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Zero Emission flexible vehicle platform with modular powertrains serving the long-haul Freight Eco System

ZEFES - Deliverable report

Deliverable D5.6 – Realization and commissioning of all BEV demonstrators

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Publishable summary

Within the Green Deal, Europe commits itself to be the first CO2 neutral continent by 2050. To achieve this, an overall CO2 reduction target of 55% by 2030 is defined as a first milestone. For the road transport sector, the target is set to 30% less CO2 emissions by 2030 (compared to 1990 emission levels) following Regulation (EU) 2019/1242. The regulation requires that manufacturers of heavy-duty vehicles (HDV) deliver more efficient vehicles to achieve a reduction of CO2 emissions for the newly produced fleet of 15% in 2025 and 30% in 2030. The deliverable D5.6 documents the realization, commissioning, and preliminary testing of the BEV demonstrator configurations, focusing on modular multi-powertrain long-haul solutions and the integration of next-generation e-trailers as range extenders. The work encompasses Scania, Volvo and Renault BEVs and e-trailer solutions from Kaessbohrer, ZF and Econogy. It outlines the commissioning, testing, regulatory approvals, and handover process to WP7 use cases. The project aims to deliver flexible, modular powertrain platforms capable of supporting long-haul missions with varying energy needs and mission profiles, while ensuring safety and regulatory compliance across Europe.

Key outputs include the realization of modular BEV powertrains designed for long-haul duty cycles. Vehicle demonstrators span three configurations: Scania demonstrations with different BEV tractors and an e-trailer provided by Kaessbohrer and Econogy, Volvo demonstrations featuring Volvo long-range tractors, and Renault demonstrations centred on Renault BEV tractors equipped with Michelin e-tire technology. The realization of the Kaessbohrer/ZF e-trailer is presented with attention to regulatory hurdles for e-trailer approval and national road permits.

The regulatory context covers EU mass and dimension regulation and country-specific deviations. All battery-electric prime movers have EU type approval or national individual approvals. For the Kaessbohrer/ZF e-trailers, a registration with ZF for test and validation purposes was obtained. The tractor – semitrailer vehicle combinations are expected to fulfil the EU Weights and Dimensions Directive (96/53/EC). The EMS2 vehicle combination, including the Scania BEV lowliner, can be used in Spain according to the requirements of the national instruction MOV2023/28, and no special permit is required.

Despite these regulatory complexities, the project has achieved substantial progress: first Scania and Volvo BEVs have been commissioned and handed over to WP7 use cases, and Renault BEVs have begun commissioning and testing.

Figure 1:battervy-electric tractors from Scania, Volvo and Renault (left to right)

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Abbreviations & Definitions

Abbreviation	Explanation
BEV	Battery-Electric Vehicle
CCS	Combined Charging System
ECU	Electronic Control Unit
EMS	European Modular System
GCW	Gross Combination Weight
GVW	Gross Vehicle Weight
HW	Hardware
MCS	Megawatt Charging System
OEM	Original Equipment Manufacturer
RDW	Netherlands Vehicle Authority
SW	Software

UTAC	Union Technique de l'Automobile, du motorcycle et du Cycle
WVTA	Whole Vehicle Type Approval
ZE	Zero-Emission

1 Introduction

In the ZEFES work package 5, modular and flexible battery-electric powertrains and their integration in five demonstrators are realized. These demonstrator vehicle combinations consist of five battery-electric towing vehicles, two electrified semitrailers, and one electrified converter dolly.
The work includes the development of a modular battery-electric powertrain concept for long-haul heavy-duty vehicle combinations, which are adaptable to daily demands of mission profiles in terms of range and power, and flexible in terms of integration of batteries and powertrains in different vehicle units. For this powertrain concept, a functional safety concept is created.
To realize the vehicle units, specific powertrain components, subsystems, control systems and energy & thermal management systems are adapted and integrated in the prime mover battery-electric powertrains. Development and integration efforts are also made to realize the next generation e-trailers serving as range extenders integrated in the electric powertrain of the prime mover.

The following list shall clarify the context of deliverable D5.6:

D5.1 - System specification for ZE modular multi-powertrain concepts: In this deliverable, the system specification of the battery-electric vehicle combinations with a modular multi-powertrain is verified and evaluated. The upgraded vehicle simulation tool IVIsion is used to verify the final design specifications of each targeted BEV demo.

D5.2 – Functional Safety Concept: The deliverable investigated the functional safety concept for the vehicle combinations with a modular multi-powertrain. The concept of an additional powertrain located in a trailer is described in terms of its application area, its functional behaviour on vehicle level, the powertrain functions and a draft system architecture. Furthermore, the results of the hazard analysis and risk assessment are presented including the derived safety goals and functional safety requirements for the development of the electrified trailers and the application in the ZEFES use cases.

D5.3 - Powertrain components and control systems for next generation battery-electric trucks: Within the deliverable, the innovations and system improvements for the battery-electric towing vehicles developed by SCA, VOL and REN are described. This includes results of the proof of concept.

D5.4 - Next generation battery-electric trailers: The deliverable describes the adaptations and improvements of the e-semitrailer and the e-dolly as part of the modular multi-powertrain vehicle combinations. This includes the improvement of the mechanical design for the trailer chassis, based on the existing ZF e-trailer, and the development efforts regarding the powertrain components, controls, and auxiliary systems.

D5.5 - Commissioning, testing and verification connectivity between BEV demonstrators and digital twin tool: The deliverable briefly describes the results of the commissioning and testing of the data interface between the demonstrator vehicles and the digital twin tool developed in work package 4.

D5.6 - Realization and commissioning of all BEV demonstrators: In this deliverable, the commissioning and testing of the six battery-electric demonstrator vehicle combinations is

presented including the results of short dry run tests. As a result of the work described in this document the vehicle combinations can be handed over to WP7 use cases.

The position of deliverable D5.6 within WP5 and the relation to other deliverables and work packages is shown in Figure 2.

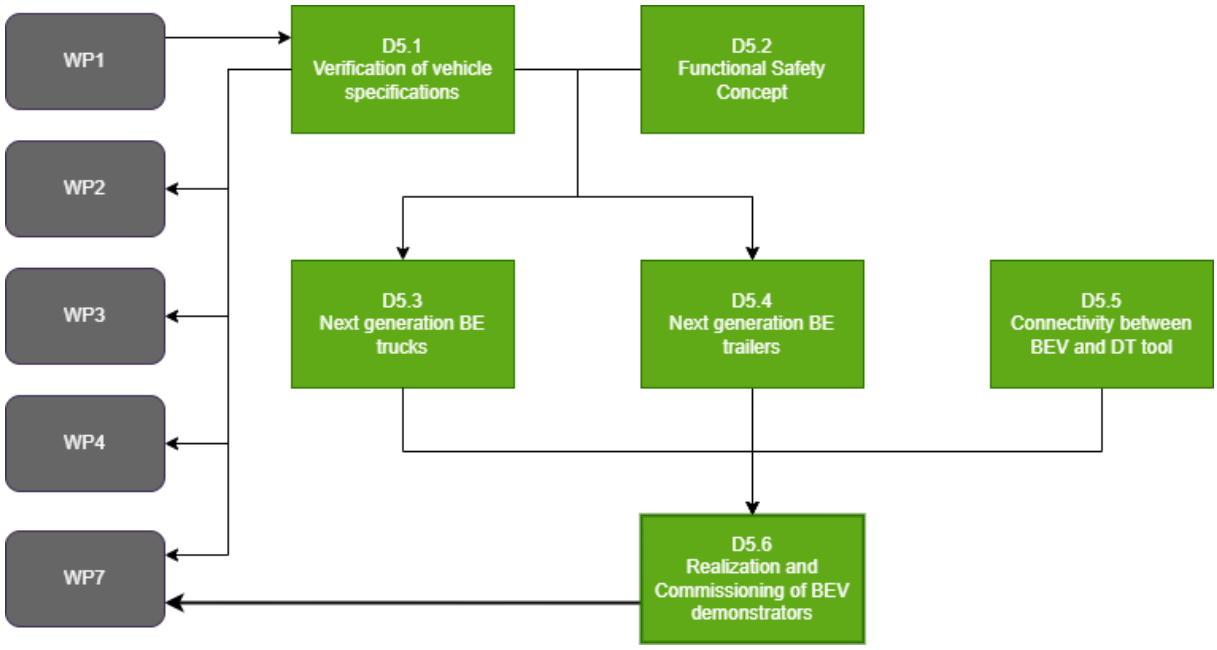

Figure 2: Relation of deliverable D5.6 to deliverables of WP5 and other WPs

Chapters 2 to 5 of the present document describe the realization and commissioning of the battery-electric vehicles from Scania, Volvo, Renault and the e-trailer from Kaessbohrer and ZF. The chapters include a short description of the technical specifications and the procedures followed during commissioning and testing. Further sections provide an overview of road permits and registration for each vehicle and its compliance with the certification process for EU type approval. The vehicle combinations for each use case are described regarding relevant aspects for the EU weights and dimensions directive, and details are given for deviations from standard vehicle combinations. Finally, the process for handing over the vehicle combinations to the use cases is presented.

2 SCA BEV demonstrators

2.1 Background

With a mentality of continuous improvement of products and services, Scania seldom thinks in terms of product generations. And thanks to the modular system, Scania can continuously expand its truck offering, addressing new applications and transport needs.

This process has now brought Scania to the point where they no longer need to differentiate between urban or regional operations on a platform level – and moving forward they can offer one consolidated battery electric truck platform which can then be specified to whichever needs their customers have. This means Scania now offers more chassis variations and wheel configurations, more cab options, as well as multiple e-machine choices – optimized for weight and energy efficiency or for torque and power. As well as battery configuration options that allow customers to optimize the capacity and range for their needs, without compromising on payload or paying more up front for unneeded maximum capacity.

With this modularity, Scania can build a vehicle that fits the use cases to a large extent. Scania has only done minor adaptations for the different Use Cases in ZEFES, which are described below.

2.2 Use Case 7.3.1 – SCA/SCA

In this use case, Scania Transport Lab operates the vehicle on its regular route from Södertälje to Zwolle in the Netherlands. As some of the legs are long, more energy might be required than the vehicle can provide when it is fully loaded and the weather is poor. This issue is solved with an e-trailer with battery storage and drive axle integrated in the trailer. Early in the project, Scania also investigated a b-trailer solution where energy is transferred to the vehicle through electric cables, but as described in report D2.6, it was decided to use the e-trailer, where the energy is used by electric axles on the trailer.

The use case route provides a limited possibility to charge the trailer alongside the truck, since charging stations rarely have two charging plugs in the correct position. Therefore, it is necessary to be able to use the trailers' energy on demand. Consequently, a button for the driver was installed to enable the e-trailer support when needed.

2.2.1 Scania BEV tractor

The base vehicle for this Use Case is a standard 4x2 tractor.

To enable long haulage drive, the maximum battery size at the time of production was chosen. At the same time the shortest possible axle distance was chosen to enable trailer operation.
To fulfil the needs of the use cases and showcase the innovation MCS charging was introduced in the vehicle. As MCS was not introduced at the time of production, Scania rebuilt the vehicle to MCS 750 kW/1000 A in their lab. The MCS charging inlet was placed at the standard position on the left side of the vehicle behind the driver’s door. Additionally, a secondary 375 kW/500 A CCS2 inlet was added to the right side of vehicle to enable the operator to use either MCS or CCS for charging.

Figure 3. Scania tractor unit for use case 7.3.1.

Table 1: Characteristics of the Scania tractor unit of use case 7.3.1.

Vehicle type	R 400E
Wheel configuration	A4x2 LB
Axle distance	4,150 mm
Electric propulsion	400 kW
Battery capacity	520 kWh usable
Charging	CCS2 375 kW/500 A DC, MCS 750 kW/1000 A
GTW	65,000 kg

A control unit for the e-trailer is installed in the tractor. It communicates with the trailer through the trailer interface. From the control unit, the driver can monitor the trailer battery status and select to use the battery.

2.2.2 Kaessbohrer/Econogy e-trailer

The ZEFES e-trailers built by Kaessbohrer and ZF Friedrichshafen AG are not available for commercial use.The road approval is restricted to run with a dummy load by ZF test drivers at a limited distance of 10.000km. Therefore, a mitigation action is planned to replace the KAE/ZF e-trailer with an e-trailer system that is provided by Econogy B.V.

The base vehicle, a three-axle curtainsider semitrailer, is supplied by Kaessbohrer. Econogy integrates its yDrive technology, including the high-torque e-axle, the energy storage system and a control system.

Table 2: Characteristics of the Kaessbohrer/Econogy e-trailer.

Component	Description
e-axle	- Permanent magnet synchronous motor (PMSM) - 250 kW peak power - 15.000 Nm maximum torque - Compatible with industry-standard brakes and air suspension
Energy storage system	- Lithium-titanate battery system - 90 kWh installed energy capacity - Power electronics - Cooling system
Control system	- Definition of brake and traction strategy - Sensor system for measurement of position, speed, acceleration, force and rotation - Utilization of information from the standard ISO 11992-2 CAN interface - Additional proprietary tractor – trailer communication to enable brake and traction blending (anticipation of upcoming revision of ISO 11992-2)

The Econogy eDrive system was originally developed for the hybridisation of conventional tractor-semitrailer vehicle combinations with diesel engines and operation in urban and regional delivery. Therefore, it is necessary to adapt the energy and torque management system of the e-trailer for operation with BEV tractors. The adapted software will be implemented on the e-trailer ECU and tested on a hardware-in-the-loop (HIL) testbed with a virtual representation of the BEV tractor.
Following the integration and commissioning of the e-trailer system, the vehicle will also be tested on a RDW test track in the Netherlands. In combination with the Scania tractor unit applied in use case 7.3.1 the e-trailer system will be calibrated and tested. Finally, e-trailer will be submitted to road approval tests by TÜV Rheinland. These activities are planned to be ready by end of Month June, so the start of the Scania use case could still be according to the adapted planning July 2024.

2.2.3 Commissioning and Testing

The Scania R&D department is developing the on-board equipment of the MCS charging interface. As they are familiar with the MCS charging standard and its requirements they can carry out all necessary testing and verification according to the regular processes.
For the ZEFES vehicle, Scania applied the approved HW and SW in the vehicle and tested it at their own MCS charger at the lab.
Prior to the application of the e-trailer in the use case, Scania will also test the tractor - e-trailer combination to ensure an optimal interaction of both vehicle units. This will be done on the Scania test track in Södertälje by Scania's brake specialists.

2.2.4 Road Permits and Registration

As this is a standard production vehicle, Scania will have a Whole Vehicle Type Approval (WVTA) from the factory. Therefore, the registration is done without any restrictions or deviations from the requirement.

The SCA-SCA BEV vehicle is registered in Sweden. As indicated by the truck OEM, the vehicle is approved with an EU Type approval, what allows the vehicle to be driven through the whole EU countries according to the 1968 Vienna Convention.

Regarding the road permits of the combination, it is expected that the vehicle units (truck and trailer) will fulfil the requirements of the current Directive 96/53 EC of masses and dimensions.
The vehicle combination (truck + semitrailer) is expected to exceed the maximum length of 16,5 m stated on the Directive. This over-length is expected to be justified by Article 9a of the Directive 96/53 EC – Directive (EU) 2019/1242 and the R(EU) 2021/535 - R(EU) 2024/883. The technical service selected by the OEM for the approval of the truck is the responsible for this justification, as it is indicated by the OEM during follow-up activities of the project.

To allow for the same cargo as an ICE truck, the GCW of the combination is considered to be increased to 44 t. A deviation is found here because the same Directive 96/53 EC only allows a maximum GCW of 40 t for a tractor – semitrailer combination with a 3-axle tractor and a 3-axle semitrailer. An increase of 2 t is allowed on this use case due to the application of vehicles with a zero-emission powertrain, with a total GCW of 42 t. This use case is taking place in Sweden, Denmark, Germany and The Netherlands. All of them allow until 44 t (or more, as Sweden) of GCW for tractor - semitrailer combinations, except for Germany, which only allows until 40 t. In Germany, it is allowed to increase the GCW until 2 t more if the vehicle is equipped with a Zero Emission powertrain, as it is the case. Considering that, Germany is also limiting the total GCW of the use case ton 42 t.

The countries in which this use case takes place, France and Spain, allow up to 44 t for national transport on these combinations. However, Directive 96/53 EC limits the maximum GCW for cross-border activities.

Regarding the e-trailer approval, different solutions were provided to ZF, VanEck and Kaessbohrer for the approval of the e-trailers used within the scope of the ZEFES project, as explained in section 4.2 of this document. Finally, a mitigation option was selected involving the use of the Econogy/Kaessbohrer e-trailer. Following this decision, Econogy and Kaessbohrer are responsible for obtaining the necessary approval for the trailer to be included in the ZEFES project, as this approval process lies outside the project's scope.

2.2.5 Handover to the Use Case

Initially, Scania performs a validation round trip with the vehicle to confirm that the chargers operate as intended and that the range is sufficient for the mission. Following this, driver training is carried out with a focus on BEV operation and charging. The training includes one supervised round trip with a Scania instructor on board. Finally, the keys are handed over, and the regular operation can start.

As the SCA-SCA use case will start without the delayed e-trailer, Scania will do extra driver training when the e-trailer arrives.

2.3 Use Case 7.3.3 – SCA/PRI

In this use case, PrimaFrio operates the truck in Spain, driving from Murcia to Le Boulou, which is just across the border in France. This is a demanding operation as the legs are long and the terrain is quite hilly. Therefore, thanks to Scania´s modular battery system, the tractor is equipped with the maximum battery capacity.

2.3.1 Scania BEV tractor

The base vehicle for this use case is a standard 4x2 tractor with an installed battery energy capacity of 623 kWh (560kWh usable), and MCS and CCS charging inlets. Apart from the battery size, it is very similar to the SCA-SCA truck used in use case 7.3.1.

Table 3: Characteristics of the Scania tractor unit of use case 7.3.3.

Vehicle type	R 400E
Wheel configuration	A4x2 LB
Axle distance	4,150 mm
Electric propulsion	400 kW
Battery capacity	560 kWh usable (623 kWh installed)
Charging	CCS2 375 kW/500 A DC
GTW	65,000 kg

As this vehicle was built later than the vehicle for Scania Transport lab (use case 7.3.1), Scania was able to produce the vehicle with MCS (left side) and CCS (right side) charging from factory.

2.3.2 Commissioning and Testing

There is no special testing needed as this is a standard vehicle.

2.3.3 Road Permits and Registration

As this is a standard vehicle from production, Scania will have WVTA from the factory. Therefore, registration is done without any restrictions or deviations from requirements.

The SCA-PRI BEV vehicle is registered in Spain. As indicated by the truck OEM, the vehicle is approved with an EU Type approval, what allows the vehicle to be driven through the whole EU countries according to the 1968 Vienna Convention.

With regard to the road permits for the vehicles (truck and trailer), it is expected that the vehicle units will fulfil the requirements of current Directive 96/53 EC on masses and dimensions.
The vehicle combination (truck + semitrailer) is expected to exceed the maximum length of 16,5 m stated in the Directive. This over-length is expected to be justified by Article 9a of the Directive 96/53 EC – Directive (EU) 2019/1242 and the (EU) 2021/535 - (EU) 2024/883. The technical service selected

by the OEM for the approval of the truck is the responsible for this justification, as it is indicated by the OEM during follow-up activities of the project.

To allow for the same cargo as an ICE truck, the GCW of the vehicle combination is increased to 44 t. A deviation is found here because the same Directive 96/53 EC only allows a maximum GCW of 40 t for a tractor – semitrailer combination with a 3-axle tractor and a 3-axle semitrailer. An increase of 2 t is allowed on this use case due to the application of vehicles with a zero-emission powertrain, resulting in a total GCW of 42 t. The countries of this use case, France and Spain, allow until 44 t for national transport on these combinations, but the Directive 96/53 EC limits maximum GCW on cross border activities.

2.3.4 Handover to the Use Case

Initially, Scania performs a validation round trip with the vehicle to confirm that the chargers operate as intended and that the range is sufficient for the mission. Following this, driver training is carried out with a focus on BEV operation and charging. The training includes one supervised round trip with a Scania instructor on board. Finally, the keys are handed over, and the regular operation can start.

2.4 Use Case 7.3.4 – SCA/GSS

In this use case, Grupo Sesé runs a route from Martorell, just outside Barcelona in Spain to Heilbronn in Germany. The semitrailers used on the route are so-called mega trailers that provide an internal

Figure 4: Scania tractor unit in EMS2 vehicle combination with two mega trailers and a standard converter dolly (use case 7.3.4)

loading height of 3 m, which is realized by a lowered loading floor. Therefore, a truck with a lower fifth wheel compared to regular vehicles is needed. The route between Le Boulou and Martorell is operated with an EMS2 combination consisting of the BEV, two semitrailers and a standard converter dolly. Part of the route is by rail, with the trailer being loaded onto the train in Dudelange, Luxembourg, and picked up in Le Boulou, France.

Between Dudelange and Heilbronn the semitrailers are driven in a standard tractor - semitrailer combination. Since there is only one Scania BEV is available for the use case, it is first operated on the leg between Martorell and Le Boulou for three months. After that the BEV is transferred to Germany and operated between Dudelange and Heilbronn for another three months.

2.4.1 Scania BEV tractor

The base vehicle for this Use Case is a standard 4x2 tractor with a usable battery capacity of 520kWh and a CCS charging inlet.

Figure 5. Scania tractor unit use case 7.3.4.

The Standard R400E Scania was modified for use in the ZEFES to fulfil the needs of the use cases and showcase the innovations: The chassis is lowered to be able to handle the extra high trailers. As MCS was not introduced at production time, Scania rebuilt the vehicle to MCS 750 kW/1000 A in their lab. The MCS charging inlet was placed at the standard position on the left side of the vehicle behind the driver´s door. Additionally, a secondary 375 kW/500 A CCS inlet was added to the right side of the vehicle to enable the operator to use either MCS or CCS for charging.

Table 4: Characteristics of the Scania tractor unit of use case 7.3.4.

Vehicle type	R 400E
Wheel configuration	A4x2 LB
Axle distance	4,150 mm
Electric propulsion	400 kW
Battery capacity	520 kWh usable
Charging	CCS2 375 kW/500 A DC, MCS 750 kW/1000 A
GTW	65,000 kg

2.4.2 Commissioning and Testing

The Scania R&D department is developing the on-board equipment of the MCS charging interface. As they are familiar with the MCS charging standard and its requirements they can carry out all necessary testing and verification according to the regular processes.
For the ZEFES vehicle, Scania applied the approved HW and SW in the vehicle and tested it at their own MCS charger at the lab.

2.4.3 Road Permits and Registration

As this is a standard vehicle from production, Scania will have WVTA from the factory. Therefore, the registration is done without any restrictions or deviations from requirements.

The SCA-GSS BEV vehicle is registered in Spain. As in the previous use case, and as indicated by the truck OEM, the vehicle is approved with an EU Type approval, what allows the vehicle to be driven through the whole EU countries according to the 1968 Vienna Convention.

EMS2 combinations are not within the scope of the Masses and Dimensions Directive (96/53 EC). At a national level, Spain has been conducting tests on several EMS combinations until 2024. Since 2024, EMS combinations have been permitted in Spain under the requirements of the national instruction MOV2023/28, for which no special permit is required.

The first deviation from the original plan found in this use case is that France does not allow EMS combinations within its territory. This fact prevents driving this type of combination in France without granting a road permit from the French authorities. The second deviation found is that masses and dimensions on cross-border activity is limited to the Directive 96/53 EC, in which EMS combinations are not included. This second deviation makes not possible the cross-border activity between Spain and France with an EMS combination.

As a mitigation, the EMS2 combination can be driven through Spain. At the French border the truck will decouple and complete the use case through France as a tractor - semitrailer combination of 42 t GCW as maximum due to Directive 96/53 EC restrictions. The second semitrailer will be picked up by a separate vehicle.

Regarding to the road permits of the combination tractor - semitrailer, the vehicles are expected to fulfil the requirements of current Directive 96/53 EC of masses and dimensions. As indicated previously, the vehicle combination (truck - semitrailer) is expected to overpass the maximum length of 16,5m stated on the Directive; the over-length is expected to be justified by article 9a of the Directive 96/53 EC – Directive (EU) 2019/1242 and the R(EU) 2021/535 - R(EU) 2024/883. This aspect is verified by the technical service in charge of vehicle approval. This justification is accepted by countries involved on this use case (Spain, France, Germany and Luxembourg).

2.4.4 Handover to the Use Case

Initially, Scania performs a validation round trip with the vehicle to confirm that the chargers operate as intended and that the range is sufficient for the mission. Following this, driver training is carried out

with a focus on BEV operation and charging. The training includes one supervised round trip with a Scania instructor on board. Finally, the keys are handed over, and the regular operation can start.

2.5 750 km Test

In alignment with the project lead, it was decided to do the 750 km test without the e-trailer
The 750 km test will be done in the vicinity of Södertälje. Professional Scania test drivers will drive the vehicle during the test. As it cannot be ensured that the vehicle can return to Södertälje before the battery is empty, Scania might place a mobile charger somewhere along the route.
Optimal range will be ensured by doing the test at the right temperature and weather, which is the reason why the test is planned to be conducted in May 2026. Scania will also use an optimised trailer with minimum air drag. For the test, the SCA-PRI vehicle will be used, as this truck has the battery with the most energy content. The GVW chosen for the test is 40 t.
It is unlikely that the 750 km will be reached with the combination. Therefore, Scania will make another test with reduced GVW to reach the required range.

2.6 Data Acquisition

A list of requirements for the signals to be monitored was agreed between Scania and the partners in WP4 and WP8. Scania has therefore implemented a gateway that filters out these signals. A logger supplied by the project has been attached to this gateway.

3 VOL BEV demonstrators

3.1 Background

Volvo Trucks drives the transition towards fossil-free transport to reach its net-zero emissions target by 2040 using a three-path technology strategy. The three-path technology approach is built on battery electric, fuel cell electric, and combustion engines that run on renewable fuels like green hydrogen and biogas.

The electrification of heavy trucks is continuing across the world, and longer distances are now becoming a possibility. Volvo's long-range version of its FH Electric will be able to reach up to 600 km on one charge. This will allow transport companies to operate electric trucks on long-distance routes and to drive a full working day without having to recharge. The enabler for the 600 km range is Volvo's new driveline technology including the e-axle, which creates space for significantly more battery capacity onboard. Further improvements in batter efficiency, an enhanced battery management system, and overall powertrain efficiency improvements contribute to the extended range.

3.2 Use Case 7.2.2 – VOL/ASSA, 7.2.3-1 – VOL/P&G and 7.2.3-2 – VOL/PRI

3.2.1 Volvo BEV tractor

The vehicles utilised in the use cases are the long-range BEV variant, configured as 6x2 tractor with a tag axle and operating at a gross combination weight of 42 t. This selection enables the transport companies to deploy electric trucks for interregional and long-haul routes, facilitating daily work operations. The long-range BEV vehicle has an installed battery capacity of 780 kWh and can reach up to 600 km on one charge.

The tractors are equipped with both CCS, supporting charging power up to 350 kW, and MCS, enabling charging power up to 720 kW.

Figure 6. Volvo FH Aero Electric 6x2 with extended range.

Table 5: Characteristics of the Volvo tractor units for use case 7.2.2 and 7.2.3-1/2.

Vehicle type	
Wheel configuration	T6x2
Axle distance	4,100 mm
Electric propulsion	e-axle 460 kW
Battery capacity	780 kWh installed, 630 kWh useable
Charging	CCS2 350 kW/500 A DC, MCS 720 kW/1000 A
GTW	46,000 kg

3.2.2 Commissioning and Testing

The commissioning and testing of Volvo's battery-electric trucks are carried out through a structured, safety-focused process. These processes emphasize high-voltage safety, system validation, diagnostics, and charging functionality, as reflected in Volvo's Certified Electric Technician training programs, which outline the components involved in commissioning, the required tools, and the safety precautions necessary when working with electric trucks.

For long-range BEV vehicles, the commissioning steps follow Volvo's general principles for preparing electric trucks for service. This includes verifying the vehicle's major systems. The introduction of long-haul electric trucks also involves validating new technologies, such as the next-generation driveline architecture and compatibility with high-power charging standards like the Megawatt Charging System (MCS),

The overall purpose of the commissioning and testing phases is to ensure safety, verify system functionality, and secure reliable operation before the vehicle enters full deployment. Objectives include validating key vehicle systems, ensuring correct interaction between subsystems, evaluating charging performance, and confirming interoperability with depot and high-power charging infrastructure.

3.2.3 Road Permits and Registration

Each vehicle is registered in the country where each specific use case originates and maintains its operational base. Additionally, the vehicles comply with the national regulations and road permits in effect. Complete vehicle type approval according to EU standards.

Table 6. Registration overview of Volvo use cases.

Use case	**Operator**	**Vehicle Registration**	**Route**
UC722	Assar Haulage	Sweden	Gothenburg / Sweden - Gent / Belgium
UC723-1	P&G / ECS	Belgium	Zeebrugge / Belgium – Amiens / France
UC723-2	Primafrio	Spain	Bettembourg / Luxemburg – Halmstad / Sweden. (One trip Murcia / Spain – Halmstad / Sweden).

Volvo's new FH Aero cab features an extended front section (approx. 24 cm) designed to improve aerodynamics and reduce energy consumption and CO_2 emissions.
The vehicles are expected to fulfil the requirements of the current Directive 96/53 EC on masses and dimensions. As indicated previously, the vehicle combination (truck + semitrailer) is expected to exceed the maximum length of 16,5m stated on the Directive; the over-length is expected to be justified by Article 9a of the Directive 96/53 EC – Directive (EU) 2019/1242 and the R(EU) 2021/535 - R(EU) 2024/883 due to the aerodynamic cabin. This aspect is verified by the technical service in charge of vehicle approval.
For use cases 7.2.2 and 7.2.3, no additional road permits are required, as the vehicles are already approved for configurations with aerodynamic cabs, as confirmed by the OEM. These aero cabs comply with national regulations on vehicle masses and dimensions in the countries involved—Sweden, Denmark, Germany, Luxembourg, France, and Spain.
Related to weight restrictions, as in previous use cases, the current Masses and Dimensions Directive 96/53EC sets the limit of 42 t for use case 7.2.3 combinations, even if in most of the involved countries, 44 t are allowed, except in Germany. Use case 7.2.2 can reach 44 t because this vehicle combination is not operated cross border, only running in Sweden, where heavy duty vehicle combinations are allowed until 60 t.

3.2.4 Handover to the Use Cases

The handover of a vehicle takes place when it arrives at the designated country or location for its intended use and follows a standardised, well-known process to ensure the vehicle is safe, functional, and ready for real-world operation. Before delivery, the vehicle undergoes basic checks of all major systems. The customer is introduced to the vehicle and informed about what is expected during the test period. Basic operational training is provided by Volvo employees, covering daily inspections, driving functions, instrument panel information, and relevant charging procedures. Prior to handover, a contract is signed to ensure alignment on the set-up, services, support, and follow-up routines. The customer receives standard documentation—such as user manuals, safety guidelines, and contact information. Any necessary systems for data collection and monitoring are installed, and the customer is informed about how to provide feedback or request assistance. The handover concludes with a drive together with the customer to ensure everything functions as expected.

3.3 Use Case 7.2.4 – VOL/DPD

3.3.1 Volvo BEV rigid

Initially, the use case involved utilising a Volvo BEV 6x2 rigid truck operating within an EMS1 vehicle combination, paired with an e-trailer from ZF and Kaessbohrer. The vehicle is a standard production model featuring an aerodynamic front and a battery electric powertrain with a 500 kWh battery, compatible with CCS charging.

In December 2025, ZF informed the ZEFES project that the e-trailer will not be available for commercial use. As a result, it was decided to cancel both the use case and the order for the Volvo BEV.

Volvo is currently evaluating a proposal to contribute to an adapted use case involving a vehicle combination consisting of a Volvo BEV truck, dolly, and Volvo e-trailer, intended for cross-border operations between Sweden and Norway. The vehicle is a Volvo FH BEV, equipped with a 195 kW, 600 V electric motor and a 360 kWh battery pack (252 kWh usable), supporting CCS charging. This vehicle combination is currently operating in Sweden as part of the REEL project, which is scheduled to conclude in June/July 2026. Upon project completion, there is potential for the combination to be transferred to ZEFES for continued operation until the end of the year 2026.

3.3.2 Commissioning and Testing

Commissioning and testing of the Volvo BEV rigid and the EMS1 vehicle combination was not planned until use case 7.2.4 was cancelled due to the non-availability of the e-trailer for commercial operation.

3.3.3 Road Permits and Registration

Use case 7.2.4 has changed from the original plan due to the availability of vehicles. Originally, it was planned an EMS1 combination (rigid truck + dolly + e-trailer) running through the Netherlands and Germany. Both countries allow EMS1 combinations, but the following issues were found:

- First, although the Netherlands allow up to 50 t of GCW for EMS1, Germany only allows up to 40 t, with the possibility for increasing to 42 t for this use case due to the zero-emission powertrain.
- Second, the final length of the combination was pending approval by the RDW and the TÜV for a certificate of compliance to operate in the Netherlands and Germany, respectively.

The issues described were not solved until use case 7.2.4 was cancelled due to the non-availability of the e-trailer for commercial operation.

Road permits on the new use case 7.2.4 are not described, waiting for a final resolution of the demonstration.

3.3.4 Handover to the Use Case

Considering the deviations on use case 7.2.4, the vehicle for this demonstration is not expected to be manufactured. In case another demonstration is substituting that one, the vehicle is expected to be already manufactured and running.

3.4 750km Test

The test will be conducted at the Volvo Proving Ground outside Gothenburg, Sweden, using a BEV long-range electric vehicle in spring 2026. The test will be scheduled to align with the demonstration and take advantage of optimal weather conditions. It is expected to last approximately one week. The UC722 vehicle will be used, operated by professional test drivers from Volvo. The test will initially follow ZEFES' proposal but may be adjusted during execution based on factors such as cargo weight and vehicle speed

3.5 Data acquisition

Volvo, in collaboration with Ricardo, has identified key signals to monitor. To ensure data security, Volvo will use its own dedicated loggers and gateway devices for data collection. Additionally, a project-supplied logger will be connected as part of the data acquisition system.

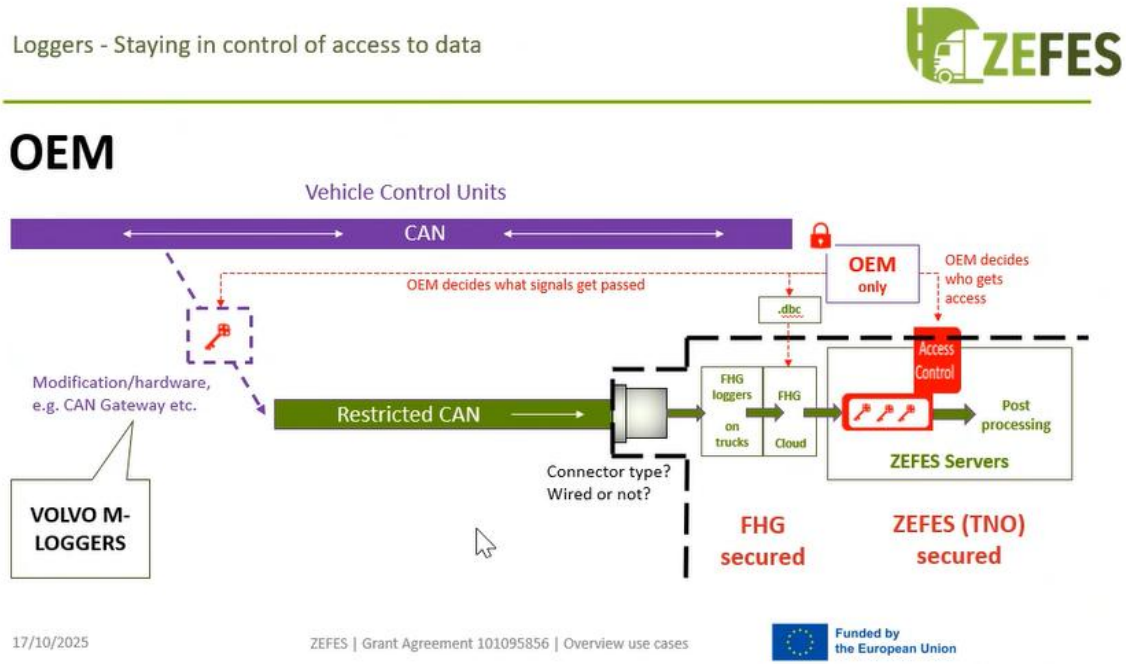

Figure 7. Schematics of the data acquisition.

4 REN BEV demonstrators

4.1 Background

In ZEFES, Renault Trucks has extended the range of its E-Tech T model. This extended range vehicle opens new prospects for the decarbonization of long-haul transport.
With 30 million kilometres of use by haulers, Renault Trucks electric trucks have already saved 29.000 t of CO_2 emissions, and with this new offer, it is further extending its product portfolio of sustainable transport solutions to support its customers in their energy transition.

Designed for long-haul transport, the Renault Trucks E-Tech T with an extended range will enhance the manufacturer's electric offering without replacing current solutions. Renault Trucks will indeed continue to offer a wide range of autonomies, configurations and equipment tailored to specific uses. To help haulers find the ideal solution, Renault Trucks is also providing them with advanced simulation tools enabling each electric truck to be configured according to their specific needs.

4.1.1 E-tires

Battery electric tractors are known to wear drive tires faster than diesel trucks due to higher braking forces resulting from brake energy regeneration and potentially higher driving torques from the e-motors. In addition, tire rolling resistance has a strong impact on truck energy consumption. Michelin provides a new tire compound in the dimension 315/70R22.5 X MULTI D, with a targeted performance of:

- Rolling Resistance (RR) reduced by 0.5 kg/t (as measured on drum)
- Wear rate reduced to increase durability by 15% with respect to vehicle mileage (with all other things equal)

In addition, the adherence of performance targets is set to be equal to or above the reference.
The evolutions considered by Michelin are an innovative tread design, a more linear innovative tread compound using a new functional styrene-butadiene rubber (SBR) compound, and the best casing for RR/endurance compromise. All these innovations have been industrially scaled-up to allow to produce 50 prototype tires “XM901”, to be used within the ZEFES project on several use-cases.

Figure 8. Michelin tires images, X MULTI D (Left) and Proto XM901 (Right)

To verify that the target tire performances have been reached by this innovative design, in-house tests have been conducted and the actual performance obtained is:

- Rolling Resistance improved by 0.3 kg/t (on drum measurements)
- Expected mileage on standard regional usage improved by 25% (road tests)

In addition, transversal adherence has been improved by +30%, in line with our objective of maintaining this level of safety performance.
All the regulatory tests required for road approval have also been conducted with success.
Two use cases are planned to be equipped with prototype tires on Renault BEV tractors. Additionally, reference diesel vehicle has been fitted to assess the effect of electrification on tire wear and projected mileage.

4.2 Use Case 7.4.1 – REN/MICH and 7.4.3 – REN/REN

The BEV truck is a tractor with a semitrailer (according to the current Directive EC 96/53 of masses and dimensions). It is fully compliant with Weight and Dimensions specifications.

4.2.1 Renault BEV tractor

Figure 9. Renault tractor unit for use case 7.4.1 and 7.4.3.

Table 7: Characteristics of the Renault tractor units for use cases 7.4.1 and 7.4.3

Vehicle type	E-Tech T-range (sleeper cab only, L2H2)
Wheel configuration	T6x2 Extra length on front face
Axle distance	4,150 mm
Electric propulsion	Renault e-axle 490 kW
Battery capacity	600 kWh usable
Charging	CCS2 350 kW/500 A DC, MCS 720 kW/1000 A
GTW	46,000 kg

4.2.2 Commissioning and Testing

Renault Trucks will put the truck on the road after assembly, commissioning and a test and validation period. Renault Trucks will proceed with its regular verification and validation tests for new products. It will include the regular EU type approval done by the French certification authority, UTAC.

4.2.3 Road Permits and Registration

Table 8: Registration overview of the Renault use cases 7.4.1 and 7.4.3.

Use case	Operator	Vehicle Registration	Route
UC741	LTR	France	Blanzy / France– Blavozy / France
UC743	Dupessey&Co	France	Lyon / France - Venissieux plant (FR69) - Frejus tunnel (FR73) - Venissieux plant (FR69)

The tractor–semitrailer combinations involved in this use cases are allowed to achieve up to 44T of GCW for internal routes in France.

Regarding the road permits of the tractor-semitrailer combination, the vehicle units are expected to fulfil the requirements of the current Directive 96/53 EC on Masses and Dimensions.
The vehicle combination (tractor-semitrailer) is expected to exceed the maximum length of 16,5 m stated in the directive due to an aerodynamic cabin. The over-length is expected to be justified by the Article 9a of the Directive 96/53 EC – Directive (EU) 2019/1242 and the R(EU) 2021/535 - R(EU) 2024/883. This justification has been accepted under the French Code de la Route, as it was explained in Deliverable D1.6. Therefore, no road permits will be needed.

4.2.4 Handover to Use Cases

The handover of the truck to the operator will be performed according to the Renault Trucks Field test procedure. It includes a presentation of the truck to the driver, an on-site driver training, and a supervised driving with a Renault instructor during the first kilometres of operation. This will be supported by the local Renault Trucks dealership.

A contract will be issued with MICHELIN for tires usage and tests, and with each use case operator.

4.3 Use Case 7.4.2 – REN/DPD

In this case, Renault Trucks will use a 2nd truck, identical to the one for UC 7.4.1 and7.4.3.

4.3.1 Renault BEV tractor

Table 9: Characteristics of the Renault tractor units for use cases 7.4.2

Vehicle type	E-Tech T-range (sleeper cab only, L2H2)
Wheel configuration	T6x2 Extra length on front face
Axle distance	4,150 mm
Electric propulsion	Renault e-axle 490 kW
Battery capacity	600 kWh usable

Charging	CCS2 350 kW/500 A DC, MCS 720 kW/1000 A
GTW	46,000 kg

4.3.2 Commissioning and Testing

Renault Trucks will put this truck on the road after assembly, commissioning and a testing. Renault Trucks will then proceed with its regular verification and validation tests for the new product.
The vehicle will be approved by RDW in the Netherlands. It is expected to have special plates, but it will be allowed to transport commercial loads.

4.3.3 Road Permits and Registration

The Netherlands is accepting 44 t of GCW for internal trips and extra-length due to an aerodynamic cab. This truck will be registered in NL by RDW.

Table 10: Registration overview of the Renault use case 7.4.2.

Use case	Operator	Vehicle Registration	Route
UC742	DPD / Van Setten	Netherland	Veenendaal / Netherland – Brussels area / Belgium – Veenendaal / Netherland Veenendaal / Netherland – Rotterdam area / Netherland – Veenendaal / Netherland

4.3.4 Handover to the Use Cases

The handover of the truck to the operator will be performed according to Renault Trucks Field test procedure. It includes a presentation of the truck to the driver, an on-site driver training and a supervised driving with a Renault instructor during the first kilometres of operation. This will be supported by the local Renault Trucks dealership.

4.4 750 km Test

The project requires the test to be performed with attention to the points below.
“All demonstrations cover at least 6 months, with daily routes of up to 1.300 km (WP7). Each of the vehicles is tested in specific conditions to make sure they reach a range of 750 km, based on their energy consumption. […]”

- In the month 18 review, the project officer highlighted the importance and need of this test. This is also why it is a separate part that is shown in the use-case planning.
- WPLB meeting 08.04.2025: “the 750 km test can also be conducted on a roller test bench”

The 750 km test will be performed on Renault Truck proving ground in La Valbonne - France.
Renault Truck professional test drivers will operate the vehicle combination during the test under the following conditions:

- vehicle combination: Tractor - Semitrailer,
- speed: 70 km/h,
- favorable weather (no wind, 10°C min, no rain)

- time: spring 2026 (planned on week 13/2026),

Some additional tests will be performed to compare to commercial conditions or other known operational conditions.

4.5 Data Acquisition

Renault Trucks has agreed with the project's researchers to provide a minimum number of signals to be monitored. Renault Trucks has its own loggers and a gateway to acquire data, as well as a logger supplied by the project and attached to the provided gateway. This gateway contains the filtered agreed signals.

Logger installations are performed by Renault Trucks instrumentation professionals. These professionals are used to working with loggers, as they are fully incorporated into their regular field test procedures and working methods.

5 ZF/Kaessbohrer e-trailer

In the ZEFES project two e-trailers were assembled and commissioned.
One e-trailer was intended for operation in use-case 724 on the DPD container transport roundtrip mission between Oirschot in the Netherlands to Aichach in Germany. One round trip is about 1450 km. The vehicle setup was a Volvo rigid BEV + dolly + e-tailer. The e-trailer has been built by integrating the ZF TrailTrax system in a Kaessbohrer container chassis.

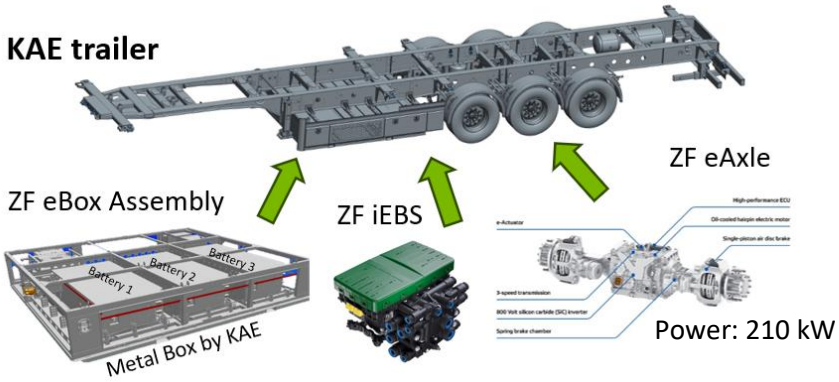

Figure 10. Schematics of the ZF/Kässbohrer e-trailer.

The second e-trailer, a Kaessbohrer curtainsider was also equipped with a TrailTrax system. This trailer was intended for use-case 731, in a Scania-owned mission between Södertälje in Sweden and Zwolle in the Netherlands. The mission consists of an approximately 2700km round trip, in which the e-trailer is towed in a regular tractor-semitrailer combination by a Scania BEV.

Curtainsider for UC731 SCA/SCA
Trailer-weight: 8100kg
Battery: 205 kWh (CCS chg.)

Container Chassis for UC724 VOL/DPD
Trailer weight: 9900t
Battery: 308 kWh (CCS chg.)

Figure 11. Image of the ZF/Kässbohrer e-trailers.

Please find details on the dimensioning, assembly and commissioning of these vehicles in deliverable report D5.4 (Next generation battery-electric trailers). This report focuses on the commissioning of vehicle combinations.

In December 2025 ZF had to announce a limited release level for the built ZF/KAE e-trailers. Fortunately, the e-trailers already had an individual vehicle approval and a registration to ZF with the restriction for use for test and validation purposes. This allowed a changed (meanwhile confirmed)

task setting (use-case) for the ZF/KAE e-trailer: 10.000 km operation on the initial cross-border mission route from UC724 (Oirschot-Aichach) operated by ZF drivers as a non-commercial validation run.

Regarding the contents of the following sub-paragraphs, the procedure for commissioning the vehicle combination of BEV and e-trailer is not different between the initial and the new task setting. For road permits and registration, the initial concept for registration for commercial use, as well as the actual registration for validation purposes are described in the following sub-paragraphs.
Even though there is no handover to the shipper and logistic provider for the KAE/ZF e-trailer any longer, the necessities formerly planned and prepared in period 2 are explained below.
Due to the use of a rented BEV instead of a ZEFES BEV in the new task, there is no datalogger installed in the towing BEV. The ability to capture data via telematic services and to store it in parallel to the e-trailer data from the ZEFES datalogger is pointed out in the corresponding sub-paragraph.

Above the use of the e-trailer in the driving demonstration, the e-trailer will also be used in the "charging on rail" use case. Necessary commission activities for this application are described in an additional sub-chapter.

5.1 Commissioning and Testing of the combination of e-trailer and BEV

Deliverable report D5.4 gives an overview of the necessary activities to assemble, commission and release the e-trailers as a discrete vehicle. Before going on a public road with the vehicle combination, ZF must do tests and validations of the vehicle combination, the e-trailer with the dedicated towing vehicle. Within ZEFES DoA, this obligation is linked to the sub-task ST 5.5.3 "[..] ZF will lead the combination of the BEV demo truck with e-trailers will be commissioned and all communications will be verified and tested via a short dry-runs to ensure the required safety during safe operations. [..]"
These tests must be done in the test track environment with any Truck and e-tailer combination which goes on public road. After commissioning of the e-trailers first operation on public roads is usually done with diesel powered tractor. For ZEFES preparation, vehicles similar to ZEFES BEV and finally the dedicated ZEFES BEVs are used. Tests are necessary not only for final use in ZEFES commercial use cases but also for testing and validation of the integrated TrailTrax System by ZF.

The tests of the truck-trailer combination comprise the following scope and levels, to release the vehicle combination for test and validation purposes on public roads:

- Basic level (without active e-trailer function):
  - Confirmation of the basic compatibility and interoperability of the vehicles. General functionality of braking system, suspension system and other data communication, e.g. for tire pressure monitoring are confirmed.
  - Test concept and execution: Check basic vehicle functions, standstill and drive on the test track.
- Basic e-trailer functionality:
  - The e-trailer must follow (and not act against) the demand of the driver or of a driver assistance or stability control system in the towing vehicle.
  - Test concept and execution: A provisionally dedicated data connection from e-trailer to engineering monitoring tools in the truck, allowing e-trailer system monitoring in the truck by a system engineer. The driver of the combined vehicle now performs diverse driving scenarios, and the system expert checks whether the e-trailer system acts as expected.

- Expected and uncritical behavior of the truck:
  - The functionality of the e-trailer may not have a negative effect on the function of the truck. Negative Effects are effects which can cause damage or have the risk of disturbing or tangling the driver or cannot be handled by the driver.
  - Test and execution: Along with the tests of the basic e-trailer functionality, the expert driver observes the behaviour of the truck. All mentionable observations like unexpected gear shifting and/or unfamiliar “pedal feeling” for acceleration and braking are noted and evaluated whether uncritical for functional vehicle operation and whether they can unproblematically be handled by the driver.
- Check of basic safety related functionality regarding truck trailer interaction with consideration of requirements as identified by the e-trailer industry working group for R13:
  - Basic safety related functionality of the e-trailer regarding truck trailer interaction, e.g. “no propulsion when a demand for braking/retardation is active” or “the e-trailer may never push the truck (in terms of higher positive forces at the kingpin, compared to a standard trailer)” shall be validated.
  - Test and execution: The correct functional behaviour of the e-trailer is already validated by the system tests of the e-trailer as a discrete vehicle. Nevertheless, for the vehicle combination, it has to be ensured that the status signals are available to trigger the mandatory functional reaction of the e-trailer. The system behaviour of the e-trailer is observed by the system expert, whether it does not exceed the mandatory limits.
- Performance of the vehicle stability system in the towing vehicle:
  - There may be no degradation of the drive stability systems in the towing vehicle, resulting from the influence of the e-trailer on the determination of system parameters in the towing vehicle.
  - Test and execution: Expert drivers in a test track development check whether the performance of the vehicle stability functions of the dedicated towing vehicle in combination with the e-trailer is degraded versus the performance without e-trailer, (considering the variance of freight/load of the vehicle combination in target operation on public roads.)
- Expected positive effect of the e-trailer on the energy balance of the combined vehicle, respectively to the operation of the towing BEV:
  - General targeted/expected support of the e-trailer for propulsion and retardation of the vehicle combination should be validated. The e-trailer system targets to give optimal support to the dedicated towing vehicle. For a BEV, considering the mission route and the characteristics of the BEV, the use of the e-trailer should optimise the driving range of the vehicle combination. E.g. before reaching the next charging point, the towing vehicle should not run out of energy while the e-trailer still has energy in the batteries.
  - Test and execution:
    Remark: In principle, this insight is not mandatory before going on the road. Nevertheless, it is mentioned in this list, as adaptations of parameters for optimization of operation strategy may make a repetition of (partly) tests above necessary.

After the combination is released for operation on public roads for further test and validation purposes, the test drivers still monitor the criteria of all these tests.

If, during public road testing in diverse driving situations, topologies, freight/load situations, observations are made which differ from previous observations, these points must be re-evaluated regarding potential criticality for function and use. If after a certain test mileage under diverse conditions, no additional insights appeared, the result of testing on the test track and open road can be rated as stable.

Finally, the output of this testing allows:

- A decision whether regular drivers (after briefing on instructions and sensibilization) can operate the vehicle without risk or whether the combined vehicle must still be operated by expert drivers on public roads.
- If an operation by regular drivers can be allowed, then the testing directly results in a list of findings which must be communicated in an instruction.
- If the operation is still restricted to ZF expert drivers, then the list of findings contains the necessary changes and corrections which must be solved in next release.

In any case, of course the operation of the vehicle combination with regular drivers is only possible if both vehicles have an individual or general approval(licensing) without a restriction of use for test and validation purposes.

5.2 Road Permits and Registration e-trailer

The e-trailers, as a concept of trailer with propulsion and regenerative braking, have a complex approval procedure due to the lack of provisions in some regulations. Concretely, the main regulation of braking systems, the UN R13, needs to define provisions for these kinds of vehicles. The lack of it does not make it possible to get regular EU Type Approval.

One of the facts to consider is the need to transport commercial loads. This is important because vehicles equipped with testing plates or with a note for restriction of use for test and validation purposes are not allowed to bring commercial loads. An alternative should be found, considering national regulations or road permits granted by national authorities. IDIADA has been looking for mitigation methods, considering the requirements of the ZEFES project

Some EU authorities (Sweden, Germany, and Spain) were asked if a national approval could be granted. The Spanish Approval Authority confirmed a clear pathway for national approval under the scope of the Spanish *RD750/2010*. This 'Particular application' could allow the use of the ZEFES e-trailers, only under the scope of the ZEFES project, granting a regular Spanish plate, which could make it possible to run the use cases through all EU countries and carrying commercial loads.

After finding a type of approval fitting the project requirements, the main topic was to find a solution to those regulatory acts which don't have provisions for e-trailers in their scope. During the project time, a proposal for the UN R100, related to Electrical Safety requirements, was presented and approved, including O-category vehicles. The only regulation which presents inconvenience against e-trailer approvals is the UN R13 for braking systems.

Different proposals of amendments for the UN R13 were presented during latest years to include regenerative braking on trailers. In 2025, a proposal was accepted, but this does not include trailers with propelled e-axles. According to a previous proposal, IDIADA and the Spanish authorities agreed on a list of requirements to be tested and demonstrated for the approval of the ZEFES e-trailers.
Several weekly and monthly meetings were held between IDIADA, ZF, Van-Eck and Kaessbohrer to clarify and set up all testing required for the approval of the e-trailers. Despite all the progress made, in December 2025, conversations were stopped, and mitigations are still under discussion with other trailer and component manufacturers to achieve the demonstration goals.

The described path for a “particular application” in Spain was not continued for the KAE/ZF e-trailers. Nevertheless, for both e-trailers, a registration to ZF for test and validation purposes was done via the authorized registration office in the region of the ZF test track location. This registration is necessary and was planned in the project by ZF anyhow, to perform the tests on public roads, for dry runs of the vehicle combination, and for a pre run on the target mission route. Initially, it was planned to replace the ZF registration in a later stage with a registration to KAE with the Spanish authorities, after approval of the “particular application” in Spain.

The details of the registration in Germany to ZF are

- Test report by German TÜV regarding the e-trailer vehicle being compliant (respectively not in conflict) with presently active regulations for Electromagnetic Compatibility (R10), High Voltage vehicle systems (R100), braking systems (R13), lateral protection (R73) and weight and dimensions.
- Certificate by the German TÜV
    - Confirming the positive result of the test report above
    - Granting Individual approval in accordance with Section 21 of the German Road Traffic Licensing Regulations (StVZO)
    - Restricting the registration to “vehicle for test and validation purposes, licensed to ZF”
    - Including explicitly the electric axle, and the high voltage REESS (Rechargeable Electrical Energy Storage System) listed in the registration papers

With this registration, a cross-border operation by ZF expert drivers for (system) test and validation purposes is possible. The restriction in use excludes the transportation of commercial freight.

Significant differences to the planned particular application via Spain, which would allow an unrestricted use (3rd party drivers / commercial goods) are:

- Test and validation regarding the present state of insight regarding coming Regulations, especially R13 for e-trailers and R100 for trailers in general.
- Description of the safety concept and measures for the e-trailer

The registration for test and validation in Germany puts a major part of accountability on the shoulders of ZF to ensure a hazard-free operation on the streets by internal processes for maturity, test, validation and release of systems and components and by the qualification of employees.
The particular application via Spain shifts tests and validations from the supplier's accountability to the responsibility level of the technical service.

As explained in the introduction to this paragraph, the new task setting for the finalization of ZEFES regarding KAE/ZF e-trailer considers the existing registration in Germany.

5.3 Handover to the Use Cases e-trailer

Within the new task setting, ZF is now the operator for the new use case. Consequently, an explicit handover is no longer needed.

Nevertheless, within ZEFES, the necessary elements of the handover process to the operator have been discussed. Therefore, it is worth mentioning the resulting list:

- Contracts with operators
  - include the terms of use for the e-trailer vehicle registered to Kaessbohrer.
  - ZF proposed to include Terms regarding the ZF TrailTrax system within the vehicle contract, e.g. to allow vehicle use only to instructed drivers and regarding guidelines for service and maintenance.
- Instructions and driver training
  - Before the handover of the vehicle drivers are instructed to driving behavior and handling of the e-trailer by ZF
  - Potentially, local service personnel are instructed on the details of the TrailTrax systems, for being able to perform basic service and maintenance
- Documentation of vehicle units (BEV and e-trailer)
  - In line with the release level of the vehicles, documentation will be provided.
  - For the BEV already series documentation is available
  - For the e-trailer, sufficient documentation, system and function will be extracted from the available documentation of the engineering, assembly, test and validation process.
  - For the basic trailer vehicle (KAE) and for the series intelligent Braking system (ZF), series documentation is available
- Service and maintenance concept
  - For service and maintenance of the basic trailer and the basic systems, the existing service network of Kaessbohrer can be used. Nevertheless, it must be considered that the e-trailer is a battery-electric vehicle. Basic High Voltage Qualifications of the service experts must be checked.
  - For service and maintenance on the TrailTrax system, ZF provides contact information to TrailTrax experts and ensures the availability of contact in normal working hours.
  - The driver will have a checklist on hand to perform self-service if possible
  - It is intended to include information and instructions in the checklist for service workshops to solve problems quickly.
- Test runs on the actual use case mission
  - Optionally, it could be agreed that a driver can participate in one of the test runs on the use case mission (optional)
- Test runs at BEV OEMs
  - The final handover to the operator will be done by the BEV OEMs as use case leaders.
  - Before the handover, a final test of the vehicle combination by the OEMs is planned.

5.4 Data Acquisition

The regular way for data acquisition in ZEFES is the use of the dataloggers provided by Fraunhofer, with handling and accessibility of data via the ZEFES cloud mechanisms realized by Ricardo and TNO. The remaining Kaessbohrer/ZF e-trailer, which will be used in the new task/use-case setting for ZF, has the datalogger installed. It is connected to a dedicated data CAN bus in the e-trailer. The agreed signals to be sent by the e-trailer are mapped to the CAN bus. The dbc (CAN database file) for decoding the CAN signals in the Fraunhofer database cloud is provided by ZF.
Therefore, all prerequisites for data acquisition are fulfilled. No blocking points are expected, even though actually, when writing this chapter, the confirmation of proper reception of the signal stream by Fraunhofer is pending.

Initially, for the e-trailer use-cases with the BEV trucks from Volvo and Scania, also the BEVs are equipped with data loggers. Now, as ZF uses a rental truck for the new task/use-case, the data logger connection in the truck is not available.

Fortunately, the rental truck is a Volvo BEV. Necessary hardware connections and software updates for the data logger connection cannot be made in a rental vehicle. But sophisticated telematic data via Volvo Connect is available and can be logged. Potentially, this data can be stored together with the other ZEFES data as a permanent result of the ZEFES project.

5.5 Preparations for “charging on rail”

After the 10.000 km demonstration of the e-trailer on the route Oirschot-Aichach has passed, the e-trailer will be prepared for the use case “e-trailer charging on rail” (see deliverable report 7.1 “Use case menu card” // 3.2.7 E-trailer charging on rail // Use Case Number “CFL-SWS”).
In this use case, the e-trailer is not connected to a towing vehicle with operation mode “driving”, but the e-trailer is laden on a rail wagon and electrically connected to an SWS Powerbox in operation mode “charging”.

Also, for this vehicle combination “e-trailer // rail wagon”, a commissioning must be considered:

- The e-trailer must fit mechanically to the wagon and the used r2l “basket” which is necessary for craning. It must be ensured that no components (especially Trail Trax components) or the chassis of the trailer collide with contours of the Trailer. The trailer must be transported on the wagon with deflated suspension of air bellows, to avoid swinging during transport.
  To ensure proper mechanical fit, different checks are performed before the demonstration starts
  - As a first estimation available, CAD data from the trailer and wagon had been checked. Result: feasible. Compared to a regular trailer the dimensional constraints of the eAxle and the eBox must be checked in detail.
  - In a visit of a railway expert at the e-trailer, the dimensions of the trailer will be checked, especially ground clearance with unpressured air-suspension.
  - 4 weeks before the planned demonstration ride, a physical test at the railway station (e-trailer physically loaded to the wagon) will finally confirm the feasibility of transport. Railway technical service finally releases the e-trailer for the demonstration
- In parallel to the mechanical/physical commissioning, the electrical compatibility with the SWS Powerbox is checked
  - First, it is checked on specification level whether compatibility of e-trailer and SWS Powerbox can be achieved. Necessary means for adaptation are identified and procured.
  - Also on the physical test day, the e-trailer will be electrically connected to the SWS Powerbox. Start/Stop of charging should work as expected.

This is a high-level overview of the activities to prepare/commission the charging operation of an e-trailer on a moving rail wagon via an SWS Powerbox. Many small details were omitted from this explanation. But it shows that also for this use-case a commissioning is necessary and is planned.

6 Conclusion and Recommendation

6.1 Conclusions

The innovations that were developed in WP5 tasks T5.3 and T5.4 were installed in the first demo-vehicles, commissioned and tested on the vehicle level. At the time this deliverable is finalized the following battery-electric vehicles are built, commissioned and tested:

- Scania:
  - BEV 1a for use case 7.3.1
  - BEV 2 for use case 7.3.4
- Volvo:
  - BEV 1 for use case 7.2.2
  - BEV 2a for use case 7.2.3-1
- Renault:
  - BEV 1 for use cases 7.4.1-1 and 7.4.1-2
- Kaessbohrer/ZF
  - E-trailer 1 for use case 7.3.1
  - E-trailer 2 for use case 7.2.4

For the remaining vehicles, build slots are allocated, or they are already in production.
Commissioning and testing were done according to the regular processes of the OEMs. All battery-electric prime movers have EU type approval. For the Kaessbohrer/ZF e-trailers, a registration with ZF for test and validation purposes was obtained. Most of the vehicle combinations are expected to fulfil the EU Weights and Dimensions Directive (96/53/EC). The EMS2 vehicle combination, including the Scania BEV lowliner, can be used in Spain according to the requirements of the national instruction MOV2023/28, and no special permit is required.
Before the start of the use cases, the vehicle combinations are tested on the planned routes with the available charging infrastructure. For handover to the use case owners, individual procedures, including driver instructions and training, are planned. At the time this deliverable is finalized the following vehicles have been handed over to the use cases:

- Scania BEV1a (UC 7.3.1)
- Scania BEV 2 (UC 7.3.4)
- Volvo BEV 1 (UC 7.2.2)
- Volvo BEV 2a (UC 7.2.3-1)

6.2 Recommendations

While most BEV demonstrators have EU type approvals, e-trailer approvals pose ongoing challenges. The e-trailers, as a concept of trailer with propulsion and regenerative braking, have a complex approval procedure due to the lack of provisions on some regulations. Particularly, the main regulation of braking systems, the UN R13, needs to define provisions for these kinds of vehicles to enable a regular EU Type Approval.

6.3 Contribution to project (linked) Objectives

The work done in task 5.5 and documented in this deliverable contributes to reaching several objectives that have been defined in the ZEFES description of action. The integration of the adapted and improved powertrain components, subsystems, control systems and energy and thermal management systems in the prime movers and the e-trailers contributes directly to objective 1, in particular sub-objective 1.1 “improve the efficiency of electrically powered vehicles”. Furthermore, sub-objective 1.2 “develop a vehicle concept with enhanced energy storage and e-axles (in the prime mover and the trailer)” was fulfilled by the realization of the modular vehicle concept for the prime movers and the combination with the e-trailer. Compliance with the verification criteria defined in the description of action will be proven by monitoring the vehicles during the demonstration and assessment of the collected data in WP7 and WP8, respectively. Building the battery-electric vehicles, their commissioning and testing are prerequisites for the realization of the use cases in WP7.

6.4 Contribution to major project exploitable result

The work done in task 5.5 and the documentation in this deliverable directly contribute to the project's exploitable results. By the integration of the improved vehicle components, three OEMs can provide modular battery-electric vehicles that are suitable for use in selected regional and national long-haul missions of at least 500 km daily, as well as in multimodal and cross-border long-haul missions up to 1.300 km single route. The modularity and flexibility of the vehicle concepts are supported by the electrified semitrailers that provide range extension and the ability to accomplish demanding road profiles. The realized vehicles and vehicle combinations will help the OEMs to secure a leading position in the automotive industry.

7 Risks and interconnections

7.1 Risks/problems encountered

There are currently no risks encountered by the partners involved in task 5.5 regarding the availability of the BEVs for the demonstrations according to the time plan defined in WP7.

7.2 Interconnections with other deliverables

The vehicles realized in task 5.5 and described in this deliverable are prerequisites for starting the use cases defined in WP7 and thus, for creating the remaining deliverables in WP7 and WP8.

8 Deviations from Annex 1

During the project timing, different deviations were found. Finally, use cases are planned to run even considering mitigations.

As a general overview, a great part of the use case has suffered deviations caused by the Weights and Dimensions Directive EC 96/53. The original weight planned for the use cases was reduced to adapt to current legal restrictions.

Another deviation was the impossibility to achieve EMS2 combinations along great part of EU countries. The contact with authorities was not fruitful in granting any permit for a time-limited demonstration for EMS2. This fact caused the modification of some use cases, using only one trailer or modifying the complete use case.

Vehicles are expected to be granted the approvals needed to run through the whole EU. Even though, the situation of e-trailers' approval is remarkable. The lack of regulations for the approval of e-trailers has been made one of the most important challenges to achieve the allowance to drive these vehicles. Solutions were found, only under the scope of the ZEFES project, but final solutions are still pending.

Finally, as explained in previous deliverables, the use of the e-dolly on the use cases was cancelled on public roads due to the complexity on approval process. Instead, the focus of the e-dolly demonstration was shifted to the remote-controlled and automated operation on yards and terminals to increase operational efficiency of EMS vehicle combinations. This will be demonstrated at the CFL Multimodal terminal in Dudelange, Luxembourg.

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Project partners:

#	Partner short name	Partner Full Name
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2	FRD	FORD OTOMOTIV SANAYI ANONIM SIRKETI
4	KAE	KASSBOHRER FAHRZEUGWERKE GMBH
5	REN	RENAULT TRUCKS SAS
6	SCA	SCANIA CV AB
7	VET	VAN ECK TRAILERS BV
8	VOL	VOLVO TECHNOLOGY AB
8.1	CPA	CPAC SYSTEMS AB
9	ABB	ABB E-MOBILITY BV
9.1	ABP	ABB E-MOBILITY SPOLKA Z OGRANICZONAODPOWIEDZIALNOSCIA
9.2	ABG	ABB E-MOBILITY GMBH
10	AVL	AVL LIST GMBH
11	CM	SOCIEDAD ESPANOLA DE CARBUROS METALICOS SA
11.1	APG	AIR PRODUCTS GMBH
12	HEPL	HITACHI ENERGY POLAND SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA
13	MIC	MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN
14	POW	OPmobility
15	RIC-CZ	RICARDO PRAGUE S.R.O.
15.1	RIC-DE	RICARDO GMBH
16	UNR	UNIRESEARCH BV
17	ZF	ZF CV SYSTEMS HANNOVER GMBH
18	ALI	ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE
19	DPD	DPD (NEDERLAND) B.V.
20	COL	ETABLISSEMENTEN FRANZ COLRUYT NV
21	GRU	GRUBER LOGISTICS S.P.A.
22	GBW	GEBRUEDER WEISS GESELLSCHAFT M.B.H.
23	PG	PROCTER & GAMBLE SERVICES COMPANY NV
23.1	PGP	PROCTER AND GAMBLE POLSKA SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA
23.2	PGA	PROCTER & GAMBLE AMIENS
23.3	PGG	PROCTER & GAMBLE SERVICE GMBH
24	PRI	PRIMAFRIO CORPORACION, S.A.
25	PTV	PTV PLANUNG TRANSPORT VERKEHR GmbH

26	Fraunhofer	FRAUNHOFER GESELLSCHAFT ZUR FORDERUNG DER ANGEWANDTEN FORSCHUNG EV
27	HAN	STICHTING HOGESCHOOL VAN ARNHEM ENNIJMEGEN HAN
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30	UIC	UNION INTERNATIONALE DES CHEMINS DE FER
31	CFL	CFL MULTIMODAL S.A.
32	GSS	Grupo Logistico Sese
33	HIT	Hitachi ABB Power Grids Ltd.
34	IRU	UNION INTERNATIONALE DES TRANSPORTS ROUTIERS (IRU)
35	RIC-UK	RICARDO CONSULTING ENGINEERS LIMITED

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