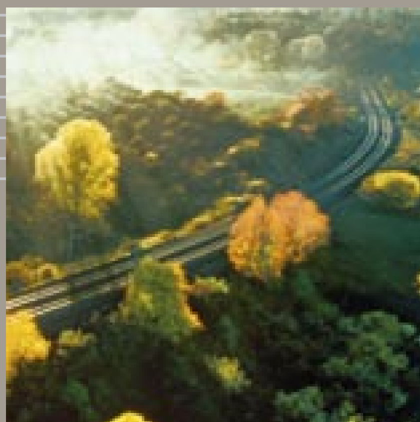
Rail Diesel emissions – facts and challenges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COMMUNITY OF EUROPEAN RAILWAY AND INFRASTRUCTURE COMPANIES
COMMUNAUTÉ EUROPÉENNE DU RAIL ET DES COMPAGNIES D'INFRASTRUCTURE
GEMEINSCHAFT DER EUROPÄISCHEN BAHNEN UND INFRASTRUKTURGESELLSCHAFTEN

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I. Introduction

The environmental benefit demonstrated by the railways over other modes of transport is a vital precondition in ensuring social and political support for this mode of transport. The railways have shown that on specific consumption of resources and specific emissions of carbon dioxide their values are lower than those obtained by their main competitors on the road (in particular due to the higher passenger densities achieved on the railways). In addition to the depletion of resources and climate change impacts, the impacts of transport on the environment, in the form of local air pollution is also important. Although road transport is considered to be the main polluter, air pollutant emissions from diesel-powered locomotives and railcars, despite their small numbers, are increasingly attracting the attention of public and authorities alike – not just on a local level, but also on a European scale.

The European Parliament and the Council agreed Directive 2004/26/EC on amendments to the Non-Road Mobile Machinery (NRMM) Directive 97/68/EC. The scope of the Directive has been extended to cover all new diesel engines for railway vehicles; this means that limit values for new engines for railway use are provided by legislation at European level. Stage IIIA limit values for NO_x and PM_{10} emissions came into force at the beginning of 2006 for railcars and will come into force by 2009 for all types of locomotives. Stage IIIB limits values will come into force in 2012 for railcars and locomotives and particularly tightens PM_{10} limits by around 90% relative to Stage IIIA. A technical review of the Stage IIIB limit values will be carried out by the end of 2007. In particular this review will examine the progress made in developing reliable technology to meet the Stage IIIB limits on all NRMM applications, and if necessary propose exemptions or derogations.

I. Introduction

In addition to the new limits provided for in the NRMM Directive, the European Commission, in direct contact with the Community of European Railway and Infrastructure Companies, called for initiatives from the railway sector in the field of diesel exhaust emissions, with particular emphasis on the existing railway fleet. As a result, the International Union of Railways (UIC) decided in October 2003 to produce the UIC Diesel Action Plan advocating pro-active measures to reduce diesel exhaust emissions.

Following the success of a pre-study by UIC into technical and operational possibilities, it was decided to follow up with a more detailed multi-partner "Rail Diesel Study" to carry out a detailed assessment of technical and operational measures and strategies that could be used to reduce NOx and PM10 emissions from diesel traction units across Europe. Project partners also included the Community of European Railway and Infrastructure Companies, the Union of European Railway Industries (UNIFE) and The European Association of Internal Combustion Engine Manufacturers (Euromot), with AEA Technology Environment as sub contractor/consultant to UIC. This cross industry input and support for the work has been essential for the study's success and for the authority of its outputs.

II. Strategic goals

Series of strategies have been proposed that could be used for reducing emissions from varying proportions of the existing fleet. Cost-benefit analysis (CBA) was used to provide initial estimates of the implementation costs and emissions benefits associated with each of these strategies, and to identify which strategies could possibly lead to net emissions benefits. CBA was also used to provide initial indicative estimates of the costs and emissions benefits associated with ensuring that future rail vehicles meet the NRMM Stage IIIA and Stage IIIB limits.

The following goals are therefore focused:

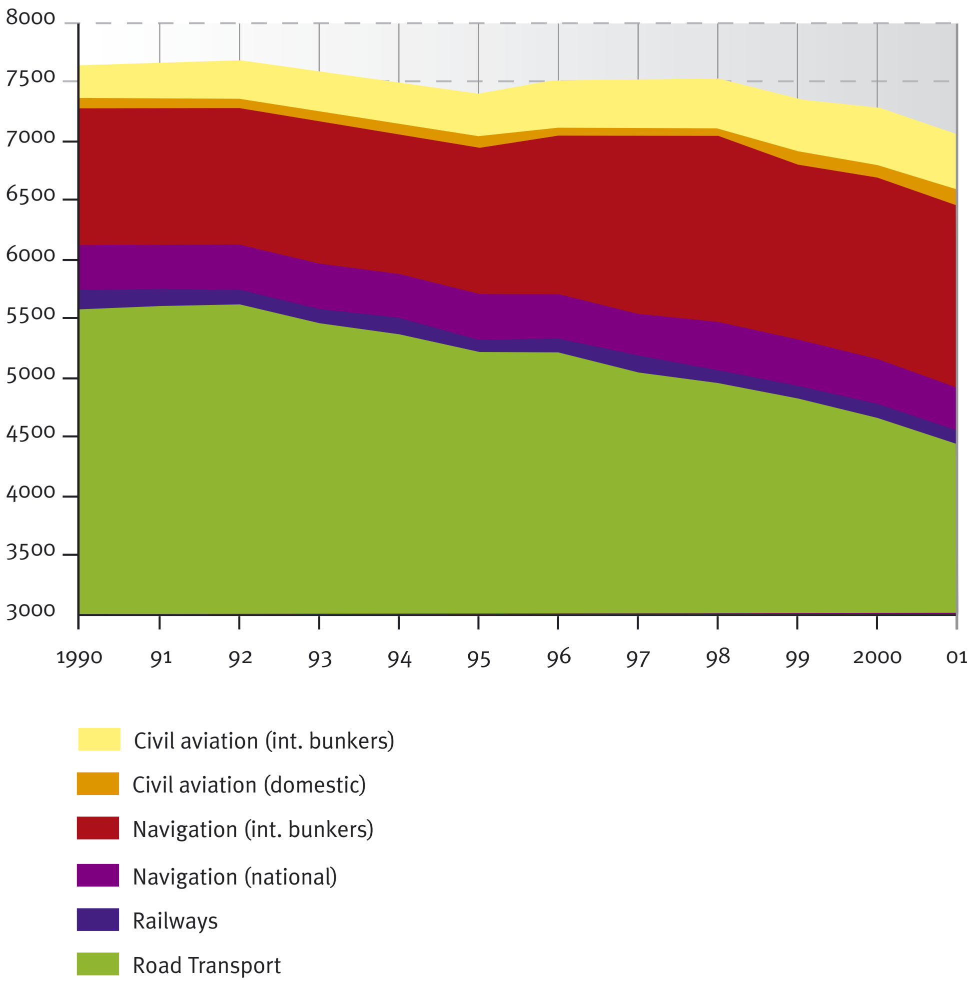
1. to support the technical review of the NRMM Directive (2004/26/EC). This review is due to be completed at the latest by the end of 2007, and the work carried out as part of this study will feed into the review process.
2. to assess the status, performance and need for (technical and operational) emission reduction measures for the existing fleet, using a cost-benefit analysis approach, whilst also taking into account the practical feasibility of applying each option.
3. to investigate the possibilities of using technical and operational measures for reducing diesel exhaust emissions by sharing knowledge and experiences (technical, economical, etc.) with the aim to prepare for implementation.

III. Railways’ share of exhaust emissions

Among surface transport modes the road transport and international waterway navigation have the highest pollutant emissions (NOx, PM). Waterway navigation emission increased between 1990 and 2001, whilst road transport emissions decreased.

Rail’s share of emissions is comparably small (1-3 %), but emissions generated locally by individual diesel vehicles may be highly perceived by the population living nearby; this is to be particularly considered since increasing attention on air quality is paid by public and authorities to air quality limits being exceeded in various European hot spots.

NOx emissions from the transport sector, EU25, 1990-2001



Source: European Environment Agency, TERM 2003 03 EEA31

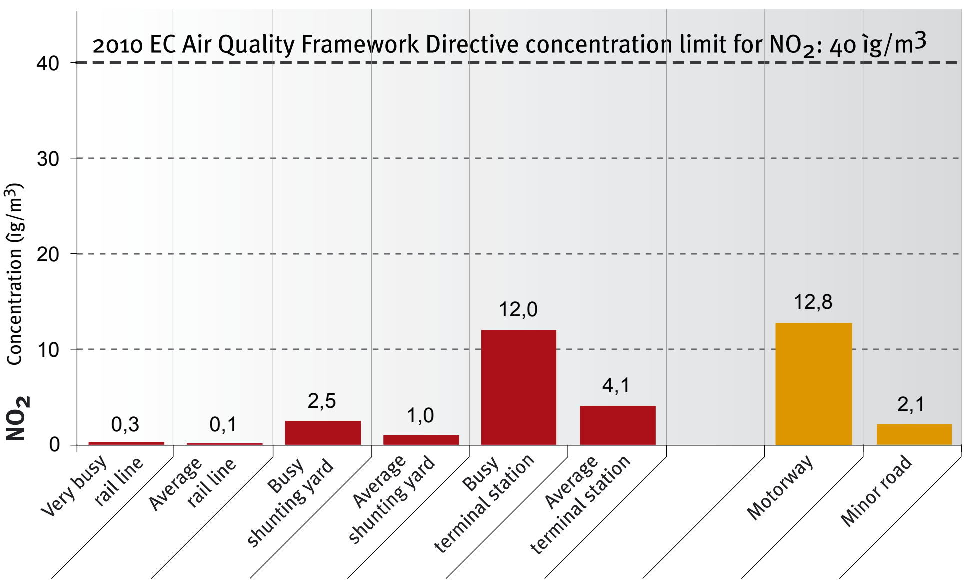
IV. Contribution of rail diesel exhaust emissions to local air quality

In spite of very low contribution of railway system to the overall pollution scheme local impacts of rail diesel exhaust should be always carefully considered. The analyses have however shown insignificant rail contributions even at very busy line sections. Even at very busy shunting yards only low level rail contributions have been detected.

More relevant contributions (but still below limit values) were only found at big terminal stations where many diesel engines are idling at the same time

It has generally been observed railway contributions to NO2 concentrations are more significant than to PM10 concentrations.

Estimated contribution of different types of rail and road locations to ambient concentrations of NO2 and PM10

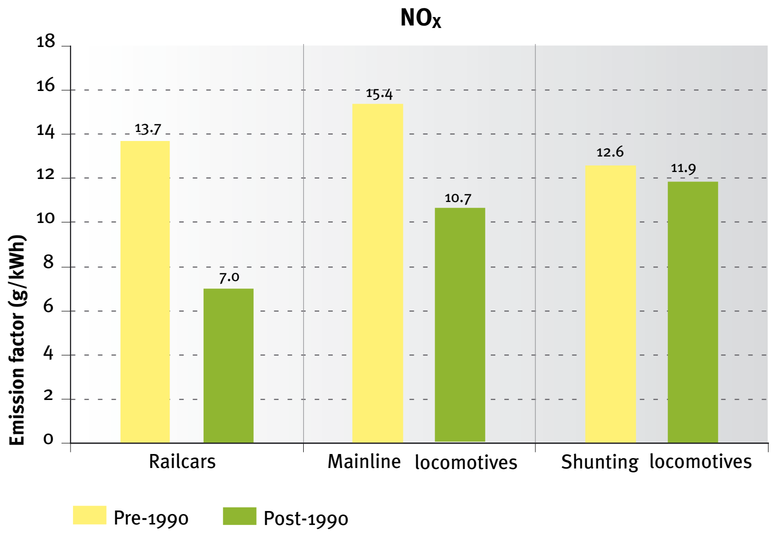


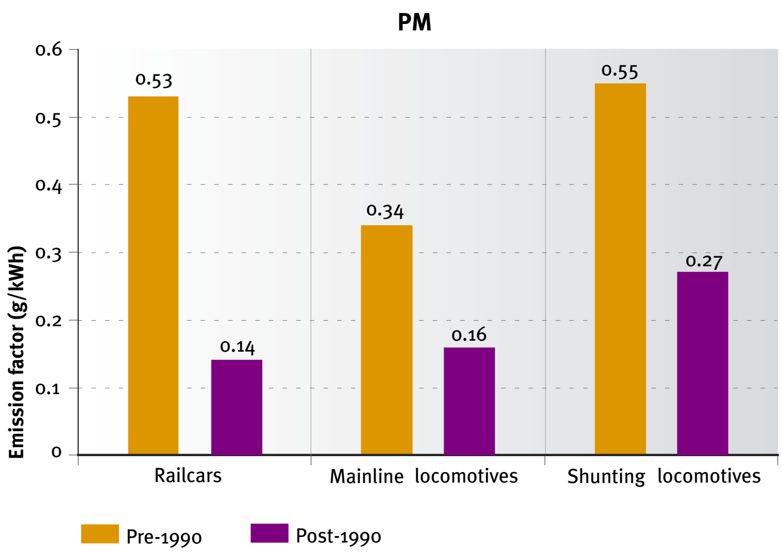
Source: Rail Diesel Study

V. Current achievements

It shall be noted; railway industry has already achieved certain progress in lowering the emission levels. The emission factors for diesel vehicles show decline with time in line with new demands. Moreover 25% of the railways in Europe already use sulphur free (<10ppm) diesel fuel.

Average emission factors for selected pre-1990 and post-1990 vehicles



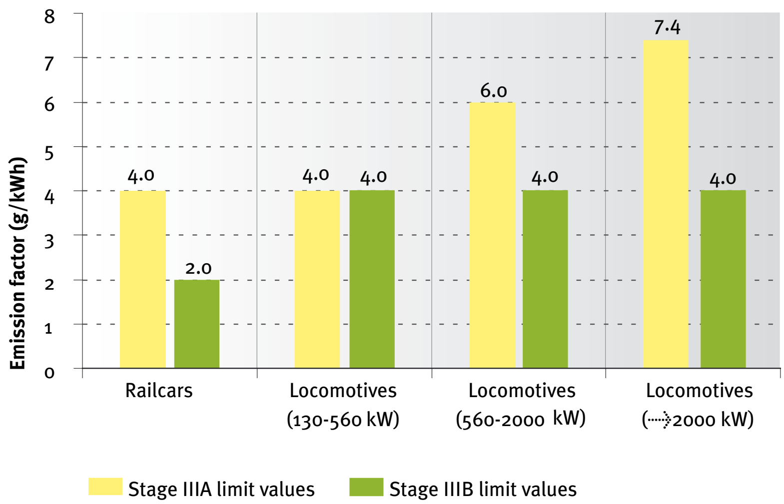


Source: UIC Questionnaire Survey

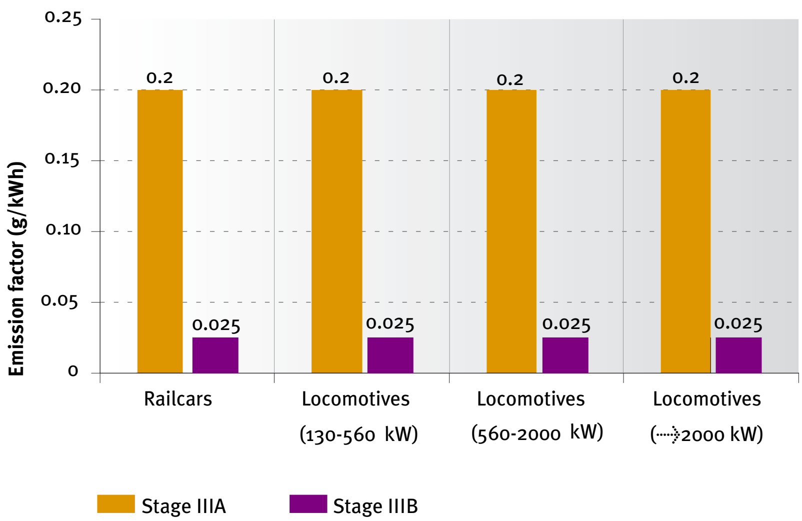
On the other hand the limits indicated in the NRMM Directive are much more restrictive and thus further improvements will be need in spite of the fact Stage IIIB limit values are subject for review before end of 2007.

Stage IIIA and Stage IIIB emission limits

NO_X



PM



Source: NRMM-Directive (97/68/EC)

VI. Future development of the diesel fleet in Europe

There are High operating performances of diesel traction in Germany, France, UK, the Baltic states and further new EU Member States – more than 1/3 of the European diesel operation is done in the new Member States.

It is expected till 2020 there will be an overall decline in the total number of diesel traction units, but increased number of diesel railcars. This will be result of progressive electrification and – at the same time – of more flexibility (and interoperability) offered by diesel railcars; this is especially the case for new operators.

Based on general assumptions it is expected that between 2006 and 2020

- 8500 new railcar and
- 9000 new locomotive engines

will be purchased in Europe.

They all will have to be compliant with new emission limits.

VII. Technical and operational measures leading for reduction of emissions

Reduction technology

The Rail Diesel study has shown that the use of SCR technology would lead to the greatest emissions benefits for the existing fleet, and for the future fleet, there is very likely to be a need for exhaust after-treatment (e.g. Diesel Particulate Filters (DPFs)) to meet the Stage IIIB limits. The Rail Diesel study has shown that at this point in time, there is very little experience of using exhaust after-treatment options on rail vehicles, and hence it is not clear at this point in time whether such equipment can, in practice, be widely used on traction units. Some of the potential limitations include a lack of available space on existing rail vehicles to fit emissions abatement equipment, and the possibility that such equipment may lead to maximum axle loads being exceeded. Furthermore, some DPF equipment may cause excessive exhaust back-pressure when fitted to rail traction units, and it is not always possible to re-engine older traction units with new engines due to the need to significantly modify off-engine support systems. All of these potential problems need to be investigated in much greater detail than was possible during this study. Detailed engineering assessments must be carried out for each individual design of traction unit in order to identify whether or not emissions abatement equipment can be used, or whether it is possible to re-engine the vehicle.

Another important implication associated with applying exhaust after-treatment equipment to both existing and future rail vehicles is that equipment such as SCR and DPF technology would require the use of sulphur-free diesel (maximum sulphur content of 10 ppm).

Operational measures for reducing emissions

The Rail Diesel study assessed a wide range of operational measures using a case study approach, and found that although in theory operational measures can be implemented more quickly than many technical measures, there are many planning and operational barriers that would need to be overcome. Furthermore, operational measures were found to be very site-specific, and there are no standard solutions that can be applied to a wide variety of situations. Best practice examples have been used to develop a basket of options that railway operators could examine in more detail with a view to using as the basis of individual options tailored to meet their own circumstances.

VII. Technical and operational measures leading for reduction of emissions

Re-engining older traction units

The amended NRMM Directive requires that any existing traction units that are re-engined in the future must be fitted with new engines that meet either the Stage IIIA or Stage IIIB limits values. As of January 2006, railway operators that wish to re-engine their railcars must fit an engine that meets the Stage IIIA limits, but at this point in time there are very few engine designs available on the market that meet these limit values, and those engines that do meet the limit values may not fit all designs of railcars. However, there may be engines available that do not quite meet limit values of the NRMM Directive, but that would significantly improve the overall emissions performance of the vehicle; at this point in time operators are prohibited from fitting such engines to their vehicles. This is an important point as the manner in which the NRMM Directive is worded may in practice be hindering the process of improving the emissions performance of the existing fleet. There may therefore be an argument for allowing greater flexibility in the types of engines that can be fitted to existing rail vehicles when they are re-engined. It is recommended that this issue should be examined in greater depth.

VIII. Costs of new emission limits

The cost of compliance with new limits given in NRMM Directive will not be negligible. The tables show estimated percentage increases of several parameters when considering Stage IIIA and Stage IIIB limits:

Estimated percentage changes in life cycle costs for technical measures to enable the future fleet to meet the Stage IIIA limits

Vehicle type	Percentage change in investment cost: loco/railcar	Percentage change in fuel cons. in cycle	Additive consumption (as a % of fuel consumption)	Percentage change in engine maintenance costs
Railcars	+3% to +7%	> 0%	0%	0% to +5%
Locomotives	+3% to +15%	+4% to +6%	0%	+5% to +10%

Source: Rail Diesel Study

Estimated percentage changes in life cycle costs for technical measures to enable the future fleet to meet the Stage IIIB limits

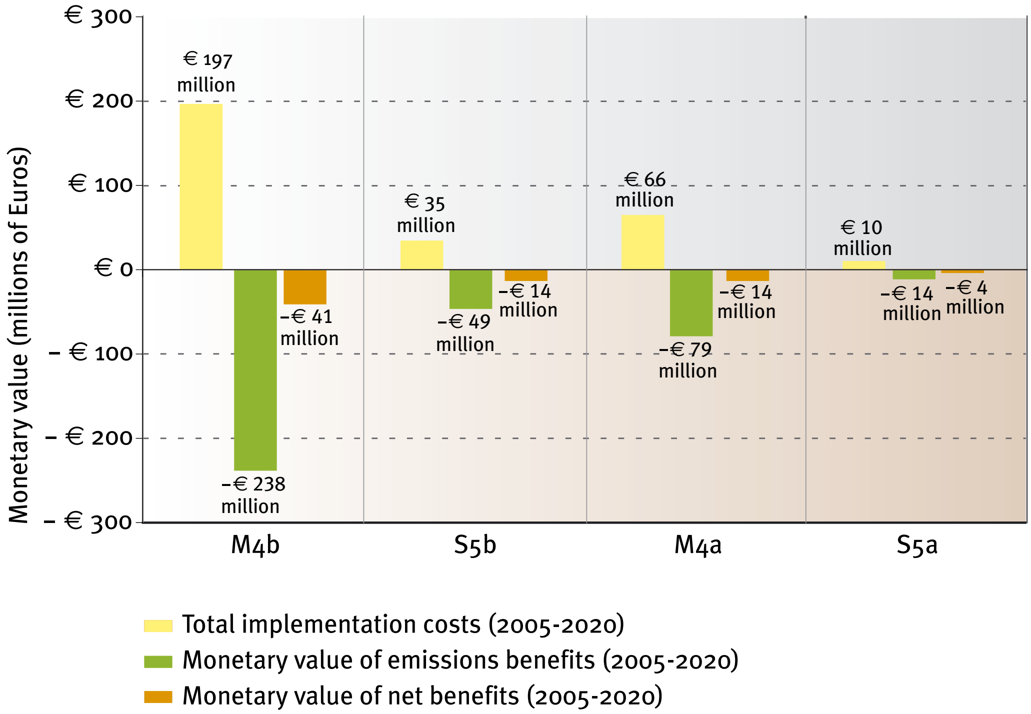
Vehicle type	Percentage change in investment cost: loco/railcar	Percentage change in fuel cons. in cycle	Additive consumption (as a % of fuel consumption)	Percentage change in engine maintenance costs
Railcars	+8% to +9%	0% to +5%	0% to 3%	+5% to +15%
Locomotives	+8% to +20%	-5% to +9%	0% to 4%	+10% to +15%

Source: Rail Diesel Study

Cost Benefit Analysis for the existing fleet

The CBA results for the existing fleet indicated that very few strategy options would lead to net emissions benefits. The only options that are anticipated to give net benefits all include the use of retrofit Selective Catalytic Reduction (SCR) technology. However, these societal benefits would have high implementation costs for the rail sector; and it is not clear at this stage how feasible it is to retrofit SCR technology to rail traction units, due to space and weight restrictions. A summary of the CBA results is presented below.

Strategy options which lead to net benefits



M4: Retrofit combined SCR+DPF technology to post-1990 mainline locomotives;

M4a: 10% of the fleet,

M4b: 30% of the fleet

S5: Retrofit SCR technology to post-1990 shunting locomotives;

S5a: 10% of the fleet,

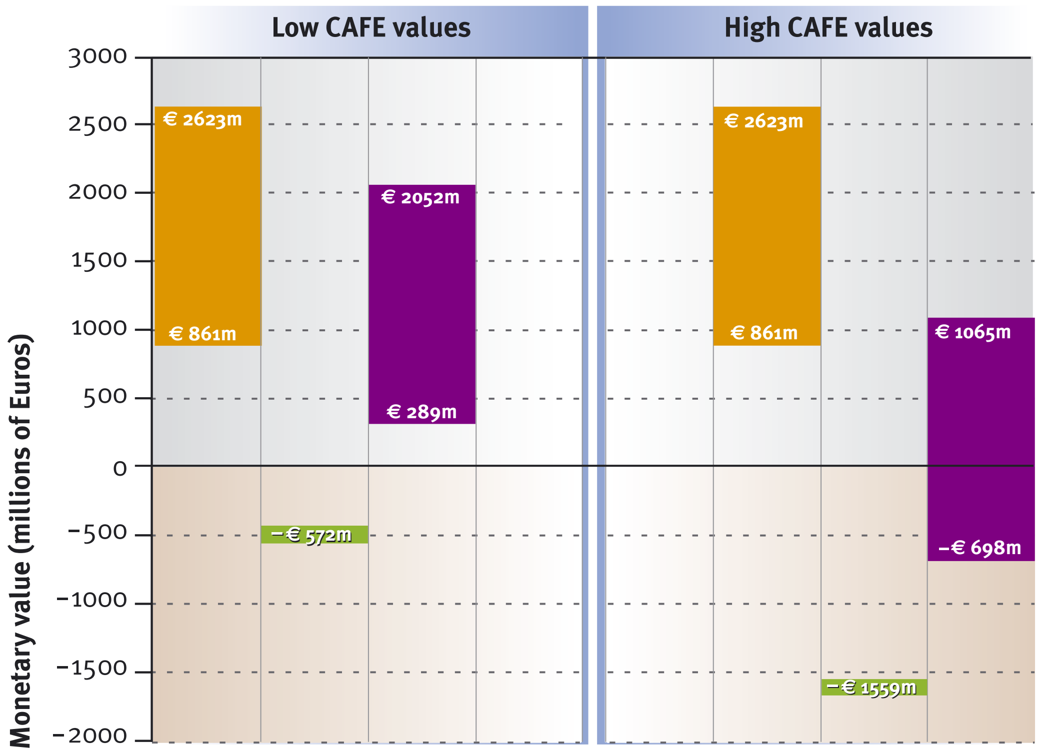
S5b: 35% of the fleet

Negative values indicate benefits, whilst positive values indicate additional costs

Source: Rail Diesel Study

Cost Benefit Analysis for the future fleet

Initial estimates of the costs and benefits associated with meeting the Stage IIIA limits



Range of implementation costs

Value of emissions benefits

Range of net costs (+ve) and net benefits (- ve)

Source: Rail Diesel Study

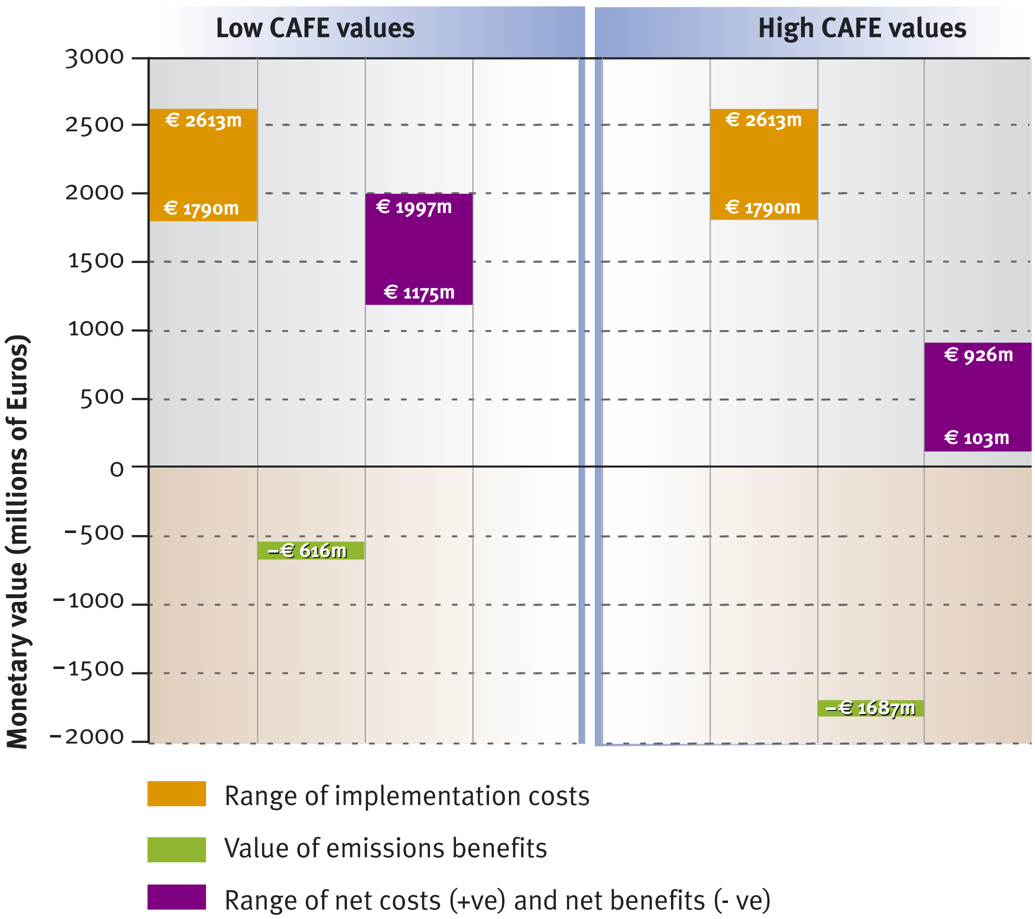
The Rail Diesel Study has made an estimation of costs and benefits associated with future vehicles meeting the NRMM Directive (97/68/EC) Stage IIIA and Stage IIIB limits. Emission benefits and implementation costs have been estimated for all new vehicles projected to come into service between 2006 and 2020. The results provide initial, indicative figures, as there is much uncertainty regarding the technologies that will be used. This is particularly the case for Stage IIIB where the technologies that will be used are still under development. And – as already mentioned – Stage IIIB is subject for review before end 2007.

VIII. Costs of new emission limits

The results show that using the low CAFE damage values, the emission benefits for implementing Stage IIIA engines are smaller than the implementation costs, resulting in net costs.

With high CAFE damage values there might be net benefits, assuming that the implementation costs are at the low end of the scale.

Initial estimates of the costs and benefits associated with meeting the Stage IIIB limits



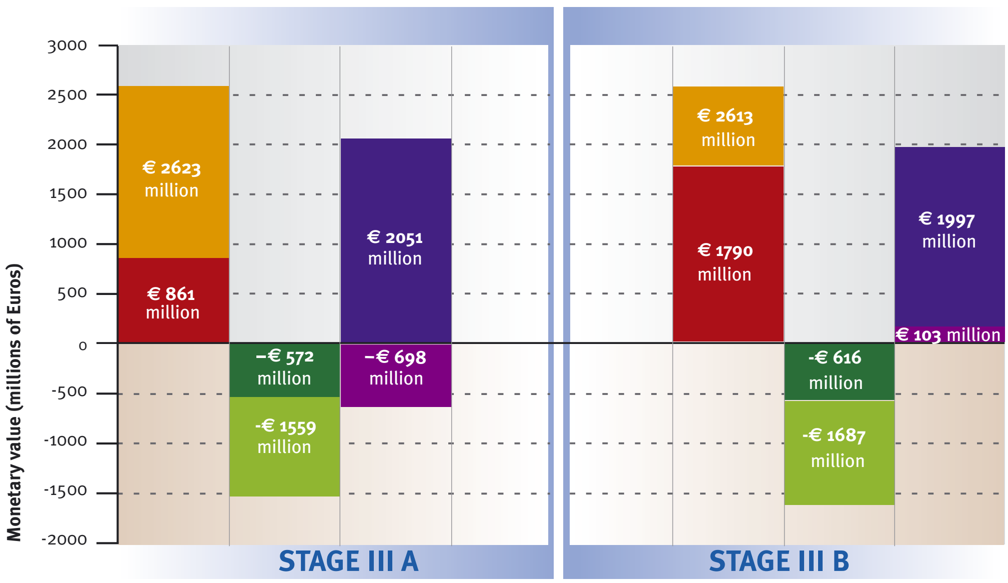
Source: Rail Diesel Study

For implementing Stage IIIB engines, the implementation costs are estimated to outweigh the emissions benefits for both low and high CAFE damage values. As a consequence there are estimated to be net costs associated with Stage IIIB ranging from 100 to 900 million Euros.

IX. Estimated costs and benefits associated with meeting the Stage IIIA and Stage IIIB limits

The Rail Diesel study has shown that there are likely to be net costs rather than net benefits associated with ensuring that new traction units meet the Stage IIIA and Stage IIIB emission limits (see Figure 2 below). The net costs associated with meeting Stage IIIA could be as high as €2045 million between now and 2020 (although the analysis results also indicated that there could be net benefits of up to €428 million). For Stage IIIB, the net costs up to 2020 could range from €379 million to €2036 million.

Negative values indicate benefits, whilst positive values indicate additional costs
Initial estimates of the costs and benefits associated with meeting the Stage IIIA and Stage IIIB limits



- Total implementation costs (2005-2020) (Low estimate)
- Total implementation costs (2005-2020) (High estimate)
- Monetary value of emissions benefits (2005-2020) (LOW CAFE DAMAGE COST VALUE)
- Monetary value of emissions benefits (2005-2020) (HIGH CAFE DAMAGE COST VALUE)
- Net costs (+ve) or net benefits (-ve) (2005-2020) (Worst case : Low CAFE + high estimate)
- Net costs (+ve) or net benefits (-ve) (2005-2020) (Best case : High CAFE + low estimate)

Source: Rail Diesel Study

X. Conclusions

There are several key issues of Rail Diesel that should be highlighted:

- Although the importance of diesel traction varies from country to country across Europe, diesel will continue to have an important role in providing rail services in the future.
- A limited number of technical options can be applied to the pre-1990 diesel fleet to reduce emissions. Open channel DPFs or re-engining (assuming that suitable engines are available) may be found to be the best options.
- A wider range of technical options may be possible for the post-1990 fleet, including SCR and closed channel DPF technology. However, there may be significant space and weight restrictions that limit the scope for applying such technologies, and it will always be necessary to conduct a full feasibility assessment for each specific class of traction unit.
- With regard to air quality, heavily trafficked line sections are insignificant contributors to atmospheric concentrations of NO_2 and PM_{10}.
  However, the contribution of very busy shunting yards to NO_2 concentrations may be important, and the contribution of very busy terminal stations with a high proportion of diesel traction to both NO_2 and PM_{10} concentrations may be significant.
- If existing traction units are to be re-engined in the future, the amended NRMM Directive requires that the replacement engines must meet the Stage IIIA or Stage IIIB limits (depending on which limit values are in force at the time of re-engining).
  In practice, suitable engines that meet these limit values may not be available, whilst there may be other engines available that would significantly improve the emissions performance of the traction unit, but that do not fully meet the relevant limit values. There may therefore be an argument for allowing greater flexibility in the types of engines that can be fitted to existing rail vehicles when they are re-engined. It is recommended that this issue should be examined in greater depth.
- For the future fleet there are no techniques available so far or coming up at the horizon allowing an economically feasible way to meet the stage IIIB values of NRMM-Directive, meaning the implementation costs (of railways) exceed the benefits (of society) by reduced emissions. This result must be considered specifically when revising the Directive.

X. Conclusions

The analysis carried out has indicated that whilst it is possible that significant environmental benefits could be achieved by reducing emissions from the existing and future rail fleets, there are very large implementation costs for the rail sector associated with achieving these emission reductions. It is very important to consider this aspect together with the minor relevancy of diesel emissions in the overall picture of the transport sector.

If the railway industry were to apply emissions reduction measures to a proportion of the fleet across Europe, then one option would be to recoup the costs associated with such actions by increasing the prices of tickets for passenger services, or increasing the costs of rail freight, and hence spreading the costs of action to society as a whole.

Whilst such a situation may mean that emissions from the rail sector decrease, there is also the possibility that increasing the costs of rail SERVICES may lead to unintended consequences, including a shift from rail transport to road transport that could lead to increases in OVERALL transport emissions, CONTRARY TO EUROPEAN TRANSPORT POLICY.

It is recommended that this aspect should be taken into account in any future work carried out on the costs and benefits of controlling pollutant emissions from the railways. Further possible actions will be investigated in the very next future to deal with the local perception of diesel emissions. Some of them, like biodiesel use, local management measures and hybride locomotives may offer good cost-benefit results.

This paper summarises the highlights of the UIC/CER Rail Diesel Emissions study

The complete study can be downloaded at
http://www.uic.asso.fr/environnement/Railways-Diesel-emissions.html

or ordered from
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