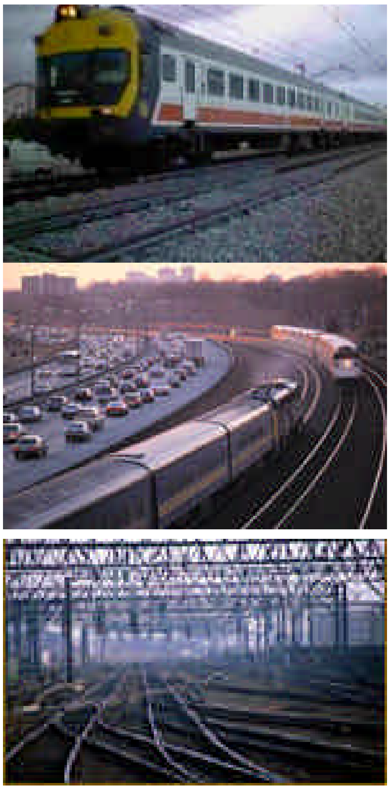
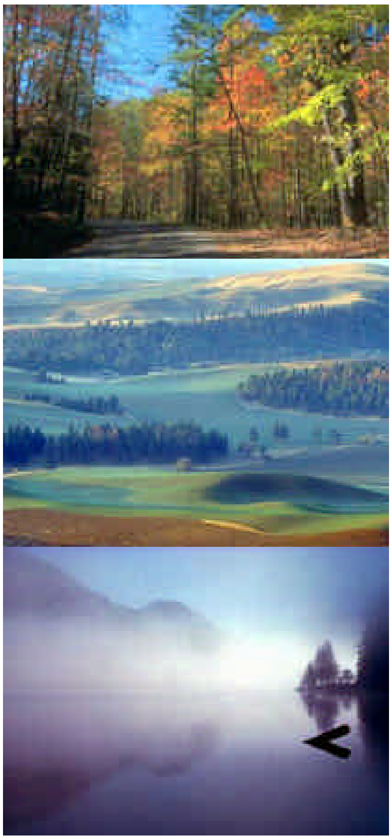


Rail Diesel Study

WP1 Final Report

Status and future development of the diesel fleet



By
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21.07.2005

Contents

1 Management summary of WP 1

The results of Work Package 1 “Status and future development of the diesel fleet” serve as an important basis for the subsequent work packages in the “Rail Diesel Study”, especially for assessing technical and operational possibilities for diesel exhaust emission reductions, to assess the relevance of diesel exhaust emissions on local air quality and to develop strategies and scenarios for emission reductions.

The information that has been collected on the existing diesel fleet in Europe, and the estimates that have been made for the future development of the fleet, highlight the complexity of the topic. There are in many cases a large number of indicators characterising the diesel fleet due to different situations in various countries or railway companies:

- Rail diesel traction has comparably high absolute operating performances in countries like Germany, France, UK, the Baltic states and further new EU member states. The new EU 10 represent more than one third of the covered European diesel operating performance.
- In the Baltic States, Ireland and Greece, there is almost no electrified track and diesel traction is the backbone of rail traffic. This is in contrast to countries such as Germany and France where diesel traction is typically used for feeder traffic on sparsely used lines (although it should be recognised that diesel traction still accounts for 10% of all rail traffic in France, and 20% in Germany). In a fully electrified country like Switzerland, diesel traction is only rarely used for some maintenance and shunting operations.
- Different situations in various countries also result in there being a large number of indicators that describe the intensity of use of the diesel fleet, e.g. the average train-km per tractive unit or the average wagon load in tonnes per diesel freight train. Due to the fact that diesel traction is widely used also for shunting and civil engineering processes and on lines with low traffic density, average utilisation is much lower compared to electric traction. The main exceptions to this are the heavy haul diesel freight trains in the Baltic countries with an average wagon load of up to 3000 tonnes per train.

As diesel exhaust emissions and the costs and benefits of applying emission abatement measures are directly related to the number of diesel engines, the investigations carried out for this study were aimed at identifying the number of diesel rail **engines** rather than of the number of diesel rail **vehicles**. UIC members’ fleets represents around 85 % of European diesel rail engines with around 17 000 locomotive and 14 000 railcar engines. Around 2 700 locomotive and 2 600 railcar diesel engines are used by non-UIC members.

It has to be noted that these engines do not represent an homogenous entity, as some of them are intensively used in heavy haul freight trains or in passenger cross country or Intercity trains, others less intensively e.g. for shunting, civil engineering or on rural passenger lines or they just fulfil the function of supplementary tractive units. The latter is often the case for very old diesel tractive units that still appear in railway rolling stock statistics.

The majority of the railways in a questionnaire survey sent to UIC members in Europe confirmed that very old tractive units are used less intensively than younger ones. The results of this survey show that one third of locomotives and 7 % of railcar diesel engines are older than 35 years. Taking these ones into account the average age of diesel railcar engines is reported to be 16 years, for locomotives the average engine age is 27 years, again with a very large range of values for different European railway companies.

Emission factors for representative vehicles reported from UIC member railways are significantly lower for newer railcars and locomotives (classified as those that entered service after 1990) compared to older ones, however with a rather high range of values. This is in accordance to the development of the UIC emission requirements with stricter limit values from stage to stage.

As SO_2 emissions are directly related to the sulphur content of the fuel and a low sulphur content is a prerequisite for some exhaust after-treatment measures, a questionnaire survey asked UIC members for the quality of the used diesel fuel. One quarter of the railway companies report that they already now use low sulphur diesel fuel with a maximum of 10 ppm sulphur content.

When asked about expectations for the future development of their diesel fleets, UIC members assumed that on average there would be a decline in the total numbers of vehicles in their entire diesel fleets, but that there would be an increasing number of diesel railcars. It can furthermore be noticed that for many new rail operators on the market, diesel traction offers more flexibility and a quicker route to some form of interoperability especially in cross-border traffic.

The main influencing parameters for scenarios to describe the future development of the diesel fleet in Europe are the life expectancy, or decommissioning age of the vehicles, and the anticipated market development for rail traffic (amended for diesel traction). Productivity development and the effects of market liberalisation have also been taken into account.

Based on basic assumptions for the different influencing parameters, it is expected that around 8 500 railcars, and between 9 000 new locomotives will be purchased in Europe between 2005 and 2020. However these values should be viewed as rough estimates as it was not possible within the scope of this study to carry out a very detailed assessment of the future development of the very complex rail diesel market.

2 Status of the diesel fleet in Europe

The aim of this chapter is to describe the existing railway diesel fleet in Europe as basis for the subsequent steps in the study. First, the relevance and role of diesel traction in different countries is examined in comparison to electric traction. Second, the composition of the diesel fleet is characterised in more detail.

The main focus of the analysis is on the UIC member railways, representing mainly the major, in most cases state owned railway companies, however rolling stock information from non-UIC railways is also taken into account (see chapter 2.2.1).

Table 16 (see Annex 4.1) lists the UIC member railways, the abbreviations used in the report and the members providing statistical data through the survey carried out as part of the study.

2.1 Relevance and role of diesel traction

The following evaluations make use of the official UIC statistic database Railisa with most recent data available from the different UIC members. Implausible and missing values have been corrected and estimated as far as possible to allow for analysing the relevance of diesel traction in Europe. Detailed validation of every value (e.g. at statistical departments of the companies) was not feasible within the time frame of the study. Nevertheless, the results allowed development of a suitable description of the relevance and role of diesel traction in different European countries.

2.1.1 Diesel traction share

When looking at the share of diesel traction in different European countries (***Figure 1***) it is obvious that diesel traction is the backbone of railway traffic in countries with little or no electrification of the railway network. This is the case for Baltic countries Estonia, Latvia and Lithuania as well as Ireland and Greece. In countries with a major proportion of electrification, diesel traction is normally used less intensively than electric traction. Non-electrified lines of them have often a low traffic density, for example feeder lines to shunting yards for freight traffic or rural lines for passenger traffic. The main corridors with high traffic density in these countries are mostly electrified.

An example with no regular diesel traffic occurring can be found in Switzerland, which has a fully electrified railway network. Diesel locomotives are only rarely used for some maintenance and shunting operations.

The average diesel traction share for all covered countries is approximately 20 % based on the operating performance. The average share of non-electrified railway lines is approximately 50%.

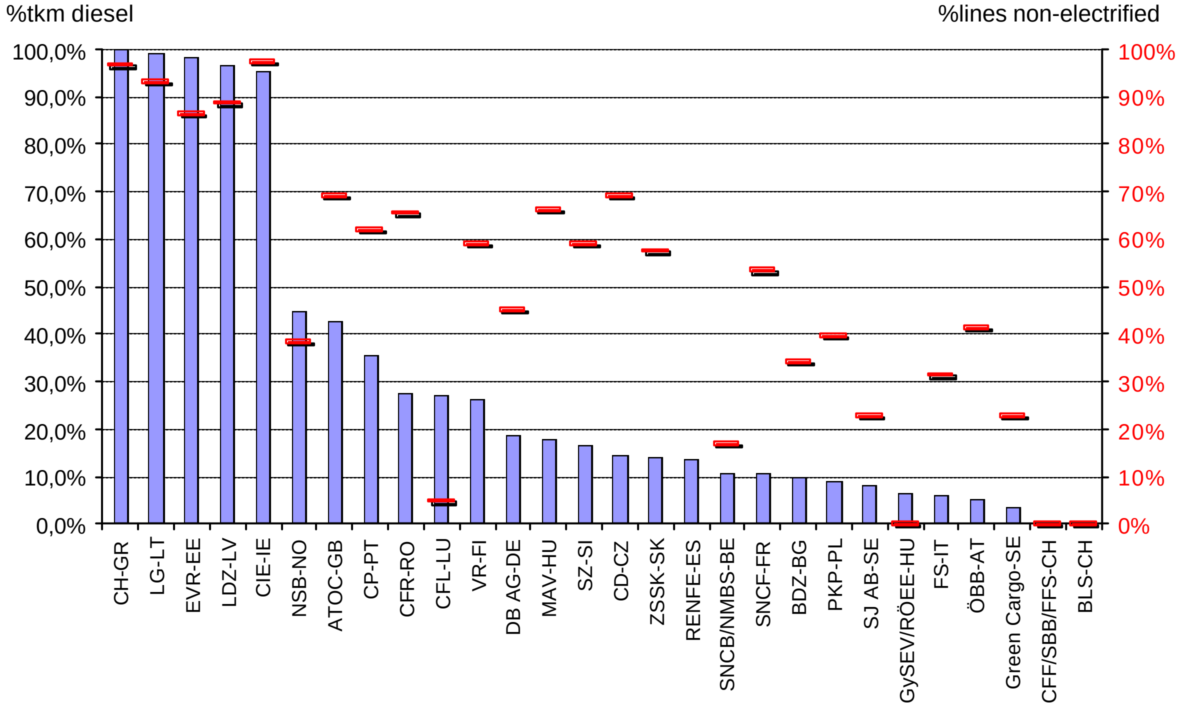


Figure 1: Share of diesel of overall operating performance in gross-tkm hauled (left axis, blue bars) & share of kilometres non-electrified (right axis, red lines)[1] (Source: UIC statistics)

It should be noted for ***Figure 1*** that the percentage of diesel traction is based upon the operating performance displayed in gross-tkm hauled. This unit describes the load hauled in tonnes (without the weight of a locomotive) times the kilometres. This value allows for a combination of both passenger and freight traffic in one unit, in contrast to traffic performance values like passenger-km in passenger traffic or net-tkm in freight traffic.

An alternative unit is running performance in train-km. Using this measure, a small railcar running one kilometre would count the same as a very long freight train running one kilometre. Thus the running performance gives a good figure for train movements, the gross-tkm hauled are more linked to the work performed by the tractive unit and consequently to the energy consumption and exhaust emission, that are the main focus of the study.

2.1.2 Absolute performance of diesel traction (UIC-member railways)

Despite of having a diesel traction share below 20 %, companies like DB AG (Germany) and SNCF (France) end up with comparably high absolute diesel operating performances simply due to their size (Figure 2). Furthermore railways in the Baltic countries and Great Britain show above-average diesel operating performance values. Smaller companies with a minor diesel traction share, such as SJ AB (Sweden), CFL (Luxembourg) or NS (Netherlands) contribute to a very low extent to the overall European operating performance with diesel traction.

[1] Data not for every country available in UIC statistics

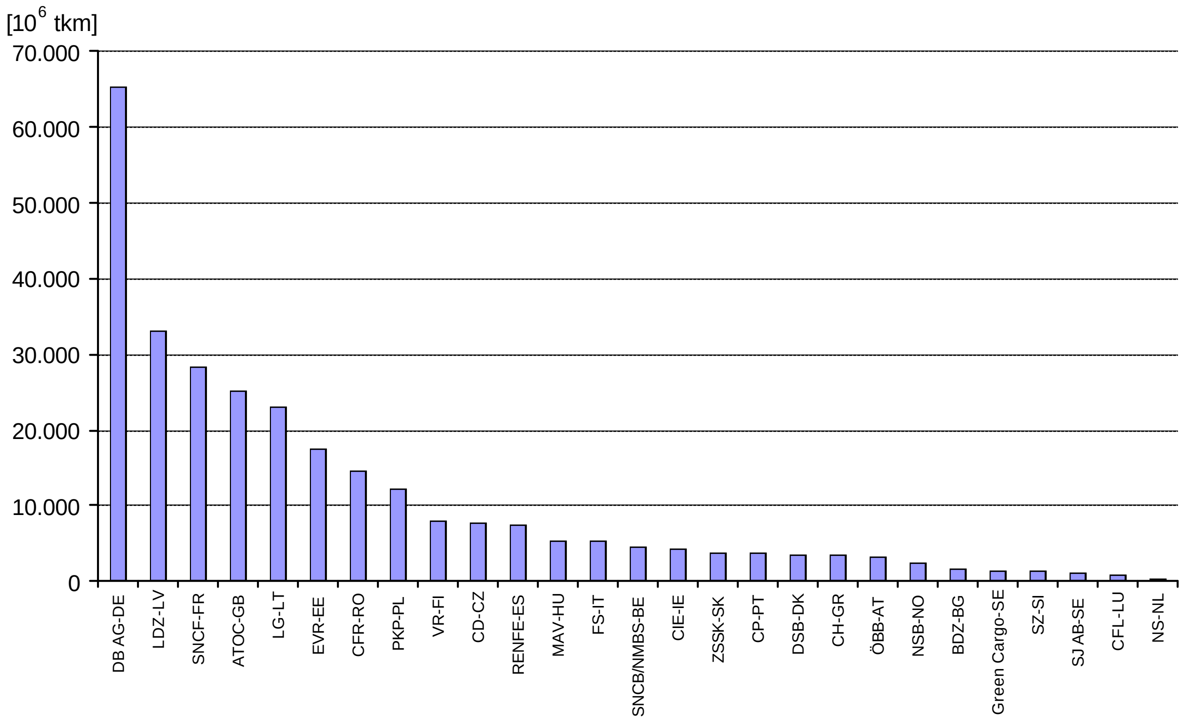


Figure 2: Operating performance of different European railways in gross-tkm hauled (Source: UIC statistics)

The importance of the new EU Member States can be seen in ***Figure 3***, as they account for more than one third of the European diesel operating performance with just 16 % of the enlarged Europe's population. The UIC member railways in EU 15 represent nearly 60 %, the other non-EU member countries covered in the study (Norway, Switzerland, Bulgaria and Romania) fill out the missing 7 %, with 5 % from Romania.

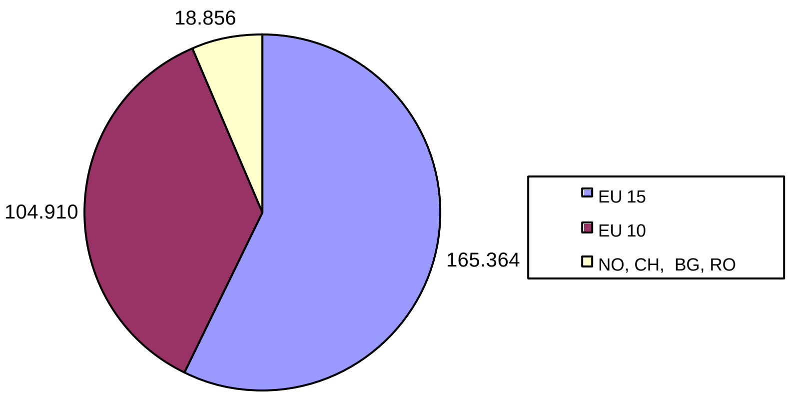


Figure 3: Diesel operating performance in gross-tkm hauled for EU 15, EU 10 (New EU members) and Norway, Switzerland, Romania, Bulgaria (Source: UIC statistics)

Comparable conclusions can be drawn when looking at the running performance measured in train-km with diesel traction (***Figure 4***). Compared with ***Figure 2*** companies with a lot of diesel passenger traffic like DB, SNCF or the ATOC companies rank relatively higher than countries with a high share of diesel freight traffic. An example for the latter are the Baltic countries with a high percentage of heavy diesel freight trains as displayed in ***Figure 5***. This figure shows the distribution of the diesel operating performance for passenger and for freight traffic in different European railway companies. A comparable figure is shown in ***Figure 6***, based on the running performance.

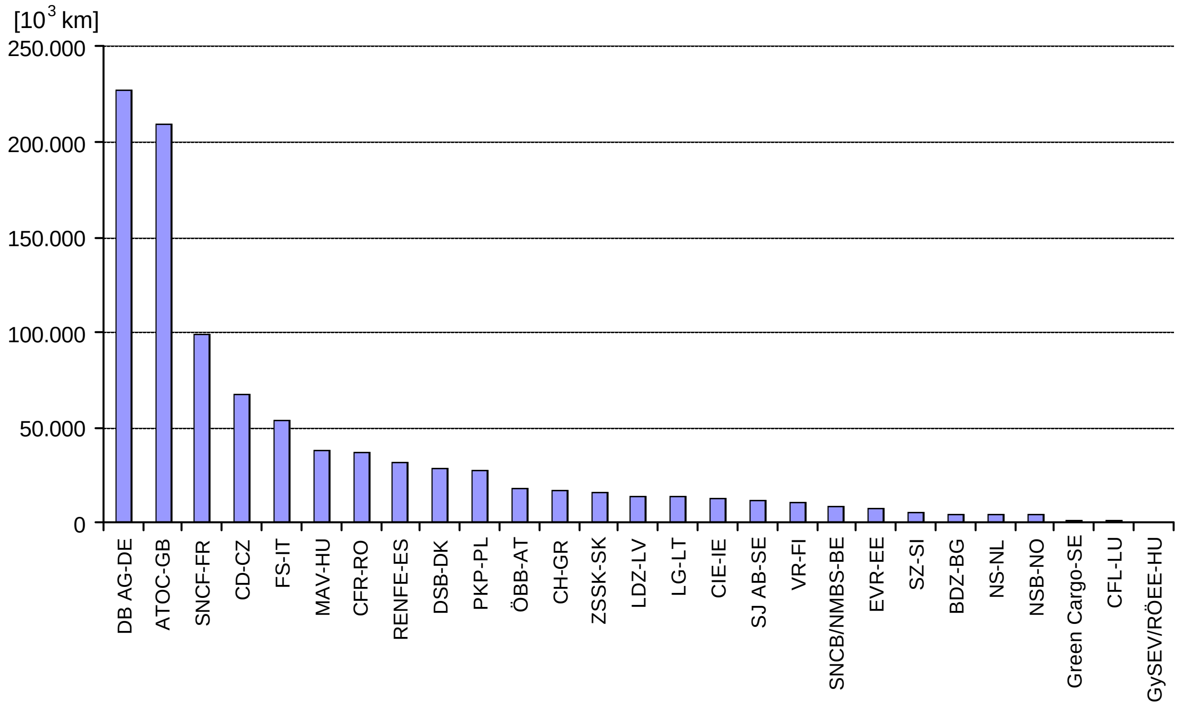


Figure 4: Diesel running performance of different European railways in train-km (Source: UIC statistics)

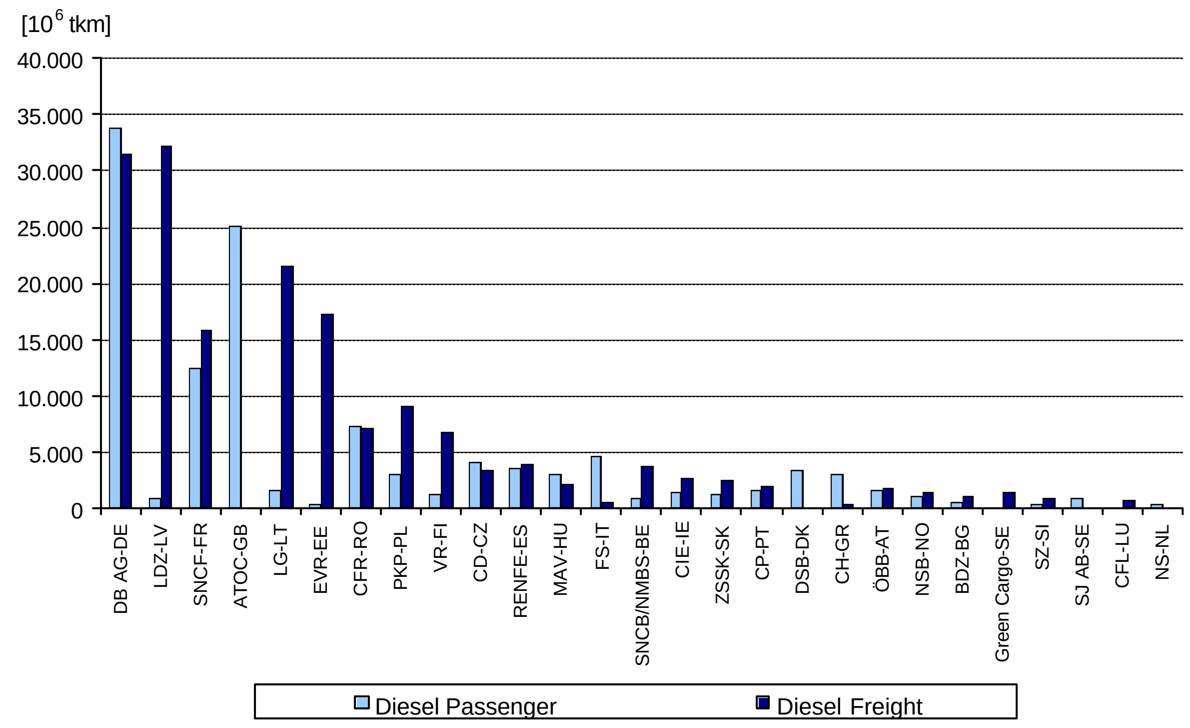


Figure 5: Diesel operating performance (gross-tkm hauled) differentiated by passenger and freight (Source: UIC statistics)

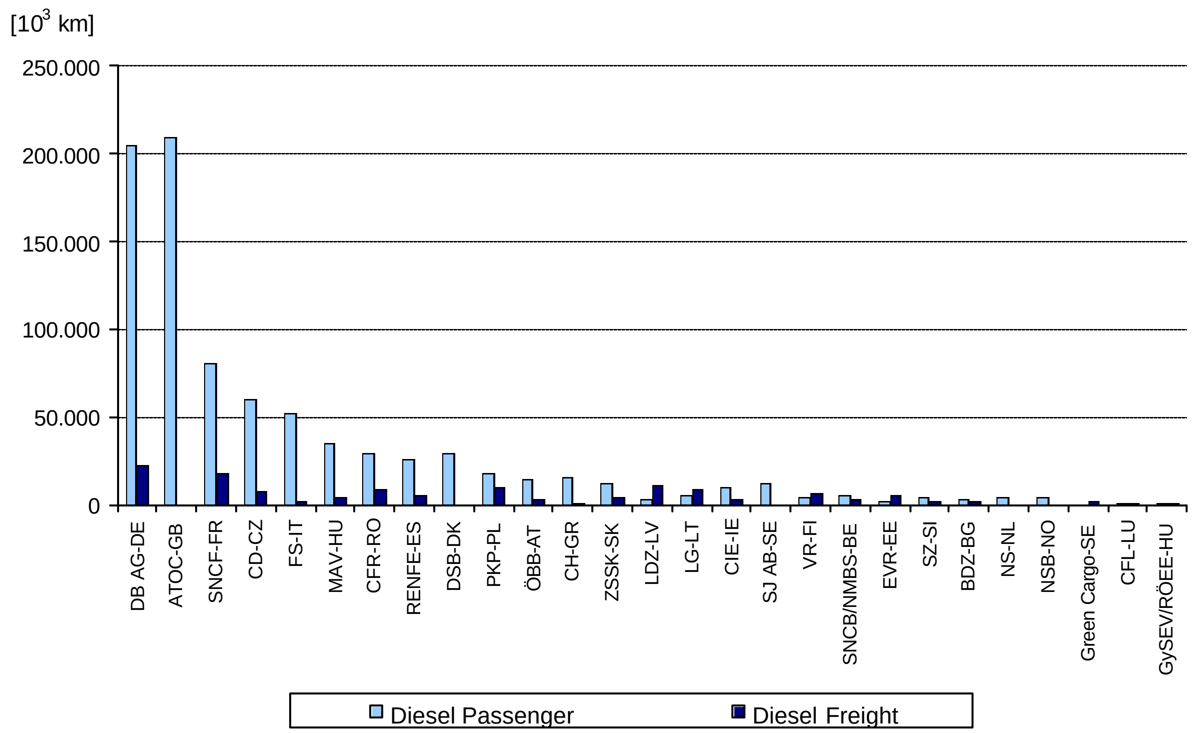
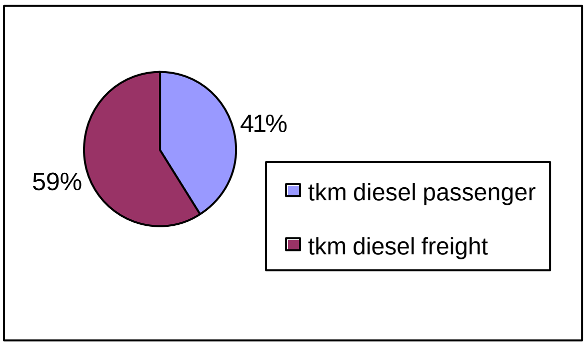


Figure 6: Diesel running performance (train-km) differentiated by passenger and freight (Source: UIC statistics)

The average for the covered companies share of diesel freight traffic is 59 % of the operating performance in gross-tkm and 13 % of the running performance in train-km (***Figure 7***). This means that in Europe more tonne-km are hauled by diesel traction in freight traffic than in passenger traffic but the diesel train movements, described by the train-kilometres, are much higher in passenger traffic.

However, the share between diesel freight and passenger traffic in single railway companies can differ significantly from these average values.



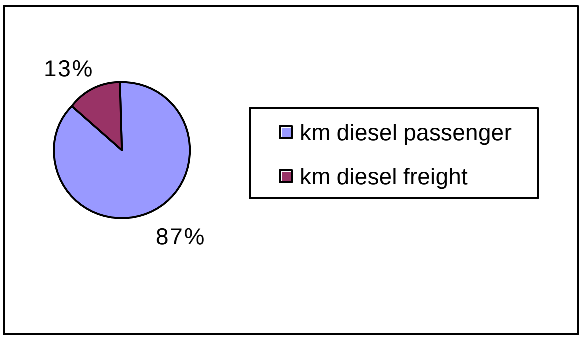


Figure 7: Share of diesel passenger and freight traffic (left: based on gross-tkm hauled, right: based on train-km) (Source: UIC statistics)

When considering passenger traffic, on average over 70 % of all train-km in UIC statistics have been performed by railcars, less than 30 % by locomotives with a high range of values depending on the company (***Figure 35*** in annex 4.2.). From the diesel locomotives in average 64 % of the train-km were performed for passenger, 36 % for freight traffic (***Figure 36*** in annex 4.2.).

2.1.3 Running performance per train traffic

The intensity of use of the tractive units can be estimated through dividing the running performance with diesel traction by the number of diesel tractive units in each company. In ***Figure 8*** the solid bars show the average train-km per tractive unit for diesel locomotives and railcars compared to an average value for electric traction. (Line bars indicate the ranges of values for different companies). In particular, diesel locomotives (around 20 000 km per tractive unit) are on average used much less than their electric counterparts. This is mainly due to their use for feeder traffic on rather short and sparsely used lines. Furthermore this very low value could also be a result of a high number of locomotives appearing in statistics, although no longer in intensive use, but rather having the function of supplementary tractive units, being used as shunting or as civil engineering locomotive.

As indicated with the span between the minimum and maximum values in ***Figure 8*** the running performance per tractive unit can differ significantly between the different railway companies. The company specific values are displayed in the annex, ***Figure 37 - Figure 39***, with for example the upper limits of about 220 000 km per railcar at SJ in Sweden and 230 000 km per diesel loco at ATOC in the UK.

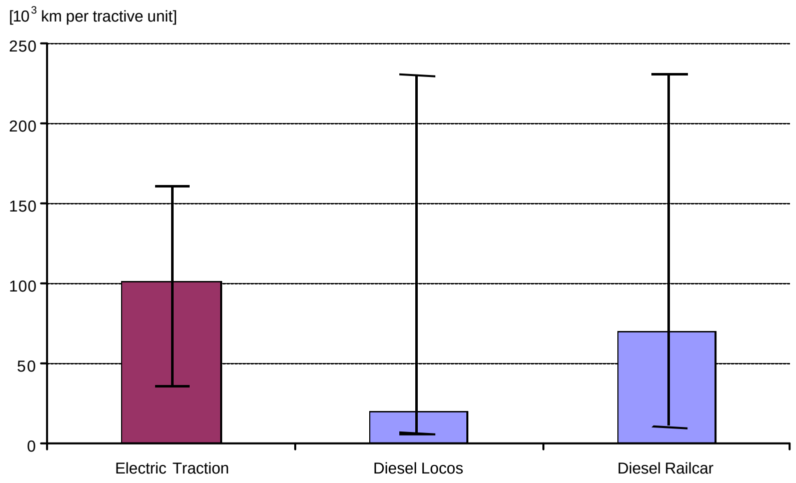


Figure 8: Average annual running performance (train-km) per tractive unit plus indicated minimum and maximum value (Source: UIC statistics)

2.1.4 Wagon-load per train in freight traffic

Another figure to describe the role of diesel traction is the average wagon load per freight train, calculated by dividing the gross-tkm hauled by the train-km. ***Figure 9*** shows the average values for electric and diesel freight traffic. Whereas an electric freight locomotive hauls on average about 1070 tonnes in Europe, an average diesel freight locomotive hauls around 2850 tonnes in the Baltic countries and around 720 tonnes in the other European countries. The broad span of values indicated in ***Figure 9*** can also be seen in ***Figure 40*** in the annex with the individual company values. Whereas in the Baltic countries diesel traction is used for very heavy bulk good trains also on main lines, it is in most other countries used more for feeder traffic. As result the wagon-loads per diesel train are lower than for electric trains. Furthermore there are higher wagon-loads possible in the Baltic state with different couplings and bigger structure gauges.

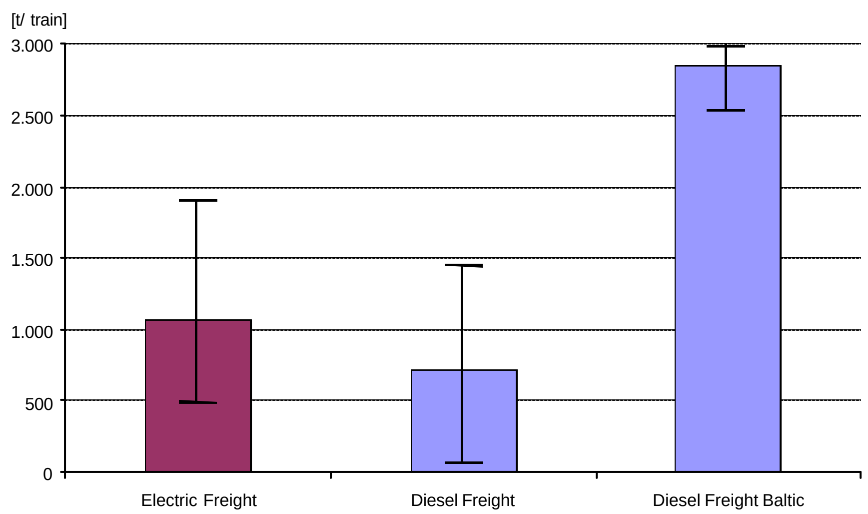


Figure 9: Wagon load (tonnes) per freight diesel train for electric and diesel traction as average and range in Europe (without Baltic nations) and in the Baltic nations. (Source: UIC statistics)

2.2 Characterisation of European diesel fleet

The following chapter describes the composition of the railway diesel fleet in Europe. The evaluation mainly utilises the feedback on a questionnaire survey of UIC members, supplemented by UIC statistic values and additional sources for non-UIC railway companies. In February 2005 this questionnaire to collect fleet details was sent out to 35 UIC member railway operating or integrated companies in Europe. 26 companies answered the questionnaire, covering most major railway companies in Europe (see annex 4.1). Fleet data from ATOC members in UK have been in this context aggregated for one value. The questionnaire with a summary of answers to each question can be found in the annex 4.5.

Additional to the absolute number of diesel engines there is other detailed information concerning power and age distribution available in the questionnaire survey data. Therefore the analysis in chapter 2.2.2 - 2.2.4 will mainly be based on this source.

2.2.1 Absolute number of diesel vehicles (including rolling stock information from non-UIC sources)

Based on the UIC statistics there are around 17640 diesel locomotives and 8775 diesel railcars in operation in UIC member railways (company specific values can be found in ***Figure 41*** in annex 4.4).

A railcar is a self-propelled railway vehicle designed to transport passengers. The term 'railcar' is usually used in reference to a train consisting of a single powered carriage (including driver's cab and seats for passengers), that may be used on its own, or that may be coupled to unpowered trailing carriages. Powered railcars may also be coupled together to form multiple unit trainsets consisting of two or more powered railcars. When powered by diesel engines, these are referred to as DMU (diesel multiple unit) trainsets. In many cases, such trainsets are always used in a fixed configuration that has more than one powered railcar. For example, in the UK, the Class 180 Adelante DMU trainset consists of five carriages, each of which has its own engine. This trainset is never split up to operate with fewer than five carriages, and for the purposes of the vehicle statistics presented in this report, such a trainset is considered as one vehicle. Where a single railcar is used to pull unpowered carriages, this is also considered as a single vehicle. However, in calculating the total number of engines in a trainset, it is clear that for the Class 180 Adelante trainset, there are five engines per trainset, and this factor is taken into account. For the purposes of this study, single railcars and DMU trainsets have been considered together, but in estimating the total number of railcar/DMU engines, it has been necessary to take into account the total number of engines in each trainset.

To crosscheck these UIC values additional the two sources Jane's World Railways (JWR) and statistics from www.Railfaneurope.net (RFE) have been used, showing a comparable vehicle proportion of one third for railcars and two thirds for locomotives (see ***Table 1***). Compared to UIC statistics, the absolute numbers of JWR and RFE are about 5-15 % lower. Possible reasons for this differences could be on one hand that UIC statistic data still contains vehicles that are no longer in use, or on the other hand that JWR and RFE do not cover all existing vehicles.

UIC member diesel vehicle numbers Source:	Locomotives	Railcars / DMU trainsets
UIC statistics	17640	8775
Share	*67 %*	*33 %*
Jane's World Railways	15402	7775
Share	*66 %*	*34 %*
Railfaneurope.net	16989 (9773 Mainline, 7216 Shunting)	7453
Share	*70 %*	*30 %*

Table 1: Number of diesel locomotive and railcar vehicles in UIC-members fleets (Sources: UIC statistics, Jane's World Railways (2004-2005), Railfaneurope.net)

As for the emission behaviour of the vehicles and possible emission abatement technologies that are subject of this study the number of diesel engines are more relevant as the number of diesel vehicles, the UIC questionnaire asked for number and characteristics of diesel engines. Within the covered companies 15844 diesel locomotive and 11074 diesel railcar engines have been reported (see ***Table 2***).
As there is often more than one engine in a railcar the proportion of railcar engines in the survey is higher than railcar vehicle numbers from UIC statistics.
To compare the questionnaire values for engines with the values for vehicles in ***Table 1*** the number of diesel railcar vehicles were corrected in ***Table 2***, assuming an average of 1.7 engines per railcar resp. diesel trainset. For locomotives it was assumed that there is always one engine per locomotive. All sources show an average proportion of 54 % - 59 % locomotive and 41 % - 46 % railcar engines.

UIC member diesel engine numbers Source:	Locomotive Engines	Railcar Engines
Questionnaire survey (not all railways	15844	11074
covered!) *Share*	*59%*	*41%*
UIC statistics (as calculation basis)	17640	14887
Share	*54%*	*46%*
Jane's World Railways (as calculation basis)	15402	13218
Share	*54%*	*46%*
Railfaneurope.net (as calculation basis)	16989 (9773 Mainline, 7216 Shunting)	12670
Share	*57%*	*43%*

Table 2: Number of diesel locomotives and railcar engines in UIC-members fleets (Sources: questionnaire survey, UIC statistics, Jane's World Railways (2004-2005), Railfaneurope.net)

Although the values show a rather consistent proportion between locomotives and railcars on average in Europeans diesel fleet, this value can differ significantly from company to company (see ***Figure 42*** in annex 4.4): from 94 % railcars at DSB (Denmark) to 0 % at ZSSK Cargo (Slovakia), CFF/SBB/FFS (Switzerland) and EVR (Estonia).

Additional to the number of locomotives and railcars from UIC members there are around 2500 locomotives and 1200 railcars from non-UIC member railways in the covered countries, based on statistics from Jane's World Railways 2003-2004 (see ***Table 3***). Locomotive and railcar vehicle proportions are similar to those from UIC statistics.

Non- UIC member diesel <u>vehicle</u> numbers Source:	Locomotives	Railcars / DMU trainsets
Jane's World Railways	2474	1184
Share	*68 %*	*32 %*
Railfaneurope.net	2917 (1958 Mainline, 959 Shunting)	1945
Share	*60 %*	*40 %*

Table 3: Number of diesel locomotive and railcar vehicles in non-UIC member fleets (Sources: Jane's World Railways (2004-2005), Railfaneurope.net statistics)

Compared to the JWR data statistics from www.Railfaneurope.net (RFE) show a higher proportion of railcars compared to locomotives. The number of railcars are with 1945 significantly higher than in JWR with 1184 railcars, whereas the locomotives are with 2917 just 18 % more than in JWR. As the RFE values for UIC-members are lower, these differences could be due to lower accuracy in tracking changes to stock between UIC and non-UIC fleets. However, RFE statistics do also show the split between mainline and shunting locomotives.

Table 4 shows the calculated number of diesel engines from non-UIC members assuming as above in average 1.7 engines per railcar resp. diesel trainset.

Non- UIC member diesel <u>engine</u> numbers Source:	Locomotive Engines	Railcar Engines
Jane's World Railways (as calculation basis)	2474	2013
Share	*55 %*	*45 %*
Railfaneurope.net (as calculation basis)	2917 (1958 Mainline, 959 Shunting)	3307
Share	*47 %*	*53 %*

Table 4: Number of diesel locomotive and railcar engines in non-UIC member fleets (Sources: Jane's World Railways (2004-2005), Railfaneurope.net statistics)

2.2.2 Engine power distribution

In the questionnaire the number of vehicles in the power categories used in the Non Road Mobile Machinery Directive (amended through 2004/26/EC) was requested.

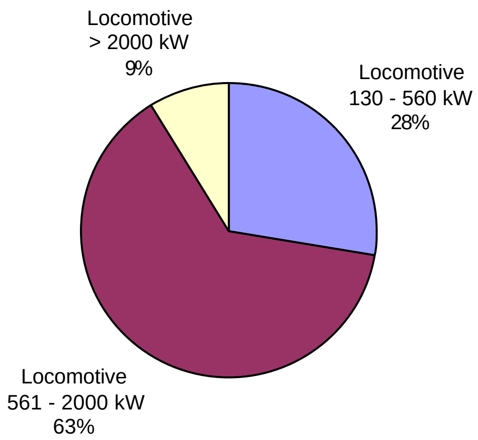


Figure 10: Engine power distribution for locomotives (Source: questionnaire survey)

Most locomotive engines (63 %) are powered with 561-2000 kW and a smaller proportion below 560 kW (28 %). Just 9 % of the locomotive engines are above 2000 kW.

For railcars a clear trend towards more powerful engines can seen from the questionnaire results (see summary of question A4.1 in annex 4.5.). For locomotives a trend to more powerful engines was reported in just in one third of the companies. The named age categories are not very helpful to differentiate between shunting and main line locomotives as the middle power class contains certainly shunting locomotives as well as mainline locomotives.

2.2.3 Average age and age distribution

The average age of diesel railcar engines from all reported countries is 16 years, for locomotives the average age is 27 years (***Figure 11***).

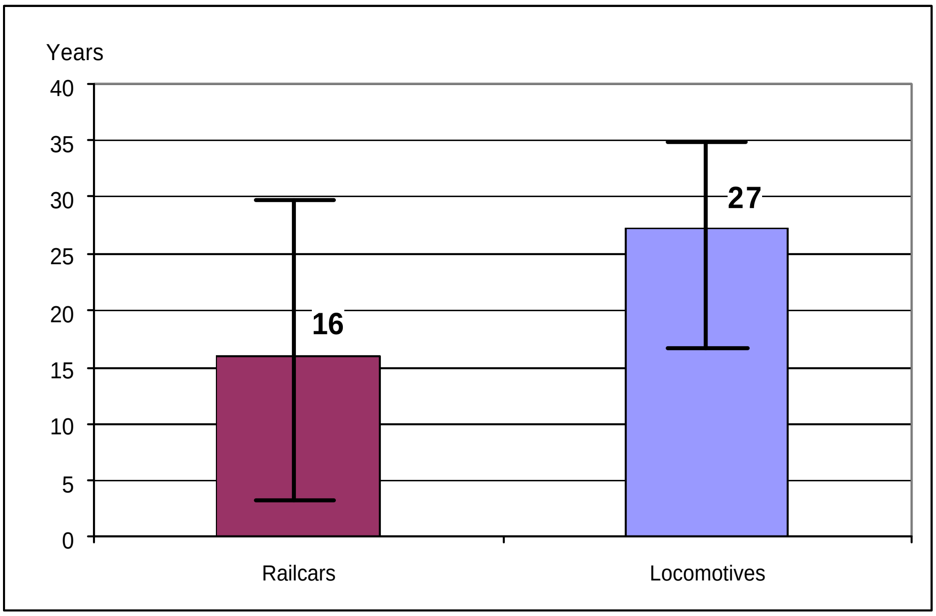


Figure 11: Average and range of age of diesel railcar and diesel locomotive engines in European railways (Source: questionnaire survey)

The results show that in the fleet the youngest railcar engines (on company's average) can be found with 3 years at SNCB (Belgium) and VR (Finland), the oldest at SZ (Slovenia) with about 26 years. The maximum value of 30 years is due to just 4 very old railcars in the fleet of the freight operator CFR Freight (Romania) and 2 railcars at ZSSK Cargo (Slovakia). For locomotive engines the span is from 17 years on average for the CFF/SBB/FFS (Switzerland) up to 35 years at SNCF (France), VR (Finland) or NSB (Norway) (***Figure 43***, annex 4.4).

Figure 12 and ***Figure 13*** show the age distribution for diesel railcars and locomotives. Whereas for railcars more than 50% of the engines are younger than 15 years (>=1990), it is just 20% for locomotives. One third of the locomotive and 7 % of the railcar engines are older than 35 years (1969 and older). However, it can be assumed that the very old vehicles are used much less intensively than more modern ones, confirmed by the majority of railways in the questionnaire responses (see summary of question A3.3 in annex 4.5). Engines older than 25-30 years are often used less intensively, although this depends a lot on the series and their reliability. There is often no formal reduced service. Newer locomotives are normally purchased with a defined application in mind and they are therefore used to cover this demand. This may lead to older locomotives (which are at the same time often less versatile, less powerful or less reliable than their new counterparts) being used less frequently.

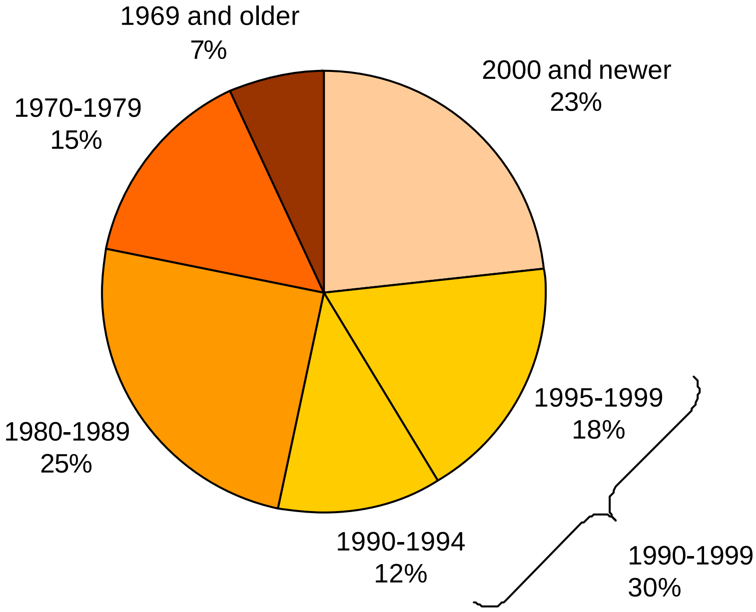


Figure 12: Age distribution of diesel railcar engines (Source: questionnaire survey)

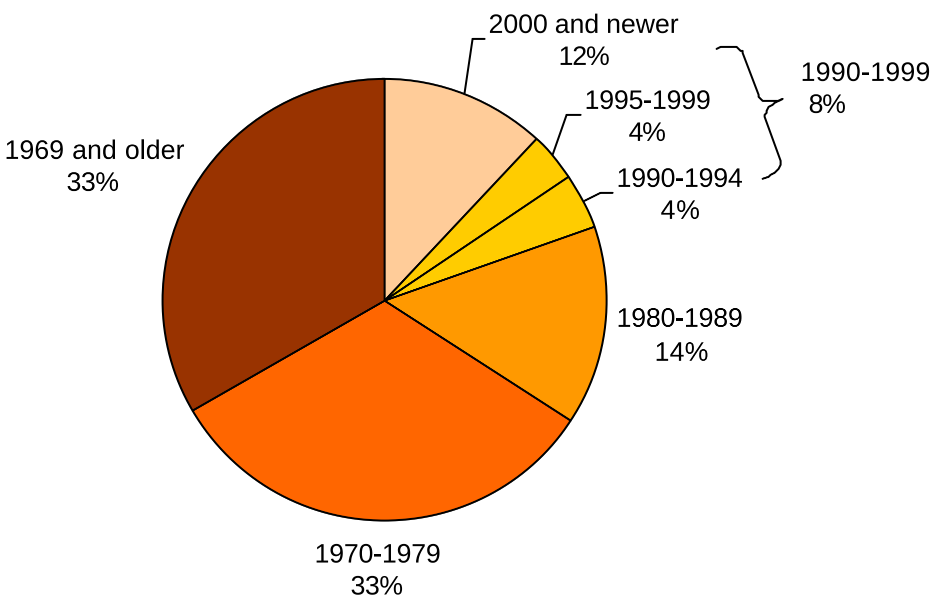


Figure 13: Age distribution of diesel locomotive engines (Source: questionnaire survey)

2.2.4 Re-engined tactive units

Re-engining in this study is defined by an engine being replaced by a different engine of a new design to that originally provided with a vehicle. Re-engining of diesel rolling stock with new modern engines can be an alternative to purchasing completely new vehicles. The results of the questionnaire showed that 18 out of 26 railway companies answering the questionnaire had done some kind of re-engining within their diesel fleet.

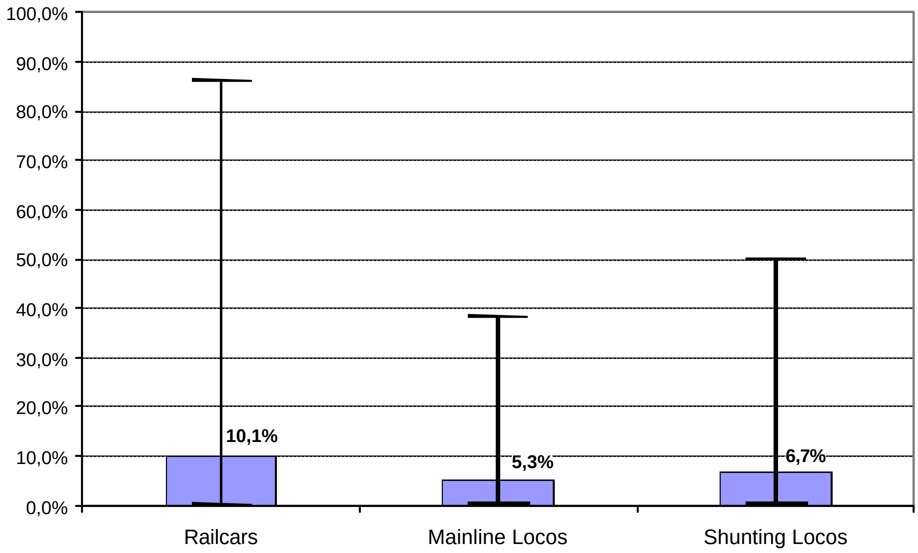


Figure 14: Percentage of engines being re-engined: average and range of individual railway values (Source: questionnaire survey)

The average of all the re-engining proportions of the companies that answered the questionnaire is between 5 % for main line locomotives and 10 % for railcars (***Figure 14***). High re-engining proportions can be found at MAV (Hungary), with 80 % of railcars, 10 % of mainline and 50 % of shunting locomotives being re-engined.

Furthermore more than 40 % of railcar engines are re-engined at ZSSK Cargo (Slovakia) and ÖBB (Austria). Mainline locomotives are re-engined in rather high percentages at ÖBB (Austria) with 38 % and at ATOC members (UK, average of the companies that answered the questionnaire) with 37 %. Re-engining quota for shunting locomotives are rather high at DB AG (36 %), FS (Italy) (29 %) and CFF/SBB/FFS (Switzerland) (22 %).

2.3 Energy consumption and exhaust emission

2.3.1 Diesel consumption

Absolute diesel consumption values are only available for a few railway companies in UIC statistics. Therefore estimation of consumption factors based on gross-tkm hauled are used to fill gaps in statistics, differentiated by freight and passenger locomotives and railcars. An estimated total of about 2 Mio tonnes of diesel is used yearly by the covered UIC-member railways.

The sum of all diesel consumption values reported in the questionnaire survey are around 1,5 Mio tonnes. This is divided between the different railway companies as shown in ***Figure 15***.

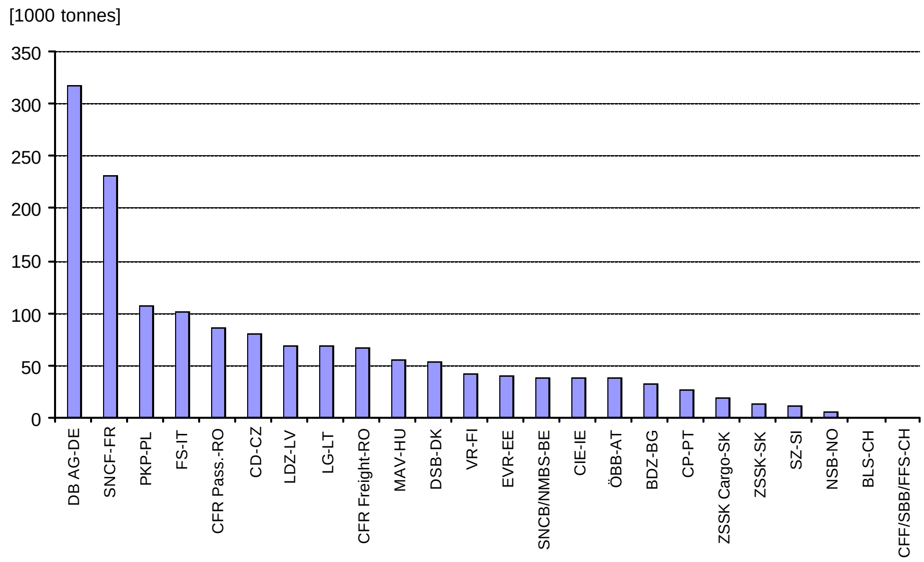


Figure 15: Diesel consumption in thousand tonnes of different railway companies (Source: questionnaire survey)

For describing the fuel efficiency of the diesel engines in operation, the railway companies were asked for diesel consumption values in g/kWh of engines in typical railcars, mainline and shunting locomotives of their fleet. The values presented have been calculated from 19 railcars, 30 mainline and 17 shunting locomotives. When comparing the average values for engines older than 1990 to the younger ones, a small decline of 3 - 4 % in fuel consumption can be seen for the newer railcars and shunting locomotives and more than 10 % for mainline locomotive engines (***Figure 16***).

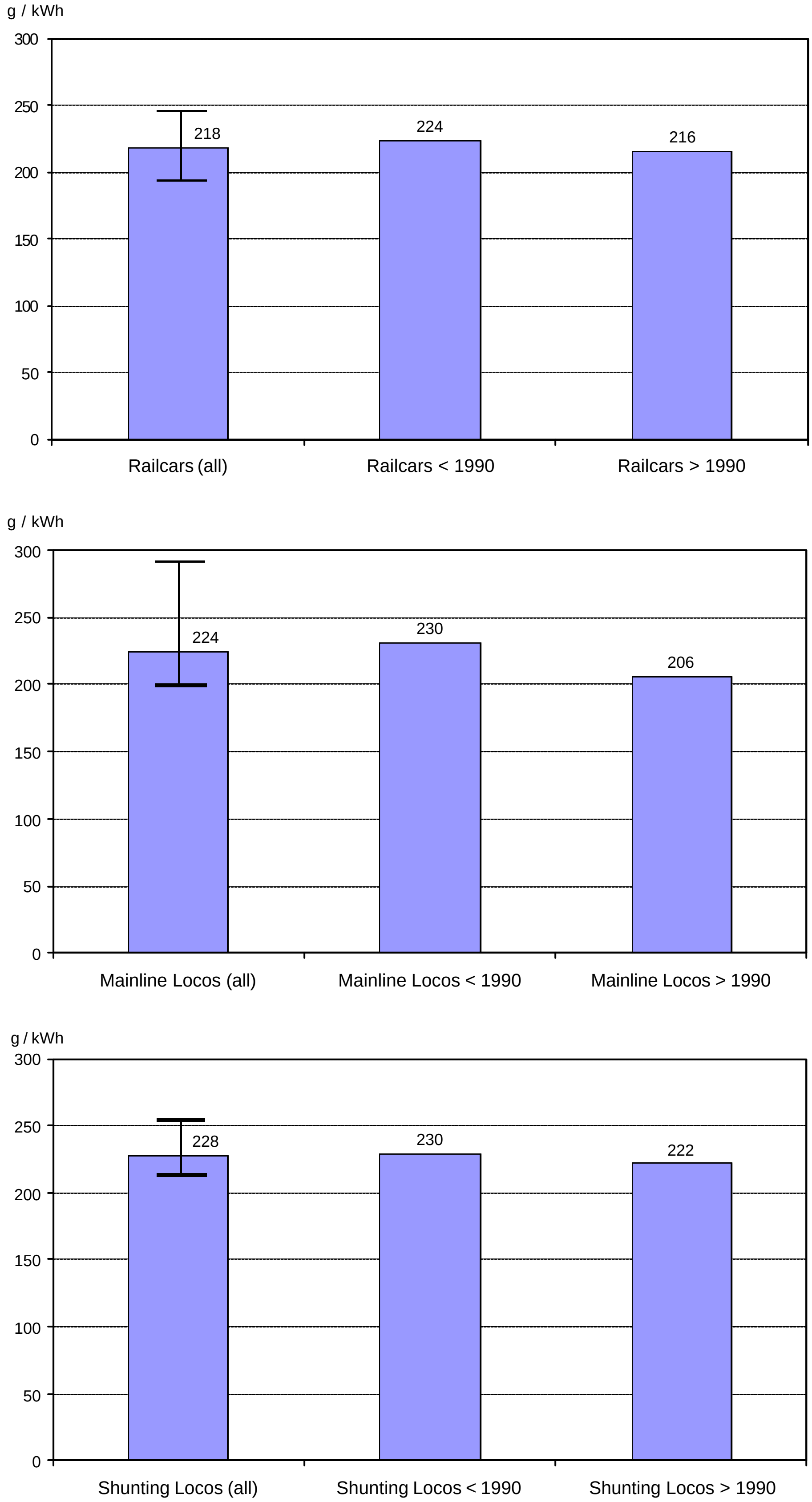


Figure 16: Average and range of diesel consumption factors (in g/kWh) for representative diesel railcar, mainline and shunting locomotive engines (Source: questionnaire survey)

2.3.2 Emission limit values

The UIC and its members have for many years had a homologation procedure for railway diesel traction units and the mandatory UIC technical leaflet 624 represents the current version ("UIC 2" in ***Figure 17***). The development of emission levels according to these railway standards has improved continuously for more than two decades (***Figure 17***).

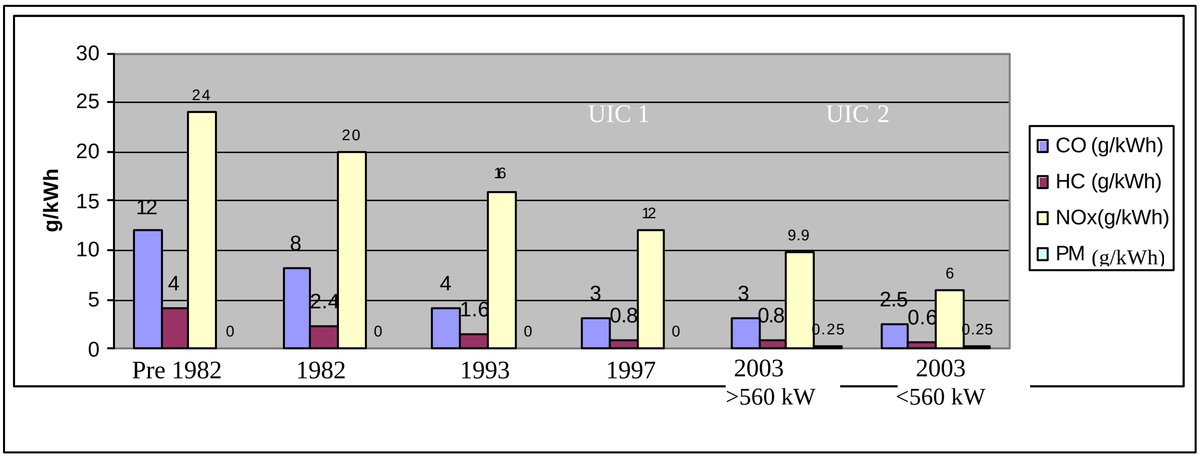


Figure 17: Development of the UIC requirements to diesel traction engines (1982 – 2003)

The UIC limit values are measured using the ISO Cycle F (60 % idling, 15 % intermediate, 25 % full power).

Future diesel exhaust emission standards for rail applications are regulated by the Non-Road Mobile Machinery Directive (amended by Directive 2004/26/EC) The amended Directive will regulate the limit values for new engines in diesel tractive units (railcars and locomotives) as listed in ***Table 5***.

Limit values according to NRMM Directive										
Stage	Category Net Power (P) (kW)		Pro-pulsion by	Limit values in force: Type approval from	Limit values in force: Placing on the market from	**CO** g/kWh	**HC** g/kWh	**NO$_x$** g/kWh	**PT** g/kWh	**Test cycle** (ISO 8178-4)
IIIA	RC A	P > 130 kW	Railcar	*01.07.2005*	01.01.2006	3,5	4,0		0,2	C1
	RL A	130 kW < P < 560 kW	Loco-motives	*01.01.2006*	01.01.2007	3,5	4,0		0,2	F
	RH A	P > 560 kW	Loco-motives	*01.01.2008*	01.01.2009	3,5	0,5	6,0	0,2	F
	RH A	P > 2000 kW and SV> 5l/cyl	Loco-motives	*01.01.2008*	01.01.2009	3,5	0,4	7,4	0,2	F
IIIB	RC B	P > 130 kW	Railcar	*01.01.2011*	01.01.2012	3,5	0,19	2,0	0,025	C1
	R B	P > 130 kW	Loco-motives	*01.01.2011*	01.01.2012	3,5	4,0		0,025	F

Table 5: Limit values according to the amended Non-Road Mobile Machinery Directive (2004/26/EC)

Stage III B of the Directive has to be reviewed before 31 December 2007. This review shall consider the available technology, including cost/benefits, with a view of the IIIB limit values for 2011/12. Further the application of test cycles for engines in railcars and locomotives and in the case of engines in locomotives the cost and benefits of a further reduction of emission limit values in view of the application of NO_x after-treatment technology shall be evaluated. Furthermore the need for a system for "in-use compliance" and possible options for its implementation shall be assessed (Article 2 of the Directive 2004/26/EC).

2.3.3 Emission behaviour of European fleet

Within the questionnaire the railway operating companies were asked to name and describe examples for representative vehicles of their fleet. As one of the characteristics the emission factors for NO_x as well as PM in g/kWh should have to be named for representative railcars, mainline and shunting locomotives. ***Figure 18*** shows the results out of 12 named railcars, 18 mainline and 11 shunting locomotives for the engines NO_x emissions in g/kWh, ***Figure 19*** for PM emission out of 9 railcars, 10 mainline and 7 shunting locomotives. The comparably low number of reported PM values is mainly due to often not available values in the unit g/kWh. PM values have been typically measured in the past in the unit “Bosch value”. The figures show a broad range of values with around +/- 50 % compared to the average NO_x and an even higher range for the PM emission factors. However, significantly lower values can be seen for the engines built after 1990 compared to those built before 1990.

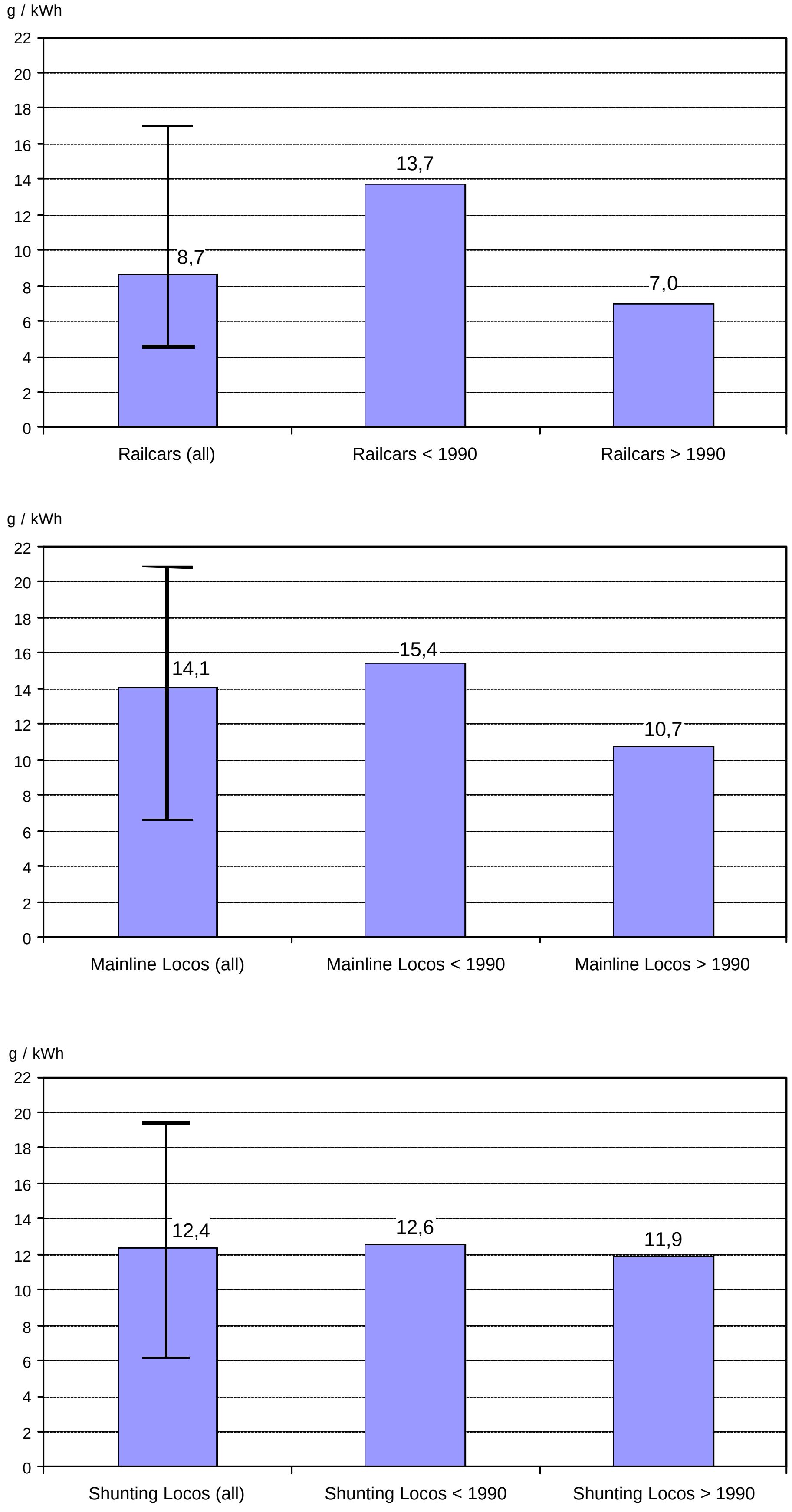


Figure 18: Average and range of NOx emission factors (in g/kWh) for representative diesel railcar, mainline and shunting locomotive engines (Source: questionnaire survey)

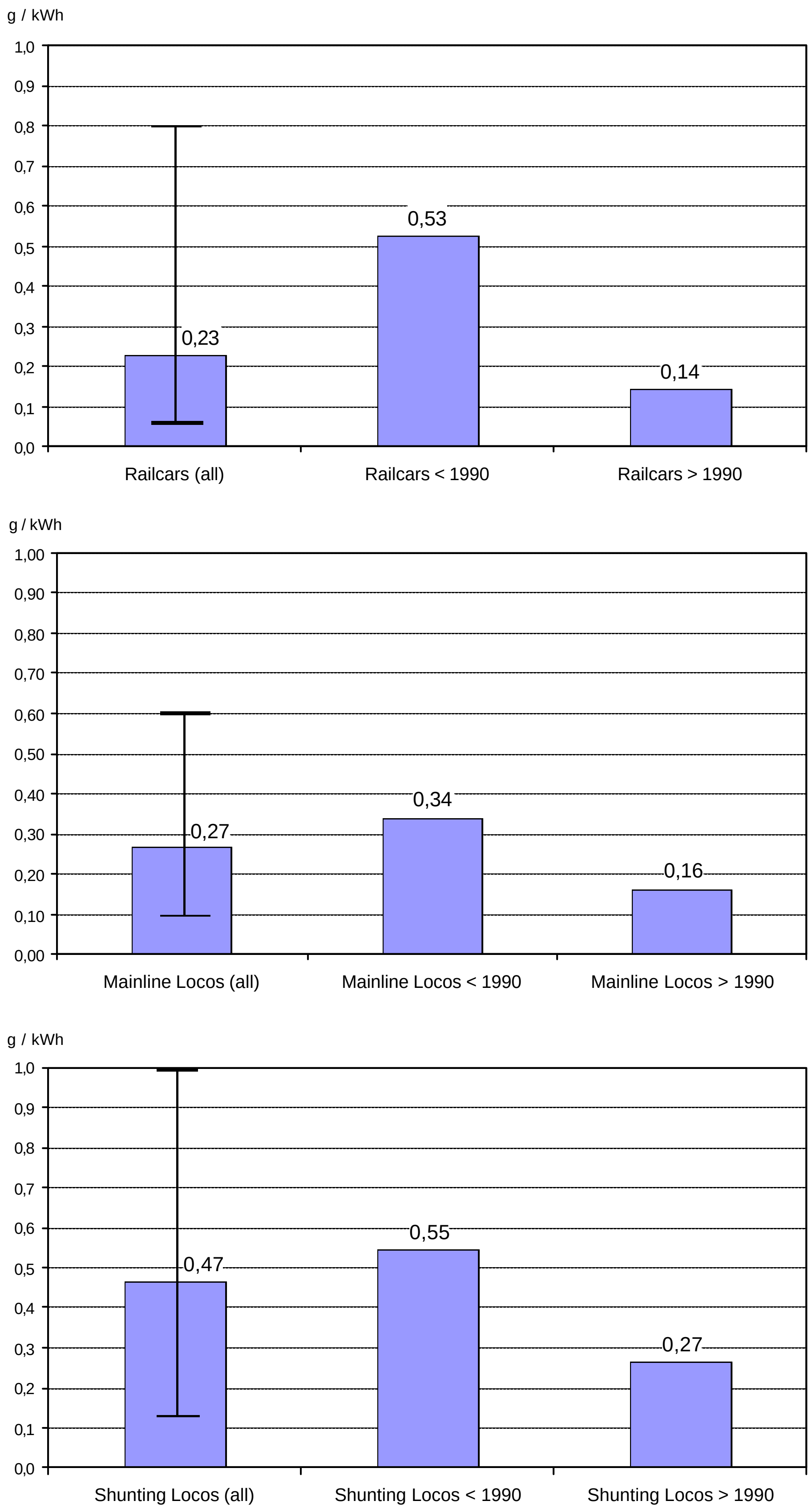


Figure 19: Average and range of PM emission factors (in g/kWh) for representative diesel railcar, mainline and shunting locomotive engines (Source: questionnaire survey)

2.3.4 Case study: Emission behaviour of DB's fleet

In the following section, some additional information describing the diesel fleet of DB AG (Germany) is provided. This has to be seen as one case study representing Europe's biggest diesel fleet company. Emission behaviour in other European companies could be similar, but could also differ significantly from this example. Conclusions on average European values should therefore be avoided.

The source of data is a project carried out with the German Federal Environmental Agency to determine emission factors for the diesel fleet. Values are either manufacturer data or measurement data using the ISO F cycle.

Figure 20 shows the average NO_x emission factors for DB's railcars and locomotives, ***Figure 21*** the average PM emission factors. When looking at the range of values indicated in the figures it is obvious that there can be quite big differences in between the different engines in operation. That is especially the case for the PM emission factors of locomotives that can be (for single engines) 8 times higher than for engines with the lowest factors. But this applies to rather old locomotives with high emission factors that are only used less intensively than newer models.

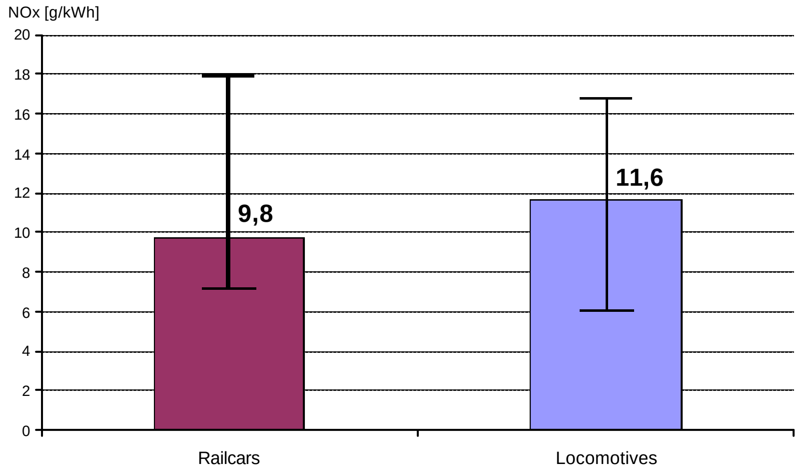


Figure 20: Average and range of NOx emission factors for DB diesel railcars and locomotives (Source: DB AG)

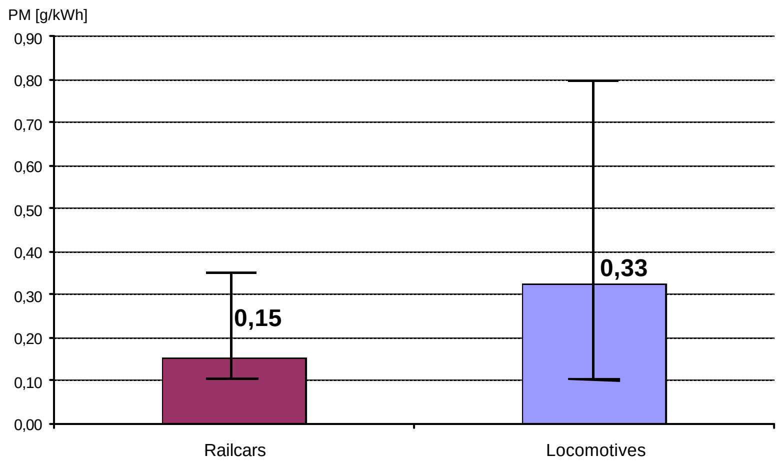


Figure 21: Average and range of PM emission factors for DB diesel railcars and locomotives (Source: DB AG)

The development of the emission factors with time shows a decline of the values, for NO_x from about 15 g/kWh before 1989 to about 9 g/kWh for engines younger than 2000 (***Figure 22***). For PM the decline from very high average values of the diesel tractive units before 1979 to the recent ones is even stronger (***Figure 23***). This goes in line with the development of the UIC values (***Figure 17***). However, it is important to take into account that there are age categories with many and some with just a few engines. The average emission factor of each age category is therefore based on a different number of existing engines. Also the composition of the fleet can differ, e.g. with relatively more railcar engines in the younger age categories.

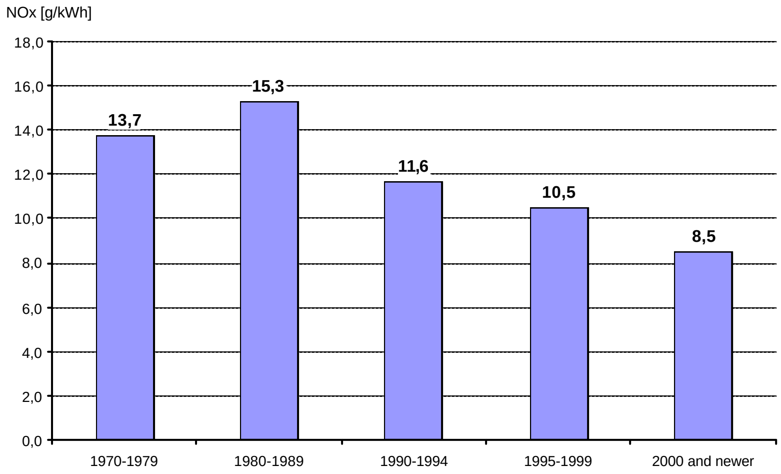


Figure 22: Average NOx emission factors for DB diesel tractive unit engines in different age categories (Source: DB AG)

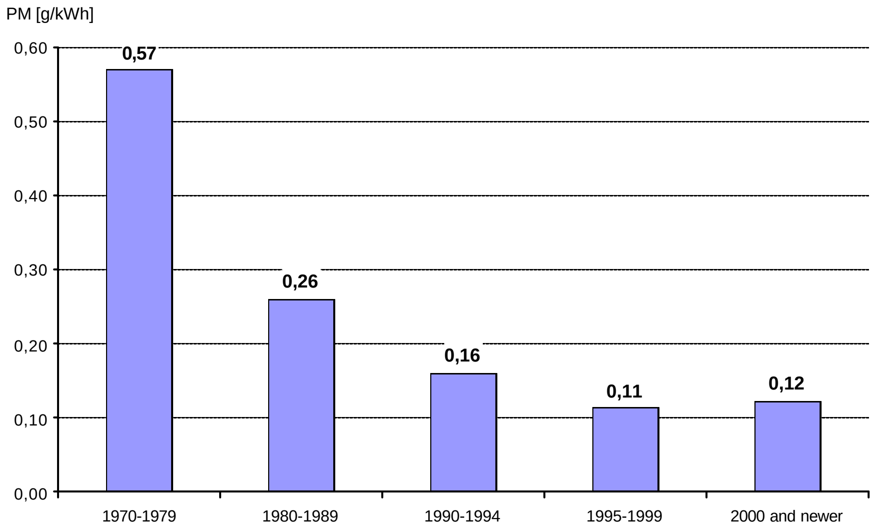


Figure 23: Average PM emission factors for DB diesel tractive unit engines in different age categories (Source: DB AG)

2.3.5 Sulphur content of diesel fuel

The sulphur content in diesel fuel is directly related to the SO_2 emission out of engine operation. A low fuel sulphur content is furthermore a prerequisite for some exhaust aftertreatment measures.

As of 2011, Non Road Mobile Machinery Directive 2004/26/EC introduces PM and NOX standards for railway engines (see chapter 2.3.2) that require on-highway engine and aftertreatment technologies to be transferred to non-road engines.
In order to meet those standards, an integrated systems approach of engine technology, aftertreatment systems and fuel quality is required. Therefore, the availability of fuel qualities that are compatible to those emission reduction technologies is a prerequisite for them to work under best possible conditions and keep their functionality over lifetime (durability and in-use compliance).
Furthermore the fuel quality by itself has a significant effect on engine emissions. The major contribution comes from sulphur that is reacting to sulphates during the combustion and the exhaust dilution process. Sulphates are one of the major components of Particulate Matter (PM). Consequently, the 2010 PM standard is likely to be exceeded at Sulphur levels above 20 mg/kg. In addition, reducing fuel sulphur will lower PM levels immediately across all engines already operating in the field.

The sulphur content of gas oil is regulated in the EU Directive 99/32/EC (amending 93/12/EEC). According to this directive Member States must ensure that gas oil (including gas oil for maritime use) is not used on their territory from:

- 1 July 2000 if the sulphur content is more than 0.20% by mass (=2000 ppm);
- 1 January 2008 if it is more than 0.10% by mass (=1000 ppm).

Fuels used in non-road mobile machinery and agricultural tractors are excluded from this definition, however.

Sulphur content of diesel fuel is regulated by EU Directives 98/70/EC and 2003/17/EC. ***Table 6*** shows the development of maximum sulphur content values of diesel fuel according to the named directives. Directive 98/70/EC states that "*For gas oils used for engines in non-road mobile machinery and agricultural tractors Member States may require the same sulphur content as defined for diesel fuels in this Directive or the sulphur content as defined for diesel fuels in Directive 93/12/EEC*".

	Maximum sulphur content in ppm
01.01.2000	350
01.01.2005	50
01.01.2009	10

Table 6: Sulphur content in diesel fuel (Source: EU Directives 98/70/EC, 2003/17/EC)

Lower sulphur content fuels are in some countries already in place before the dates named for mandatory introduction in the Directives. For example, in Germany the mineral oil industry is offering all diesel fuel with <10 ppm sulphur (also known as zero sulphur or sulphur free fuel) already since 01.01.2003 due to tax reasons. As railway fuel consumption is relatively low compared to road, the diesel fuel for railways has in this case the same properties as road diesel fuel.

DB AG in Germany is therefore one of the 28 % of railway companies using diesel fuel with at maximum 10 ppm sulphur (***Figure 24***) according to the questionnaire survey results.

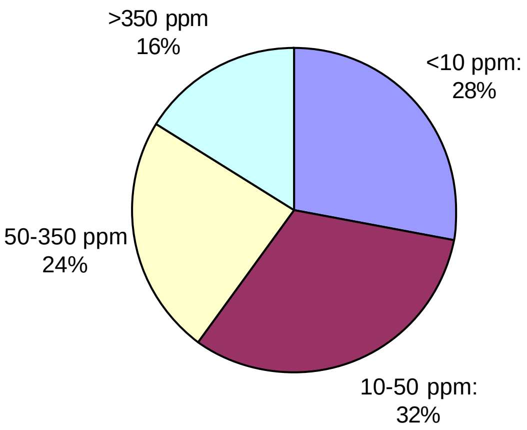


Figure 24: Percentage of companies in different diesel fuel sulphur content classes (Source: questionnaire survey)

3 Future development of the diesel fleet in Europe

Based on the information about the existing diesel fleet in the previous chapter and the answers collected from UIC-members within the survey about future expectations, possible scenarios for the future fleet development until 2020 are set up and described in the following sections.

3.1 UIC member's expectations for their fleet development

A basis for estimating the future development of the diesel fleet in Europe are the answers given by railway operators to the questions on how they expect their fleets to develop. For the total fleet, and especially for locomotives, only a small percentage of operators expect their fleets to increase in size. However, for railcars, 45 % of operators assume that their railcar fleets will increase in size, and just 20 % expect a decrease in the number of railcars in operation (***Figure 25***). The expectations for a growing number of diesel railcars is even more explicit when the answers given are weighted by the number of vehicles in each fleet. More than three quarter of the weighted companies expect an increasing number of railcars. This reflects the general trend towards using railcars instead of locomotives for passenger rail vehicles. Reasons for this trend to railcars are besides others that they allow complex routes with the possibility to couple and de-couple for optimisation of load factors according to changing passenger numbers on a route. Furthermore smaller passenger numbers especially in rural areas can be transported more flexible and with less vehicle weight resulting in lower fuel consumption compared to a heavy locomotive hauling just few wagons.

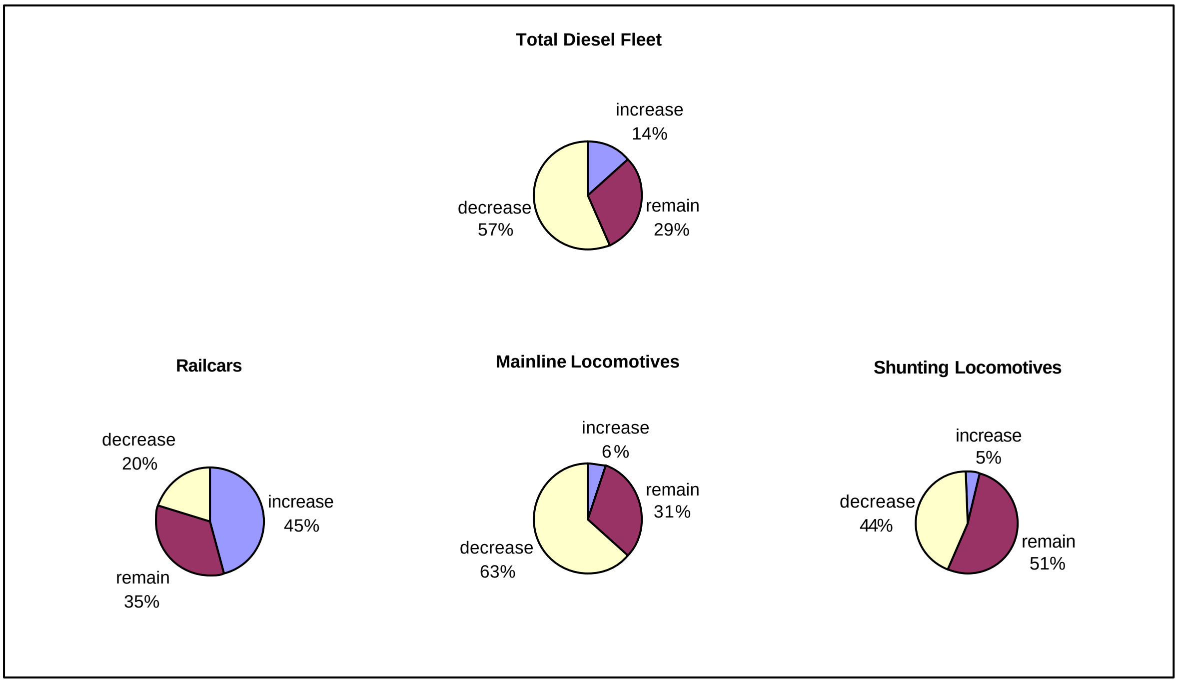


Figure 25: UIC-members' expectations for the development of their diesel fleets (Source: questionnaire survey)

However, it has to be taken into account that this data has only been obtained from UIC member railways. Many new rail operators are entering the market, and they will also take some of the market share of the incumbent railway operators. Where some UIC member railways have estimated that their diesel fleets could be smaller in the future, this could be due to expected higher market shares for new operators.

According to a study carried out by Vossloh and SCI (“Der Weltmarkt für Bahntechnologie”, 2003, on www.vossloh.com), around 200-250 new diesel railcars are manufactured and delivered to railway operators every year in Western Europe. Whereas there is already a high share of new vehicles in the fleets of state owned railways in central and northern Europe, and in the fleets of many private operators, in Southern and Eastern European countries there is still a high demand for modern diesel railcars.

Other reasons for the expected decrease in the size of diesel fleets could be due to plans for electrification, or for increased productivity of the existing fleet meaning a more effective use of the existing vehicles. Furthermore diesel traction is often used for, in many cases, economically less attractive feeder traffic, a shift of feeder traffic to the road, and a concentration on more attractive long distance rail traffic (often on electrified routes) would also mean a reduction in the number of diesel tractive units needed.

Operators were also asked whether they planned to move towards using higher or lower powered engines for their fleets in the future (see ***Figure 26***). The majority of operators (53 %) believed that for railcars, they would be using higher powered engines in the future, whilst for mainline locomotives, the majority (64 %) indicated that the engine power would remain the same in future. No operator expects decreasing engine powers for mainline locomotives. For shunting locomotives, 68 % of operators believed that their future fleets would use engines of broadly the same power as now, with 23 % expecting to use higher power engines.

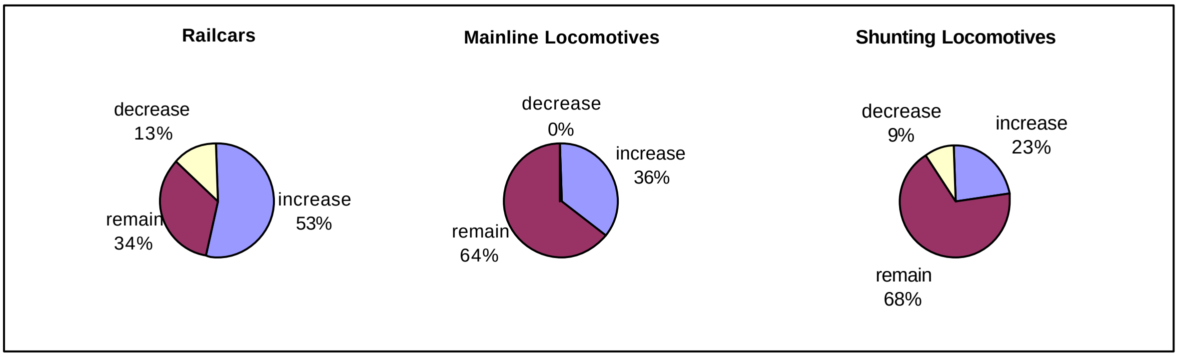


Figure 26: UIC-members’ expectations for future engine power (Source: questionnaire survey)

When weighting the answers by the number of railcars, resp. locomotives of the companies, the expectations for a growing engine powers for railcars with nearly 90 % of the weighted answers are even more obvious. For locomotives the answers show a comparable distribution.

Although just a minor percentage of the diesel fleet has so far been re-engined with engines of a newer design (***Figure 14*** in chapter 2.2.4), about half of the operators surveyed plan to re-engine at least part of their locomotive fleet in the next 10 years. For railcars, just one third of the responding operators stated that they have re-engining plans (***Figure 27***).

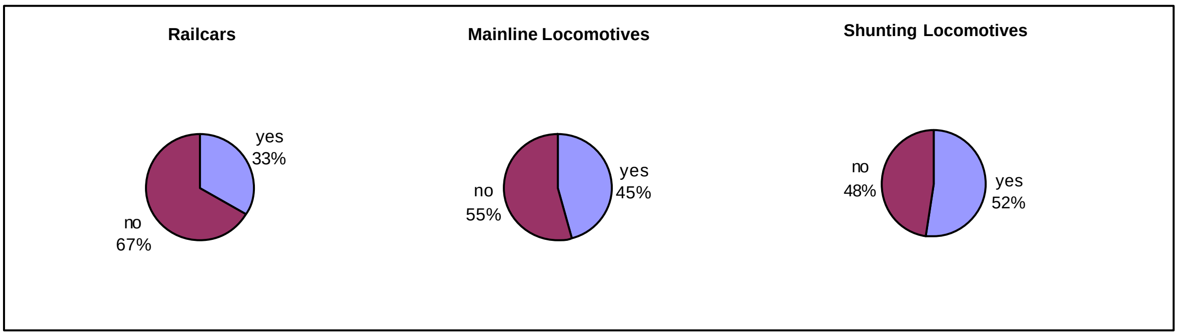


Figure 27: UIC-members' answers for the question if they plan to re-engineer parts of their fleet in the next 10 years (Source: questionnaire survey)

When weighing the answers by vehicle numbers of the companies' fleets more than 60 % have re-engining plans for railcars and mainline locomotives. For shunting locomotives nearly 80 % of the weighted operators stated that they have plans for re-engining parts of their fleet.

Besides purchasing new diesel tractive units or modernising the existing fleet, another alternative could be the leasing of diesel tractive units. The latter is especially an option for new operators that do not have existing fleets and maintenance facilities. From the surveyed UIC member railways, just 4 out of 23 stated that leasing will be an alternative for the future.

3.2 Decommissioning age and future life expectancy

Chapter 2.2.3 describes the age of UIC members' diesel railcar engines, with an average of 16 years for railcars, 27 years for locomotives. Additionally, the questionnaire survey asked operators to supply information on the average age of their diesel engines when they are decommissioned (***Figure 28***). Furthermore it was asked for the life expectancy of new diesel engines (***Figure 29***).

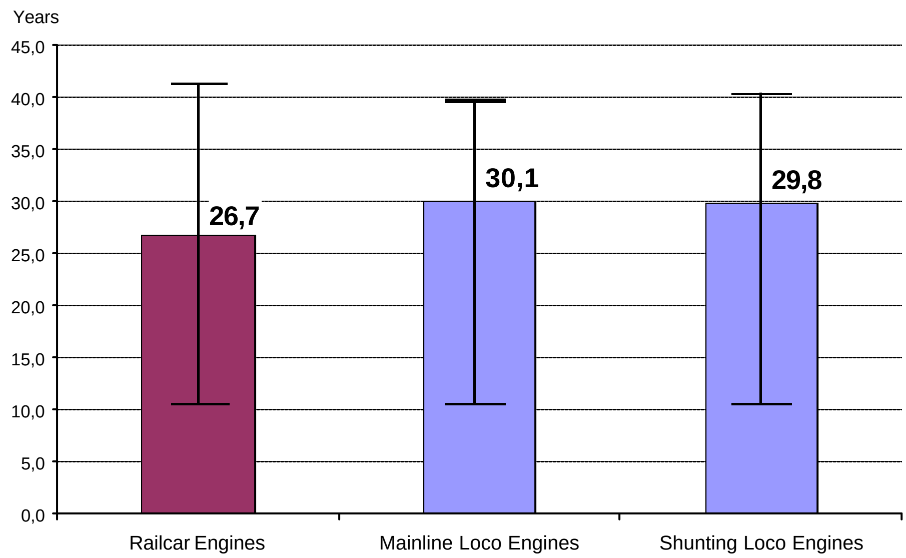


Figure 28: Average value and range of average diesel engine age when decommissioned (Source: questionnaire survey)

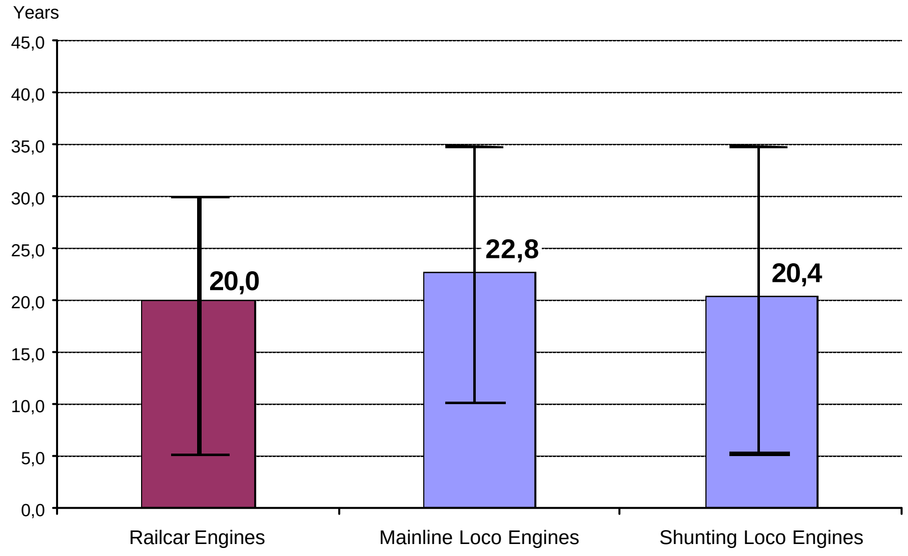


Figure 29: Average value and range of life expectancies in years for new diesel engines (Source: questionnaire survey)

The current average age for engines being decommissioned at this point in time is about 27 years for railcars, and 30 years for locomotives. For new railcar and locomotive engines, operators have indicated that the average anticipated life expectancy for rail cars and shunting locomotive engines to 20 years, whilst for mainline locomotive engines this rises to almost 23 years. The range bars on the graph in the above figure indicate the large variation in anticipated life expectancy for new engines, ranging from 5 years to 30 years for railcars engines, and from 10 years to 35 years for mainline locomotive engines. It is possible that these large variations are indicative of the different procurement and maintenance strategies in different railway companies.

In addition to data on the life times of current and new engines, the questionnaire also asked operators to provide life expectancy estimates for current and new diesel vehicles (see ***Figure 44*** and ***Figure 45*** in Annex 4.4). The average age at which diesel rail vehicles are decommissioned ranges from 32 to 35 years, whilst the average future life expectancy for new diesel vehicles is about 27 years for railcars, and 30 years for locomotives.

3.3 Scenarios for European diesel fleet development

Scenarios have been developed to describe the possible future development of European diesel rail fleet. The main influencing parameters expected to affect the future development of the fleet are described in the following two tables. ***Table 7*** describes the parameters which have been varied for the different scenarios, whilst ***Table 8*** shows the parameters that remain the same in all scenarios.

Influence Parameter	Explanation
Life expectancy of vehicles	According to the results of the questionnaire survey (chapter 3.2), the average age of diesel railcar engines being decommissioned in the next years is about 27 years, whilst for locomotive engines this figure is about 30 years. Newly purchased railcar engines are judged to have, on average, a life expectancy of 20 years; for new locomotive engines, this is about 22 years.
Market development for rail traffic as such	<u>Market development for passenger and freight traffic:</u> Market development figures for European traffic and rail traffic as such can be found in ProgTrans "European Transport Report 2004" for the years 2005-2015. This report indicates the following: + 1,9 % per year for freight + 1,3 - 1,6 % per year for passenger transport Further sources are values from the the EU White Book: + 2,8 % per year for freight, + 1,9 % per year for passenger transport These figures are more or less in line with statistics in the EU Energy and Transport in Figures statistical pocketbook 2004. Higher values are assumed in the ERRAC Rail Research Agenda[2]: + 6 % per year for freight, + 5 % per year for passenger transport <u>Derived market development for railcars and locomotives:</u> Based on the above described market developments for freight and passenger traffic the figures for railcars and locomotives have been derived taking into account the following aspects (see chapter 2.1.2): ▪ Current share of railcars in passenger traffic: 70% of train-km ▪ 64 % of diesel locomotives train-km are used for passenger traffic. (percentage of <u>number</u> of vehicles is probably lower as diesel locomotives are often used less intensively for feeder traffic in freight transport) ▪ Trend in passenger traffic to railcars instead of locomotive driven trains (see ***Figure 25***) In consequence the market growth for railcars is assumed to be higher than the indicated growth in passenger traffic. The growth for locomotives is assumed to be in between the value for passenger and freight traffic.
Adapted market development for diesel traction	Most growing sectors for rail traffic will be inner-city traffic, commuter traffic, Point-to-point relations in between conurbations, long distance freight traffic. These sectors are in many countries mainly served by electric traction, whereas, e.g. rail diesel feeder traffic is often switched to road. Diesel traction will therefore contribute to a lower extent to the market growth than electric traction.

Table 7: Influence parameters on diesel fleet development taken into account in the scenarios (adapted for each scenario)

[2] The values have been recalculated based on the following assumptions in the description of the Agendas Business environment for Europe 2020:
Freight: Market share in 2020: 15 %; Growth in traffic volume (from 2000, Western Europe): + 70 % to 6000 billion tkm
Passenger: Market share in 2020: 12 %; Growth in traffic volume (from 2000, Western Europe): + 40 % to 7500 billion Pkm

<table>
<tr><th rowspan="2">Influence Parameter</th><th rowspan="2">Explanation</th><th colspan="2"><u>Yearly</u> change of absolute number in %</th></tr>
<tr><th>Railcars</th><th>Loco-motives</th></tr>
<tr><td>Productivity development</td><td>Productivity improvements are achieved by more efficient use of tractive units or higher load factors.

Use of <u>railcars</u> on fixed and optimised routes, often linked to public orders (less potential for improvements like higher running performance per railcar).
Assumption for all scenarios: growth of load factor, e.g. from 20 % as typical value for today regional passenger traffic to 25 % means an annual growth of around 1 %.

Often low running performance and low wagon loads offer higher improvement potential especially for freight traffic <u>locomotives</u> (see chapter 2.1.3 and 2.1.4), plus growing competitive pressure. A trend to economically more attractive long distance heavy haul traffics will result in higher operating performances per diesel tractive units and thus higher productivity.
Assumptions for all scenarios: 3 % productivity improvement per year.</td><td>- 1,0</td><td>- 3,0</td></tr>
<tr><td>New operators</td><td>New train operating and rolling stock companies that offer leasing of rolling stock often work only with diesel traction for reasons like:
▪ higher interoperability of diesel for growing cross-border transports
▪ higher flexibility and risk avoidance, lower investment and maintenance cost for diesel tractive units compared to a mixed or only electric fleet
▪ public tender for regional traffic are seen more often for non-electrified lines as there is a lower market barrier for new market entries, new operators have higher flexibility to apply for different public tenders with diesel vehicles.

When electric tractive units are replaced by diesel tractive units the entire diesel fleet number will grow and more diesel tractive units will be purchased. It is assumed that this effect will be stronger for freight traffic it is assumed that the described effect will result in a growth of 0.5 % for diesel locomotives and 0.3 % for diesel railcars.</td><td>+0,3</td><td>+0,5</td></tr>
<tr><td colspan="2" align="right">Sum of influences</td><td>-0,7</td><td>-2,5</td></tr>
</table>

Table 8: Influence parameters on diesel fleet development taken into account in the scenarios (same assumption for each scenario)

Other parameters that could influence the future fleet development could include:
- influence of prices or taxes for diesel and electricity (e.g. higher electricity price due to CO_2-emissions trading)
- reluctance of operators to purchase new diesel rolling stock when development of pollutant emission limit values is unclear (review of NRMM Directive)
- further electrification of rail networks

However, for this study these factors have been judged as either less relevant, or too difficult to assess in a quantitative manner, and therefore they have not been taken into account.

Three scenarios are defined. Scenario A aims to describe the most probable development of the fleet. In scenarios B and C, the influencing parameters are set to find a possible low and a high number of diesel engines to be purchased between now and 2020, thereby setting some kind of framework for further investigations. The scenarios build on the number of diesel railcar and locomotive engines existing in today's European fleet, as described in chapter 2.2.1. Detailed information about age distributions as taken from the questionnaire survey results for UIC-members have also been applied to non-UIC members. The same applies for the above described average life expectancies and different assumptions for decommissioning of very old engines. New engines to be purchased are either to replace decommissioned ones or to meet new market demands, taking into account the influencing parameters described in ***Table 8***. It was assumed that all influence parameters are directly connected to the number of diesel tractive units needed.

For 2004 the number of diesel railcars and locomotives is based on the numbers out of the statistical sources described in chapter 2.2.1. As there is a significant number of locomotive and railcar engines in the fleet that are older than the typical decommissioning age (see chapter 3.2) it is assumed that these ones appear in statistic but are not used in the same intensity as younger ones. In consequence they would not be replaced one by one with newer ones when finally officially decommissioned and erased from statistics. This assumption is backed by the answers in the questionnaire survey (see Annex 4.5, question A 3). A majority of the railway companies confirmed that older vehicles are used less intensively. For this reasons locomotive engines from before 1969 and railcar engines from before 1979 are counted with half of their number already for the starting year 2004 of the scenarios.

Based on the available information and the scope of the study the scenarios are described on a more global level for locomotives and railcars as such. Taking into account more specific market related aspects for different types of locomotives and railcars (e.g. shunting, heavy haul, transfer or civil engineering locomotives; Intercity, cross country or rural railcars) was not possible within the study.

As result of the three scenarios that are described in more detail below, it has been estimated that the following numbers of new rail diesel engines will be needed up to 2020 (***Table 9***).

Sum of New Engines until 2020	Scenario A	Scenario B	Scenario C
Number of New Locomotive Engines	8.576	7.894	13.253
Number of New Railcar Engines	9.024	8.441	14.790
Total number of Rail Diesel Engines	***17.600***	***16.335***	***28.043***

Table 9: Sum of new diesel railcar and locomotive engines to be purchased according to scenario A-C

3.3.1 Scenario A "Average number of new diesel engines"

This scenario describes a moderate level of decommissioning of the existing old fleet, and their replacement to meet the needs of a moderate market and productivity growth. A detailed description of the assumptions made for the different influence parameters can be found in ***Table 7*** and ***Table 8***.

Scenario A "Average number of new diesel engines"			
Influence Parameter	**Explanation**		
Decommissioning of old diesel rolling stock	Moderate decommissioning of the engines already older than life expectancy over the next 10 years. Decommissioning of engines from 2000 onwards after 20 years (railcars) res. 25 years (locomotives). Older engines of railcars after 25 years, of locomotives after 30 years according to questionnaire survey (see also ***Table 7***)		
		Yearly change of absolute number in %	
Development of absolute number		Railcars	Locomotives
Market development for diesel traction	Market development for rail traffic (diesel+electric) according to ProgTrans "European Transport Report 2004" Railcars: +2,0 % per year (+ 1,5 % for passenger traffic plus trend from locomotives to railcars of assumed + 0,5 %) Locos: +1,4 % (average of + 1,0 % for passenger (= 1,5 – 0,5 % due to trend from locomotives to railcars) for passenger and 1,9 % for freight traffic) Assumption: diesel traction participates to lower extent of about 50 % at the rail traffic market growth. (see also ***Table 7***)	+ 1,0	+ 0,7
Productivity development and new operators	See ***Table 8***	- 0,7	- 2,5
Sum of Influences		**+0,3**	**-1,8**

Table 10: Description of Scenario A "Average number of new diesel engines"

Figure 30 shows the development of the entire number of diesel engines in Europe until 2020. It also shows to which extent older engines are replaced by newer locomotive and railway engines in the fleet. Diesel engines from the 2004 existing fleet are displayed in darker blue and red colour, engines expected to be purchased from 2005 onwards are represented by brighter colours. These new engines are assumed to be purchased in order to fulfil the assumed market needs taking also into account the decommissioned engines to be replaced.

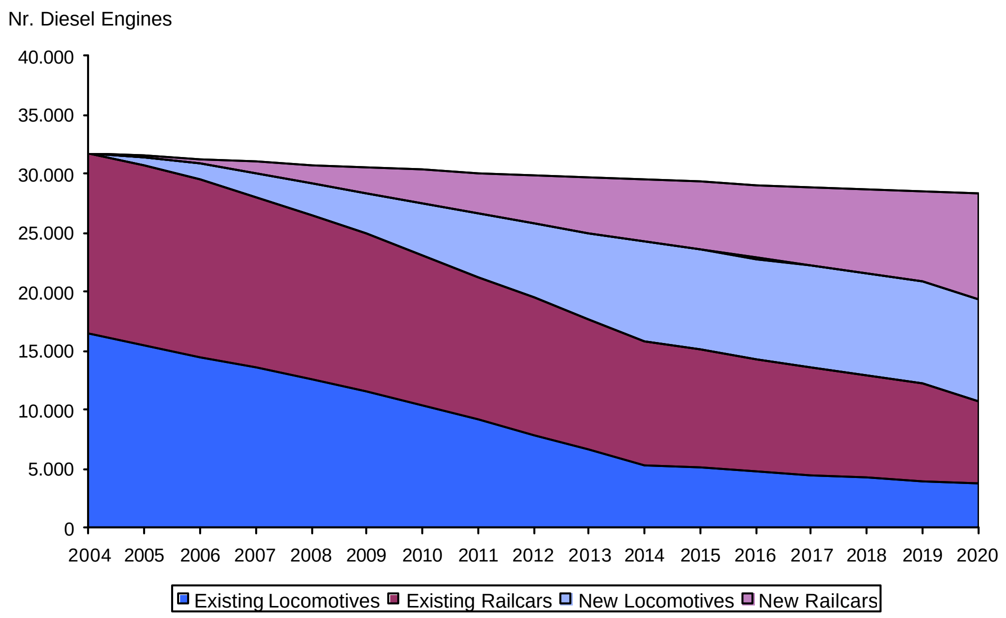


Figure 30: Scenario A "Average number of new diesel engines" for future development of European diesel fleet

The results show a small decline in the absolute number of railway diesel engines in Europe with 25 % less locomotive and 5 % more railcars engines in 2020 compared to 2004. The decline for locomotives is mainly due to the assumed much higher productivity especially in freight traffic. In this scenario, by 2016 the number of diesel engines purchased in 2005 or later would be higher than the number of engines dating from before 2005. In 2020 less than 40 % of engines are older than 2005 (***Table 11***).

Scenario A	2010		2015		2020	
Existing Diesel Engines	23.072	*76%*	15.043	*51%*	10.730	*38%*
New Diesel Engines	7.231	*24%*	14.217	*49%*	17.600	*62%*

Table 11: Scenario A: Number and Percentage existing diesel engines (before 2005) compared to new engines (2005 and later)

3.3.2 Scenario B "Low number of new diesel engines"

For scenario B it is assumed that the existing old fleet will be decommissioned rather slowly. Furthermore, the assumption of relatively low market growth leads to a comparably low figure for the number of new diesel engines to be purchased. The assumptions for product development and new operators have been kept the same as in scenario A.

The total number of railcars and the total number of locomotives are expected to decline between 2005 and 2020 at rates of –0.2% and –2,2% per year respectively **(*Table 12*).**

Scenario B “Low number of new diesel engines”			
Influence Parameter	**Explanation**		
Decommissioning of old diesel rolling stock	Slow decommissioning of the engines already older than life expectancy within next 15 years. Other assumptions for life expectancy like in scenario A. (see also ***Table 7***)		
		Yearly change of absolute number in %	
Development of absolute number		Railcars	Locomotives
Market development for diesel traction	Half of predicted growth values from Scenario A (EU White Book, around 30 % lower values than in ProgTrans) (see also ***Table 7***)	+ 0,5	+ 0,4
Productivity development and new operators	See ***Table 8***	- 0,7	- 2,5
Sum of Influences		**- 0,2**	**- 2,2**

Table 12: Description of Scenario B “Low number of new diesel engines”

In 2020, Scenario B assumes that the absolute number of diesel locomotive engines will be 29 % lower, and the number of railcar engines will be 3 % lower compared to 2004 (***Figure 31***).

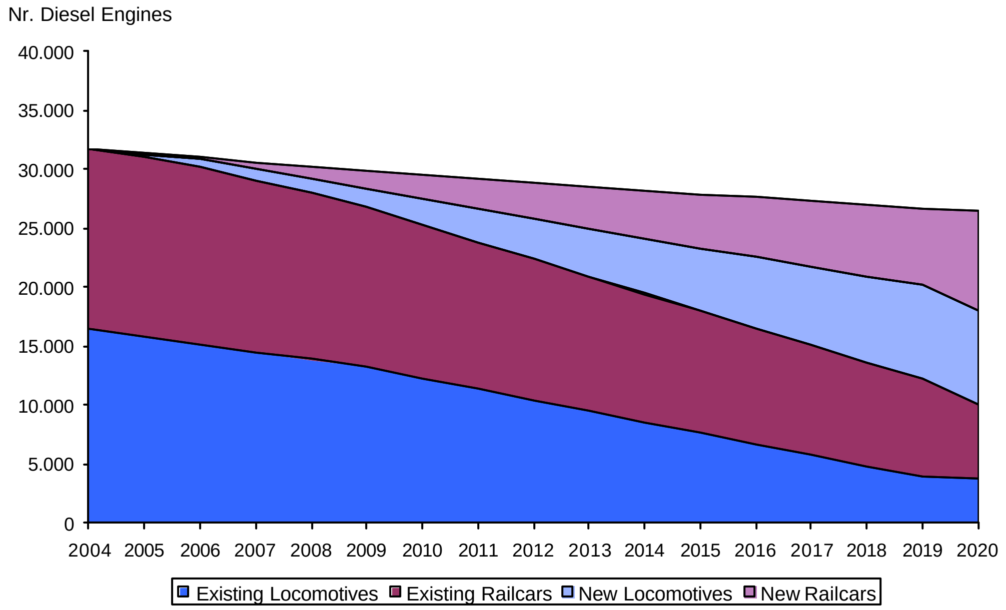


Figure 31: Scenario B “Low number of new diesel engines” for future development of European diesel fleet

By 2019, the proportion of “new” engines (meaning engines purchased after 2004) would be higher than the remaining engines dating from 2004 and before, 3 years later than in Scenario A. In 2010 there would still be 86 % of all diesel engines from 2004 and before in service, mainly due to the slow decommissioning rate of very old existing engines in this scenario. In 2020 this proportion will drop to below 40 % of all engines (***Table 13***).

Scenario B	2010		2015		2020	
Existing Diesel Engines	25.274	*86%*	17.978	*64%*	10.080	*38%*
New Diesel Engines	4.258	*14%*	9.918	*36%*	16.335	*62%*

Table 13: Scenario B: Number and Percentage existing diesel engines (before 2005) compared to new engines (2005 and later)

3.3.3 Scenario C "High number of new diesel engines"

In scenario C, a high market growth for rail traffic is assumed (*Table 14*). Based on an assumed fast rate of decommissioning of the existing old fleet, a high number of new diesel engines would be needed. Again, the assumption for productivity development and effects through new operators are taken unmodified from Scenario A.

Scenario C "High number of new diesel engines"			
Influence Parameter	**Explanation**		
Decommissioning of old diesel rolling stock	Fast rate of decommissioning of engines already older than life expectancy within the next 5 years. Other assumptions for life expectancy are the same as for scenario A. (see also ***Table 7***)		
		Yearly change of absolute number in %	
Development of absolute number		Railcars	Locomotives
Market development for diesel traction	Market development for rail traffic (diesel + electric) according to ERRAC Rail Research Agenda Railcars: + 5 % for passenger traffic, plus trend from locomotives to railcars (+ 0,5 %) Locomotives: average of + 5 % for passenger and 6 % for freight traffic minus trend from locomotives to railcars in passenger traffic Assumption: diesel traction participates to lower extent of 50 % at the rail traffic market growth (see also ***Table 7***)	+ 2,8	+ 2,7
Productivity development and new operators	See ***Table 8***	- 0,7	- 2,5
Sum of Influences		**+ 2,1**	**+ 0,2**

Table 14: Description of Scenario C "High number of new diesel engines"

The high market growth for rail traffic would in this scenario mean that large increases in the numbers of vehicles in the total fleet would be expected by 2020, even after taking into account the more efficient use of rolling stock and increased productivity. As result of this scenario, in 2020 it is anticipated that there would be 38 % more railcars and 3 % more locomotives needed than in 2004 (***Figure 32***).

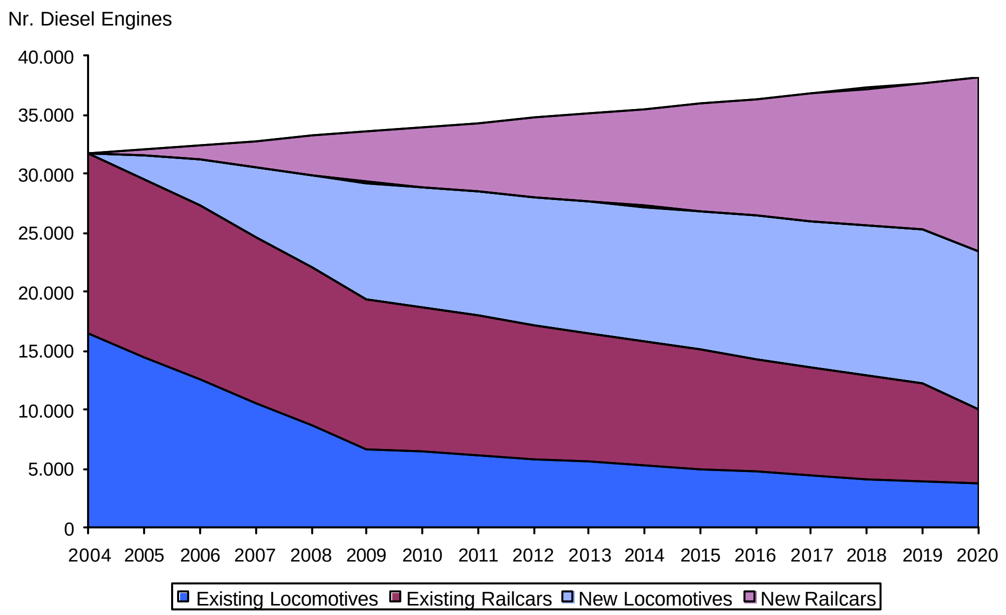


Figure 32: Scenario C "High number of new diesel engines" for future development of European diesel fleet

As a result of the assumed fast rate of decommissioning for this scenario, by 2012 there would already be considerably more "new" diesel engines in the fleet than the ones that came into service before 2005. By 2020 this proportion would rise up to 74 % (***Table 15***).

Scenario C	2010		2015		2020	
Existing Diesel Engines	18.670	*55%*	15.043	*42%*	10.080	*26%*
New Diesel Engines	15.231	*45%*	20.870	*58%*	28.043	*74%*

Table 15: Scenario C: Number and Percentage existing diesel engines (before 2005) compared to new engines (2005 and later)

This scenario has been judged by the reference and steering group of the study to be less realistic than Scenario A and B.

4 Annex

4.1 Covered UIC member railways

Nation	UIC member	Activity	ID	Survey
Austria	Österreichische Bundesbahnen	IC	ÖBB-AT	X
Belgium	Société Nationale des Chemins de fer Belges	IC	SNCB/NMBS-BE	X
Bulgaria	Bulgarian railways	RO	BDZ-BG	X
Bulgaria	National Railway Infrastructure Company	IM	NRIC-BG	
Czech Republic	Ceské drahy	IC	CD-CZ	X
Denmark	Danske Statsbaner	PO	DSB-DK	X
Denmark	Banedanmark	IM	BDK-DK	
Estonia	Aktsiaselts Eesti Raudtee	IC	EVR-EE	X
Finland	Ratahallintokeskus	IM	RHK-FI	
Finland	VR-Group Ltd	RO	VR-FI	X
France	Connex	IC	CONNEX-FR	
France	Réseau Ferré de France	IM	RFF-FR	
France	Société Nationale des Chemins de fer Français	RO	SNCF-FR	X
Germany	Deutsche Bahn AG	IC	DB AG-DE	X
Greece	Organisme des Chemins de fer helléniques	IC	CH-GR	
Hungary	Györ-Sopron-Ebenfurti Vasut Részvénytarsasag	IC	GySEV/RÖEE-HU	X
Hungary	Magyar Allamvasutak Rt.	IC	MAV-HU	X
Ireland	Coras Iompair Eireann	IC	CIE-IE	X
Italy	Ferrovie dello Stato SpA	IC	FS-IT	X
Latvia	Valsts Akciju Sabiedriba "Latvijas Dzelzcels"	IC	LDZ-LV	X
Lithuania	SPAB "Lietuvos Gelezinkeliai"	IC	LG-LT	X
Luxembourg	Société Nationale des Chemins de Fer Luxemb.	IC	CFL-LU	
Netherlands	N.V. Nederlandse Spoorwegen	PO	NS-NL	X
Netherlands	ProRail	IM	ProRail-NL	
Norway	Jernbaneverket	IM	JBV-NO	
Norway	Norges Statsbaner BA	RO	NSB-NO	X
Poland	Polskie Koleje Panstwowe S.A.	IC	PKP-PL	X
Portugal	Caminhos de Ferro Portugueses, E.P	RO	CP-PT	X
Portugal	Rede Ferroviaria Nacional, E.P.	IM	REFER-PT	
Romania	Societatea Nationala a Cailor Ferate Române	IC	CFR-RO	X
Slovakia	Zeleznice Slovenskej Republiky	IM	ZSR-SK	
Slovakia	Zeleznica spolocnost', a.s.	PO	ZSSK-SK	X
Slovakia	Zeleznica spolocnost Cargo Slovakia, a.s.	FO	ZSSK Cargo-SK	X
Slovenia	Slovenske Zeleznice d.d.	IC	SZ-SI	X
Spain	Red Nacional de los Ferrocarriles Españoles	RO	RENFE-ES	
Spain	Administracion de infrastucturas ferroviarias	IM	ADIF-ES	
Sweden	Banverket	IM	BV-SE	
Sweden	Statens Järnvägar AB	PO	SJ AB-SE	
Sweden	Green Cargo AB	FO	Green Cargo-SE	
Switzerland	BLS Lötschbergbahn AG	IC	BLS-CH	X
Switzerland	Chemins de fer fédéraux	IC	CFF/SBB/FFS-CH	X
United Kingdom	Association of Train Operating Companies	PO	ATOC-GB	X
United Kingdom	Eurostar (UK) Ltd.	PO	Eurostar-GB	
United Kingdom	Eurotunnel	IC	Eurotunnel-GB	
United Kingdom	Network Rail Ltd	IM	Network Rail-GB	
United Kingdom	English Welsh & Scottish Railway Limited	FO	EWS-GB	

IM = Infrastructure manager; FO= Freight operator; PO= Passenger transportation operator; RO= Freight and passenger transportation operator; IC= Integrated company

Table 16: Covered UIC member railways by UIC statistics and the questionnaire survey (last column) with IDs used in figures of the study

4.2 Absolute performance figures

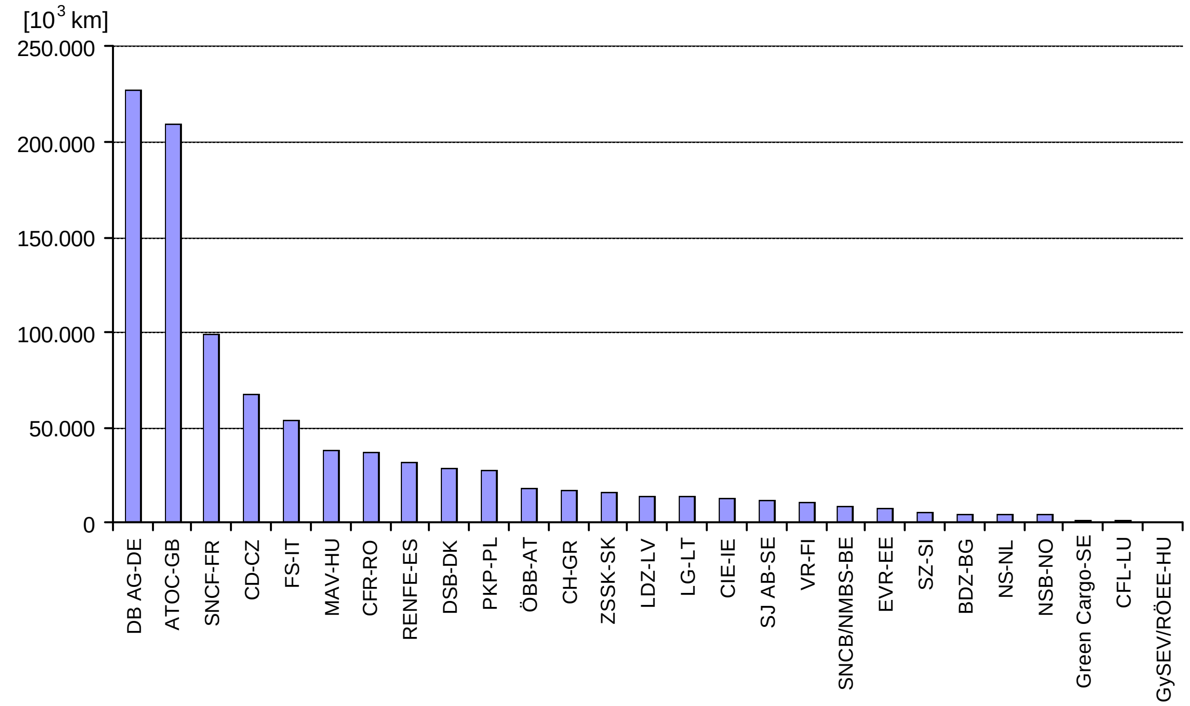


Figure 33: Diesel running performance of different European railways in train-km (Source: UIC statistics)

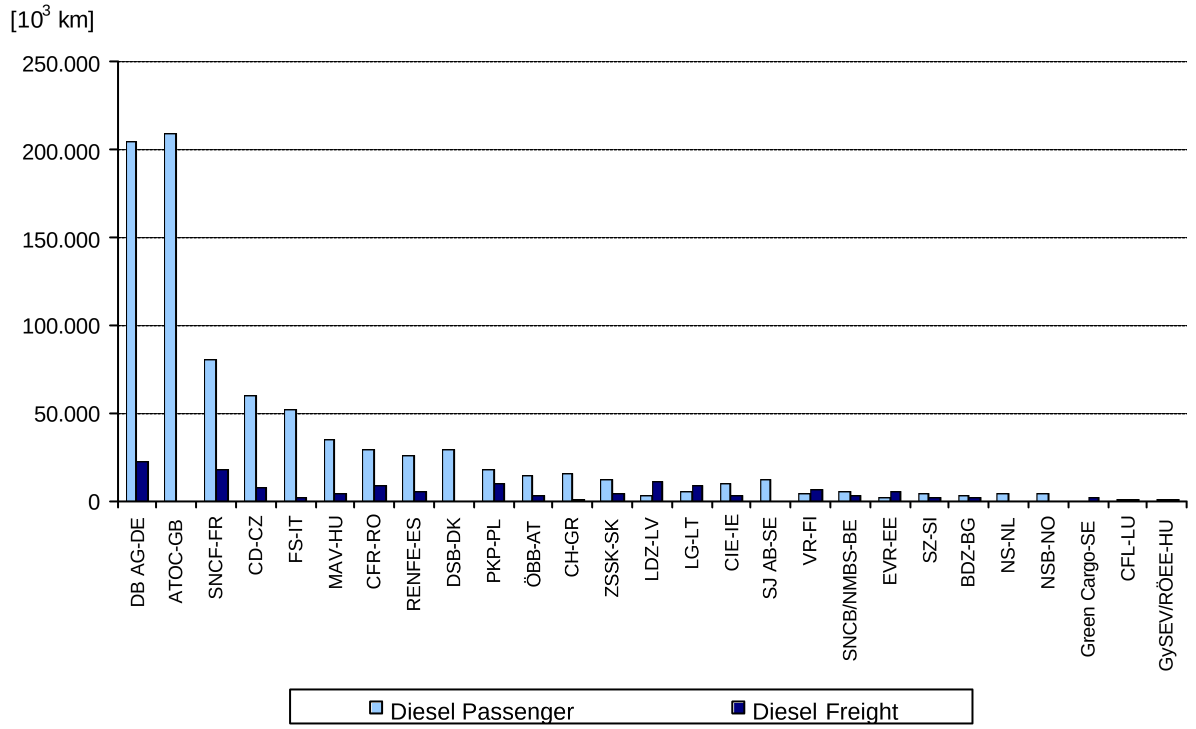


Figure 34: Diesel running performance (train-km) differentiated by passenger and freight (Source: UIC statistics)

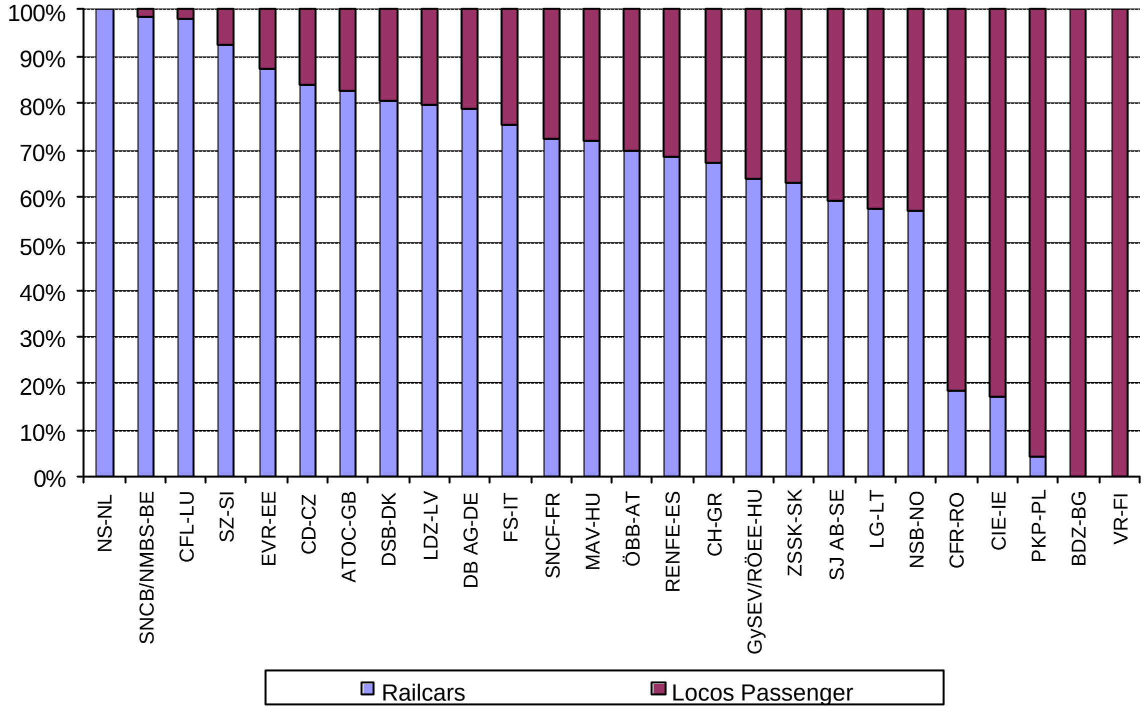


Figure 35: Share of diesel railcars resp. locomotives in passenger traffic in different European railways based on running performance(train-km) (Source: UIC statistics)

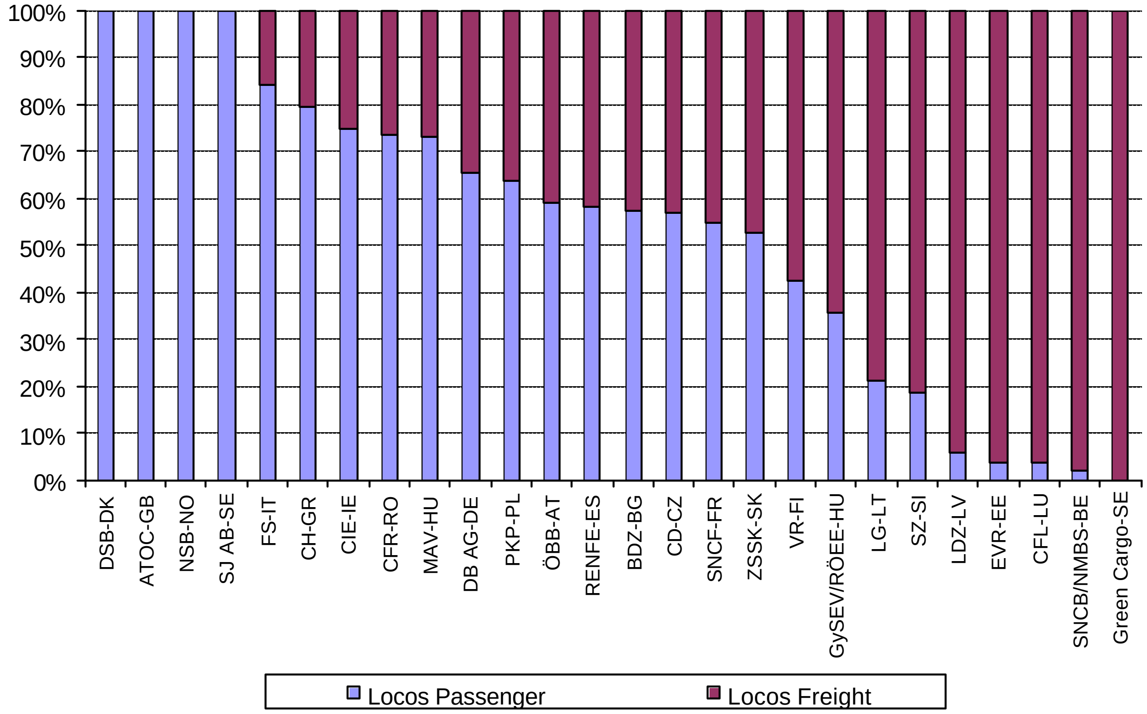


Figure 36: Share of diesel locomotives for passenger and freight traffic in different European railways based on running performance(train-km) (Source: UIC statistics)

4.3 Figures with specific wagon load / performance values

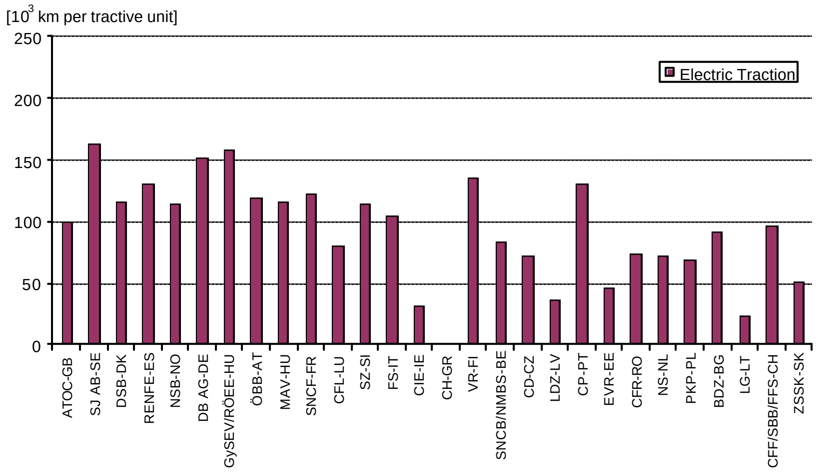


Figure 37: Running performance (train-km) per electric tactive unit for different European railways (Source: UIC statistics)

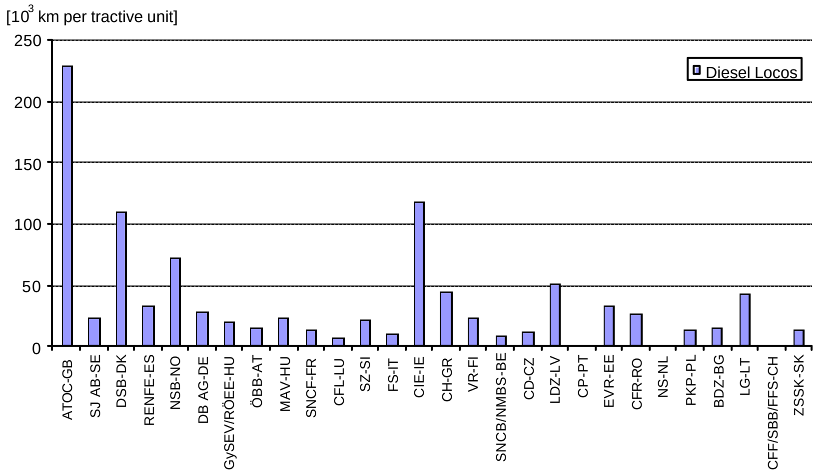


Figure 38: Running performance (train-km) per diesel locomotive for different European railways (Source: UIC statistics)

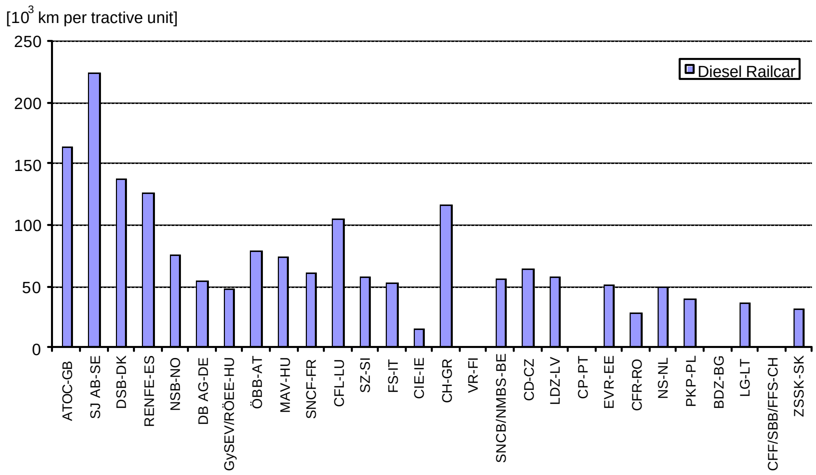


Figure 39: Running performance (train-km) per railcar for different European railways (Source: UIC statistics)

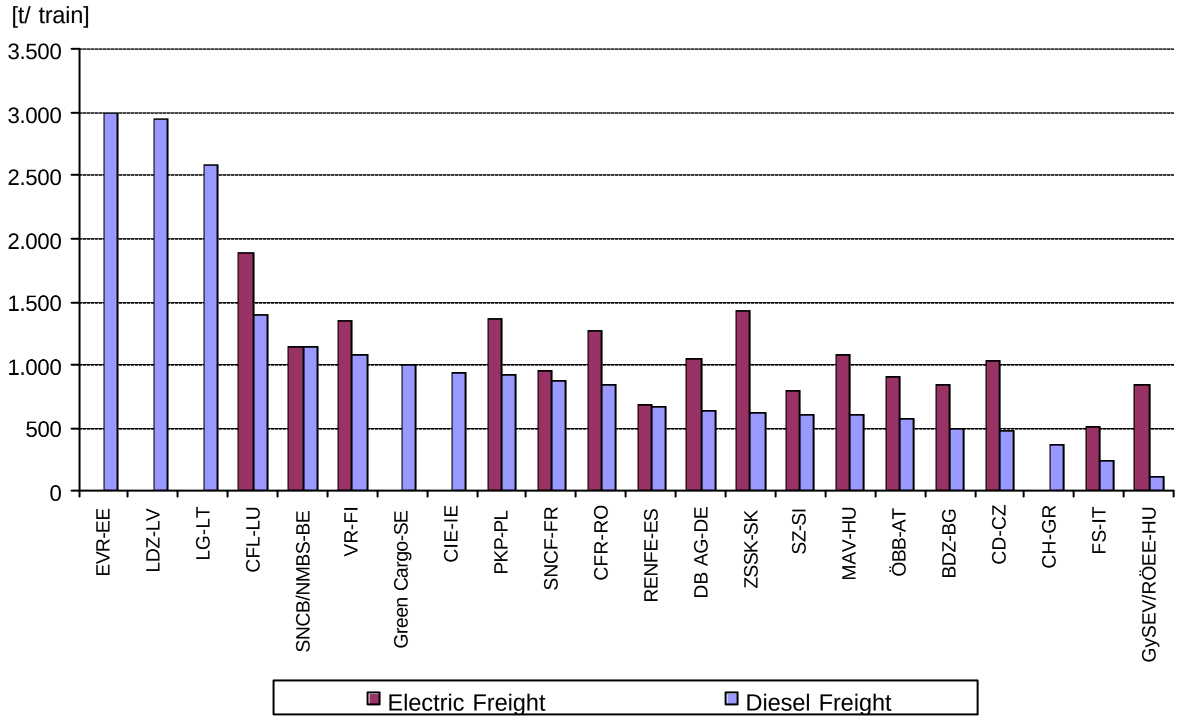


Figure 40: Wagon load (tonnes) per freight diesel train for electric and diesel traction for different European railways (Source: UIC statistics)

4.4 Figures characterising the diesel fleet composition

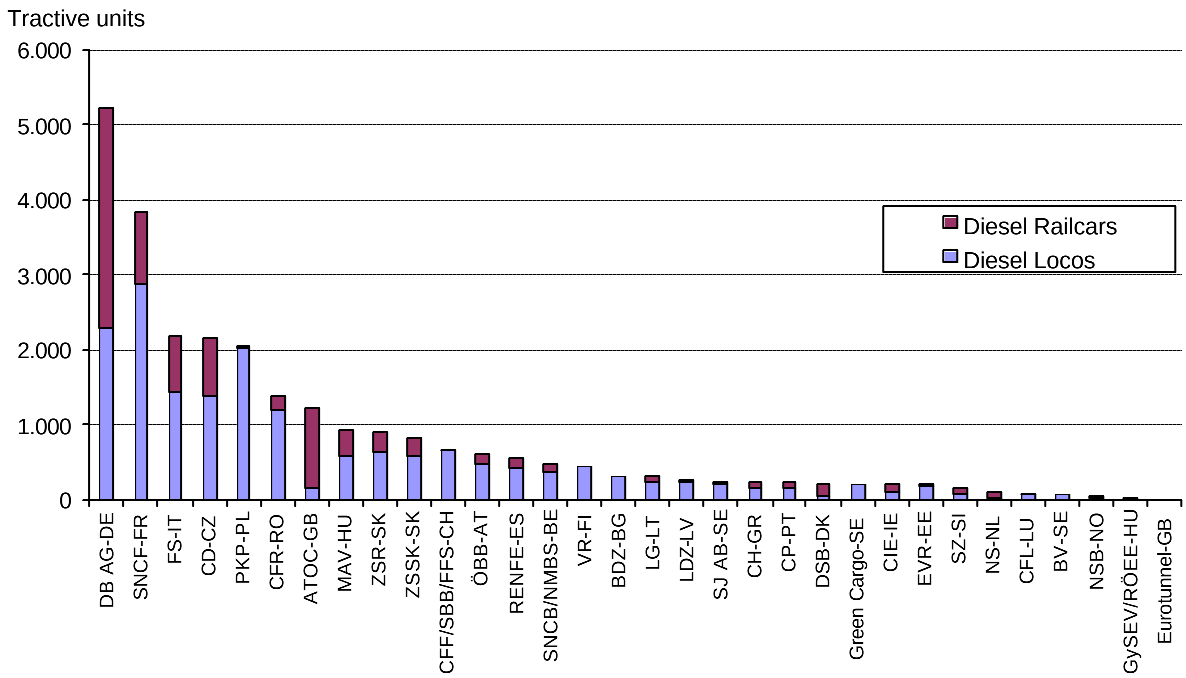


Figure 41:. Number of diesel tractive units (railcars and locomotives) in different European railways (Source: UIC statistics)

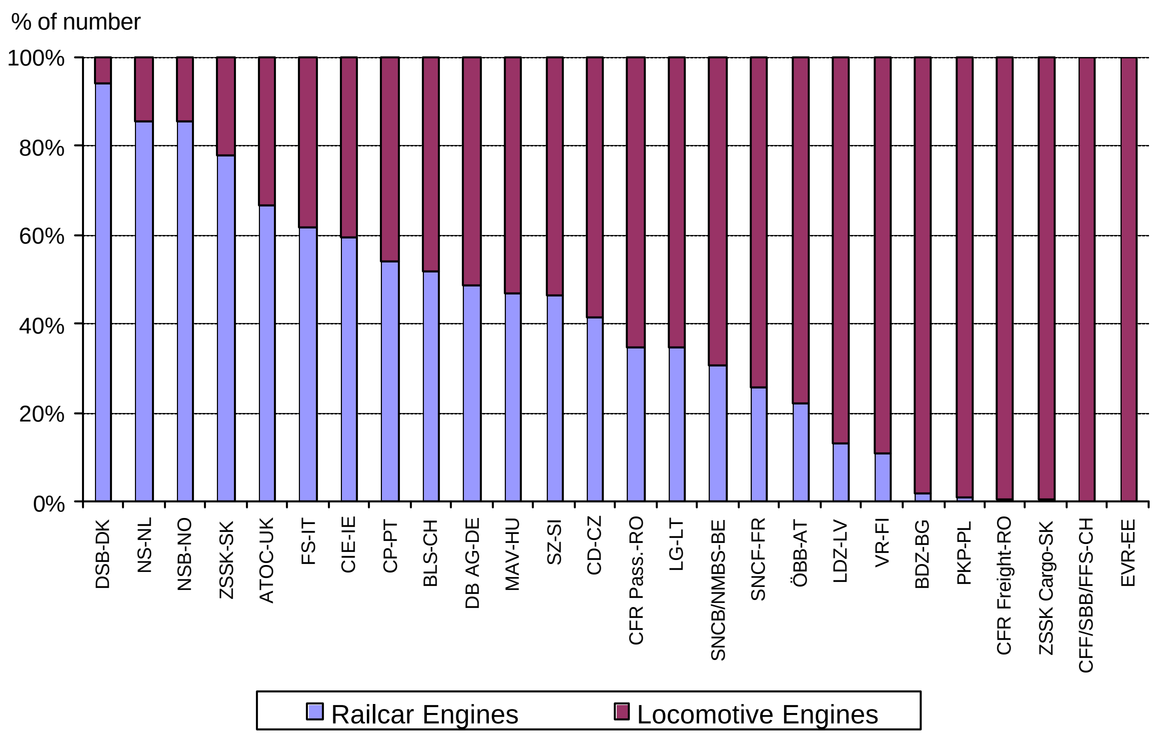


Figure 42: Share of number of railcar engines resp. locomotive engines in different European railways (Source: questionnaire survey)

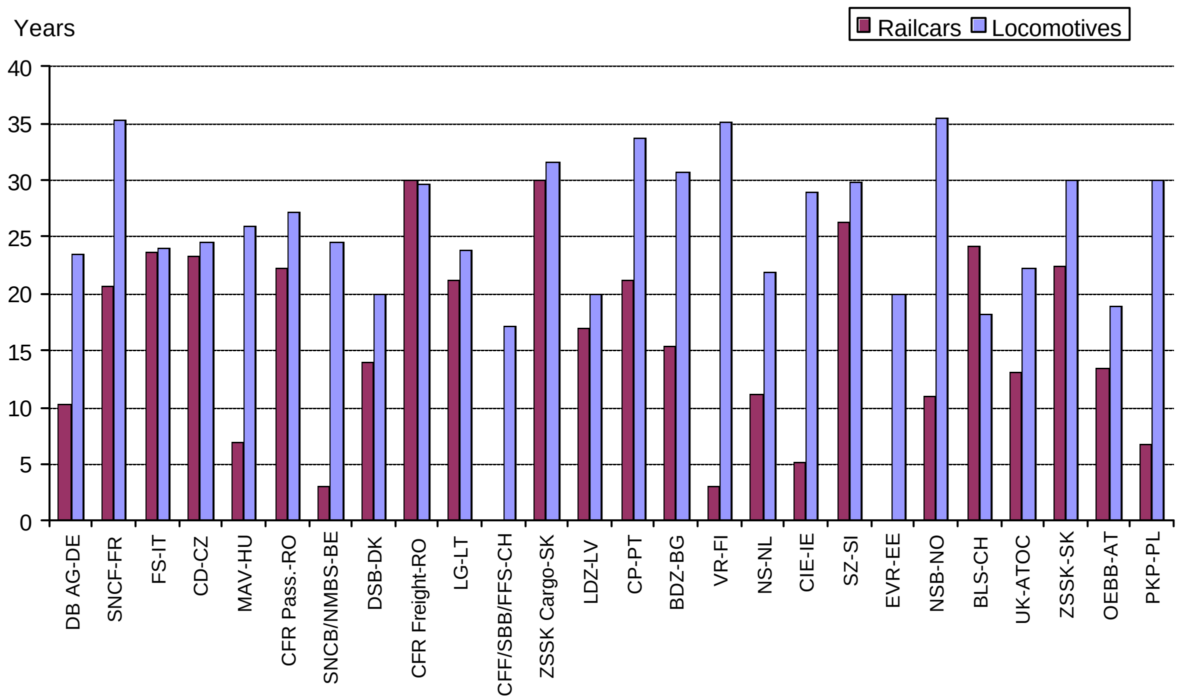


Figure 43: Average age of railcar and locomotive engines in different European railways (Source: questionnaire survey)

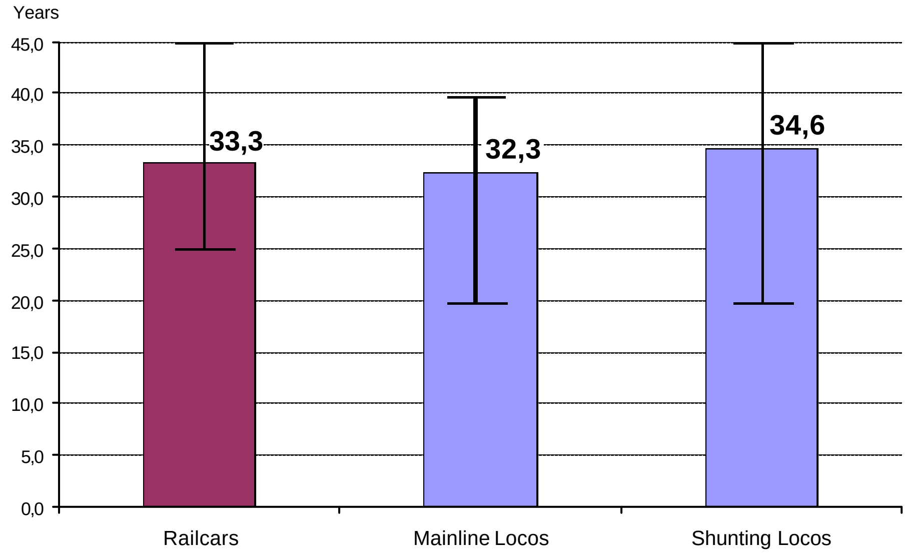


Figure 44: Average value and range of average diesel vehicle age when decommissioned (Source: questionnaire survey)

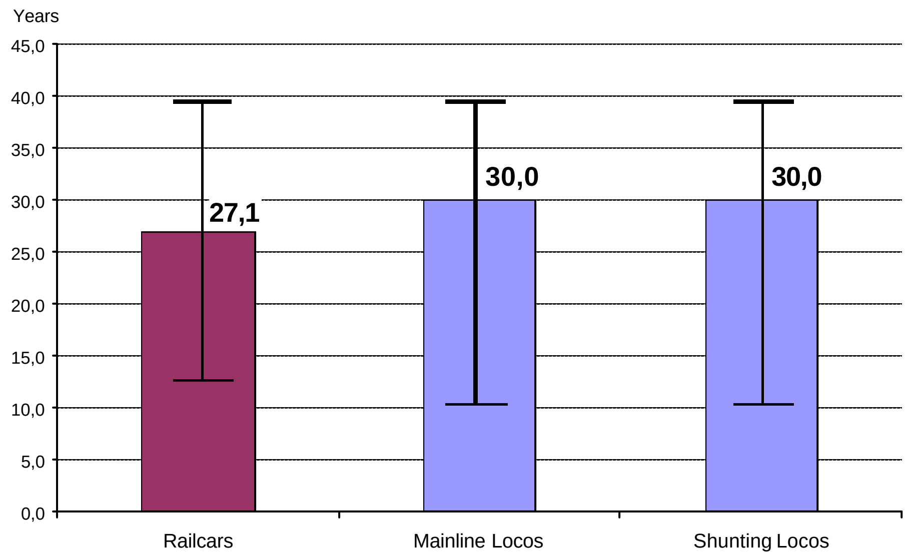


Figure 45: Average value and range of life expectancies in years for new diesel vehicles (Source: questionnaire survey)

4.5 Questionnaire A: Fleet details

The following questionnaire as first section out of 3 has been sent to UIC member railways in Europe on 3rd of February 2005 with deadline 1st of March 2005. Later incomes until 17th of June 2005 had been taken into account in an update of the report. The questionnaire was answered by the railway companies marked in ***Table 16*** in Annex 4.1. A summary of the collected answers is filled in each question box in cursive and red letters.

The other sections of the questionnaire are focussing on emission reduction measures (Section B) and air quality (Section C). They are a basis for the work packages 2 and 3 of the Rail Diesel Study.

RAIL DIESEL STUDY QUESTIONNAIRE
SECTION A: FLEET DETAILS

QUESTION A1: Data on Fleet Age and Power

Purpose of question:	*The data matrix will be the basis for all analysis of the current state and future development of the European diesel fleet.*
A1.1: Please fill in the following matrix about the current state of the DIESEL fleet of your company. If you already participated in the pre-study, please note that the age categories have been updated.	

Categories according to amendment of directive 97/68	Year that traction engine* was placed into service	Number of traction engines* - sum
Railcar > 130 kW	2000 and newer	*2.575*
	1995-1999	*2.005*
	1990-1994	*1.334*
	1980-1989	*2.717*
	1970-1979	*1.661*
	1969 and older	*782*
	Total no. of traction engines	*11.074*
Locomotive 130 - 560 kW	2000 and newer	*717*
	1995-1999	*112*
	1990-1994	*333*
	1980-1989	*555*
	1970-1979	*645*
	1969 and older	*2.018*
	Total no. of traction engines	*4.380*
Locomotive 560 - 2000 kW	2000 and newer	*806*
	1995-1999	*321*
	1990-1994	*167*
	1980-1989	*1.560*
	1970-1979	*3.994*
	1969 and older	*3.196*
	Total no. of traction engines	*10.044*
Locomotive > 2000 kW	2000 and newer	*348*
	1995-1999	*139*
	1990-1994	*176*
	1980-1989	*178*
	1970-1979	*532*
	1969 and older	*47*
	Total no. of traction engines	*1.420*

** Please indicate the number of engines for traction, not auxiliary engines (e.g. generators) and not the number of vehicles.*

Year data collected:	*2004-2005*

See also: **Figure 10**, **Figure 11**, **Figure 12**, **Figure 13**, **Figure 42**, **Figure 43**.

QUESTION A2: Additional fleet data

Purpose of question:	*These are important statistical values which allow us to calculate a number of indicators on the general performance of the European diesel fleet. We will also be able to compare the data from this questionnaire with older UIC statistics in order to assess the current (and possibly future) development of the fleet.*

A2.1: What percentage of engines in your company's fleet have been replaced by different engines of a new design? (Do not include engines that were replaced by new engines of the same design as the old engine)

	Railcars	Mainline Locomotives	Shunting locomotives
Percentage of engines replaced	*Average: 10* *Min: 0* % *Max: 87*	*Average: 5* *Min: 0* % *Max: 38*	*Average: 7* *Min: 0* % *Max: 50*

See also: **Figure 14**.

A2.2: Please give details of the annual diesel fuel consumption of your company's fleet
(please provide answers either in litres per year or in tonnes per year in the box below)

	Amount of diesel
Total annual fuel consumption (in LITRES of diesel) **OR**	*Sum: 1923 Mio. Litres*
Total annual fuel consumption (in TONNES of diesel)	*Sum: 1546,8 Thousand Tonnes*

Year data collected:	*2002-2005*

See also: **Figure 15**.

A2.3: Please give details of the sulphur content of the diesel fuel your company uses	
	Amount of sulphur (in parts per million)
Sulphur content of diesel fuel	*<10 - 2000* ppm

*See also: **Figure 24**.*

If you can make a judgement on the quality of the data provided above or give additional information, please do so here:

Single comments:

- *"This is highest allowable sulphur content determined from delivery agreement. Actual sulphur content is lower and variable over delivery case."*
- *"These data are collected from the analysis documents of the diesel fuel – delivery made by few companies."*
- *"related to SR EN ISO 20846:2004 –max. limit for S content = 50 mg/ kg fuel and SR EN ISO 20884:2004 – max. limit for S content = 350 mg/ kg fuel."*
- *"Since 2004, a levy is collected on fuel containing more than 10 ppm sulphur. As a consequence, there is virtually no more fuel available commercially that exceeds 10 ppm sulphur."*

QUESTION A3: Life expectancy of vehicles in your company's fleet

Purpose of question:	*One of the crucial parameters for the assessment of the future development of the European diesel fleet and the total emissions by rail vehicles is the renewal rate of the fleet.*

A3.1: What is the average age (in years) of vehicles and engines when they are decommissioned from service?	
Pre-study results:	*The answers to this question in the pre-study were very diverse. The average life expectancy was approx. 25-35 years for a locomotive and 15-20 years for a railcar. Some train operating companies replace the engines of their vehicles regularly, others stated that the life expectancy of their diesel engines was higher than that of their vehicles.*

	Railcars	Mainline Locomotives	Shunting locomotives
Vehicles	*Average: 33* *Min: 25* *Max: 45*	*Average: 32* *Min: 20* *Max: 40*	*Average: 35* *Min: 20* *Max: 45*
Engines	*Average: 27* *Min: 10* *Max: 42*	*Average: 30* *Min: 10* *Max: 40*	*Average: 30* *Min: 10* *Max: 41*

Additional information, comments:

Single comments:

- *"In the past, tractive units for shunting and maintenance operations had a life expectancy of 40 years. Diesel engines in these tractive units averaged also about 40 years. However, with new locomotives life expectancy is assumed to be 25 years (as a consequence of accelerated technical development). When it reaches the end of the calculatory life expectancy, a locomotive series is evaluated with respect to the economical, ecological an technical benefits of replacement, retrofitting or overhaul. There are no experiences on mainline locomotives, since until recently all of them used to be run with electricity."*
- *"Normally the engine replacement occurs when there are no spare parts available or when its maintenance cost became too high."*

*See also: **Figure 28**, **Figure 44**.*

A3.2: How long does your company expect NEW vehicles and engines to <u>remain in operation</u>?

	Railcars	Mainline Locomotives	Shunting locomotives
Vehicles	*Average: 27* *Min: 13* *Max: 40*	*Average: 30* *Min: 10* *Max: 40*	*Average: 30* *Min: 10* *Max: 40*
Engines	*Average: 20* *Min: 5* *Max: 30*	*Average: 23* *Min: 10* *Max: 35*	*Average: 20* *Min: 5* *Max: 35*

Please explain if the conclusion of the pre-study, that life expectancy is decreasing, also applies to your company.

Single comments:

- *"We expect life expectancy to decrease, although as of now there are many old locomotives still in service. Reasons are accelerated technical development regarding engines and locomotives on one hand, accelerated organisational changes leading to shifting demands for traction units on the other hand."*
- *"The minimum life expectancy for "body" is 30 years, for the engines at least the half (15 years) but you have to consider that during an engine's overhaul his life is resettled so if you don't have any external constraint (new emission limits for example) you could maintain the same engine in use till the vehicle (30 years). This is what happened, in fact, till now."*

See also: ***Figure 29***, ***Figure 45***.

A3.3: Reduced use of old engines	
Pre-study result:	*From comments to the pre-study, we concluded that vehicles with old engines are often not used anymore but kept in standby for backup and auxiliary services (but still appear in statistics), while a major part of the rail operations are carried out with newer vehicles.*

Are newer engines used more intensively than older engines in the fleet of your company? *(Please mark appropriate answer with "X")*	**Yes:**	*15 answers*
	No:	*10 answers*
If you answered with "Yes" above, as of what engine age are vehicles usually put into reduced service in your company?	*Average: 27* *Min: 18* Max: 33	***years***

Please provide numbers if possible (e.g. X % of operations performed by vehicles with engines newer than year Y), additional information, comments:

Single comments:

- *"Due to delivery of new locomotives the use of the older types is automatically decreasing, no number can be defined since it is depending on locomotive series."*
- *"It's impossible to indicate a exact number of years: this number depends on engine's "residual" reliability. If an engine, even if very old, is reliable his vehicles will have a very high level of utilisation."*
- *"There is no formal reduced service. The fact that newer locomotives are used more heavily is that they are purchased with a defined application in mind and they are therefore used to cover this demand. This may lead to older locomotives (which are at the same time often less versatile, less powerful or less reliable than their new counterparts) being used less frequently."*

QUESTION A4: Future development of your company's vehicle fleet

Purpose of question:	*The information given here will help us predict the future ratio between newly procured and re-engined vehicles, between decommissionings and new procurements and finally also between the three types of locomotives specified hereunder.*

A4.1: Compared to the current size and composition of your company's fleet, how do you expect the number of vehicles to change in the future?
(Please mark "X" in the relevant boxes below).

	Railcars	Mainline locomotives	Shunting locomotives	Total diesel fleet
Number of vehicles will **increase**	*9 answers*	*1 answer*	*1 answer*	*3 answers*
Number of vehicles will **stay the same**	*10 answers*	*7 answers*	*11 answers*	*7 answers*
Number of vehicles will **decrease**	*4 answers*	*14 answers*	*9 answers*	*13 answers*

Please provide numbers if possible, additional information, comments:

Single comments:
- *"There may be a slight increase in diesel mainline locomotives for transboundary lines. More importantly, the number of vehicles for shunting and the diversity of types will decrease in an attempt to reduce costs of maintenance."*
- *"the strategy is railcars"*
- *"old locomotives with new engines of a new design and new locomotives will be more powerful. So number of vehicles will decrease"*
- *"Electrification of track net is continuing so need of diesel traction is decreasing."*

See also: Figure 25.

A4.2: For vehicles in your company's fleet, is there a trend towards using more powerful or less powerful engines, or are engine power categories remaining broadly the same?
(Please mark "X" in the relevant boxes below).

Trend	Railcars	Mainline locomotives	Shunting locomotives
Trend to **more** powerful engines	*12 answers*	*8 answers*	*5 answers*
Engine power is **remaining the same**	*8 answers*	*15 answers*	*15 answers*
Trend to **less** powerful engines	*3 answers*	*0 answers*	*2 answers*

Please provide numbers if possible, additional information, comments:

Single comments:
- *"By increasing the performance/power of the engines we aim at increasing the operation life of the combustion engine."*
- *"For mainline locomotives discussions are ongoing for more powerful engines and locomotives but no decision has been taken."*

See also: Figure 26.

A4.3: Does your company have plans to re-engine part of its diesel fleet in the next ten years? (Please mark "X" in the relevant boxes below).* *Only mark "Yes" if the new engines will be of a newer design.			
	Railcars	**Mainline Locomotives**	**Shunting locomotives**
YES, part of the fleet will be re-engined	*6 answers*	*10 answers*	*11 answers*
NO, the fleet will not be re-engined	*12 answers*	*12 answers*	*12 answers*

Please provide numbers if possible, additional information, comments:

See also: **Figure 27**.

A4.4: In future, does your company plan to externalise its fleet and to rely more on leased or rented vehicles owned by rolling stock leasing companies?
(Please mark "X" in appropriate box and give more details below)

Yes	*4 answers*	**No**	*19 answers*

Please quantify, if possible, additional information, comments:

QUESTION A5: Representative vehicles and emissions factors

Purpose of question:	*One of the central aspects of the rail diesel study is the evaluation of the life-cycle costs of different emissions reduction technologies for vehicles which are typical of the European diesel fleet. Your information will be used to find the best representative vehicles for life cycle cost assessments, feasibility analyses of emissions reduction measures etc. The results of the Rail Diesel Study will be available to the participants.*

A5.1: Instructions: Please describe a railcar, a mainline locomotive, and a shunting locomotive which you feel are typical for the vehicles owned by your company. We recommend choosing vehicles with a high operating performance (i.e. vehicles that are highly used) compared to the rest of your fleet. If you would like to describe more than one railcar, mainline or shunting locomotive, please feel free to copy this table to the next page for further vehicles (e.g. from different age categories).

	Railcar	**Mainline locomotive**	**Shunting locomotive**
Type of vehicle	*5 vehicles with engine age < 1990*	*23 vehicles with engine age < 1990*	*13 vehicles with engine age < 1990*
Type and name of engine			
Age of vehicle	*14 vehicles with engine age >1990*	*7 vehicles with engine age >1990*	*4 vehicles with engine age >1990*
Age of engine			
Engine power [kW]	*Average: 337* *Min: 155* *Max: 560*	*Average: 337* *Min: 155* *Max: 560*	*Average: 337* *Min: 155* *Max: 560*
Type of power transmission (diesel-electric, diesel-hydraulic, diesel mechanical)	*4 diesel mechanic* *14 diesel hydraulic* *1 diesel electric*	*5 diesel hydraulic* *25 diesel electric*	*11 diesel hydraulic* *6 diesel electric*
Diesel consumption [g/kWh], average value (if available):	*Average: 218* *Min: 191* *Max: 245*	*Average: 224* *Min: 198* *Max: 293*	*Average: 228* *Min: 212* *Max: 256*
NOx emissions factor [g/kWh]	*Average: 8,7* *Min: 4,7* *Max: 17,0*	*Average: 4,1* *Min: 6,5* *Max: 20,9*	*Average: 12,4* *Min: 6,2* *Max: 19,4*
For comparison: Average NOx emissions factor of your fleet [g/kWh]	*Just few answers*	*Just few answers*	*Just few answers*
PM emissions factor [g/kWh]	*Average: 0,23* *Min: 0,06* *Max: 0,80*	*Average: 0,27* *Min: 0,10* *Max: 0,61*	*Average: 0,47* *Min: 0,12* *Max: 1,00*
For comparison: Average PM emissions factor of your fleet [g/kWh]	*Just few answers*	*Just few answers*	*Just few answers*
Test cycle (ISO-F, EURO etc.)	*11 x ISO F* *6 x EURO* *1 x "direct measurements"*	*13 x ISO F* *3 x ORE* *1 x "direct measurements"*	*9 x ISO F* *1 x ORE*
Annual average operating performance [gross tkm]			

Please add additional information and comments here. If possible, please explain how you calculated average values.

See also: ***Figure 16*, *Figure 18*, *Figure 19*.**

QUESTION A6: Additional information

A6.1: If you have additional information, a comment or a personal opinion on the subject of emissions from railway diesel vehicles and emissions control, please feel free to add it here. Any contribution is welcome!
Just few data/company specific answers