Report

Commercial Vehicle of the Future

A roadmap towards fully sustainable truck operations

iru.org

Commercial Vehicle of the Future

A roadmap towards fully sustainable truck operations

Author:
Transport & Mobility Leuven
and IRU contribution.

January 2017

Contents

Executive summary

The freight transport and logistics industry is an important driver of economic growth in Europe. As the most flexible and, in many cases, least expensive mode of transport, road freight is by far the most commonly used method to carry goods. As such, it also carries a great responsibility: to provide transport services for European citizens and industry in an efficient, reliable, safe and sustainable manner.

This report's aim is to take stock of how evolving technologies and trends could shape the use of commercial vehicles in the future, how they might help the sector meet the EU's ambitious CO_2 emissions reduction goals for 2050 and how these measures might have positive cross-over benefits for improving road safety and operational efficiency.

The report is based on the outcome of the work of the IRU Reflection Group on the Commercial Vehicle of the Future (CVOF), which is a public–private group of EU road transport professionals, civil servants and experts. The IRU Reflection Group was convened between September 2015 and January 2016 to discuss medium- and long-term policy and business recommendations and to propose an action plan on how to reach a 30% reduction in CO_2 emissions by 2030 and a 60% reduction by 2050. The participants were also tasked with considering the conditions needed to significantly increase road safety and operational efficiency by the 2030 and 2050 horizons.

For each of the three targets (CO_2 emissions reduction, road safety and operational efficiency improvements), the report outlines operational objectives and scenarios for 2030 and 2050. It then looks at how the potential contributions of different measures could help meet the targets for urban delivery, regional delivery or long-haul cycles. The results are then consolidated in an integrated approach outlining the potential characteristics of a commercial vehicle operating in 2050. Finally, the report lays out a roadmap with the key steps that decision-makers and industry would have to take in the following decades to meet the long-term targets.

The report assumes that in 2050, freight will still be carried by the vehicle types recognisable today. There is currently insufficient knowledge to adequately measure the impact of certain new trends in road freight transport and logistics, including the accelerating emergence of the "sharing economy." As a starting point, a background scenario for 2050 was developed for transport growth and the subsequent potential increase in CO_2 emissions. Parallel scenarios were developed for road safety and operational efficiency. Building up these background scenarios, even when considering potential corrections, convinced the IRU Reflection Group that it would be very difficult to meet any targets with a "business-as-usual" approach.

A wide variety of measures is examined which could contribute to reducing emissions and further increasing road safety and operational efficiency. The list is non-exhaustive because the development of some measures, such as hydrogen fuel cell technology, is not advanced enough to give an accurate picture of their potential contribution. These measures include a number of propulsion systems and energy carriers, such as further technological improvements to internal combustion engines (ICEs) running on diesel, the use of natural, bio- and synthetic gas or advanced biofuels and different technologies for electrification. Other vehicle-related aspects are also examined including aerodynamics, tyres and lightweighting. Vehicle driving, including the use of Advanced Driver Assistance Systems, driver training and awareness raising are examined. The impact of a greater use of Intelligent Transport Systems is considered, as are increased connectivity between vehicles and between vehicles and infrastructure. That enhanced connectivity should enable a Europe-wide roll-out of truck platooning technology and its potential evolution towards the use of fully autonomous vehicles. The contribution of changes in the organisation of logistics and supply chains is also considered, including the potential impact of further digitalisation, the emergence of practices linked to the sharing economy and changes in the rules on the weights and dimensions of road freight transport vehicles.

The contributions of the different measures for reducing CO_2 emissions are summarised in tables for long-haul and regional delivery cycles and are described for the urban delivery cycle. The interactions between the different measures and their overlapping benefits are taken into account.

A one-size-fits-all solution is not available. The tables in the report show that targets can only be met using a combination of measures. Although the 2030 targets are within reach if a wide variety of measures relating to legislation, vehicles, fuels (including alternative fuels) and operations are rolled out, it will be very difficult to reach the 2050 targets without fundamental changes. These would have to include the large-scale use of renewable energy sources and the development of different ways to carry freight by road. In this perspective, it must be remembered that the potential benefits of these measures (including alternative technologies, fuels and operational practices) will continue to vary according to each heavy goods vehicle's usage profile and the specific duties that it has been contracted to carry out.

The road freight transport and logistics sector thus faces ambitious targets for reducing its environmental impact, improving safety and increasing operational efficiency. The latter target should be seen in two dimensions. The first is an increase in the operational efficiency of road freight transport itself. The second and more significant dimension is an increase in the efficiency of the road freight transport sector as a key component of a wider EU freight transport network and logistics chain, also acting as a connection between the EU, its neighbouring countries and the rest of the world.

With society experiencing ever faster developments in the field of connectivity, road freight transport and logistics cannot lag behind. The future of road freight transport lies in full connectivity between companies, people, infrastructure, vehicles, loading units, logistical partners, authorities and governments.

Several innovative developments will have a very strong impact on how road freight transport and logistics operations will be organised in the future and could contribute to a reduction in the sector's environmental footprint. Firstly, the wider use of Intelligent Transport Systems (ITS) by road freight transport and logistics operators and the competent authorities is laying the groundwork for greater innovation in the future. The political and legislative facilitation of new, compatible, EU-wide solutions, as well as interoperability between existing systems, should be promoted—they will generate even greater progress. The implementation of large-scale truck platooning across the EU is a good example of this. Truck platooning will lead the way towards increased vehicle automation and then to the use of fully autonomous road freight vehicles. This will require a fundamentally different approach to the traditional rules on the use of the road, especially regarding the role of the professional driver. Fully autonomous commercial vehicles will undoubtedly provide new opportunities for vehicle and loading-unit design and substantially overhaul the way freight is moved by road and multimodal transport. Further deployment of ITS will also speed up the digitalisation of road freight transport and logistics processes and the entire multimodal transport chain. The political and legislative groundwork that will allow further EU-wide progress needs to carried out in advance. Wide-scale use of ITS and digitalisation will also create new opportunities for road freight transport and logistics operators to collaborate. The collaborative economy is introducing new ways of sharing resources and cooperating which could contribute to more efficient load factors.

Looking at commercial vehicles themselves, meeting the targets set for them regarding CO_2 emissions reduction will be a challenge—especially a reduction of 60% by 2050. Difficult and potentially expensive decisions will have to be made by the different industry stakeholders, including road freight transport and logistics operators and society as a whole. Meeting the reduction targets for long-haul and regional delivery may prove impossible without fundamental changes in powertrain and fuel technologies, where there will have to be a fundamental leap forward in the use of renewable transport fuels. The currently available propulsion systems and energy sources provide a number of CO_2 emissions reduction options, including increasing the efficiency of the ICE, the use or the blending of biofuels with diesel, and the use of gas, hybridisation or electrification. From a tank-to-wheel perspective, biofuels and gas have significant CO_2 reduction potential. From a well-to-wheel perspective, indirect land-use changes, the primary source of the biofuels and methane emissions for gas are just some of the aspects which will have to be addressed. Biomethane or synthetic methane, produced from renewable sources, are alternatives that should be promoted as one of the ways forward. Biofuel and gas options need to be developed further and should certainly not be discarded. When looking at the potential for extensive road electrification, vehicle technology, infrastructure, grid capacity and the well-to-wheel emissions performance of the electricity produced and distributed are some of the aspects to be addressed. Investment costs would be substantial. For vehicle manufacturers, this would be in terms of vehicle technology research and development; for road freight transport and logistics operators, this could be in higher vehicle investment costs. Fuel producers and society as a whole would have to pay for upgrading the infrastructure to produce and distribute energy. Governments will have to create the necessary financing mechanisms to facilitate any change and innovation in terms of the types of energy used for freight transport and logistics. Further research should be undertaken in the field of technology and infrastructure solutions, and there should be a roadmap on how this development could be financed in a balanced manner acceptable to all the different stakeholders involved. There is a persistent concern among road freight transport and logistics operators that they will have to absorb a disproportionately high percentage of the total bill, which would undoubtedly jeopardise the acceptability of this key move. The important message is that further research into economically viable alternative energy sources for the long-distance, heavy-duty cycle must continue and be encouraged.

The measures proposed for emissions reduction could also open up new opportunities for improving road safety, as human error is gradually reduced by technology. However, it is difficult to quantify the impact of emissions reduction measures on road safety improvement.

There is also a great deal of potential for CO_2 emissions reduction measures to improve operational efficiency, although there is much uncertainty about its scope. This is an important domain for further research. Emissions reduction measures will very much continue to depend on decisions made at the company level. Technology, vehicle model and depreciation, developments in alternative fuels (especially renewable ones) for commercial vehicles, the scope for the development of existing technologies, innovative technologies finding their way to market, digitalisation, transport policy and legislation, general geopolitical and economic developments and new working practices in road freight transport and logistics could all influence the speed at which the sector adopts innovation and its potential to improve operational efficiency. Much will also depend on ownership structures, which are still evolving. Greater transparency about the impact that new technologies could have on their business would put road freight transport and logistics operators in a position to make well-informed investment decisions. Road freight transport and logistics operators should receive more encouragement to commit to reducing fuel consumption and improving their operational efficiency, as this, in turn, will contribute to reducing CO_2 emissions. Individual companies will require tailor-made solutions based on their structure and type of activities. Small and medium-sized companies may have to be offered guidance. A harmonised methodology for collecting, reporting, monitoring and certifying the emissions reductions resulting from these efforts should be established. The sector's acceptance of CO_2 emissions reduction measures will depend largely on their potential to contribute to improvements in operational efficiency and cost reductions, as well as on road freight transport and logistics operators' ability to absorb additional initial costs: transport operators will require assurance that their costs will somehow be offset.

Within the context of the general, vehicle, safety and operational efficiency considerations that we have mentioned, the Commercial Vehicle of the Future can be envisioned as a "carrier" of road freight. This could be a vehicle and/or a loading unit. This carrier will have to be highly modular, with a very high degree of interoperability between modules and more flexibility in weights and dimensions (especially in terms of length and weight); it will have to make more use of swap bodies and loading modules, and the potential for double stacking or using a movable roof. Most of these carriers will have to run on renewable energy sources which are currently difficult to predict with sufficient accuracy. The carrier should be fully connected to other carriers, human beings and infrastructure, as well as being fully autonomous. The carrier's shape may be completely different from the vehicles we know today. Intelligent transport systems will have to be very extensively used to facilitate the carrier's development. Such a "carrier" is likely to perform best in the 2050 scenario: that is, meeting the ambitious target of reducing CO_2 emissions by 60% or more by that year.

A roadmap has been developed based on discussions within the IRU Commercial Vehicle of the Future Reflection Group, work carried out by other experts and information currently available on emissions reduction options. This roadmap comprises a number of important steps and measures which would have to be implemented to ensure the wide-scale use of such "carriers" in the EU's road freight transport and logistics sector. However, regardless of other steps, this report suggests that the CO_2 emissions reduction target of 60% by 2050 will be impossible to meet without fundamental improvements in powertrain and fuel technologies. If pre-set targets are to be met, renewable energy sources will have to be in the ascendancy by around 2035 and gradually increase their market share towards 2050. This timeline cannot be fixed, however, and over time it will have to be fine-tuned and adjusted, either as new information becomes available or as new developments take place. Based on information available today, 2035 should, therefore, be considered a highly significant deadline for action in the current roadmap. If not, the possibility of meeting the 2050 targets could be jeopardised.

The immediate situation: 2016–2020

- Manufacturers are expected to keep improving vehicle engine efficiency, within the current EU legal framework, but fleet renewal takes time. The EC and Member States should seriously consider close dialogue with industry stakeholders on policy action on vehicle emission standards. Measures to give road freight transport and logistics operators an incentive to speed up their fleet renewal rate should be considered.

- Further vehicle hybridisation is expected in urban and regional delivery.

- Gas-powered vehicles are expected to command a larger share of vehicle sales if the Member States rapidly implement the Directive on Alternative Fuel Infrastructure. Further efficiency improvements to the gas powertrain are to be expected. Solutions are needed to minimise methane emissions. The blending of natural gas with biomethane and synthetic gas should be encouraged.

- The provisions of the Fuel Quality Directive and Renewable Energy Directive remain valid until 2020. However, a cap on the volume of food-based biofuels should stimulate interest to increase the production of second generation biofuels in the future. To enable this, legislators should immediately start preparing new EU rules to support the use of these fuels, which are expected to remain more expensive than their fossil counterparts. New legislation should account for the near future and set the stage for the long term.

- The 2015 revision of the EU weights and dimensions Directive 96/53/EC should be fully implemented during this period. Vehicle design is expected to remain largely similar in the 2016–2020 period, with the possible exception of the boat tails fitted to new semi-trailers to improve their aerodynamic performance. The cost for retrofitting existing trailers could be prohibitive (especially those approaching their end of life) with regard to depreciation. Legislators should consider introducing incentives to accelerate the market uptake of new technologies that improve vehicles' aerodynamic performances. Preparation for a new revision of EU weights and dimensions legislation and related EU and UN type-approval and general safety rules should start in 2020.

- Further research and trials into economically viable solutions for the electrification of long-distance HGVs are expected. Economically viable finance and investment mechanisms will have to be thought out too. Important points will be the carbon-free production of electricity, grid capacity and solutions usable for a wide range of vehicles.

- Further research will be needed into the opportunities and challenges offered by developments and trends in the collaborative economy, as well as their impact on the EU road freight transport and logistics market and its legislative framework. Collaborative logistics platforms will have to be tested and data management systems secured.

- A fully operational emissions certification tool will be required for all types of new HGVs being type-approved in the EU by 2020. The subsequent preparation of CO_2 and fuel consumption performance standards for new HGVs should be based on work performed on complete vehicle combinations. A transparent information system on the fuel consumption and CO_2 emissions reduction potential of different vehicles and technologies should be available to the market in order to facilitate informed investment choices based both on optimal efficiency and the environment.

- Further progress is expected in the compatibility and interoperability of national ITS domains and applications.

- An EU legal framework should be prepared to enable cross-border trials of truck platooning and its use on a wider scale.

- Road freight transport and logistics operators are expected to make more active use of fuel consumption reduction measures, such as voluntary speed reductions and generalised eco-driver training. This would be accompanied by voluntary carbon footprinting as a means of monitoring results and making successful CO_2 emissions reduction more transparent.

- Driver training to improve road safety and fuel efficiency will be needed, as will incentives for the market uptake of vehicles equipped with ADAS.

- Low rolling resistance tyres must be chosen consistently when replacement is needed.

Decisions and preparations: 2020–2030

- Continued steady improvement of the diesel powertrain is expected, as is accelerated market uptake of new vehicles which have been type-approved in accordance with the VECTO methodology.

- Work towards decarbonising the (electric) power generation system will continue.

- Measures to prepare the electricity grid for increased usage by road transport vehicles, including commercial freight vehicles, should be taken.

- Hybrid vehicles are expected to contribute more to long-haul transport (including the use of on-demand hybrid systems to provide auxiliary power); a very high share of regional delivery, and especially urban delivery, should move to electric battery-powered operations.

- Advanced testing of electrified long-distance transport, including via the electricity grid, should be occurring. The nature of this measure does not allow for coexisting incompatible systems. Thus unanimous action by the Member States/road infrastructure authorities will be needed to ensure unified standards, perhaps considering a technology that can be used by different types of vehicles. An EU-level financing mechanism will have to be developed, and electric long-distance transport will have to be rolled out by the end of the decade to allow for sufficient infrastructure development in the long term.

- An incentive scheme for road freight transport operators should be created to encourage investments in alternative fuel vehicles.

- Continued steady improvement in the gas powertrain is expected, as is the development of biogas capacity for use in commercial road freight transport.

- Alternative-fuel infrastructure will have to be fully ready for use, as determined by the applicable Directive. The EU's Alternative Transport Fuel and Infrastructure legislation will have to be revised to enlarge the scope for alternative, renewable fuels for use in heavy commercial vehicles, including the use of electricity produced from renewable energy sources.

- Technological development of advanced biofuels is expected to speed up, aided by a long-term legislative framework which could include incentives, quotas or CO_2-based fuel taxes. Long-term electricity production plans should account for increases in power requirements.

- Advanced driver assistance systems should be standard in new HDVs. The focus of driver training is expected to shift from taking action to properly reading and reacting to ADAS. ITS should ensure optimal routing.

- Implementation of the EU regulatory framework should allow regular truck platooning on all major European roads by 2025—a first step towards the use of fully autonomous vehicles. Further developments in EU and UN regulatory frameworks should enable progress in vehicle automation.

- A revision of EU weights and dimensions legislation and related EU and UN type-approvals and general safety rules should start by 2020. This will allow further flexibility in weights and dimensions on the grounds of environmental performance and road safety. Furthermore, this should create possibilities for increased carrying capacity provided that infrastructure-related performance standards are met, including turning-circle, vehicle width and axle (weight, number and type) requirements.

- Aerodynamic cabs should become the norm. Further steps in weights and dimensions regulation should improve vehicle design and the aerodynamics of complete vehicle combinations.

- A complete removal of restrictions on the cross-border use of LHV combinations is expected, provided that infrastructure can accommodate them. There may be increases in the maximum authorised weights of all cross-border road freight transport vehicles above 3.5 t provided they comply with a set of environmental performance, operational performance and road safety-related rules.

- A move towards the integration of toxic and non-toxic emissions norms is expected, as is the gradual introduction of global rather than regional norms.

- Taxation based on vehicle ownership or the type of energy used is expected to gradually move to taxation based on environmental performance and the type of vehicle use. This principle should apply to all road vehicles, not only commercial road freight transport vehicles. The environmental performance of a road freight transport vehicle should be calculated based on the entire vehicle or vehicle combination, not just its engine/gearbox.

- An evaluation of the achievements of emission certification tools should be carried out, as should an analysis of the performance of CO_2 reduction and fuel consumption standards for heavy commercial vehicles.
- The testing of collaborative logistics platforms should be expanded, with harmonisation coming towards the end of the decade. Integration should be fully multi-modal.
- Fully interoperable, compatible, cross-border ITS applications should be helping infrastructure managers, road transport users and enforcement authorities.
- Road pavement renewal should focus on reducing rolling resistance while improving grip.

Time for major action: 2030–2040

- Alternative-fuel infrastructure for road transport should be widely available throughout the European Union.
- The conditions should have been met to allow alternative propulsion and energy sources to reach a significant share of the road transport energy market.
- An advanced biofuel production breakthrough will be needed to power long-haul operations off the grid and regional deliveries when battery operation is impossible. Gas vehicles should be switching mostly to biomethane.
- Diesel engines are expected to be fully ready for high proportions of biofuel.
- Single wide, latest generation, low rolling resistances tyres are expected to be standard.
- Logistics harmonisation should be moving ahead at full steam, resulting in increasing load factors and even in longer, heavier vehicles (which are also used in regional delivery cycles).
- Weights and dimensions regulation should be based on standards of operational performance. Modularity should move towards the "physical internet."
- Legislative processes authorising fully autonomous vehicles should be complete (including provisions for driving/resting times).

Rolling towards the goal: 2040–2050

- Autonomous vehicles are expected to be in common use, 24 h per day, 7 days per week. The driver's role will have changed to that of a cargo manager. Fundamental vehicle redesigns are to be expected, taking into account the changed role of the human being.
- Investment renewable energy sources for all types of road freight transport operations will continue in. At least 30% of the average blend should be advanced biofuels; 40%–45% of long-haul road transport should be powered through road network charging infrastructure.

Preparations are expected to be underway for a complete phasing-out of fossil fuels as an energy source.

About the Initiative

The freight transport and logistics industry is an important driver of economic growth in Europe. As the most flexible and, in many cases, least expensive mode of transport, road freight is by far the most commonly used method to carry goods. As such, it also carries a great responsibility: to provide transport services to European citizens and industry in an efficient, reliable, safe and sustainable manner.

This report presents the work of the Reflection Group on the Commercial Vehicle of the Future (CVOF), which held sessions during the second semester of 2015 and the first semester of 2016, as part of an IRU initiative. As a representative public–private group of EU road transport professionals, civil servants and experts, the Group's objectives were to develop medium- and long-term policy and business recommendations, to propose an action plan on how to reach a 30% reduction in CO_2 emissions by 2030 and a 60% reduction by 2050, and to draw up the framework conditions needed to significantly increase the safety and efficiency of commercial vehicles (in both new and existing fleets), operations and infrastructure within this time frame.

During the CVOF Reflection Group meetings, different ways of meeting the targets were discussed at length, supported by documentation provided by the participating stakeholders themselves, input prepared by Transport & Mobility Leuven, an independent consultant, and IRU. In addition, several other researchers were invited to present the results of their findings on similar topics.

For each of the three targets mentioned (CO_2 emissions, road safety and operational efficiency), the present report initially discusses what the objectives are and tries to sketch out a scenario in which the CVOF could be expected to be in operation by 2030 and 2050. Subsequently, the different options are presented, along with an assessment of their potential contribution to each of the three targets. Both the positive and negative interactions between the different options are given specific attention, as are the actions of the different stakeholders that would be required to implement measures. The results of many different kinds of measures are brought together in an integrated approach. The report's final section presents a roadmap containing the important steps needed in each of the future decades to meet the long-term targets for a commercial vehicle that emits little CO_2, causes a minimal number of accidents and does so at the highest possible level of operational efficiency.

DISCLAIMER

This report aims to bring together the views of a wide range of stakeholders and experts in order to contribute to an informed debate on the measures which could help the road freight transport and logistics industry reduce its environmental footprint and further improve road safety and operational efficiency.
The views expressed in this report are a collection of those of the different stakeholders involved in the IRU Reflection Group on the Commercial Vehicle of the Future and of IRU and its Members. As such, not everyone involved in this initiative may necessarily fully support all the views expressed in the report. All the stakeholders involved do share a common interest, however: encouraging positive change to enable CO_2 emissions reduction together with improvements in road safety and operational efficiency.

Foreword

In today's globalised economy, professional road freight transport is no longer merely another way of moving goods, but rather an essential tool of production. Through its unique, high quality, door-to-door service, road transport is a vital means of connecting businesses to all the world's markets. In 2015, the international community adopted the Paris Climate Change Agreement (COP21), to "strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty." The EU has become one of the frontrunners in the decarbonisation process. Increasingly, transport and mobility are also expected to contribute to this process, and the EU is setting the sector ever more ambitious targets.

Innovation is revolutionising and speeding up the way people and goods move. Digitalisation, e-commerce, electro-mobility, automated driving, connected vehicles and infrastructure, and new logistical concepts and practices are among the initiatives already shaping the way both businesses and citizens approach mobility and transport. Modal thinking about transport is making way for complementary multimodal freight and logistics networks, interconnected worldwide.

EU transport and logistics policies are at a crossroads, however. Customer expectations are rising and competition is strong. There is constant pressure on businesses to become more efficient and socially responsible, improve road safety and reduce their environmental footprint. Road freight transport and logistics will continue to play a pivotal role in Europe's multimodal transport network for many decades to come. However, a different approach will be needed if the EU's public and private stakeholders are to reach a common understanding with national and European regulators on the priorities and policies required to establish an even safer, more innovative, socially conscious, environmentally sustainable and efficient transport system across the region. This can be achieved by allowing each transport mode to maximise its efficiency and interact more effectively with the others. This would enable better transport, rather than simply more transport, thanks to the use of new technologies and more efficient working practices. In 2009, IRU and its Member Associations voluntarily committed to reducing CO_2 emissions by 30% by 2030, recognising that this target could only be achieved in cooperation with other industry partners and governments.

In 2015, IRU brought together public and private stakeholders to explore the concrete progress to date, and they were also challenged to look as far ahead as 2050 to create a vision of how freight would need to be carried in order to meet the EU's ambitious CO_2 emissions reduction objectives. The process involved significant deliberations about new opportunities to improve safety, environmental performance and efficiency. This was the starting point for the IRU Reflection Group on the Commercial Vehicle Of the Future—the CVOF. IRU is conscious that changes in the way society thinks about the movement of people and goods will be vital to the success of these commitments and it is excited to be leading this effort. The report upholds calls for change and makes a number of challenging business and policy proposals on how to achieve further reductions in fuel consumption and CO_2 emissions, as well as how to improve road safety and allow road freight transport and logistics operators to improve efficiency and develop their businesses. The report's conclusions should be seen as the start of an ongoing process, taking stock of the progress achieved, considering new trends and developments and continuing to drive change.

I would like to express my great appreciation to all the public and private stakeholders who contributed to this IRU Reflection Group and thank them for their dedicated commitment to carrying out this task.

As a global leader in nurturing and promoting innovative freight transport and logistics solutions, IRU is ready and willing to work with its public and private sector partners to develop the sustainable transport system of the future and meet the ever-growing economic, social and environmentally friendly mobility needs of EU citizens.

Umberto de Pretto
IRU Secretary General

The stakeholders

Different stakeholders from the public, private and non-profit sectors participated in the work of the IRU Reflection Group on the Commercial Vehicle Of the Future, either in an active, observer or expert role. The participants are listed below.

Active participants

CLECAT
Conservation of Clean Air & Water in Europe (CONCAWE)
Electricity for Europe (EURELECTRIC)
ERTICO – ITS Europe
European Automobile Manufacturers' Association (ACEA)
European Shippers' Council (ESC)
European Transport and Safety Council (ETSC)
European Tyre and Rubber Manufacturers' Association (ETRMA)
Daimler
FuelsEurope
International Association of the Body and Trailer Building Industry (CLCCR)
Natural Gas Vehicle Association (NGVA)
Scania
Siemens
Transport & Environment (T&E)
Volvo

Observers

Conference of European Directors of Roads (CEDR)
European Commission, Directorate-General for Climate Action (CLIMA)
European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (GROWTH)
European Commission, Directorate-General for Mobility and Transport (MOVE)

Experts Consulted

Dr Philip Greening, Centre for Sustainable Road Freight, United Kingdom
Adithya Hariram, P&G, Brussels Innovation Centre
Dr Richard Smokers, TNO
Bert Witkamp, the European Association for Battery, Hybrid and Fuel Cell Electric Vehicles (AVERE)

1. Definition of targets

In this chapter, we discuss exactly what each objective covers and what its specific targets are.

1.1 The targets for CO_2

The IRU Reflection Group on the Commercial Vehicle of the Future was asked to examine two specific emissions reduction targets for transport: achieving a 30% reduction in CO_2 emissions by 2030 (compared to 2007) and a 60% reduction by 2050 (compared to 1990).

Commercial vehicles' fuel efficiency and emissions are influenced by several factors, including vehicle design, size and weight regulations, load factors, the powertrain, type of fuel and areas of operation, driver technique, weather and infrastructure conditions, and management and national policy.

The definition of fuel efficiency can be expanded to include a measure of productivity, such as "tonne–km of payload transported or passenger–km transported". This takes into consideration the balance between the fuel used and the work done. It offers a useful method of addressing the practical efficiency of transport units while still paying attention to the vehicle's environmental performance itself. Reducing CO_2 emissions (fuel consumption), therefore, is all about moving freight and passengers in the most efficient way possible while considering all the elements of sustainability (environmental, social and economic).

The above emissions targets are based on two sources. The 2030 target is based on the "30-by-30 Resolution" adopted by the IRU General Assembly in 2009. The Resolution is a voluntary commitment to reduce CO_2 emissions by 30% by 2030, as compared to 2007 values. The Resolution indicates that investments in the latest innovative engine and vehicle technologies could contribute 10%, driver training could contribute another 10%, and innovative logistics concepts, such as Intelligent Transport Systems (ITS) and optimised weights and dimensions, could contribute a further 10%.

The long-term target for 2050 is based on the 2011 European Commission (EC) Transport White Paper and is a 60% reduction of the emissions in 1990. The White Paper also included a target for 2030 which differs from the one set out in the "30-by-30 Resolution"; it suggested that greenhouse gas (GHG) emissions in 2030 should be 20% lower than in 2008. The White Paper sets no sub-targets for individual transport modes or types of transport, with the potential exception of a goal to "achieve essentially CO_2-free city logistics in major urban centres by 2030".

Table 1:
Transport GHG emission targets (source: 2011 EC White Paper)

	Ref. 1990	Ref. 2008
Medium-term target (2030)	+8%	-20%
Long-term target (2050)	-60%	-70%

More recent EC publications (including DG CLIMA's 2030 climate and energy framework) have set a more ambitious 2030 target of 30% fewer CO_2 emissions than in 2005. This was confirmed in the Low-Emission Mobility Strategy published in July 2016.

It is very important that all stakeholders use the same reference values. According to the European Environmental Agency (EEA) (indicator CSI010)[1], road transport CO_2 emissions should be measured as follows (1 Gg = 1,000 tonnes; 1,000 Gg = 1 Mt):

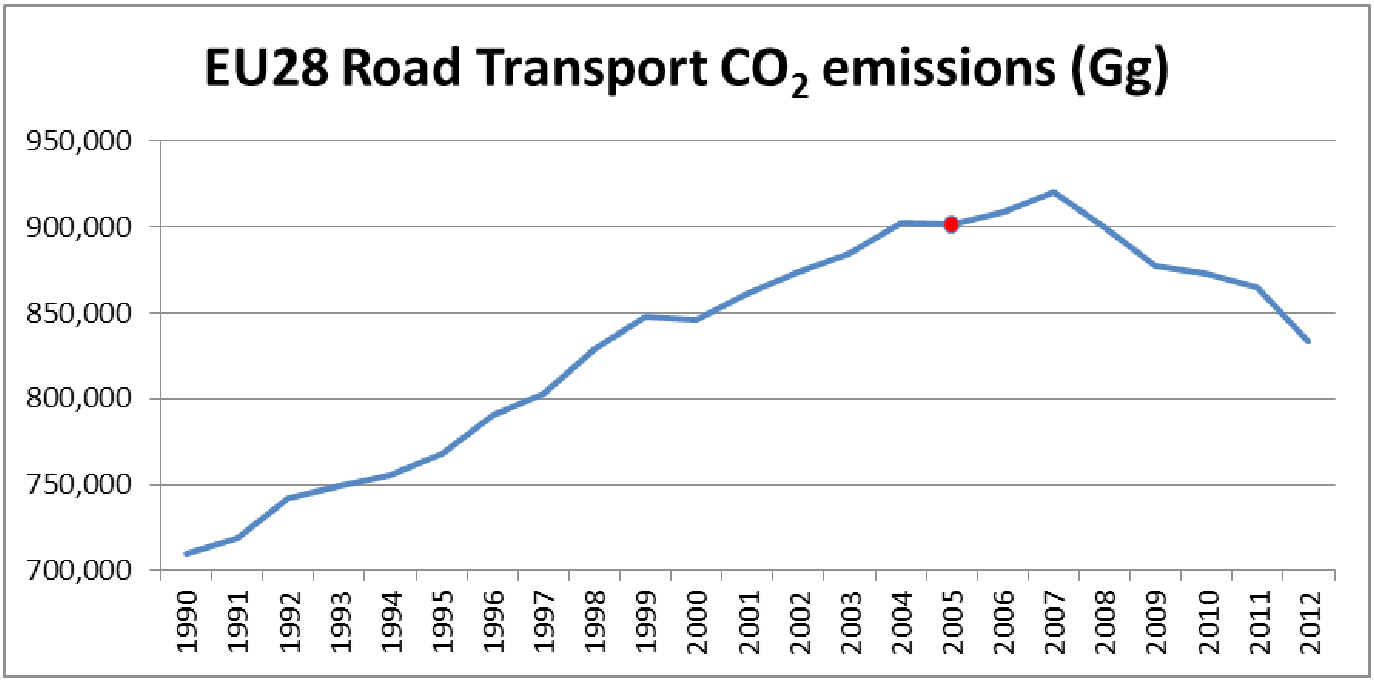

Figure 1: Evolution of EU28 road transport CO_2 emissions (source: EEA)

The emission levels for key years are:

Table 2: Historic Road Transport CO_2 emissions

Year	Emissions	Comment
1990	710,771 Gg	Long-term reference year
2005	901,438 Gg	EC policy framework reference year
2007	918,922 Gg	"30-by-30" reference year
2008	899,518 Gg	Medium-term reference year
2010	874,097 Gg	Reference year for demand growth
2013	829,318 Gg	Most recent reported data

The TREMOVE 3.5c transport model can be used as a starting point for estimating the absolute reduction in CO_2 emissions from road freight, as it provides a split between road freight and passenger transport.

By assuming the 60% reduction target set in the White Paper will apply equally to all non-Emissions Trading System (ETS) sectors, road transport as a whole should be able to reduce its CO_2 emissions by just over 425 Mt in 2050 in comparison to 1990, and by around 625 Mt in comparison to 2008. If all the road transport sub-modes are assumed to split the overall reduction effort in proportion to their share of emissions

1 http://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-5

in 2008 (as found in TREMOVE), then around 30%2 would have to come from road freight vehicles (of all motor vehicle categories). Certain decarbonising road transport technologies can be more efficient for light-duty vehicles and could, therefore, have a greater impact on emissions reduction, which could leave some margin of error for freight transport. The present report does not account for this, however.

This target is in line with the latest developments at the EC level, i.e. in its Strategy for Low-Emission Mobility and the proposed extension of the Effort Sharing Decision's targets (30% reduction on 2005's emissions levels by 2030).

1.2 The targets for road safety

The reference safety target for this project is in line with the target set in the 2011 Commission Transport White Paper. The target is formulated as: "By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport."

2 Assuming that CO_2 emissions from road freight transport are about 30% of total road transport CO_2 emissions

Assuming a proportional effort across different modes of transport, this translates into the following targets for heavy goods vehicles (HGVs):

- halving fatalities from accidents involving HGVs by 2020,
- halving fatalities from accidents involving HGVs by 2030, compared to 2020 figures,
- (close to) zero fatalities from accidents involving HGVs by 2050.

1.3 The target for operational efficiency

No specific targets have been set in terms of operational efficiency. However, two elements do need to be considered when looking to set any potential objectives regarding this. Firstly, the 2011 Commission Transport White Paper aimed to increase the efficiency of the EU transport network. In addition, road freight transport is expected to continue to play the key role in the freight modal mix. Therefore, the significant efforts expected of road freight transport operators in meeting CO_2 emissions reduction targets and contributing to the process of improving road safety must also provide them with opportunities to reduce costs, increase operational efficiency and further develop their businesses. This win–win situation will be essential to encourage acceptability.

2. Background scenarios

As a starting point for compiling a background scenario for this study, it must be pointed out that based on information available today, we assume that road freight transport in 2050 will still be carried out by vans and light and heavy goods vehicles. It is known that other ways of transporting goods by road (such as the physical internet, drones and superconductors) are currently being researched, developed, tested and even used. However, there is as yet insufficient knowledge to measure their potential impact on the reduction of CO_2 emissions, the improvement of road safety and operational efficiency.

In terms of the projected growth in freight transport, the starting point for this background scenario is the 2016 EU Reference Scenario, as described in "EU Energy, Transport and GHG Emissions: Trends to 2050", an EC publication. It should be noted that since the publication of this scenario, several developments have taken place which require its re-evaluation. Below, we first describe the scenario's main elements and then give the comments and modifications deemed necessary to update it.

2.1 Background scenario for transport growth and CO_2

2.1.1 EC Reference Scenario 2016 for transport growth

The first key parameter for a projection of future freight transport demand is GDP. Traditionally, there has been a close link between GDP and the demand for freight transport and subsequent carbon emissions. However, it has become clear that these variables are decoupling and this trend will certainly have to continue in order to meet the CO_2 emissions reduction target for 2050. According to the EC reference scenario 2016[3], GDP is expected to grow by 1.4% p.a. from 2020–2030, and by 1.5% p.a. from 2030–2050. GDP/capita should thus increase by a factor 1.67 over the period from 2010–2050.

3 See https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf, p128.

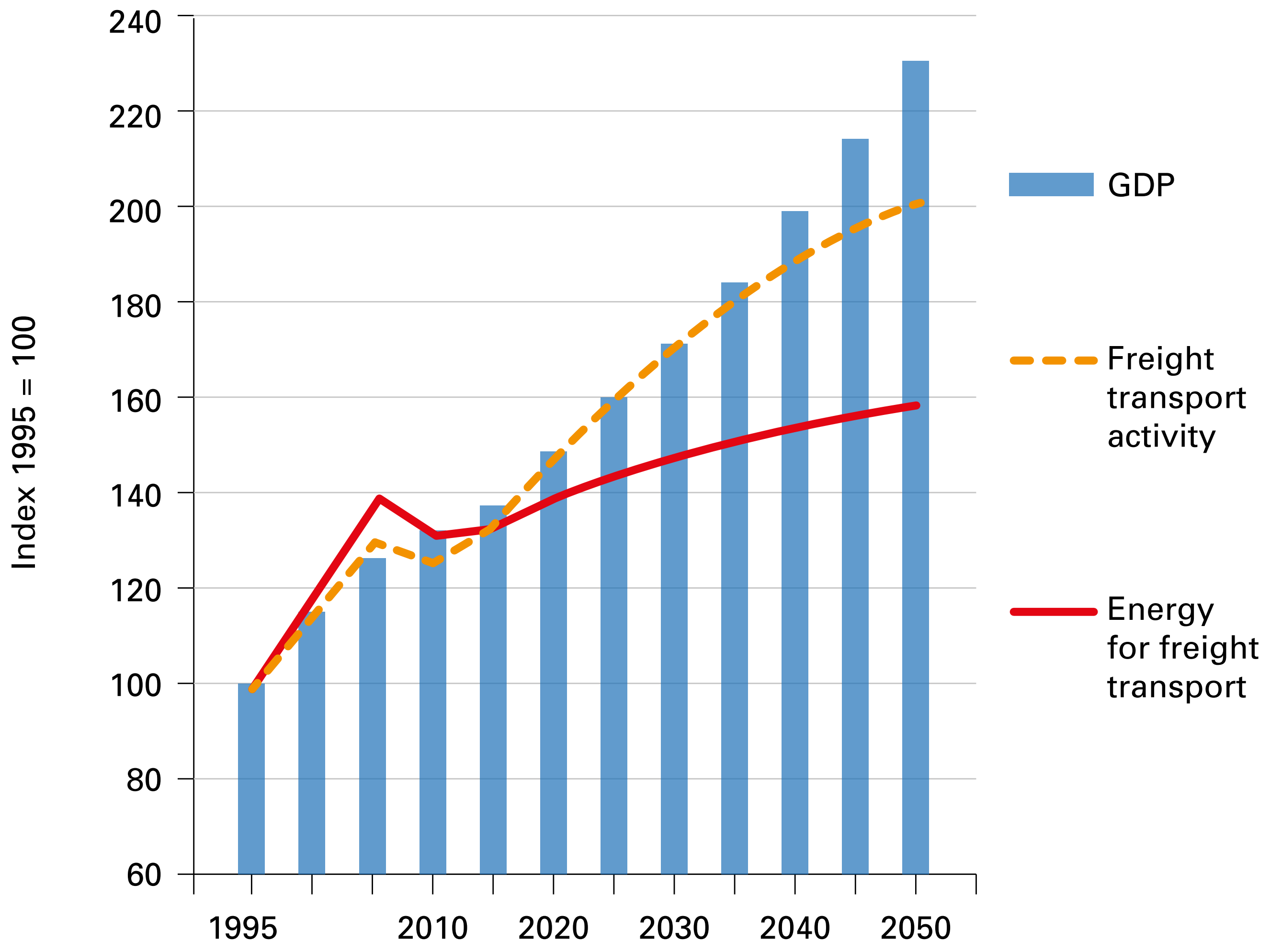

Figure 2: Projected change in GDP, transport activity and energy demand for transport (source: EC reference scenario 2016)

Figure 2 shows that freight transport growth correlates closely with GDP up to 2030. After that, decoupling is projected to occur due to more numerous long-distance flows on improved infrastructure (completion of TEN-T core and other comprehensive networks). Road freight specifically is projected to grow by 57% between 2010 and 2050 (1.1% p.a.), but with an uneven distribution between the EU15 and EU13 countries. Over this period, total growth for the EU13 is assumed to be 95%.

2.1.2 Implications for the targets

The emissions reduction targets are given amounts of CO_2 (tonnes), i.e. absolute values. Throughout the rest of this report, CO_2 reductions at the vehicle level (in contrast to the overall reduction targets set by the Transport White Paper) are considered relative to vehicles from a reference year, on a per vehicle-km (vkm) or per tonne-km (tkm) basis. The relative emission reduction target per vehicle thus needs to account for the projected increases in transport volumes between the reference year and 2050 in order to give the absolute reduction target. This report uses 2010 as its reference year.

If we assume that:

- no improvements have been achieved to CO_2 emissions/tkm since 2010;
- freight transport is responsible for a constant 30% share of total road transport emissions; and
- there will be a 57% increase in the demand for road freight transport (tkm);

Then, in 2050, the CO_2 emission level for road freight would be around 411 Mt (874 x 1.57 x 0.3), whereas the target value is 85 Mt. This would put the real reduction target per tkm at just under 80%. Even assuming a lower, 40% growth in demand for road freight transport (as suggested by some members of the IRU CVOF Reflection Group), the reduction target is still 77%. With even lower growth (say 20%), the reduction target is still over 70%.

2.2 Background scenario for improving road safety

Based on the latest available information from the European road safety database (CARE, May 2015), we put together a background scenario for the evolution of road safety up to 2050 and compared it with the 2011 Transport White Paper targets. Road safety figures comprise those accidents which occur on public roads and exclude accidents during the loading or unloading of a goods vehicle. Information was available for 2001–2013 for most of the EU28 countries[4], plus Switzerland and Norway. Figures are presented in the table below. Figures highlighted in green are registered fatalities from accidents involving goods vehicles > 3.5 t. From 2014–2050, an extrapolation was made using an exponential regression.

When looking at the key target years (2020, 2030[5] and 2050) these figures suggest the following:

- Based on current extrapolations, the 2020 target (~2,250 fatalities) is 7.2% below the estimate in the table. Assuming a non-linear improvement in safety effects, by 2030, a target of between 800 and 1,000 fatalities (or fewer) should be aimed for. This is roughly 15% below the current extrapolation. This means that safety improvements, insofar as they can be identified in the current fatality statistics, are not having the required magnitude of effect. Stronger action will be needed to speed up safety improvements in order to reach the 2011 Transport White Paper targets.
- Based on current extrapolations, the 2050 "close to zero" target is off by 265 fatalities. One important challenge to this long-term estimation is that the current extrapolation of effects assumes that although road safety is expected to improve over time, the year-to-year impact of road safety measures becomes smaller. For example, if there were 70 fewer fatalities in 2020 than in 2019, then we would expect that the same combination of measures would be incapable of saving more than 70 additional fatalities in 2021 (compared to 2020). In other words, merely extrapolating estimates about current road safety improvements and their impacts shows that the results are not changing fast enough to reach the White Paper's safety target. Thus, more or new measures will be required ensure continual improvements to safety.

Table 3: Background scenario for road fatalities

Year	Fatalities	Year	Fatalities	Year	Fatalities	Year	Fatalities	Year	Fatalities
2001	8845	2011	4509	2021	2241	2031	1072	2041	513
2002	8816	2012	4297	2022	2081	2032	996	2042	477
2003	8280	2013	3985	2023	1934	2033	926	2043	443
2004	8006	2014	3753	2024	1796	2034	860	2044	412
2005	7744	2015	3486	2025	1669	2035	799	2045	382
2006	7361	2016	3238	2026	1550	2036	742	2046	355
2007	6940	2017	3008	2027	1440	2037	689	2047	330
2008	6336	2018	2795	2028	1338	2038	640	2048	306
2009	5128	2019	2596	2029	1243	2039	595	2049	285
2040	4656	2020	2412	2030	1154	2040	553	2050	265

4 For Cyprus and Malta, missing information was added based on similarity to previous years. For Estonia, missing values were added based on their high correlation with the evolution of road safety statistics for fatalities from accidents involving HGVs in the United Kingdom for the period 2005–2009. For Slovakia, missing values were added based on their high correlation with the evolution of road safety statistics for fatalities from accidents involving HGVs in Finland for the period 2005–2010. For Bulgaria, missing values were added based on assumed similarity to neighbouring countries of regional relevance (Romania, Greece and Croatia).

5 2030 was not explicitly mentioned as target year in EU communication. This target year is relevant for the current report only.

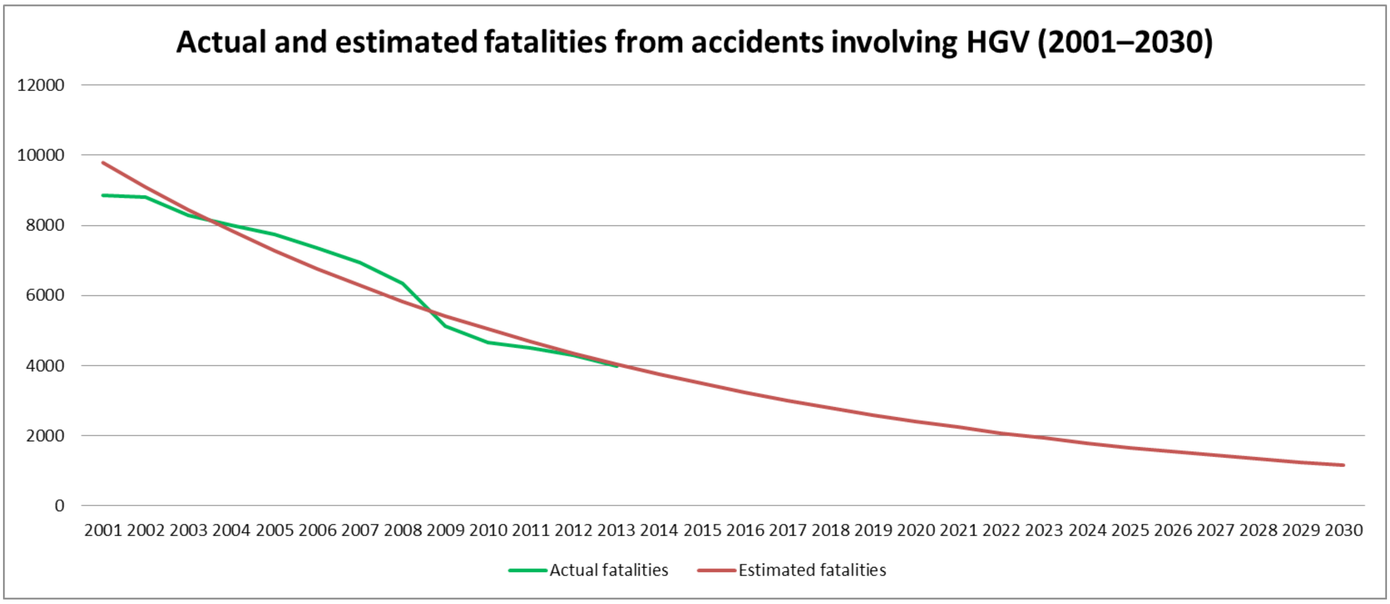

Figure 3: Actual and estimated fatalities involving heavy goods vehicles (> 3.5 tonnes) up to 2030

2.2.1 Comments on the background scenario

In accordance with the IRU CVOF Reflection Group's discussions, the estimations in the background scenario do not take into account the number of vehicle kilometres (vkm) driven. In general, however, it should be noted that absolute fatality, injury and accident figures are directly correlated to the vkm driven. There is no evidence in the literature to suggest that accident risk (the number of accidents per vkm) decreases as vkm driven increase. In other words, there is no literature to dispel the hypothesis that more accidents happen when people or goods become more mobile. Given no changes in relative fatality or injury risk (the number of fatalities or injuries per 1,000 accidents), this means that an increasing number of vkm implies an increasing number of fatalities or injuries. Reducing the relative risk of fatality or injury is exactly what most safety measures aim to do.

Omitting this correlation means that the report's baseline represents absolute risk based on identified fatalities in accidents involving HGVs, rather than an extrapolation based on relative risk (accidents/vkm) and vkm. Obviously, a change in the number of vkm would influence the extrapolated number of fatalities based on relative risk and vkm.

The baseline scenario was calculated using estimated regression coefficients for each of the countries for which information on fatalities was available or could be extrapolated. This scenario estimation (the red line in Figure 3) implies that the impact of existing road safety measures, particularly newly implemented safety measures, is expected to continue up to 2050. However, this scenario estimation concurrently presupposes that this continued impact provides smaller and smaller safety gains over the years (as the absolute number of fatalities reduces). The safety measures involved embrace safety technology, infrastructure and/or legislation, including the measures that are already implemented by national and European stakeholders. Examples include the use of active and passive safety measures such as seat-belt reminders, electronic stability control, ABS, front under-run protection and advanced emergency brake systems. There are also safety efforts relating to driver training, driver certification and so on.

It should be noted that the statistics underlying the baseline scenario do not distinguish between fatalities from accidents where HGV drivers were liable and fatalities where they were not.

The source of relevant information for distinguishing between fatal HGV accidents where the professional driver was or was not liable is the 2005 European Truck Accident Causation (ETAC) study[6], co-funded by the EC and IRU. ETAC was an in-depth accident causation study covering 624 accidents involving trucks and more than 3,000 parameters (2004–2006); it covered a limited number of countries. In total, 303 people were killed and 774 injured in these accidents. The ETAC study's findings, however, are still considered very

6 IRU (2007): "The European Truck Accident Causation study" https://www.iru.org/resources/iru-library/european-truck-accident-causation-study-etac-executive-summary

relevant. Trucks were the main cause of 25% of accidents. This suggests that a specific focus on trucks/truck drivers could eliminate at least 25% of accidents. This percentage should be considered as a minimum “truck-allocated target”. If we include measures that could influence outcomes in accidents for which trucks were partially responsible (i.e. trucks did not initiate the chain of events leading to an accident, but failed to take appropriate evasive actions) or not at all responsible (i.e. measures reducing injury risks when accidents occur), this figure could be higher. More reflection is required on the extent to which potential measures aimed at reducing CO_2 emissions could also provide new opportunities to introduce measures which will further help to reduce fatalities in accidents involving HGVs.

2.2.2 Accident characteristics

Truck accident statistics can be used to identify possible safety measures in different ways, depending on the distinctions that they make. The literature identifies two major types of analyses, although without suggesting which is more appropriate or whether they are mutually exclusive:

1. Analyses dependent on the descriptive statistics linked to the accidents;

2. Analyses dependent on in-depth data linked to the accidents, including error allocation, vehicle manoeuvring phases, and so on.

The following findings from these two types of analyses are most relevant:

- Fatalities from accidents involving HGVs tend to be the occupants of other vehicles or other road users[7]. Only 13% of the people killed are occupants of the HGV. The remainder is, in decreasing order, car occupants (49%), pedestrians (17%), cyclists (7%), motorcyclists (5%), light goods vehicle occupants (5%), moped riders (2%) and others.

- Fatalities from accidents involving HGVs tend to be in rural areas (58%), followed by urban areas (25%) and then motorways (16%)[8].

- The way HGV drivers deal with critical situations associated with accidents with fatal outcomes tends to differ from the way other drivers handle them. HGV drivers tend to take more deliberate actions than non-HGV drivers (i.e. they take risk-related actions)[9].

- A poor assessment of the situation (an information failure) and unseen hazards due to line-of-sight obstructions are relatively frequent causes associated with fatal accidents involving HGVs.

- Accidents with truck occupant fatalities are mostly linked to straying from the lane, loss of control, oncoming traffic and rear-ending other vehicles[10].

- Accidents with fatalities in other vehicles are mostly linked to oncoming traffic (frontal or side-swipe collisions), intersections (truck front–car side under-run or truck side under-run), front-to-rear accidents (truck front–car rear under-run or truck tail under-run)[11].

- Accidents with unprotected road users (on two-wheelers or on foot) are mostly linked to sudden crossing, trucks turning and same direction side-collision[12].

- Truck drivers are considered the primary cause of 25% of accidents involving HGVs. This percentage should be considered the minimum “truck allocated target”[13]. Depending on the inclusion of measures influencing accident outcomes for which trucks were partially responsible (i.e. did not initiate the chain of events leading to an accident, but failed to take appropriate evasive action) or not at all responsible (i.e. measures reducing injury risks when accidents occur), this target figure could increase.

- Measures and policies aimed at improving road safety can have impacts on different phases of an accident: (1) driving phase (vehicle is driving on the road, normal operation); (2) rupture phase (i.e. driver sees traffic stopping ahead); (3) emergency phase (i.e. driver brakes strongly); (4) collision phase (crash); and (5) post-collision phase (slide into end position). Common sense dictates that safety measures can be relevant or operational from the first phase, but their impact only becomes evident in later phases. For example, Brake Assistance Systems are available during phases 1 (driving) and 2 (rupture), but only become operational when the brakes are activated by the driver or other vehicle functions in phase 3 (emergency), on into phases 4 (collision) and 5 (post-collision). Similarly, seatbelts are available during phases 1 (driving), 2 (rupture) and 3 (emergency) but only become highly relevant during phases 4 (collision) and 5 (post-collision).

It is important to note that it is well outside of the scope of this study to quantitatively identify first-order or interaction

7 http://ec.europa.eu/transport/road_safety/pdf/statistics/dacota/bfs2016_hgvs.pdf
8 ibidem
9 ibidem

10 ibidem
11 ibidem
12 ibidem
13 ibidem

effects between measures. The current document only identifies and lists possible measures based on the literature and expert opinion on effectiveness.

2.2.3 General measures to improve road safety

2.2.3.1 Enforcement

To improve on the current or projected advances in road safety, it may be necessary to rely on more than just public sector initiatives (legislation, enforcement, etc.). Additional efforts can be made at the initiative of private road transport companies of all types and sizes, as well as by individual road users. Indeed, this report considers that all stakeholders have an important role to play.

Enforcement authorities could improve enforcement efficiency by making it more intelligence-led. Over the last few years, improvements have been made in this respect, but more compatibility between the different national systems needs to be achieved in order to render it fully successful.

Cross-border cooperation between enforcement authorities could also be taken a step further. In March 2015, EU legislation was passed on the cross-border exchange of information on road safety-related traffic offences. This should be fully implemented by all Member States in May 2017[14]. This legislation is an important step forward in facilitating cross-border cooperation. Cross-border cooperation is also a key prerequisite for successful compatibility between the national intelligence-led enforcement systems.

Within the field of enforcement, positive actions need not only be taken by enforcement agencies. Road transport companies can, for example, adopt Road Traffic Safety (RTS) performance indicators, helping to create an industry-led movement towards improved road safety. With regard to this, working towards ISO 39001:2014 certification is another potential step forward. However, special care needs to be taken so that drivers adopt any new culture of safety effectively, not just the company. Conscientious involvement by road freight transport and logistics operators should enable them to:

– achieve RTS results that exceed what could be achieved through mere compliance with laws and standards, and
– reach their own objectives, taking into account customer demand and, concurrently, contribute to the achievement of societal goals.

Given that the first point of contact in relation to road safety is always the driver, and his safe or unsafe driving behaviour, driver-related enforcement remains an important part of the overall task of improving or maintaining any safety measure. Of particular relevance, given previously reported findings, are checking seatbelt use, speed and (safety) distances. Alcohol use, physical health (including lifestyle, rest times, etc.) and vehicle inspections (including tyre maintenance, braking system function, load securing, etc.) should, of course, not be forgotten.

The task of reaching RTS objectives should be shared among other relevant stakeholders, not just drivers and carriers. Infrastructure providers have a key role to play in addressing RTS in environments they control. Important factors include: separation from oncoming traffic, vulnerable road users, speed limits (especially curve-speed management, design of road cross-sections and superelevation in curves), water drainage gradients in transition curves, road maintenance, surface texture and friction, the design of crash barriers and their end terminals, road entrances and exits, side areas/hard shoulders/safety zones and intersection design.

All these points should be considered in addition to the current enforcement activities focussing on HGVs, such as driver fatigue and drive time regulation, goods loading and so on. Enforcement campaigns should be combined with awareness-raising campaigns.

2.2.3.2 Awareness-raising campaigns

Awareness-raising campaigns for professional drivers and other road users are particularly efficient when combined with enforcement campaigns; the reverse is also true. Many road freight transport and logistics operators, for example, spend resources on teaching schoolchildren about trucks and what they can and cannot do in traffic. This includes visits to schools with vehicles to demonstrate real-life situations in a protected environment. Enforcement and awareness-raising campaigns should not simply cover the same or similar topics; they should ideally be synchronised so as to achieve maximum effectiveness.

Such (combined) campaigns can be supported by road freight transport and logistics operators. An RTS Management programme can be a tool to help road transport companies reduce, and ultimately eliminate, the occurrence and risk of fatalities and serious injury related to road traffic crashes. Such a focus can result in a more cost-effective use of the RTS system, which will also minimise costs.

14 Directive 2015/413/EU covering the following offences: speeding, wearing of the seatbelt, passing a red traffic light, driving under the influence of alcohol or drugs, wearing of the safety helmet, driving in a forbidden lane and use of the mobile phone or other communication devices.

Prioritising RTS targets and action plans can include efforts to:
- minimise high accident-risk situations,
- minimise the overall number of accident risks,
- minimise serious consequences (injury or fatality risks), and
- adhere to legal and customer requirements.

A properly implemented RTS Management programme is a valuable guide for road freight transport and logistics operators preparing work-related analyses, measures, targets and objectives in RTS. The overarching aim is to contribute to a decrease in the consequences of road traffic accidents at the national level. An important part of this is guiding all stakeholders on the tangible and efficient actions that can contribute to mitigating incidents and accidents.

The RTS Management programme promotes the use of a repeatable process (plan, do, check and act) that can guide road freight transport and logistics operators towards delivering better RTS results.

All the stakeholders in transportation—not just road users—must accept their share of the responsibility for safer traffic. The following are examples of the RTS issues that road authorities should deal with:
- separation from oncoming traffic,
- vulnerable road users, speed limits—especially curve-speed management,
- design of road cross-sections and superelevation in curves,
- water drainage gradients in transition curves,
- maintenance,
- surface texture and friction,
- design of crash barriers and their end terminals,
- entrances and exits, side areas/hard shoulders/safety zones,
- intersection design, and so on.

Furthermore, a standardised RTS Management programme should contain a (non-exhaustive) list of items. For example, awareness-raising campaigns about drivers' health and lifestyle could be considered. A drivers' lifestyle behaviour includes:
- safety belt use,
- speeding,
- securing cargo,
- seeing and being seen,
- fitness, especially with regard to fatigue,
- distraction,
- alcohol and drugs, and
- company attitudes and communication.

2.3 Improving operational efficiency in the CO_2 emissions reduction and road safety scenarios

The economic scenario envisaged considers a continuous annual GDP growth of 1.1% and an overall increase in the demand for freight transport of around 57% by 2050. Although the road safety scenario does not explicitly mention it, the increase in vkm driven could actually lead to more HGVs being involved in road accidents, but this is not a given. Congestion will remain an important challenge. Road freight transport sometimes has limited access to road infrastructure, obliging transport operators to use infrastructure at peak times when congestion is usually densest. Because there are limits to how much new road infrastructure can be built, the challenge will be how to improve the utilisation of the existing road capacity. Utilisation could be influenced by new trends in the organisation of work (office hours, opening times, teleworking) as well as by emerging ways of organising road freight transport and logistics in order to cope with increasing e-commerce. Taking these aspects into account will be essential to improving operational efficiency in road freight transport.

3. Measures to shape the Commercial Vehicle of the Future

The outcomes of the IRU CVOF Reflection Group meetings (held during the second semester of 2015 and the first semester of 2016), the input provided by their participants and invited external experts, together with a review of the available literature, have been synthesised to establish potential long-term CO_2 emissions and fuel consumption reduction targets for three operational profiles: long haul, regional delivery and urban delivery. These are discussed below, in order.

We start with a short description of the EU road haulage market, in order to provide some additional context to the three operational profiles. Next, we briefly describe each profile's main characteristics: types of vehicles or vehicle combinations most commonly used, where they drive, and which loads they carry over which distances. Then, we assess the potential for different types of reduction measures, following a general classification:

- **Propulsion systems and energy carriers**: nearly 100% of the current HGV fleet is equipped with a typical internal combustion engine (ICE) and most burn diesel to generate energy for propulsion. Alternative propulsion and energy systems are expected to develop and gradually gain market share. Based on today's knowledge, vehicles with ICEs will probably use energy from diesel fuel or gas (fossil, renewable and/or synthetic). Energy for electric engines is likely to be stored in batteries as hydrogen (H_2) or to be delivered directly from the electricity grid to the engine via energy transfer systems built into the road infrastructure. These measures will affect CO_2 emissions and fuel consumption directly (CO_2 emissions are proportional to fuel consumption). The use of fuel cells as an energy carrier is also being examined, but currently, too little information is available to discuss this solution's potential in detail.

- **Other vehicle-related measures** include aspects of vehicle design, including rigid vehicles, tractor units, trailers and semi-trailers (aerodynamics or lightweighting) and vehicle equipment (tyres).

- **Vehicle driving** can be optimised by the systems built into it (advanced driver assistance systems, ADAS), systems communicating with other vehicles and infrastructure (ITS measures) and, of course, by training drivers to (1) change their behaviour and (2) use driver assistance and ITS systems in an optimal manner. Measures could include platooning and even moving down the path towards fully autonomous vehicles.

- Among other options, **logistics and supply chain organisation and legislation** can be optimised or fundamentally modified with the aim of minimising fuel consumption. Measures include improving vehicle load factors, routing, driving at fuel efficient speeds (reducing maximum speeds), using vehicles, trailers and loading units in the most suitable combination (including but not limited to weights and dimensions) or using more digital or collaborative transport and logistical solutions.

- **Infrastructure** can either contribute to reductions in CO_2 emissions on its own merit (reducing the rolling resistance of road pavements) or be installed as a complement to systems built into vehicles, e.g. ITS systems and energy transfer systems.

All these measures can affect CO_2 emissions, road safety and operational efficiency.

3.1 The structure of the EU road haulage sector

Road transport plays key roles in the EU freight transport network and logistics chain, both as a sector in itself and as a complement to other freight modes or activities such as warehousing. The increasing speeds at which people are doing business, shopping and organising their professional and private lives has undoubted impacts on the organisation of road freight transport and logistics. Digitalisation, collaborative systems and connectivity are driving the collection, monitoring and appropriate use of operational data, providing new opportunities for optimising operational efficiency and often for reducing environmental footprints.

Since 1998, access to the traditional EU road freight transport market has been very largely liberalised. Quantitative restrictions on market access have been replaced by extensive sets of rules and regulations meant to contribute to ensuring the quality of EU road freight transport operations. These rules and regulations cover technical and road safety matters, fiscal issues, and environmental and social conditions. In 2013, there were about 630,000 road freight transport companies in the EU, including postal and courier services, with small and medium-sized enterprises (SMEs) dominating the market. The sector employs about 3 million people. AECOM's report (2013) indicated that only the Netherlands and Luxemburg had an average of more than ten employees per transport company; 99% of companies had fewer than 50 employees. However, one trend shows that intermediaries—including freight forwarders and multimodal integrators such as DB Schenker, DHL and XPO—control an increasing part of road freight movements. Subcontracting is common practice by both larger and smaller companies. Figures from CLECAT[15] indicate that its Members handle two-thirds of the cargoes carried by road in the EU. These elements all have impacts on the sector's profit margins, which have been very tight recently, contributing to a very high degree of competition. Transports for hire and reward represent 95% of all road freight transports. Around 64% are domestic transports within a single Member State; 35% are cross-border transports (including cabotage). Domestic transports tend to represent a more significant share in the larger Member States and over the years have gained in importance in the EU[15]. Regarding the average distances covered, 55% of freight tonnage is carried over distances up to 50 km. Three quarters of freight tonnage are carried up to 150 km. Looking at road freight movements in terms of tkm provides a different picture. Here, 76% of tkms are generated over distances longer than 150 km; the proportion below 50 km only represents around 8%[16]. These figures show that depending on the approach chosen, long-haul transport and regional delivery gain in significance. The tkm approach makes long haul transport and regional delivery much more dominant than the weight approach. With the latter, the emphasis is more on shorter distances and thus tends to raise the importance of regional and urban delivery. However, the sources consulted provided no indications of the size of the urban delivery cycle in the EU road freight transport market.

It is also interesting for this report to briefly examine the cost structures of EU road freight transport companies. The two largest operational expenses facing these companies are drivers (20%–48% of costs) and fuel (26%–38%). Other costs, including vehicle and depreciation costs, range from 17%–42%. Fuel and driver costs can vary across the Member States. Efforts to improve productivity and competitiveness are being made by reducing empty running, subcontracting and cutting fuel costs. Any increase in costs affects profitability, and many transport operators struggle to pass on cost increases to their clients[17].

It is extremely difficult to obtain detailed information on the purchase prices of articulated vehicles. On average, it can be assumed that a new vehicle costs EUR 90,000–120,000. Calculating depreciation depends on many elements which influence the second-hand market, including mileage and types of use. Figure 4 shows that a vehicle loses a percentage of its value every year: 34% after 1 year, 46% after two years, 55% after three years, 63% after 4 years, 67% after 5 years, 71% after 6 years, 75% after 7 years and 77% after 8 years. On average, vehicles are used for 7 years.

15 European Association for Forwarding, Transport, Logistics and Customs Services, which represents 20 national organisations of European freight forwarders and customs agents.

16 Sources: Eurostat, Statistical Pocketbook, 2016; "Report of the High Level Group on the Development of the EU Road Haulage Market", June 2012, European Commission "Road Freight Transport Vademecum", September 2011; AECOM, "Collection and Analysis of Data on the Structure of the Road Haulage Sector in the European Union", February 2014.

17 AECOM, "Collection and Analysis of Data on the Structure of the Road Haulage Sector in the European Union", February 2014

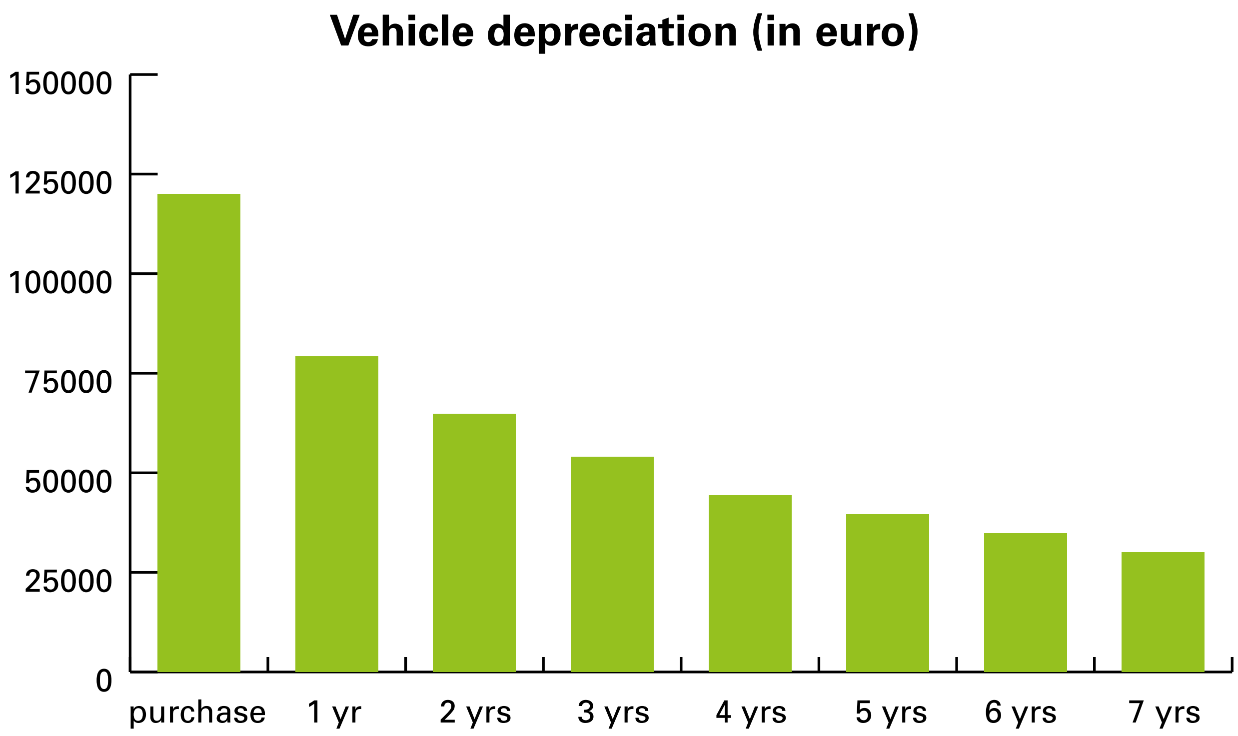

Figure 4: Vehicle depreciation

Transport operators deal with vehicle depreciation differently, with one approach being to declare the costs in their tax declarations. Normally, companies purchasing a vehicle put the acquisition costs on their books as a capital asset, and tax law in many countries then permits them to deduct acquisition costs from profits, thus reducing income tax.

In their overall calculations, road freight transport and logistics operators will also consider that new vehicles often exhibit better environmental performance than older vehicles, leading to lower vehicle tax and infrastructure charges. Furthermore, large operators often have special deals with manufacturers offering them considerable rebates on vehicles and special guarantee services.

Road freight transport and logistics operators, who do not have the financial means to buy new vehicles, lease them instead. This is an equally efficient strategy to cope with vehicle depreciation and its influencing factors. However, there is an on-going trend moving away from full vehicle or shared vehicle ownership towards leasing and hiring, whereby towing vehicles and their trailers or semi-trailers are not necessarily connected to the same companies. This trend could have an impact on vehicle renewal rates and could facilitate the uptake of newer, cleaner vehicles.
In summary, the EU road freight transport sector is highly fragmented, with a very large proportion of SMEs. Notwithstanding a small number of very large companies, over the years there has been no significant move towards more consolidation in the sector.

3.2 The long-haul cycle

The long-haul cycle covers long distance transport, largely on motorways (80%–90%) and at close to the maximum allowed speeds. There is little braking or manoeuvring, except for in the first and last parts of the trip. Long-haul cycles currently involve large tractor–semi-trailer combinations with a gross vehicle weight of at least 40 t (and around 26 t maximum payload). Weight-based load factors are in the range of 60%–70%, going up to 75% or more, based on volume. Average annual driving distance per vehicle is around 130,000 km, and individual trips are generally at least 100 km long, but could well be multi-day journeys of 1,000 km or more. According to the AEA (2010), long-haul cycle transports represented 37.1% of HGV CO_2 emissions in 2010. To put this in perspective, road freight operations over distances of 150 km or more represented more than 75% of tkm performance[18].

18 Based on Eurostat. Methodological note: there is no 1-to-1 match between long-haul operations as defined in the AEA report (2010) and the Eurostat distance classes. The comparison is made only to provide a frame of reference.

3.2.1 Propulsion systems and energy carriers

3.2.1.1 Diesel ICE vehicles

The traditional propulsion system of a long-haul road freight truck is a diesel ICE. To reduce emissions from this type of engine, its thermal efficiency needs to improve from current levels. That efficiency was around 26% in its original 1880s design, modern trucks achieve 43%–44% thermal efficiency, and it is believed that 50% will be within reach by 2030[19].

The AEA-Ricardo[20] and TIAX[21] reports described extensive research into the options available for increasing diesel engine efficiency. Improving the combustion system (high pressure fuel injection, reducing engine friction, etc.), waste-heat recovery (turbo-compounding, bottoming cycles, etc.) and other general improvements (friction reduction in other parts of the powertrain, electrification of accessories, etc.) should all help to reduce vehicle CO_2 emissions by at least **15%** compared to 2010 levels, possibly by 2030 (the present report assumes a stepwise movement in this direction and sets the 2030 potential at **10%**). Assessments of potential reductions in emissions in the more distant future are not available.

3.2.1.2 Gas powered vehicles

Vehicles powered by gas (LNG, CNG, biogas or synthetic gas) use a very similar ICE to diesel powered vehicles. Although the fuel's energy content is lower, so is its carbon content, leading to an overall potential reduction in tank-to-wheel (TTW) CO_2 emissions per tkm of 15%–20% compared to a diesel vehicle (not accounting for market penetration).

The use of natural gas as a transport fuel was presented as an important option in the future of heavy duty road freight transport in the EC's 2016 Strategy for Low-Emission Mobility, albeit with the notion that LNG's potential can be increased significantly if it is biomethane or synthetic methane. The Directive On Alternative Fuels Infrastructure requires Member States to set up a sufficiently dense network of refuelling points for alternative fuels (including LNG and compressed natural gas, CNG, by 2025) along primary road networks. This supports the EC's presentation of gas as a good alternative to diesel for heavy-duty vehicles in the long term. Indeed, the deployment of adequate refuelling infrastructure throughout Europe by 2025 will facilitate the uptake of gas as an alternative fuel in road freight transport. However, additional efforts will be required to further develop the use of bio- and synthetic gas if this alternative fuel is to reach its full potential. The NGVA has suggested uptake rates of over 20% by 2030 and over 40% by 2050[22].

Although the use of natural gas as a transport fuel is positive from a vehicle emissions perspective, it remains a fossil fuel and one into which renewable energy sources would need to be gradually integrated. Indeed, current EU Energy Policy has set clear targets for reducing dependence on fossil fuels. Biomethane or synthetic methane, produced from renewable sources, are alternatives that should be promoted as the way forward, similarly to renewable alternatives for other energy sources. This is also highlighted by the EC Strategy for Low-Emission Mobility.

A second important issue is the need to avoid methane emissions during the well-to-tank phase. Some studies[23,24,25] indicate that the advantages of natural gas as a vehicle fuel could be scaled down if methane emissions (which have a global warming potential up to 25 times higher than CO_2) are not properly managed. This is one of the main—although manageable—issues facing the use of LNG in transport. The technology to address this is available.

Another consideration, often cited by users, is vehicle performance. Gas powered engines currently on the market are generally not suitable for all mission types; they cannot yet deliver the same maximum power as diesel vehicles can. Current gas powered technology can deliver 400 horsepower. However, road freight transport operators require even higher horsepower and torque for trips close to the maximum allowed cargo mass or in mountainous regions. New engine developments (such as high-pressure direct injection, HPDI) will help overcome this problem in the very near future.

The most important strategic issue will be ensuring a sufficient supply and allocation of biomethane to replace fossil gas, which, like all fossil fuels, will eventually need to be phased out. By 2050, total energy demand by road freight transport will be around 92 million tonnes of oil equivalent (Mtoe), according to the 2016 EC Transport & Energy Reference scenario. To put this in perspective, biomethane production in 2013 was around 1.1 Mtoe, and overall methane demand (all sectors) was 387 Mtoe. In order to address this issue, it should be seriously considered to substantially increase the allocation of the amount of available biomethane to use in road freight transport. Synthetic methane also shows good potential in terms of integrating a more renewable energy source into gas-powered technology. In the short

19 See http://www.theicct.org/blogs/staff/ever-improving-efficiency-diesel-engine

20 AEA-Ricardo (2011): "Reduction and Testing of Greenhouse Gas (GHG) Emissions from Heavy Duty Vehicles – Lot 1: Strategy"

21 TIAX (2011): "European Union Greenhouse Gas Reduction Potential for Heavy-Duty Vehicles"

22 Natural & bio Gas Vehicle Association

23 ICCT (2015): "Assessment of Heavy-Duty Natural Gas Vehicle Emissions: Implications and Policy Recommendations"

24 LBST et al (2014): "LNG as an alternative fuel for the operation of ships and heavy-duty vehicles"

25 Ricardo (2016): "The role of natural gas and biomethane in the transport sector"

term, the focus should be on limiting well-to-tank emissions, in order to reap the overall CO_2 benefits of operating gas-powered goods vehicles.

Although these are important challenges, gas-powered vehicles remain an important contributor to CO_2 emissions reduction in the transport sector, including commercial road freight transport, and as such, they have the support of policy makers. Based on the information provided by stakeholders and the available research, gas-powered vehicles are projected to contribute a **2%** overall reduction in emissions by 2030 and **4%** by 2050 (depending on the market uptake of vehicles running on gas). Note that this does not include the well-to-tank reduction provided by using more blends of natural gas and renewable or synthetic methane.

3.2.1.3 Renewable fuels

The historical case for renewable fuels or biofuels was built on the fact that only the carbon captured by their respective feedstocks during growth is emitted during combustion, creating an essentially CO_2 neutral source of energy. Based on this argument, the EU set targets for a minimum blend of these renewable fuels in the mix (the Fuel Quality Directive, FQD, calls for a 6% reduction of lifecycle GHG emissions by 2020), whereas the Renewable Energy Directive (RED) called for 10% of the energy used in transport to be from renewable sources. This created markets for these fuels, despite the fact that crude oil prices in recent years meant that they were not economically viable.

However, since mass production of renewable fuels began, in practice, emissions from them have been greater than anticipated. Direct and indirect land-use changes have shifted the balance for many types of first generation biofuels: in several cases, they are worse than their fossil equivalents. This results from the conversion of ecologically valuable land (e.g. rainforests or grasslands) into land producing feedstock for renewable fuels (direct land-use changes) or from food crop production to renewable fuel feedstock (indirect land-use changes, ILUC). To mitigate these issues, the recently adopted ILUC Directive (2015/1513/EU) limits the amount of food-based crops (starch crops, sugar crops and oil crops) that can be mixed into fossil fuels to 7% of the energy content.

The post-FQD/RED era remains very uncertain. As the market would revert to a more competitive situation should minimum limits be lifted, demand for biofuels will depend on the relative price differences between fossil and renewable fuels. Second generation biofuels (produced from non-food crops or waste materials), which are generally more sustainable than most first generation biofuels, are currently still more expensive than fossil fuels. Nevertheless, the use of hydrotreated vegetable oils from non-food crops is expected to contribute to further CO_2 reduction when fatty-acid methyl esters (FAME, presently the most used alternative to diesel, with a 7% blend wall[26]) reach their potential around 2020. Synthetic fuels (primarily biomass-to-liquid), which are in an earlier phase of technological development (mainly with regard to production cost) should also come into use before 2030.

The uncertainty surrounding the market for renewable fuels could lead to a shortage in production capacity in the short to medium term. This will have to be resolved if liquid biofuels are to be part of the solution in HGV transport, and this is particularly important for advanced biofuels. It should also be noted that there is currently a lack of harmonisation between the different national rules relating to blending biofuels with diesel. This has an impact on biofuel use in vehicles for cross-border operations as certain blends are not accepted by all Member States. The EC is expected to present its plans for biofuel policy for the post-2020 era by 2018 at the latest.

As for their long-term contribution, the 2011 International Energy Agency (IEA) roadmap for biofuels predicts that by 2050, 27% of global transport fuels should be renewable (at least second generation). Although this covers all transport modes, we assume that the 27% level will be valid specifically for road freight transport in Europe too (though it could be argued that aviation and maritime transport will command a larger share). However, much will depend on the right decisions being taken to allocate the necessary resources to commercial road freight transport. According to the RED (Annex V), second generation biofuels have a well-to-wheel (WTW) CO_2 reduction potential of over 90%, without accounting for land use changes. Their indirect emissions due to land use changes are considered to be around zero (some negative, some positive, depending on the production pathway and feedstock)[27]. If these long-term plans come to fruition, a **24%** reduction would thus be achievable. Given the current state of the market (in terms of petrol prices, biofuel prices, availability of feedstock and of fuel production plants), a breakthrough may not happen before 2030–2035. Medium-term (2030) expectations should probably be tempered. In a 2013 study, E4tech estimated the 2030 share of advanced biofuels would be 9%–21% of the total amount of biofuels used as diesel substitutes, which was estimated at 11% of diesel volume (up from 7% in the current B7 blend). These calculations would put the potential reduction by 2030 at just over **2%**: a maximum 11% (share of biofuel) multiplied by 21% (advanced biofuel share of biofuel mix) multiplied by 90% (reduction in second generation biofuels).

---

26 The blend wall is the highest concentration of an alternative fuel that can be added to conventional fuel without creating fuel quality or engine operation issues. For FAME, the blend wall is 7%, but hydrotreated vegetable oil has a much higher blend wall (around 35%) and some synthetic fuels (such as biomass-to-liquid or BtL) essentially have no blend wall. These alternatives are also called “drop-in fuels”.

27 Ecofys, IIASA & E4Tech (2015): “The land use change impact of biofuels consumed in the EU” and T&E (2016): “Globiom: the basis for biofuel policy post-2020”

3.2.1.4 Electricity

Another alternative to fossil fuels is using more electricity in commercial road freight transport. Indeed, using electricity as energy for transport is one of the best GHG reduction measures available—provided that it is generated in a sustainable manner (the 2016 EC reference scenario predicts that the carbon intensity of electricity generation will drop from 0.33 T CO_2/MWh in 2010 to 0.08 T CO_2/MWh in 2050, a decrease of 74%) and that the electricity grid can provide sufficient capacity to supply the different forms of road transport. In light-duty transport, hybrid and fully electric vehicles are already carving out a market share and may well dominate the market by 2050.

However, testing the use of electricity in long-haul, heavy-duty transport operations is still in a very early phase. Although batteries have improved enough to provide an acceptable range of use for light-duty applications and prices are expected to come down over the next 5–10 years, it is unclear whether storing electricity in the quantities required for heavy-duty transport can be done in batteries with sizes and weights that do not have a significant impact on the vehicle's maximum payload, even with a weight derogation for alternatively powered vehicles (as was included in Directive 2015/719/EU amending Directive 96/53/EC[28] for rigid vehicles). Other options will therefore have to be explored and tested in more depth.

Hybridisation

In the short-to-medium term, hybridisation could be the first step. Although primarily useful in shorter distance operations, full hybridisation could generate benefits for the long-haul cycle in the range of 7%–12% (according to studies by AEA and TIAX; OEM estimates that the potential is in the 3%–5% range, in combination with ADAS), in addition to the potential engine efficiency improvements. However, even in a hybrid configuration, vehicle manufacturers still face the challenge of creating a hybrid system with a short enough depreciation period and a non-prohibitive impact on payload. Scale effects are expected to play an important role.

Electric Road Systems

As an alternative to energy storage in a battery, energy could also be delivered to the vehicle directly from the grid. Although different technological options exist and are currently being tested, they generally rely on one of the following principles:

28 Currently, these weight derogations only apply to rigid vehicles, not to vehicle combinations.

- Overhead catenary wires continuously transmit energy to an electric commercial vehicle via a pantograph apparatus mounted on its roof. This overhead line technology is based on traditional contact line systems used today in trains, trams and trolleybuses.

Figure 5: ERS in operation (Source: Scania)

  The eHighway system using catenary wires is currently being tested along a 2-km strip of road in Sweden[29] by a consortium including Siemens. An IFEU report (2015)[30] suggested that by 2050, 38% (more than 25,000 km) of EU motorways could be equipped with an overhead power system. It calculated that 43% of long-haul road freight transport in 2050 could be powered through overhead wires (its 85% CO_2 reduction compared to fossil diesel would mean a **37%** reduction overall). The cost of installing infrastructure would be from EUR 30–65 billion (EUR 1.1–2.5 million/km[31], though other sources claim this should be higher) plus another EUR 5 billion annually for operation and maintenance.

- Conductive systems transmit energy from the power grid to rails in the ground and then to the vehicle via a slide-in current collector system (a pick-up)—the interface between the vehicle and the road. Compared to overhead lines, the visual impact is minimised. To increase safety, the power supply rail is segmented, meaning that a segment is only powered when occupied by a vehicle.

29 https://www.scania.com/group/en/worlds-first-electric-road-opens-in-sweden/
30 IFEU et al (2015): "INTERAKTION EE-STROM, WÄRME UND VERKEHR"
31 Presentation by Christian Hey, German Advisory Council on the Environment (SRU), for the European Parliament, 16/2/16

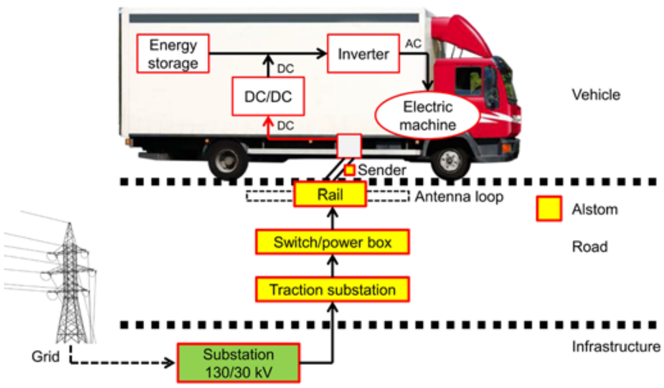

Figure 6: Conductive electric road systems (Source: Vattenfall)

- Inductive charging transmits energy from the road to the moving vehicle wirelessly via a magnetic field—there is no mechanical contact. For the power transfer to work correctly, it is important that the vehicle's pick-up area be located immediately above the inductive power source. Tests with systems based on inductive charging are being conducted by several parties, including Scania[32] and Bombardier (PRIMOVE[33]).

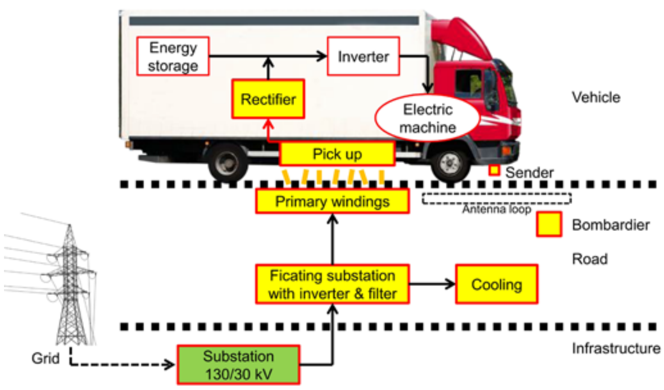

Figure 7: Inductive electric road systems (Source: Vattenfall)

These three options all have their merits and disadvantages. Points which must be taken into account include:

- Investment costs in fixed infrastructure and the allocation of sufficient means to finance its implementation,
- Vehicle investment cost and return (including impact on payload),
- Maintenance costs,
- Suitability in different meteorological and climate-related circumstances,
- Robustness of the infrastructure and flexibility in case of damage,
- Energy transfer losses,
- Usability for different types of vehicles, such as private cars, light-duty vehicles, HGVs and buses and coaches.

Whatever the option, the technologies are still in test phases and there are on-going discussions over feasibility. These tests do have the merit of showing that potential solutions are available for the electrification of long-haul commercial road freight transport. Large investments would be needed in power infrastructure, and as the systems are not compatible between themselves, a coordinated decision on harmonised standards would have to be made, if a sufficient penetration rate were to be reached in time to achieve the required CO_2 reductions. A solution usable by different types of vehicles, especially private cars, would need to be considered as well. This raises a number of key questions. What would be the impact on vehicle prices, depreciation and life cycles? What would have to be done in terms of adapting road infrastructure? What would be the scope of the network? More importantly, who would foot the bill for these investments: the EU, Member States, end users or a combination of all three? If it were a combination, how much should be covered by each?

Hydrogen Fuel Cells

Trucks powered by hydrogen fuel cells could display similar operational behaviour to current diesel trucks; this energy solution comes with many of the same emission benefits as electric ones. However, further research is needed to assess this technology's long-term potential for heavy-duty road freight.

3.2.1.5 Operational efficiency

Based on current knowledge, it is very difficult to pinpoint what the impact of developments in the fields of propulsion systems and energy sources will have on operational efficiency. Diesel has the highest energy content and density, and it is unclear to what extent any alternative energy sources could replace it on a large scale in commercial road freight transport. It is also unclear to what extent a road freight transport and logistics operator could carry out the same range of activities using alternative fuel vehicles rather than diesel ones. It is noteworthy that some companies active in long haul have invested in dual propulsion solutions, such as diesel–gas or diesel–hybrid vehicles. There is also increasing interest in gas, but usually for lighter duty transports. Companies' investments and operational decisions will

32 See http://www.scania.com/group/en/scania-drives-development-for-electrified-roads/
33 See http://primove.bombardier.com/

continue to depend on elements such as the specific activities of road freight transport and logistics operators, developments in given technologies, price developments for fuels and vehicles, impacts on payload, the establishment of adequate refuelling infrastructure, vehicle depreciation and their contractual relationships with clients and intermediaries. One or more of these elements may have to be examined and/or fine-tuned in order to facilitate the use of alternative fuel vehicles further. Road freight transport and logistics operators must be in a position to make a sound cost-benefit analysis of their investments and operational decisions based on transparent information about the performance of the different available propulsion systems and energy carriers. It should be noted that current higher purchase prices for alternative fuel vehicles[34] mean that road freight transport and logistics operators may not be able or may not want to make the necessary additional investment, despite the advantages of such vehicles: the higher investment comes up-front and the benefits will only be felt in the future. Different approaches to spreading risk might ease this challenge, such as through commercial vehicle suppliers offering their clients alternative fuel commercial vehicles at a per-kilometre rate.

Market uptake will also depend strongly on the level and type of incentives provided for certain technologies/fuels. Political decision-makers at EU, national and even regional levels play a key role in enabling appropriate and sustainable incentive packages which can facilitate market uptake. These packages could contain further weight and length exemptions for safer, cleaner vehicles, as well as investment incentives for the uptake of safer, cleaner technology.

3.2.1.6 Summary for propulsion systems and energy carriers

In summary, the currently available propulsion systems and energy sources provide a number of CO_2 emission reduction options, including increasing the efficiency of the ICE, the use of biofuels or the blending of biofuels with diesel, and the use of gas, hybridisation or electrification. The two latter options may provide the largest potential for CO_2 reduction if a number of conditions are met. Although they are currently in the early stages of development for long-haul heavy-duty use, they are being tested and political interest is being raised—this is important and should continue. From a TTW perspective, biofuels and gas also have significant CO_2 reduction potential. From a WTW perspective, the indirect land-use change, the primary source of biofuels and methane emissions for gas are some of the aspects which will have to be addressed. Biofuels and gas are currently important potential alternatives to diesel, but they need to be developed further; they should certainly not be discarded. The potential for alternative technologies and fuels varies according to the usage profile of the HGV and its particular requirements for carrying out specific duties. Therefore, all options should be pursued, including improving the efficiency of the ICE. The important message is that further research into economically viable alternative energy sources for the long-distance, heavy-duty cycle must continue and be encouraged.

34 NEA, TLN and ING (2012): "Alternatieve brandstoffen: Gat in de markt of verre toekomstmuziek?" study indicates higher prices between 2600-6500 euro depending on the alternative fuel and the purpose of the vehicle.

Figure 8: Example of optimised cab design (source: FKA)

3.2.2 Other vehicle-related measures

In addition to measures based on engine efficiency and energy carriers, other modifications can be made to vehicles in order to reduce emissions, such as lowering aerodynamic drag or rolling resistance. Overcoming these forces uses most of the energy delivered by the engine and their relative importance is a function of the vehicle's speed.

It is important to note that whereas the measures mentioned in the previous section focus on making fuels cleaner or burning them more efficiently, this section focuses on measures that reduce the energy required to move the vehicle, which makes their effectiveness independent of the energy source or propulsion type.

3.2.2.1 Vehicle aerodynamics

The maximum authorised weights and dimensions of European road freight vehicles intended for cross-border transport are governed by Directive 96/53/EC and Regulation (EC) No 1230/2012. Within the strict limits imposed by those rules, vehicle and equipment manufacturers are trying to build vehicles that can maximise their payloads, while still providing a sufficient level of comfort for the driver and fulfilling the legal and customer requirements on safety, flexibility and environmental and operational performance. Current vehicles are able to fulfil their missions but suffer from several design compromises in order to fit within the legal limits. Some of the

Figure 9: Application of rear flaps (source: Daimler Efficiency Run)

most important suboptimal choices in terms of aerodynamic performance are the flat nose (cab over engine) and trailer backside designs required to stay within the maximum vehicle length requirements. This flat nose structure has important repercussions in front-on crashes, where there is no space for effective crumple zones (see the section on road safety).

The 2015 amendment to Directive 96/53/EC created derogations to maximum length regulations by allowing for design changes specifically intended to improve vehicles' aerodynamic performance, i.e. by addressing the issue of airflow along the vehicle, starting with the front but also including solutions to allow aerodynamic devices, such as a boat tail, on the (semi-) trailer.

CO_2 emissions

According to an ICCT assessment[35], the combined potential for CO_2 savings from these and other currently permitted adaptations (e.g. roof deflectors or side fairings) is around 7%–10%. A study by FKA[36] calculates that just using an aerodynamic tractor, rather than a generic but state-of-the-art design, could reduce fuel consumption by 3.2% for 40-tonne vehicles. However, there is an on-going debate about the impact of cabin redesign. An older VDA study[37] finds the reduction in dynamic drag from frontal modifications to be about five times lower than the FKA study (4% reduction versus more than 21%). As boat tails can be retrofitted to existing vehicles or easily added to new semi-trailers, they are expected to enter the market well before 2020. Cab modifications could take longer to realise their full potential as they will require a significant overhaul of tractor design. Based on indications from vehicle manufacturers, these redesigned vehicles are expected to enter the market in the early 2020s.

The potential for aerodynamic improvements does not stop there. Further steps can probably be made by redesigning trailer shapes. The teardrop trailer, for example, follows on from the contours of the cab, allowing air to pass evenly over the back of the trailer. The trailer-top bump provides a 10% increase in space. For a fully optimised design, further amendments to Directive 96/53/EC may allow for greater

35 ICCT, the International Council on Clean Transport (2013): "Proposed amendments to EU rules affecting HDV configurations" http://www.theicct.org/sites/default/files/publications/ICCTupdate_EU_HDVconfigurations_Jun2013.pdf
36 FKA (2011): "Design of a tractor for optimised safety and fuel consumption"
37 VDA (2010): "FAT 237: Verbrauchsreduktion an Nutzfahrzeugkombinationen durch aerodynamische Maßnahmen"

trailer height. However, increased height might also restrict the use of such trailers or semi-trailers, as some bridges and tunnels—and thus transport routes—might not be adapted to handle teardrop trailers.

The TRANSFORMERS project takes another approach, conducting trials with adaptable trailers. Depending on the mission, the semi-trailer's floor and/or roof can be adjusted to optimally match the cargo's requirements with aerodynamic performance.

An important point to remember about the effectiveness of aerodynamic modifications is their interaction with vehicle speed limits. As speed decreases, so does the savings reduction potential of aerodynamic measures. A 10% reduction in aerodynamic drag at 90 km/h leads to a 3.9% reduction in fuel consumption. At 80 km/h, this results in a 3.4% reduction in fuel consumption (or a 13% "efficiency loss").

Figure 11: Teardrop semi-trailer (source: Don-Bur website)

Accounting for interactions and market penetration, the fuel use reduction potential of aerodynamic measures is estimated to be **6%** by 2030 and **9%** by 2050.

It should be noted that optimal results are achieved when the aerodynamics of the entire vehicle combination are improved. With changing ownership structures, whereby the tractor unit and the trailer or semi-trailer are not always owned by the same entity, and with frequent interchanges, assembling optimal vehicle combinations could be a challenge. The fact that the entity investing in better aerodynamics is not necessarily the entity receiving the investment's benefit should be taken into account.

Road safety

Changing a vehicle's (nose) shape can have an impact on the rupture phase of an accident (enhanced visibility can lead to earlier risk detection) as well as the collision phase (changing vehicle shape and crash structures can reduce peak deceleration values during a collision).

Representatives of EU member states, the European Parliament and the EC have agreed on new legislation enabling, but not requiring, manufacturers to make changes to lorry cabs that improve visibility. This could reduce the impact of crashes on other vehicles, pedestrians and cyclists. We foresee a slow change of technical vehicle structures as of 2020–2025. These optional changes will be legally possible from 2022 onwards.

It should be noted that improving aerodynamics and visibility, while reducing collision intensity, do not necessarily occur simultaneously. The effect on aerodynamics is mostly felt at high speeds on roads with relatively little interaction with vulnerable road users (certainly without pedestrians and cyclists), whereas improved visibility and reduced collision intensity will generally be more significant in (sub)urban areas at lower speeds.

Our literature review indicated that making changes to HGV cab design could reduce accident fatalities by up to 300–500 per year. However, the time scale for this change is unclear and the figure seems on the high side. A very significant impact on particular types of accidents was assumed, i.e. with vulnerable road users, specific front-end accidents, and so on. The present report attributes the majority of this reduction in fatalities to the required ongoing changes that are assumed in the baseline scenario because: (1) future vehicle cabs will use similar structures and materials to current vehicles (we do not expect new materials or new material properties to become available on the market in the short term); (2) cab design and other safety specific technologies that become available will interact positively with each other; and (3) product lead times are long. As such, we do not assume any additional effects beyond the baseline scenario.

Operational Efficiency

More aerodynamic vehicles can have a positive impact on operational efficiency, providing they do not reduce load capacity. That impact will also depend on the road freight transport and logistics operator's type of activity. Aerodynamic devices have a larger impact over longer distance journeys. The envisaged savings on fuel consumption could encourage companies to invest and innovate further. Again, much will depend on the legislation allowing the use of these devices, initial investment in more aerodynamic vehicles and the expected amortisation—decisions which can vary from company to company. The frequent interchange between combinations of tractor and trailer units should not be ignored. Better operational efficiency will thus depend, to a great extent, on the aerodynamic compatibility between different units of such combinations. In this respect, it should also be noted that tractors and trailers/semi-trailers are no longer necessarily owned by the same party in the logistics chain. Changing ownership structures could have an impact on the market uptake of more aerodynamic vehicle combinations. The benefits of investment in a more aerodynamic semi-trailer might not fully accrue to the investor, which could challenge the investment in the first place. Again, the availability of transparent information on performance and the costs/ benefits of an investment, together with the contractual relationship between the various parties in the logistics chain, could determine market uptake.

3.2.2.2 Tyres

Choosing the right tyres can have a large impact on fuel consumption. However, they also affect a vehicle's performance in terms of road safety and noise production, which are arguably more important factors than fuel consumption. Nonetheless, some options available on the market can meet requirements at all levels, and further improvements should be expected. Aspects to consider are the material composition of the tyre (e.g. for low rolling resistance tyres), its dimensions (standard or single wide tyres) and the use of a tyre pressure monitoring system (TPMS).

CO_2 emissions

Rolling resistance is the second force which road vehicles must overcome, and indeed it is the most important one for speeds up to the maximum limits set for HGVs by national and EU rules.

The use of low rolling resistance tyres (LRRT) is expected to provide significant benefits to CO_2 emissions reduction, according to a review study of the Tyre Labelling Regulation (EC) No 1222/2009 by Viegand Maagøe A/S (2016)[38]. In 2015, the average C3 tyre (for heavy-duty vehicles, HDVs) had a rolling resistance coefficient (RRC) of 6.1, equivalent to class D. By 2030, this could evolve to class B (RRC = 4.6) or even class A (RRC = 3.5) according to the most optimistic scenario. This is equivalent to CO_2 emission reductions of **7.5%** and **12.5%**, respectively.

A study by the ICCT[39], focussed on the US market, found that with reference to 2010 figures, there was potential for a 10%–14% reduction in rolling resistance by 2030, which translates to a 3%–5% reduction in CO_2 emissions per vehicle. The additional cost of LRRTs over standard tyres is limited, and although the tyres' longevity is slightly reduced, fuel savings far outweigh investment costs[40]. The Tyre Labelling Regulation includes an indication of the fuel efficiency effects of tyres, but it explicitly quantifies neither the savings nor the expected payback period. In the longer term (post-2030), further advances in tyre technology could reduce rolling resistance by up to 20%, bringing a reduction in fuel consumption of almost 7% within reach[41].
With regard to tyre dimensions, rolling resistance can also be reduced by exchanging pairs of tyres for single wide tyres (also known as super singles). Current EU rules allow these to be fitted, however, some restrictions on the total weight of the vehicle are given when they are fitted with pneumatic suspension or a recognised equivalent, and there must be pairs of tyres on the driving axles. In the US, using super singles made of low rolling resistance materials was calculated to reduce overall rolling resistance by up to 23% (an 8% reduction in fuel consumption). One problem with early versions of wider tyres in the US was that they caused additional damage to road surfaces, however, more recent versions seem to have provided a solution[42]. According to the ICCT, the long-term potential (to 2050) for new generation, single wide, low rolling resistance tyres on the whole vehicle or vehicle combination, would be a reduction in rolling resistance of 36.5%. This is equivalent to a potential CO_2 emissions reduction of 12%. Although the market conditions are different and the technology is not yet available, manufacturers present in both markets should lead to product convergence and a similar rolling resistance reduction potential would then be available in Europe.

In Europe, the potential future rolling resistance benefits of single wide tyres in comparison to pairs of tyres are less marked than in the US. Indeed, the European market penetration of single mounted tyres on trailers and semi-trailers and the use of LRRTs is already significant. Tyres with an "A" label for rolling resistance in the European Labelling System (Directive 1222/2009/EC) are already available for all positions: front axle, drive axle and trailer axles. Future developments in the field of single wide tyres for truck drive-axles are reported to provide an equivalent level of performance.

38 Viegand Maagøe A/S (2016): "Review study on the Regulation (EC) No 1222/2009 on the labelling of tyres"
39 ICCT, the International Council on Clean Transport (2015): "Cost Effectiveness of Advanced Efficiency Technologies for Long-Haul Tractor-Trailers in the 2020–2030 Time Frame" http://www.theicct.org/sites/default/files/publications/ICCT_tractor-trailer_tech-cost-effect_20150420.pdf
40 See http://www.lowcvp.org.uk/assets/reports/Review%20of%20low%20carbon%20technologies%20for%20heavy%20goods%20vehicles%20Annex.pdf, p29
41 ICCT, the International Council on Clean Transport (2015): "Cost Effectiveness of Advanced Efficiency Technologies for Long-Haul Tractor-Trailers in the 2020–2030 Time Frame"
42 Greene et al. (2009): "Impact of Wide-Base Single Tires on Pavement Damage" http://www.dot.state.fl.us/statematerialsoffice/administration/resources/library/publications/researchreports/pavement/09-528.pdf

The reduced weight and rotational inertia of current single wide tyre/wheel assembly already provide a reduction in fuel consumption and CO_2 emissions. In some operations, this gain of approximately 100 kg could be used to increase payload, making road transport more productive and increasing operational efficiency. Weight reduction will also be crucial for future truck concepts with hybrid and fully electric propulsion systems where heavy batteries will carve out payload.

Single wide tyre/wheel assemblies on truck drive-axles need less physical space than pairs of mounted tyres; this favours the development of new and innovative vehicle design concepts.

The use of TPMS can provide additional benefits, as properly inflated tyres reduce fuel consumption (and improve safety). However, TNO[43] assessed the CO_2 emissions reduction potential for pressure monitoring in HGVs above 12 t (N3 vehicles) at just 0.42% in its most optimistic scenario. AEA-Ricardo estimated a maximum potential at 3%. One obstacle which may limit the uptake is that HGVs perform many different missions (cargo density), over distances that often bring them into contact with different meteorological conditions. The optimal tyre pressure setting should be adjusted for each mission; as tractors and trailers can be decoupled, the TPMSs on both vehicle components need to be recalibrated after every recoupling in order to achieve the best results. In addition, if we look solely at CO_2 emissions, some sources say that the cost is prohibitive, with amortisation periods exceeding the lifetime of the vehicle (TIAX mentions a 40-year amortisation period). However, these assumptions are not necessarily shared by industry stakeholders. It remains to be seen how this challenge can be addressed.

The present report sets the projected CO_2 emissions reductions from improved tyre technologies to 7.5% by 2030 and to 12.5% by the 2050 scenario.

Road safety

Tyre-related technologies can also have an impact on safety. It should be noted, however, that this appears to be more relevant to tyre pressure-related technologies than rolling resistance reduction technologies. Rolling resistance should not be mistaken for reduced traction (and friction).

TPMSs have also been the subject of a study touching on safety issues. This estimated that the influence of TPMSs could have reduced the number of accidents by between 0.8% and 4%[44].

Operational efficiency

According to the report by TIAX, it appears that vehicle owners do not always choose to equip their vehicles with LRRT, despite an amortisation period of no more than one year and evident advantages in terms of reduced fuel consumption, which in turn leads to reduced costs. It is therefore essential that the advantages of using LRRT are clearly documented and communicated to road freight transport and logistics operators, and that tyres perform as they are labelled. As mentioned above, it must be emphasised that reduced rolling resistance is not the same as reduced traction. The performance of winter tyres should not be compared to those of summer tyres.

3.2.2.3 Lightweighting

CO_2 emissions

The use of lighter materials in the construction of HGVs is a topic of ongoing research for vehicle and trailer manufacturers. Lightweighting would primarily be useful for operations that are restricted by weight rather than volume or floor space, where any weight saved in the vehicle would imply that more cargo can be carried and fewer vehicles are needed.

Both TIAX and AEA-Ricardo have reported that a CO_2 emissions reduction of 2.2% is possible with appropriate lightweighting, however, due to weight increases from other types of measures, the net effect of all modifications is probably closer to **zero**. Material substitution is also among the more expensive ways to reduce fuel consumption. A study by AEA-Ricardo (2015)[45] found that the cost-effective weight reduction potential for an articulated vehicle by 2030 was 2,275 kg (16% of its weight), which could increase to 4,341 kg by 2050 (30%). The (weight restricted) payloads could then be increased by 9% and 17%, respectively.

Operational efficiency

Lightweighting provides the potential for increased operational efficiency as any kg saved in vehicle weight can be replaced by cargo. There is a counteracting trend, however, of adding equipment (and thus weight) to the vehicle, such as the aerodynamic features mentioned above (boat tails and roof deflectors) or alternative propulsion technologies, including batteries to extend the capabilities

43 TNO (2013): "Study on Tyre Pressure Monitoring Systems (TPMS) as a means to reduce Light Commercial and Heavy-Duty Vehicles' fuel consumption and CO_2 emissions" http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/tno_2013_final_report_en.pdf

44 http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/tno_2013_final_report_en.pdf

45 AEA Ricardo: "Lightweighting as a means of improving Heavy Duty Vehicles' energy efficiency and overall CO_2 emissions", 2015

of electric/hybrid operation. However, the AEA-Ricardo report indicated that much depends on the type of transport activity undertaken. Construction trucks have the highest cost-effective weight and CO_2 reduction potential through lightweighting.

3.2.3 Vehicle driving

3.2.3.1 Advanced Driver Assistance Systems

CO_2 emissions

Like the measures discussed above, the advanced driver assistance systems (ADAS) built into new vehicles often serve a dual purpose: improving safety and reducing fuel consumption. ADAS are based on different sensors, such as radar, infrared, cameras, lidar and ultrasound, in order to provide the best end-user application. A non-exhaustive list of technologies providing better fuel efficiency includes:

- *Predictive Cruise Control* is a system using GPS to determine the vehicle's position and anticipate shifts in power requirements, mainly due to upward and downward sloping roads. Fuel efficiency improvements of 2%–5% are possible, depending on the route.

- *Adaptive Cruise Control* (ACC) is a sensor-based technology to detect the speeds of nearby vehicles. By better anticipating the behaviour of other drivers, excessive braking and accelerations can be avoided. This measure's contribution will be greater in more congested areas. In a way, ACC is a step towards vehicle platooning (see further).

- *A Green Zone Indicator* is a dashboard meter that shows fuel consumption in real-time and suggests modifications to driving behaviour (changing gear, braking, etc.). In itself, this measure does not reduce fuel consumption, but it guides the driver towards a more efficient driving style.

- *Speed limiters* can help engines to run at more efficient levels. A limit of 80 km/h instead of 90 km/h can reduce fuel consumption by almost 4%. This can also be done by drivers voluntarily adopting speed reductions. A majority of European countries already limit the maximum speed of HGVs to 80 km/h[46] (e.g. Germany and Italy, but not France or the UK).

- *Acceleration control* limits the time the engine can perform at peak load, when fuel consumption increases disproportionately. In the long- haul cycle, with relatively little acceleration and braking, its effect is likely to be small.

- *Eco-rolling* is a practice where the engine goes into idle mode when the HGV is coasting down a hill. The effectiveness depends on the route, but average savings of 1% could be realistic.

Road safety

In recent decades, vehicle manufacturers and their system suppliers have made great efforts to improve vehicle technologies for better road traffic safety. ADAS have also contributed to this in a major way.

Various ADAS exist to help improve road safety:

- *Seatbelt reminders.* Seatbelt use is particularly important in HGV accidents involving no other vehicles. Although the presence and use of seatbelts are, obviously, already mandatory, their effective use remains suboptimal. Seatbelt use by HGV drivers seems to be improving (reports from Sweden and Germany indicate a rise from 5%–10% in 2001 to ~65% in 2014). However, a Volvo study reported significant rates of non-use in single (HGV) vehicle accidents; it mentioned that seatbelt use in these cases might reduce accident severity by 50%. Seatbelt reminders, perhaps in combination with focussed information campaigns, might help to improve seatbelt use rates further and reduce accident severity. Given the current presence of seatbelts in HGVs, we consider the possible impact associated with seatbelt reminder systems and their use to be part of the ongoing efforts to achieve the baseline scenario prediction.

- *An Accident Emergency Call System (AECS)/eCall* sends a message to the emergency services if a vehicle suffers a serious road accident and provides two-way voice communication on mobile telephone communication networks. AECS provides the vehicle's location using signals from an existing global satellite navigation system and optionally provides information such as a vehicle's speed and direction of travel and, in the future, information on the consignment note. Whereas private car eCall should come into operation in 2018, a similar system for heavy duty vehicles is still under development.

- *Unprotected road-user detection.* Limited visibility (blind spots) is one of the major causes of accidents involving unprotected road users (pedestrians, cyclists, etc.). These people constitute around 25% of those killed in accidents involving HGVs. One possible solution for reducing such accidents involves helping HGV drivers with (new or improved) means of detecting other road users in so-

46 See http://ec.europa.eu/transport/road_safety/going_abroad/search_en.htm

called blind spots (particularly for vehicles with trailers). Such aids should (1) notify drivers about the presence of such road users (through visual or vibrating warnings) and (2) let them visually check for dangers (visual detection and verification). However, given the existing implementation of legislation on the presence of devices aimed at reducing blind-spot accidents with HGVs, we consider the possible impact of these measures to be part of the ongoing efforts to achieve the baseline scenario prediction[47].

- *Advanced Emergency Brake Systems (AEBS)* were introduced in new vehicles from 2013–2015. They influence vehicle braking behaviour during the emergency phase by shortening stopping distances and improving vehicle control. Given the introduction period, we consider the effects of AEBS to be fully integrated into the baseline scenario.

- *Lane Departure Warning Systems (LDWS)* were introduced in new vehicles from 2013–2015. They influence vehicle behaviour during the driving phase, with some expected to influence behaviour during the emergency phase (if systems allow for more direct feedback or action while the driver is actively in control). Given the introduction period, we consider the effects of LDWS to be fully integrated into the baseline scenario.

- *Electronic Stability Control* was introduced in new vehicles from 2012–2014. This influences vehicle behaviour during the driving and emergency phases. Given the introduction period, we consider its effects to be fully integrated into the baseline scenario.

- *Advanced Cruise Control (ECC), Headway Detection, Speed Limitation and Intelligent Speed Adaptation (ISA)* all assist the driver during the driving phase by setting an appropriate or maximum speed for the vehicle. These measures have the potential to reduce vehicle speed during evasive manoeuvring or impact speed during a collision. There are as yet no direct test comparisons between vehicles with and without these technologies, which would help estimate their potential impacts on safety. The literature available from theoretical studies indicates a wide range of impact. A recent study by TML[48] estimated scenarios for heavy commercial vehicles. This suggested that the introduction of ISA might reduce the number of fatal accidents in the EU involving light and heavy goods vehicles by about 25%, accidents resulting in serious injury by 18%–19% and all injuries by 11%. Decreasing speed limits to 80 km/h and 90 km/h for HGVs and buses, respectively, leads to a decrease in fatal accidents involving HGVs of about 5%. These effects would be partially integrated into the baseline scenario, but no estimation is provided on their surplus effect.

- *Road Sign Recognition (RSR)* systems assist drivers in situations such as speed or overtaking restrictions, but can also identify a No Entry sign or a Stop sign. Such systems should eventually be able to detect height restriction signs as well, as RSR works with the vehicle navigation system by using a video camera; it could then propose detours.

- *Curve Speed Warning (CSW)* is a Vehicle-to-Infrastructure application (V2I) which alerts the driver when the vehicle is approaching a curve at a speed higher than the recommended safe speed. The CSW uses a combination of GPS and digital maps to assess the hazard level for a vehicle approaching a curve too quickly.

Operational efficiency

Some transport operators already acknowledge that reducing speed to 80 km/h offers opportunities to improve operational efficiency by reducing fuel consumption. Such measures are also part of carbon footprinting schemes, which will be dealt with later in this report. Although lower speeds affect logistics chains and customers at a fundamental level (travel times, driving/resting time regulations), lower fuel consumption and associated costs (when passed on to consumers) could be a strong incentive to apply them nonetheless.

3.2.3.2 Driver training/awareness raising

Many of the effects above can also be achieved by training drivers to adopt a more fuel-efficient and safe driving style—these measures are mostly complementary.

Training requirements for professional drivers are covered by EU Directive 2003/59/EC, including both the initial training for the Certificate of Professional Competence (CPC) and the periodic training updates which must be attended every five years. Although this directive's primary goal is to improve road safety, these rules can provide a platform from which to enhance drivers' skills and professionalism.

Annex I to Directive 2003/59/EC outlines the content of the courses that drivers can follow during their periodic training. These courses cover the following topics:

- Advanced training in rational driving based on safety regulations
  - To know the characteristics of the transmission system in order to make the best possible use of it

47 http://ec.europa.eu/transport/road_safety/pdf/retrofitting_mirrors.pdf
48 http://tmleuven.be/project/speedlimiters/home.htm

- To know the technical characteristics and operation of the safety controls in order to control the vehicle, minimise wear and tear and prevent malfunction
- Ability to optimise fuel consumption
- Ability to load the vehicle with due regard for safety rules and proper vehicle use

- Application of rules
  - To know the social environment of road transport and the rules governing it
  - To know the regulations governing the carriage of goods
  - To know the regulations governing the carriage of passengers
- Health, road and environmental safety, service, logistics
  - To make drivers aware of the risks of the road and of accidents at work
  - Ability to prevent criminality and trafficking in illegal immigrants
  - Ability to prevent physical risks
  - Awareness of the importance of physical and mental ability
  - Ability to assess emergency situations
  - Ability to adopt behaviour to help enhance the image of the company
  - To know the economic environment of road haulage and the organisation of the market
  - To know the economic environment of the carriage of passengers by road and the organisation of the market

Good implementation of this directive – meaning implementation that goes beyond mere legal compliance and incorporates high-quality driver training as well as motivated trainees – can benefit the carrier in more than just issues of safety and reducing CO_2 emissions and fuel consumption. It should also lead to lower maintenance costs, less vehicle damage, a better corporate image and so on.

CO_2 emissions

According to McKinnon (2008)[49], CO_2 emissions savings of up to 10% per vehicle are possible. At the fleet level in the UK, Faber Maunsell (2008)[50] projected a reduction in fuel consumption of 2%–8%, with an average of around 5%. Effects are, however, likely to diminish as time progresses, meaning that regularly recurring training is recommended. The ECOeffect project[51] carried out limited real-world testing and found that immediate reductions of up to 20% were possible, dropping off to 7%–10% later. In the GHG-TransPoRD study, the potential of eco-driving training for the whole road transport sector was estimated at 10%. The same number was found by AEA-Ricardo (2011) for the UK. Driver training is likely to be more effective in situations where lots of driver action is needed, i.e. in urban areas rather than motorway driving. However, incentivising fuel efficient driving can be done for any mission profile. A company-based reward scheme, supported by a centrally managed driving assessment system[52], can create a win-win situation for the driver (who is financially or otherwise rewarded for a fuel-efficient driving style), the road freight transport and logistics operator (who saves fuel costs), as well as the environment and society.

As a conclusion on the potential for CO_2 emissions reduction, it is best to assess the combined potential of ADAS and driver training, as these measures mostly follow the same impact pathways. Driver training works for any vehicle but requires frequent refresher sessions to maintain results. As ADAS increase their penetration in vehicle fleets, they will progressively automate many of the actions a well-trained driver would take to reduce fuel consumption. A total potential reduction of around **8%** seems realistic for the long-haul cycle, made up of short-term (training) and medium-term (combined training and ADAS) efforts. If operators decide to apply a reduction in maximum speeds to 80 km/h, an additional 4%–5% could be saved in countries where such speed limits have not already been put in place by national law—around a **2%** reduction for Europe, on average. There is little or no information available on the long-term perspectives, so our scenario keeps this constant.

Road safety

The 2005 ETAC Study recommended better training for truck drivers, with the aim of preventing accidents, such as those occurring during an overtaking manoeuvre or those where a single truck is involved and drivers make an improper manoeuvre. Current driver training legislation has a strong focus on trainee drivers being able to control a vehicle. Although this is obviously an important step towards safe vehicle operation, more steps are required to enhance safety associated with HGVs. In a 2015 study for DG MOVE[53], the following elements, directly related to driver training, were identified and should be considered:

- mutual recognition of Certificates of Professional Competence (CPC) which could be supported by

49 McKinnon, A.C., (2008): “Advice on CO_2 emissions from the UK Freight Transport Sector” Committee on Climate Change, London.
50 Faber Maunsell, (2008), Fuel Efficiency Trials Research, conducted for Freight Best Practice, May 2008
51 http://ecoeffect.org/

52 See for example https://www.arvato.com/dk-en/news/2014/trucker-league-offers-incentives-for-fuel-efficient-driving.html, https://www.wi.tum.de/contact/news-events/news-single-view/article/incentives-for-energy-efficient-behavior-at-work-the-importance-of-non-monetary-elements/ and http://ntl.bts.gov/lib/51000/51800/51836/13-020-Study_of_the_Impact_of-a_Telematics_System_Full_Report.pdf
53 http://tmleuven.be/project/professionaldrivers/2014_ex_post_evaluation_study_training_drivers_en_final.pdf

mandatory national electronic registers for completed CPC;
- professional driver training to be based on learning outcomes, particularly in relation to "risk identification", and structured in modules that cover the most relevant aspects for professional drivers;
- periodic training would be structured in mandatory and optional modules in order to avoid obviously repetitive training;
- combinations with other forms of mandatory training, such as on the carriage of dangerous goods (ADR).

However, driver training and examination is only one part of the story. Although it is expected that driver behaviour will improve once such conditions are met, there is also a need to be realistic in assuming that maximal effects will not be achieved without supporting measures. Such measures could be in the form of incentive schemes, for example, rewarding companies which actually encourage the diversification of driver training over several relevant topics, or rewarding professional drivers who can prove exceptional skills and insight (although this would also require a change in the examination system, see Directive 2006/126/EC).

3.2.3.3. The role of the driver in a more autonomous vehicle environment

Drivers work in an increasingly complex legal and operational environment, and their proficiency has more impact than ever before on the performance of road freight transport and logistics companies. They contribute to society as a whole by improving road safety, reducing CO_2 emissions and facilitating the movement of passengers and goods.

Autonomous driving seems to be the ultimate goal for road safety. The gradual implementation of the advanced technologies required for automation is an incremental process. Highly automated driving will have an impact on the role and liability of drivers and transport operators. Today, the driver must always be in control of his/her vehicle and carries all liability. The more a vehicle drives autonomously, the more the drivers' role will change from a control function to a monitoring one. This may raise questions about drivers' current levels of liability and shift more of that liability to third parties such as vehicle and component manufacturers.

Subsequently, if a driver were to intervene in the autonomous driving process, this would also imply that his share of liability had increased again. For example, if a dangerous driving situation were exacerbated by the driver trying to prevent a vehicle system´s intervention (e.g. by overriding/aborting an emergency braking intervention, overriding/aborting an emergency swerving intervention, or simply switching off the system), this could be considered an adverse intervention.

As a phased approach towards fully autonomous vehicles is the most likely, liability issues will have to be dealt with in parallel to the developments in and deployment of automation. Based on today's knowledge and technologies in development, a system without a professional driver or in fact any human "cargo manager" on board seems unlikely in the near future. However, a shift in the role of today's professional driver is certainly possible: working conditions, training, working, driving and rest time rules are all subject to change.

It follows that there are key human factors to be addressed. When developing or introducing a new technology, drivers' attitudes must be considered. Drivers' perceptions of connected and autonomous mobility could be different from those of the technology specialists.

In-vehicle systems might also become an obstacle to entering or staying in the profession. Governments aware of the economic and social benefits of a workforce of highly qualified commercial drivers are placing increasing emphasis on driver training. Training schemes will have to integrate new technologies flexibly in order to allow drivers to become familiar with them. Developing specific training on advanced vehicle and cooperative systems would have to be considered, involving road freight transport and logistics operators, vehicle and systems manufacturers and training centres. New professional drivers can easily be taught new ways of working, but the main concern is for existing drivers, who have established particular ways of working over many years. Advanced technologies should, therefore, be included in both initial and continuous driver training. Helping and teaching drivers to use these technologies could play a key role in improving the way goods get to where they need to go in the safest, most efficient and environmentally friendly way.

Operational efficiency

From an operational efficiency perspective, driver training shows clear benefits. However, on-the-job training should be continuous, regularly recurring and fine-tuned to maintain all its benefits. Maintaining driver motivation is also important and their willingness to remain actively involved in improving operational efficiency through training could well depend on the incentive schemes used by individual companies.

3.2.4 Intelligent Transport Systems

The use of intelligent transport systems (ITS) in freight transport and logistics covers a broad range of applications, which can generally be classified into three categories[54]:

54 ADAS, covered in section 3.2.3.1, could also be classified as ITS, but they are excluded here as they do not exchange information with other entities, they only receive it.

- Vehicle to vehicle (V2V) communication systems;
- Vehicle to infrastructure (V2I) communication systems;
- Underlying data support systems for logistics optimisation.

As this section is focussed on measures related to driving, only the first two categories will be considered here. The third category will be discussed in the section on logistics optimisation.

ITS for road freight transport and logistics, as described above, can provide fuel efficiency improvements, mainly through improving traffic flows on the road network (more specifically by properly matching road capacity with traffic volumes at any given time) and by ensuring that vehicles drive at optimal speeds and appropriate distances. In principle, long-haul transport suffers less from congestion, which reduces the use of congestion-limiting ITS applications for this type of mission[55]. A promising ITS application for long-haul transport is vehicle platooning.

CO_2 emissions

A platoon of HGVs is essentially an organised, semi-automated vehicle column, each following closely behind the other in a centrally coordinated manner (using V2V ITS-based communication). Platooning would be able to significantly reduce the air turbulence between vehicles. Given that aerodynamic drag represents 34%–39% of the force that an HGV needs to overcome at motorway speeds, the resulting reduction in fuel consumption could be significant.

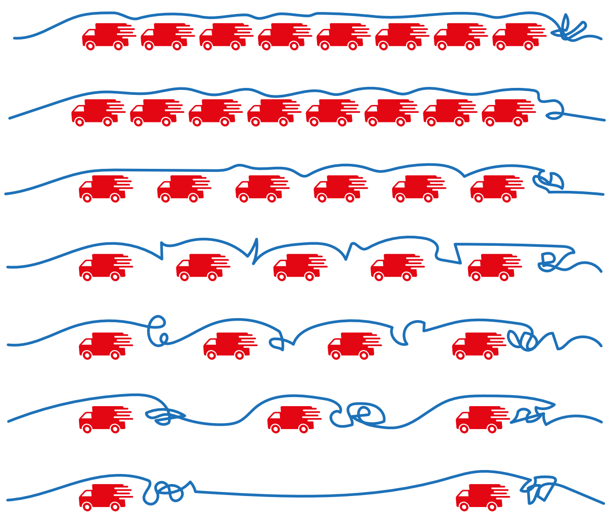

Figure 12: Schematic view of the concept of vehicle platooning

55 See also ERTICO (2016): "Study of the scope of Intelligent Transport Systems for reducing CO_2 emissions and increasing safety of heavy goods vehicles, buses and coaches"

Platooning differs from adaptive cruise control as it is not solely based on a reactive system, but also allows simultaneous actions through two-way communication between vehicles.

The literature suggests that reductions in emissions of up to 25% are possible, with an average of 5%–10%. In practice, the potential could well be lower, for the following reasons:

- The highest reduction figures are probably based on a comparison between a platoon and a single truck. In practice, HDVs already form de facto platoons, driving at close[56] distances.
- Design improvements to vehicles, as described in section 3.2.2.1, will already reduce the aerodynamic drag of the vehicles involved.
- The effectiveness of platooning increases with vehicle speed. If voluntary speed limits of 80 km/h are introduced, the effect will be lower (though studies such as TNO's (2015)[57] already take that speed into account).
- A first, wide-scale, cross-border platooning test by a consortium of road transport stakeholders took place in April 2016 as part of the European Truck Platooning Challenge[58] under the Dutch EU Presidency. Follow-up initiatives are in preparation.
- One of the key enablers of this practice will be the establishment of a legal framework allowing cross-border HGV platooning throughout the EU. Such legislation should ensure the full interoperability of the technologies used by individual vehicle manufacturers as well as the national systems of EU Member States. This will take time to materialise, but progress is being made. Furthermore, the 1968 Vienna Convention on Road Safety will need to be updated to redefine the driver's role in a vehicle equipped with an advanced level of automation.
- Platooning is expected to pose some challenges in terms of infrastructure use; these should be addressed. Vehicle combinations in platoon mode may create issues regarding the platoon's combined weight, which is decisive for load-dependent wear on bridges, and increased wear in the wheel tracks on thin road pavements or poorly constructed roads.
- Not all vehicles can be expected to drive in a platoon for their entire journey. Ideally, platoons will have to be very flexible, with vehicles being allowed to leave and join on-route. It will also be essential to speed up the market uptake of vehicles equipped with platooning technology. Even then, platoon formation may take some time. Our scenario assumes that 40% of long-haul freight transport will be performed in platoons by 2050, with a 10% share possible in 2030.

56 "Close" is defined as a distance where aerodynamic drag is lower than it would be if the vehicle were driving alone. Legal limits vary between countries.
57 TNO (2015): "Truck Platooning: Driving the Future of Transportation"
58 https://www.eutruckplatooning.com

This would put the potential contribution towards CO_2 emission reduction at a maximum of **1%** by 2030 and **4%** by 2050, which is consistent with TNO's White Paper on platooning.

Other applications for ITS in long-haul transport that can provide a useful contribution to improving fuel efficiency were already covered as a part of section 3.2.3.1.

Operational efficiency

Truck platooning has a potential to offer improvement in operational efficiency.

It is acknowledged that platooning can improve:

- **Traffic flow/capacity in platoon mode**
  When vehicles are moving on adapted cruise control, using wireless technology, a higher traffic density could be allowed. Capacity could be regulated using headways, calculating the overall route capacity of any transit system and monitoring road capacity. Based on the gaps between vehicles, this could also relieve driver workload and stress.
- **Fuel economy**
  Fuel economy, depending on the gap configuration in platoon mode, is improved by the reduction in drag. Fuel savings can go up by 10% using adaptive cruise control. The closer vehicles are to each other, the greater the potential fuel saving.
- **Traffic safety**
  Safety benefits could arise from the reduced risks of human factors and the elimination of driver reaction time: platoon mode with adaptive cruise control can drastically decrease braking distances as response times are almost instantaneous. Vehicles in platoon mode reduce congestion, as wireless technologies maintain safe distances between vehicles. Vehicles in platoon mode in bad driving conditions (such as dust or snow) might automatically disconnect their ADAS when sensors and actuators are obstructed, as it might create an adverse situation.
  Drivers should nevertheless be trained to understand platoon mode and how to react accordingly. There is a risk that drivers feel less in control of their own driving and in the hands of computer software or the lead driver. Drivers might become inattentive and thus unable to react as quickly as possible or usual to adverse situations.

However, the true scale of the potential for platooning is currently still being examined within the framework of the outcomes of the 2016 European Truck Platooning Challenge.

Further developments in ITS technology are expected to contribute significantly to improved operational efficiency.

Building on platooning technology, more advanced vehicle automation could lead to fully autonomous vehicles. These offer new perspectives in terms of driving/resting time restrictions and access to road infrastructure (24-hour use); they allow for much larger operational windows for the other parts of the logistics chain and could also bring cost savings. The legislative process to guide this transition is still in its initial phase, and progress in this domain is also dependent on technological advances.

3.2.5 Logistics and supply chain organisation

3.2.5.1 Logistics optimisation by operators and service providers

The options discussed above are generally of a technical nature, requiring the application of either innovative systems built into the vehicle as hardware and/or software components or advanced processes to provide low-carbon energy. The exception is driver training, which becomes the responsibility of the vehicle operator once a driver has been hired, and relies on good practices not directly linked to an individual vehicle.

An important component of optimising efficiency is avoiding empty runs or sub-optimally loaded vehicles. Several developments in road freight transport and logistics could contribute towards this. Further digitalisation of the sector, including the wide-scale introduction of electronic transport documents, could considerably reduce administrative burdens and facilitate logistics chain efficiency (including load optimisation), as the communication of information and data between different parties becomes easier and more accurate. Road safety could improve as access to electronic data on vehicles and loads could allow more rapid and targeted interventions in case of incidents. Digitalisation could also render enforcement more efficient by making it more intelligence-led. Collaborative systems are already rapidly finding their way into road freight transport and logistics. These include sharing digital networks, warehousing, loading and unloading facilities and space in vehicles. Sharing vehicle space should contribute to maximising the load factors of laden vehicles and minimising avoidable empty runs[59]. Further benefits should accrue if these developments also find their way into multimodal freight transport and logistics systems and come into large-scale use.

59 Some empty runs cannot be avoided. Much depends on instructions relating to the carriage, received from clients or intermediaries.

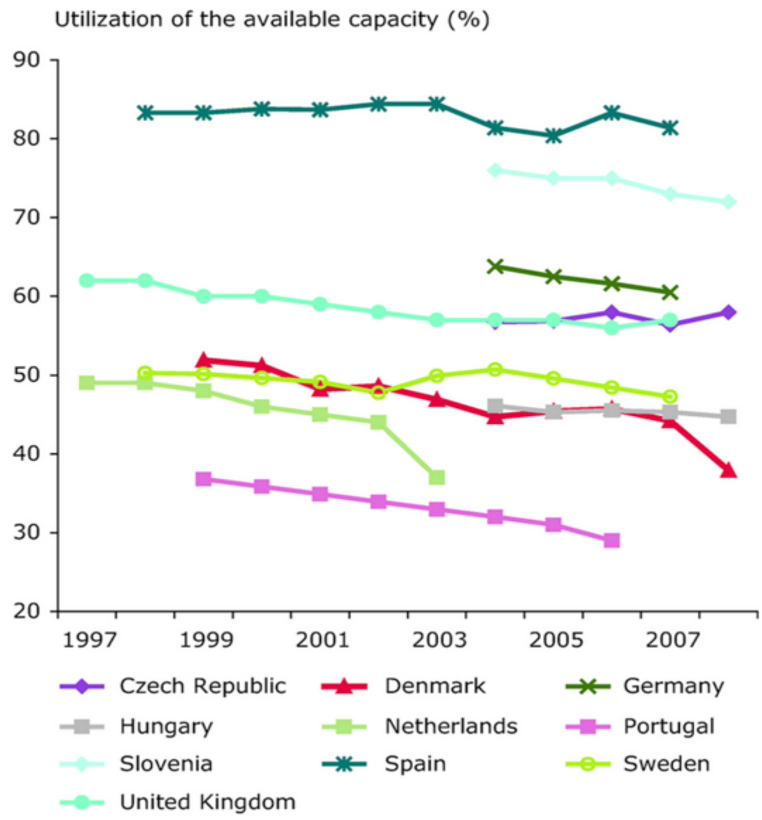

Figure 13: Load factor of HDV in different countries (source: EEA)[60]

The load factor/fill rate is not a straightforward term: it refers to the percentage of the maximum payload on a vehicle during a trip, but the payload is often expressed in weight terms. This definition works for high-density goods, but an important part of the goods transported by road are low density, and a vehicle's loading unit may run out of volume before the maximum payload weight is reached ("cubing out"). For palletised goods, it may also be that floor space runs out before the maximum weight or volume is reached[61].

The incentive to maximise HGV fill rates is very strong: within the requirements for service levels (delivery dates/ times), it is in the road freight transport and logistics operators' best interest to have as much payload in their vehicles as possible, provided that revenue is higher than incremental cost—which is basically the extra fuel cost (and the incentive gets stronger as fuel prices rise). Data from the EEA nevertheless indicate that load factors in road freight decreased in most European countries between 1997 and 2006[62], which could imply that service level requirements became stricter (tighter delivery windows). The load factor is determined by several elements, including the type of journey, type of load, availability of a return load, vehicle payload, customer requirements, intermediaries, rules and regulations, and whether the transport is for hire and reward or on the operator's own account. A road freight transport and logistics operator has control over a number of these elements, such as the choice of the type of vehicle or combination to use. However, this is not the case for some customers requiring that their loads must be delivered during fixed

60 http://www.eea.europa.eu/data-and-maps/indicators/load-factors-for-freight-transport/load-factors-for-freight-transport-1
Note that the absolute differences are probably due to differences in definition or data collection methods. The graph's most important revelation is the decreasing trend.

61 It should be noted that using "load factor" to measure freight transport efficiency is not generally accepted practice in the road freight transport sector because it does not take into account the specific circumstances of many dedicated transport operations and because it does not necessarily consider the differences between hire and reward operations on the one hand and own account operations on the other.

62 The EEA has not updated these figures since.

time slots if a contractual penalty is to be avoided (delivery space booking). This influences planning flexibility and load factors. Also, traffic bans and other rules such as those relating to working time and driving and rest times influence the load factor.

The 2011 European Commission Road Freight Transport Vademecum[63] indicates that load factors are higher for international journeys than for national journeys and that hire and reward transport scores better than own account transport. Price levels and profitability are major determinants of the number of empty runs. Increased empty running could be a signal of lower profits or even losses in the sector, which could be the result of too much competitive pressure. Road freight transport is a service industry and notwithstanding operators' interests to have the highest possible load factors, customers' conditions and instructions often determine the efficiency of a road freight transport journey.

Load factors should be approached with care, even though they have an important impact on the CO_2 emissions and fuel consumption allocated to a vehicle or an operation. Nonetheless, even in these circumstances, the incentive to maximise efficiency is still present. The key to increasing load factors and fuel efficiency per tkm lies in improving operational conditions.

There is clearly potential for improvement, but it is very difficult to assess the magnitude. Data and information integration are expected to be key in the load factor optimisation process. Developing the collaborative economy could help on-going efforts to optimise capacity use in the sector[64]. Freight transport and logistics platforms supported by ITS (the third pillar mentioned in section 3.2.4) can be used to consolidate loads via horizontal or vertical collaboration between transport operators[65], intermediaries, shippers and subcontractors, and to help hauliers more easily locate potential cargo during their operations. However, some ITS standardisation will be required, and concerns about security (both information and goods[66]) and competition will have to be overcome. Much will depend on who runs the platforms and on the extent of mutually shared benefits. They could be run by shippers or intermediaries where the emphasis is on driving down prices. On the other hand, they could be run by transport operators themselves, where they offer empty capacity on a certain route or journey and where they set the price. The European Commission is increasingly focussing on such efforts in its policy formulation and research funding.

The total overall improvement possible from greater logistics efficiency (i.e. covering more than just long-haul) over the entire road freight sector is estimated to be around 20% (GHG-TransPoRD (2011)[67], PBL (2014)[68]). This includes digitalisation, collaboration, load optimisation, avoiding empty running, right-sizing the vehicle (e.g. longer, heavier vehicles or small delivery vans), and a relaxation of certain operational conditions such as driving/resting time regulations and delivery windows[69]. With regard to how effective these tools might be at increasing the load factors of laden road freight transport, few or no separate estimates were to be found in the literature. A study by CfSRF[70] estimates the CO_2 emissions reduction potential of synchronised load consolidation (for laden vehicles) at 0.8% when supported by an ICT platform. Very rough estimates of the contribution these tools could make to increasing load factors for the 2030 and 2050 horizons are **2%** and **10%**, respectively.

Operational efficiency

Based on a single estimate, it is difficult to accurately assess the potential for improving fill rates at the EU scale. Road freight transport and logistics operators tend to question observations that fill rates are declining, arguing that very low fill rates are impossible to sustain and would lead to excessive losses and eventual bankruptcy. Opportunities to improve operational efficiency through operators and service providers optimising their logistics will always be dependent on commercial and contractual relationships, the ability to turn challenges into opportunities and to extract a fair share of the benefits out of the relationship. The present report thus identifies this as an area requiring further fundamental research before reliable projections can be made. Fleet management, fleet routing and intelligent truck parking would provide reliable information about overall capacity, as would facilities such as real-time urban delivery-space management, comprising online information and booking. The interwoven and competing aspects of weight, volume and floor space restrictions play an important role in the matter, and improved statistics would be the first step towards a better understanding of the issues.

63 http://ec.europa.eu/transport/modes/road/doc/2010-road-freight-vademecum.pdf
64 See, for example, the Modulushca project (http://www.modulushca.eu/index.php/the-project/expected-results), which combines a logistical organisation system as a pilot for the Physical Internet, with an innovative approach to modular logistical units.
65 This could also include pre-agreed platooning, where cost savings are shared equally over the vehicles in platoon mode.
66 See IRU Guidelines on freight exchanges: https://www.iru.org/resources/iru-library/iru-guidelines-on-freight-exchanges-2013
67 TML (2010): "Ranking of measures to reduce GHG emissions of transport: reduction potentials and feasibility qualification" (GHG-TransPoRD D2.1)
68 PBL (2014): "Options for the Road Freight Sector to Meet Long-Term Climate Targets"
69 For instance, delivery space booking can reduce CO_2 emissions by over 20%, as well as illegal parking. The system allows advance delivery-space booking before reaching the delivery point. It allows an optimisation of the designated deliveries in a shorter time and the reduction of negative consequences (stress and the number of stops).
70 CfSRF (2015): "An assessment of the potential for demand-side fuel savings in the Heavy Goods Vehicle (HGV) sector"

3.2.5.2 Carbon footprinting

Carbon footprinting for road freight transport and logistics operators provides an objective measurement of the CO_2 emissions generated all along the transport and logistics chain; it can be used for different purposes. Shippers can use it to reduce the carbon footprint of the logistics related services that they carry out themselves or contract out; they can use it in their contracting procedures, rewarding operators which offer the best "conditions". However, it is important to build the necessary incentives for road freight transport operators into this process to create win–win situations and encourage them to get involved. Road freight transport and logistics operators can also use carbon footprinting directly themselves to measure reductions in fuel consumption and CO_2 emissions and to optimise operational efficiency. It is essential that carbon footprinting methodologies be compatible and interoperable throughout the entire multimodal freight transport and logistics chain. It is also important to ensure that participating companies are offered the necessary guidance (on which measures to undertake) in order to obtain optimal results[71]. Some examples of this practice are:

- France set up the "Objectif CO_2" label with the support of the Ministry of the Environment (MEDDE) and the environmental agency (ADEME).
- Netherlands awards the "Lean & Green" label to transport companies that make efforts to upgrade their fleets' environmental footprints. The system has also been adopted in Flanders (BE).
- The UK FTA's Logistics Carbon Reduction Scheme is a voluntary initiative to record, report and reduce carbon emissions. It allows the UK's logistics sector to publicly report its contribution towards national carbon reduction targets.
- The GreenFreight Europe platform provides a label for green performance based on standardised European levels.

CO_2 emissions and operational efficiency

Carbon footprinting road freight transport and logistics services does not reduce fuel consumption and CO_2 emissions, of course. It measures, monitors and reports on the operational actions taken to reduce fuel consumption, which could include route optimisation, tyre pressure monitoring, eco-driving, improved maintenance, using aerodynamic devices and double stacking. The scope and output of measures relating to carbon footprinting depend on each road freight transport and logistics operator's profile. Those who commit to it tend to renew their commitment, as they get a positive return. There is, however, a natural tendency: the further an operator goes in trying to reduce fuel consumption through measures related to carbon footprinting, the more challenging it becomes to obtain incremental positive results.

3.2.5.3 Legislation: weights and dimensions

In a single road freight transport market based on principles relating to the freedom to provide services, legislators have the task of remaining neutral, providing a level playing field for all participants and setting priorities in the process of achieving common societal goals—in this case, the climate change mitigation and transport network efficiency objectives set out in the 2011 EU Transport Policy White Paper.

Since the adoption of the first rules on maximum vehicle weights and dimensions, in 1985, there has been a tendency to very strictly regulate road freight transport vehicles, to avoid, as much as possible, any potential increases in the carrying capacity of a vehicle or vehicle combination. This has restricted the potential for designers, builders and users of commercial vehicles to innovate. Working within a very strict set of rules to reduce dependence on fossil fuels, fuel consumption and CO_2 emissions, while adding vehicle technologies aimed at improving road safety and fuel efficiency, has made trying to deliver economically viable solutions an increasing challenge. Additional road-safety and alternative-propulsion technology tend to use up space and weight at the expense of payload. With this in mind, there are increasing calls for more flexibility in terms of the weights and dimensions of road freight transport vehicles in order to better meet the challenges posed by the greening of the transport system and improvements in road safety.

Creating more flexibility regarding weights and dimensions could imply simply adding extra weight, length or height. Alternatively, customisation could lead to vehicles being designed specifically for certain missions. If all the conditions are met with regard to safety requirements, manoeuvring ability (turning circle), suitable axle loads and other relevant parameters for a certain trajectory, vehicle manufacturers and owners could be given more freedom to build optimised vehicles, perhaps with fully modular units to maximise flexibility. A precondition for this approach would be that road infrastructure is adequately mapped and documented in order to define the requirements to be met by vehicles driving on them. Although executing this approach could largely be left to the initiative of the transport industry, framework conditions would need to be set by EU and national legislators.

Furthermore, when it comes to road freight transport and logistics organisation, one very important decision which

71 An example of such guidance not linked to a carbon footprinting scheme is the "Transport Sector's Plan for a better climate: 49 ways to save fuel", Dansk Transport og Logistik, at https://issuu.com/sandgreen/docs/transport-sector-better-climate

legislators will have to make in the near future is whether or not to extend the scope for the use of longer and/or heavier vehicles (LHV, including those combinations of 25.25 m and up to 60 t based on the principles of the European Modular System, or EMS) in cross-border transport. The EU weights and dimensions Directive 96/53/EC has already been mentioned in the context of aerodynamic improvements to vehicles, but it also covers the use of LHVs. LHVs have been in operation in Sweden and Finland for decades, and have recently been allowed in the Netherlands too, after an extensive trial period. LHVs are also being tested (freely or with restrictions) in Denmark, Germany, Belgium and Spain.

Proponents of LHVs refer to their superiority in terms of operational efficiency (50% more cargo can be carried in a single trip) and environmental performance (CO_2 reductions of between 10%–25% per tkm; 17.5% is taken as an average). Opponents of their wider use mention the additional wear and tear on infrastructure (e.g. pavements, bridges) caused by 60-t LHV combinations, which was confirmed by the TML study (2008) [72], whereas 50-t combinations perform remarkably better than current vehicles; they also bring up the risk of lower transport prices.

CO_2 emissions

The positive environmental effects of LHVs for road transport are not disputed. As for their contribution to CO_2 reduction, the assumptions made by TML (2008) lead to an overall decrease in road freight transport sector emissions of 3.8 Mt CO_2 annually, or just over 1% of total road freight emissions in 2010, a figure supported by the EC's Joint Research Centre (JRC) (2009)[73]. If we assume that the 1% reduction was fully achieved in the long-haul cycle, this would mean that the cycle's emissions could be reduced by 2.5%–3%. Reductions per vehicle in the JRC study were assumed to be around 12.5%, which implied that the market share of LHV in total long-haul tkm was from 20%–24%. This also assumes that LHV combinations are only used on those trips where they provide a benefit, i.e. with high payloads and on suitable parts of the network, not passing through urban areas.

For the present report's assessment of the CO_2 emissions reduction potential of LHVs, we assume that the 2030 potential in the long-haul segment is at **3.5%**, based on the 17.5% reduction and a 20% market share. For 2050, we assume that the emissions reduction per vehicle increases to 25% thanks to the use of even larger, heavier vehicles (possibly in dedicated lanes) and that market share increases to 30%, thus putting the contribution at **7.5%**.

72 TML (2008): "Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC"
73 JRC (2009): Longer and Heavier Vehicles for freight transport

Road Safety

The road behaviour of an LHV differs from that of a standard vehicle combination. However, the rearward amplification and stability of an LHV are similar to or better than a standard transport combination, whether articulated or road train. Furthermore, an LHV combination has the same or better braking performance than standard vehicle combinations. Braking performance is related to axle load and the axle load does not change on an LHV. Apart from the use of existing safety technologies, such as electronic braking systems (EBS), LHVs can also be equipped with the latest active and passive features for improving road safety, such as lane-assistant warning, proximity-controlled cruise control, adaptive cruise control to lower the risk for rear-end collisions, and electronic stability programmes (ESP). Furthermore, LHV drivers usually receive better safety-related training than regular drivers, which may help reduce the direct human risks associated with LHVs.

The risk of traffic accidents is usually considered highly dependent on the number of vehicles in the traffic. The reduction in the number of HGVs in traffic has a positive influence on road safety as there is less congestion and more road space. More frequent use of LHVs could lead to a reduction of almost 20% in the number of heavy duty vehicles on motorways. Using two LHVs instead of three standard vehicle combinations requires 33% less road space for the actual vehicle combinations. However, due to the mandatory safety distances, the real gain in road space is reduced to 25%.

According to the TFK study (2002)[74], using longer trucks reduced the number of trips taken by an average of 32%, though the results varied depending on which routes the transport operators used.

Operational efficiency

Any weight or dimension-related measure which increases a road freight transport vehicle's payload can contribute to improving operational efficiency. However, some significant points must be considered. Firstly, limitations imposed by infrastructure and land use can prohibit the use of LHVs in certain places. The scope of such prohibitions will be different according to the Member State. Secondly, it is very difficult to clearly quantify payload gains as these depend on how the load-bearing area is constructed, on how much of the allowed length, width, height or weight improvement is used and on the type of freight carried (weight versus volume). More capacity on an LHV combination could lead to fewer standard

74 TFK (2002): "Improved Performance of European Long Haulage Transport"

combinations on the road carrying the same amount of goods. This could, in turn, lead to a reduction in the vkm driven. More payload per trip will also push down transport rates per unit, which puts additional pressure on transport operators to keep fill rates high.

With a particular regard to LHVs, it is known that two LHV combinations can replace three standard combinations. There is thus a potential to reduce the number of vehicles on the road and the number of vkm driven. However, because of the current, very limited use of LHVs in the EU, it is difficult to quantify to what extent replacement will happen on an EU-wide scale. Interpretations of the current Directive vary with regard to the number of borders that can be crossed by an LHV combination. An important question is what the market share will be if all Member States allow LHVs to circulate freely on their territories. In Sweden and Finland, LHVs were found to have tkm market shares of 90% and 70%, respectively. These countries are not representative of the EU, however, as they are large, sparsely populated and have industries which benefit especially from the additional length and carrying capacity provided by LHVs. After extensive trials in the Netherlands, the current market share of 25.25-m, 60-T LHV combinations is around 5.4%. Considering that these LHVs are only used in domestic transport, a calculation of the tkm share is only relevant in that market: 12.4% of tkm in domestic transport are performed using LHVs. In Danish trials, participating operators transported up to 22% of goods using LHVs. The share in tkm is probably higher. However, the limited scale of the trial implies that general conclusions should not be drawn from it.

Due to the current legal limitations imposed on the cross-border use of LHV combinations, it is very difficult to get a clear view of their impact on long-distance intra-EU freight transport and logistics. LHV combinations seem best suited for connecting industrial hubs (which could involve trips of any distance) or for long-distance trips. Opponents argue that greater use of LHV combinations could entail a reverse modal shift from rail to road. Considering this argument, it should be noted that none of the LHV trials or use reports has substantiated that shift. Even the theoretical studies[75] hint more at the potential for highly significant gains in road freight transport efficiency than at the danger of a significant modal shift back from rail. It should also be noted that purely vertical modal transport activities are dwindling and that multimodal logistics operations will become more important. DB Schenker, a key multimodal freight transport and logistics integrator, is already a keen user of LHV combinations of up to 25.25 m in Sweden and is testing even longer combinations, of up to 32 m. Within this framework, limiting the use of one mode or means of transport to the advantage of another would be counterproductive. Also, with transport volumes projected to grow significantly, there would not be any actual decrease in volume for either mode.

If a higher share of trips can be made suitable for LHV transport, through the optimisation of logistics (improving fill rates), including the use of LHVs in multimodal and combined transport, then their market share can grow even further. Uptake will depend mostly on

- the growth of suitable commodities for transport;
- potential adaptations to road infrastructure (pavements, tunnels, bridges) at a reasonable cost;
- legal provisions (at national and supranational level) that allow free circulation of higher capacity vehicles;
- the willingness of road freight transport and logistics operators to invest in the additional equipment—although these modular vehicles can theoretically be adapted as required, some capital investment will be needed and very small (owner-)operators may not be able to do that; some operators will merely be towing a longer trailer or semi-trailer on a dolly, which will require no major investment.

3.2.6 Infrastructure

Infrastructure mainly affects HGV emissions and safety through the road pavement, the location of road signs and, to a lesser extent, as a framework of conditions (e.g. refuelling stations or V2I ITS devices). Access to infrastructure also has an impact on the extent to which it can be used by road freight transport vehicles at times when it is not much used by others.

3.2.6.1 Rolling resistance of road pavement

Rolling resistance occurs at the contact point between the vehicle and the road it drives on. It mainly plays a role at lower speeds, but even at higher speeds, it remains an important aspect (although aerodynamic drag becomes more important). The rolling resistance of tyres was already discussed in section 3.2.2.2. It also has possible links to safety effects.

Two main types of road pavement exist in Europe: asphalt and concrete (composites of the two are also applied). Although each material has its specificities, with associated advantages and disadvantages, our focus will be on the main infrastructure-related factor with an impact on fuel consumption—the rolling resistance coefficient (RRC).

75 K+P Consultants in cooperation with Fraunhofer-ISI (2011): "Study on the Effects of the introduction of LHVs on Combined Road-Rail Transport and Single Wagonload Rail Freight Traffic"

Other factors also play a role in the choice of one pavement material or the other (e.g. traffic density, temperature resistance, acoustics, water drainage, cost), but these should be considered in a full cost–benefit analysis. The RRC is a function of a number of underlying parameters, including, most importantly, the pavement's macrotexture (Mean Profile Depth, MPD), roughness (International Roughness Index, IRI) and road gradient.

- Of the three, road gradient is the most difficult and costly to manipulate. Generally, whenever the road gradient is above 2%, uphill and downhill variations are not balanced. For higher gradients, the impact is negative (surplus energy needed for climbing is greater than saved energy in descent), as confirmed by Wyatt (2014)[76], among others. This highlights the importance of considering the instantaneous rather than the average road gradient when assessing vehicle emissions, and can serve as a guideline to infrastructure managers when the decision on road gradient comes up in the process of (re)building roads. However, the gradient usually depends on given terrain conditions, and creating detours to avoid high gradients could also increase travel distance such that the positive effects of a lower gradient are completely lost.
- MPD and IRI determine the amount of friction generated between the tyre and the road surface, and although these can cause local deformations to the tyres, the impact must not be transferred to the axles. Although different materials do not necessarily differ much according to these parameters, road deterioration has a strong impact on both MPD and IRI, which calls for good road maintenance programmes across Europe.
- The impact of pavement stiffness, which is arguably the main variable parameter between concrete and asphalt, is much less well defined than that of MPD and IRI. The literature is inconclusive about the effect of stiffness, with some studies claiming a lower rolling resistance from concrete pavements, whereas others conclude that any such differences are not statistically significant.

CO_2 emissions

According to Schmidt (2012)[77], a rule of thumb is that a 10% reduction in the RRC should generate a fuel saving of about 3% for HDVs. Descornet (1990)[78] estimated a maximum difference in fuel consumption between different road types of 9%, which would represent a difference in RRC of 47%.

Several contributions to the MIRIAM project[79] suggest that a 10% improvement in RRC can be achieved, citing country examples like Denmark and Sweden. As part of a normal road-maintenance cycle (resurfacing roads for the sole purpose of emissions reduction does not happen), this could lead to a 3% decrease in fuel consumption by 2030. Although it is possible that further specialised pavement surfaces (or other modifications) allow for greater reductions by 2050, no information is available on this matter.

The great advantage of pavements that induce a lower RRC is that the benefits of lower fuel consumption accrue to all road users; they will be greatest for HDVs on heavily used regional roads with lower maximum speeds, but all road users will reap the benefits. It is unclear how long it would take for such a measure to reach its full potential, as it is largely dependent on proper funding for road infrastructure[80]. The key objective is to ensure that sufficient road maintenance is performed to optimise texture and roughness for CO_2 emissions reduction.

Another interesting opportunity for road pavements would be to move from a passive to an active role, e.g. for roads to generate electricity by having built-in solar panels[81].

Road Safety

- *Improving road friction* can help vehicle stability. This is of particular relevance for single vehicle accidents (e.g. loss of control, cornering) and potentially for tailgating accidents (reduced braking distances). It should be noted that road friction is different from the road infrastructure objective of reducing rolling resistance. Friction is determined at the micro level, whereas rolling resistance is more affected by the road's macrotexture.
- *Improving visibility (intersections) and obstacle removal*: as indicated in section 3.2.3.1 of this report, visibility problems are an important causal factor of fatal accidents involving HGVs and unprotected road users. Although this can be partly solved by equipping vehicles with better systems to detect unprotected road users, improving infrastructure to maximise safety by reducing potential hazardous traffic situations should also be considered. Many existing intersection designs do not fit into overall safety systems. A roundabout (considered to have 4 major points of conflict versus 24 for a normal road intersection)—based on ITF recommendations (2016)[82]—guides the road user towards a safe form of behaviour and mitigates the consequences of common human errors. A Safe System intersection

76 Wyatt, D. et al.: "The impact of road grade on carbon dioxide (CO_2) emission of a passenger vehicle in real-world driving" (2014), http://www.sciencedirect.com/science/article/pii/S136192091400100X?np=y
77 Schmidt, Dyre (2012): CO_2 Emission Reduction by Exploitation of Rolling Resistance Modelling of Pavements
78 Descornet (1990): Road Surface Influence on Tyre Rolling Resistance
79 http://miriam-co2.net/
80 See e.g. for the UK the ALARM survey: http://www.asphaltindustryalliance.com/images/library/files/ALARM%202015/ALARM_survey_2015.pdf
81 http://www.solarroadways.com/
82 International Transport Forum (2016): "Zero Road Death and Serious Injuries

is one where road users will not get seriously or fatally injured even if they make a simple mistake. The positioning of (vertical) road signs, street-side infrastructure, vegetation (greenery), and so on, all needs to be considered carefully in any locations where interactions between road users can be expected. This is particularly the case for pedestrian crossings or intersections.

3.2.6.2 Availability of fuel and energy infrastructure

A significant part of projected short- and long-term CO_2 emissions reduction will come from the use of non-fossil diesel fuels: (advanced) biofuels, natural gas (and specifically its renewable equivalent) and electricity. Infrastructure investments for all these options will be needed to produce and distribute these energy sources.

- For liquid synthetic and biofuels, no specific refuelling infrastructure will be needed per se. The main requirement for a breakthrough in liquid biofuel use will be the establishment of the political and legislative enablers to manufacture them sustainably, in sufficient quantities and at an acceptable cost. Apart from production infrastructure, investments in research and development are needed to improve the resource efficiency of advanced biofuels.
- In the past, natural gas was mainly used in light duty or local transport operations, in the form of CNG. For long-haul cycle applications, more energy-dense LNG is the preferred source, but it requires adapted refuelling infrastructure to ensure the appropriate fuel storage conditions until the moment of transfer into the vehicle tank. LNG refuelling stations will need to be available in sufficient numbers along Europe's main road transport arteries if it is to gain a significant market share. Directive 2014/94/EU on alternative-fuel infrastructure explains that Member States should ensure that "an appropriate number of refuelling points for LNG accessible to the public are put in place by 31 December 2025, at least along the existing TEN-T Core Network, in order to ensure that LNG heavy-duty motor vehicles can circulate throughout the Union, where there is demand, unless the costs are disproportionate to the benefits, including environmental benefits." This legislation also states that a distribution network for LNG should be put in place to supply these distribution points.
- Furthermore, the production capacity of synthetic and biogas will need to be increased and allocated to road freight transport in sufficient quantities to guarantee that the continued use of gas as a transport fuel does not remain dependent on fossil gas, as this is not in line with long-term reduction targets.
- The current outlook for electricity as a vehicle's main power source in long-haul, heavy-duty road freight transport operations will rely on power from the electricity grid rather than the energy stored in batteries or hydrogen fuel cells, though these are not excluded a priori. The costs of setting up such a network were briefly discussed in section 3.2.1.4. On the other hand, for regional delivery and urban distribution, energy storage in batteries is a much more feasible option.

3.2.6.3 Infrastructure and operational efficiency

Infrastructure has an important impact on operational efficiency as traffic fluidity determines journey times and whether delivery windows are met. Delays, including those caused by congestion, can have a negative impact on working, driving and rest times and costs in general. Traffic rules and regulations, social legislation and business practices often force road freight transport and logistics operators to use infrastructure when it is also most used by others, which in turn can be considered as a barrier to optimising operational efficiency. One deterrent to using road infrastructure during peak times could be to levy higher user charges on HGVs during those periods. However, this generally leads to higher revenues, but not necessarily to the desired behavioural change, as road freight transport and logistics operators often have no alternative to driving during peak periods. Finding an incentive that optimises operational efficiency for road freight transport in terms of infrastructure use at off-peak periods would encourage HGVs to travel then. This would allow road freight transport and logistics operators to carry out more precise and efficient planning and would open a window to additional fuel consumption reduction opportunities and would reduce congestion. Road safety would be enhanced because interactions with other users would be reduced and traffic fluidity improved.

3.2.7 The CO_2 reduction potential for the long-haul cycle

Based on the information provided in Chapter 3.2, on the contributions of the different available options for reducing CO_2 emissions, the following table summarises their reduction potential in the long-haul cycle using the 2030 and 2050 horizons. It captures their emissions reduction potential compared to the state of the vehicle market in 2010. Different measures can have overlapping benefits which cannot be taken into consideration twice. The bottom figures of the last two columns in the table, therefore, are the total cumulative reduction potentials for 2030 and 2050, taking into account overlapping; they are not the sum of each potential improvement. Given the range of uncertainty associated with such long-term projections, however, the amount of interaction between lower speeds, aerodynamic improvements and vehicle platooning, for example, could be within the given intervals for the reduction potentials.

Long haul	Potential 2030	Potential 2050	Comment	Cumulative reduction 2030	Cumulative reduction 2050
Powertrain efficiency (diesel)	10%	15%	Includes engine, transmission, auxiliaries, …	10.0%	15.0%
Gas vehicles	2%	4%	Methane emissions should be minimised	11.8%	18.4%
Renewable fuels (gas & liquid)	2%	24%	IEA general target, large increase in 2nd generation biofuels needed; includes biogas	13.6%	38.2%
Driver training and ADAS	6%	8%	Includes ACC, PCC, …	18.8%	43.2%
Reduced max. speed	2%	2%	To 80 km/h	20.4%	62.8%
ITS & communications	1%	4%	Platooning	21.2%	46.5%
Aerodynamics	6%	10%	Important contribution expected from trailers and semi-trailers, including solutions developed in the TRANSFORMERS Project	25.9%	51.3%
Tyres	7.5%	12.5%	Includes super singles	31.5%	57.4%
Lightweighting	0%	0%	Compensated by increased weight from other measures	31.5%	57.4%
Pavement	3%	3%	Improved rolling resistance (maintenance or new pavement)	33.5%	58.7%
Logistical efficiency improvements, including digitalisation, collaboration on reducing empty running & improve load factors	2%	10%	Rollout of coordinated system needed	34.8%	62.8%
More flexibility in weights and dimensions (including LHV)	3.5%	7.5%	LHVs permitted to carry out cross border transport within the EU	37.1%	65.6%
Hybridisation (2030)/ electrification (2050)	3%	37%	For 2050, most from full electrification	39.0%	78.2%

3.2.8 Findings and recommendations on the potential for CO_2 emissions reduction in the long-haul cycle

Based on the available information, there is a potential for long-haul road freight transport to reach both its medium and long-term CO_2 emissions reduction targets. If the necessary measures are developed and put in place, and the necessary framework conditions are met, current levels of long-haul road freight transport could see reductions in fuel consumption and CO_2 emissions of 39% by 2030 and up to 78% by 2050. A wide range of options and measures will have to be implemented to reach them.

There is a significant difference in the potential to meet the 2030 and 2050 targets. Meeting the 2030 targets could be possible without having to make substantial changes to the energy mix in use today for long-haul freight operations, including for HDVs. The traditional diesel engine and alternative fuels such as biofuels and gas need to be further developed, but there would be no need for a fundamental change to the large-scale use of renewable energy sources such as electricity. This picture changes completely when looking towards 2050. Here, fundamental change will be needed to meet existing targets. Large-scale electrification is certainly an option, but solutions are still only in an early stage of development. A number of conditions would have to be met to enable electrification, including the full decarbonisation of electricity production, the creation of a compatible EU-wide system which could be used for several types of vehicles and the necessary heavy investments that would be attached to such a project. Any decisions to enable such a fundamental change will have to be taken soon. The dilemma is that decision-makers face a lack of certainty regarding whether any potential solution—in this case electrification—is the right one for the long-term future of European transport up to 2050.

Vehicle-related measures are likely to be the main contributors (around two thirds of the total reduction) for the 2030 horizon, with a multi-faceted approach ranging from improvements to the ICE's efficiency, to ADAS and improved aerodynamics. The wheels have been set in motion with all these measures, but the strength of the underlying incentives will determine where and to what extent the potential is met. Currently, the strongest incentive for vehicle owners to reduce CO_2 emissions is a lower fuel bill. In addition to the cost of the vehicle, fuel prices are expected to play a major role in purchase decision processes through their impact on depreciation periods. Members of the IRU CVOF Reflection Group indicated that depreciation periods generally need to be three years or less for vehicle buyers to consider an investment. A 2012 survey of IRU Members showed that the average depreciation period was still seven years. Many road freight transport and logistics operators are moving away from vehicle ownership to other structures, such as leasing. Such developments could have an impact on amortisation periods and depreciation in second-hand values. This could accelerate fleet renewal which could, in turn, bring about a faster market uptake of new technologies. As fossil fuel prices have decreased significantly over the past few years and may remain low for the foreseeable future (also caused by strategic decisions in oil exporting countries), a sustainable incentive system may be needed to ensure technological development continues to support the sector's long-term goals.

As a proof of concept for general emissions reduction, Daimler set up an "Efficiency Run" field test in 2015[83], running a comprehensively optimised truck (engine, tyres, semi-trailer, etc.) in real-world traffic. It discovered that with technologies and measures available in 2014, its optimised truck emitted 12%–14% less CO_2 than the average truck.

It must, however, be understood that the success of vehicle-related measures will not only depend on developing technology. Political decision-makers and legislators will have to agree to and put in place a legislative framework which facilitates further innovation and takes into consideration the underlying development and market uptake costs, including potential incentives.

Most of the remaining projected reduction is expected to come from measures that will ramp up after 2030. The long-term contribution from biofuels hinges on political and legislative facilitation, advances in production capacity and improvements in the WTW emission profile of advanced biofuels—this needs to be 90% lower than fossil diesel (including direct and indirect land-use change effects) to achieve its projected target. Further development of such biofuels will need renewed political backing at EU and Member State level if they are to play their full role in the CO_2 emissions reduction for HDVs. Gas-powered vehicles could also be important contributors to CO_2 emissions reduction in the long-haul cycle. The size of their contribution would depend on the further development of gas engine technology, the use of bio and synthetic gas, the market uptake of vehicles running on gas and solutions to methane emissions issues. The application of ITS to improve collaboration between transport operators, both on the road and in planning (improving load factors), will require time to reach one (or more) sufficiently harmonised platform(s) for secure, reliable data transfers between all the parties involved. However, it should have a major impact on fuel

83. http://media.daimler.com/marsMediaSite/en/instance/ko.xhtml?oid=9915514&ls=L2VuL2luc3RhbmNlL2tvLnhodG1sP29pZD05MjY2MTQ1JnJlbElkPTYwODI5JmZyb21PaWQ9OTI2NjE0NSZib3JkZXJzPXRydWUmcmVzdWx0SW5mb1R5cGVJZD00MDYyNiZ2aWV3VHlwZT1saXN0JnNvcnREZWZpbml0aW9uPVBVQkxJU0hFRF9BVC0yJnRodW1iU2NhbGVJbmRleD0wJnJvd0NvdW50c0luZGV4PTU!&rs=1

consumption per tkm. A framework ensuring fair shares of the benefits will be an essential incentive for such practices.

The electrification of heavy-duty road freight transport could arguably provide the largest reduction in transport CO_2 emissions in the long run up to 2050, provided that the electricity is generated in a sustainable manner and that sufficient grid capacity is allocated to commercial road freight transport. Large investments in better infrastructure and vehicle technology would be needed. A framework needs to be created to facilitate the development and testing of HGV electrification technology, as well as a financing mechanism for the distribution network (be it in the construction of roadside infrastructure or the production and distribution of vehicle-based power storage solutions, like hydrogen or batteries). Technology which could be used for a wide range of vehicle types may have to be developed in order to increase its acceptability. Very clear, EU-wide, harmonised standards providing a single EU solution would be required to generate the desired effect, and it is not certain that full technological neutrality could be maintained. If EU road networks are to be electrified, given the time and cost involved in the establishment of a sufficiently extensive network, the decision process would have to be well advanced by 2025–2030, and the system would have to start to roll out by 2035. Potential strong opposition to such developments could not be excluded from other stakeholders in the freight transport and logistics markets.

More flexibility in the rules about the weights and dimensions of road freight transport vehicles will also be necessary in order to enable a number of other measures in the list. These include the further market uptake of alternative fuel vehicles, the use of aerodynamic devices and the general cross-border use of longer, heavier vehicles, including LHVs. Political decision-makers at national and EU levels have until now restricted that flexibility for a multitude of reasons, including the condition of road infrastructure, road safety and competition with other freight transport modes. However, the 2015 modification of the EU rules opened a new window of opportunity on the grounds of environmental performance, road safety and operational efficiency. The present report's findings indicate that this window may not be sufficiently large to facilitate the innovation in road freight transport needed to meet the medium and longer-term targets for lower CO_2 emissions and fuel consumption. It will, however, be essential that key aspects related to infrastructure use, such as vehicle width, number of axles, axle weight and turning circle, are duly considered in this respect.

There are severe concerns about the lack of weight exemption incentives for vehicle combinations using alternative fuel technologies—vehicle combinations predominantly used in the long-haul cycle. The prices of alternative fuel vehicles also continue to restrict market uptake, as do their limited availability and the narrow range of manufacturers; this is despite substantial improvements in recent years. Member States will also have to ensure that their policy plans for alternative light and heavy goods vehicles are implemented and that adequate fuelling infrastructure is available by 2030, as prescribed by EU legislation

A number of developments contributing to improvements in the logistics chain could have a very strong impact on how long-haul road freight transport and logistics operations will be organised in the future and contribute to reducing their environmental footprint. Firstly, the wider use of ITS by road freight transport and logistics operators and the competent authorities could lead to further innovation in the sector. The political and legislative facilitation of new and existing, compatible, interoperable, EU-wide solutions will be essential to generating further and faster progress. The implementation of large-scale truck platooning across the EU is a good example of this. Truck platooning could, in turn, open the way for gradually increasing vehicle automation, which could eventually lead to the use of fully autonomous HGVs. This will require a fundamentally different approach to the traditional road-use rules, especially in terms of the professional driver's liability. Fully autonomous commercial vehicles could encourage new vehicle and loading unit designs and substantially overhaul the way long-distance freight is moved by road and multimodal transport. ITS could also drive faster digitalisation of road freight transport and logistics processes, and indeed those of the multimodal chain. Wide scale use of ITS and digitalisation could also create new collaborative opportunities for road freight transport and logistics operators, with new forms of sharing resources and cooperation which could contribute to more efficient load factors.

The present report's scope did not allow an in-depth analysis of the potential contributions of these developments in CO_2 emission reductions, and more research would be needed to better identify the scope of the opportunities they offer.

3.3. The regional delivery cycle

The regional delivery cycle covers the transport of goods from a central warehouse to local stores, over distances of no more than 100 km (typically 20–50 km). A significant part of an average trip occurs on local and regional roads, but this could easily be either a domestic or cross-border transport. About half of regional deliveries still use motorways at higher speeds. This report uses an 18-t rigid truck as its reference vehicle, but there is no single dominant vehicle type operating in this cycle, as is the case for tractor/semi-trailer combinations in the long-haul cycle. Load factors are lower, around 50%, partly due to more empty runs. Typical annual mileage for these vehicles is around 60,000 km. According to AEA (2011), they represented 13.9% of HDV CO_2 emissions in 2010.

The regional delivery cycle can use many of the same measures as the long-haul cycle, although possibly with different levels of effectiveness. In this section, we briefly discuss the main differences between the cycles before presenting the summarised projections.

3.3.1 Main differences with the long-haul cycle

- Improvements in engine efficiency have less of an impact on a regional delivery cycle as vehicles spend less time at the engine's designed optimal speed.
- The opposite holds true for hybridisation. A regional delivery vehicle goes through more braking and acceleration events during which energy can be stored and released by its electric system. These events are responsible for a substantial part of energy consumption (or fuel consumption in a non-hybrid vehicle), and having a hybrid-electric engine support system in place can deliver extra power without generating excessive emissions . Furthermore, hybrid systems can recover and store braking energy that would otherwise be lost. The more common use of rigid vehicles also provides the opportunity to benefit from a weight exemption of up to 1 t for vehicles using alternative fuel technologies; this is provided by the EU rules on weights and dimensions. This can counterbalance potential payload losses due to heavy battery technology, such as in on-demand hybrids.
- In regional delivery operations, both LNG and CNG could be options for natural gas vehicles.
- Driver training/education and awareness of ADAS have a bigger impact when more driver interaction is needed, as is the case in the regional delivery cycle. Slower acceleration, faster, more frequent gear changing and better anticipation of on-coming traffic and road conditions can all be more effective when more such events occur in a cycle.
- The use of ITS in the context of regional delivery operations is similar to that in the long-haul cycle, where it is mainly concerned with platooning. Given the more limited share of motorway driving and the shorter operational distances as a whole, it is likely that platooning would be used less often than in the long-haul cycle. However, ITS can help by applying dynamic routing algorithms that incorporate traffic conditions and optimise the delivery route based on them. A further step could be a centrally managed system guiding traffic flows so as to minimise time losses and fuel consumption for all drivers—though this would require a majority of road users to subscribe to the system. Based on a review study by ERTICO on the measures in commercial vehicle ITS for CO_2 emissions[84], we have set the potential for reduction at 2.5% by 2030 and 8% by 2050.
- Aerodynamic improvements can reduce fuel consumption in the regional delivery cycle as well, but given the lower average speed, they are relatively less effective.
- The effects of reducing the rolling resistance of both tyres and road pavements are lower due to the lower speeds and weights in the regional delivery cycle.
- The regional delivery cycle typically has a lower load factor than long haul, which provides a greater opportunity for consolidation and cooperation to improve this.
- A reduction in maximum speeds has a larger effect on regional delivery than on long haul because more accelerations use more fuel. Intelligent Speed Adaptation warns the driver when the speed limit is reached or exceeded using a visual, audible or vibrating alarm. The system can directly control the vehicle's speed and thus prevent the driver form exceeding the speed limit.
- LHVs can also contribute to the regional delivery cycle, as proven by their current use in the Netherlands. However, the socio-economic situation (including population density, location of urban areas and transport hubs) and the density of the transport network could have an impact on the scope of the potential network available to longer, heavier vehicles on regional delivery operations.
- Regional delivery vehicles are not planned to be equipped for use on electrified roads, based on current projections for the development of the network and the business case for compatible vehicles. However, based on what we know today, they are more likely to use battery power and hybrid systems as the limited range of these technologies is compatible with the short distances they cover. Battery-powered regional delivery vehicles with a range of 200–300 km are already on the market.
- Regional delivery vehicles spend more of their driving time in urban or built-up environments. This automatically means that their relative likelihood of involvement in an accident (particularly with vulnerable road users) and the associated accident outcomes remains important. Regional delivery vehicles should, therefore, be the first category of vehicles to implement safety measures that could reduce these types of accident and injury risks. In 2015, representatives of the EU Member States, the European Parliament and the EC agreed on new legislation enabling, but not requiring, manufacturers to make changes to truck cabins that improve visibility. This could reduce the impact of crashes on other vehicles, pedestrians and cyclists. A slow change in technical-

84 ERTICO (2016): "Study of the scope of Intelligent Transport Systems for reducing CO_2 emissions and increasing safety of heavy goods vehicles, buses and coaches."

vehicle structures is expected from 2020–2025.
- Intelligent traffic-signal control can increase infrastructure capacity, reduce congestion and influence driving dynamics. On motorways, ramp metering can be used to smooth traffic flow.
- Delivery space booking as part of an intelligent truck parking system for delivering goods efficiently.

3.3.2 The CO_2 reduction potential for the regional delivery cycle

Based on the information provided in Chapter 3.1, the following table summarises the CO_2 emission reduction potential in the regional delivery cycle using the 2030 and 2050 horizons.

Regional delivery	**Potential 2030**	**Potential 2050**	**Comment**	**Cumulative reduction 2030**	**Cumulative reduction 2050**
Powertrain efficiency	7%	11%	Includes engine, transmission, auxiliaries,…	7.0%	11.0%
Hybridisation/electric operation	4%	15%	Mostly through improved batteries and on-demand hybrids	10.7%	24.4%
Gas vehicles	2%	4%	Methane emissions should be minimised	12.5%	27.4%
Renewable fuels (gas & liquid)	2%	24%	IEA general target, large increase in 2nd generation biofuels needed	14.3%	44.8%
Driver training and ADAS	8%	10%	Includes ACC, PCC, …	21.1%	50.3%
ITS & communications	2%	5%	Dynamic (eco)routing	23.1%	54.3%
Aerodynamics	3%	5%		25.4%	56.6%
Tyres	3%	7%		27.6%	59.6%
Lightweighting[1]	0%	1%	Higher ratio of vehicle/cargo weight than long haul	27.6%	60.0%
Pavement	2%	2%	Improved rolling resistance (maintenance or new pavement)	29.1%	60.8%
Logistical efficiency improvements	4%	12%	More potential for improvement than in long haul due to lower average load factors; includes digitalisation, collaboration to reduce empty runs & improve load factors	31.9%	65.5%
Reduced max speed	6%	6%	To 80 km/h	36.0%	67.6%
LHV	0.5%	1%	Limited penetration	36.3%	67.9%
Electrification of roads	0%	0%	The business case may not be suitable for regional delivery operations	36.3%	67.9%

3.3.3 Findings and recommendations on the potential for CO_2 emissions reduction in the regional delivery cycle

Based on currently available information, the regional delivery road freight cycle has the potential to reach its medium-term CO_2 emissions reduction targets for 2030. If the necessary measures are developed and put in place, and the framework conditions are met, regional delivery could reduce fuel consumption and CO_2 emissions by 36.3% by 2030.

However, on current assumptions, regional delivery vehicles could fall short of their long-term target and only achieve a 67.9% CO_2 emissions reduction by 2050. The main chances of reaching its target probably lie in improving the logistics chain. Load consolidation could also create a stronger business case for the use of High Capacity Vehicles. A higher contribution from electric vehicles, whether battery powered or using electrified roads (if a business case can be developed) would also be a prime option for further reducing CO_2 emissions. As indicated for the long-haul cycle, this is not only a question of making the necessary technology available but also of creating the required regulatory framework for enabling innovation and easier market uptake of the latest, most efficient, green technologies.

Apart from the measures already considered for long haul, hybridisation and electrification (through batteries) are expected to contribute significantly to reductions in regional delivery vehicle emissions. The three main improvements in energy and propulsion technology are quite complementary: improvements to the ICE can be combined with hybrid technology, although there are possibly some losses in the combined efficiency improvements; battery technology is expected to improve significantly as production scales up over the next 15 years and beyond; and the use of renewable fuels does not affect the efficiency of the ICE or hybridisation. Another major advantage is that rigid vehicles powered by alternative fuel technologies and used in regional delivery can benefit from weight exemptions of up to 1 t, which could make transport and logistics service providers less hesitant about investing in such vehicles.

Although substantial improvements have been made over the last few years, the prices of alternative fuel vehicles continue to harm their market uptake, as does the limited number of models.

Furthermore, Member States will have to ensure that they implement their policy plans for alternative commercial light and heavy goods vehicles and that adequate fuelling infrastructure is available by 2030, as prescribed by EU legislation.

3.4 The urban delivery cycle

Decision-makers are making considerable efforts to improve the sustainability of urban transport, as air quality, road safety and operational efficiency directly affect the lives of millions of city dwellers. City authorities across Europe are undertaking numerous initiatives[85], and freight and logistics providers are developing and implementing solutions to meet these requirements.

The CO_2 emissions target for the urban delivery cycle is more straightforward than for the other two operational cycles examined. The 2011 Transport White Paper seeks to "achieve essentially CO_2-free city logistics in major urban centres by 2030." Depending on the definition of "major urban centres", all other urban areas should reap the benefits of this emissions target well before 2050.

Urban delivery vehicles are rigid or smaller vehicles delivering goods from local warehouses to retailers, mainly on inner-city and suburban roads, with frequent stops and starts, some congestion and average speeds well below 50 km/h. Even more so than for the regional delivery cycle, vehicle configuration is mission dependent: a maximum gross vehicle weight of 7.5 t is assumed, with a significant number under 3.5 t. Total annual mileage for these vehicles averages 40,000 km. Urban delivery represented 3.7% of heavy-duty transport CO_2 emissions in 2010 according to the AEA (2011), but the share of urban transport activity is expected to increase with further growth in e-commerce.

Greater rigid vehicle use also provides the opportunity to benefit from weight exemptions of up to 1 t for vehicles using alternative fuel technologies, as set in the EU rules on weights and dimensions. This can offset the potential payload losses due to heavy technologies such as those used by on-demand hybrids. On the other hand, weight increases caused by alternative fuel technology could easily push a vehicle into a higher weight category (e.g. moving a vehicle from below 3.5 t to above 3.5 t), with implications for the type of drivers licence needed and the profitability of this option. In an urban delivery cycle, using professional drivers holding a C-licence is less profitable than using drivers with a B-licence[86].

There are, nevertheless, also numerous challenges to consider. Consumers' changing purchasing habits and the growing use of e-commerce are fundamentally changing the

85 More detailed information on the type of measures put in place by municipal authorities can be found on www.urbanaccessrestrictions.eu
86 Source: NEA, TLN and ING (2012): "Alternatieve brandstoffen: Gat in de markt of verre toekomstmuziek?" - indicates costs of between EUR 2,600–6,500 higher, depending on the alternative fuel and the purpose of the vehicle.

ways in which urban freight logistics are organised. Same-day delivery is commonplace, and shippers and logistics providers are constantly trying to find solutions to accommodate customers' demands. Solutions are often found in practices outside the normal legal framework within which road freight transport and logistics providers traditionally operate, increasing the competitive pressure on them. Also, increasing restrictions on larger vehicles have led to the use of smaller ones; combined with more frequent delivery rounds, this has led to more movements per day in urban areas and more congestion.

3.4.1. The CO_2 emissions reduction potential for the urban delivery cycle

Full electrification could achieve the White Paper target, which will primarily occur through fleet renewal. To achieve this, given vehicle lifecycles, sales of new urban delivery vehicles need to be 100% electric by 2025 at the latest in major urban centres (and possibly in all urban areas). The only possible alternative would be the 100% use of biofuels with zero WTW emissions, but these are not expected to be available in sufficient quantities or at a reasonable cost by 2030. The vehicle type used in urban delivery is small enough for the battery technology of the near future to provide sufficient capacity. This could be combined with (inductive) charging technology at loading and unloading locations to allow smaller battery capacity and volume while leaving more space and weight for cargo. There are already solutions on the market for converting diesel vehicles into fully electric ones, and transport operators are using them. This process could kick-start the necessary changes and perhaps speed the urban delivery cycle towards its goal.

Several countries are promoting the sale and use of light- and medium-duty electric vehicles. Norway and the Netherlands have taken legislative initiatives that could lead to the phasing out of the sale and use of all petrol and diesel cars after 2025. Germany has launched a major support scheme for the deployment of electric cars up to 2020. Electric passenger vehicles and associated infrastructure can only help the development of electric freight deliveries in urban areas. Implementing delivery-space booking and intelligent speed adaptations will also be major contributors to the reduction of CO_2 emissions in the urban delivery cycle.

Some cities, like Paris, are seriously considering an outright ban on diesel vehicles by 2020, which would also have a strong impact on the type of commercial vehicles used in those conurbations.

3.4.2 Findings and recommendations on the potential for CO_2 emissions reduction in the urban delivery cycle

Although totally decarbonised urban freight transport is still far from reality, the process towards it is ongoing and should be complete well before 2050—a 100% reduction of TTW CO_2 emissions is possible (provided electricity generation is also completely carbon-emission free). The target for 2030—for this to be true in "major urban centres"—is a stepping stone to all urban areas. This will also help to reduce other transport externalities, such as local pollutants (mono-nitrogen oxides, NOx, and particulate matter, PM, although it has been shown that electric vehicles do not perform much better than recent ICE vehicles for the latter pollutant) and noise. However, the main challenge to optimising urban deliveries probably lies in the struggle for space, as urban congestion and the lack of parking/loading/unloading locations cannot be solved through electrification alone and could continue to disturb logistics processes. Rules on access for urban freight delivery vehicles will surely continue to play an important role.

As indicated for the long-haul and regional delivery cycles, the urban delivery cycle's ability to meet its CO_2 emission reduction targets is about more than just making the necessary technology available. A regulatory framework will have to be established to facilitate innovation and market uptake of the latest, most efficient, green technologies. It will also have to ensure that freight vehicles have continued adequate access to urban areas and guarantee fair competition between freight transport and logistics providers. However, an additional challenge could be the fact that the political authority to make the appropriate decisions lies with municipalities. Cities often have highly divergent priorities, including in terms of technological development and innovation. Dialogue between authorities and the exchange of best practices should be encouraged. This could create more homogeneity in their approaches and reduce the implementation costs of potential solutions through economies of scale. This approach could also have a positive impact on operational efficiency as transport operators' costs could be significantly reduced if investments were made in solutions acceptable to many urban areas.

However, if the weight of alternative fuel technologies pushes urban delivery vehicles from under 3.5 t to over it, they would have to be driven by drivers with a C-licence—a more expensive solution and one that may need solving.

The prices of alternative fuel vehicles continue to restrict their market uptake, as does the limited range of models available, despite substantial improvements over the last few years.

Furthermore, Member States will have to ensure that they implement their policies on alternative commercial light and heavy goods vehicles and that adequate fuelling infrastructure is available by 2030, as prescribed by EU legislation.

3.5 Conclusions for CO_2 reduction potential

Based on the information currently available, meeting the targets for CO_2 emissions reduction in the road freight transport and logistics sector will be challenging for both the 2030 and 2050 horizons. A wide range of measures can contribute to meeting them, but it is highly unlikely that the 2050 targets will be met without fundamental changes in the ways goods are transported and in the vehicles and energy sources used to do so. This is very clear for the long-haul and regional delivery cycles. These measures are in the hands of different industrial, political and legislative stakeholders, and will require a vision for road transport which goes beyond one legislature—a vision that could require decisions with far-reaching, long-term financial implications. Dialogue and cooperation will be essential to enable continuing innovation and to facilitate its market uptake. The cost/benefit factor and incentives will play key roles in this process. However, decisions to initiate long-term fundamental changes should be taken soon—preferably by 2020.

In heavy duty applications, ICE technology is likely to remain important. More improvements are expected in the efficiency of the powertrain, and more advanced hybridisation should also reduce CO_2 emissions. This should be achieved through market forces, where technology development and investment costs on the one hand, and amortisation and depreciation on the other, are the determining factors. Good results could also be achieved through incentives encouraging reductions in fuel consumption. These could be led by road freight transport and logistics operators, such as measures to encourage reductions in fuel consumption, accompanied by voluntary carbon footprinting. They could also be encouraged to develop solutions to unblock the financial bottlenecks caused by investments in more expensive alternative fuel vehicles through a better diversification of risk. Incentives could encourage vehicle renting or leasing solutions, which could encourage more frequent vehicle renewal and accelerate the uptake of cleaner and safer vehicles. Regulatory incentives could also be given; there is an on-going debate about the most efficient approach. A suitable combination of all the options should be put together to balance opposing results and create acceptable solutions for society, the environment and the economy. Eventually, as market uptake of alternative fuel vehicles increases and more fuelling infrastructure becomes available, market forces should bring the price of such vehicles to more acceptable levels.

One of the most important challenges to the transport decarbonisation process will be to expand the availability of advanced biofuels that provide WTW CO_2 emissions reductions of 90% and have higher blend walls than current biofuels. This may have to occur in parallel with a further harmonisation of the national rules on fuel quality as well as those relating to the fuel taxes applied to such blends. If this can be combined with electrified roads (primarily for long-haul transport) or (network charged) batteries, the carbon intensity of the propulsion system will drop significantly. Several conditions will have to be met before that becomes a reality. Based on currently available information, gas in fossil and biogas forms could play a more important role than is projected today, provided some key challenges are addressed. For long haul, the considerable potential of gas should not be abandoned. The IEA roadmap claims that advanced biofuels will eventually be produced at more or less the same cost as conventional fuels, but it will be essential to overcome the current political reluctance in the EU to further develop biofuel solutions. For electrification, long-term projections already see very high shares of electricity with low CO_2 emissions. However, the development of technological solutions for some of the long-haul cycle are still at a very early stage and will require adequate financing mechanisms to implement them. A more in-depth review of this process is outside the scope of this report.

In urban transport, full electrification is the most likely way to meet the 2030 and 2050 reduction targets. However, the huge likely costs of long-distance, heavy-duty electrification solutions would require the creation of financing frameworks, and the capacity and environmental performance of the electricity grid would be the key challenges for political decision-makers at EU and Member State levels. These should be addressed sooner rather than later if all the appropriate building blocks are to be put in place to achieve reduction targets.

Additional measures mainly aim to reduce energy consumption per unit of transport. Improved aerodynamic properties, either by modifying vehicle shapes or truck platooning, are currently limited by EU legislation. Recent actions, however, including the 2016 EU Truck Platooning Challenge, will facilitate new advances, mainly in the long-haul cycle. The prospect of fully autonomous road freight transport vehicles driving on European roads should no longer be excluded, and nor should claims that these innovations could be the answer to numerous challenges facing the road freight transport and logistics industry, including accidents, increasing costs, traffic density and driver shortages. These innovations will nevertheless pose some challenges to the current legal framework governing road transport, including the 1968 Vienna Convention, product and insurance liability and data protection. The road freight and logistics industry is very interested in these developments but needs to be more closely involved in trials and implementation. As the scope for automation increases, there will be more clarity on the opportunities which that automation can provide. Upcoming legislation on tyres could boost their potential contribution to CO_2 emissions reduction beyond improvements in their material composition.

A final set of measures aims to increase the load carried per trip. This can, in fact, be done within the dimensions of current reference vehicles through better coordination and cooperation in the logistics chain. Vehicle construction and load organisation (such as double stacking), within the current limits relating to weights and dimensions, could be improved, as is being demonstrated for the semi-trailer in the TRANSFORMERS Project. These improvements have limits, of course. The second possibility is to adapt the maximum allowed dimensions and weights for those operations that could benefit. The third possibility is to speed up the digitalisation of road freight transport and logistics, which should simplify processes and facilitate data exchange. The fourth possibility is to take full advantage of the opportunities provided by the collaborative economy, including the sharing of networks, infrastructure and vehicle space.

Combining these diverse ranges of measures should result in fuel efficiency improvements of 78% for long haul, 68% for regional delivery and 80%–90% for urban delivery (or 100% if electricity generation emissions are excluded).

Most of the obstructions in the path to these objectives are of a technical nature, with advances needed in engine efficiency, (hybrid) electric propulsion, intelligent transport systems and sustainable large-scale biofuel production. Legislative coordination and optimisation, together with some important political decisions, will also be needed to allow technological breakthroughs to reach their full potential or to get going. The challenge that the road transport sector must solve itself is how to set up a secure cooperative platform with a sustainable business model.

3.6 Conclusions for safety potential

The current safety improvement rate is progressing too slowly to reach the proposed 2050 target of zero fatalities from (HGV) road accidents. Logically, therefore, the 2020 and 2030 intermediate (interpolated) targets will not be achieved either.

There are three major domains where tangible road safety improvements can be achieved: vehicle technology and maintenance, infrastructure, and human behaviour, including enforcement. There is a wide range of vehicle technology safety options, a significant number of which are on the brink of production and implementation in all newly manufactured vehicle fleets. However, the most important advances in safety are currently not precisely known, as great potential is thought to lie in changing the shape of HGVs. Indeed, there is an on-going debate about how new vehicle designs could improve road safety. Current type-approval and general safety rules at the EU and UN levels, as well as EU rules on weights and dimensions, may have to be revised in order to create more flexibility in designs intended to make vehicles safer. As human error continues to be the main cause of road accidents involving HGVs, measures aimed at reducing human error will continue to play a major role.

A wide variety of ADAS solutions are becoming standard in commercial vehicles and could further improve road safety and reduce the hazardous blind spots which pose risks to HGVs, especially in built-up and urban areas.

It should be stressed, however, that the correct use of vehicle-based safety technologies is just as important as their installation. This implies that driver training needs to be of a sufficiently high quality to make appropriate use of such ADAS.

The development of ever greater vehicle automation could also provide new opportunities to improve safety as technology takes over more human actions. However, it is too early to determine the scope of these opportunities.

It is currently very difficult to quantify the risk reduction impact of these technical and technological solutions.

As 75% of all accidents involving HGVs are caused by other road users, knowledge transfer via awareness raising campaigns could promote a better mutual understanding and would surely have the potential to reduce fatalities.

3.7 Conclusions for operational efficiency

The focus on “Doing more with less” could become the slogan for the commercial vehicle of the future. The previous two sections concentrated more on the “less” side (less CO_2, fewer accidents, fewer injuries and deaths), but when discussing operational efficiency, “doing more” is just as important. Moving more freight to more customers with fewer vehicles, while offering a better service at a more competitive price (for both operator and client)—this is the road transport sector’s target as a service industry. Several of the measures discussed in this report can contribute to this.

Additional performance-related rules, taxes, charges and duties will not encourage a shift in mentalities unless economically viable alternatives are available for road freight transport and logistics operators to revert to.

Road freight transport and logistics operators should receive some of the benefits from their efforts to reduce CO_2 emissions and improve road safety. First and foremost, the voluntary uptake of industry-led measures aimed at reducing fuel consumption could be encouraged via transport information and advice on vehicle performance and cost/benefit analyses of the various measures possible. This could be accompanied by voluntary carbon footprinting of freight transport and logistics services.

This should also contribute positively towards meeting the objectives of logistical improvements in terms of both increasing operational efficiency and reducing CO_2 emissions. Increasing fill rates while reducing empty runs should be something that is strived for at the company level, but it could be more even effective if cooperative platforms were set up.

Operational efficiency can also be improved at the vehicle level. New opportunities to innovate could be created by fairer compensation for the payload and space losses resulting from the installation of additional road safety and environmental technologies. A move could also be made towards customising vehicles to every specific mission.

The use of modular units, both for the towing vehicle and the load carrier, will ensure that vehicles are neither over- nor undersized. Current vehicle ownership structures may not be flexible enough to support this approach, and changes should be expected. These changes could also encourage fleet renewal or other significant investments; many vehicle owners may not have the skills or knowledge to select an optimal investment timeframe when making purchase decisions (the amortisation periods chosen are often too short). Using modular units effectively also implies that longer, heavier combinations, which require the deployment of fewer towing vehicles and drivers, do have their place in the market. In order to determine which vehicle types could be allowed on Europe's roads (and where and how), it will be essential to consider parameters related to the continent's basic infrastructure—vehicle width, number of axles, axle weight and turning circle.

Adequate road infrastructure and traffic fluidity are very important for operational efficiency. Measures allowing road freight transport better access to that infrastructure at off-peak times should be examined. Simply charging road freight vehicles for participating in congestion during peak periods without providing an adequate alternative is clearly not a solution.

Opportunities provided by new, innovative trends and developments in road freight transport and logistics should be embraced. Further digitalisation of the sector, including the wide-scale introduction of electronic transport documents, will considerably reduce administrative burdens and facilitate logistics chain efficiency. This includes load optimisation, as information and data can be more easily and accurately communicated between the different parties involved. Access to electronic data on a vehicle and its load allows more rapid and targeted interventions in case of incidents, thus improving road safety. It could also improve the efficient enforcement of road safety legislation, which could become more intelligence-led, thus reducing the time lost in road-side inspections. Collaborative systems are rapidly finding their way into the domain of road freight transport and logistics, such that stakeholders can share digital networks, warehousing and loading and unloading facilities, in addition to vehicle space. Sharing vehicle space can contribute to maximising the load factors in laden vehicles and minimising avoidable empty runs. Further benefits could accrue if these developments also found their way into multimodal freight transport and logistics systems and grew into large scale use.

When vehicle automation aimed at road safety can also contribute to expanding delivery windows and easing the restrictions of driving/resting time regulations, operational efficiency also stands to benefit greatly. The increased flexibility in the planning of logistics processes will allow better levels of service for warehouse customers and help planners to avoid periods of heavy congestion.

Notwithstanding the potential improvements in operational efficiency created by CO_2 emissions reduction and road safety improvement measures, its scope will largely be determined by the political and legislative framework. The commercial vehicle and road transport industry of the future will require a modernised framework—one that enables the innovative initiatives needed for more efficiency. Political decision-makers and legislators at the national and EU levels will have to allow each individual transport mode to improve in terms of environmental performance and operational efficiency and move away from trying to artificially force freight to be shifted from road to other modes.

4. Overall conclusion, vision and roadmap towards the commercial vehicle of the future

The purpose of this concluding chapter is to give a general outline of the Commercial Vehicle of the Future in the European Union and how it is expected to operate in the described scenario for 2050. It assumes that road freight in 2050 will still be carried by vans and light and heavy goods vehicles. The chapter sets out a timeline of the actions that will be required to fulfil this report's vision of the commercial vehicle of the future, as described in the previous chapters. After discussing the immediate situation (2016–2020), it will list the most import milestones for each 10–year interval (2020–2030, 2030–2040 and 2040–2050). The analysis focuses on the technical feasibility of the different commercial vehicle GHG reduction measures, road safety options and operational efficiency improvements, without considering their costs in detail.

Today, road transport plays a key role in the EU freight transport network and logistics chain, both as an activity in itself and as a complement to other freight modes or activities such as warehousing. It is expected to continue to play a key role in the medium and long term.

From a general perspective, the road freight transport and logistics sector faces ambitious targets in terms of reducing its environmental impact, improving safety and increasing operational efficiency. The latter should be seen in two dimensions. The first dimension is an increase in the operational efficiency of road freight transport itself. The second and more significant dimension is an increase in the efficiency of the road freight transport sector as a key component of a wider EU freight transport network and logistics chain, also acting as a connection between the EU, its neighbouring countries and the rest of the world.

With society experiencing ever faster developments in the field of connectivity at different levels, road freight transport and logistics cannot lag behind. The future of road freight transport lies in full connectivity involving the company, people, infrastructure, the vehicle, loading units, logistical partners, authorities and governments.

Several innovative developments will have a very strong impact on how road freight transport and logistics operations will be organised in the future and could contribute to a reduction in the sector's environmental footprint. Firstly, the wider use of Intelligent Transport Systems (ITS) by road freight transport and logistics operators and the competent authorities is laying the groundwork for possible future innovation. The political and legislative facilitation of new, compatible, EU-wide solutions and the interoperability between existing systems should be promoted—they will generate even greater progress. The implementation of large-scale truck platooning across the EU is a good example of this. Truck platooning will lead the way towards increasing vehicle automation and then to the use of fully autonomous road freight vehicles. This will require a fundamentally different approach to the traditional rules on the use of the road, especially in relation to the role of the professional driver. Fully autonomous commercial vehicles would surely open new avenues in vehicle and loading unit design and substantially overhaul the way freight is moved by road and multimodal transport. Further deployment of ITS will also speed progress in terms of digitalising road freight transport and logistics processes and indeed those of the whole multimodal transport chain. The political and legislative groundwork that will allow further EU-wide progress needs to carried out in advance. Wide-scale use of ITS and digitalisation will also create new opportunities for road freight transport and logistics operators to collaborate. The collaborative economy offers new forms of sharing resources and cooperation which could contribute to more efficient load factors.

Looking at commercial vehicles themselves, meeting the targets set for them regarding CO_2 emissions reduction will be a challenge, especially a reduction of 60% by 2050. Difficult and potentially expensive decisions will have to be made by the different industry stakeholders, including road freight transport and logistics operators and society as a whole. Meeting the reduction targets for long-haul and regional delivery may not be possible without fundamental changes in powertrain and fuel technology, where there will have to be a fundamental leap forward in the use of renewable transport fuels. The currently available propulsion systems and energy sources provide a number of CO_2 emissions reduction options, including increasing the efficiency of the ICE, the use or the blending of biofuels with diesel, and the use of gas, hybridisation or electrification. From a TTW perspective, biofuels and gas have significant CO_2 reduction potential. From a WTW perspective, the indirect land-use change, the primary source of biofuels and methane emissions for gas are some of the issues which will have to be addressed. Biomethane or synthetic methane, produced from renewable sources, are alternatives that should be promoted as one of the ways forward. Biofuels and gas need to be developed further and should certainly not be discarded. When looking at the potential for extensive road electrification, vehicle technology, infrastructure, grid capacity and the WTW emissions performance of the electricity produced and distributed are some of the aspects to be addressed. Investment costs would also be substantial. For vehicle manufacturers, this would be in terms of vehicle technology research and development; for road freight transport and logistics operators, this could be in higher vehicle investment costs. Fuel producers and society would have to upgrade the infrastructure for producing and distributing energy. Governments would have to create the necessary financing mechanisms to facilitate change and innovation in terms of the types of energy used for freight transport and logistics. Further research should be undertaken in the field of technology and infrastructure solutions, and there should be a roadmap of how this development could be financed in a balanced manner acceptable to all the different stakeholders involved. There is a persistent concern among road freight transport and logistics operators that they will have to absorb a disproportionately high percentage of this total bill, which would undoubtedly jeopardise the acceptability of this key move. The important message is that further research into economically viable alternative energy sources for the long-distance, heavy-duty cycle must continue and be encouraged.

The measures proposed for emissions reduction could also open new opportunities for improving road safety, as human error is gradually reduced by technology. However, it is difficult to quantify the impact of the emissions reduction measures on road safety improvement.

There is also a great deal of potential for the different CO_2 emission reduction measures to improve operational efficiency, although there is much uncertainty about the scope of this. This is an important domain for further research. Emission reduction measures will very much continue to depend on decisions made at the company level. Technology, model and vehicle depreciation, developments in alternative fuels (especially renewable ones) for commercial vehicles, the scope for the development of existing technologies, innovative technologies finding their way to the market, digitalisation, transport policy and implementing legislation, general geopolitical and economic events and new working practices in road freight transport and logistics could all influence the speed at which the sector adopts innovation and its potential to improve operational efficiency. Much will also depend on ownership structures, which are still evolving. Greater transparency about the impact which new technologies could have on their business would put road freight transport and logistics operators in a position to make well-informed investment decisions for their companies. Road freight transport and logistics operators should be further encouraged to commit to reducing fuel consumption and improving their operational efficiency, as this, in turn, will contribute to reducing CO_2 emissions. Individual companies will require tailor-made solutions based on their structure and type of activities. Small and medium-sized companies may have to be offered guidance. A harmonised methodology for collecting, reporting, monitoring and certifying the emission reductions resulting from these efforts should be established. The acceptability of CO_2 emissions reduction measures will depend largely on their potential to contribute to improvements in operational efficiency and cost reductions, as well as on the road freight transport and logistics operators' ability to absorb any additional costs occurred. Transport operators will, therefore, require some assurance that the costs they incur when reducing CO_2 emissions will somehow be offset.

Within the context of the general, vehicle, safety and operational efficiency considerations that we have mentioned, the Commercial Vehicle of the Future can be envisioned as a "carrier" of road freight. This could be a vehicle and/or a loading unit. This carrier will have to be highly modular, with a very high degree of interoperability between modules and more flexibility in weights and dimensions (especially in terms of length and weight); it will have to make more use of swap bodies and loading modules, and the potential for double stacking or using a movable roof. Most of these carriers will have to run on renewable energy sources which are currently difficult to predict with sufficient accuracy. The carrier should be fully connected to other carriers, human beings and infrastructure, as well as being fully autonomous. The carrier's shape may be completely different from the vehicles we know today. Intelligent transport systems will have to be very extensively used to facilitate the carrier's development. Such a "carrier" is likely to perform best in the 2050 scenario: that is, meeting the ambitious target of reducing CO_2 emissions by 60% or more by that year.

A roadmap has been developed based on the discussions within the IRU Commercial Vehicle of the Future Reflection Group, on work carried out by other experts and on the information currently available on reduction emissions options. This roadmap comprises a number of important steps and measures which would have to be implemented in order to ensure the wide-scale use of such "carriers" in the EU's road freight transport and logistics sector. However, regardless of other steps, this report suggests that the CO_2 emissions reduction target of 60% by 2050 will be impossible to meet without fundamental improvements in powertrain and fuel technologies. If pre-set targets are to be met, renewable energy sources will have to be in the ascendancy by around 2035 and gradually increase their market share towards 2050. This timeline cannot be fixed, however, and over time it will have to be fine-tuned and adjusted, either as new information becomes available or as new developments take place. Based on information available today, 2035 should, therefore, be considered a highly significant deadline for action in the current roadmap. If not, the possibility of meeting the 2050 targets could be jeopardised..

4.1 The immediate situation: 2016–2020

- Vehicle manufacturers are expected to keep improving vehicle engine efficiency within the current EU legal framework, but fleet renewal takes time. The EC and Member States should seriously consider close dialogue with industry stakeholders before taking policy action on vehicle emission standards. Measures to give road freight transport and logistics operators an incentive to speed up their fleet renewal rate should be considered.

- Further vehicle hybridisation is expected in urban and regional delivery.

- Gas-powered vehicles are expected to command a larger share of vehicle sales if the Member States rapidly implement the Directive on Alternative Fuel Infrastructure. Further efficiency improvements to the gas powertrain are to be expected. Solutions are needed to minimise methane emissions. Blending natural gas with biomethane and synthetic gas should be encouraged.

- The provisions of the Fuel Quality Directive and Renewable Energy Directive remain valid until 2020. However, a cap on the volume of food-based biofuels should create an interest to increase the production capacity of second generation biofuels in the future. To enable this, legislators should start preparing new EU rules to support the use of these fuels today, as they are expected to remain more expensive than their fossil counterparts. New legislation should account for the near future and set the stage for the long term.

- The EU weights and dimensions Directive 96/53/EC, revised in 2015, should be fully implemented during this period. Vehicle design is expected to remain largely similar in the 2016–2020 period, with the possible exception of the fitting of boat tails to new semi-trailers to improve their aerodynamic performance. The cost for retrofitting existing trailers could be prohibitive (especially those approaching their end of life) with regard to depreciation. Legislators should consider introducing incentives to accelerate the market uptake of new technologies improving the aerodynamic performance of commercial vehicle. Preparation for a new revision of the EU weights and dimensions legislation and related EU and UN type-approval and general safety rules should start in 2020.

- Further research and trials of potential economically viable solutions for the electrification of long-distance HGVs are expected. Potential economically viable finance and investment mechanisms will have to be thought out. Important points will be the carbon-free production of electricity, grid capacity and solutions usable for a wide range of vehicles.

- Further research will be needed into the opportunities and challenges of the developments and trends in the collaborative economy, as well as their impact on the EU road freight transport and logistics market and its legislative framework. Collaborative logistics platforms will have to be tested and data management systems secured.

- A fully operational emissions certification tool will be required for all types of new HGVs being type-approved in the EU by 2020. The subsequent preparation of CO_2 and fuel consumption performance standards for new HGVs should be based on work performed in complete vehicle combinations. A transparent information system on the fuel consumption and CO_2 emissions reduction potential of different vehicles and technologies should be available on the market in order to facilitate informed investment choices based both on optimal efficiency and the environment.

- Further progress is expected in the compatibility and interoperability of national ITS domains and applications.

- An EU legal framework should be prepared to enable cross-border trials of truck platooning and its use on a wider scale.

- Road freight transport and logistics operators are expected to make more active use of fuel consumption reduction measures, such as voluntary speed reductions and generalised use of eco-driver training. This would be accompanied by voluntary carbon footprinting as a means of monitoring the results of such measures and making CO_2 reduction achievements more transparent.

- Driver training to improve road safety and fuel efficiency will be needed, as will incentives for the market uptake of vehicles equipped with ADAS.

- Low rolling resistance tyres must be chosen consistently when replacement is needed.

4.2 Decisions and preparations: 2020–2030

- Continued steady improvement of the diesel powertrain is expected, as is accelerated market uptake of new vehicles which have been type-approved according to the VECTO methodology.

- Working towards decarbonising the (electric) power generation system will continue.

- Measures should be taken to prepare the electricity grid for increased usage by road transport vehicles, including commercial freight vehicles.

- Hybrid vehicles are expected to contribute more to long-haul transport (including the use of on-demand hybrid systems to provide auxiliary power); regional delivery and especially urban delivery should move to a very high share of electric battery-powered operations.

- Advanced testing of electrified long-distance transport, including via the electricity grid, should be occurring. The nature of this measure does not allow for coexisting incompatible systems. Thus unanimous action will be needed from the Member States/road infrastructure authorities in order to decide on unified standards, potentially considering a technology that can be used by different types of vehicles. An EU-level financing mechanism will have to be developed, and electric long-distance transport will have to be implemented by the end of the decade to allow for sufficient infrastructure development in the long term.

- An incentive scheme for road freight transport operators should be created to encourage investments in alternative fuel vehicles.

- Continued steady improvement of the gas powertrain is expected, as is the development of biogas capacity for use in commercial road freight transport.

- Alternative-fuel infrastructure will have to be fully ready for use, as determined by the applicable Directive. The EU Alternative Transport Fuel and Infrastructure legislation will have to be revised to enlarge the scope for alternative, renewable fuels for use in heavy commercial vehicles, including the use of electricity produced from renewable energy sources.

- Technological development of advanced biofuels is expected to speed up, aided by a long-term legislative framework which could include incentives, quotas or

CO_2-based fuel taxes. Long-term production plans should account for increases in electric power requirements.

- Advanced driver assistance systems should be standard in new HDVs. It is expected that the focus of driver training shifts from taking action to properly reading and reacting to ADAS. ITS should ensure optimal routing.

- Implementation of the EU regulatory framework should allow regular truck platooning on all major European roads by 2025 as a first step towards the use of fully autonomous vehicles. Further developments of EU and UN regulatory frameworks should enable progress in vehicle automation.

- A revision of the EU weights and dimensions legislation and related EU and UN type-approvals and general safety rules should start in 2020. This will allow further flexibility in weights and dimensions on the grounds of environmental performance and road safety. Furthermore, this should create possibilities for increased carrying capacity provided that infrastructure related performance standards are met, including turning-circle, vehicle width and axle (weight, number and type) requirements.

- Aerodynamic cabs should become the norm. Further steps in weights and dimensions regulation should improve vehicle design and the aerodynamics of complete vehicle combinations.

- A complete removal of restrictions on the cross-border use of LHV combinations is expected if infrastructure can accommodate them. There may be increases in the maximum authorised weights of all cross-border road freight transport vehicles above 3.5 t provided they comply with a set of environmental performance, operational performance and road safety-related rules.

- A move towards the integration of toxic and non-toxic emissions norms is expected, as is the gradual introduction of global rather than regional norms.

- Taxation based on vehicle ownership or the type of energy used is expected to gradually move to taxation based on the environmental performance and the type of vehicle use. This principle should apply to all road vehicles, not only commercial road freight transport vehicles. The environmental performance of a road freight transport vehicle should be calculated based on the entire vehicle or vehicle combination, not just its engine/gearbox.

- An evaluation of the achievements of emission certification tools should be carried out, as should an analysis of the performance of CO_2 reduction and fuel consumption standards in heavy commercial vehicles.

- The testing of collaborative logistics platforms should be expanded, with harmonisation coming towards the end of the decade. Integration should be fully multi-modal.

- Fully interoperable, compatible, cross-border ITS applications should be helping infrastructure managers, road transport users and enforcement authorities.

- Road pavement renewal should focus on reducing rolling resistance while improving grip.

4.3 Time for major action: 2030–2040

- Alternative fuel infrastructure for road transport should be widely available throughout the European Union.

- The conditions should have been met to allow alternative propulsion and energy sources to reach a significant share of the road transport energy market.

- An advanced biofuel production breakthrough will be needed to power long-haul operations off the grid and regional deliveries when battery operation is impossible. Gas vehicles should be switching mostly to biomethane.

- Diesel engines are expected to be fully ready for high proportions of biofuel.

- Single wide, latest generation, low rolling resistances tyres are expected to be standard.

- Logistics harmonisation should be moving ahead at full steam, resulting in increasing load factors, even in longer, heavier vehicles (which are also used in regional delivery cycles).

- Weights and dimensions regulation should be based on standards of operational performance. Modularity should move towards the “physical internet”.

- Legislative processes authorising fully autonomous vehicles should be complete (including provisions for driving/resting times).

4.4 Rolling towards the goal: 2040–2050

- Autonomous vehicles are expected to be in common use, 24 h per day, 7 days per week. The driver's role will have changed to that of a cargo manager. Fundamental vehicle redesigns are to be expected, taking into account the changed role of the human being.

- Investment will continue in renewable energy sources for all types of road freight transport operations. At least 30% of the average blend should be advanced biofuels; 40%–45% of long-haul road transport should be powered through road network charging infrastructure.

- Preparations are expected to be underway for a complete phasing-out of fossil fuels as an energy source.

List of Abbreviations

ABS – Anti-lock Braking System

ACC – Adaptive Cruise Control

ACEA – European Automobile Manufacturers' Association

ADAS – Advanced Driver Assistance Systems

ADEME – French environmental agency

ADR – carriage of dangerous goods training

AEBS – Advanced Emergency Brake Systems

AECOM – Worldwide Engineering, Design, Construction and Management consultant

AECS – Accident emergency call system (or eCall)

AVERE – European Association for Battery, Hybrid and Fuel Cell Electric Vehicle

BE – Belgium

CfSRF – The Centre for Sustainable Road Freight

CLCCR – International Association of the Body and Trailer Building Industry

CLECAT – European Association for Forwarding, Transport, Logistics and Customs Services

CNG – Compressed Natural Gas

CONCAWE – Conservation of Clean Air & Water in Europe

COP21 – Paris Climate Change Agreement

CPC – Certificate of Professional Competence

CSW – Curve Speed Warning

CVOF – Commercial Vehicle of the Future

DG CLIMA – European Commission, Directorate-General for Climate Action

DG GROWTH – European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and Small & Medium-Sized Enterprises

DG MOVE – European Commission, Directorate-General for Mobility and Transport

EBS – Electronic Braking Systems

EC – European Commission

EEA – European Economic Area

EEA – European Environmental Agency

ERTICO – European Road Transport Telematics Implementation Co-ordination Organisation

ESC – European Shippers' Council

ESP – Electronic Stability Programmes

ETAC – European Truck Accident Causation (study)

ETRMA – European Tyre and Rubber Manufacturers' Association

ETS – Emissions Trading System

ETSC – European Transport and Safety Council

EU – European Union

EURELECTRIC – Electricity for Europe

FAME – Fatty-acid methyl esters

FQD – Fuel Quality Directive

FTA – Freight Transport Association (UK)

GDP – Gross Domestic Product

Gg – Greenhouse gas

GHG – Greenhouse Gas

GHG -TransPoRD – Reducing GHG emissions of transport beyond 2020: linking R&D, transport policies and reduction targets

GPS – Global Positioning System

HDV – Heavy Duty Vehicle

HGV – Heavy Goods Vehicle

HPDI – High-Pressure Direct Injection

HVO – Hydrotreated vegetable oils

ICE – Internal Combustion engine

ICTT – International Council on Clean Transport

IEA – International Energy Agency

IFEU – Institut für Energie und Umweltforschung Heidelberg

ILUC – Indirect Land-Use Change

IRI – International Roughness Index

ISA – Intelligent Speed Adaptation

ITS – Intelligent Transport Systems

JRC – European Commission's Joint Research Centre

LDWS – Lane Departure Warning Systems

LHV – Longer Heavier Vehicles

LNG – Liquefied Natural Gas

LRRT – Low Rolling Resistance Tyres

MEDDE – French Ministry of the Environment

MIRIAM project – Models for rolling resistance In Road Infrastructure Asset Management Systems

MPD – Mean Profile Depth

Mt – Million Tonnes

Mtoe – Million Tonnes of Oil Equivalent

MWh – Megawatt Hour

NGVA – Natural Gas Vehicle Association

NOx – Nitrogen Oxides

PBL – Netherlands Environmental Assessment Agency

PCC – Predictive Cruise Control

PM – Particulate Matter

RED – Renewable Energy Directive

RRC – Rolling Resistance Coefficient

RSR – Road Sign Recognition

RTS – Road Traffic Safety

SMEs – Small and Medium-sized Enterprises

T – Tonne

T&E – Transport & Environment

TEN -T – Trans-European Transport Network

TFK – Transport Forskning Komission

TKM – Tonne-kilometre

TML – Transport and Mobility Leuven

TPMS –Tyre Pressure Monitoring System

TTW – Tank-To-Wheel

UK – United Kingdom

V2I – Vehicle to Infrastructure communication systems

V2V – Vehicle to Vehicle communication systems

VECTO – European Commission’s Vehicle Energy Consumption Calculation Tool

Vkm – Vehicle-km

WTW – Well-To-Wheel

IRU

La Voie-Creuse 16, CP 44
CH-1211 Geneva 20, Switzerland
+41-22-918 27 00 (tel)
+41-22-918 27 41 (fax)
iru@iru.org

Learn more here about IRU
and its activities

iru.org