



## D6.6 – Documentation of control system test results

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## Publishable summary

Heavy-duty vehicles are widely used in the transport sector in Europe. Heavy-duty vehicles transport 75% of freight over land in Europe (1). Because of their load capacity and annual mileage, heavy-duty vehicles are also a significant source of greenhouse gas (GHG) emissions in Europe. Therefore, any reduction in the emissions of these vehicles will aid in overall reduction of GHG.

Ford Otosan proposed the hybridization of the long haul tractors as a solution to support the efforts to reduce GHG emissions of heavy-duty vehicles.

The hybrid truck proposed by Ford Otosan will include an e-axle as the key component of electrified powertrain. The e-axle is a powerpack that consists of electric motor(s), a multi-speed gearbox and a differential. Project partners Ford Otosan and FEV will design and implement an e-axle to the baseline truck within this work package, in order to reach the project targets of at least 10% energy saving and zero emission drive.

In the first phase “Requirements - Target Definition and Concept Study”, several concept design options were reduced to two distinct topologies. For both topologies, the optimum gear numbers and gear ratios were identified in order to meet the vehicle performance and efficiency targets. Their performance and efficiency were evaluated in different drive cycles. Furthermore, the most promising topology was implemented in a hybrid F-max tractor analytical model. The energy saving through hybridization with an e-axle was calculated in the reference cycles (2).

In the second phase “Layout Design”, the most promising topology was further detailed. Successfully completed activities in this layout design phase include: e-Motor selection, evaluation of vehicle level requirements with traction curve analyses, development of a duty cycle from Ford Otosan target drive cycles, 3D layout modelling; gear design, modelling of system deformations; safety analyses of transmission components such as gears, bearings, shafts and splines; housing concept design, lubrication system development, shifting system development, and initial supplier selection for sensors. According to the results of the layout design phase, the selected concept can be implemented in an e-axle system that will satisfy the project targets hence could evolve into the final product.

In the third phase “Detailed Design”, all work conducted so far has been elaborated and deepened with additional activities such as the finite element analysis of the housing, multibody simulations of the shifting system and additional detail design work such as generation of the drawings and tolerance stack up analyses being performed.

In the fourth phase “e-Axle Prototype”, detailed process regarding e-axle prototype production has been explained. The fourth deliverable (D6.4) focused on the general description of the e-Axle system including the assembly review. Then the e-axle assembly separated into 3 sub-assemblies as mechanical component assembly, high voltage component assembly and electrical control system component assembly. These sub-system prototypes have been reviewed separately in the delivery. Although the Covid-19 pandemic affected the delivery times from the suppliers and some quality issues observed on some parts which had required update, the first physical prototype has been assembled.

In the fifth phase “Comparative Engine Dyno Test Results HVO vs Diesel” effects of hydrotreated vegetable oil (HVO) fuel on performance and emission characteristics of heavy duty engine (Ecotorq) is investigated. Base engine, calibration, test room and environmental conditions are kept same during this comparison. Characterization tests like engine mapping and emission transient WHTC are run for both HVO and Diesel fuels. In conclusion, HVO seems to be a transparent fuel to be used as a Diesel



alternate. A couple of changes in engine calibration would be needed to smoothly operate a heavy duty truck with HVO fuel like soot load estimation calibration and extra heating in cold start mode.

In this deliverable of the project, documentation of the control system test results is reported by containing the test results of the algorithms for hybrid control strategy, vehicle control, electrical system and e-axle transmission control. The report informs about the latest status of the algorithms in current level of the project. The reported tests that have been executed at least in one of the MIL, HIL and test rig environments depending on the algorithm and prototype maturity.

The next phase of the project will be reported by deliverable 6.7 This final deliverable will include demonstrator vehicle test results. Tests will include real world driving emission (RDE) test with a portable emission measurement device (PEMS), CO2 measurement tests, zero emission drive and a smart algorithm test. Demonstrator vehicle test result will be compared with the baseline vehicle and will be published in the D6.7.

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### Project partners:

#	Partner	Partner Full Name
1	FEV	FEV EUROPE GMBH
2	DAF	DAF TRUCKS NV
3	FPT	FPT INDUSTRIAL SPA
4	FORD	FORD OTOMOTIV SANAYI ANONIM SIRKETI
5	IRIZAR	IRIZAR S COOP
6	IVECO	IVECO S.p.A.
7	VOLVO	VOLVO TECHNOLOGY AB
8	VDL	VDL ENABLING TRANSPORT SOLUTIONS BV
9	ABEE	AVESTA BATTERY & ENERGY ENGINEERING
10	AVL	AVL LIST GMBH
11	EATON	EATON ELEKTROTECHNIKA SRO
12	GARR	GARRETT MOTION CZECH REPUBLIC SRO
13	IDIADA	IDIADA AUTOMOTIVE TECHNOLOGY SA
14	IFP	IFP Enegeies Nouvelles
15	AVL	AVL MTC MOTORTTESTCENTER AB
16	NESTE	NESTE OYJ
17	PRIMA	PRIMAFRIO SL
18	SHELL	SHELL GLOBAL SOLUTIONS (DEUTSCHLAND) GMBH
19	SIE	SIEMENS INDUSTRY SOFTWARE SAS
20	TECHNA	FUNDACION TECHNIALIA RESEARCH & INNOVATION
21	TOTAL	TOTAL MARKETING SERVICES
22	UMIC	UMICORE AG & CO KG
23	UNR	UNIRESEARCH BH
24	JRC	JRC -JOINT RESEARCH CENTRE – EUROPEAN COMMISSION
25	CHALM	CHALMERS TEKNISKA HOEGSKOLA AB
26	RWTH	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN
27	TU/e	TECHNISCHE UNIVERSITEI EINDHOVEN
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