Clean European Rail-Diesel

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Start date of project: 01/06/2009
Duration: 56 months

Instrument: Large-scale Integrated Project
Thematic priority: Sustainable Surface Transport
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This deliverable’s intention is to summarise the main achievements of the CleanER-D FP 7 project and to provide recommendations towards all involved stakeholder were derived how to activate further potential and accelerate the emissions reduction of rail diesel traction in Europe in the future to further rail diesel emissions.

This document was distributed at the CleanER-D final conference and made available on the CleanER-D website www.cleanER-D.eu.
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3. GRAPHIC DESIGN
Clean European Rail-Diesel

RECOMMENDATIONS
TO IMPROVE THE ENVIRONMENTAL PERFORMANCE
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INTRODUCTION

Background of the CleanER-D project

Rail Diesel in Europe at a glance

The environmental benefit that rail carries over other modes of transport is a vital precondition to ensure social and political support for this mode of transport. Although air pollutant emissions from the railways only contribute to a small proportion of total emissions from the transport sector, rail diesel exhaust emissions are increasingly attracting the attention of the public and authorities alike. As data from the European Environment Agency show the total emissions from rail diesel traction are very low today compared to the whole transport sector (less than 2.5% for NOx and less than 4.5% for PM in 2008).

Nevertheless, the European railway sector is prepared to meet these challenges and the stricter environmental framework set by the European Union.

As the European railways have committed to “reduce their total exhaust emissions of NOx and PM10 by 40% in absolute terms even with projected traffic growth” from 2005 to 2030, CleanER-D results highlight some points which can help the sector to reach these targets.

Even if about 80% of total rail transport volume is hauled on the electrified part of the network, diesel traction plays an important role in providing rail services and serves as the backbone of railway operation in countries with little electrification, such as the UK, the Baltic states of Estonia, Latvia and Lithuania, as well as Ireland and Greece. Diesel locomotives have key importance for freight transportation and the liberalization of the freight market.

A new legal framework, a new challenge for rail diesel traction:

In 2004, the European Commission amended the Non-Road Mobile Machinery Directive (NRMM). This amendment (2004/26/EC) put railway engines in the scope of the Directive, from which they were previously excluded. The step change from stage IIa to stage IIb, three years only after the implementation of IIa as far as locomotives are concerned represents a major step in terms of engine and after-treatment technology. Due in particular to limitations of weight and space inherent to railways vehicles, advanced technical adaptations were requested. Although some EU stage IIb engines were available before the new emission legislation came into effect in 2012, it had become clear that their integration into the vehicles still required in-service experience before they could be considered as proven systems guaranteeing the high reliability demanded in rail applications.
A collaborative project to face the challenges

With the new emission level limits set by the European Directive 2004/26/EC coming into force in 2012, the CleanER-D, a 4 ½ year collaborative research project co-funded by the European Commission under its 7th Framework programme was launched in June 2009 to find technical solutions to the challenges faced in complying with this new regulation framework. The project also anticipated that further regulation will be likely and sought to provide the sector with dynamic and innovative solutions for future applications should new limits be introduced. Keeping this in mind, the project analysed hybrid technologies and their contribution to the reduction of energy consumption and CO₂ emissions. In order to reach the goal of “greening” diesel vehicles, the consortium’s 25 partners from across Europe put forth a strong collaborative effort.

The project was structured in two main frameworks:

- The operational or demonstration part, where significant applications of railway vehicles were selected in order to give the opportunity to engine manufacturers to test their new concept engines conceived to migrate from compliance with IIIA to compliance with IIIB, in the short time frame granted by the NRMM directives.

- The scientific part which investigated innovative solutions, including hybrid applications, that focused on the further NRMM implementation phases and emission limits beyond IIIB. The potential technologies were studied and analysed with regard to sustainable solutions and the ratio cost/benefits was evaluated. Based on the results of the entire project recommendations were developed how to accelerate emission reduction of rail diesel traction in Europe.

The project’s main goal was to demonstrate the feasibility and reliability in service of railway rolling stock powered with diesel engines compliant with the requirements of state IIIb of the NRMM Directive.
KEY RESULTS OF THE CLEANER-D PROJECT

All along the project duration, the two main parts of the project works progressed in parallel. While operational subprojects were aimed at demonstrating the technical feasibility of developing Stage IIIB compliant propulsion system for locomotives, the scientific subprojects studied innovative solutions that would enable meeting the stage IIIB requirements and even go beyond them at affordable cost.

CLEANER-D VEHICLE DEVELOPMENTS

TECHNICAL SOLUTIONS IMPLEMENTED IN THE CLEANER-D DEMONSTRATION PROJECTS

System Requirements

Acting as an umbrella for the work of the demonstration subprojects, the subproject System Requirements was launched to achieve the following objectives: providing a platform to engine and vehicle manufactures as well as operators to collect, monitor and evaluate the results delivered by the demonstration subprojects. In addition to the coordination activity, the subproject was responsible for developing the FMEA (Failure Mode and Effects Analysis) and the LCC (Life Cycle Cost) model to achieve a common understanding on the availability, reliability, safety and cost details.

Thus this subproject acted as a facilitator for the exchange of information between the other demonstration subprojects. Moreover it coached the work progress of both subprojects Heavy Haul and Light Weight and contributed substantially to the delivery of results within the deadlines.

It also helped defining priorities by establishing a common understanding for “necessary requirements” (stage IIIB, welding, TSI noise…), “highly recommended requirements” (design margin recommendation, mechanical design for rail vehicles,…) and the “nice-to-have requirements” (light weight design, economic and ergonomic design, …).

Moreover the Subproject System Requirements helped the consortium to solve issues like:

- How to handle the operational part of CleanER-D?
- What are the requirements to be met?
- What is important when designing, building and testing Stage IIIB compliant vehicles?
- What is the impact in terms of cost on key indicators like RAM & LCC when strengthening the legislation requirements relating to exhaust gas emissions for rail vehicles?

The basic requirement for operators to deliver competitive service was highlighted by the Life Cycle Cost work package. This reminded the manufacturing partners that the best possible technology must be clean, reliable, affordable and competitive.
Heavy Haul Subproject

The Heavy Haul main objectives consisted in the installation of a stage IIIB compliant engine into an already existing locomotive platform originally designed for an equivalent stage IIIA engine. This would allow to assess the cost-effectiveness of stage IIIB implementation in mainline locomotives in terms of impact on vehicle design and operational and maintenance aspects.

A stage IIIB compliant 16-C175 prototype engine developed by Caterpillar producing 2800 kW was installed in the new Vossloh diesel-electric locomotive platform EUROLight. Exhaust Gas Recirculation (EGR) and a Diesel Particulate Filter (DPF) were the technologies chosen in order to comply with the stage IIIB emission limits without requiring the use of a second fluid (urea). In addition a pre-oxydation catalyst (DOC) integrated in the DPF system enabled its passive regeneration. The modification works on the locomotive in order to install the new engine package resulted in additional vehicle weight as well as required space, especially for the integration of the cooling plant.

Following the installation tasks, a complete set of stationary validation tests was carried out on the locomotive to ensure a correct integration of the new engine prototype. The test program included emissions measurements carried out by CMT Motores Térmicos of Universitat Politècnica de València which confirmed that the prototype met stage IIIB emission regulations and verified the DPF filtration efficiency.

Finally, the locomotive and its new engine package were tested on a field trial performed by Trenitalia Cargo. This permitted to evaluate the performance of the new emission reduction technologies under real rail conditions and duty cycle.

Light Weight Subproject

The Light Weight subproject had to achieve two objectives over the project duration. The core of the subproject consisted in carrying out a field trial with a modified freight locomotive from Deutsche Bahn AG compliant with the Stage IIIB emissions requirements. In addition, the subproject focused on monitoring the performance of a SNCF locomotive Type BB69400 equipped with a DPF.

A prototype 12V4000 engine that produces 1800 kW at 1800 rpm was developed by MTU. The engine was equipped with new engine technologies and connected to a diesel particulate filter to meet the emission regulation IIIB. The prototype IIIB system was calibrated to enable the operation of the DPF in a completely passive manner.

Deutsche Bahn AG installed this prototype system into a freight locomotive class 225, dating from 1971. Therefore, modifications to the engine bed, gearbox, cooling system and other assemblies were required to adapt the locomotive to its new power source. The German Federal Railway Authority (EBA) accepted the modifications, so that all obstacles to the homologation of the locomotive have been cleared.

After completion of integration, the locomotive started operation in regular service. A mobile emission measurement performed in the locomotive at the end of the field test measured gaseous and particulate emissions in steady state operation. After rebuilt of the locomotive the DPF was inspected.

The BB69419 locomotive from SNCF was equipped with a commercially available DPF-system and a data logging system. SNCF operated the locomotive during common service. Different temperature- and pressure sensors gave an indication on how the system performed.
CHALLENGES AND EXPERIENCES DURING THE DEMONSTRATION WORK

Heavy Haul Subproject

Within Heavy Haul subproject emission reduction technologies for diesel locomotives were developed and integrated successfully and proved in service. Nevertheless, the subproject showed that moving from stage IIIA to stage IIIB implies a significant weight increase and space requirements in order to install the new IIIB compliant engines. In particular, the weight increase lead to an important designing effort in order to reduce weight in other vehicle areas so the same power output and axle load limit could be maintained.

Even if solutions were available from the engine manufacturers to comply with new emission regulations, the subproject showed that a long period of time is still required for validation of the vehicle and engine changes, as well as for vehicle homologation. Several years are required before the new compliant vehicles can enter into service.

Light Weight Subproject

This subproject investigated ways to develop, improve and integrate new emission reduction technologies for diesel locomotives and demonstrated its reliability in common service. Stage IIIB is already an option that can provide significant emission reductions, but adaptation of IIIB technology into the 40-year old class 225 locomotive also demonstrated that introduction is a “challenging task”. It succeeded because of its specific feasibility for substitution of engine, thanks to good mass balance and available space. Refurbishment of old locomotives is however not always possible, but in cases like the current study, it contributed to reaching the ecological targets of the EU.

More stringent limits will further increase the challenge due to integration of the required technologies. Furthermore lifecycle costs could be expected to increase! Hence these locomotives would be available only at higher costs and would probably not be very attractive to operators.

Mobile emission measurement in this locomotive was successful, but it was made possible only thanks to the very intense preparation phase preceding the installation of the engine into the locomotive, and operation under “ideal” conditions. Installation in an existing locomotive causes much higher efforts and operation in regular service influences the reliability of measuring devices and consequently the quality of collected data.

Different temperature- and pressure sensors of the SNCF Type BB69400 gave an indication on how the system performed and provided an invaluable basis for the development of future, environmentally friendly rail vehicles.

In summary, the intensive cooperation of all partners involved in the Light Weight Subproject enabled to complete successfully a challenging project and proved performance of new emission control technologies for cleaner rail vehicles.

General conclusions of the Demonstration Subprojects:

The demonstration subprojects proved that stage IIIB can be implemented, not only from a manufacturing, but also from an operational point of view.
The subproject Railcar successfully developed a Stage IIIIB compliant railcar power pack. It proved that a railcar of considerable age can be repowered with an efficient, clean and modern Stage IIIIB engine. Finally, during the CleanER-D project an identically constructed Railcar, not part of the CleanER-D consortium, made use of the new Stage IIIIB technology and successfully started revenue service in Slovakia. Last but not least, this subproject evaluated the feasibility of the railcar power-pack for applications in the UK.

The subproject Heavy Haul invested considerable efforts and successfully upgraded the Stage IIIA compliant diesel electric Vossloh Eurolight heavy haul freight locomotive. As a result, the vehicle is now compliant with Stage IIIIB requirements. Not only developing and enhancing the engine technology, but also making the vehicle fit for stage IIIIB (weight, noise, LCC, cooling, design …) was achieved.

The Light Weight team also carried out the refurbishment of a 40-year old diesel hydraulic locomotive. The subproject partners took components of two locomotives, integrated them into a modern Stage IIIIB engine and built a Stage IIIIB compliant vehicle. In-service testing proved the technology is fit for purpose.

Technical aspects aside, the demonstration subprojects were supported in their work by the team of the System Requirements Subproject, in charge of reliability, availability, maintainability (RAM) and life cycle cost (LCC), thus ensuring that those issues of key importance to the operators of the new vehicles were always taken into account.

As far as RAM aspects were concerned, a general product break-down structure (PBS) has been agreed on and a qualitative evaluation of the possible impacts on missions due to failure modes of the new engine components has been carried out.

Concerning LCC aspects, the System Requirements Subproject worked in collaboration with the Sustainability and Integration Subproject to elaborate a model and a tool for preliminary assessment. This allowed evaluating the possible advantages of adopting Stage IIIIB.

CLEANER-D SUSTAINABILITY AND INNOVATION: ACHIEVEMENTS OF THE SCIENTIFIC SUBPROJECTS

EMISSION STATUS AND DEVELOPMENT

As data from the European Environment Agency show the total emissions from rail diesel traction are very low today compared to the whole transport sector (less than 2.5% for NOx and less than 4.5% for PM in 2008).

The total emissions of both NOx and PM have already decreased by about 35% from 1990 to 2008 (EEA) and it is expected that emissions will further decrease due to:

- introduction of cleaner technologies, re-motorisation schemes and a shift from locomotives to DMUs in passenger transport,
- better operating regime – like driver trainings, less idling or higher load factors,
- the electrification of the European rail network has increased by approx. 4% in the past years (2003-2008); this trend will most likely continue in the next years, with higher rates in the UK.
The emission scenario developed in the CleanER-D project estimates that the total emissions of NOx and PM from rail diesel traction will further decrease by approx. 37% for NOx and approx. 46% for PM until 2020 compared to 2008 (see Figure 1.1 and Figure 1.2).

**Emissions**

![Figure 1.1: Total NOx Exhaust Emissions from Rail Diesel Traction in EU27 & EFTA, CleanER-D estimation until 2020](image1)

![Figure 1.2: Total PM Exhaust Emissions from Rail Diesel Traction in EU27 & EFTA, CleanER-D estimation until 2020](image2)
RAIL DIESEL FLEET SCENARIOS

The data analysis has shown that the number of rail diesel vehicles at UIC member companies in the EU27 and EFTA decreased from 2003 to 2010. For diesel locomotives there was a significant drop in numbers (from 16,700 in 2003 to 13,300 in 2010) and only about 75% of these locomotives were in active service (2010: 10,200 active diesel locomotives). The number of DMUs increased slightly (from approx. 6,900 in 2003 to 7,100 in 2010).

Based on extensive surveys and data analysis, a CleanER-D rail diesel fleet scenario was developed covering also the non-UIC diesel fleet (see Figure 1.3 and Figure 1.4). In this scenario the number of active diesel locomotives decreases significantly from 14,100 in 2008 to approx. 9,150 in year 2020 and the number of DMUs increases from 8,900 to approx. 11,100 in the same period.

The share of stage IIIA and IIIB compliant engines for locomotives will be about 30% and for DMUs about 41% by 2020.
COST BENEFIT ANALYSIS

The socio-economic impact of the introduction of the stages IIIA and IIIB was investigated in a cost/benefit analysis. The benefits for society are measured as avoided external costs, due to reduced emissions compared to a continuation of UIC II emission standard.

Based on the fleet scenario and related emission reduction the external costs caused by NOx and PM will reduce by more than 40% from 2008 to 2020. This reduction is a result of fleet development, fleet change and fleet renewal with NRMM stages IIIA & IIIB compliant engines in new and existing rail diesel vehicles. In total the introduction of stages IIIA and IIIB will generate societal benefits from cumulated avoided external costs of about 1.4 billion € until 2020.

In the same period the life-cycle costs for the introduction of engines with the emission stages IIIA and IIIB in comparison to UIC II emission standard cumulate for the railway sector to about 780 million € in the high technology cost scenario and 680 million € in the low technology cost scenario (see Figure 1 5). In these costs system integration and platform development costs for the industry are not included.

Figure 1 5: Cumulated avoided external costs (benefits) vs. cumulated life cycle technology costs from introduction of NRMM stages IIIA/IIIIB (2008 – 2020), European railway operators, EU27 & EFTA
Emerging Technologies

After-treatment technologies can lead to further reduction of emissions however there are implications and trade-offs that can prove to be complex and potentially critical for their implementation, particularly those related to systems integration. Cutting the emission levels has the tendency to yield to heavier and bigger propulsion units. In addition the fuel consumption rises, which might be compensated with emerging engine technologies. In general terms, the outlook for meeting potentially more restrictive emission levels beyond Stage IIIB would require the use of a multi-technology after-treatment design combining EGR, SCR and DPF capabilities making it necessary to develop again new vehicle platforms because of new weight and volume requirements. For example simulation work in SP6 (Emerging Technologies) has shown for engines up to 560 kW that such combined designed propulsion unit (BSNOx 1 g/kWh) is about 18 % heavier than a conventional Stage IIIB propulsion unit. Similarly, it is considered that technologies currently in the research domain for automotive Euro VI heavy duty application could eventually achieve a status that would allow them to be the state-of-the-art for railway application in the future. While predicting a timeframe for this is not possible at this stage, it can be estimated that this will not be feasible before at the very least 2020. The key factor for simultaneous pollutant emissions and fuel consumption reduction is - and will be - the correct integration of those emerging technologies that will be gradually available for production series application.

Three key scenarios were explored as can be seen in Figure 1 6 below. All three scenarios consider measures beyond Stage IIIB. These have been considered only for engines up to 560 kW.

![Figure 1 6: Technologies considered in Scenarios 1, 2 and 3 within SP6](image)

The process of diluting new technology into the market is a long and complex one that is not only constrained by the speed of progress in technology but also constrained by legal frameworks, demand from operators and strategic decisions made years before the emergence of a new technology.

In addition there is a pre-tender period where OEMs invest capital and time to R&D of components for engine development as well as system integration and platform development.

Against this background about 10 years between new legislation is essential to allow for satisfactory engine and integration developments.
The emission scenarios within SP5 (Sustainability & Integration) up to 2030 revealed that a high commissioning rate of IIIB engines after 2020 could yield even higher emission reduction than a hypothetical introduction of a “zero emission” stage (see Figure 17). An earlier uptake of higher commissioning rates of stage IIIB would even further increase the positive effect.

Hybrid Solutions

The potential of hybridization to reduce fuel consumption as well as emissions was analysed and demonstrated in the Hybrid Solutions by using different Energy Storage Systems (ESS) for several vehicles on defined duty cycles as well as various system architectures. Today it can be concluded that the mainly beneficial applications are regional/suburban DMU and shunter locomotives. The results prove that a reduction of fuel consumption up to 20 % compared to eco-driving can be achieved for DMUs. Energy management strategies can allow even higher savings up to 25 %. The reduction of CO2-emissions is in the same range as for the fuel consumption.

A simultaneous overall reduction of all emissions including CO2, NOx and/or PM is contradictory in some use cases. This trade off can be solved by energy management strategies and appropriate system architectures.
One promising example: For a shunter locomotive with Start-Stop strategy and downsizing of Internal Combustion Engines (ICE) from 1000 kW to 560 kW PM-emissions can be reduced up to 73 %, while NOx can be decreased up to 57 %. At the same time fuel consumption is lowered by 34 %, if a traction battery of 235 kWh is applied and when avoiding a big share of its predominating idling operations.

Not considering the fact, that the NRMM is not specifying emissions on a system level, the reduction of PM-emissions by hybridization (overall system view) is not as high as the legislative requests by 90 % for the step from IIIA to IIIB (only engine view). Therefore a hypothetical replacement of after treatment systems to reach the defined limits of emissions for stage IIIB due to use of ESS is unrealistic.

Besides the fuel and emission reduction potential of hybrid solutions a significant downsizing of ICE can be possible depending on the duty cycle and use case in order to optimize the best fit for LCC (for example use one ICE instead of three in a DMU).

LCC assessment indicates that certain combinations for system architectures (type of ESS and transmission) and duty cycles (service types) can have lower LCC than corresponding non-ESS configurations, even though every transmission type (diesel-electric, diesel-mechanic, diesel-hydraulic) has a different baseline of LCC for a non-hybrid solution. From the LCC perspective view there are promising ESS technologies based on electric, hydrostatic or kinetic principles.

The Figure 1.8 and Figure 1.9 below show the calculation for a 20 year period for different fuel cost scenarios (low/ medium/ high) for another promising example: regional DMU (diesel-electric system architecture with 3x 560 kW ICE).


Figure 1.8: LCC-reduction for regional train (3x 560 kW, diesel-electric system architecture) due to hybridization within a 20 year time period, related to the medium price scenario
Within the Cleaner-D project investigations for hybridization of diesel-driven rolling stock with energy management possibilities were analysed in detail for the first time by a European-funded project consortium. Operation and field experiences are still at the beginning, but an optimization of ESS with energy management and operational strategies can already be done. Generally every application or use case has to be assessed for the benefit of hybridization.

It is necessary to prove the various energy management strategies of hybrid solutions in revenue service operation in order to gain more reliable data and experience. Additionally new train generations will need an optimization of the overall system architecture with energy management and customer's operational strategies. For example electrification of auxiliaries is necessary if Start-Stop strategy and emission-free tunnel operation are used.
CONCLUSIONS

- From an economic and technical perspective, refurbishment of old existing vehicles with IIIb engines has to be carefully analysed.
- Vehicle authorisation, even due to the partial changes on the vehicle, could require significant time, and as a consequence have an impact on the availability of compliant vehicles on the market.
- The Life Cycle Cost model for diesel vehicles can be applied for all available diesel applications including various technology options such as the one using of urea.
- The total emissions from rail diesel traction are very low today compared to the whole transport sector (NOx: less than 2.5%; PM less than 4.5% in 2008). And emissions of NOx and PM have already decreased by about 35% from 1990 to 2008.
- The fleet and emission development scenarios until 2020 estimate a considerable further reduction of emissions (NOx more than 35% and PM more than 45%) with a share of stage IIIA and IIIb engines of 30% for locomotives and 41% for DMUs.
- An additional reduction of emissions would be possible if the migration of current engine technologies into the fleet will be accelerated, this is seen as the key factor to further reduce the fleet emissions.
- The migration of new technologies into the fleet can only be accelerated if adequate market conditions will be provided (legislation framework, i.e. time between new legislation, and incentives as well as technologies with low LCC), which increase the fleet renewal rates.
- The introduction of stages IIIA and IIIB will generate societal benefits from cumulated avoided external costs of about 1.4 billion € by 2020, whereas the costs for the railway sector for the introduction of stage IIIA and IIIB technology cumulate to 680 – 780 million €. However system integration and vehicle platform development costs for the industry could not be considered within the CleanER-D Project and would have to be included in any impact assessment.
- Emerging after-treatment technologies can lead to further reduction of emissions. However, there are implications and trade-offs that can prove to be complex and potentially critical for their implementation, particularly those related to systems integration. Cutting the emission levels has the tendency to yield to heavier and bigger propulsion units. Thus, the key factor for simultaneous pollutant emissions and fuel consumption reduction is - and will be - the correct integration of those emerging technologies which needs further investment and time to develop.
- The outlook for meeting potentially more restrictive emission levels beyond Stage IIIb would require the use of a multi-technology after-treatment design.
- Hybrid technologies could substantially reduce fuel consumption and hence CO2 emissions up to 25 % as well as NOx and PM emissions depending on the duty cycle, system architecture and if appropriate energy management strategies will be applied. Furthermore a downsizing of the internal combustion engine can be achieved in some cases. LCC assessment shows that certain combinations of Energy Storage Systems (ESS), transmission and duty cycle can have lower LCC than corresponding non-ESS configurations. The positive results have to be further validated in full revenue service operation.
RECOMMENDATIONS TO FURTHER REDUCE DIESEL EMISSIONS

Based on the results of the CleanER-D Project recommendations towards all involved stakeholder were derived how to activate further potential and accelerate the emissions reduction of rail diesel traction in Europe in the future.

Summary of the Key Recommendations

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<th>Key Recommendation</th>
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<td>European Commission</td>
<td>“Create framework conditions supporting an increase of fleet renewal rates”</td>
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<td>Member States and Public Procurement Authorities</td>
<td>“Provide framework conditions and incentives supporting an increase of fleet renewal rates and the use of innovative technologies”</td>
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<tr>
<td>Railway Operators</td>
<td>“Use every possible economic solution over the life of the vehicle to introduce energy efficiency and emission reduction technologies in the rail diesel fleet”</td>
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<tr>
<td>Engine Manufacturers and Vehicle Integrators</td>
<td>“Provide economically viable solutions, which reduce emissions, fuel consumption and LCC”</td>
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<tr>
<td>Infrastructure Managers</td>
<td>“Support energy efficient operation by intelligent traffic flow management on the network”</td>
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RECOMMENDATIONS TO THE EUROPEAN COMMISSION

Key Recommendation:
“Create framework conditions supporting an increase of fleet renewal rates”

Specific Recommendations

Legislation (NRMM Directive)

1. Any potential further exhaust emission limit stage should allow enough time for the engine manufacturers and OEMs to develop viable technical solutions and to provide stability to the railway market (e.g. 10 years after publication of the new legislation)

2. Any potential further exhaust emission limit stage should be designed as to provide the framework for a business case for the rail operators, i.e. new limit values should be set so as to allow lower fuel consumption

3. Another impact assessment would be required to validate requirements for further emission limits based on the results of the cost-benefit analysis and methodology developed by the CleanER-D project and taking into account system integration and platform development.
Framework for Market Incentives
1. Establish a legislative framework, which allows member states to provide market incentives

Research and Development
1. Facilitate research for innovative emission reduction technology for low LCC of the propulsion system
2. Facilitate demonstration projects with Energy Storage System solutions for DMUs and shunting locomotives

RECOMMENDATIONS TO MEMBER STATES & PUBLIC PROCUREMENT AUTHORITIES

Key Recommendation:
“Provide framework conditions and incentives supporting an increase of fleet renewal rates and the use of innovative technologies”

Specific Recommendations
1. Local Authorities should explicitly ask for IIIB technology as well as innovative technologies for public transport in new transport service contracts (Green Public Procurement initiatives).
2. Provide incentives for emission reduction technologies
3. Incentivise Re-Powering projects
4. Balance requirements regarding time schedule, acceleration and engine power

RECOMMENDATIONS TO RAILWAY OPERATORS

Key Recommendation:
“Use every possible economic solution over the life of the vehicle to introduce energy efficiency and emission reduction technologies in the rail diesel fleet”

Specific Recommendations
1. Promote and introduce energy and emission efficient operational schemes for rail diesel traction
2. Increase the average load factor / occupancy rate
3. Focus on LCC of emissions reduction technology in the procurement process
4. Promote clean technologies in the market
5. Introduce a reporting system that monitors the EU-wide direct exhaust emission from rail diesel traction
RECOMMENDATIONS TO ENGINE MANUFACTURERS AND VEHICLE INTEGRATORS

Key Recommendation:
“Provide economically viable solutions, which reduce emissions, fuel consumption and LCC”

Specific Recommendations
1. Develop new innovative solutions for application in railways (engine manufacturers)
2. Especially for repowering projects, provide a variety of engine solutions at the latest emission stage considering overall weight and space constraints for integration into existing vehicles (engine manufacturers and vehicle integrators)
3. Optimize the traction system and auxiliaries (vehicle integrators)
4. Offer IIIB technology as well as innovative technologies for public transport in new transport service contracts, even if not explicitly required by the local authorities (vehicle integrators)
5. Offer specific service concepts and structures which could ease the introduction of new engine types and technologies for the operator (engine manufacturers and vehicle integrators)
6. Indicate emission characteristics of NOx and PM beside the specific fuel consumption in the product specification (engine manufacturers)

RECOMMENDATIONS TO INFRASTRUCTURE MANAGERS

Key Recommendation:
“Support energy efficient operation by intelligent traffic flow management on the network”

Specific Recommendations
1. Support fluent traffic and eco-driving by communication board to ground
2. Consider Energy Efficiency in long term planning
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