PROJECT PERIODIC REPORT

Grant Agreement number: 284909

Project acronym: CORE

Project title: CO2 Reduction for long distance transport

Funding Scheme: Collaborative project

Date of latest version of Annex I against which the assessment will be made:

Periodic report: 1st 2nd ☐ 3rd ☒

Period covered: from 1st January 2015 to 31 of December 2015

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Declaration by the scientific representative of the project coordinator

I, as scientific representative of the coordinator of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate) [1]:

  ☐ has fully achieved its objectives and technical goals for the period;

  ☒ has achieved most of its objectives and technical goals for the period with relatively minor deviations.

  ☐ has failed to achieve critical objectives and/or is not at all on schedule.

- The public website, if applicable
  is up to date

  ☐ is not up to date

- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.4) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 3.2.3 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

Name of scientific representative of the Coordinator: .....
Johan Engström..

Date: ....6......../ .....3......./ ....2016.....

For most of the projects, the signature of this declaration could be done directly via the IT reporting tool through an adapted IT mechanism and in that case, no signed paper form needs to be sent

List of Beneficiaries

Project Number [1]	284909	Project Acronym [2]	CORE

List of Beneficiaries

No	Name	Short name	Country	Project entry month[10]	Project exit month
1	VOLVO TECHNOLOGY AB	Volvo	Sweden	1	48
2	CENTRO RICERCHE FIAT SCPA	CRF	Italy	1	48
3	CHALMERS TEKNISKA HOEGSKOLA AB	Chalmers	Sweden	1	48
4	DAIMLER AG	DAI	Germany	1	48
5	FEDERAL-MOGUL BURSCHEID GMBH	F-M	Germany	1	48
6	GOTTFRIED WILHELM LEIBNIZ UNIVERSITAET HANNOVER	LUH	Germany	1	48
7	HONEYWELL TECHNOLOGIES SARL	HTT	Switzerland	1	48
8	INGENIEURGESELLSCHAFT FUER AUTO UND VERKEHR GMBH	IAV	Germany	1	48
9	JOHNSON MATTHEY PLC.	JM	United Kingdom	1	48
10	JRC -JOINT RESEARCH CENTRE- EUROPEAN COMMISSION	JRC	Belgium	1	48
11	METATRON SRL	MT	Italy	1	48
12	POLITECNICO DI MILANO	POLIMI	Italy	1	48
13	POLITECNICO DI TORINO	POLITO	Italy	1	48
14	Rhodia Operations	RES	France	1	48
15	RICARDO UK LIMITED	Ricardo	United Kingdom	1	48
16	UMICORE AG & CO KG	Umicore	Germany	1	48

1 Publishable summary

Summary

The main objective for CORE is to demonstrate a substantial reduction of CO_2 emissions through improved powertrain efficiency with technologies having the potential to be implemented in production around 2020. The consortium consists of 16 partners from truck manufacturers, automotive industries and universities. The main focus areas are improved engine concepts featuring variable valve actuation with new turbocharger systems, reduced friction and improved aftertreatment performance, specifically in the low temperature range. In addition, hybridisation and natural gas will be utilised. All results achieved will be evaluated over legislation test cycles and in real life driving cycles. The project will demonstrate three Diesel engines and one natural gas truck.
The project was completed on time and the progress was almost according to plan. The final results show that improved fuel efficiency is obtained in all sub-projects. The best experimentally achieved result is 13% reduced CO_2, demonstrated on an CORE engine at EURO VI compared to an engine at EURO V legislation levels. Taking into account the recalibration of a EURO V engine to EURO VI emission legislation and combined CORE technologies, vehicle simulations show four different powertrain concepts with CO_2 reductions in the target zone of 11-18% compared to current EUROVI engined vehicles. These results show that the CORE project reached its targets and has highlighted achievable path ways for CO_2 reduction for long haul commercial vehicle applications.

Objectives

The objective is to demonstrate a substantial reduction of CO_2 emissions, 15% improved fuel efficiency compared to a EURO V engine and at the same time fulfilling EURO VI emission legislation. By using novel technology combined in flexible engines with a high level of precise control, performance advantages will be achieved with improvements in emissions and fuel consumption. The legislative emission test cycles ETC and the WHTC will serve as the baseline test cycles but, in order to show the improved fuel efficiency and consider the hybrid electric powertrain, specific duty cycles will be used for each application.
The target fuel economy improvement of 15% is based on a EURO V state-of-the-art technology operating at the EURO VI emission standard. It is envisioned to achieve 6 to 9% in the sub-projects (see Figure 1) with different engines, powertrains and fuel approaches. The hybridization of the powertrain will contribute with an estimated 3 to 5% fuel economy improvement dependent on the vehicle test cycle through usage of energy recuperation during deceleration events. An additional 2 to 4% of fuel economy improvement is attributed to friction reduction of the combustion engine and energy efficient exhaust gas aftertreatment systems and operation.

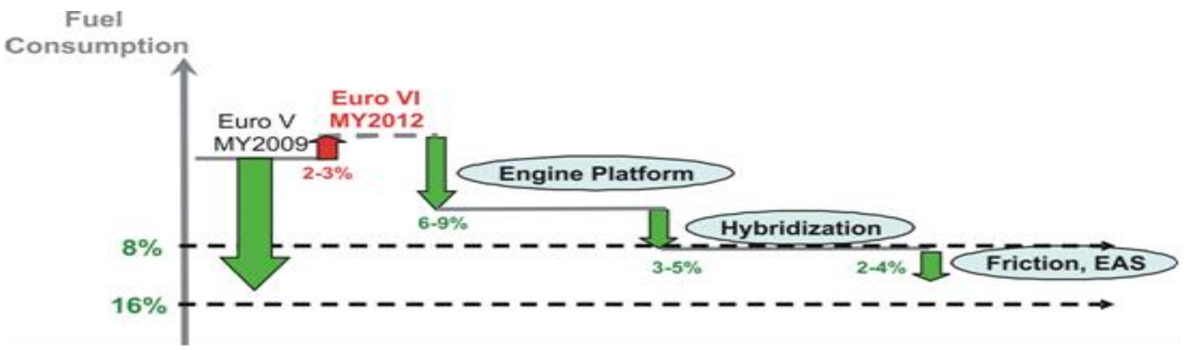

Figure 1: Roadmap towards fuel consumption reduction.

Description of Work

CORE is divided into six sub-projects (see Figure 2), three of which focus on different engine and powertrain technologies. Major areas for these are: optimizing the existing Diesel engine: combustion, air management, aftertreatment and controls, decreasing rated engine speed (“down-speeding”), optimizing the powertrain layout (hybrid electric components) and using alternative fuels as natural combined with variable valve actuation.
These three sub-projects are supported by two projects (shown horizontally in Figure 2) where friction reduction and improvement of low temperature performance of NOx aftertreatment technologies are studied. Accomplished results are adapted on the three engine and powertrain arrangement. Finally in the last sub-project, to ensure knowledge and technology transfer, all results will be assessed by vehicle simulations for final achievement of the fuel economy target.

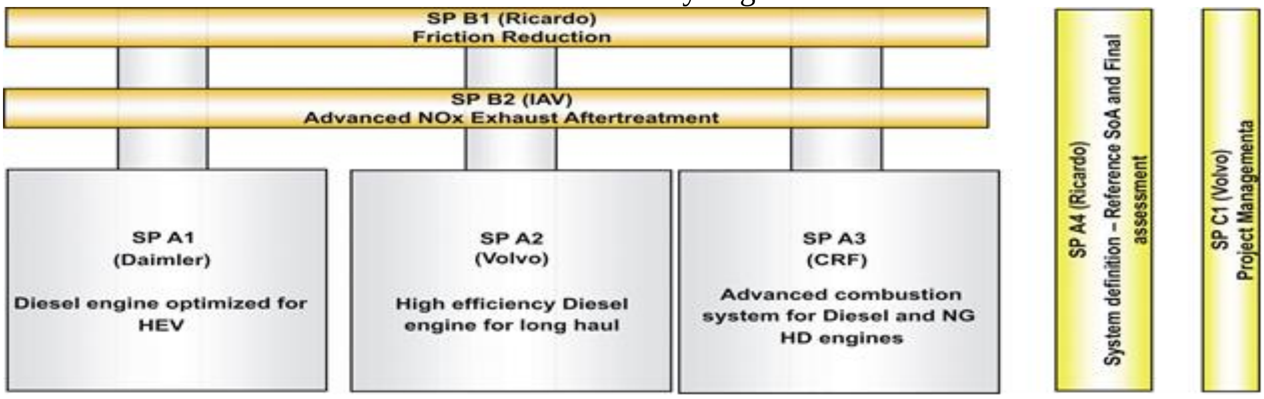

Figure 2: CORE project organisation.

Results

Results show that improved fuel efficiency has been obtained in all sub-projects. The main results are:

- The best measured result was 13% lower fuel consumption on the Daimler CORE engine fulfilling EURO VI emissions legislation compared to a Daimler engine at EURO V emissions.
- In the assessment of CORE technologies the best combination of technologies was simulated to give 18% reduced fuel consumption when compared to the EURO VI vehicle as reference.

An overview and a summary of the results achieved is given here with respect to Figure 1 and results are presented in Figure 3:

Engine platform (SPA1, SPA2 and SPA3): Engine application work has been completed. Four different engine systems have been calibrated for transient operation. Thereafter optimisation of the engine and integration of the exhaust aftertreatments system were completed. In order to reach the target all engines have been demonstrated at EURO VI emission regulation, over the transient cycles ETC and WHTC and real life cycles. The achieved results show 2-5 % improved fuel consumption for the Diesel engines compared to the EURO V engines, and 4-7 % improved fuel consumption compared to the EURO VI references.

The natural gas engine was demonstrated on a prototype vehicle (rolling test bench and on-road) with PEMS instrumentation on-board. The CORE CNG engine showed a reduction of 6.5% compared to the EURO VI engine. In second loop of demonstrator testing an LNG tank circuit was installed on the prototype vehicle together with integration of an electronic pressure regulator for the LNG and NG. Additional safety considerations for the LNG operating mode were also implemented. The final results showed improvement of in the range of the vehicle in line with calculation predictions and no impact on the VVA engine behaviour.

Hybridisation (SP A1): This work was performed in SPA1. The first task was to development an engine-in-the-loop system (EiL) system including a combined shifting and hybrid operation strategy. This work was completed and EiL has successfully been applied in the test cell together with the engine developed in SPA1. The achieved result from the test cell shows fuel efficiency improvements of 12.9% over a real life operating cycle.

Friction (SPB1): Improved design, low friction piston rings and pistons were tested together with modified bearings. Three different oil types were also tested: the production oil, a special blended oil with same viscosity as the production one but with friction modifier additives, and a lower viscosity oil. With the new engine parts and the low viscosity oil, motored friction (FMEP) reductions of up to 9% were measured to a high level of accuracy. Overall, a fuel consumption (BSFC) reduction of about 1% was achieved in some operating points, especially at low loads, with the new engine parts.

EATS (SPB2): Integration of EATS to the complete engine system has been completed. This work was supported by a new developed kinetic model of SPAB2 of the SCR catalyst, integrated into the EAT system software, enabling model-based EAT system development. The model was used by SPA1 and SPA3 in their work with integration and optimisation of the SCR system to the respective engine. Injection of ammonium nitrate (AdBlue Additive) has been investigated in detail, and the mechanism of the additive reactions on the Fe-SCR catalyst has been identified.

Final Assessment (SPA4): The aim of SPA4, to use a vehicle simulation tool to estimate the CORE technology benefits on vehicle efficiency, has been achieved. The most promising technologies from SP A1, A2, A3, B1 and B2 were grouped together in compatible vehicle packages. Simulation models of the base vehicles were validated through comparison with real vehicle measurements over representative cycles. These models were then extended to include the most promising technologies vehicle packages and further simulations undertaken. The results from these simulations showed that each of these vehicle packages were predicted to achieve the proposed targets of an 11% to 18% fuel consumption reduction from the Euro VI vehicle configuration.

The individual vehicle simulation results show that the relative benefits of each of the CORE technology depends upon the vehicle application and its duty cycle.

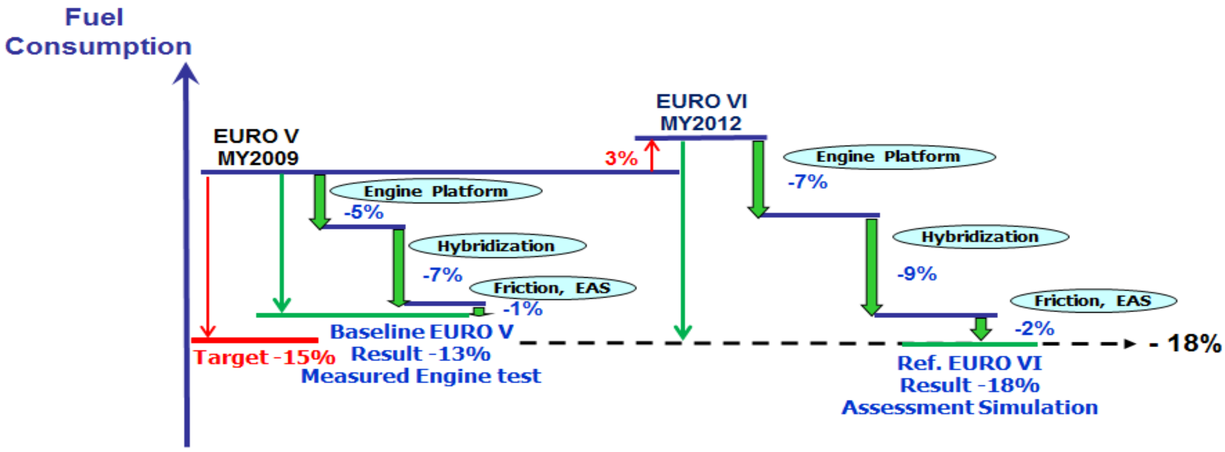

Figure 3: The diagram shows the achieved CORE results of reduced CO2 by improved powertrain efficiency.

Conclusions

- The best experimentally achieved result was 13% reduced CO_2, demonstrated on an CORE engine at EURO VI compared to an engine at EURO V legislation levels.
- Taking into account the recalibration of a EURO V engine to EURO VI emission legislation and combined CORE technologies, vehicle simulations show four different powertrain concepts with CO_2 reductions in the target zone of 11-18% compared to current EUROVI engined vehicles.
- The results show that the CORE project reached its targets and has highlighted achievable path ways for CO_2 reduction for long haul commercial vehicle applications.

Impact and use of results

The CORE project is designed to have a direct impact on the next generation of heavy duty transport vehicles enabling them to run more energy efficiently whilst meeting future emissions standards. By developing three advanced heavy duty engine systems adapted to the OEM´s widely used vehicle configurations, and providing these on an industrial scale and commercial basis, the CORE project will have an impact on the rate of emissions from the next generation of European long distance surface transport.

The presented CORE results show a substantial reduction in CO_2 emissions by improved fuel efficiency in the powertrain. The different developed and analysed concepts will support the new products for introduction on the market in 2020 in long haul applications. Some of the demonstrated sub-systems or complete powertrains may be fully introduced in the future. In others applications parts of CORE technologies will be integrated into products for market introduction. Further, simulation studies have shown that the CORE project technologies have potential for application in other areas, such as city buses and delivery vehicles, or off-road machinery.

The developments of engine testing and simulation methods are other important outcomes from CORE. New developed simulation models applied and verified in different sub-project have been delivered. These models are already in use by partners for tomorrow's research and product development. Some of the new developed software will also progress to commercialisation and be available on the market.