CleanER-D

Clean European Rail-Diesel

SEVENTH FRAMEWORK PROGRAMME

CleaneER-D (Clean European Rail-Diesel) is a research project partly funded by the European Commission under the 7th Framework Programme that started in June 2009. This 4 year project (budget: 13.6 M€ of which 8 M€ is funded) aims at developing, improving and integrating emissions reduction technologies for diesel locomotives and railcars.

The CleanER-D project was launched to tackle the technical challenges that need to be solved in order to comply with this new emissions regulation. The quantitative target of the project is to achieve emission levels within the limits established by the new European Directive 2004/26/EC and to be prepared for further upcoming regulation by evaluating the best possible innovative solutions. Hybrid technologies will also be evaluated for their contribution to the reduction of energy consumption and CO_2 emissions. The 26 consortium partners from all over Europe are taking a strong collaborative effort in order to reach the goal of greening diesel vehicles.

The research of CleanER-D is divided into several subprojects. A technical management team ensures a harmonised work flow among the subprojects and oversees rail system integration.

The main goals of the project are to demonstrate the feasibility and reliability of railway rolling stock powered with diesel engines in service, which are compliant to the requirements of stage IIIB of the NRMM Directive. To ensure the success of the project target, three operational projects have been established. Two of them focus on re-powering existing diesel vehicles through a low emission engine. The re-powering exercise will be performed on a railcar and a locomotive.

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 it had been excluded so far. The step change from stage IIIA to stage IIIB, 3 years only after the implementation of IIIA 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 will be necessary. It has become clear that the technology for locomotives will not be mature before the exhaust gas requirements, according to stage IIIB, will come into effect in 2012.

Railcar Demonstration project

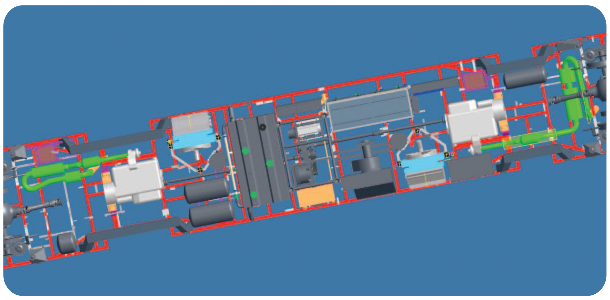
This subproject aims at refurbishing a class 842 railcar with a new power-pack which complies with stage IIIB requirements. The objective of this exercise is also to deliver valuable information to engine manufacturers, integrators and operators concerned with local emission reduction for diesel railcars. The main partners in this process are:

- **Czech Railways** is responsible for integrate the engine into the diesel railcar
- **TEDOM** delivers the stage IIIB compliant engine package,
- **Consiglio Nazionale delle Ricerche** is in charge of the emission measurements campaign on the vehicle
- **ATOC** will ensure at the end of the project that the results of this subproject can be implemented also for the UK vehicles which are known to have limited gauge restrictions.

The target of this re-powering exercise is to replace an almost 20 year old engine with an IIIB engine. In parallel, the Czech Railways are equipping the same Class 842 diesel railcars with IIIA engines in order to compare the emission as well as technical performances of IIIA and IIIB compliant engines.

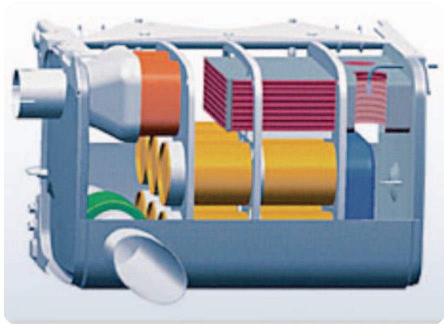
In autumn 2010 the feasibility analysis, the vehicle requirement specifications and the engine specification were finalised.

In the feasibility study, a preliminary space analysis was carried out comparing alternative diesel engines of similar size to the existing one. The study confirmed that space existed for the integration of SCR after-treatment equipment, including a urea tank, assuming the urea consumption being approximately 3% of the fuel consumption. The study also concluded that the railcar weight would not increase significantly.



Traction arrangement (plan view)

- SCR, DPF, silencer, exhaust manifold
- urea tank 60 l
- Diesel engine, traction gearbox
- cooler, fan



Combined system: Diesel Particulate Filter + Selective Catalytic Reduction muffler

The customer requirement specification defines the power pack requirements of the vehicle, offered to the owner for in-service trials. The specific requirements focus on:

- Technical requirements (axle load, space, power supply, data transmission)
- Operational requirements (environmental conditions, running, fuel quality, filling and intervals)
- Legislative regulations (welding, structural requirements on vehicle body, fire protection, noise, vibrations, running through tunnels)
- Economical requirements (time between overhauls, mean time between failures)

The primary aim of the engine specification is for emission limits to meet stage IIIB requirement. TEDOM started the development of a new modification of the engine type TD 242 series for railway application. This new propulsion system is a further development of the current engine. Within the subproject the following technologies are currently under development:

- Selective Catalytic Reduction system to reduce NOx emissions
- Injection system with higher injection pressure
- New piston design for low emission combustion
- Closed wall-flow Diesel Particulate Filter with regeneration system.

These data and results were reviewed and gathered in harmonised common requirement specifications which are followed by the system requirement subproject.

The test bed and in-service trials will produce valuable information about the engine package system durability, reliability and endurance, and testers will gain experience and information on operational and maintenance aspects of IIIB emission reduction technology in rail application. The above mentioned tests will be carried out after the specifications are defined. The results will be useful for future procurement of railcars.

Heavy Haul Demonstration project

The Heavy Haul demonstration subproject involves:

- The installation of a new-generation C-175 series engine manufactured by **Caterpillar**.
- The16 cylinder rail engine is designed to comply with the stringent stage IIIB emission limits and will be integrated in the newly designed **Vossloh** diesel-electric locomotive EURO Light.
- Once the installation is completed, exhaust gas emissions measurements will be carried out on the locomotive by the thermal engines research centre CMT of the **Technical University of Valencia** UPV.

Finally the prototype locomotive will be operated, performing revenue service under a special monitoring program.

This demonstration subproject faces a weight challenge, mounting a 2800 kW power stage IIIB diesel engine in a typical European four axle locomotive configuration while not exceeding the maximum axle load restrictions. The emission reduction to Stage IIIB exhaust emissions will add additional engine weight and therefore weight reduction in other areas of the locomotive will be required. This subproject will also extract useful and validated technical information on the new low-emission technologies from tests.

During the first phase of the project general specifications for the new Stage IIIB compliant engine package were defined with the reference of a common requirement specification subproject. These were complemented with the specific locomotive specification and its maintenance intervals requirements.

The next step was the selection of emission technology to be used for this diesel engine. As single fluid was preferred, the EGR technology plus particulate after-treatment DPF was selected. The EGR technology will reduce the Nitrogen Oxides (NOx). The DPF will reduce the particulates (Soot and Ash) and replace also the locomotive silencer. In order to remove the soot accumulated in the DPF at lower exhaust temperatures a pre-oxidation catalyst (DOC) is installed. This avoids the use of burners for active regeneration, and reduces maintenance.

Although the new components allow the locomotive engine to comply with the Stage IIIB exhaust emission limits, they also involve additional weight and installation constraints requiring vehicle modifications for their integration. While Caterpillar is currently conducting engine tests at their test bed facilities in the USA, Vossloh is busy finishing the design of the necessary vehicle modifications, affecting mainly the cooling plant, locomotive roof hatches and engine air intake filters.

The main targets for the design modifications are:

- Maintaining the same high power output of 2800 kW and at the same time keep the low axle load, despite the additional components to be added to the original vehicle.
- Minimising maintenance and operational costs related to the new after-treatment components.

During 2011, the engine package will be mounted in the locomotive, undergoing the defined installation and commissioning audits before being placed in service in order to validate and optimise under real conditions the correct performance of the new low-emission components.

Light Weight Demonstration Subproject

In the Light Weight subproject, five international companies will be conducting field trials with a modified DB AG freight locomotive which meets at least stage IIIB emissions requirements.

- **MTU Friedrichshafen GmbH** is heading the subproject. The company will be providing a prototype engine which complies with stage IIIB emissions legislation.
- **Deutsche Bahn AG** will be installing the stage IIIB-compliant drive system in an existing freight locomotive (BR225 008-2) and operating the prototype in normal service.
- **Voith AG** will provide the project team with support on transmission and cooling system technology.
- **SNCF** will contribute expertise gathered from its experience with diesel particle filter (DPF) systems in marshalling locomotives.
- The research laboratory **APTL/CERTH** will conduct measurements in the locomotive.

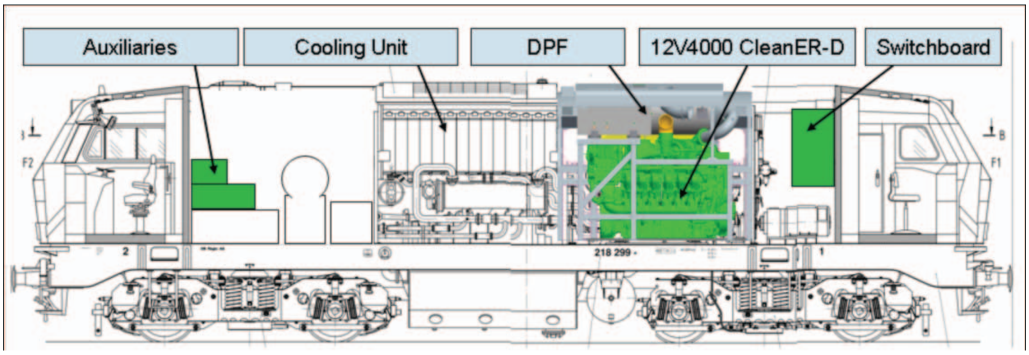
The project team will equip the locomotive with a prototype 12V4000 engine with exhaust after-treatment technology for a 14-month period of field trials under realistic working conditions. The prototype 12V4000 engine produces 1800 kW at 1800 rpm and the exhaust after-treatment system incorporates a passive regeneration DPF dimensioned and designed by engineers at MTU Friedrichshafen GmbH.

In order to achieve high-quality field trials, the engine and its DPF system are currently being fine-tuned on the test stand by MTU specialists with the aim of ensuring that it meets all the demands placed on it in terms of emissions and vehicle requirements.

At the same time, Deutsche Bahn AG is making preparations for integrating the prototype system in the Type BR225 freight locomotive that is now almost 40 years old. At present, the locomotive is powered by a 12V956TB10 engine dating from 1971 and modifications to the engine bed, gearbox, cooling system and other assemblies will be needed in order to adapt it for the new engine which is designed for future needs. Deutsche Bahn AG and MTU Friedrichshafen GmbH are working together closely here whilst the other partners involved in the subproject are also making valuable contributions to the success of the endeavor. Intensive cooperation between all of the participants has facilitated the development of an extremely promising concept.

In December of this year, the engine and DPF system will be transferred to Deutsche Bahn in Bremen where they will be installed in the locomotive. In the first quarter of 2011, the locomotive will be handed over to DB Schenker and over the following 14 months of field trials, the prototype locomotive will be operated in regular service by Deutsche Bahn AG. Subsequently, the locomotive will be returned to its original condition. The engine and exhaust after-treatment system will undergo a comprehensive program of inspections in order to gain information on how the system has performed.

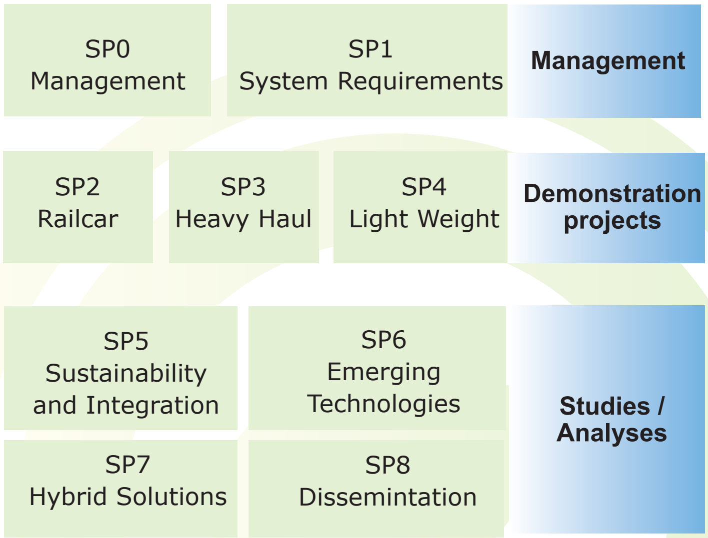
In addition to the field trials described above, SNCF will be using its BB69419 locomotive which is fitted with a DPF, to collect further data. Together, the collective experience and information gathered throughout all the phases of the project will provide an invaluable basis for the development of future, environmentally-friendly rail vehicles.



Integration of the EU Stage IIIB-compliant drive system in freight locomotive BR225 008-2

Requirement Specification subproject

The subproject provides a platform to engine and vehicle manufacturers as well as operators to coordinate and monitor the results coming from the demonstration subprojects. In addition to the coordination task, the subproject develops RAM and LCC models to achieve a common understanding on the reliability, safety and cost details.



Sustainability and Integration

This subproject will focus on the socio-economic and green aspects of rail diesel applications. Rail is proven to be the most environmentally-friendly mode of transport. Special attention must be devoted to improve the emission performance of diesel-powered vehicles which still constitute for about 20% of the European operations. In addition, the European railway sector is set to meet the challenges of increasing energy prices and stricter environmental frameworks set by the European Union.

The first study of this subproject will be the "Sustainability Study", which will give a consistent picture of the current and future use of diesel fuel and related emissions for transport purpose in the railway sector. The study will take into account the major factors that influence the European rail diesel vehicle fleet and related future diesel exhaust emissions in Europe. Push and pull factors, such as legislation, market development, the development and operation of emissions reduction technologies of competing modes etc. will be taken into account. The Sustainability Study is expected to be finalised by the end of 2010.

Together with an assessment of future emission reduction technologies the findings of the Sustainability Study will be completed in an Impact Assessment. The calculation of Life Cycle Costs and development of a methodology for cost/benefit analysis are core elements of this specific work. The optimisation of technical solutions and possible trade-offs will be studied and identified. Finally, the subproject will develop sector-wide agreed recommendations on future emission reduction approaches and strategies of rail diesel traction in Europe.

Emerging Technologies

This subproject aims to investigate existing and potential emission reduction technologies for integration into locomotives, DMU, railcars diesel plants and power packs leading to recommendations concerning these technologies. Best practices from other transport sectors will be considered. The objectives of this group are as follows:

- Identifying the state-of-the-art on low emission technologies suitable for railway application;
- Benchmarking low emission technologies applied to other transport sectors;
- Assessing the impact and feasibility of using innovative low emission technologies on engine and rail vehicle performance and integration;
- Providing recommendations on existing and alternative solutions for emission reduction of diesel railway vehicles based on potential scenarios beyond stage IIIB.

So far state-of-the-art in after-treatment technologies for rail and automotive applications in particular has been identified, which will be used at a later stage to assess the most promising solutions.

Currently, the subproject focuses on investigating the influence of fuel type and quality on emissions, evaluating diesel particle filter (DPF) strategies and assessing emerging after-treatment technologies using stage IIIB emissions levels as a baseline but also researching the suitability of these solutions beyond IIIB. Numerical simulation tools, including computing fluid dynamics (CFD) are being developed to complete these tasks.

In addition, an investigation of vehicle-related topics associated with the integrations of using such technologies will be carried out. These vehicle-related topics include optimum management and utilisation of dissipated heat from engine, packing, control, durability and maintenance. This activity will complete the assessment of technology innovations for future measures beyond IIIB on diesel railway applications.

Hybridisation

Sector-wide agreement is that energy efficiency is best reached by reducing fuel consumption and minimizing both CO_2 and pollutant emissions of diesel-driven trains is through hybrid solutions. This subproject evaluates the energy saving potential of onboard energy storage system concepts. A conventional diesel-driven train mainly dissipates the braking energy into heat by the braking resistor.

The subproject is investigating technologies of hybrid drive systems for rail applications and their influence on reduction of fuel consumption and emissions due to the following objectives:

- Identification of the state of the art hybrid technologies,
- Definition of "standard duty cycles" for different rail vehicles types,
- Investigation of influences on energy use and emission of the drive systems and management of the auxiliary systems,
- Comparison of innovative energy storage technologies,
- Assessment of impacts due to hybrid technologies,
- Recommendations for further reduction of fuel consumption and emissions using innovative hybrid technologies.

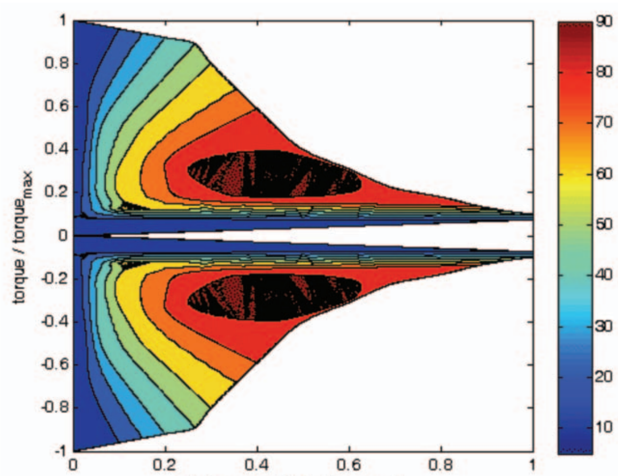


Figure 1: Efficiency of an electrical motor for a virtual vehicle

There has been a special emphasis on identifying state of the art hybrid technologies for onboard storage systems such as flywheel, hydrostatic accumulator, double layer capacitors and batteries. It has described recent innovative developments made for different types of railway applications, particularly in urban rail vehicles, trams and metros but also for mainline rail vehicles and especially in the field of diesel-driven vehicles as well as potential technology transfer from developments made in road transport and stationary applications.

The review has identified a high potential for energy storage technologies in rail applications. This is particularly relevant for urban and suburban rolling stock as duty cycles involve multiple frequent stops that maximise the potential of these technologies. Based on these options, battery technology and double layer capacitors seem to be the preferred solution.

Duty cycles for different diesel powered rail vehicles – suburban, regional, high speed DMU, intercity locomotive, freight mainline locomotive and shunter – were defined to determine the energy performance and the emissions. Furthermore this requires the preparation of comparable data for rolling stock to define standardised duty cycles which make emission and fuel consumption comparable. The objectives are:

- Defining duty cycles and parameters to run an emission simulation based on a evaluation of existing driving cycles and the results of the Railenergy project,
- Proposing to CEN these standard duty cycles for a possible EN standard and
- Identifying the effect of the required pollution values.

Different energy storage technologies for diesel hybrid rail vehicles were evaluated. The defined duty cycles for the different train types were analysed to identify the train behaviour as well as to elaborate the power at wheel. The repartition between the several energy storage systems and the diesel motors were fixed with integration of auxiliary supplies considering the engine stop periods and the equalization of the energy content for the whole duty cycle. Figure 2 shows the consideration of the different energy storage units/systems for further investigations.

SP7 ESS final perimeter

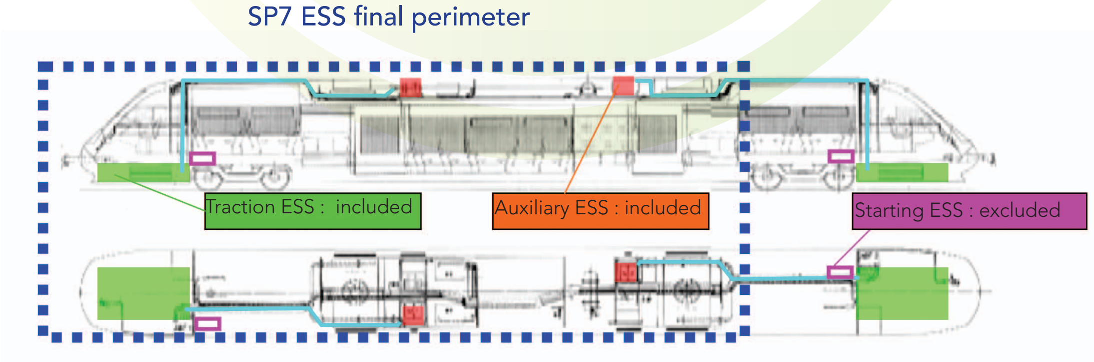


Figure 2: Energy storage units/systems boundary for SP7

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