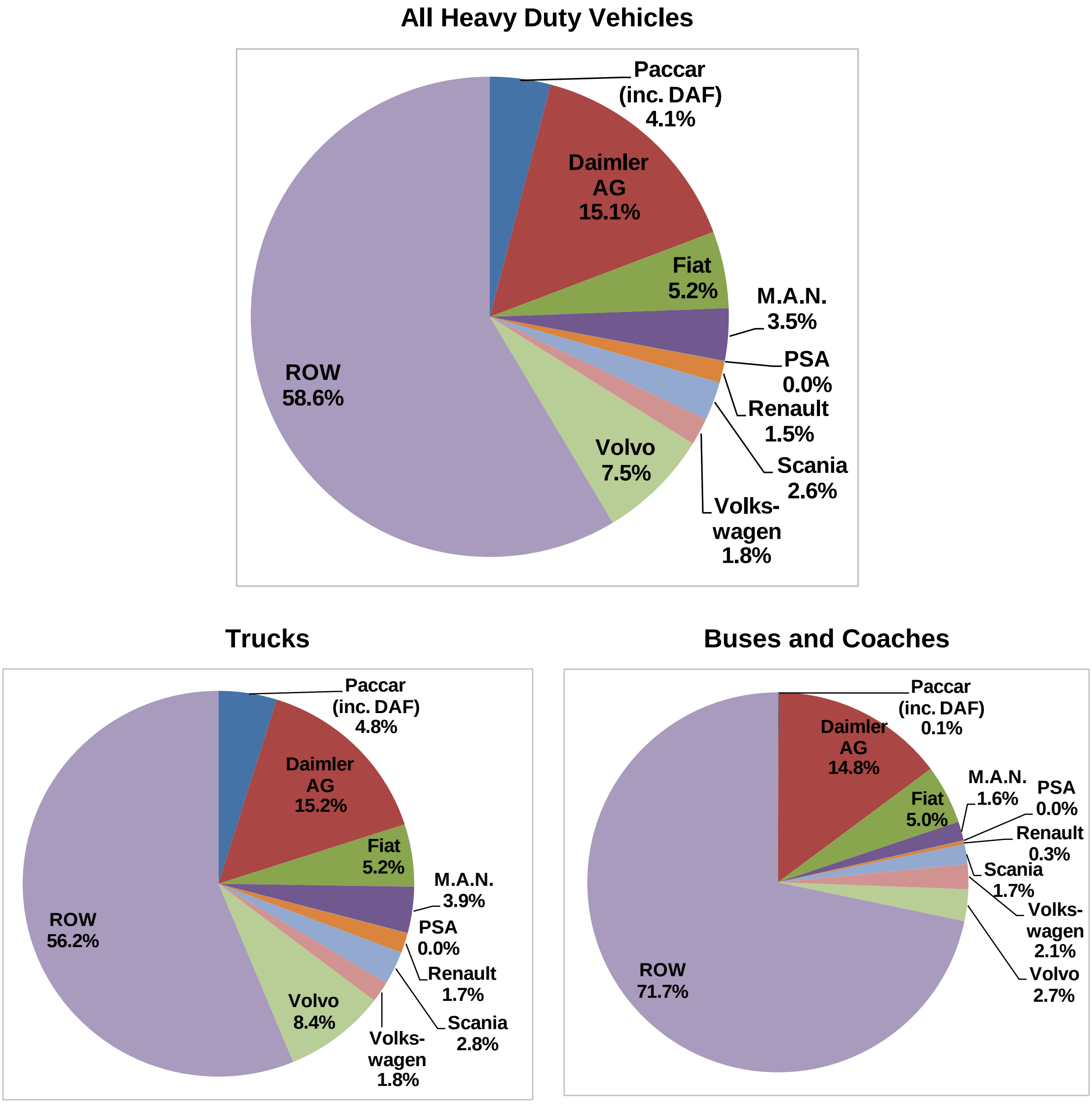
Figure 2–4: Worldwide production of Buses and Coaches by region, 2000-2009



Source: OICA, 2010.

In terms of global production by manufacturer, the following Figure 2–5 provides the 2008 split of the HDV production by different European manufacturers, plus manufacturers in the rest of the world. The major European manufacturers account for over 40% of total global production according to OICA statistics, with Daimler being the largest European HDV manufacturer (and the second largest worldwide after Isuzu) and the Volvo Group (which includes Volvo Tucks and Renault Trucks) being the second larges. However, it is important to note that the presented information is an aggregate for all HDVs above 3.5 tonnes, and some manufacturers produce vehicles in very high numbers predominantly in the 3.5-7.5 tonne GVW range. For example if vehicles within that range are excluded then Daimler is the largest manufacturer globally. In the buses and coaches subsector the proportion of production by the major EU manufacturers is lower at around 28%. The HDV production by EU manufacturers also fell more sharply than others between 2008 and 2009 due to the global recession.

Figure 2–5: Split of worldwide production of HDVs by manufacturer for 2008



Source: OICA, 2010.

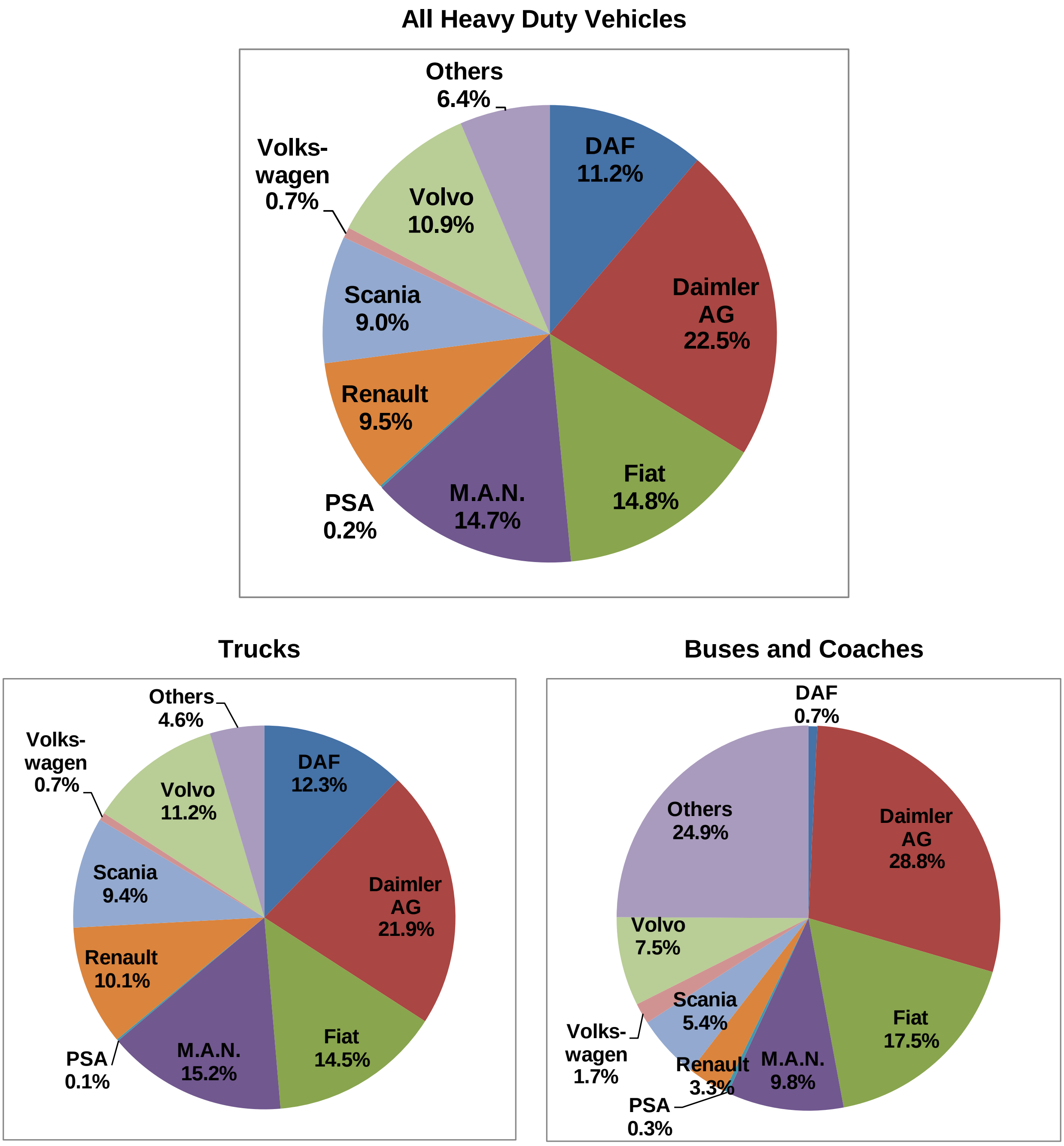
Notes: ROW = rest of the world, i.e. manufacturers that do not originate from the EU. No information was available in the OICA statistics on the worldwide HDV production of Renault and PSA, so their EU registrations have been used as a substitute. Includes all vehicles >3.5 tonnes GVW.

In terms of EU registrations, statistics are available from ACEA (2010)[4] on European registrations by country and by manufacturer (group and brand). The following Figure 2–6 through to Figure 2–9, provide an illustration of the breakdown of HDV registrations by manufacturer and temporal trend since 2001. The Figures provide a clear illustration of the dominance of the major European manufacturer groups in the EU market, accounting for 95% of all new registrations of trucks and 75% of bus and coach registrations. The major EU manufacturers are also major players globally with EU registrations of their HDVs

[4] ACEA (Association des Constructeurs Européens d'Automobiles) is the European Automobile Manufacturer's Association. Statistics on vehicle registrations are available from ACEA's website (updated monthly) at: http://www.acea.be/index.php/collection/statistics

representing only around 15% of their total global production in 2008. Hence developments within the EU will have the potential for significant impacts more globally, where EU measures have a global relevance (i.e. cost-effective on a global perspective). Other manufacturers play a more significant role in the bus and coaches subsector. Ford accounts for around 7% of this subsector, with the remainder due to smaller specialised manufacturers, such as Alexander Dennis Group and Wright Group, which in particular serve a significant portion of the UK market. Other significant European manufacturers include VDL Bus & Coach (Netherlands), van Hool (Netherlands), Temsa (Turkey), Solaris (Poland), Noge (Spain) and BMC (Turkey).

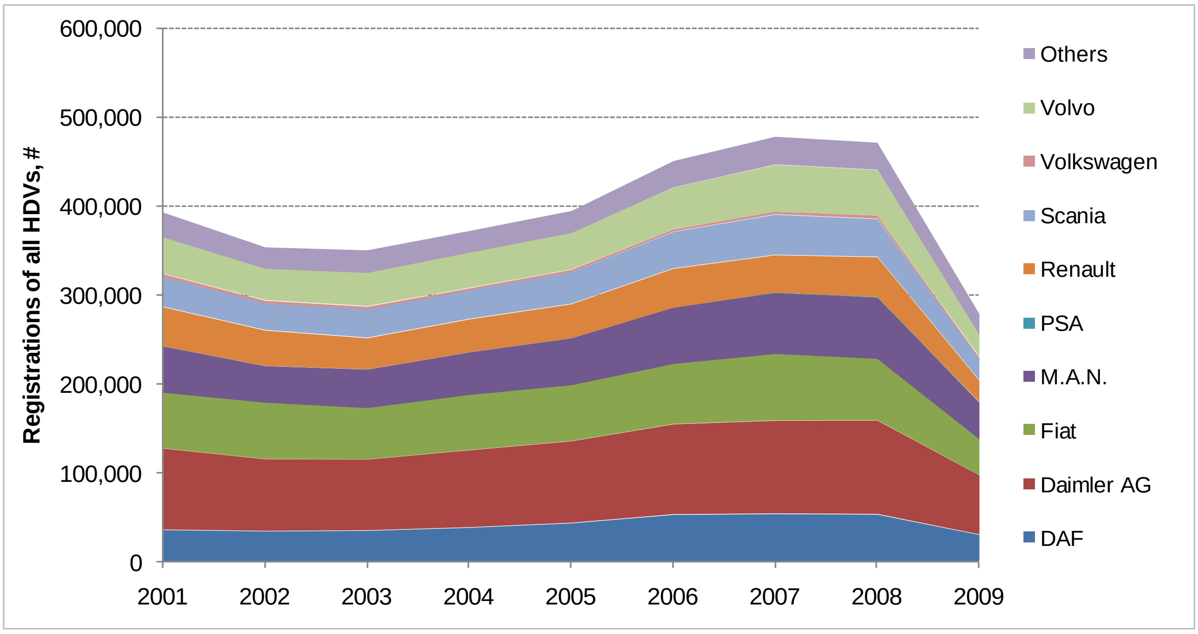
Figure 2–6: EU Registrations of all HDVs by manufacturer group in 2008



Source: ACEA, 2010.

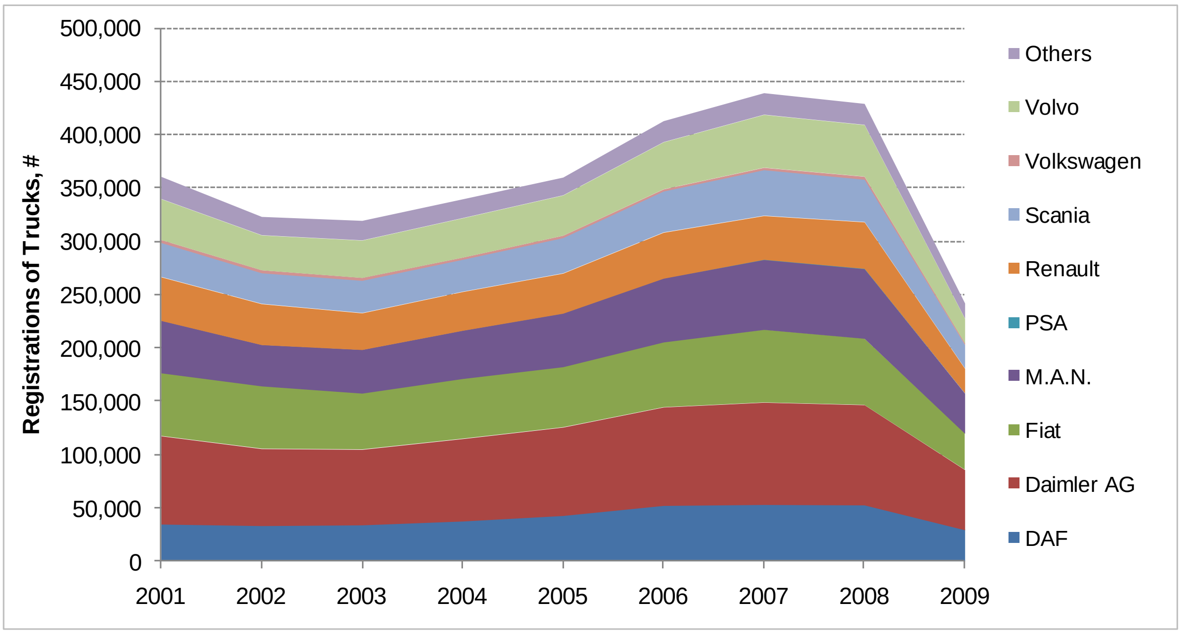
Notes: Includes all vehicles >3.5 tonnes GVW.

Figure 2–7: EU registrations of all HDVs by manufacturer group, 2001-2009



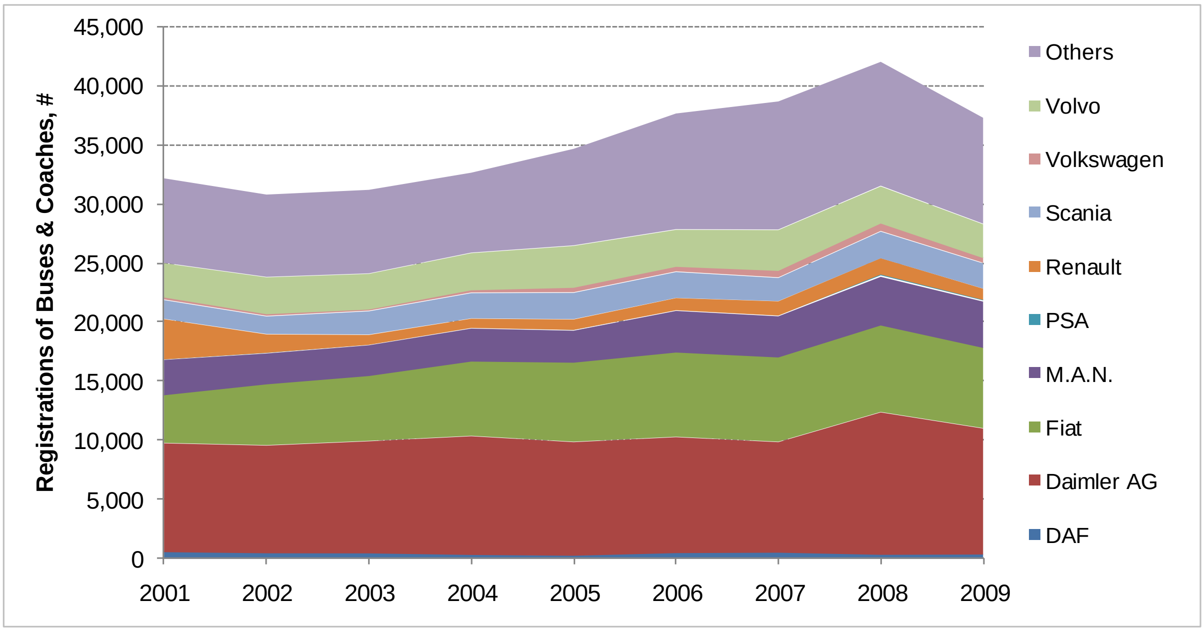
Source: ACEA, 2010.
Notes: Includes all vehicles >3.5 tonnes GVW.

Figure 2–8: EU registrations of Trucks by manufacturer group, 2001-2009



Source: ACEA, 2010.
Notes: Includes all vehicles >3.5 tonnes GVW.

Figure 2–9: EU registrations of Buses and Coaches by manufacturer group, 2001-2009



Source: ACEA, 2010.

Notes: Includes all vehicles >3.5 tonnes GVW.

2.4.2 Trailer Builders

In 2008, EU wide new registrations of trailers equalled approximately 250,000, of which 200,000 are semi-trailers and 50,000 are drawbar trailers (CLEAR, 2010).

There is not an established pan-European system for the registration of trailers at present. Therefore, in terms of characterising the trailer market in 2009 there is not an objective, independent body to record transactions. Some individual member states, such as Germany, publish information on the trailer manufacturing industry – however, this is the exception rather than the norm.

A database of trailer production figures by manufacturer for the top 7 European trailer producing countries has been purchased from CLEAR, together with data on EU27 registrations (by body type) and the trailer parc. The production data was collated as a result of ongoing consultation with the largest trailer manufacturers across Europe, providing figures for the 69 largest producers (those with production over 100 units per year). Due to the commercial sensitivity of the names of the manufacturers who provided data to CLEAR and the focus on company production size for the study, the company names of manufacturers have had to remain confidential. The dataset represents the majority of EU trailer production, for example the 2008 production for the 7 top trailer producing countries corresponds to 95% of the total EU trailer registrations for the same year.

In terms of manufacturers, the European trailer manufacture is highly diverse with thousands of organisations (Daimler alone has over 5000 in its database), most of which operate only in local markets. However, the top seven suppliers produced over 53% of the trailers manufactured in 2008 and the top 69 suppliers produced over 90% of the total trailers produced, as illustrated by Table 2.7 below.

Table 2.7: The 69 largest trailer manufacturers in the 7 EU Member States sampled (grouped by size of production)

Size Range	2004	2005	2006	2007	2008	2009
Number of Companies						
Other (99 or less)	N/A	N/A	N/A	N/A	N/A	N/A
99 or less	2	2	1	1	0	1
100 to 499	12	14	13	11	14	30
500 to 999	17	19	13	12	13	15
1000 to 1999	21	17	24	22	22	17
2000 to 4999	11	12	12	14	13	5
5000 or more	6	5	6	9	7	1
Total	**69**	**69**	**69**	**69**	**69**	**69**
Production Units						
Other (99 or less)	24,230	18,902	20,222	33,333	22,685	9,951
99 or less	85	87	90	89	0	70
100 to 499	3,310	4,456	4,004	3,688	4,589	8,642
500 to 999	12,157	14,378	9,316	9,121	9,581	10,185
1000 to 1999	30,593	25,727	33,307	31,494	30,891	22,529
2000 to 4999	34,121	34,195	36,363	41,095	41,712	14,717
5000 or more	79,223	77,352	105,314	145,744	126,603	11,503
Total	**183,719**	**175,097**	**208,616**	**264,564**	**236,061**	**77,597**
% Total Trailer Production						
Other (99 or less)	13.2%	10.8%	9.7%	12.6%	9.6%	12.8%
99 or less	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
100 to 499	1.8%	2.5%	1.9%	1.4%	1.9%	11.1%
500 to 999	6.6%	8.2%	4.5%	3.4%	4.1%	13.1%
1000 to 1999	16.7%	14.7%	16.0%	11.9%	13.1%	29.0%
2000 to 4999	18.6%	19.5%	17.4%	15.5%	17.7%	19.0%
5000 or more	43.1%	44.2%	50.5%	55.1%	53.6%	14.8%
Total >100 units	**86.8%**	**89.2%**	**90.3%**	**87.4%**	**90.4%**	**87.2%**

Source: CLEAR International Consulting (2010)
Notes: Data is for trailer production in Belgium, France, Germany, Italy, Netherlands, Spain and the UK.

However, in terms of production by country, the trailer market is concentrated particularly around Germany, with the three largest manufacturers accounting for 48% of the European market in 2007 according to information from the German VDA (2008)[5]. Germany has the largest number of manufacturers, also illustrated in Table 2.8, and consequently produced the largest number of trailers in 2008, illustrated by Figure 2–11. Some of the top European trailer manufacturers include the following organisations, with some the locations of their main trailer factories also provided in the following Figure 2–10:

[5] Internationalization of the European trailer and body industry: the changing industry, presentation by Alexander Tietje - Chairman of Management, Kögel Fahrzeugwerke GmbH, VDA, Germany, July 2008. Available at: www.vda.de/en/downloads/652/

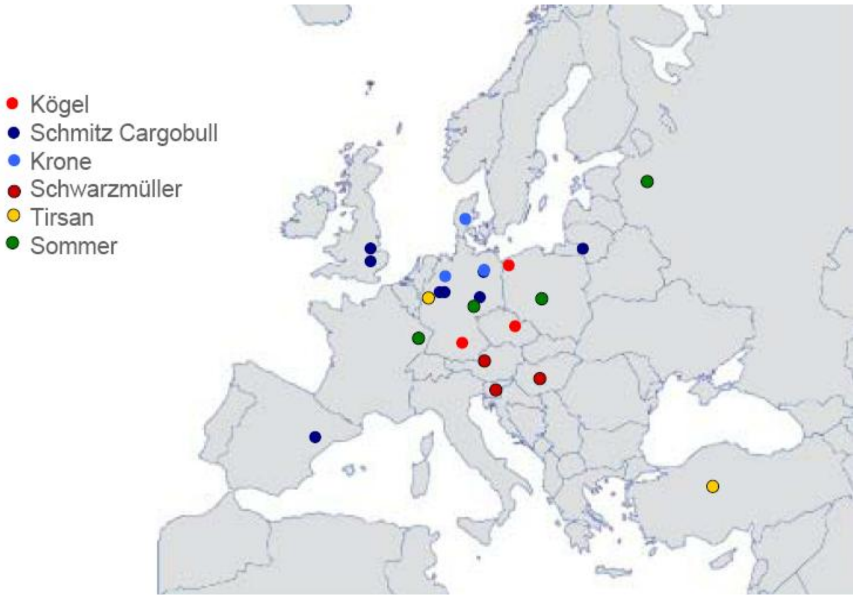
1) *Schmitz Cargobull (Germany)* ~26% total EU in 2007/8;
2) *Krone (Germany):* ~14% total EU in 2007/8;
3) *Kögel Fahrzeugwerke (Germany):* ~8% total EU in 2007/8;
4) *Schwarzmüller (Austria):* 4% total EU in 2007/8;
5) *Tirsan (Turkey):* ~1.5% total EU in 2007/8[6]
6) *Sommer (Germany)*

Across all of the countries covered, manufacturing decreased in 2009 compared with previous increases. This can be primarily attributed to the impact of the global economic recession during this time which has had an impact across the manufacturing industry. As the largest producer of trailers in Europe, Germany experienced the largest decline in production in 2009, producing over 100,000 fewer trailers in 2009 when compared with 2008, as illustrated in Figure 2–11.

Table 2.8: Total number of trailer manufacturers in 7 EU Member States producing more than 99 trailers in 2008

Country	Number of trailer manufacturers (producing > 99 trailers in 2008)
Belgium	5
France	11
Germany	21
Italy	11
Netherlands	12
Spain	9
UK	13
Total	**69**

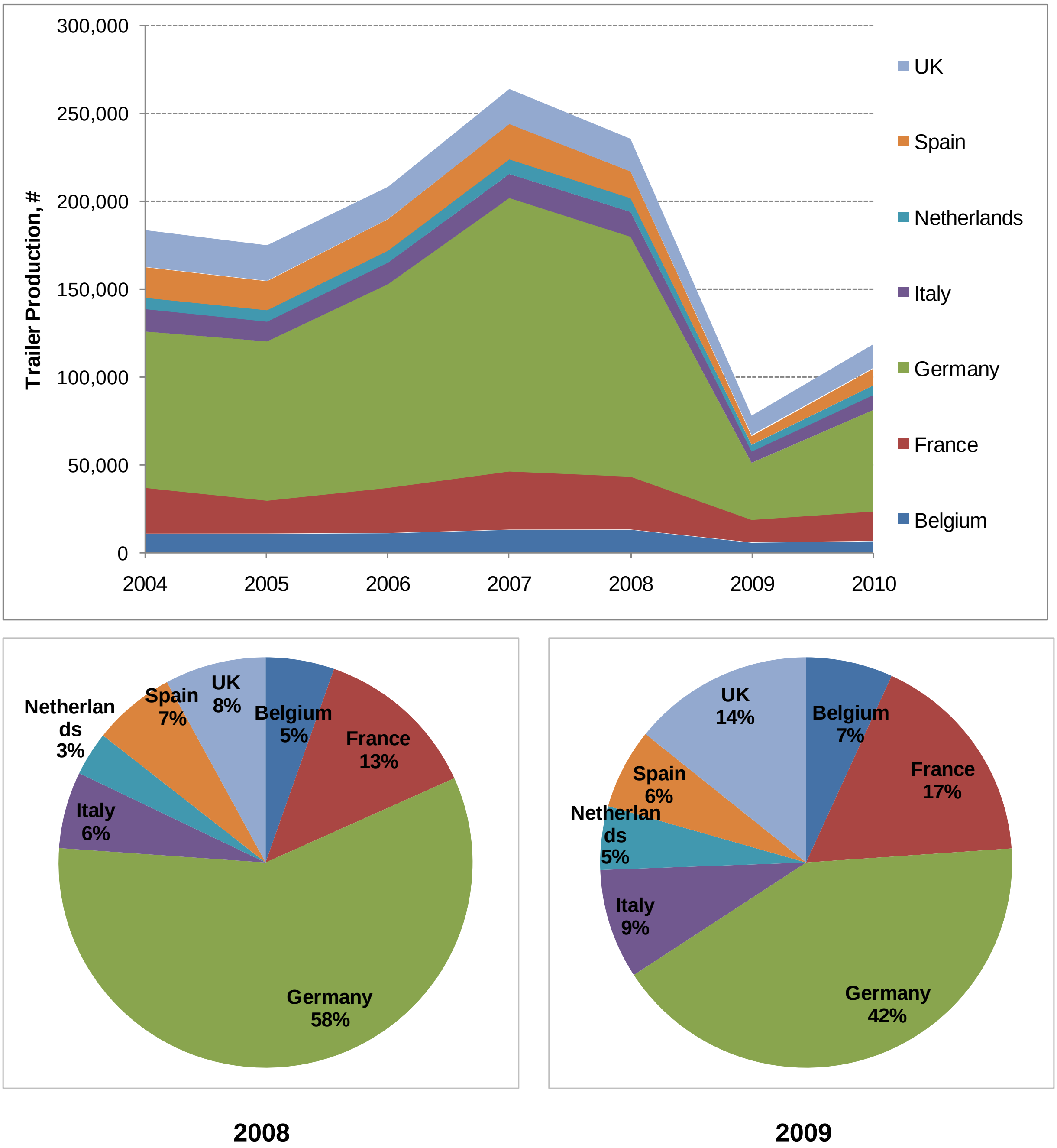
Figure 2–10: Trailer factories in Europe



Source: German VDA (2008).

[6] http://www.daftirsan.com.tr/en/president.aspx

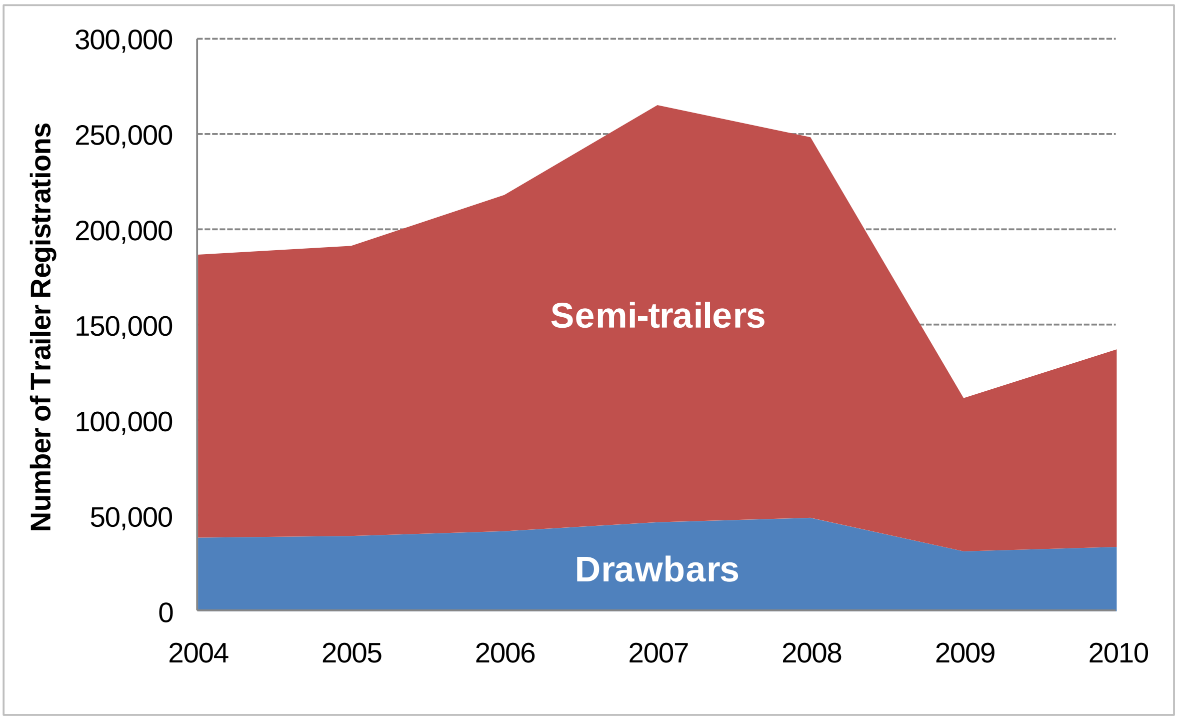
Figure 2–11: Trailer production for the 7 largest countries for EU trailer production (CLEAR, 2010)



Source: CLEAR International Consulting Ltd (2010)

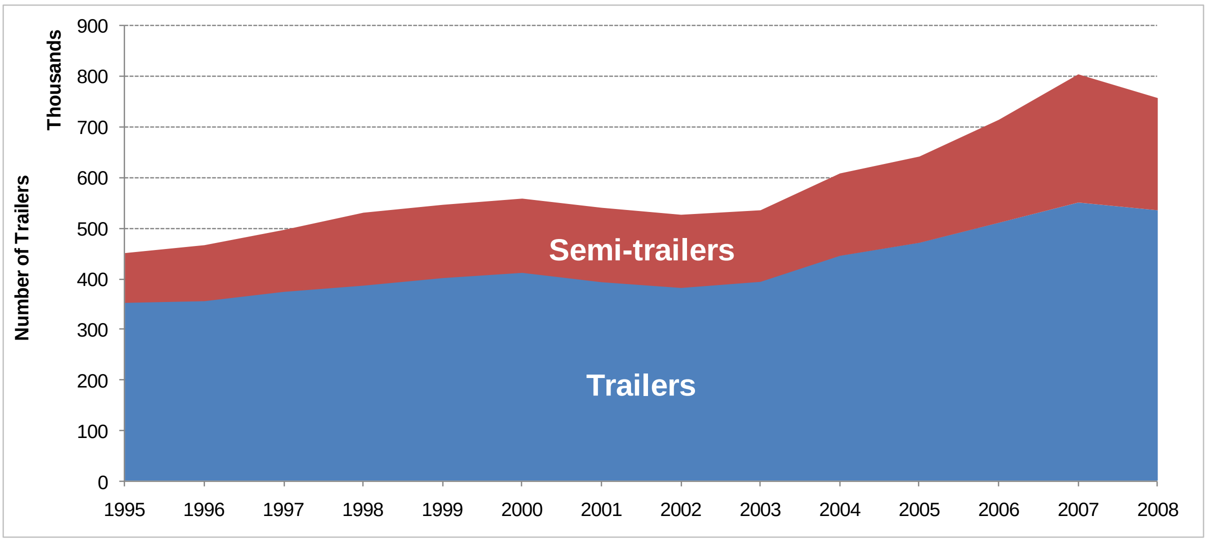
Information from CLEAR on the timeseries of EU27 trailer registrations by type of trailer is also presented in the following Figure 2–12. In comparison a longer time series of trailer registrations is presented in Figure 2–13, which was sourced from Eurostat (and gap-filled for missing country data in order to estimate the wider EU27 timeseries – see Table 2.2). Immediately obvious from comparison of the two data-series is the much higher number of trailers present in dataset from Eurostat. This arises mainly due to two key problems: (a) the dataset includes trailers used by light duty vehicles, (b) the gap-filling necessary to make estimates for missing data. There are further discrepancies when considering comparable datasets for the trailer parc (also discussed further in the later Section 2.7) which also result from additional problems in the way national statistical data is compiled.

Figure 2–12: Timeseries of EU27 trailer registrations by type 2004-2010 (CLEAR, 2010)



Source: CLEAR International Consulting Ltd

Figure 2–13: Timeseries of EU27 trailer registrations by type, 1995-2008 (Eurostat, 2010)



Source: Eurostat, 2010

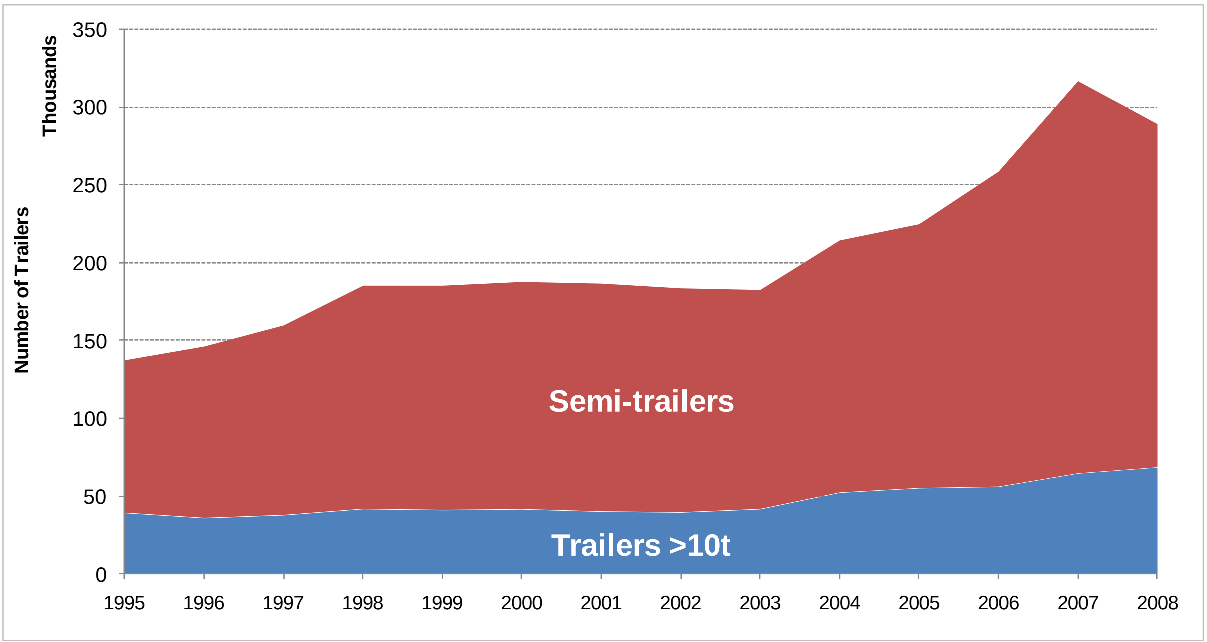
CLEAR International Consulting has been analysing trailer markets since 1992 from both the sales and production perspective. As a consequence they have developed robust methodologies for defining both historical datasets and developing forecasts for the trailer markets of Western & Eastern Europe and the rest of the world. The base data from CLEAR is mainly sourced from trade associations, government bodies and national statistics centres. Where no trailer data is available industry surveys are conducted. This is usually only an issue in the UK and Ireland plus some East European markets. The CLEAR dataset is the most comprehensive and complete data available and has been developed to remove inaccuracies and inconsistencies in trailer parc data in particular.

According to CLEAR, many of the data sets published by national governments are rendered of little value by mixing light weight (less than 3.5 or 6.0 tonnes) with heavy commercial trailers (typically 15 tonnes GVW or more). For semi-trailers this is not usually an issue, since there is no significant market for semi-trailers below 10 tonnes GVW. However, the registration numbers for light weight trailers are very large in many countries due to significant numbers of lightweight drawbar (and centre axle) trailers. This also means that figures produce for trailer parc (fleet size) cannot be used for any meaningful analysis, without eliminating these light weight trailers from the data. Using Eurostat statistics on trailer registrations by load capacity (see Figure 2–15 and Figure 2–16) to remove the proportion of trailers that is <10 tonnes load capacity from the wider trailer time-series gives much closer alignment to the CLEAR dataset, see Figure 2–14.

Another issue is that old trailers no longer in use are not deleted from the databases maintained by national governments. As a result the figures for trailer fleet size that are published greatly exaggerate the number of heavy commercial trailers in use. Some governments attempt to get round this by estimating the parc size by adding up historic registration figures, e.g., France where the fleet size is estimated by adding together the last twenty years registrations figures. Again, this exaggerates the number of trailers in use.

Where national data is unreliable CLEAR used a scrappage model to provide a more accurate estimate of historic trailer numbers and to forecast future fleet size for each country.

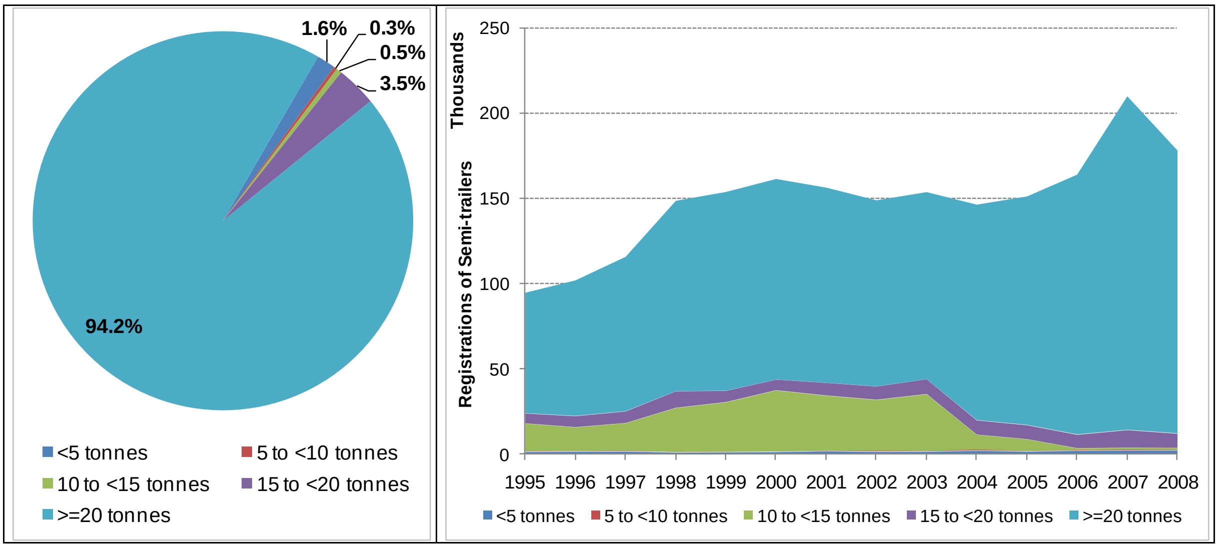
Figure 2–14: Timeseries of EU27 trailer registrations by type (with trailers <10t removed), 1995-2008 (Eurostat, 2010)



Source: Eurostat, 2010

Notes: Data on registrations of trailers by load capacity was used to remove trailers most likely to not be for heavy truck application from the Eurostat dataset.

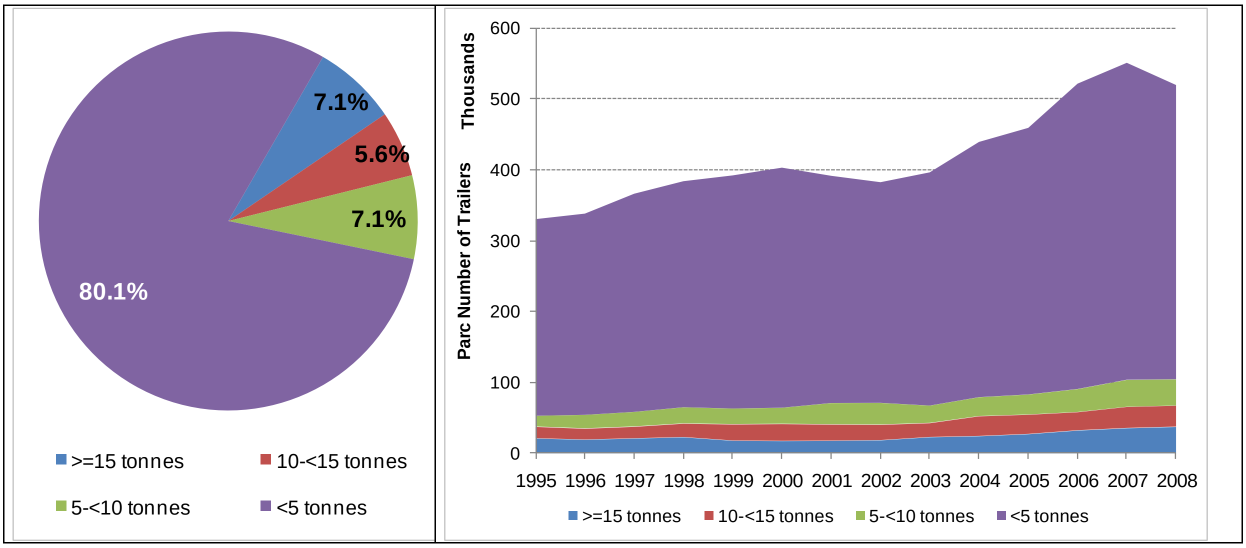
Figure 2–15: New registrations of semi-trailers, by load capacity (number), timeseries 1995 to 2008 and 2008 split



Source: Eurostat (2010)

Notes: Data excludes UK, Ireland, Belgium and Estonia where no data exists.

Figure 2–16: New registrations of drawbar trailers, by load capacity (number), timeseries 1995 to 2008 and 2008 split



Source: Eurostat (2010)

Notes: Data excludes UK, Ireland, Belgium and Estonia where no data exists.

2.4.3 Body Builders

Like the overlapping trailer market, the EU body building market is highly disaggregated due to the bespoke specification required for operators of heavy commercial vehicle and heavy bus and coach fleets. Sales are closely aligned to the point of sale retailers of the vehicle manufacturers. Once a vehicle purchaser has decided on the vehicle type and specified the requirements for the body type, the retailer will utilise a preferred contractor to build the body for the purchaser. This means that body builders are often regionally located and can specialise in specific 'niche markets', although there are a few major players.

The major EU body building manufacturers have been investigated as part of this study. A summary of some of the main European organisations supplying the UK and German markets is provided in Table 2.9. Many of these companies have already been mentioned in the previous section as they also manufacture truck trailers. Figures on the scale of production, volume sales and market share for each company were unavailable and consultation with a number of key organisations such as CLCCR (Liaison Committee of the Body and Trailer Building Industry), the Society of Motor Manufacturers and Traders (SMMT) in the UK, the VDA (the German Association of the Automotive Industry), and others has confirmed the findings. Our investigation has revealed that sales data is not widely published by body and therefore it is not possible to report on sales volumes and market share. Obtaining this confidential information would require individual consultation and agreement from each of the manufacturers and is beyond the scope of this project.

Table 2.9: Examples of major body building manufacturers operating in the EU

Name	Manufacturing Sector	Head Office
Ackermann Automotive GmbH	Truck bodies and trailers	Wolfhagen (Germany)
Alexander Dennis	Bus and Coach chassis and body	Falkirk (UK)
Bernard Krone GmbH	Truck bodies and trailers	Werlte (Germany)
Freightshield	Truck body builders and customisation	Newbury (UK)
Geesink Norba Group	Body builders specialising in commercial waste vehicles	Emeloord (Netherlands)
Gerd Bär GmbH (Bear Cargolift)	Truck bodies and trailers	Heilbronn (Germany)
Kögel vehicle Werke GmbH	Truck bodies and trailers	Burtenbach (Germany)
McComb Coachwork	Truck, bus and coach chassis and body builders	Tattershall (UK)
Optare	Bus and Coach chassis and body	Blackburn (UK)
Ratcliff Palfinger	Body builders and custom applications	Welwyn Garden City (UK)
Schmitz Cargobull	Truck bodies and trailers	Horstmar (Germany)
Shawtrack	Body builders	Clipstone (UK)
Temsa	Bus and coach chassis and body builders	Istanbul (Turkey)
VBG Group	Body builders and customisation	Vänersborg (Sweden)
Wright Group	Bus and Coach chassis and body	Ballymena (N. Ireland)

Source: CLCCR, SMMT (UK), VDA (Germany). More information on the VDA and its trailer and body manufacturers is available from the VDA's website at: http://www.vda.de/de/downloads/618/?PHPSESSID=qmjgb050se8rq0k08ghcfucs74

2.4.4 Suppliers

A limited survey was also conducted on the suppliers to the major HDV manufacturers, which produce number of components and systems in the manufacture of a HDV. In order to assess the suppliers for the European HDV market it is necessary to understand what components and systems carry the manufacturers' brands by Tier 1 suppliers. To narrow the scope within this project these suppliers would comprise of manufacturers of components and systems that materially impact on the fuel consumption of the vehicle including:

- Gearboxes;
- Exhaust systems;

- Catalytic converters;
- Heating/Cooling systems;
- Glass and panelling;
- Braking systems;
- Tyre manufacturers;
- Steering and braking.

In our investigation we conducted a review of the Tier 1 suppliers in an attempt to identify the sales volume and market share of all OEMs. In our analysis we explored all manufacturers in the European Association of Automotive Suppliers (CLEPA) list, as well as contacting them for further information. Each has a corporate membership comprising a number of key manufacturers based in Europe. A summary of these organisations is listed in Table 2.10.

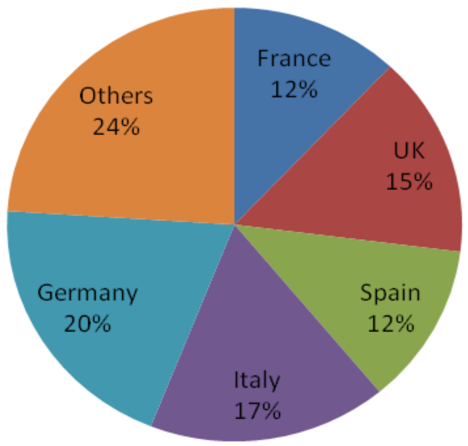
Table 2.10: EU HDV OEM suppliers Tier 1

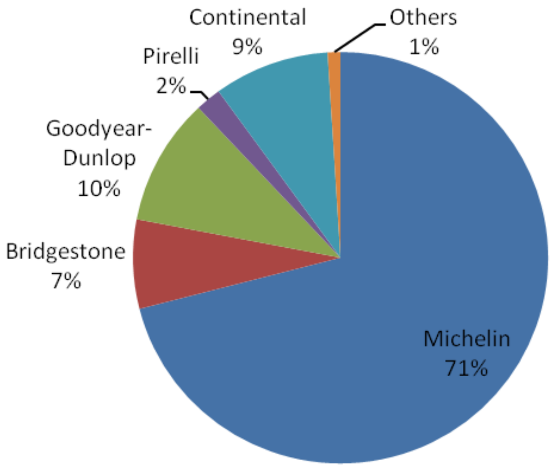
Name	Manufacturing Sector	Head Office
Bosch	Various systems and products	Karlsruhe (Germany)
Delphi	Powertrains, electronic architecture	Luxembourg (European)
BPW	Range of applications	Wiehl (Germany)
Dunlop	Tyres	Hanau (Germany)
Continental	Multiple systems and components, Tyres	Hanover (Germany)
Michelin	Tyres	Clermont-Ferrand (France)
GKN PLC	Multiple components	Redditch (UK)
Saint-Gobain-Sekurit	Glass manufacture and panelling	Paris (France)
TRW automotive	Multiple systems including steering and braking systems	Multiple EU locations
VBG Group	Multiple systems and components	Vänersborg (Sweden)
Mann – Hummell Group	Multiple vehicle systems and air filters	Ludwigsburg (Germany)
Mahle Group	Multiple vehicle systems and components	Multiple EU sites
Knorr-Bremse	Braking and control systems	Langenfeld (Germany)
Emitec	Catalytic Converters	Lohmar (Germany)
CIE Automotive	Multiple Systems	Multiple EU sites
CIMOS Group	Various components	Koper (Slovenia)
Bosal	Exhaust systems and other components including wind deflectors	Lummen (Belgium)
BEHR Group	Air conditioning and engine cooling systems	Stuttgart (Germany)
ZF Group	Driveline and chassis technology, for cars and commercial vehicles	Friedrichshafen (Germany)
Eaton	Automotive drivetrain and powertrain systems	Cleveland, Ohio (USA)
Allison Transmission	Transmissions	Indianapolis, Indiana (USA)
Federal Mogul	Various components	Southfield, Michigan (USA)
Magneti Marelli	Various components (a subsidiary of Fiat)	Sesto San Giovanni (Italy)

Data from suppliers is not generally aggregated or required to be reported under international frameworks. Whilst some research into all the companies listed above has been undertaken, information regarding gear boxes, exhausts, catalytic converters, braking systems etc. is not readily unavailable and a considerable amount of additional work beyond the scope of this study would be required in order to obtain an accurate picture of the market. However, information regarding the market share of one Tier 1 supplier of tyres has been found through Michelin who have a 71% share of the market.

Figure 2.17 shows the size of the five largest European truck tyre markets in 2001, and the share of the Western European market for tyres fitted to new vehicles held by the major OEMs. The source of the data is the European Rubber Manufacturer Conference, as quoted by Michelin. Michelin also quote figures for the replacement tyre market in Western Europe, which although consolidated in the same suppliers is much less dominated by Michelin, who have a 33% market share.

Figure 2.17: Weight of the 5 largest European truck tyre markets and the Western European tyre supplier market shares (i.e. the choice of tyre fitted to new vehicles sold, excluding trailers)





Source: Michelin (2001)[7]

2.5 Number and distribution of vehicle users, by Member State

Objectives:

The purpose of this sub-task was to provide an information on:

"Number and distribution of vehicle users, by Member State:

- *Distribution by type of operator (long-haul transport, distribution, public authority etc);*
- *Size distribution of transport operators;*
- *Own-account transport by non-transport firms"*

[7] The Heavy Truck Tire Market. Michelin Fact Book 2001, available at: http://www.michelin.com/corporate/front/templates/document.DocumentRepositoryServlet?codeDocument=1924&codeRepository=MICHCORP&codeRubrique=FB_01_EN

Summary of Main Findings

⇒ Data characterising the number and distribution of HDV operators across Europe is not collected in any standard format, and is very difficult to locate. More data is available for freight vehicles than for other HDV categories.

⇒ A high proportion (~40%) of the Freight Tonne km in the EU are associated with longer distance trips (>500 km);

⇒ Cabotage is on the increase in the EU – possibly linked to recent EC legislation;

⇒ The majority of freight operators are smaller in size, with 85% of operators having fewer than 10 vehicles;;

⇒ Hire or reward accounts for 85% of tonne km and travel further, possibly with larger vehicles;;

⇒ Own account journeys tend to be much shorter than hire or reward;

⇒ The EU bus industry tends to be dominated by large national/international companies, while the coach sector is made up of a considerable number of much smaller operators;;

⇒ Coach industry passenger km appear to be mainly associated with higher mileage ‘Occasional Service’ type journeys, typical of the tourism industry.

This task aims to provide the basis on which an assessment might be made of how any future action might affect different sizes and types of transport operator.

It is possible that some measures could lead to a requirement to fit new low carbon technologies to these types of vehicles, and this could lead to changes (increases or decreases) in whole-life vehicle costs. By understanding the numbers and types of operators that could be affected by any future legislation, it will in the future be possible to calculate the costs and benefits of any future action to control, CO_2 emissions from heavy duty vehicles.

At the inception stage of the work, we outlined a range of potential sources of information that it was hoped would provide the necessary information to provide this understanding. This comprised the International Road Transport Union (IRU), the Union of Public Transport (UITP) and several other international stakeholder organisations. Information from these organisations was to be supported by the Transport Ministries and statistical offices for a number of individual member states. We also undertook a review of a number of national/international reports and publications.

For Heavy Goods Vehicles, we found that publicly available data which would be of use in this task was limited. The bulk of data presented in this section has come from Eurostat, supported to a limited extent by information provided by the IRU (International Road Transport Union) and some evidence from the UK Department for Transport. The AEA language team was used to translate some of the information and consult with individual member states. Table 2.11 below shows the results of these attempts to contact member states directly.

Table 2.11: Research from EU Member States statistics offices and transport departments

Country	Organisation	Findings
Austria	Federal Minister for Transport, Innovation and Technology	No data characterising fleet operators found.
Belgium	Service Public Fédéral Mobilité et Transports	No data characterising fleet operators found.
Czech Republic	Ministry of transport statistics	Data available on vehicle km for goods and passengers, but no characterisation of operators.
Denmark	Statistics Denmark Ministry of Transport	Data available on vehicle stock, which provides indirect support for some conclusions about goods vehicle operators.
France	Le Service de l'observation et des statistiques (SOeS) Ministère de l'Equipement des Transports et du Logement	Some data found on distribution of goods vehicle traffic on different road classes, but no data found from these sources to characterise operators.
Germany	Federal Statistical Office	No data characterising fleet operators found.
Italy	Italian National Institute of Statistics Ministero delle Infrastrutture e dei Trasporti	No data characterising fleet operators found.
Nether-lands	Statistics Netherlands (CBS) Ministry of Transport, Public Works and Water Management	Data available on vehicle stock, which provides indirect support for some conclusions about goods vehicle operators.
Poland	Ministry of Infrastructure:	No data characterising fleet operators found.
Sweden	Statistics Sweden	Data available on vehicle stock and activity, but no data found to characterise operators
Slovakia	Statistical Office of Slovak Republic Ministry of transport, post and telecommunications	No data characterising fleet operators found.

Information for Bus and Coach operations came mainly from a 2009 report for the (then) EC DG Transport and Energy (now DG Mobility and Transport) by Steer Davies Gleave (SDG, 2009)[8].

[8] Study of passenger transport by coach - Final Report, a study by Steer Davies Gleave for DG TREN (ref. TREN/E1/409-2007, June 2009, available at: http://ec.europa.eu/transport/road/studies/doc/2009_06_passenger_transport_by_coach.pdf

2.5.1 Trucks

2.5.1.1 Type of operator

Information to break down the activity type of operators (i.e. long-haul transport, distribution, public authority, etc) on a member state basis has not been identified. However, to compensate for this gap, we have instead taken a bottom-up look at available statistics on the journey types within each country.

Information on the fleets of EU public authorities was not identified, however the impact assessment carried out for Directive 2009/33 on the promotion of clean and energy-efficient road transport vehicles provides an indication. The assumption here was around 35,000 HDV registrations per year (around 7% of total registrations, which are ~480,000) in 2008 were for EU public authorities. It might be expected that these could be largely utility/service vehicles such as refuse collection vehicles (RCVs) and buses. For example, in the UK RCVs and street cleaning vehicles account for over 7% of all rigid trucks (around 5% of all heavy trucks) according to statistics from the UK Department for Transport (2010).

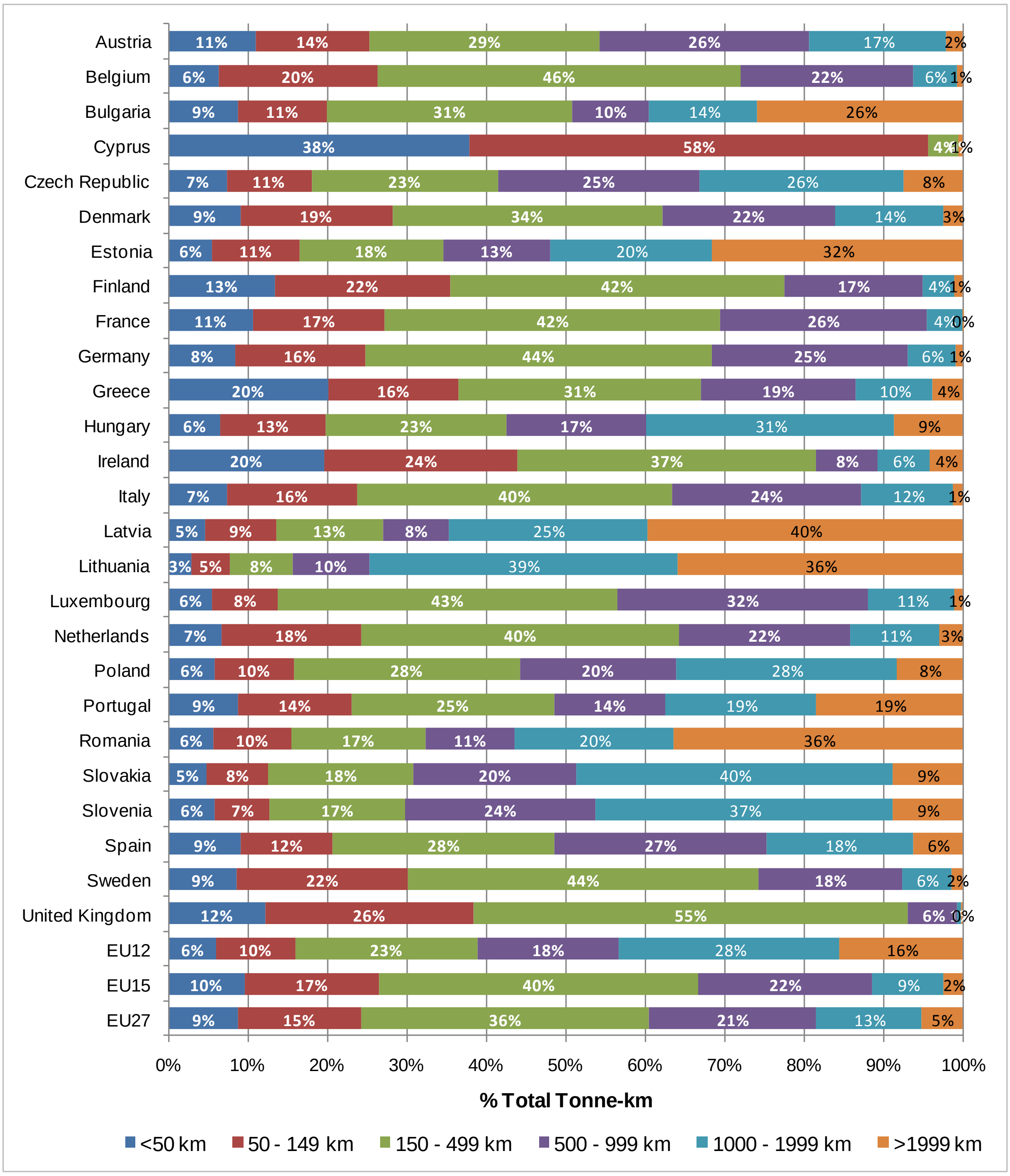
Eurostat data provides information on the proportion of tonne-km by distance (bands) in 2009, which gives an indication of the relative significance of short-haul v long haul within each member state, and the overall EU 27 (Figure 2–18).

This chart illustrates that across the EU15 and EU27 countries, more than 60% of the total tonne km could be thought of has short or medium-haul (i.e. <500km). It should be noted that those tonne km for journeys <149km are likely to contain an increasing proportion of local transport deliveries by LGVs (light goods vehicles) and will therefore not all be HGV journeys.

In some countries (particularly BE, FR, DK, SE), there is an increasing proportion of Cabotage - where goods or passengers are moved between two points in the same country by a vehicle registered in another country (Figure 2–19; Table 2.12). Often, countries restrict or do not permit cabotage – In the EU this has led to new rules for road cabotage, which are laid down in Regulation (EC) 1072/2009. Restrictions on cabotage are thought of as a form of protectionism, and there is a link with the difference between EU27 fuel duty (tax) rates.

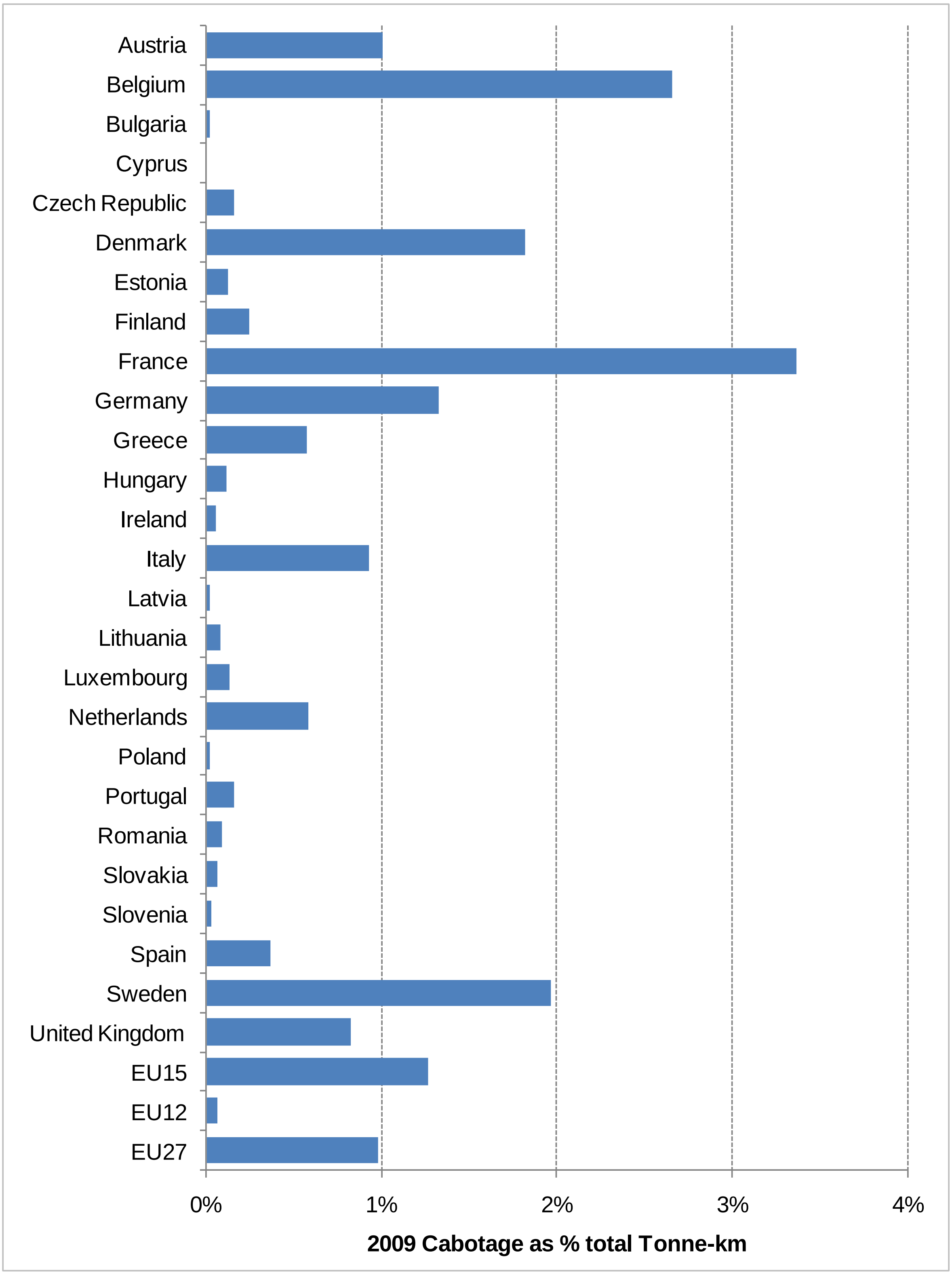
However, overall the relative proportion of Cabotage in any member state to its total tonne-km is low.

Figure 2–18: Proportion of total tonne-km for different journey distance bands by Member State in 2009



Source: Based on data from Eurostat (2010)

Figure 2–19: % Cabotage as a proportion of total tonne-km by Member State in 2009



Source: Based on data from Eurostat (2010)

Table 2.12: Trend in the % cabotage as a proportion of total tonne-km

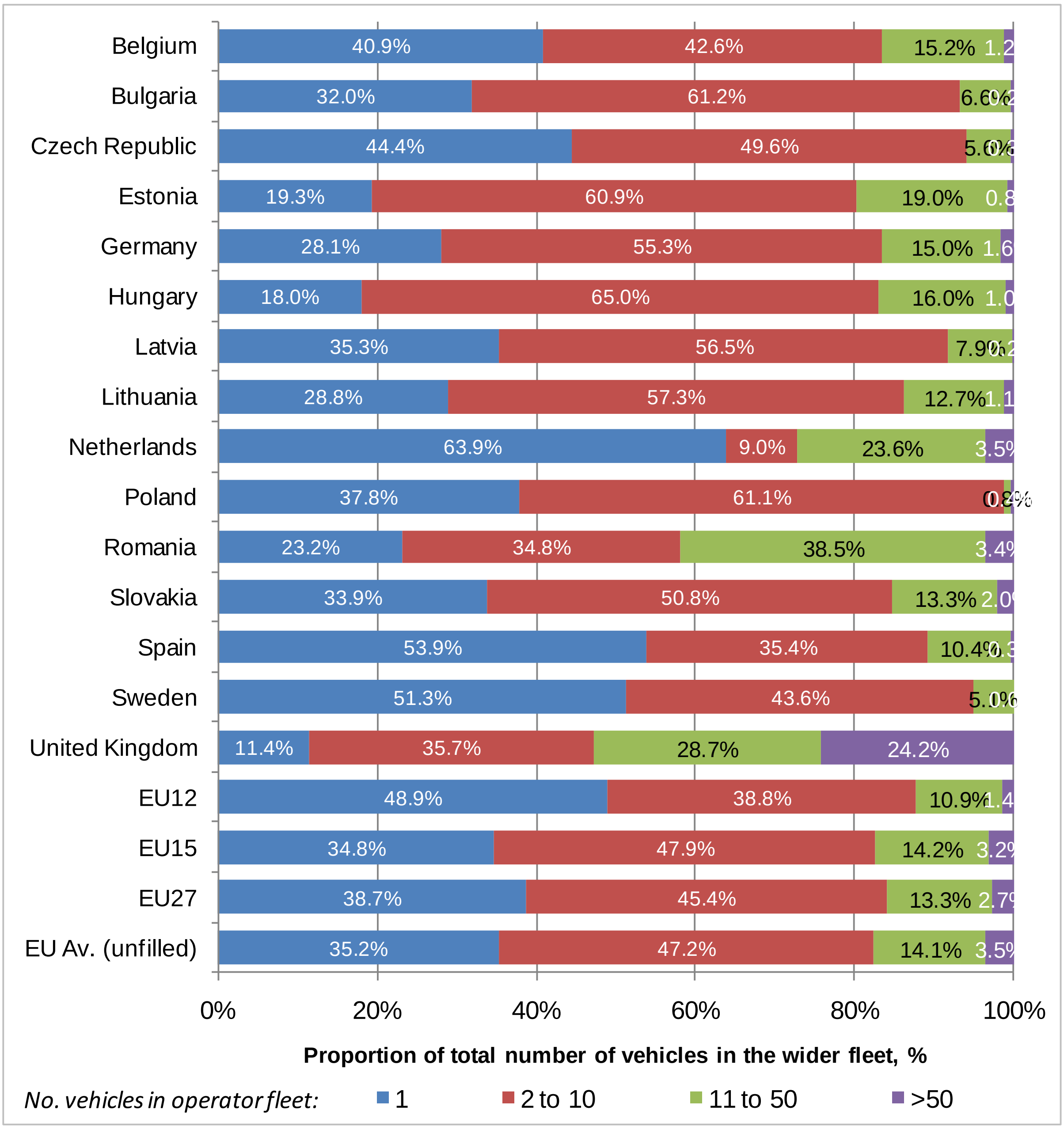
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Austria	0.42%	0.62%	0.81%	0.59%	0.57%	0.62%	0.66%	0.72%	1.02%	1.23%	1.01%
Belgium	1.12%	0.91%	1.15%	0.83%	1.06%	1.20%	1.34%	1.64%	1.57%	2.27%	2.66%
Bulgaria	0.01%	0.00%	0.02%	0.01%	0.03%	0.08%	0.00%	0.11%	0.11%	0.02%	0.02%
Cyprus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Czech Republic	0.05%	0.04%	0.04%	0.03%	0.06%	0.06%	0.08%	0.13%	0.18%	0.15%	0.16%
Denmark	0.18%	0.22%	0.46%	0.48%	0.56%	0.80%	0.92%	0.96%	1.28%	1.89%	1.82%
Estonia	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.04%	0.01%	0.03%	0.12%
Finland	0.00%	0.01%	0.11%	0.01%	0.08%	0.04%	0.07%	0.09%	0.16%	0.11%	0.24%
France	0.73%	1.02%	1.29%	1.62%	1.77%	2.16%	2.26%	2.14%	2.19%	2.64%	3.37%
Germany	0.91%	0.92%	0.94%	1.08%	1.04%	1.25%	1.18%	1.05%	1.05%	1.19%	1.33%
Greece	0.03%	0.24%	0.33%	0.45%	0.24%	0.16%	0.31%	0.43%	0.54%	0.58%	0.57%
Hungary	0.04%	0.11%	0.12%	0.12%	0.13%	0.14%	0.11%	0.12%	0.02%	0.06%	0.12%
Ireland	0.05%	0.20%	0.08%	0.10%	0.05%	0.71%	0.82%	1.01%	1.03%	0.00%	0.06%
Italy	0.53%	0.39%	0.49%	0.42%	0.55%	0.51%	0.41%	0.55%	0.59%	0.59%	0.93%
Latvia	0.00%	0.00%	0.00%	0.00%	0.15%	0.27%	0.02%	0.02%	0.01%	0.07%	0.02%
Lithuania	0.00%	0.00%	0.00%	0.00%	0.00%	0.04%	0.04%	0.02%	0.01%	0.03%	0.08%
Luxembourg	0.18%	0.12%	0.19%	0.26%	0.08%	0.12%	0.31%	0.20%	0.08%	0.07%	0.14%
Netherlands	0.20%	0.28%	0.35%	0.38%	0.27%	0.29%	0.33%	0.47%	0.49%	0.57%	0.58%
Poland	0.02%	0.03%	0.02%	0.03%	0.03%	0.04%	0.03%	0.02%	0.01%	0.03%	0.02%
Portugal	0.12%	0.16%	0.10%	0.12%	0.15%	0.17%	0.13%	0.05%	0.09%	0.01%	0.15%
Romania	0.03%	0.03%	0.04%	0.03%	0.13%	0.04%	0.09%	0.08%	0.06%	0.03%	0.09%
Slovakia	0.00%	0.00%	0.08%	0.01%	0.02%	0.04%	0.17%	0.10%	0.18%	0.18%	0.06%
Slovenia	0.01%	0.04%	0.08%	0.08%	0.01%	0.02%	0.08%	0.00%	0.02%	0.03%	0.03%
Spain	0.40%	0.28%	0.38%	0.35%	0.37%	0.42%	0.50%	0.58%	0.54%	0.49%	0.37%
Sweden	0.80%	0.60%	0.67%	0.58%	0.70%	0.96%	1.34%	1.37%	1.97%	2.20%	1.96%
United Kingdom	0.43%	0.80%	0.79%	0.90%	0.98%	1.11%	1.12%	1.02%	0.90%	1.00%	0.82%
EU15	**0.57%**	**0.64%**	**0.74%**	**0.79%**	**0.84%**	**0.95%**	**0.97%**	**0.98%**	**1.01%**	**1.13%**	**1.26%**
EU12	**0.02%**	**0.03%**	**0.04%**	**0.03%**	**0.06%**	**0.06%**	**0.07%**	**0.06%**	**0.06%**	**0.06%**	**0.06%**
EU27	**0.45%**	**0.52%**	**0.60%**	**0.65%**	**0.71%**	**0.80%**	**0.81%**	**0.81%**	**0.81%**	**0.90%**	**0.98%**

Source: Based on data from Eurostat (2010)

2.5.1.2 Size distribution

Data from the IRU (2004) has been supplemented with information from the UK Department for Transport (2010) have been combined to produce a picture of fleet size variation across Member States. Across the EU as a whole it is estimated around 85% of fleets are made up of vehicles with fewer than 10 vehicles (Figure 2–20). The only country with available data which is significantly different to this is the UK, which appears to have a larger proportion of bigger fleets compared to the other countries in this table. However, it is difficult to draw firm conclusions here as this result may be strongly influenced by different statistical basis for the UK figure in comparison to those for other countries.

Figure 2–20: Size distribution of companies active in domestic and international goods road transport, % total number of vehicles in the wider truck fleet



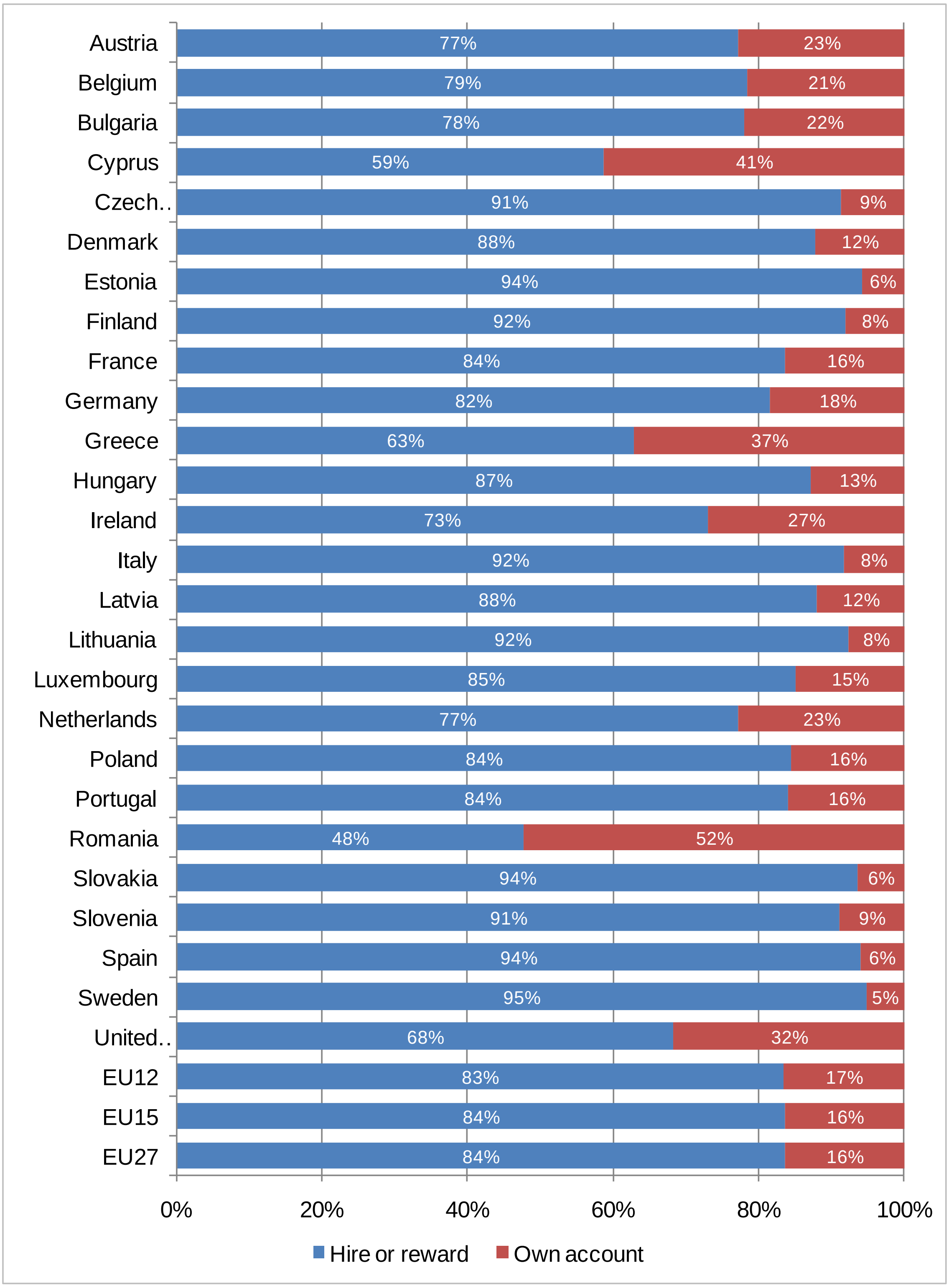
Source: Based on data from the IRU (2004) and UK DfT (2010)

Notes: Fleet size breakdown for missing EU countries has been estimated in order to calculate approximate figures for the EU15, EU12 and EU27. For the purposes of this estimation it was assumed the splits for the missing countries were equivalent to those for which there were data as follows:
AT, FR, LU = Germany; CY, GR, IT, MT, PT = Spain; DK, FI = Sweden; IE = UK, and SI = Slovakia.
The average based on the countries for which there is data has also been presented for comparison.

2.5.1.3 Own-account versus Hire or Reward

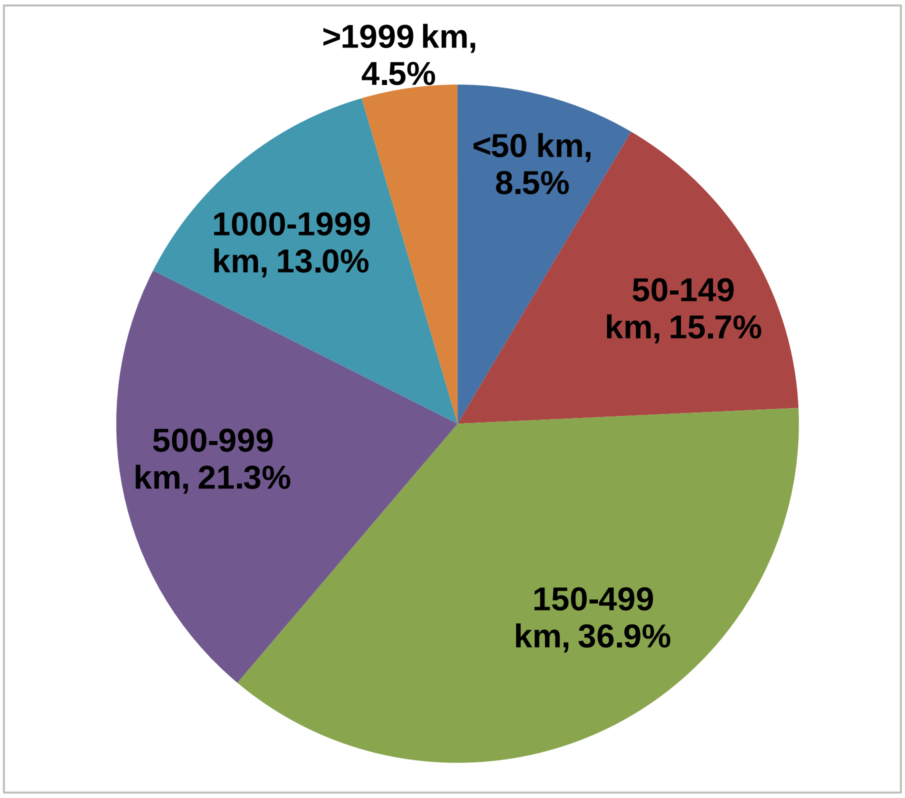
Figure 2–21 illustrates that across the EU around 85% of the tonne km are carried out on a Hire or Reward (HoR) basis, with the remainder as Own Account (OA). The reason for this appears to be that for longer haul operations transport is predominantly provided by HoR operations as part of a 3rd Party Logistics (3PL) provider service. Evidence for this is provided by Eurostat data that allows further disaggregation to show tonne km by distance band (Figure 2–22). Own account operators can be seen to operate much shorter trips; only 15% of Own Account tonne km are greater than 500km, compared to approximately 50% of Hire and Reward.

Figure 2–21: % road freight transport, tonne-km split by operation type (own-account and hire or reward), by Member State for 2009

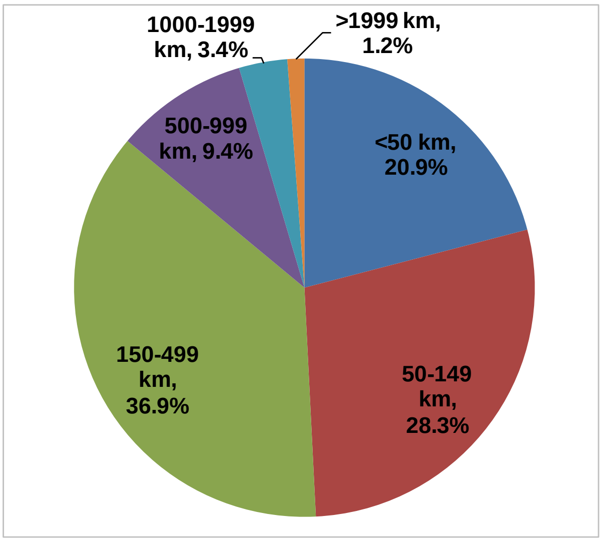


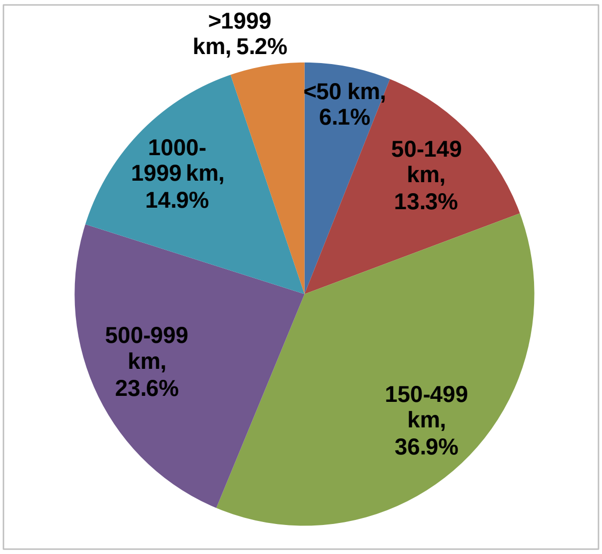
Source: Based on data from Eurostat (2010)

Figure 2–22: EU27 Tonne km by distance band for own account and hire or reward operations for 2009



Total





Own Account **Hire or Reward**

Source: Based on data from Eurostat (2010)

Using the data presented in Table 2.13 below, it is possible to derive average journey distances and average loading for the two operator types (shown in Table 2.14). The rather unexpected trend in loading by distance band is most likely due to differences in empty running (i.e. greater for longer journeys), since the vkm statistics included both loaded and unloaded vehicles. This appears to be supported by Eurostat analysis on equivalent datasets not readily available in the public domain from their data portal (Eurostat, 2007)[9].

This appears to show that Hire or Reward operations are on average travelling further and which may be due to their operations using either (a) larger vehicles, (b) vehicles with better load factors, or (c) a combination of (a) and (b).

It is not possible to confirm from these figures exactly which of these is the actual situation. However, UK data from the Department for Transport (Table 2.15) seems to indicate that Hire or Reward on average use larger vehicles in the UK at least.

Table 2.13: EU27 activity by distance band for own account and hire or reward operations for 2009

2009 Total EU27	Own Account			Hire or Reward		
	Vehicle km (millions)	Tonne km (millions)	1000 Tonnes	Vehicle km (millions)	Tonne km (millions)	1000 Tonnes
Less than 50 km	6,266	57,158	3,634,258	5,796	83,792	4,728,502
From 50 to 149 km	9,773	77,284	1,014,235	13,569	183,413	2,159,833
From 150 to 499 km	13,725	100,679	490,945	39,221	510,613	2,029,526
From 500 to 999 km	3,334	25,570	43,440	23,851	326,272	504,866
From 1 000 to 1 999 km	2,152	9,268	7,462	15,367	206,176	154,925
Over 1999 km	368	3,241	1,258	4,942	72,060	30,028
Total	**35,618**	**273,200**	**5,191,599**	**102,745**	**1,382,326**	**9,607,680**
Less than 50 km	17.6%	20.9%	70.0%	5.6%	6.1%	49.2%
From 50 to 149 km	27.4%	28.3%	19.5%	13.2%	13.3%	22.5%
From 150 to 499 km	38.5%	36.9%	9.5%	38.2%	36.9%	21.1%
From 500 to 999 km	9.4%	9.4%	0.8%	23.2%	23.6%	5.3%
From 1 000 to 1 999 km	6.0%	3.4%	0.1%	15.0%	14.9%	1.6%
Over 1999 km	1.0%	1.2%	0.0%	4.8%	5.2%	0.3%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Based on data from Eurostat (2010)

Table 2.14: Derived EU27 average journey distances and vehicle loading for own account and hire or reward operations for 2009

	Own Account		Hire or Reward	
	Av. journey distance (km)	Av. loading (tonnes)	Av. journey distance (km)	Av. loading (tonnes)
Less than 50 km	16	9.12	18	14.46
From 50 to 149 km	76	7.91	85	13.52
From 150 to 499 km	205	7.34	252	13.02
From 500 to 999 km	589	7.67	646	13.68
From 1 000 to 1 999 km	1,242	4.31	1,331	13.42
Over 1999 km	2,576	8.81	2,400	14.58
Total	**53**	**7.67**	**144**	**13.45**

Source: Based on data from Eurostat (2010), derived from figures in Table 2.13

[9] "Average loads, distances and empty running in road freight transport - 2005", Eurostat Statistics in focus, TRANSPORT 117/2007 by Simo PASI, available at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-07-117/EN/KS-SF-07-117-EN.PDF

Table 2.15: Types of vehicles used by own account and hire and reward fleets in the UK for 2008

	Vehicle type and size (GVW tonnes)	Tonne kilometres (millions)			Vehicle kilometres (millions)		
		Mainly public haulage	Mainly own account	Total	Mainly public haulage	Mainly own account	Total
Rigid vehicles	Over 3.5 to 7.5	874	2,236	3,110	932	2,558	3,490
	Over 7.5 to 17	752	1,655	2,407	305	814	1,119
	Over 17 to 25	3,872	4,414	8,286	1,027	1,514	2,540
	Over 25	10,735	9,527	20,262	1,506	1,665	3,172
	All rigids	**16,232**	**17,833**	**34,065**	**3,770**	**6,551**	**10,321**
Articulated vehicles	Over 3.5 to 33	2,389	2,790	5,179	419	520	939
	Over 33	84,235	28,233	112,469	7,084	2,826	9,910
	All artics	**86,624**	**31,023**	**117,647**	**7,503**	**3,346**	**10,850**
All vehicles	Over 3.5 to 25	5,640	8,465	14,106	2,295	4,940	7,235
	Over 25 to 35	13,611	12,463	26,074	1,970	2,181	4,151
	Over 35	83,605	27,927	111,532	7,008	2,777	9,785
	Total	**102,856**	**48,856**	**151,712**	**11,273**	**9,898**	**21,171**
Rigid vehicles	Over 3.5 to 7.5	5.4%	12.5%	9.1%	24.7%	39.0%	33.8%
	Over 7.5 to 17	4.6%	9.3%	7.1%	8.1%	12.4%	10.8%
	Over 17 to 25	23.9%	24.8%	24.3%	27.2%	23.1%	24.6%
	Over 25	66.1%	53.4%	59.5%	39.9%	25.4%	30.7%
	All rigids	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Articulated vehicles	Over 3.5 to 33	2.8%	9.0%	4.4%	5.6%	15.5%	8.7%
	Over 33	97.2%	91.0%	95.6%	94.4%	84.5%	91.3%
	All artics	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
All vehicles	Over 3.5 to 25	5.5%	17.3%	9.3%	20.4%	49.9%	34.2%
	Over 25 to 35	13.2%	25.5%	17.2%	17.5%	22.0%	19.6%
	Over 35	81.3%	57.2%	73.5%	62.2%	28.1%	46.2%
	Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: UK Department for Transport (2010)

2.5.2 Buses and Coaches

As with HGV operators, little statistical detail has been found to be available to show the number and distribution European of bus and coach operators. One example of why information is harder to come by is the UK operating licence process. Freight vehicle operators must apply to a central Government agency for an operating license, whereas Passenger Service Vehicle (PSV) operators often receive their license from a local authority, meaning no overall central record is compiled.

The paucity of data was highlighted in a recent study for the EC by Steer Davies Gleave (SDG)[10], which took the approach of focussing on the data of 8 Member States. As a result the report provides a clear caveat up front that the results are based on significant assumptions and hence uncertainties. However, the findings of this study are the most comprehensive identified and therefore most of the figures quoted in this section are either based on or directly replicated from data and figures in this report.

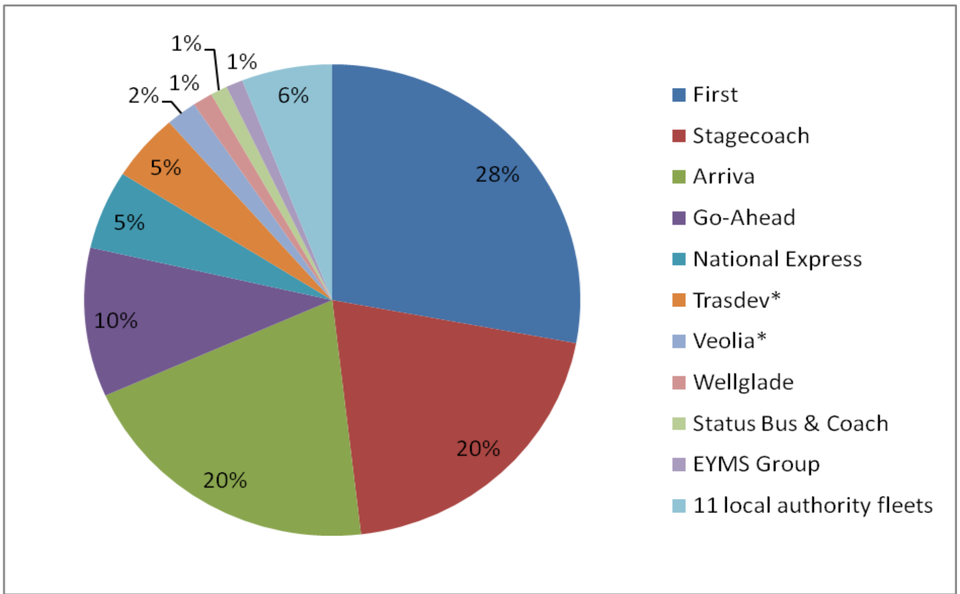
The Bus industry tends to be a mix of public fleets and private companies operating under public contracts (e.g. UK split by operator). Coach operators are predominately private sector organisations, operating commercial trips for tourism, and some school/local authority contracts for certain trip types.

[10] Study of passenger transport by coach - Final Report, a study by Steer Davies Gleave for DG TREN (ref. TREN/E1/409-2007, June 2009, available at: http://ec.europa.eu/transport/road/studies/doc/2009_06_passenger_transport_by_coach.pdf

Across Europe many bus services have been privatised in the last 20 years. In terms of fleet sizes, this has generally resulted in the formation of many new small operators, followed by successive periods of agglomeration through mergers and acquisitions. As a result, there are a large number of small operators still in existence across Europe, many of them publicly owned. However, the majority of the market is serviced by a smaller number of large companies. Figure 2–23 illustrates the position in the UK, where the four largest operators (First, Stagecoach, Arriva and Go-Ahead) account for 78% of the overall market. Despite the dominance of the market by this group, there remains a number of smaller independent bus operators along with a few bus operators that are Local Authority owned.

Smaller operators dominate the UK coach industry. Unlike the bus industry, many are family owned and managed businesses. They provide the majority of school transport services to Local Authorities and very often supply transport to holiday and touring companies as their sub-contractors. The larger coach organisations are also very much integrated into the tourist industry.

Figure 2–23: Market share of bus and coach operators in the UK, 2008



On the European level, the EPTO is the trade association of the European Passenger Transport Operators, whose members are the ten largest private public transport companies in Europe[11]. Members and include the following organisations which operate 80,000 buses & coaches in 25 countries (22 in the EU) in urban, regional, national and international bus and coach services:

- Arriva (www.arriva.co.uk)
- First Group (www.firstgroup.com)
- Go-Ahead Group (www.go-ahead.com)
- Grupo Barraqueiro (www.barraqueiro.com)
- Keolis (www.keolis.com)
- National Express (www.nationalexpress.com)
- Stagecoach (www.stagecoach.com)
- Transdev (www.transdev.eu)
- Transdev-Connexxion (www.connexxion.nl)
- Veolia Transport (www.veolia-transport.com)

[11] More information on EPTO is available at: http://epto.net/index.html

However, SDG (2009) have estimated the total fleet size to be around 680,000 vehicles (see Table 2.16), meaning the 10 largest private operators account for only around 12% of the total bus and coach fleet in the EU. This is also consistent with previous SDG (2009) estimates for numbers of EU operators presented in Table 2.17.

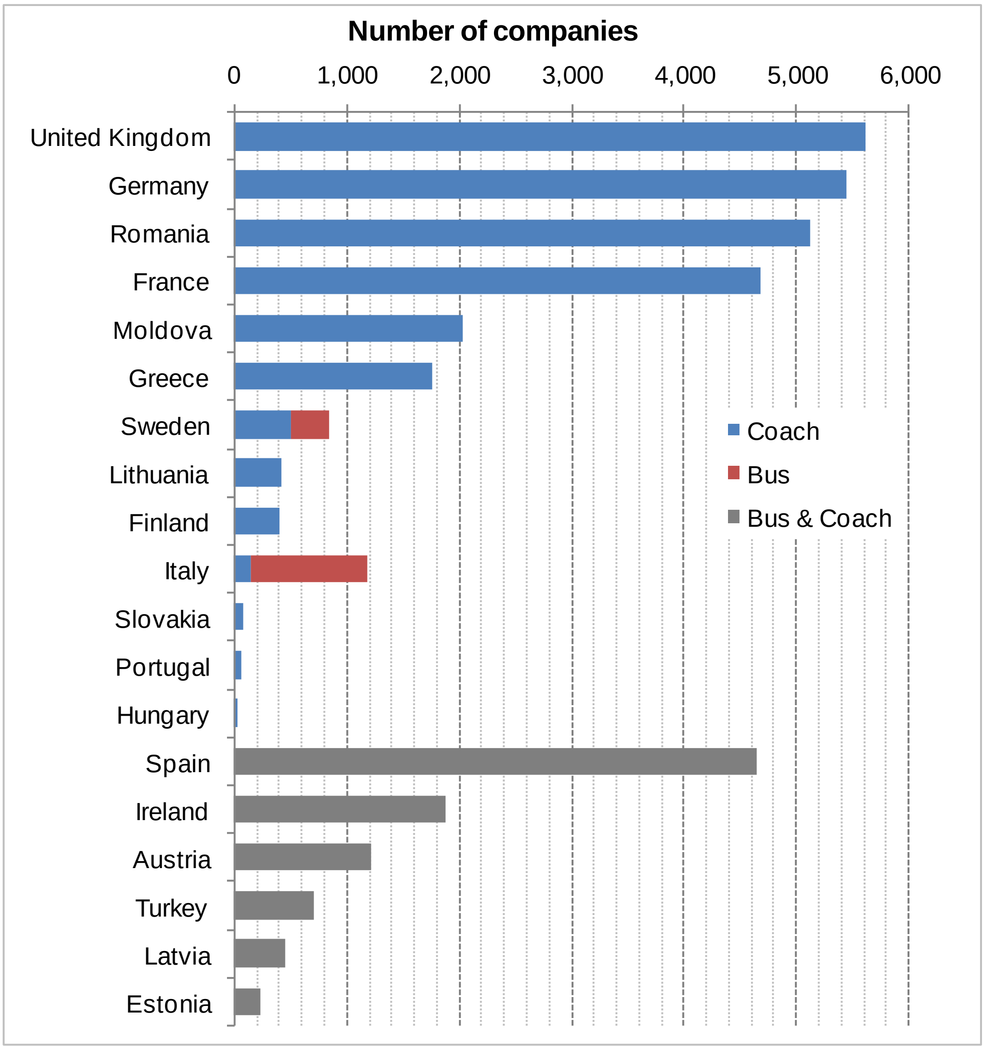
Figure 2–24 illustrates the number of coach operators in the countries included in the SDG study. On this basis the average fleet size for coach operators was estimated at 16 vehicles, though this was found to be even smaller in some member states (e.g. 4 vehicles in the UK).

Table 2.16: Estimate of European bus and coach fleet size

	Coach	Bus	Bus & Coach	% Total
EU15	180,185	277,167	457,352	67%
EU12	68,694	153,020	221,714	33%
EU Total	**248,879**	**430,187**	**679,066**	
EPTO Fleet			80,000	12%

Source: EU figures reproduced from Figure 4.11 of a report on the coach sector for DG TREN by Steer Davies Gleave (2009). EPTO fleet based on figure quoted on their website (2010).

Figure 2–24: Number of companies operating coach services by country



Source: Reproduced from Figure 4.16 of a coach sector report for DG TREN by Steer Davies Gleave (2009)

Table 2.17: Indicative estimate of the number of EU bus and coach companies

	Coach	Bus	Bus & Coach
Number of companies			
EU15	21,842	7,976	29,818
EU12	7,379	6,021	13,400
Total EU	**29,221**	**13,997**	**43,218**
Average company fleet size			
EU15	8.2	34.8	15.3
EU12	9.3	25.4	16.5
Total EU	**8.5**	**30.7**	**15.7**

Source: Reproduced from a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

Notes: Average fleet size estimated from Table 4.16 (number of companies) and Table 4.11 (estimate of European bus & coach fleet size) of SDG (2009)

The coach industry is generally thought to be seeing increased activity in recent years. Coaches are generally used for longer journeys, and account for more passenger km, at a greater efficiency due to the operational cycle. This is supported by estimates derived by SDG (2009) for European fleet sizes and activity of buses and coaches. Table 2.18 illustrates the higher number of passenger km's undertaken by coaches in relation to buses.

The SDG report suggests that EU enlargement has contributed to the increased importance of scheduled coach travel, where it accounts for a higher proportion of inter-city passenger transport in new member states.

Table 2.18: Indicative estimate of overall market size of bus and coaches in the EU

Passenger km (million)	**Estimate based on global averages**			**Estimate based on State groupings**		
	Bus	Coach	Bus and Coach	Bus	Coach	Bus and Coach
EU15	209,519	207,381	416,900	192,091	224,809	416,900
EU12	49,998	55,602	105,600	46,076	59,524	105,600
Total EU	**259,517**	**262,983**	**522,500**	**238,167**	**284,333**	**522,500**

Source: Reproduced from Table 4.4 of a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

Table 2.19: Additional EU indicative estimates of overall coach market

	Coach Vehicle km (millions)	Coach passenger journeys (millions)	Average Occupancy (No. Passengers)*	Av. annual km per vehicle **
EU15	8,055	4,895	25.7	44,704
EU12	2,079	1,726	26.7	30,265
Total EU	**10,134**	**6,621**	**26.0**	**40,719**

Source: Reproduced from Table 4.5 of a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

Notes: * Average occupancy derived from SDG (2009) estimates for passenger-km and vehicle-km
** Average annual km derived from SDG (2009) estimates for fleet size and total vehicle km

The SDG (2009) report categorised coach operations into three different types (consistent with EC Regulation 684/92):

a) *Regular (domestic and international) services* operate at specified times on defined routes, with specific boarding and alighting points, and are open to all, i.e. most scheduled services for bus and coach.

b) *Special regular services* operate on defined routes and at defined times, but provide for the carriage of specific types of passengers to the exclusion of others, e.g. school buses, employee buses, etc.

c) *Occasional services are services* which do not meet the definition of regular or special regular services, and which are characterized above all by the fact that they carry groups of passengers assembled on the initiative of the customer or the carrier itself. Examples include tourist coaches, coaches for excursions, etc.

However, SDG do note in their report that there are very few cases where national data is disaggregated in this way, and where it is, there are differences between Member States in how different services are classified.

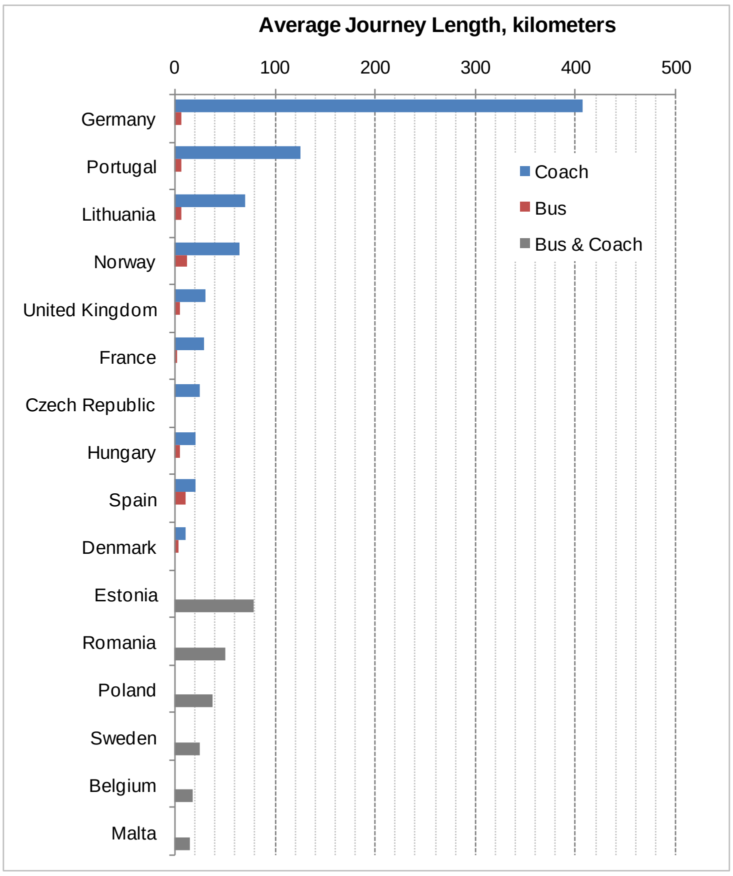
Table 2.20 shows that the greatest proportion of passenger km (pkm) in the EU are attributed to the Occasional Services category – the lower number of journeys associated with the passenger km travelled reinforce the fact that these tend to be longer journeys of the type associated with tourist trips. The following Figure 2–25 illustrates the long average journey distance for coaches for a number of different countries. Average journey distances are particularly large for Germany, which has a very active touring coach sector. The following Figure 2–26 also illustrates the total passenger km by country. According to the SDG (2009) report, France does not have a large scheduled coach service sector, due to the strength of its rail network, so much of their passenger km are likely also attributable to coach tourism.

Table 2.20: Indicative estimate of EU-wide coach demand by category

	Journeys (millions)	Passenger km (millions)	% pkm
Regular (Coach)	2,912	81,226	30.9%
Special Regular (Coach)	2,226	52,572	20.0%
Occasional (Coach)	1,484	129,185	49.1%
Total Coach	**6,622**	**262,983**	

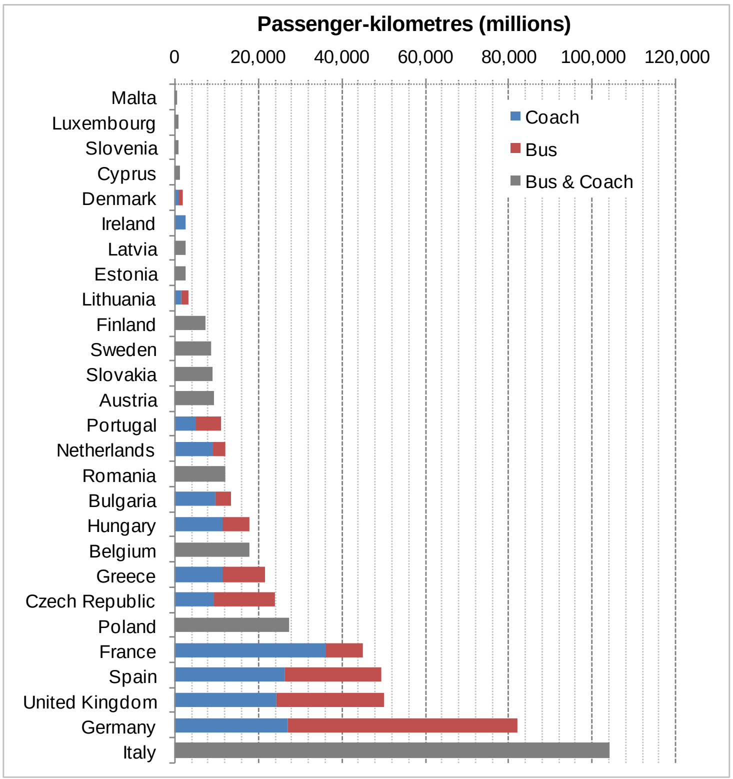
Source: Coach statistics reproduced from Table 1.3 of a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

Figure 2–25: Average journey length (km) for bus and coach journeys by country



Source: Reproduced from a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

Figure 2–26: Passenger km by country



Source: Reproduced from a report on the coach sector for DG TREN by Steer Davies Gleave (SDG, 2009)

2.6 New vehicle market size and structure

Objectives:

The purpose of this sub-task was to provide an information on:

"New vehicle market size and structure:

- *distribution by type of application: road freight (long-haul, inter-urban, urban distribution etc), construction, vocational, buses (long-distance vs urban etc)"*

Summary of Main Findings

⇒ The majority of new road tractor registrations are by Hire or Reward (HoR) operators (as opposed to Own Account (OA) operators). Because European statistics are mixed together for vans and rigid trucks it is difficult to make comparisons for rigid trucks. However, datasets on new trailer registrations appear to indicate a greater proportion of these are purchased by OA operators leading to a split in ownership (and incentives for fuel efficiency) between the vehicles and the trailers they pull in some cases.

⇒ Datasets on rigid vehicle and trailer body types have allowed the evaluation of the significance of important truck sub-categories, such as refrigerated/temperature controlled freight transport which are estimated to account for around 7% of all new vehicle and 10% of new trailer registrations. This is important as such vehicles typically consume in the order of 20% more fuel than other body types due to the refrigeration equipment.

Summary of Main Findings

⇒ Information provided by ACEA has also allowed the estimation of the split of heavy duty trucks between different mission profiles with different activity and fuel consumption profiles, such as urban delivery, municipal utility vehicles, regional distribution, long haul freight transport and construction.

⇒ Little information is available on the European new bus and coach market other than the split into weight categories and a gradual shift to the lighter <16t class buses. A recent report by SDG (2009) on the bus sector has suggested that most coaches fall into the heavier >16 t weight category. This category currently accounts for around 60% of total new registrations, but will also contain heavier single-deck as well as double-deck and articulated buses.

⇒ According to data provided by ACEA from its members, recent registrations of buses have accounted for almost 76% of all bus and coach registrations from 2007-2009. In addition, almost 26% of all bus and coach chassis produced by ACEA members also went for final completion by other bus/coach bodybuilders, with a greater proportion of coach chasiss (37%) compared to bus chassis (22%). Double-deck and articualted buses and coaches accounted for 13% of all registrations, with the vast majority being for urban bus applications.

In order to build up a comprehensive picture of the new vehicle market size for heavy duty vehicles, it has been necessary to obtain sales and registration data from a number of sources including Eurostat, individual member states and from ACEA. The most reliable of the datasets is that from ACEA who produce data on the new commercial vehicle registrations figures for all the EU27 Member States.

ACEA use the Association Auxilliaire de l'Automobile (AAA) classification system which is updated every month for the current year and previous years. This enables us to present data on the new vehicle market size and structure under the following weight categories.

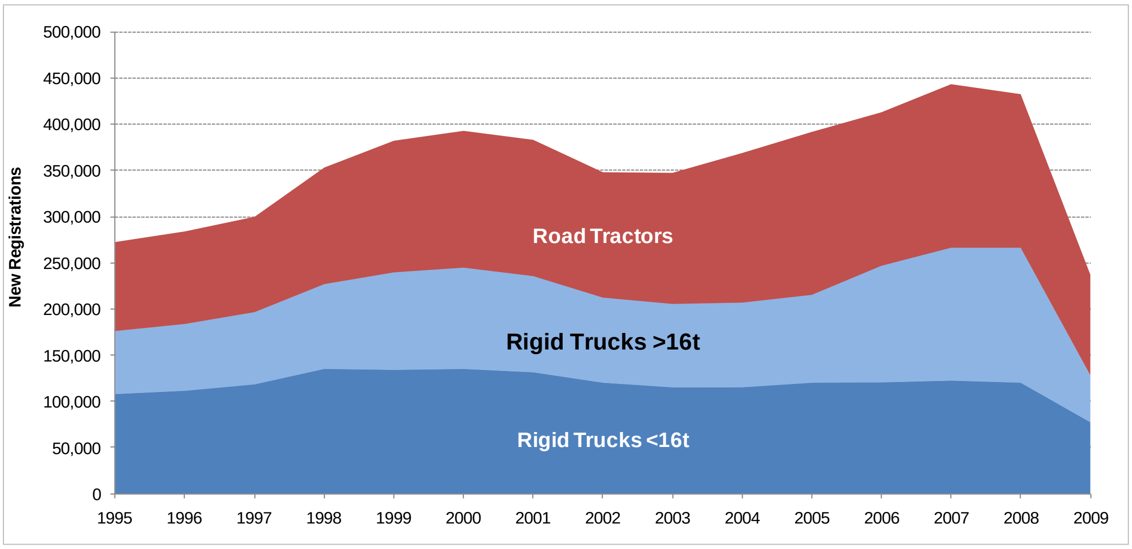
1. Commercial Vehicles – 3.5t - 16t GVW
2. Commercial Vehicles – Buses and Coaches 3.5t - 16t GVW
3. Heavy Commercial Vehicles – Heavy vehicles >16t GVW
4. Heavy Buses and Coaches – Buses and Coaches >16t GVW

However, the ACEA dataset is incomplete for earlier years for the newer Member States and so estimates needed to be developed based on other statistics (such as those available from Eurostat). Additional information has also been collected from a variety of sources to enable better characterisation of the new vehicle market and is presented in the following sections.

2.6.1 New Trucks

The following Figure 2–27, Figure 2–28 and Figure 2–29 present summaries of the time-series of registrations of new trucks and trailers in the EU27. Eurostat compiles registration statistics for road tractors and lorries. The lorries category combines data for light commercial vehicles (LCVs) as well as rigid trucks. ACEA provides statistics for LCVs and separately trucks split by two weight categories but not by rigid trucks and road tractors. AEA have estimated the corresponding split of registrations of new trucks in Figure 2–27 and Figure 2–28 by combining these two datasets. These estimates are based on the following key approximations: (i) Road Tractors are all >16 tonnes GVW (i.e. all trucks <16t are rigids), (ii) Rigid Trucks = Lorries minus LCVs.. In Figure 2–29, trailers less than 10 tonnes load capacity have been excluded as they are mostly for use with light commercial vehicles and not applicable to heavy duty trucks. In general the figures indicate a gradual increase in the proportion of new registrations of road tractors and larger rigid trucks. However, in 2009 registrations of rigid trucks >16 tonnes declined more than those of road tractors and lighter rigid vehicles, which comprised respectively of 33% and 46% of total 2009 truck registrations.

Figure 2–27: EU27 New registrations of rigid trucks and road tractors

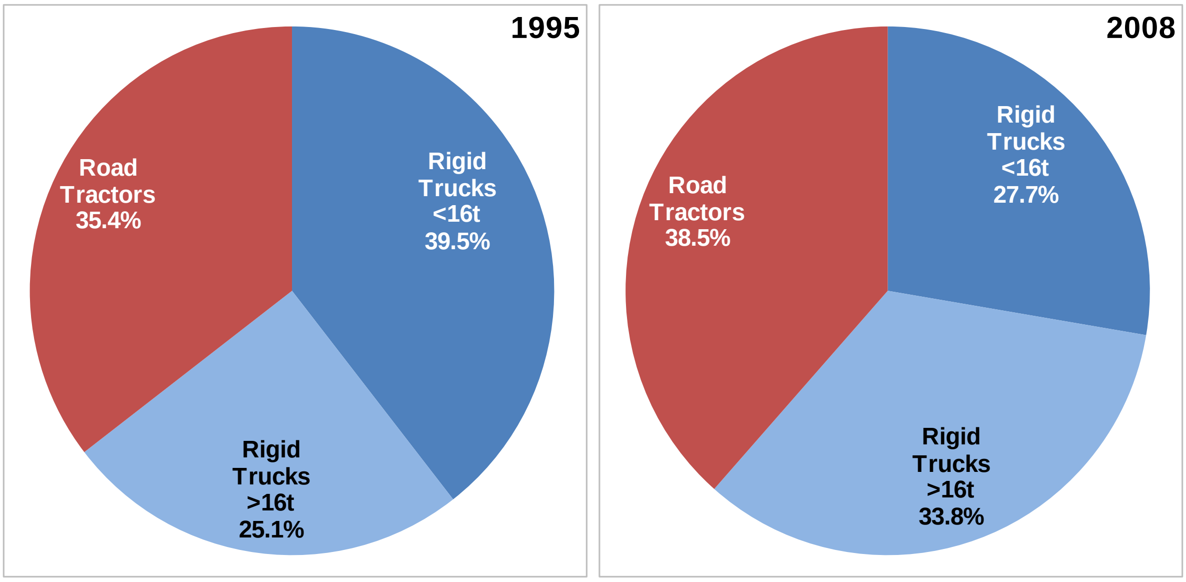


Source: Based on datasets from ACEA (2010) and Eurostat (2010)

Notes: Rigid Trucks < 16 t include all trucks from 3.5 tonnes to 16 tonnes GVW. AEA have estimated the corresponding split of registrations of new trucks (above) by combining the ACEA and Eurostat datasets which provide different breakdowns of light and heavy commercial vehicles.

It is also worth noting that the new registrations of road tractors and semi-trailers presented in Figure 2–27 and Figure 2–29 appear to be on an approximately 1:1 basis. This is also consistent with information on the existing parc (presented in later Section 2.7).

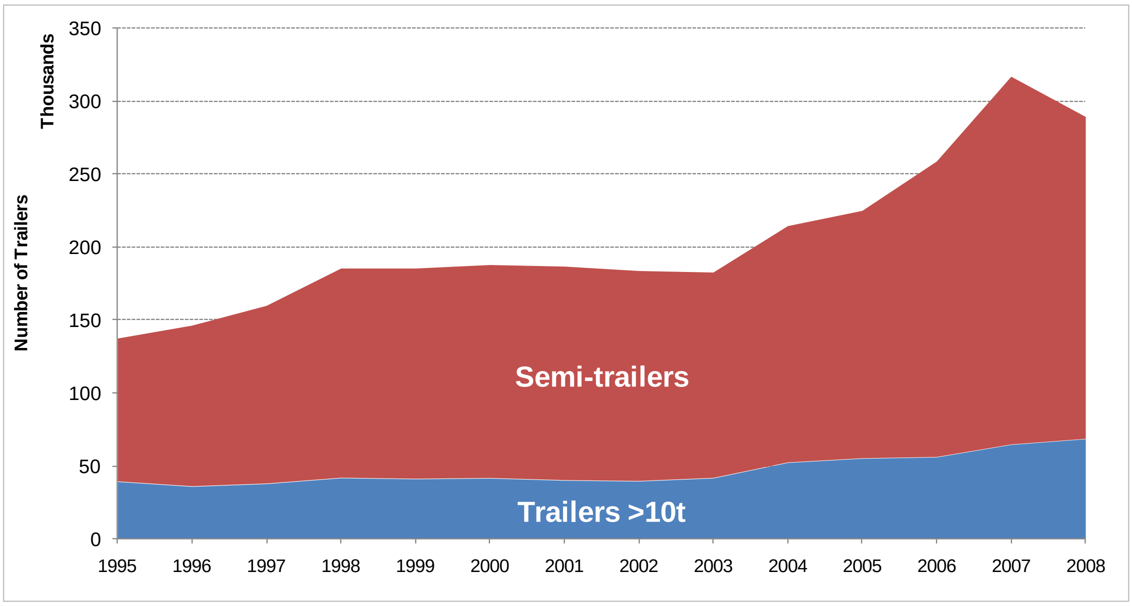
Figure 2–28: EU27 split of new registrations of rigid trucks and road tractors for 1995 and 2008



Source: Based on datasets from ACEA (2010) and Eurostat (2010)

Notes: Rigid Trucks < 16 t include all trucks from 3.5 tonnes to 16 tonnes GVW. AEA have estimated the split of registrations of new trucks by combining ACEA and Eurostat datasets.

Figure 2–29: EU27 trailer registrations by type (with trailers <10t removed), 1995-2008 (Eurostat, 2010)

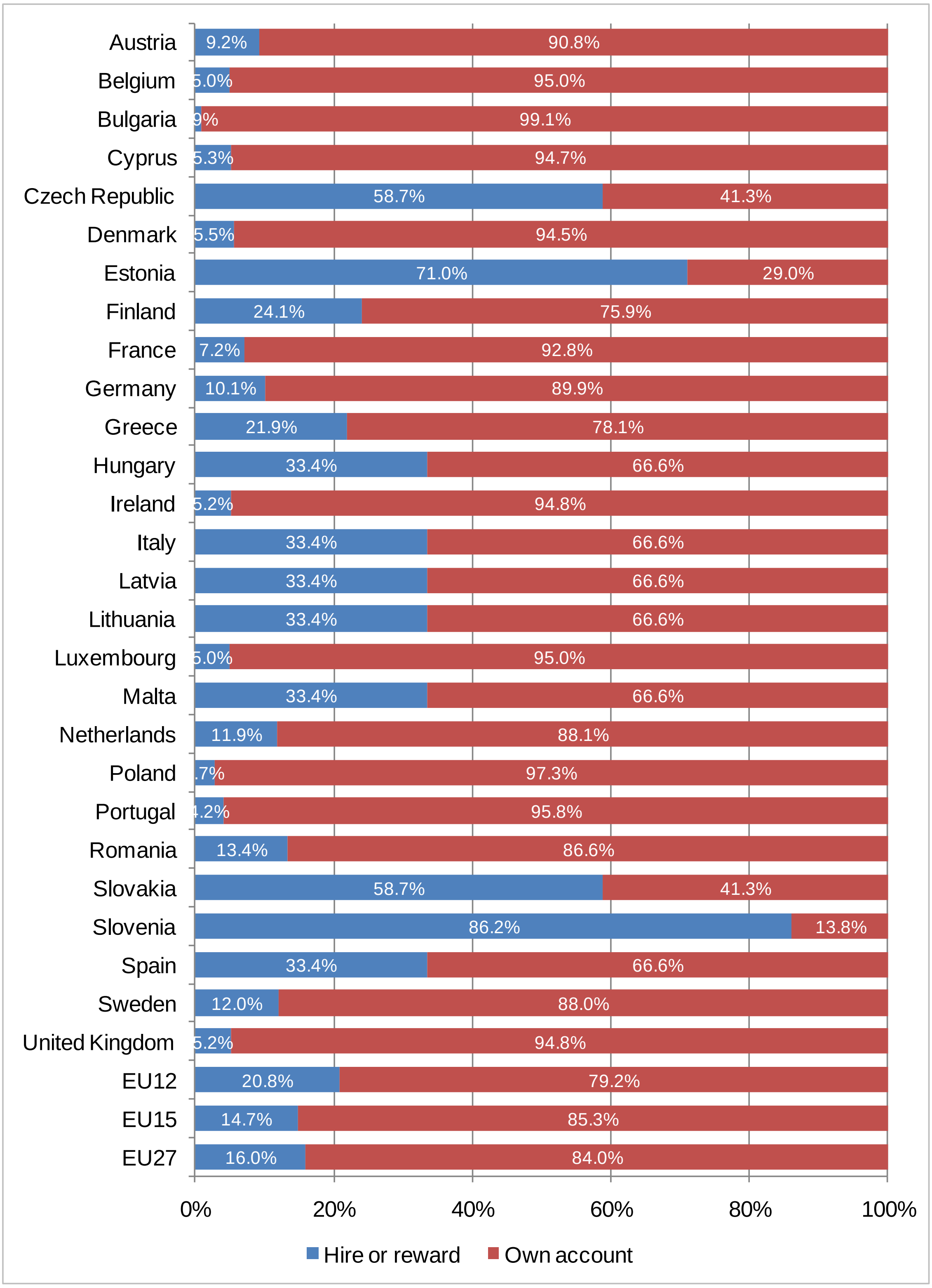


Source: Eurostat, 2010

Notes: Data on registrations of trailers by load capacity was used to remove trailers most likely to not be for heavy truck application from the Eurostat dataset.

Also available from Eurostat are national statistics on how new truck registrations split between own account (OA) and hire or reward (HoR) vehicle operators. These are presented in Figure 2–30 (for lorries = LCVs and rigid trucks) and Figure 2–31 (for road tractors). These statistics illustrate a marked difference in the relative split of ownership of lorries - which are predominantly registered first by OA operators, and road tractors – predominantly first registered by HoR operators. There is also significant variation between EU Member States in this regard. Some caution does need to be applied in interpreting apparent trends in ownership for rigid trucks, however. This is because around 90% of the vehicles included in the lorries category are light commercial vehicles (as opposed to rigid trucks), which are used predominantly by OA operators for deliveries or as service vehicles.

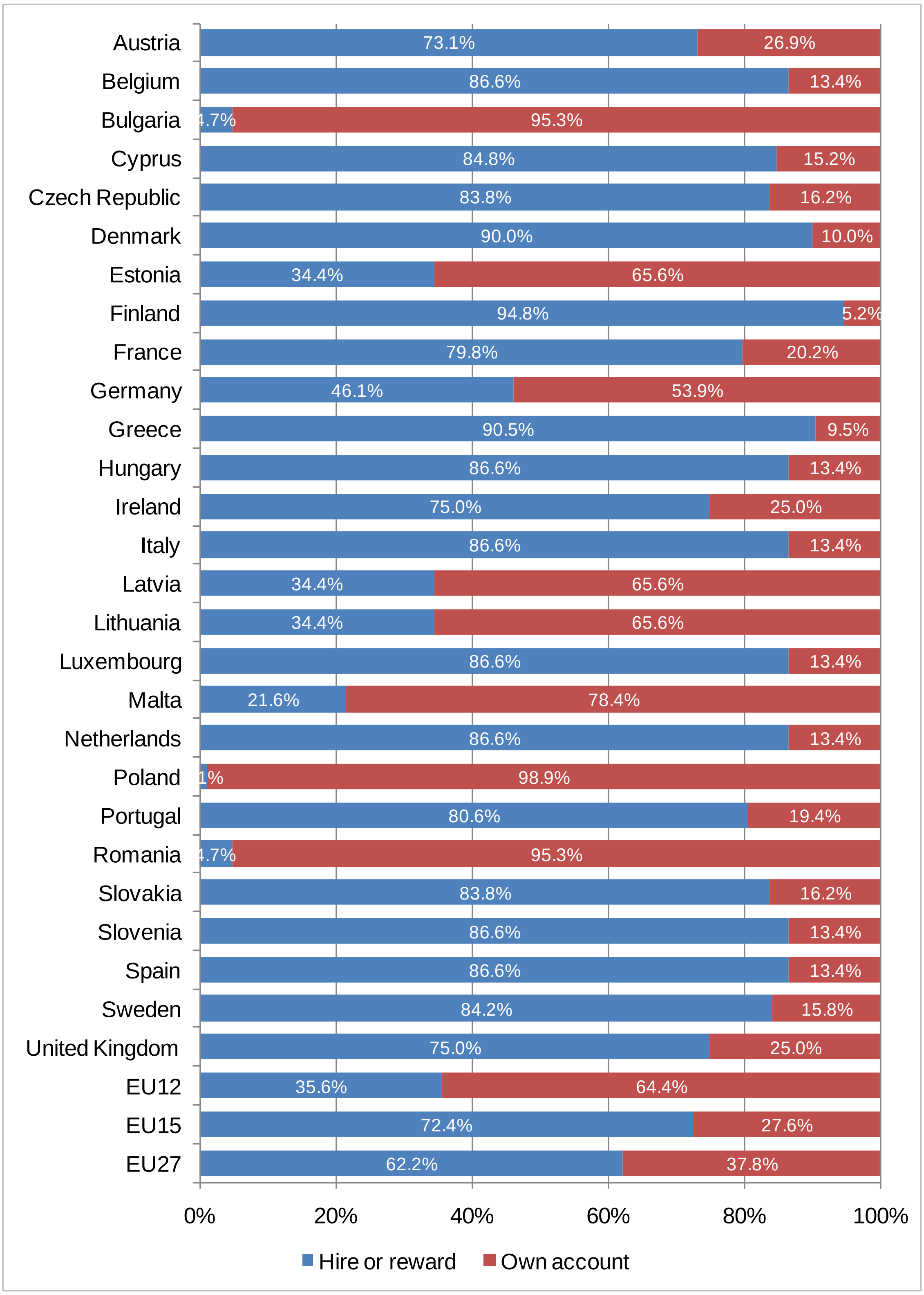
Figure 2–30: EU27 New registrations of lorries by kind of transport (number) by Member State



Source: Eurostat (2010)

Notes: The Eurostat lorries category combines data for light commercial vehicles (LCVs) as well as rigid trucks.

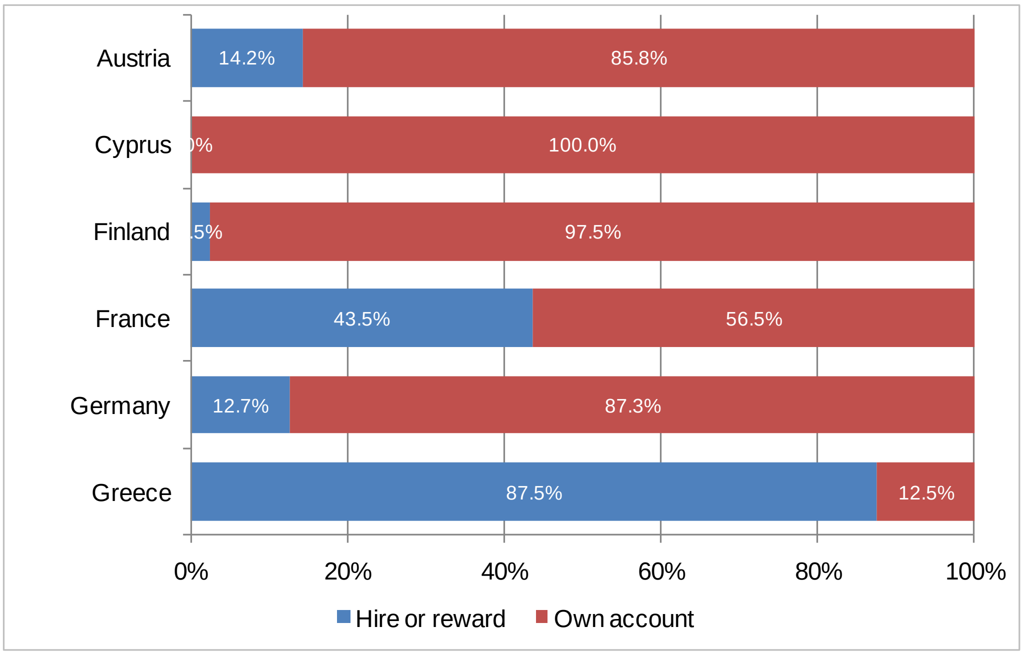
Figure 2–31: EU27 New registrations of road tractors by kind of transport (number) by Member State



Source: Eurostat (2010)

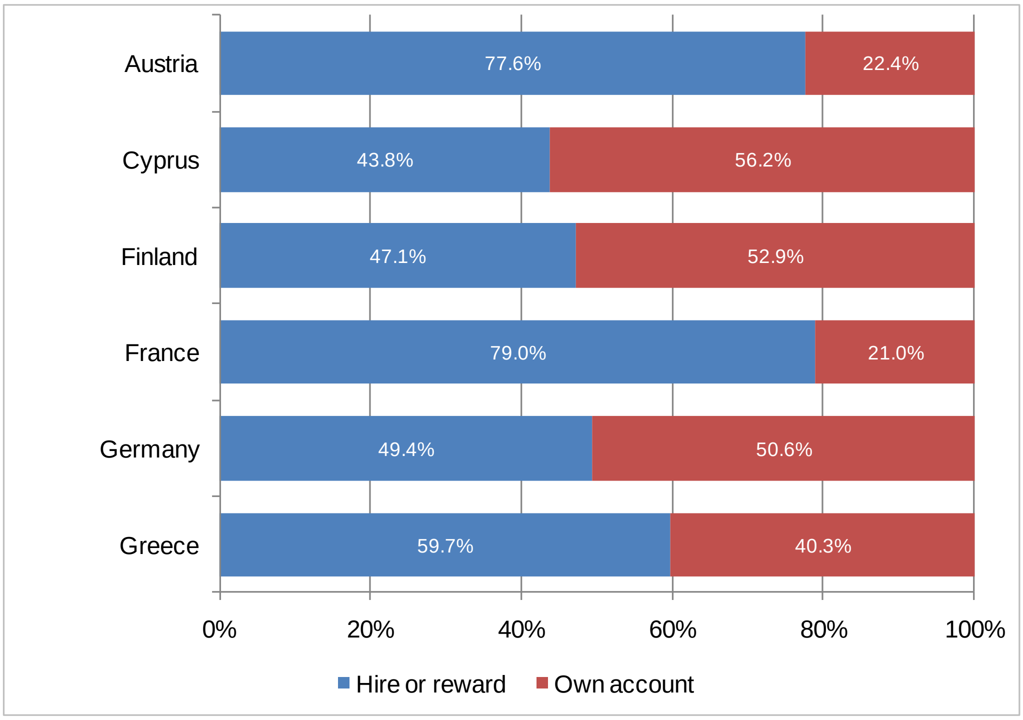
Similar statistics for trailers are only available for very few EU Member States and are therefore it was not possible to develop EU averages. Where datasets are available these have been presented in Figure 2–32 (for trailers) and Figure 2–33 (for semi-trailers). These show that a greater proportion of new trailers of all types appear to be registered by OA operators. This provides some evidence for the commonly made assertion of a split of ownership between vehicle operators and the towed trailers, i.e. HoR operators often tow trailers belonging to their customers.

Figure 2–32: New registrations of trailers by kind of transport (number) by EU Member State



Source: Eurostat (2010)

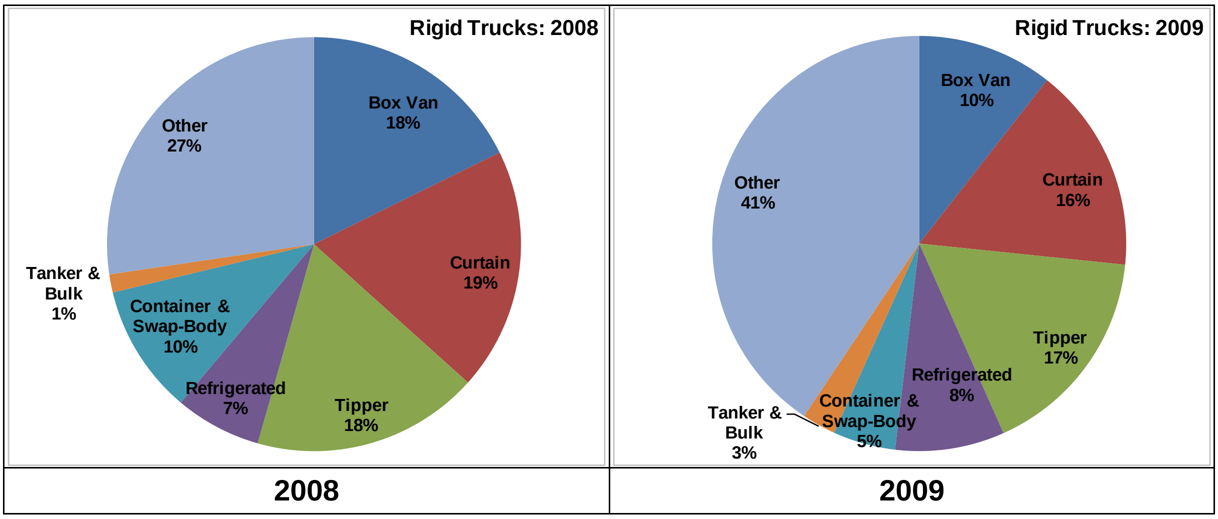
Figure 2–33: New registrations of semi-trailers by kind of transport (number) by EU Member State



Source: Eurostat (2010)

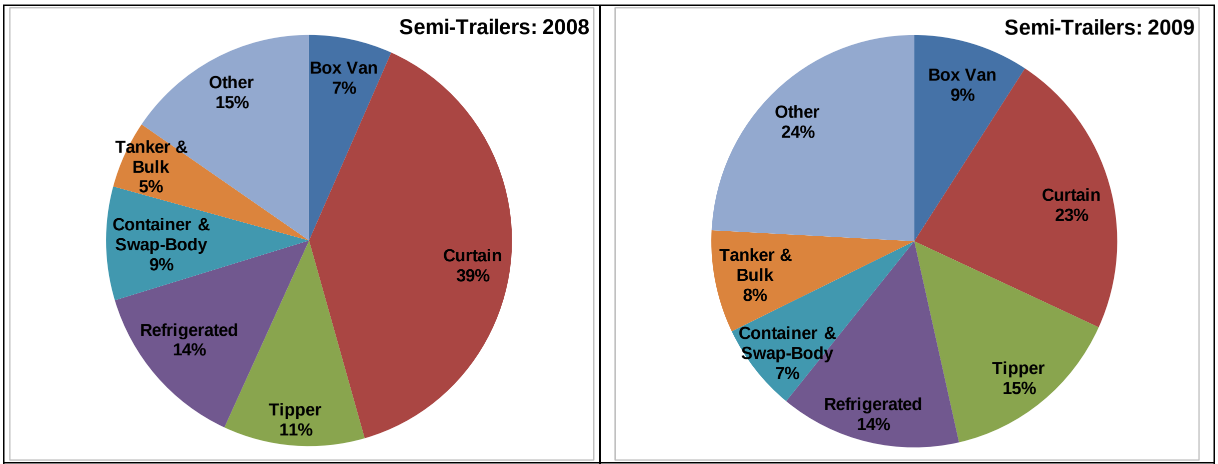
In terms of the application of heavy duty trucks, information was sourced from the German Association of the Automotive Industry (Verband der Automobilindustrie, VDA, 2010) on new registrations of rigid trucks and truck trailers by body type for their members. This information is presented in the following Figure 2–34, Figure 2–35 and Figure 2–36. Since the German trailer and body builders account for a significant proportion of the EU market (as discussed in earlier Section 2.4), this information is a good indication of overall EU registrations of new rigid trucks and truck trailers. The separate dataset purchased from CLEAR (2010) on the all EU registrations of truck trailers, summarised in Figure 2–37 and Figure 2–38, shows similar breakdown providing support for this assumption. Data for 2008 and 2009 is presented for comparison in these figures in order to highlight the changes in the respective market segments that accompanied the overall sharp decline in sales/registrations from 2008 to 2009. For the years previous to 2008 the proportions for different segments were broadly similar in both the German VDA and CLEAR datasets. These datasets are particularly important as body type has a significant impact on the potential for vehicle-based efficiency improvements (i.e. as opposed to improvements in the powertrain), such as in aerodynamics and auxiliaries. Of particular significance are the refrigerated trailers, where fuel consumption is typically around 20% higher (see later Section 2.8). On the aerodynamic improvements side, the greatest potential exists for box and curtain-sided body types (with more limited potential for other more irregular body types). The tipper type proportion is also a good indication of truck use in the construction sector.

Figure 2–34: New registrations of rigid trucks by body type from German VDA members for 2008 and 2009



Source: VDA (2010)

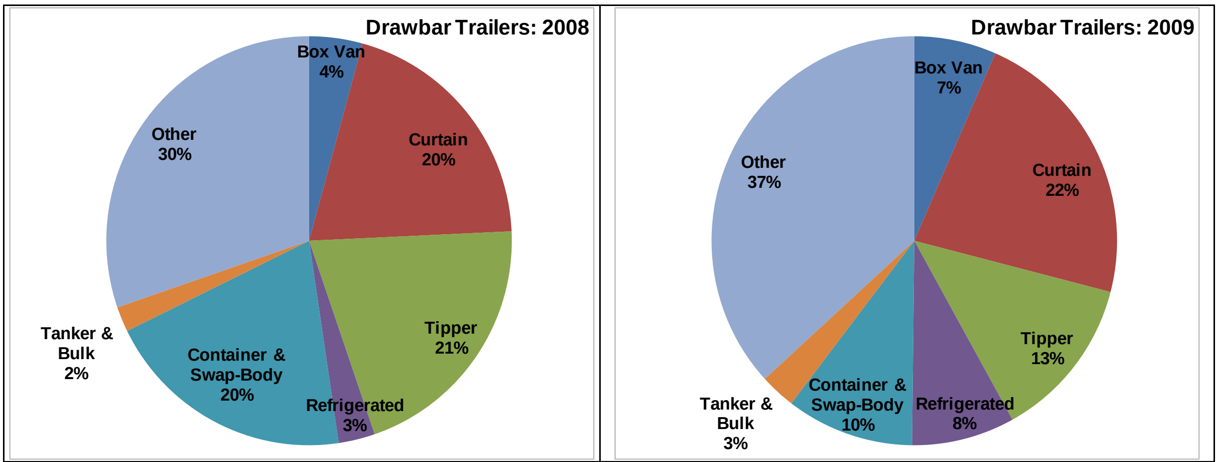
Figure 2–35: New registrations of semi-trailers by body type from German VDA members for 2008 and 2009



2008	2009

Source: VDA (2010)

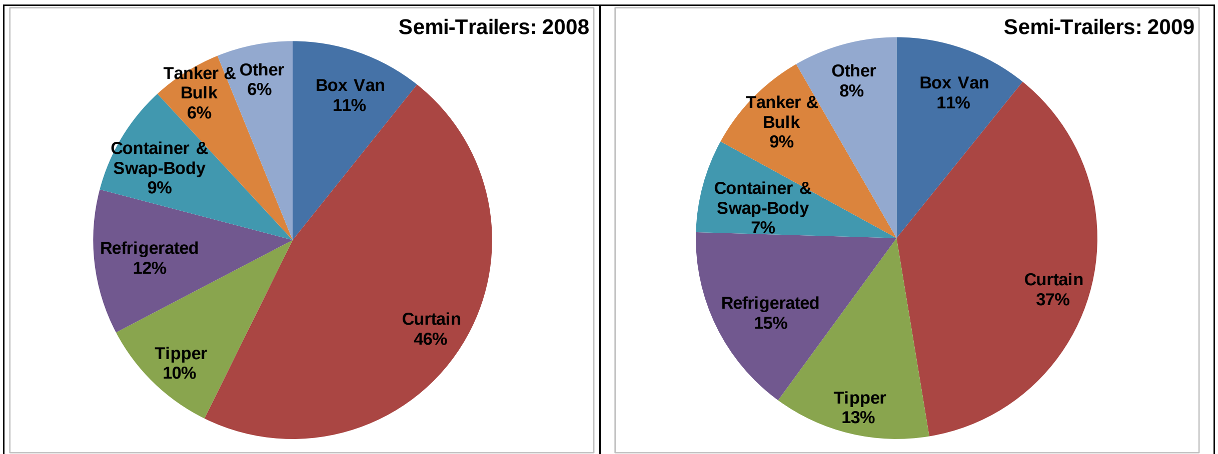
Figure 2–36: New registrations of drawbar-trailers by body type from German VDA members for 2008 and 2009



2008	2009

Source: VDA (2010)

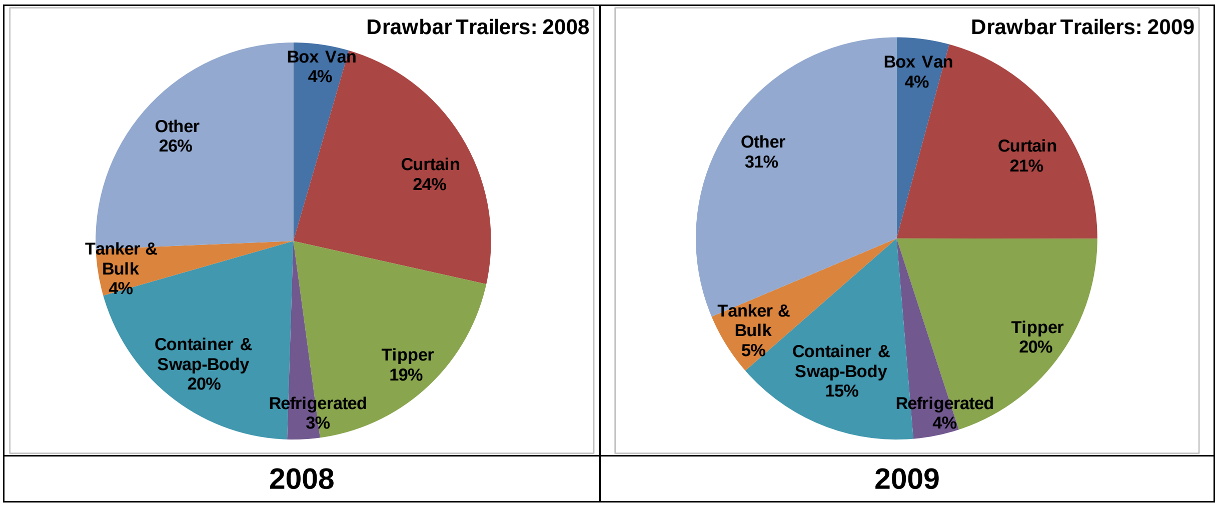
Figure 2–37: EU27 new registrations of semi-trailers by body type (CLEAR data) for 2008 and 2009



2008	2009

Source: CLEAR International Consulting (2010)

Figure 2–38: EU27 new registrations of drawbar-trailers by body type (CLEAR data) for 2008 and 2009



Source: CLEAR International Consulting (2010)

Besides the specific body type of the vehicle it is important to consider the typical duty cycles of trucks which will significantly effect both their efficiencies and their overall activity (in km). There was no suitable information available in the public domain to enable such an assessment to take place at an EU level. However, fortunately the HDV manufacturers have been working together as part of ACEA coordination to better understand how their vehicle sales break down into different applications for trucks >7.5 tonnes GVW. Since the final vehicle specification comes from the dealer and is finished separately by body-builders (at least for rigid vehicles) this has not been a trivial task. Nevertheless a number of conclusions can be drawn on the purpose for which a particular vehicle is intended depending on a number of factors (such as axel configuration, chassis configuration and weight class). ACEA has facilitated the provision of detailed information to AEA that has come out/been possible as a result of this analysis by the HDV manufacturer's expert group. As part of this analysis seven broad mission / vehicle cycle categories have been defined, which are presented in Table 2.21.

Table 2.21: ACEA /HDV manufacturer's definition /assumptions for split of sales by vehicle cycle/ mission type for trucks ≥ 7.5t GVW

Mission Class	Vehicle cycle /Mission	Mission / Vehicle Cycle Description	Payload factor*	Average km / yr
1	Urban Delivery /Collection	Distribution in cities or suburban sites of consumer goods from a central store to selling points.	50%	40,000
2	Municipal Utility	E.g. refuse collection trucks, road sweepers, etc	50%	25,000
3	Regional Delivery /Collection	Regional delivery of consumer goods from a central warehouse to local stores (inner-city or suburban, also mountain road goods collection, etc)	50%	60,000
4	Long Haul	Delivery to international sites more than one day trip	75%	135,000
5	One Daytrip	Delivery to national/international sites on a 1 day trip.	75%	130,000(5)
6	Light Construction	Construction site vehicles on light mission (e.g. concrete mixers, tipper trucks). 10% off-road	50%	60,000
7	Heavy Construction	Construction site vehicles on heavy missions. 60% off-road	50%	40,000

Notes:
1) Weight for CO_2/FE-simulation = individual overall curb-weight (2) + (payload factor x max individual payload (3))
2) Depending on the vehicle class 3 different vehicle configurations are possible: tractor + semitrailer or rigid + body + trailer or rigid + body OEM's provide only the tractor or rigid curb-weight;
3) Maximal individual payload = vehicle class specific reference weight(4) – individual overall curb-weight
4) Reference weight = vehicle individual GVW or GCW released by OEM but maximal up to legal limit
5) 115,000km (1 shift), 160,000 (2 shifts)

The following Table 2.22 provides the expert group's assessment of which mission class different vehicle specifications will be applicable. The subsequent Table 2.23 provides the summary of the EU27 deliveries data split into the different configuration categories. In order to translate this information into a quantified split of the deliveries data between different mission classes, it was necessary for AEA to make a number of assumptions as to the proportion of the deliveries data that fell into different mission categories, where more than one category was possible for a particular configuration. As far as possible these have been informed/sense-checked by other information, such as the information on body types (since tipper trucks are a good indication of the relative size of the construction sector). A summary of this allocation is provided in Table 2.24.

Table 2.22: ACEA/HDV manufacturer's mission categorisation by HDV class for trucks ≥7.5 tonnes GVW

				1	2	3	4	5	6	7
Axle configuration		**Chassis config.**	**GVW**	**Urban Delivery**	**Municipal Utility**	**Regional Delivery /Collection**	**Long Haul**	**One day trip**	**Light Off-road**	**Heavy Off-road**
2 axles	4x2	Rigid	7.5-10t	R/GVW	R/GVW	R/GVW				
	4x2	Tractor	7.5-10t							
	4x2	Rigid	>10-12t	R/GVW	R/GVW	R/GVW		R+T/GCW		
	4x2	Tractor	>10-12t					T/GCW		
	4x2	Rigid	>12-16t	R/GVW	R/GVW	R/GVW				
	4x2	Tractor	>12-16t							
	4x2	Rigid	≥16t	R/GVW	R/GVW	R/GVW	R+T/GCW	R+T/GCW		
	4x2	Tractor	≥16t			T/GCW	T/GCW	T/GCW	T/GCW	
	4x4	Rigid	7.5-16t		R/GVW				R/GVW	
	4x4	Rigid	≥16t		R/GVW				R/GVW	
	4x4	Tractor	≥16t						T/GCW	
3 axles	6x2/2	Rigid	All			R/GVW	R+T/GCW	R+T/GCW		
	6x2/2	Tractor	All					T/GCW		
	6X2/4	Rigid	All		R/GVW					
	6X2/4	Tractor	All				T/GCW			
	6x4	Rigid	All					R+T/GCW	R/GVW	R/GVW
	6x4	Tractor	All				T/GCW	T/GCW	T/GCW	T/GCW
	6x6	Rigid	All							R/GVW
	6x6	Tractor	All							T/GCW
4 axles	8x2	Rigid	All		R/GVW	R/GVW				
	8x4	Rigid	All						R/GVW	R/GVW
	8x8	Rigid	All							R/GVW
	8x8	Rigid	All							R/GVW

Notes: T = Tractor + Semitrailer; R+T = Rigid + Body + Trailer; R = Rigid + Body

GVW = reference weight for FE simulation = vehicle individual GVW released by OEM but maximal up to legal limit (26 t for 3-axle rigid vehicle)

GCW = reference weight for FE-simulation = vehicle individual GCW released by OEM but maximal up to legal limit (e.g. 40 t for 18t 4x2 Tractor or 60 t for 6x4 R+T)

Table 2.23: EU27 Deliveries from the 7 major European manufacturers for trucks ≥ 7.5 tonnes GVW

Axle/Chassis config'n			GVW	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	TOTAL	TOTAL
2 axles	4X2	Rigid	7.5-16t	82,885	75,301	67,509	62,038	65,285	68,987	67,891	68,961	61,925	33,059	**653,841**	20.3%
	4X2	Rigid	≥16t	43,470	40,267	35,735	32,488	33,405	36,057	37,401	40,342	39,072	18,399	**356,636**	11.1%
	4X2	Tractor	>=16t	123,813	114,897	106,966	109,049	130,927	130,113	146,488	172,983	165,387	47,190	**1,247,813**	38.7%
	4X4	Rigid	7.5-16t	2,189	2,385	2,297	2,272	2,534	2,653	2,692	2,580	3,385	2,865	**25,852**	0.8%
	4X4	Rigid	≥16t	2,324	2,276	1,969	2,021	2,144	2,179	2,447	4,207	4,976	3,487	**28,030**	0.9%
	4X4	Tractor	≥16t	1,091	817	765	838	1,212	1,497	1,782	1,868	1,715	705	**12,290**	0.4%
3 axles	6X2/2	Rigid	All	27,970	25,353	25,735	27,226	30,058	31,462	32,930	37,252	35,007	16,643	**289,636**	9.0%
	6X2/2	Tractor	40t	11,253	9,980	13,301	14,956	16,279	19,036	18,186	18,524	22,017	6,617	**150,149**	4.7%
	6X2/4	Rigid	All	5,061	4,777	4,449	3,797	4,932	6,125	6,793	5,192	8,542	5,472	**55,140**	1.7%
	6X2/4	Tractor	40t	21	15	16	20	20	27	60	465	508	202	**1,354**	0.0%
	6X4	Rigid	All	16,535	14,665	12,727	11,714	12,996	14,924	15,653	17,269	15,485	6,080	**138,048**	4.3%
	6X4	Tractor	40t	3,513	2,833	2,905	2,534	2,606	3,240	3,447	3,974	4,466	2,038	**31,556**	1.0%
	6X6	Rigid	All	2,909	2,522	2,054	2,394	2,721	2,374	3,212	3,606	3,937	2,343	**28,072**	0.9%
	6X6	Tractor	40t	225	323	241	182	180	211	275	428	546	151	**2,762**	0.1%
4 axles	8X2	Rigid	All	561	626	664	682	853	1,035	1,236	1,315	1,572	754	**9,298**	0.3%
	8X4	Rigid	All	14,257	13,457	14,113	14,599	16,712	20,628	24,528	30,224	26,674	5,605	**180,797**	5.6%
	8X6	Rigid	All	673	421	448	455	547	724	1,118	1,520	1,627	377	**7,910**	0.2%
	8X8	Rigid	All	452	304	366	296	373	727	894	1,171	1,742	1,016	**7,341**	0.2%
Grand Total				**339,202**	**311,219**	**292,260**	**287,561**	**323,784**	**341,999**	**367,033**	**411,881**	**398,583**	**153,003**	**3,226,525**	**100.0%**

Source: ACEA (2010)

Notes: Sum of data provided by the 7 major European manufacturers: DAF, Iveco, MAN, Mercedes (Daimler), Renault Trucks, Scania and Volvo.

Table 2.24: Allocation of EU27 deliveries of trucks ≥ 7.5 tonnes into different mission classes

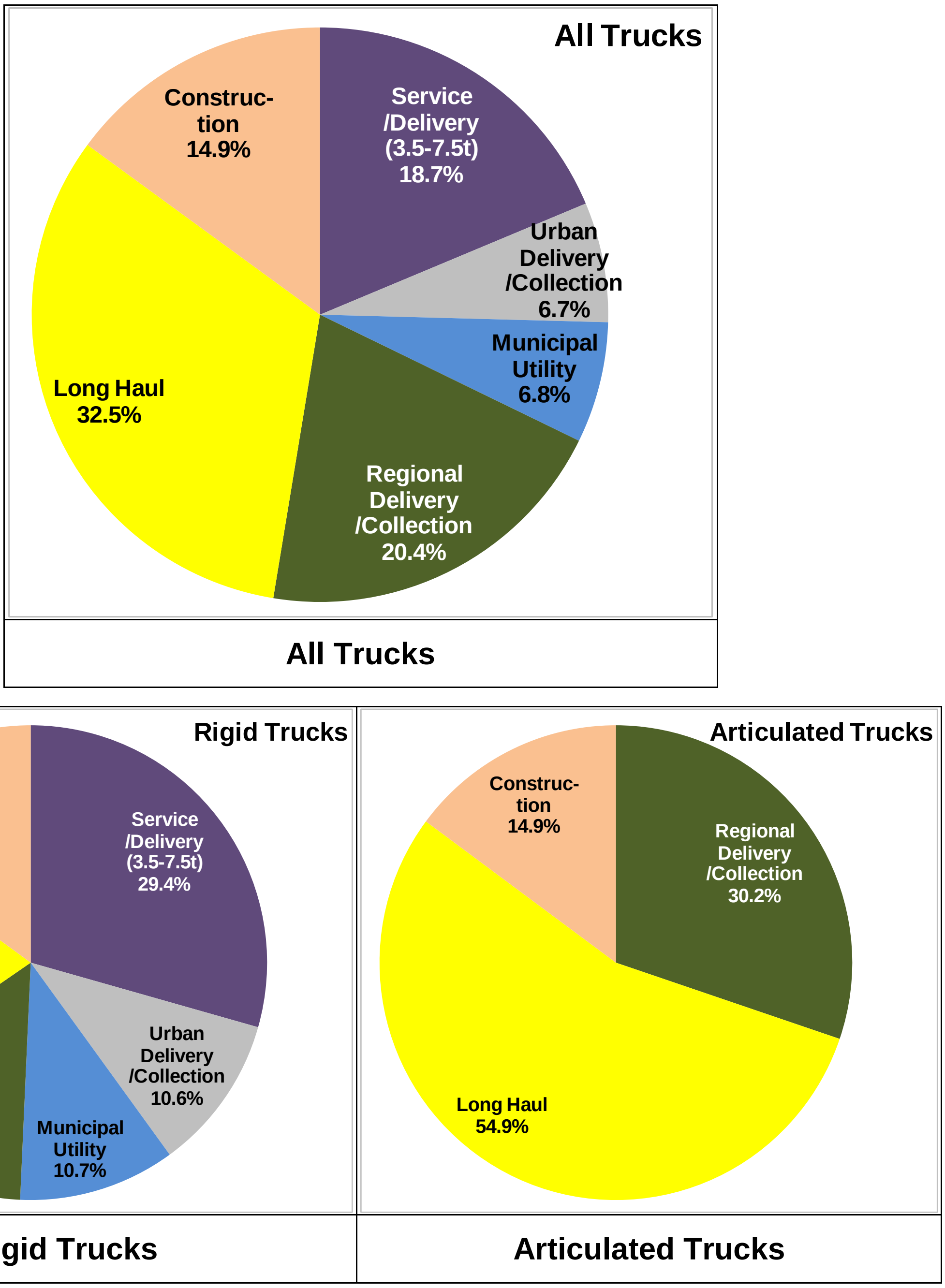
				Allocation of Registrations by Mission Classification, %							
Axle/Chassis config'n			**GVW**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
2 axles	4X2	Rigid	7.5-16t	30%	20%	30%		20%			100%
	4X2	Rigid	≥16t	20%	20%	20%	20%	20%			100%
	4X2	Tractor	>=16t			35%	25%	25%	15%		100%
	4X4	Rigid	7.5-16t		20%				80%		100%
	4X4	Rigid	≥16t		20%				80%		100%
	4X4	Tractor	≥16t						100%		100%
3 axles	6X2/2	Rigid	All			33%	33%	33%			100%
	6X2/2	Tractor	40t					100%			100%
	6X2/4	Rigid	All		100%						100%
	6X2/4	Tractor	40t				100%				100%
	6X4	Rigid	All					20%	40%	40%	100%
	6X4	Tractor	40t				30%	30%	20%	20%	100%
	6X6	Rigid	All							100%	100%
	6X6	Tractor	40t							100%	100%
4 axles	8X2	Rigid	All		25%	75%					100%
	8X4	Rigid	All						50%	50%	100%
	8X6	Rigid	All							100%	100%
	8X8	Rigid	All							100%	100%

Notes: AEA estimates on based on expert judgement and comparison with information from the German VDA (2010), CLEAR (2010) and UK DfT (2010) on body type proportions for rigid and articulated vehicles and trailers.

The result of the process of allocating sales to different mission classes is summarised in the following Figure 2–39 with a split provided for rigid trucks and road tractors for articulated vehicles averaged across the timeseries. In this summary we have aggregated the two long-haul categories (4 and 5) and the two construction categories (6 and 7). This was necessary for the purposes of simplification of the overall assessment and using the information in the process of quantifying fuel consumption and emissions (discussed later in Section 4). In addition the proportion due to registrations of trucks <7.5 tonnes GVW has been added. This was obtained through simple subtraction of the totals provided in the mission classification dataset from the overall truck registrations data for the same 7 manufacturers available for the same period from ACEA's website. The <7.5 tonne vehicle category is the subject of a separate (but related) analysis by the manufacturers that has only recently started, so specific data was unavailable at this time. However, these vehicles comprise a mix of large vans (i.e. >3.5 tonnes) and small rigid trucks that are used in both non-freight service type operations and in short-distance delivery /collection operations.

In terms of the variations through the times-series, there is an increase in the proportion of road tractors to rigid vehicles. In terms of the mission classes, in general the relative splits have remained relatively stable, with the exception of an increase in construction for rigids in long-haul for road tractors. However, it is difficult to make firm assertions on these trends given the unavoidable uncertainty in the estimates of the split of different vehicle configurations into different mission classes.

Figure 2–39: EU Sales of Trucks by mission profile (average for sales 2000-2009)



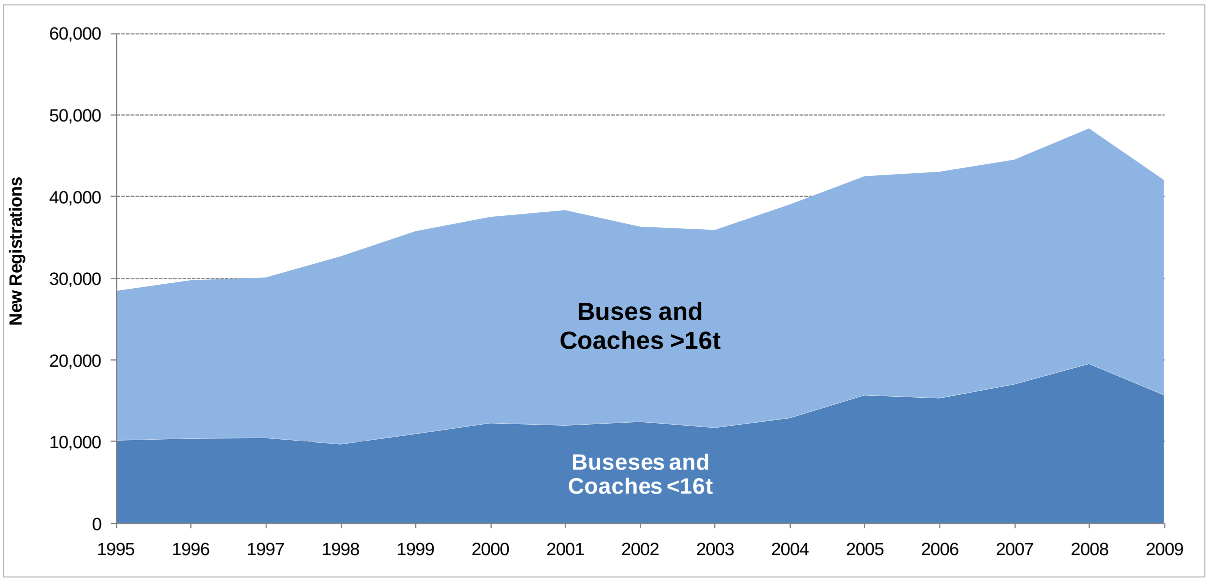
Source: AEA estimates based on dataset provided by ACEA (2010)

Notes: Based on data provided by the 7 major European manufacturers. For the purposes of simplification, AEA have aggregated the ACEA 'long haul' and 'one day trip' categories into a single total for long haul, and the light and heavy off-road/construction categories into a single total for construction. 3.5-7.5 tonne category added by comparing total HCV registrations from ACEA including these over the same period.

2.6.2 New Buses and Coaches

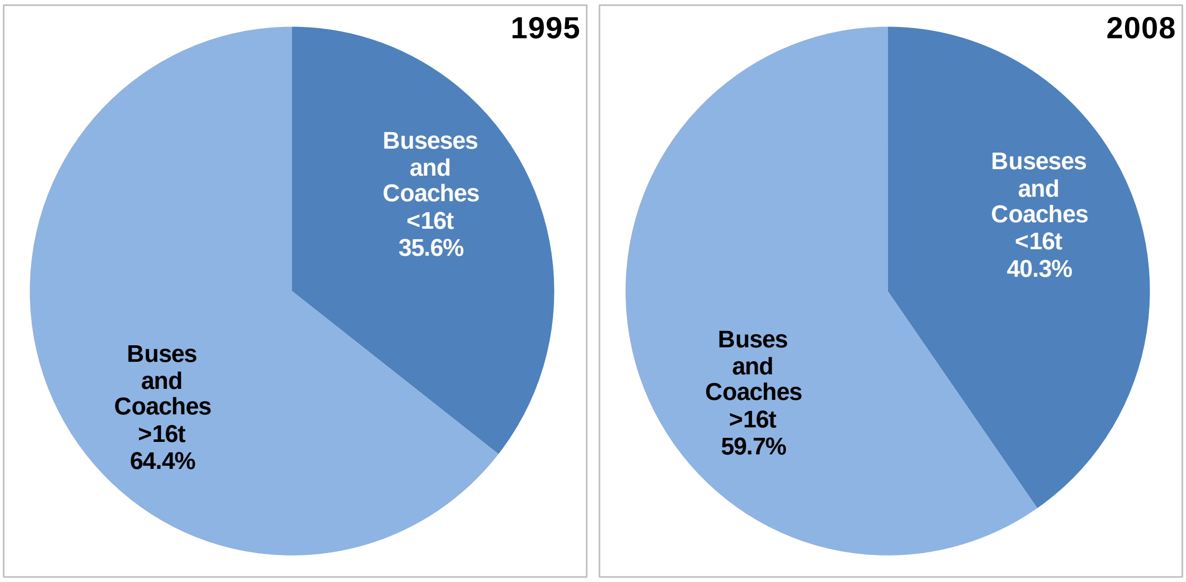
There appears to be little additional information available on the European bus and coach sector, beyond the information on new registrations already presented in earlier Section 2.4 (Figure 2–4 and Figure 2–9) to facilitate a broader assessment of the new vehicle market size and structure. The split of weight categories provided by the datasets on new vehicle registrations from ACEA's website (2010) are provided in Figure 2–40 and Figure 2–41. Other than illustrating an increasing demand for lower weight category buses between 1995 and 2009 this dataset does not allow for the differentiation between urban (or interurban) bus classes and longer range coach classes. However, Section 2.5 has already characterised the end users of buses and coaches together with relative fleet sizes (see Table 2.16) and the split of coach use between regular services (e.g. intercity express coaches), special services (e.g. school buses) and occasional use (e.g. touring) (see Table 2.20).

Figure 2–40: EU27 split of buses and coaches by weight class from 1995 to 2009



Source: Estimates based on ACEA (2010) dataset of registrations of new buses and coaches by weight class

Figure 2–41: EU27 split of buses and coaches by weight class



Source: Estimates based on ACEA (2010) dataset of registrations of new buses and coaches by weight class

A similar piece of work for the bus and coach sector is currently in progress by manufacturer experts as part of an ACEA expert group as is being carried out for trucks discussed earlier. However, this work was still at a much earlier phase at the time of preparing this report. The following list summarises the proposals received by AEA on the categorisation used in this work, with the Class I, II and III categories being consistent with EU Directive 2007/46/EC:

1) **Class I City Bus**
- a) *2 axles (single-deck)*
- b) *3 axles (single-deck)*
- c) *Double-decker*
- d) *Articulated*

a) **Class II Interurban Bus***
- a) *2 axles (single-deck)*
- b) *3 axles (single-deck)*
- c) *Double-decker*
- d) *Articulated*

b) **Class III Coach ****
- a) *2 axles (single-deck)*
- b) *3 axles (single-deck)*
- c) *Double-decker*
- d) *Articulated*

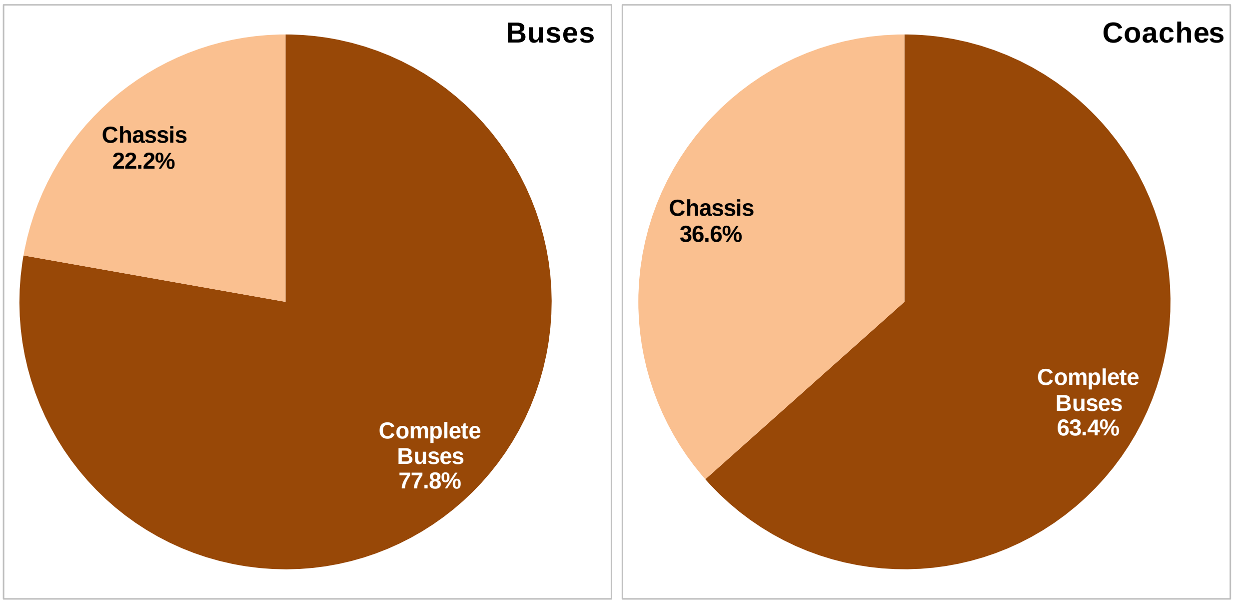
Notes: * floor height ≤ 900mm; ** floor height > 900mm.

ACEA were only able to provide comparable data to that for trucks in Section 2.6.1 very late in the project, however this is summarised in the following Figure 2–42 and Figure 2–43. These figures provide a summary of bus and coach registrations in terms of:

- The relative proportions of Class I, II and III vehicles at an aggregate level;
- Their level of completion (i.e. a proportion are simply 'chassis' that go on for completion by bus/coach bodybuilders);
- The breakdown of Class I, II and III vehicles into the four different configuration categories.

The data presented in Figure 2–42 clearly show that a higher proportion of coaches (36.6%) go for completion by bodybuilders than buses (22.2%). In total almost 26% of buses and coach chassis produced by ACEA members go for completion by bus/coach bodybuilders. The data presented in Figure 2–43 are aggregate figures for all chassis and completed buses and illustrates that the majority of recent new registrations from ACEA members are of buses (almost 76%), which is significantly higher proportion than the estimates of the composition of the overall bus and coach fleet that are presented later in Section 2.7.2.

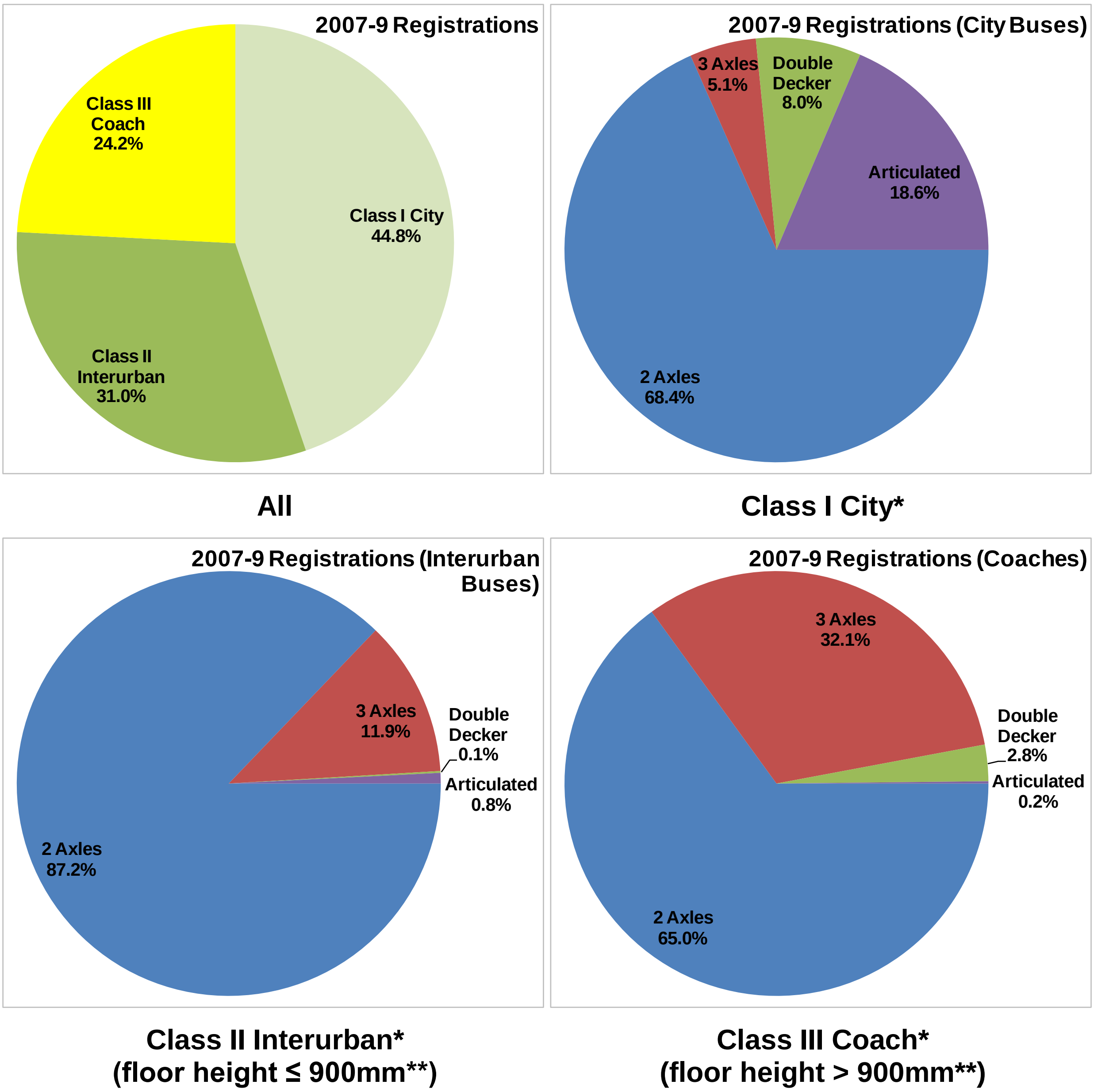
Figure 2–42: EU27 split of bus and coach registrations from ACEA members by bus (or coach) completion level (average for period 2007-2009)



Buses (Class I and Class II) **Coaches (Class III)**

Source: Data provided by ACEA based on total registrations for 2007-2009 of complete buses/coaches plus. Includes data from EvoBus (Daimler), Irisbus/Iveco (Fiat), MAN, Scania, Volvo and Solaris.

Figure 2–43: EU27 split of bus and coach registrations from ACEA members by class and axle/body configuration (average for period 2007-2009)



Source: Data provided by ACEA based on total registrations for 2007-2009 of complete buses/coaches plus chassis. Includes data from EvoBus (Daimler), Irisbus/Iveco (Fiat), MAN, Scania, Volvo and Solaris.

Notes: Assumptions for ACEA supplied data as follows:
*referring to EU Directive 2007/46/EC; **estimated for differentiation (basis e.g. for financial support of interurban buses) floor height referring to measurement from ground to floor.
If buses registered as class I and II following differentiation:
- Low-Floor or Low Entry (e.g. minimum 2 doors with low entrance) -> class I – city
- Raised-Floor (luggage compartment) -> class II – Interurban
GVW > 7.5 to according truck sales figures; M3 quantities < 7.5 to most likely negligible.

2.7 Existing fleet size and structure

Objectives:

The purpose of this sub-task was to provide an information on:

"Existing fleet size and structure:
- *distribution by type of application*
- *distribution by age and mileage*
- *characteristics of the used vehicle market"*

Summary of Main Findings

⇒ The relative proportion of road tractors /articulated vehicles is increasing in the fleet and these vehicle accounts for the vast majority of total tonne km in the EU due to higher average loading and longer journey distances.

⇒ Information provided by ACEA has allowed the estimation of the split of heavy duty trucks between different mission profiles with different activity and fuel consumption profiles.

⇒ RCVs are estimated to account for between 2% and 3.5% of all heavy trucks. RCVs typically have very high fuel consumption due in part to auxiliary loads but also their typical drive cycle. However, due to their relatively low annual km they are not anticipated to contribute to a significantly higher proportion of total fuel consumption and CO_2 emissions compared to other vehicle types (maybe 2.2% to 3.8% of total).

⇒ Refrigerated rigid trucks and all trailers may account for around 7% and 10% respectively of their respective total body types. Since temperature controlled transport typically consumes around 20% more fuel (used by diesel APUs to power the refrigeration units) their contribution to total fuel consumption is expected to be higher.

⇒ The proportion of coaches of the total bus and coach fleet appears to be relatively uncertain, with estimates varying between 37% (SDG, 2009) and 48% (FLEETS database).

⇒ In terms of vehicle age there are clear differences in the distribution of vehicles by age category (and average vehicle age/lifetime in the country fleet) between trucks and buses/coaches. There is also significant variation between Member States and in general between the Northern and the Southern and Eastern European countries. For trucks the average vehicle lifetime appears to be greater than the 10 years often cited as being typical. For buses and coaches it appears the average vehicle lifetime is even higher with implied average lifetime of around 15 years for the EU27. European statistics also show that newer vehicles account for a greater proportion of total vehicle km compared to their overall numbers.

⇒ The use of alternatively fuelled vehicles is very limited for heavy trucks, except in a few Member States. However, there is more widespread use of alternatively powered buses across a number of countries, but in particular in Sweden, Poland, the Czech Republic and in Austria. Of particular note is that whilst natural gas is the most used alternative in the EU15, a significant number of the EU12 states have electrically powered trolley-bus systems.

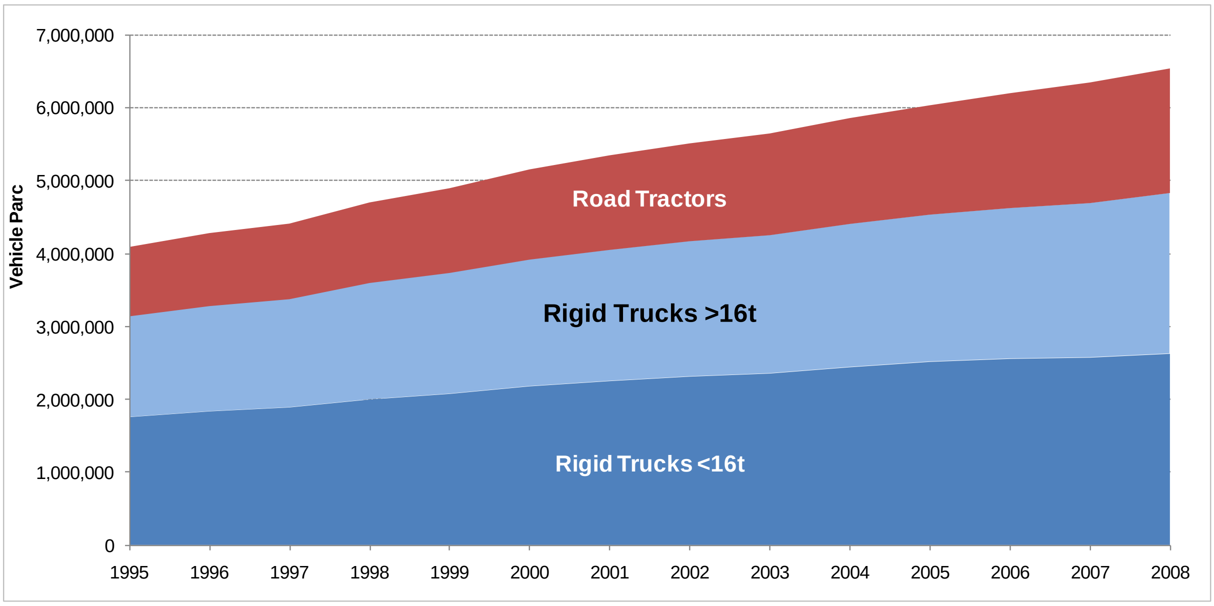
⇒ Little information is available on the second hand vehicle markets for HDVs. However, the available information suggests movements of older used HDVs vehicles from the major EU economies to southern Europe and also the newer EU Member States.

2.7.1 Trucks

2.7.1.1 General

The following Figure 2–44 summarises the trend in the EU27 truck vehicle parc, with the 1995 and 2008 splits by truck class provided in Figure 2–45. These figures illustrate that road tractors currently account for just over a quarter of all heavy trucks and this proportion has only increased by a small amount since 1995.

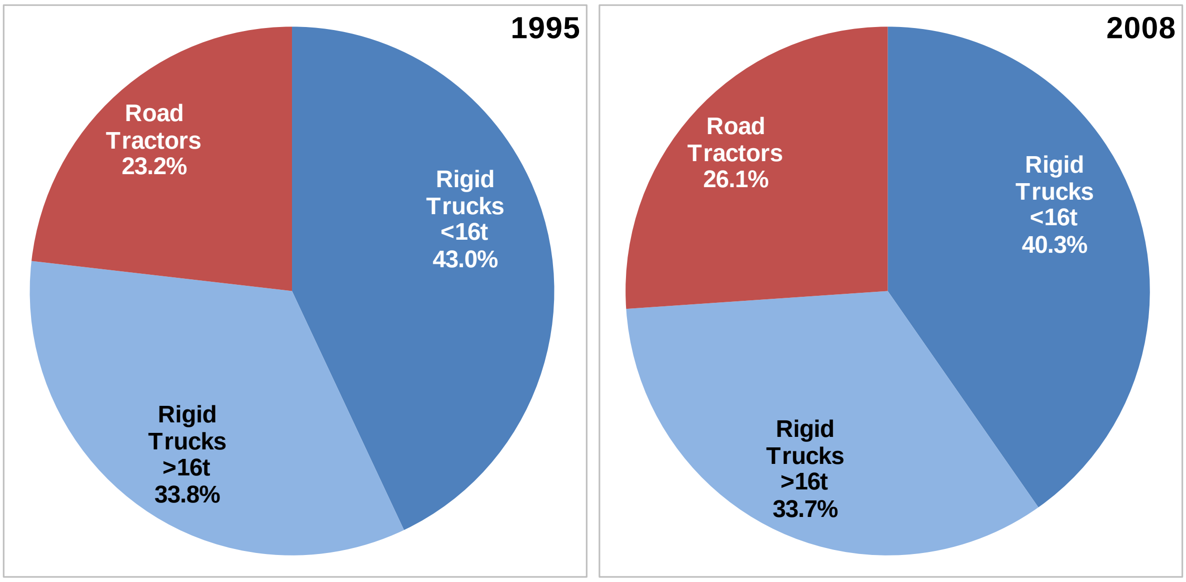
Figure 2–44: EU27 vehicle parc of rigid trucks and road tractors



Source: Based on datasets from ACEA (2010) and Eurostat (2010)

Notes: Eurostat compiles statistics for road tractors and lorries. The lorries category combines data for light commercial vehicles (LCVs) as well as rigid trucks. ACEA provides registration statistics for LCVs and separately trucks split by two weight categories but not by rigid trucks and road tractors. AEA have estimated the corresponding split of the truck vehicle parc (above) by combining these two datasets.

Figure 2–45: EU27 split of vehicle parc of rigid trucks and road tractors in 1995 and in 2008

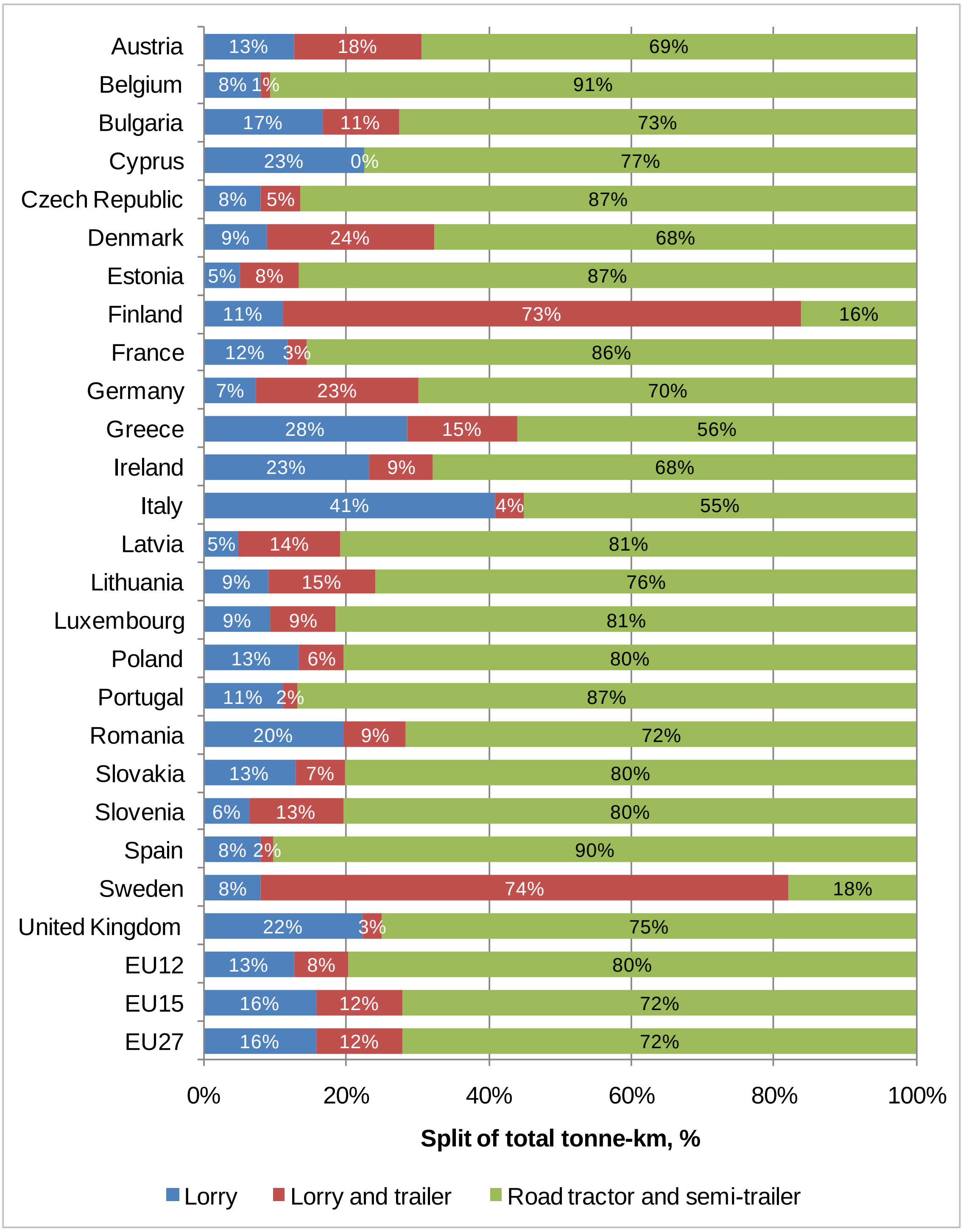


Source: Based on datasets from ACEA (2010) and Eurostat (2010)

Notes: AEA have estimated the split of the truck vehicle parc by combining ACEA and Eurostat datasets.

Although articulated vehicles only comprise a smaller proportion of the total EU truck fleet, they account for the vast majority of tonne-km according to statistics from Eurostat presented in Figure 2–46. These statistics highlight the dominance of articulated vehicles (road tractor + semi-trailer) in transporting freight almost all EU countries. The exception to this is Sweden and Finland, where road trains (lorry/rigid truck + trailer) combinations dominate. The figure also highlights the significance of road trains across a number of other countries in the EU.

Figure 2–46: % split of activity (tonne km) for lorries, lorries plus trailers and articulated trucks, by Member State in 2009



Source: Based on data from Eurostat (2010)

Notes: The Eurostat 'Lorries' category includes data for light commercial vehicles for many Member States.

The reason for the predominance of articulated vehicles is a combination of both their size and their typically longer journey distances, as illustrated in Table 2.25 below, as well as earlier Figure 2–18 in Section 2.5.

Table 2.25: EU27 Summary of statistics for freight transport by lorries, lorries + trailers and articulated trucks for 2009

2009 Total EU27	Vehicle km (millions)	Tonne km (millions)	Av. Loading (tonnes)	1000 Journeys	Av. km per journey
Lorry	37,224	237,302	6.38	646,877	58
Lorry and trailer	12,420	177,830	14.32	88,125	141
Road tractors and semi-trailers	68,637	1,181,163	17.21	375,660	183
TOTAL	**118,568**	**1,598,719**	**13.48**	**1,115,493**	**106**
Proportion in relation to Total, %					
Lorry	31.4%	14.8%	47.3%	58.0%	54.7%
Lorry and trailer	10.5%	11.1%	106.2%	7.9%	133.0%
Road tractors and semi-trailers	57.9%	73.9%	127.7%	33.7%	172.6%

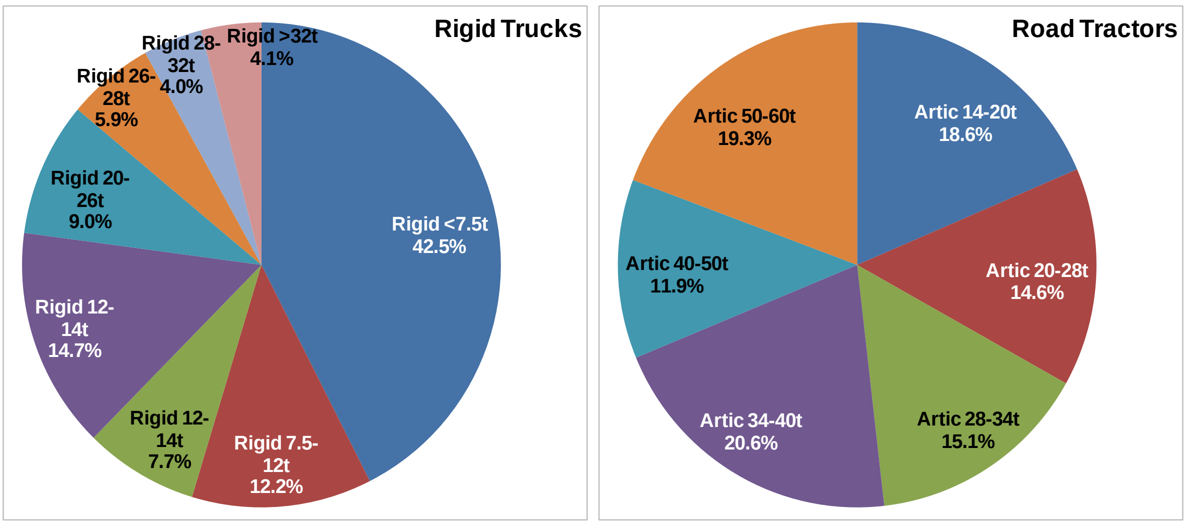
Source: Based on data from Eurostat (2010)

Notes: The Eurostat 'Lorries' category includes data for light commercial vehicles for many Member States. Figures for average loading and average km per journey have been derived from figures for vkm, tkm and 1000 journeys.

2.7.1.2 Fleet composition by weight, mission and body type/application

In terms of rigid trucks, information is available on the breakdown of the European fleet by weight category and Member State from the FLEETS database. The following Figure 2–47 provides a summary of this breakdown for the whole EU27, highlighting the dominance (at least in terms of numbers) of the <7.5 tonne category that is predominantly used for service operations as well as for delivery operations.

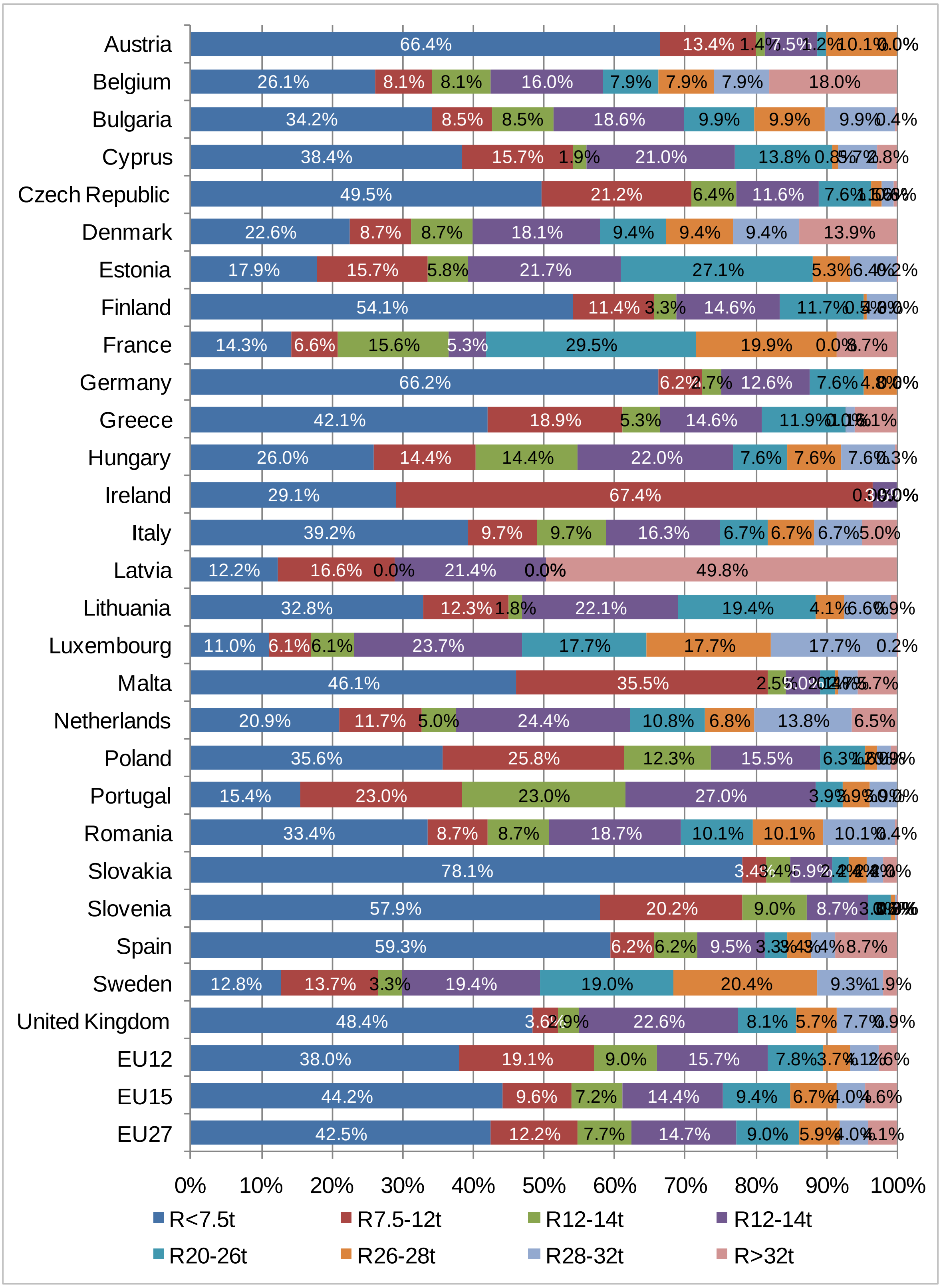
Figure 2–47: Estimated breakdown of the total EU27 parc of trucks by weight category



Source: Based on data from the FLEETS database for 2005

A further breakdown by Member State is provided in Figure 2–48 (with data also in Table 2.26) and Figure 2–49, which highlights a significant degree of variation in the composition of the rigid truck and to a much lesser degree for the articulated truck fleets across the EU.

Figure 2–48: Estimated EU27 parc of rigid trucks by weight category and by Member State

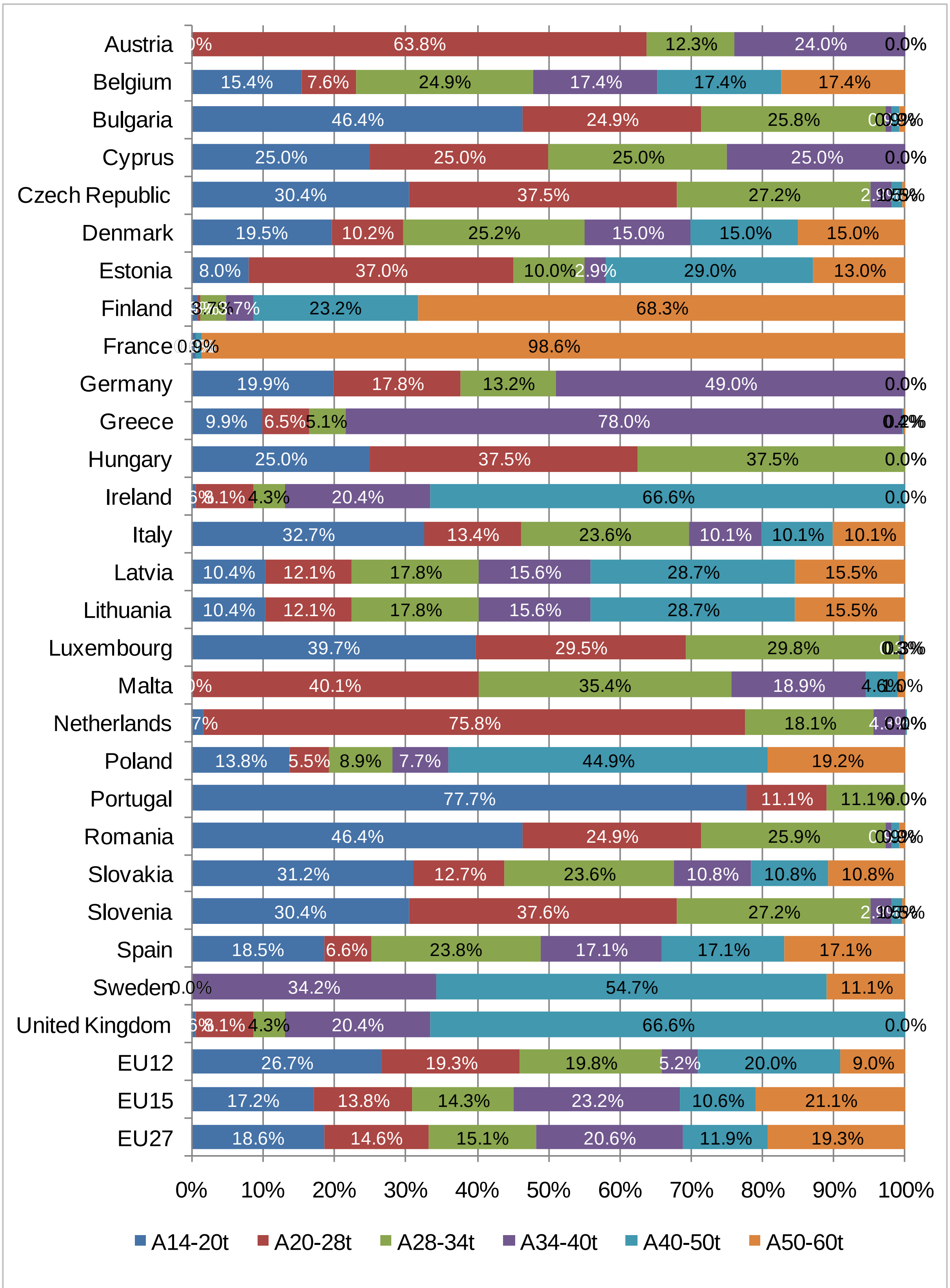


Source: Based on data from the FLEETS database for 2005

Table 2.26: Estimated EU27 parc of rigid trucks by weight category and by Member State

Year 2005	Vehicles, %Total							
Rigid Trucks	R<7.5t	R7.5-12t	R12-14t	R12-14t	R20-26t	R26-28t	R28-32t	R>32t
Austria	66.4%	13.4%	1.4%	7.5%	1.2%	10.1%	0.0%	0.0%
Belgium	26.1%	8.1%	8.1%	16.0%	7.9%	7.9%	7.9%	18.0%
Bulgaria	34.2%	8.5%	8.5%	18.6%	9.9%	9.9%	9.9%	0.4%
Cyprus	38.4%	15.7%	1.9%	21.0%	13.8%	0.8%	5.7%	2.8%
Czech Republic	49.5%	21.2%	6.4%	11.6%	7.6%	1.5%	1.6%	0.6%
Denmark	22.6%	8.7%	8.7%	18.1%	9.4%	9.4%	9.4%	13.9%
Estonia	17.9%	15.7%	5.8%	21.7%	27.1%	5.3%	6.4%	0.2%
Finland	54.1%	11.4%	3.3%	14.6%	11.7%	0.5%	4.3%	0.0%
France	14.3%	6.6%	15.6%	5.3%	29.5%	19.9%	0.0%	8.7%
Germany	66.2%	6.2%	2.7%	12.6%	7.6%	4.8%	0.0%	0.0%
Greece	42.1%	18.9%	5.3%	14.6%	11.9%	0.0%	1.1%	6.1%
Hungary	26.0%	14.4%	14.4%	22.0%	7.6%	7.6%	7.6%	0.3%
Ireland	29.1%	67.4%	0.0%	3.5%	0.0%	0.0%	0.0%	0.0%
Italy	39.2%	9.7%	9.7%	16.3%	6.7%	6.7%	6.7%	5.0%
Latvia	12.2%	16.6%	0.0%	21.4%	0.0%	0.0%	0.0%	49.8%
Lithuania	32.8%	12.3%	1.8%	22.1%	19.4%	4.1%	6.6%	0.9%
Luxembourg	11.0%	6.1%	6.1%	23.7%	17.7%	17.7%	17.7%	0.2%
Malta	46.1%	35.5%	2.5%	5.0%	2.1%	0.4%	2.7%	5.7%
Netherlands	20.9%	11.7%	5.0%	24.4%	10.8%	6.8%	13.8%	6.5%
Poland	35.6%	25.8%	12.3%	15.5%	6.3%	1.6%	2.0%	0.9%
Portugal	15.4%	23.0%	23.0%	27.0%	3.9%	3.9%	3.9%	0.0%
Romania	33.4%	8.7%	8.7%	18.7%	10.1%	10.1%	10.1%	0.4%
Slovakia	78.1%	3.4%	3.4%	5.9%	2.4%	2.4%	2.4%	2.0%
Slovenia	57.9%	20.2%	9.0%	8.7%	3.3%	0.6%	0.3%	0.0%
Spain	59.3%	6.2%	6.2%	9.5%	3.3%	3.4%	3.4%	8.7%
Sweden	12.8%	13.7%	3.3%	19.4%	19.0%	20.4%	9.3%	1.9%
United Kingdom	48.4%	3.6%	2.9%	22.6%	8.1%	5.7%	7.7%	0.9%
EU12	**38.0%**	**19.1%**	**9.0%**	**15.7%**	**7.8%**	**3.7%**	**4.1%**	**2.6%**
EU15	**44.2%**	**9.6%**	**7.2%**	**14.4%**	**9.4%**	**6.7%**	**4.0%**	**4.6%**
EU27	**42.5%**	**12.2%**	**7.7%**	**14.7%**	**9.0%**	**5.9%**	**4.0%**	**4.1%**

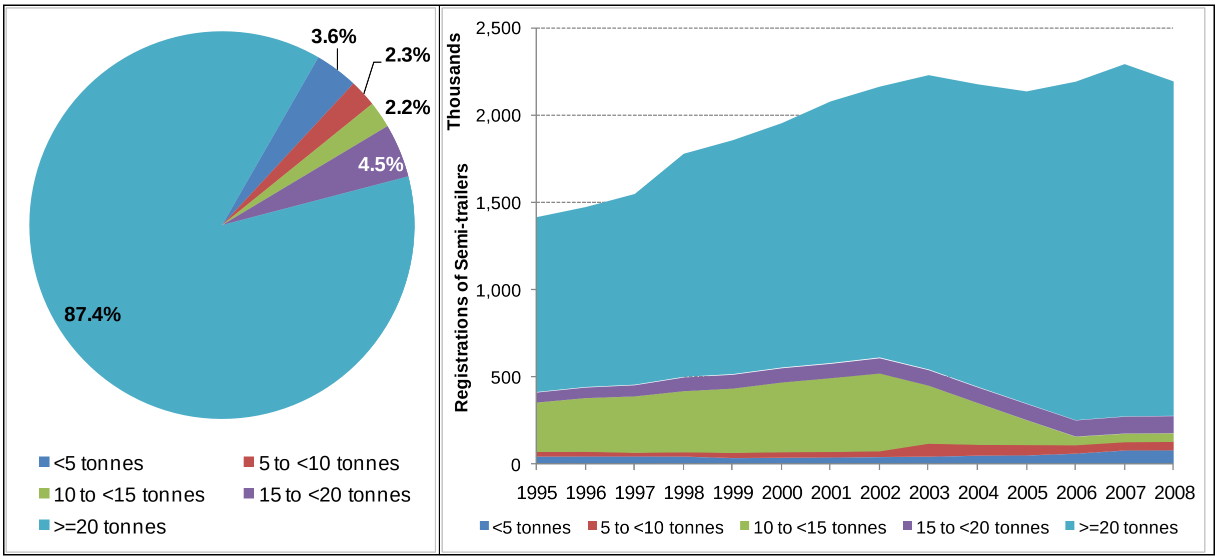
Figure 2–49: EU27 parc of Articulated Trucks (road tractors) by weight category



Source: Based on data from the FLEETS database for 2005

European statistics for the trailer parc also provide a breakdown of the fleet by load capacity, which is summarised in the following Figure 2–50 and Figure 2–51. The first figure illustrates a significant shift in the trailer parc towards higher capacity semi-trailers for articulated vehicles, with the > 20 tonne category dominating the trailer fleet. The second figure conversely illustrates the very high numbers of light trailers (< 5 tonnes) not applicable to heavy truck transport in the regular trailer fleet.

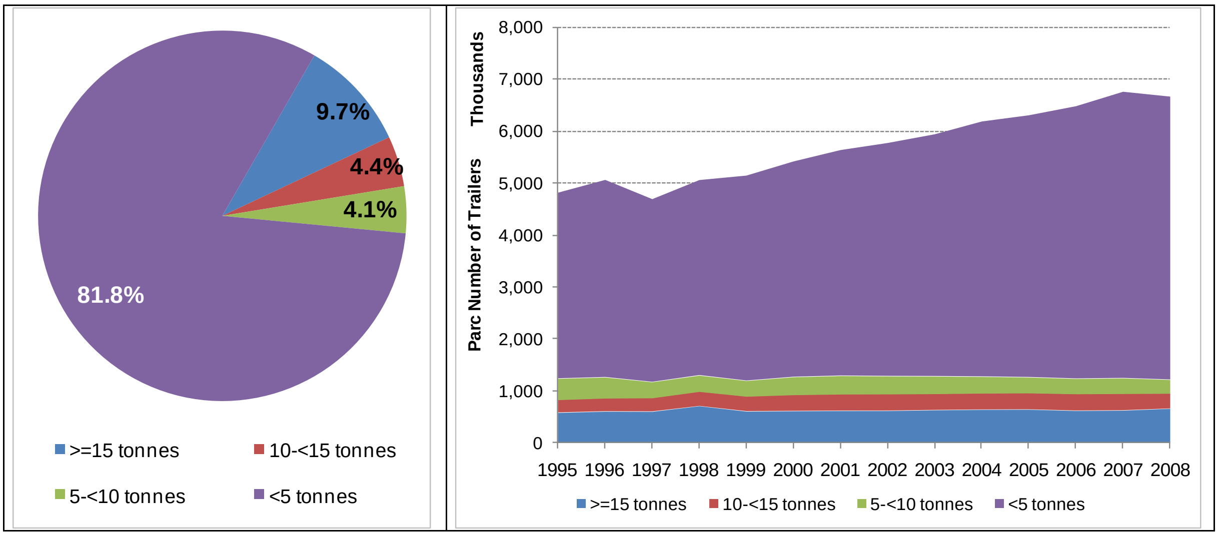
Figure 2–50: EU27 Semi-trailer parc, by load capacity (number), timeseries 1995 to 2008 and 2008 split



Source: Eurostat (2010)

Notes: Data excludes UK, Ireland, Belgium and Estonia where no data exists.

Figure 2–51: EU27 Trailer parc, by load capacity (number), timeseries 1995 to 2008 and 2008 split



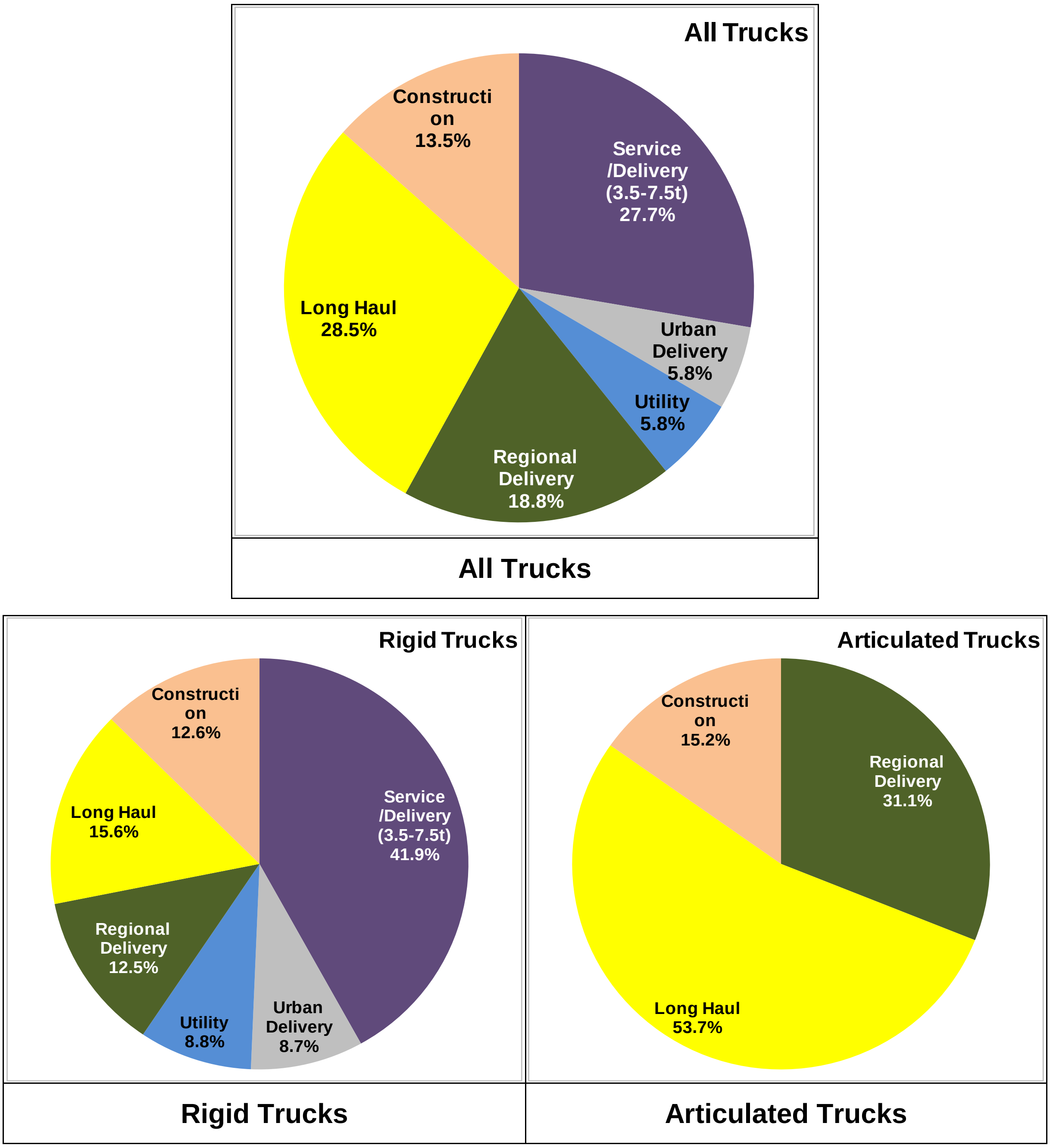
Source: Eurostat (2010)

Notes: Data excludes UK, Ireland, Belgium and Estonia where no data exists.

As mentioned in an earlier section (2.6.1), information on the existing parc shows a ratio of around 1:1 for road tractors:semi-trailers. For drawbar trailers the relationship is just under 10:1 for rigid trucks:drawbar trailers (known as a road train), or 3:1 for road tractors:drawbar trailers.

In terms of the breakdown by application / mission categories of trucks, this has already been discussed in the previous section based upon information provided by ACEA (see Figure 2–39). However, of particular note are the lower proportions of <7.5 tonne vehicles (~29% of rigid trucks) present in this breakdown in comparison with estimates for the entire parc from the FLEETS database for 2005 (~43% of rigid trucks), and also used in TREMOVE (version 3.3.1). However, this might be explained by the fact that this segment comprises of a mixture of rigid truck body types and large vans, which may be sold in greater numbers by the smaller manufacturers not included in the ACEA dataset. An accordingly adjusted estimate of truck fleet composition is provided in the following Figure 2–52, adjusted to 2010.

Figure 2–52: Estimated EU truck vehicle parc by mission profile for 2010



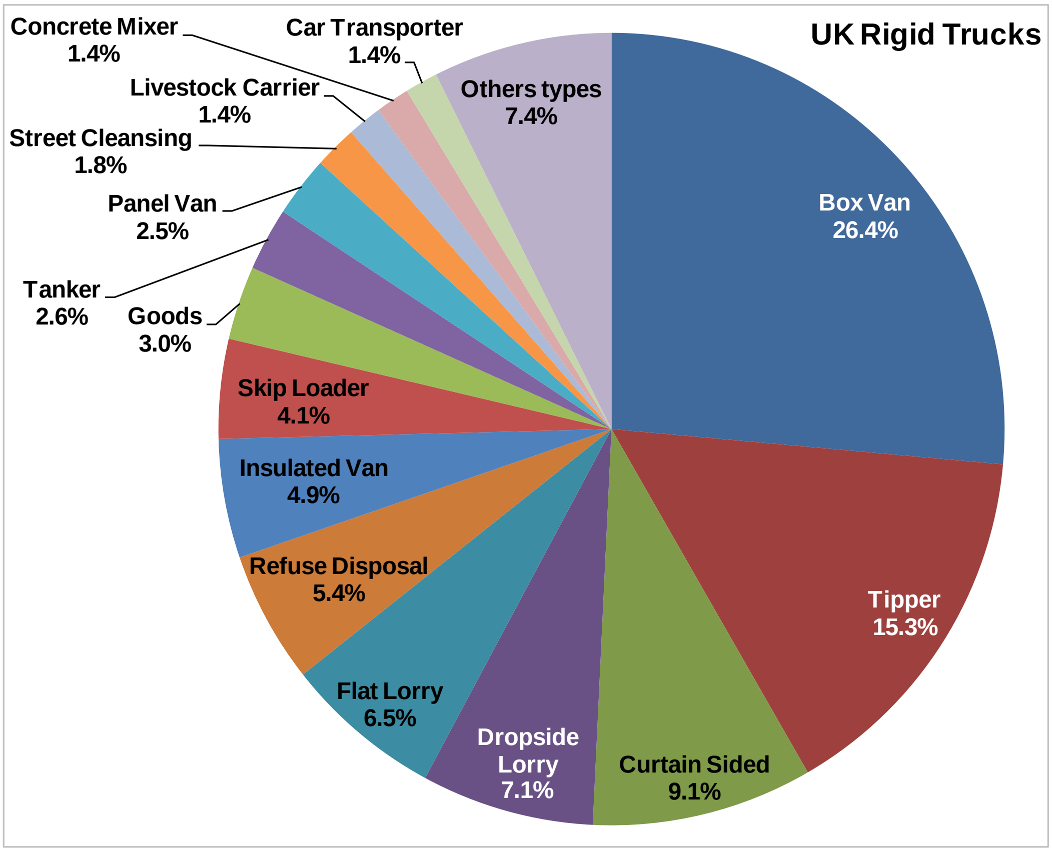
Source: AEA estimates based on dataset provided by ACEA (2010)

Notes: Based on data provided by the 7 major European manufacturers. For the purposes of simplification, AEA have aggregated the ACEA 'long haul' and 'one day trip' categories into a single total for long haul, and the light and heavy off-road/construction categories into a single total for construction. 3.5-7.5 tonne category added by comparing total HCV registrations from ACEA including these over the same period.

The breakdown of vehicles into different body types has also been explored in the earlier section dealing with new registrations (see Figure 2–34 to Figure 2–36). However, whilst there are no European level statistics readily available that break down vehicle and trailer body types further into more specialised categories and weight categorise, there are statistics available in some countries for rigid vehicles. For example, the following Figure 2–53 and Figure 2–56 provides a summary of the 2009 breakdown of rigid trucks by body type and by weight classification for Great Britain from the UK Department for Transport (2010)[12]. Statistics in a similar form are also available for France (SOeS, 2010), see Figure 2–54, and for the Netherlands (although these also include other vehicle types), see Figure 2–55.

Of particular note are the refuse collection vehicle (RCVs) and insulated/refrigerated transport categories that have particularly high fuel consumption compared to other types of truck (~100-150% higher). RCVs receive a lot of attention because of their often cited very high fuel consumption due to a combination of their very slow stop-start duty cycle and the additional auxiliary power needed to operate the waste compaction equipment (also discussed in later Section 2.8).

Figure 2–53: Rigid goods vehicle parc in Great Britain, proportion of numbers by body type, 2009

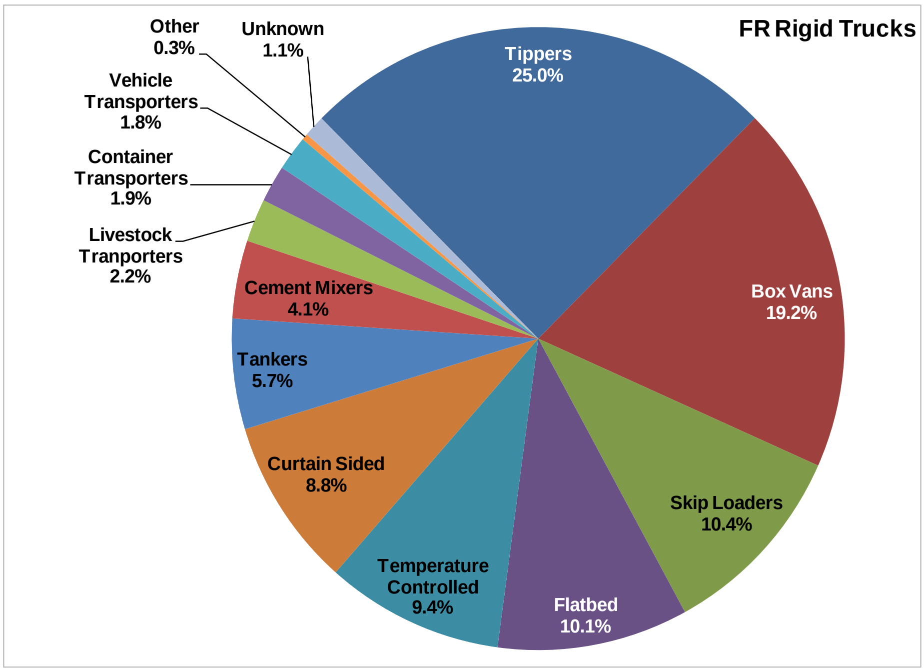


Source: ‘Road Freight Statistics 2009’, Table 4.3 (UK DfT, 2010)

Notes: The figure includes the numbers for all goods vehicles licensed in Great Britain (i.e. the total fleet).

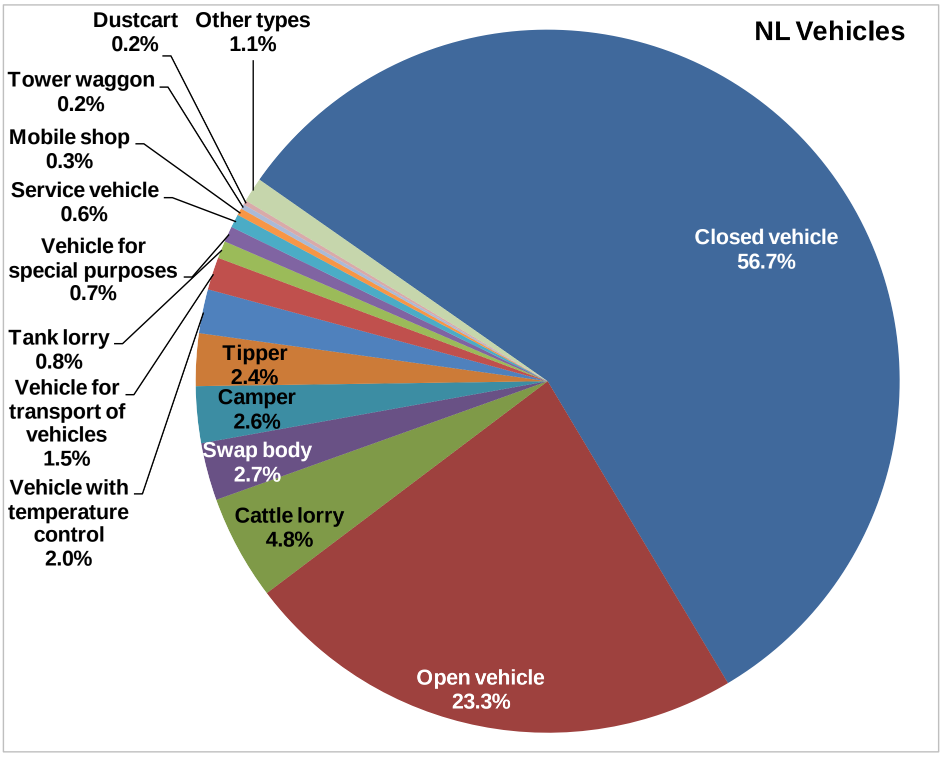
[12] Comprehensive statistics are available on road freight from DfT’s website at: http://www.dft.gov.uk/pgr/statistics/datatablespublications/freight/goodsbyroad/

Figure 2–54: Rigid truck vehicle parc in France, proportion of numbers by body type, 2008



Source: Based on French government transport statistics for 2008, "Vehicle parc utilised during the survey week by body type", from Department of Observation and Statistics (SOeS), 2010.

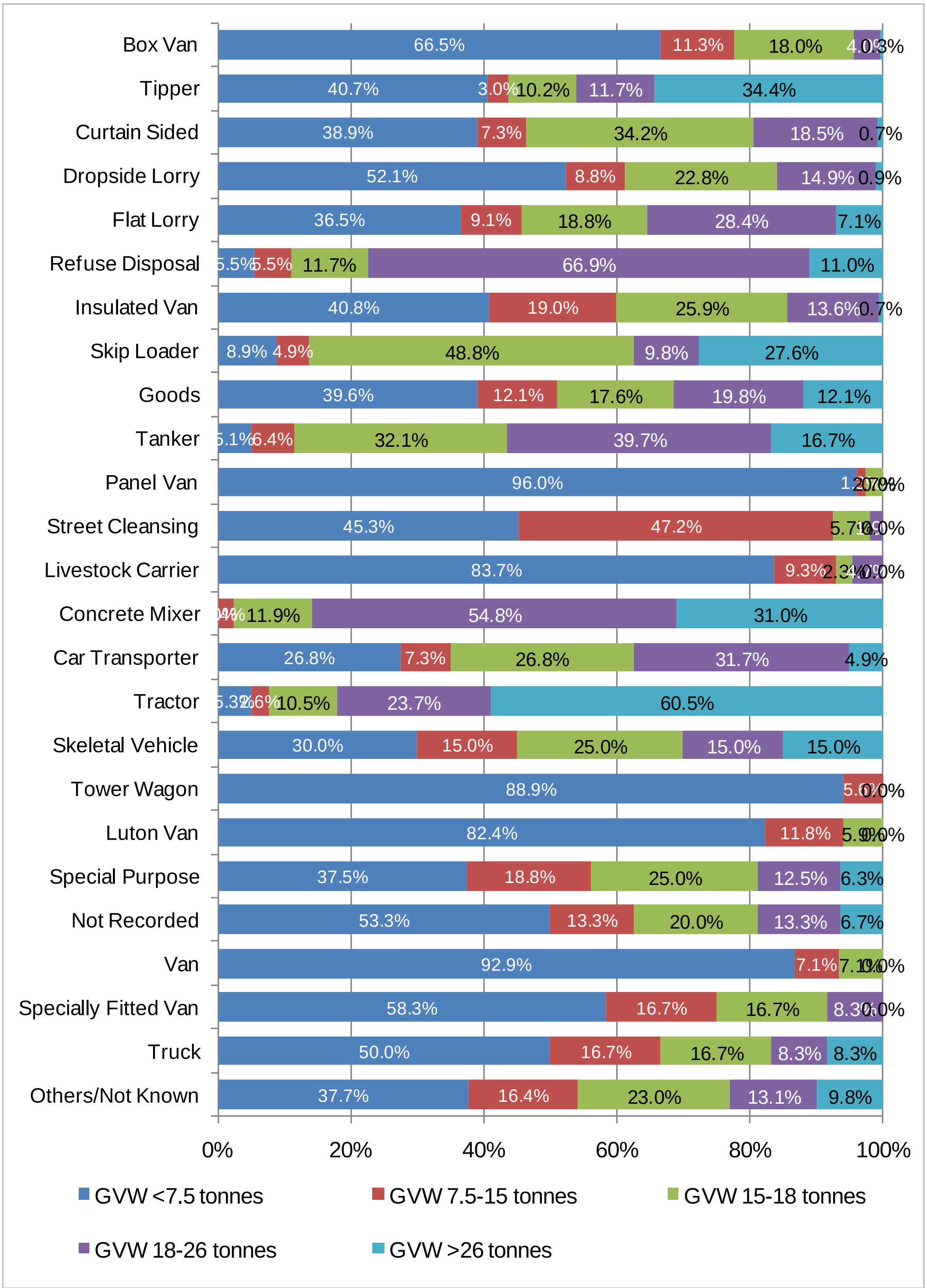
Figure 2–55: Goods vehicles licensed in the Netherlands*, proportion of numbers by body type, 2009



Source: Based on Netherlands national transport statistics for 2009: "Motor vehicles; general overview per period and technological features", from Statistics Netherlands (2009)

Notes: NL statistics are for all commercial vehicles including vans (i.e. light commercial vehicles) and trailers as well as all HDVs. Although it has been possible to remove buses and around half the trailer figures from the dataset, the remaining set still comprises some 30% trailers and 56% vans (mostly closed vehicles)

Figure 2–56: Rigid goods vehicles licensed in Great Britain by gross weight and body type, 2009



Source: 'Road Freight Statistics 2009', Table 4.3 (UK DfT, 2010)

Notes: Vehicle categories in the figure above are also ordered in order of total population, with the types with the highest numbers at the top.

Whilst we have not been able to identify little European level information on RCV performance and numbers, we have estimated the potential significance of RCVs for the EU27. The result of this analysis is presented in the following Table 2.27, which has used three alternative methodologies for arising at figure for the total EU27 stock, vehicle-km and CO_2 emissions from RCVs using as a basis data that is available for the UK. The figures have been estimated based on UK data scaled up to EU27 by population, waste production or proportion of total truck fleet. The average fuel consumption of RCVs is assumed to be 64 l/100km on the basis of UK mix of vehicle sizes, with average annual distance covered of 15,000 km per truck. Although, clearly this is a rough approximation, the conclusion is that RCVs do not appear likely to contribute a particularly large component of total truck fuel consumption / CO_2 emission. Neither does it seem likely they contribute to a significantly greater degree in comparison to their relative numbers. The significance of RCVs and other municipal utility vehicles is also explored in greater detail in later sections 4.4 and 4.5.

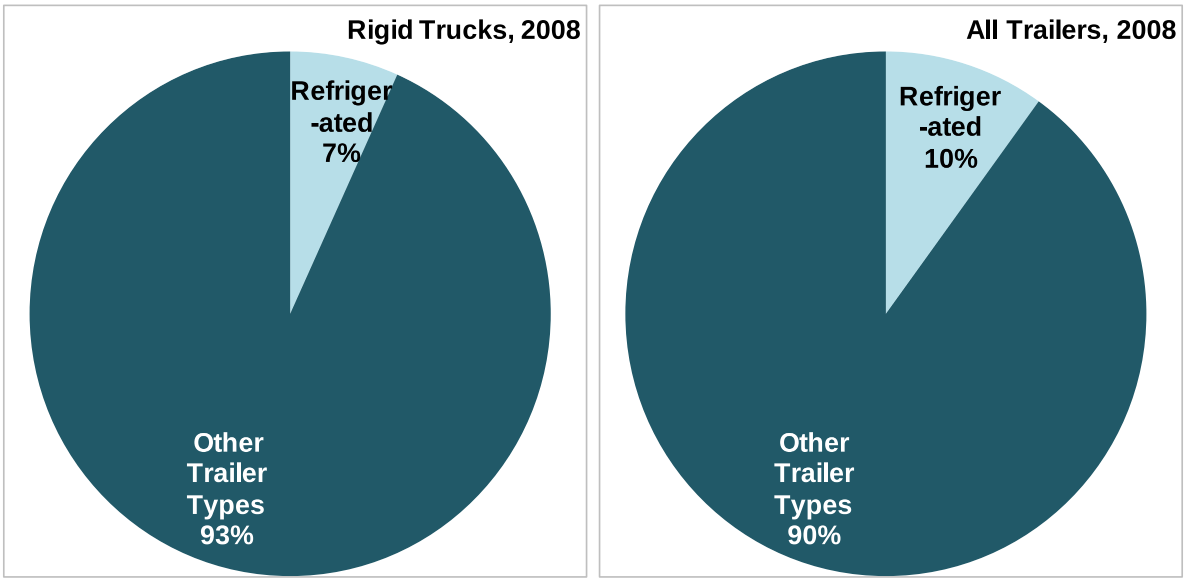
Table 2.27: Estimates for the significance of Refuse Collection Vehicles to total EU27 truck fleet numbers, activity and emissions using three different methodologies.

	Estimated RCV contribution to EU27 totals for:		
Estimation Method	**Truck Stock %**	**Truck vkm %**	**Truck CO_2 %**
Population	2.03%	0.91%	2.20%
Waste generated	1.88%	0.84%	2.04%
UK truck fleet proportion of RCVs	3.50%	1.57%	3.81%

Source: Estimates made by AEA on the basis of RCV numbers from the UK Department for Transport (2010), and datasets on EU population and waste production from Eurostat (2010) and data from TREMOVE version 3.3.1 for total vehicle numbers, vehicle km and heavy duty truck CO_2 by Member State.

For temperature controlled/refrigerated transport the situation is slightly different. Whilst these vehicles do not have nearly such a high fuel consumption per km compared to RCVs: (a) they do use around 20% more than equivalent vehicles, (b) they comprise a significantly larger proportion of the overall truck fleet (see Figure 2–57), and (c) also travel over much greater distances per year in comparison to RCVs.

Figure 2–57: EU27 parc of insulated/refrigerated body type vehicles (rigid trucks and all trailers) for 2008



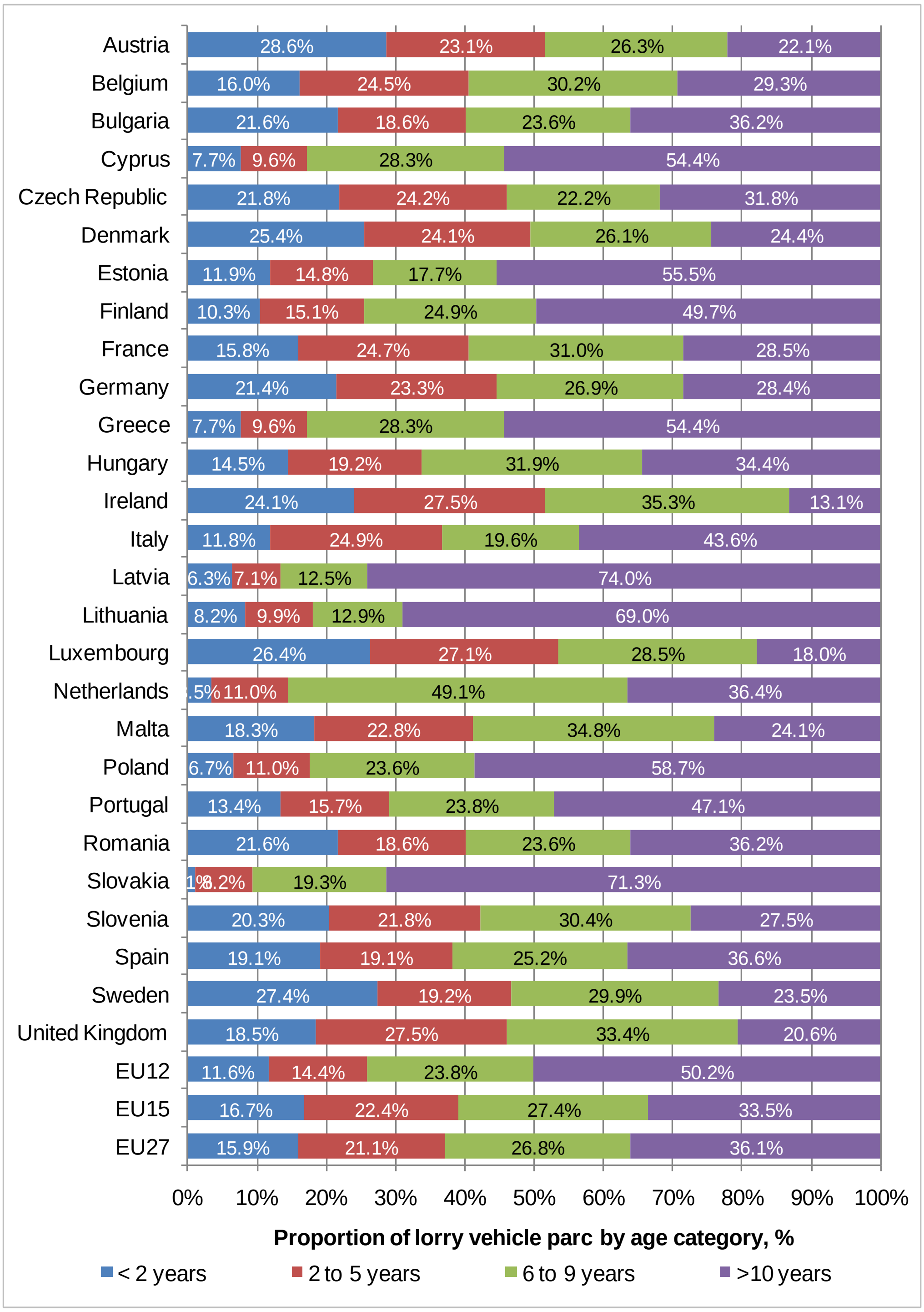
Source: CLEAR International Consulting (2010) for trailers, German VDA (2010) for rigid trucks.

Due to these considerations it therefore seems highly likely that such vehicles will contribute to a significant proportion of overall fuel consumption and CO_2 emissions from heavy trucks. This will be discussed /investigated in more detail in later Sections 2.8.1.3 and 4.2.2.

2.7.1.3 Age profile of the European truck fleet

In terms of the age profile of the European lorry and road tractor fleet, statistics available from Eurostat indicate significant variations in the numbers of vehicles in different age bands by Member State, as illustrated in Figure 2–58 below and Figure 2–59 on the following page.

Figure 2–58: EU27 lorry vehicle parc, by age category and Member State in 2008

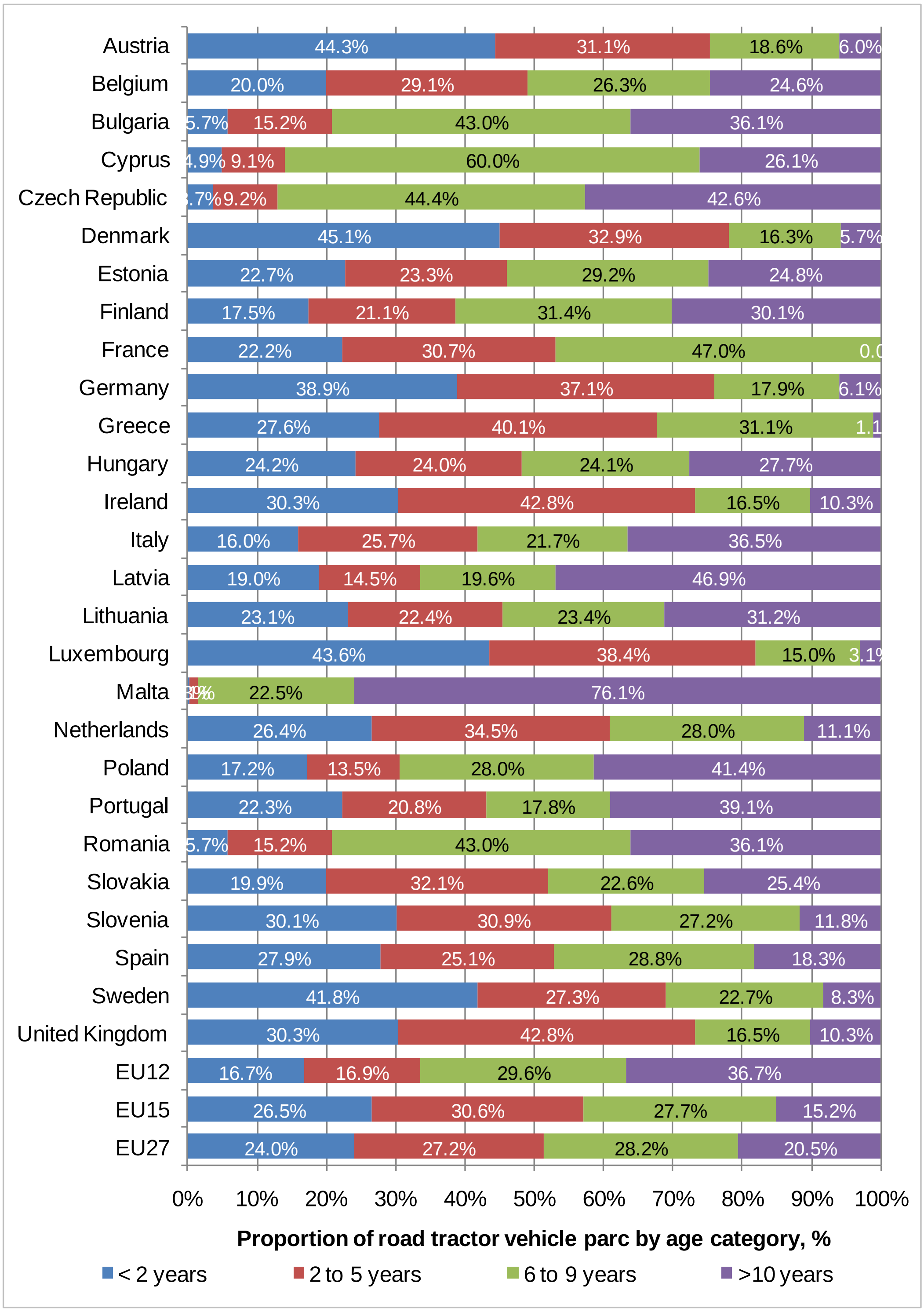


Source: Based on data from Eurostat (2010)

Notes: The Eurostat 'Lorries' category includes data for light commercial vehicles for many Member States.

In general the Southern and Eastern European countries appear to have higher proportions of older lorries and road tractors in their fleets. Also notable is the larger predominance of the higher age bands in the lorries dataset, however this seems likely to be due to the high numbers of LCVs included in this category, which tend to have longer lifetimes.

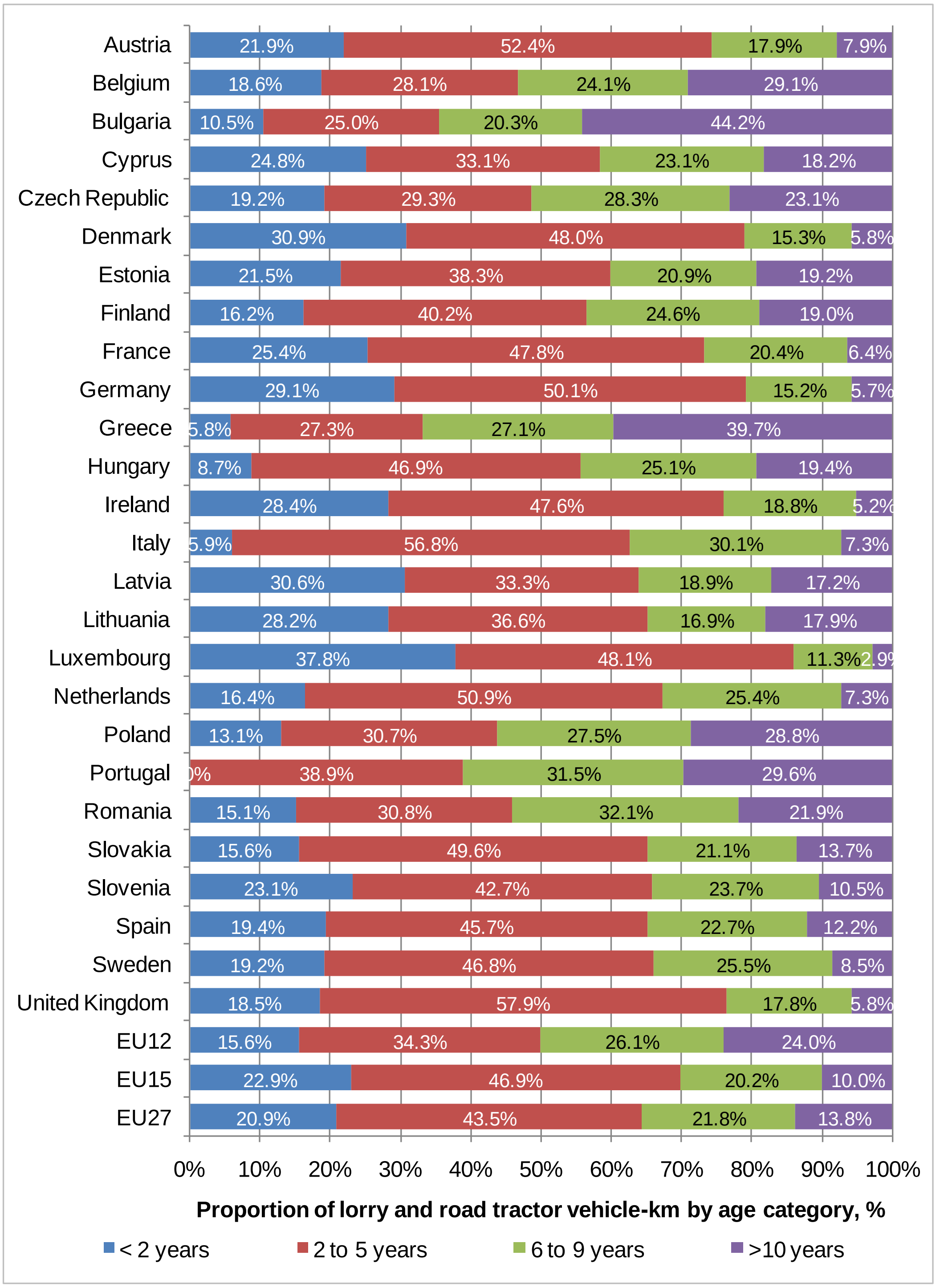
Figure 2–59: EU articulated truck (road tractor) vehicle parc, by age category and Member State in 2008



Source: Based on data from Eurostat (2010)

In terms of overall activity (in vehicle km) there is also clear and strong predominance of newer vehicles being used for the majority of vehicle km. This appears to confirm more anecdotal evidence for this from discussions with industry stakeholders indicating that newer vehicles are used for longer journeys in general due to their greater reliability (of critical importance for such operations).

Figure 2–60: EU27 activity (in vehicle-km) of all lorries and road tractors, by age category and Member State in 2008



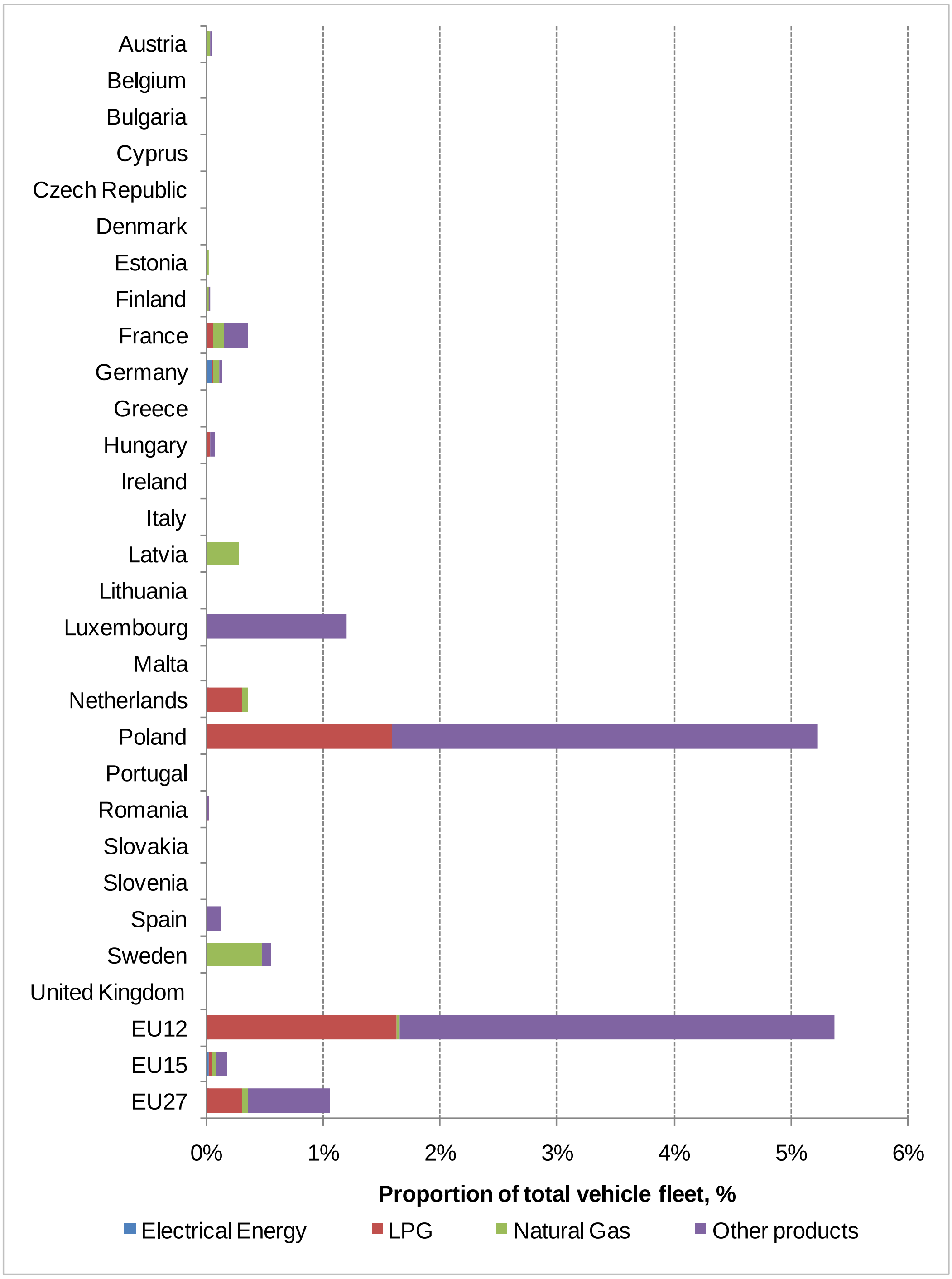
Source: Based on data from Eurostat (2010)

Notes: The Eurostat 'Lorries' category includes data for light commercial vehicles for many Member States.

2.7.1.4 The use of alternative fuels in the European truck fleet

The following Figure 2–61 summarises the picture in terms of the uptake of alternative fuels within the European lorry sector. Lorries with load capacities <1.5 tonnes have been excluded from the figure, which should account for essentially all of the light commercial vehicles included together with rigid trucks in this Eurostat category. The figure quite clearly demonstrates that with very few exceptions there are very few alternatively fuelled vehicles in the European truck fleet. However, in Poland there are a significant number of LPG vehicles and trucks using biofuels appear to be included in Eurostat statistics under 'Other products'.

Figure 2–61: % fleet by alternative fuel category of lorries >1.5t load capacity by Member State for 2008



Source: Based on data from Eurostat (2010)

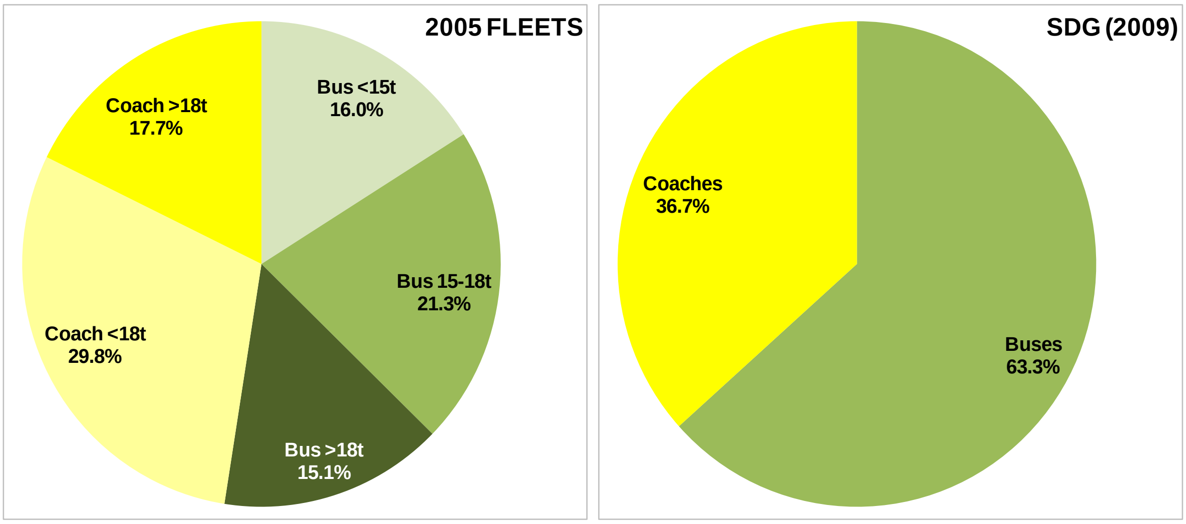
Notes: Data presented is for lorries with a load capacity >1500kg, which should exclude the majority of LCVs present in the wider lorries dataset.

2.7.2 Buses and Coaches

2.7.2.1 Fleet composition by weight and mission category

Information on the disaggregation of vehicle numbers between different bus and coach categories is available from the FLEETS database for the 2005 vehicle fleets across the EU27. The following Figure 2–62 provides a summary of the split of vehicles by weight class in these categories for the aggregated EU27 fleet from the FLEETS database, in comparison to the independently estimated figures for buses and coaches by SDG (2009). It is unclear to what degree the variation in the relative split between buses and coaches for the two fleet estimates are a result of (a) actual changes in total fleet composition between 2005 and the estimate by SDG (assumed to be for 2007/8), (b) methodological differences in building the estimates. It is also worth highlighting that there are significantly lower proportions of coaches in new registrations by ACEA members, according to data provided by ACEA that was presented previously in Section 2.6.2. The picture from the FLEETS database is also presented in Figure 2–64 showing the different split by Member State.

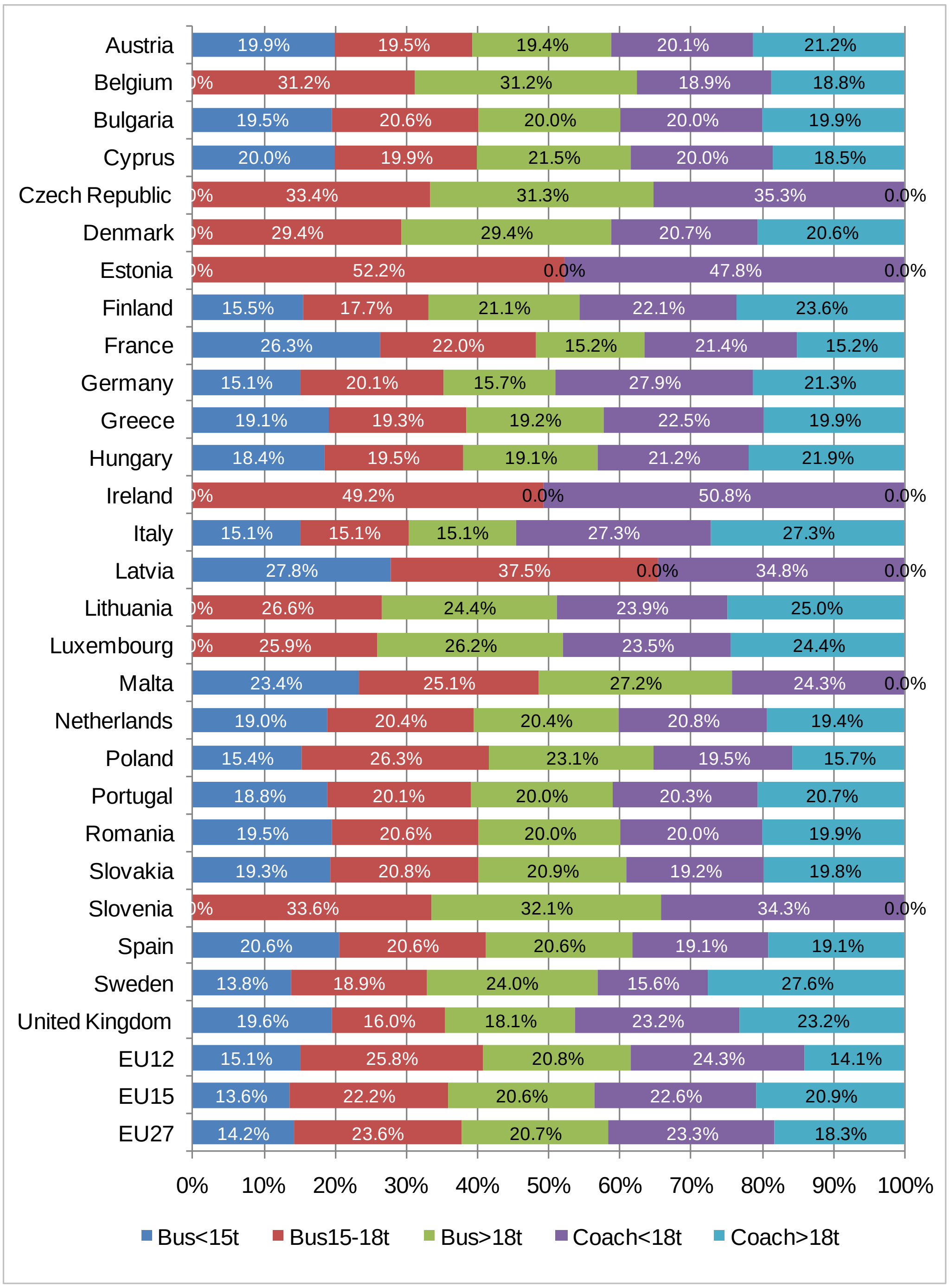
Figure 2–62: EU27 estimated fleet split of buses and coaches by type and weight class



Source: Estimates based on dataset FLEETS-COPERT dataset for the year 2005 and from SDG for 2007.

Notes: FLEETS categories buses <15t as midi buses, buses 15-18t as regular single deck buses, buses >18t as articulated or double-deck buses. Similarly, coaches <18t are classified as single-deck, and those >18t as double-deck or articulated coaches.

Figure 2–63: EU27 parc of buses and coaches by weight category and Member State



Source: Based on data from the FLEETS database for 2005

2.7.2.2 Age profile of the European bus and coach fleet

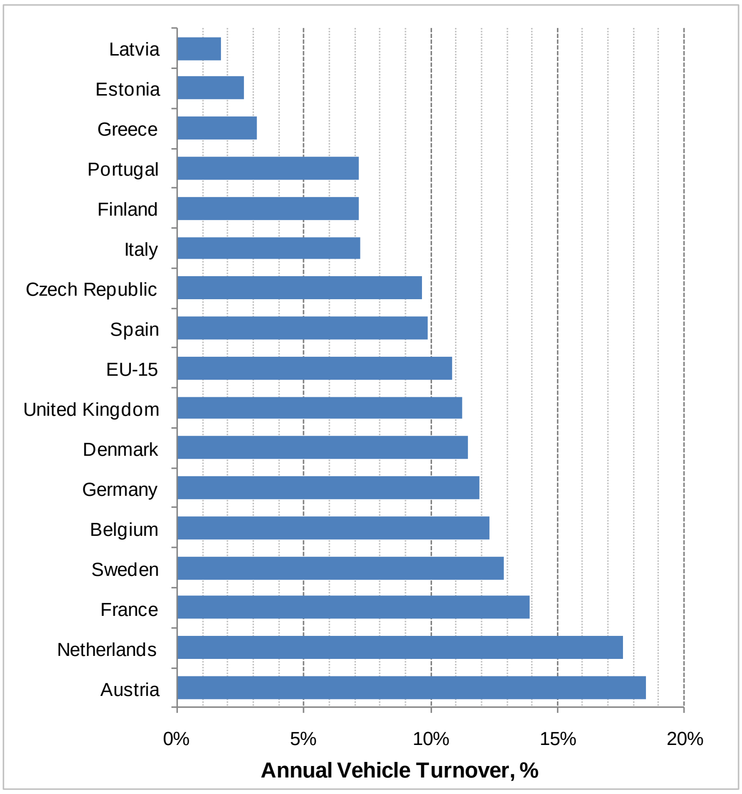
The following Table 2.1 and Figure 2–64 summarise the information reported by SDG (2009) for coaches (unless otherwise stated) and buses in the EU fleet. SDG note in their report that there are significant differences in the average vehicle ages in different Member States. This is reinforced when considering alternative datasets, such as the Eurostat statistics on bus numbers by age category presented in Figure 2–65, and the results of a recent survey by UITP presented in Figure 2–66. This later dataset seems to indicate that the average operating life of a bus is roughly 15 years in the EU, whilst for trolleybuses this rises to 20 years. SDG also observe that the implied average operating life from their dataset is of a similar magnitude.

Table 2.28: Average age of vehicles

State	Average vehicle age (years)	Notes
Austria	6.5	Includes buses
Finland	11.9	Includes buses
Germany	6.3	
Greece	> 10 years	Refers to tourist coaches only. KTEL (regular) coaches are newer.
Italy	10	Includes buses
Poland	17	Includes buses
Portugal	12	Includes buses
Romania	Median 5-10 yrs	
Spain	11	Vehicles on long distance regular concessions newer (av. 5.7 years)
Sweden	8.8	Includes buses. Average for coach slightly higher.
UK	8.1	Includes buses

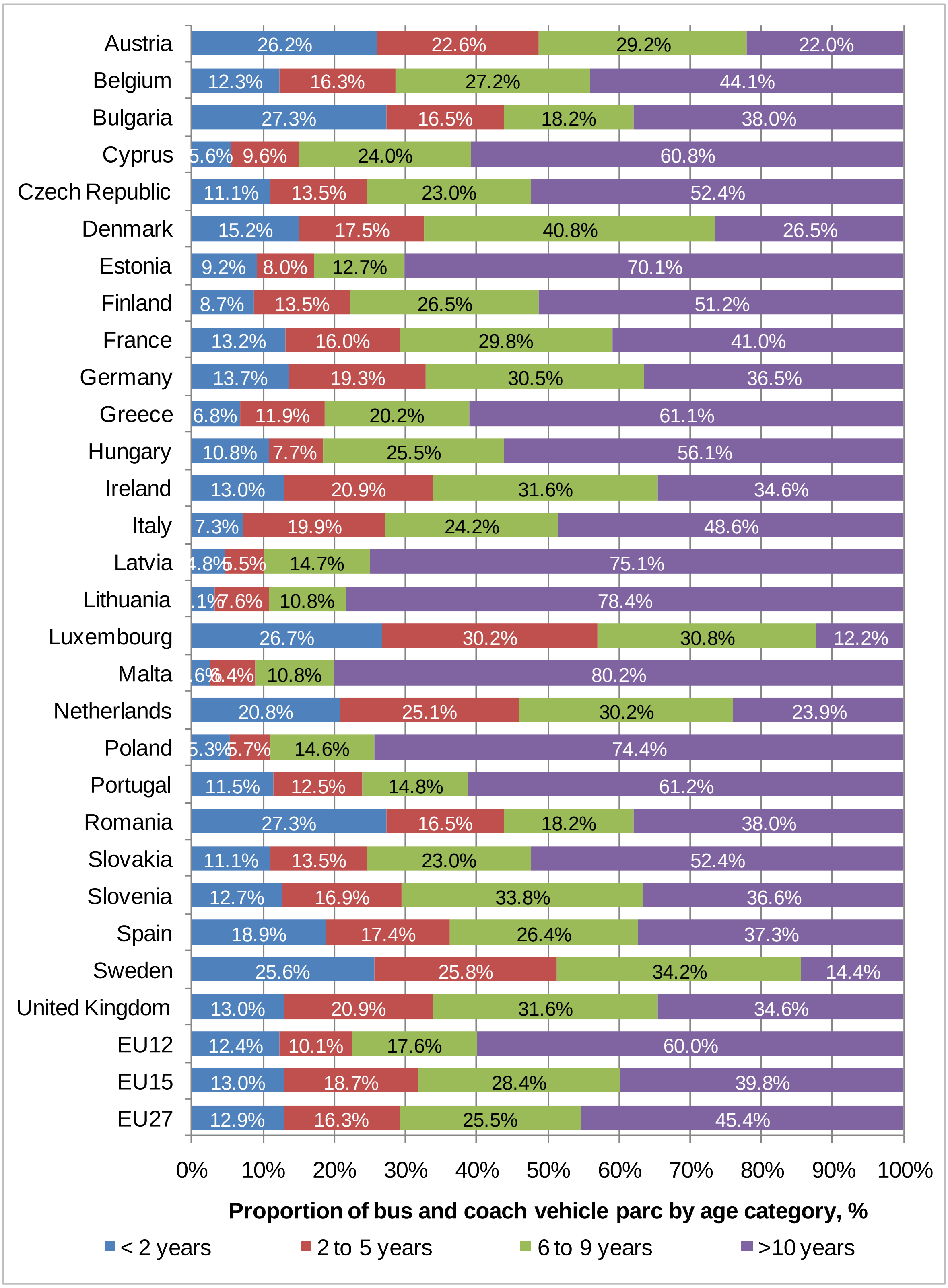
Source: Reproduced from Table 4.12, SDG (2009)

Figure 2–64: Bus and coach turnover in European countries



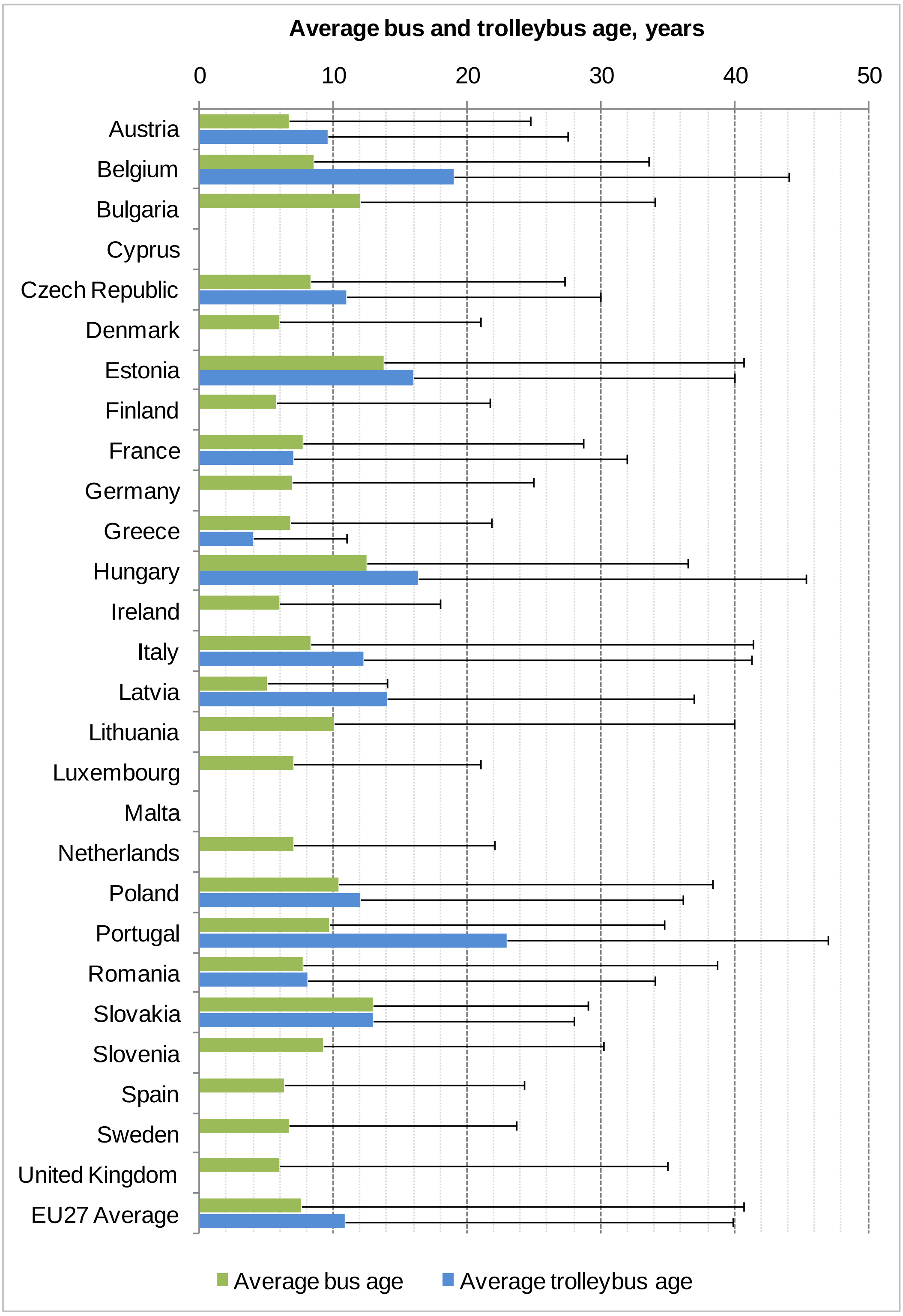
Source: Reproduced from Figure 4.12, SDG (2009)

Figure 2–65: % split by age category of buses, coaches and trolleybuses by Member State for 2008



Source: Based on data from Eurostat (2010)

Figure 2–66: Average bus and trolleybus age for respondents to the UITP survey



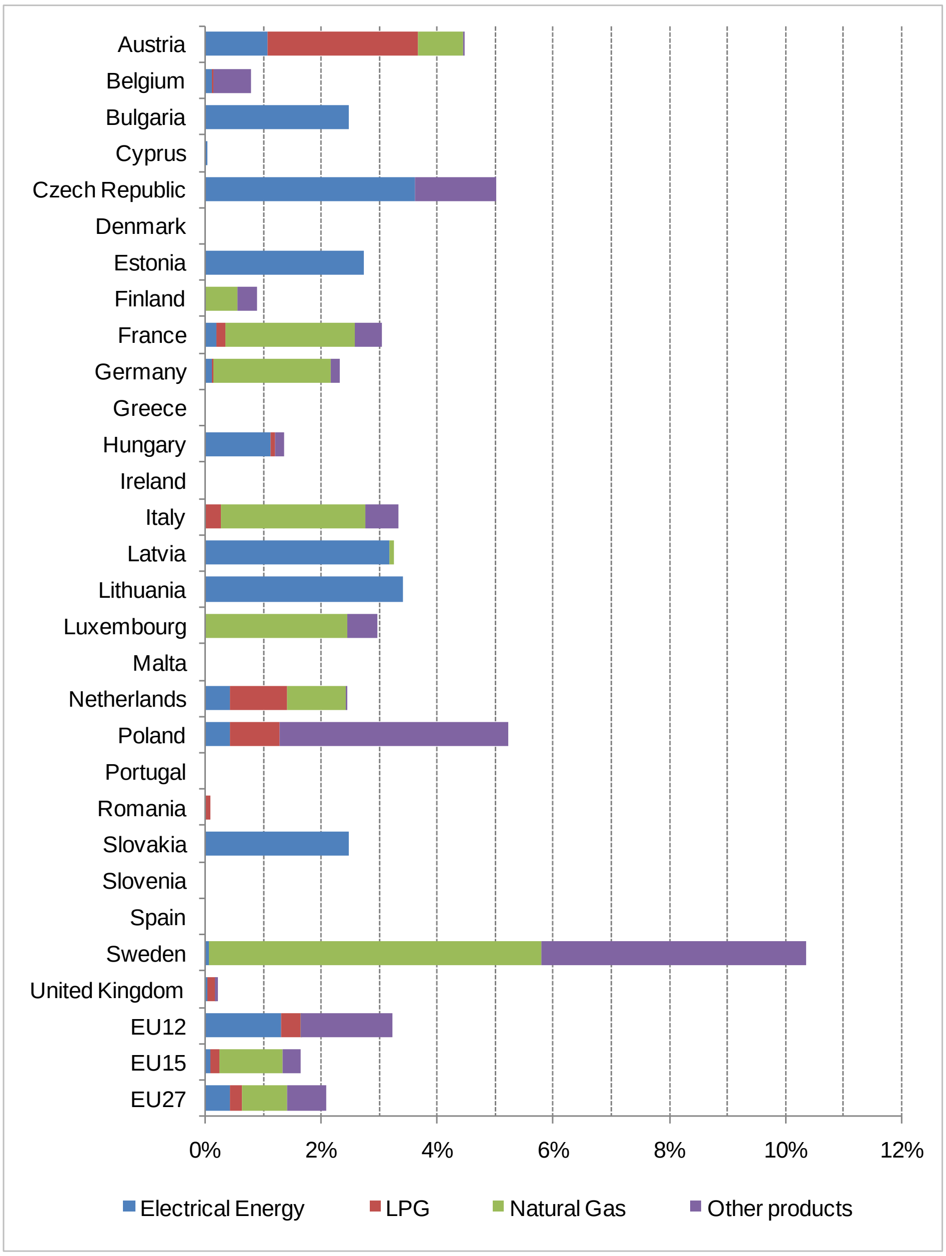
Source: Based on data from UITP (2010)

Notes: Data was collected by UITP in a survey of EU cities of over 100,000 inhabitants, with reference to the year 2005. Error bars indicate the maximum vehicle age reported in the survey.

2.7.2.3 The use of alternative fuels in the European bus and coach fleet

The picture in terms of the use of alternative fuels in European buses, coaches and trolleybuses is presented in the following Figure 2–67. Unlike the situation for trucks, there appear to be significant numbers of alternatively fuelled vehicles in the fleet. It is expected that the majority (if not indeed all) of the electrically powered vehicles are trolleybuses, such as the systems that have operated for a long period of time in many of the Eastern European states. Natural gas powered buses appear to be the most widely used alternative technologies across the EU15 member states, with biofuel powered buses (included in the 'other products' category) featuring across the original and newer EU states – most notably in Sweden (with its fleet of ethanol fuelled buses) and in Poland.

Figure 2–67: Proportion of fleet by alternative fuel category for buses, coaches and trolleybuses by Member State for 2008



Source: Based on data from Eurostat (2010)

Notes: The 'Other products' category typically contains vehicles operating on high-blend biofuels, e.g. the significant fleet of ethanol powered buses in Sweden.

2.7.3 Used vehicle market

Little information has been identified / appears to be available on the second hand vehicle markets for HDVs. However, the available information suggests movements of older vehicles from the major EU economies with higher fleet turnover and newer vehicles) to southern Europe and also the newer EU Member States. As already discussed, in these countries the average fleet ages are much higher but new registrations do not appear to satisfy even these coupled to increases in fleet size. This suggests an influx of additional used vehicles from elsewhere. This observation is also supported by information on the numbers of imported used HDVs in the Czech Republic and Slovakia from their national automotive industry association's statistics, provided by DG CLIMA[13]. These used HDV imports accounted for almost 30% of sales (new registrations + used vehicle imports) in 2007 and further increased in 2008 and 2009 - most likely as a result of the downturn in the global economy.

One possible source of information that was identified was a dataset from POLK, who indicated they may hold information on the HDV used vehicle market. However, it has not been possible to obtain this dataset with current project resources and timescales.

2.8 Energy consumption from on board equipment and vehicle adaptation to different mission profiles

Objectives:
The purpose of this sub-task was to provide information on:

"Types of equipment on board the vehicles and energy consumed by the equipment; description of the degree of adaptation of vehicles carried out by vehicle manufacturers to support different emission profiles."

Summary of Main Findings

⇒ Running auxiliary equipment off the main HDV engine, such as cab heaters and air conditioners results in efficiency losses that can be significant;

⇒ The most common heating systems in use in cabs operate whilst the vehicle engine is turned on as they rely upon the heat generated by the engine as their heat source;

⇒ The refrigeration units of temperature controlled vehicles are mostly powered with auxiliary diesel engines which can account for between 15 and 25% of the total fuel consumption for the vehicle (with significant variability depending on both technical and operational factors as well as external temperatures).

⇒ One of the most successful mediums of vehicle adaptation that can result in the reduction of energy and fuel used for medium to long-distance vehicle operations is aerodynamic body styling. However, this has limited (or can even have disbenefits) in short distance / urban operations;

⇒ There are a number of auxiliary equipments for trucks that have a direct effect on the energy use. They include (1) Power Take Off (PTO), (2) Auxiliary Power Unit (APU), (3) Battery powered and (4) Direct plug-in electrical power supply;

⇒ The most common ancillary equipments found on city buses are (1) Heating and air conditioning (which can account for 9% of total fuel consumption), (2) Doors that operate through air compressors and (3) Tilting mechanisms.

[13] Data was originally sourced from (a) Sdružení Automobilového Průmyslu (Automotive Industry Association) in the Czech Republic - http://www.autosap.cz/, (b) Združenie Automobilového Priemyslu Slovenskej Republiky (Automotive Industry Association) - http://www.zapsr.sk/

Running auxiliary equipment off the main HDV engine, such as cab heaters and air conditioners - used when the vehicle is stationary, results in efficiency losses. Although the overall absolute impacts of efficiency improvements in auxiliary system is lower than for other systems (~7% of overall potential efficiency improvements according to the US Department of Energy), the relative improvement potential could be quite high (up to a 50% improvement). Besides air conditioners and cab heaters, other typical systems that contribute to the auxiliary load include air compressors, air control units, water and steering pumps, and fans and other embarked electronic engines. The attachment of cranes and other lifting mechanisms also contribute significantly to the fuel usage as these equipments slave their power from the vehicle engine. In addition, refrigeration units can add very significantly to the overall energy consumption in refrigerated vehicles, this will depend on whether vehicle engines or auxiliary powers sources are used.

The work for this subtask involved a number of activities:

- Collection of existing internal knowledge from AEA and Ricardo;
- Literature review and web search for information;
- Additional information collected from earlier survey questionnaires.

A review of all on board equipment and vehicle adaptation for HDVs has been made and AEA have discounted the equipment which has little significant contribution to CO_2 reduction in total HDVs. In order to complete this subtask, AEA and Ricardo have collected and collated information on the energy consumption of such auxiliary equipment. Moreover, an assessment of the significant equipment/components and measures that can affect the overall energy consumption of HDVs has been made.

There are a significant number of on board equipment types and vehicle adaptations to be found on both goods and passenger carrying Heavy Duty Vehicles (HDVs). These equipment types and adaptations are directly related to both the mission profiles and as a result of higher expectations from vehicle users. The types are vastly different and are examined below under the following common categories:

- **Trucks, including:**
  - Fixed Chassis
  - Articulated Trucks consisting of:
    - Tractor unit
    - Trailer unit
- **City Bus**
- **Coach**

There are a number of vehicles that are in reality pieces of specialist equipment that are mobile for ease of transportation to their primary place of work and are not used for the purpose of transporting goods or passengers. These include mobile heavy lift cranes, agricultural vehicles, earth moving equipment, engineering equipment and plant. For the purpose of this study it is not appropriate to included them as HDVs as their primary power source is their engine which has been orientated and configured to the provision of power to carry out a primary task other than their means of movement/propulsion.

2.8.1 Trucks

Trucks are manufactured by a number of Original Equipment Manufacturers (OEMs) across Europe, with the distribution by manufacturer provided in Section 2.4. However, unless the vehicle is designed for a standard cargo carrying mission and lifecycle, the body and equipment configuration will be provided by one or more manufacturers who will add to the basic cab and chassis provided by the OEM. In some cases an individual vehicle may be produced as a result of several manufacturers' contribution to the overall vehicle equipment specification. For example, an articulated tipper may have a tractor unit, trailer unit and a trailer mounted crane. This has the potential to affect many of the vehicle's operating and energy consumption characteristics including weight and aerodynamic performance.

The complex and highly variable manufacturing supply chain required to produce a truck, results in there being no holistic audit trail for the variants manufactured and/or on the road in Europe.

2.8.1.1 In-Cab Cooling and Heating Equipment

Regardless of an individual truck manufacturing chain, the cab is most likely to be produced by the OEM to a customer specification. Each OEM provides a variety of designs and internal features, with differing levels of benefit provision. The most common single source of on board equipment related to power usage with a direct effect on energy consumption that are found on all truck variants are heating and air conditioning systems.

The type of vehicle cabs most commonly available from OEMS are:

- Short Cabs – with reduced space and comfort, designed for day use, in particular multi-drop operations where the drivers' work environment is not restricted to the vehicle cab;
- Day Cabs – with more space and storage facilities, orientated towards drivers whose work pattern requires most of the day spent driving the vehicle;
- Sleeper Cabs – these may have one of more sleeping compartments incorporated within the cab design.

The more time spent within a cab, the more likely that the operator will require increased heating and ventilation (including air conditioning) facilities to be included in the vehicle features. Therefore, the most energy consuming cabs are likely to be sleeper cabs, particularly when fitted with on board heaters. On board heaters are independently powered by a small motor, usually diesel, and transfer heat to the cab through either an air or water heat exchange mechanism. Independent in-cab heaters can also be fitted to include the engine compartment to reduce the energy required to cold start. In both instances timing mechanisms are available.

The most common heating systems in use in cabs operate whilst the vehicle engine is turned on as they rely upon the heat generated by the engine as their heat source. There is an electric fan to distribute the heat to the cab through a series of vents and channels. The biggest disadvantage of these systems is that in an environment of a low ambient temperature, truck drivers can be inclined to turn on engines and leave them idling in order to heat the cab. This can be either prior to commencing a journey or during the statutory driving hour breaks. This is an energy consuming activity.

Air conditioning systems will be more prevalent in parts of Europe where the ambient temperature is at its highest. Such systems require a compressor to generate cold air which belt driven by the engine. Therefore there is an associated energy and fuel usage for the use of air conditioning. The additional fuel usage will vary between air conditioning systems and the operating environment.

Regardless of the heating and air systems used to condition the climate of the cab, these facilities all have provide additional weight to the vehicle itself with a retrospective energy use. The one that has the most significant effect on energy consumption is air conditioning.

2.8.1.2 Auxiliary Equipment

There are a number of types of auxiliary equipment for trucks that have a direct effect on the energy use. They are either complete vehicle adaptations, a bespoke manufacture to fit a specific mission profile; or an additional feature to enhance the vehicle characteristics and to ensure that it is more adaptable to the specific working environment. Both adaptations require auxiliary equipment to be powered through one or more of the following power sources:

- *Power Take Off (PTO)* – from the vehicle engine itself, or the gearbox
- *Auxiliary Power Unit (APU)* – a separate engine that powers the auxiliary equipment
- *Battery Powered*
- *Direct plug-in electrical power supply* – power supplied to the auxiliary equipment when stationary.

Power Take Off

PTO is a very common form of provision of energy to auxiliary equipment, which can be attached to either an engine or gearbox. Normally PTO is used where:

- The equipment is required as an integrated part of the vehicles mission profile – a primary element of the vehicle use;
- The power required to operate the equipment is not suited to provision from another source because of either the torque required or vehicle chassis space available to mount another power source.

When specifying ancillary equipment to be driven from a gearbox-mounted power take-off (PTO), it is important for operators to consider the gear ratio to be used. Modern engines have efficient power and torque curves starting at around 1,000 rpm. This provides an ideal position to set the PTO gearing for optimum fuel economy. Lower gearing may produce additional power to drive the ancillary equipment, but at higher fuel consumption. When specifying engine-driven ancillary equipment, it is important for operators to specify PTO ratio. This should be matched to the engine in order to provide the required power at the most fuel-efficient engine speed.

Auxiliary Power Unit

An APU is used most commonly where the equipment concerned is require to run during periods when the vehicle is stationary or when the load’s integrity would be compromised by engine failure (for example in refrigerated transport). APU’s are most commonly powered by diesel. In some cases this can be diesel that is subject to a lower rate of excise duty.

Battery Powered

Battery power is used most commonly where the energy used is sufficiently low as not to require a powerful source and where there is the opportunity to recharge the battery on a regular basis.

Direct Plug-in Electrical Power Supply

This is used in situations where power is required for significant periods of engine inactivity, such as overnight temperature controlled storage.

Common Auxiliary Equipment

There are a large number of truck variants and ancillary equipment types that are fitted in vehicles. These include:

- Vehicle Mounted Cranes – including pallet grab lifters – Cranes and grab lifters are commonly found where bulk and/or weight items are required to be dropped as part of a vehicle mission profile. The torque required will make PTO necessary for this equipment. Current improvement activity focuses on reduction in the weight of the materials in the manufacture of the equipment. Loading at a logistic site should be conducted using independent forked lifting equipment.
- Hook Lifts – Hook lifts are used to uplift a variety of rack systems which are heavy and bulky in nature and due to this characteristic use PTO. Such vehicles are specifically built for hook lift and they have their origin in military application, known as Dismountable Rack Offload and Pickup System.
- Tippers – Tippers can be either fixed axel or articulated. They can be built to include other auxiliary equipment suck as vehicle mounted cranes. They use PTO due to their size and the torque required.
- Refuse Collection Vehicles – Including Compacting Mechanisms – Specifically manufactured for purpose refuse collection and compacting vehicles use PTO to both compact refuse and to tip the load when the journey is completed.
- Tankers – Tankers are required to deliver bulk liquids, normally on a multi-drop pattern. Pumping equipment is integrated to the vehicle design and use PTO.
- Winches – Winches are primarily required for recovery vehicles. Due to the power weight ratio required PTO is used.
- Multi Lifts (Skips) – Skips, as they are common known have a significant power weight ration lift requirement and employ PTO.
- Mobile Mixers – Mobile mixers are used in restricted applications; typically for the delivery a wet cement mixtures within restricted journey times to the construction environment. PTO is used for this application.
- Temperature Controlled Carriage Units – Frozen and Chilled – Temperature controlled vehicles are the most flexible for their energy source. They can operate on either PTO, APU or electrical plug-in. The mission profile of the vehicle will determine which of the energy sources is employed. Most common usage is a diesel APU as this is unaffected by the vehicle itself and the load integrity is retained when the vehicle engine is turned off. The power required by an APU is less than PTO. APU is supported in most applications by electrical plug in, particularly at the point of loading.
- Tail Lifts – tail lifts are a common auxiliary equipment, especially for multi-drop deliveries. These are most often electric battery powered.

2.8.1.3 Refrigerated / Temperature Controlled Carriage Units

According to Defra (2009)[14], there are 650,000 refrigerated road vehicles in the EU accounting for around 600 million tonne-km of road freight. An auxiliary diesel engine is used to provide temperature control in the vast majority of cases. However, there is little real-world data available for in-use energy consumption of refrigerated transport equipment and this fuel consumption is dependent on many factors, the principal ones include:

- Refrigeration capacity and efficiency of the fridge unit;
- The size and insulation efficiency of the floor, body and doors;

[14] Reducing Energy Use in Food Refrigeration: Sector Focus – Transport , work carried out for UK Defra by The Grimsby Institute of Higher Education and the Universities of Bristol, Brunel, London South Bank and Sunderland, 2009. Available at: http://www.grimsby.ac.uk/documents/defra/sectrep-transport.pdf

- The type of operation/ number of deliveries being carried out and type of product transported;
- Solar load / external temperature;
- Control software setup;
- Whether the refrigeration unit is a single or multi-temperature unit.

Fridge units consume higher levels of fuel during multi-drop deliveries as more energy is required to maintain the load temperature at the required level and offset the warmer air entering the body or trailer when the doors are open (DfT, 2010)[15]. Also, in many cases, the field energy consumption for chilled distribution can be higher than frozen food distribution due to the more stringent temperature control requirements, product respiration and the higher air flow rates required to maintain uniform temperature distribution (Tassou et al, 2009a[16]).

According to S. A. Tassou et al (2009)[17], the majority of refrigerated road transportation is conducted with semitrailer insulated rigid boxes (e.g. in the UK articulated vehicles >33t account for >80% of refrigerated food transportation). The typical European construction dimensions of a semi-trailer rigid box are fixed for the external length and width but the external height and internal dimensions can vary depending on the individual design type. In the UK, articulated vehicles over 33t are responsible for over 80% of refrigerated food transportation.

A summary of the typical motive and refrigeration fuel consumption of temperature controlled trucks is provided in the following Table 2.29.

Table 2.29: Summary of typical motive and refrigeration fuel consumption of temperature controlled truck bodies and trailers

Vehicle class	Fuel efficiency (motive), km/l	Refrigeration fuel consumption, litres/day	Overall fuel efficiency (motive + refrigeration), km/l	Refrigeration to motive energy, %
Medium Rigid	3.70	21.0	3.09	18.9%
Large Rigid	3.15	17.7	2.63	19.5%
City Articulated	2.98	26.1	2.42	23.2%
32 tonne Artic	2.97	34.1	2.40	24.2%
38 tonne Artic	3.04	24.9	2.52	15.6%

Sources: Reproduced from Defra (2009), Tassou et al (2009a)

Options to reduce energy consumption (and greenhouse gas emissions) from refrigerated units include the following (Defra, 2009):

- *Vacuum Insulated Panels:* The use of advanced insulation such as VIPs which have the ability to reduce heat load across insulation. VIPs are retrofitable and if they are used to replace current insulation they could reduce energy consumption by 5-10%.
- *Photovoltaic (PV) systems:* The application of photovoltaics to refrigeration for the distribution of chilled produce has the potential for the operating power to be solely derived from solar energy.

[15] Cooling Cost and Boosting Efficiency through Eco-friendly Refrigeration Equipment, Freight Best Practice Programme, UK Department for Transport, May 2010. Available at: http://www.freightbestpractice.org.uk/products/3705_6574_cooling-costs---refrigeration-case-study.aspx
[16] Food transport refrigeration – Approaches to reduce energy consumption and environmental impacts of road transport, S.A. Tassou *, G. De-Lille, Y.T. Ge, School of Engineering and Design, Brunel University, UK. Applied Thermal Engineering 29 (2009) 1467–1477.
[17] FOOD TRASPORT REFRIGERATION, by S. A. Tassou, G. De-Lille, J. Lewis, Brunel University, Centre for Energy and Built Environment Research, School of Engineering and Design, 2009. Available at: http://www.grimsby.ac.uk/documents/defra/trns-refrigeenergy.pdf

- *Cryogenic Cooling Systems:* such systems typically use liquid nitrogen or carbon dioxide as an alternative to mechanical refrigeration. These are total loss systems (i.e. the refrigerant gas is vaporises as it is released into the container reducing the temperature uniformly and eventually vented to the atmosphere) and are mainly beneficial to shorter-distance transport.

Other future possibilities being developed /evaluated for food transport refrigeration include absorption and adsorption systems, thermoelectric cooling and air cycle refrigeration.

2.8.1.4 Truck Aerodynamics

One of the most successful mediums of vehicle adaptation that can result in the reduction of energy and fuel used is aerodynamic body styling. This is equally applicable to fixed axel and articulated trucks. The direct economic benefits of effective aerodynamics have made them an attractive option to many European operators. The proportion of benefit is not universal and is related to the vehicle mission profile: the more distance travelled on open road the more the direct benefits of aerodynamic body styling. Trunking will benefit more than urban multi-drop, for example. It should be mentioned that under the existing European regulations aerodynamic improvements in the European truck business are always a compromise between social aspects (driver comfort, luggage space etc.) and aerodynamics (ACEA, 2010). Extreme aerodynamic improvements may lead to unacceptable workplace conditions to the driver.

Initially aerodynamic body styling was introduced to truck design as ancillary features that were bought and retrospectively fitted. This has evolved and aerodynamic styling can be part of the OEM build specification for both trucks and trailers. The aerodynamic styling can take the form of several pieces of fabricated air deflectors or interventions. They each have varying degrees of known benefit in respect of fuel consumption. The most common aerodynamic features are:

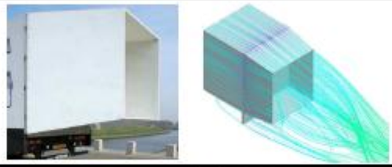
- **Tractor / Cab**
  - Cab Roof Fairing / Deflector
  - Shaped Sun Visor
  - Air Dams
  - Cab Extension Panels / Collar
  - Cab Side Edge Turning Vanes
- **Trailer / Main Body**
  - Trailer Side Panels
  - Container Roof Tapering
- **Both**
  - Vortex Generators

At present there are a number of vehicle and trailer OEMs producing Fuel Saving Curve (FSC) trailers and vehicle bodies. These have made a radical change to the design of standard cargo carrying trailer and body design and applying more advanced aerodynamic principles. These include repositioning the point of maximum height of the vehicle/vehicle trailer combination towards the centre and tapering the rear of the vehicle/trailer to address tail turbulence that conventional aerodynamic features have been unable to address. In many instances in the UK, where there are no height restrictions, the payload is increased through the added height of the re-centred highpoint of the load carrying area. However, this is not the case for other European countries where height a restriction of 4.9m is in place and instead may result in a *reduction* in load capacity. Organisational trials of FSC articulated heavy trucks and fixed chassis medium trucks have shown 10% - 15% fuel savings.

A report by Transport and Environment (T&E, 2010)[18] has suggested that aerodynamic drag is responsible for 40% of HGV fuel consumption at motorway speeds, with drag at the rear side of the truck being the major contributor. There are a number of technical solutions are on the market that have a strong potential to reduce CO_2 emissions and fuel consumption of lorries, particular in motorway driving. Examples provided in the report by T&E (2010) are provided in Figure 2–68. However, it is should be noted that some of the figures quoted are based on US conditions and so may overestimate some of the potential CO_2 reductions due to differences in standard vehicle characteristics. More detailed information on the application and performance of current, new and emerging aerodynamic technology options as applied to EU trucks has been provided in Task 3 of this study (see Sections 3.2 and 3.3).

As can be seen in Figure 2–68, there are numerous types of device that can be fitted onto the tail of trailers to improve fuel consumption and reduce CO_2 emissions, from open cavity tails to active flow controls. In the cases of city buses and coaches that are not articulated with fixed chassis, the scope for aerodynamic design improvement is limited. At present all new vehicles, similar to passenger cars and light goods vehicles are manufactured with a more rounded profile, sometimes referred to as 'jelly mould'. There is more limited scope for further aerodynamic improvements.

Figure 2–68: Aerodynamic solutions with the potential to reduce fuel consumption of trucks

Device	approx. additional dimension required	best suiting trailer type	approximate CO2 reduction long haul	Image / working principle
Open cavity tails	1.0 - 1.5 m	box, curtain, refridgerated box (reefer)	6%	
Inset open cavity tails	0.6 m - 0.8m	box, curtain, refridgerated box (reefer)	5-8%	
Inflatable open cavity tails	0.4 - 0.6 m	box, curtain, refridgerated box (reefer)	3-4%	
Inflatable closed cavity tails	1.0 - 1.5 m	box, curtain, refridgerated box (reefer), chassis	5%	
Active Flow Control / Difusors	0.3 m	box, curtain, refridgerated box (reefer)	7%	

Source: Reproduced from T&E (2010)

Notes: Some of the figures quoted are based on US conditions and so may overestimate some of the potential CO_2 reductions due to differences in standard vehicle characteristics.

[18] T&E, 2010. The case for the exemption of aerodynamic devices in future type-approval legislation for heavy goods vehicles, Jos Dings, Transport & Environment, January 2010.

2.8.2 Buses and Coaches

As is the case with trucks, the manufacture of passenger carrying HDVs (PCVs – i.e. buses and coaches) involves many manufacturers beyond the conventional OEM/major vehicle manufacturers. Normally body-builders and fitters are regional companies that are supplied by the major vehicle manufacturers with (typically) the chassis and engine and then manufacture bus and coach bodies to customer specification. The distribution by OEM of European bus and coach manufacture has been provided earlier in Task 1.2 (Section 2.4), with manufacturers other than the major European HDV manufacturers accounting for around a quarter of all new registrations.

2.8.2.1 City Bus

The city bus mission profile is quite unique as an HDV. Characteristically they are:

- Used repetitively for short (<80km round trips) individual journeys
- Used throughout the 24 hour day
- Are purpose built rather than adapted for purpose being either
  - Double deck
  - Single deck
  - Articulated
- Have a driver who is integrated within the passenger (load) space and environment
- Have a limited range of ancillary equipment all of which source their primary energy through PTO
- Make frequent stops requiring the driver and passenger environment to change with frequent door opening
- Have an increasing requirement for ancillary equipment to comply with EU laws on disability access adding to the overall gross kerb weight

According to ACEA, buses are very highly adapted to mission profiles by manufactures and bodybuilders to specific customer's operational requirements. This means there is quite high variability in the relative performance of different buses and so a standardised test cycle may have more limited benefits compared to those for light duty vehicles which are mostly relatively homogenous for a particular base model.

The most common ancillary equipments found on city buses are:

- <u>Heating and air conditioning</u> – The mechanics are very similar to those of trucks, with the difference being that the space required to be either heated or cooled is significantly larger and will require more power. The frequent opening and closing of doors on city buses contributes to the heating and cooling systems being required to run throughout the journey. The energy source is PTO
- <u>Doors</u> – Doors are operated through air compressors which are maintained at pressure by the bus engine.
- <u>Tilting mechanisms</u> – The requirement to tilt to allow ease of access from the kerbside is provided by air compressors using the same principles as the doors.

2.8.2.2 Coach

The coach mission profile differs significantly from city bus. They are characterised by:

- Being used to make journeys to and from a destination rather that a round trip.

- Have a driver who is integrated within the passenger (load) space and environment
- Have a wider range of auxiliary equipments than city buses

The most common ancillary equipments found on city buses are:

- Heating and air conditioning – The mechanics are very similar to those of trucks and city buses, with the differences being that the space required to be either heated or cooled is significantly larger than a truck, require more power; and that there are individual air systems to each passenger seat. There is not the frequent opening and closing of doors as on city buses. The energy source is PTO
- Doors – Doors are operated through air compressors which are maintained at pressure by the coach engine.
- Ramps – Many coaches have ramps for disability access that is electric powered. Although this does not use more engine energy it adds to the vehicle gross kerb weight
- Toilet and wash facilities – These are found on many coaches and are electric powered

2.8.3 Overview of energy consumption of auxiliaries and application

Unlike the passenger car, HDVs of both freight and passenger carrying design are manufactured individually to the customer requirement. Very often, particularly in the case of trucks, this can be a standard off the self component build. However, the production of vehicles with additional features – both specific build and auxiliary equipment added – is undertaken as a bespoke manufacturing chain that will involve at least one manufacturer in addition to the OEM. In the case of passenger carrying HDVs the build will be specific to requirement and involve regional industry body-builders and fitters. The result is that there is no holistic data available on adaptations or ancillary equipment fittings to the European HDV fleet.

Of the power options available to HDVs for ancillary equipment and special adaptation, the most common used in PTO. This is as a result of the requirement for most equipment fittings to carry out a heavy load orientated task. Where this can be avoided, electric power with battery support is utilised. The use of APUs is not common outside of the application of temperature controlled freight – usually food.

The most common application of auxiliary equipment to all HDVs is heating and air conditioning. Whilst heating is a harnessed bi-product of the engine, air conditioning is a designed and fitted feature that involves a mechanical application that contributes to increased energy use and fuel consumption.

A very successful intervention for trucks, and to a lesser extent PCVs, is the application of aerodynamic design. This can very successfully applied to both fixed chassis and articulated vehicles. This is one area of vehicle design that seeing an immediate payback benefit to HDV operators and several manufacturers have begun to introduce FSC trailers and freight bodies to their manufacturing capability. Several operator trials have shown at least 10% fuel savings. Articulated trucks are, by design, the most susceptible to wind turbulence and can benefit most from aerodynamic styling.

The following Table 2.30, provides a summary of the typical specifications, power and for truck auxiliary equipment that has been identified as part of this study. Information on temperature controlled units has already been provided earlier in Table 2.29. In most cases estimated energy consumption has also been provided on the basis of the available data. Although it has not been possible to provide a typical estimate for tail lifts, an indication on the potential savings is available from a case study from the UK's Freight Best Practice

Programme. In this case study a UK operator that uses tail-lifts on his box-bodied trucks was able to achieve significant fuel savings by changing the tail lift power source. Power for the tail-lifts used to come from the vehicle's standard electrical system, driven by the engine. However, by adapting the vehicles and fitting separate batteries to power the tail-lifts, engine running time was reduced by 27 hours a week. The cost of the battery system was £700 (~€810) but the annual fuel saving amounted to over £4,000 (~€4,600), even before lower maintenance costs were taken into account.

Additional indicative estimates on the application of different auxiliary equipment in new heavy duty vehicles has also been provided in Table 2.31, based on estimates by Ricardo.

Table 2.30: Summary of typical specifications, power and estimated energy consumption for truck auxiliary equipment

Auxiliary Equipment	Power Source	Continuous / Stationary PTO	Average annual usage, hrs	Power (kW)		Av. annual fuel cons., litres/yr		Notes [e]
				Low	High	Low	High	
In Cab Cooling & Heating [e]	Engine			5				
Vehicle Mounted Cranes [f]	PTO	Stationary	100	30	60	826	1689	(1)
Hook Lifts [f]	PTO	Stationary	95	50	65	1223	1723	(1)
Tippers [f]	PTO	Stationary	120	20	60	805	2587	(2)
Refuse Trucks [f]	PTO	Continuous[a]	250 - 470	20	40	1916	7655	(3)
Tanker Pumping [f]	PTO	Stationary	220 - 400	20	30	1370	4168	(4)
Winches [c] [d]	Electric / PTO	Stationary	250	1.6	2.7	383	808	(5)
Cement Mixer [f]	PTO	Continuous[a]	200 - 725	15	20 [b]	1257	6251	(3)
Tail Lift [d]	Electric	Stationary	?	1.5	3.5			(5)

Notes and Sources:

a) Assumed for continuous operation PTO is run off engine at most optimum fuelling point

b) 40 - 90 max (15 - 20 average)

c) Electric requires engine to idle for alternator to charge battery. Annual hours usage based on maintenance schedule of 250 hours or annually.

d) Based on manufacturers data (Superwinch for winches and Hiab for tail lifts)

e) Expert assumptions based on Ricardo experience and knowledge

f) Based primarily on Volvo estimates in Power Take-Offs and Hydraulic Pumps - Fields of application calculation guide, 2007-06-15 ENG Version 08 available at: http://productinfo.vtc.volvo.se/files/pdf/lo/Power%20Take-off%20(PTO)_Eng_08_580114.pdf

(1) Used on a wide range of trucks. Assumed typical case is 2 axle rigid truck with ~7 litre engine

(2) Typically ~30 tonne 4 axle rigids or 44 tonne artics - Assumed 11 litre engine

(3) Typically 17~24 tonne 2 or 3 axle rigids - Assumed 9 litre engine

(4) Typically 44 tonnes - Assumed 12.5 litre engine

(5) Usually smaller delivery type vehicles - assumed 4 litre

For buses and coaches, there is much more limited information available on auxiliary energy consumption. The following information has been identified based on data from Ricardo sourced from OEMs:

- Heating & Air Conditioning: Drivers AC only (electrically drive compressor) 30-40 Amps, Saloon & Drivers AC (engine driven compressor) 40-50 Amps. Energy consumption is typically ~9% of total fuel consumption for a bus

- Doors: Intermittent 0.25 Amps solenoid activation for pneumatic doors
- Tilting Mechanism: Typically 0.25-0.5 Amps for activation of valves

Table 2.31: Summary of estimated application of different auxiliary equipment to new HDVs

Component	Percentage (of new vehicles)			
	Heavy Truck > 16t	Medium Truck 3.5-16t	Bus	Coach
Engine cooling fan:	100	100	100	100
Rigid		*10*	*10*	
Viscous	*100*	*90*	*90*	*100*
Compressed air system	100	80	100	100
Alternator	99	99	98	99
% Hybrid (no alternator)	1	1	2	1
Power assisted steering pump	100	100	100	100
Transmission type:				
Manual	*33*	*80*	*0*	*80*
Automated manual	*67*	*10*	*0*	*20*
Automatic with torque convertor	*0*	*10*	*100*	*0*
Air conditioning compressor	*100*	*80*	*100*	*100*
PTO (Power Take Off):	13	8	0	0
Cranes	*1*	*0*		
Hook lifts	*1*	*0*		
Tippers	*4*	*0*		
Refuse trucks	*0*	*3*		
Tanker pumping	*3*	*0*		
Winches	*1*	*0*		
Cement mixer	*2*	*0*		
Tail lift	*1*	*5*		
Diesel APUs	8	8	0	0

Notes: Estimates by Ricardo based on experience and brochure information, not based on feedback from dealers.

3 Technology

Objectives:

The main objectives of Task 3 are to understand the technology that is and can be applied to heavy duty vehicles and the impact this will have on fuel consumption and GHG emissions. The main objectives of this task are as follows:

- Provide an overview of the existing and planned state of the art in technology (engine, drive-train, vehicle, ICT/ITS, any other) for heavy duty vehicles in the major markets
- Provide an overview of the new and emerging technological options (engine, drive-train, vehicle, ICT/ITS) for heavy duty vehicles along with their emission reduction potential, identifying obstacles for such technologies
- Provide an overview of technical and management solutions to monitor and report fuel consumption, including systems based on wireless data transmission
- Provide a simple analysis to demonstrate the effect of vehicle speed on drag and hence fuel consumption, CO_2 emissions, operating costs and production scheduling and logistics
- Provide a maximum of three ad-hoc analyses to the Commission's services on specific technical issues that arise during the duration of the contract.
- Model the uptake of new and emerging technologies and assess the impact on the possible future reduction in total EU fuel consumption and greenhouse gas emissions from HDV.

Outputs:

A concise chapter within the final report containing the following:

- Summary table of the key technologies by vehicle type and region, including description of the key technologies
- Summary table of new and emerging technologies, technology descriptions, potential CO_2 benefit and barriers to adoption
- Summary of main technical and management solutions to monitor fuel consumption
- Illustration of variation of rolling resistance and aerodynamic drag with vehicle speed along with narrative of the impact of vehicle speed on fuel consumption, operating costs and logistics.
- Results of the scenario analysis illustrating a possible reduction in GHG emissions from HDVs through the uptake of the most promising new and emerging technologies.

Task Lead: Ricardo

3.1 Overview and methodology

To understand what options there are to reduce CO_2 emissions from heavy goods vehicles an understanding of the current and future low carbon technologies is necessary. While some of these technologies have significant CO_2 reduction potential, the benefit can vary significantly with vehicle operations along with the cost associated with introducing them, which may or may not be acceptable to the end user. Further legislative requirements of heavy duty vehicles vary with differing markets globally and as such the uptake of a technology developed for one market may be limited in another.

The work carried out for this section of the report has aimed to identify the current and future low carbon technologies that are being and could be implemented, highlighting the benefits and costs associated with these along with limitations for implementation. Further solutions to monitor vehicle fuel consumption which can be used by fleet operators to monitor fleet performance have also been addressed at a higher level, along with the impact that vehicle speed can have on fuel consumption and operating cost. This information has been used to input to a simple scenario analysis in later Section 4.5, which provides some insight into the level of CO_2 reduction that may be possible from the introduction of a number of the most promising low carbon technologies.

In the context of the above need to assess impact of technological improvements on future HDV fuel consumption and CO_2 emissions, in this section we set out our methodology for undertaking Task 3. This involves subdividing the whole into the following six sub-tasks:

- Sub-task 3.1: Existing and planned state of the art technology (Section 3.2);
- Sub-task 3.2: Emerging and new technological options (Section 3.3);
- Sub-task 3.3: Technical and management solutions to monitor and report fuel consumption (Section 3.4);
- Sub-task 3.4: Influence of vehicle speed (Section 3.5);
- Sub-task 3.5: Ad-hoc analyses to Commission Services (later Section 4.5);
- Sub-task 3.6: Assessment of possible future reduction in total EU fuel consumption and GHG emissions from HDVs (later Section 4.5).

Details for each sub-task, preceded by their context, are given in the following sections.

3.2 Survey of existing state of the art technology

Objectives:

The purpose of this sub-task was to:
"Survey existing and planned state of the art in technology (engine, drive-train, vehicle, ICT/ITS, any other), on a global level"

Summary of Main Findings

⇒ The survey has revealed that there are numerous technologies available for use on all HDV;

⇒ Many more technical features are employed on trucks compared to buses and coaches;

⇒ Engine technologies across Europe, USA and Japan are very similar in terms of engine displacement, fuel injection equipment and after-treatment;

⇒ While engine technology is similar there is much less emphasis on vehicle technologies, particularly city buses, than for the freight segment;

⇒ While city buses and coaches have similar engine technology, transmission types are very different;

⇒ Only coaches appear to employ ITS/ICT features such as cruise control and brake assist with further optional features such as tyre pressure monitoring and adaptive cruise control.

Before it is possible to estimate potential CO_2 reductions that could be achieved through the introduction of policies to encourage low carbon technologies, it is first necessary to understand the current state of the art for technology in heavy duty vehicles and the level of technology applied to the different types of vehicles and how this varies by Original Equipment Manufacturer (OEM) and also geographic market. Legislation is a key driver for the introduction of technology into vehicles, with countries having the most stringent legislation in terms of emissions, vehicle attributes and recyclability having the most technologically advanced vehicles.

As the most advanced technology is likely to appear in the most stringently legislated markets, key consideration will be given to OEMs and vehicles for the West European, North American and Japanese markets. All three markets have stringent emissions legislation which drives the introduction of advanced powertrain technology, but it is currently only Japan which has fuel consumption legislation for heavy duty vehicles. These three markets also have differing vehicle requirements with legislation on vehicle weight and size driven by typical annual mileages and road conditions.

Table 3.1: Benchmarked Vehicles

HDV Type	Europe	USA	Japan
Medium Duty Truck	• Iveco Eurocargo • Mercedes-Benz Atego • DAF LF	• Ford F450 • Freightliner M2 • International Durastar	• Hino Ranger • Isuzu Forward
Heavy Duty Truck	• Mercedes-Benz Actros, • MAN TGX • DAF XF105	• Freightliner Columbia, Cascadia • International Lonestar, 900 series, Prostar, Transtar	• Hino Profia • Isuzu Giga
Bus and Coach	• Mercedes-Benz Citaro, Turismo • Iveco Citelis, Domino, Evadys, Magelys		

The current state of the art in technology has been assessed through a benchmark of the models of the leading two OEMs in each region for medium and heavy duty truck and the global leader in the bus and coach market. Assessment of leading manufacturers in each region is from JAMA, Wards Auto and ACEA data. Buses and coaches considered are major European manufacturers as this is the region of focus for this study. Table 3.1 provides an overview of the models benchmarked in each of the regions for each vehicle type. Medium duty trucks are defined as those with a gross vehicle weight (GVW) between 7.5t and 16t and heavy duty truck are defined as trucks with a GVW of over 16t. Greater consideration is given to medium and heavy duty trucks as these vehicles constitute by far the greatest proportion of the heavy duty vehicle parc, and the main contributors to heavy duty CO_2 emissions are freight vehicles. As such this is where it is most important to have an understanding of the current levels of technology.

Current state of the art technology is defined as that which is offered by a number of OEMs within a specific market across more than one model. It covers both standard and optional factory fit equipment for currently available models. For optional technologies an initial indication of the contribution to vehicle CO_2 missions is provided here with further information provided in the following section, new and emerging technologies as mandating an optional technology could have a significant benefit on vehicle CO_2 emissions. Technologies such as hybrid and electric vehicles, which are available in these global markets, shall be considered under future and emerging technology due to their limited market penetration and model offerings. The benchmark data is be based on public domain information from OEM websites, press releases and industry news.

Table 3.2: Current State of the Art Technology for Medium Duty Trucks

Area	Europe	USA	Japan
Engine	• Euro V Emissions level • Inline 4 cylinder circa 4L or inline 6 cylinder circa 6L • SCR or EGR + POC • Common Rail or Unit Injectors • FGT or 2 stage Turbocharging	• EPA10 emissions level • 6.7L V8, 7L, 9L or circa 13L inline 6 • Common rail injection • Dual sided compressor VGT (single sequential) or dual stage turbo • SCR + EGR + DPF • 2011 model year B20 compatible (Ford & GM)	• Japan New Long Term emissions • Inline 4 cylinder circa 5L, inline 5 cylinder circa 6L or inline 6 cylinder circa 8L • EGR + DPF or SCR + EGR + DPF (5/6 cyl.) • Common rail injection • VGT
Drivetrain	• 5,6 or 9 speed manual • 6 speed AMT – O • 5 speed automatic – O	• or 6 speed automatic • 6 to 13 speed manual or AMT – O	• speed manual • speed AMT – O • 5 speed automatic – O
Vehicle	• Front bumper with air dam • Cab side edge turning vanes • Rounded cab corners • Cab deflector – O • Cab collars – O	• Aluminium cab and doors (M2) • Aerodynamic air-shield roof deflector or roof fairing – O • Cab side extenders – O	• Aerodynamic cab styling • Front bumper with air dam – O
ITS/ICT	• Driver display, including fuel consumption • Tyre pressure indication – O	• Voice controlled navigation and phone • LCD productivity screen – monitors fuel consumption among other things	• Automatic reading of journey details on memory card • Display of instantaneous fuel consumption • Adaptive cruise control – O

Notes: Optional items are indicated: – O

Source: OEM websites of benchmarked vehicles

Table 3.2 is a summary of the currently applied technology within the US, European and Japanese markets for medium duty trucks. Each of these markets has stringent emissions legislation and for Japan also additional fuel consumption legislation. Engine displacement and type are similar across the regions as are the aftertreatment systems used to meet emissions legislation. While in Europe and Japan manual transmissions are standard fit for the majority of medium duty trucks, in USA automatic transmissions are most common. The adoption of an AMT over a manual transmission can be up to 5% depending on the level of driver skill with highest values for lower skilled drivers. While automatic transmissions tend to have higher fuel consumption than manuals or AMTs there remain certain vehicle applications in Europe where an automatic transmission has more desirable characteristics.

Vehicles across all regions have aerodynamic design; however it is in Europe that the largest numbers of aerodynamic aids are standard fit. Across all markets cab roof air deflectors are optional for this vehicle segment. These aerodynamic aids can contribute up to 0.7% fuel consumption saving for air dams, up to 0.5% for side edge turning vanes, up to 2.4% for cab deflector, up to 4.8% for cab roof fairings and up to 0.6% for cab collars/ side extenders. The absolute level of benefit is very dependant on duty cycle with greatest benefit for those vehicles with large proportions of high speed running.

In terms of ITS/ICT features, driver information displays including instantaneous fuel consumption are common in all markets. The impact which these can have on fuel consumption is varied and difficult to quantify as it depends on the extent to which this influences driver behaviour. Studies such as SAFED have indicated that driver training in fuel efficient driving can have up to 10% benefit in fuel consumption, although the longevity of such benefit is uncertain. Further optional features are limited and include tyre pressure monitoring and adaptive cruise control. Tyre pressure monitoring indicates to the driver when tyres are under inflated which can have benefits on fuel consumption of up to 8% for an individual vehicle. Adaptive cruise control is a safety feature although smoother use of accelerator and brake may provide some fuel consumption benefit. Table 3.3 provides a description of the key benchmark technologies found on heavy duty vehicles in the key developed markets.

Table 3.3: Technology Descriptions

Technology	Description
Adaptive Cruise Control	System which controls a vehicle to a set speed, but which also adapts the speed based on the distance to the vehicle in front and maintains a safe distance to the vehicle in front
Aerodynamic mirrors	Truck mirrors protrude and can affect the airflow around the cab. Rounding the front face of the mirrors can reduce drag
Air dam	These are downward extensions of the bumper that go towards the front wheels close to the ground. These reduce vehicle drag by diverting air around the side and over the roof of the vehicle rather than under the rough under-body
AMT (Automated Manual Transmission)	A manual layshaft transmission which has automatic actuation of gearshifts and clutch operation
Automatic transmission	Transmission with automated gear shifts which typically uses epicyclic gear sets and a torque convertor
Cab collar / Cab side extenders	Located at the sides of the rear cab edges, these bridge the gap between cab and body
Cab deflector / Roof fairing	These are three-dimensional mouldings which fit on the cab roof and, if adjustable, can allow maximum savings with a range of differing body heights. They work by presenting the airflow with a smooth transition from the cab roof to the container
Cab side edge turning vanes	Usually located on the cab front edges below the windscreen level, these small extension pieces can reduce drag if they cover sharp edges and also help to reduce the build-up of road film and dirt. The feature needs to be specified when ordering a vehicle from new
Chassis skirts	These side panels cover the gaps next to the under-body on rigid vehicles or articulated vehicle trailers.
Collision Warning / Mitigation	Using a high performance sensor system collision risk is assessed. If the system detects possibility of a collision it will warn the driver and provide automatic maximum braking to reduce accident severity if deemed unavoidable
Common Rail	A high pressure fuel rail used for fuel injection

Technology	Description
Cruise Control	System which control the vehicle to a set speed
DPF (Diesel Particulate Filter)	A porous filter which removes particulate matter (PM) from exhaust gas
EGR (Exhaust Gas Recirculation)	Recirculation of exhaust gases into combustion chamber to reduce formation of NOx emissions
FGT (Fixed Geometry Turbocharger)	An exhaust-driven air pump that forces more air into the engine. Response is controlled simply by diverting exhaust gas around it using a wastegate
Low rolling resistance tyres	Tyres which are optimised to provide lowest levels of rolling resistance, particularly aimed at long haul vehicle applications
POC (Particle Oxidation Catalyst)	A flow through metallic filter with a reactive wash coat used to reduce particulate matter from the exhaust gas
SCR (Selective Catalytic Reduction)	Provides continuous NOx reduction using ammonia generated from injected urea. Urea consumption depends engine-out NOx level and catalyst temperature
Tractor and fuel tank fairings	These are panels which enclose the gaps between the front and rear tractor wheels and also cover the fuel tank. These provide a smoother airflow along the side of the vehicle reducing drag
Turbocompounding	Turbo-compounding utilises an additional exhaust turbine which delivers power to the crankshaft via mechanical gears and a hydraulic coupling. Primarily for Heavy Duty applications
Twin Turbocharging (series)	Uses a large (low pressure stage) and a small (high pressure stage) wastegated or VGT turbocharger arranged in series
Tyre pressure indication / monitoring	A system which monitors and can also adjust the tyre pressures to ensure that all tyres are operating at optimal pressures and warns the driver if any tyre is underinflated
Unit injectors	Unit fuel injectors used in heavy duty diesel engines to inject fuel in the cylinder - is an alternative fuel supply system to common rail
VGT (Variable Geometry Turbocharger)	Turbocharger with a variable turbine vane mechanism to control its response to a given exhaust gas flow (no wastegate)

Source: Ricardo, Freight Best Practice, Aerodynamics for Efficient Road Freight Operations, June 2007

For the heavy duty truck segment, Table 3.4 provides an overview of the current state of the art technologies. Engine technologies across all three markets are very similar in terms of engine displacement, fuel injection equipment and aftertreatment. With emissions legislation currently most stringent in USA and Japan (prior to the mandatory adoption of Euro VI limits in 2013), heavy duty diesel engines require the use of both EGR and SCR aftertreatment to meet limits. International who currently offer an EGR + DPF only solution on their MaxxForce engines are able to do so based on credits obtained from exceeding EPA07 limits. This is only permissible for a short period and it is expected that International will also need to adopt SCR in addition to EGR to comply with EPA10 limits. Currently in Europe at Euro V there are two widely adopted solutions to meeting emissions legislation, one using high levels of EGR along with a DPF or the other using SCR. At Euro VI it is anticipated that OEMs will follow current technologies in Japan and USA using both SCR and EGR to meet the new limits. This will have an impact on fuel consumption which is discussed further on. Standard fit transmissions in USA and Japan are both manuals, whilst in Europe the AMT is favoured. Both transmission types are available in each market. The use of AMTs can bring fuel consumption benefits of up to 7% depending on the driver skill. Benefits over a manual with a skilled driver are likely to be marginal as the driver will already change gear at the optimum point.

Table 3.4: Current State of the Art Technology for Heavy Duty Trucks

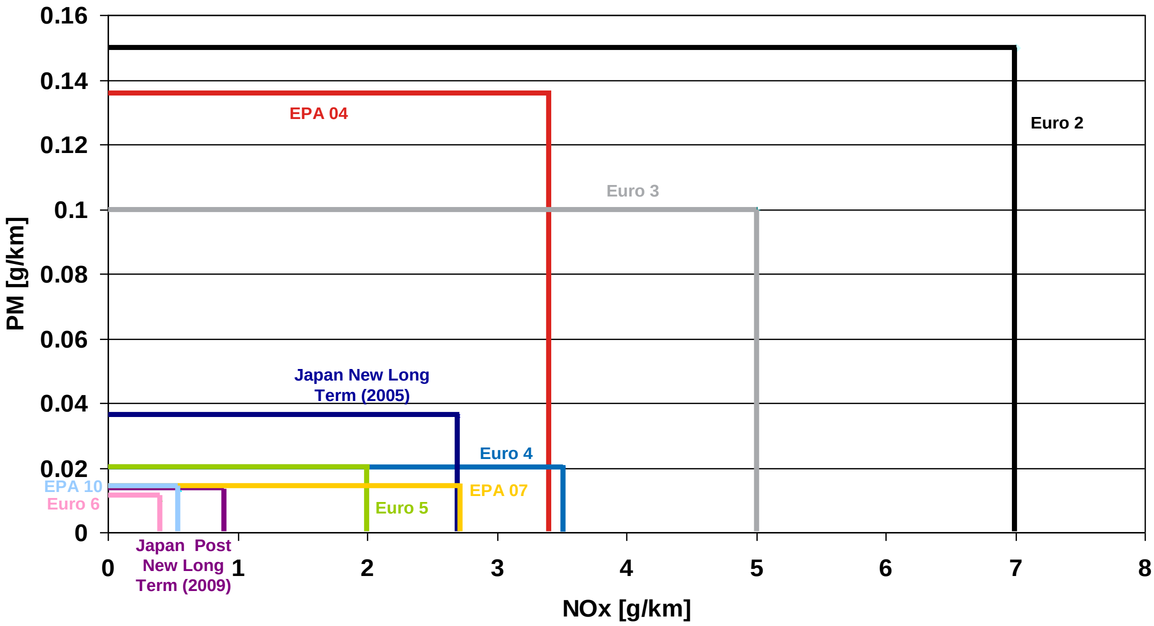
Area	Europe	USA	Japan
Engine	• Euro V emissions legislation • 10, 11, 12, 13 or 16L inline 6, 12L V6 or 16 or 18L V8 • Unit injectors or common rail • SCR or EGR + DPF • FGT, VGT or 2 stage turbocharger • 100% biodiesel compatible (Daimler)	• Meets EPA 2010 • Inline 6 cylinder 10.5L, 12.4L, 12.8L or 15L engine • Common Rail • EGR + DPF + SCR • VGT or twin series turbocharging (FGT) • Mechanical Turbocompounding – Detroit Diesel 560hp only • B5 compatible	• Meets Japan New Long Term emissions • Inline 4 cylinder 13 L • Common Rail injection • SCR + EGR + DOC + DPF • VGT or FGT
Drivetrain	• 12 or 16 speed AMT • 16 speed manual – O	• 10 to 18 speed manual • 10 or 18 speed AMT – O	• 7 or 16 speed manual • 7,12 or 16 speed AMT – O
Vehicle	• Integrated air dam • Cab side edge turning vanes • Tyre pressure monitoring – O • Roof and side air deflector (Articulated) – O (Rigid)	• Aerodynamic styled cab including rounded bumper and air dam • Aluminium cab • Cab deflector – O • Tractor and fuel tank fairings – O • Low rolling resistance tyres – O • Aero mirrors – O • Chassis skirts – O	• Rounded cab corners • Integrated air dam • Minimised body gap • Cab side edge turning vanes • Cab deflectors – O • Cab collars – O • Tyre pressure monitoring – O
ITS/ICT	• Adaptive cruise control – O • Navigation system - O • Fleetboard Telematics system – O • Forward collision warning – O	• Vehicle information display – O • Adaptive cruise control – O	• Display of instantaneous fuel consumption • Pre-crash safety (Collision Mitigation)

Notes: Optional items are indicated: – O

Source: OEM websites of benchmarked vehicles

The heavy duty market employs a larger number of vehicle aerodynamic features than medium duty with air dams and rounded cab corners seen as standard, however cab deflectors are still optional equipment on most vehicles in all markets. Only in Europe on articulated vehicles are they standard equipment. Aerodynamic aids can have a large impact on vehicle fuel consumption, particularly for those vehicles whose duty cycle includes long periods at high speed. Standard fit aids such as air dams and side edge turning vanes can contribute up to 0.3% each on articulated vehicles and up to 0.7% and 0.5% respectively on rigid vehicles. Cab deflectors can have benefits of up to 2.4% for both rigid and articulated vehicles with cab roof fairings offering greater benefits of up to 3.7% for articulated and 4.8% for rigid vehicles and when combined with cab collars can achieve up to 6.5% savings. Chassis and fuel tank fairings can have fuel consumption benefits of up to 1% and aero mirrors contributing a small amount of between 0.1 – 0.2%. Further optional vehicle technologies include low rolling resistance tyres which can provide up to 5% benefit depending on the number of tyres replaced and tyre pressure monitoring which offers benefits of up to 8% for an individual vehicle.

Figure 3–1: Heavy Duty Diesel Emissions Legislation



ITS/ICT features for heavy duty trucks tend to be option fit, with the exception of Japan where driver information of fuel consumption and collision mitigation are standard fit technologies. Within Europe and USA similar technologies are offered but only as options. While adaptive cruise control and collision mitigation systems are foremost comfort and safety systems respectively they may have some benefit on fuel consumption by removing harsh acceleration and braking manoeuvres which, depending on the driver, may have a fuel consumption benefit of up to 1%. Driver telematics and fuel consumption display could have an impact if it influences driver behaviour and as such quantifying the benefit is difficult.

Telematic systems employed by vehicle operators such as the Fleetboard system offered by Daimler record data of several vehicle parameters which can be transmitted real-time or at set intervals. The data captured varies and is customised for each individual operator application. Typically, where available, the vehicle CAN bus is used to capture information on vehicle speed, engine rpm, rate of braking and acceleration, idling time etc. This information combined with the driver ID from digital tachograph means driving style and fuel consumption can be analysed for each driver and vehicle. Raw data can either be sent directly to the operator to be analysed using in-house software, analysed using proprietary software of the telematics supplier or provided as reports. Only from the analysis and understanding of the data can measures be introduced to reduce fuel consumption. Tracking data alone will have no impact.

Savings can be made through improvement in driving style resulting in lower fuel consumption and improved vehicle visibility and utilisation. The level of savings achieved are very much dependant on each application and the level to which driver training and use of telematics is currently employed.

Table 3.5: Current State of the Art Technology for City Buses and Coaches

Area	City Bus	Coach
Engine	• Meets Euro V and EEV emissions legislation • 6L, 8L or 12L inline 6 cylinder • SCR or EGR + POC • Unit injectors or common rail • FGT, VGT or 2 stage Turbocharger	• Meets Euro V and EEV emissions legislation • 6L or 12L inline 6 cylinder • SCR or EGR + POC • Unit injectors or common rail • FGT, VGT or 2 stage Turbocharger
Drivetrain	• 4 or 6 speed automatic	• 6 speed manual • AMT – O
Vehicle		
ITS/ICT		• Cruise control • Brake Assist • Adaptive cruise control – O • Integrated tyre pressure monitoring – O

Notes: Optional items are indicated: – O

Source: OEM websites of benchmarked vehicles

Comparing Table 3.5 to Table 3.2 and Table 3.4 highlights the greater technical features employed on trucks over bus and coaches. While engine technology is similar, there is much less emphasis on vehicle technologies, particularly city buses, than for the freight segment. While city buses and coaches have similar engine technology, transmission types are very different. City buses only use automatic transmissions due to their frequent stop / start drive cycle whereas coaches have manual transmissions with the option of AMTs. Only coaches appear to employ ITS/ICT features such as cruise control and brake assist with further optional features such as tyre pressure monitoring and adaptive cruise control. Further the use of CNG buses is increasingly common in several European cities to reduce local air quality and reduce noise. Further local rules require buses to be fitted with DPFs in an increasing number of cities again with the aim to improve air quality.

3.2.1 Impact of Euro VI on Fuel Consumption

The technologies which are found across the different types of trucks, buses and coaches all have an impact on vehicle fuel consumption. Current engine technology for Europe is Euro V which is achieved through either SCR only or EGR + DPF. For USA and Japan SCR + EGR + DPF is required for the majority of engines to meet the more stringent emissions legislation. It is anticipated that when Euro VI becomes mandatory in Europe in 2013/2014 that OEMs will also need to adopt SCR + EGR + DPF to meet the new standards. With the majority of engines using SCR only to meet Euro V, the move to SCR + EGR + DPF at Euro VI will have a fuel consumption penalty. The increase in fuel consumption is driven by higher back pressures required to drive EGR, the additional back pressure of a DPF and the need for intermittent active regeneration events for the DPF. Ricardo expects this increase to be circa 3% for early Euro VI engines, evolving to closer to zero within 3 years of introduction due to technological developments by OEMs. For engines which at Euro V use EGR + DPF only the move to SCR + EGR + DPF at Euro VI should not incur a fuel consumption penalty as the EGR rates required will be lower than is currently being used. Moreover for Euro V SCR only engines moving to Euro VI the increase in fuel consumption does not necessarily mean an increase in cost. With the requirement to use both SCR and EGR the levels of SCR shall be reduced over Euro V levels. At Euro V levels Ricardo estimates the volume of urea required to be 6% volume equivalent to fuel consumption. For Euro VI it is expected that this will drop to circa 2% volume equivalent to fuel consumption due to lower engine out NOx and higher efficiency SCR catalysts. Then assuming urea is 50% of the cost of fuel (volume for volume) then the total fluid costs (fuel and urea) does not change significantly moving from Euro V to Euro VI.

The technology benchmark data sets for each vehicle type shall be used as the basis for the assessment of potential CO_2 benefit of new and emerging technologies that are covered in the following section. Optional technologies offered for today's vehicles also appear in new and emerging technologies, such that the mandated adoption of such market ready technology could have potential CO_2 reductions.

3.3 Survey of new and emerging technology

Objectives:

The purpose of this sub-task was to carry out a:

"Survey of emerging and new technological options (engine, drive-train, vehicle, ICT/ITS) and their emission reduction potential, on a global level. Identification of legislative boundary conditions and any regulatory obstacles for such options"

Summary of Main Findings

⇒ There are a large number of technologies which can be applied to heavy duty vehicles to reduce greenhouse gas emissions

⇒ Technologies in the drivetrain and vehicle categories can have the largest impact on fuel consumption

⇒ Fuel consumption benefit is highly dependent on vehicle duty cycle. While some technologies can provide benefit across a range of vehicle duty cycles others have much greater benefits for some and none for others

⇒ For vehicles with an urban duty cycles with frequent stop / start behaviour hybrid vehicles offer benefits of between 20 and 30%

⇒ For heavy duty vehicles aerodynamic aids such as aerodynamic trailers can offer the greatest benefits of circa 10% reduction in fuel consumption

⇒ Benefits of technologies are not cumulative – some technologies will conflict and for others the sum is less than the individual parts

This sub-task aims to identify the new and emerging technologies that are being developed by the industry. This is important as information from this section is used in Task 3.5 to provide the Commission with an assessment of the abatement potential available from heavy duty vehicles in the coming years. As new technology developments most often occur in the developed western markets where legislation on vehicle weights, sizes and emissions are most stringent, the markets of USA, Japan and Europe have been researched for new technologies. Meeting air pollutant emissions legislation can have a negative impact on fuel consumption and as such OEMs are developing technologies which allow vehicles to meet emissions legislation but also still provide economic fuel consumption to consumers.

New and emerging technologies covered are those that are under development and have the potential to come to market between 2010 and 2020. However some technologies which are currently in the market are also covered. New and emerging technologies are generally defined as those technologies which are not offered as standard fit or standard optional fit; however some technologies which are offered as options or are already in the market are included. These include technologies such as electric and hybrid vehicles, which while available in some markets are very limited in models available and are still in very low numbers, dual fuel systems, which while considered in the past are now increasing in interest due to lower cost of gas as a fuel, and also some ITS systems such as fleet monitoring and tyre pressure indication, which are optional and further implementation of them in the vehicle fleet, could influence heavy duty GHG emissions. Further technologies which are in the market but are unrelated to OEMs, for example, aerodynamic fairings and trailers and low rolling resistance tyres are also included under new and emerging technology as these technologies are not yet widely employed in the market but have the potential to be retrofitted to older vehicles and consequently may have significant fleet GHG emissions benefit.

Table 3.6: New and Emerging Technologies

Engine	Vehicle
Dual Fuel Systems	Low rolling resistance tyres
Variable flow / Electric water pump	Single Wide Tyres
Variable speed Oil pump	Automatic Tyre Pressure Adjustment
Hydrogen Fuel Cells	Spray Reduction Mud Flaps
Electric Vehicles	Aerodynamic Trailers
Stop/Start Hybrid	Aerodynamic Fairings (Cab, Chassis, Body & Trailer)
Hydraulic Hybrid	Active Aero
Flywheel Hybrid	Lightweight Materials
Pneumatic Booster System – Air Hybrid	Alternative Fuel Bodies
Mechanical Turbocompound	**ITS/ICT**
Electrical Turbocompound	Predictive Cruise Control
Bottoming Cycles	Vehicle Platooning
Controllable Air Compressor	Green Zone Indicator
Electric Engine Accessories	Smart Alternator, Battery Sensor & AGM Battery
Driveline	Acceleration Control
Automated Transmission	Governing Speed Control – Progressive Shift
Full hybrid	Eco Roll – Freewheel Function

Technologies included are "headline" technologies which are individual bolt on technologies which have a positive impact on reducing CO_2 emissions. Other technologies which are intrinsic to engine design have not been included in this study but allowances are made for their introduction in the market in the later scenario analyses as natural improvements in vehicle efficiency. This is due to the fact that as they are intrinsic to engine design quantifying individual benefits of the technologies is very difficult. This includes technologies such as two stage turbocharging, improvements in common rail injection, variable valve actuation and friction reduction.

New and emerging technologies have the potential to reduce CO_2 emissions but the degree to which the technologies can reduce emissions is dependent on the vehicle type and the duty cycle over which the vehicle operates. It is clear that some technologies are only applicable to some vehicle types, for example aerodynamic trailers are only applicable to articulated vehicles and cab collars do not apply to city buses or coaches. However the potential CO_2 reduction of a technology is also dependent upon the vehicle duty cycle. Heavy duty vehicles can be broadly classified into four main vehicle types for the European market – medium duty truck (7.5 < GVW < 16t), heavy duty truck (GVW>16t), city bus and coach. The usage of these vehicles can then be broadly categorised by two duty cycles, one an urban cycle with a high degree of stop / start activity and the other a highway cycle with long periods of operation at higher vehicle speeds. Medium duty trucks and city buses follow usage patterns that are similar to that described by the urban duty cycle, with city buses stopping frequently to pick-up and drop-off passengers. Medium duty trucks are often used in urban delivery applications also with frequent stopping. Heavy duty trucks are often used for long haulage applications and similar to coaches typically cover long distances at constant higher speed on highways. While individual vehicle applications will not exactly match these cycles, they provide a good approximation to the level of potential CO_2 reduction that could be achieved from the heavy duty vehicle fleet as a whole. Table 2.21 highlights the differences in load factors and annual average mileage of different vehicle mission profiles.

The potential CO_2 emissions reduction over these two different cycles has been assessed from a combination of data sources including OEM press releases, journal articles, Ricardo experience and public domain internet sources. This assessment provides estimates of potential CO_2 benefit for urban and highway applications and from this highlights the applicability of the different technologies to different vehicle segments. Some technologies have similar benefits for both duty cycles, whereas others are much more duty cycle specific.

The new and emerging technologies have been classified into the four main areas used for state of the art technologies which are: Engine, Drivetrain, Vehicle and ITS/ICT. For each of these technologies the applicable vehicle segments have been defined along with a description of the technology, the estimated CO_2 benefit for the different vehicle duty cycles and an overview of the barriers that exist in bringing the technology to market.

Technologies which have been identified as new and emerging are presented in Table 3.6. Here the technologies have been grouped by area. These are described in more detail in the following sections.

3.3.1 Engine Technologies

New and emerging engine technologies focus around the reduction of parasitic losses, increased thermal efficiency and engine energy reduction as detailed in Table 3.7. The majority of these technologies are not retrofitable due to the complexities involved and the large impact they have on engine operation and associated costs. These technologies are most likely to come to market in new engine and vehicle designs when the technology can be fully integrated during the development stage. Technology description, potential CO_2 reduction benefit and barriers to market introduction are presented in more detail below.

Table 3.7: Engine Technologies by Type

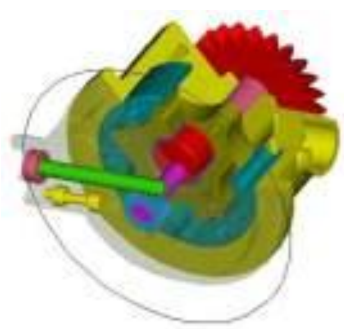
Technology Benefit			
Reduction of parasitic losses	**Increased Thermal Efficiency**	**Engine Energy Reduction**	**Alternative Powertrains**
Variable flow / Electric water pump	Mechanical Turbocompound	Stop/Start Hybrid	Dual Fuel Systems
Variable speed Oil pump	Electrical Turbocompound	Hydraulic Hybrid	Hydrogen Fuel Cells
Controllable Air Compressor	Bottoming Cycles	Flywheel Hybrid	Electric Vehicles
Electric Engine Accessories		Pneumatic Air Booster – Air Hybrid	

3.3.1.1 Reduction of Parasitic Losses

A first step to reducing GHG emissions is to try and reduce the parasitic losses on a vehicle. From an engine perspective this means reducing the load on the engine of the drive of auxiliary systems such as coolant and oil pumps, air conditioning and cooling fans. Reducing the amount of energy required to drive these systems will result in lower fuel consumption and lower GHG emissions. The level of savings that can be achieved vary from 0.7 - 3% depending on the ancillary, the type of drive and the vehicle application. For instance electrically driven pumps will result in greater CO_2 savings than variable mechanical pumps, however electrically driven pumps face greater barriers to market due to concerns of the impact of failure, with mechanically driven systems seen as more robust and durable. Clutchable air compressors have a greater benefit on medium duty vehicles rather than heavy as there is greater benefit over a stop/start cycle rather than long periods of high speed running. Further description of the different technologies, CO_2 benefit, barriers to introduction and vehicle applicability are given in the following tables.

Variable Flow / Electric Water Pump	
Description:	Mechanical variable flow and electric water pumps vary pump speed, hence coolant water flow according to the engine demand (speed / load condition)
CO_2 Benefit:	Variable Flow: Estimated average of 0.7% improvement in fuel consumption / CO_2 emissions Electrical: Average of 1% - 1.5% reduction in CO_2 emissions
Barriers:	• Fully electric pumps are only applicable to new engine designs • Increased costs • Pump must fail safe • Durability of electric pumps
Vehicle Applicability:	• Available for heavy duty application and intended for production in 2009 by Mercedes (mechanical variable flow pumps) • Medium duty applications may acquire technologies from light duty sector

Source: Picture - Electric water pump, Wilkinson; Transport Engineer, Autoasia, KPSG

<table>
<tr><th colspan="3">Variable Speed Oil Pump</th></tr>
<tr><td>Description:</td><td colspan="2">Oil flow amount adjusted to engine speed and requirement to optimise oil flow and oil pump power consumption</td></tr>
<tr><td>CO_2 Benefit:</td><td colspan="2">Average fuel consumption / CO_2 improvements of 1 – 1.5% are possible</td></tr>
<tr><td>Barriers:</td><td>• Applicability to existing engines
• Durability concerns with full electric oil pumps
• Impact of pump failure is severe
• Increased costs</td><td rowspan="2"></td></tr>
<tr><td>Vehicle Applicability:</td><td>• Variable speed pumps available and in production medium and heavy duty vehicles
• Electric oil pumps not in series production
• Demonstrator and research projects</td></tr>
</table>

Source: Picture – Variable displacement oil pump, Concentric

<table>
<tr><th colspan="3">Controllable Air Compressor</th></tr>
<tr><td>Description:</td><td colspan="2">• Air compressor with electric / air actuated clutch to de-connect compressor in idle status or when compressor not required
• Current truck airbrake systems simply dump excess pressure to ambient when the air tanks are full, the compressor keeps running
• For long-haul truck work, the airbrake system may not be used for up to 90% of the time</td></tr>
<tr><td>CO_2 Benefit:</td><td colspan="2">HGV: Average of 3.5% CO_2 reduction, range of 1 – 4%
Intercity / Coach: Average of 1.5%, range 1% to 2%
City / Bus / Utility: Limited benefit due to frequent stop / start</td></tr>
<tr><td>Barriers:</td><td>• Increased costs
• In medium duty scenarios, like delivery routes with start / stop, have less compressor idle time
• Compressor clutch must fail safe to eliminate risk of brake pressure depletion</td><td rowspan="2"></td></tr>
<tr><td>Vehicle Applicability:</td><td>• Available for heavy duty application and in series production (MAN)
• Medium duty applications possible – might be less effective (more stop / start scenario)</td></tr>
</table>

Source: Picture – Transport Engineer; Schaller

Electric Engine Accessories	
Description:	Electrification of Power Steering, A/C Compressor, Air Compressor, Engine Cooling Fan, Fuel Pump, etc.
CO_2 Benefit:	Benefits vary between 0 – 8%
Barriers:	• Some systems unproven on HDD • Increased costs • System must be fail safe • Will not be seen on non-hybrid vehicles
Vehicle Applicability:	• Heavy duty application requires component development by Tier 1's • Heavy duty long haul application expected to offer best improvements with most systems • Electric auxiliaries are mostly only suitable for electric hybrids due to the high current requirements which cannot be met with a standard 24volt battery 

3.3.1.2 *Increased Thermal Efficiency*

A large proportion of the waste energy from an ICE is in the form of heat. An area to reduce fuel consumption and hence GHG emissions from diesel engines is the recovery of this waste heat into useful energy. Technologies available which can be used to recover waste heat are mechanical and electrical turbocompounding and bottoming cycles. The level of potential CO_2 reduction that these technologies can bring varies from 3% to 6% for all systems. Greatest benefit will be achieved from those vehicles which have a duty cycle where long periods are spent at high engine load. However the cost and complexity of these systems along with the increase in powertrain weight are some of the barriers which limit market acceptance. Further for bottoming cycles the addition of a working fluid adds in concerns over crash safety and adds to complexity. Further technology details, CO_2 benefits, barriers to introduction and vehicle applicability are covered in the following tables.

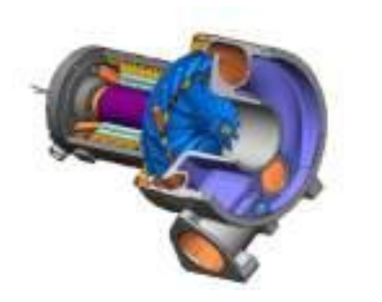
Mechanical Turbocompound	
Description:	Exhaust gas energy recovery with additional exhaust turbine, which is linked to a gear drive and transfers the energy on to the crankshaft providing extra torque.
CO_2 Benefit:	Overall fuel economy benefit ranges from 0% to a maximum of 5% depending on duty cycle with greatest benefit in long haul applications
Barriers:	• Complicated gear drive (turbine, engine speed difference) • Increased costs • Turbocompound system cools down exhaust temperature system and can affects aftertreatment efficiency • Advanced, highly cooled EGR system reduce available exhaust energy
Vehicle Applicability:	• Available for heavy duty application (Scania, Volvo, Detroit Diesel) • Fuel / CO_2 benefits confirmed • Medium duty applications not in production and benefits might be less significant depending on drive cycle

Source: Picture – Scania, Greszler, Detroit Diesel

Electrical Turbocompound	
Description:	Exhaust turbine in combination with an electric generator / motor to recover exhaust energy • Recovered energy can be stored or used by other electrical devices • Motor during transients to accelerate
CO_2 Benefit:	Overall fuel economy benefit of 0 - 8% depending on duty cycle • HGV: Benefit ranges from 2 – 8%, averaging at 3% • Intercity / Coach: Benefits range from 1 – 5%, averaging at 2.5% • City / Utility / Bus: Benefits range from 0 – 2%, averaging 1%

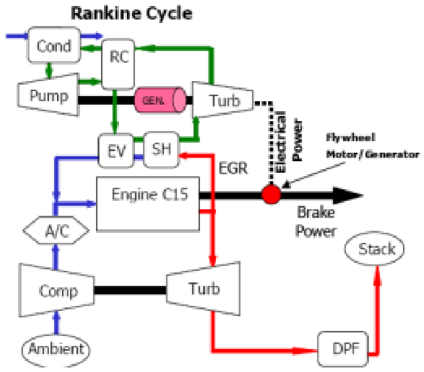
Barriers:	• Added complexity for energy storage, control
	• Exhaust energy stream has conflicting constraints:
	  ○ Advanced, highly cooled EGR system reduce exhaust energy
	  ○ Turbocompound system cools down exhaust temperature and affects aftertreatment efficiency
	• Increased costs of generator turbine, energy storage, crank mounted motor
	• Increased powertrain weight
	• High voltage system

Vehicle Applicability:	• Electric turbocompounding systems for medium and heavy duty application in development phase • Fuel / CO_2 benefits confirmed



Source: Picture – John Deere – Bowman Power Turbogenerator, Vuk (2006 & 2007)

Bottoming Cycles	
Description:	Exhaust gas energy recovery with heat exchangers. Sometimes called “bottoming cycles“, this concept uses exhaust gas heat in an exchanger to drive an additional power turbine to generate energy • Brayton cycle • Rankine cycle
CO_2 Benefit:	Benefits range from 1 – 6% CO_2 / fuel consumption benefit depending on cycle and turbine efficiency • HGV: Benefit ranges from 1.5 – 6% with average values of 5% • Intercity / Coach: Benefits rage 1 – 3% with average value of 2.5% • City / Bus / Utility: Benefits range 1 to 3% with average value of 1.5%
Barriers:	• Additional working fluid (Rankine cycle) • Added complexity for energy storage, control, packing • Increased costs and powertrain weight • Safety issues with organic working fluids, e.g. crash protection • Best performance with higher grade heat – puts system into competition with exhaust gas aftertreatment • Additional system maintenance, like fluid change intervals
Vehicle Applicability:	• Research phase • Introduction in heavy duty application might be easier due to packaging



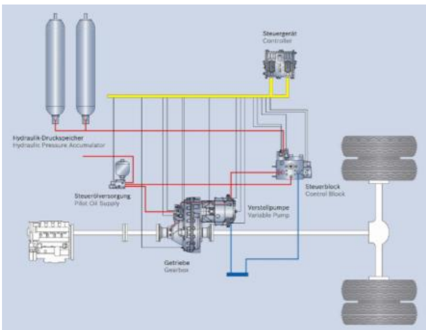
Source: Picture – Kruiswyk; Freymann et al., Ricardo Analysis

3.3.1.3 Engine Energy Reduction

Further to engine parasitic loss reduction and increased thermal efficiency reducing the work that the engine is required to do or the amount of time spent idling can bring a reduction in GHG emissions. Technologies which aim to do this are stop/start systems and other hybrids which recover and store brake energy. Stop/start hybrid systems aim to reduce unnecessary engine idling when the vehicle is stationary whilst the other hybrid systems recover energy under braking which is then stored and used to help accelerate the vehicle. Both technologies are applicable to vehicles operating over an urban cycle with frequent stop / start activity. Potential CO_2 benefits can be in the region of 4% to 30% with brake energy storage providing higher overall benefits than stop/start technology. Barriers to these technologies are the level of vehicle applicability, limitations for vehicles with engine driven bodies (e.g. refrigerated trucks) and brake energy storage systems are more costly and have trade-offs between energy and power density for different storage mechanisms. These technologies are further summarised in the following tables.

Stop/Start Hybrid		
Description:	System uses a high-voltage e-motor mounted to the crankshaft to operate stop / start, i.e. stopping the engine running whenever the vehicle is stationary, along with regenerative braking	
CO_2 Benefit:	0 – 30%, averaging around 6%, but very dependent on duty cycle. HGV: Benefit ranges form 0 – 3% with average of 1% Intercity / Coach: Benefit up to 15% with an average of 3% City / Bus / Utility: Benefit up to 30% with an average of 6% for City / Utility and 4% for Buses	
Barriers:	• Not suitable for vehicle bodies which are engine powered when vehicle is stationary • Only suitable for urban applications with frequent stop/start	
Vehicle Applicability:	Greatest CO_2 reduction potential for vehicles operating over an urban duty cycle	

Source: Picture – Ricardo HyTrans, Mercedes Corporate Website

Hydraulic Hybrid		
Description:	Convert the waste kinetic energy from braking into hydraulic energy by using an accumulator to store hydraulic fluid. This is then released and used to aid vehicle acceleration	
CO_2 Benefit:	Estimated CO_2 benefit varies greatly with duty cycle but can be up to a maximum of 25% in frequent stop / start cycles with average "real world" usage seeing 15 - 18% in similar applications	
Barriers:	• Hydraulic has good power density but accumulator has poor energy density • Weight of system and packaging for the accumulators	
Vehicle Applicability:	• Provides greatest benefit to applications where there is a large degree of stop / start activity	

Source: Bosch Rexroth, Eaton

Flywheel Hybrid		
Description:	An additional flywheel that stores and releases energy from/to the vehicle driveline. The flywheel stores energy, while braking for example, releasing it to supplement or temporarily replace the engine output	
CO_2 Benefit:	Benefits vary with duty cycle: • HGV / Intercity / Coach: Benefits range from 5 – 15% with an average of 5% for HGV and 7.5% for Intercity and coach • City / Utility: Benefit varies from 15 – 22% with an average of 15% • Bus: Benefit ranges from 18 - 25% with an average of 20%	
Barriers:	• Flywheel system adds weight to the vehicle (additional mass estimated to be less than 0.1% GVW) • Technology immature for commercial vehicle applications	
Vehicle Applicability:	• Technology tends to be more effective for vehicles with an urban duty cycle • Currently applied in race car application • Flywheel hybrid systems can be used to deliver power in a number of different forms: electrical; mechanical; pneumatic or hydraulic outputs	

Source: Flybrid systems website, Williams hybrid power website, Ricardo

Pneumatic Booster System – Air Hybrid		
Description:	Compressed air from vehicle braking system is injected rapidly into the air path and allows a faster vehicle acceleration, which allows an earlier gear shift (short shifting), resulting in the engine operating more in an efficient engine speed / load range	
CO_2 Benefit:	Average benefits are in the range of 1.5 – 2%, however this will depend on base engine BSFC map characteristic, ability of system to support repeated short shifts and efficiency of generating compressed air in the first place	
Barriers:	• System must not risk loss of air from brakes • Boost limitations on air system (regulating to maximum boost limit) • Requires air compressor with higher capacity • Requires larger air reservoir tank, which adds weight and could result in packaging issues	• 
Vehicle Applicability:	• Provides greatest benefit to applications where there is a large degree of stop / start activity such as buses and delivery trucks	

Source: Knorr-Bremse PBS system, Nemeth (2008).

3.3.1.4 Alternative Powertrains

An alternative method to GHG emission reduction for heavy duty vehicles is the replacement of the diesel engine with an alternative prime mover. Included in these alternative powertrains are dual-fuel engines, hydrogen fuel cells and electric vehicles. Dual-fuel engines are not a new technology, for example Wärtsilä have had dual-fuel engines in production since 1995 (Eykerman, 2009), however with increasing fuel costs and local air emissions problems they are gaining increasing levels of interest. Dual fuel engines use diesel as a liquid spark plug to ignite the gas and combine the benefits of efficient diesel engine operation with the cleaner burning benefit of CNG to provide a reduction in CO_2 emissions of between 10 and 20% across all vehicle applications. Hydrogen fuel cells have the potential to eliminate heavy duty vehicle tailpipe CO_2 emissions, however the production of hydrogen can be energy intensive and the infrastructure for vehicle refuelling is lacking. Electric vehicles can also offer zero tailpipe CO_2 emissions, however CO_2 will be emitted during electricity generation and the well to wheel benefit of this technology will be influenced by the fuel source used to generate electricity. Further due to the limited maturity of battery technology the size of battery electric commercial vehicle is currently limited to 12t.

Further description of the technologies, potential CO_2 benefits, barrier and vehicle applications are covered in the following tables.

Dual Fuel Systems	
Description:	Dual fuel system which enables a diesel engine to run primarily on gas using diesel as a liquid spark plug. Typical average levels of diesel substitution of 50 – 90% gas are possible depending on the level of system integration and will also vary with engine operating point - as such average rates will also vary with vehicle duty cycle.
CO_2 Benefit:	Between 10 and 20% depending whether ECU interfaced or aftermarket Aftermarket fit solutions offer lower benefits
Barriers:	• CNG infrastructure is limited in Europe with some countries better served than others • CO_2 benefit is very dependant on the level of gas substitution and tend to be higher with long haul than with urban cycles • Additional cost of system • Increased complexity of systems • Availability of technology as an OEM fit option is limited • Integration of additional LNG or CNG tanks on the vehicle - adds weight and can impact payload
Vehicle Applicability:	Applicable to all vehicle types, however those operating from a depot where CNG is more readily available will be able to consistently run higher levels of gas substitution

Source: Clean Air Power – www.cleanairpower.com

Hydrogen Fuel Cells		
Description:	Fuel cells convert the chemical energy of hydrogen into electrical energy that can be used to power the vehicle. A hybrid Polymer Electrolyte Membrane (PEM) fuel cell system is used as the prime mover for the vehicle	
CO_2 Benefit:	PEM FC systems run on hydrogen produce zero tailpipe emissions, however the Well To Wheel CO_2 benefit depends on how the H2 was produced	
Barriers:	• The lack of hydrogen infrastructure limits current use to fleets that regularly return to a depot • Staff training would be required to ensure safe handling of the hydrogen fuel and fuel cell system • Overall weight on the fuel cell system, including hydrogen storage tanks and batteries, is heavier than the conventional diesel powertrain, hence the payload is compromised	
Vehicle Applicability:	• Fuel cell technology has successfully been demonstrated in city buses • At least one European developer plans to market a fuel cell hybrid 7.5 tonne truck, however since production volumes will initially be low, this will be a niche product	

Source: Picture – EU FP6 HySYS Project, HyTruck

<table>
<tr><th colspan="3">Electric Vehicles</th></tr>
<tr><td>Description:</td><td colspan="2">Vehicle is driven by an electric motor powered by batteries which are charged from mains electricity. The vehicle has no other power source other than the battery</td></tr>
<tr><td>CO_2 Benefit:</td><td colspan="2">Tailpipe CO_2 emissions are 0g/km and overall emissions are estimated to be 40% lower than conventional diesel, but this is dependent on fuel source used to generate electricity</td></tr>
<tr><td rowspan="2">Barriers:</td><td colspan="2">• Lower vehicle payload than comparable diesel vehicle
• Limited to GVW of 12t
• Low residual vehicle values
• Operation limited to central depot based fleets - vehicle charge time needs to be planned into daily operation schedule
• Reduction in road noise needs to be handled carefully to ensure no adverse effects for vulnerable road users
• Training of maintenance staff to work safely with high voltage vehicle</td></tr>
<tr><td>• Potential of reduced operating range in cold weather
• Manufacturers’ warranties can vary</td><td rowspan="2">
</td></tr>
<tr><td>Vehicle Applicability:</td><td>• Best suited to vehicles operating from a single depot and with daily mileage of <100miles
• Greatest benefit for urban applications where exemption from congestion charge and low emission and noise operation is beneficial</td></tr>
</table>

Source: Smiths Electric Vehicles, Freight Best Practice Scotland (2009a)

3.3.2 Drivetrain Technologies

Drivetrain technologies which can be used to reduce GHG emissions from heavy duty vehicles focus around hybrids and automated transmissions. Benefits of these systems can be quite varied. Automated manual transmissions can give benefits of between 7 and 10% reduction in CO_2 over a manual based on shifting occurring at optimal points. However this benefit is likely to be quite variable with driver, with those drivers who are experienced and have been well trained are likely to shift close to this optimum point giving lower benefit.

Hybrid systems have greater benefits for vehicles operating over an urban duty cycle with a frequent stop and start activity. Electrical hybrids offer benefits of around 7% for long haul and intercity applications and up to 20-30% for urban cycles. While the benefits are attractive the barriers to market uptake include the cost of the system, uncertainties over vehicle residual values and battery life and loss of payload which may be critical for some applications.

These technologies are described in greater detail in the following tables.

Automated Transmission		
Description:	Replacement of manual transmissions with automated transmission based on a manual (AMT) which has similar mechanical efficiency to a manual transmission but automated gear shifts to optimise engine speed	
CO_2 Benefit:	• Up to 10% benefit replacing a manual with AMT, highest for applications with frequent gear changes • If drivers of manual transmission vehicles are trained in eco driving via programs such as SAFED, real world benefit of AMT could be lower	
Barriers:	Shift quality is not as smooth as a torque converter automatic	
Vehicle Applicability:	AMT technology is applicable to both medium and heavy duty applications, offering good CO_2 benefits over both urban and highway duty cycles	

Source: Picture – ZF ASTronic Family

Full Hybrid		
Description:	Typically implemented as hybrid electric vehicles where electrical energy is stored in batteries which can be used to drive an electric motor to power the vehicle or supplement engine power	
CO_2 Benefit:	• HGV: Benefit ranges 4 – 10% with an average of 7% • Intercity / Coach: Benefit up to 20% with an average of 10% • City / Utility: Benefit ranges from 15 – 30% with an average of 20% • Bus: Benefit ranges from 20 – 40% with an average of 30%	
Barriers:	• Some vehicles have a reduction in payload • Engine stop/start unsuitable for some applications • Requires training of maintenance staff to safely work with high voltage systems	
Vehicle Applicability:	• Greatest CO_2 reduction potential for vehicles operating over an urban duty cycle • CO_2 savings still possible for long haul applications but business case requires more consideration	

Source: Picture – DAF (2009), Iveco (2009), Kendall (2009), MAN (2008), Daimler (2008), Renault Trucks (2008a, 2008b), Volvo Corporate Website

3.3.3 Vehicle Technologies

Vehicle technologies that can be applied to heavy duty vehicles focus on tyres, aerodynamics, use of lightweight materials and alternative fuelled bodies and are listed in

Table 3.8. Some of these technologies are already available in the market however their uptake is not necessarily high and further reduction in the overall heavy duty vehicle fleet CO_2 emissions may be achieved though retro-fitting of these types of technologies. The potential benefits of these technologies and their barriers to market are discussed in more detail.

Table 3.8: Vehicle Technology Types

Vehicle Technology		
Tyres	**Aerodynamics**	**Other**
Low rolling resistance	Aerodynamic trailers	Lightweight materials
Single Wide Tyres	Cab aerodynamic fairings	Alternative Fuel Bodies
Tyre Pressure Monitoring	Chassis aerodynamic fairings	
	Body aerodynamic fairings	
	Trailer Aerodynamic Tail Extensions	
	Spray Reduction Mud Flaps	
	Active Aero	

3.3.3.1 Tyres

The use of low rolling resistance and single wide tyres along with ensuring tyres are always at the optimum level of inflation can result in potential CO_2 savings of 5% to 10%. Greatest savings for the implementation of low rolling resistance tyres will be for long haul applications where tyres will have the lowest possible rolling resistance and also from replacing tyres on all vehicle axles. Barriers to introduction are legislation, with use of single wide tyres on drive axles limited and cost of systems for tyre pressure monitoring which is required with use of single wide tyres. These are discussed in more detail in the following tables.

Low Rolling Resistance Tyres		
Description:	Tyres designed to minimise rolling resistance whilst still maintaining the required levels of grip	
CO_2 Benefit:	Achievable CO_2 benefit depends on the number of tyres replace but trials suggest an average of 5% is possible for HGV, 3% for intercity and coach and 1% for other applications	
Barriers:	• Specific low rolling resistance tyres are only available for long haul applications where benefit will be greatest • Benefit reduces as tyres wear	
Vehicle Applicability:	Technologies tend to be aimed at long distance vehicles rather than vehicles operating over an urban cycle	

Source: Picture – Michelin XZA 2 Energy, Michelin Corporate Website; Michelin, Goodyear, Freight Best Practise (2006), Road Transport (2006), Faber Maunsell (2008), Bridgestone (2009)

Single Wide Tyres

Description:	Replacement of dual tyres on an axle with a lower aspect ratio single wide tyre	
CO_2 Benefit:	Average benefits are 2% reduction for single tractor axle and between 6% to 10% for whole vehicle	
Barriers:	• UK Legislation requires twin wheels on the drive axle of vehicles over 40 tonnes • Requires fitment of a tyre pressure monitoring system • Increased damage to roads, particularly those with a thin top layer • Initial tests on new generation wide-base tyres indicates single wide are no worse than standard	
Vehicle Applicability:	• Most applicable for vehicles travelling long distances • More benefit for applications where payload increase is of benefit	

Source: Picture – Michelin X One, Michelin Corporate Website; Verband der Automobile (VDA) (2008), Bachman et al. (2005), Diller et al. (2009), US EPA (2004), Lockridge (2008)

Automatic Tyre Pressure Adjustment		
Description:	Automatic tyre pressure monitoring automatically monitors and adjust tyre pressures Automatic Tyre Pressure systems use the air compressor on the vehicle to automatically monitor and adjust tyre pressures to optimum levels for load and terrain conditions	
CO_2 Benefit:	In fleet trials have demonstrated average benefits for HGVs at 3 – 4% fuel consumption reduction	
Barriers:	Systems are expensive	
Vehicle Applicability:	Applicable to all vehicles, but benefit likely to be greatest on high mileage vehicles and those operating on a range of different terrains	

Source: Picture – Automatic Tyre Pressure System (Freight Best Practice Scotland (2009b)), BigLorryBlog (2008), T-Comm Tracking & Tracing (2008), American Trucking Association (2008), Freight Best Practice Scotland (2009b), Verband der Automobile (VDA) (2008)

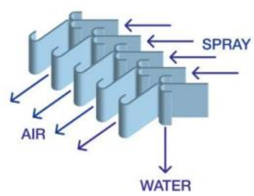
3.3.3.2 Aerodynamics

A large amount of energy is used to overcome aerodynamic drag for heavy duty vehicles travelling at motorway speeds. Reducing aerodynamic drag will reduce the amount of energy required to overcome it resulting in fuel savings. Aerodynamics play a greater role for vehicles travelling at constant high speed and as such technologies aimed at reducing aerodynamic drag will have a much larger impact on long haul and inter-city distribution vehicles than for vehicles on a low speed duty cycle. Benefits from aerodynamic technologies are in the range of 10% for aerodynamic trailers, between 0.6% and 4.8% for cab aero devices, 0.4% and 1% for chassis aerodynamic features, 0.1% to 3.6% for body aerodynamics, 3% to 6% for trailer tail extensions and circa 8% for active aero systems. Barriers to the technologies vary. Aerodynamic trailers are more expensive than their standard counterpart and will lose some load volume for the standard European 4m trailer height requirement. Aerodynamic fairings will add weight to the vehicle and if incorrectly adjusted can actually create a fuel penalty. Benefits will vary between vehicle types and not can be retrofitted to vehicles. Active aero systems may require some additional maintenance and there will be some challenges associated with the routing of air.

The benefits, barriers and vehicle applicability are discussed in more detail in the following tables.

Aerodynamic Trailers		
Description:	Trailers designed to improve vehicle aerodynamics. Types include: • A teardrop shape rising up from standard 4m height of cab to a max. of 4.5m and then reducing to the rear or 4m max height for European applications (due to motorway bridge height restrictions) • Those integrating multiple aerodynamic features into a complete vehicle package	
CO_2 Benefit:	Average of circa 10% but varies with application and vehicle usage. Most benefit on constant high speed routes	
Barriers:	• Potential loss of load volume for double deck and pallet applications • Additional up-front purchase cost	
Vehicle Applicability:	• Best suited to long-haul motorway type driving for maximum benefit • Best suited for applications where use can be made of additional load volume to further improve fleet emissions	

Source: Pictures – TNT Cartwright Cheetah trailer and DHL Teardrop trailer, Don-Bur, Swallow (2007a, 2007b), Cartwright

Spray Reduction Mud Flaps		
Description:	The mud flap separates the water from the air through a series of vertical passages created by vanes which makes the spray change direction a number of times eliminating the water	
CO_2 Benefit:	Estimated at an average of 3% for vehicles with large proportion of high speed driving	
Barriers:	• Small additional on cost for product	
Vehicle Applicability:	• Can be fitted to any standard mud wing • Provides greatest benefit to vehicles with a large proportion of high speed running	

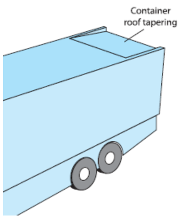
Source: Spraydown corporate website, The Engineer Online (2008)

Chassis Aerodynamic Features	
Description:	• Additional add-ons to vehicle chassis that help reduce aerodynamics drag and improve fuel consumption • Technologies include tractor and chassis/trailer side panels
CO_2 Benefit:	This varies with technology and ranges between 0.4% and 1.0% Tractor Side Panels: • Articulated: 0.6%  Chassis/Trailer Side Panels: • Rigid: 1.0% • Articulated: 0.4% • Drawbar:0.7% 
Barriers:	• Addition of aerodynamic fairings adds weight and can reduce the payload
Vehicle Applicability:	• Greatest benefit from aerodynamic devices is for vehicles that travel the longest distances at highest speeds • For all vehicle types over similar driving conditioned highest benefit is for rigid type vehicles

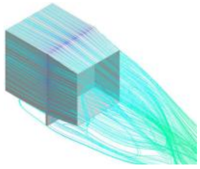
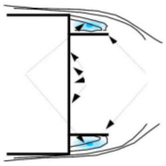
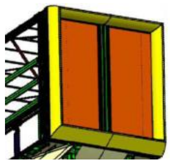
Source: Freight Best Practice (2007)

Cab Aerodynamic Fairings	
Description:	• Additional add-ons to cabs that help reduce aerodynamics drag and improve fuel consumption • Technologies include cab deflectors and cab collars and can be added as aftermarket additions
CO_2 Benefit:	• This varies with technology and averages range between 0.6% and 6.5% with roof fairings combined with cab collars offering the greatest reduction • All vehicle types analysed over same driving route Cab Deflector: • Rigid: 2.4% • Articulated:2.4% • Drawbar:1.2%  Cab Roof Fairing: • Rigid: 4.8% • Articulated: 3.7% • Drawbar:2.3%  Cab Collar and Roof Fairing: • Rigid: 6.5% • Drawbar:3.2%  Cab Side Edge Fairings: • Articulated: 0.6% 
Barriers:	• Addition of aerodynamic fairings adds weight and can reduce the payload • Correct adjustment is required to obtain full benefit and if incorrect can lead to a fuel penalty
Vehicle Applicability:	• Greatest benefit from aerodynamic devices is for vehicles that travel the longest distances at highest speeds • Cab roof fairings are single most effective technology and still offer benefit for local distribution vehicles

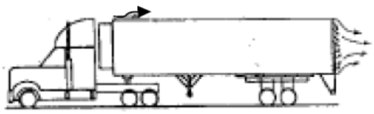
Source: Freight Best Practice (2007)

Body Aerodynamic Features	
Description:	• Vehicle body designs aimed at reducing aerodynamic drag • Technologies include gap seals, body roof tapering and container / trailer front fairings
CO_2 Benefit:	• Average benefits vary between 0.1% and 3.6% depending on vehicle type and technology • All vehicle types assessed over the same drive cycle Gap Seals or Vortex Stabilisers / Generators: • Articulated: 0.6% • Drawbar:0.8%  Container/Trailer Roof Tapering: • Rigid: 0.5% • Articulated: 0.3% • Drawbar:0.1%  Container Front Fairing: • Rigid: 3.6% • Articulated: 1.8% • Drawbar (tractor): 1.6% • Drawbar (trailer): 0.7% 
Barriers:	• Fitting gap seals on the edges of box trailers can, in some cases, lead to a truck exceeding the maximum legal width limits • Container / Trailer roof tapering impractical to retrofit and could result in potential loss of some internal load space • The effect of the container fairing will be minimal if the cab fairings cover the entire front of the container when viewed from the front, or if the cab fairings are very close to the container
Vehicle Applicability:	Applicable to all vehicle types however greatest benefit for those with a large degree of high speed operation

Source: Freight Best Practice (2007)

Trailer Aerodynamic Tail Extensions	
Description:	• Extension of trailer beyond load length to improve aerodynamic performance of the trailer • There are a number of solutions available
CO_2 Benefit:	Fuel consumption benefits varies with the different solutions (average benefits are provided for long haul applications): Open Cavity Tails: 6%   Inset Open Cavity Tails: 5 – 8%   Inflatable Open Cavity Tails: 3 – 4%   Inflatable Closed Cavity Tails: 5%  
Barriers:	• Currently vehicles are limited with maximum length which aerodynamic features would have to be included in resulting in a loss in load space • Long trailer extensions can adversely impact trailer stability
Vehicle Applicability:	Can be applied to all vehicles but most applicable to long haul vehicles which consistently operate long stretches of high speed driving

Source: Dings (2010)

Active Aero		
Description:	Active aerodynamics to reduce vehicle drag where air is blown from trailer trailing edge and over trailer roof to reduce drag caused by low pressure region behind trailer	
CO_2 Benefit:	Tests by GeorgiaTech Research Institute have shown a maximum of 8.7% fuel consumption improvement at 65mph (after accounting for energy to pump air)	
Barriers:	• Operation in adverse climatic conditions could give reduced effectiveness • Moderate increase in maintenance requirement • Routing air to rear of trailer is issue to be addressed	
Vehicle Applicability:	• Fuel consumption savings are greatest at high speeds making it suitable for long haul applications • Air supply could be integrated solution with powertrain or stand-alone on trailer (power supply requirement) • Early stage technology but readily applicable	

3.3.3.3 Other

In addition to low rolling resistance tyres and aerodynamic aids further vehicle technologies aimed at reducing GHG emissions from heavy duty vehicles are the use of lightweight materials and alterative fuelling for vehicle bodies other than running on engine driven PTO or separate diesel generator. Lightweight materials can help reduce fuel consumption through increased payload and fewer vehicle journeys or by lighter vehicles. These bring benefits of 1-2% per ton of weight saved equating to 1.7% on volume limited goods (i.e. lighter vehicle) and 4% for weight limited applications, i.e. fewer journeys. The use of alternative fuelled bodies can bring 10 to 20% savings depending on the application and alternative fuel source used. Barriers include the cost of lightweight materials such as aluminium and the higher energy intensity used in the manufacturing process while alternative fuel bodies are limited by application and suitability. These are discussed in more detail in the following tables.

Lightweight Materials		
Description:	• Apply aluminium alloys intensively in tractor chassis and body, trailer and powertrain • Use of aluminium alloy may achieve total combined unit weight savings of up to 2,000kg –estimate for tractor body and chassis ~ 900 kg	
CO_2 Benefit:	• 1-2% per tonne of weight saved, slightly better on freight efficiency basis • European Aluminium Association claim 1.7% on volume limited applications and 4.2% on weight limited applications (assuming articulated vehicle fuel consumption of 35.7l/100km)	
Barriers:	• Increased cost • More energy intensive manufacture • Need application specific design, cannot use existing steel sections • Degree of benefit strongly influenced by percent of weight limited kilometres over vehicle life	
Vehicle Applicability:	• Applicable to both medium and heavy duty vehicles • Aluminium alloy trailers in use in US and EU • Next step is application to tractor unit and more Al intensive powertrain • Established material technology	

Source: International Aluminium Institute, European Aluminium Association, Picture – Bolted Aluminium chassis for trailer (European Aluminium Association)

Alternative Fuel Bodies		
Description:	Replacement of existing power sources for vehicle bodies which use diesel for power	
CO_2 Benefit:	Varies between 10% and 20% depending on the body power system being replaced, average of 15%	
Barriers:	• Not suited to all applications • Safety of nitrogen system for refrigerated trailer	
Vehicle Applicability:	• Suited to applications where electrical motors have sufficient torque to drive load • For use in hybrid vehicle applications where hybrid battery can be used to power trailer	

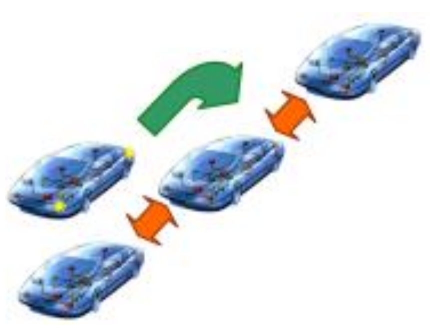
Source: Picture – Volvo Hybrid Refuse Truck (gizmag), Finanz Nachrichten (2009), Geesink Norba, Transport Canada, ecoFridge, ecoFridge Corporate Website, McKeegan (2008), Renault (2008b)

3.3.4 ITS/ICT Technologies

With electronics increasing in all areas of the vehicle, ITS systems are also arising in the fields of fuel consumption reduction. Technologies which are found to be developing in this area but which are yet to be widely applied to commercial vehicles are predictive cruise control, vehicle platooning, green zone indicators, smart alternators, acceleration control and eco-roll functions. These features can save between 1 and 20% depending on vehicle application and route type. Benefits will also vary with the level of driver skill, with those trained in eco driving benefiting less from these new technologies. Barriers to introduction are the maturity of some of the technologies and ensuring driver understanding of what the system aims to do. These systems are discussed in more detail in the following tables.

Predictive Cruise Control		
Description:	• Development of systems that use electronic horizon data to improve the fuel efficiency of vehicles • Combining GPS with Cruise Control to better understand the road ahead for optimal speed control	
CO_2 Benefit:	• Initial reports indicate average fuel economy benefits in the range 2 – 5% but this will vary with route • Prediction from Sentience collaboration suggest 5-10% improvement by eliminating inconsistent accelerator pedal pressure and sudden braking	
Barriers:	• Journey times can increase due to greater speed variations below set speed ○ Time differences simulated by Daimler for the PCC system range from between +0.3% to +1.9% increase in journey time	
Vehicle Applicability:	Most applicable to long haul vehicle applications where cruise control is used most often	

Source: Crosse (2009), Freightliner (2009), Ramsey, Lattemann et al. (2004), Hellstroem (2005), Ricardo (2009)

Vehicle Platooning	
Description:	• Vehicle driving in close proximity to each other to create a train • Vehicles are able to follow each other closely and safely to reduce aerodynamic drag and fuel consumption and increase safety
CO_2 Benefit:	In the region of 20% for motorway speeds
Barriers:	• Liability issues associated with autonomous vehicle control, probability and consequences of system failure • Contravenes current road regulations • System performance in adverse driving conditions • Risk of driver underload and of copy cat driving outside the platoon • Possible feeling of being out of control due to the close proximity to vehicle in front, interaction with and intimidation of other road users • Vehicle needs to be equipped with sensors, communication equipment etc. • Risk of driver underload in platoon vehicles and of copy cat driving outside the platoon • Increased responsibility on the lead driver • Obstruction when passing motorway exits and transient manoeuvres in and out of the platoon 
Vehicle Applicability:	• Greatest benefit is at higher vehicle speeds such as motorway driving • This technology is therefore more applicable to long haul HGVs where there is a greater business case

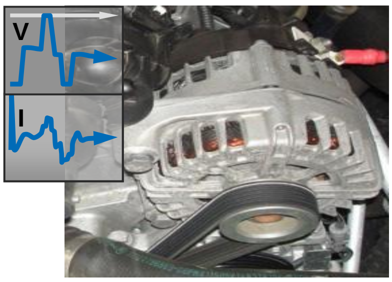
Source: SATRE FP7 Proposal, Zabat et al. (1995), Bonnet (2003)

Green Zone Indicator		

Description:	• Green zone indicates real-time fuel economy to encourage better driving
	• Display real-time fuel economy with a 3-10s time constant with jump-out for mode changes e.g. gear change, braking
	  ○ Option 1) Use a radial display for the tacho and calculate indicated green zone to show engine speed is in optimum range
	  ○ Option 2) Use a separate radial fuel economy meter (can be combined with digital average fuel economy meter)	

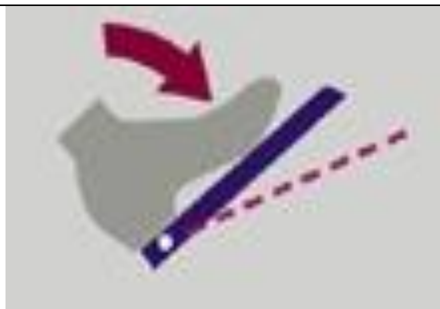
CO_2 Benefit:	• Better driver behaviour can save 5-10% fuel	
Barriers:	• Option 1) preferable for real-time fuel economy as less distracting • No benefit on drive cycle test • Less benefit from more experienced drivers of LDT HDT	
Vehicle Applicability:	• Driver Experience - Jumpiness not acceptable or helpful to driver • Average fuel economy of limited benefit to driver, improved driving experience from a helpful real-time economy indication	

Source: Isuzutruckomaha.com; Autometer.com, Arriva Buses

Smart Alternator, Battery Sensor & AGM Battery		
Description:	• Control alternator voltage to that required for the current battery condition and vehicle mode to maximise overall electrical generation efficiency • Typically, an absorbent glass mat (AGM) battery is used to decouple alternator and vehicle electrical loads with State of Charge (SOC) varying between 50-75% according to vehicle mode • In overrun, a high alternator voltage and fast charging is used to maximise brake energy regeneration • To reduce engine load in acceleration, the alternator voltage is reduced below that required for the current battery condition such that discharge occurs	
CO_2 Benefit:	Estimated to be 1 – 2%	
Barriers:	• Reduced voltage regulation and/or auto load switching may be noticed by critical drivers as light flicker • Need to change SOC strategy if battery changed to flooded type	
Vehicle Applicability:	• In market on passenger car (e.g. Kia Ceed, Ford Focus, BMW Efficient Dynamics, GM) • Applicable to all HDVs	

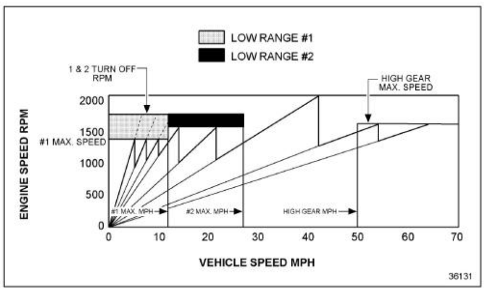
Source: Picture – Valeo 180A 2.5kW Smart Alternator; Ricardo projects, Harmohan (2000)

Acceleration Control	
Description:	• Limit acceleration rate to avoid full use of the available power reserve • On commercial vehicles, rated power is required to achieve acceptable acceleration for a heavily loaded vehicle. The high power regions of the BSFC map can be avoided when the vehicle is lightly loaded to limit CO_2 emissions • Scania offer acceleration control on lightly loaded buses, limiting the rate of acceleration as a function of vehicle mass and speed • An alterative approach proposed by Nissan on passenger cars is to control acceleration demand by increasing pressure required to achieve a particular pedal angle (Pedal push-back) when acceleration is above a calculated optimum
CO_2 Benefit:	• A potential reduction up to 6% depending on the amount of acceleration and driving style • Highest savings expected in busy stop-and-go city traffic
Barriers:	• For safety reasons system must permit overtaking • Problematic transition when downshifting due to suppressed pedal position
Vehicle Applicability:	• All commercial vehicle classes with variable payload • All vehicles with high performance low fuel economy regions on their BSFC map

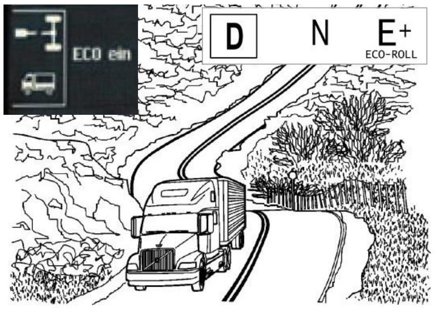


Source: Picture – Nissan Eco Pedal; Ricardo benchmark data, Scania (2008), Nissan (2008)

Governing Speed Control - Progressive Shift	
Description:	• Encourage upshift when engine speed is above optimum range (low speed) but below engine rated speed – When engine speed is above optimum range, limit the rate of acceleration, the driver will feel this and be encouraged to up-shift – Limit engine speed to a threshold that depends on vehicle speed – This will force up-shift at low speed and encourage use of top gear during cruise
CO_2 Benefit:	Estimated to be 1 – 4% depending on driving style and cycle
Barriers:	Driver understanding of system
Vehicle Applicability:	• Applicable to MT and AT operating in manual mode • Maximum benefits during frequent stop/go urban delivery driving cycles



Source: Picture – Daimler AG – Detroit Diesel EC V; Ricardo projects, Harmohan (2000)

<table>
<tr><th colspan="3">Eco-Roll – Freewheel Function</th></tr>
<tr><td>Description:</td><td colspan="2">Automatically disengage the driveline when engine is not required to maintain vehicle speed. Re-engage when brake or accelerator pedals are pressed or engine brake is applied
When the ECU detects that no power or braking is needed, the transmission is shifted into neutral and an indication put up on the driver display
The Volvo version on their I-Shift AMT operates during normal driving with the accelerator released or in cruise control for any gear between 7 and 12. When active, it shifts the splitter into neutral and changes the current gear indication from (7-12) to N
Mercedes offer a similar function as an option on their PowerShift AMT</td></tr>
<tr><td>CO2 Benefit:</td><td colspan="2">Volvo claims a massive 30hp benefit while Mercedes claim a lower 1% CO2 reduction. Ricardo expected this to be highly application dependent.</td></tr>
<tr><td>Barriers:</td><td colspan="2">Requires failsafe mode</td></tr>
<tr><td>Vehicle Applicability:</td><td>Available on Volvo FH12 HDT with I-Shift AMT. `Eco-Roll` brand
Mercedes offer Eco-Roll function on their 2009 Actros HDT trucks with PowerShift AMT. This has an iconic indication of mode
Eco-Roll is offered to Operators as part of optional economy package.
Mercedes are not offering it on their Acor LDT. They see it as more relevant to high mileage motorway operation</td><td>
</td></tr>
</table>

Source: Picture – Mercedes-Benz; Volvo Corporate Website, Road Transport (2003), Mercedes Actros Brochure, 2008 Mercedes-Benz CV312 brochure

The benefits that these technologies can have on vehicle CO_2 emissions are summarised in Table 3.9. These are also compared against figures reported in a recent study published by the US National Academy of Sciences (NAS, 2010) /National Research Council titled *“Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles”*. The study report was conducted for the US Department of Transport National Highway Traffic Safety Administration. Some of the technologies covered in this report are not covered by the NAS (2010) study and likewise some technologies covered by the NAS (2010) study are not covered in this report. Technologies covered by the NAS (2010) study and omitted from this report are primarily not "headline" technologies rather technologies which are a gradual evolution of the existing product and often included in engine upgrades or redesigns. For example such technologies include turbo charging, improved combustion, cooled EGR, ECU calibration, VVA etc.

For the technologies included in both reports estimates of CO_2 benefit are generally in agreement. Larger discrepancies arise with technologies which are yet to see extensive market uptake or which are very dependent on vehicle duty cycle. Technologies which have differences in estimated CO_2 benefit include electric turbocompounding, bottoming cycles, full hybrid, hydraulic hybrids, tyre pressure adjustment, and aerodynamic fairings.

In general the main reasons for the variation in CO_2 benefit estimates arise from the technologies being new and emerging with limited real world data available and that the benefit gained is very dependent on vehicle duty cycle. The National Research Council report focuses on the US market. In the US vehicles are different to Europe with trucks being long nose (conventional) variants rather than cab over engine as is common in Europe. Vehicle fuel consumption figures may also differ between regions based on the different vehicle types and as such the level of benefit that a technology brings will vary. Also vehicle duty cycle may be different between regions which will lead to differences in potential benefits.

For electric turbocompounding the differences are not significant, with ranges quite consistent and averages generally being slightly higher in the NAS (2010) study report due to the inclusion of electrification of engine accessories in the benefits.

The variation in benefits from bottoming cycles can arise from the limited level of maturity of the technology. Benefits estimated in this report stem from literature and Ricardo experience in this area. Figures reported by NAS (2010) study are those reported from individual technology demonstrations. Real world benefit is generally lower than simulations or technology demonstrators as the benefit will vary depending on the level of heat in the vehicle exhaust (affected by duty cycle) and the efficiency of the bottoming cycle.

Electric and hydraulic hybrid vehicles also have some variation in the benefits quoted. Vehicle duty cycle is a significant influencer on CO_2 benefit for hybrid vehicles. Vehicles which have a large degree of stop/start driving will obtain much greater benefit than those operating at constant high speeds. Driving conditions and vehicle duty cycles and vehicle sizes vary between regions leading to differences in the benefits of these technologies. The trend however is clear that vehicle applications involving a high degree of stop/start driving have the potential for higher CO_2 benefits.

Differences in the benefit provided by automatic tyre pressure adjustment most likely arise from the limited information on the percentage of vehicles running with under inflated tyres and the extent to which they are under inflated. Figures in this report come from fleet trials. No figures for tyre inflation systems were provided in the NAS (2010) study report however from a fleet operator using nitrogen rather than air 1 – 1.5% benefit is seen which indicates that tyre pressure monitoring would have a benefit. The use of nitrogen rather than air results in tyres maintaining pressure for longer as nitrogen has a slower rate of diffusion through the tyres than oxygen. From this it is reasonable to assume that a tyre pressure inflation system could offer increased benefit.

Lastly aerodynamic fairings have differences in the range of CO_2 benefit they can bring. Estimates in this report are approximately half that reported in the NAS (2010) study report. This difference arises from the difference in vehicle type – cab over engine in Europe compared to long nose in USA and the higher distances that US Class 8 trucks generally travel. In the US it is still possible to buy a number of tractor cabs which have traditional styling which have very poor aerodynamics with OEMs offering specific "aero" cab styles. In Europe no such "aero" style is offered with all vehicles designed to minimise air resistance. This provides different benchmarks against which benefits of fairings are measured resulting in different levels of benefit. Further the different styles of cab can lead to different frontal areas which has a large impact on aerodynamic drag. In addition the vehicle duty cycle will impact the level of benefit. In the US many vehicles operate at constant high highway speed for several hours. Across Europe driving conditions are more mixed between highway and urban roads and with higher levels of congestion. This again will impact the benefits obtained from these technologies. Estimates used in this report are predominantly based on European styled vehicles.

Table 3.9: Summary of Technology CO_2 benefits and comparison with those reported by NAS (2010)

Technology	CO_2 Benefit (AEA/Ricardo)	NAS (2010) CO_2 Benefit
Dual Fuel Systems	10 – 20%	N/A
Variable flow / Electric Water pump	0.7% for variable flow 1 – 4% electric	N/A
Variable speed oil pump	1 – 3% possible	N/A
Hydrogen fuel cells	100% - tailpipe reduction only	N/A
Electric Vehicles	100% tailpipe reduction	N/A
Stop / Start Hybrid	HGV: 0 – 3%, average 1% Intercity / Coach: Up to 15%, average 3% City / Bus / Utility: Up to 30%, average of 6%	N/A
Mechanical Turbocompound	3 – 5% - best for long haul applications	2.5 – 5%
Electrical turbocompound	HGV: 2 – 8%, averaging at 3% Intercity / Coach: 1 – 5%, average 2.5% City / Utility / Bus: 0 – 2%, average 1%	3 – 10%, average benefit of 4 – 5% estimated including electric accessories
Bottoming Cycles	HGV: 1.5 – 6% with average values of 5% Intercity / Coach: 1 – 3%, average 2.5% City / Bus / Utility: 1 to 3%, average 1.5%	Up to 10%, Cummins demonstrated 7.2% using a Rankine cycle
Controllable Air Compressor	HGV: Average of 3.5% CO_2 reduction, range of 1 – 4% Intercity / Coach: Average of 1.5%, range of 1 – 2% City / Bus / Utility: Limited benefit due to frequent stop / start	N/A
Electric Engine Accessories	0 – 8%	2 – 4%
Automated Transmission	Up to 10% replacing manual with AMT	4 – 8%
Full Hybrid	HGV: Benefit ranges 4 – 10%, averaging 7% Intercity / Coach: Benefit ranges 5 – 20% with an average of 10% City / Utility: Benefit ranges from 15 – 30% with an average of 20% Bus: Benefit ranges from 20 – 40% with an average of 30%	Class 8: 5 – 10% Class 6: 20 – 45% Refuse: 20 – 35% Urban Bus: 12 – 50% Coach: 5 – 40% Van: 18 – 30%
Flywheel Hybrid	HGV / Intercity / Coach: Benefits range from 5 – 15% with an average of 5% for HGV and 7.5% for Intercity and coach City / Utility: Benefit varies from 15 – 22% with an average of 15% Bus: Benefit ranges from 18 - 25% with an average of 20%	N/A
Hydraulic Hybrid	Estimated CO_2 benefit varies greatly with duty cycle but can be up to a maximum of 25% in frequent stop / start cycles with average "real world" usage seeing 15 - 18% in similar	City use: 20 – 25% Highway: 12% UPS demonstrated 60 - 70% reduction

Technology	CO_2 Benefit (AEA/Ricardo)	NAS (2010) CO_2 Benefit
	applications	
Low Rolling Resistance Tyres	Achievable CO_2 benefit depends on the number of tyres replace but trials suggest an average of 5% is possible for HGV, 3% for intercity and coach and 1% for other applications	Between 4 and 11%: Class 8 – 4.5% average, Class 6: 1.4 – 1.8%, Refuse 1.5%, Bus/Van 1%, Coach 1.8%
Single Wide tyres	2% for single axle and 6 – 10% for whole vehicle	5 – 10% varying with baseline tyre
Automatic Tyre Pressure Adjustment	In fleet trials have demonstrated average benefits for HGVs at 3 – 4% fuel consumption reduction	1 – 1.5% for Walmart using nitrogen
Aerodynamic Trailers	Average 10%	Full aero packages 7.8 – 9.3%
Aerodynamic Fairings	0.4 – 4.8% depending on fairing and vehicle type and duty cycle	2 – 10% depending on fairing type
Active Aero	Up to 8.7%	8%
Lightweight Materials	1-2% per tonne of weight saved, slightly better on freight efficiency basis 1.7% on volume limited applications and 4.2% on weight limited	1 – 2% per 1,000lb weight reduction Bus – 3.75 – 7.5% per 10% reduction
Alternative Fuel Bodies	10 – 20% depending on body power system replaced	N/A
Predictive Cruise Control	2 – 5% but will vary with route	Figures vary between 1 – 5% benefit
Vehicle Platooning	~20% for motorway speeds	N/A
Green Zone Indicator	5 – 10%	N/A
Smart Alternator, Battery Sensor & AGM Battery	Estimated at 1 – 2%	N/A
Acceleration Control	Up to 6% depending on driving style	N/A
Governing Speed Control – Progressive Shift	1 – 4% depending on driving style	N/A
Eco Roll – Freewheel Function	~1% - expected to be highly dependent on application	N/A

Source: Ricardo estimates, National Research Council, Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles

3.4 Survey of technical and management solutions

Objectives:

The purpose of this sub-task was to carry out a:

"Survey of technical and management solutions to monitor and report fuel consumption, including systems based on wireless data transmission"

Summary of Main Findings

⇒ There are no mandatory requirements to monitor and report fuel use for HDVs within the EU;

⇒ Accurate management of fuel requires data capture that can identify and record the three critical influence (1) the driver, (2) the vehicle and (3) the journey;

⇒ The collection of data can be either a manual paper based system, or through the employment of telematic systems;

⇒ There are no set rules determining the applicability of individual systems to an HDV operator.

The monitoring and reporting of fuel consumptions is an important element of the effective and efficient management of any organisation that operates Heavy Duty Vehicles (HDVs). This has been made more pertinent the recent years by the increase in the cost of fuel and the expectations to report fossil fuel usage as a component of Corporate Social Responsibility. The level of accuracy in the monitoring and reporting of fuel use varies from organisation to organisation; depending on many circumstances. These include the size of the operator, its ability to invest in technology support, and the managerial importance placed on monitoring and reporting fuel consumption within individual HDV operating businesses.

There are no mandatory requirements to monitor and report fuel use for HDVs within the EU. This places the initiative for taking action within the managerial decision making process of individual organisations. The monitoring and reporting of fuel use is normally part of organisational accounting and fiscal procedures and is normally undertaken by large National and International businesses with a high degree of accuracy. This accuracy is normally as a result of an investment of management and technology resource made with an anticipated financial payback. Small and Medium Enterprise (SME) systems of fuel monitoring and reporting are more varied and inconsistent. These can range from a full system of accurate data capture to as basic as being captured as an annual cost to the business. Fuel usage in some organisations may not be captured.

The greater the granularity of fuel use data the greater the visibility of use and the ability to take managerial action to make an improvement in performance: this can be across a number of possible intervention measures – such as the application of vehicle aerodynamics or eco-driver training. Without fuel consumption information down to individual vehicle, driver and journey level, the aggregation of data reduces its accuracy and usefulness as a managerial tool. It is for that reason that IT solutions are beneficial and are sought by HDV operators wishing to manage fuel usage.

There are many systems available to HDV operators including those which are paper based and those which are IT. Paper based systems require detailed collection of fuel and mileage information through manual record keeping and can include data provided by retail fuel card receipts as well as collection of odometer readings. Such paper based systems are subject to the manual transfer of information on a regular basis and associated opportunity for error.

There are no set rules determining the applicability of individual systems to an HDV operator. However, some government initiatives such as the UK Government Bus Service Operators Grant requires operators to accurately record and authenticate all fuel used in return for direct financial remuneration within set parameters.

Management of fuel usage is an ongoing business activity that has to take in to account factors such as seasonality (fuel use is greater in winter than summer due to the direct effects of ambient temperature to engine efficiency) and any changing business profile. It has to be dynamic to be effective.

Accurate management of fuel requires data capture that can identify and record the three critical influences:

- the driver
- the vehicle
- the journey

The Driver: The driver, arguably, can have the biggest single influence on fuel usage. This will be as a result of many factors, dominant of which are the level of driving competence, level and frequency of training, familiarity with the vehicle and drivers' personal view of their role towards fuel management within the organisation.

The Vehicle: HDVs have their own characteristics, and by the nature of their mass are heavy users of fuel. The vehicle needs to be the right tool for the task; avoiding being over or undersized, underutilised, and consisting of the optimal engine and gearing configurations and fitted with appropriate fuel saving interventions.

The Journey: Fuel use is heavily influenced by the route taken, which needs to minimise mileage whilst balancing this against engine idling time resultant from standing in traffic. Fuel monitoring will identify such patterns of journey profile.

3.4.1 Technical Solutions

Accurate collection of fuel use data has been made available to HDV operators through the widespread introduction of telematics systems. Systems available to operators are commercially orientated and, therefore, seek to provide a range of additional features in order to make them commercially attractive items. That said, the most common feature of these systems is the widespread use of wireless networks to transmit data: this can be either in real time or at set regular intervals. Transmission is made at speeds of 32-48 kilobytes per second.

At the most basic level, many HDVs are now fitted with colour coded rev counter displays that provide the driver with optimum engine labouring information. This has benefits but is real time and does not retain historic data.

3.4.1.1 Fuel consumption

Telematic systems provide operators with the date required to monitor and report on fuel consumption which is the critical to the identification of areas for fuel consumption improvement, and subsequent monitoring of improvement progress. Telematics enables operators to monitor fuel consumption in a number of ways beyond total usage data. They include a range of other factors that relate to how a vehicle is being driven and is performing. These factors include making it possible for operators to identify:

- The total amount of fuel being used, including fuel use by individual drivers over any given period.
- Disproportionate or increasing fuel use, which highlights a possible problem with either driving technique or the vehicle.
- Variance in driving techniques. Systems can record details on braking, revs and acceleration of the vehicle. Therefore where there is evidence of heavy braking, over revving in a gear or changing gear at these high revs, or excessive acceleration, there may be opportunities to improve fuel consumption. These records allow the operator to identify the need to promote more efficient driving styles, and/ or highlight drivers that would benefit from training to improve the efficiency of their driving.
- How a vehicle is performing by monitoring fuel use, engine idling time, engine revs, and braking.
- Possible mechanical problems with a vehicle, as the data the system provides will enable the operator to identify where a vehicle is using more fuel than is the normal operating expectation.

The functions listed above summarise fuel use performance, but there are other ways in which technical systems can directly provide support to managerial action to reduce fuel consumption. These include:

- Navigation systems that help drivers to locate delivery or collection locations, therefore optimising the route driven, reducing mileage and subsequent fuel use. These systems can also use wireless technology to update the navigation system to inform the driver of any incidents and congestion and provide alternative routes. This minimises the fuel that is used whilst stationary or slow moving in traffic congestion.
- Computerised vehicle routing and scheduling (CVRS) systems can also help operators to use their vehicles more efficiently. CVRS is used to optimise the routes used to ensure minimal mileage, both loaded and empty, and therefore minimising fuel used. Numerous customer orders can be imputed into a CVRS system, along with the resources available to fulfil the orders, and the systems can plan the resources required for the workload and the routes to be taken. Therefore it is possible that CVRS systems can lead to the removal of vehicles from the road, and improve the efficiency of those undertaking the deliveries or collections. However, transport managers can often optimise the information provided further using their customer knowledge, local knowledge or other factors, meaning that the system does not have to be 100% automatic – there is opportunity for human interface.
- The fuel consumption information provided by telematics systems can be used to create league tables of driver performance. Competition from this can lead to improvements in the driving style of employees.

The vehicle data that telematic systems provide vary between manufacturers as system are often designed to meet the needs of differing business profiles. However, the majority of the solutions do not actively lead to a change in fuel consumption, their function is to collect and present data to the user, and rely on the user being able to draw on the data to identify any areas for improvement and put actions in place that will lead to fuel consumption improvements.

3.4.1.2 Other features and benefits of technical solutions

Technical solutions have a number of features and benefits in addition to providing information that can enable fuel consumption and related managerial action to be undertaken. These include a number of areas which are summarised below.

- Providing data on performance to measure progress towards meeting individual business KPIs and allowing operators to monitor operations in real time rather than wait of a period of operation to end.
- Vehicle and load security- telematics can be used to alert users if a vehicle travels outside of the area it is expected to operate, or if someone has entered the vehicle without the driver's authorisation. Panic buttons can also be installed in vehicles providing real time alerts.
- GPS vehicle tracking- the enables the user to see the vehicle position at any time. The user can use this to check whether the delivery is proceeding as planned. It can also be used to send automated messages to customers when the vehicle is a specified time or distance away from arriving at destination.
- Indicating to the operator when a vehicle arrives at a set point, such as a pick up or drop off, and providing real time proof of delivery or collection.
- Improving customer service by providing operators with the facility to meet some customer requirements, such as requests to see service delivery data and compare actual to expected delivery time, to determine patterns and, if necessary, edit the anticipated delivery times it uses.
- Providing management information such as speed and location. Therefore, if an accident occurs these details can be used to verify an insurance claim.
- Providing the information necessary for compliance with legislation, such as speed, laden weight and the working time directive.

The benefits provided by telematic systems are summarised in Table 3.10 below:

Table 3.10: Telematic systems

Fuel consumption benefits	Other features and benefits
• **Provides information on** ○ Driving style ○ Fuel consumption ○ Braking ○ Revving ○ Acceleration ○ Idling time • **Enables action to be taken on** ○ Training ○ Maintenance ○ Management	• **GPS, providing:** ○ On board navigation ○ Real time proof of delivery/collection ○ Details of route deviations • **Security benefits, through** ○ Out of zone alert ○ Unauthorised entry alerts ○ Panic button • **Customer service** ○ Meets requirement

The management and reporting of fuel usage is a management activity that requires management commitment from HDV operators. Its effectiveness is dependent on the accuracy of data collection which has to include detail of individual driver, vehicle and journey in order to provide meaningful information upon which management action can be taken to improve fuel consumption. The collection of data can be either a manual paper based system, or through the employment of telematic systems. Whilst telematic systems are commercial products, that require HDV operator investment, they have the advantages of enhanced accuracy and automated ease of data collection. In addition, most telematic systems work in real time data collection which has the added benefits of providing operators with information of vehicle location that can be used for other managerial functions.

3.5 Effect of vehicle speed on fuel consumption

Objectives:

The purpose of this sub-task was to:

"Investigate the influence of vehicle speed on fuel consumption, CO_2 emissions, operating costs, and on production scheduling and logistics"

Summary of Main Findings

⇒ Variations of speed for Medium Duty vehicles from 70km/h to 90km/h can result in a 21% increase in fuel consumption

⇒ A reduction from 90km/h to 80km/h maximum speed for heavy duty commercial vehicles can result in a 6% reduction in fuel consumption

⇒ Fuel represents the single largest cost for an operator at 30% of operations for a 40t articulated vehicle

⇒ A 5% reduction in fuel consumption would result in a 1.5% reduction in operating costs for a typical operator of long haul vehicles, which can amount to significant monetary sums

⇒ Safe and fuel efficient driving has little impact on journey times, however a 10km/h reduction in maximum vehicle speed could have implications on increased journey times requiring additional driver rest periods resulting in longer journey times which would then impact some just-in-time logistics

Vehicle speed can have a significant impact on the fuel consumption of a vehicle with fleet operators able to specify both axle and gear ratios to optimise a vehicle for most fuel efficient operation over its likely duty cycle. Fuel consumption is influenced by the level of rolling resistance and aerodynamic drag along with the area of the engine map the engine is operating in. For minimum fuel consumption an operator wishes to minimise all three. While the choice of axle and gear ratios help operate the engine in its optimum range for the largest portion of time, rolling resistance and aerodynamic drag are linked to vehicle speed increasing proportionally and exponentially respectively with increasing speed.

To illustrate the variation of fuel consumption with vehicle speed, the fuel consumption of two "typical" trucks have been modelled demonstrating how both rolling resistance and aerodynamic drag and hence fuel consumption vary with vehicle speed. The two vehicle types chosen were an 11t medium duty vehicle which is typically used in an urban delivery environment and a 40t articulated vehicle which is commonly used in long haul applications. The input data for the models is summarised in Table 3.11 and Table 3.12 below. Further to this a transmission efficiency of 95% is assumed and engine fuel maps for a 6 litre engine used for the 11t truck and 12 litre engine for 40t truck based on Ricardo experience of typical figures for such engine sizes.

Table 3.11: Model Parameters for Medium Duty Truck

Medium Duty Truck – 11t GVW	
Drag coefficient, Cd	0.45
Frontal area [m^2]	5.5
Rolling Resistance coefficient	0.0068
Gear Ratios (6 speed)	1st: 6.69 2nd: 4.34 3rd: 2.82 4th: 1.83 5th: 1.19 6th: 0.77
Final drive ratio	4.1
Engine peak power (@ speed)	170kW @ 2230 rpm
Engine peak torque (@ speed)	880Nm @ 1300 rpm

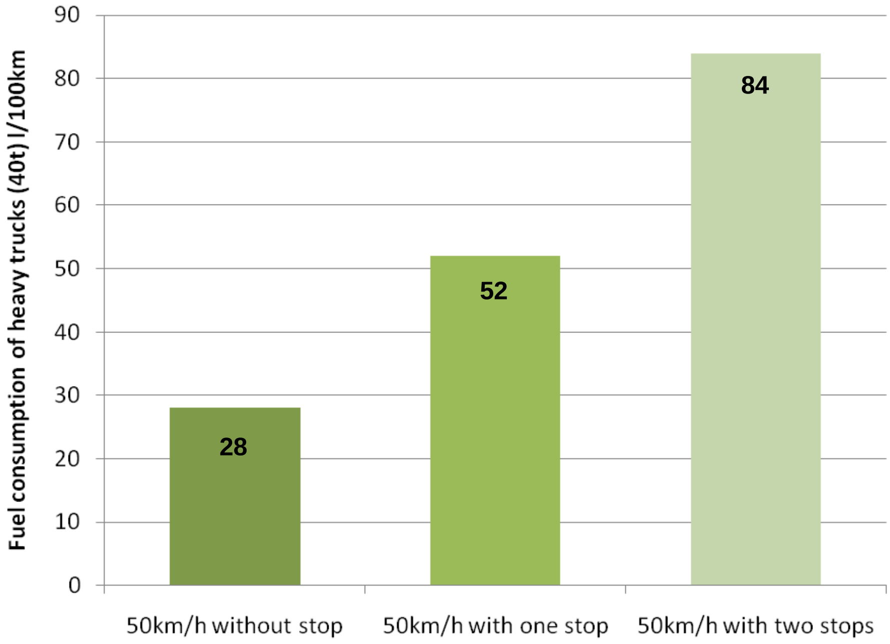
To illustrate the variation of fuel consumption with vehicle speed, the fuel consumption of two "typical" trucks have been modelled demonstrating how both rolling resistance and aerodynamic drag and hence fuel consumption vary with vehicle speed. The two vehicle types chosen were an 11t medium duty vehicle which is typically used in an urban delivery environment and a 40t articulated vehicle which is commonly used in long haul applications. The input data for the models is summarised in Table 3.11 and Table 3.12 below.

Table 3.12: Model parameters for Heavy Duty Truck

Heavy Duty Truck – 40t GVW		
Drag coefficient, Cd	0.6	
Frontal area [m^2]	7.7	
Rolling Resistance coefficient	0.0068	
Gear Ratios (12 speed)	1st: 10.85 2nd: 8.43 3rd: 6.55 4th: 5.09 5th: 3.96 6th: 3.07	7th: 2.39 8th: 1.86 9th: 1.44 10th: 1.12 11th: 0.87 12th: 0.68
Final drive ratio	3.71	
Engine peak power (@ speed)	293kW @ 1700 rpm	
Engine peak torque (@ speed)	1955Nm @ 1200 rpm	

These simulations are conducted for vehicles travelling at a constant speed and as such are not representative of fuel consumption for journeys with low average speed where there is frequent stopping and starting. Figure 3-2 shows the impact that stopping can have on the fuel consumption of a vehicle over constant speed driving, highlighting that only a single stop can almost double fuel consumption over constant speed driving.

Figure 3-2: Influence of traffic flow on fuel consumption



Source: VDA taken from VDA, The Commercial Vehicle – environmentally friendly and efficient

Figure 3-2 shows the variation in resistive power for both rolling resistance and aerodynamic drag for the medium duty truck at different vehicle speeds along with the fuel consumption at these speeds. Resistive power required to overcome rolling resistance increases linearly with vehicle speed and is the dominant drag force at lower vehicle speeds. Aerodynamic drag is proportional to the square of vehicle speed and becomes a much larger influence in total resistive power at higher vehicle speeds. For the medium duty truck fuel consumption is minimised at low speeds of only 50km/h. This corresponds with the type of speeds that this vehicle would be expected to average in typical daily usage. At these types of speed rolling resistance is the dominant force and reductions in this will have some benefit in reducing fuel consumption.

Maximum vehicle speed limits for this type of vehicle vary between 70km/h and 90km/h for use on rural roads and dual carriageways in among European member states. Fuel consumption for this type of vehicle is lower at 70km/h than at 90km/h increasing by 21% as the vehicle speed increases. This suggests that a reduction in the maximum vehicle speed could have an impact on the overall fuel consumption of this type of vehicle; however the extent of this fuel consumption reduction will greatly depend on the duty cycle of each vehicle and the time spent travelling at high speeds. The majority of operation for this type of vehicle is estimated to be around or below speeds of minimum fuel consumption. For vehicles operating in urban environment fuel consumption also increases at very low speeds as the engine is not able to operate in its most efficient zone. Minimising time spent travelling at low speeds will also have a beneficial impact on fuel consumption.

Figure 3–4 shows the variation in rolling resistance, aerodynamic drag and fuel consumption with vehicle speed for a heavy duty articulated vehicle of 40t. Similar to the medium duty truck, rolling resistance is the dominant force at low speeds with aerodynamic drag becoming increasingly important as vehicle speed increases. However at motorway speeds of 100km/h, rolling resistance is the dominant resistive drag force (assuming no cross wind) accounting for 69% and aerodynamic drag 31% of all resistive forces. However as heavy duty trucks may spend long periods of time at these higher speed aerodynamic drag has an important influence on fuel consumption, which if reduced can result in significant fuel savings.

Figure 3–3: Variation in Fuel Consumption with Vehicle Speed for Medium Duty Truck (11t)

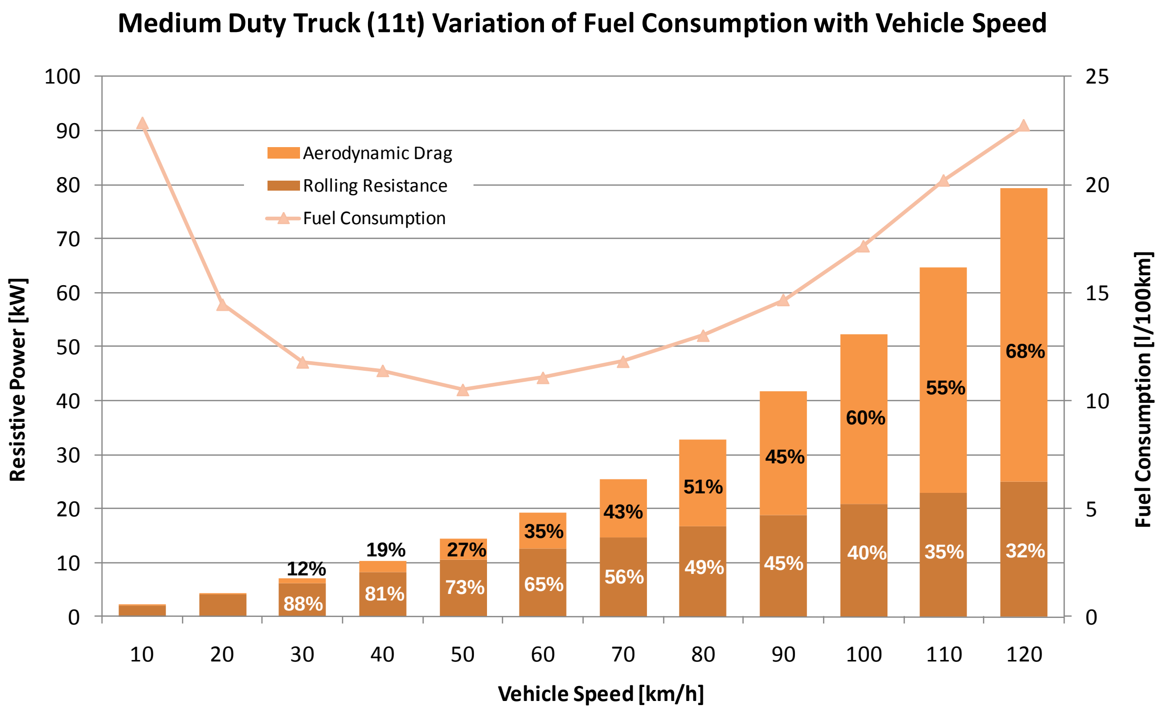
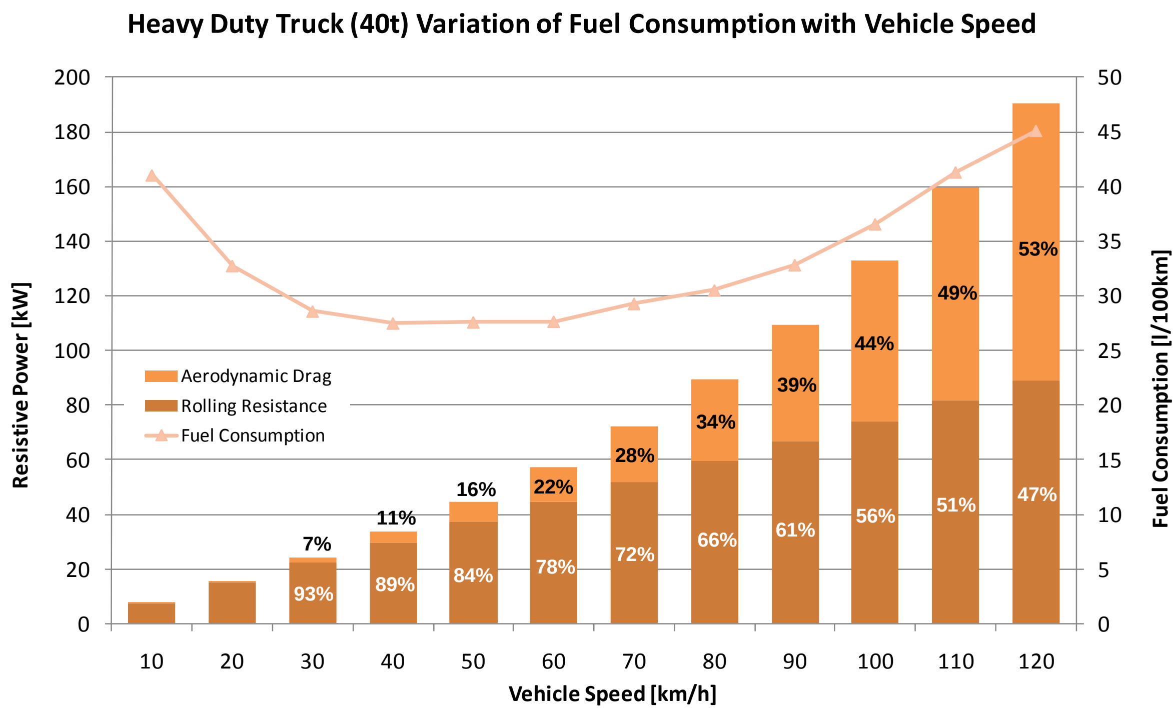


Figure 3–4: Variation in Fuel Consumption with Vehicle Speed for Heavy Duty Truck (40t)



Fuel consumption for heavy duty trucks is lowest at circa 50km/h and increases exponentially with increases in vehicle speed. The variation in fuel consumption within this speed range is quite considerable. Compared to 70km/h, fuel consumption increases by 44% at 80km/h, 12% at 90km/h and 25% at 100km/h. Reducing the maximum vehicle speed of long haul heavy duty trucks has the potential to save fuel and reduce CO_2 emissions, the extent of which is dependent on the driveline ratios chosen and the routes over which vehicles are operated, but could be in the region of 5%.

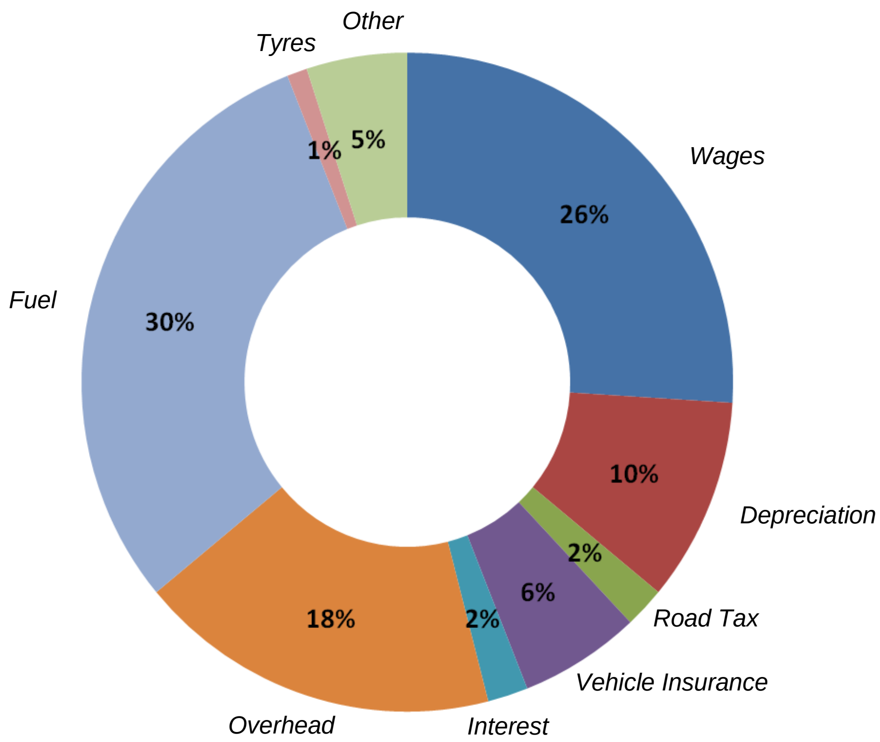
Maximum speed limits for heavy duty trucks in Europe vary from 70km/h to 100km/h for use on motorways, with maximum speed limited to 80km/h in many countries. However, EU Directives (e.g. covering speed limiters) now effectively reduce heavy duty truck speeds to 90km/h within Europe for all but a very small number of exemption cases.

It has to be noted that any reduction to the speed limit applicable to heavy duty trucks could have wider implications for all traffic journey times on Motorways and primary truck routes. In many cases within the EU these are just 2 lanes in each direction and slower heavy duty traffic will have a direct impact on road speeds.

A reduction in fuel consumption of commercial vehicles is attractive from both an environmental perspective and economical perspective of the vehicle operator. Figure 3–5 provides a breakdown of the relative costs to an operator for a 40t heavy duty articulated vehicle. The single largest cost is fuel at 30% of operating costs. This is closely followed by wages at 26%. These two are the largest costs for the majority of operators Europe-wide.

Given the large contribution of fuel to the overall operating costs any potential reduction is of interest to an operator. For example if an operator was able to save 5% fuel in vehicle operation this would account to an overall reduction of 1.5% in operating costs, which given that heavy duty vehicles can travel 100,00km per year arises in significant amounts.

Figure 3–5: Total Operating Costs (TOC) – 40t Tractor – Semitrailer Combination



Source: Iveco, reproduced from ACEA (2009)

While reducing maximum vehicle speed can have significant benefits in terms of fuel consumption reduction and also in minimising operators cost, consideration must also be given to the impact that lower vehicle speeds would have on logistic operations. The reduction in maximum permissible vehicle speed by 10km/h would have the greatest impact on long haul operations where vehicles spend the majority of time at maximum speeds. This could result in increased journey times, causing biggest problems for journeys which may then require further mandatory driver rest periods. While work undertaken by AEA in Safe and Fuel Efficient Driving (SAFED) with the UK HGV sector has demonstrated that there are no significant time penalties associated with erratic increases in vehicle speed, this does not assess the impact of a significant reduction in overall vehicle speed which a reduction of 10km/h of maximum vehicle speed would result in. The true extent to the impact of a reduction in maximum speed would require a full investigation across a range of fleet operators.

The case for the introduction of fuel efficient driving is however clear. Implementation of schemes such as SAFED have resulted in initial reductions in fuel consumption in the order of 10%, however there is little data on how this changes with time and the long term benefit of such initiatives. Case studies into SAFED have shown that there is no more than + or - 1% to the norm of journey time for more fuel efficient driving.

As stated, reduction of maximum speed limits will have most effect on EU operators that provide long distance freight services on motorways and primary trunk routes. Those providing urban services and/or short journeys are least likely to be effected. Routing and scheduling of heavy duty lorries is a complex activity that has to respond to a number of imperatives which include legal compliance (such as the European Working Time Directive and EU Drivers Hours) and commercial imperatives (such as the maximum utilisation of vehicles, choice of distribution site locations and investment in fleet sizes).

Supply chain management planning includes journey time factoring between distribution nodes as part of the physical delivery parameters within any distribution network configuration. However, this is just part of the vehicle utilisation process which includes turnaround time between nodes and driver availability within the confines of the law. The location of Distribution Centres' is made strategically to include optimisation of vehicle usage that will be influenced by many factors including vehicle utilisation patterns which are in turn influenced by speed limits. Less mileage capability from individual vehicles resultant from reduced speed limits, could result in more vehicles required to fulfil supply chain commitments.

Any European reduction in speed limits for heavy duty trucks would affect many aspects of physical supply chain operations and would need industry attestation as to it's viability as a fuel saving measure balanced against potential increase in vehicle assets.

Finally ACEA have also commented that any measure that have a negative effect on the efficiency of the operation is likely to be compensated by countermeasures. Reduced capacity due to slower speed may be addressed by increasing the number of vehicles used. ACEA cite experiences from USA that also indicate that reduced speed increased the request for higher engine power to maintain high average speed. These countermeasures increase fuel used and thereby offset the expected CO_2 reduction. As a result of reducing speed the cost of road transport may also increase[19].

[19] A study on this effect of lower speed of HDVs in Flandern has been performed by T&M Leuven and is available at: http://www.tmleuven.be/project/80km/home.htm

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4 Fuel Use and GHG Emissions

Objectives:

- *To provide an assessment of the current fuel usage, and hence CO_2 emissions, from HDVs in EU27 member states (MS), disaggregating by sectors. Also to quantify how new HDV and likely future developments in HDV technology will impact on fuel consumption and CO_2 emissions.*

Outputs:

- *A matrix indicating the current fuel use and CO_2 emissions for the EU27 member states (MS), disaggregating by sector, and an assessment as to the impact of new HDVs and likely future developments in HDV technology on these.*

Task Lead: AEA

4.1 Overview

This section reports on the work carried out under Task 2 of the project, as well as related future scenario analyses carried out under Sub-tasks 3.5 and 3.6. The chapter is subdivided into four further main sub-sections:

- ***Sub-section 4.2 - the fuel use and GHG emitted by the existing EU fleet:*** This section is split into two parts. First, a high level assessment initially made of the contribution of HDVs to total GHG emissions in the EU. Second, a more detailed estimate is made of how these emissions are disaggregated into different classes of vehicles and different mission types using the information reported in Section 2 of this report.
- ***Sub-section 4.3 - an assessment of the fuel consumption and GHG emissions for new HDVs:*** This section provides a brief assessment of the performance of new HDVs.
- ***Sub-section 4.4 – a baseline future development of fuel use and GHG emissions:*** In this section an estimate of the likely future development of fuel use and CO_2 emissions has been developed, both for the existing fleet and for new vehicles. This has been disaggregated in a similar way to the assessment of the current fleet from sub-section 4.2.
- ***Sub-section 4.5 - a scenario assessment of possible future reduction in total EU HDV fuel consumption and GHG emissions:*** This section provides an assessment of possible future reduction in total EU fuel consumption and greenhouse gas emissions from HDV, given new and emerging technologies and associated costs and benefit.

4.2 Fuel use and GHG emitted by the existing EU fleet

Objectives:

The purpose of this sub-task (2.1) was to:

"Quantify the amount of fuel used and CO_2 emitted in the EU by the existing vehicle fleet in different types of application."

Summary of Main Findings

⇒ Heavy duty vehicles are estimated to account for around 26% of all CO_2 emissions from road transport in the EU. HDVs consume ~3200 PJ of (predominantly diesel) fuel and generate direct emissions of ~240 Mt CO_2. Of this, over 85% is due to trucks, with the remainder due to buses and coaches.

⇒ Building on the bottom-up methodology based on the FLEETS database, estimates for fuel consumption and emissions from European HDVs were developed for 2010 based on eight mission categories (Service/Delivery (≤7.5t), Urban Delivery/Collection, Municipal Utility, Regional Delivery/Collection, Long Haul, Construction, Buses, and Coaches);

⇒ The main elements highlighted in the analysis of the results include:

- The importance of long-haul and regional distribution activity in total energy consumption and emissions (around 37%, 14% respectively) due to higher activity levels and larger vehicles;
- The high fuel consumption of utility vehicles increases their energy consumption and emissions (5.2% total for HDVs) in comparison to relatively low vkm (4.0 % of total);
- The energy consumption and CO_2 emissions from service/delivery and urban delivery vehicles are relatively low versus their numbers (due to lower annual km and smaller vehicles), at 12.8% and 3.7% of all HDV emissions.
- Relative to coaches, bus energy consumption emissions account for a larger proportion (58% bus and coach emissions, 8.7% total HDV emissions) in comparison to their vehicle numbers and activity. Coaches are estimated to account for around 6.3% of all HDV emissions in 2010.

In this section, high-level estimates of fuel consumption and GHG emissions have been developed to calculate the relative contribution of HDVs to total EU GHG emissions using two methodological approaches (detailed in subsection 4.2.1):

A. Using pollutant emissions reported to CLRTAP[20];

B. Using a vehicle fleet and activity model (i.e. based on the FLEETS database[21] on the fleet composition, characteristics and activity for Member States).

This approach has been carried out as a precursor/methodological validation to more detailed calculations disaggregating HDVs further into vehicle type, mission class and body type (detailed in subsection 4.2.2).

[20] The UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP)

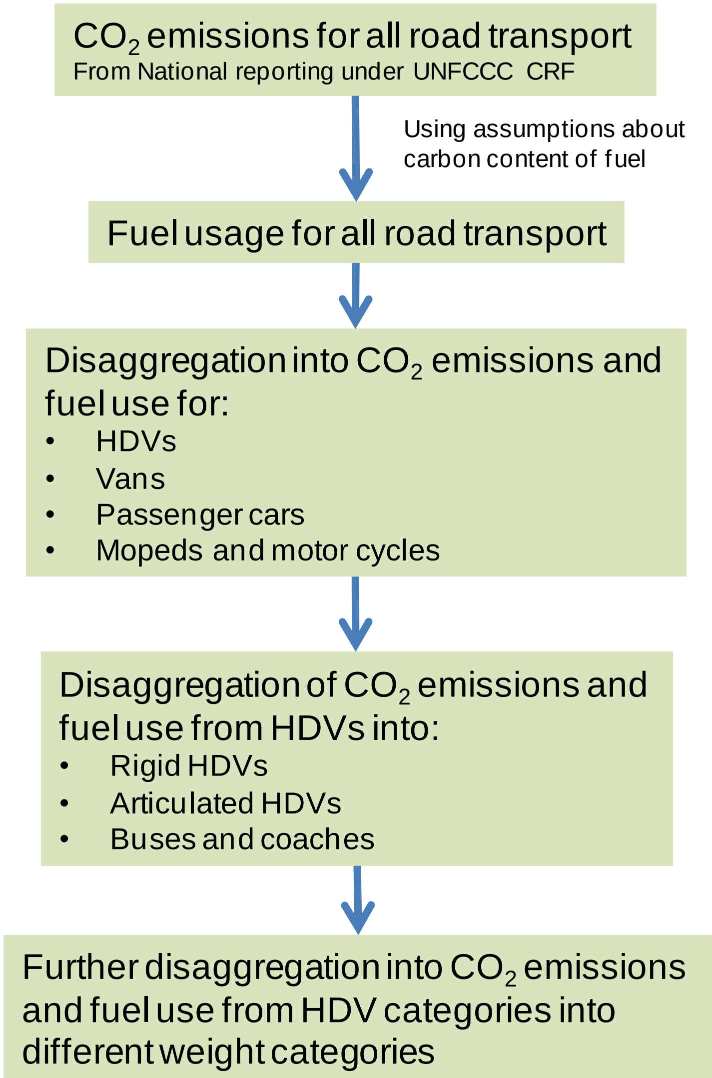
[21] The FLEETS database is the *"European Database of Vehicle Stock for the Calculation and Forecast of Pollutant and Greenhouse Gases Emissions with TREMOVE and COPERT"*, available from the website COPERT website at: http://lat.eng.auth.gr/copert/

4.2.1 Estimating total fuel consumption and GHG emissions from EU HDVs

A pre-requisite to the generation of proposals in the area of reducing CO_2 emissions from HDVs (both freight and passenger carrying) is an understanding of the current fuel usage and CO_2 emissions from these vehicles – hence the need for this study to consider these issues. Ideally what is required is a validated inventory of CO_2 emissions from all HDVs disaggregated by different types of application (road freight, construction, vocational and passenger transport) for a recent year to provide a starting, baseline figure.

Figure 4–1 gives a schematic overview of the methodology used to develop an initial top-level estimate of the fuel used, and CO_2 emitted, by the existing EU-27 heavy duty vehicle fleet. The method is based on the road transport CO_2 emissions reported to the UNFCCC under international agreements. From the CO_2 emissions, knowing the carbon content of fuel, the fuel consumption data for road transport can be calculated.

Figure 4–1: Overview of methodology used to find disaggregated fuel use and CO_2 emissions for the existing EU-27 heavy duty vehicle fleet.



The road transport totals are then disaggregated in stages to give:

- Disaggregation into heavy duty, light commercial vehicles, passenger cars and two wheeled vehicles,

- Disaggregation of the heavy duty vehicles into the broad categories of rigid and articulated trucks, buses and coaches,
- Further disaggregation of the four broad categories of heavy duty vehicles into different weight classes.

4.2.1.1 Road transport CO_2 emissions and fuel use data for the EU-27 member states

The 27 member states of the EU are required to submit annual greenhouse gas (GHG) inventories to the EEA, prepared in accordance with IPCC[22] GHG Inventory Guidelines and the Good Practice Guide. The advantage of using these data as the foundation for this study is that the calculation methodology is internationally agreed leading to relatively consistent, directly comparable data, across all Member States. The multilateral approach also reduces the likelihood of double counting and minimises errors.

The key disadvantage of this dataset is that CO_2 emissions, and consequently fuel use data, are aggregated at the "all road transport" level.

The most recent data available from the European Environment Agency greenhouse gas data viewer[23] were for 2007. Figure 4–2 shows the 2007 road transport CO_2 emissions for the EU-27 member states, in alphabetical order of their country codes.

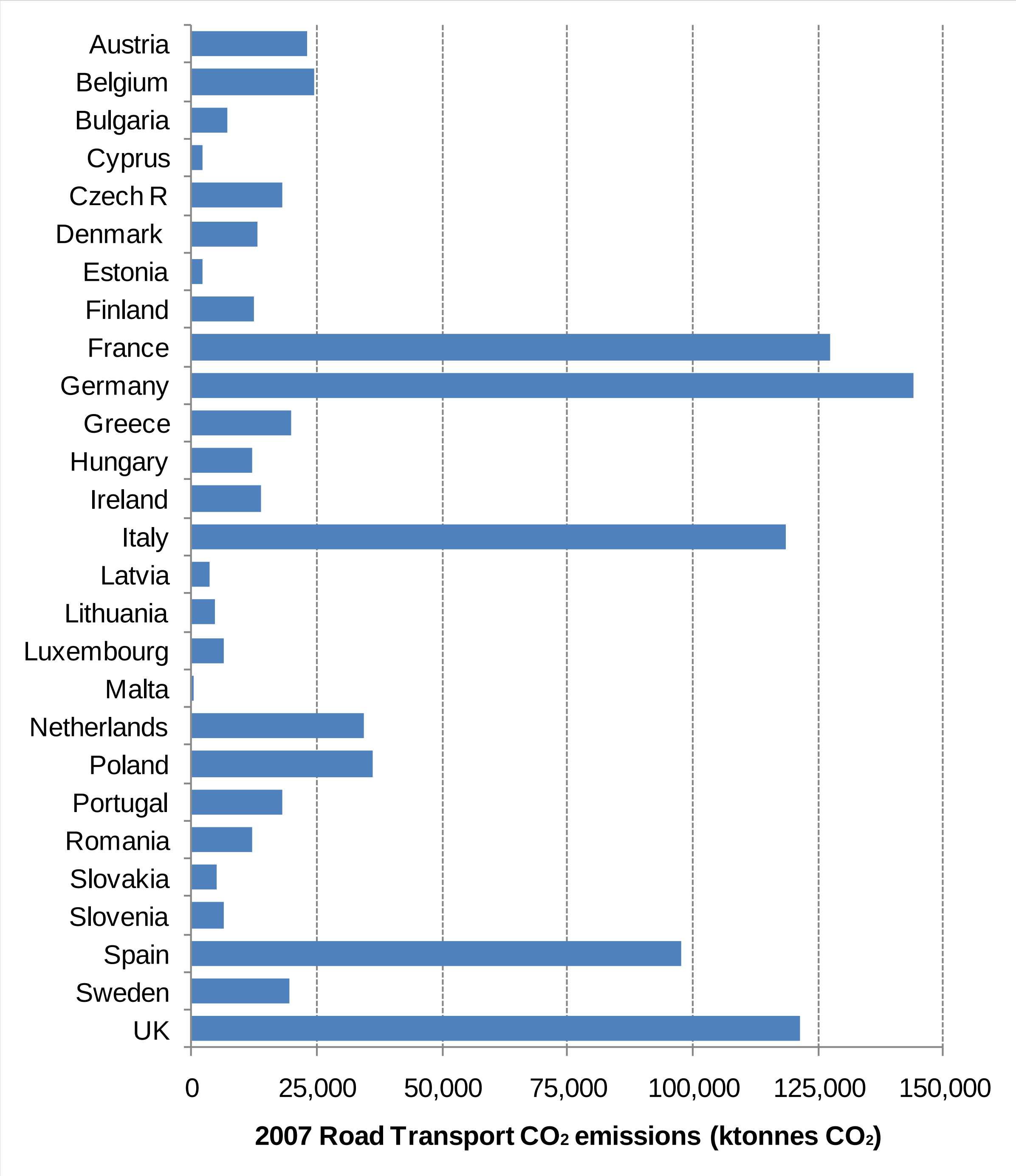
An immediate impression from Figure 4–2 is that road transport CO_2 emissions in five member states are much larger than for the other member states. The five countries with the greatest road transport emissions (Germany, France, UK, Italy and Spain) were each responsible for more than 95,000 ktonnes of road transport CO_2 emissions in 2007. Cumulatively, these five countries contribute around 67% of EU-27 total road transport CO_2 emissions. Below these five countries, the Netherlands and Poland are the next most significant emitters; their road transport CO_2 emissions are around 35,000 ktonnes each. For the remaining twenty member states emissions are less than 25,000 ktonnes each. The ten countries with the lowest road transport CO_2 emissions contribute around 5% of the EU-27 total, i.e. analysis of 17 of the 27 member states covers 95% of road transport CO_2 emissions.

Table 4.1 contains this data, alongside data for total CO_2 emissions, and the 2005 road transport CO_2 emissions data (the 2005 data is also used in this report). The data are sorted in decreasing order of the 2007 road transport CO_2 emissions.

The total for the EU-27 member states is given in the row at the bottom of the table. The fifth column gives the percentage of all CO_2 emissions that are due to road transport. For the EU-27 as a whole, the average is 21.6%. However, this percentage varies markedly between different Member States. Of the five large road transport CO_2 emitters, France has 32.1% of its total CO_2 generated by road transport. This is principally a consequence of a low carbon electricity supply industry, which is dominated by nuclear power generation. Similarly, Sweden with its low carbon electricity supply (with most power being generated by hydro-electric generators or nuclear plant) has a high road transport proportion of its overall CO_2 emissions.

[22] Intergovernmental Panel on Climate Change
[23] The EEA greenhouse gas data viewer is available from: http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=475

Figure 4–2: Road transport CO_2 emissions for 2007 from EU-27 member states



Source: European Environment Agency (2010).

Table 4.1: Road transport CO_2 emissions and fuel consumption, in the context of total CO_2 emissions, from EU-27 member states

Country code	Country	2007 Road Transport CO_2 emissions (kt)	Total 2007 CO_2 emissions (kt)	RT as % of whole	2007 Road transport fuel consumption (kt)	2005 RT CO_2 emissions
DE	Germany	144,114	841,152	17.1%	45,755	151,123.1
FR	France	127,356	397,076	32.1%	40,435	129,482.8
GB	UK	121,242	543,220	22.3%	38,494	119,616.2
IT	Italy	118,721	475,302	25.0%	37,693	117,034.8
ES	Spain	97,848	366,366	26.7%	31,066	92,665.7
PL	Poland	36,275	328,275	11.1%	11,517	34,172.0
NL	Netherlands	34,458	172,657	20.0%	10,940	33,902.0
BE	Belgium	24,318	114,545	21.2%	7,721	24,928.2
AT	Austria	23,167	74,177	31.2%	7,355	24,145.3
GR	Greece	19,785	113,566	17.4%	6,282	18,308.8
SE	Sweden	19,369	51,621	37.5%	6,150	19,304.6
PT	Portugal	18,165	62,793	28.9%	5,767	18,542.1
CZ	Czech R	18,039	129,950	13.9%	5,727	16,862.3
IE	Ireland	13,755	47,499	29.0%	4,367	12,350.9
DK	Denmark	13,198	53,228	24.8%	4,190	12,213.5
FI	Finland	12,320	66,103	18.6%	3,912	11,786.6
HU	Hungary	12,233	57,752	21.2%	3,884	11,602.5
RO	Romania	12,028	110,883	10.8%	3,819	11,490.0
BG	Bulgaria	7,298	58,890	12.4%	2,317	7,177.6
LU	Luxembourg	6,569	11,844	55.5%	2,086	7,006.4
SK	Slovenia	6,375	38,141	16.7%	2,024	6,095.0
SI	Slovakia	5,148	16,989	30.3%	1,635	4,347.6
LT	Lithuania	4,819	15,915	30.3%	1,530	3,861.0
LV	Latvia	3,495	8,608	40.6%	1,110	2,732.8
EE	Estonia	2,225	19,093	11.7%	706	1,935.2
CY	Cyprus	2,194	8,328	26.3%	696	2,049.3
MT	Malta	506	2,685	18.9%	161	505.1
EU27		**905,020**	**4,186,657**	**21.6%**	**287,338**	**895,241**

Source: European Environment Agency (2010).

4.2.1.2 Disaggregation of road transport CO_2 emissions and fuel use by vehicle type using pollutant emissions reported to CLRTAP

The reporting of greenhouse gas emissions under UNFCCC common reporting format (CRF) combines all road transport emissions into a single total. These official totals contain no disaggregation, not even according to petrol and diesel fuels. In contrast, the reporting of air pollutants, e.g. oxides of nitrogen, hydrocarbons and sulphur dioxide to the Committee on Long Range Transport of Air Pollutants (CLRTAP) are according to the "Nomenclature for

Reporting" (NFR) codes[24]. These provide greater detail than for CO_2, with road transport emissions being disaggregated into:

- Road Transport, Passenger cars
- Road Transport, Light duty vehicles
- Road Transport, Heavy duty vehicles
- Road Transport, Mopeds & Motorcycles.

The quantity of many pollutants emitted by vehicles (for example, NO_X, CO, HCs, PM[25], etc) are engine technology dependent. Consequently the derivation of emissions of these species is relatively complex to calculate. In contrast, the emissions of SO_2 are not engine technology dependent, but are solely fuel derived. Consequently, they can be used as a marker as to how much fuel is used.

However, there is a complication in that the sulphur content of diesel fuel and petrol fuel probably differs, and there is no prior way of knowing these values with reasonable certainty. Table 4.2 provides a breakdown of which fuels are used in the different types of road vehicles:

Table 4.2: Summary of which types of vehicles use which fuels

	Petrol	Diesel
Passenger cars	Yes (~55%*)	Yes (~45%*)
Light duty vehicles (vans)	Little (~9%*)	Majority (~91%*)
Heavy duty vehicles	Virtually none	Yes
Mopeds & Motorcycles	Yes	No

Notes: * EU27 average, based on information from TREMOVE v3.3.1

As a high level estimation it is assumed that the sulphur content of each Member States' petrol and diesel fuel is the same. Based on this assumption, the disaggregation of road transport CO_2 emissions into the four different types of vehicle is as shown in Table 4.3.

Table 4.3: Disaggregation of total road transport fuel use and CO_2 emissions into four broad vehicle groups using CLRTAP SO_2 emissions methodology

	Percentage of RT inventory			
Country	Passenger Cars	2-wheelers	Vans	HDV
Austria	48.50%	0.00%	8.26%	43.24%
Belgium	57.60%	0.33%	5.50%	36.58%
Bulgaria	100.00%	0.00%	0.00%	0.00%
Cyprus	54.17%	0.00%	28.83%	17.00%
Czech Republic	49.35%	0.15%	10.58%	39.93%
Germany	69.21%	0.99%	6.39%	23.42%
Denmark	51.84%	0.79%	21.14%	26.23%
Estonia	33.33%	0.00%	16.67%	50.00%
Spain	50.83%	0.19%	14.71%	34.27%
Finland	54.70%	0.68%	10.85%	33.77%

[24] The EEA Air pollutant emissions data viewer (CLRTAP Convention) is available from: http://dataservice.eea.europa.eu/PivotApp/pivot.aspx?pivotid=478
[25] NOx = oxides of nitrogen; CO = carbon monoxide; HC = hydrocarbon; PM = particulate matter; SO_2 = sulphur dioxide.

	Percentage of RT inventory			
Country	**Passenger Cars**	**2-wheelers**	**Vans**	**HDV**
France	54.65%	0.76%	17.22%	27.37%
Greece	34.75%	5.18%	14.20%	45.86%
Hungary	46.53%	0.00%	0.00%	53.47%
Ireland	51.58%	0.00%	34.38%	14.04%
Italy	56.59%	2.05%	17.97%	23.39%
Lithuania	22.96%	0.01%	22.26%	54.77%
Luxembourg	63.57%	0.55%	12.85%	23.03%
Latvia	52.29%	0.00%	5.50%	42.20%
Malta	36.32%	0.29%	1.16%	62.23%
Netherlands	81.49%	2.22%	6.83%	9.46%
Poland	45.21%	0.24%	14.24%	40.31%
Portugal	50.44%	0.86%	18.64%	30.06%
Romania	34.74%	0.15%	18.80%	46.31%
Sweden	77.77%	0.95%	6.70%	14.58%
Slovenia	59.35%	0.00%	2.11%	38.54%
Slovakia	35.78%	0.00%	7.84%	56.37%
United Kingdom	80.41%	0.51%	6.70%	12.39%
Average (weighted by CO_2 emissions)	**60.32%**	**0.91%**	**12.15%**	**26.62%**
Total Mt CO_2	**545.88**	**8.20**	**109.99**	**240.95**
Total PJ				**3,248**

Notes: Calculated assuming similar sulphur content of petrol and diesel

The headline approximation from this analysis is that **26.6%** (241 Mt CO_2) of EU road transport CO_2 emissions arise from heavy duty vehicles (HDVs). However, if the sulphur content of petrol and diesel differs significantly, then the picture will change. For example if the sulphur content of the diesel is higher than that of petrol, then this methodology will underestimate the CO_2 emissions from vehicles that use petrol – i.e. passenger cars, mopeds and motor cycles (which mostly or entirely use petrol, see Table 4.2) - and overestimate the CO_2 emissions for LDVs and HDVs (where the vast majority of the fuel used is diesel). This initial estimate has therefore been refined using more detailed information by Member State on:

a) Average sulphur content of petrol and diesel from fuel quality reporting;

b) Split of petrol and diesel use for vans and cars based on TREMOVE v3.3.1.

Using this additional information (presented in Table 4.4) gives a very similar total result for the EU27 total, but with some variations for different countries. The refined approximation from this analysis is the figure of around **26.4%** (and 239 Mt CO_2) of EU road transport CO_2 emissions arising from heavy duty vehicles (HDVs).

Table 4.4: Disaggregation of total road transport fuel use and CO_2 emissions into four broad vehicle groups using CLRTAP SO_2 emissions methodology refined to adjust for different petrol and diesel sulphur content (by member state)

	% of RT inventory			
Country	**Passenger Cars**	**2-wheelers**	**Vans**	**HDV**
Austria	51.44%	0.00%	7.98%	40.58%
Belgium	58.87%	0.41%	5.40%	35.32%
Bulgaria	100.00%	0.00%	0.00%	0.00%
Cyprus	59.47%	0.00%	25.75%	14.77%
Czech Republic	25.54%	0.05%	12.06%	62.35%
Germany	71.91%	1.13%	5.86%	21.10%
Denmark	69.20%	1.51%	13.47%	15.82%
Estonia	51.46%	0.00%	12.81%	35.73%
Spain	52.95%	0.25%	14.29%	32.51%
Finland	51.89%	0.61%	11.43%	36.08%
France	57.38%	1.06%	16.30%	25.26%
Greece	39.08%	6.03%	13.19%	41.69%
Hungary	49.27%	0.00%	0.00%	50.73%
Ireland	56.15%	0.00%	31.32%	12.53%
Italy	62.93%	3.68%	14.92%	18.47%
Lithuania	23.64%	0.01%	22.18%	54.18%
Luxembourg	65.42%	0.83%	12.36%	21.39%
Latvia	57.72%	0.00%	5.02%	37.26%
Malta	40.51%	0.38%	1.11%	58.00%
Netherlands	68.50%	1.43%	11.39%	18.69%
Poland	51.83%	0.34%	12.87%	34.96%
Portugal	55.65%	1.19%	16.86%	26.30%
Romania	40.65%	0.20%	17.49%	41.66%
Sweden	70.09%	0.79%	8.79%	20.33%
Slovenia	61.95%	0.00%	2.00%	36.05%
Slovakia	41.61%	0.00%	7.30%	51.08%
United Kingdom	68.31%	0.35%	10.13%	21.21%
Average (weighted by CO_2 emissions)	**60.57%**	**1.18%**	**11.89%**	**26.37%**
Total Mt CO_2	**548.14**	**10.65**	**107.58**	**238.65**
Total PJ				**3,217**

Notes: Calculated using data on different average sulphur content of petrol and diesel and split of petrol and diesel use for vans and cars by country.

4.2.1.3 Disaggregation of road transport CO_2 emissions and fuel use by vehicle type using a vehicle fleet and activity model

The preceding inventory methodologies used are known as Top Down, or Tier 1 type inventories[26], where the inventory totals (CO_2 or SO_2 in these cases) are derived from total fuel use (or sales). More detailed inventories are compiled from the bottom up, such as the Tier 3 methodology from the EMEP EEA Emission Inventory Guidebook 2009, which can be expressed as:

$$\text{RT total} = \sum_{\text{Vehicle types}} \sum_{\text{Sizes}} \sum_{\text{Technologies}} \text{No of vehicles} \times \text{Average distance} \times \text{Emission Factor}$$

Where:

RT total	is the Road Transport total emissions inventory
$\sum_{\text{Vehicle types}}$	is a summation over the different types of vehicles (e.g. diesel fuelled passenger cars, petrol fuelled passenger cars, vans, heavy duty vehicles and mopeds and motor cycles)
$\sum_{\text{Sizes}}$	is a summation over the different vehicle/engine sizes for each type of vehicle, e.g. <1.4 litres, 1.4 to 2.0 litres and >2.0 litres engine capacity for the petrol fuelled cars,
$\sum_{\text{Technologies}}$	is a summation over the different technologies, e.g. pre Euro 1, Euro 1, Euro 2 etc passenger cars
No of vehicles	is the number of vehicles in the nation's fleet of a specific vehicle type, size and technology,
Average distance	is the average number of kilometres travelled by each vehicle, and
Emission Factor	is the emission factor (EF), in units of g CO_2 /km.

In practice, the emission factor is a function of speed, and the average distance travelled is split into the distances travelled on urban, rural and motorways. The average speed for each type and size of vehicle travelling along each of these types of road is estimated, and so the Emission Factor component becomes a distance weighted average of three figures for the three types of roads, i.e.:

Emission Factor (total) = EF (urban) x urban vkm % + EF (rural) x rural vkm % + EF (motorway) x motorway vkm %

Where:

EF (urban), EF (rural) and EF (motorway) are calculated based on the average speed on these roads for a particular country.

The data for all the factors in the equation above, except the emission factors, can be found within the FLEETS report, *"European Database of Vehicle Stock for the Calculation and Forecast of Pollutant and Greenhouse Gases Emissions with TREMOVE and COPERT"*[27].

The speed related emission factors for CO_2 used within the COPERT 4 model are described in the EMEP/EEA air pollutant emissions inventory guidebook - 2009[28].

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[26] See page 19 of 128 in the EMEP CORINAIR Emissions inventory guidebook, found from http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-road-transport.pdf

[27] The FLEETS database is available from the website COPERT website (http://lat.eng.auth.gr/copert/), but access does require users to be registered.

[28] Specifically in Part B: Sectoral guidance chapters, 1.A.3.b Road Transport, and its appendix on HDV, available from http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

Using the data and methodology described above the Road Transport CO_2 inventory was calculated using a bottom up approach. The total can be compared with that submitted to the UNFCCC. More specifically, the bottom up inventory for the four broad vehicle categories (passenger cars, vans, heavy duty vehicles and two-wheeled vehicles) can be expressed as a percentage of the road transport total inventory, and used to disaggregate the HDV component from the whole road transport inventory. This disaggregated total can be compared with that obtained from the SO_2 inventory method, described earlier.

In addition, the HDV CO_2 emissions, and associated fuel usage, disaggregated from the UNFCCC road transport total, can then be further disaggregated into further categories, for example, on the basis of the bottom up inventory:

- Rigid trucks;
- Articulated trucks;
- Buses; and
- Coaches.

Whilst the above methodology appears straightforward, there were some challenges and certain changes needed to be made to improve the accuracy of the calculations. For example:

- The speed given for UK HGV motorway driving (110 km/h) is higher than the 90 km/h speed limiters fitted to all HDVs. Therefore this speed was adjusted to 90 km/h.
- Not all the required data were present for all countries. For Sweden and Finland there was no breakdown of the total distance travelled into that travelled on urban, rural or highway roads. Discussions with Swedish colleagues led to the adoption of the profile for Norway as the appropriate profile.

These two examples are intended to illustrate how the bottom up inventories did not simply use the FLEETS database, but did include a critical assessment of the data used, and when appropriate an amendment was made. This also means that the data reported here will differ, albeit only slightly, from simply running the COPERT 4 model using the existing FLEETS database as a key input. Table 4.5 provides the disaggregated inventories for the EU27 member states.

Table 4.5: Disaggregation of total road transport fuel use and CO_2 emissions into five broad vehicle groups using FLEETS database and bottom up inventory methodology

Country	Passenger Cars	Two wheelers	Light Duty Vehicles	Heavy Duty Trucks	Buses & Coaches	All HDVs
Austria	64.56%	0.97%	8.55%	10.33%	2.63%	12.96%
Belgium	65.68%	0.56%	5.88%	23.53%	4.36%	27.89%
Bulgaria	39.72%	1.57%	7.60%	31.04%	20.08%	51.12%
Cyprus	55.15%	0.80%	26.88%	8.80%	8.38%	17.18%
Czech Republic	58.19%	2.59%	6.22%	26.46%	6.54%	33.00%
Germany	59.68%	0.93%	6.08%	30.89%	2.42%	33.31%
Denmark	51.09%	0.63%	17.19%	23.86%	7.23%	31.09%
Estonia	57.39%	0.29%	7.07%	35.26%	0.00%	35.26%
Spain	52.98%	0.51%	12.10%	29.95%	4.46%	34.41%
Finland	64.37%	0.76%	7.53%	23.66%	3.68%	27.34%
France	54.31%	0.70%	16.22%	26.36%	2.42%	28.78%

Country	Passenger Cars	Two wheelers	Light Duty Vehicles	Heavy Duty Trucks	Buses & Coaches	All HDVs
Greece	42.39%	4.98%	20.53%	28.25%	3.84%	32.09%
Hungary	55.36%	0.81%	11.57%	24.66%	7.60%	32.26%
Ireland	49.11%	0.52%	26.11%	18.56%	5.70%	24.25%
Italy	58.05%	2.88%	10.40%	24.70%	3.97%	28.67%
Lithuania	70.68%	0.25%	2.41%	22.27%	4.39%	26.66%
Luxembourg	66.44%	0.80%	5.85%	21.90%	5.02%	26.91%
Latvia	47.97%	0.39%	4.44%	34.21%	12.99%	47.21%
Malta	37.72%	0.47%	1.20%	57.01%	3.60%	60.61%
Netherlands	61.32%	1.28%	17.52%	18.60%	1.29%	19.88%
Poland	53.60%	0.80%	11.99%	25.50%	8.10%	33.60%
Portugal	42.94%	0.66%	32.31%	20.16%	3.93%	24.09%
Romania	44.90%	0.50%	8.16%	33.40%	13.04%	46.44%
Sweden	76.81%	0.56%	7.51%	11.02%	4.10%	15.12%
Slovenia	49.74%	0.53%	9.55%	32.93%	7.26%	40.18%
Slovakia	73.37%	0.26%	4.72%	18.86%	2.78%	21.64%
United Kingdom	64.38%	0.53%	13.18%	18.07%	3.84%	21.91%
EU27 Average	**57.36%**	**1.14%**	**11.78%**	**25.25%**	**4.19%**	**29.45%**
Total Mt CO_2	**471.25**	**9.33**	**96.76**	**207.47**	**34.45**	**241.92**
Total PJ				**2,797**	**464**	**3,261**

These data give the total for HDVs (trucks plus buses and coaches) as **29.45%** of the road transport emissions. This proportion is slightly higher than the proportion estimated using the alternative SO_2 inventory methodology (this gave a figure of 26.5%). However, the total figure for estimated CO_2 emissions from HDVs is very close at an aggregate EU level, although there are significant differences by Member State. Some variation for individual countries is to be expected due to the different bases of the two methodologies; the CLRTAP reporting is for emissions (or fuel consumption) within a country (typically normalised to fuel sales in national inventories). However, the bottom-up estimate using FLEETS will include activity of vehicles both in domestic transport activity, but also international transport activity (i.e. in other countries both within the EU and in neighbouring non-EU countries).

Overall, although the bottom-up methodology appears to underestimate fuel consumption/CO_2 emissions from other modes (particularly for passenger cars, by some 14%), it appears to serve as a good approximation for HDVs in the EU.

4.2.2 Disaggregating HDV GHG emissions according to different categories

The vehicle fleet and activity model calculations discussed in the previous sub-section (4.2.1.3) were used as a starting point for the further estimated disaggregation of HDV activity and emissions.

The first step was to take the FLEETS stock data, activity data and energy consumption figures for the year 2005 and forward project them to 2010. This was achieved by the development of simple vehicle stock based model calculations and using a combination of the historical datasets from Eurostat (to 2008/9) and data from the most recent complete version of the TREMOVE model available – version 3.3.1 (supplied by DG Climate Action).

In overview, the simple stock model was constructed on the following key assumptions (with data split by Member State):

- A total vehicle and trailer parc and new registration numbers based on historic data sets from 1995 to 2009, with removals calculated as the difference of these two figures.
- From 2010 onwards the total vehicle parc was forward projected based on increases in stock from TREMOVE (split into the four weight categories defined in this model). Vehicle removals are calculated based on assumed vehicle lifetimes of 11 years for trucks and 15 years for buses, coaches and trailers (e.g. number of removals in 2010 = number of new vehicles in 1999). New registrations are calculated resulting from the figures for the parc and the removals.
- Proportion of alternative fuel (diesel, natural gas, electric) new vehicles / fleet consistent with Eurostat statistics;
- Direct and lifecycle GHG emission factors for conventional fuels (diesel, natural gas) based on TREMOVE derived data. GHG emission factors for electricity based on projections from EUROLECTRIC (2009)[29];
- Vehicle efficiencies based on calculations (by vehicle gross vehicle weight (GVW) category) from the previous section for 2005 projected backwards (to 1995) and forward (to 2010) to be consistent with changes in vehicle efficiency derived from TREMOVE datasets (with trucks split by vehicles <16 t GVW and >16 t GVW).

The next step was the reallocation of HDV stock, activity and energy efficiency datasets split by GVW category (and by Member State) into the different mission categories developed and discussed in sections 2.6 and 4.5, namely:

- Service /Delivery (≤7.5t)
- Urban Delivery
- Municipal Utility
- Regional Delivery
- Long Haul
- Construction
- Buses
- Coaches

In order to carry out this reallocation for trucks, it was necessary to develop a matrix of factors to translate the datasets split by FLEETS weight categories (GVW) into the different mission categories, which are summarised in Table 4.6. For example, the table indicates that 65% of the 7.5-12t GVW rigid trucks and 10% of the 12-14t GVW rigid trucks are allocated to the urban delivery mission category. The matrix of Baseline figures presented in Table 4.6 was estimated based on:

a) A comparison with the vehicle specification and categorisation provided by ACEA, and
b) The achievement of the overall proportion of rigid and articulated trucks in different mission categories (i.e. the totals in bold) consistent with those presented previously for the EU fleet in Figure 2–52.

In order to assess the sensitivity of these assumptions, an alternative allocation matrix was also developed and is presented in Table 4.7. These alternate assumptions primarily represent a larger allocation of the heavier truck categories into the Long Haul mission class and smaller allocation of the lighter trucks to this category.

[29] EURELECTRIC (2009). Data on fossil fuel prices, electricity price and CO_2 intensity projections to 2050 provided by EURELECTRIC in December 2009 as input to the *EU Transport GHG: Routes to 2050?* project's scenario analysis (see: http://www.eutransportghg2050.eu); the data is based on modelling using the PRIMES model.

Table 4.6: Baseline assumptions matrix used to allocate truck stock by vehicle type and GVW into different mission classes

FLEETS Weight Category (GVW)	Service /Delivery (<7.5t)	Urban Delivery	Municipal Utility	Regional Delivery	Long Haul	Construction
Rigid <=7.5 t	100%	0%	0%	0%	0%	0%
Rigid 7.5 - 12 t	0%	65%	15%	20%	0%	0%
Rigid 12 - 14 t	0%	10%	15%	25%	25%	25%
Rigid 14 - 20 t	0%	0%	20%	30%	25%	25%
Rigid 20 - 26 t	0%	0%	20%	25%	25%	30%
Rigid 26 - 28 t	0%	0%	15%	20%	35%	30%
Rigid 28 - 32 t	0%	0%	0%	0%	70%	30%
Rigid >32 t	0%	0%	0%	0%	70%	30%
Total Rigid	**42.5%**	**8.7%**	**8.6%**	**12.2%**	**15.5%**	**12.5%**
Articulated 14 - 20 t	0%	0%	0%	60%	25%	15%
Articulated 20 - 28 t	0%	0%	0%	40%	40%	20%
Articulated 28 - 34 t	0%	0%	0%	35%	45%	20%
Articulated 34 - 40 t	0%	0%	0%	25%	55%	20%
Articulated 40 - 50 t	0%	0%	0%	20%	60%	20%
Articulated 50 - 60 t	0%	0%	0%	0%	100%	0%
Total Articulated	**0.0%**	**0.0%**	**0.0%**	**29.8%**	**55.0%**	**15.2%**
TOTAL Trucks	**28.1%**	**5.7%**	**5.7%**	**18.2%**	**28.9%**	**13.4%**

Source: Estimates made by AEA.

Table 4.7: Alternative assumptions matrix used to allocate truck stock by vehicle type and GVW into different mission classes

FLEETS Weight Category (GVW)	Service /Delivery (<7.5t)	Urban Delivery	Municipal Utility	Regional Delivery	Long Haul	Construction
Rigid <=7.5 t	100%	0%	0%	0%	0%	0%
Rigid 7.5 - 12 t	0%	67%	13%	20%	0%	0%
Rigid 12 - 14 t	0%	6%	19%	43%	0%	32%
Rigid 14 - 20 t	0%	0%	20%	30%	20%	30%
Rigid 20 - 26 t	0%	0%	20%	15%	40%	25%
Rigid 26 - 28 t	0%	0%	15%	10%	50%	25%
Rigid 28 - 32 t	0%	0%	0%	0%	80%	20%
Rigid >32 t	0%	0%	0%	0%	80%	20%
Total Rigid	**42.5%**	**8.6%**	**8.7%**	**12.1%**	**15.9%**	**12.2%**
Articulated 14 - 20 t	0%	0%	0%	84%	0%	16%
Articulated 20 - 28 t	0%	0%	0%	60%	20%	20%
Articulated 28 - 34 t	0%	0%	0%	25%	55%	20%
Articulated 34 - 40 t	0%	0%	0%	10%	70%	20%
Articulated 40 - 50 t	0%	0%	0%	0%	85%	15%
Articulated 50 - 60 t	0%	0%	0%	0%	100%	0%
Total Articulated	**0.0%**	**0.0%**	**0.0%**	**30.1%**	**55.1%**	**14.8%**
TOTAL Trucks	**28.1%**	**5.7%**	**5.7%**	**18.2%**	**29.2%**	**13.1%**

Source: Estimates made by AEA.

To account for different mission duty cycles, it was also necessary to make a number of other adjustments to the baseline average annual activity (in vkm) and average fuel consumption figures. The baseline average annual vehicle km and fuel consumption by different mission categories were derived from the individual figures for different vehicle GVW weight classes, weighted according to the total vehicle numbers derived using Table 4.6. These were then adjusted, using the "Baseline" assumptions summarised in Table 4.8, to account for particular activity and duty cycle characteristics by:

1) Reallocating activity from mission categories with lower annual km activity vs the average by vehicle weight to the long-haul category (which has higher than average km by vehicle weight).
2) Uplifting the basic fuel consumption figures, which were based on average speeds on different road types (see section 4.2.1.3) to account for higher fuel consumption in:
    a) Primarily urban conditions with a high proportion of stop-start driving, i.e. for service/delivery (<7.5t), urban delivery and municipal utility truck categories, as well as for urban buses.
    b) Operating refrigeration equipment in insulated/temperature-controlled trucks.

An "Alternative" set of assumptions for the annual km activity and (lower) fuel consumption uplifts was also developed to help assess the sensitivity of these assumptions to the overall result. These Alternative assumptions are presented in Table 4.9.

Table 4.8: Summary of adjustments made to base activity and fuel consumption by vehicle GVW classes to account for specific mission profiles / duty cycles - Baseline assumptions

	Proportion of average vehicle km by GVW category reallocated to long haul (1)		Duty cycle % uplift to average fuel consumption by vehicle GVW (2)
	Rigid	Articulated	
Service/Delivery (≤7.5t)	N/A	N/A	40%
Urban Delivery	N/A	N/A	25%
Municipal Utility	50%	N/A	150%
Regional Delivery	0%	10%	N/A
Construction	10%	25%	N/A
All Refrigerated Trucks	N/A	N/A	20%
Buses			20%

Source: Estimates made by AEA.

Notes: These are the adaptations to the default FLEETS / bottom-up methodology dataset made in the calculations to account for differences in activity and fuel consumption of specific mission profiles.
(1) Average annual activity (in vkm) for different mission profiles were adjusted to be more in line with ACEA provided information on typical figures for particular mission profiles.
(2) Uplifts estimated based conservative comparison of information on (i) differences between figures derived for UK based on speed emission curves vs actual fuel consumption data from UK DfT statistics for trucks in similar weight categories, and for buses from the bus service operators grant (BSOG); (ii) typical fuel consumption of refuse collection vehicles of different sizes from a number of sources, including Ricardo. These estimates are therefore based on the assumption that urban usage patterns for such vehicles are broadly similar across the EU. (iii) Information on the typical additional fuel consumption of diesel auxiliary power units for refrigerated transport.

Table 4.9: Summary of adjustments made to base activity and fuel consumption by vehicle GVW classes to account for specific mission profiles / duty cycles - Alternative assumptions

	Proportion of average vehicle km by GVW category reallocated to long haul (1)		Duty cycle % uplift to average fuel consumption by vehicle GVW (2)
	Rigid	Articulated	
Service/Delivery (≤7.5t)	N/A	N/A	20%
Urban Delivery	N/A	N/A	12.5%
Municipal Utility	54%	N/A	100%
Regional Delivery	0%	17%	N/A
Construction	14%	23%	N/A
All Refrigerated Trucks	N/A	N/A	20%
Buses			10%

Source: Estimates made by AEA.

Notes: These are the adaptations to the default FLEETS / bottom-up methodology dataset made in the calculations to account for differences in activity and fuel consumption of specific mission profiles. Alternate values to those presented in Table 4.8 are provided here, which have been used to explore the sensitivity of the baseline assumptions.

Table 4.10 summarises the resulting Baseline derived estimates for average annual activity and new vehicle fuel consumption by mission category for 2010. There are significant differences in average annual km between different Member States and between the EU15 and EU12 in general. A comparison is also provided with the indicative estimates provided by ACEA (2010) for different mission categories. There are significant deviations in some cases - particularly for the 'Long Haul' mission category, where estimates derived on the basis of the study assumptions (in terms of vehicle weights allocated to different mission categories) are only 50% of the ACEA figure. The principal reason for this difference is likely to be due to a difference in definitions and our interpretation / estimates for the allocation of trucks of different GVW to different mission categories. Table 4.11 presents the derived estimates for average annual activity based on the Alternative assumptions in Table 4.7 and Table 4.9. These show relatively small changes in average annual activities, but more significant changes to average new vehicle fuel consumption (particularly where uplifts have been reduced).

Table 4.10: Baseline estimates for average annual activity and new vehicle fuel consumption by mission class

Vehicle Category	Average Annual Activity (km)				Average New Vehicle Fuel Consumption (l/100km)
	ACEA Indicative Estimates	Derived Estimates			
		EU27	EU15	EU12	
Service / Delivery (≤7.5t)	35,000	34,400	36,200	29,100	16.0
Urban Delivery / Collection	40,000	35,600	40,000	29,600	21.0
Municipal Utility	25,000	19,500	21,700	15,700	55.2
Regional Delivery / Collection	60,000	47,300	51,600	36,600	25.3
Long Haul	130,000	65,000	67,900	53,400	30.6
Construction	40,000 – 60,000	41,100	44,500	31,800	26.8
Bus	50,000	47,900	49,100	46,500	36.0
Coach	52,000	52,300	53,400	47,100	27.7

Notes: * The derived figures are calculation outputs based on the original figures from FLEETS split by GVW category which primarily used National Statistics as a source for such data.

Table 4.11: Alternate estimates for average annual activity and new vehicle fuel consumption by mission class

Vehicle Category	Average Annual Activity (km)				Average New Vehicle Fuel Consumption (l/100km)
	ACEA Indicative Estimates	Derived Estimates			
		EU27	EU15	EU12	
Service / Delivery (≤7.5t)	35,000	34,400	36,200	29,100	13.7
Urban Delivery / Collection	40,000	35,600	40,000	29,700	18.8
Municipal Utility	25,000	19,500	21,700	15,700	44.1
Regional Delivery / Collection	60,000	45,500	49,600	35,900	22.6
Long Haul	130,000	66,500	68,900	56,250	32.1
Construction	40,000 – 60,000	40,500	44,200	31,200	25.9
Bus	50,000	47,900	49,100	46,500	33.0
Coach	52,000	52,300	53,400	48,100	27.7

Notes: * The derived figures are calculation outputs based on the original figures from FLEETS split by GVW category which primarily used National Statistics as a source for such data.

Finally, in addition to the disaggregation by mission class, a further disaggregation was also carried out by body type (using the CLEAR and VDA datasets referenced earlier in sections 2.6 and 2.7). This was implemented in order to:

a) Estimate the additional fuel consumption due to refrigerated freight transport (using the assumptions in Table 4.8);

b) Enable development of different assumptions on the reduction in energy consumption due to the application of vehicle/trailer based efficiency measures for the calculation of future GHG emissions (covered in sections 4.4 and 4.5) for regular and irregular body types.

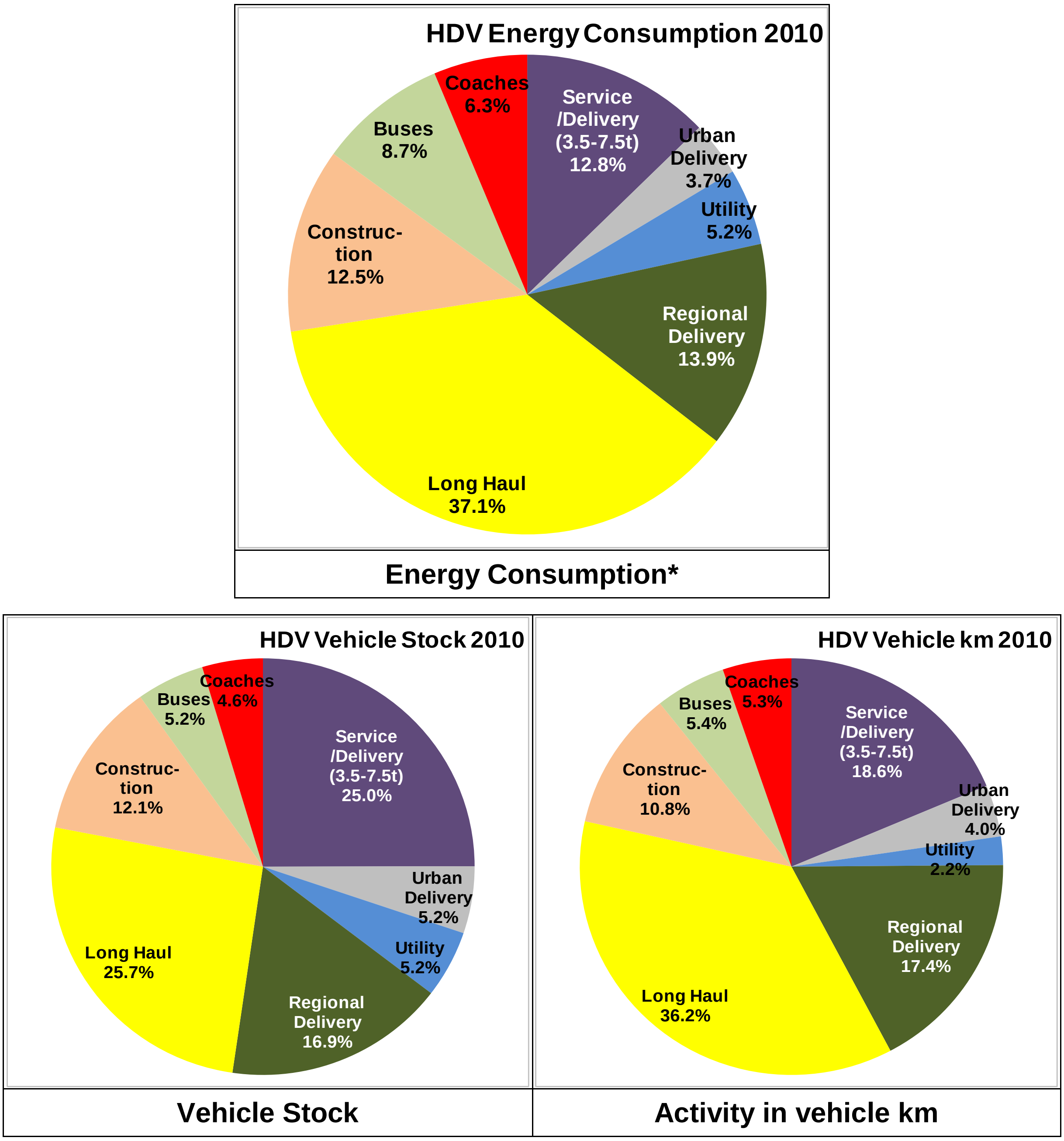
The results of the overall calculations are presented at an aggregate EU level in Figure 4–3 for the mission profile split, and Figure 4–4 for the split by body type. The figures provide a comparison of the how the split by mission category varies by stock, activity and energy consumption (= same split of CO_2 emissions in 2010). In particular, Figure 4–3 shows that in 2010 trucks accounted for around 85% of total HDV energy consumption (and GHG emissions). The figure also illustrates the overall significance of regional and long haul freight transport, which account for over half of all the energy consumption (and CO_2 emissions) from EU HDVs due to high activity levels and larger vehicles. In particular, whilst the service/delivery and urban delivery categories account for over 25% of vehicles, they only contribute to 16.5% of total emissions. This result is not particularly surprising since they are predominantly the smaller trucks operating with lower annual km. However, their higher fuel consumption due to urban operations will have offset this to a degree. Similarly the impact of significantly higher fuel consumption of municipal utility vehicles (predominantly refuse collection vehicles) counterbalances their relatively low annual km activity. Long-haul truck operations are estimated to account for around 37% of all HDV emissions, and ~44% of total truck emissions. This appears to be in reasonable agreement with European statistics by journey distance band (presented in Figure 4–6), where journeys >500km account for around 40% of all truck vehicle km.

A sensitivity analysis on some of the key assumptions was also performed using the Baseline and Alternative assumption sets previously discussed. A summary of the analysis for total energy consumption is presented in Table 4.12. This shows that overall the alternative assumptions only result in up to a 4% change in overall emissions, but with greater variations within different mission categories.

Figure 4–4 provides an indication of the overall significance of truck activity by broad body category. Long haul transport (with larger vehicles travelling greater distances annually) is dominated by more regular body types in comparison to other mission classes. Therefore the contribution of vehicles (including their trailers) with more regular body types to overall fuel consumption is estimated to be greater than their numbers and activity. This is significant as there is greater technical potential to improve the overall future efficiency of trucks with regular body types.

The overall split of greenhouse gas emissions by mission category is also presented by Member State in Figure 4–5. This figure shows reasonable variation between different countries – in some cases the variation is quite significant. However, it should be noted whilst the mission-based disaggregation is expected to be a reasonable approximation at the EU level, it is likely to be a much more uncertain representation at the Member State level, since the original ACEA datasets were not provided at this resolution. Some results may present a distortion of the true picture due to the reallocation methodology developed for the EU level data. For example, Figure 4–6 presents the total vehicle-km by distance band for 2009 from Eurostat statistics. Comparison of Figure 4–5 and Figure 4–6, illustrates there may be some significant discrepancies in the estimated split of activity (and emissions) for certain countries (such as Spain).

Figure 4–3: Estimated breakdown of the EU HDV energy consumption, activity and vehicle parc by mission profile for 2010



Notes: * Greenhouse gas emissions follow the same proportional split as energy consumption.

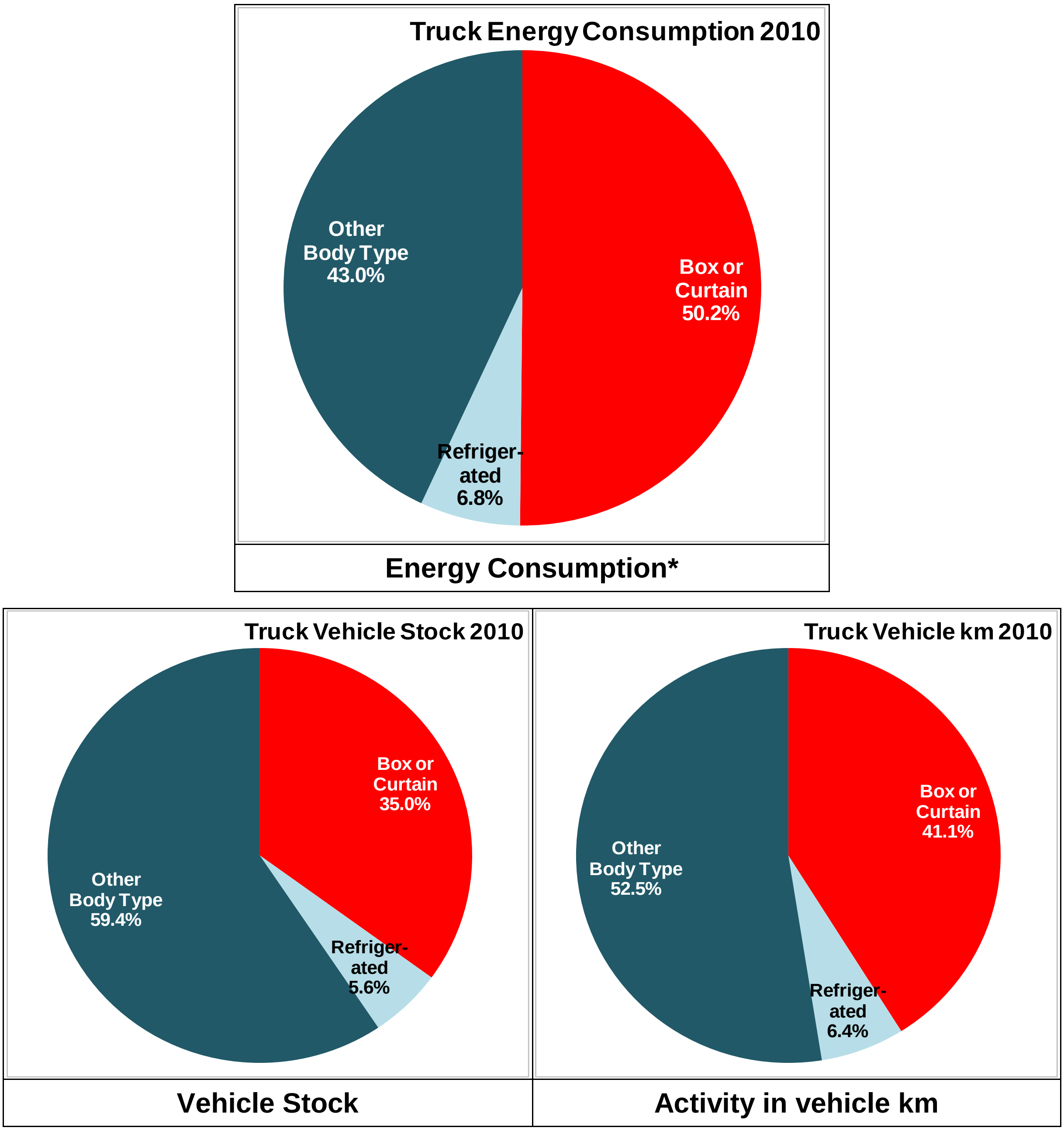
Table 4.12: Comparison of estimates for average vehicle fuel consumption by mission class for Baseline and the Alternative assumptions

2010	% Split of Total HDV energy consumption				Energy % change vs Baseline		
Allocation [(a)]:	Baseline	Baseline	Alt.	Alt.	Baseline	Alt.	Alt.
Uplifts [(b)]:	Baseline	Alt.	Baseline	Alt.	Alt.	Baseline	Alt.
Service/Delivery (3.5-7.5t)	12.8%	11.4%	12.8%	11.4%	-14.3%	0.0%	-14.3%
Urban Delivery/Collection	3.7%	3.4%	3.6%	3.4%	-10.0%	-1.0%	-10.9%
Municipal Utility	5.2%	4.3%	5.2%	4.3%	-20.0%	0.6%	-19.5%
Regional Delivery/Collection	13.8%	14.4%	12.4%	12.9%	0.0%	-10.1%	-10.1%
Long Haul	37.1%	38.6%	39.3%	40.9%	0.0%	5.9%	5.9%
Construction	12.5%	13.0%	11.7%	12.2%	0.0%	-6.0%	-6.0%

2010	% Split of Total HDV energy consumption				Energy % change vs Baseline		
Allocation [(a)]:	Baseline	Baseline	Alt.	Alt.	Baseline	Alt.	Alt.
Uplifts [(b)]:	Baseline	Alt.	Baseline	Alt.	Alt.	Baseline	Alt.
Total Buses	8.7%	8.3%	8.7%	8.3%	-8.3%	0.0%	-8.3%
Total Coaches	6.3%	6.6%	6.3%	6.6%	0.0%	0.0%	0.0%
Total Trucks	**85.0%**	**85.1%**	**85.0%**	**85.1%**	**-3.8%**	**0.1%**	**-3.7%**
Total Buses and Coaches	**15.0%**	**14.9%**	**15.0%**	**14.9%**	**-4.8%**	**0.0%**	**-4.8%**
Total HDVs	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**-4.0%**	**0.1%**	**-3.9%**

Notes: Sensitivity analysis were carried out using baseline and alternative assumptions for (a) the allocation of different vehicles by GVW to the mission profile categories – see Table 4.6 and Table 4.7, (b) fuel consumption uplifts and reallocation of vehicle km to long haul operations – see Table 4.8 and Table 4.9.

Figure 4–4: Estimated breakdown of the EU truck energy consumption, activity and vehicle parc by body type for 2010



Notes: * Greenhouse gas emissions follow the same proportional split as energy consumption.

Figure 4–5: Estimated breakdown of HDV GHG emissions by mission profile and Member State for 2010

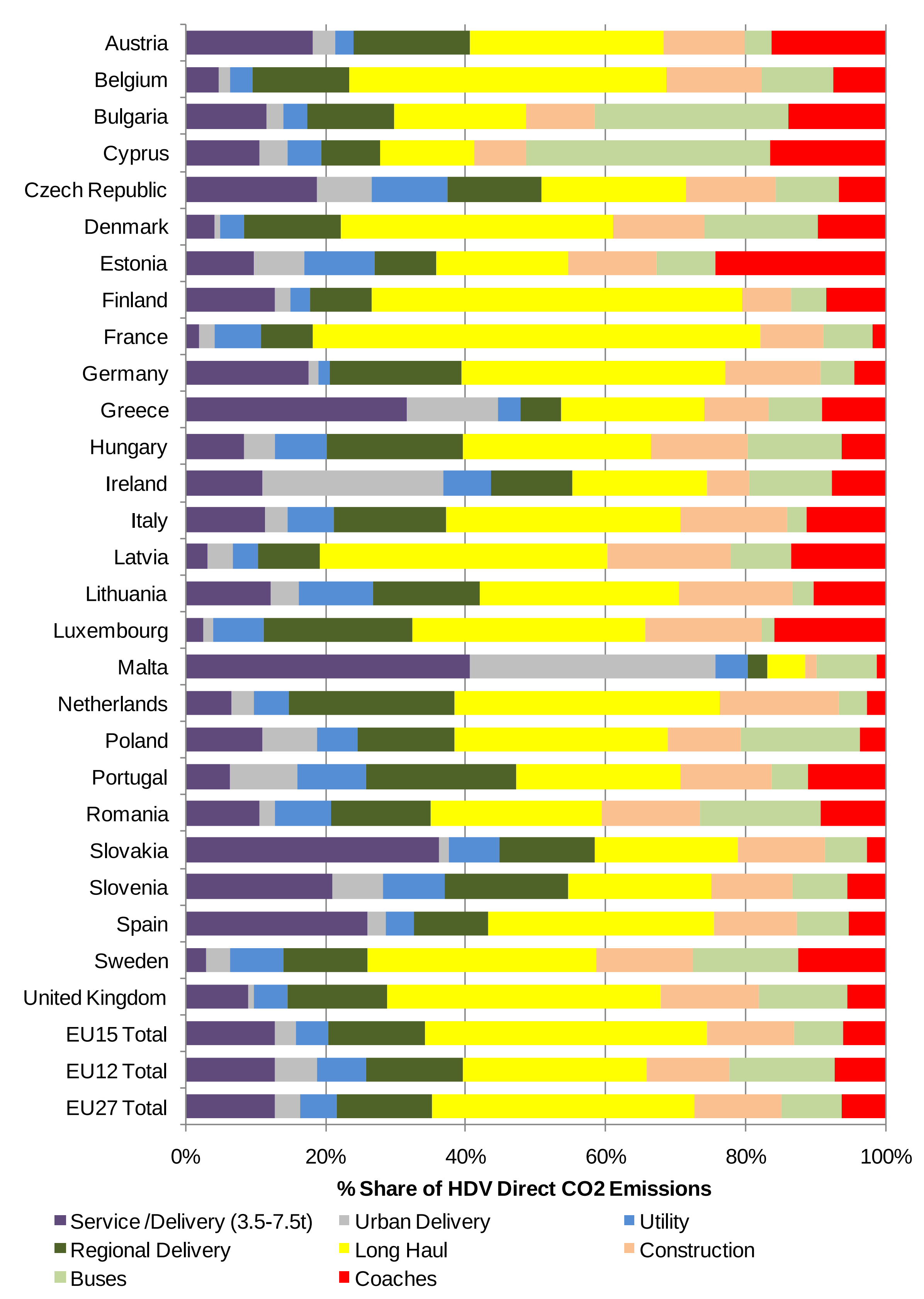
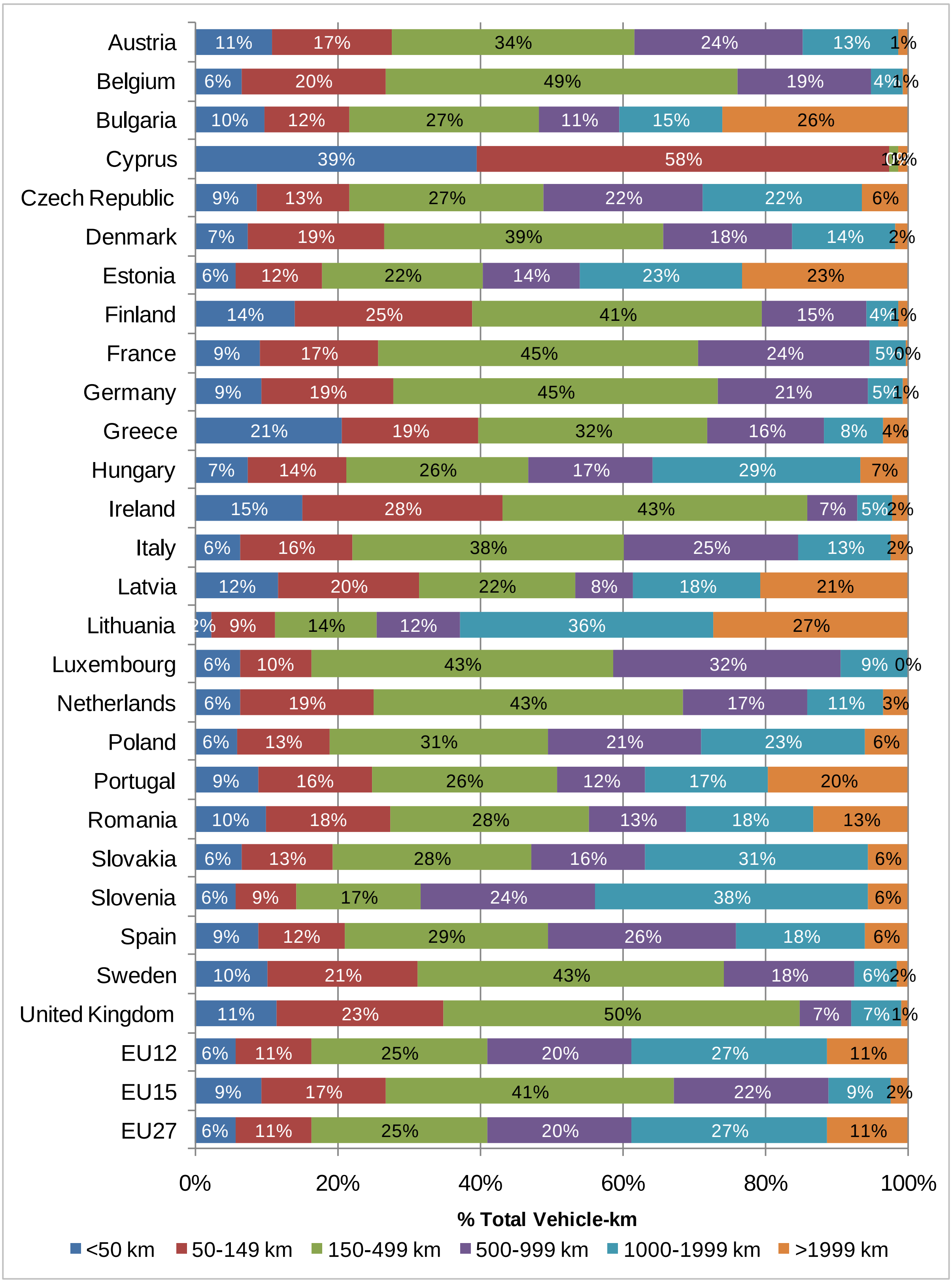


Figure 4–6: Proportion of total vehicle-km for different journey distance bands by Member State in 2009



Source: Based on data from Eurostat (2010)

4.3 Fuel consumption and GHG emissions for new HDVs

Objectives:

The purpose of this sub-task (2.2) was to:

"Quantify the current fuel consumption and CO_2 emission levels for new HDV."

Summary of Main Findings

⇒ The fuel consumption and emissions of HDVs is highly dependent on the specification of the vehicle and the operational cycle employed, which are very highly variable.

⇒ Information on fuel consumption from road tests of typical new rigid trucks and road tractors has been presented to illustrate the typical performance for conventional freight transport by truck.

⇒ The fuel consumption and CO_2 emissions of average new HDVs by GVW category and mission category have been presented, estimated on the basis of EU average road speeds and the proportions of km travelled on urban, rural and motorway roads.

The purpose of this sub-task was two-fold; firstly to benchmark typical performance of new HDVs in the current market, and second to feed into the more detailed analysis of the potential evolution of future fuel consumption and greenhouse gas emissions of HDVs covered in sections 4.4 and 4.5.

As already discussed under Task 1 of this project (Section 2), the HDV sector is highly diverse with the final vehicles delivered to customers' particular specifications/needs for use in widely different operational cycles. Therefore it is only possible to present broad generalisations in terms of vehicle fuel efficiency and emissions.

Table 4.13 and Table 4.14 present information provided by Ricardo characterising typical new rigid trucks and road tractors across a range of weight categories. The fuel consumption data for the trucks used for freight transport are mainly based on real-world driving tests principally over A-roads and Motorways. For the smaller rigid truck categories this is therefore expected to underestimate fuel consumption for the much greater portion of urban driving typical for these vehicles.

This information from Ricardo was compared to the fuel consumption derived for different FLEETS weight categories discussed in earlier sections of this report. The resulting EU average figures are presented in Table 4.15 and were derived on a similar basis to the speed-emission/fuel consumption calculations outlined in Section 4.2.1.3 for the bottom-up inventory calculations. It should be noted that the fuel consumption figures presented are unadjusted for mission-specific duty cycles (e.g. higher fuel consumption due to the stop-start nature of urban service and delivery cycles for small rigid HDV classes). The corresponding figures for direct CO_2 emissions are also presented in the table.

Using the methodology and assumptions outlined in Section 4.2.2, these fuel consumption figures were used to calculate the equivalent performance of trucks by mission category, with the corresponding figures for buses and coaches calculated in a similar way. The resulting EU average new vehicle fuel efficiency and CO_2 emissions by HDV mission category are presented in Table 4.16.

These figures have been used as a basis for the simple stock model based calculations used to estimate the possible future evolution of fuel consumption and greenhouse gas emissions discussed in subsequent sections 4.4 and 4.5 and 4.5.

Table 4.13: Characteristics and performance of typical new rigid trucks

Make	Iveco	M-Benz		Isuzu	DAF		A	B		
Model	Eurocargo MI75E16S	Atego 816	Av.	F180.260	CF75.360	Av.	Refuse Collection Vehicle	Refuse Collection Vehicle	Av.	Concrete Mixer
Type	Freight	Freight		Freight	Freight					
Vehicle GVW [tonne]	7.50	7.50	**7.50**	18.00	26.00	**22.0**	26.00	26.00	**26.0**	
Configuration	4 x 2	4 x 2		4 x 2	6 x 4					
Swept Volume [litres]	3.92	4.25		7.79	9.19					
Power [kW/tonne]	15.73	15.33	**15.53**	10.61	10.19	**10.40**	8.46	8.46	**8.46**	
Power [kW/l]	30.1	27.1		24.5	28.8					
Rated Speed	2700	2200		2400	2200					
Torque [Nm/l]	135.1	143.6		97.7	138.8					
Torque [Nm/tonne]	70.7	81.3		42.3	49.0					
Torque Speed [rev/min]	1200-2100	1200-1600		1450-2450	1200-1700					
Max. BMEP	17.1	18.0		12.3	17.4					
Engine Certification	Euro V	Euro V		Euro V (EGR +DPF)	Euro V SCR		Euro V SCR	Euro V SCR		
Average speed for test [km/hr]	69.9	64.2	**67.1**	61	62.8	**61.9**				
Payload [tonnes]	3.02	3.218	**3.12**	10.123	16.18	**13.2**				
Fuel Consumption [litre/100km]	13.2	13.6	**13.4**	22.4	29.8	**26.1**	72.9	78.9	**75.9**	67.5
Fuel Cons. [litre/100km.tonne GVW]	1.76	1.81	**1.78**	1.25	1.14	**1.19**	2.80	3.03	**2.92**	
Fuel Cons. [litre/100km.tonne payload]	4.36	4.22	**4.29**	2.21	1.84	**1.98**				
Fuel Cons. [km/litre]	7.59	7.36	**7.48**	4.46	3.36	**3.91**	1.37	1.27	**1.32**	1.48
Emissions, kg CO_2 /km	0.349	0.360	**0.355**	0.594	0.789	**0.692**	1.933	2.092	**2.01**	1.790

Source: Data provided by Ricardo (2010)

Table 4.14: Characteristics and performance of typical new 40-44 tonne GVW trucks used in regional distribution and long-haul operations

Make	DAF	Iveco	MAN	M-Benz	M-Benz	M-Benz	Renault	Renault	Scania	Scania	Scania	Volvo	Volvo	
Model	XF105.460	Stralis AS450	TGX 18.480	A1840S	Actros 1848 LS	Actros 2546	Magnum 500 Classic	Premium 450.24 TML E5	R620 Topline	R440 LA	R480 Topline	FM11.430	FH13.480	Av.
Vehicle GVW [tonne]	44.00	44.00	44.00	40.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00	
Configuration	4 x 2	6 x 2	4 x 2	4 x 2	4 x 2	6 x 2	6 x 2	6 x 2	6 x 2	6 x 2	4 x 2	6 x 2	6 x 2	
Swept Volume	12.90	10.31	12.42	11.97	11.95	11.95	12.82	10.84	15.61	12.74	12.74	10.84	12.82	
Power [kW/tonne]	7.73	7.52	8.02	7.38	7.95	7.73	8.36	7.52	10.36	7.36	8.02	7.19	8.02	
Power [kW/l]	26.4	32.1	28.4	24.7	29.3	28.5	28.7	30.5	29.2	25.4	27.7	29.2	27.5	
Rated Speed	1900	1550-2100	1900	1900	1800	1800	1900	1900	1900	1900	1900	1800-1900	1400-1800	
Torque [Nm/l]	178.3	208.6	185.2	167.1	192.5	184.2	191.2	197.5	192.2	180.5	196.2	193.8	187.3	
Torque [Nm/tonne]	52.3	48.9	52.3	50.0	52.3	50.0	55.7	48.6	68.2	52.3	56.8	47.7	54.5	
Torque Speed [rev/min]	1000-1400	1100-1450	1050-1400	1100	1080	1080	1050-1400	1100-1300	1100-1400	1000-1300	1000-1300	1100-1300	1050-1400	
Max. BMEP	22.4	26.2	23.3	20.9	24.1	23.0	24.1	24.9	24.2	22.7	24.7	24.4	23.6	
Engine Certification	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (SCR)	Euro V (EGR)	Euro V (EGR)	Euro V (SCR)	Euro V (SCR)	
Average test speed [km/hr]	83.25	74.1	82.8	72.9	82.8	73	75.8	72.7	74.0	73.5	82.67	70.6	70	**76.0**
Payload [tonnes]		29.03		25.09		31.43	28.19	28.87	27.77	28.78		28.84	28.00	
Fuel Cons. [litre/100km]	39.0	36.4	38.5	31.5	38.9	34.7	35.7	35.2	37.3	37.3	38.9	35.8	34.9	**36.46**
Fuel Cons. [litre/100km.tonne GVW]	0.89	0.83	0.87	0.79	0.88	0.79	0.81	0.80	0.85	0.85	0.88	0.81	0.79	
Fuel Cons. [litre/100km.tonne payload]		1.25		1.25		1.10	1.27	1.22	1.34	1.30		1.24	1.25	
Fuel Cons. [km/litre]	2.56	2.75	2.60	3.18	2.57	2.88	2.80	2.84	2.68	2.68	2.57	2.79	2.87	**2.75**
Emissions, kg CO_2 / km	1.034	0.965	1.020	0.835	1.031	0.920	0.945	0.934	0.988	0.989	1.031	0.949	0.924	**0.967**

Source: Data provided by Ricardo (2010)

Table 4.15: Estimated fuel efficiency and GHG emissions of 2010 new trucks by type and GVW category

Year 2010 trucks	New MJ/km	New litres/100km	New $kgCO_2/km$
Rigid ≤7.5 t	4.0	11.3	0.300
Rigid 7.5 - 12 t	5.9	16.6	0.441
Rigid 12 - 14 t	6.2	17.5	0.463
Rigid 14 - 20 t	7.5	20.9	0.554
Rigid 20 - 26 t	9.5	26.5	0.703
Rigid 26 - 28 t	10.0	28.0	0.741
Rigid 28 - 32 t	11.4	31.9	0.845
Rigid >32 t	11.5	32.3	0.857
Total Rigid	**6.5**	**18.3**	**0.485**
Articulated 14 - 20 t	7.2	20.1	0.534
Articulated 20 - 28 t	9.3	26.1	0.693
Articulated 28 - 34 t	9.9	27.6	0.732
Articulated 34 - 40 t	11.3	31.6	0.836
Articulated 40 - 50 t	12.7	35.5	0.940
Articulated 50 - 60 t	14.5	40.6	1.077
Total Articulated	**11.1**	**31.2**	**0.827**
TOTAL Trucks	**8.7**	**24.3**	**0.643**

Notes: Based on activity weighted EU averages for different weight classes – unadjusted for mission-specific duty cycles (e.g. stop-start nature of urban service and delivery cycles for small rigid HDV classes)

Table 4.16: Estimated fuel efficiency and GHG emissions of 2010 new HDVs by mission profile

Year 2010 trucks	New MJ/km	New litres/100km	New $kgCO_2/km$
Service /Delivery (≤7.5t)	5.7	16.0	0.423
Urban Delivery	7.5	21.0	0.557
Utility	19.7	55.2	1.463
Regional Delivery	8.8	24.6	0.653
Long Haul	11.1	30.9	0.821
Construction	9.6	26.8	0.710
Buses	12.9	36.0	0.956
Coaches	9.9	27.7	0.734

Notes: Based on activity weighted EU averages for different mission classes – adjusted for mission-specific duty cycles (e.g. stop-start nature of primarily urban cycles for first three categories and for buses).

4.4 Baseline future development of fuel use and GHG emissions

Objectives:

The purpose of this sub-task (2.3) was to:

“Indicate the likely future development of fuel use and CO_2 emissions, both for the existing fleet and for new vehicles”

Summary of Main Findings

- ⇒ BAU assumptions include natural development of powertrain and vehicle based efficiency improvements. Benefits are offset to a significant degree by in-year increases in fuel consumption of 3% following the introduction of Euro VI in 2013 and a purely speculative Euro VII in 2018. Introduction of significant alternative fuel / powertrain options (e.g. hybrid, dual-fuel vehicles) is assumed to be restricted.
- ⇒ BAU scenario results show overall energy consumption and direct CO_2 emissions increase by almost 15% by 2030 (+21% for trucks, -21% for buses and coaches). Correspondingly total HDV numbers increase by almost 31% and total vkm by more than 27%. The increase for lifecycle GHG emissions is estimated to be lower (8%) due to the impact of the Fuel Quality Directive requirements and existing biofuel commitments;
- ⇒ Trucks account for 85% of energy/CO_2 in 2010, rising to almost 90% by 2030. This change is principally due to a *decrease* in stock / activity for buses and coaches (by 9% /10% respectively) and an *increase* in stock / activity for trucks (by 35% / 32% respectively).
- ⇒ Long-haul trucks account for over 37% of energy consumption and CO_2 emissions from all HDVs in 2010 (vs 26% of HDV numbers), rising to almost 39% by 2030 under BAU conditions. However, their share decreases in comparison to other truck categories and their anticipated reduction in fuel consumption is the greatest of all HDV categories (at over 10% by 2030);
- ⇒ Refrigerated transport is estimated to account for 5.8% of total energy/CO_2 from HDVs;
- ⇒ The combined energy consumption and CO_2 emissions due to the vocational truck categories increases from 17.7% (12.5% construction, 5.2% utility) in 2010 to 19% (13% / 6%) in 2030. These vehicle categories also have the smallest reductions in fuel consumption principally because the possibilities for vehicle based improvements (e.g. drag reduction and light-weighting) are less.

In this section an estimate of the baseline ‘business as usual’ (BAU) future development of fuel use and GHG emissions from the European heavy duty vehicle fleet has been developed for the period 2010 to 2030. The following subsections outline methods employed to develop this baseline, the principal assumptions and the results of the calculations.

NOTE: Biofuels are excluded from analysis scope in this study, other than their contribution to the attainment of targets in reducing lifecycle emissions from road transport fuels as required under the Fuel Quality and Renewable Energy Directives.

4.4.1 BAU Scenario Assumptions

The methodology employed to estimate the evolution of activity, fuel consumption and emissions to 2030 was to extend the simple bottom-up stock-based calculations already discussed in subsections 4.2 and 4.3. The projection in activity (in vehicle km) and vehicle stock from 2010 to 2030 was developed on the basis of the TREMOVE model baseline. It is assumed that the relative split of vehicle types / mission categories will remain essentially the same in the absence of available information on how these subsectors might develop. Some limited changes are included in the projections resulting from differences in the change in projected stock and activity levels of trucks by the four TREMOVE weight categories.

In order to estimate the future development of new HDV energy consumption and emissions it was also necessary to develop baseline scenario assumptions for the natural improvements to conventional diesel powertrains, vehicle based efficiency improvements (e.g. light weighting and drag reduction) and the penetration of new technologies and alternative fuelled vehicles. In defining this BAU scenario from a technology perspective it was assumed that it characterised the situation where no incentives or legislative CO_2 for HDV are developed in the future.

Natural improvement of vehicle efficiency occurs as manufacturers endeavour to offer the most competitive product to the market and refine their products. Technologies which are classed under natural improvement include those which offer low levels of fuel consumption benefit and are an intricate part of the vehicle design (including vehicle and trailer body improvements). For example variable flow and electric pumps are considered part of natural improvement as these are inherent to the engine design. Likewise electrification of engine auxiliaries are not considered separately as these will only appear on electric hybrids due to current requirements and as such their benefit is included within the benefit hybridised vehicles can offer. Improvements in base diesel engine design that will occur without the introduction of “headline” technologies were modelled separately.

A summary of the BAU estimates in the natural improvement of vehicle efficiency is provided in the following Table 4.17. Of particular note within this table is the impact of the Euro VI emission standards for new HDVs (mandatory from 2013). This is anticipated to result in an initial fuel consumption penalty of around 3% due to the necessary application of technology to control NOx and PM emissions to the levels required by Euro VI. Also built into the BAU scenario is an assumption that a similar impact might be expected with the possible introduction a Euro VII standard in 2018. **Note this is a purely speculative LOT 1 assumption**, as at the moment no plans to develop and introduce such a standard have been produced. However, this would be consistent with historical trend in the introduction of such standards (and the ongoing need to reduce emissions from road transport).

Table 4.17: BAU estimates on evolution of fuel consumption benefit (penalty) for base conventional diesel vehicles - figures indicate benefit/penalty compared to previous year

		2010	2013	2015	2018	2020	2025	2030
New Vehicle % powertrain natural improvement [(a)]	Truck	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
	Bus / Coach	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
New Vehicle % vehicle FC improvement	Long Haul Truck [(b)]	0.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	Coach [(c)]	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
	Bus [(d)]	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Vehicle Parc % vehicle FC improvement	Long Haul Truck	-	-	-	-	-	-	-
	Coach	-	-	-	-	-	-	-
	Bus	-	-	-	-	-	-	-
% FC penalty from emissions legislation [(e)]	All	0.0%	-3.0%	0.0%	-3.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)

Notes: BAU scenario of fuel consumption of new vehicles - assuming no incentives or legislative CO_2 for HDV
(a) Natural improvement in powertrain efficiency includes transmission and engine auxiliaries
(b) Assume overall circa 10% reduction using vehicle aids by 2030

(c) Some aero improvements and weight reduction
(d) Forecast reduction in vehicle mass to increase fuel economy of vehicles - assume 1% reduction in weight every 5 years - 0.8% fuel consumption improvement every 5 years
(e) Penalty from increasing emissions legislation in 2013 and then potential Euro 7 around 2018

The BAU scenario assumptions for the penetration of new/alternative technologies and alternative fuelled vehicles are also provided in the following Table 4.18. Here it is assumed that the current average rate of introduction of electric (mostly trolleybuses) and conventional natural gas buses is maintained to 2030, with very modest rates of introduction of electric trucks used for service / urban delivery applications. The introduction of hybrid-electric powertrain technology into heavy duty vehicles is also assumed to be relatively modest in the absence of further incentives due to cost. However, stop-start technology is expected to be introduced rapidly into vehicles operating predominantly within urban environments.

Table 4.18: BAU estimates on penetration of alternative technology and alternative fuelled vehicles (% of new vehicle sales)

		Energy benefit: % improvement vs conventional diesel	Technology deployment into new HDV				
			2010	2015	2020	2025	2030
% Natural Gas Vehicles [a]	Bus	-15.0%	0.8%	0.8%	0.8%	0.8%	0.8%
	Truck	-15.0%	-	-	-	-	-
% Electric Vehicles	Service/ Delivery (≤7.5t)	70.0%	0.2%	0.2%	0.2%	0.2%	0.2%
	Urban Delivery	70.0%	0.2%	0.2%	0.2%	0.2%	0.2%
	Bus	70.0%	0.2%	0.2%	0.2%	0.2%	0.2%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Hybrid [b]	Service/ Delivery (≤7.5t)	20%	0.0%	0.0%	1.0%	3.0%	5.0%
	Urban Delivery	20%	0.0%	0.0%	1.0%	3.0%	5.0%
	Utility	20%	0.0%	0.0%	1.0%	3.0%	5.0%
	Regional Delivery	10%	0.0%	0.0%	1.0%	3.0%	5.0%
	Long Haul	7%	0.0%	0.0%	0.1%	0.2%	0.5%
	Bus	30%	0.2%	0.5%	1.5%	3.0%	5.5%
	Other HDV	0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Stop Start [c]	Service/ Delivery (≤7.5t)	6%	0.0%	30.0%	99.0%	97.0%	95.0%
	Urban Delivery	6%	0.0%	30.0%	99.0%	97.0%	95.0%
	Utility	6%	0.0%	0.0%	0.0%	0.0%	0.0%
	Regional Delivery	3%	0.0%	30.0%	99.0%	97.0%	95.0%
	Bus	4%	0.0%	40.0%	98.5%	97.0%	94.5%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)

Notes: (a) Greater energy consumption for dedicated natural gas ICE (spark-ignition), similar or lower CO_2 emissions
(b) Greatest penetration in bus and urban settings where vehicles can deliver cost savings operators, long haul applications minimal
(c) Average benefit although maximum can be up to 30%. Implementation driven by air quality rather than CO_2 or fuel consumption. Technology common in new passenger car and expected to proliferate quickly across vehicles, already available on Mercedes Atego.

4.4.2 BAU Scenario Results

The results of the scenario modelling are provided in the following Figure 4–7 and Figure 4–8, with Table 4.19 showing the evolution of the average fuel consumption of each vehicle type. For the technology uptake rates as proposed in the BAU scenario, the average new vehicle fuel consumption can be reduced between 6 – 10% between 2010 and 2030 for most HDV classes (with the exception of Utility vehicles, where just 1.1% reduction is achieved).

Overall, fuel consumption and direct CO_2 emissions from European HDVs are anticipated to increase by 15% from 2010 (3,151 PJ, 234 $MtCO_2$) to 2030 (3,613 PJ, 268 $MtCO_2$). In terms of lifecycle emissions, these are expected to be relatively flat to 2020 due to the requirements for reductions in the lifecycle emissions of road transport fuels under the Fuel Quality Directive and existing biofuel commitments. The overall increase in lifecycle GHG emissions from HDVs from 2010 to 2030 is therefore lower at 8%.

The variations in the reduction of fuel consumption for the different vehicle categories results in a relatively small change in the relative contributions of the vehicle categories to fleet direct CO_2 emissions as shown in Figure 4–8. For the BAU scenario, in general the proportion of truck emissions increases from around 85% in 2010 to just under 90% in 2030. The principal reason for this appears to be a *decrease* in overall stock and vkm by buses and coaches at an EU level by 9% and 10.5% respectively. The corresponding changes in vehicle stock and vkm for trucks are 35% and 32% *increases* respectively, whilst the same parameters for buses/coaches decrease by 9% and 10.5% respectively. The largest improvement in vehicle fuel consumption is in the long haul vehicle category (see Table 4.19). For this segment the contribution to fleet direct CO_2 emissions reduces slightly in comparison to the other truck mission categories. In contrast to this is the relative contribution from the Municipal Utility category which increases its relative contribution to the total HDV fleet direct CO_2 emissions from 5.2% to 5.8% over the BAU due to relatively little improvement in fuel consumption to 2030. This is because the impacts of future air quality pollutant limits for new vehicles counteract most of the natural powertrain efficiency improvements. The category with the next lowest improvement in fuel consumption is construction vehicles, where there is relatively low potential for non-powertrain improvements to improve vehicle efficiency (e.g. drag reduction and light-weighting). Energy consumption and CO_2 emissions due to the vocational truck categories increase from 17.7% (12.5% construction, 5.2% utility) in 2010 to 19% (13% / 6%) in 2030.

Table 4.19: Development of New Vehicle Fuel Consumption – BAU Scenario

Vehicle Type	Average New Vehicle Fuel Consumption (l/100km, diesel equivalent)			% Reduction 2010 to 2030
	2010	2020	2030	
Service Delivery (3.5-7.5t)	16.0	15.5	14.9	6.6%
Urban Delivery / Collection	21.0	20.3	19.6	6.6%
Municipal Utility	55.2	56.7	54.6	1.1%
Regional Delivery / Collection	24.6	23.6	22.2	9.8%
Long Haul	30.9	30.1	27.7	10.4%
Construction	26.8	26.7	25.2	5.7%
Bus	36.0	34.8	32.8	9.0%
Coach	27.7	27.7	26.1	5.9%

Overall, natural development of powertrain efficiency improvements appear in general to be offset by in-year *increases* in fuel consumption of 3% due to the introduction of Euro VI in 2013 and a speculative Euro VII in 2018. Net improvements in overall vehicle performance therefore mainly result from limited introduction of alternative technologies, such as stop-start in vehicles with primarily urban cycles, and by non-powertrain vehicle improvements to those categories with high proportions of motorway activity.

Long-haul trucks account for over 37% of energy consumption and CO_2 emissions from all HDVs in 2010 (vs 26% of HDV numbers), rising to almost 39% by 2030 under BAU conditions. However, their share decreases in comparison to other truck categories and their anticipated reduction in fuel consumption is the greatest of all HDV categories (at over 10% by 2030).

Refrigerated transport is estimated to account for 5.8% of total energy/CO_2 from HDVs in 2010, which remains roughly constant to 2030.

Figure 4–7: Baseline BAU estimates of the future development of EU HDV vehicle parc, energy consumption, activity and greenhouse gas emissions by mission category from 2010 - 2030

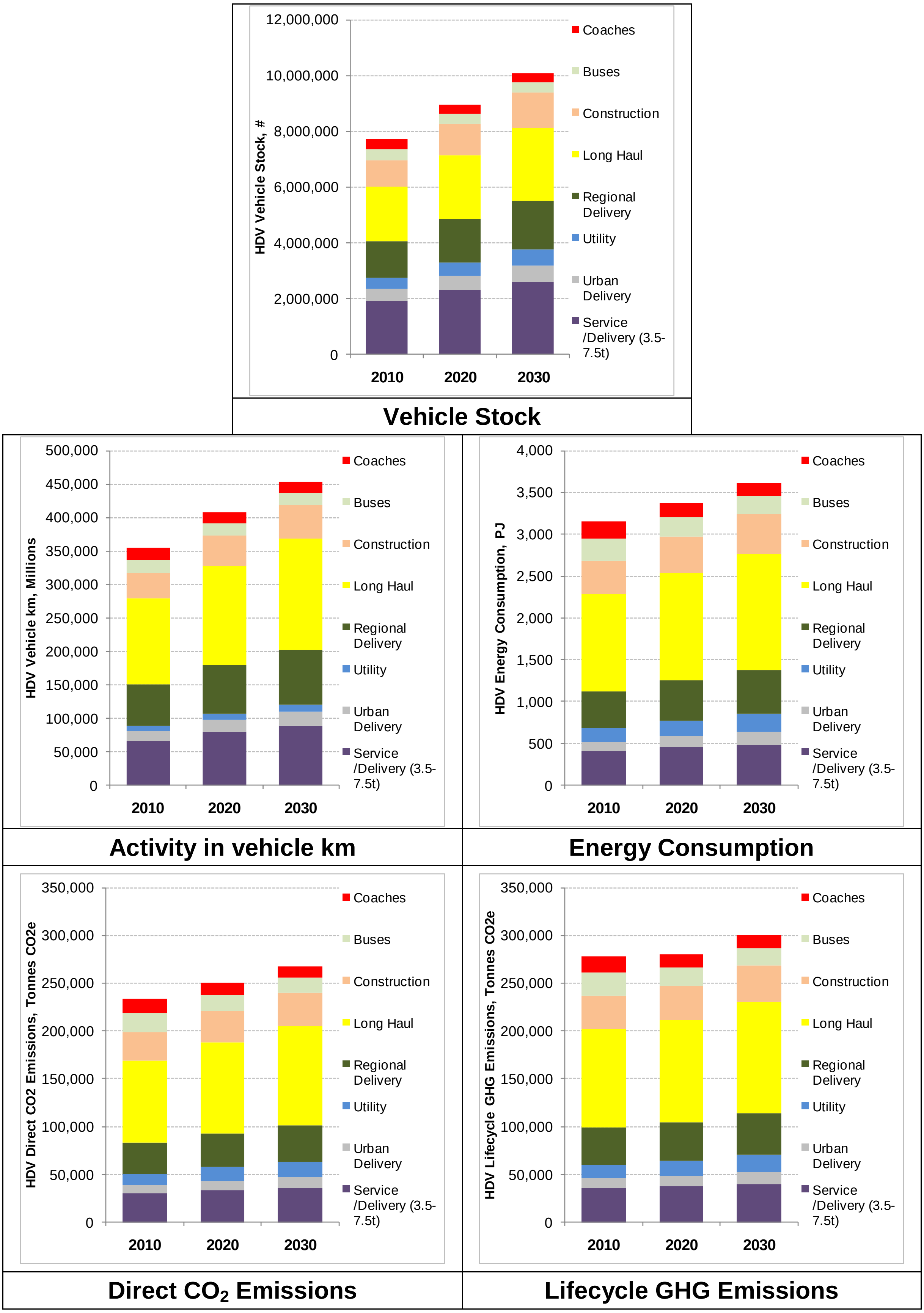
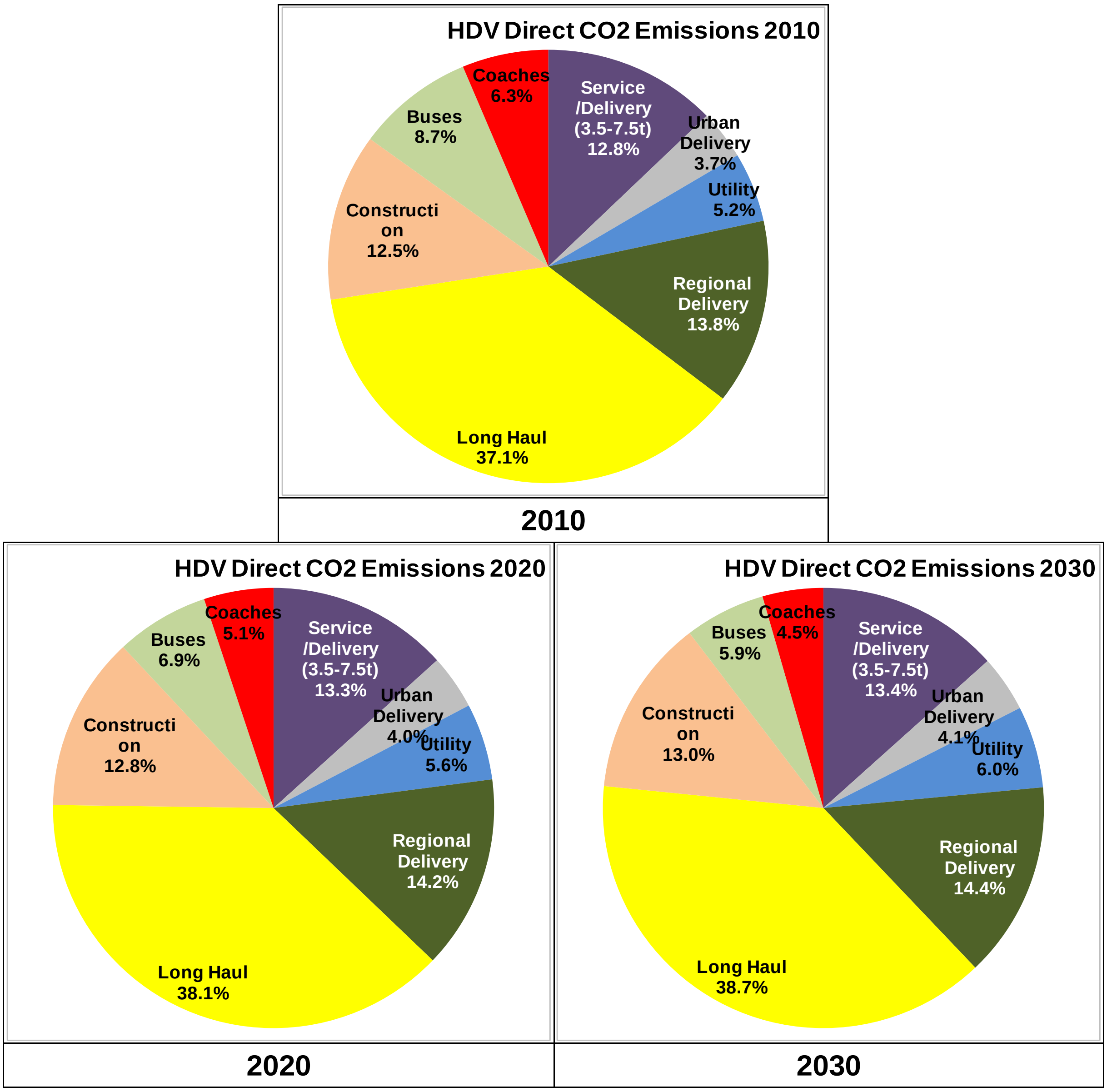


Figure 4–8: Baseline BAU estimates of the future development of EU HDV direct greenhouse gas emissions by mission category from 2010 - 2030



4.5 Scenario assessment of possible future reductions in total EU HDV fuel consumption and GHG emissions

Objectives:

The purpose of this sub-task was to provide an:

"Assessment of possible future reduction in total EU fuel consumption and greenhouse gas emissions from HDV, given new and emerging technologies and associated costs and benefit. The analysis should also identify other environmental effects and quantify them as much as possible (e.g.: noise, air pollution) and any other effects."

Summary of Main Findings

⇒ Only through the ambitious uptake of new technologies can the continual increase in both heavy duty lifecycle GHG and direct CO_2 emissions be reduced compared to today's levels.

⇒ Through technology uptake as proposed by the challenging scenario, heavy duty vehicle fleet lifecycle GHG emissions can be reduced by 7.3% and direct CO_2 emissions by 2%.

⇒ The Cost Effective technology scenario results in the greatest fuel consumption reduction for Long Haul vehicles, with a reduction in fleet emissions of 10.5% and a decrease in new vehicle fuel consumption of 15.4%.

⇒ The Challenging technology scenario results in the greatest reduction in fuel consumption for Urban Delivery vehicles and Buses with the largest reduction in total fleet emissions for Urban Delivery vehicles at 18.6% and the largest new vehicle fuel consumption improvement for Buses of 33.8%.

In this section, the possible impact that the uptake of technology can have on the level of CO_2 reduction from the European heavy duty vehicle fleet is considered. Two technology scenarios have been developed representing different levels of technology uptake. Technology uptake rates and average benefits have been defined for six vehicle categories for each technology scenario, with the technologies adopted varying between vehicle types. Technologies included in the scenarios are those that are expected to reach commercial maturity within the timeframe considered, i.e. from 2010 to 2030.

Technologies which are deemed unlikely to be commercialised within this time period, such as vehicle platooning, are excluded along with those that are deemed to fall into the category of natural improvement. As noted earlier in section 4.4.1, natural improvement of vehicle efficiency occurs as manufacturers strive to offer the most competitive product to the market and refine their products. Technologies included under natural improvement include those that are an intricate part of the vehicle design and offer low levels of fuel consumption benefit. An example of a technology that is inherent to the engine design is variable flow and electric coolant pumps, which are considered part of natural improvement. Similarly electrification of engine auxiliaries will only appear on electric hybrids due to current requirements and as such their benefit is included within the benefit hybridised vehicles can offer, they are therefore are not considered separately. The rate of natural improvement has also been assumed consistent with that of the Business as Usual Scenario to still allow for improvements in base diesel engine design that will occur without the introduction of "headline" technologies.

Table 4.20: Vehicle Categories used for technology uptake rates in the scenario analysis

Vehicle Category	Description	Average Annual Mileage (km)	Average New Vehicle Fuel Consumption (l/100km)	Average Annual Fuel Cost (€)[1)]
Service / Delivery (3.5 – 7.5t)	Urban operation including frequent stop start	35,000	16.0	€5,600
Urban Delivery / Collection	Distribution in cities or suburban areas including frequent stop start driving	40,000	21.0	€8,400
Municipal Utility	Typical duty cycle is low speed urban operation with frequent stop starts, typical vehicle is a refuse truck	25,000	55.2	€13,800
Regional Delivery / Collection	Regional delivery of consumer goods from a central warehouse, includes periods of constant high speed and urban operation	60,000	25.3	€15,180
Long Haul	Long periods of constant high speed travel with very few periods of urban operation	130,000	30.6	€39,780
Construction	Vehicles operating on and off-site both light and heavy duty	40,000 – 60,000	26.8	€13,400
Bus	Low speed travel with frequent stop starts	50,000	36.0	€18,000
Coach	Long periods of constant high speed travel with periods of urban operation	52,000	27.7	€14,404

Notes: 1) Average fuel price assumed of €1/litre

4.5.1 Vehicle Categories

In order to retain consistency with the analysis of the fuel efficiency of the current and business as usual future European heavy duty vehicle fleet, eight different vehicle categories have been defined. These categories take into account the wide variations in fuel efficiency improvements associated with specific technologies when used on particular vehicle duty cycles. This approach enables a more accurate estimation of future technology uptake rates and hence of the potential impact that the adoption of low carbon technology can have on the entire EU27 heavy duty vehicle fleet, as the technologies adopted and fuel efficiency benefits will vary with each of these vehicle categories. The eight vehicle categories which have been defined are:

- Service / Delivery (3.5 – 7.5t);
- Urban Delivery / Collection;
- Municipal Utility;
- Regional Delivery / Collection;
- Long Haul;
- Construction;
- Buses; and
- Coaches.

Descriptions of the vehicle categories are provided in Table 4.10. Along with the description of the vehicle category mission profile are estimated average annual vehicle mileages, new vehicle fuel consumption (l/100km) and average annual fuel costs.

4.5.2 Technology Benefit and Cost

To help define the technology scenarios, the payback period of the technologies was considered as this will be a key influence for a vehicle operator when selecting a vehicle for their operations. If a technology has a payback period of –two to three years then this is more likely to be considered as an operator can recover and benefit from the technology over the lifetime of the vehicle. A two to three year payback is a common timeframe which large fleet operators use to assess lifetime costs, and with these operators purchasing large numbers of new vehicles this could significantly influence the technologies that are adopted. However it is appreciated that this may not be representative for all operators.

In order to estimate the payback period of the different technologies, both the fuel consumption benefit and technology cost were estimated. Average fuel consumption benefit and cost were estimated for each technology and for each vehicle category to which the technology was applicable. This information is summarised in Table 4.21. Combining this information with the average annual fuel costs as presented in Table 4.20, the annual fuel savings were calculated along with the time required to cover the additional cost of the technology, i.e. the payback period. The results of this analysis are summarised in Table 4.22 and Table 4.23.

There are a larger number of cost effective technologies available for Regional and Long Haul trucks as well as for coaches than for vehicles operating over a more urban cycle. Technology adoption is more cost effective for these vehicles due to their higher annual mileage and hence higher annual fuel costs. There are very few technologies within a two year payback for Service Delivery and Utility vehicles. For Service vehicles the lower annual mileage and lower average fuel consumption makes the addition of expensive technology difficult to justify. For Utility vehicles the often complex bodywork and frequent stop / start duty cycles means that suitable technologies are expensive.

Despite the payback cost of some technologies falling outside the desired payback period technologies can have other benefits which make them attractive to operators and justifiable.

For example an electric vehicle at current prices is not cost effective over a two to three year period on fuel savings alone. However, it has additional benefits such as lower noise, allowing it to operate at night and in restricted zones as well as a reduction in other air quality pollutants and exemption from city congestion charging. Depending on an operator's location, and additional charging schemes such as road usage or city congestion charging to which the operator might be subject to, more expensive technologies may be justified. Furthermore, the adoption of low carbon technologies may also be driven from a business strategy rather than purely commercial aspect, since with large companies are often keen to promote low carbon technology as part of their corporate social responsibility targets.

Table 4.21: Technology CO_2 Benefit by Vehicle Category

Technology	Service & Urban	Municipal Utility	Regional & Coach	Long Haul	Bus
Pneumatic Booster – Air Hybrid	1.5%	1.5%	1.5%	3.5%	N/A
Electrical Turbocompound	1.0%	1.0%	2.5%	3%	1%
Heat Recovery	1.5%	1.5%	2.5%	5%	1.5%
Automated Transmission	5%	5%	1.5%	1.5%	5%
Electric Vehicle	100%	100%	100%	100%	100%
Stop / Start System	6%	6%	3%	1%	4%
Full Hybrid	20%	20%	10%	7%	30%
Flywheel Hybrid	15%	15%	7.5%	5%	20%
Low Rolling Resistance Tyres	1%	1%	3%	5%	1%
Single Wide Tyres	4%	4%	6%	5%	4%
Automatic Tyre Pressure Adjustment	1%	%	2%	3%	1%
Aerodynamic Trailers / Bodies	1%	0%	11% (truck only)	11%	0%
Aerodynamics – irregular body type	1%	0%	6.5% (truck only)	5%	0%
Aerodynamic Fairings	0%	0%	1%	0.4%	0%
Spray Reduction Mud Flaps	1%	0%	2%	3.5%	0%
Light weighting	2.2%	4.7%	2.2%	2.2%	6.0%
Controllable Air Compressor	0%	0%	1%	1.5%	0%
Predictive Cruise Control	0%	0%	5%	5%	0%
Dual Fuel	21%	21%	21%	21%	21%
Alternative Fuel Bodies	0%	15%	15% (Truck only)	15%	0%
Hydraulic Hybrid	10%	15%	0%	0%	15%

Source: Ricardo estimates

Table 4.22: Technology Cost by Vehicle Category

Technology	Service & Urban	Municipal Utility	Regional & Coach	Long Haul	Bus
Pneumatic Booster – Air Hybrid (1)	€800	€800	€800	€800	€800
Electrical Turbocompound (1)	€7,000	€7,000	€7,000	€7,000	€7,000
Heat Recovery (1)	€11,570	€11,570	€11,570	€11,570	€11,570
Automated Transmission (1)	€3,500	€3,500	€3,500	€4,716	€3,500
Electric Vehicle (2)	€108,000	€108,000	€108,000	N/A	€108,000
Stop / Start System (3)	€640	€640	€640	€940	€640
Full Hybrid (4)	€24,000	€24,000	€24,000	€24,000	€24,000
Flywheel Hybrid (1)	€3,500	€3,500	€3,500	€5,900	€3,500
Low Rolling Resistance Tyres (5)	N/A	N/A	€350	€350	N/A
Single Wide Tyres (1)	€825	€825	€825	€1,300	€825
Automatic Tyre Pressure Adjustment (6)	€11,790	€11,790	€11,790	€11,790	€11,790
Aerodynamic Trailers / Bodies (7)	N/A	N/A	€3,500	€3,500	N/A
Aerodynamics – irregular body type (8)	N/A	N/A	€880	€880	N/A
Aerodynamic Fairings (8)	€1,180	€770	€1,180 (truck only)	€1,180	€350
Spray Reduction Mud Flaps (1)	€14	€14	€14	€14	€14
Light weighting (9)	€375	€5,650	€375	€1,600	€300
Controllable Air Compressor (1)	€140	€140	€140	€190	€140
Predictive Cruise Control (10)	€1,400	N/A	€1,400	€1,400	N/A
Dual Fuel (11)	€26,000	€26,000	€26,000	€26,000	€17,700
Alternative Fuel Bodies (12)	N/A	€14,000	€14,000 (truck only)	€14,000	N/A
Hydraulic Hybrid (1)	€13,200	€13,200	€13,200	N/A	€13,200

Source: Ricardo estimates based on public domain information

Notes:

(1) Ricardo estimates

(2) Based on price list from Smiths Electric vehicles UK Price Guide, 2011 and exchange rate £1 = €1.2

(3) Based on price differential on Mercedes Sprinter Van and Ricardo estimate of additional cost for larger engines

(4) Ricardo estimate based on component costs and target battery costs

(5) Faber Maunsell, Fuel Efficiency Trials Research, conducted for Freight Best Practice, May 2008

(6) Freight Best Practice Scotland, Innovation in Scottish Timber Haulage: Tyre Pressure Control Systems (TPCS), April 2009

(7) Don-Bur

(8) Based on average cost of likely additional aerodynamic fairings from FleetOwner, Aerodynamics and trailers, March 2009; Freight Wing Fleet Trial Programme on Aerodynamic Fairings available at https://www.tc.gc.ca/programs/environment/ecofreight/casestudies; Freight Best Practice, Aerodynamics for Efficient Road Freight Operations, June 2007

(9) Estimates based on European Aluminium Association financial benefits simulator, available at: http://eaa.net/financialanalysis/financialanalysis.asp. Assumes 10% reduction in vehicle mass

(10) Ricardo estimate based on additional cost of adaptive cruise control and lane departure warning systems on passenger car as technology will use similar sensors and software

(11) Clean Air Power from Transport Engineer, Biogas beckons, 6th April 2010, http://www.transportengineer.org.uk/article/23601/Biogas-beckons.aspx

(12) http://www.tc.gc.ca/innovation/tdc/summary/14400/14431e.htm

Table 4.23: Technology Payback period by Vehicle Category

Technology	Payback Period (years)						
	Service Delivery	Urban Delivery	Municipal Utility	Regional Delivery	Long Haul	Bus	Coach
Pneumatic Booster – Air Hybrid	9.5	6.4	3.9	3.5	0.57	N/A	3.7
Electrical Turbocompound	125	83.3	50.7	18.5	5.87	38.9	19.4
Heat Recovery	137.7	91.8	55.9	30.5	5.8	42.9	32.1
Automated Transmission	12.5	8.3	5.1	15.4	7.9	3.9	16.2
Electric Vehicle	19.3	12.9	7.8	7.1	N/A	6.0	7.5
Stop / Start System	1.9	1.3	0.8	1.4	2.4	0.9	1.5
Full Hybrid	21.4	14.3	8.7	15.8	5.6	4.4	16.7
Flywheel Hybrid	4.2	2.8	1.7	3.1	3	1	3.2
Low Rolling Resistance Tyres	N/A	N/A	N/A	0.8	0.2	N/A	0.8
Single Wide Tyres	3.7	2.5	1.5	0.9	0.7	1.2	1.0
Automatic Tyre Pressure Adjustment	211	140	85.4	38.8	9.9	65.5	40.9
Aerodynamic Trailers / Bodies	N/A	N/A	N/A	2.1	0.8	N/A	N/A
Aerodynamics – irregular body type	N/A	N/A	N/A	0.9	0.4	N/A	N/A
Aerodynamic Fairings	N/A	N/A	N/A	7.8	7.4	N/A	8.2
Spray Reduction Mud Flaps	0.3	0.2	N/A	0.05	0.01	N/A	0.05
Light weighting	3.0	2.0	8.7	1.1	1.8	0.3	1.2
Controllable Air Compressor	N/A	N/A	N/A	0.9	0.3	N/A	1
Predictive Cruise Control	N/A	N/A	N/A	1.8	0.7	N/A	1.9
Dual Fuel	14.8	9.8	6	5.5	2	3.1	5.7
Alternative Fuel Bodies	N/A	N/A	6.8	6.2	2.4	N/A	N/A
Hydraulic Hybrid	23.6	15.7	6.4	N/A	N/A	4.9	N/A

As part of the scenario analysis, the additional environmental benefits that the technologies have to offer have also been considered as these may influence their rate of adoption. The environmental benefit analysis is a subjective qualitative assessment based on any differences in the maintenance and servicing requirements, manufacturing process and materials, noise impact and effect on noxious emissions. Ratings are based from 1 to 10 according to the following scale:

⇒ 1 = Worst = Technology will cause significant damage to the environment during production and disposal

⇒ 3 = Life-cycle environmental impact expected to be worse than incumbent technology

⇒ 5 = Neutral – new technology no better and no worse that incumbent technology

⇒ 8 = Life-cycle environmental impact expected to be better than incumbent technology

⇒ 10 = Best = Life-cycle environmental impact expected to be significantly less than incumbent technology

The rating for additional environmental benefit along with the key impacts the technology has are summarised in Table 4.24.

Table 4.24: Additional Environmental Benefits by Technology

Technology	Environmental Benefit Rating	Comment
Pneumatic Booster – Air Hybrid	6	Reduction of vehicle emissions during acceleration and hill climbing. Minimal additional components required. Less use of service brakes – less wear
Electrical Turbocompound	4	Additional components add to lifecycle CO_2, could result in neutral impact on noxious emissions
Heat Recovery	4	Additional organic fluids, might require special maintenance and training of service personnel. Increase in vehicle weight and manufacture required of additional components
Automated Transmission	5	Benefits of lower clutch wear, increased service intervals offset by manufacture of additional components
Electric Vehicle	7	Reduction in noise pollution and air quality emissions, but increased CO_2 in manufacture and recycling of batteries
Stop / Start System	5	Minimal impact
Full Hybrid	5	Increase in manufacture CO_2 with batteries and electric motors offset by improvement in noise, air quality emissions and lower wear on service brakes
Flywheel Hybrid	6	Less additional manufacturing effort than full hybrid, less wear on service brakes, no additional maintenance required, lower air quality pollutants
Low Rolling Resistance Tyres	4	Tyres difficult to recycle and with a potential lower life tyre change rates increase
Single Wide Tyres	8	Less scrap rubber, Bridgestone estimate 25% reduction in their GREATEC over twin tyres
Automatic Tyre Pressure Adjustment	5	Overall neutral benefit. Additional impact of system manufacture offset by increase in tyre life due to running at correct pressures
Aerodynamic Trailers / Bodies	5	Limited change to materials and processes already used in trailer manufacture
Aerodynamic Fairings	4	Additional energy required to manufacture these add-on components
Spray Reduction Mud Flaps	5	Limited impact – same material used in manufacture
Light weighting	8	Light weighting vehicle structure can result in ability to use lighter weight components elsewhere and smaller powertrain reducing air pollution
Controllable Air Compressor	6	Small additional impact from components required offset by noise benefits from declutching compressor rather than venting

Technology	Environmental Benefit Rating	Comment
Predictive Cruise Control	5	None over other GPS and cruise control systems
Dual Fuel	6	Much lower particulate emissions, quieter operation
Alternative Fuel Bodies	6	Quieter and smoother operation of body equipment, engine can also be switched off when vehicle is stationary
Hydraulic Hybrid	5	Requires additional components but reduces air pollution and reduces wear on service brakes

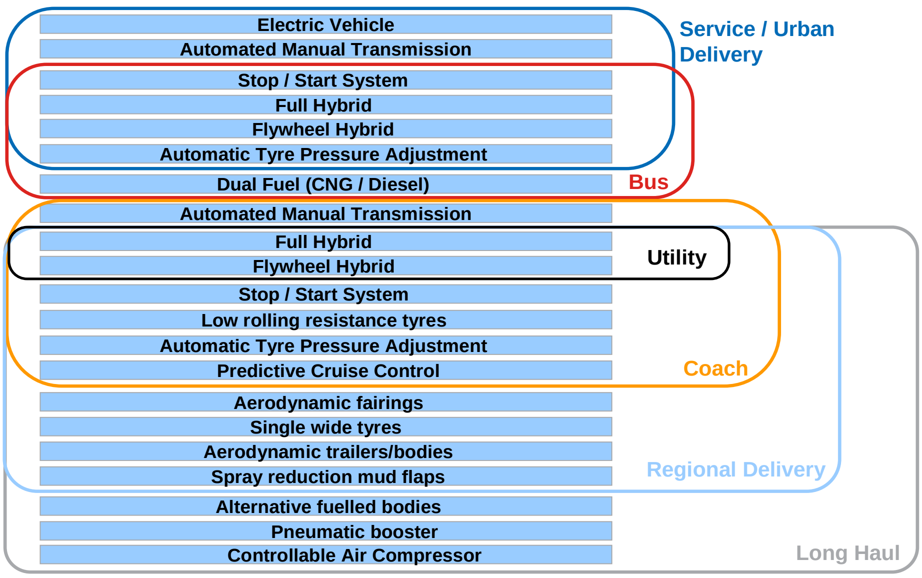
Common additional environmental benefits are the reduction in air pollutants from the use of less fuel, reduction in noise of operation and less wear on service brakes. The ratings provided enable a relative comparison of the different technologies, however for a better understanding of the full extent of the environmental impact a full lifecycle analysis would need to be conducted.

The payback periods of the different technologies for the vehicle categories, along with the additional environmental benefits of these technologies were then used to help select the technologies to be included for each vehicle type in the scenarios to be modelled.

4.5.3 Technology Scenarios

The two technology scenarios that were defined have been named "Cost Effective" and "Challenging". Figure 4-1 and Figure 4-2 highlight the technologies applied per vehicle category for each of these scenarios. The Cost Effective technology scenario includes technologies presented in Section 3.3 – Review of new and emerging technology, which in general have a payback of around 2 years along with some uptake of electric and hybrid vehicles by technology adopters. Rates of technology uptake are moderate and take into account the applicability of a technology to a particular mission profile and the maturity and likely commercialisation of the given technology.

Figure 4-9: Technologies selected by vehicle category for the Cost Effective scenario



The Challenging scenario assumes a higher degree of incentivisation to adopt fuel efficient technologies and covers all technologies which are likely to become commercialised in the considered time frame from 2010 to 2030 regardless of the additional on cost and pay back period with estimated fuel efficiency benefits. This scenario also includes higher rates of penetration of technologies which appear in the Cost Effective scenario, reflecting the influence that greater incentive is likely to have.

For each technology scenario the uptake rates of each technology have been defined for each vehicle category. For the Cost Effective scenario, the rate of natural improvement for conventional diesel fuelled vehicles in both powertrain and vehicle efficiency remains constant with that assumed for the Business as Usual scenario. For the Challenging scenario, the natural rate of improvement of powertrains for conventional diesel fuelled vehicles is at an increased rate as this assumes a greater focus on improved design such as reduction in friction, improved combustion and increased turbocharging as fuel consumption will be the main driver rather than cost. The BAU rates were summarised earlier in Table 4.17 and a comparison of the figures for the Cost Effective and Challenging scenarios is presented in Table 4.25. Technologies are modelled as those that improve engine efficiency and apply to new vehicles, those that improve vehicle efficiency and apply to new vehicles and those that improve vehicle efficiency and apply to the whole vehicle fleet.

Figure 4-10: Technologies selected by vehicle category for the Challenging scenario

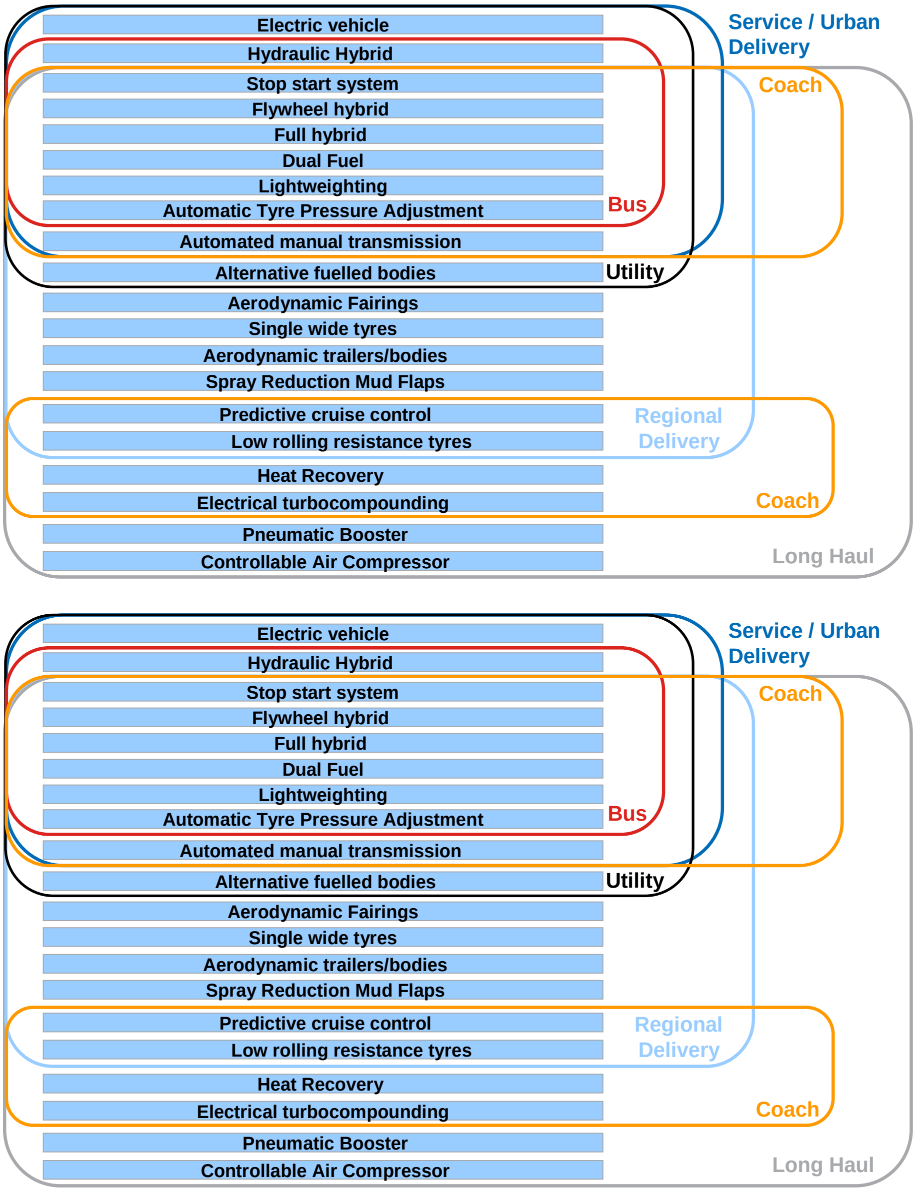


Table 4.25: Estimates on evolution of fuel consumption benefit (penalty) for base conventional diesel vehicles - figures indicate benefit/penalty compared to previous year

		2010	2013	2015	2018	2020	2025	2030
Cost Effective								
New Vehicle % powertrain natural improvement [a]	Truck	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
	Bus / Coach	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
New Vehicle % vehicle FC improvement	Long Haul Truck [b]	0.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	Coach [c]	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
	Bus [d]	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
% FC penalty from emissions legislation [e]	All	0.0%	-3.0%	0.0%	-3.0%	0.0%	0.0%	0.0%
Challenging								
New Vehicle % powertrain natural improvement [a]	Truck	0.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	Bus / Coach	0.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
New Vehicle % vehicle FC improvement	Long Haul Truck [b]	0.0%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
	Coach [c]	0.0%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
	Bus [d]	0.0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
% FC penalty from emissions legislation [e]	All	0.0%	-3.0%	0.0%	-3.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)

Notes: BAU scenario of fuel consumption of new vehicles - assuming no incentives or legislative CO_2 for HDV
(a) Natural improvement in powertrain efficiency includes transmission and engine auxiliaries
(b) Assume overall circa 10% reduction using vehicle aids by 2030
(c) Some aero improvements and weight reduction
(d) Forecast reduction in vehicle mass to increase fuel economy of vehicles - assume 1% reduction in weight every 5 years - 0.8% fuel consumption improvement every 5 years
(e) Penalty from increasing emissions legislation in 2013 and then potential Euro 7 around 2018

For the cost effective scenario, Table 4.26 summarises the technologies and uptake rates per vehicle category for powertrain technologies applied to new vehicles. Uptake rates of the cost effective scenario for vehicle technologies applied to new vehicles are summarised in Table 4.27 and uptake rates of vehicle technologies which are applied to the vehicle fleet are summarised in Table 4.29. For the Challenging scenario, technology uptake rates are summarised in Table 4.29, Table 4.30 and Table 4.31 respectively.

Table 4.26: Technology Uptake Rates and Benefits of powertrain technologies in new vehicles as estimated for the Cost Effective technology scenario

		Energy benefit:	Technology deployment into new HDV				
		% improvement vs conventional diesel	2010	2015	2020	2025	2030
% Natural Gas Vehicles [a]	Bus	-15.0%	0.8%	0.8%	0.8%	0.8%	0.8%
	Truck	-15.0%	-	-	-	-	-
% Dual Fuel	Urban Delivery	21%	0.1%	0.5%	1.0%	3.0%	5.0%
	Bus	21%	0.0%	1.0%	2.0%	5.0%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Electric Vehicles	Service/ Delivery (<7.5t)	70.0%	0.0%	0.1%	0.5%	0.8%	1.0%
	Urban Delivery	70.0%	0.0%	0.1%	0.1%	0.1%	0.1%
	Bus	70.0%	0.2%	0.2%	0.5%	0.8%	1.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

		Energy benefit:	Technology deployment into new HDV				
		% improvement vs conventional diesel	2010	2015	2020	2025	2030
% Hybrid (b)	Service/ Delivery (<7.5t)	20%	0.1%	2.0%	3.0%	5.0%	10.0%
	Urban Delivery	20%	0.1%	2.0%	3.0%	5.0%	10.0%
	Utility	20%	0.0%	0.0%	1.0%	3.0%	5.0%
	Regional Delivery	10%	0.1%	0.5%	2.0%	3.0%	5.0%
	Long Haul	7%	0.0%	0.1%	0.2%	1.5%	2.0%
	Bus	30%	0.1%	2.0%	4.5%	9.0%	18.0%
	Coach	10%	0.0%	0.1%	0.2%	1.5%	2.0%
%Flywheel Hybrid	Urban Delivery	15%	0.0%	0.1%	1.0%	4.0%	10.0%
	Utility	15%	0.0%	0.1%	0.9%	2.9%	5.0%
	Bus	20%	0.0%	0.1%	1.0%	4.0%	10.0%
	Coach	7.5%	0.0%	0.1%	0.9%	2.9%	5.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Stop Start [(c)]	Service/ Delivery (<7.5t)	6%	0.0%	20.0%	97.0%	95.0%	90.0%
	Urban Delivery	6%	0.0%	15.0%	96.0%	91.0%	80.0%
	Utility	6%	0.0%	0.0%	8.0%	20.0%	20.0%
	Regional Delivery	3%	0.0%	10.0%	90.0%	97.0%	95.0%
	Long Haul	1%	0.0%	1.0%	80.0%	98.5%	98.0%
	Bus	4%	0.0%	15.0%	94.5%	87.0%	72.0%
	Coach	3%	0.0%	1.0%	80.0%	95.6%	93.0%
% Automated Transmission	Service/ Delivery (<7.5t)	5%	2.0%	3.0%	5.0%	7.5%	10.0%
	Urban Delivery	5%	0.1%	2.5%	5.0%	7.5%	10.0%
	Regional Delivery	1.5%	0.1%	2.5%	5.0%	7.5%	10.0%
	Long Haul	1.5%	67.0%	77.0%	87.0%	97.0%	100.0%
	Coach	1.5%	0.0%	2.5%	5.0%	7.5%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Pneumatic Booster	Long Haul	3.5%	0.0%	0.1%	0.2%	0.5%	16.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Control Air Compressor	Long Haul	1.5%	1.0%	2.5%	10.0%	18.8%	30.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)

Notes: Cost Effective scenario of fuel consumption of new HDV - assumes incentives or legislative CO_2 for HDV
(a) Greater energy consumption for dedicated natural gas ICE (spark-ignition), similar or lower CO_2 emissions
(b) Greatest penetration in bus and urban settings where vehicles can deliver cost savings operators, long haul applications minimal
(c) Average benefit although maximum can be up to 30%. Implementation driven by air quality rather than CO_2 or fuel consumption. Technology common in new passenger car and expected to proliferate quickly across vehicles, already available on Mercedes Atego.

Table 4.27: Technology uptake rates and benefits of vehicle technologies as applied to new vehicles in the Cost Effective scenario

		Energy benefit:	Technology deployment into new HDV				
		% improvement vs conventional diesel	2010	2015	2020	2025	2030
% Predictive Cruise Control	Regional Delivery	5%	0.0%	0.5%	5.0%	11.0%	15.0%
	Long Haul	5%	0.0%	0.5%	5.0%	11.0%	15.0%
	Coach	5%	0.0%	0.5%	5.0%	11.0%	15.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Alternative fuelled Bodies[a]	Long Haul	15%	0.0%	0.5%	2.0%	3.6%	5.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Automatic Tyre Pressure Adjustment	Service/ Delivery (<7.5t)	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Urban Delivery	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Utility	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Regional Delivery	2%	1.0%	15.0%	50.0%	100.0%	100.0%
	Long Haul	3%	1.0%	15.0%	50.0%	100.0%	100.0%
	Bus	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Coach	2%	1.0%	15.0%	50.0%	100.0%	100.0%
% Aerodynamic Fairings	Regional Delivery	6.5%	80.0%	85.0%	95.0%	100.0%	100.0%
	Long Haul	5%	80.0%	85.0%	95.0%	100.0%	100.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)
Notes: Cost Effective scenario of fuel consumption of new vehicles - assuming some incentives or legislative CO_2 for HDV

Table 4.28: Technology uptake rates and benefits of vehicle technologies as applied to the vehicle fleet in the Cost Effective scenario

		Energy benefit:	Technology deployment into new HDV				
		% improvement vs conventional diesel	2010	2015	2020	2025	2030
% Low rolling resistance tyres	Regional Delivery	2.5%	20.0%	50.0%	80.0%	100.0%	100.0%
	Long Haul	5%	20.0%	50.0%	80.0%	100.0%	100.0%
	Coach	5%	20.0%	50.0%	80.0%	100.0%	100.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Single wide tyre	Regional Delivery	6%	0.1%	1.3%	2.5%	3.7%	5.0%
	Long Haul	5%	0.1%	1.3%	2.5%	3.7%	5.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Aerodynamic trailers / bodies	Regional Delivery	11%	0.0%	0.1%	1.0%	9.0%	20.0%
	Long Haul	11%	0.1%	1.0%	10.0%	15.0%	25.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Spray reduction mudflaps	Regional Delivery	2%	0.0%	1.5%	3.0%	5.0%	10.0%
	Long Haul	3.5%	0.0%	1.5%	3.0%	5.0%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Aerodynamics irregular body types	Regional Delivery	1.0%	0.0%	0.1%	1.0%	5.0%	10.0%
	Long Haul	0.4%	0.0%	0.1%	1.0%	5.0%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.29: Technology Uptake Rates and Benefits of powertrain technologies in new vehicles as estimated for the Challenging technology scenario

		Energy benefit: % improvement vs conventional diesel	Technology deployment into new HDV				
			2010	2015	2020	2025	2030
% Natural Gas Vehicles [(a)]	Bus	-15.0%	0.8%	0.8%	0.8%	1.0%	1.0%
	Truck	-15.0%	-	-	-	-	-
% Dual Fuel	Urban Delivery	21%	0.1%	2.5%	5.0%	7.5%	10.0%
	Utility	21%	0.1%	2.5%	5.0%	7.5%	10.0%
	Regional Delivery	21%	0.0%	0.2%	0.4%	1.0%	2.0%
	Long Haul	21%	0.0%	0.2%	0.4%	1.0%	2.0%
	Bus	21%	0.1%	2.5%	5.0%	10.0%	15.0%
	Coach	21%	0.0%	0.2%	0.4%	1.0%	2.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Electric Vehicles	Service/ Delivery (<7.5t)	70.0%	0.2%	0.5%	5.0%	10.0%	15.0%
	Urban Delivery	70.0%	0.2%	0.5%	5.0%	10.0%	15.0%
	Bus	70.0%	0.2%	0.5%	5.0%	10.0%	15.0%
	Utility	70.0%	0.0%	0.0%	0.3%	2.5%	5.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Hybrid (b)	Service/ Delivery (<7.5t)	20%	0.1%	2.0%	3.0%	5.0%	25.0%
	Urban Delivery	20%	0.1%	2.0%	3.0%	5.0%	25.0%
	Utility	20%	0.1%	2.0%	5.0%	10.0%	30.0%
	Regional Delivery	10%	0.1%	0.5%	2.0%	3.0%	10.0%
	Long Haul	7%	0.0%	0.5%	2.0%	3.0%	10.0%
	Bus	30%	0.2%	5.0%	8.0%	15.0%	40.0%
	Coach	10%	0.0%	0.5%	2.0%	3.0%	10.0%
%Flywheel Hybrid	Service/ Delivery (<7.5t)	15%	0.0%	0.1%	3.0%	10.0%	20.0%
	Urban Delivery	15%	0.0%	0.1%	3.0%	10.0%	20.0%
	Utility	15%	0.0%	0.1%	3.0%	10.0%	20.0%
	Regional Delivery	7.5%	0.0%	0.0%	1.2%	3.0%	10.0%
	Long Haul	5%	0.0%	0.0%	1.2%	3.0%	10.0%
	Bus	20%	0.0%	0.1%	3.0%	10.0%	20.0%
	Coach	7.5%	0.0%	0.1%	2.0%	5.0%	10.0%
% Hydraulic Hybrid	Urban Delivery	10%	0.0%	2.0%	5.0%	10.0%	200%
	Utility	15%	0.0%	2.0%	5.0%	10.0%	200%
	Bus	15%	0.0%	2.0%	5.0%	10.0%	200%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Stop Start [(c)]	Service/ Delivery (<7.5t)	6%	0.0%	30.0%	99.0%	97.0%	95.0%
	Urban Delivery	6%	0.0%	80.0%	89.0%	75.0%	40.0%
	Utility	6%	0.0%	3.0%	20.0%	20.0%	20.0%
	Regional Delivery	3%	0.0%	80.0%	97.5%	96.0%	88.0%
	Long Haul	1%	0.0%	5.0%	60.0%	97.5%	93.0%
	Bus	4%	0.0%	80.0%	84.0%	65.0%	20.0%
	Coach	3%	0.0%	5.0%	60.0%	93.5%	85.0%
% Automated Transmission	Service/ Delivery (<7.5t)	5%	2.0%	5.0%	20.0%	30.0%	50.0%
	Urban Delivery	5%	0.1%	5.0%	20.0%	30.0%	50.0%
	Regional Delivery	1.5%	0.1%	5.0%	20.0%	30.0%	50.0%
	Long Haul	1.5%	67.0%	77.0%	100.0%	100.0%	100.0%
	Coach	1.5%	0.0%	5.0%	20.0%	30.0%	50.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Pneumatic Booster	Long Haul	3.5%	0.0%	0.1%	1.0%	3.4%	6.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

		Energy benefit: % improvement vs conventional diesel	Technology deployment into new HDV				
			2010	2015	2020	2025	2030
% Control Air Compressor	Long Haul	1.5%	1.0%	10.0%	20.0%	30.0%	50.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Heat Recovery	Long Haul	5.0%	0.0%	0.0%	1.0%	4.0%	10.0%
	Coach	2.5%	0.0%	0.0%	0.1%	0.5%	1.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Electrical Turbo-compounding	Long Haul	3.0%	0.0%	0.0%	1.0%	4.0%	10.0%
	Coach	2.5%	0.0%	0.0%	0.1%	0.5%	1.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)

Notes: Challenging scenario of fuel consumption of new HDVs - assuming incentives or legislative CO_2 for HDV
(a) Greater energy consumption for dedicated natural gas ICE (spark-ignition), similar or lower CO_2 emissions
(b) Greatest penetration in bus and urban settings where vehicles can deliver cost savings operators, long haul applications minimal
(c) Average benefit although maximum can be up to 30%. Implementation driven by air quality rather than CO_2 or fuel consumption. Technology common in new passenger car and expected to proliferate quickly across vehicles, already available on Mercedes Atego.

Table 4.30: Technology uptake rates and benefits of vehicle technologies as applied to new vehicles in the Challenging scenario

		Energy benefit: % improvement vs conventional diesel	Technology deployment into new HDV				
			2010	2015	2020	2025	2030
% Predictive Cruise Control	Regional Delivery	5%	0.0%	0.5%	5.0%	15.0%	30.0%
	Long Haul	5%	0.0%	0.5%	5.0%	15.0%	30.0%
	Coach	5%	0.0%	0.5%	5.0%	20.0%	50.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Alternative fuelled Bodies[(a)]	Utility	15%	0.0%	0.5%	5.0%	7.5%	10.0%
	Regional Delivery	15%	0.0%	0.5%	5.0%	7.5%	10.0%
	Long Haul	15%	0.0%	0.5%	5.0%	7.5%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Automatic Tyre Pressure Adjustment	Service/ Delivery (<7.5t)	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Urban Delivery	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Utility	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Regional Delivery	2%	1.0%	15.0%	50.0%	100.0%	100.0%
	Long Haul	3%	1.0%	15.0%	50.0%	100.0%	100.0%
	Bus	1%	1.0%	15.0%	50.0%	100.0%	100.0%
	Coach	2%	1.0%	15.0%	50.0%	100.0%	100.0%
% Aerodynamic Fairings	Regional Delivery	6.5%	80.0%	85.0%	95.0%	100.0%	100.0%
	Long Haul	5%	80.0%	85.0%	95.0%	100.0%	100.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Light-weighting [(b)]	Urban Delivery	2.2%	0.0%	0.0%	4.0%	15.0%	30.0%
	Utility	4.7%	0.0%	0.0%	4.0%	15.0%	30.0%
	Regional Delivery	2.2%	0.0%	0.0%	4.0%	15.0%	30.0%
	Long Haul	2.2%	0.0%	0.0%	4.0%	15.0%	30.0%
	Bus	6.0%	0.0%	0.0%	4.0%	15.0%	30.0%
	Coach	2.4%	0.0%	0.0%	4.0%	15.0%	30.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	00%

Source: Estimates by Ricardo (2010)

Notes: Challenging scenario of fuel consumption of new vehicles - assuming some incentives or legislative CO_2 for HDV
(a) Alternative fuel bodies applied as a percentage of full hybrid vehicles
(b) Assumes a 10% reduction in vehicle weight over current vehicles

Table 4.31: Technology uptake rates and benefits of vehicle technologies as applied to the vehicle fleet in the Challenging scenario

		Energy benefit:	Technology deployment into new HDV				
		% improvement vs conventional diesel	2010	2015	2020	2025	2030
% Low rolling resistance tyres	Regional Delivery	2.5%	20.0%	55.0%	97.0%	100.0%	100.0%
	Long Haul	5%	20.0%	55.0%	97.0%	100.0%	100.0%
	Coach	5%	20.0%	55.0%	97.0%	100.0%	100.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Single wide tyre	Regional Delivery	6%	0.1%	1.3%	5.0%	7.4%	10.0%
	Long Haul	5%	0.1%	1.3%	5.0%	7.4%	10.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Aerodynamic trailers / bodies	Regional Delivery	11%	0.0%	0.5%	7.0%	24.0%	40.0%
	Long Haul	11%	0.1%	3.0%	12.0%	32.0%	60.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Spray reduction mud-flaps	Regional Delivery	2%	0.0%	2.0%	5.0%	10.0%	20.0%
	Long Haul	3.5%	0.0%	2.0%	5.0%	10.0%	20.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%
% Aerodynamics irregular body types	Regional Delivery	1.0%	0.0%	0.1%	1.0%	9.0%	20.0%
	Long Haul	0.4%	0.1%	1.0%	10.0%	15.0%	25.0%
	Other HDV	N/A	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Estimates by Ricardo (2010)
Notes: Challenging scenario of fuel consumption of new vehicles - assuming some incentives or legislative CO_2 for HDV

4.5.4 Scenario Modelling Results

Results of the scenario modelling are provided in comparison to the heavy duty vehicle fleet emissions as forecast in the Business As Usual scenario.

Both the Cost Effective and Challenging technology scenarios have a noticeable impact on the European heavy duty vehicle fleet greenhouse gas emissions. Table 4.32 summarises the reduction in direct GHG emissions over the BAU for both technology scenarios at 2020 and 2030. These results show that the Cost Effective scenario technology uptake can reduce direct GHG emissions of the Heavy Duty vehicle fleet by 2.5% by 2020 and by 6.2% by 2030 compared to the emissions forecast in the BAU scenario. For the Challenging scenario this increases to 5.1% by 2020 and 14.5% by 2030. The larger difference in fleet GHG reduction benefit in 2030 between the Cost Effective and Challenging scenarios comes from the take up of the more expensive technologies which are forecast to become commercially viable post 2015 and increased technology penetration rates in this timeframe. The majority of the additional benefit in reduction of GHG emission by 2020 comes from a more aggressive rate of uptake of similar technologies to those that feature in the Cost Effective scenario.

Table 4.32: Reduction of Direct CO_2 emissions by vehicle category compared to the BAU for the Cost Effective and Challenging scenarios

% Reduction between Scenarios	Benefit over BAU			
Vehicle / Mission Type	Cost Effective		Challenging	
	2020	2030	2020	2030
Service / Delivery (3.5 – 7.5t)	0.84%	1.39%	4.18%	16.31%
Urban Delivery / Collection	0.73%	2.54%	4.96%	18.59%
Municipal Utility	0.33%	2.31%	2.95%	12.32%
Regional Delivery / Collection	1.70%	4.40%	4.58%	10.40%
Long Haul	4.83%	10.49%	7.15%	17.35%
Construction	1.09%	4.60%	2.53%	8.14%
Buses	0.40%	3.64%	3.49%	17.85%
Coaches	2.51%	6.49%	4.00%	10.37%
TOTAL Trucks	**2.70%**	**6.38%**	**5.24%**	**14.46%**
TOTAL Buses & Coaches	**1.30%**	**4.86%**	**3.71%**	**14.64%**
Overall TOTAL	**2.53%**	**6.23%**	**5.06%**	**14.48%**

The greatest reduction in GHG emissions for the Cost Effective scenario is in the Long Haul vehicle segment where a maximum direct GHG emission benefit of 4.8% is achieved by 2020, increasing to 10.5% by 2030 over the BAU scenario. The lowest reduction in GHG emissions for the Cost Effective scenario is for Utility vehicles which only show a reduction of 0.33% by 2020 and 2.31% by 2030 over the BAU.

For the Challenging scenario, Long Haul vehicles show the greatest reduction in direct CO_2 emissions over the BAU to 2020 at 7.2%. By 2030 Urban Delivery vehicles show the greatest reduction in direct GHG emissions by 2020 with an 18.6% reduction over the BAU. The change in vehicles with greatest CO_2 reduction comes about from the initial high rate of technology adoption in the Long Haul segment and the later high uptake rates of hybrid and electric vehicles which are more applicable to urban vehicles and offer greater CO_2 benefits than the technologies applied to long haul vehicles. Minimum benefits in the Challenging scenario are for Construction vehicles, which in 2020 have a 2.53% reduction in direct GHG emissions and 8.14% reduction by 2030. GHG emission reduction is more limited in this vehicle type due to a mixed duty cycle and the use of irregular body types.

The variations in reduction of fuel consumption of the different vehicle categories result in a change in the relative contributions of the vehicle categories to fleet direct CO_2 emissions as shown in Figure 4-11. For the Cost Effective scenario, the largest improvement in vehicle fuel consumption is in the long haul vehicle category. For this segment the contribution to fleet direct CO_2 emissions reduces and remains around 37% rather than increasing to almost 39%. In contrast is the relative contribution from the Service/Delivery category which increases its relative contribution to fleet direct CO_2 emissions by 0.7% over the BAU. The other vehicle categories' contributions remain in line with that of the BAU.

For the Challenging scenario the larger reduction in GHG emissions from Long Haul and Urban delivery vehicles results in these vehicle segments reducing their contributions to fleet CO_2 emissions over the BAU by 1.5% for Long Haul vehicles and 0.2% for Buses and Urban Delivery vehicles. Construction and Regional Delivery both increase their contribution by 1% due to lower than average reduction in emissions whilst the other vehicle segments remain in line with the BAU.

Table 4.33: Development of New Vehicle Fuel Consumption – Cost Effective Scenario

Vehicle Type	Average Vehicle Fuel Consumption (l/100km, diesel equivalent)			% Reduction 2010 to 2030
	2010	2020	2030	
Service Delivery (3.5-7.5t)	16.0	15.3	14.6	8.8%
Urban Delivery / Collection	21.0	20.1	19	9.5%
Municipal Utility	55.2	56.1	53.0	4.0%
Regional Delivery / Collection	25.3	24.1	22.6	10.7%
Long Haul	30.6	28.9	25.9	15.4%
Construction	26.8	26.1	24.0	10.4%
Bus	36.0	34.3	30.8	14.4%
Coach	27.7	26.6	24.5	11.6%

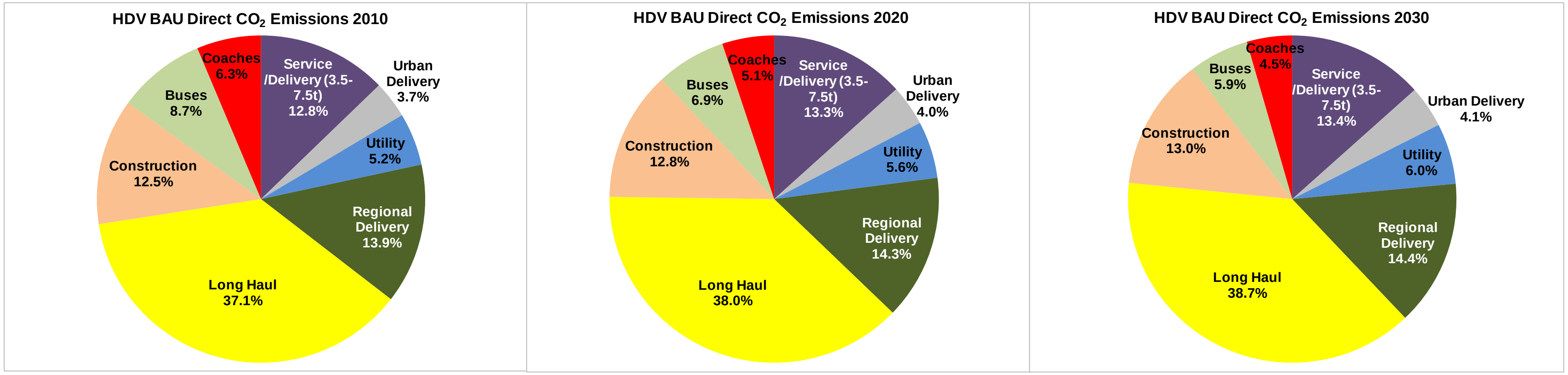
In terms of the impact on new vehicle fuel consumption this follows a similar pattern. Table 4.33 and Table 4.34 show the evolution of the average fuel consumption of each vehicle type. As expected for the cost effective scenario the greatest improvement in fuel consumption is for long haul trucks and for the challenging scenario for Service and Urban delivery vehicles. For the technology uptake rates as proposed in the cost effective scenario the average new vehicle fuel consumption can be reduced by 10 – 15% between 2010 and 2030. For the Challenging scenario this increases to 14 – 34% reduction with the largest fuel efficiency improvements for Buses and Long Haul vehicles.

Table 4.34: Development of New Vehicle Fuel Consumption - Challenging Scenario

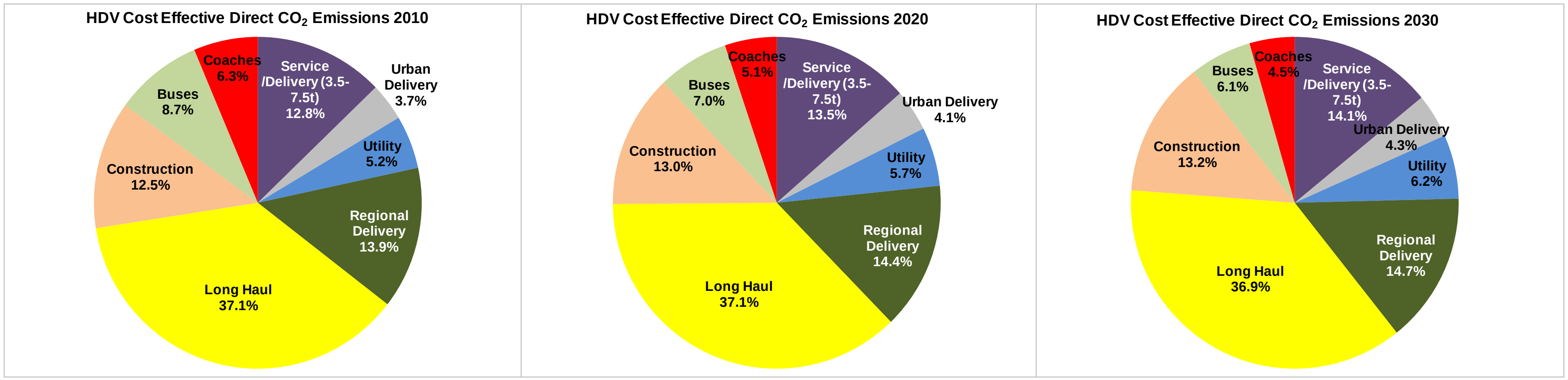
Vehicle Type	Average Vehicle Fuel Consumption (l/100km, diesel equivalent)			% Reduction 2010 to 2030
	2010	2020	2030	
Service Delivery (3.5-7.5t)	16.0	14.9	13.2	17.2%
Urban Delivery / Collection	21.0	19.5	17.1	18.5%
Municipal Utility	55.2	53.5	45.2	18.1%
Regional Delivery / Collection	25.0	23.4	21.2	15.3%
Long Haul	30.6	28.2	23.9	22.0%
Construction	26.8	25.6	22.9	14.5%
Bus	36.1	31.6	23.9	33.8%
Coach	27.7	26.0	22.6	18.4%

Figure 4-11: Direct CO_2 Emissions contributions by vehicle type

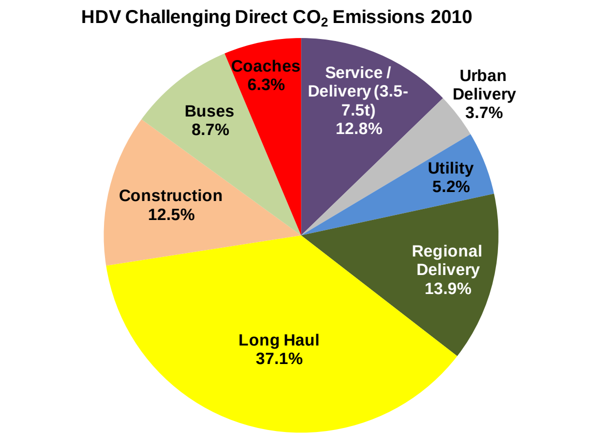
a) BAU Scenario

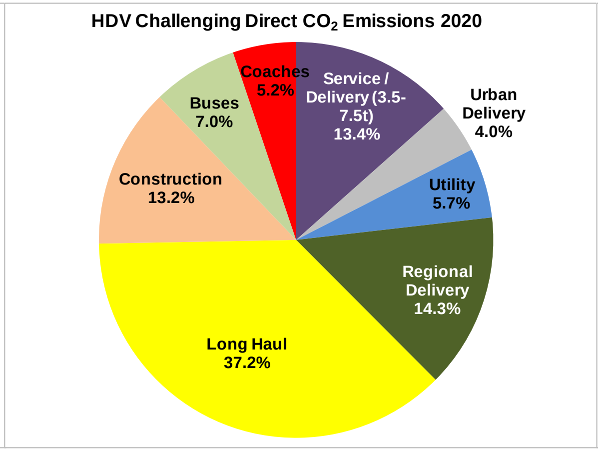


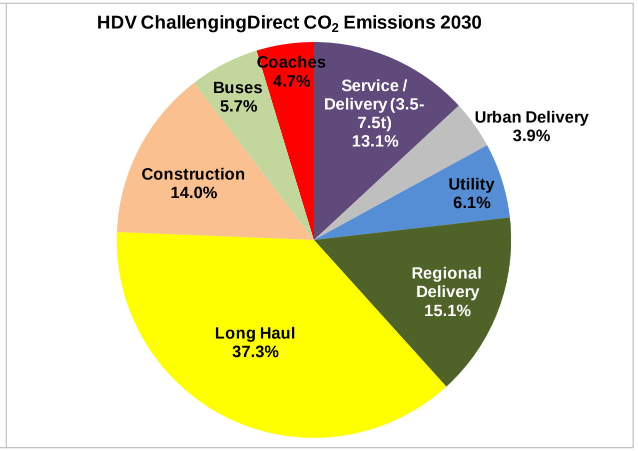
b) Cost Effective Scenario



c) Challenging Scenario







While the BAU scenario forecasts an increase in both lifecycle GHG emissions and direct CO_2 emissions between 2010 and 2030 of 7.9% and 14.7% respectively for the heavy duty vehicle fleet, the uptake of technology can limit the extent to which it does increase. As is shown in Figure 4-12 and Figure 4-13 an uptake of technology aimed at reducing vehicle fuel consumption has positive impacts at limiting the growth of GHG emissions from the heavy duty transport sector. For the cost effective scenario the increase in lifecycle GHG and direct CO_2 emissions can be reduced compared to the BAU and increase by only 1.1% and 7.5% over 2010 levels to 2030. However with the increased levels of technology penetration in the market as proposed by the challenging scenario both the lifecycle GHG and direct CO_2 emissions of the heavy duty vehicle fleet can be reduced below 2010 levels by 7.3% and 2% respectively.

Figure 4-12: Comparison of Lifecycle GHG emissions for BAU, Cost Effective and Challenging scenarios

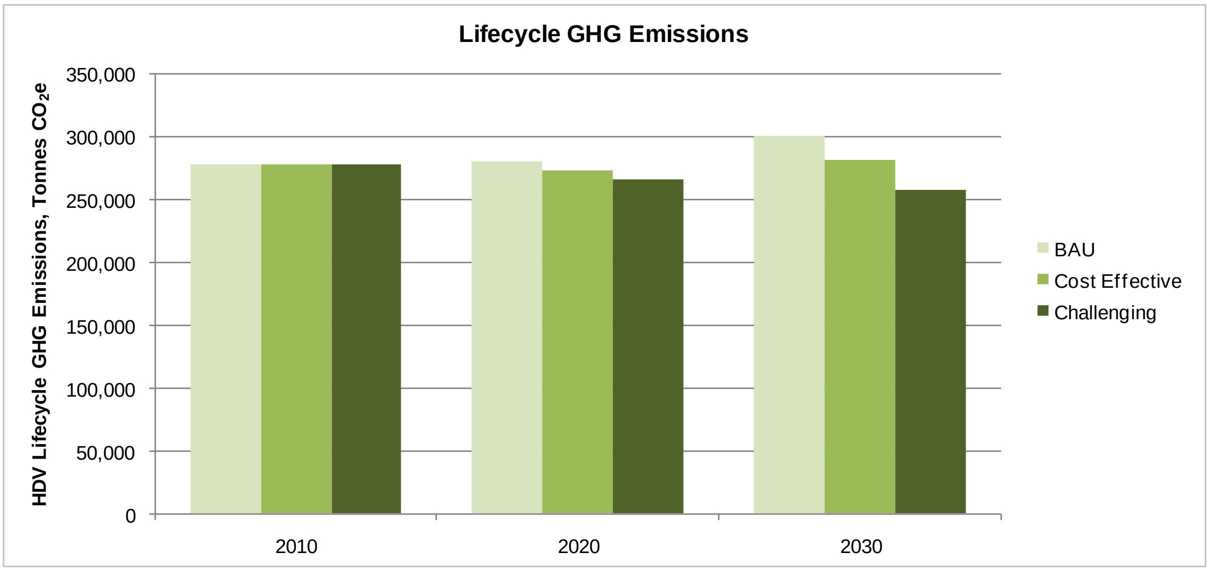
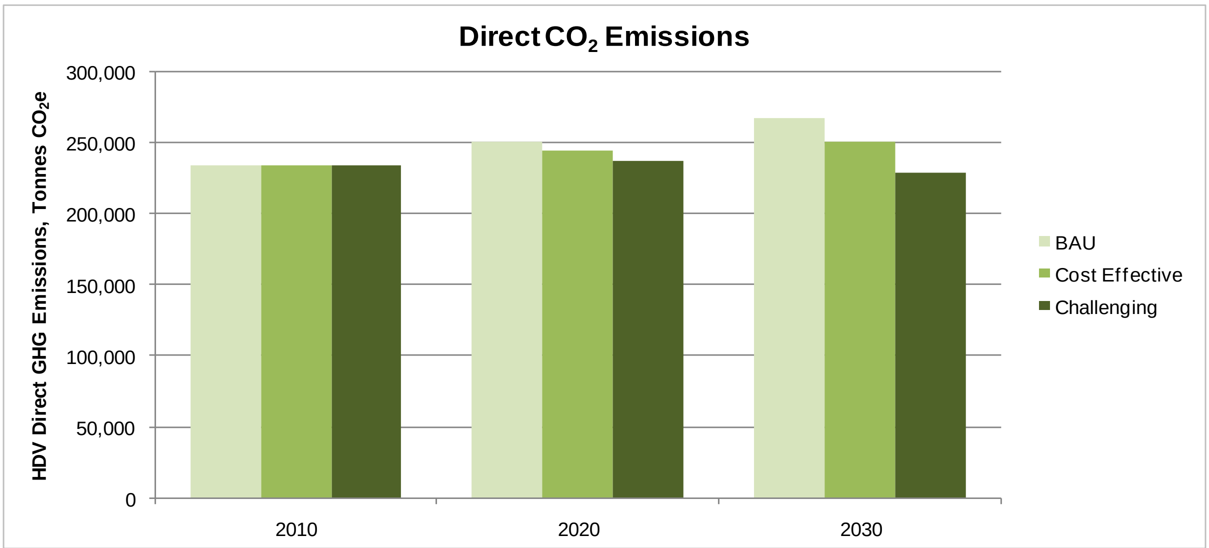


Figure 4-13: Comparison of Direct CO_2 emissions for the BAU, Cost Effective and Challenging scenario



These reductions in CO_2 emissions by 2030 over the BAU are based on estimates of average CO_2 benefit for each technology. Some technologies have a wide range of benefit that they can bring depending on the vehicle duty cycle. To provide some clarity of the possible variation in benefit from the two modelled technology scenarios a low case and a high case have been modelled. Assuming a normal distribution over the benefit range of any technology the low case provides an estimate of CO_2 reduction using the tenth percentile value whilst the high case uses the ninetieth percentile value for technologies where there is a range of benefit. For those technologies where there is little range there is no change to the estimated benefit. These percentile values have been chosen to represent the outer bounds of CO_2 reduction. Overall benefit as low or as high as these cases, however, is unlikely.

Table 4.35 shows the results of the scenario analysis using the high and low benefit cases against the original average scenario. Using the extremes of benefit has a relatively small impact on the overall fleet direct CO_2 emissions, resulting for the cost effective scenario in 3.9% higher CO_2 emissions for the low case and 8.8% lower emissions for the high case. For the Challenging scenario the variation is slightly greater with the low case having direct CO_2 emissions 5.4% higher than the average case and the high case 9.8% lower. This indicates that the uncertainty of the scenario analyses is within 10%.

Considering the reduction in direct CO_2 emissions over the BAU, as shown in Table 4.36, for the low and high case these vary between 2.6% and 14.5% for the cost effective scenario and 9.9% and 22.8% for the challenging scenario. For both scenarios the variation between the low and high case extremes is circa 12 percentage points. Average values are on the more conservative side closer to the low case than the high case.

Table 4.35: Variation in Direct CO_2 emissions for Low and High cases

Scenario	2030 Direct CO_2 emissions			% variation	
	Low	Average	High	Low to Average	High to Average
Cost Effective	261,058	251,264	229,028	3.9%	8.8%
Challenging	241,485	229,156	206,786	5.4%	9.8%

Table 4.36: Variation in reduction of Direct CO_2 emissions to BAU

Scenario	Percent Direct CO_2 emissions reductions compared to BAU		
	Low	Average	High
Cost Effective	2.6%	6.2%	14.5%
Challenging	9.9%	14.5%	22.8%

In order to halt the continual increase in the heavy duty vehicle fleet GHG emissions, high levels of fuel efficient technology are required as is demonstrated here by the Challenging scenario. While the uptake of currently cost-effective measures does go some way towards minimising the increase in emissions, higher levels of technology penetration are required than may today make commercial sense. Achieving the required levels of technology uptake will be challenging due to the conservative nature of the market, the importance of reliability and durability of vehicles and the increased cost. Technologies which can offer additional environmental benefits will help justify the business case for implementation.

5 Policy Assessment

Objectives:

The purpose of this task was to:

- To provide an assessment of selected policy instruments that could be used to reduce CO_2 emissions from HDVs, taking into account economic, social and environmental impacts, including rebound effects, such as the impact of lower fuel prices.

Outputs:

- An assessment of these selected policy measures in the form of a report providing summaries of all the policies identified for investigation, qualitative assessments of a short-list of policies agreed with the EC (summarised tables where possible) and a final prioritised list of instruments that could be taken forward by the European Commission to reduce GHG emissions from HDVS.

Task Lead: AEA

5.1 Context

The policy assessment undertaken in this task (Task 4) drew on existing evidence, where this was available; where appropriate, inferences are made. Additionally, the views of key stakeholders and experts were sought at appropriate stages, as set out below. Given the scope of the project and the budget available, the policy assessment that was undertaken under Task 4 was a relatively high level exercise, which consisted of a largely qualitative analysis, supported by a quantitative assessment where this is available.

The Commission's technical specification for this project set out some of the policy instruments that might usefully be covered by this task, including:

- Emissions trading, either as part of the EU ETS or as a stand alone system.
- Legislation to set performance requirements for vehicles, their components and trailers.
- Labelling of vehicles and/or components in order to enhance the transparency of the vehicle market.
- A monitoring system covering the performance of vehicles sold and fuel used in the EU.
- Strengthened programme for disseminating best practice to freight forwarders.
- Changes to existing weights and dimensions legislation.
- Reduction in the existing speed limitation for heavy duty vehicles.

This list was taken as the starting point for the analysis of Task 4. It was complemented with other policy measures that were also potentially relevant, such as those already in place in the EU and elsewhere as identified by Task 1.1 (see Section 2.3). A review was also made of policy instruments that are applied more generally in transport, e.g. to modes other than HDVs, in order to identify whether there were any additional instruments that could also be applied to HDVs. Finally, existing EU policy instruments that potentially act as a barrier to reducing CO_2 emissions from HDVs were also identified and included in the analysis. The collation and initial review of relevant reports was sub-task 4.1 and is reported upon in Section 5.2, below. The policy instruments of concern in this study are those that focus on the vehicle. Hence, policy instruments that could contribute to the decarbonisation of the fuels used by HDVs or instruments that focus on changing the infrastructure that vehicles used are not covered.

Even though the assessment being undertaken within this task was not a full Impact Assessment, the Commission's Impact Assessment (IA) Guidelines, which were revised early in 2009[30], were followed. Hence in this respect, the following approach was taken:

- Develop and assess a **long-list of policy instruments** that could be used to reduce the CO_2 emissions of HDVs (Stage 3 of the IA process). The aim of this stage is to identify a short-list of policies to be assessed in more detail. This was effectively sub-task 4.2 of this project and is reported upon in Section 5.3.
- **Assess this short-list of policy instruments** in more detail against environmental, social and economic criteria (Stage 4). This is sub-task 4.3 of the project and its results are presented in Section 5.4.
- Propose a **prioritisation of policy instruments** (Stage 5) and identify gaps in the knowledge that need further work was sub-task 4.4 and is presented in Section 5.5.

The assessment takes into account that the term HDV covers a wider range of vehicles that provide the economy and society with a wide range of functions. Hence, these vehicles are used differently and so it might be relevant to apply different policy instruments in order to deliver reductions in CO_2 emissions. For example, urban buses and inter-urban buses are used for different types of journey and are thus experience different driving conditions. Similarly, smaller freight vehicles used for urban distribution will face different driving conditions to larger vehicles primarily used for inter-urban freight -transport. Even within urban or inter-urban conditions, there is a wide range of vehicle types that are used differently (discussed in more detail in Section 2). Additionally, as was discussed earlier, fuel efficiency is an important consideration in the purchase of vehicles for commercial use, without any additional policy intervention. The market conditions within the EU are already a driver of fuel efficiency improvements. The challenge for policy intervention, therefore, is how best to complement and clarify the existing signals in terms of the need to reduce CO_2 emissions further.

So that the assessment was carried out in as transparent way as possible, clear references are made to the sources used.

In order to bring in some expert views into the project, key stakeholders and experts were consulted for their views on drafts of the work at important stages within the project. These consultations took place at the following stages:

- After the compilation of a **draft list of relevant reports** (i.e. sub-task 4.1; see Section 5.2) and **an initial assessment of the long-list of instruments**, i.e. Stage 3 of the IA process (sub-task 4.2; see Section 5.3). This involved stakeholders reviewing earlier versions of Table 5.1 and Table 5.2.
- After the first draft of the more detailed assessment of short-listed policies and proposed prioritisation, in line with Stages 4 and 5 of the IA process (i.e. sub-tasks 4.3 and 4.4, as covered in Sections 5.4 and 5.5).

This task was led by Ian Skinner, an associate of AEA, supported by AEA staff including AEA's project manager and technical experts, who also reviewed the work. In addition, Ricardo was consulted at various stages in the task with respect to the technical implications of the various policies being assessed.

[30] See the Guidelines themselves at http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_en.pdf and their annexes at http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_annex_en.pdf

5.2 Collation and assessment of existing reports and information

Objectives:

The purpose of this sub-task was to:

- *Build on sub-task 1.1 to collate and assess existing reports and information on heavy duty vehicle policy and legislative instruments.*

Summary of Main Findings

⇒ There are a range of reports looking at the potential implications of the introduction of various policy instruments on the CO_2 emissions of heavy duty vehicles.

⇒ These sometimes focus on a particular instrument in a particular context, e.g. the introduction of larger and heavier trucks in a particular country, or on a range of policy instruments at a higher, or summary, level.

⇒ Some reports have been produced in support of the policy making of the European Commission or other administrations, particularly in the US, while others have been produced for, or by, various different stakeholder groups.

⇒ Most reports focus on heavy freight transport, with significantly fewer looking at policy instruments for reducing CO_2 from heavy duty passenger vehicles.

Under Task 1.1 (see Section 2.3):

- A number of reports containing potential policy instruments for reducing CO_2 emissions from HDVs were collated, which contributed to the review of such policy instruments that are currently in place in the EU and elsewhere in the world under Task 1.1.
- Member States were asked to provide the project team (via a questionnaire) with examples of existing policies in place to reduce CO_2 emissions from HDVs, as well as copies of (or links to) any relevant reports.

This information was used as the basis for Task 4.1, but additional reports and information was collected. Additionally, relevant stakeholders and experts were contact in order to ensure that the project had taken account of all of the relevant reports. In this respect, stakeholders and experts were sent an earlier version of Table 5.1 for comment.

In addition to reports and information on policies that potentially reduce the CO_2 emissions of HDVs, this sub-task, as noted above, also covered:

- **Policy instruments that have been applied to other modes of transport** that could also be applied to HDVs. In this respect, the collation of existing reports also covered wider studies that cover policy instruments for reducing transport's CO_2 emissions more generally, for example of policy instruments, which could be applied to reduce the CO_2 emissions of HDVs.
- **Existing policies that currently act as a barrier to reducing HDVs CO_2 emissions**. Relevant studies were collated on legislation, such as existing weights and dimensions legislation, cabotage and the limitation of speed limits for example, which potentially act as a barrier to reducing transport's CO_2 emissions.

With respect to reports on policy instruments that have been applied more widely within the transport sector, it is recognised that the findings of such reports in relation to other modes, e.g. passenger cars, may not be directly applicable to HDVs. However, it was considered that it was still worthwhile to review some of these reports in case any policy instruments of relevant were identified.

The reports reviewed are listed in Table 5.1 together with an initial assessment as to their relevance to the evaluation of particular modes by policy instrument. Note that a number of other reports were also reviewed, but these did not provide evidence on GHG emissions or the potential application at the European level. Several of these additional reports, however, are relevant to the more detailed review undertaken in Task 4.3 (Section 5.4) and so are referred to there.

As noted above, Task 4.1 followed the approach proposed in the European Commission's IA Guidelines. The first two stages of the IA process are to identify the problem and define the objectives of any subsequent intervention. It was confirmed with the Commission that:

- The **problem that has been identified** is that CO_2 emissions from HDVs are increasing and need to be brought under control in light of economy-wide targets to reduce GHG emissions.
- The **objective of the policy intervention** that is being considered is to reduce CO_2 emissions from HDVs. Given that the project focuses on assisting the Commission, the policy instruments under consideration are also those that could **potentially be implemented at the European level**. These assumptions are reflected in Table 5.2, which was used in the assessment of the third stage of the IA process that was undertaken in Task 4.2.

Table 5.1: List and summary of reports reviewed under Task 4.1

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
HDV-specific reports											
H1	Faber Maunsell, NEA, CST and Newcastle University (2008) *Reducing Greenhouse Gas Emissions from Heavy Duty Vehicles*	HDVs	HDVs		HDVs, inc tyres	HDVs	HDVs	MBIs, including taxation, road user charging and ETS; HDV driver training		HDVs	
H2	NESCCAF et al (2009) *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions*	Long-haul trucks				Long-haul trucks		Note – measures implied, speed reduction is mentioned as having CO_2 reduction potential; concludes that regulation is likely to be necessary		Long-haul trucks	Note – measures implied, as the option is mentioned as having CO_2 reduction potential
H3	Akyelken, N (2010) *Policy Analysis for Sustainable Freight Transport and Economic Growth in UK and Ireland. University of Oxford. Working paper N° 1047. Transport Studies Unit School of Geography and the Environment.*		HGV – brief mention					Overview of SAFED (driver training)	Overview of rules – no explicit CO_2-realted statement		

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
H4	Ricardo (2009) *Review of Low Carbon Technologies for Heavy Goods Vehicles*							Contains no policy analysis			
H5	ECORYS and Ernst & Young (2006) *Study on Road Cabotage in the freight transport market* for DG TREN								For HGVs, gives an overview and implies CO_2 benefits		
H6	TML et al (2008) *Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC* for DG TREN									For HGVs, estimates CO_2 (and other) benefits	
H7	TRB (2008) *Safety Impacts of Speed Limiter Device Installations on Commercial Trucks and Buses*	Trucks, buses									
H8	McKinnon, A (2007) *Advice on CO_2 Emissions from the UK Freight Transport Sector*					HGVs		Driver training			
H9	Freight Vision 2009 *Management Summary and Relevance of policies*							User charging, e.g. Eurovignette	Summary of H5	Summary of H6	
H10	CE (2009) Are trucks taking their toll?							Focus on informing			

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							*Existing Policy Barriers to reducing HDVs CO_2 emissions*		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
								revision of Eurovignette Directive, so has external costs, etc			
H11	JRC 2010 Impacts of proposed Eurovignette amendment							Focus on impacts of proposed revision of Eurovignette Directive			
H12	Malczyk (2007?) The Influence of recent legislation for HVs on the risk of underrun collisions							Focuses on safety implications of vehicles			
H13	National Academy of Sciences (2010) *Technologies and approaches to reducing the fuel consumption of medium- and heavy-duty vehicles*	MDVs and HDVs	MDVs and HDVs			MDVs and HDVs	MDVs and HDVs	For HDVs, MDVs: Driver training; fuel taxes; ITS to improve flow		HDVs: Longer vehicles, increasing weight, size	
H14	Odhams et al (2009) *Factors Influencing the Energy Consumption of Road Freight Transport*							Relevant findings for traffic flow and charging		Relevant findings	
H15	Prog Trans (2010) *Internalisation of eternal costs: Relevant findings for traffic flow and charging*							Relevant findings for charging			

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
H16	SMMT (2010) *HGV ULC Strategy*						HGV	HGV: Compare ETS to charging			
H17	T&E (2010) *The case for the exemption of aerodynamic devices in future type approval legislation for HGVs*							HGV: Type approval legislation			
H18	OECD/ITF (2010) *Moving freight with better vehicles*	Trucks – only in relation to safety						Road pricing		Trucks	
H19	VITO (2008) Speed and fuel consumption HDVs in Belgium	HDVs									
H20	McKinnon (no date) Assessing the Economic and Environmental benefits of the Lorry Weight increase to 44 tonnes									HGVs – 44t in UK	
H21	RMI (2008) Transformational trucks									HGVs – Long combination	
H22	SDG (2009) Study of passenger transport by coach								Coaches – case study		
H23	MJ Bradley & Associates (2009 for ICCT) Setting the stage for Regulation of HDV fuel economy and GHG emissions	HDVs				HDVs				HDVs	

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							*Existing Policy Barriers to reducing HDVs CO_2 emissions*		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
H24	Interaction (no date) Acquisition assistance and help in determining measures							HGV: Driving behaviour; monitoring fuel usage; cleaner fuels/vehicles		HGVs	
H25	T&E (2010) Understanding the effects of introducing lorry charging in Europe							Effects of charging, e.g. Eurovignette			
H26	Rijkswaterstaat (2010) Longer and heavier vehicles in the Netherlands									LHVs for freight	
H27	Union of Concerned Scientists (2008) Delivering the Green				Trucks	Trucks		Also discussed retrofitting			
H28	McKinnon (2008) Economic incentives to reduce CO_2 emission from goods transport		Advice re trucks				Trucks	Internalisation of external costs; driver performance			
H29	Knight et al (2008) Longer and/or Longer and Heavier Goods Vehicles (LHVs) – a Study of the Likely effects if permitted in the UK										
H30	BEES (2010) *Technologies and approaches to reducing the fuel consumption of medium and heavy duty vehicles*, Board on Energy and Environmental Systems (BEES), National Research Council, USA.	HGVs	HGVs				HGVs	Also considers costs and benefits		HGVs	

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							*Existing Policy Barriers to reducing HDVs CO_2 emissions*		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
H31	Significance, CE Delft (2010) *Price sensitivities of road freight transport – towards a better understanding of existing results.*							Road pricing/tolling; fuel taxes		HGVs	
H32	Fraunhofer Institute (2009) *Long-term climate impacts of the introduction of mega-trucks*									HGVs / LGVs	
H33	KfV (2009) *Long and Heavy Vehicles (LHV): Auswirkungen auf das Autobahnen- und Schnellstra-Bennetz* (Impact on the highways and expressways networks)									HGVs / LHVs	
H34	BMVIT (2009) *Der Gigaliner: Auswirkungen auf den Kombinierten Verkehr in Osterreich* – Final report. (The Gigaliner – Impact n combined transport in Austria).									HGVs / LHVs	
H35	Bundesanstalt für Strassenwesen (BASt) (2006) *Auswirkung von neuen Fahrzeugkonzepten auf die Infrastruktur des Bundesfernstrassennetztes* (Impact on new vehicle concepts on the infrastructure of the national trunk road network). http://www.bast.de/nn_42642/DE/Publikationen/Download-Berichte/unterseiten/60-tonner.html									HGVs / LHVs	
General transport reports, with mention of HDVs											
M1	DfT (2009) *Low Carbon Transport: A Greener Future.*		HGVs					Driver training for HGVs,		HGVs – mention of	

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							*Existing Policy Barriers to reducing HDVs CO_2 emissions*		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
								buses and coaches; modification of bus operators grants		UK study on semi-trailers	
M2	ECMT (2007) *Cutting Transport CO_2 emissions.*					HDVs		Fuel efficient driving for trucks; km charging for trucks; awareness campaigns/VAs for trucks			
M3	IEA (2008) *Review of international policies for vehicle fuel efficiency. IEA Information Paper.*				Vehicles	Vehicles		Discussion was general, but referred to Japan for HDVs; also noted importance of financial incentives			
M4	ECMT ITF (2008) Transport and Energy: The Challenge of climate change					CO_2 standards for truck fleets	Freight	Listing of various policies for freight; taxes, charges, eco-driving, VAs			

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
M5	STEPS (2006) Transport strategies under the scarcity of energy supply					General: Need for regulation		All modes: Fuel taxes; focus is on general strategies; general policy findings			
M6	TRIAS (2008) Alternative pathways for energy and transport							General: Use of C tax; subsidies for alt fuels; general findings			
M7	INFRAS (2006) Cost effectiveness of GHG reduction in various sectors							HDV: Driver training;		HDVs: Increased weights	
M8	SwEPA (2008) Emissions trading and fuel efficiency regulation in road transport						Road Transport	Minor mentions of trucks; general comparison			
M9	Rommerskirchen et al (2010) Internalisation of External Costs: Direct impact on the economies of the individual EU Member States, and the consequences on the European road haulage industry, ProgTrans final report.							Internalisation of external costs.			
Other transport reports											
O1	UK ERC (2009) *What policies are effective at reducing carbon emissions from surface passenger transport?*										

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
O2	TNO, IEEP & LAT (2006) *Review and analysis of the reduction potential and costs of technological and other measures to reduce CO_2-emissions from passenger cars*				Cars	Cars		Cars – CO_2 based vehicle taxes; fuel efficient driving; public procurement			
O3	TNO, LAT and IEEP (2004) *Measuring and preparing reduction measures for CO_2 emissions from N1 vehicles,* for DG Environment				Vans	Vans		Vans – high level overview of range of policies			
O4	Skinner et al (2010) To*wards the decarbonisation of the EU's transport sector by 2050 - Final Report of the EU Transport GHG: Routes to 2050 project*, for DG CLIMA					General – all modes		Argued that a range of complementary policy instruments are necessary			
O5	World Energy Council (2007) *Transport Technologies and Policy Scenarios to 2050*							General overview of policy principles			
O6	German Advisory Council on the Environment (2005) *Reducing CO_2 Emissions from Cars*						Cars	For cars, VAs and CO_2-based vehicle taxes			
O7	WWF (2008) *Plugged in*							Focuses on electric vehicles, so mentions urban buses			

No	Report details, e.g. title, author, year	Policy instruments covered									
		In the context of reducing CO_2 emissions of…							Existing Policy Barriers to reducing HDVs CO_2 emissions		
		Reduction in speed for heavy duty vehicles	Programme to disseminate best practice	System to monitor performance of vehicles sold, fuel used	Labelling of vehicles, vehicle combinations or components	Regulation to set performance requirements for vehicles or their components	Emissions trading (stand alone or EU ETS)	Other, please state	Cabotage	Weights and dimensions legislation	Other
O8	McKinsey (2009) *Roads toward a low-carbon future: Reducing CO_2 emissions from passenger vehicles in the global road transportation system*							Focus on technology for cars; some high level policy options			

5.3 Development of a long list of policy instruments

Objectives:

The purpose of this sub-task was to:

Follow the third stage of the IA Guidelines by developing a long list of policy options that could address the problem of concern and assess for their potential for European application.

Summary of Main Findings

⇒ There are a number of policy instruments that have the potential to deliver significant CO_2 reductions from heavy duty vehicles, and which can be implemented at the European level.

⇒ However, in many cases the actual CO_2 emissions reductions that would result from the introduction of the respective instruments would depend on the detail of the instrument, including its ambition and, in many cases, the prevailing circumstances in which the instrument is introduced.

Task 4.2 followed the third stage of the IA Guidelines by developing a long list of policy options that could address the problem of concern, i.e. that CO_2 emissions of HDVs need to be brought under control. Each of these policy instruments was then assessed for its potential to be introduced at the European level in order to reduce CO_2 emissions from HDVs. A more detailed assessment, i.e. against a wider range of criteria, will be undertaken in Task 4.3 (see Section 5.4).

The reports collated under Task 4.1 were used to develop this long list of policy instruments. The assessments undertaken for Task 4.2 are presented in Table 5.2. The second and third columns of the table reflect the two main factors against which the assessment is taken, i.e. the potential of the policy instruments presented to reduce CO_2 emissions and the potential for it to be introduced at the European level. The fourth column assesses each instrument's potential to improve the monitoring and reporting of CO_2 emissions, which is important to measure the actual contribution of the respective instruments to reducing CO_2 emissions from HDVs. The next four columns evaluate the potential of the respective policy instruments to affect different types of vehicle, i.e.:

- Purchase of new vehicles – in this column an assessment is made as to whether the respective policy instrument has the potential to affect the type of new vehicles that are purchased.
- Emissions of existing vehicles – in this column, each instrument is assessed for its potential to affect, either the way in which vehicles are used or the emissions that would be emitted by the vehicle when it is used.
- Purchase of second hand vehicles – in this column an assessment is made of the potential for each instrument to affect the purchase of second hand vehicles.
- Different HDV categories – in this column, an initial assessment is made as to the potential types of HDV for which the respective instrument could be applied with the aim of reducing its CO_2 emissions.

In the sections below, a summary assessment of each instrument is presented, based on the review of the literature listed in Table 5.1. It should be remembered that the assessment undertaken in this section is only to identify whether the policy instrument could deliver CO_2

reductions from HDVs and whether it could be implemented at the European level. Hence, the literature has been reviewed, and is discussed below, in this context. Additionally, the conclusions of the previous study on reducing CO_2 emissions from HDVs (Faber Maunsell, 2008) are also presented for each instrument in order to ensure that the results of that assessment are included in this one. A more detailed assessment of the short-listed policy instruments, against a wider range of criteria, is undertaken in Task 4.3 (see Section 5.4). This includes an assessment of the economic impacts of the instruments, both to operators and regulators, as well as other environmental and social considerations, such as changes to the levels of other pollutants emitted and safety issues.

5.3.1 Emissions trading (stand alone or EU ETS)

On the basis of the literature reviewed, the assessment concluded that emissions trading should be included on the short-list for further assessment, as:

- The fact that there is already a European emissions trading scheme (EU ETS), which focuses on industrial plants although now also covers aviation, suggests that a scheme could be designed and implemented at the European level for HDVs.
- Theoretically, there is the potential for CO_2 emissions reductions to be delivered by the application of ETS, although whether this would happen in practice would depend on the design of the scheme.

A study for the Netherlands, suggested that tradable permits for transport had less than a 2% impact on CO_2 emissions, which was lower than other CO_2 reduction measures, but had a high level of cost-effectiveness, as did other instruments (COWI and ECN, 2003, quoted in ECMT, 2007). However, in terms of delivering CO_2 reductions from HDVs, the design of any ETS is fundamentally important. In a review of studies focusing on the use of ETS in the road transport sector as a whole, the Swedish EPA (2008) concluded that many of these concluded that ETS for transport would be feasible and cost-effective, if trading was upstream, i.e. at the level of fuel suppliers. However, it notes that, if similar levels of CO_2 reductions were required in a closed system than in the wider ETS, the cost of emissions reductions for road transport could be higher than other sectors, which might be politically difficult and would be economically inefficient. However, a closed system, which would only cover HDVs and have no links to other systems, has the potential to deliver greater CO_2 emissions reductions from HDVs than an open system, which is part of or linked to other ETS, all other things being equal. If consideration is given to an open system for HDVs, then the effectiveness of the wider system, i.e. the EU ETS itself, needs to be taken into account. The wider issues associated with the implementation of ETS for HDVs are covered in Section 5.4.2.

The previous report for the Commission on reducing CO_2 emissions from HDVs (Faber-Maunsell, 2008) noted that emissions trading could be an attractive option, although due to (unspecified) difficulties with the EU ETS suggested that a closed system might be appropriate. It also noted that the monitoring of small operators could be problematic.

An emissions trading scheme could be designed at a number of different levels, although as noted above the most cost-effective scheme would probably be an upstream scheme, i.e. targeting fuel suppliers. Such a scheme would increase the price of fuel and therefore affect how vehicles are used. In this respect it would apply to all HDVs when they are used. The feasibility and potential effectiveness of designing a scheme targeting only the fuel used by HDVs would need further assessment. Alternatively, it might be possible to design a scheme targeting, say engine or vehicle manufacturers, but this would require a significant amount of analysis and assessment in order to identify its potential effectiveness given the fact that engines emit CO_2 only when in use in combination with the other elements of the HDV.

5.3.2 Performance requirements for vehicles or their components

On the basis of the literature reviewed, the introduction of performance targets for vehicles or their components was included on the short-list because:

- It could be implemented at the European level. Indeed, if such requirements are to be implemented in the EU, they should be implemented at the EU level in light of single market concerns. Additionally, performance standards for air (i.e. non greenhouse gases) pollutants have been set at the European level for HDV engines and CO_2 performance standards are in place for cars, which shows that developing such standards at the European level is possible.
- Significant reductions in CO_2 emissions could be delivered, e.g. the Japanese legislation aims to deliver reductions of around 12% over 13 years (ICCT and NESCAFF, 2009). However, clearly the reductions that could be achieved would depend on the level of ambition of the requirements, which are linked to their cost-effectiveness.

COWI and ECN (2003, quoted in ECMT, 2007) concluded that in the Netherlands, CO_2 emissions standards for transport vehicles generally had more than a 5% impact on CO_2 and a high level of cost-effectiveness. Faber-Maunsell (2008) noted that developing a fuel efficiency standard for HDV engines was an "important area" where the Commission could influence improvements in propulsion technologies. It also noted that consideration would need to be given to the link to emissions standards for air pollutants. In order that such standards can be developed, it would be necessary to be able to measure the CO_2 emissions of HDV engines based on a standardised test procedure, as well choosing an appropriate metric that stimulates the required response on behalf of manufacturers and operators.

The purchase of new vehicles or their components would be the main focus of performance requirements. From the literature, the most useful initial focus appears to be on the engine, which could possibly be factored up to an entire vehicle using modelling or simulation. Standards could be developed for all types of HDV, but the standards, and potentially the metrics used, would need to recognise the different ways in which vehicles are used. Depending on the way in which the standard is developed, and its stringency, there might be implications on the vehicle second hand market. There is also the potential to apply standards to existing vehicles, e.g. by retrofitting aerodynamic accessories, as is done in California.

5.3.3 Labelling of vehicles, vehicle combinations or components

In the context of HDVs, labelling is less straightforward than it is for passenger cars, as HDVs are often assembled from various complements to the requirements of the eventual user. Hence, some components, e.g. engines and tyres, could be readily labelled to communicate their influence on fuel efficiency and CO_2 emissions. Providing a label for a vehicle or vehicle combination is more difficult, as the impact on fuel efficiency will depend on the way in which the various components work in combination. In order to reflect this difficulty, some stakeholders spoke of using the term "Certified Declaration of fuel-efficiency" instead of a label for HDVs and HDV combinations. In this report, the term "label" is taken more broadly to mean a way of communicating fuel efficiency to a user, which could cover certified declarations.

On the basis of the assessment, it was decided to include the labelling of vehicles, vehicle combinations or their components on the short-list of instruments, as:

- Labelling could be implemented at the European level, as there are already energy efficiency labels that have been implemented at the European level for a range of energy consuming products and for other products that influence energy consumption, e.g. EC Tyre Labelling Regulation 1222/2009 that is aimed at

promoting the use of low rolling resistance tyres. Additionally, from the perspective of the single market, implementing a label at the European level would be more useful than national or other measures.
- While not directly contributing to CO_2 reductions, labelling helps to overcome informational barriers by providing purchasers with information on the energy and CO_2 performance of vehicles or components, which could enable CO_2 reductions.

Faber-Maunsell (2008) proposed that labelling for HDVs could be developed as part of a three step process that first focused on the labelling of CO_2 emissions of HDV engines based on a standardised test procedure. This would be followed by labelling of vehicles for the overall efficiency of a whole vehicle combination in operation, probably with the aid of modelling, followed by the labelling of vehicle components, e.g. superstructures, trailers, etc. It proposed that engine labelling should be mandatory and that the others could be voluntary, at least initially. The report also made the link between labelling and regulation, as the information provided on a label could be used to develop a performance standard.

Labelling could be applied to new vehicles or components, and possibly to second hand vehicles or components, but this is likely to be more complicated. All types of HDV category could be targeted, but, as with performance standards, the label would need to recognise the different ways in which vehicles are used. There are potential synergies between labels and performance standards, as both would use information obtained from the same test or modelling procedure.

5.3.4 Programme to disseminate best practice

The assessment concluded that a programme to disseminate best practice should be included on the short-list of measures, as:

- Such a programme could be implemented at the European level, as similar programmes exist in the UK and US.
- Experience suggests that there is potential to achieve significant CO_2 emissions reductions through the use of vehicles and improved logistics, e.g. emissions reductions in practice in the UK and North America can be significant per company.

The dissemination of best practice includes not only information about vehicle performance and maintenance, but also sustainable logistics. This may include information on ‘smart freight’, such as ITS smartphone applications or via on-board units improving real-time route planning, load sharing, capacity sharing to reduce empty running and improve load factors.

ICCT and NESCAFF (2009) contained an overview of US EPA’s SmartWay programme, which brings together industry stakeholders to implement fuel savings and GHG reduction strategies. This programme aims to save between 33 and 66 million tonnes of CO_2 a year (as well as reductions in other pollutants). The US National Academy of Sciences (2010) reviewed experience with such schemes and noted that Canadian experience has delivered reductions in fuel consumption of 2% to 8% resulting from driver training. It also notes that this is consistent with English Freight Best Practice (FBP) case studies which have an average reduction of 5% and a range of 1.9% to 17%.

A similar initiative is currently being set up in the European Union, called Climate TransAct[31]. Climate TransAct aims to reduce the impact of freight transport on the environment and to help transport service providers and transport users see the rewards to their businesses. The initiative is based on the US SmartWay programme.

Faber Maunsell (2008) assessed the potential CO_2 emissions benefits of a “European HDV Operational Efficiency Programme” based on experience with the English FBP Programme.

[31] http://www.climatetransact.eu/index.html

It estimated that total industry emissions savings would be around 0.5% of GHG emissions, which was based on an extrapolation of English experience across the EU.

The main focus of programmes to disseminate best practice would be on the use of vehicles, but would also include vehicle maintenance and sustainable logistics. However, as awareness of the implications of best practice increases, there might be a knock-on effect on the types of vehicles that are subsequently bought, particularly if operators realise that another type or make of vehicle is actually more appropriate for their purpose. Programmes would have to recognise the different ways in which different types of HDV are used; best practice training and sharing would need to be tailored to the way in which vehicles are used.

From a practical perspective the question arises of how an EU-wide programme would be implemented and whether the scheme would be compulsory or optional. For example, an EU programme would have to be funded from somewhere, which could be funds diverted from the TEN-T programme, from Cohesion Policy funds, or other transport funding. Such considerations would have implications for the potential effectiveness of any scheme to deliver CO_2 emissions reductions.

5.3.5 Reduction in speed for heavy duty vehicles

The reduction of speed limits for heavy duty vehicles has been included on the short-list of policy instruments, as:

- It could be implemented at the European level by amending speed limiter legislation.
- It has the potential to deliver CO_2 emissions reductions of up to 5%, although the potential emissions reductions depend on the speeds prior to the reduction of the limit and the level to which the speed limit is reduced.

For long-haul trucks in the US, ICCT and NESCAFF (2009) suggested that for each mph reduced, a 1% reduction in fuel consumption can be delivered. Hence, the report concluded that reducing the speed limit to 60mph (96km/h) delivered a 5% reduction in fuel consumption/CO_2 reduction. This limit was chosen to minimise potential increase in traffic density. TRB (2008) quoted a Dutch study had estimated benefits of 5% in fuel savings from speed limiters. In a project for DG CLIMA, Skinner et al (2010) estimated reducing speed limits for HDVs from a current average of 87kph to 80kph would save 5.2MtCO_2e in 2030, which is equivalent to 1.4% of HDV's total greenhouse gas emissions.

Faber Maunsell (2008) noted that speed limits could be reduced in the EU for HDVs by amending Directive 2002/85, which sets restrictions for speed limiters to be fitted to HDVs. The report assessed the CO_2 benefits of limiting motorway speed limits for HDVs to 80kph (50mph), which would reduce speeds from the current average of 86kph. This concluded that would result in CO_2 emissions reductions "for all Long Distance HGV km" of 3.3%, which would deliver an overall parc reduction of 2.6% (5.3 million tonnes) of CO_2.

Speed limiters could be required in new vehicles and retrofitted in existing vehicles. They could potentially be fitted to all categories of HDV as all could potentially use major roads where high speeds are allowed. However, the most important application of speed limiters would be to long-distance HDVs, which are more likely to travel at higher speeds along major roads. However, an important consideration related to the use of speed limiters is the potential rebound effects associated with reduced speeds and the potentially wider effects on the economic system (see Section 5.4.5 for further discussion).

5.3.6 Changes to weights and dimensions legislation

Changes to existing weights and dimensions legislation for HGVs were included on the short-list of policy instruments to be assessed in more detail because:

- The weights and dimensions of HGVs are already regulated at the European level. Changes to this legislation would be necessary if changes were to be introduced if larger and heavier vehicles are to be allowed on cross-border operations.
- Studies suggest that there is the potential to deliver reductions in CO_2 emissions from allowing longer and heavier vehicles, or longer vehicles incorporating technical devices that have been retrofitted delivering CO_2 benefits (e.g. aerodynamic characteristics). The latter option could be undertaken without increasing the load capacity.

There are two aspects associated with potential changes to the weights and dimensions legislation to be considered:

- Changes to the weight and/or dimensions of the vehicle itself to enable increased carrying capacity; and
- Exemptions to the legislation in order to allow alterations to the existing standard lengths of vehicles, e.g. to improve their aerodynamics, without increasing the load capacity.

With respect to amending the weights and dimensions legislation to increase capacity, TML (2008) assessed the potential impact on CO_2 and other emissions of the introduction of Europe-wide long and heavy vehicles (LHVs; i.e. trucks having a length of 25.25m and weighing up to 60 tonnes) in the European Union. It concluded that allowing LHVs at least on European motorways would deliver CO_2 savings of 3.6% compared to BAU. (However, we understand that DG MOVE has re-commissioned this study, as a result of criticisms of the methodology used in TML (2008), including the consideration of rebound effects.)

In the US context, ICCT and NESCAFF (2009) evaluated the CO_2 benefits of various combinations of longer and heavier vehicles, one of which provided a 25% to 28% reduction in fuel consumption and CO_2 emissions, while several other combinations delivered reductions of more than 10%. The National Academy of Sciences (2010) concluded that increasing size and weight limits in the US could deliver fuel savings of up to 15% or more. OECD and ITF (2010) concluded that case study results suggest that higher capacity vehicles reduce the number of trucks on the road, thus delivering CO_2 reductions.

In the Netherlands, regular truck combinations are allowed to weigh 60 tonnes. An assessment of the impact of the use of such vehicles concluded that their use lowers CO_2 emissions per transported tonne by 11%, while the CO_2 emissions of the entire fleet would decline by 6% (Rijkswaterstaat, 2010). INFRAS (2006) estimated, on the basis of a model simulation, that increasing weight limits of trucks to 60 tonnes could deliver 4% savings in CO_2 emissions. However, a study to estimate the effects of changes to EU weights and dimensions legislation on the UK concluded that allowing the types of trucks assessed in TML (2008) in the UK would lead to increases in CO_2 emissions by between 0.52% and 1.35%, as a result of the modal shift that would result (Knight et al, 2008).

Austria's Federal Ministry for Transport, Innovation and Technology (BMVIT, 2009) suggested that allowing the use of LHVs is likely to stimulate a shift from the use of rail and other less CO_2 intensive modes to the use of LHVs on roads. This shift was estimated by the study to be accompanied by an increase in more than 200,000 tonnes of CO_2 emitted per year. If the use of LHVs were permitted in Austria, it is estimated that approximately three quarters of all traffic would be moved on roads, in contradiction to policies aimed at using more less CO_2 intensive modes both within Austria and internationally. Faber Maunsell (2008) did not cover this policy change in detail, due to the fact that TML (2008) had been commissioned.

It is also possible to improve the CO_2 performance of a vehicle by allowing exemptions to the weights and dimensions legislation with respect to the permitted lengths, e.g. to allow improvements in their aerodynamics, without allowing increases in the load capacity of the vehicles allowed. Aerodynamic drag is responsible for up to 40% of HGV fuel consumption when travelling at motorway speeds. T&E (2010) considered the pros and cons of a range of technical solutions that have a strong reduction potential of CO_2 emissions and fuel consumption in terms of aerodynamics. It concluded that including aerodynamic devices in the list of items to be excluded from lorry length measurements in the HGV type approval Directive would lead to the widespread application of devices, which would subsequently lead to reductions in CO_2 and cost savings for the industry. Fuel and CO_2 savings of 5% to 8% could be expected compared to the no-change scenario on a per-vehicle basis, representing a cost saving for long-distance operators of about €2,000 per year. The report makes a conservative estimate that 5-7MT CO_2 savings could be made by 2020, which is 3-4% of total HGV emissions.

5.3.7 Cabotage

As a result of the assessment of the relevant literature it was concluded that cabotage should not be included on the short-list of policy instruments. In the literature, there was no mention of CO_2 savings that might result from any changes to the existing legislation. In its study on road cabotage in the EU road freight market, Ecorys (2006) explored measures to reduce the amount of empty running and in this respect proposed that foreign hauliers should not be allowed to perform cabotage when they enter or leave a country with empty vehicles. However, given that in 2009 cabotage made up only 0.98% of road transport in the EU (see Table 2.12) and the relatively small proportion of these journeys that this rule would affect, it is unlikely that the total CO_2 savings from changing this rule would be significant. Hence, it is not proposed to assess this policy instrument in any more detail, although the potential change proposed by Ecorys could save some CO_2. In a study on cabotage for passenger transport, in concluding that there might be a benefit to opening up the occasional coach market to fully liberalised cabotage, SDG (2009) made no assessment of the impact on fuel use or CO_2 emissions.

5.3.8 Driver training

As a result of the review of the literature, it was concluded that driver training should be included on the short-list of policy instruments, as:

- European legislation requires professional drivers to hold a certificate of professional competence (CPC), which is attained through training. CPCs could require driver training to take account of fuel efficiency.
- UK experience suggests that there is the potential to deliver reductions in significant CO_2 emissions of up to 10% per vehicle (McKinnon, 2007)

Faber Maunsell (2008) also drew heavily on UK experience in their assessment, which concluded that implementing driver training as part of a fuel management programme could improve a fleet's fuel consumption by 5%. The report noted that this could be introduced through Best Practice Programme (see Section 5.3.4). Additionally, the report also noted that the CPC could be extended to include fuel efficient driving.

Driver training, as with the best practice programme, would directly affect the way in which vehicles are used, but could affect the purchase of new and second hand vehicles if increased awareness of fuel efficiency techniques leads to improved knowledge with respect to the types of vehicles that are used.

5.3.9 Fuel taxes

Fuel taxes are included on the short-list of policy instruments, as:

- Minimum rates are currently regulated at the European level, i.e. in the taxation of energy products Directive, which could be increased.

- There is the potential to reduce CO_2 emissions by increasing fuel taxes, but clearly the reductions that would be achieved by any increase would depend on the extent of the increase.

Increasing fuel taxes can be justified in a number of ways. For example, CE (2010) concluded that there is currently a gap between the costs incurred by trucks and the taxes that they pay, although only 4% of the total external costs from HGV transport are attributable to emissions of CO_2. However, McKinnon (2008) notes that applying the social cost of carbon advocated in the Stern report would require a doubling in the taxes on road haulage (all else being equal). Faber Mansell (2008) provided an overview of the energy products Directive, but did not reach any further conclusion.

5.3.10 Road user charging

Road user charging, specifically km charging for trucks, has been included on the short-list of policy instruments, as:

- The framework for such charging is set at the European level, e.g. in the Eurovignette Directive.
- Experience in Europe suggests that truck km charges can reduce CO_2 emissions by between 0.2% and 3.5% (ECMT, 2007).

JRC (2010) estimated the impact of allowing external cost charging for certain environmental impacts (not including CO_2 emissions) on selected corridors. This assessment concluded that allowing for such charging would lead to reductions in CO_2 emissions and fuel consumption from road freight of 8%. Faber Mansell (2008) provided an overview of the Eurovignette Directive, but did not reach any further conclusion. Whether road user charging is an appropriate instrument for reducing CO_2 emissions from HGVs will depend on the type, and extent of, its other impacts (see Section 5.4 for further discussion).

5.3.11 Differentiating purchase taxes or providing incentives

Possible changes to the price of HDVs by the differentiation of purchase taxes or the provision of incentives was included on the short-list, as:

- The use of incentives, in particular, is possible in order to provide incentives for the purchase of less polluting vehicles or components. IEA (2008) notes this with respect to all road vehicles, but could be applied to HDVs. Also, incentives could be used to stimulate retrofitting, in parallel to a best practice programme.
- Theoretically could assist with delivering CO_2 emissions reductions in spite of the fact that no studies were found that estimated the potential of applying either differentiated purchase taxes or incentives to HDVs.

The fact that no studies have really covered such instruments explicitly to date could be used as a reason to exclude the instruments from the short-list. However, given the references to the potential to use incentives in particular in parallel with other instruments, it was decided to keep the instrument on the short-list.

Table 5.2: High level assessment of the potential of policy measures to reduce GHG emissions from freight and passenger HDV vehicles

Policy instrument	Policy evaluated according to							Include on short-list for more detailed assessment
	Potential to reduce GHG emissions from *Demand / Supply*	Potential to be implemented at European level	Potential to improve monitoring and reporting	Potential to affect different types of vehicle				
				Purchase of new vehicles	*Emissions from existing vehicles*	*Purchase of second hand vehicles*	*Different HDV categories*	
Emissions trading (stand alone or EU ETS)	Demand, and indirectly supply (unless designed to target supply); reductions dependent on cap applied and approach taken	Potentially, as EU ETS in place and aviation has already been included	Monitoring, reporting and verification would be a fundamental element to any such scheme.	Could probably be designed to target new vehicles	An upstream system, e.g. targeting fuel suppliers, would target use of all vehicles directly	Not directly	Potentially (ideally?) applicable to all HDV categories	**Yes**, as potential to efficiently reduce emissions and could be used instead of, or complementary to existing legislation
Performance requirements for vehicles and their components	Supply; level of reductions would depend on level of ambition;; for example, Japanese legislation requires average reductions of just over 12% over 13 years	Potentially, as Euro standards for HDV engines and CO_2 performance standards for cars already in place; if performance standards are developed, should be at European level to preserve single market; legislation in place in Japan and under development in the US	A monitoring and reporting requirement could be introduced as part of the legislation, as CO_2 emissions would need to be measured.	Would be the main focus	Existing vehicles could be required to retrofit	Potential second order effects on second hand market? Would depend, at least in part, on whether the vehicle was going to be used for a similar application	Potentially applies to all types of HDVs, although different uses would need to be recognised by using an appropriate metric – e.g. CO_2 per tonne-km, or m^3-km or passenger-km.	**Yes**, as there appears to be technical options (to be confirmed by Task 3 of this project) that could deliver reduced CO_2 emissions, but which might not be introduced without legislation; new European legislation would probably be needed, potentially based on Japanese and/or US regulations.

Policy instrument	Policy evaluated according to							Include on short-list for more detailed assessment
	Potential to reduce GHG emissions from *Demand / Supply*	Potential to be implemented at European level	Potential to improve monitoring and reporting	Potential to affect different types of vehicle				
				Purchase of new vehicles	*Emissions from existing vehicles*	*Purchase of second hand vehicles*	*Different HDV categories*	
Labelling of vehicles, vehicle combinations or components	Demand, potentially supply indirectly if buying patterns change sufficiently; considered to work beneficially with other policy instruments	Common label at European level would be preferable (to different national labels) from the perspective of the single market. Labels have been used to communicate energy efficiency of other products, including cars. Energy labelling will already be mandatory for tyres from 2012, so further labelling of vehicles or components should be coherent with that approach.	Information on label could be used for the purposes of monitoring and reporting	Main focus would be new components or vehicles	Focus is on the purchase, so less relevant	Could be used on second hand vehicles or components, but more complicated - particularly if applied retrospectively.	Could potentially be applied to all HGV categories, but would need to take account of the different ways in which they are used (including duty cycles)	**Yes**, as could provide improved information to operators to complement other policy instruments. Could be particularly useful for trailers. Label may need to reflect performance under different use conditions/duty cycles to help in particular decisions at point of change in ownership.
Programme to disseminate best practice	Demand; reductions of around 5% per company, 0.4% industry wide; estimated by HDV type in absolute terms; potentially higher reductions, e.g. experience with US SmartWay Programme	Could be undertaken at European level; programmes exist in the UK and US	Potentially delivers examples of real-world savings, but would not contribute to comprehensive monitoring and reporting	Could influence purchase decision if awareness increases. Particular synergies with labelling.	Focus would be on the use of vehicles	Could influence purchase decision if awareness increases. Particular synergies with labelling.	Could potentially apply to all categories of HDV, but programme would need to recognise differences	**Yes**, as potential CO_2 reductions.
Reduction in speed for heavy duty vehicles	Demand; reductions of up to 3.3% by reducing to 80kph compared to current average. For each mph reduced, a 1% reduction in fuel consumption can be delivered. Therefore, a reduction from 65mph to 60 mph would result in a 5% reduction in fuel consumption/CO_2.	Could be introduced by amending speed limiter legislation	Limited	Speed limiters could be required	Speed limiters could be retrofitted or adjusted		All categories, although more relevant for those travelling longer distances at high speeds?	**Yes**, as potential CO_2 reductions could be achieved and could be implemented at the European level; impacts would need to be assessed

Policy instrument	**Policy evaluated according to**							**Include on short-list for more detailed assessment**
	Potential to reduce GHG emissions from *Demand / Supply*	**Potential to be implemented at European level**	**Potential to improve monitoring and reporting**	**Potential to affect different types of vehicle**				
				Purchase of new vehicles	***Emissions from existing vehicles***	***Purchase of second hand vehicles***	***Different HDV categories***	
Changes to weights and dimensions legislation	Supply; reductions of 3.6% estimated in EU for freight vehicles Demand; potential reductions of CO_2 up to 5-8% per vehicle when aerodynamic changes are made to the vehicle	Increasing weights and measures allowed wouldw need amendment to existing weights and dimensions legislation; in some Member States, larger trucks are used. Amendments to the existing legislation would allow be needed to allow exemptions for aerodynamic changes (without increasing capacity).	No	Would directly affect specification of new freight vehicles	Could potentially reduce the anticipated life span of existing vehicles	Possible indirect effects on second hand market?	Long-distance, larger trucks	**Yes**, as there is there is an apparent potential to reduce CO_2 emissions and could be taken forward by amending existing European legislation
Cabotage	Demand; total reductions limited from amending existing rules, as cabotage still less than 1% of EU market	Would need amendment to cabotage legislation	No	Would not affect purchase of new vehicles	Would affect trucks used for cabotage	Would not affect purchase of second hand vehicles	More likely to affect larger vehicles?	**No**, as impact from the perspective of CO_2 emissions; should be assessed as part of amendment to cabotage legislation
Driver training	Demand; could reduce a fleet's fuel consumption by 5%	Could be required by Driver Training Directive; driver training used as part of existing good practice programmes	No	Could influence purchase of new vehicles if awareness of fuel efficiency increases	Primary focus would be on use	Could influence purchase of second hand vehicles if awareness of fuel efficiency increases	Potentially relevant to all types of HGV	**Yes**, as appears to be a cost-effective means of delivering not insignificant CO_2 reducing emissions, which could be taken forward at the European level
Fuel taxes	Demand; level of reductions dependent on tax, external cost charging could reduce emissions by 8%	Within EU, minimum levels are set by energy products Directive; Member States apply taxes in excess of these levels to varying degrees.	No	Could influence purchase of new vehicles if awareness of fuel efficiency increases	Primary focus would be on use	Could influence purchase of second hand vehicles if awareness of fuel efficiency increases	Would apply to all vehicles, unless these were exempted	**Yes**, as benefits and complementary nature of fuel taxes often mentioned; higher rates would need an amendment to energy products Directive.

Policy instrument	**Policy evaluated according to**							**Include on short-list for more detailed assessment**
	Potential to reduce GHG emissions from *Demand / Supply*	**Potential to be implemented at European level**	**Potential to improve monitoring and reporting**	**Potential to affect different types of vehicle**				
				Purchase of new vehicles	***Emissions from existing vehicles***	***Purchase of second hand vehicles***	***Different HDV categories***	
Road user charges	Demand; level of reductions dependent on charge, external cost charging could reduce emissions by 8%	Would require changes to the Eurovignette Directive to achieve full benefits; HGV distance charging is applied in Germany, Austria, Czech Republic and Switzerland	No	Could influence purchase of new vehicles if awareness of fuel efficiency increases	Primary focus would be on use	Could influence purchase of second hand vehicles if awareness of fuel efficiency increases	Focus would be on (larger) vehicles used for long-distance freight	**Yes**, evidence from existing schemes suggests benefits. Note that amendments to charging framework are being taken forward within current amendment to Eurovignette Directive.
Vehicle purchase taxes or incentives	Supply; level of reductions dependent on tax; no evidence for impact on HDV emissions	Eurovignette Directive covers circulation taxes for trucks; does not currently cover purchase taxes and would not need amendment to allow incentives	No	Would influence purchase of new vehicles directly	Would target new vehicles	Could influence purchase of second hand vehicles as cost of new vehicles would be affected directly	Could potentially apply to any subset of vehicle	**Yes,** as could be combined with other mechanisms, e.g. best practice programmes.

5.4 Assessment of the impact of policy instruments

Objectives:

The purpose of this sub-task (4.3) was to:

- *Assess the policy instruments identified in Task 4.2 in more detail against a wider range of economic, social and environmental criteria in a manner consistent with the fourth stage of the IA Guidelines.*

Summary of Main Findings

⇒ Instruments that deliver CO_2 reductions by reducing the amount of travel undertaken by HDVs will also result in reductions of emissions of air pollutants, as less fuel will be used. This in turn delivers economic benefits in terms of fuel savings. Lower levels of traffic would also have benefits for noise and safety.

⇒ Some instruments have potential longer-term or indirect effects, which must be taken into account in the development of policy in order to ensure that CO_2 emissions reductions are the eventual impact of the policy.

⇒ Instruments that deliver CO_2 reductions by introducing CO_2 reduction technologies would also generally deliver reductions in emissions of air pollutants, as the emission of such pollutants is linked to the power used by vehicles. CO_2 reduction technologies generally reduce the power used by vehicles, and thus the quantity of other pollutants that are emitted.

⇒ Capital costs are likely to be increased by instruments that require the uptake of technologies that deliver CO_2 reductions, as these are generally more expensive and would add to the cost of a vehicle. Instruments provide different incentives in this respect.

⇒ The administrative costs associated with different instruments vary and are a factor that should not be overlooked in considering which instruments should be introduced to reduce CO_2 emissions from HDVs.

⇒ Instruments can be used together to either enhance beneficial impacts, e.g. labelling can be used to reinforce performance requirements or taxation, or address any rebound effects, e.g. instruments targeting demand can complement instruments that introduce less CO_2 intensive technologies, which could reduce the costs of use.

Task 4.2 identified a short list of policy instruments that could be implemented at the European level to reduce CO_2 emissions from HDVs. The aim of Task 4.3 was to assess these policy instruments in more detail against a wider range of economic, social and environmental criteria in a manner consistent with the fourth stage of the IA Guidelines. These criteria were derived from an assessment of the criteria proposed in the tables of Section 8 of the Impact Assessment Guidelines (i.e. Tables 1 to 3). The selected criteria are presented in Table 5.3.

In order to assess the criteria, a qualitative rating, i.e. “+3” for very beneficial according to the criteria, via “0” for neutral to “-3” for very detrimental, has been used. When rating criteria in this way, it is important to ensure that, for example, a “+2” rating on one policy has a broadly similar impact to a “+2” rating on any other policy. It is also important to be clear about what is meant when an impact is given a particular rating. As a positive rating is to be used when the impact is beneficial, there are clearly implicit assumptions with respect to what is considered to be beneficial, and what is considered detrimental. Consequently, broadly speaking a positive sign in Table 5.3 should be interpreted as follows:

- Environmental impacts: As emissions of air pollutants and noise are considered to be negative, a positive sign for either of these in Table 5.3 implies that the policy instrument being assessed would deliver **reductions in emissions** of air pollutants and noise.
- Social impacts:
    - Safety: Clearly, it is preferable for policy instruments to deliver safety improvements. Hence, a positive sign for safety implies that safety would be **improved** as a result of the introduction of the policy instrument.
    - Impacts on drivers: The “impacts on drivers” category attempts to capture other potential impacts on drivers in addition to any safety impacts, e.g. working hours or potential income. Consequently, a positive sign in Table 5.3 implies that the instrument would **be beneficial** to drivers, e.g. either improving their working conditions or their remuneration.
- Economic impacts: Increased costs, no matter where they are incurred, are considered to be negative, so a positive sign for these impacts implies that **reductions in costs** would be delivered by the respective policy instrument.

In terms of the assessment of scale, the rating that was used was as follows:

- +1/-1: Minor positive/negative impact, e.g. around 1%.
- +2/-2: Significant positive/negative impact, e.g. in the order of 5%.
- +3/-3: Major positive/negative, e.g. 10% or more.
- +?/-?: Positive/negative impact, the scale of which will depend on the ambition of the policy instrument.

Once the initial sign and scale (i.e. 1, 2 or 3) of the impact had been assessed within the evaluation of each instrument, the rating according to each criterion was compared across instruments, i.e. all of the safety ratings were compared. The aim of this was to ensure the ratings (both sign and scale) were comparable across all of the instruments.

While this assessment is largely qualitative, we have included quantitative data where possible, particularly where information on GHG reduction potential has been suggested by any of the information collated as part of Tasks 1.1 and 4.2. The impacts included in Table 5.3 reflect the impacts that have been raised in the review of previous studies and the consultation with stakeholders. Sections 5.4.1 to 5.4.11 provide a summary assessment of the impacts of each instrument.

5.4.1 Emissions trading scheme

As noted in Section 5.3.1, the design of an emissions trading scheme (ETS) scheme has a significant impact on its operation, not least on where emissions reductions occur. Of particular importance is whether a scheme is closed, i.e. it is a stand alone system not linked to any other scheme, or open in that it is linked to other schemes, such as the existing EU ETS that covers some industrial sectors and aviation. If heavy road transport was included in a closed scheme emissions reductions would occur in this sector, whereas if heavy road transport was included in an open scheme, say one linked to the EU ETS, emissions reductions would occur in whichever sector had the most cost effective reductions potential. Consequently, the distinction between a closed (or stand alone) scheme and an open (linked) scheme is made in the following discussion, as well as in Table 5.3.

An open scheme is generally considered to be more economically efficient, but would not necessarily reduce emissions from HDVs, in which case it would have implications for other economic sectors (see Section 5.5.1). SMMT (2010) considered that including goods transport by road in the EU ETS may be worthy of consideration if it is connected to vehicle usage (where traders would be the freight forwarders, common carriers, actual carriers and transport buyers, who all have major influences in CO_2 performance). The report considered that the link to the EU ETS was important is it enabled traders to trade with any other entity, not just those within the road transport sector.

The principal difference from the perspective of the heavy road transport sector that would result from the introduction of a closed or open ETS would be the sector in which emissions reductions would result. It is generally considered that it is more expensive to reduce CO_2 emissions in the transport sector than in other sectors. If this is the case, then the impact of the introduction of a closed or open emissions trading system would be significantly different. In an open system, emissions reductions would occur where these would be cheapest, which, as noted, is generally considered to be in other sectors of the economy. Consequently, the inclusion of heavy road transport vehicles into the EU emissions trading scheme would probably lead to more reductions being required in the other sectors covered by the scheme, rather than in the transport sector. In this case, the impacts of expanding this instrument to include heavy road transport would be felt largely in sectors other than the transport sector. Consequently, for many of the criteria assessed in Table 5.3 the impact on heavy road transport would be minimal, while the net impact would depend on the technologies that were introduced in other sectors to reduce CO_2 emissions.

However, even if there were, say, improvements in emissions of air pollutants and noise resulting from heavy road transport being included in an open scheme, these would occur at industrial locations, rather than on roads, so the impact in terms of the numbers of people affected is likely to be less. Similarly, the minimal impact on the transport sector would probably lead to minimal impacts on safety, drivers, and even capital and variable costs for the transport sector. Any capital costs that did occur would be in the sectors in which emissions reductions were stimulated.

On the other hand, the development of a closed ETS to cover heavy road transport would have more direct impacts on the transport sector compared to an open system that had the same level of ambition in terms of emissions reductions[32]. As changes in use of HGVs in particular are considered to be more cost-effective than technical changes, it is likely that the development of a closed ETS for heavy road transport would result in emissions reduction from more efficient use of transport, first, and then by technical improvements in the medium- to longer-term. Consequently, in the short-term, the impacts would be associated with more efficient use, i.e. reduced levels of emissions of air pollutants, reduced noise and improved safety, as a result of there being fewer vehicles on the road. Fewer drivers, or at least, fewer hours driving would be needed, which could have some implications for employment. In the short-term, the impact on capital costs would be minimal; the impact on variable costs would depend on whether the savings from using less fuel balanced the increased cost of the fuel resulting from the ETS.

Whether the scheme was open or closed, it would impose an administrative burden. Under the EU ETS, there are requirements to monitor, report and verify emissions, which fall on the trading entity. In a closed scheme, these requirements could be less rigorous than in the EU ETS, but some similar requirements would be needed. If the trading entities were transport operators, then the administrative burden on the transport sector resulting from either an open or a closed ETS could be high, particularly on SMEs. Alternatively, if fuel suppliers were the trading entity, the total administrative (and transaction) costs incurred by the ETS would be lower and indeed the administrative costs would not be incurred directly by the transport industry, but by the fuel suppliers (although these could be passed on to operators).

[32] Of course, if an open system had very high levels of ambition, it would eventually have an impact on the heavy road transport sector as the more cost effective reduction options in other sectors were taken up.

5.4.2 Performance requirements for vehicle or their components

Previous legislation to reduce the emission of air pollutants from HDVs has resulted in increased emissions of CO_2, which has led to talk about trade-offs between reducing the different types of pollutants. However, the quantity of air pollutants that are generally emitted is dependent on the technology used in the engine and, in general, emissions increase in proportion to the power developed. As the introduction of CO_2 reduction technologies on HDVs will generally reduce the power used by the vehicle, such technologies will lead to lower levels of air pollutants, including NO_X, being emitted.

The impact of the introduction of performance requirements on noise and safety will depend on the technologies that are introduced. However, there is scope for improvements to both depending on the technology that is introduced. Additionally, given that existing noise and safety standards will still have to be complied with, it is likely that there will at least not be any detrimental impacts in this respect. Some changes in the design of vehicles, or the technologies used by vehicles, might require some additional training for drivers.

It is likely that the introduction of performance requirements would increase capital costs, but the improved fuel efficiency associated with the new technologies should reduce the costs of use. For improvements with short pay back periods, operators would recoup the increased costs associated with the purchase of vehicles within a number of years. For improvements with longer payback periods, there would be an economic benefit to society overall from the introduction of performance standards, but individual operators might not experience an economic benefit from the use of a particular vehicle. In the latter instance, it might be the smaller operators that experience the impacts most significantly. However, the total costs to the industry as a whole would be reduced over the lifetimes of the new vehicles.

5.4.3 Labelling of vehicles, vehicle combinations or components

Labelling has the potential to help to overcome an informational barrier. The Union of Concerned Scientists (2008) suggest that this might be particularly relevant for smaller operators who may not be able to test their own vehicles.

As with the regulation of performance standards, labelling needs a standardised means of measuring CO_2 emissions from the labelled entities. Additionally, in order to be useful, labels would need to be relevant for the way in which the labelled entity would be used. A label might be more appropriate for individual vehicle components, whereas certified declarations of efficiency might be more appropriate for vehicles and vehicle combinations.

While fuel is a major factor in the operating costs of HDVs, and therefore fuel efficiency is an important factor in the choice of vehicles purchased, labelling has the potential to enable operators to make more informed purchase decisions, which might benefit smaller operators in particular.

There are few direct impacts of labelling. Rather, labelling should stimulate changes in behaviour, which would in turn lead to more efficient use of vehicles, and so to fewer emissions of air pollutants, less noise and savings in fuel costs. IEA (2008) noted generally that there might be synergistic results if labels are accompanied by appropriate standards and that labelling could also be effective when used with financial incentives.

5.4.4 Programme to disseminate best practice

The fact that there appears to be the potential for CO_2 reduction from the dissemination of best practice suggests that operators do not necessarily have the capacity or knowledge to optimise their operations with such programmes. The dissemination of best practice has the potential to improve the usage of vehicles, as well as encouraging business to identify the most appropriate vehicles, in terms of type, size and power, for their needs. The programmes could be supported by ITS applications that enable load- and capacity-sharing, and more efficient freight distribution, e.g. freight consolidation centres. Incentives can also be used in parallel to such programmes in order to further stimulate the purchase and use of less CO_2 intensive vehicles, e.g. differentiated taxes and road user charges, access restrictions, etc.

In addition to their potential to deliver CO_2 emissions reduction, programmes to disseminate best practice have the potential to deliver other benefits. If vehicles are used less and are better maintained, then emissions of air pollutants and noise could decline, and there could be benefits for safety. Operators taking up best practice should experience cost savings through both lower fuel use and potentially reduced capital outlay if vehicles are better maintained.

The main potential negative impact is on the level of resources needed to implement the best practice programme. This will depend on the way in which the programme is implemented and the level of training required. In order to implement such a programme at the European level, an assessment would need to be made of how best this would be done given that the recipients of the information would be local operators.

5.4.5 Reduction in speed for heavy duty vehicles

On the level of the individual HDV, it seems clear that a lower speed would reduce CO_2 emissions, as well as reducing emissions of air pollutants and noise, and deliver potential safety benefits, as well as potential benefits in terms of lower driver stress and less wear and tear on infrastructure. Additionally, there would be fuel savings, which would deliver savings in variable costs to operators.

However, reduced speeds could also increase travel times. This might stimulate some efficiency savings, but it could also mean that more trucks could be required to deliver a given amount of freight over a given distance on any day. ICCT and NESCAFF (2009) noted that "overly aggressive" speed limits would increase truck density and potentially impede flow. From the perspective of the operators, reduced speed limits would affect the efficiency of operations and so operators would take action to compensate for this. It has been suggested that experience in the US has shown that lower speed limits result in an increased demand for higher engine powers so that high average speed can be maintained. TML (2006) suggests that lower speed limits would increase the costs of road transport. Hence, in considering whether to reduce speed limits for HDVs, it will be important to identify whether there is a speed limit that the balances the potential costs and benefits and the extent to which trade-offs exist.

5.4.6 Changes to weights and dimensions legislation

As noted above, there are two possible ways of changing weights and dimensions legislation that might deliver CO_2 emissions reductions: allowing larger and heavier trucks in order to increase loading capacity; or making exemptions to the length limits of the existing legislation in order to allow aerodynamic improvements, without allowing for increases in loading capacity. Both of these changes would be to allow longer and/or heavier trucks, so this would largely apply directly to new vehicles, which would generally be used on longer-distance freight routes. There is a possibility, if operators are attracted to use these larger/heavier vehicles, that existing smaller trucks might be scrapped or put onto the second hand market earlier than they would otherwise have been if using new vehicles, which might affect the second hand market, at least in the short-term.

The aim of the first of the possible changes, which would result in increased loading capacity being allowed for inter-Member State journeys, is to take advantage of the perceived efficiencies of using larger vehicles. Where smaller vehicles are combined into longer combinations, existing vehicles, trailers, infrastructure can be used more efficiently (e.g. use of EMS concept). The use of combinations of existing loading units (modules) in longer and sometimes heavier vehicle combinations can be used on some parts of the road network –

know as the 'European Modular System' (EMS) without changes to the legislation[33]. However, currently these are not allowed to be used on international travel within the EU, although there is some dispute as to what is allowed by the existing legislation. The changes could also potentially apply to existing vehicles, whereby transporters will be able to add additional EU loading units to their vehicles. Therefore this requires the installation of a towing device at the rear end of semi-trailers, or in the case of rigid trucks, to connect the existing towing device to a dolly enabling towing of a regular sized semi-trailer. Although commonly used for long-haul operations, they are not restricted to doing so.

Whilst the studies mentioned in Section 5.3.6 have identified some of the potential CO_2 emission reduction benefits of allowing the use of LHVs (with increased capacities), there seems to be differences of opinion in the wider literature as to whether these benefits outweigh possible negative effects of LHV use, including costs associated with upgrading infrastructure and safety issues. Additionally, a regulatory structure would be needed that assured safety and compatibility with infrastructure (NAS, 2010). MJ Bradley (2009) also noted that the potential benefits would need to be weighed against potential disbenefits from reduced safety and increased damage to roads, as well as the implications for modal shift. From a review of the studies, a number of issues arise with respect to changing EU weights and dimensions legislation.

With respect to the impact of any potential modal shift, there is the issue of the extent to which the findings of the various studies are transferable, e.g. due to differences in respective rail freight markets (OECD and ITF, 2010). Studies for Austria (KfV, 2009) and the UK (Knight et al, 2008) suggested that there would be modal shift from rail to road as a result of allowing larger trucks, and thus increased CO_2 emissions, whereas other studies have concluded that there would be a net benefit in terms of CO_2 emissions from allowing such vehicles.

Second, within the literature there is some disagreement as to whether the use of longer and heavier vehicles will lead to increased costs associated with infrastructure repair and maintenance. INFRAS (2006) suggested that if a constant axle limit (e.g. of 8 tonnes) was maintained, then there would be no increased damage to road surfaces from the use of heavier vehicles. KfV (2009) concluded that allowing tractor-trailer combinations of up to 60 tonnes and 25.25m in length in Austria would need prior investment to upgrade the infrastructure. However, any upgrades would lead to improvements in the infrastructure's performance, leading to increased technical life and potentially cost savings in the longer term. In a study for Germany, BASt (2006) concluded that roads, bridges and tunnels would all need investment in order to facilitate the use of LHVs.

One of the potential issues relating to changing weights and dimensions legislation to increase capacities is the potential rebound effect that might eventually result from a measure that is effectively increasing the capacity of the road network to move transport around.

The second option to change the weights and dimensions legislation would be to allow exemptions to the length limitations in order to allow the fitting of aerodynamic devices without increasing loading capacity. This approach has the advantage that it would be

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33 To enable foreign transporters to compete on equal terms in Sweden and Finland (who had previously used longer and heavier vehicles prior to joining the EU), a compromise was reached to allow increased vehicle length and weight all over the EU on the condition that the existing standardized EU modules were used. This is the so-called European Modular System (EMS). The EMS, also referred to as "modular concept", is defined in Directive 96/53 EC, Article 4, § 4 (b) as follows: ***"the Member State which permits transport operations to be carried out in its territory by vehicles or vehicle combinations with dimensions deviating from those laid down in Annex I also permits motor vehicles, trailers and semi trailers which comply with the dimensions laid down in Annex I to be used in such combinations as to achieve at least the loading length authorized in that Member State, so that every operator may benefit from equal condition of competition (modular concept)."*** The EMS is a concept "invented" or first introduced by Directive 96/53. Neither 25,25m length nor 60t weight is mentioned in the Directive: those are national rules applying to Sweden and Finland only. Therefore each Member State remains free to allow different combinations of the existing standardized EU modules.

improve the operation and therefore fuel efficiency without increasing capacity, and so would reduce the risk of the adverse effects of the first option, e.g. impacts on modal split, potential rebound effects and infrastructure damage, that might result.

5.4.7 Driver training

The potential CO_2 benefits from driver training result from there being less fuel used, as a result of improvements in driving behaviour. As a result of the reduced fuel use, there would be reduced emissions of air pollutants, as well as savings in variable costs for operators resulting from lower fuel costs. Additionally, it is possible that improved driving behaviour would also have benefits on safety, noise and drivers' stress levels. The principal negative impact would be the cost of driver training, which might be noteworthy for small operators unless these are covered by government.

5.4.8 Fuel taxes

Fuel taxes are a transparent and efficient means of internalising societal costs of climate change and energy security, as well as reducing fuel consumption from transport. They offer incentives, require regulators to need less information and involve fewer unintended consequences than standards (NAS, 2010). ECMT (2007) notes that fuel taxes and specific fuel carbon taxes could have a powerful impact on emissions and that fuel taxes had lower implementation costs than substitute schemes, such as emissions trading. However, there are political problems with raising fuel taxes as a means of CO_2 abatement (NAS, 2010; ECMT, 2007). Additionally, fuel taxes could be justified for a number of different reasons, e.g. to deliver an estimated reduction in CO_2 emissions, to cover external costs or to reflect the social cost of carbon. SMMT (2010) suggested that the introduction of CO_2 taxation of all fuels would provide long term incentives for an increased market penetration of alternative fuels by reflecting their respective global warming potential, although they argued that the penalisation of diesel in wider transport policy should be avoided.

Oliver Wyman (2010) suggested that other issues, such as reliability, were becoming a higher priority than fuel efficiency for operators when purchasing a truck in Germany and some other countries. If operators prove to be less sensitive to fuel consumption in future, it might be appropriate to increase fuel taxes or kilometre charges in order to increase the incentive for fuel consumption.

Increasing fuel taxes reduces CO_2 emissions by reducing the use of vehicles and thus the amount of fuel that is consumed by the transport sector. Consequently, the reduced consumption of fuel would lead to lower levels of emissions of air pollutants, while lower traffic levels would have benefits for noise and safety. However, as fuel costs would increase, the variable costs of operators would increase, which could to some extent be overcome by the introduction of efficiency savings.

5.4.9 Road user charging

If road user charging reduces the amount of freight on the road network, there will be subsequent reductions in the emissions of air pollutants and noise, as a result of the lower levels of traffic. The revised Eurovignette Directive will allow Member States to internalise a part of the costs of air pollution and noise, so road user charging within the EU could contribute towards such benefits. Lower levels of traffic might also result in benefits for safety, contribute to reducing drivers' stress and result in less wear and tear on the road network. When road user charging is applied to a selected part of the road network, e.g. motorways and trunk routes, there is the potential for diversion of freight traffic onto other routes, which could have adverse impacts on these routes, in terms of safety, noise, emissions of air pollutants and congestion.

As road user charging directly affects the costs of transport, there is clearly the potential for wider economic impacts. The ProgTrans study (Rommerskirchen et al, 2010) concluded that, after having tested various scenarios, the internalisation of external costs in the European road haulage industry would lead to substantially increased costs for the road freight sector as well as the foreign trade economy. It argued that this would potentially affect European competitiveness and the internal aim of equal opportunities for economic development, employment and competitiveness. On the other hand, JRC (2010) concluded that the benefits of charging for external costs outweigh the limited negative impacts on individual operators.

5.4.10 Differentiating purchase taxes or providing incentives

The aim of differentiating purchase taxes according to CO_2 emissions, or of providing incentives for the purchase of less CO_2 intensive vehicles, is to change the purchase price of vehicles in favour of those that are less CO_2 intensive. The detail of the instruments differ, as an incentive would reduce the cost of less CO_2 intensive vehicles, whereas differentiating purchase taxes could also increase the cost of more CO_2 intensive vehicles, but the signal they provide is similar. With respect to HDVs, such an instrument is potentially more complex than applying it to cars, due to the range of different HDVs available, and the differences in the ways in which these are used. However, if performance standards or labelling can be devised for HDVs, then an incentive system could be devised, or purchase taxes could be differentiated, on the basis of the same approach and metric.

Both instruments should be technology-neutral and be designed to take into account the likely improvements in the fuel efficiency of the vehicle fleet, which would be at least partially stimulated by the instrument itself. Incentives are also likely to be more expensive than purchase taxes, and could be considered to be a subsidy, so they should be time-limited if they are used.

As reductions in fuel use would be expected to result from the introduction of more fuel efficient vehicles, emissions of air pollutants would also be reduced. From an economic perspective, incentives could partially offset the increased capital costs of less CO_2 intensive vehicles; however, these would generally be expensive for government. Differentiated purchase taxes could be designed to increase revenue to the government, or be introduced to be revenue-neutral.

Table 5.3: Assessment of the potential economic, social and environmental impacts of selected policy instruments that could be implemented at the European level to reduce CO_2 emissions from HDVs

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
Stand alone emissions trading scheme	A stand alone emissions trading scheme would ensure that CO_2 reductions occur in the heavy road transport sector. In the first instance, it is likely that CO_2 reductions would occur as a result of changes in the use of HDVs, which would in turn lead to reductions in the emission of air pollutants. In the medium- to long-term, it might be expected that CO_2 reductions would be delivered by developments in HDV technology. These would generally deliver reductions in emissions of air pollutants unless the engine technology is changed. **RATING: +?**	The likely short-term changes in the use of HDVs that would that result from the introduction of a stand alone scheme (see previous column) would deliver some benefits in reduced noise resulting from less use. The noise implications from any longer-term technical changes would depend on the noise characteristics of the technologies that are introduced, and these could be negligible, positive or negative. However, existing noise standards would have to be complied with. **RATING: +?**	Any initial reductions in use could deliver improvements in safety due to the fact of there being fewer vehicles in the road. In the longer-term, any safety impacts would depend on the CO_2 reduction technologies that were introduced. However, given that existing safety criteria would have to be met all the same, it is unlikely that there would be a negative impact on safety. **RATING: +?**	If the amount of trucks on the road declines, then fewer drivers might be needed, or those that are needed might be needed less. In the longer-term, any changes to the vehicle, engine or powertrain of an HDV resulting from an ETS scheme should not adversely affect the operation of an HDV. Some technologies, particularly alternative fuels, may require some training. **RATING: 0/-1**	In the first instance, there would little impact on capital costs, as changes in use would result in the short-term. In the longer-term, it is likely that capital costs would increase, as a result of the technologies that would need to be introduced to reduce CO_2 emissions in heavy duty transport vehicles. **RATING: -1**	There could be fuel savings in both the short- and longer-term, as a result of the introduction of a closed ETS. In the short-term, CO_2 savings would come from changes in use, i.e. lower fuel use, while in the longer-term, more efficient technologies would also reduce the amount of fuel required to transport the same amount of goods or passengers. Savings would be balanced against the reduction incentives introduced by the scheme, which could increase the cost of fuel. **RATING: -?/0/+?**	It is likely that administrative burdens for monitoring and policing emissions trading systems will be increased (BEES, 2010). Such costs would be incurred both by operators (or other trading entity) and government. The actual administrative burden would depend on the number of trading entities. Given the large number of HDV operators, the costs would be high if these were the trading entities; if fuel suppliers were the trading entities, then the administrative costs would be lower. **RATING: -?**	Other than the administrative infrastructure (see previous column) that would need to be put in place, there might be minor benefits for infrastructure resulting from lower use. **RATING: -1**	Experience with the EU ETS[34] suggests that monitoring, reporting and verification costs associated with smaller operators could be significant. If the ETS increased costs of new HDVs, then the impact on small operators would need to be assessed. However, if the fuel supplier were the trading entity, the impact on SMEs would only result from the increased fuel costs caused by the scheme, which could still be significant for smaller operators. **RATING: -1/-2**

[34] E.g. IMPEL (2007) "Options and Proposals for Consistency in the Implementation of the EU Emission Trading Scheme - Report 2: Good Practice in Regulating Small Installations"; see http://impel.eu/projects/emission-trading-options-and-proposals-for-consistency-in-the-implementation-of-the-ets

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
Integrating HDVs into the EU Emissions Trading Scheme	The integration of HDVs into the EU ETS is more likely to lead to emissions reductions in other sectors covered by the EU ETS, as opportunities for CO_2 reduction in the transport sector are generally considered to be more expensive than those that exist in other sectors. Any changes that did occur in transport would be more likely to affect use, than technical options. Consequently, there would probably be little impact on emissions of air pollutants from the transport sector. There might be reductions in air pollutants in other sectors, but this would depend on the technology that is used in whichever sectors the subsequent CO_2 reductions occur. **RATING: 0/+**?	As an open scheme is more likely to deliver CO_2 reductions in other sectors covered by the scheme (see previous column), the impact on noise would depend on the noise characteristics of the technologies introduced in these other sectors. However, existing noise standards would have to be complied with. **RATING: 0/+?**	As the CO_2 reductions, and therefore new technologies, would be expected to be introduced in other sectors, there is unlikely to be any significant road implications. **RATING: 0**	Given that any changes would be expected in other sectors, then it is unlikely that there would be a significant impact on drivers of the integration of HDVs into the EU ETS. **RATING: 0**	As the aim of ETS is to reduce CO_2 emissions, investments would need to be made to reduce CO_2 emissions, but these would be likely to be in sectors other than transport. Hence, the impact on the transport industry is likely to be minimal. **RATING: 0**	An adapted EU Emissions Trading Scheme including GHG emissions from transport could be an effective method of encouraging take up of fuel savings in commercial transport operation (Faber Maunsell, 2008), Indeed, an ETS scheme would deliver reductions primarily through fuel savings. However, given that most reductions resulting from the integration of HDVs in the EU ETS would be likely to happen in other sectors, any cost savings for operators would probably not be significant. **RATING: 0/+1**	It is likely that administrative burdens for monitoring and policing emissions trading systems will be increased (BEES, 2010). Such costs would be incurred both by operators (or other trading entity) and government. The actual administrative burden would depend on the number of trading entities. Given the large number of HDV operators, the costs would be high if these were the trading entities; if fuel suppliers were the trading entities, then the administrative costs would be lower. **RATING: -?**	Other than the administrative infrastructure (see previous column) that would need to be put in place, it is not obvious that there would be additional costs for physical infrastructure, as the impacts would largely be in other sectors. **RATING: 0**	Experience with the EU ETS[35] suggests that monitoring, reporting and verification costs associated with smaller operators could be significant. If the ETS increased costs of new HDVs, then the impact on small operators would need to be assessed. However, if the fuel supplier were the trading entity, the impact on SMEs would not likely to be significant given the likely low impact on the transport sector as a whole. **RATING: 0/-2**

[35] E.g. IMPEL (2007) "Options and Proposals for Consistency in the Implementation of the EU Emission Trading Scheme - Report 2: Good Practice in Regulating Small Installations"; see http://impel.eu/projects/emission-trading-options-and-proposals-for-consistency-in-the-implementation-of-the-ets

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
Performance requirements for vehicles and their components	The quantity of many air pollutants emitted is dependent on the technology used in the engine and, in general, increase in proportion to the power developed. Vehicle-based CO_2 –reduction technologies that reduce the power used by the vehicle would also deliver reductions in absolute emissions of air pollutants if the engine technology is not changed. **RATING: +?**	The impact on noise levels would depend on the performance requirements introduced for vehicles and their components. These would determine the type of technology required, which in turn, would impact on noise emissions. Some measures to reduce CO_2 could also reduce noise. Additionally, noise legislation covering HDV components would still have to be complied with, so it is unlikely that there would be an adverse impact on noise. **RATING: 0/+?**	The impact on safety will depend on the performance requirements introduced for vehicles and their components. There is the potential for some measures to improve safety. Given that safety standards would have to be complied with, it is likely that performance requirements would not adversely affect safety. **RATING: 0/+?**	Any changes made to the vehicle, engine or powertrain of an HDV resulting from the introduction of performance standards should not adversely affect the operation of an HDV. Some technologies, particularly alternative fuels, may require some training. **RATING: 0**	The use of fuel efficiency standards will increase purchase prices of HDVs (incremental cost of compliance). (M.J. Bradley Associates LLC, 2009). In particular, the cost of trailers might increase. **RATING: -2?**	Making performance requirements for vehicles and their components mandatory would encourage manufacturers to take advantage of proven technology to reduce fuel consumption. This would mean that vehicles would use less fuel in order to do the same work/carry the same load, delivering savings in annual fuel costs for the vehicle owner (M.J. Bradley Associates LLC, 2009). Benefits accrue over time, as opposed to one-off, upfront capital costs. **RATING: +?**	A monitoring system would need to be set up in order to assess and report on progress, as with Regulation 443/2009 on passenger cars. **RATING: -2**	It is not likely that there would be any direct significant cost implications for infrastructure, as the size and weight of vehicles would not be affected. **RATING: 0**	Independent owners or SMEs may be constrained in their ability to purchase newer, more efficient vehicles due to limited access to capital funds (M.J. Bradley Associates LLC, 2009). Small operators may be less likely to be able to benefit from the subsequent fuel savings. **RATING: -1**
Labelling of vehicles, vehicle combinations or components	This policy instrument is aimed at enabling the purchaser to buy the most efficient and clean vehicle. With this information available to potential buyers, reductions in air pollutant emissions may be achieved as an indirect impact, but this would depend	No direct impacts; indirect impacts would depend on impacts of parallel policies, e.g. emissions performance standards (see above). **RATING: 0**	No direct impacts; indirect impacts would depend on complementary policy instruments. **RATING: 0**	No direct impacts; indirect impacts would depend on parallel policy instruments. **RATING: 0**	No capital costs associated with this instrument. **RATING: 0**	If more efficient vehicles were purchased as a result of vehicle/component labelling, then fuel consumption is likely to be reduced across the fleet. **RATING: +1**	Setting up the labelling scheme would require some administrative costs to Government, vehicle manufacturers and distributors. Costs may also be incurred when monitoring the	No infrastructure (other than administrative infrastructure) associated with this instrument. **RATING: 0**	SMEs may be able to benefit from the existence of labelling schemes as they are able to identify the most fuel efficient vehicles to purchase. **RATING: +1**

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
	on the technologies used (as above). **RATING: 0**						effectiveness of the scheme. **RATING: -1**		
Programme to disseminate best practice	The anticipated reduced demand for fuel (see Table 5.2 in Section 5.3) would deliver reductions in air pollutants, as well as reduction in CO_2 emissions. **RATING: +1**	Best practice can result in the more efficient use of vehicles, which could lead to reductions in noise if fewer vehicles are subsequently used. **RATING: +?**	If HDVs are driven better and less as a result of the uptake of best practice, then there might be beneficial impacts on safety. **RATING: +1**	It is not clear whether there would be any additional impacts on drivers resulting from the uptake of best practice. **RATING: 0?**	No direct capital costs, but capital costs may be incurred if there is a realisation that other vehicles better suit the needs of a particular operator. On the other hand, improved maintenance may reduce the need for as much capital outlay. Any increased costs should be recuperated through savings in fuel consumption over a longer period of time. **RATING: 0**	The savings noted in Table 5.2 (Section 5.3) result from the use of less fuel, so there would be cost savings as a result. Additionally, best practice could deliver other cost savings, e.g. if vehicles are better maintained. **RATING: +1**	Costs associated with producing the materials to disseminate best practice and any training required. Costs will also be incurred in monitoring the impact of the best practice dissemination. **RATING: -1**	There might be benefits in terms of reduced wear and tear, if vehicles are used less, as a result of the uptake of best practice. **RATING: +1**	SMEs are likely to benefit from programmes to disseminate best practice, as they would be provided with free materials to enable them to reduce their operating costs (and environmental impacts). **RATING: +1**
Reduction in speeds for heavy duty vehicles	As noted in Table 5.2 in Section 5.3, reducing the speed limit of long-haul trucks has the potential to result in savings in fuel consumption, and therefore emissions of air pollutants should also decline. Where speeds are reduced from 86.3kph to 80kph, a	Noise levels could potentially be reduced depending on the speed reductions achieved. However, noise levels would have to be reduced in excess of 1dB(A) in order for it to be audible to humans. In areas of traditionally heavy HDV traffic, the net	Speed reductions are likely to lead to an increase in highway safety by reducing crash risk and the severity of a crash (BEES, 2010; TRB, 2008). Concerns have been raised about the inability to accelerate in risky	Where drivers are paid by the mile, they may incur an effective pay cut as a result of lower speed limits. There may be an increased incentive for drivers to run longer (illegal) driving hours (BEES, 2010).	Where the use of speed limiters is mandatory, there will be costs involved to operators in term of installing them in vehicles. Where more vehicles are required in order to deliver the same goods as a result of reduced speeds,	The use of speed limiters to a set speed of 60mph is likely to result in 10-15% reductions in costs – the majority of which will come from fuel consumption reduction, but also reduced costs associated with tyres and maintenance (primarily brakes) (TRB, 2008). Reducing highway	The principal additional administrative costs will be associated with changing the speed limiters that are currently in place. **RATING: -1**	Reduced speeds may result in potentially less wear and tear of road infrastructure, and therefore reduced maintenance costs. However, if the number of vehicles used	SMEs could be disproportionately affected by the reduction in speed with regards to costs, including costs of installing speed limiting devices, and purchasing or running additional vehicles to deliver the same amount of goods etc.

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
	3.9% reduction in NOx could be achieved for all long distance HGVs. with an overall parc reduction of 3.9% (30,000 tonnes) (Faber Maunsell, 2008). However, if reduced speeds lead to increased numbers of trucks on the road, these benefits would be reduced, and potentially negated. **RATING: +?**	impact of these individual noise reductions could be noticeable. However, if speed reductions lead to an increased number of trucks on the road, this benefit could be reduced or negated. **RATING: +?**	traffic situations where speed limiters are used. However, fewer than 2% of crashes/collisions use acceleration as an evasive action (TRB, 2008). Reducing the speed of HDVs and not other traffic would increase the differences in speeds of the vehicles on the road, which might have safety implications. However, lower speeds may require more trucks to deliver a given amount of freight over a given distance per day (NESCAFF et al, 2010) (see capital costs). This could reduce and potentially negate the other benefits. **RATING: +?**	There might be a benefit for drivers if lower speeds resulted in lower levels of stress. However, if more trucks are needed, there could be beneficial impacts on net employment. **RATING: -?**	there will be additional capital costs borne by operators in terms of new vehicles. TML (2006) estimated that reducing speed limits to 80km/h in Belgium would increase the total costs of truck sector by around 1.5% **RATING: -1**	speeds from 70mph to 60mph will increased fuel economy for a typical class 8 combined truck by 1 mile/gallon, saving over 1,200 gallons of fuel annually per truck (M.J. Bradley Associates LLC, 2009). Reducing the speed limit of long-haul trucks can deliver up to 1% reduction in fuel consumption per mph reduced. Therefore, a reduction from 65mph to 60 mph would result in a 5% reduction in fuel consumption/CO_2 (US ICCT and NESCAFF, 2009). However, if the number of trucks in use increases, some of these benefits might be reduced or negated. **RATING: +?**		increases, then this benefit could be reduced or negated. **RATING: +?**	**RATING: -1**
Changes to weights and dimensions legislation	As noted in Table 5.2 in Section 5.3, changes to weights and dimensions legislation have the potential to reduce	A Dutch study on LHVs showed that their use had a negligible effect on noise. The use of LHVs was found to	The literature is currently divided on the potential safety impacts of the use of LHVs.	Additional training may be required for the driver in order to be able to operate a long	Vehicle purchase costs may be higher for operators, but this is likely to be offset by a reduced need for as many	TML (2008) assumed that LHVs cost 20% more to operate than traditional HGVs. However, studies	Vehicle testing procedures would need to be amended to take account of the	The literature is divided on whether there is likely to be costs or impacts	It is not clear whether there would be any differential impacts on SMEs of changes to weights

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	**Noise levels**	**Safety impacts**	**Impacts on drivers (other than safety)**	**Capital costs**	**Variable costs, including fuel**	**Administrative costs, including monitoring**	**Infrastructure costs, including wear and adaptation**	**Operating costs of SMEs**
	fuel consumption, and hence emissions of air pollutants. A Dutch study suggested that truck combinations up to 50 tonnes have resulted in a reduction in emissions of NOx per transported tonne by 14%, whereas emissions of PM10 are also expected to be reduced (as they are linked to fuel consumption and type of engine) (Rijkswaterstaart, 2010). TML et al (2008) estimated that LHVs could be 12% more efficient in terms of fuel consumption per tonne-km performed, thus leading to reduced NO_X emissions of 4% and PM by 5% (mainly due to less non-exhaust PM – fewer km driven causes less resuspension and mechanical wear) . **RATING: +2**	result in an increase of 0.8dB(A) compared to a two-truck combination. If the decrease in the number of trips is figured into the noise increase per passage, the total sound benefit is 0.6dB(A) (Rijkswaterstaart, 2010). **RATING: 0?**	BEES (2010) voice concerns that highway safety may be reduced as a result of use of larger trucks. One of the reasons is that their use may induce a shift from rail to road, due to the increased capacity – therefore having negative effect on safety. Conversely, other studies do not consider there to be any increases in safety risk as a result of their use. Rijkswaterstaart (2010) found that drivers of LHVs were more responsible and serious about their work than regular truck drivers. Concerns were raised about the safety of existing infrastructure (road layout etc). Accident statistics also suggest that LHV use is no less safe.	and heavy vehicle, increasing driver skills. **RATING: 0**	vehicles, reduced maintenance costs, and potentially fewer drivers. **RATING: 0**	estimate total benefits resulting from the assumption that there would be fewer lorries in use, so that there would be cost savings associated with the reduction in fuel consumption as a result of the use of LHVs. Various combinations of longer and heavier vehicles in the US could deliver reductions in fuel consumption and CO_2, including between 25% to 28%, with other combinations delivering reductions of more than 10% (ICCT and NESCAFF, 2009). In the US, National Academy of Sciences (2010) suggested that increasing weights and size limits in the US could deliver fuel savings of up to 15% or more. A Dutch study revealed that the cost per km of LHVs compared to regular trucks is 6% higher. However, load capacity Is 40% higher, resulting in average savings of around 35% per LHV trip (Rijkswaterstaart, 2010).	new dimensions. **RATING: -1**	associated with the use of LHVs in terms of infrastructure wear and tear/adaptation. A Dutch study stated that the use of 60 tonne LHVs should not have a negative impact on pavement quality or strength of bridges or other structures, as long as maximum axel loads are not exceeded and that weight is distributed proportionally. Impact is reduced further when LHV has more than 5 axels (Rijkswaterstaart, 2010). However, BEES (2010) stated that there may be costs associated with upgrading infrastructure to accommodate larger trucks.	and dimensions legislation. SMEs would make the decisions about purchasing these vehicles, and therefore benefiting from any fuel savings, in the same way in which they would make decisions about other vehicle purchases. **RATING: 0?**

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
			TML et al (2008) concluded that any potential increase in safety risk associated with the use of LHVs would be balanced with the potential reduction in the number of lorries that LHVs may enable. **RATING: ?**			**RATING: +2**		This was echoed by other studies. Various combinations of vehicles, gross weights, pavement types and bridges were assessed in a study (TML et al, 2008). Whilst the results were varied, it concluded that in any case heavier vehicles would require some investments for infrastructure safety equipment (safety barriers, bridge pier protection, emergency stopping lanes etc). Consideration would need to be given to vehicle parking. However, it is thought that infrastructure investment costs could be lower than the savings in the	

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
								transport sector and in society (emissions and safety) (TML et al, 2008). **RATING: ?**	
Driver training	As fuel consumption has been shown to be reduced as a result of driver training programmes, so should emissions of air pollutants. **RATING: +1**	The impact of driver training on noise is not known, but noise could be reduced if a quieter driving style is adopted. **RATING: 0/+?**	It is likely that safety may be increased as a result of the training, including reduced vehicle and personal injury accidents/ incidents (Faber Maunsell, 2008). Driver training is likely to lead to an increase in highway safety (BEES, 2010). **RATING: +1**	Drivers may experience possible reduced stress levels and enhanced satisfaction of driving (Faber Maunsell, 2008). Drivers also benefit from increased training and skills, relating to driving and safety. **RATING: 0/+?**	No direct impacts. There may be possible indirect ('knock on') effects on the types of vehicles subsequently bought by operators as a result of driver training, (new and second hand) - increased awareness of fuel efficiency techniques may lead to improved knowledge with respect to the types of vehicle that are used. **RATING: 0**	Fuel consumption reduction has been shown to be an impact of driver training programmes. This is likely to lead to considerable cost savings for operators, e.g. 5% on an annual £3m fuel bill could be approximately £150,000 (Turners (Soham) Ltd, in Faber Maunsell, 2008). Other impacts that may have positive implications for operators variable costs include possible improved resale value of fleet, reduced running costs (particularly relating to maintenance and tyres), and potential reductions in insurance premiums (Faber Maunsell, 2008). A Canadian study estimates that fleets could achieve savings up to 10% in fuel economy improvement	The costs of the driver training, if these are incurred by the government. Additionally, the cost of developing and operating the programme. Costs associated with monitoring of fuel consumption reductions. Although likely to be small, as probably collated already. **RATING: -1**	No infrastructure (other than administrative infrastructure) associated with this instrument. **RATING: 0**	SMEs could incur costs associated with implementing driver training (if not paid for by government or other source, e.g. private sector). However, these costs are likely to be offset through savings associated with reduced fuel consumption. **RATING: +1**

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
						through driver training and monitoring. Annual one-day driver training courses were reported to improve truck fuel efficiency by 5% in a study for the EC (M.J. Bradley Associates LLC, 2009). **RATING: +1**			
Fuel taxes	The level of pollutant emissions reduction is dependant on the tax. **RATING: +?**	Where traffic levels are reduced as a result of fuel tax implementation, there may be reductions in noise levels. **RATING:+?**	Where traffic levels are reduced as a result of fuel tax implementation, there may be improvements in road safety. **RATING: +?**	No direct impact on drivers of increased fuel taxes. **RATING: 0**	There would be no direct capital costs as a result of increasing fuel taxes. **RATING: 0**	The cost of fuel will be higher if tax were increased. **RATING: -?**	There would be relatively minor administrative costs associated with implementing the increased tax rates. **RATING: 0**	No infrastructure (other than administrative infrastructure) associated with this instrument. **RATING: 0**	Increased fuel taxes are likely to have negative implications for operating costs of SMEs, e.g. owner-operators. **RATING: -?**

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	Noise levels	Safety impacts	Impacts on drivers (other than safety)	Capital costs	Variable costs, including fuel	Administrative costs, including monitoring	Infrastructure costs, including wear and adaptation	Operating costs of SMEs
Road user charges	Allowing external cost charging for certain environmental impacts (not including CO_2 emissions) on selected corridors would lead to reductions in fuel consumption from road freight of 8%, and therefore likely to also reduce emissions of air pollutants (JRC, 2010). Truck tolling systems in Germany, Austria and Switzerland demonstrated how km-based charges can promote better loading and reduced journeys, which in turn should lead to lower emissions of air pollutants. **RATING: +2**	If traffic levels decline, there might be a benefit in terms of lower noise levels. **RATING: +?**	Safety impacts may be achieved along corridors or within areas where road user charges are applicable and traffic is reduced. These might be undermined if traffic diverts to routes on which the charges do not apply. **RATING: +?**	Lower traffic levels might result in better driving conditions for drivers, as, for example, congestion could be reduced. **RATING: +1**	There will be capital costs involved where charging schemes are introduced for the first time in terms of installing the charging infrastructure. **RATING: -1**	Increasing variable costs is the mechanism that the instrument uses to change behaviour, so variable costs would increase. Increased costs would be likely to be offset to some extent by efficiency savings. **RATING: -1**	There would be administrative costs involved with charging schemes, including monitoring of the scheme. **RATING: -1**	Potential benefits in terms of less wear and tear, and so reduced maintenance costs, if use declines. Also charges can take account of impact on infrastructure, thus providing an incentive to use less damaging trucks. **RATING: +1**	SMEs are likely to incur increased costs as a result of charging schemes, although these could be offset by efficiency gains. **RATING: -1**

Policy instrument*	Environmental impacts		Social Impacts		Economic impacts				
	Emissions of air pollutants (i.e. not greenhouse gas emissions)	**Noise levels**	**Safety impacts**	**Impacts on drivers (other than safety)**	**Capital costs**	**Variable costs, including fuel**	**Administrative costs, including monitoring**	**Infrastructure costs, including wear and adaptation**	**Operating costs of SMEs**
Vehicle purchase taxes or incentive	Less polluting vehicles may be purchased (or retrofitted) due to vehicle purchase taxes or other incentives, therefore leading to reduced emissions of pollutants. Purchase taxes are being reduced in some cases for more fuel efficient trucks in order to accelerate the move to increased emission standards (for example in the case of Japan) (McKinnon, 2007). **RATING: +?**	The impact on noise levels would depend on the relative noise levels of the more efficient vehicles compared to those that otherwise would have been bought. Given that safety standards would have to be complied with, it is likely that performance requirements would not adversely affect safety. **RATING: 0?**	The impact on safety will depend on the relative safety performance of the more efficient vehicles compared to those that otherwise would have been bought. Given that safety standards would have to be complied with, it is likely that performance requirements would not adversely affect safety. **RATING: 0**	The relative impact on the driver would depend on any differences between the more efficient vehicles compared to those that otherwise would have been bought. Some technologies, particularly alternative fuels, may require some training. **RATING: 0**	Incentives could be used to counter (at least partially) the increased capital costs associated with more efficient vehicles. **RATING: 0/-1**	Where more efficient vehicles are used as a result of the incentives/taxes, then fuel consumption will be reduced in the longer term. **RATING:+1**	Costs to government in terms of offering reductions in purchase tax or other financial incentives to potential buyers. **RATING: -2/+1**	No infrastructure (other than administrative infrastructure) associated with this instrument. **RATING: 0**	If SMEs purchased more fuel efficient vehicles as a result of incentives, they would benefit from reduced costs of use. **RATING:+1**

5.4.11 Policy packages: Rebound effects and complementary instruments

For various reasons, it might be appropriate to introduce more than one policy instrument in order to deliver a particular policy objective. Instruments could be used together in order to:

- Enhance each other's benefits.
- Address differing incentives of various actors.
- Counteract potential rebound effects.
- Address wider indirect effects.

It is important to note that, where policy instruments are used together, there combined impact on CO_2 reductions is unlikely to be the total of their impacts if they were implemented separately. In other words, their CO_2 reductions, as well as their other benefits and adverse impacts, cannot be considered to be cumulative. Some potential interactions between complementary instruments are set out in Table 1-4 below.

There are many situations where the implementation of a package of **complementary** policy instruments is more effective than implementing instruments in isolation. For example, requiring that new vehicles, their components or vehicle combinations meet more stringent performance standards could be complemented by labelling, or certified declarations of efficiency. These would communicate the benefits of these stricter performance standards to potential users, for example in terms of potential fuel savings, with the aim of stimulating their uptake. Similarly, the differentiation of purchase (or registration) taxes, or the provision of incentives to purchase such vehicles, also has the potential to influence purchasers by providing a financial incentive to buy such vehicles.

While higher fuel taxes, the introduction of an ETS and road user charging are all likely to result in higher costs for the user, policy instruments can be used to complement such instruments. For example, the dissemination of best practice or the provision of driver training may help operators to reduce fuel consumption, thus counteracting the increased costs of the fuel.

ETS could be used as a complementary instrument alongside fuel efficiency regulations (Swedish EPA, 2008). This would also minimise any rebound effects associated with improved vehicle performance and increased demand for travel. In fact, road user charging, if the charges applied are differentiated based on vehicle emissions, and higher taxes could also complement fuel and vehicle efficiency standards. Using ETS and performance requirements as complementary instruments helps to address the problem of **split incentives** within the transport, in that it the manufacturers that are required to invest in technological improvements to their vehicles, while it is the users who benefit from the subsequent reduced fuel consumption (Skinner et al, 2010).

In the assessment of policy instruments that might be used to reduce CO_2 emissions from heavy duty vehicles, it is important to recognise and assess any **rebound effects** associated with the various policy instruments, particularly if an instrument potentially makes the cost of use cheaper, e.g. an instrument such as performance requirements or driver training. In such cases, a rebound effect might be occur if use of the vehicle increases as a result of the lower costs of use. Such an effect would lessen the impact of the instrument in terms of CO_2 emissions reductions, as fuel use would not have declined by as much as had been expected. Such an effect would need to be identified and taken into account in any subsequent policy assessment. This impact has been identified for cars and vans, whereby the annual distance travelled by new vehicles increased by 10% as a result of the improved fuel efficiency of new vehicles (UK Energy Research Centre, 2007). However, it is likely that this figure would be different for trucks due to the fact that fuel economy is more central to their operation.

Whilst limiting the speed of HDVs may result in reduced fuel consumption and emissions of CO_2, it may also lead to a range of rebound effects. Initially, the number of trucks used to deliver the same amount of freight may increase as a result of slower speeds due to the reduced time allowed to make deliveries. If additional vehicles are used, then benefits relating to reduced emissions of CO_2 will potentially be negated. HDVs moving at slower speeds are also likely to have a slowing impact on other traffic using the road network. In this situation, where network capacity is reduced, subsequent creation of capacity may take place, again reducing positive effects. Where speeds are effectively lowered, the cost effectiveness of other measures to improve the aerodynamic characteristics of HDVs (which are more effective at higher speeds and reduce fuel consumption/emissions of CO_2) may also be reduced.

ICCT and NESCAFF (2009) identified potential synergies between changes to weights and dimensions legislation and speed reduction. It noted that a proportional increase in truck size and weight could eliminate any possible increase on the numbers of trucks that might result from lowering speeds. The report also noted that changes to weights and dimensions legislation and reduced speeds would probably be required in addition to improved fuel efficiency the emissions reductions that it considered to be possible, i.e. 50% by 2017, were to be achieved.

Examples of **wider effects** that need to be taken into account include effects on other modes and boundary effects associated with instruments that are confined to specific parts of the network. As discussed above, using longer and heavier vehicles instead of shorter and smaller vehicles can be effective in terms of reducing fuel consumption and thus emissions of CO_2 due to higher carrying capacity and the direct need for fewer trucks. However, it is also important to understand the potential wider impacts on CO_2 emissions of this instrument. So, whilst permitting the use of LHVs may lead to an increase in their use as an alternative to conventional HGVs, there may also be a modal shift from other modes, such as rail, thus leading to increases in CO_2 emissions, as noted above.

The instrument at most obvious risk from boundary effects is road user charging, which is likely to reduce emissions of CO_2 where the number of vehicles on the road network or the distance travelled is reduced. However, where road user charging is applied to selected parts of the road network (e.g. motorways or trunk roads), there is the potential for diversion of freight traffic onto other routes, which could have adverse impacts on these routes in terms of safety, noise, emissions of air pollutants and congestion.

Table 5.4: Potential interaction of complementary instruments

Policy instrument	Complementary instruments to:	
	Enhance benefits	Mitigate rebound effects
Emissions trading (stand alone or EU ETS) limitation		See performance requirements and labelling.
Performance requirements for vehicles and their components	See labelling.	As performance requirements would reduce fuel use, and therefore variable costs, they have the potential to increase the demand for travel, thus undermining some of the potential reduction benefits. This rebound effect could be countered by complementary measures that increase the costs of use, e.g. **emissions trading**, **fuel taxes** or **user charging**.
Labelling of vehicles, vehicle combinations or components	The main use of labelling would be as a complementary instrument to support, for example, **performance requirements for vehicles**. Labelling could also be linked to **vehicle purchase taxes or incentives** and **user charges**. In both cases, labelling could be seen as a complementary instrument that aims to overcome informational barriers to the effectiveness of other instruments.	As labelling has the potential to reduce fuel costs, it has the potential to increase the demand for travel. This rebound effect could be countered by complementary instruments that increase the costs of use (as with performance standards), e.g. **emissions trading**, **fuel taxes** or **user charging**.
Programme to disseminate best practice		As with other instruments that could reduce fuel use, and thus variable costs, the wider use of best practice has the potential to increase the demand for travel. Hence, instruments that increase the costs of use, e.g. **emissions trading**, **fuel taxes** or **user charging**, could be used to mitigate this effect.
Reduction in speed for heavy duty vehicles		NESCAFF et al (2010) noted that a proportional increase in truck **weights and dimensions** could eliminate any possible increase in the numbers of trucks that might result from lowering speeds.

Policy instrument	Complementary instruments to:	
	Enhance benefits	Mitigate rebound effects
Changes to weights and dimensions legislation		See reduction in speeds.
Driver training		See programme to disseminate best practice.
Fuel taxes		See performance requirements and labelling.
Road user charges	See labelling.	See performance requirements and labelling.
Vehicle purchase taxes or incentives	See labelling.	As with other instruments that could reduce fuel use, and thus variable costs, incentives for the purchase of more efficient vehicles have the potential to increase the demand for travel. Hence, instruments that increase the costs of use, e.g. **emissions trading**, **fuel taxes** or **user charging**, could be used to mitigate this effect.

5.5 Prioritisation of policy instruments

Objectives:

The purpose of this sub-task was to:

- *Assess the selected policy instruments against a range of implementation criteria*
- *Propose a prioritisation of the instruments on the basis of the various assessments undertaken in Task 4.*

Summary of Main Findings

⇒ Fiscal instruments such as the integration of HDVs into the ETS and fuel taxes based on carbon content could be considered to be the most economically efficient instruments, whereas other instruments, such as performance standards and labelling aim to address market failures.

⇒ Most of the instruments are cost-effective to some extent. Labelling, best practice programmes and eco-driving, all have the potential to lead to emissions reductions for a relatively limited financial outlay, while the cost effectiveness of other instruments is based on their potentially high CO_2 savings. The perspective from which costs are estimated also makes a difference.

⇒ The effectiveness of some instruments in delivering CO_2 reductions depends on the balance of first order effects and rebound and wider effects. In particular reducing maximum speeds and amending weights and dimensions legislation to allow for the wider use of larger and heavier vehicles.

⇒ For some instruments, such as labelling, best practice programmes and eco-driving, it is not possible to guarantee emissions reductions; rather the evidence suggests that reductions should be delivered.

The aim of Task 4.4 is, as far as possible, to prioritise the selected policy instruments that were assessed in Task 4.3 according to the potential economic, social and environmental impacts, i.e. to identify which of these instruments could be taken forward by the European Commission to reduce GHG emissions from HDVs. This stage is analogous to the fifth stage of the Impact Assessment process in which options are prepared and a preferred option is identified. At this point in the development of policy instruments for reducing CO_2 emissions from HDVs, a preferred option will not be identified; rather an attempt will be made to prioritise the policy instruments based on the assessment undertaken in the previous section. A summary of the advantages, disadvantages and outstanding issues with respect to each of the instruments is also presented in order to justify the prioritisation.

The fifth stage of the IA Guidelines also requires that the various policy options be assessed against a number of implementation criteria. A review of the relevant section of the IA Guidelines concluded that the following implementation criteria would be appropriate for the assessment within this report:

- Cost-effectiveness and economic efficiency
- Effectiveness of instruments, including its enforceability
- Ease of monitoring and reporting
- Coherence with EU policy objectives, strategies and priorities
- Impacts in other sectors

A summary assessment of the policy instruments against these criteria is presented in Table 5.5. In order to assess the criteria, it was necessary to use a qualitative rating, so in this respect a similar approach to that used in Table 5.3 (in Section 5.3) has been used. However, it was not possible to use the same scale as was used in the previous section as the definition of the ratings used there would not be meaningful with respect to the implementation criteria. For example, it is not immediate clear what the benefit would be of concluding that an instrument would lead to a 1% increase in ease of monitoring. Hence, it was decided to use a different qualitative scale to the one used for Table 3, as follows:

- "- -": Significantly negative
- "-": Minor negative
- "0": Neutral
- "+": Minor positive
- "++": Significantly positive

The interpretation of the signs in Table 5.5 is relatively straightforward, as it is clearly beneficial to increase most of these, e.g. an increase in the cost effectiveness, the effectiveness in reducing GHG emissions, the ease of monitoring and reporting and coherence are all beneficial. Hence, a positive sign should be taken as indicating an increase in the respective criterion. For the impact on other sectors, the sign indicates whether a negative or positive impact on other sectors might be expected. Sections 5.5.1 to 5.5.10 present a summary assessment of the information contained in Table 5.5. The results of the prioritisation of the instruments are presented in Table 5.6 and are discussed in Section 5.5.11.

5.5.1 Emissions trading scheme

As with the discussion in Section 5.4.1, the assessment of the implementation of ETS differs depending on whether an open or a closed scheme is being considered. Consequently, as previously, the discussion in this section makes a distinction between the two types of scheme, although they are discussed together, as there are similar issues.

ETS is often considered to be an economically efficient instrument as it stimulates measures to reduce CO_2 emissions in the most cost effective manner by letting the market decide. However, the current EU ETS only applies to selected sectors in the EU, so does not cover the entire EU economy. Additionally, there are links to instruments in other parts of the world, e.g. via the Clean Development Mechanism. Consequently, the incentives provided by the EU ETS only apply to a limited part of the EU economy.

Consequently, the design of the existing EU ETS has implications for its economic efficiency. However, including heavy duty road vehicles in the EU ETS, i.e. applying an open scheme to this sector, is generally considered to be more economically efficient than a closed system would be. In such a case, it is likely that emissions reductions would occur in sectors other than the transport sector due to the general view that GHG reduction potentials are more cost-effective in other sectors. Consequently, an open system would not necessarily reduce emissions from HDVs, in which case it would have implications for other economic sectors. On the other hand a closed scheme would stimulate CO_2 reduction in HDVs.

As noted previously, the effectiveness of any ETS therefore depends on the way in which it is implemented. An ETS will only be as effective as the system that has been set up, or into which HDVs have been integrated. The cap is fundamentally important in this respect, as it sets the level of emissions reductions required by the sectors could be the whole system within a given timeframe. This cap influences the market and thus the carbon price, which in turn provides an incentive for the uptake of low carbon technology. The EU ETS includes some sectors that are considered to be at risk of leakage, i.e. that might be at risk from foreign competition if the cap, and therefore carbon price, are too stringent. Hence, such considerations influence the stringency of the cap and thus the CO_2 reductions that the EU ETS has the potential to deliver. If heavy road transport was included in the EU ETS, the potential emissions reductions that might be realised in the sector would be limited by the consideration of the risks posed to other sectors. On the other hand, the transport of goods to EU consumers needs to be undertaken within the EU, so the transport sector itself does not face the same competitive risks as other sectors.

Additionally, the way in which emission allowances are allocated is also important to the effectiveness of a scheme. In the early phases of the EU ETS, most allowances were grandfathered (i.e. given out without a charge), while only a small amount were auctioned, i.e. were effectively bought in the open market.

Consequently, while some argue that an advantage of ETS is that the establishment of a cap ensures that this level of emissions reductions are achieved (e.g. SMMT, 2010), in practice there are considerations in addition to emissions reductions that influence the setting of this cap. NAS (2010) notes that the cost of meeting the cap is also uncertain, so the signal that is provided is more uncertain and volatile than, say, that provided by fuel taxes. Some consider that CO_2 taxes might even achieve the same reduction effect as ETS, but at lower cost (Swedish EPA, 2007), while ECMT (2007) suggest that other approaches might be more effective. On the other hand, a potential advantage of an emissions trading scheme is that it requires regulators to have less knowledge about cost, feasibility and effectiveness of technology, unlike regulation.

Whether a system is open or closed, the EU ETS does require a significant level of monitoring, reporting and verification in order to ensure that the emission reduction targets are met. This is particularly important given that there will be financial penalties on trading entities if emissions reductions are not achieved. Within road transport, including heavy duty road transport, the number of operators would make it very difficult for a scheme to be introduced at this level, due to the high administrative (and transaction) costs involved. As noted in Section 5.3.1, an upstream scheme targeting fuel suppliers is considered to be a better option for transport. This would also introduce inconsistencies within the EU ETS, as at the moment, it is the end users, e.g. industrial installations and airlines, who are targeted by the scheme. Additionally, integrating only heavy duty vehicles, and not lighter vehicles, into an ETS might also prove to be challenging.

5.5.2 Performance requirements for vehicle or their components

The introduction of performance requirements for vehicles, their components and vehicle combinations aims to stimulate the uptake of the CO_2 reduction technologies. Setting and applying performance requirements for components would be more straightforward than performance standards for whole vehicles due to the way in which HDVs are assembled (see Section 2.4).

Performance standards aim to stimulate the uptake of technical improvements that would not otherwise be introduced under existing market conditions. To some extent, the market will stimulate the uptake of technical improvements, but the cost effectiveness of options varies according to the price of fuel, which is itself variable. Hence, the market does not necessarily supply consistent long-term signals to stimulate the uptake of technical improvements. ICCT and NESCAFF (2009) argue that one of the benefits of setting performance requirements for vehicles and their components is that, in making their purchase decisions operators tend to use short payback periods (e.g. up to 2 years), whereas some of the technologies to reduce CO_2 emissions deliver benefits when measured over their 15 year lifecycle. Hence, such technologies would not be likely to be introduced without regulation (or subsidies).

MJ Bradley (2009) notes that barriers to setting performance standards for HDVs include the diversity of the fleet, the shared responsibility for the different components that lead to fuel use, ownership patterns and changes. NAS (2010) notes this complexity, but concludes that the problems are not insurmountable. McKinnon (2007) concludes that setting performance standards is not the most efficient way of reducing CO_2 emissions.

One of the key challenges in introducing performance standards for HDVs is improving the fuel efficiency of the various different types of vehicle, which would need to take into account of the various ways in which they are used. It is important to recognise these complexities within the design of the instrument in order to ensure that the appropriate incentives are provided, based on ownership and use considerations. There is also a need for a standardised means of measuring CO_2 emissions from the regulated entities.

In this respect, it is important to ensure that an appropriate metric is used that incentivises the uptake of technologies that would lead to actual CO_2 reductions and which do not implicitly rule out potential CO_2 reduction technologies. For passenger cars, CO_2 emissions per kg has been used, which has been criticised for a number of reasons, including that mass does not really reflect the performance of a car and that the use of mass makes it more difficult to reduce CO_2 emissions by reducing the weight of vehicles. For heavy goods vehicles, it has been argued that a more suitable performance related standard would be based on a metric that reflected the performance of freight transport in moving goods, e.g. base performance standards on a metric such as CO_2 emissions per tonne-kilometre or per m^3-km. At the same time, it is important that overall CO_2 emissions reductions are delivered, which might require the introduction of complementary instruments (see Section 5.4.11).

5.5.3 Labelling of vehicles, vehicle combinations or components

As discussed in Section 5.3.3, labelling does not directly deliver emissions reductions; rather it facilitates changes in behaviour that subsequently lead to emissions reductions. In this respect, it is potentially useful as a complementary instrument (see Section 5.4.11). It is difficult to measure the impact of labels in their own right[36], but given the relatively low level of costs associated with labelling, they are likely to be a relatively cost effective instrument. The information used on the labels could facilitate monitoring and reporting of impacts, although it has to be recognised that the CO_2 emissions figure on the label does not accurately reflect real world emissions. Consequently, while the label can be used to assess the uptake of more fuel efficient vehicles, it is more difficult to identify the actual emissions savings.

From the perspective of the European single market, a common label, or common declaration of fuel efficiency, would be beneficial in order that operators in all Member States are provided with the same level of information, thus avoiding a market distortion in this respect.

An important element of the design of any label, or declaration, is to ensure that it can take account of future improvements in fuel efficiency, while still remaining meaningful to users (see TNO et al, 2006, for a discussion of different types of label).

5.5.4 Programme to disseminate best practice

For the apparent reductions in emissions that can result, it appears that best practice programmes have the potential to be a relatively cost effective instrument. However, the subsequent emissions reductions cannot be guaranteed, as it depends on the way in which operators manage their fleets. Additionally, where emissions reductions are achieved, it is not possible to guarantee that these are maintained, as habits may change or revert back to previous behaviour. It would not be possible to monitor and report on all emissions savings, although the fuel used by companies could be used as a proxy.

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[36] For example, see ADAC (2005) *Study on the effectiveness of 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* A study for DG Environment, contract No.: 07010401/2004/377013/MAR/C1

5.5.5 Reduction in speed for heavy duty vehicles

From the perspective of an individual vehicle and the potential fuel savings, speed reduction for heavy duty vehicles would appear to be a cost effective instrument for reducing CO_2 emissions from heavy duty vehicles. However, given that operators do not lower speeds to benefit from such fuel savings without additional incentives or regulations suggests that there are wider economic circumstances that are being taken into account. As was discussed in Section 5.4.5, lowering speeds has the potential to increase the number of vehicles required to move the same amount of goods around. These additional journeys would clearly counteract some of the CO_2 savings resulting from lowering speeds in the first place. Hence, the cost-effectiveness and effectiveness of the instrument in terms of delivering CO_2 emissions reductions would depend on the balance of such conflicting impacts. In this respect, it would also be important to distinguish between short- and long-term impacts. For example, while in the short-term lower speeds might lead to more trucks on the road, in the longer-term they might contribute to stimulating structural changes that would be beneficial to delivering a low carbon economy. Additionally, lower speeds for road freight might stimulate modal shit towards less CO_2 intensive modes, although the potential for such a shift would depend on the goods being transported.

The enforcement of reduced speed limits could be relatively straightforward and effective if it were implemented by requiring all vehicles covered by Directive 2002/85 to be fitted with appropriate speed limiters (see Section 5.3.5).

5.5.6 Changes to weights and dimensions legislation

There appears to be little consensus on the benefits or otherwise of changes to weights and dimensions legislation that would allow the use of larger and heavier freight vehicles. The cost-effectiveness and effectiveness on reducing CO_2 emissions from allowing such vehicles to be used in freight transport between Member States depends on the extent of wider impacts on modal shift, as well as the fact that allowing the use of such vehicles would increase the capacity of the network. Allowing longer vehicles, where the additional length allows for the fitting of improved aerodynamics without allowing increases in loading capacity, has the potential to reduce the risk of some of these adverse impacts, while allowing improvements in fuel efficiency. If instruments, such as lower speeds, that reduce the capacity of the transport network lead to cost increases for operators, it seems possible that instruments that would increase the capacity of the transport network could reduce costs, and thus make transport cheaper. If this was the case, then there would likely be a rebound effect from allowing the wider use of larger and heavier vehicles. We understand that DG MOVE has recently commissioned a study to look at the same issues as TML (2008), but which would take more account of these wider issues.

5.5.7 Driver training

While driver training might be considered to be a cost-effective instrument, CO_2 savings cannot be guaranteed. Evidence suggests that drivers do respond to training by adopting more CO_2-efficient driving behaviour. However, one of the key issues with respect to driver training is how to ensure that the instrument has an impact in the longer term, i.e. to ensure that drivers turn what they learn on their courses into longer-term habits. In this respect, it might be appropriate to have some type of regular “refresher” training in order to ensure that benefits are maintained. This could be delivered by training under best practice programmes, or required by amendments to EU legislation. Driver aids could also support fuel efficient driving.

5.5.8 Fuel taxes

In order to deliver CO_2 reductions, fuel taxes could be raised and/or differentiated by the carbon content of the fuels or the global warming potentials of the greenhouse gases released. Fuel taxes are considered to be relatively cost-effective, as they are a low cost instrument, although the CO_2 reductions that are delivered will depend on *inter alia* the level of increase/differentiation applied. As with other instruments that target fuel use, the most obvious method for monitoring and reporting the impact on CO_2 emissions is to monitor fuel use. However, fuel use is influenced by a range of factors, so identifying the impact of the increases/changes to fuel taxation would not be straightforward.

As noted in Section 5.3.9, within the EU minimum rates of fuel duty are set in EU legislation. Currently, the rates are set significantly below the rates of fuel duty that are applied in most EU Member States, so increasing these minimum rates (assuming that this increase would not be substantial) would only affect those countries where the existing duty rates are just above the existing minimum rates. Currently, the variation in duty rates stimulates “fuel tourism” whereby drivers have an incentive to drive farther to refuel, e.g. by refuelling in a neighbouring country that has lower duty rates, or to choose longer journey routes, e.g. diverting long journeys by countries with cheaper fuel duties. Increasing minimum rates of duty would reduce such incentives, although it is likely that significant increases in these rates would be needed to remove such incentives altogether. Removing such incentives would also have benefits in terms of reducing the distances travelled and thus have beneficial air pollution, noise and safety impacts.

5.5.9 Road user charging

As with fuel taxation, the impact of road user charging will depend on the levels, and the structure, of the design of the instrument. It is considered to be a relatively cost effective instrument as it has the potential to improve efficiency without impacting on the amount of freight transported (see Section 5.3.10). It is potentially easier to monitor than the impact of increases or changes in fuel taxation, as it targets a sub-section of the vehicles on the road, the use of which is relatively better monitored in the first place. User charging can be applied to be consistent with the polluter pays principle, particularly as the revised Eurovignette Directive will allow for some degree of external cost pricing.

5.5.10 Differentiating purchase taxes or providing incentives

As noted in Sections 5.3.11 and 5.4.11, differentiated purchase taxes, or incentives, could be used most effectively to complement other instruments, notably vehicle performance standards.

Table 5.5: Assessment of the short-listed instruments against the implementation criteria

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Stand alone emissions trading scheme	The use of tradable permits for transport has resulted in a high level of cost-effectiveness (COWI and ECN, 2003 in ECMT, 2007). The introduction of a closed emissions trading scheme is considered to be less efficient than an open system. The cost of meeting the cap on transport emissions is uncertain, so the signal that is provided is more uncertain and volatile than that provided by instruments such as fuel taxes (NAS, 2010). Therefore, upstream systems, i.e., those targeting fuel suppliers, would have the greatest impact as it would subsequently affect the use of all vehicles. **RATING: +**	The effectiveness of emissions trading schemes depend on the way in which they are implemented. The cap that is set is fundamentally important in this respect. In a closed system, the CO_2 emissions reductions implied by the cap should be delivered in the transport sector. **RATING: +**	Monitoring, reporting and verification are fundamental to any emissions trading scheme, and are likely to be complex and timely processes Emissions trading schemes are therefore likely to be accompanied by increased Governmental administrative burdens for monitoring and policing the system (BEES, 2010). **RATING: - -**	A closed system would aim to deliver CO_2 savings in the most cost-effective manner from heavy duty transport. Would be consistent with polluter pays principle, if allowances were auctioned. **RATING: +**	A closed system would lead to reduced CO_2 emissions from heavy duty transport. Any subsequent increases in transport costs could impact on those sectors for which transport is a significant cost. **RATING: -**

[37] Coherence with the Community's climate change objectives is not covered here, as these policies all have the potential to deliver GHG emissions reductions, as this was one of the criteria for the assessment on Task 4.2.

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Integrating HDVs into the EU ETS	The use of tradable permits for transport has resulted in a high level of cost-effectiveness (COWI and ECN, 2003 in ECMT, 2007). The introduction of an open emissions trading scheme is considered to be more cost effective that a closed system. The cost of meeting the cap on transport emissions is uncertain, so the signal that is provided is more uncertain and volatile than that provided by instruments such as fuel taxes (NAS, 2010). Therefore, upstream systems, i.e., those targeting fuel suppliers, would have the greatest impact as it would subsequently affect the use of all vehicles. **RATING: ++**	The effectiveness of emissions trading schemes depend on the way in which they are implemented. The cap that is set is fundamentally important in this respect. However, in an open system, the CO_2 emissions reductions would probably be more likely to occur in sectors other than transport, although from an economy-wide perspective, the CO_2 emissions reduction implied by the cap should be achieved. **RATING: +**	Monitoring, reporting and verification are fundamental to any emissions trading scheme, and are likely to be complex and timely processes Emissions trading schemes are therefore likely to be accompanied by increased Governmental administrative burdens for monitoring and policing the system (BEES, 2010). **RATING: - -**	An open system would aim to deliver CO_2 savings in the most cost-effective manner across the economy as a whole. Would be consistent with polluter pays principle, if allowances were auctioned. **RATING: +**	Depending on the design of the EU ETS system, an open system could lead to increased CO_2 reduction requirements in other economic sectors, including those that are prone to carbon leakage. **RATING: --**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Performance requirements for vehicles and their components	The use of fuel efficiency standards is likely to increase purchase prices of HDVs (incremental cost of compliance). However, more efficient vehicles will use less fuel to do the same work/carry same amount of goods, offsetting savings in annual fuel costs for the vehicle owner (M.J. Bradley Associates LLC, 2009). The largest CO_2 abatement opportunities in the transport sector lie in initiatives to improve energy efficiency, including those aimed at creating regulations for some currently unregulated vehicle components. Emissions performance standards are able to steer the market to greater fuel economy at very little cost, e.g. by promoting the best performing tyres amongst those already available (ECMT, 2007). Quotes COWI and ECN (2003), which concludes that emissions standards could have a high level of cost-effectiveness. **RATING: ++**	The requirement for emission standards will have a positive effect on reducing emissions of GHG emissions. The level of reductions in CO_2 achieved (and other pollutants) will depend on the level of ambition (e.g. Japanese legislation required average reductions of just over 12% over 13 years). Purchase tax reductions are sometimes offered to accelerate the move to these higher standards (e.g. fuel economy standards for new trucks in Japan, McKinnon, 2007). These initiatives may also need to be in conjunction with labelling of vehicles. Additionally, ultimate reductions would depend on the extent to which the reduced costs of use led to increased demand for travel. **RATING: ++**	Monitoring and reporting is likely to be required as part of any legislation introduced, including the measurement of GHG emission reductions. Information on vehicle registrations and emission standards could be captured for monitoring purposes. A system would need to be set up to ensure that emissions from new vehicles are monitored, but monitoring of impacts while in use would be more difficult. **RATING: -**	Introducing performance requirements for HD vehicles and their components would be coherent with the approach taken for other road vehicles. Likely to contribute to reductions in emissions of air pollutants, and so would be coherent with EU air quality objectives. **RATING: +**	If the costs of goods transport increases, then this has the potential to impact on many economic sectors, particularly those that are transport-intensive, at least in the short-run. If the costs of transport subsequently decline, the short-term impacts might be reversed as the more efficient technologies deliver fuel cost savings. **RATING: -/0**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Labelling of vehicles, vehicle combinations or components	This is likely to be a cost effective instrument, as any resulting savings could be delivered relatively cheaply. **RATING: +**	Without complementary measures, it is unlikely that labelling would deliver emissions reductions on its own. **RATING: 0**	Monitoring and reporting could be aided through using information provided on labels. **RATING: +**	Having a common level at a European level would be preferable (to different national labels) from the perspective of the single market. **RATING: +**	There are no significant impacts on other sectors. **RATING: 0**
Programme to disseminate best practice	Although little information is available regarding the development and implementation costs of best practice and its dissemination, it is likely to be relatively cost effective considering the potential positive impacts on reducing fuel consumption and thus GHG emission reductions compared to the comparatively low costs. **RATING: ++**	Best practice dissemination has been shown to have positive effects on reducing fuel consumption and thus GHG emission reductions. The dissemination of best practice materials could be enforced at the Member State level, but it will be voluntary in terms of uptake by freight operators. **RATING: +**	Comprehensive monitoring and reporting would be difficult to achieve due to the differences in the way in which best practice may be disseminated, identifying the direct impacts of the best practice dissemination on operations (i.e. separating these effects from those of other initiatives), and the fact that the best practice examples provided will illustrate real-world savings, but these are likely to be different in every case (depending on a range of local factors). **RATING: -**	Likely to contribute to reductions in emissions of air pollutants, and so would be coherent with EU air quality objectives. **RATING: +**	If the cost of transport declines, there could be a benefit to other economic sectors, particularly those that are transport-intensive. **RATING: +**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Changes to dimensions and weights legislation	The benefits achieved through implementation would need to be weighed against potential disbenefits from reduced safety and increased damage to roadways, and the possibility that policy may provide a disincentive for shifting more freight away from trucks to more efficient modes such as rail and water transport (MJ Bradley Associates, 2009). A Dutch study revealed that the cost per km of LHVs compared to regular trucks is 6% higher. However, load capacity Is 40% higher, resulting in average savings of around 35% per LHV trip (Rijkswaterstaart, 2010). A cost benefit analysis undertaken by TML et al (2008) revealed that all scenarios give an overall positive effect on society, as society has to spend less money transporting the same goods. LHVs transport more tonne-km (+1%) with less vehicle-km (-12.9%). **RATING: +**	Where HDVs are able to carry a higher volume/ heavier freight, there will be the potential to carry the same total amount of freight using less fuel, and thus having a positive effect on GHG emissions. Amendments to existing weights and dimensions legislation would be required prior to implementation, but larger trucks are already used in some Member States. Where LHVs are used, they are likely to lead to reductions in fuel consumption and CO_2 emissions per tonne-km transported. However, reductions in CO_2 are not guaranteed, as it depends on the impact on modal shift, which can vary between country, and the scale of induced demand resulting from the increased capacity **RATING: -/0/+**	The number and size of trucks, and volume of freight transported would need to be monitored. Each of these parameters may be captured currently at a Member State level. Additionally, the distance travelled by trucks would need to be identified in order to monitor accurately the impact of the instrument on GHG emissions. **RATING: -**	Potential conflicts with aim of promoting use of potentially more carbon efficient modes such as rail and water transport for freight transport. If contributes to reductions in emissions of air pollutants it would be coherent with EU air quality objectives. **RATING: +/-**	If the cost of transport declines, there could be a benefit to other economic sectors, particularly those that are transport-intensive. **RATING: +**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Reduction in speed for heavy duty vehicles	The implementation of lower speeds for HDVs is likely to lead to less freight being moved/delivered due to slower speeds with possible negative implications (in terms of cost to operator and need for more vehicles on the road to deliver same amount of goods). However, it is likely that the reduction of speeds will result in a significant reduction in fuel use from the freight sector, but that average transit times would increase, affecting driver hours, productivity and shipper costs and revenue – any potential fuel efficiency benefits need to be weighted against these factors (MJ Bradley Associates, 2009). ECMT (2007) quoted COWI and ECN (2003), which concluded that speed enforcement could have a high level of cost-effectiveness. **RATING: +**	Introducing speed reductions for HDVs will be effective in terms of reducing emissions of GHGs, as long as this is enforced properly. However, some operators may find that they need to use more vehicles to deliver the same amount of goods in the required time, leading to an increase in GHG emissions. Similarly, this issue may lead to a modal shift (e.g. to rail) if more goods can be moved faster, leading to a reduction in GHG emissions. The use of speed limiters may assist enforceability of the instrument – either retrofitted to vehicles or adjusted. Speed limiter legislation could also be amended to assist the introduction of lower speeds. Additional enforcement will be by local law enforcement authorities. **RATING: +**	There are likely to be limited monitoring opportunities. Monitoring could come in the form testing vehicles and extrapolating results to the fleet to estimate savings. **RATING: -**	Speed reductions for HDVs may lead to an increase in the number of trucks on the road in order to deliver the same amount of goods in the required time. This may then lead to an increase in GHGs, and other negative transport impacts, including congestion, which will have a negative impact on coherence with EU policy objectives, strategies and priorities. However, a positive effect may be achieved where the result is that mode shift occurs to rail (or other modes). **RATING: +/-**	If the speed at which goods can be transported is reduced, there might be impacts for those industries that rely on the fast transport of goods. **RATING: -**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Driver training	There are likely to significant costs involved in delivering driver training, although results are often very positive in terms of reducing fuel consumption and thus emissions of GHGs. The largest CO_2 abatement opportunities in the transport sector lie in initiatives to improve energy efficiency, including those aimed at fuel efficient driving through training and feedback (ECMT, 2007). Such initiatives are likely to offer significant cost-effective savings. ECMT (2007) quotes COWI and ECN (2003), which concluded that eco-driving could have a high level of cost-effectiveness. **RATING: ++**	Driver training initiatives are likely to have a positive effect on reducing emissions of GHGs from HDVs. Repeat training may be required to ensure continued reductions in subsequent years to avoid drivers reverting back to previous bad driving habits (possibly annual training). Training for HDV drivers could be enforced through amendments to the Driver Training Directive. **RATING: +**	The training courses that have been undertaken by drivers could be monitored and reported on, but there are likely to be difficulties in terms of identifying the impacts that driver training has had on reductions of GHG emissions (and other impacts), particularly at the Member State level. The main issue is differentiating between the effects of the driver training and the other instruments that are being implemented aimed at HDVs and reducing emissions of GHGs more generally. **RATING: -**		If the cost of transport declines, there could be a benefit to other economic sectors, particularly those that are transport-intensive. **RATING: +**
Fuel taxes	The use of fuel taxes is an ideal instrument for addressing GHG emissions, as they send clear signals and distort the economy less than any other approach, and is considered to be a low cost measure. Fuel taxes are reported to have the highest impact of any of the CO_2 abatement measures (ECMT, 2007). Fuel taxes are therefore likely to be very cost effective and economically effective to implement. Again, it quoted COWI and ECN (2003), which concluded that fuel taxes were also highly cost-effective. **RATING: ++**	The use of fuel taxes is likely to have positive effects on reducing emissions of GHGs. However, the level of success/effectiveness depends on the level of tax that is implemented. **RATING:++**	The level of fuel taxes set within EU Member States should be relatively easy to monitor and report on. While it would be difficult to monitor actual CO_2 savings, the fuel savings resulting from the tax increase could be estimated, and used with carbon intensity factors to estimate CO_2 savings. **RATING: -**	The use of fuel taxes as an instrument to reduce emissions of GHGs supports the 'polluter pays' principle. Would lead to reductions in emissions of air pollutants, and so would be coherent with EU air quality objectives. Where fuel taxes are high, a shift to alternative modes (e.g. rail) to move freight may be made, supporting the EU's policies on this. **RATING: ++**	If the costs of goods transport increases, then this has the potential to impact on many economic sectors, particularly those that are transport-intensive, at least in the short-run. In the longer-term, structural adjustments would be made, which could reduce the impacts. **RATING: -**

Policy instrument*	Cost-effectiveness and economic efficiency	Effectiveness of instrument in reducing GHG emissions, including its enforceability	Ease of monitoring and reporting	Coherence with EU policy objectives, strategies and priorities[37]	Impacts in other sectors
Road user charges	The cost effectiveness of road user charging schemes is likely to vary greatly depending on how the scheme has been implemented. Evidence suggests that the CO_2 reductions that result from user charges are from gains in efficiency. **RATING: ++**	Road user charging is likely to have positive effects on reducing emissions of GHGs. However, the level of reduction is dependent on how scheme is implemented (area covered, charges etc). Truck km-charges provide strong incentives to rationalise distribution systems and logistic organisation (ECMT, 2007). **RATING: +**	Monitoring of road user charging schemes can, and has, been carried out. This can include monitoring of a range of impacts, including changes in traffic flow, speed, air pollutant emissions, safety and impacts on business/economy. From this information, CO_2 savings could be estimated. **RATING: -**	User charging supports the “polluter pays” principle. Therefore the use of road use charging for HDVs in Europe will be coherent with this policy. Road user charging may also encourage a shift to alternative modes, such as rail. Would lead to reductions in emissions of air pollutants, and so would be coherent with EU air quality objectives. **RATING: ++**	If the costs of goods transport increases, then this has the potential to impact on many economic sectors, particularly those that are transport-intensive, at least in the short-run. However, if charge is set at appropriate levels, the amount of freight transported does not change, only the way in which it is transported **RATING: 0**
Vehicle purchase taxes or incentives	The largest CO_2 abatement opportunities in the transport sector lie in initiatives to improve energy efficiency, including those aimed at incentives for car buyers to chose lower emissions vehicles where stringent but voluntary emissions targets have been agreed with car manufacturers. (ECMT, 2007). It quoted the conclusion of COWI and ECN (2003) that CO_2 differentiation of fuel taxation has variable cost-effectiveness. **RATING: +/++**	Positive effects on reducing emissions of GHGs, but level of GHG emission reduction is dependent on the reduction in tax/incentives offered to purchasers. Additionally, ultimate reductions would depend on the extent to which the reduced costs of use led to increased demand for travel. **RATING: +**	Purchase taxes and incentives offered should be relatively easy to collate and monitor at a Member State level, including the number of vehicles sold within a year and incentives that have therefore applied to them. Further monitoring/research would have to be undertaken to identify whether the use of taxes and incentives had influenced purchaser’s decisions. From this information, CO_2 savings could be estimated. **RATING: -**	The use of vehicle purchase taxes and incentives are coherent with policies to encourage the use of cleaner and more efficient vehicles, such as the clean vehicles Directive, and will support the reduction of the environmental impacts of transport. **RATING: +**	If the cost of transport declines, there could be a benefit to other economic sectors, particularly those that are transport-intensive. **RATING: +**

5.5.11 Prioritisation of the instruments

As can be seen in the preceding sections, there are many instruments that could contribute to reducing CO_2 emissions from heavy duty vehicles and which could be implemented at the European level. On the other hand, the actual impact on CO_2 emissions of introducing these instruments depends on a number of factors, including the detail design of the instrument. In this respect, given that the assessment undertaken in this task of the project has only been undertaken at a relatively high level, it has not been possible to prioritise the instruments, as more work would need to be undertaken to assess the cost effectiveness and practicalities of introducing the instruments with the aim of delivering comparable levels of emissions reductions.

On the other hand, it could be argued that prioritising the instruments is not necessarily an appropriate action to take, as different instruments deliver different incentives to different actors. In this respect, the interaction between complementary instruments is important. There is therefore a case to be made for an assessment that develops technology packages and policy packages in order to identify the most appropriate policy instruments to be introduced to reduce CO_2 emissions from heavy duty vehicles. For the instruments assessed in Section 5.4 and earlier in this section, an overview of the advantages, disadvantages and outstanding issues is provided in Table 5.6. The potential of the instruments to reduce CO_2 emissions from HDVs and the potential for the instrument to be assessed at the European level, are not included in this table, as all of the instruments have such potential (see Section 5.3).

Table 5.6: Summary assessment of policy instruments for reducing the CO_2 emissions from HDVs

Policy instrument	Advantages of taking forward the instrument	Disadvantages of taking forward the instrument	Outstanding issues
Stand alone emissions trading scheme	• Would ensure that emissions reductions occur in the transport sector • Co-benefits on air pollution, noise and safety would occur, first from reduced levels of traffic and then from technical improvements to vehicles	• Theoretically, less efficient than an integrating HDVs into the EU ETS • Potentially high administrative costs, particularly if operators were the trading entity • Costs to the transport industry would be higher than an open ETS, although the costs of meeting the cap are unknown • Effectiveness depends on the design of the system	• Whether a closed system is worthwhile, or whether other instruments, such as a combination of performance requirements and taxation or charging would be more effective • What the implications might be of introducing a closed system on the potential use of other instruments to reduce CO_2 emissions from HDVs
Integrating HDVs into the EU Emissions Trading Scheme	• Generally considered to be one of the most economically efficient instruments, as it incentivises emissions reductions where these are most cost-effective • Impact on operators reduced, as reductions are would be anticipated to be stimulated in other economic sectors	• Emissions reductions would not necessarily occur in the transport sector • Potentially high administrative costs, particularly if operators were the trading entity; if fuel suppliers were the trading entity, this would be inconsistent with the approach currently taken in the EU ETS were end users are the trading entities. • Co-benefits are likely to be less than compared to an closed scheme, as any reductions in emissions of air pollutants and noise would occur at industrial installations rather • Effectiveness would depend – at least in part – to the effectiveness of the ETS itself	• The extent to which other sectors covered by the ETS could withstand a stricter cap to take account of the integration of HDVS into the EU ETS • The practicalities of introducing HDVs into the EU ETS without also including light duty vehicles, and the implications for the potential use of other instruments to reduce CO_2 emissions from HDVs
Performance requirements for vehicle or their components	• Addresses the inconsistency of the long-term signals supplied by the market by requiring the uptake of technologies that are not yet considered to be cost effective, or which have longer payback periods • Likely co-benefits in terms of lower emissions of air pollutants, as CO_2 reduction technologies will reduce the	• Increases the cost of vehicles from the introduction of new technologies that were not considered to be cost effective under current market conditions	• Requires a method an agreed method for assessing the CO_2 emissions of vehicles and vehicle combinations that would stimulate the uptake of CO_2 reduction technologies • Requires agreement on a suitable metric for relating CO_2 emissions to the performance of vehicles and vehicle combinations that would

Policy instrument	Advantages of taking forward the instrument	Disadvantages of taking forward the instrument	Outstanding issues
	power used by the engine, and thus reduce its emissions of air pollutants • Reduced cost of use, as a result of the fuel savings resulting from the use of more fuel efficient technologies.		stimulate the uptake of CO_2 reduction technologies
Labelling of vehicles, vehicle combinations or components	• Communicates potential savings to operators, about which they might not have been previously aware • Likely to be most effective as a complementary instrument • Relatively cost effective	• The impact of labelling in the absence of technical developments or other policy instruments is likely to be limited	• Needs agreements on measuring methods and metrics in the same way that performance requirements do
Programme to disseminate best practice	• Relatively cost effective • Communicates practice that deliver potential savings to operators, about which they might not have been previously aware • Co-benefits on air pollution, noise and safety would occur, as result of a more efficient use of vehicles		• The practicalities of developing an EU level programme would need to be thought through, including the most appropriate way in which best practice could be disseminated to operators in the 27 Member States, given local circumstances, and languages.
Reduction in speed for heavy duty vehicles	• Could be relatively easily implemented by fitting speed limiters on relevant vehicles • Potential direct co-benefits on air pollution, noise and safety, but these risk being outweighed by the impacts of any rebound effect	• Potential rebound effects due to the fact that the measure effectively reduces the capacity of the transport system	• Whether it would be possible to strike a balance that would deliver some of the CO_2 reduction benefits of reducing speed limits, without adverse rebound effects or adverse effects on the wider economy
Changes to weights and dimensions legislation	• Would be relatively easy to implement • Potential co-benefits at the level of the individual vehicle/journey	• Potential rebound effects due to the fact that the measure effectively increases the capacity of the transport system • Potentially significant investments in infrastructure required	• Whether it would be possible to strike a balance that would deliver some of the CO_2 reduction benefits of reducing speed limits, without adverse rebound effects or adverse effects on the wider economy • Whether allowing increased lengths (to allow the fitting of aerodynamic devices) without allowing increased

Policy instrument	Advantages of taking forward the instrument	Disadvantages of taking forward the instrument	Outstanding issues
			loading capacities would be an option to improve efficiency without the risk of the potential disadvantages
Driver training	• Relatively cost effective • Communicates improvements in driving behaviour, about which drivers might not have been previously aware • Co-benefits on air pollution, noise and safety would occur, as result of a more efficient use of vehicles	• Maintaining benefits over time	
Fuel taxes	• Cost effective instrument, particularly if increases or differentiation linked to carbon content of the fuel, or the global warming potential of the pollutants	• Difficult to implement at European level, as a result of the need for unanimity on tax measures	
Road user charging	• Allowed by the Eurovignette Directive, so could be implemented in Member States • Revised Directive also allows partial external cost pricing, which would lead to co-benefits if applied	• Would need to be implemented at the Member State level, within the framework set at the European level	
Differentiating purchase taxes or providing incentives	• Potentially used a complementary instrument alongside performance requirements	• Would need to be implemented at the Member State level	

6 Summary of Principal Findings, Conclusions and Recommendations

The following section provides a summary of the main findings, conclusions and recommendations across each of the four different task areas, followed by the overall conclusions and recommendations resulting from the work.

6.1 Vehicle Market and Fleet

Task 1 of the project characterised the existing European vehicle market and fleet and the current state of legislation in the EU (and the rest of the world) that influences the fleet energy efficiency.

The European HDV market is dominated by seven major manufacturers (accounting for 93% of EU registrations), which also account for an estimated 40% of worldwide HDV production. In the buses and coaches sub-sector there are also a significant number of smaller manufacturers/bodybuilders accounting for ~25% of all new vehicle registrations.

A review of readily available literature on policy and legislation has revealed that the majority of EU countries have policies to improve the efficiency of freight operations, to promote low emissions vehicles and to control emissions. Taxation, driver training and regulation, all aimed at improving efficiency, are also common practice inside the EU. However, a number of countries in the EU and beyond have indicated that a lack of a standardised method for measuring and reporting fuel consumption on new vehicles makes it difficult to regulate CO_2 emissions from HDVs. Outside of Europe, Japan is already regulating for the future efficiency of HDVs and proposals have recently been put forward in the US for future regulation. However, it is important to take into account regional differences when considering the applicability of experiences in other regions to Europe. For example, the European HDV market is already significantly focused on improving fuel efficiency due to high fuel prices compared to the rest of the world. As a result, the European manufacturers of HDVs are at the forefront of efficient HDV production (hence their significant success in global markets).

When compared to light duty vehicles, the HDV market is highly complicated, with the party responsible for the final truck configuration often not well defined. The major OEMs are for the most part not responsible for the final vehicle configuration (at least for rigid trucks) other than the powertrain, chassis and cab. In addition, in general the final heavy duty vehicles are highly adapted to specific customer requirements and for particular operational cycles / mission profiles – e.g. aerodynamic body styling and various types of auxiliary equipment for long distance, high-speed trucks. As a result, many trucks are produced to bespoke specifications and are essentially one of a kind. In addition, for articulated vehicles (road tractor-trailer combinations), the tractor and trailer are always made and often owned by different organisations. A given road tractor may also pull many (maybe hundreds of) different trailers of different configurations over its working lifetime. A range of auxiliary equipment is utilised in HDVs that runs off the main engine (e.g. cab heaters and air conditioners), resulting in efficiency losses. Other auxiliary equipment (e.g. tippers, refrigeration, tail-lifts) may be run using Power Take-Off (PTO), separate diesel auxiliary power units (APUs), battery power, or a direct plug-in to an electrical power supply. This all leads to a high level of diversity in the resulting final fuel consumption performance of the vehicles creating significant challenges in both adequately characterising the sector and the potential for designing suitable potential policy measures.

In contrast to the vehicle manufacturers, the trailer and body-builder sector is highly diverse with thousands of organisations, most of which operate only in local markets. Consequently very little information is available on the EU market as a whole. However, there are a number of larger players, with the top seven trailer manufacturers accounting for over 50% of new trailer registrations.

Data characterising the number and distribution of HDV operators across Europe is not collected in any standard format, and is very difficult to locate. More data are available for freight vehicles than for other HDV categories. In general, a higher proportion (60%) of the freight tonne km in the EU is associated with longer distance trips. The majority of freight operators are smaller in size, with 85% of operators having fewer than ten vehicles. Of these, hire or reward (HoR) operations account for 85% of tonne km and travel longer distances on journeys compared to own account (OA) operations. HoR operators also purchase and own the majority of road tractors although the proportion of ownership of the trailers they pull appears to be lower. Road tractor numbers are also increasing relative to rigid trucks.

The EU bus industry tends to be dominated by large national/international companies, while the coach sector is made up of a considerable number of much smaller operators. The coach industry activity appears to be mainly associated with higher mileage 'Occasional Service' type journeys, typical of the tourism industry. New registrations of coaches account for around 24% of all bus and coach registrations from 2007-2009 of ACEA members, in contrast to estimates for the composition of the whole fleet which range from 37% to 48%.

Datasets obtained on rigid vehicle and trailer body types have allowed the evaluation of the significance of important truck sub-categories, such as refrigerated/temperature controlled freight transport, which typically consume 20% more fuel than other vehicles. These body types account for around 7% of all new truck registrations and 10% of new trailer purchases. Information provided by ACEA has also allowed the estimation of the split of heavy duty trucks between different mission profiles with different activity and fuel consumption profiles, such as urban delivery, municipal utility vehicles, regional distribution, long haul freight transport and construction.

In terms of vehicle age there are clear differences in the distribution of vehicles by age category (and average vehicle age/lifetime in the country fleet) between trucks and buses/coaches. There is also significant variation between Member States and in general between the Northern, Southern and Eastern European countries. For trucks the average vehicle lifetime appears to be greater than the ten years often cited as being typical. For buses and coaches it appears the average vehicle lifetime is even higher with implied average lifetime of around 15 years for the EU27. European statistics also show that newer vehicles account for a greater proportion of total vehicle km compared to their overall numbers.

Alternative fuel powertrains are in use in only very small numbers for heavy trucks, except in a few Member States. However, there is more widespread use of alternatively powered buses across a number of countries, but in particular in Sweden, Poland, the Czech Republic and in Austria. Of particular note is that whilst natural gas is the most used alternative in the EU15, a significant number of the EU12 states have electrically powered trolley-bus systems.

Little information is available on the second hand vehicle markets for HDVs. However, the available information suggests movements of older used HDVs vehicles from the major EU economies to southern Europe and also the newer EU Member States.

6.2 Technology

Task 3 of the project considered the technological possibilities for reducing energy consumption and greenhouse gas emissions from heavy duty vehicles. The technology that is employed by the heavy duty vehicle fleet will have an impact on the fuel efficiency of the vehicles. The survey of current state of the art technology has revealed that there are numerous technologies available for use on all HDVs in developed countries, however many more technical features are employed on trucks compared to buses and coaches. The survey revealed that while engine technologies across Europe, USA and Japan are very similar in terms of engine displacement, fuel injection equipment and after-treatment there is much less emphasis on vehicle technologies, particularly for city buses, than for the freight segment. The key difference between technologies employed on buses and coaches are the transmission types. Furthermore, only coaches appear to employ ITS/ICT[38] features such as cruise control and brake assist with further optional features such as tyre pressure monitoring and adaptive cruise control.

There are further technologies aside from those already available which can be applied to heavy duty vehicles to reduce greenhouse gas emissions. Technologies have been broadly classified into four categories: engine, drivetrain, vehicle and ITS/ICT. Technologies in the drivetrain and vehicle categories have the potential for the greatest impact on fuel consumption. However fuel consumption benefit is highly dependent on vehicle duty cycle. While some technologies can provide benefit across a range of vehicle duty cycles, others have much greater benefits for some cycles and none for others. For vehicles operating on urban duty cycles with frequent stop/start behaviour, hybrid vehicles offer the most potential with benefits of between 20% and 30% reduction in CO_2 emissions. For vehicles with a large portion of constant high speed operation, aerodynamic aids such as aerodynamic trailers and fairings can offer the greatest benefits of up to 10% reduction in fuel consumption.

To help operators and drivers monitor fuel consumption there are a number of technologies available. However there are no mandatory requirements to monitor and report fuel use for HDVs within the EU. This leaves the selection of such a system down to the individual operator and the system chosen will depend on their needs and the extent to which they actively try to manage fuel consumption. Accurate management of fuel requires data capture that can identify and record the three critical influences: (1) the driver, (2) the vehicle and (3) the journey. The collection of data can be either a manual paper based system, or through the employment of telematic systems with no set rules determining the applicability of individual systems to an HDV operator. Whilst these systems may be in place, unless an operator has the desire to actively manage their fuel requirements and effectively utilises the data captured, they will have no impact on fuel consumption.

Consideration has also been given to the impact of vehicle speed on fuel consumption and the impact this could have on operating costs and logistics. Simple simulations show that for a 10km/h reduction in constant speed from 90km/h to 80km/h for a HGV can result in a 6% reduction in fuel consumption. With fuel representing the single largest cost for an operator at 30% of operations for a 40t articulated vehicle, a 5% reduction in fuel consumption would result in a 1.5% reduction in operating costs. For a typical operator of long haul vehicles, such a reduction can amount to significant monetary sums. Safe and fuel efficient driving has little impact on journey times, however a 10km/h reduction in maximum vehicle speed could have significant implications requiring additional driver rest periods resulting in longer journey times which would then have impacts on some just-in-time logistics. The extent of the impact of a reduction in maximum vehicle speed would need further consideration as current infrastructure does not enable a vehicle to always travel at maximum speed and as such any fuel benefits are likely to be lower than those simulated.

6.3 Fuel Use and GHG Emissions

Task 2 of the project has developed estimates to quantify the level and contribution of HDVs to European energy consumption and greenhouse gas emissions from road transport. It has also developed estimates of how these are split between different HDV applications and scenarios on how this might develop in the future to 2030.

[38] ITS = Intelligent Transport System; ICT = Information and Communication Technology.

Heavy duty vehicles are estimated to account for around 26% of all CO_2 emissions from road transport in the EU. HDVs consume ~3200 PJ of (predominantly diesel) fuel and generate direct emissions of ~240 Mt CO_2. Of this, over 85% is due to trucks, with the remainder due to buses and coaches.

Estimates for the breakdown of fuel consumption and emissions from European HDVs between different applications were developed based on eight mission categories:

- Service/Delivery (≤7.5t);
- Urban Delivery/Collection;
- Municipal Utility;
- Regional Delivery/Collection;
- Long Haul, Construction;
- Buses; and
- Coaches.

This analysis highlighted the importance of long-haul and regional distribution activity in total energy consumption and emissions. These currently account for around 37% and 14% of all HDV fuel consumption respectively, due to higher activity levels (in vehicle km) and larger vehicles. Fuel consumption and CO_2 emissions from the vocational use categories - municipal utility and construction – together currently account for around 17.7% of the total for all HDVs (5.2%, 12.5% individually). The energy consumption and CO_2 emissions from service/delivery and urban delivery vehicles are relatively low versus their numbers (due to lower annual km and smaller vehicles), at 12.8% and 3.7% of all HDV emissions.

Bus energy consumption and emissions (which are 58% of total bus and coach emissions, or 8.7% of total HDV emissions) account for a larger proportion, relative to coaches in comparison to their respective vehicle numbers and activity. Coaches are estimated to account for around 6.3% of all HDV emissions in 2010.

A baseline Business as Usual (BAU) scenario was developed to estimate the potential evolution of fuel consumption and greenhouse gas emissions of HDVs to 2030. BAU assumptions include natural development of powertrain and vehicle based efficiency improvements. Benefits are offset to a significant degree by in-year increases in fuel consumption of 3% following the introduction of Euro VI in 2013 and a speculative Euro VII in 2018. Introduction of significant alternative fuel/powertrain options (e.g. hybrid, dual-fuel vehicles) is assumed to be restricted.

The BAU scenario results showed that overall energy consumption and direct CO_2 emissions might increase by almost 15% by 2030 (+21% for trucks, -21% for buses and coaches) without further actions. Correspondingly, total HDV numbers increase by almost 31% and total vkm by more than 27%. The increase for lifecycle GHG emissions is estimated to be lower (8%) due to the impact of the Fuel Quality Directive requirements and existing biofuel commitments. In terms of the breakdown by category, trucks accounted for 85% of energy/CO_2 in 2010, which is estimated to rise to almost 90% by 2030. This change is principally due to a decrease in stock and activity (by 9% and 10% respectively) for buses and coaches and increases in stock and activity for trucks (by 35% and 32% respectively). The contribution of long-haul trucks to the share of the total for trucks decreases in comparison to other categories. This is principally due to an anticipated reduction in fuel consumption greater than all other HDV categories (at over 10% by 2030) largely due to additional vehicle based measures (e.g. aerodynamic body styling). Refrigerated freight transport is estimated to account for 5.8% of total energy/CO_2 from all HDVs, so action taken to improve the efficiency of both the vehicle and refrigeration equipment/insulation/operations has the potential for a reasonable impact here.

To understand the overall impact that the introduction of fuel efficient technologies can have on the European Heavy Duty vehicle fleet two technology scenarios have been proposed in addition to the Business as Usual (BAU) scenario, which provide an overview of the level of technology required to have a significant impact on fleet emissions and the rate at which technology uptake may be possible. The BAU scenario provides a baseline of expected improvements in vehicle efficiency without any legislative stimulus. The Cost Effective and Challenging scenarios are proposed technology uptake rates incentivised by some means. The scenarios propose uptake rates of technologies applicable for each of the eight different vehicle mission profiles from 2010 to 2030. The Cost Effective scenario proposes uptake rates for technologies which generally have a payback period of around two years along with rates for the uptake of more effective but more costly emissions abatement technology by early adopters. The Challenging scenario proposes uptake rates for all technologies expected to be commercialised between 2010 and 2030 by vehicle mission profile regardless of the length of time required to achieve technology payback. Uptake rates of technology are aggressive and represent a likely maximum benefit.

Results of this analysis show that only through the ambitious uptake of new technologies can the continual increase in both heavy duty lifecycle GHG and direct CO_2 emissions be reduced compared to today's levels. Through technology uptake as proposed by the challenging scenario, the heavy duty vehicle fleet lifecycle GHG emissions can be reduced by 7.3% and direct CO_2 emissions by 2% compared to 2010 levels. While the Cost Effective scenario reduces emissions over the period 2010 to 2020, due to the forecast increase in the size of the vehicle fleet, direct CO_2 emissions still increase by 7.5% against 2010 levels by 2030.

The Cost Effective technology scenario results in the greatest fuel consumption reduction for long haul vehicles, with a reduction in fleet emissions of 10.5% and a decrease in new vehicle fuel consumption of 15.4%. The Challenging technology scenario results in the greatest reduction in fuel consumption for Buses and Urban Delivery vehicles. The largest reduction in fleet emissions is for Urban Delivery vehicles at 18.6% with Buses having the largest reduction in new vehicle fuel consumption of 33.8%. Cost effective technologies are those aimed at long haul vehicles where high mileage and high operating speeds cover the additional cost of technologies such as aerodynamic bodies / trailers and fairings. With the much greater rate of adoption of expensive technologies such as hybrid vehicles in the Challenging scenario, substantial fuel consumption improvements can be achieved for vehicles operating over urban duty cycles. For long haul vehicles higher rates of technology adoption lead to increased overall fuel consumption savings over the cost effective scenario, but urban vehicles achieve even greater improvements between these two scenarios.

6.4 Policy Assessment

Task 4 of the project was a high level policy assessment of the potential instruments that could be implemented at the European level in order to reduce CO_2 emissions from HDVs. The assessment was necessarily high level as a result of the relative resources allocated to this task, which was influenced by the fact that the data gathering of the previous tasks is an important stage that needs to be taken prior to any in-depth policy assessment.

The approach that was taken followed the Commission's Impact Assessment Guidelines, as far as was possible, with the respective sub-tasks mirroring different stage of the IA process. The assessment drew on existing evidence where this was possible, but also included some assessment on the basis of expert judgement.

The first sub-task (4.1) was the collation and high level review of relevant reports. There are a range of reports looking at the potential implications of the introduction of various policy instruments on the CO_2 emissions of heavy duty vehicles. These sometimes focus on a particular instrument in a particular context, e.g. the introduction of larger and heavier trucks in a particular country, or on a range of policy instruments at a higher, or summary, level.

Some reports have been produced in support of the policy analysis and formulation carried out by the European Commission or other administrations, particularly in the US, while others have been produced for, or by, various different stakeholder groups. Most reports focus on heavy freight transport, with significantly fewer looking at policy instruments for reducing CO_2 from heavy duty passenger vehicles.

The first two stages of the IA process, which were also undertaken as part of sub-task 4.1, were to identify the problem and define the objectives of any subsequent intervention. It was confirmed with the Commission that:

- The **problem that has been identified** is that CO_2 emissions from HDVs are increasing and need to be brought under control in light of economy-wide targets to reduce GHG emissions.
- The **objective of the policy intervention** that is being considered is to reduce CO_2 emissions from HDVs. Given that the project focuses on assisting the Commission, the policy instruments under consideration are also those that could **potentially be implemented at the European level**.

The third stage of the IA process (and sub-task 4.2) was to develop a long-list of policy instruments based on evidence in the literature against their potential to achieve the objectives of the required intervention, as noted above. This assessment concluded that there are a number of policy instruments that have the potential to deliver significant CO_2 reductions from heavy duty vehicles, and which can be implemented at the European level. However, in many cases the actual CO_2 emissions reductions that would result from the introduction of the respective instruments would depend on the detail of the instrument, including its ambition and, in many cases, the prevailing circumstances in which the instrument is introduced. However, as a result of this assessment, the following short-list of policy instruments to be assessed further was identified:

- Emissions trading scheme, either a stand alone scheme or integration into the EU ETS;
- Performance requirements for vehicles, their combinations and their components;
- Labelling of vehicles, combinations or components;
- Programme to disseminate best practice;
- Reduction in speed for heavy duty vehicles;
- Changes to weights and dimensions legislation, including the possibility of allowing longer vehicles without allowing for increases in capacity;
- Driver training;
- Fuel taxes;
- Road user charges;
- Differentiated vehicle purchase taxes or incentives.

Sub-task 4.3 followed the fourth stage of the IA process by assessing the short-listed instruments against a wider range of economic, environmental and social criteria. This found that instruments that deliver CO_2 reductions by reducing the amount of travel undertaken by HDVs will also result in reductions of emissions of air pollutants, as less fuel will be used. This in turn delivers economic benefits in terms of fuel savings. Lower levels of traffic would also have benefits for noise and safety. On the other hand, some instruments have potential longer-term or indirect effects, which need to be taken into account in the development of policy in order to ensure that CO_2 emissions reductions are the eventual impact of the policy. Instruments that deliver CO_2 reductions by introducing CO_2 reduction technologies would also generally deliver reductions in emissions of air pollutants, as the emission of such pollutants is linked to the power used by vehicles. CO_2 reduction technologies generally reduce the power used by vehicles, and thus the quantity of other pollutants that are emitted.

From an economic perspective, capital costs are likely to be increased by instruments that require the uptake of technologies that deliver CO_2 reductions, as these are generally more expensive and would add to the cost of a vehicle. Instruments provide different incentives in this respect. Additionally, the administrative costs associated with different instruments vary and are a factor that should not be overlooked in considering which instruments should be introduced to reduce CO_2 emissions from HDVs.

Instruments can be used together to either enhance beneficial impacts, e.g. labelling can be used to reinforce performance requirements or taxation, or address the differing incentives of various actors, e.g. improved technology imposes costs on manufacturers. By contrast,, whereas operators obtain the benefits, or address any rebound effects or wider indirect effects. For example, instruments targeting demand can complement instruments that introduce less CO_2 intensive technologies, which could reduce the costs of use.

Sub-task 4.4, which was equivalent to the fifth stage of the IA process, assessed the short-listed instruments against a range of implementation criteria. This assessment found that fiscal instruments, such as the integration of HDVs into the ETS and fuel taxes based on carbon content, could be considered to be the most economically efficient instruments, whereas other instruments, such as performance standards and labelling aim to address market failures. Most of the instruments were cost-effective to some extent. Labelling, best practice programmes and eco-driving, all have the potential to lead to emissions reductions for a relatively limited financial outlay, while the cost effectiveness of other instruments is based on their potentially high CO_2 savings. The perspective from which costs are estimated also makes a difference. However, the effectiveness of some instruments in delivering CO_2 reductions depends on the balance of first order effects, rebound and wider effects. In particular, reducing maximum speeds and amending weights and dimensions legislation to allow for the wider use of larger and heavier vehicles. For some instruments, such as labelling, best practice programmes and eco-driving, it is not possible to guarantee emissions reductions; rather the evidence suggests that reductions should be delivered.

6.5 Overall Conclusions and Recommendations

Overall it is clear that tackling the ongoing trend in the increase of fuel consumption and GHG emissions from HDVs will be difficult in comparison to LDVs. The sections above provide a summary of each task, which is condensed further below:

- The heavy duty vehicle market is complex with significant diversity in final vehicle specification and performance/use. European manufacturers dominate the EU market and are significant/influential players globally.
- The vast majority of road freight is associated with longer distance trips transported primarily by hire or reward operators with relatively small fleet sizes.
- The future energy/GHG reduction potential of specific power train and vehicle technologies is extremely dependent on the vehicle type /application /duty cycle. The greatest total (and percentage) potential savings achieved for the cost-effective scenario were for long-haul operations. However, even greater savings were achieved for vehicles operating over urban duty cycles in the challenge scenario which assumed significant uptake of expensive technologies such as hybrid and battery electric vehicles. Under the challenge scenario, further improvements to long-haul vehicles were more limited.
- Heavy duty vehicles are designed as load carrying vehicles and have a considerable range in their size (and also duty cycles). From the work carried out for this (LOT 1) report, it would therefore appear that the most meaningful metric of fuel efficiency or GHG emissions for HDVs will be in relation to the work performed, such as fuel consumption per unit payload carried (i.e. weight in tonnes, volume in m^3 or

passengers). The results of policy assessment work also suggest that any developed standards would also best take into account specific duty cycles for different applications or classes of HDV. However, this subject is being investigated in greater detail in LOT 2 of the work, which will be able to provide firmer conclusions and recommendations in this area.

- A high level policy assessment of identified instruments applicable to the EU has been carried out following the EC Impact Assessment Guidelines. However, prioritisation of these instruments has not been possible as cost-effectiveness and GHG reduction potential of each instrument depends on the detail of the instrument, which was outside the project scope.

The analysis carried out for this project showed that even under challenging technology uptake levels starting immediately, GHG emissions from HDVs may only reduced to levels slightly below today's levels by 2030. Should there be significant delay to the stimulation of the HDV market to accelerate the improvement of technical efficiency, the potential future GHG emissions could be significantly higher. However, there are also a number of important elements/areas that have not been covered in this project, or at least not specifically modelled in the estimation of potential future energy and greenhouse gas emissions savings. These would also need to be taken into account when considering the design of future policy and regulation to reduce greenhouse gas emissions and include some of the following:

- Fuel measures, such as uptake and savings from the use of biofuels and infrastructure considerations for alternative fuels;
- Regulations on vehicle dimensions and weight – e.g. longer and heavier vehicle (LHV) combinations may have a beneficial role to play as they are more efficient in transporting freight than smaller vehicles. However, this improvement will be counteracted to an extent depending on the degree to which LHVs divert traffic from less greenhouse gas emitting modes of transport and the size of rebound effects due to reduction in transport operating costs. Their introduction, even on dedicated routes, may require major infrastructure expenditure and raises potential safety concerns.
- Possible impacts of speed controls or reductions on heavy duty vehicle fleet fuel consumption;
- Road infrastructure measures, such as measures to improve capacity, reduce inclines and reduce bottlenecks;
- Operational measures, including ITS for:
  - fleet management and logistics, such as driver training, efficient routing, vehicle tracking and remote diagnostics; and
  - traffic management and control, such as for reducing congestion, managing dedicated lanes, access control and dynamic speed limits;

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