

# 1. Publishable summary

## 1.1 Summary description

The CONVENIENT project targets a 30% reduction of fuel consumption on long-haul heavy-trucks by developing a suite of innovative energy-saving technologies and solutions.

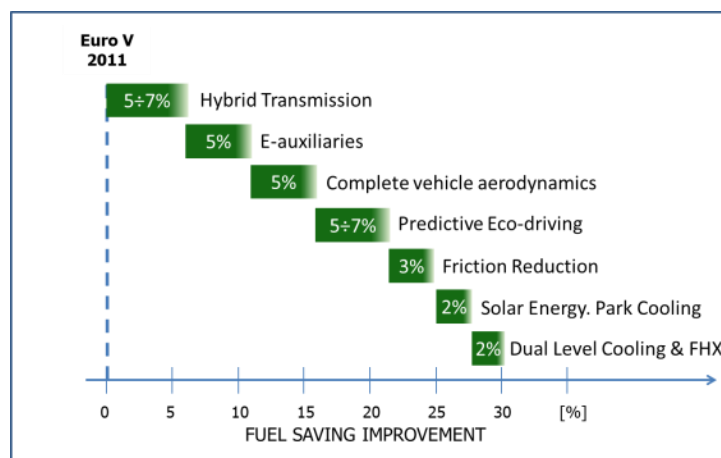
The focus of the project is to leverage on a holistic approach to energy management of complete vehicle, considering the truck, the semi-trailer, the driver and the mission as a whole.

In the course of the project, 3 heavy-trucks will be developed by CONVENIENT Consortium, which comprises 3 major EU truck manufacturers (IVECO, VOLVO, DAF), 10 suppliers Tier1/Tier2 and a network of 9 research centres and Universities, with the common aim to demonstrate and to validate the fuel-saving solutions adopted on validator vehicles, featuring:

- innovative energy efficient systems, including hybrid transmission, electrified auxiliaries, dual level cooling system;
- parking HVAC;
- energy harvesting devices, like photovoltaic solar roof for truck and semitrailer;
- advanced active and passive aerodynamics devices for the truck and for the semitrailer;
- Holistic Energy Management system at vehicle level;
- Predictive Driver Support to maximize the energy saving benefits;
- novel Hydraulic Kinetic Energy Recovery System for the semitrailer.



The overall target is to achieve 30% fuel-saving improvement on the reference complete vehicle, thanks to the adoption of new technologies, adopted both on the trucks and also on the semitrailer.



Deployment of fuel economy target in CONVENIENT project

## 1.2 Project objectives and major achievements during the period

The scientific objectives and the major results to be achieved in year-1 (period M1-M12) are summarized below for each Sub-Project:

### SP A1: Prototype Truck 1 (IVECO)

The main objective of **SP A1** is to develop the IVECO long-haul truck prototype capable to achieve the challenging target of 30% fuel-saving, by means of the following main energy-saving technologies:

- hybridization of the transmission,
- electrification of auxiliaries,
- passive and active aerodynamic solutions,
- Dual-Level Cooling system,
- low-friction rear axle,
- predictive eco-driving HMI
- energy-saving solutions for parking, like photovoltaic solar-roof and electric HVAC system

In **WP 101**, led by IVECO, the Partners have performed the concept analysis and simulations phase, which includes the concept study and CAD installation analysis for integrating an Electric-Hybrid transmission on the validator truck. See Deliverable Report DR 101 (version 1.0).

Deliverables 101 has been delayed for a few months, due to delayed fuel-consumption simulation results. The reasons of this delay are discussed later in SP C1. The Deliverables 101 has been finally delivered, but the delay of this report will have no relevant effect on the remaining part of WP, since the main decisions regarding the hybrid transmission, which is the main item investigated in WP1, have been taken well in advance, without waiting for the simulations results.

In **WP 103**, the system architecture of a Dual Level Cooling system has been defined and the development of a proper simulation model is also in progress.

In **WP 104** the aerodynamic CFD simulations are in progress, with the aim to define the proper active and passive aerodynamic solutions to be adopted on the IVECO truck, focusing on Active Grill Shutters combined with novel devices for wheel-arch flow-control on the tractor, together with proper aerodynamic fairings (which include side-wings, boat-tails and spoilers) on the semi-trailer; current simulation results have already shown a relevant potential improvement of drag-resistance for the truck-semitrailer combination adopting a proper aerodynamic kit.

In **WP 107** the on-board integration of electrified auxiliaries is in progress. In particular, ECS has developed the Electro-Hydraulic Power-Steering system (EHPS), while the supplier MATTEI is developing the electric-driven brake air-compressor, with modelling support from Univ. Aquila.

In **WP 108** the partners IVECO, CRF and ZF are progressing in the integration of the Electric Hybrid Transmission on the Stralis truck; the CAD packaging study has been completed and the electric/electronic architecture has been defined as well; the delivery of the prototypal hybrid transmission from ZF is expected by the beginning of Year-2.

## **SP A2: Prototype Truck 2 (VOLVO)**

The main objective of **SP A2** is the development of advanced predictive energy management control strategies for VOLVO long-haul truck prototype. This addresses cohesive control of cooling systems, propulsion systems and adaptive aerodynamics (by means of controllable air-deflectors).

Also the electrical architecture as well as the electrical power supply needs to be further developed to encompass the new highly integrated control strategies.

Moreover, controllable electrified auxiliaries will be used in this prototype truck: an electrically driven cooling pump and an electro-hydraulic power-steering pump will be used to reduce energy demands; both components will contribute in different manner to improve the fuel efficiency of the vehicle, depending on the operating conditions.

Prediction and integrated controls are applied on several subsystems featuring electrified actuators. The technologies developed in this project are applied to a tractor semi-trailer combination. The predicted fuel efficiency gain will be demonstrated on a Volvo prototype truck meeting the Euro6 emission standard.

The main objective of **WP A2.1** is to build up a complete vehicle model of the prototype truck. This model will be primarily used for control development and fuel saving assessment. The work during this period has focused on specifying the prototype truck, collecting model data, collecting measurements for validation, and of course building up the simulation model. Problems related to collecting correct physical parameters and validations data have delayed the modelling work. However, these obstacles have been resolved and the work proceeds quite well. The outcome of other work-packages will not be affected by this delay.

**WP A2.2** focuses mainly on preparing the electrical and functional architecture of the VOLVO prototype truck. The main challenges are packaging the electrical actuators and sizing the electrical systems (batteries, generators, etc.) for higher electrical power consumption. The work has progressed according to the plan. The chosen electrical architecture will be tested in the simulation model developed in WP A2.1.

Prediction is a key part in reducing fuel consumption; **WP A2.3** focuses on a system called eHorizon that collects GPS data and map data. The work progresses according to plan. Volvo has received a first version of prototype hardware from Continental. Integration tests are initiated.

The development of the Human Machine Interface (HMI) is performed in **WP A2.4**. It is believed that a good communication between the control system, the driver and the back-office reduces the fuel consumption. Driver use-cases and HMI strategies has been developed. Volvo has received a full dynamic instrument-cluster from the partner Continental, which has been programmed according to the developed strategies. The prototypal HMI includes a full digital cluster unit, which is used to develop the graphical user interfaces and the signal converter provided by CONTI, which converts DVI signals to LVDS and makes it possible to transfer the graphical interfaces from a desktop computer to the full digital cluster itself. This prototypal HMI has been documented by the Deliverable Report D204.1 "HMI System for Driver evaluation and coaching", issued by VOLVO.

**WP A2.5** develops the Predictive Energy Management system that will be used to control the electrified auxiliaries. During the first year, the activities have included: literature studies, set-up of the control structure and decision on approaches to be considered. Moreover, a thermal system model has been developed and optimized for on-board controllers. Improved aerodynamics by

using adaptable air deflectors are considered in WPA2.5.3. IDIADA has assessed the optimal air deflector angles by means of CFD simulation, while Volvo is responsible for controlling the adaptable deflectors. WPA2.5 has progressed according to work-plan.

### **SP A3: Prototype Truck 3 (DAF)**

The main objective of SP-A3 is to develop a complete vehicle energy management concept for a hybrid electric long-haul truck with reefer trailer. This concept falls apart into innovative hardware and smart control strategies. Altogether, the following research topics are addressed in SP-A3:

#### **Smart vehicle powernet**

- Research on control strategies for smart auxiliaries (Smart alternator, Smart air supply, Smart thermal management, Smart DPF, Smart Reefer).
- Smart auxiliaries take into account e-horizon information and adaptive engine models (for robustness on short and long timescale incl. lifetime).
- Development of “Open vehicle management platform” which offers a plug&play interface for auxiliaries to reduce complexity/development time and cost.

#### **R&D on innovative energy saving technologies**

- Novel hybrid powertrain with downscaled engine (11 liters instead of 13 liters)
- Smart electrified auxiliaries
- Plug-in connection for energy supply from grid
- (Adaptive) Aerodynamic hardware for tractor and trailer
- Low-friction rear axle
- E-steering pump
- Adsorption storage system (only simulation based)

DAF coordinates the activities within SP-A3. Technical meetings with partners are organized on a frequent basis to discuss their progress: TUE weekly, TNO monthly, IKA bi-monthly and TUD quarter meetings.

Besides meetings with individual partners, also joint meetings/workshops with all partners from SP-A3 are organized. On March 6, 2013, DAF organized a meeting in Eindhoven with all partners to review the specifications given in Deliverable Report D301.1. The next milestone meeting with all SP-A3 partners will be a workshop related to the concept selection for the smart vehicle powernet (as defined for milestone MS35). This workshop is scheduled on December 11, 2013.

All partners are working towards the deliverables with the technological breakthrough as described in the DoW. Furthermore, DAF started with front loading activities (like the integration of the rear axle). This will reveal possible unexpected design problems in an early stage and will avoid possible delays when building up the final CONVENIENT DAF proto truck.

A status overview of the work packages included in SP-A3 is given in the table below. This table also summarizes the main results which have been achieved in the period M1-M12. More details of these results have been given in the next sections.

<b>Work package</b>	<b>Status</b>	<b>Main results</b>
A3.1	Completed	Definition of vehicle mission, duty cycle, functional requirements and HMI concept. Deliverable Report D301.1 completed and released on Web-site
A3.2	In progress	Selection of e-auxiliaries for integration in smart powernet Vehicle simulation model under construction
A3.3	In progress	Definition of aerodynamic solution concept for tractor and trailer
A3.4	In progress	Definition of E/E architecture Communication protocol e-auxiliaries under construction
A3.5	In progress	Case study on smart powernet with two energy buffers (high voltage battery and reefer trailer)
A3.6	In progress	ICE and EAS model development under construction
A3.7	In progress	Study for mechanical integration of Meritor low-friction rear-axle
A3.8	Not started	-
A3.9	Not started	-
A3.10	Not started	-

There are no major delays reported in the work-packages in SP-A3. Nonetheless, the final selection of the electric-hybrid powertrain hardware (e-machine and inverter) is still pending. To prevent that this becomes critical, corrective actions are taken where ZF and DAF investigate which hardware configurations are feasible in order to satisfy the timeline of the SP-A3 prototype truck. During the last teleconference on November 27, 2013 the number of possible hardware configurations has been limited to two scenarios. A final decision is envisioned within M14.

The initial plan was to apply the same hybrid powertrain for both SP-A1 and SP-A3. Unfortunately, the interface of the inverter for the e-machine turns out to be fixed and not in line with the “plug & play” requirements from the Open Vehicle Management Platform (as developed in WP A3.4). An alternative inverter with e-machine has been studied. ZF meeting with DAF on January 20, 2014 has led to agreement on the final hybrid transmission specification. This solution is feasible for SP A3 with no delay on original project deliverables. Further next steps are already planned for each WP in the upcoming period M13-M24. Important decisions have been identified and they are listed in the table below, together with the official Milestones of the DoW.

<b>WP</b>	<b>Deadline</b>	<b>Upcoming decisions in period M13-M24</b>
A3.2	M14 M18	Final selection of hardware components for hybrid powertrain Integration. Vehicle simulation model with smart vehicle powernet control strategy
A3.3	M20 M24	Selection of solution concept for adaptive aerodynamic technology MS21: Prototypes prepared for full-scale testing
A3.4	M20 M24	ECU hardware selection for prototype build-up in task A3.4.4 MS19: Prototype open management platform prepared
A3.5	M14	Concept selection for smart vehicle powernet (related to MS35 in B2.2)
A3.6	M18	MS22: Preview combustion engine management finished
A3.7	M16	Decision on how to integrate SKF bearings in rear-axle from Meritor

## **SP A4: Vehicle Simulations and Final assessment (CRF)**

The main objective of SP A4 is to evaluate the enhancement of proposed technologies in terms of fuel efficiency at complete vehicle level, by means of the selected simulation tools, namely PERFECTS and AVL Cruise respectively, both well-established tools for such fuel-consumption evaluations. Correspondingly, an important goal is to define the scope of the simulation by identifying appropriate reference missions to be used for the simulation activities. The activity performed in year-1 led to the definition of the reference assessment criteria to be used to simulate the average fuel-consumption of a complete heavy-duty vehicle (truck-semitrailer combination), hence enabling also the validation of such simulations during the successive developing phases of the project.

During this activity, the interested partners of CONVENIENT have agreed that the reference missions should be coherent with the activities underway in the Working Group “Heavy-Duty Vehicles” of ACEA ([www.acea.be](http://www.acea.be)); in particular, it has been decided that the reference assessment mission in CONVENIENT will be the “Standard ACEA Regional Delivery cycle”, together with a modified version named ‘Legal ACEA Regional Delivery cycle’, coherent with the speed limitation in force in Italy. These reference cycles are reasonably well correlated with the available experimental data-base related to IVECO Stralis long-haul trucks; their compliancy with real-user missions of Iveco fleet has been checked by CRF.

Moreover, in addition to the ACEA “Regional Delivery” cycle, other real-usage missions will be used during the course of project, with the aim to evaluate deeply some solutions under specific usage conditions. E.g. the ACEA “Urban Delivery” cycle will be adopted for the evaluation of fuel-efficiency improvements related to hybrid transmission, while the on-highway mission Turin-Genova-Turin will be largely used for an overall comparison against real-usage data extracted from IVECO testing Data-base.

This activity has conducted to issue the deliverable DA4.1.1 “Report on Assessment Criteria”.

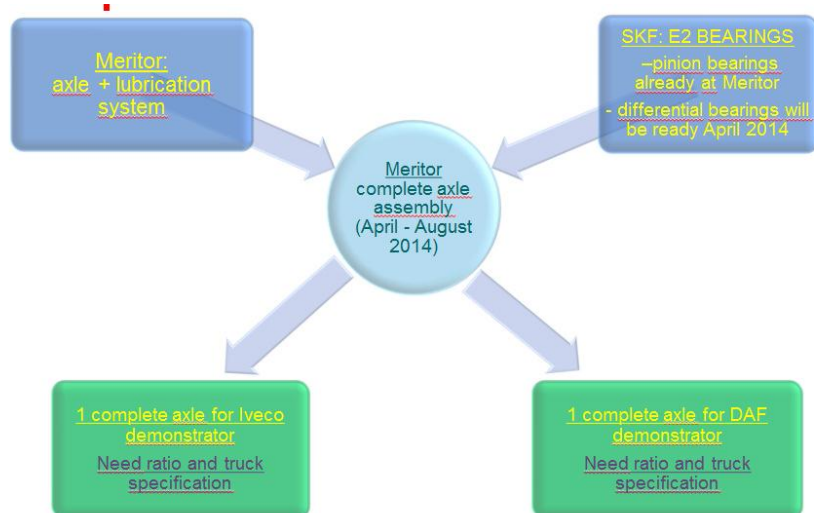
## **SP B1: Friction Reduction (MERITOR)**

The main objective of SP B1 is the reduction of friction generated by rear-axle bearings and lubricating oil in the differential case. The outcome of this SP will be a novel rear-axle prototype to be integrated both on IVECO truck and on DAF truck.

MERITOR will provide Iveco and DAF with two axles for the final demonstrator; the development of the two prototypes is proceeding in parallel, so the preparation is in good progress.

The plan to complete the prototypes is in the following scheme.

The implementation of new bearings on IVECO axle is more complex, because the wheel-ends are supplied by another supplier (FPT), not by Meritor. The DAF axle will implement the new bearings using the wheel-ends from Meritor.



Additional objectives of SP B1 are the development of models of specific bearing design and friction model with detailed knowledge of the sources of friction (bearing friction, gear friction, lubrication splash losses) on rear-axle; the friction model will be used to develop the new rear axle and also to contribute to the complete vehicle simulation model.

During the first year of activity, MERITOR has developed the complete axle 3D model with features to enhance efficiency and lubrication. This 3D model has been used by IDIADA for generating a CFD calculation model for the lubrication study; in the meantime, SKF has started the development of low friction bearings.

Concerning progress beyond the state of the art, MERITOR is developing the low friction axle starting from an existing one. The integration on the trucks is not complex, since the mechanical interfaces are the same as for normal production, but it is difficult to integrate the new lubrication system inside the axle.

Actuator, reservoir and valve are at prototype stage; during the second year of the project we will work in order to upgrade at production stage.

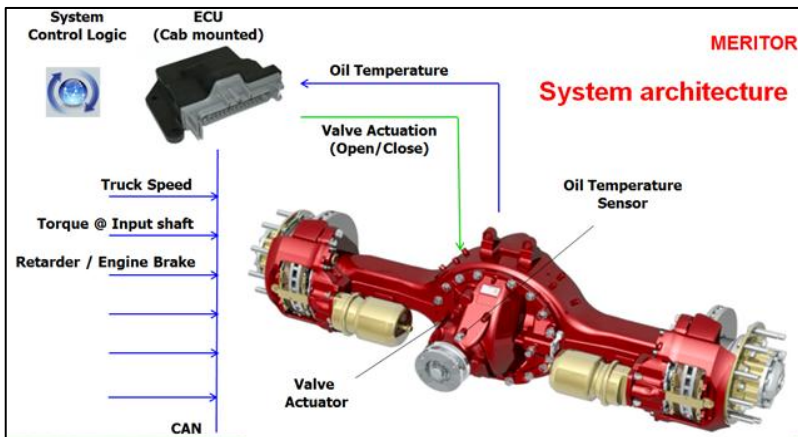
Also oils will be tested in the second year of the project. MERITOR selected different specifications from different suppliers, that are:

- Basf
- Shell
- Chevron Phillips
- Pakelo

There is no specific problem on the definition of oil specification; the aim of this activity is to select the most efficient oil in order to improve the total axle efficiency.

The picture below shows a demo-bench with oil level control system in the differential, aimed to simulate the oil flow around the crown-gear and churning losses with different level of oil inside the differential case.

Details about the Low-Friction Rear-Axle Prototype are available in the [Deliverable Report D501.1](#) issued by MERITOR; this report outlines also the control strategies implemented in the ECU for controlling the level of lubricant oil in the differential case.



**Figure 1 - System architecture of MERITOR intelligent low-friction rear-axle**



**Fig. 2 - Demo-bench with oil level control system in the differential.**

The activity will lead to install the new complete rear-axle on IVECO and DAF truck demonstrators; during the Year-1 activity, it has been agreed to integrate also the low friction wheel-end bearings into the wheel-end supplied by IVECO-FPT.

An early prototype of the rear-axle with the new Friction Reduction Lubrication System was showed during FENATRAN exhibition (Brasil, October 2013). During the exhibition, MERITOR showed the demo-bench with live demonstration of oil level control system in the differential.



## **SP B2: Holistic Energy Management & Fuel-Saving Systems (CRF)**

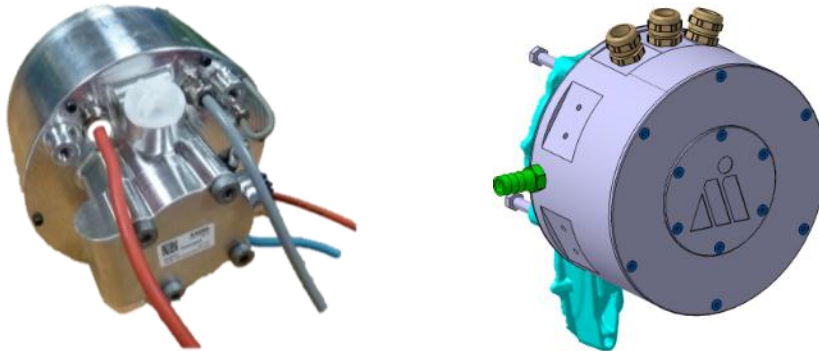
The Sub-Project B2, led by CRF, is a cluster of activities aimed to develop several technologies to be transversally used in the 'vertical' SPs A1, A2 and A3.

The WP B2.1 (WP601) contributes to develop an Holistic Energy Management system; the partner TUE has prepared a Roadmap of on-board energy management for heavy-truck; this WP is completed and all tasks are finished within the planned PM. The deliverable report D601.1 entitled "Roadmap and concepts for smart vehicle powernet" has been issued by TUE; this concept for smart vehicle powernet is planned to be implemented in DAF prototype vehicle in SP-A3.

In Year-1, the main scope of B2.3 (WP603) is the development of a realistic simulation model for the electro-hydraulic power steering (EHPS) in MATLAB Simulink. This energetic model of the EHPS power-pack, based on the characteristics of the e-motor and the hydraulic pump, has been developed by ECS and provided to AVL and Fraunhofer Institute for the integration into a complete vehicle simulation model.

In WP B2.4 (WP604), aimed to develop Electrified auxiliaries prototypes, ECS is involved in the development and testing of a functional prototype of a 24V Electro-Hydraulic Power Steering unit. The first samples are already available in hardware; testing is also in progress on a hydraulic test bench and on a truck at MAGNA-ECS. The EHPS is a fully integrated power pack containing vane-pump, e-motor and power electronics in a single housing. The prototypes are planned to be sent to the three OEMs until February 2014.

Moreover, in the Task B2.4.2, ECS is also developing an Electrified Water Pump (EWP), based on the requirements of VOLVO, using the same 24V electrical architecture of the EHPS. In this case, the power electronics for driving the EWP is separated from the EWP housing in a passive cooled external box to avoid the thermal impact of the hot cooling water. The EWP prototypes are planned to be tested on a pump test-bench in February 2014.



**Figure 3 - Electro-hydraulic power steering (EHPS) and Electrified water pump (EWP)**

## 1.3 CONVENIENT web-site

The CONVENIENT web-site ([www.convenient-project.eu](http://www.convenient-project.eu)) has been activated since April 2013 and it has been periodically updated both in the public area and in the private area.



In particular, the public area contains a detailed description of the project objectives and the planned technical activities, including a page for each Sub-project Work-package; the “Links” page contains references to dissemination documents, while the “News” page contains information about period meetings and dissemination actions (e.g. conferences).

The official logo is also available in order to be used for public events.

Non-public deliverables and confidential technical documentations are stored for internal use in the Private Area, which is restricted to the Partners and to P.O.

Public Deliverables are stored for public access in Results / Public Deliverables page, which is fully accessible by external users.

## 1.4 Conclusions

The main technical objectives useful for the completion of the activities have been finalized on time with reference to the project plan.

In particular, the main specifications for the 3 targeted vehicles have been defined in SP1 by IVECO, in SP2 by VOLVO and SP3 by DAF. Additionally, several key components have been developed by supplier partners, e.g. the electric-hybrid transmission by ZF and the low-friction rear-axle by Meritor. Additionally, several important ‘building blocks’ of the project have progressed well, e.g. the electrified water-pump and the electro-hydraulic steering-pump by ECS. Also the Low-Friction Rear-Axle Prototype issued by MERITOR is an important building-block for the development of both IVECO and DAF complete demonstrators.

In conclusion, the consortium has achieved most of its objectives and technical goals for the first period, with some minor deviations, mainly related to delayed simulation results, e.g. fuel-consumption simulations by VOLVO and by CRF.