



# SHELL COMMERCIAL VEHICLE STUDY

## Shell Deutschland

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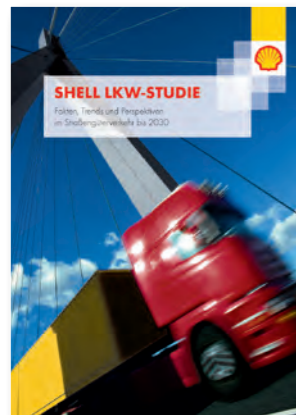
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The 2016 Shell Commercial Vehicle Study for Germany is a follow-up to the first Shell Goods Vehicle Study in 2010 (Shell 2010). The scope has been extended to all commercial vehicles in Germany and the study now covers buses and coaches in addition to goods vehicles. It thus provides a counterpart to the Shell Passenger Car Scenarios, which have been published since 1958 and are now in their 26<sup>th</sup> edition (Shell 2014). The 2016 Shell Commercial Vehicle Study has once again been prepared in cooperation with the Institute of Transport Research at the German Aerospace Center (DLR).

The objective of the 2016 Shell Commercial Vehicle Study is to explore the future of German road freight and bus & coach travel up to the year 2040. Current trends in transport logistics for goods and passengers as well as in commercial vehicle statistics have been examined. Assessments of the future potential of relevant drive-train, fuel and vehicle technologies have been made. In addition, freight transport modelling and scenario techniques have also been used, taking into account the important traffic, energy, environmental and political factors, to create a comprehensive view of expected developments in Germany.

On the following pages, key findings and highlights of the Shell Commercial Vehicle Study 2016 are summarised.



The 2014 Shell Passenger Car Scenarios are still available, also as an English summary on: [www.shell.de/pkwszenarien](http://www.shell.de/pkwszenarien)



## TRANSPORT LOGISTICS AND TRANSPORT FORECASTS



### 1 GLOBAL LOGISTICS PERFORMANCE INDEX

- 1 GERMANY
- 2 NETHERLANDS
- 3 BELGIUM
- 4 UNITED KINGDOM
- 5 SINGAPORE

World Bank 2014

The logistics performance of a site or location is regarded as a key requirement for its economic development and competitiveness. The World Bank's current Logistics Performance Index ranks Germany at the top ahead of The Netherlands, Belgium, the United Kingdom and Singapore (World Bank 2014).

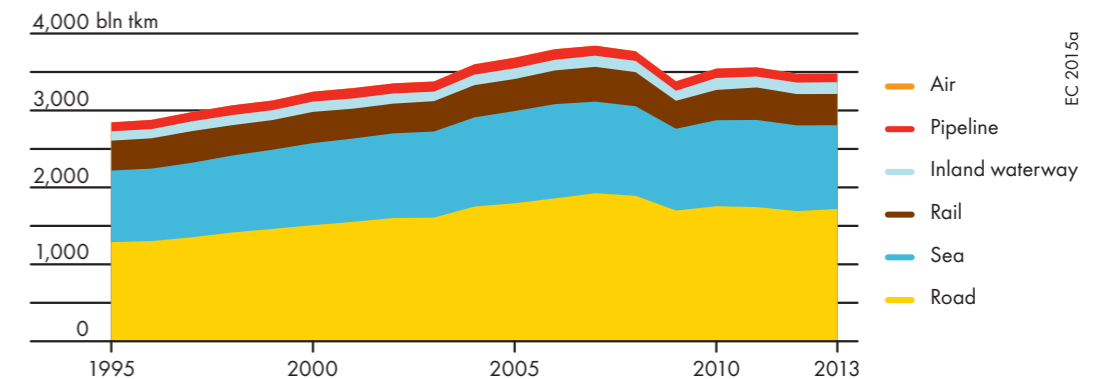
Today, the German logistics business has an annual turnover of more than 200 bln Euro and employs approx. 2.7 mln people (Kille/Schwemmer 2012, Destatis 2015a, b). The annual turnover of the entire EU logistics industry over the past few years was approx. 900 bln Euro (EC 2015b).

Generally, transport logistics belong to the services industry, but are also a part of the various sectors of the economy. Typically, the physical transport of goods is at the core of logistics services. Road freight transport with commercial vehicles is a central component of transport logistics.

In 2013, the total freight transport activities in the EU-28 amounted to 3,481 bln tonnes-kilometres (tkm). The transport performance of the national transport carriers of road, rail, inland waterways and pipelines was 2,391 bln tkm, where road freight transport reached 1,719 bln tkm. A comparison with other economic regions shows that in the US and in China the road freight transport performance is much higher than in the EU with 3,886 bln tkm and 5,573 bln tkm respectively.

Above and beyond the national transport carriers, the maritime transport between the EU Member States with approx. 1,100 bln tkm plays an important role for the European Single Market. Road transport accounted for nearly 50% of this total (modal split), rail for 11.7%, inland waterways

### 2 EU-28 TRANSPORT PERFORMANCE



for 4.4% and oil pipelines for 3.2%. Intra-EU maritime transport was the second most important mode with a share of 31.3%, while intra-EU air transport only accounted for 0.1% of the total (EC 2015a).

From the mid-1990s until 2007, the EU-28 total freight transport increased by approx. 35% and the road freight transport increased fastest among all modes of transport by almost 50%. As a result of the financial and economic crisis, these figures significantly decreased, and the freight transport hasn't yet recovered from that downturn (EC 2015a). According to the Reference Scenario (dating from 2013) of the EU transport strategy, the freight transport performance will increase again in the coming decades to 2050, with road transport as the main transport carrier (EC 2015b). However, as the mid- and long-term consequences of the financial and economic crisis on EU transport activities cannot yet be adequately assessed, any EU freight transport forecast suffers from significant uncertainties.

**EU freight transport has not yet recovered from financial and economic crisis**

The German share in the EU freight transport is between 20 and 25%. Since the early 1990s, the German freight transport performance has increased by more than 60%. After accelerated growth in the 1990s, Germany also experienced a downturn as a result of the financial and economic crisis, followed by a period of recovery. Most recently (2014), a freight transport performance of more than 635 bln tkm (without pipelines) was recorded, which is split amongst the three surface-based transport carriers as

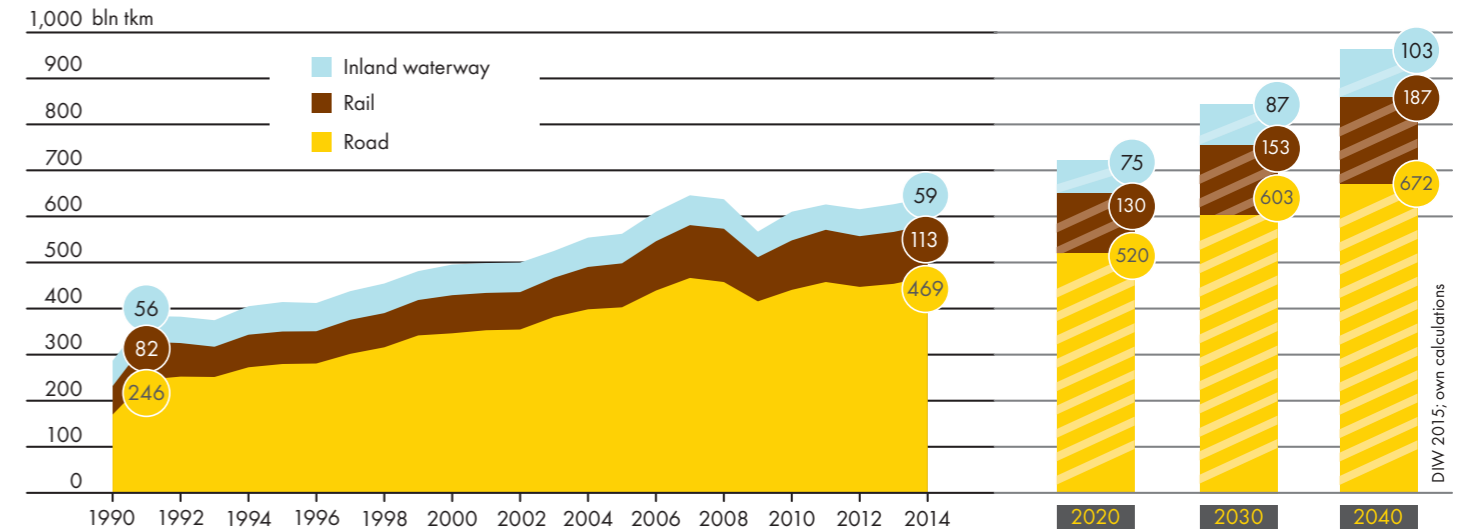
follows: road 73%, rail 18% and inland waterways 9% (DIW 2015).

For the Shell Commercial Vehicle Study, the relevant parameters are adopted from the government's most recent transport forecast to 2030 (BVU et al. 2014a, b) and developed up to 2040. The most important change compared to the previous forecasts is that the assumptions about the freight transport growth are significantly more moderate. For example, the freight transport performance in Germany across all transport carriers is now only forecast to grow by 38% and for road freight transport only by approx. 39%. The previous government transport forecast 2025 (ITP/BVU 2007), on the other hand, had forecast growth figures of 71% and 79% respectively.

**Freight Transport Germany +50% to 2040  
Road Freight Transport Germany +43% to 2040**

For this Commercial Vehicle Study, it is forecast that the freight transport volume will increase from today's (2014) 4.1 to 4.8 bln tonnes (t) by 2040. The road freight transport volume will increase from 3.5 to 3.9 bln t from 2014 to 2040. The overall freight transport performance will increase by 50%, i.e. it will grow from 641 to 962 bln tkm. The road freight transport will grow from 469 to 672 bln tkm, equalling an increase by 43%. The share (modal split) of road transport in the surface-based freight transport performance will slightly decrease in the future from 73% (2014) to 69% (2040). The main reason for this development is the increase of the transport distances and the cross-border transport, which favour rail transport over road freight transport (fig. 3).

**3 FREIGHT TRANSPORT PERFORMANCE GERMANY**



The road transport carrier also provides public road passenger transport, which is mainly covered by buses and coaches, but partly also by tram and metro. In the EU-28, all passenger transport modes achieved 4,672 bln passenger-kilometres (pkm), of which 526 pkm was via public road transport. As EU-public road transport increased only slightly since the mid-1990s, its share in passenger transport decreased gradually. In 2013, buses and coaches delivered 9% of the transport performance of passenger modes of transport on land, tram and metro 1.6%; German figures were at 5.7% or 1.6% respectively (EC 2015a).

In 2014, the entire public road passenger transport in Germany amounted to approx. 80 bln pkm, thereby taking a share of approx. 7% in the national passenger transport performance (as measured by pkm). Due to the shorter transport distances, most recently (2014), the public road

passenger transport share in the passenger transport volume of approx. 9 bln passengers or trips was as much as 13% (DIW 2015).

Approx. 80% of German public road transport can be split into four segments: Approximately half of the transport performance or approx. 39 bln pkm are provided by local regular services using city buses. The local regular services also use regional buses which are often deployed in rural areas. Separate from the regular service is the occasional transport which amounts to approx. one-quarter of the public road transport performance or approx. 20 bln pkm, but which has been showing a decreasing trend for several years.

Since its liberalisation in 2013, the long-distance regular bus service has been a heavily growing bus segment, but its share in the public road passenger transport is still significantly below 10%.

For the forecast up to 2040, it is assumed that slight decreases in local transport and occasional transport will be compensated by the growth of the long-distance bus services. This would result in a passenger transport performance delivered by buses and coaches to the amount of 64.7 bln pkm.

### COMMERCIAL VEHICLE FACTS AND FIGURES

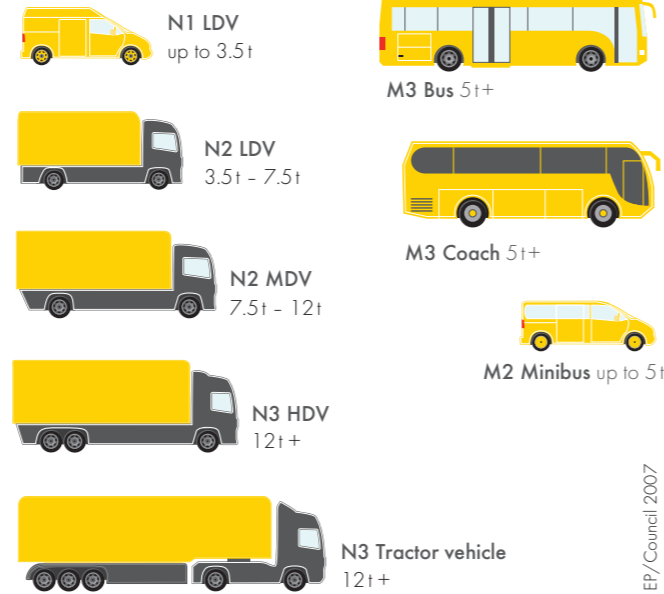
In general, a commercial vehicle is a motorised vehicle used in commerce and/or registered to a company. In the EU, "[...] a commercial motor vehicle means any motorised road vehicle (including tractors [...]) which [...] is designed for and capable of transporting, whether for payment or not, more than nine persons including the driver, or goods [...]" (Council 1983). In the EU, motorised vehicles are classified according to EU Framework Directive 46/2007/EC (EP/Council 2007).

European goods vehicles (vehicle class N) are differentiated by weight or mass, ranging from class N1 light duty vehicles (LDV) with gross weight up to 3.5 tonnes, to class N2 medium-duty vehicles (MDV) from 3.5 to 12t (in Germany subdivided into two sections with masses ranging from 3.5 to 7.5 and 7.5 to 12t), and class N3 heavy duty vehicles (HDV) with more than 12t. The latter class also includes as a sub-category tractor vehicles designed to be coupled to semi-trailers, excluding agricultural or forestry tractors.

European passenger vehicles (vehicle class M) are differentiated by number of seats and weight resp. mass. Vehicles designed and constructed for the carriage of more than eight passengers in addition to the driver are not passenger cars (class M1).

### 4 EU COMMERCIAL VEHICLE CLASSIFICATION

Gross weights



EP/Council 2007

Passenger vehicles with more than nine seats and a maximum weight not exceeding 5t are M2 vehicles (also minibuses), and such vehicles with a mass exceeding 5t are M3 vehicles, either (city)buses for urban line operation or more comfortable coaches for long haul trips.

### Goods vehicle fleets are dominated by Light Duty Vehicles (LDV) and Tractor vehicles

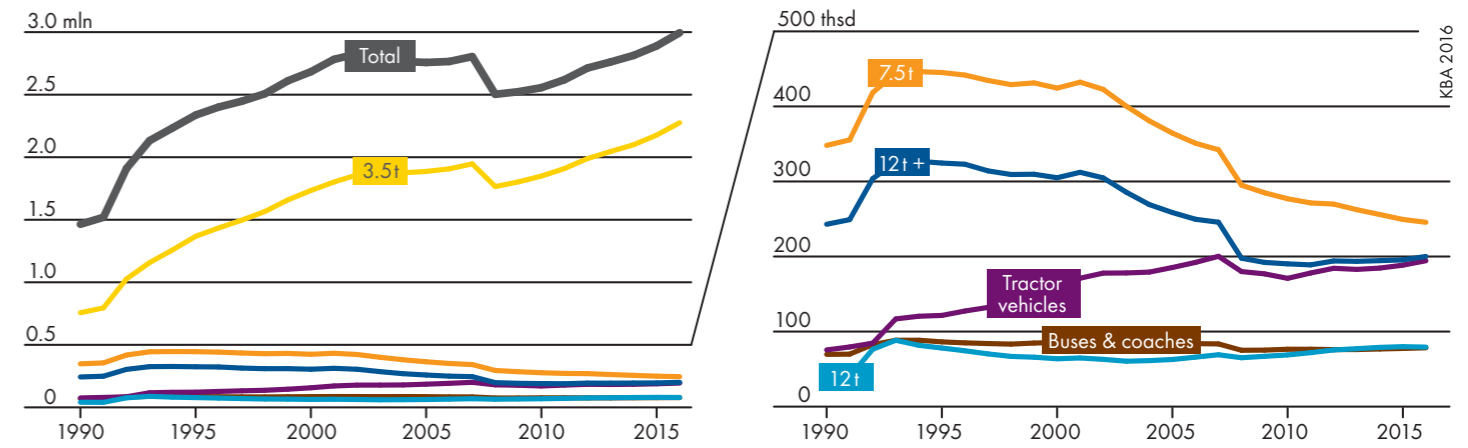
In 2014, 223.4 mln commercial vehicles were registered worldwide. The majority of commercial vehicles are operated in Asia, especially in China with 62.9 mln as well as in Japan and India with

14.9 and 10.9 mln vehicles respectively, followed by Mexico with 10.4 and Russia with 9.7 mln commercial vehicles (VDA 2015).

Also, the US are a leading truck nation. In 2013, 10.9 mln heavy duty vehicles (large single-unit or combination trucks) were operated in the US, added to which are 52.6 mln light duty vehicles which are however often used as passenger cars (BTS 2016; FMCSA 2016).

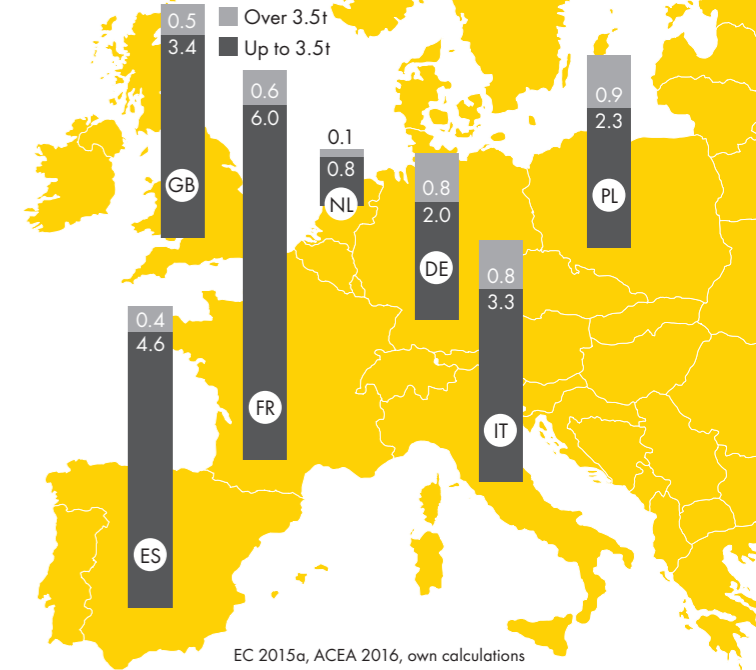
Today (2013), 35.6 mln goods vehicles are registered in Europe (fig. 5). France has by far the biggest fleet of goods vehicles with approx. 6.5 mln vehicles, while Germany is in 6<sup>th</sup> place (EC 2015a). All European goods vehicle fleets are dominated by the light commercial vehicles up to 3.5t gross weight. Poland, Italy and Germany operate the largest fleets of heavy duty vehicles over 3.5t gross weight with more than 800,000 vehicles registered in each of these countries.

### 6 COMMERCIAL VEHICLE FLEET IN GERMANY



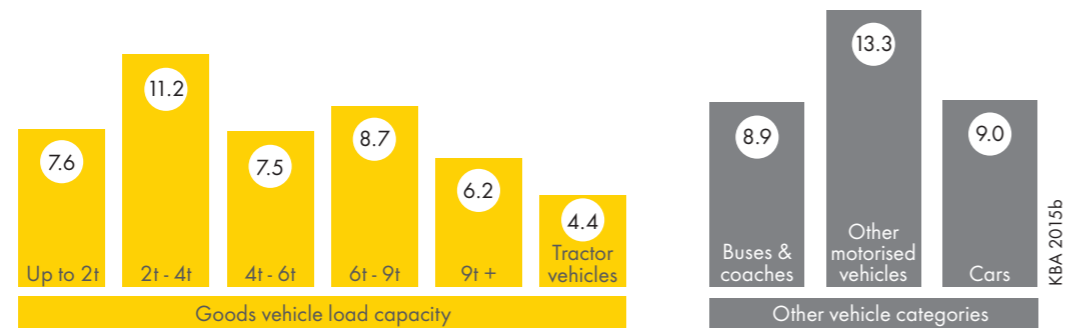
### 5 LARGEST GOODS VEHICLE FLEETS IN THE EU 2013

mln units



EC 2015a, ACEA 2016, own calculations

7 AVERAGE AGE IN YEARS OF VEHICLE FLEETS IN GERMANY 2015



New commercial vehicle registrations heavily depend on the economic situation. Most recently (2015), approx. 2 mln new goods vehicles were registered in Europe. In contrast, before the financial and economic crisis, the new goods vehicle registrations in the EU amounted to approx. 2.5 mln units (ACEA 2016).

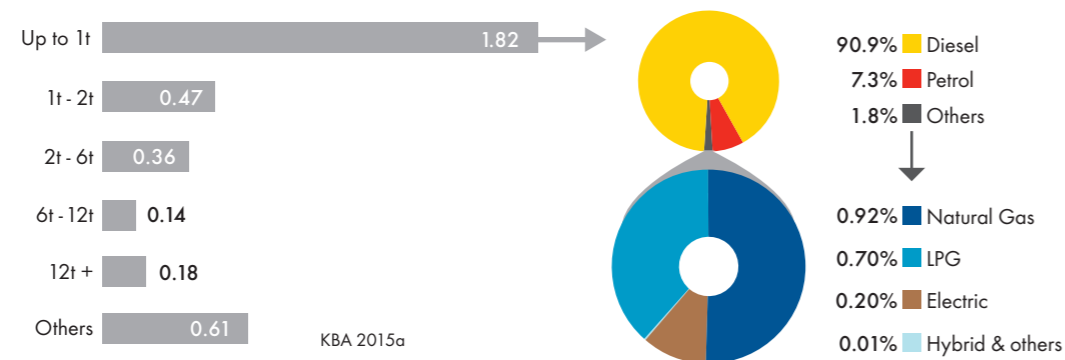
The United Kingdom and France show the highest numbers of newly registered vehicles across all goods vehicle classes. With a new registrations

share of more than 25%, Germany plays an important role in the EU with regard to heavy duty vehicles over 3.5t.

In 2016, a total of 2,995,166 goods vehicles are registered in Germany (cf. fig. 6, KBA 2016). The goods vehicle fleet development is characterised by the light duty vehicles whose numbers have tripled to approx. 2.3 mln units since the early 1990s and which amount to approx. three quarters of the total fleet numbers. Next in line are the tractor

8 ALTERNATIVE DRIVE-TRAINS IN THE GERMAN GOODS VEHICLE FLEET

by load capacity



vehicles whose numbers have more than doubled to approx. 200,000 vehicles during the same period. The overall goods vehicle fleet age is on average 7.7 years, with tractor vehicles being the youngest vehicle segment with an average age of 4.4 years (KBA 2015b).

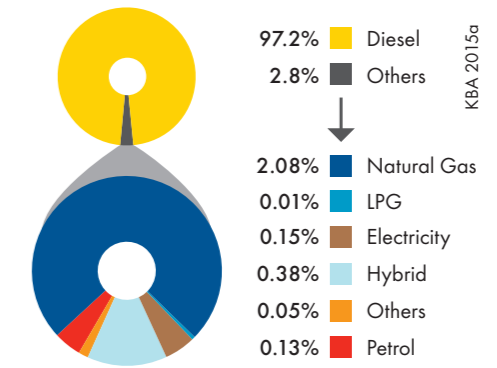
New goods vehicle registrations in Germany vary between approx. 200,000 and 300,000 vehicles per year. Here, too, light duty vehicles with their share of three quarters of the total figure dominate the development. And again, at approx. 20%, the tractor vehicles show the highest annual replacement rate amongst all vehicle classes (KBA 2015d, 2016; cf. fig. 7.)

With regard to the emission classes (Euro standards), clean vehicle exhaust gas technology is becoming ever more prevalent. In 2015, approx. every second light or heavy duty vehicle was a Euro IV or 4 vehicle or better. The heavy duty vehicles, in particular tractor vehicles have the highest emission standards, and - due to their low replacement rates - the emission classes of the light to medium duty vehicles used for local transport are the lowest (KBA 2015a).

More than 99% of all HDVs are powered by diesel engines

Amongst the drive-trains, diesel technology with a share of 95% is the standard drive-train across all classes of goods vehicles. The most important alternative to Diesel is the petrol engine with a share of approx. 4%. The basic rule is: The heavier the vehicle, the less often an alternative drive-train including petrol vehicles is used.

9 DRIVE-TRAINS GERMAN BUS FLEET 2015



The alternative drive-trains are focussing, in particular, on the class of the light duty vehicles, especially the passenger-car-like vehicles. However, today (2015), even for the vans up to a load capacity of 1 t, the share of alternative drives is a mere 1.8% (cf. fig. 8). In contrast, more than 99% of all heavy duty vehicles are powered by diesel engines (KBA 2015a).

Today (2013), 822,900 buses and coaches are operated in Europe. The biggest bus fleets are operated by the UK, Poland and Italy with approx. 100,000 vehicles or more, while Germany is in 5<sup>th</sup> place (fig. 10, EC 2015a). In the US, 872,000 buses are registered, which is more than in the entire EU (BTS 2016). Most recently (2015), approx. 46,000 buses are newly registered in Europe, with Germany showing a relatively high number of new bus registrations (ACEA 2016).

In Germany, the fleet size has been almost constant for a number of years with approx. 75,000 vehicles. Most recently (2016), 78,345 buses were in operation (cf. fig. 6). The average age of the German bus fleet is approx. 9 years, with the age

10 LARGEST BUS FLEETS IN THE EU 2013



of the buses increasing with the number of seats (KBA 2015b). The number of new bus registrations has also been relatively steady between 5,500 and 6,000 vehicles annually for several years (KBA 2015d).

With regard to the exhaust gas emission standards, almost half of all buses are classified as Euro IV or better. This means that the bus emission standards are slightly higher than those of all goods vehicles, but significantly lower than those of the tractor vehicles used for long-distance road freight transport. For buses and coaches, the EEV standard (Environmentally Enhanced Vehicle) with a share of 23% in the bus fleet plays a special role (KBA 2015a).

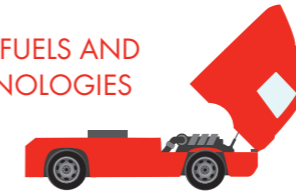
In Germany, more than 97% of all buses are diesel-powered. In 2015, the share of alternative drive-trains was 2.8%, i.e. almost double that in the German passenger car fleet and significantly higher still than in comparably heavy duty vehicles. The most important alternative drive-train are CNG- resp. natural gas-powered vehicles with a share of

approx. 2% of all buses and coaches registered (KBA 2015a).

In addition to goods vehicles, buses and coaches, there is another national class of vehicles, the class of the other motor vehicles with 275,000 units in Germany today (2015). Although their vehicle technologies and in particular drive-trains are often identical or similar to those of commercial vehicles, they are nevertheless not classified as commercial vehicles. With a share of almost 30%, fire-fighting vehicles are the largest group of body types amongst those other motor vehicles, followed by street sweeper, collection vehicles and others (KBA 2015c).

The average age of the other motor vehicles is 13.3 years (cf. fig. 7). Each year, approx. 15,000 new other vehicles are registered. Only approx. one quarter of all other motor vehicles achieve Euro IV standards or better. With a 92.4% share, the diesel drive-train is the standard drive-train, ahead of petrol engines at 7%. Alternative drive-trains at 0.6% are virtually negligible within the fleet of the other vehicles (KBA 2015a).

DRIVE-TRAINS, FUELS AND VEHICLE TECHNOLOGIES



The most important trends for drive-trains, fuel and energy supply as well as vehicle technologies and the mode of operation are being investigated using a medium-term assessment of technology development. This investigation focuses on the three drive-train-and-fuel combinations of diesel, gas and electric. The drive-train-fuel combinations are assessed with regard to typical areas of application using relevant selection criteria for commercial vehicle technologies. The results are visualised using network diagrams.

The assessment criteria include the technological maturity which is classified using the NASA Technology Readiness Levels (TRL) 6 (prototype) to 9 (standard product) (NASA 1995, DOD 2011, ISO 2013), the vehicle user costs (total cost of ownership), the availability of energy or fuel, further user preferences as well as the emissions balance. With regard to the deployment areas, in principle, a distinction is made between urban driving profiles, which are characterised by numerous start-and-stop processes and shorter distances, as well as transregional or long-distance deployment with its continuous vehicle operation and higher average speed.



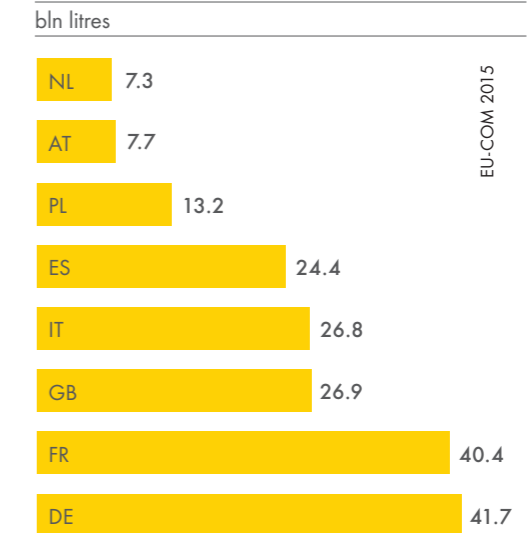
**DIESEL** In the commercial vehicle sector, the diesel drive-train is the most wide-spread concept, and as such it provides both the technical and economic

benchmarks for all other drive-trains. Further substantial potential for efficiency improvements is observed in the following areas (Hoepke/ Breuer 2013; ika 2014; Süßmann/Lienkamp 2015; UBA 2015b): Improvement of the efficiency of engine and transmission, waste heat recovery, electrification of accessories as well as (mild) hybridisation - the latter mainly for urban vehicles.

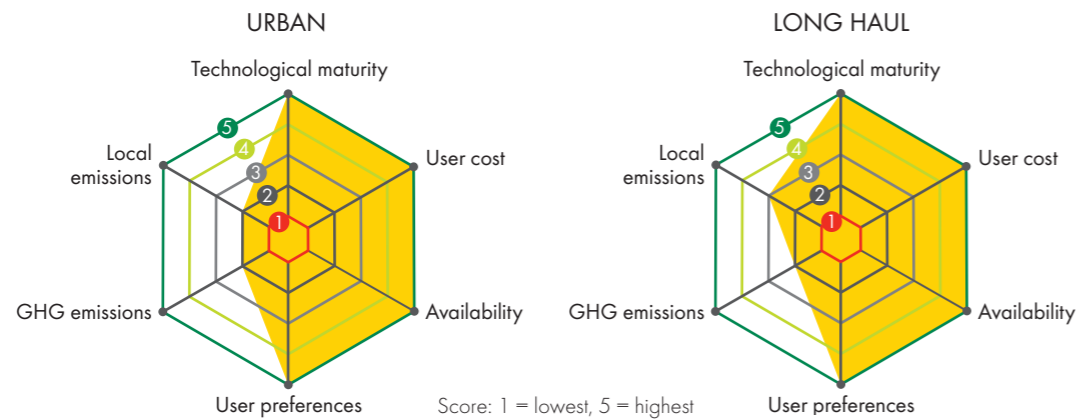
The diesel drive-train provides the benchmark for all other commercial vehicle drive-trains

In the EU, Germany and France are the biggest diesel fuel markets, both exceeding 40 bln litres (l) of Diesel sales (EU-COM 2015). Diesel fuel is an energy carrier with a high energy density of nearly 36 Megajoules per litre (MJ/l) or more than 43 Megajoules per kilogram (MJ/kg) (fig. 14). In fact, more than 99% of the diesel fuel sold in the EU is B7, i.e. it consists of up to 7% biodiesel.

11 2013 EU DIESEL FUELS MARKETS



## 12 DIESEL DRIVE-TRAINS AND FUELS



Diesel is easy to handle and the most easily available of all fuels. Also, it can be supplemented or replaced by lower-emission biogenic, paraffinic or Power-to-Liquids (PtL) fuels (EU-COM 2015)

The network diagram (fig. 12) shows that the diesel drive-train-and-fuel combination represents the reference technology for all commercial vehicles, mainly with regard to technical, economic and user criteria. The technological maturity, user costs, availability as well as user preferences all achieve the highest level (5).

However, the diesel technology shows potential for improvement with regard to the emissions, in particular with respect to local emissions. Nowadays, comparatively old light and medium-duty vehicles with low exhaust gas emission standards are used in urban areas. Therefore it might be possible to solve the emissions issue (at least partially) by using alternative liquid fuels in existing vehicles.

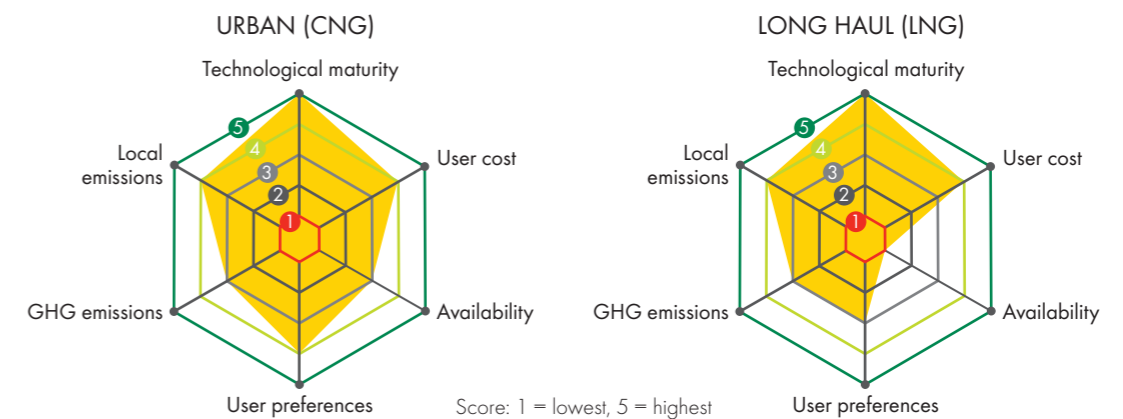


**NATURAL GAS** Most recently, natural gas drive-trains have become a relevant drive-train and fuel alternative for commercial vehicles. Light

and medium duty vehicles as well as buses and coaches have been available in combination with compressed natural gas (CNG) for quite a while. Following the global natural gas boom – especially in North America – the use of Liquefied Natural Gas (LNG) has become a further option (DLR et al. 2014).

The most important drive-train innovation is dual fuel technology for heavy duty vehicles for long haul road freight transport. It applies the diesel principle, and its efficiency is therefore similar to that of diesel drive-trains. Dual fuel drive-trains can be predominantly or entirely operated with natural gas. However, at the current time, gas commercial vehicles available in Europe are limited to CNG-fuelled petrol engine vehicles (EC/DGM 2014b).

## 13 NATURAL GAS DRIVE-TRAINS AND FUELS



**LNG is the only alternative drive-train-fuel-combination for long haul HDVs**

LNG is a low-emission fuel with an energy density close to that of diesel fuel (cf. fig. 14); that is 21 MJ/l or approx. 60% of the volumetric energy density of diesel fuel (EC/DGM 2014a). Up until now there is just a CNG filling station infrastructure in Germany in place, while an LNG infrastructure is yet to be built. Since LNG is only an option for transregional deployment, a small number of large filling stations in the motorway and highway network would be sufficient to guarantee a safe supply. LNG and CNG can be supplemented or replaced by biogenic or electricity-based gaseous fuels (Power-to-Gas).

The network diagram (fig. 13) shows that natural gas commercial vehicles have reached technological maturity. However, they do not score as high as diesel vehicles in most of the user criteria.

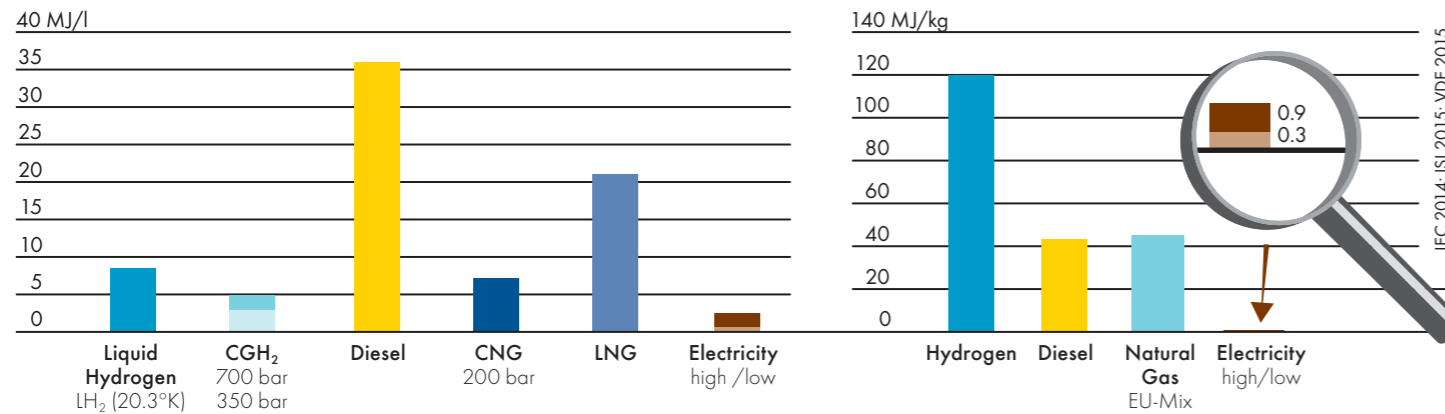
Whereas CNG vehicles are primarily designated for urban or regional use, LNG commercial vehicles are the only relevant drive-train-and-fuel alternative to diesel vehicles for transregional deployment up until now. Moreover, the availability of CNG is limited to approx. 900 retail sites, and LNG is not yet available at all as road transport fuel in Germany. On the other hand, compared to diesel vehicles, natural gas vehicles display emission advantages, in particular for local emissions.



**ELECTRIC** Similar to the passenger car sector, the industry is also developing concepts for the hybridisation or electrification of commercial

vehicles. Electric mobility means that the sole drive-train or main drive-train is electric. These drive-trains include, in particular, plug-in hybrids (PHEV), battery-electric vehicles (BEV) and hydrogen-powered

14 ENERGY DENSITY OF FUELS



fuel cell electric vehicles (FCEV). On the other hand, mildly hybridised vehicles, which are mainly propelled by internal combustion engines, are not (yet) electric vehicles.

The biggest potential for electric mobility is seen for passenger car-like light duty vehicles as well as vehicles with urban driving profiles, such as

vans or city buses. At the current time, there are no commercial approaches to the electrification of long haul heavy duty vehicles with high mileage.

The core element of electromobility is the battery technology (ISI 2015; VDE 2015) as well as the fuel cell for fuel cell-powered vehicles. The crucial factor for commercial vehicle applications is the low

density of energy stored in batteries. Presently, the gravimetric energy density of batteries is between 0.3 to 0.9 MJ/kg, whereas the volumetric energy density is between 0.5 to 2.4 MJ/l (cf. fig. 14). Therefore, in order to store 30 litres of diesel fuel – which is equivalent to the specific fuel consumption per 100km of an energy-efficient heavy duty vehicle – a battery with a weight of approx. 2 t would be required.

However, the problem of the low density of electricity stored in batteries might be partially solved by storing compressed gaseous hydrogen (CGH<sub>2</sub>). Apart from an improved battery technology, the prerequisites for nation wide electric mobility are powerful quick-charge options and a hydrogen filling station infrastructure.

Only electric vehicles (BEV, FCEV) allow completely local emission-free mobility. However, as both the electricity and the hydrogen are secondary energy carriers, their method of provision is key with regard to sustainability.

transport. However, for transregional use, plug-in hybrids have to be operated in combustion mode in order to comply with relevant user criteria.



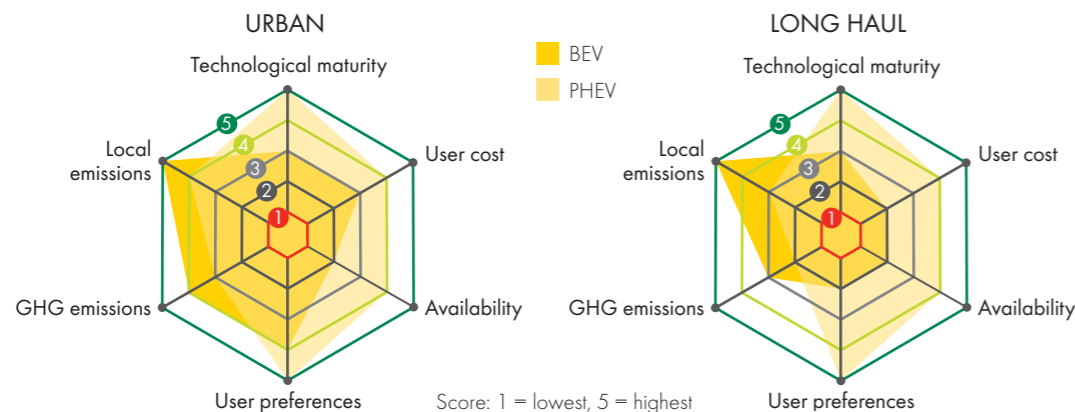
DRIVING RESISTANCE AND VEHICLE OPERATION

In addition to the drive-train technology and fuels, the energy consumption and the emissions of commercial vehicles can also be improved by developing the non-drive-train-related vehicle technology. The main lever is the reduction of the vehicle's driving resistance which is mainly composed of its air, rolling, acceleration and gradient resistance.

The main beneficiary of aerodynamic improvements due to optimised vehicle shapes is the long-distance transport with its high average speeds (FAT 2012). The rolling resistance is heavily influenced by the tyre technology (low-resistance tyres, optimum tyre pressure) (Goodyear Dunlop 2013). The reduction of the vehicle weight by using a lightweight-design not only affects the payload, but also the rolling, acceleration and gradient resistance, and this has a positive effect particularly on urban driving profiles.

Finally, additional potential for efficiency savings can be realised by optimising the way of driving/mode of operation and the scheduling of commercial vehicles. The optimisation range from driver assistance systems and predictive cruise control to platooning and automated driving assisted by state-of-the-art information and communication technologies.

15 ELECTRIC DRIVE-TRAINS AND FUELS

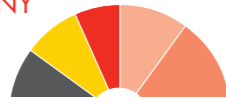


At present, there are no commercial approaches to electrify HDVs

The network diagram (fig. 15) shows that only plug-in hybrid electric vehicles have reached technological maturity, battery electric commercial vehicles still haven't. And PHEV score as high as natural gas vehicles regarding user criteria, while BEV don't. PHEV are fit-for-purpose in regional as well as transregional transport, BEV are only an alternative for regional applications. The main advantage of electric vehicles is zero-emission



### SCENARIOS FOR COMMERCIAL VEHICLES IN GERMANY UP TO 2040



Finally, scenario technique and fleet modelling are used to investigate future developments of drive-train technologies, fuels, energy demand and greenhouse gas emissions for commercial vehicles in Germany up to 2040.

Initially, two different scenarios for future commercial vehicle drive-trains and fuels are developed: a Trend Scenario and an Alternative Scenario. The key drivers of these different development paths are the framework conditions as specified by society and politics, the purchase decisions made by users and companies, the technical progress of

the drive-train and vehicle technologies as well as developments with regard to availability and prices of the energy and fuel supplies.

The Trend Scenario updates the most important developments of the recent past. Here, the efficient and further improved diesel drive-train and liquid fuels remain by far the most economical option for almost all commercial vehicles. In the Alternative Scenario, on the other hand, new drive-trains and vehicle technologies and fuels, especially electric drive-trains as well as gas drive-trains and gas fuels, will increasingly penetrate vehicle and fuel markets.

The developments of the national commercial vehicle fleet and the numbers of new registrations up to 2040 are updated with the help of trend extrapolations and fleet modelling. Then, the goods

vehicle and bus fleets are developed according to different drive-train technologies.

The number of annual new vehicle registrations across all goods vehicle classes will increase from 290,000 today to 344,000 in 2040. The strongest new registrations increase will be that of the light duty vehicles which will go up from 220,000 to 260,000 units per year. In the Trend Scenario, the alternative drive-trains (PHEV, BEV) will only achieve a substantial market share of approx. one fifth for the light duty vehicles, and approx. 15% for buses and coaches by 2040.

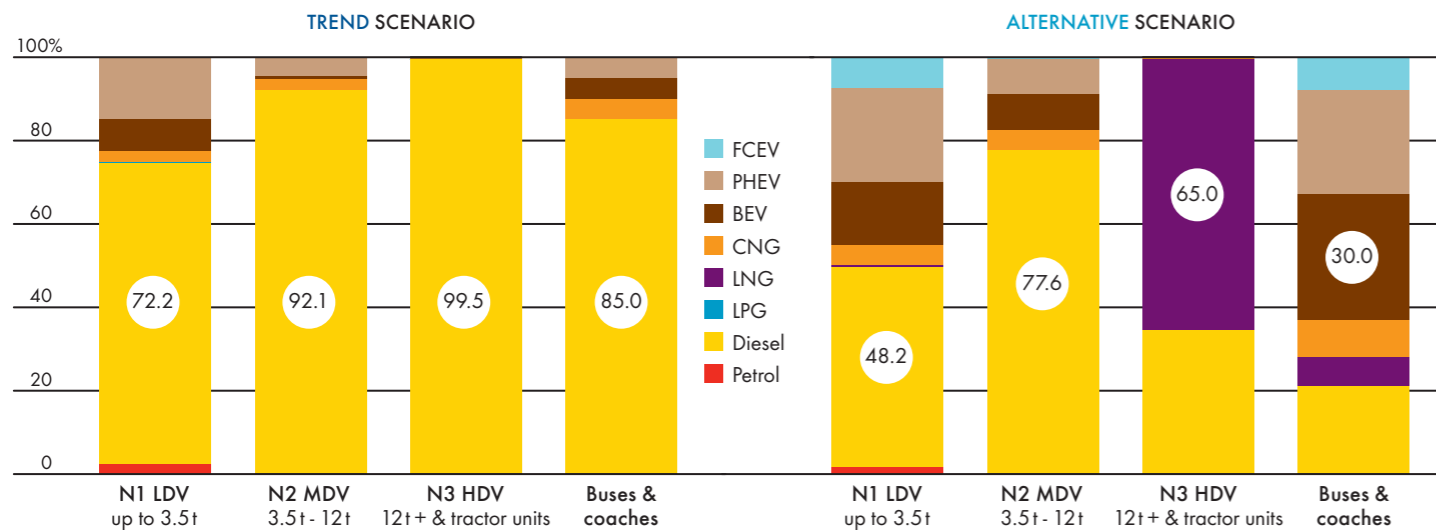
In the Alternative Scenario, alternative drive-trains - electric (PHEV, BEV, FCEV) for the light duty vehicles and buses as well as gas (LNG) for the long haul heavy duty vehicles - will outnumber the new diesel

registrations in almost all vehicle classes by 2040, except for mid duty goods vehicles with gross weight between 3.5 and 12t (fig. 16).

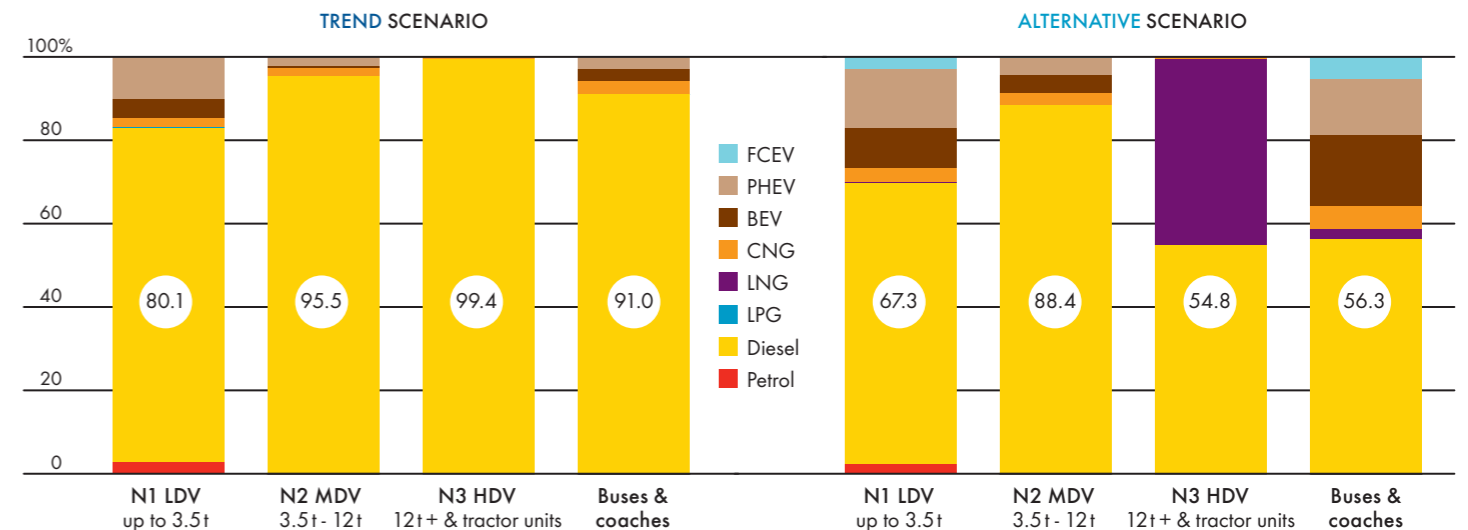
**The German goods vehicle fleet will grow by more than 20% from 2014 to 2040**

Between 2014 and 2040, the goods vehicle fleet in Germany will grow by more than 20% from 2.9 to almost 3.5 mln vehicles. The number of light duty vehicles, in particular, will grow from 2.1 to almost 2.8 mln units. In the heavy duty vehicle fleet of the Trend Scenario, the alternative drive-trains will tend to remain the exception - with shares worth mentioning only for light duty vehicles (17%) and buses and coaches (9%).

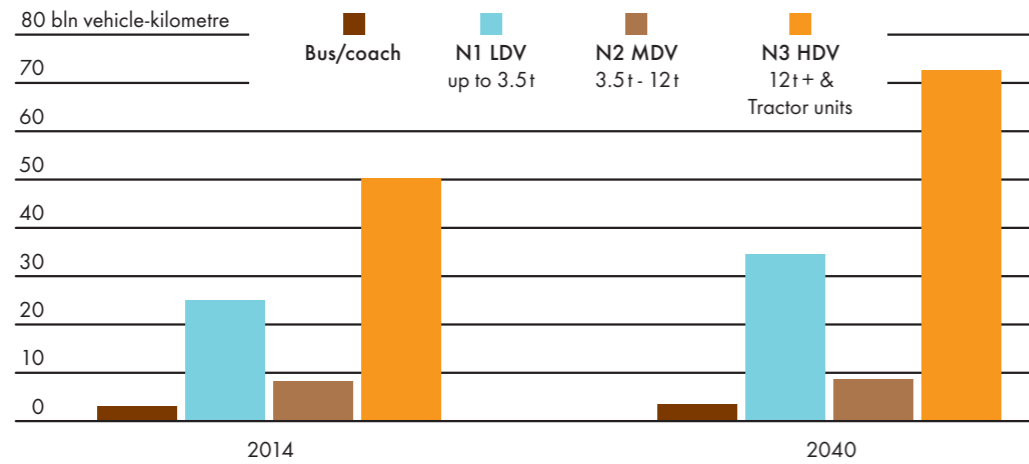
16 COMMERCIAL VEHICLE NEW REGISTRATIONS BY DRIVE-TRAIN IN 2040



17 COMMERCIAL VEHICLE FLEET BY DRIVE-TRAIN IN 2040



18 COMMERCIAL VEHICLE MILEAGE 2014 VS. 2040



In the Alternative Scenario, virtually all vehicle classes will show a clearly changed drive-train mixture. Here, approx. one third of the light duty vehicles will have an electric drive, 45% of the heavy duty vehicles will use LNG and one third of buses and coaches will be electrically powered (PHEV, BEV, FCEV, cf. fig. 17).

This means that new drive-trains will only establish themselves in the vehicle fleet with a time delay. Due to the rapid fleet turnover, the fleet of long haul heavy duty vehicles and long-distance buses and coaches will be the first to be modernised. On the other hand, due to its high average age, the fleet of medium duty vehicles used for local transport and distribution of goods as well as large parts of the light duty vehicles will show the slowest changes.

The mileage of goods vehicles will increase by 39% or from approx. 83 to approx. 116 bln

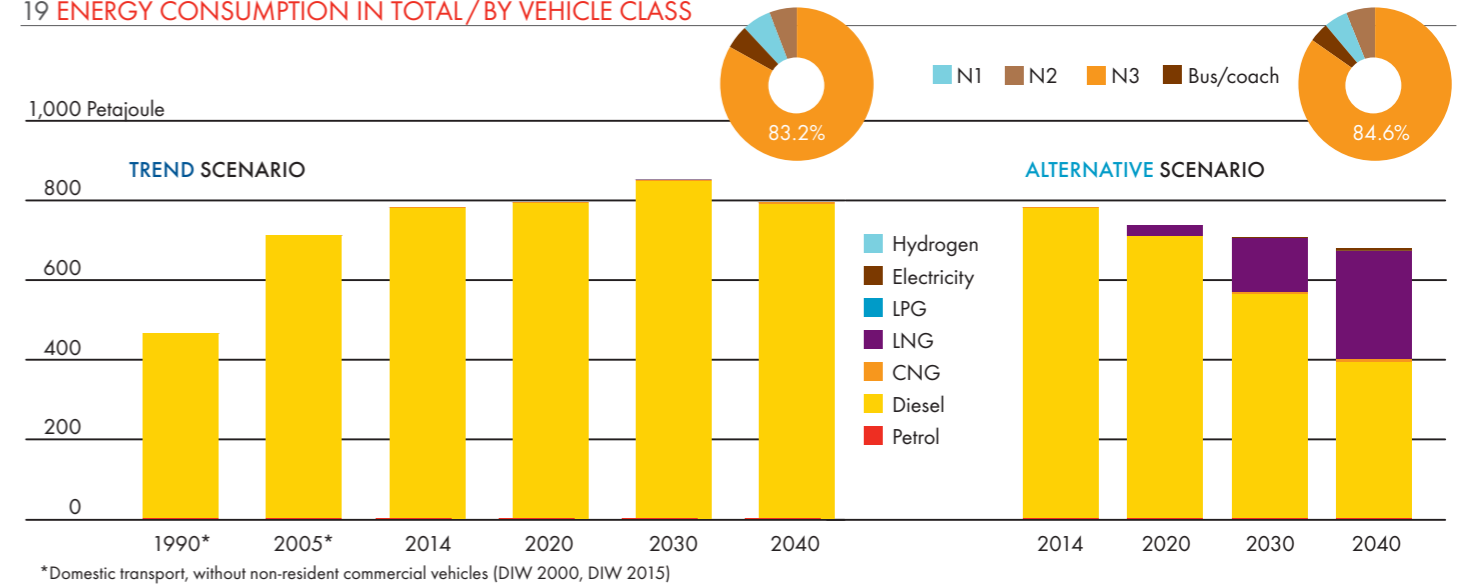
vehicle-kilometres (vkm). The highest mileage growth will be shown by the long haul heavy duty vehicles, amongst them an increasing number of non-resident vehicles.

**The mileage of goods vehicles will increase by 39% from 2014 to 2040**

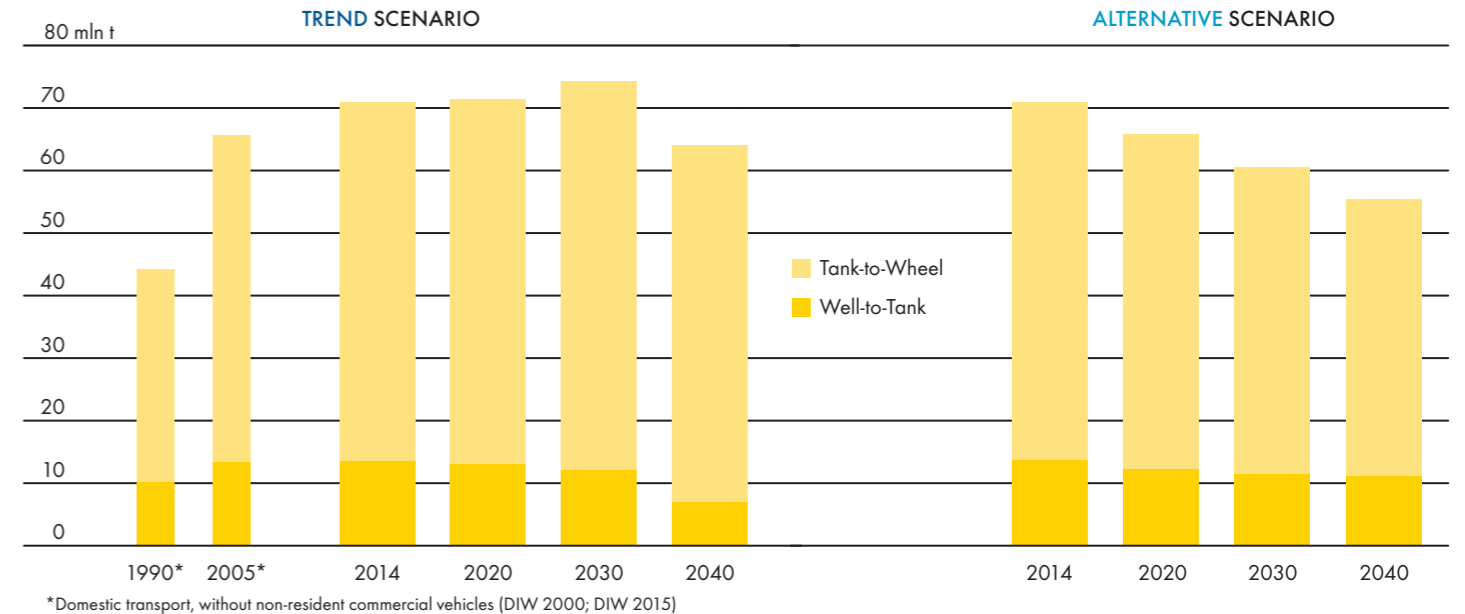
Due to their increasing number, light duty vehicles will also contribute substantially to vehicle mileage growth (fig. 18). The mileage of buses and coaches will grow from 3.1 bln vkm today to 3.5 bln vkm in 2040. In contrast to the passenger cars (Shell 2014), the goods vehicle fleet and its mileage will continue to increase in the coming years. The growth of the goods vehicle traffic will predominantly affect the motorway and highway network.

The Trend Scenario shows an increase of the energy demand of all commercial vehicles

19 ENERGY CONSUMPTION IN TOTAL/BY VEHICLE CLASS



20 GREENHOUSE GAS EMISSIONS



- calculated on the basis of average fuel consumption and respective mileage of vehicles - from 783 Petajoules (PJ) today to 853 PJ in 2030. After that it will decrease to 786 PJ by 2040. In the Alternative Scenario, the energy demand will have continuously decreased by 13% (or to 682 PJ) by 2040 despite the simultaneous mileage increase by 39% during that period.

In the Trend Scenario, diesel fuel with its share of more than 99% or 22 bln litres will virtually remain the only relevant energy carrier, whereas in the Alternative Scenario the diesel demand will almost be halved, mainly taken over by gas fuels (LNG) and, to a lesser extent, also by electricity. Heavy duty vehicles consume by far the most energy. Their share in the energy demand of all commercial vehicles will increase from 79% today to 83% (Trend) and 85% (Alternative) respectively in 2040 (fig. 19).

**The HDV share in energy demand of all commercial vehicles will increase from 79% to 83 resp. 85%**

All measures for reducing the energy demand of commercial vehicles are facing the following **challenge**: Vehicle segments where new and energy-saving drive-train technologies could be introduced only feature low mileages per vehicle with low average fuel consumption levels. For the long haul road freight transport with its high and heavily increasing mileage levels, alternative drive-trains will not (yet) fulfil user requirements for the time being.

Today, goods vehicles and buses and coaches are responsible for approx. 5.6% of the combustion-related CO<sub>2</sub> emissions in Germany, which amounts to approx. half of the CO<sub>2</sub> emissions from passenger car traffic (fig. 21).

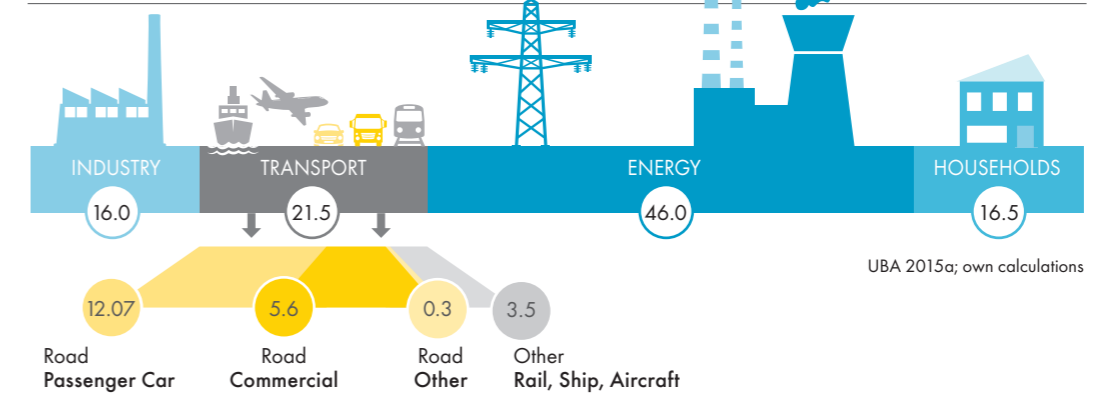
In the Trend Scenario, the entire well-to-wheel emissions will slightly increase by 2030 from today's levels of 71 mln t, and by 2040 they will have gradually decreased to approx. 64 mln t. This decrease of approx. 10% will primarily be achieved by biofuels which are lower in CO<sub>2</sub> than diesel (JEC 2014). In the Alternative Scenario, well-to-wheel emissions will decrease to 55.4 mln t of CO<sub>2</sub>. The reasons for this reduction by more than 20% include the declining energy demand as well as the introduction of natural gas fuels and - to a lesser extent - electric mobility (fig. 20).

**Commercial vehicle final energy consumption will decrease by up to 13%, fleet greenhouse gas emissions by up to 20% from today's levels**

The German energy transition targets are as follows: From 2005 to 2050, the final energy consumption of the transport sector is to decrease by 40% - with an intermediate target of minus 10% by 2020. Furthermore, a national cross-sector greenhouse gas reduction target has been set - with an intermediate target for 2040. After that, the direct or tank-to-wheel greenhouse gas emissions are to decrease by at least 70% from 1990 to 2040. Meanwhile, the EU has established a new greenhouse gas reduction target of minus 30% from 1990 to 2030 for Non-Emissions-Trading-System Sectors (like transport, fig. 22).

21 CO<sub>2</sub> EMISSIONS IN GERMANY

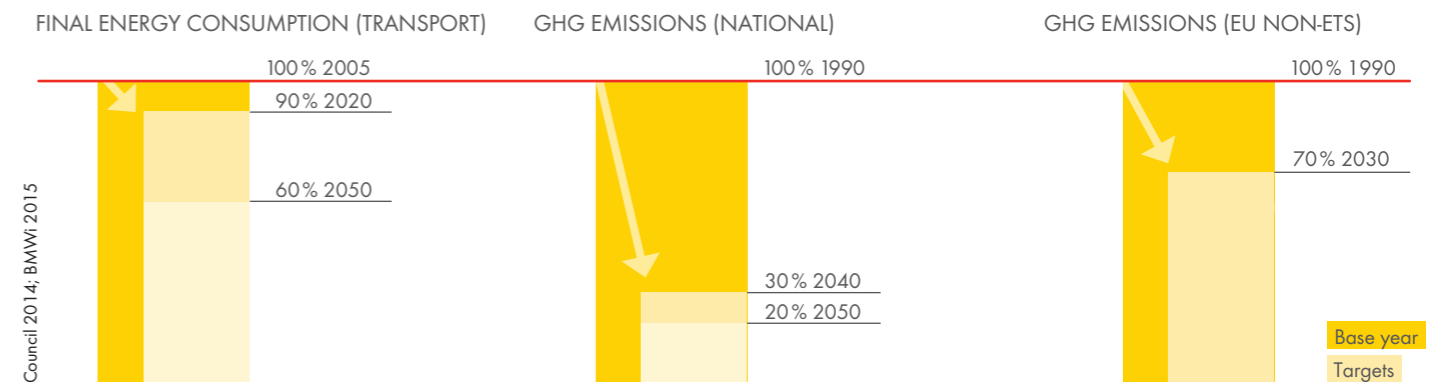
shares in %



Since the final energy consumption of commercial vehicles will hardly fall below the 2005 levels by 2040 even in the Alternative Scenario, it seems rather unlikely that commercial vehicles alone will achieve or substantially contribute to the 2050 energy target for the transport sector. A 40% reduction of final energy consumption would only be attainable jointly with passenger car transport, i.e. in combination with substantial final energy savings of passenger cars (Shell 2014).

Finally, the 1990s commercial vehicle CO<sub>2</sub> emissions will be significantly surpassed both in the Trend and the Alternative Scenario by 2040. This means that, irrespective of the scope of emissions reporting, commercial vehicles are only expected to make a below-average contribution to the national climate target as well as to the EU Non-ETS target. Finally, the CO<sub>2</sub> emissions from goods vehicles and buses and coaches would be approximately as high as the passenger car emissions in 2040 (Shell 2014).

22 ENERGY TRANSITION TARGETS



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