HORIZON EUROPE PROGRAMME

TOPIC HORIZON-CL5-2022-D5-01-08

Clean and competitive solutions for all transport modes

GA No. 101084046

Zero Emission, flexible vehicle platform with modular powertrains, serving the long-haul Freight EcoSystem

ZEFES - Deliverable report

D8.1 Assessment framework

Co-funded by the European Union

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V2.1	2025-03-20	Akshay Bhoraskar	Updated use case and reference vehicle information in chapter 2.3.

Publishable summary

In the ZEFES project zero-emission heavy-duty vehicles are demonstrated on real-world logistic use cases across Europe. The vehicles, vehicle components and any innovations in support of the vehicles and their users will be evaluated in work package 8. The use case evaluation will compare the demonstrated vehicles to reference vehicles that are currently used in the use cases. The life cycle analysis, upscaling potential and impact assessment will extrapolate the results from use cases with limited number of vehicles and duration in order to assess the uptake potential and associated impacts. A framework has been developed that shall be used to calculate the needed results in the limited time available.

The work previously performed in the project and the needs of the users (of the vehicles, the innovations and the results of the analysis), are summarized in a set of requirements to the framework, grouped in the following categories:

- Vehicle platform and trailer configurations;
- Efficiency improvements;
- Typical European long-haul road transport operations on TEN-T corridors;
- Real traffic and conditions evaluation;
- Charging (MCS) and H_2 refueling infrastructure;
- Realistic simulations;
- 2ZERO Partnership requirements.

In order to meet all the requirements from the stakeholders, and in order to evaluate the 15 use-cases that will be demonstrated, a set of Key Performance Indicators has been collected and elaborated.

The assessment framework itself is based on the assessment framework from the AEROFLEX project [1]. The nature of the project, e.g. diesel vehicles in AEROFLEX and ZE vehicles in ZEFES, and the nature of the use cases, i.e. mostly simulated use cases in AEROFLEX and lots of real-world data in ZEFES necessitate a number of changes and additions to the assessment framework. The ZEFES assessment framework consists of:

- A toolset for the technical evaluation of the use cases.
- An LCA methodology to calculate the lifetime impact on greenhouse gas emissions of the vehicles.
- A methodology to estimate the upscaling potential.
- A methodology for the assessment of the logistic, societal and environmental impact of changing from conventional to zero-emission vehicles.

The feasibility of (timely) completion of the evaluation and assessments depends on the planning of the use case demonstrations and the availability of data from the use cases. The required data from the use cases and the methods to gather this data have been discussed with OEMs and use case owners, the results are summarized in Chapter 4 and should be updated according to the final planning of the use cases.

Further, the following recommendations are made for the future work within the work package:

1. Perform pilot assessments, based on provisional or simulated data, to inform the consortium and other stakeholders on the expected results and provide opportunities to provide input to these results.
2. Perform sanity checks on the generated data, right from the start of the demonstrations, in order to adjust data loggers and data interfaces in due time.
3. Cross-check the assumed properties of the use cases, vehicles, powertrains, innovations etc. with the respective OEMs, shippers and other suppliers.
4. Monitor the planning of the use case demonstrations and relate any changes to the results being created by the assessment framework.

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Abbreviations & Definitions

Abbreviation	Explanation
KPI	Key Performance Indicator
BEV	Battery Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
ZE	Zero Emission(s)
HD	Heavy-Duty
WP	Work Package
GCW	Gross Combination Weight
VCU	Vehicle Control Unit
HVAC	Heating, Ventilation and Air Conditioning
SiC	Silicon Carbide
LDV	Light-Duty Vehicle (passenger car or van)
HDV	Heavy-Duty Vehicle (truck, bus or coach)
SoC	State of Charge
MCS	Megawatt Charging System
CCS	Combined Charging System
SW & HW	Software & Hardware
UC	Use case
EMS	European Modular System

Item	Definition
B-trailer	A trailer equipped with batteries that can store energy. This stored energy can be transferred to the prime mover (the main truck) to be used for its propulsion.
E-trailer	A trailer equipped with an electric drive and batteries that store energy. This energy provides power directly to the trailer's wheels, assisting the propulsion of the entire vehicle combination (trailer and prime mover).
E-dolly	A dolly (a wheeled device placed between the prime mover and the trailer) equipped with an electric drive and batteries that store energy. This energy provides power to the dolly’s wheels, assisting the propulsion of the trailer and supporting the prime mover.

1 Introduction

This chapter will give the context of this report within the ZEFES project and the 2ZERO Work Programme overall. First, the objectives of the ZEFES project are summarized, linking the activities in Work Package 8 (WP8) to them. Then, the position of WP8 in the project and its relation to the other work packages are discussed. Thirdly, the function of the different WP8 tasks and their relation to Task 8.1 is described. And, finally, the structure of this deliverable is given.

1.1 The ZEFES project

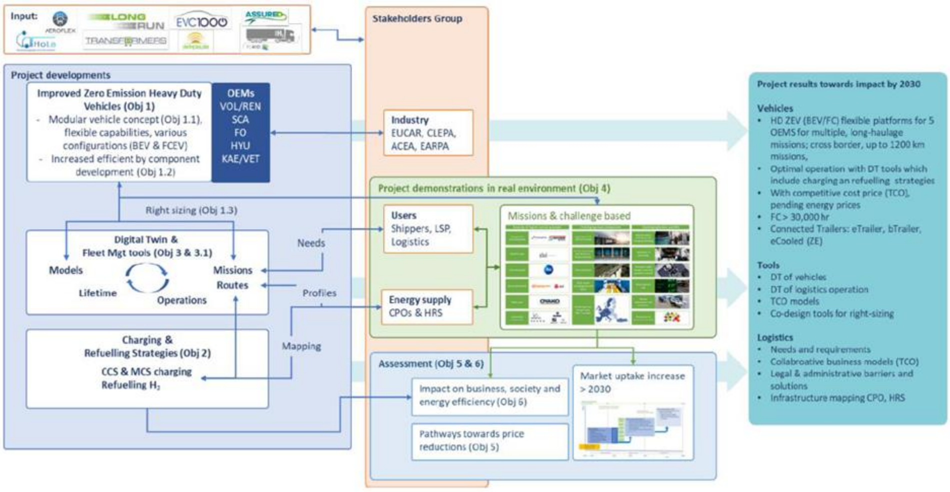


Figure 1.1 Concept and objectives of the ZEFES project.

The ZEFES (Zero Emission Freight EcoSystem) project contributes to the commitment of the European Union to be CO_2 neutral by 2050. The focus of the project is on the decarbonization of the transport sector, more specifically on long-haul heavy-duty logistics. It does so by real-world demonstrations of long-haul Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEV) on logistic missions across Europe and by defining the next steps needed for a broader uptake of such vehicles in the near future. The project does not only look at the technical innovations at the vehicle level but aims to involve the whole ecosystem, including but not limited to vehicle (component) manufacturers, infrastructure providers, logistics companies and developers of supportive tools. Figure 1.1 shows the concept and objectives of the project. The demonstrations in real logistic use cases (Obj. 4) are at the center of the project. Before the demonstrations can take place, the project foresees further development of Zero Emission (ZE) Heavy-Duty (HD) vehicles (Obj. 1), digital twins and fleet management tools (Obj. 3), and charging and refueling strategies (Obj. 2). The demonstrations show what is needed in order to make ZE HD transport possible and provide input to an assessment on the impacts of ZE HD transport on business, society and energy efficiency (Obj. 6) and the definition of pathways towards price reductions (and broader uptake) (Obj. 5). WP8 focusses on the latter two objectives, i.e., objectives 5 and 6.

1.2 WP8 and Task 8.1

Thus, the main objective of WP8 is to evaluate the use cases and assess the impact of further uptake of the demonstrated innovations. Figure 1.2 shows the structure of the work package and the relationships with or dependencies upon other work packages. The core of the work in WP8 consists of the evaluation of the use cases, where a comparison is made between the current situation (reference evaluation) and the situation in which demonstrators are applied (use-case evaluation and life-cycle analysis). To perform these evaluations, performance data of the use cases is required from WP7 (demonstrations). This data will be made available through the data platform developed in WP4. The use-case evaluation provides input to the impact assessment, that, in turn, flows into WP9 for dissemination and exploitation of the project results and provide data to support the objective (and their KPI) of the 2ZERO partnership. To provide useful results, the evaluation and assessment should match the needs and requirements of the end users, the scoping and the logistic KPI defined in WP1, the innovations and vehicle KPI's defined in WP2-6 and consider all use cases demonstrated in WP7. The use-case evaluation requires an assessment framework, that is used for the analyses in WP8, and which provides requirements for the data being gathered from the use cases.

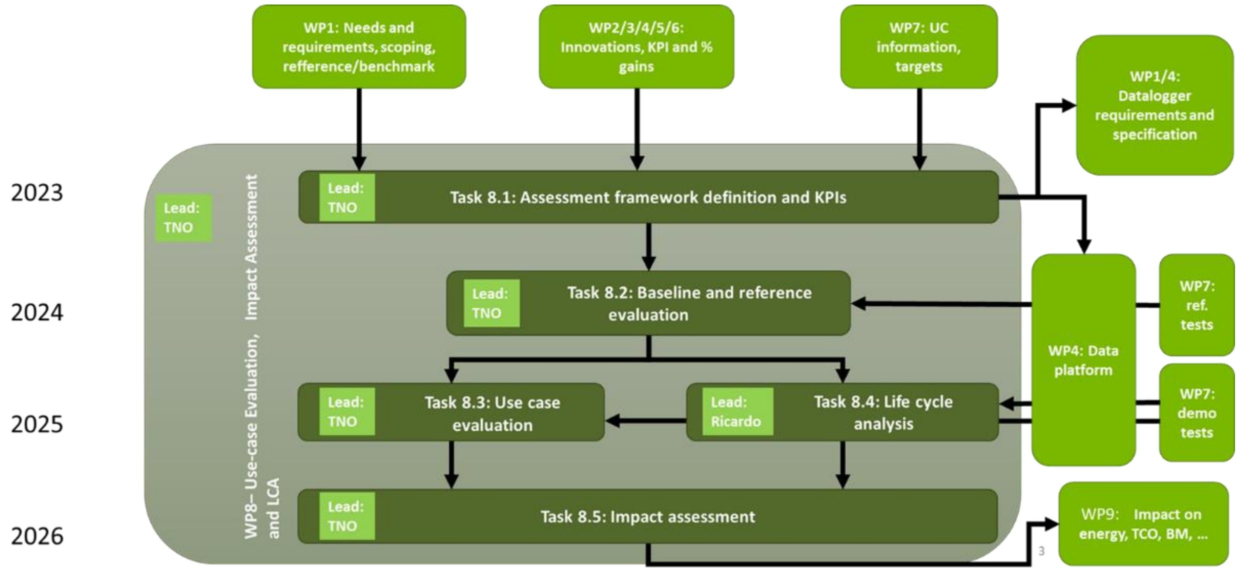


Figure 1.2 Structure of WP8 within the ZEFES project.

1.3 Use-case evaluation and impact assessment

Thus, the work in WP8 can be divided into two parts: the use-case evaluation and the impact assessment. Figure 1. shows, schematically, the difference between the parts. The use-case evaluation focuses on a finite set of use cases (specific demonstrations of ZE vehicles in existing real-world logistic missions), by definition representing only a subset of all long-haul HD missions in Europe. The impact assessment generalizes the results from the use-case evaluation, in order to assess the impact of ZE HD vehicles on European long-haul logistics as a whole.

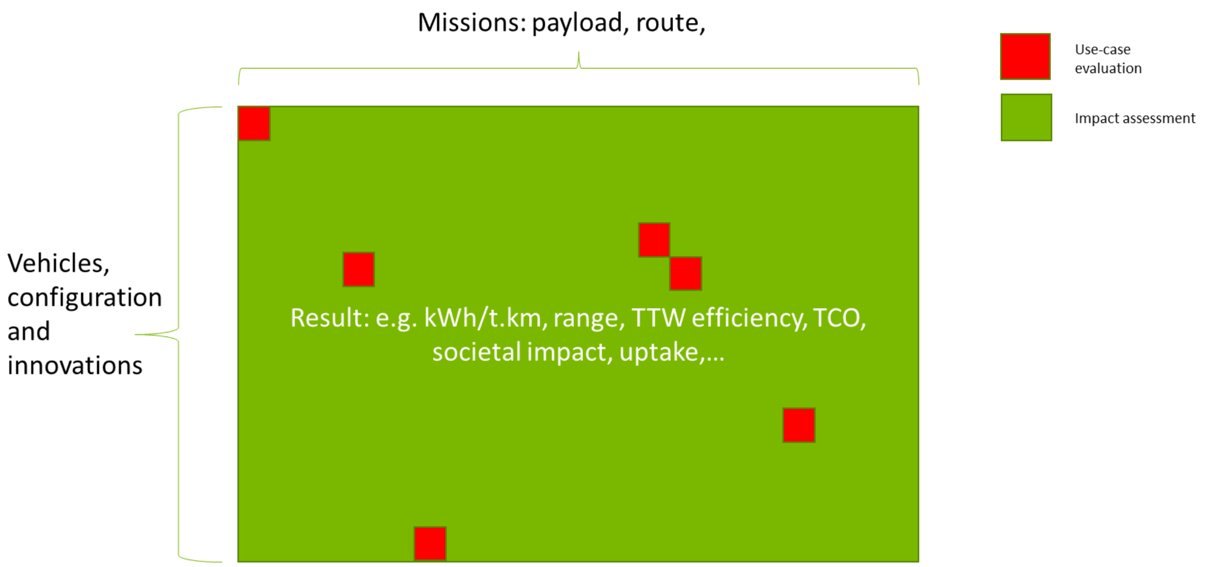


Figure 1. The use-case evaluations and their relation to the impact assessment "space".

1.4 Report structure

Chapter 2 describes the input to the assessment framework, such input being the work performed by the other work packages in the first stages of the project. The chapter concludes with a set of requirements for the evaluation and assessment, based on which the framework will be built. Chapter 3 continues to describe the assessment framework, starting from the assessment framework used in the AEROFLEX project. Chapter 4 defines the inputs required from the demonstrations, based on the description of the assessment framework. Chapter 5 shows the results of the report and links it to the project objectives and major project exploitable results. Chapter 6 concludes the report and presents recommendations for the assessment framework's further use within the project.

2 Inputs to the assessment framework

This chapter describes the inputs to the assessment framework. The input includes all the work being carried out in other work packages that set boundary conditions to the assessment framework and the analyses required from the assessment framework. First, the requirements to the assessment framework are described. Then the Key Performance Indicators (KPI) – defined in WP1 – are discussed and defined further. In the following sections, the use cases and innovations that need to be assessed are discussed. The chapter concludes with a table linking all of the above.

2.1 Requirements

To achieve the objective of energy efficiency (Obj. 6) and the definition of pathways towards price reductions (and broader uptake), it is necessary to establish a good set of requirements for the assessment framework. This chapter outlines the considerations that the framework should address to provide valuable insights into the performance of the ZEFES trucks and innovations within logistics operations.

2.1.1 Vehicle platform and trailer configurations

The requirement for the vehicle platforms and trailer configurations was established in WP1 (D1.1 [2] and D1.2 [3]). In the ZEFES project, a variety of BEV and FCEV trucks will be utilized in conjunction with different trailer types to fulfill various logistics operations. BEV and FCEV trucks will be developed by ZEFES OEMs, whilst trailer OEMs will supply E-dollies, E-trailers and B-trailers. Given the modular design approach and adaptability to end-user needs, the assessment framework must accommodate the diverse configurations of vehicles and trailers seamlessly.

Component groups							
engines	gearbox	axles	cabs	chassis	systems	electric	air

Figure 2.1 ZEFES vehicles

Figure 2.2 ZEFES trailers and e-dolly

In conclusion, the following functional requirements of the assessment framework can be defined:

- The assessment framework should enable the evaluation of Battery Electric Vehicles (BEV) and Fuel Cell Electric Vehicles (FCEV).
- The assessment framework should enable the evaluation of E-dollies, E-trailers and B-trailers.
- The assessment framework should enable the evaluation of all combinations in all use cases.

2.1.2 Efficiency improvements

The goal of ZEFES technologies is to enhance the overall energy efficiency of BEVs and FCEVs used in long-haul road transport by 4-8%. This overall target is to be reached by the implementation of different measures (modular multi-powertrain, maximized recuperation during braking, improved inverter and DC/DC technologies, improved HVAC, optimised thermal and energy management), each with specific sub-targets (see Section 2.4). However, these innovations will not be evaluated separately because some innovation's improvement targets are in the range of 0.1% to 1%. Detecting such small changes in real-world conditions is very difficult due to the variability and noise in the data from real-world driving conditions, which can obscure the minor efficiency gains achieved by individual innovations. Additionally, some of the improvements are directly related to the usage of the ZEFES powertrain and cannot be isolated. For example, maximized recuperation during braking depends on the overall powertrain design and cannot be tested separately from other systems. Similarly, the integration of improved inverters and DC/DC technologies works in tandem with other components to enhance overall vehicle efficiency.

Lastly, the vehicle is delivered as a complete system and cannot be used in real-world conditions with components removed or isolated. Testing these components separately would not reflect the real-world performance of the vehicle as a whole. Therefore, a total improvement of all combined innovations on the truck will be measured. The efficiency improvement will focus on assessing the energy need of the vehicle, specifically showing the energy consumption in kilowatt-hours per km driven (kWh/km) and the energy needed to transport a tonne of payload for one kilometre (kWh/tkm).

In conclusion, the following functional requirements of the assessment framework can be defined:

- The assessment framework should enable the calculation of energy consumption in kWh.
- The assessment framework should enable the calculation of travel distance in kilometres.
- The assessment framework should enable the calculation of travel time in hours.
- The assessment framework should enable the calculation of the refueling and/or recharging time in hours.
- The assessment framework should allow for the simulation of vehicles with battery electric and fuel cell electric drivetrains.
- The assessment framework should allow for the simulation of vehicles with Diesel and LNG drivetrains.

2.1.3 Typical European long-haul road transport operations on TEN-T corridors

With the final technical assessment, the potential energy efficiency gains of the ZEFES innovations for typical European long-haul operations on the TEN-T corridor should be estimated. The deliverable D1.2 shows the planned ZEFES driving routes and applications that will be used in the use cases. In D1.5 [4], a set of customer requirements was listed, and the use cases have been selected as a

Figure 2.3 Comparison ZEFES & TEN-T corridors. Source: D1.2 Defined Use cases, Target metrics and needs (PUB) [3].

representative subset of all TEN-T corridors. This means that the requirement regarding typical European long-haul operations has already been satisfied and will not be elaborated on further in this document. However, there is a risk that certain use cases cannot be demonstrated due to technical (vehicles and/or trailers), legal (homologation and/or permits) or infrastructural (Charging or H_2 Stations) setbacks. Therefore, the requirement that the final technical assessment should satisfy is the following:

- The assessment matrix should consist of selected use cases for typical long-haul road transport in Europe, representing at least major goods categories and applications.
- The assessment framework should allow for the simulation of use cases that cannot be demonstrated on the road but represent a significant share of total long-haul heavy-duty logistics.

2.1.4 Real traffic and condition evaluation

The ZEFES innovations will be tested on the road in accordance with the use case description created in D7.1, "Use-case plan" and D7.2. "Overview performed use cases". Reference tests will be performed on the same use-case scenarios for the vehicles currently used and later on in the demonstrator phase with the demonstrator vehicles with ZEFES drivetrains and innovations. The final technical assessment will simulate more vehicles across different use cases and/or routes. For the vehicles that are tested in the test programme, similar results should be achieved in the simulation. Therefore, the models should be calibrated and validated with the reference and demonstrator test results:

- The assessment framework should be calibrated with reference and demonstrator test results.

2.1.5 E-tyres evaluation

Michelin will supply e-tyres for evaluation on the trucks, to assess the effect of the drivetrain on tyre performance. The assessment framework must be capable of considering the impact of tyres on truck performance and energy consumption, as well as the influence of the drivetrain on tyre wear:

- The assessment framework should consider the tyre model and its impact on energy consumption.
- The assessment framework should enable simulations of different tyres.

2.1.6 Charging (MCS) and H_2 refuelling infrastructure

As part of the change to hydrogen and, especially, electric vehicles, the refuelling habits will change in comparison to the refuelling of Internal Combustion Engine (ICE) trucks, the usage patterns will change as well as the refuelling opportunities. The amount of energy that can be taken on-board to travel the needed range is limited mainly due to the low energy density of hydrogen and batteries compared to fossil fuels and the time required to refuel of charge an additional kilometre of range is significantly longer compared to refuelling fossil fuels. The time needed to do this is very different for the new energy carriers and vehicle from the case of an ICE vehicle. Therefore, the assessment framework should be able to take into account the charging and refuelling time and energy taken on-board during this time:

- The assessment framework should be capable of accounting for the time needed for vehicle refuelling and/or recharging equivalent driving range.
- The assessment framework should be capable of accommodating the varying energy and range intake requirements during charging or refuelling sessions for different vehicle types.
- The assessment framework should be capable of accommodating the varying energy distribution capabilities of different charging or fuelling stations.

2.1.7 Realistic simulations

Calibration and validation of the assessment framework using the results from the demonstrations ensure that the assessment framework will generate good results for routes similar to the ones driven in the use cases. However, the conditions of the routes in the demonstrations may not necessarily represent all typical traffic and road conditions. This means that traffic conditions, such as congestion, traffic dynamics, inclinations may be different during the demonstrations. Secondly, different routes in the use cases are conducted in different parts of Northern and Western Europe, meaning a lot of variation in the weather conditions, which will have an impact on the outcomes. Third the vehicle power train characteristic differ as different OEM are providing their trucks. Finally, the innovations are spread through different vehicle combinations and use cases and not all of them can be applied at the same time. All these factors should be studied in a sensitivity analysis:

- The sensitivity analysis should include variations in traffic conditions.
- The sensitivity analysis should include variations in weather conditions.
- The sensitivity analysis should include variations in road conditions.
- The sensitivity analysis should include variations in vehicle characteristics.

2.1.8 2ZERO Partnership requirements

The 2ZERO partnership is a cPPP (co-programme Public-Private Partnership) which has just over 30 projects running at the moment under the Horizon Europe (Zero Emissions Road Transport) programme. This partnership produces a monitoring report every two years. Within this monitoring report, the success of the Partnership is expressed, in part, as the estimated values for the Partnership's Key Performance Indicators (KPIs). These KPIs are given in the 2Zero Strategic Research and Innovation Agenda (SRIA)[1].

Two of the KPIs of the 2ZERO Partnership are the impact of the participating projects on the energy intensity (kWh/tkm) and the greenhouse gas (GHG) emissions per tonne.kilometre (or per passenger

[1] See https://www.2zeroemission.eu/what-we-do/strategic-research-and-innovation-agenda-sria/

kilometre for PSV) within the transport sector. To support this monitoring, a Coordination and Support Action (CSA), called "*Le*Mesurier", active from January 2024 to December 2025, will conduct an in-depth analysis of the expected KPIs, their values. *Le*Mesurier will collect data and estimate the KPI values based on inputs from all 2Zero projects, including the ZEFES project. In particular, this analysis aims to evaluate the actual impact of the projects on emissions and energy efficiency. This evaluation will be conducted with reference to the baseline year of 2019/20 and with projections of the likely values in 2025, 2030 and 2035 in Europe.

In conclusion, the following functional requirements of the assessment framework can be defined:
- The assessment framework should enable the calculation of energy intensity in kWh/tkm.
- The assessment framework should enable the calculation of greenhouse gas (GHG) emissions per tonne.kilometre [g(GHG)/tkm].
- The assessment framework should enable the calculation of the above mentioned values for years 2019/20, 2025, 2030 and 2035.

2.1.9 Evaluation use of VECTO Cycles

VECTO is used for the calculation of fuel consumption and CO_2 emissions of current ICE heavy-duty vehicles in specific cycles. This tool needs to be assessed for use in the calculations of energy consumption of BEV and FCEV trucks. Inside ZEFES, a review of this tool will take place under VUB, which will lead this task based on the developments of previous projects, e.g. LONGRUN[2]. For more information regarding the LCA and the VECTO tools see deliverable D1.2.

2.2 Key Performance Indicators

In this deliverable, all the Key Performance Indicators (KPIs) that were identified in previous work packages, especially in WP1, Deliverables 1.1 and 1.2, are gathered and standardized. They are divided into six categories:

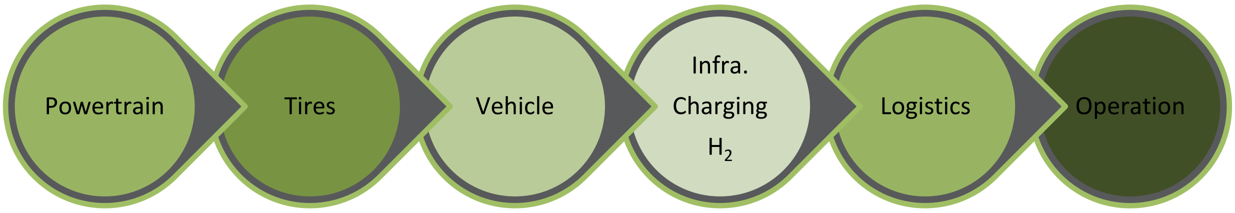


Figure 2.4 KPI Categories

To align all information related to the KPI, a template table with the categories described below was defined:

[2] See https://h2020-longrun.eu/

Table 2.1 ZEFES KPI template table

<table>
<tr><td colspan="4">Category: <<Contain category name in accordance to the selected category>></td></tr>
<tr><td>Name</td><td colspan="3"><<Contain a name that consists of 1 letter representing category and a number followed by the name example L1 Duration of Trip.>></td></tr>
<tr><td>Description</td><td colspan="3"><<Describes that future clarifies the purpose of the KPI>></td></tr>
<tr><td>Unit</td><td><<Provides the desired unit for the KPI. The unit can be either absolute or relative and is defined if applicable.>></td><td>Target value including reference</td><td><<Provides the target reference vehicle or target value for the KPI. The assessment of the KPI requires a predefined target value and reference value to which the actual performance is compared.>></td></tr>
<tr><td>Equation</td><td colspan="3"><<Provides a calculation or definition of how the KPI is determined. This uniquely defines how the KPI is built.>>

[Insert equation if applicable]</td></tr>
<tr><td>Data and/or signals required</td><td colspan="3"><<Provides a list of essential signals required to calculate the KPI.>></td></tr>
<tr><td>Use case and/or exceptions</td><td colspan="3"><<Identifies the use cases for which this KPI is calculated or specifies for which use cases this KPI is not calculated.>></td></tr>
</table>

The table below shows a full list of all ZEFES KPIs, the category they fall under and the source of the KPI where it was defined. In the following subsections the abovementioned template tables are provided for each ZEFES KPI.

Table 2.2 KPI Overview Table

No.	KPI Id.	KPI category	KPI short name	KPI source
1	KPI_P1	Powertrain	Energy consumption	D1.1, D1.2; 2Zero
2	KPI_P2	Powertrain	Energy intensity	D1.1, D1.2; 2Zero
3	KPI_P3	Powertrain	Average speed	D1.1
4	KPI_P4	Powertrain	Emissions WTW or CO_2 emissions	D1.4 [5]
5	KPI_T1	Tyre	Tyre wear	D1.1; D1.2
6	KPI_T2	Tyre	Tread depth loss	Michelin
7	KPI_V1	Vehicle	Range	D1.2, D1.4
8	KPI_V2	Vehicle	Charging during break	D1.2 D1.4
9	KPI_V3	Vehicle	Payload	D1.2 D1.4
10	KPI_C1	Infrastructure	Charging efficiency	Verification Criteria
11	KPI_C2	Infrastructure	Charging duration	D1.5; 2Zero
12	KPI_C3	Infrastructure	Charger Average power	D1.5; 2Zero
13	KPI_C4	Infrastructure	Charger Maximum power	D1.5; 2Zero
14	KPI_C5	Infrastructure	SoC at arrival	D1.5
15	KPI_C6	Infrastructure	SoC at departure	D1.4, D1.5
16	KPI_C7	Infrastructure	Charge energy	D1.5
17	KPI_C8	Infrastructure	Charge energy cost	D1.5
18	KPI_C9	Infrastructure	Moveable charger commissioning/disassembly time (Moveable ABB charger only)	ABB
19	KPI_H1	Infrastructure	Hydrogen refuelling speed	D1.5
20	KPI_H2	Infrastructure	Amount of refuelled H_2	D1.5
21	KPI_H3	Infrastructure	Amount of H_2 at arrival	D1.4, D1.5
22	KPI_H4	Infrastructure	Amount of H_2 at departure	D1.5
23	KPI_H5	Infrastructure	H_2 cost	D1.5
24	KPI_L1	Logistics	Duration of trip	D1.2, D1.4
25	KPI_L2	Logistics	Duration (un-)loading	D1.2
26	KPI_L3	Logistics	Delivered quantity during trip	D1.2
27	KPI_L4	Logistics	Delivery cost of trip	D1.2, D1.4
28	KPI_L5	Logistics	Number and Duration of stops and stop type (…)	D1.2
29	KPI_O1	Operator	Driver satisfaction - Driver acceptance of new drivetrains	D1.5
30	KPI_O2	Operator	Fleet manager satisfaction	D1.5

2.2.1 Powertrain KPI

This chapter provides a detailed description of KPI's related to the powertrain of vehicles.

Table 2.3 Powertrain KPI_P1 Energy Consumption

<table>
<tr><th colspan="4">Category: Powertrain</th></tr>
<tr><td>Name</td><td colspan="3">KPI_P1 Energy Consumption</td></tr>
<tr><td>Description</td><td colspan="3">This KPI evaluates the energy consumption of the vehicle, measured in kilowatt-hours per kilometre. It also assesses the percentage reduction in energy consumption relative to the baseline vehicle, providing insights into the efficiency improvements achieved across different vehicle configurations while maintaining the same payload.</td></tr>
<tr><td>Unit</td><td>kWh/km</td><td>Target value including reference</td><td>Up to 8% efficiency gain over State of Art</td></tr>
<tr><td>Equation</td><td colspan="3">
equation absolute numbers:
$$\frac{absolute\ energy\ consumptioin\ [kWh]}{distance\ [km]}$$
equation relative numbers:
$$\frac{energy\ consumption\ baseline\ \left[\frac{kWh}{km}\right] - energy\ consumption\ ZEFES\ \left[\frac{kWh}{km}\right]}{energy\ consumption\ baseline\ \left[\frac{kWh}{km}\right]} * 100\%$$
For hydrogen use, the following equation will be used:
equation absolute numbers:
$$\frac{absolute\ hydrogen\ consumptioin\ [kg]}{distance\ [km]}$$
The hydrogen use case will be recalculated to kWh (1 kgH_2=33.3kWh)
</td></tr>
<tr><td>Data/ signals required</td><td colspan="3">Absolute Energy Consumed [kWh] (from the battery)
Distance [km]
Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload.</td></tr>
<tr><td>Use case /exceptions</td><td colspan="3">All use cases
Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI;
Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI;
Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI;
Use case 7.3.2 Scania – VET, GRU;
Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM;</td></tr>
</table>

	Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

Table 2.4 Powertrain KPI_P2 Energy intensity

Category: Powertrain			
Name	KPI_P2 Energy intensity		
Description	This KPI assesses the energy intensity of the vehicle concerning its cargo weight. It quantifies the energy use per weight of cargo transported, represented as ton-kilometres per kilowatt-hour. Additionally, it measures the percentage of energy intensity gain compared to the baseline vehicle, highlighting enhancements in energy utilization across various cargo loads.		
Unit	tkm/kWh	**Target value including reference**	Same as ref. ICE vehicle
Equation	• equations absolute numbers: $$\frac{payload\ [t]\ *\ distance\ [km]}{absolute\ energy\ consumption\ [kWh]}$$ • equation relative numbers: $$\frac{fuel\ efficiency\ ZEFES\ vehcile\ \left[\frac{t.km}{kWh}\right] - fuel\ efficiency\ baseline\ vehicle\ \left[\frac{t.km}{kWh}\right]}{fuel\ efficiency\ baseline\ vehicle\ \left[\frac{t.km}{kWh}\right]} * 100\%$$ For hydrogen use, the following equation will be used: • equation absolute numbers: $$\frac{absolute\ hydrogen\ consumption\ [kg]}{distance\ [km]}$$ The hydrogen use case will be recalculated to kWh (1 kg H_2=33.3kWh) For Diesel, the following equation will be used: • equation absolute numbers: $$\frac{absolute\ diesel\ consumption\ [l]}{distance\ [km]}$$ The diesel use case will be recalculated to kWh (1litre Diesel =10.9kWh) In the case of LNG, the following equation will be used: • equation absolute numbers:		

	$$\frac{absolute\ LNG\ consumption\ [kg]}{distance\ [km]}$$ The LNG use case will be recalculated to kWh (1 kg LNG = 13.89 kWh)
Data/ signals required	Absolute Energy Consumed [kWh] (from the battery) Distance [km] Fuel consumed [kg or litre] Payload [t] Additional parameters to consider: Weather conditions, Traffic conditions and Speed profile.
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

Table 2.5 Powertrain KPI_P3 Average Speed

Category: Powertrain			
Name	KPI_P3 Average Speed		
Description	This KPI evaluates the average speed of trucks in kilometres per hour, reflecting the efficiency of transportation operations. Higher average speeds are often associated with earlier deliveries (within the road speed regulations limits), maximizing delivery efficiency. This KPI will also be used to compare the energy consumption of different vehicle configurations validity, the average speed should be approximately the same in that case.		
Unit	km/h	**Target value including reference**	Same as ref. ICE vehicle
Equation	• Equation absolute numbers: $$VSpeed\left[\frac{km}{h}\right] = \frac{distance\,[km]}{time\ to\ complete\ cycle\ [h]}$$ • equation relative numbers:		

	$$VSpeed_{rel}[\%] = \frac{VSpeed_{ZEFES}\left[\frac{km}{h}\right] - VSpeed_{baseline}\left[\frac{km}{h}\right]}{VSpeed_{baseline}\left[\frac{km}{h}\right]} * 100\%$$
Data/ signals required	Time to complete cycle [h] Distance [km] Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload.
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

Table 2.6 Powertrain KPI_P4 Emissions WTW or CO2

Category: Powertrain			
Name	KPI_P4 Emissions WTW or CO_2		
Description	This KPI calculates the total CO_2 emissions that the energy carrier (fuel) produces from the well to the wheels, i.e. from the source up to and including the journey. The total WTW emissions will be calculated on the basis of the country where the vehicle was refuelled (or charged).		
Unit	kg or tonnes	**Target value including reference**	TBD
Equation	$$CO_{2_{WTW}} = FC * CEF_{WTW}$$ Where, CO_{2WTW}: well-to-wheel emissions in [kg (or tonnes)] FC: fuel consumption [in kg (or litres) for diesel/LNG/H_2 and kWh for electricity] CEF_{WTW}: well-to-wheel carbon dioxide equivalent factor for the fuel [g_{CO2}/g_{fuel} or $kWh_{CO2}/kWh_{electricity}$] A factor will be used to convert kWh of electricity to kg of CO_2 depending on the year and the country of refueling.		

Data/ signals required	Energy consumption, Charge energy] Refuel H_2 [kg] H_2 production CO_2 intensity [kg/H_2kg] Specific country energy mix and CO_2 emissions from energy production. [kg/kWh]
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

2.2.2 Tyre KPI

This chapter provides a detailed description of KPIs related to the tyres for electric vehicles.

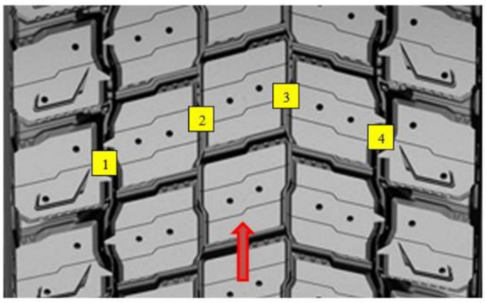
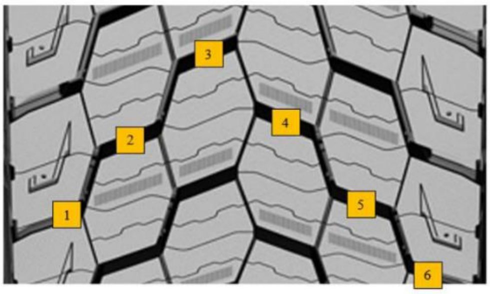
Table 2.7 Tyre KPI_T1 Tyre Wear

Category: Tyre			
Name	KPI_T1 Tyre Wear		
Description	This KPI quantifies the tyre wear in milligrams per kilometre. Calculations are performed for the same tyres as KPI_ T2. This metric aims to evaluate the influence of the drivetrain on tyre wear.		
Unit	mg/km	**Target value including reference**	ref. ICE vehicle; TBD
Equation	An estimation of the mass loss will be calculated. This will be done based on the geometric values of the tyre and the density of the materials. $$absolute\ tyre\ wear\ [mg] = Tread\ Depth\ Loss \cdot 2\pi R \cdot (1 - VoidRatio) \cdot Width \cdot \rho$$ where $Tread\ Depth\ Loss$ = based on KPI_T2, $VoidRatio$ = Ratio of void volume (gaps in the tread) with respect to the total volume (void + rubber patterns) [%], ρ = density of the tyre material [mg/mm3], $Width$ = Transversal width of the tread [mm], which may be different to the overall tyre size (it is usually close to 90% of the overall tyre width), R = external radius of the tyre [mm]. Example: For a 315/70R22.5, the width would be 283.5mm (0.9*315), and the external radius 506.25mm (315*70/100 + 22.5/2*25.4).		

	• equation absolute numbers: $$Tyre\ Wear\ \left[\frac{mg}{km}\right] = \frac{absolute\ tyre\ wear\ [mg]}{distance\ [km]}$$ • equation relative numbers: $$Tyre\ Wear\ [\%] = \frac{tyre\ wear\ ZEFES\ tyre\ \left[\frac{mg}{km}\right] - tyre\ wear\ baseline\ tyre\ \left[\frac{mg}{km}\right]}{tyre\ wear\ baseline\ tyre\ \left[\frac{mg}{km}\right]} * 100$$ Depending on the need to compare different vehicles with different tyre sizes, this value needs to be normalized. Different tyre dimensions may allow different loads, so if we want to compare different dimensions among them, we should use: $$Tyre\ Wear\ per\ transported\ mass = \frac{Tyre\ Wear \left[\frac{mg}{km}\right]}{Nominal\ Load [kg]}$$ The nominal load should be based on the load index. If the data is available, we will compare this mass loss estimation to mass measurements. However, it is practically unfeasible to regularly unmount the tyres from the vehicle to measure their mass. Therefore, only the initial and final mass measurements are optionally considered.
Data/ signals required	Tread depth [mm] Distance driven [km] Payload [1000 kg] Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload.
Use case /exceptions	Use case: Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM;Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD

Table 2.8 Tyre KPI_T2 Tread depth loss

Category: Tyre	
Name	KPI_T2 Tread depth loss
Description	This KPI measures the tyre depth loss in mm/10.000km. Measurements on tread depth are taken at the front steer non-driven axle equipped with standard tyres, at the rear driven axle equipped with XM901 tyres, and for the 6x2 vehicle at the second rear axle that is non-driven (tag axle) equipped with standard tyres.

<table>
<tr><td></td><td colspan="3">It will be possible to compare drive axles among them, steer axles among them and tag axles among them. No inter-axle comparisons should be done: for example, it is not possible to compare the wear rate of the drive axle to the steer axle.
This is an example of the tread depth measurement positions for
• 315/70R22.5 XMultiD (on the left)
• 315/70R22.5 XM901 (on the right)

These measurements should be done at, at least, 4 different azimuths equally distributed. If possible, 8 different azimuths would be preferred.</td></tr>
<tr><td>Unit</td><td>mm/10 000km or km/mm</td><td>Target value including reference</td><td>ref. ICE vehicle</td></tr>
<tr><td>Equation</td><td colspan="3">The measurement is made directly on the tyre by the technician. Tread depth [mm] is measured on different parts of the tyre, which gives the information (wear profile). The average value of all the measurements on the tyre is determined per tyre.

Based on the measurements, the tread depth loss and the tread efficiency can be specified according to:
$$Tread\ depth\ loss\ rate\left[\frac{mm}{10000km}\right] = \frac{TreadDepth_0[mm] - TreadDepth_t\ [mm]}{DistanceDriven[km] * 10000}$$
$$Tread\ efficiency\left[\frac{km}{mm}\right] = \frac{DistanceDriven[km]}{TreadDepth_0[mm] - TreadDepth_t\ [mm]}$$</td></tr>
<tr><td>Data/ signals required</td><td colspan="3">Tread depth [mm]
Distance driven [km]
Payload [1000 kg]
Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile, Payload and type of reference tyres</td></tr>
<tr><td>Use case /exceptions</td><td colspan="3">Use case:

Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM;Use case 7.4.1 Renault – MIC;
Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD</td></tr>
</table>

2.2.3 Vehicle KPI

This chapter provides a detailed description of KPIs related to ZE vehicles.

Table 2.9 Vehicle KPI_V1 Range

Category: Vehicle			
Name	KPI_V1 Range		
Description	The Range KPI measures the distance an electric truck or fuel cell truck can travel on a single charge or refuelling in a given real-world conditions. The target for this KPI is to achieve a range of 750 kilometres with a hydrogen fuel capacity of 70 kilogrammes for an FCEV truck, or to reach a range of 400 kilometres within 45 minutes of charging for a BEV truck. Testing will be conducted using the VECTO long-haul profile, a standardized driving cycle for heavy-duty vehicles, as well as in real-road conditions selected based on the VECTO cycle to ensure realistic performance assessment.		
Unit	km	**Target value including reference**	FCEV: 750km (70kg hydrogen) BEV: 400km)
Equation	The truck range will be estimated based on the driven range and SoC. Truck range between charging: $$Range\ [km] = \frac{\sum Range\left(between\ \frac{charging}{refueling}\right)}{number\ charging\ events}$$ The above range will be disclosed in a set SoC range (example from 20% to 80%). Total truck range: $$Total\ Real\ World\ \ Range\ [km] = \frac{Usable\ battery\ size\ or\ hydrogen\ [kWh\ or\ kg]}{Energy\ consumptio\ \left[\frac{kWh}{km}\ or\ \frac{kg}{km}\right]}$$ This calculation shows the total available truck range assuming driving the truck from full to empty battery.		
Data/ signals required	Distance driven [km] Charging time [%] SoC [%] Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload.		

Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G;

Table 2.10 Vehicle KPI_V2 Charging during break

Category: Vehicle			
Name	KPI_V2 Charging during break		
Description	The charging during break KPI assesses the vehicle's capability to recharge needed amount of energy required to cover the target distance of 400 kilometres within a 45-minute break that the driver is taking. The charge rate is measured as the energy gain per unit of time and translated to km-equivalent gain based on the vehicle's KPI_P1 Energy Consumption.		
Unit	kWh/min(or h) $km_{eq.}$/min(or h)	**Target value including reference**	400km in 45min 8.8$km_{eq.}$/min or 530$km_{eq.}$/h
Equation	• Charging rate $$Charging\ rate\ \left[\frac{kWh}{h}\right] = \frac{Charge\ Energy\ [kWh]}{Charging\ Time\ [h]}$$ • Charging speed per energy consumption: $$Charging\ speed\ \left[\frac{km_{eq}}{h}\right] = \frac{Charging\ speed\ \left[\frac{kWh}{h}\right]}{Energy\ consumption\ \left[\frac{kWh}{km}\right]}$$		
Data/ signals required	Charger energy [kWh] or Refuelled Hydrogen [kg] Charging Time [h] Truck energy Consumption [kWh/km or kg/km] Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload		

Use case /exceptions	All use cases with Electric trucks: Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD

Table 2.11 Vehicle KPI_V3 Payload

Category: Vehicle			
Name	KPI_V3 Payload		
Description	The payload KPI assesses the maximum weight and load capacity that a vehicle can carry safely. It depends on each OEM and vehicle specifications, design. This value will depend on the vehicle type and the trailer. (The load carried in each use case is determined by the logistic KPI_L3 Delivered quantity during the trip)		
Unit	Ton	**Target value including reference**	Min. of 90% payload of ref. vehicle
Equation	The KPI is determined based on truck and trailer manufacturers specifications. Specification base: • absolute numbers: Truck payload $ZEFES_{payload}[t] = GVWR \text{ or } GVCWR\ [t] - curb\ weight\ [t] - other[t]$ • equation relative numbers: $\frac{ZEFES\ truck\ payload\ [t]}{ref.Truck\ payload\ [t]} * 100$		
Data/ signals required	GVW (Gross Vehicle Weight) [t] GCVW (Gross Combined Vehicle Weight) [t] Curb weight [t] Other weight [t] – other added weight to the vehicle that is not included in the curb weight. Additional parameters to consider: Weather conditions, Traffic conditions, Speed profile and Payload.		

Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

2.2.4 Infrastructure KPI

This chapter provides a detailed description of KPIs related to the charging and refuelling infrastructure for ZEFES vehicles.

Table 2.12 Infrastructure KPI_I1 Charger Electrical efficiency

Category: Infrastructure			
Name	KPI_I1 Charger Electrical efficiency		
Description	This KPI evaluates the charger's efficiency during charging. It looks at the charger power provided to the truck and the power consumed from the grid.		
Unit	[%]	**Target value including reference**	80% Target
Equation	Electrical efficiency will be calculated: $$\eta_{Charger} = \frac{P_{Charger_{out}}[kW]}{P_{Grid}[kW]}\ [\%]$$ The efficiency will be calculated for the full charging event.		
Data/ signals required	P_{Grid} [kW] is defined as power consumed by the charger from the grid. $P_{Charger\ out}$ [kW] is defined as power delivered to the charging vehicle. SoC [%] The SoC provided to the charger by the vehicle. Charging time [s] The time when the current flows from the charger to the battery. Session time [s] The time when the vehicle is connected to the charger via the charging plug. Session start date and time Vehicle Mac ID, Tag ID		
Use case /exceptions	Use Case 7.2.2 Volvo – SLI -MCS Hamburg-; Use Case 7.2.3 Volvo – P&G; MCS Dudelange; Use case 7.3.1 Scania – SLI-MCS Hamburg; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera, Use case 7.3.4 Scania – GSS MCS Dudelange		

Table 2.13 Infrastructure r KPI_I2 Time to charge default vehicle

Category: Infrastructure			
Name	KPI_I2 Time to charge default vehicle		
Description	This KPI will measure the duration, the time it takes to charge a truck from 20% to 80 % SoC. This KPI can be measured directly by the charger or delivered later from the charge energy and charge power. It looks at how the truck can work together with the charging infrastructure to achieve the best charging times. Note: this KPI is looking at the charging time defined as the time the charger starts providing energy to the vehicle and the time it stops providing energy. Therefore, it is not the charging session time that starts at the moment of plugging in the vehicles and may contain delays related to postponed charging.		
Unit	[h]	**Target value including reference**	45 min from 20% to 80%SOC 0,75 h
Equation	Charging time is provided directly by the charger. In the situation that the charging time is not provided by the charger the time will be calculated as follows: $Charging\ time[h] = \frac{Charge\ Energy\ [kWh]}{Avg.Charging\ Power\ [kW]}$		
Data/ signals required	Charging time [min or h] Average Charging Power [kW] Charge Energy [] SoC [%]		
Use case /exceptions	Use Case 7.2.2 Volvo – SLI - MCS Hamburg; Use Case 7.2.3 Volvo – P&G; MCS Dudelange; Use case 7.3.1 Scania – SLI-MCS Hamburg; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera, Use case 7.3.4 Scania – GSS MCS Dudelange		

Table 2.14 Infrastructure KPI_I3 Charger sustainable power

Category: Infrastructure			
Name	KPI_I3 Charger sustainable power		
Description	The charger sustainable power KPI assesses the power the charger can provide continually for a period of 45 minutes, defined as the minimum power level that the charger achieved and sustained in a 45-minute charging session from 20 to 80% SoC of the vehicle battery.		
Unit	[kW]	**Target value including reference**	Charger specification

Equation	Charger sustainable power based on charger specification.
Data/ signals required	Charger power that can be sustained for a minimum of 45 min continually.
Use case /exceptions	Use Case 7.2.2 Volvo – SLIUse Case 7.2.2 Volvo – SLI -MCS Hamburg; Use Case 7.2.3 Volvo – P&G; MCS Dudelange; Use case 7.3.1 Scania – SLI-MCS Hamburg; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera, Use case 7.3.4 Scania – GSS MCS Dudelange

Table 2.15 Infrastructure KPI_I4 Charger maximum power

Category: Charger			
Name	KPI_I4 Charger maximum power		
Description	The Maximum Power KPI assesses the maximum power output capability of the charger, defined as the highest power level that the charger can achieve and sustain for at least 5 minutes during the charging process in the range from 20 to 80% SoC of the vehicle battery. This KPI can be also determined from the charger specification as the charger maximum power that can be provided continually for 5 min.		
Unit	[kW]	**Target value including reference**	Charger and vehicle specification
Equation	Option 1: This KPI requires time-based data from the charging event. Maximum Power=Highest Average Power sustained for at least 5 minutes. Option 2: KPI based on specifications.		
Data/ signals required	Charging data: detailed charging data, including: Power coming out of the charger [kW] over the entire charging session. Time [s]: Identification of the time intervals during the charging session where the power output is sustained at its highest level for at least 5 minutes. SoC [%] Charger specifications: Charger max power that can be sustained for a minimum of 5 min continually.		
Use case /exceptions	Use Case 7.2.2 Volvo – SLI -MCS Hamburg-; Use Case 7.2.3 Volvo – P&G; MCS Dudelange ; Use case 7.3.1 Scania – SLI-MCS Hamburg; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera, Use case 7.3.4 Scania – GSS MCS Dudelange		

Table 2.16 Infrastructure KPI_I5 SoC at departure

Category: Infrastructure			
Name	KPI_I5 SoC at arrival		
Description	Monitors the battery efficiency usage saying what is the leftover charge at the moment of charging.		
Unit	[%]	**Target value including reference**	Between 5 to 20%
Equation	N/A		
Data/ signals required	SoC [%] Truck location State of Charge (SoC) at Start: The initial SoC of the truck's battery at the beginning of the charging session.		
Use case /exceptions	Use Case 7.2.2 Volvo – SLI -MCS Hamburg; Use Case 7.2.3 Volvo – P&G; MCS Dudelange; Use case 7.3.1 Scania – SLI-MCS Hamburg; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera, Use case 7.3.4 Scania – GSS MCS Dudelange		

Table 2.17 Infrastructure KPI_I6 SoC at departure

Category: Infrastructure			
Name	KPI_I6 SoC at departure		
Description	Monitors the battery's efficient usage by monitoring the battery usage and the charging time usage by looking at the battery SoC after recharging.		
Unit	[%]	**Target value including reference**	Above 80%
Equation	N/A		
Data/ signals required	SoC [%] Truck location State of Charge (SoC) at End: The final SoC of the truck's battery at the end of the charging session.		
Use case /exceptions	All use cases with Electric trucks: Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD		

Table 2.18 Charger KPI_I7 Charge energy

Category: Infrastructure			
Name	KPI_I7 Charge energy		
Description	This KPI measures the amount of energy transferred to the vehicle during each charging session. It evaluates the efficiency and effectiveness of charging stops, providing insights into how well charging stops are utilized and how much energy is replenished during each stop.		
Unit	[kWh]	**Target value including reference**	Min. 400 km equivalent in 45 min.
Equation	N/A		
Data/ signals required	Charging data: detailed charging data, including: Power coming out of the charger [kW] over the entire charging session. Time [s]: Identification of the time intervals during the charging session where the power output is sustained at its highest level for at least 5 minutes. SoC [%]		
Use case /exceptions	All use cases with Electric trucks: Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD		

Table 2.19 Infrastructure KPI_C8 Charge energy

Category: Infrastructure			
Name	KPI_I8 Charging cost		
Description	This KPI measures the total cost incurred for charging the vehicle during each charging session.		
Unit	[€]	**Target value including reference**	TBD
Equation	The total cost for charging in the event: $$Cost\ [€] = Total\ cost\ of charging\ [€]$$ The cost per kWh: $$Cost\left[\frac{€}{kWh}\right] = \frac{Total\ cost\ of charging}{Charge\ energy}$$		

Data/ signals required	Total cost of charging [€] Charge energy [kWh] SoC [%]
Use case /exceptions	All use cases with Electric trucks: Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD

Table 2.20 Infrastructure KPI_I9 Moveable charger set-up time

Category: Infrastructure			
Name	KPI_I9 Moveable charger setup time (Moveable ABB charger only)		
Description	This KPI will measure the set-up/disassembly time of the movable charger. It will look at the time that is required for a set-up by a trained crew from the time of arrival of the charger package at a fully prepared site and the first charging operation, with a test vehicle. It will also look at the disassembly time. Seen as the time that is required to disconnect a fully de-energized and "cold" charger and get it packaged and ready for transport to the next site.		
Unit	Working time [person hours] Time [hours]	**Target value including reference**	TBD
Equation	$\mathrm{Time\ req.,start[h]} = \mathrm{Arrivel\ time[hh:mm]} - \mathrm{Ready\ to\ operation\ time[hh:mm]}$ $\mathrm{Time\ req.,stop[h]} = \mathrm{Deenergizetime[hh:mm]} - \mathrm{Transport\ rdy\ time[hh:mm]}$ $Working\ time\left[\frac{h}{person}\right] = \frac{\mathrm{Time\ req.,start[h]\ or\ Time\ req.,stop[h]}}{Number\ of\ persons\ working}$		

Data/ signals required	Data to be gathered by means of a logbook Arrival time[hh:mm] Ready to operation time[hh:mm] Deenergize time [hh:mm] Transport ready time[hh:mm] Number of persons working
Use case /exceptions	Interop test IDIADA & Use Case 7.2.3 Volvo – P&G; MCS Dudelange; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM IDIADA / MCS ABB Le Jonquera; Use case 7.3.4 Scania – GSS MCS Dudelange

Table 2.21 H2 refueling KPI_I10 Hydrogen refuelling time

Category: Infrastructure			
Name	KPI_I10 Hydrogen refuelling rate.		
Description	This KPI measures the rate at which hydrogen can be fuelled into the vehicle. It aims to ensure that the refuelling rate meets the operational requirements for minimal downtime during logistics operations. The purpose of this KPI is to compare the hydrogen refueling rate of ZEFES vehicles against industry standards and ICE vehicle refuelling times, to ensure competitiveness and practicality.		
Unit	g/s $km_{eq.}/s$	**Target value including reference**	Deepening on specification 90g/s (700bar)
Equation	$$Refueling\ Rate\ \left(\frac{g}{s}\right) = \frac{Total\ Hydrogen\ Refuelled\ (g)}{Refuelling\ time\ [s]}$$		
Data/ signals required	Total Hydrogen Refueled (kg)) (provided from the station or recorded by the driver) Refueling time [min] (provided from the station or recorded by the driver) Temperature [°C]		
Use case /exceptions	Use Case 7.2.1 Volvo – OVA, APG; Use case 7.3.1 Scania – SLI; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.22 Infrastructure KPI_I11 Refuelled H_2

Category: Infrastructure			
Name	KPI_I11 Refueled H_2		
Description	This KPI will measure the amount of refueled H_2. This amount will vary based on the surrounding temperature and the initial temperature and pressure in the vehicle; therefore, it is important to understand the influence and the capabilities of the system to take on board as much fuel as possible. This KPI needs to be logged by the driver or provided by the infrastructure operator.		
Unit	[kg]	**Target value including reference**	[depends on specifications]
Equation	**Based on data from the pump station or driver logbook.**		
Data/ signals required	Driver logbook with the time of refuelling the truck. Surrounding Temperature [°C] Initial tank temperature [°C] H_2 pressure in the vehicle tank(s) [bar].		
Use case /exceptions	Use Case 7.2.1 Volvo – OVA, APG; Use case 7.3.1 Scania – SLI; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.23 Infrastructure KPI_I12 Amount of H_2 at arrival

Category: Infrastructure			
Name	KPI_I12 Amount of H_2 at arrival		
Description	Monitors the hydrogen tanks efficiency usage saying what is the leftover amount of H_2 at the moment of refuelling.		
Unit	[%] of [kg]	**Target value including reference**	5 - 20%
Equation	N/A Depending on the working pressure, you can add an equation if the unit is [%] SOC(%) = density_H_2 in truck / density_H_2 (working pressure, 15°C)		
Data/ signals required	The amount of Fuel [%] of [kg]		
Use case /exceptions	Use Case 7.2.1 Volvo – OVA, APG; Use case 7.3.1 Scania – SLI; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.24 Infrastructure KPI_I13 Amount of H_2 at departure

Category: Infrastructure			
Name	KPI_I13 Amount of H_2 at departure		
Description	Monitors the hydrogen tanks efficiency usage saying what is the amount of H_2 at the moment of departure from the station.		
Unit	[%] of [kg]	**Target value including reference**	100% (kg – depends on the fuel tank size)
Equation	N/A		
Data/ signals required	The amount of Fuel [%] of [kg]		
Use case /exceptions	Use Case 7.2.1 Volvo – OVA, APG; Use case 7.3.1 Scania – SLI; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.25 Infrastructure KPI_I14 Cost of H_2

Category: Infrastructure			
Name	KPI_I14 Cost of H_2		
Description	This KPI measures the cost per kg and the total cost incurred for refueling the vehicle at the station.		
Unit	[€]	**Target value including reference**	Equaled to the cost of diesel equivalent
Equation	Cost per kgH_2 = Total cost of H_2 refuelled/ H_2 refuelled		
Data/ signals required	Total cost of H_2 refuelled [€] H_2 refueled [kg] Temperature [°C]		
Use case /exceptions	Use Case 7.2.1 Volvo – OVA, APG; Use case 7.3.1 Scania – SLI; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

2.2.5 Logistic KPI

This chapter provides a detailed description of KPIs related to the logistic operations with ZEFES vehicles.

Table 2.26 Logistic KPI_L1 Duration of Trip

Category: Logistic

Name	KPI_L1 Duration of trip		
Description	The KPI measures the time that passed between each origin and destination pair for each use case. This duration is recorded in hours and aims to be comparable to that of the reference ICE vehicle. It provides insight into the efficiency of trip durations and is calculated by dividing the total duration of trips by the number of trips undertaken. The KPI time counting starts when the truck leaves the location of origin and stops when it reaches the destination.		
Unit	[h]	**Target value including reference**	Same as ref. vehicle (ICE)
Equation	The KPI will be calculated as $$Avg. Duration\ of\ trips = \frac{\sum Time\ stamp\ at\ origin - Time\ stamp\ at\ destination}{nNumber\ of\ trips}$$		
Data/ signals required	Truck location Timestamp		
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.27 Logistic KPI_L2 Duration of (un)loading

Category: Logistic			
Name	KPI_L2 Duration un-/loading		
Description	The time that passed between the vehicle arriving at the destination to unload and load goods and departing.		
Unit	[h]	**Target value including reference**	Same as ref. vehicle (ICE)
Equation	Time spent on un-/loading Option 1: Value will be manually recorded. Option 2: Value will be determined as the time between the arrival at the destination and the time the truck leaves the destination location.		

	$$Duration\ (un)loading = \frac{\sum(un)loading\ \ time}{nNumber\ of\ events}$$
Data/ signals required	Recorded by the driver: Truck location Vehicle weight
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

Table 2.28 Logistic KPI_L3 Delivery quantity

Category: Logistic			
Name	KPI_L3 Delivery quantity during the trip		
Description	The KPI assesses ZEFES vehicles' ability to match ICE vehicles in fulfilling missions and carrying equivalent cargo weights and volume. It compares the maximum cargo loaded and transported during the mission to that of ICE vehicles in the same class combination, thereby evaluating the maximum weight of goods the vehicle can transport.		
Unit	[t] and [m^3]	**Target value including reference**	Same as ref. vehicle (ICE)
Equation	The data from the shipping document. The data from truck's measurements. • absolute numbers: absolute delivered quantity $$Delivered\ quantity\ [t\ or\ m^3]$$ • equation relative numbers: $$\frac{ZEFES\ truck\ delivered\ quantity\ [t\ \ or\ m^3]}{ref.Truck\ delivered\ quantity\ [t\ or\ m^3]} * 100\%$$ (Depending on the used system the calculation needs to be adjusted)		

Data/ signals required	Shipping documents information Truck suspension measurement and calculations Truck acceleration [m/s^2]
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

Table 2.29 Logistic KPI_L4 Delivery cost of the trip

Category: Logistic			
Name	KPI_L4 Delivery cost of the trip		
Description	This KPI is part of the TCO and will be calculated fully there. The outcome will be used to evaluate the KPI. This cost can include various expenses such as fuel, labour, maintenance of vehicles, tolls and other related costs (depending on the sensitivity of the data, price value might need to be used).		
Unit	[€]	**Target value including reference**	Same as ref. vehicle (ICE)
Equation	See LCA chapter		
Data/ signals required	See LCA chapter		
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW;		

	Use case 7.6.3 Ford – P&G

Table 2.30 Logistic KPI_L5 Number and duration of stops and stop type

Category: Logistic			
Name	KPI_L5 Number and duration of stops and stop type		
Description	The number of stops (not related to normal traffic stops) that happened between the time of the last goods pick-up and the first drop-off (fueling/charging/resting/maintenance/(un)loading/other).		
Unit	[n] and [h]	**Target value including reference**	Same as ref. vehicle (ICE)
Equation	The number and duration of the stops should be gathered in two ways: 1. It should be noted by the driver. 2. Determine from the data based on the vehicle speed and location.		
Data/ signals required	Truck location; Truck IG on[-]; Truck odometer[km]; Speed[km/h]; Power consumption [kWh/km]		
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

2.2.6 Operator KPI

Table 2.31 KPI_O1 Driver satisfaction Driver acceptance for new drivetrains

Category: Operator	
Name	KPI_O1 Driver satisfaction - Driver acceptance for new drivetrains
Description	The KPI for driver satisfaction and driver acceptance for new drivetrains aims to measure how well drivers adapt to and accept the innovations implemented in the ZEFES project. This KPI will provide insights into the drivers' experiences, preferences and overall satisfaction with the new electric and hydrogen-powered

	drivetrains, as well as trailers, in comparison to traditional ICE vehicle and trailer combinations.		
Unit	Satisfaction scale	**Target value including reference**	High
Evaluation Method	Currently, the method for evaluating this KPI is under consideration and may involve either interviews or surveys. The evaluation process aims to gather qualitative and quantitative data from the drivers to assess their level of satisfaction and acceptance. The language in which the survey/interview will be conducted is yet to be determined. It will be determined based on the driver capabilities.		
Data/ signals required	User experience		
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G		

Table 2.32 KPI_O2 Fleet manager satisfaction

Category: Operator			
Name	Fleet manager satisfaction		
Description	The KPI for fleet manager satisfaction and acceptance for new drivetrains aims to measure how well fleet managers adapt to and accept the new technologies implemented in the ZEFES project. This KPI will provide insights into the fleet managers' experiences, preferences and overall satisfaction with the new electric and hydrogen-powered vehicles compared to traditional ICE vehicles.		
Unit	Satisfaction scale	**Target value including reference**	High
Evaluation Method	Currently, the method for evaluating this KPI is under consideration and may involve either interviews or surveys. The evaluation process aims to gather qualitative and quantitative data from fleet managers to assess their level of satisfaction and acceptance. Relevant Points for Fleet Managers will be taken to account, such as:		

	• Operational Efficiency: Assessing the impact of new drivetrains on the overall efficiency and productivity of the fleet operations. • Reliability: Understanding the reliability and uptime of the new drivetrains compared to traditional vehicles. • Integration: Examining how well the new drivetrains integrate with existing fleet management systems and processes. • Sustainability Goals: Aligning the new drivetrains with the company's sustainability and environmental goals.
Data/ signals required	User experience
Use case /exceptions	All use cases Use Case 7.2.1 Volvo – OVA, APG; Use Case 7.2.2 Volvo – SLI; Use Case 7.2.3 Volvo – P&G; Use Case 7.2.3 Volvo – PRI; Use case 7.2.4 Volvo – DPD; Use case 7.3.1 Scania – SLI; Use case 7.3.2 Scania – VET, GRU; Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM; Use case 7.3.4 Scania – GSS; Use case 7.4.1 Renault – MIC; Use case 7.4.2 Renault – Renault; Use case 7.4.3 Renault – DPD; Use case 7.6.1 Ford – EKO; Use Case 7.6.2 Ford – GBW; Use case 7.6.3 Ford – P&G

2.3 Use cases

There are 15 use cases to be assessed in the course of this project. Every one of these use cases has been designed to study a particular technology – either the drivetrain technology, charging technology or another innovation. Each use case has a reference vehicle, which preferably provides data from a year (or two) of use before the actual demonstration vehicle is assessed. The reference vehicle is the one that is used for benchmarking to assess the technologies or improvements. At the time of writing, not all detailed information about the reference vehicles is known, therefore the description is made in accordance with the consortium agreements plans and the most recent available information. The final description of the use-cases will be published in D7.1 of this project. Disclaimer: The orchestration of all 15 use cases is on-going and depends on many external factors, e.g., road permits, refuellinginfrastructure and freight contracts. The use cases described below are preliminary and will have a final state earliest at month 24-27 of the project, therefore, it must be recognized that the changes might still occur after 2025.

2.3.1 Use Case 7.2.1 Volvo – OVA, APG

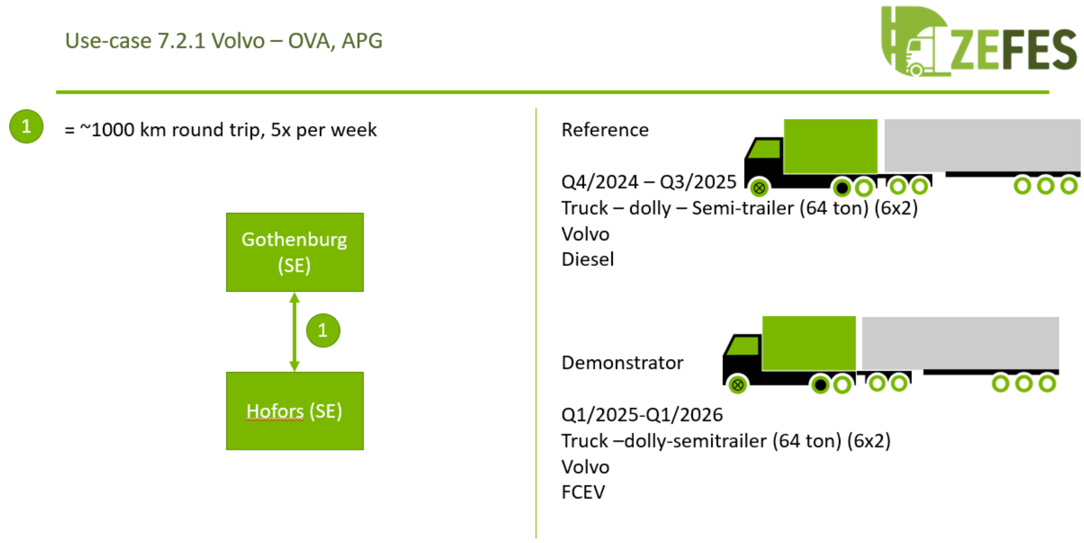


Figure 2.5 Use case 7.2.1 - Volvo-OVA,APG

The Use case 7.2.1 is a Volvo use case, where OVA acts as the stakeholder. The demonstrator vehicle will operate for a period of 12 months.
The vehicle: The vehicle used for demonstration is a 6x2 64-ton truck-12m Swedish trailer (EMS1) configuration. It will be an FCEV.
The route: The vehicle drives from Gothenburg in Sweden to Hofors in Sweden. This is an approximately 1000 km trip and is expected to be performed 5 times a week.
USP: The USP of this use case is demonstrating the usability of a HD FCEV (EMS1) for long-haul transportation.

The reference vehicle is a 6x2 64-ton truck. It will have a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.2 Use Case 7.2.2 Volvo – SLI

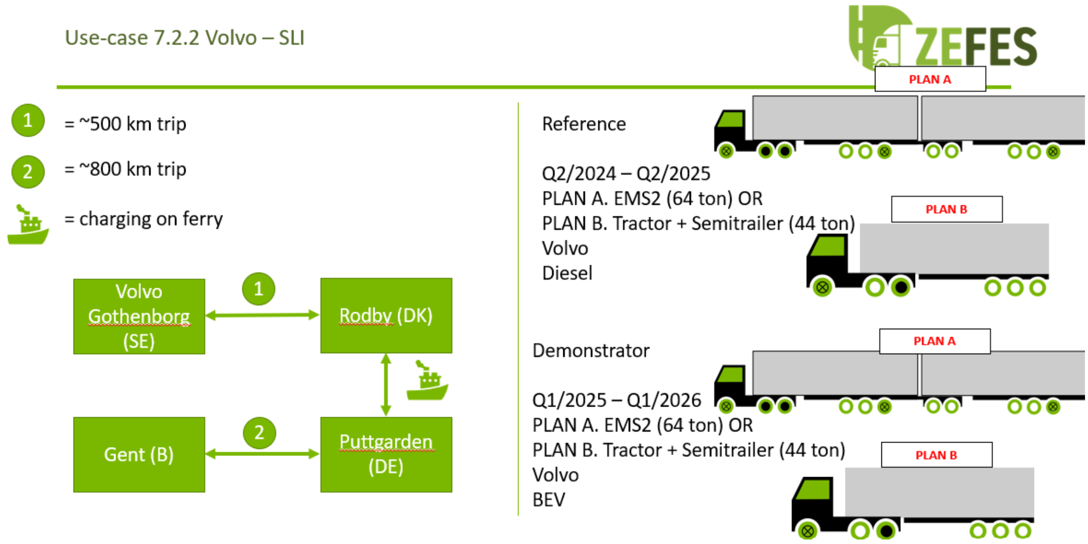


Figure 2.6 Use case7.2.2 Volvo - SLI

The Use case 7.2.2 is a Volvo use case where Volvo Logistics is the stakeholder. Since the demonstration is not yet fully finalized, there are two plans proposed for the demonstrator vehicle. The demonstrator vehicle will operate for a period of 12 months.

The vehicle: Plan A is to use a 6x2 64-ton EMS2 vehicle configuration, whilst Plan B is to use a 6x2 44-ton tractor-semitrailer combination. In either plan the vehicle will have a fully electric (BEV) powertrain.

The route: The vehicle starts at the Volvo factory in Gothenburg, Sweden and drives towards Rodby in Denmark, a trip of about 500 km. Here, it is loaded on a ferry towards Puttgarden in Germany. The vehicle could charge on the ferry depending on the available technology on board. Finally, the vehicle leaves the ferry and drives towards Gent in Belgium, a trip of about 800 km.

USP: The USP of this use case is the demonstration of a completely electrified, cross-border, multi-modal, logistics operation with a single driver.

The reference vehicles are assumed to be the same as the demonstrator vehicles but with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.3 Use Case 7.2.3 Volvo – P&G

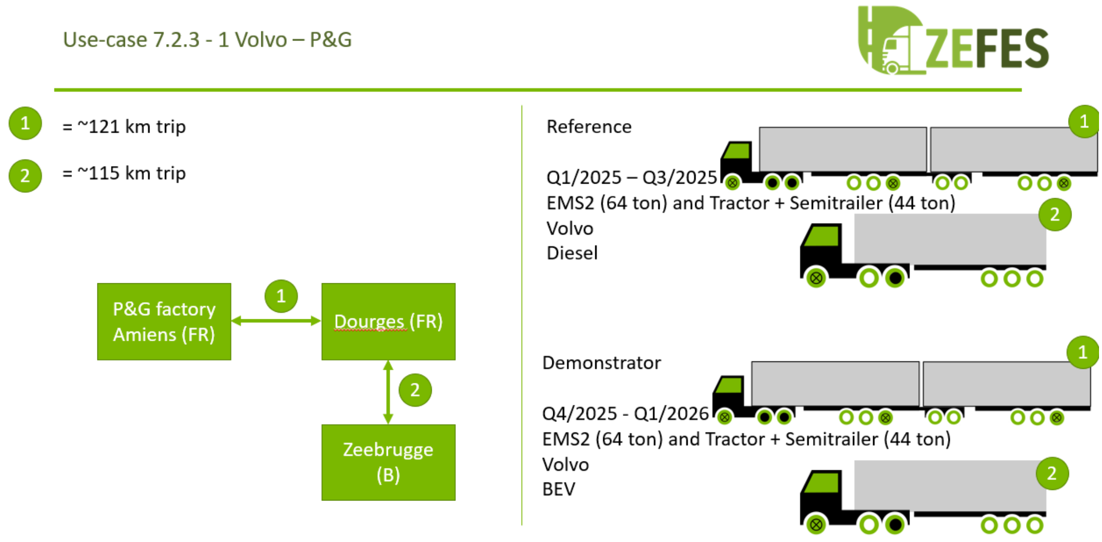


Figure 2.7 Use case 7.2.3. Volvo - P&G

The Use case 7.2.3 has two sub parts: the first part runs for 6 months. This is a Volvo use case where P&G is the stakeholder. (For the second part see Section 2.3.4)

The vehicle: The vehicle used for the demonstration is a 6x2 64-ton tractor + duo container-trailer (EMS2) for one part of the trip. In the second part of the trip, the dolly would decouple from the vehicle and it would operate remotely controlled as a 44-ton tractor + semitrailer combination. Throughout the use case it will be a fully electric (BEV) powertrain.

The route: The vehicle (in EMS2 configuration) starts at the P&G factory in Amiens, France and drives towards the multimodal terminal in Dourges, France. Finally, it drives (in tractor + semitrailer configuration) from Dourges to the multimodal terminal in Zeebrugge, Belgium. The total round trip is about 550 km. The use case will be set up along three phases, Phase 1) the operation as a standard tractor + semi-trailer, Phase 2) the operation as duo trailer and, Phase 3) the remote-controlled operation at the terminal.

USP: The USP of this use case is the demonstration of duo trailer of a fully electric vehicle with remote dolly operation at the terminal in Dourges.

The reference vehicles are assumed to be the same as the demonstrator vehicles with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.4 Use Case 7.2.3 Volvo – PRI

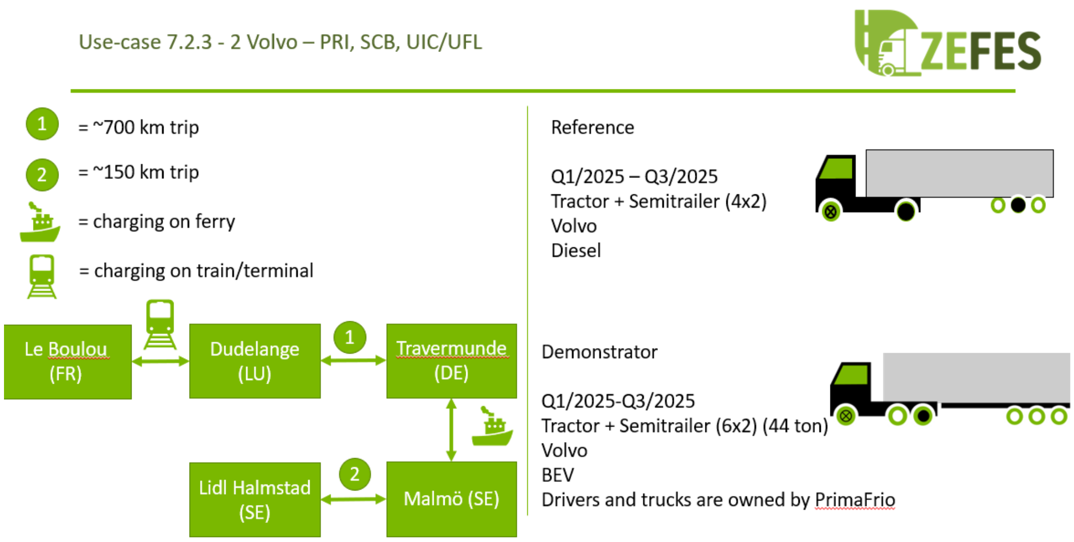


Figure 2.8 Use case 7.2.3. Volvo - PRI

Use case 7.2.3 has two parts, where the second sub-use case runs for 6 months. This is a Volvo use case, where PRI, SCB and UCI/CFL are the stakeholders. The first part was already described in Section 2.3.3)

The vehicle: The vehicle used for the demonstration will be a 6x2 44-ton tractor + semitrailer combination. It will be a fully electric (BEV) powertrain vehicle with an e-trailer with a cooling compartment (e-cooled trailer) and an e-axle.

The route: The route starts in Le Boulou, France, where the e-cooled trailer is transported by rail to the CFL multimodal terminal in Dudelange in Luxembourg. There is charging on the train. From Dudelange the vehicle drives to Travemünde in Germany, where it is loaded on the ferry to Malmo in Sweden. The final leg is the drive from Malmo to Lidl in Halmstad, Sweden.

USP: The USP of this use case is the demonstration of a BEV tractor + semitrailer with 2 drivers for 1200 kms daily and charging on the rail wagon.

The reference vehicle is a 4x2 tractor semi-trailer combination with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.5 Use case 7.2.4 Volvo – DPD

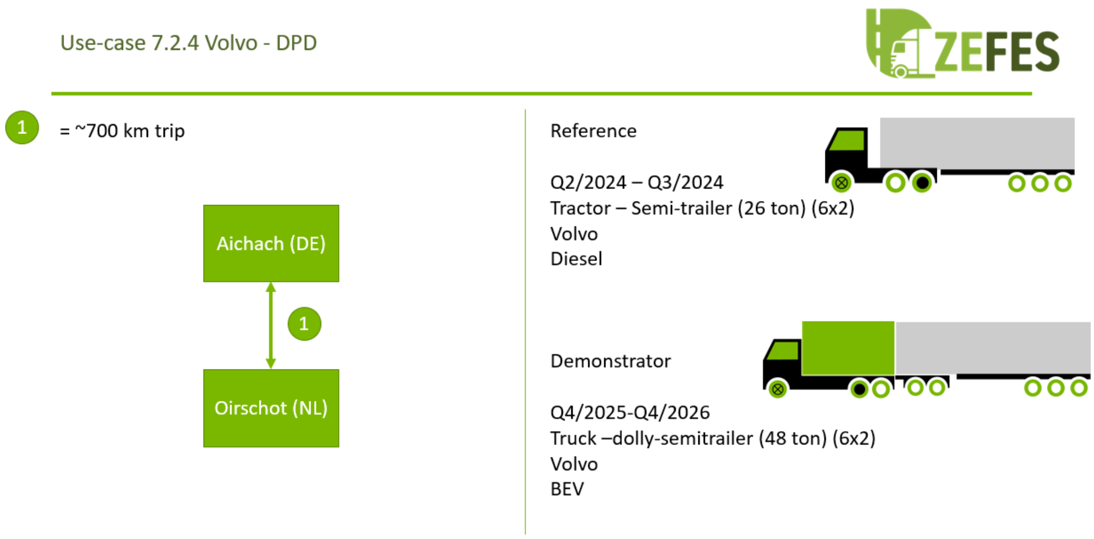


Figure 2.9 Use case 7.2.4. Volvo - DPD

The Use case 7.2.4 is a Volvo use case, with DPD as the stakeholder. The demonstrator vehicle will operate for a period of 6 months.

The vehicle: The vehicle used for the demonstration will be a 6x2 rigid truck with a dolly and E-trailer with a full operational propulsion. It will run at 48 tonnes gross combination weight. It will be a fully electric vehicle, a BEV. The E-trailer is developed and supplied by VET / KAE.

The route: The route starts in Aichach, near Munich, Germany and ends in Oirschot, near Eindhoven in the Netherlands. The trip is about 700 km in distance.

USP: The USP of this use case is the demonstration of 3 swap bodies and the e-powertrain within each vehicle unit.

The reference vehicle is a tractor semi-trailer combination with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.6 Use case 7.3.1 Scania – SLI

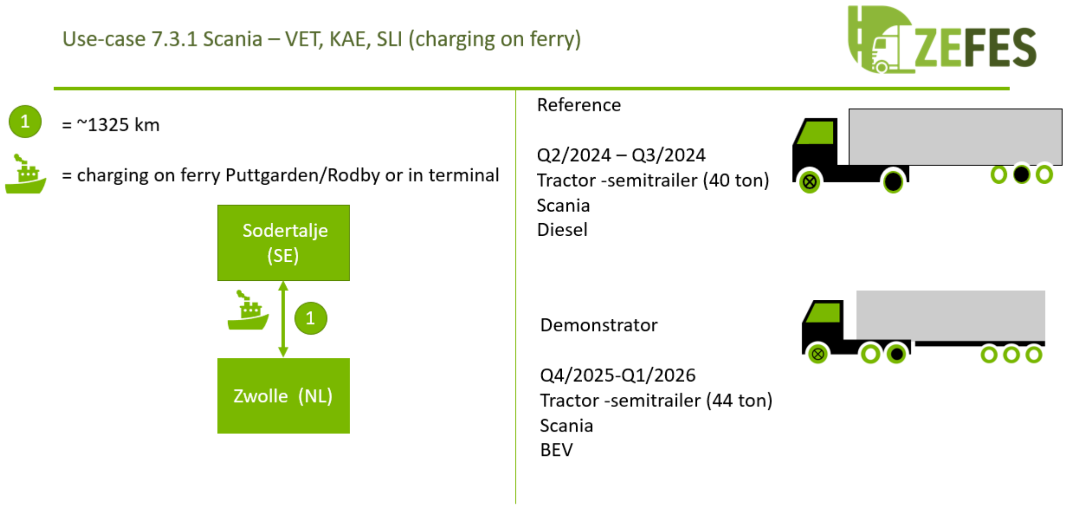


Figure 2.10 Use case 7.3.1. Scania - SLI

The Use case 7.3.1 is a Scania use case with Scania Logistics as the stakeholder. The demonstrator vehicle will operate for a period of 6 months.

The vehicle: The vehicle used for the demonstration will be a 4x2 44-ton tractor + semi-trailer and alternatively an E-trailer (equipped with an electric axle). It will be a fully electric vehicle, a BEV. The E-trailer is developed and supplied by VET / KAE.

The route: The route is a round-trip starting in Sodertalje, Sweden and ending in Zwolle, in the Netherlands. There is a ferry between Puttgarden in Germany and Rodby in Denmark, with possible charging on the ferry or in the terminal. The trip is about 1325 km distance.

USP: The USP of this use-case is the evaluation of a cross-border multi-modal operation with a fully electric vehicle.

The reference vehicle is a Scania 4x2 40-ton tractor + semi-trailer with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.7 Use case 7.3.2 Scania – VET, GRU

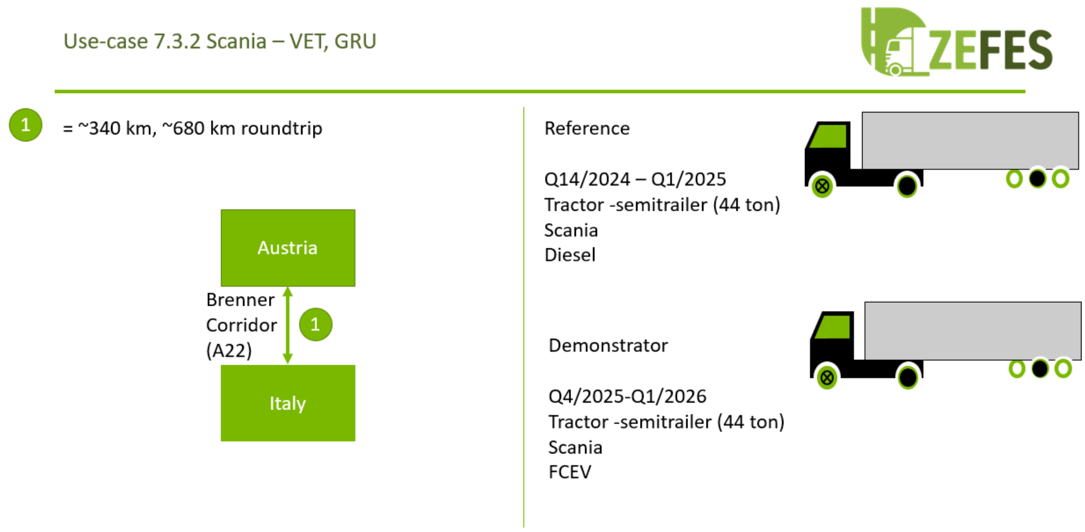


Figure 2.11 Use case 7.3.2. Scania - VET, GRU

The Use case 7.3.2 is a Scania use case with GRU as stakeholders. The demonstrator vehicle will operate for a period of 6 months.

The vehicle: The vehicle used for demonstration will be a 6x2 or a 6x4, 44-ton tractor + semi-trailer. It will be a FCEV.

The route: The route is based on the A22 in the Berner corridor. It drives from Austria to Italy. The operator (GRU) has the possibility to choose a different destination to check the performance of the vehicle. It is about a 680 km roundtrip.

USP: The USP is to demonstrate a 100% green transportation on an international corridor.

The reference vehicle is a Scania 4x2 44-ton tractor + semi-trailer with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.8 Use case 7.3.3 Scania – PRI, IDI, MIC, GSS, CM

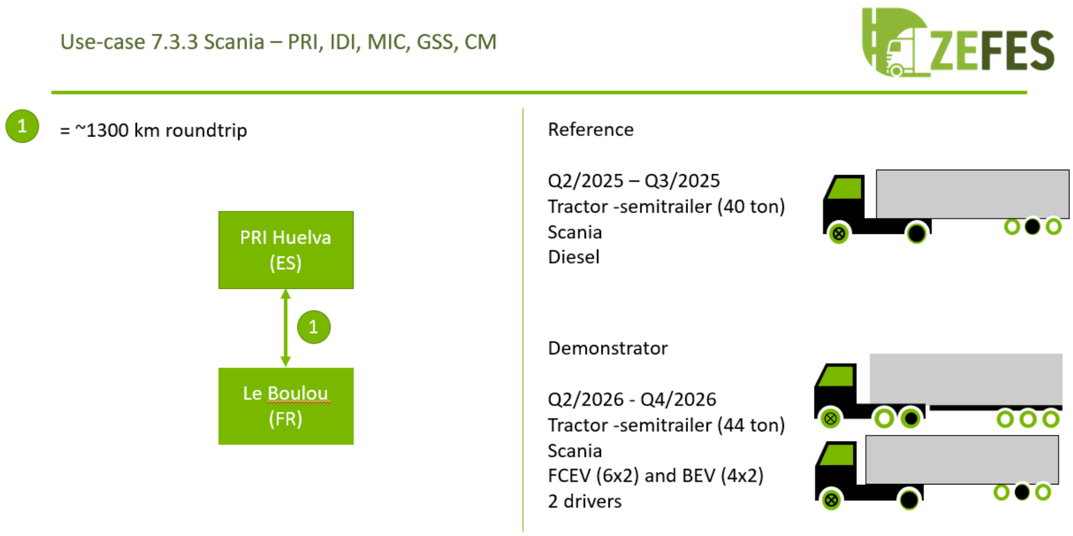


Figure 2.12 Use case 7.3.3. Scania - PRI, IDI, MIC, GS, CM

The Use Case 7.3.3 is a Scania use case with PRI as stakeholders. This use case provides a direct comparison between a FCEV and a BEV under identical conditions on the same operation. The demonstrator vehicles will operate for a period of 6 months each.
The vehicle: The vehicles used for demonstration will be a 4x2 44-ton tractor + semi-trailer BEV and a 6x2 44-ton tractor + semi-trailer FCEV. The semi-trailer will be an e-reefer type, operating emission free.
The route: The route is a 1300 km round trip between PRI Huelva in Spain and the multimodal terminal in Le Boulou, France. It will be a 2-driver operation.
USP: The USP of this use case is the direct comparison of a FCEV and a BEV on an identical route.

The reference vehicle is assumed to be a Scania 4x2 40-ton tractor + semi-trailer with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.9 Use case 7.3.4 Scania – GSS

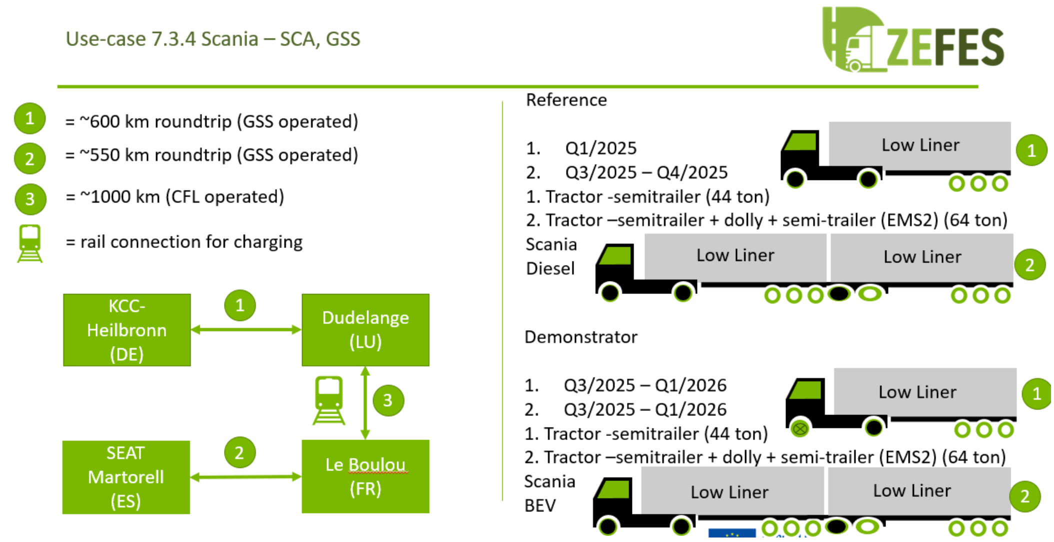


Figure 2.13 Use case 7.3.4. Scania - GSS

The Use case 7.3.4 is a Scania use case where GSS acts as the stakeholder. It includes driving 3 months on one route in one vehicle configuration, followed by driving for 3 months on another route in another vehicle configuration.
The vehicle: The vehicle for the first three months is a 4x2 44-ton (low-liner) tractor + (low-liner) semi-trailer. The vehicle driven for the next 3 months is a 4x2 64-ton (low-liner) tractor + (low-liner) semi-trailer + dolly + (low-liner) semi-trailer (EMS2). Both of these configurations would be BEV.
The route: The first three months of the demonstration would be driven on the route between KCC-Heilbronn in Germany and Dudelange in Luxembourg, a roundtrip of around 500 km. This would be done in the first vehicle configuration defined. For the next three months, the vehicle, in its second vehicle configuration, drives between Le Boulou in France and SEAT Martorell in Spain, a roundtrip of around 550 km. The rail operation between Dudelange and Le Boulou is about 1000 km distance.
USP: The USP of this use case is the operation of a BEV low-liner with battery on the low-liner semi-trailer.

The reference vehicles are assumed to be the same as the demonstrator vehicles with a diesel powertrain running on the same route as the demonstrators. The final description of the use-cases will be published in D7.1 in the project.

2.3.10 Use case 7.4.1 Renault – MIC

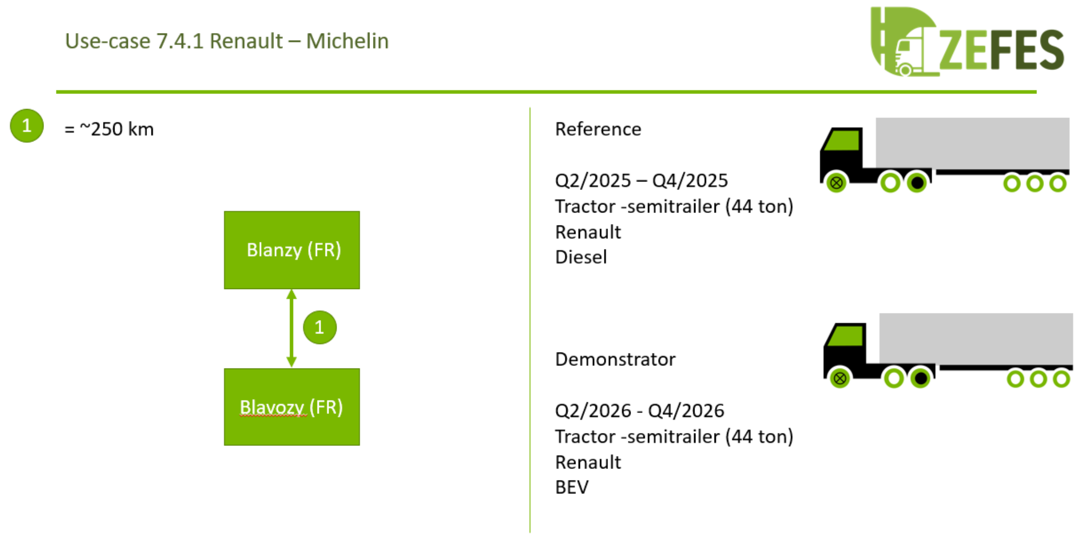


Figure 2.14 Use case 7.4.1. Renault - MIC

The Use case 7.4.1 is a Renault use case where MIC acts as the stakeholder. It includes driving 3 to 6 months on an existing route, between two Michelin plants.

The vehicle: The vehicle is a 6x2 44-ton tractor + semi-trailer combination vehicle. It is a BEV and will have prototype Michelin tyres.

The route: The route is roughly 250 km that runs from the Michelin plant in Blanzy, France to Blavozy, France. The vehicle will drive back and forth between these places to cover a distance of about 500 km daily. There is a rest time of 45 minutes planned for the driver at Blavozy.

USP: The USP of this use case is the evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin. It is also to check the impact of improvement in the wear resistance, with a compromise in rolling resistance as compared to the current market tyres.

The reference vehicle is assumed to be the same as the demonstrator vehicle with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.11 Use case 7.4.2 Renault – Renault

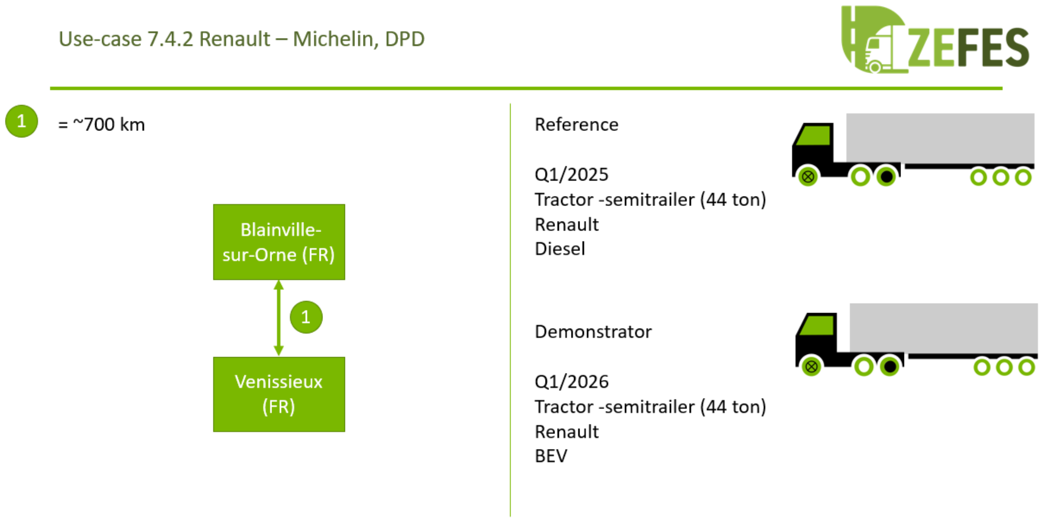


Figure 2.15 Use case 7.4.2. Renault - Renault

The Use case 7.4.2 is a Renault use case where Renault also acts as the stakeholder. It includes driving on an existing Renault trucks logistics flow for 3 months.
The vehicle: The vehicle is a 6x2 44-ton tractor + semi-trailer combination vehicle. It will be a BEV and will have prototype Michelin tyres.
The route: The route is roughly 700 km, it runs from the Blainville in France to Venissieux in France. The trailer is swapped from one tractor to the other at Courtenay in France, after about 350 km from the start.
USP: The USP of this use case is the evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin. The checks for durability will be performed during the demonstration.

The reference vehicle is assumed to be the same as the demonstrator vehicle with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.12 Use case 7.4.3 Renault – DPD

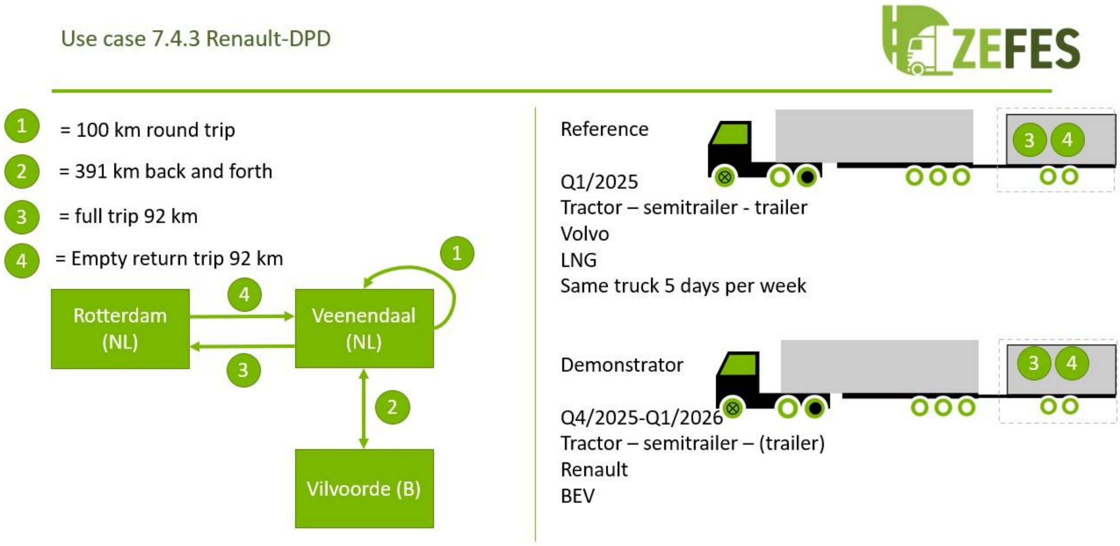


Figure 2.16 Use case 7.4.3. Renault - DPD

The Use Case 7.4.3 is a Renault use case where DPD acts as the stakeholder. It includes driving on an existing DPD logistics flow for 6 months. For one part of the logistics route, the vehicle drives in one configuration and as another configuration on the other part of the route.

The vehicle: The two configurations are a 6x2 44-ton tractor + semi-trailer and a 6x2 44-ton tractor + semi-trailer + trailer (EMS1). Both will be BEV.

The route: The route is a total of about 675 km. It starts with a pick -up round in Veenendaal , in the Netherlands of about 100 km long, as a tractor + semi-trailer combination. This is followed by driving about 400 km from Veenendaal to Vilvoorde near Brussels, Belgium and back to Veenendaal. This part is also driven as a tractor + semi-trailer combination. The last leg of the journey is a about 200 km trip from Veenendaal to Rotterdam in the Netherlands and back. The return trip is an empty vehicle returning to Veenendaal. This part of the trip is driven as a tractor + semi-trailer + trailer combination (EMS1).

USP: The USP of this use case is the evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin. It is also to evaluate the feasibility of a traditional full round trip cross border logistics parcel route in 2 different vehicle configurations. The charging times will have to be aligned with driving/rest time schedule and critical time slots at depots.

Since it is an existing logistics route, a reference test is already being performed in the same vehicle configurations defined above. It is a Volvo tractor that runs on LNG.

2.3.13 Use case 7.6.1 Ford – EKO

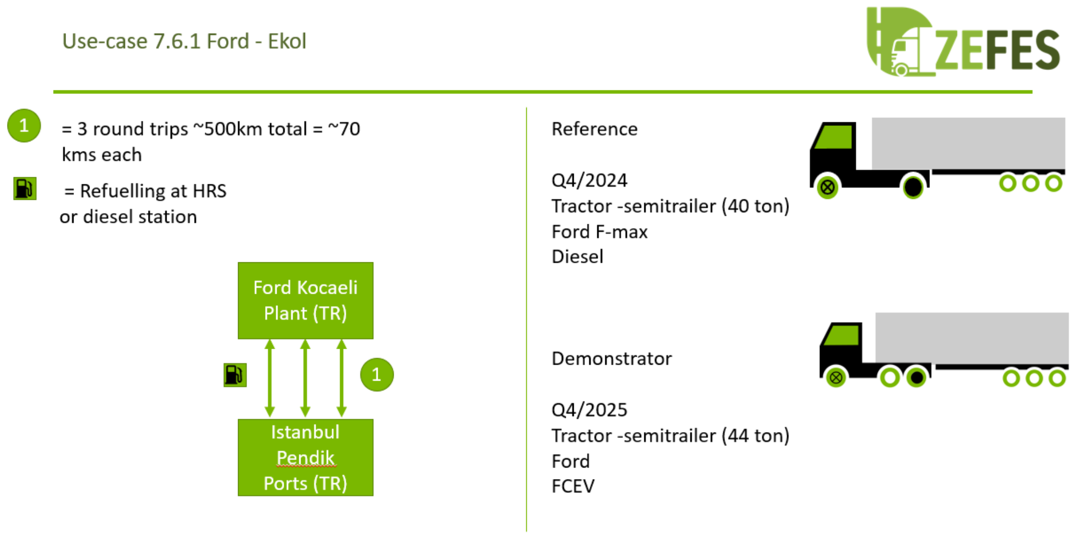


Figure 2.17 Use case 7.6.1. Ford - Ekol

The Use case 7.6.1 is a Ford use case where EKO acts as the stakeholder. It includes driving on a regional, national, long-haul profile for 2-3 months.

The vehicle: The vehicle is a 6x2 44-ton tractor + semi-trailer combination vehicle. It will be a FCEV.

The route: The route is roughly 70 km. it runs from the Ford plant in Kocaeli, Turkey to the Istanbul Pendik Ports. There will be 3 round trips per day, thereby covering a total distance of about 500 km daily.

USP: The USP of this use case is the operation of an FCEV heavy-duty vehicle in a non-EU country.

The reference vehicle is a 40 ton tractor semi-trailer with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.14 Use Case 7.6.2 Ford – GBW

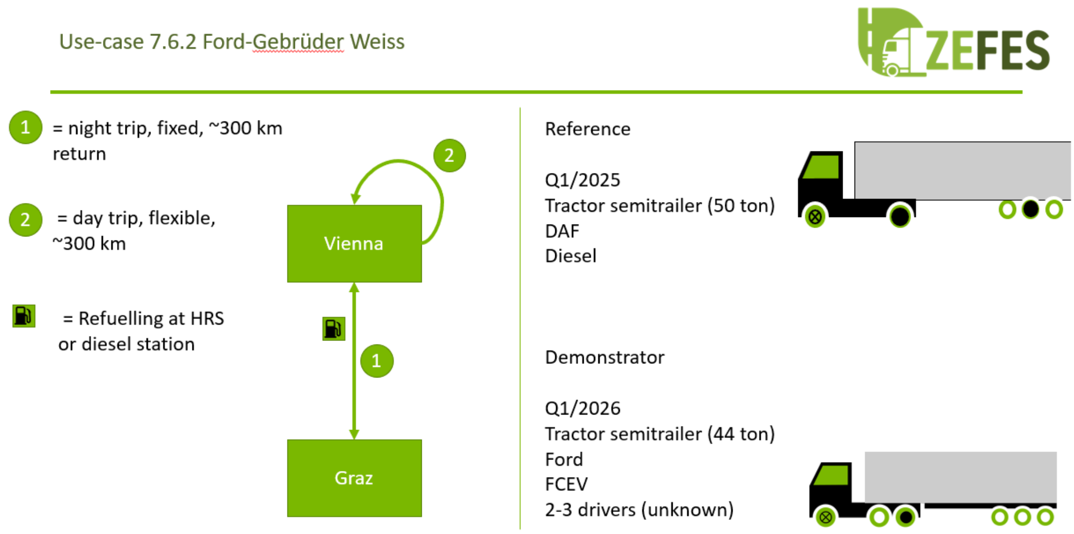


Figure 2.18 Use Case 7.6.2. Ford - GBW

The Use case 7.6.2 is a Ford use case where GBW acts as the stakeholder. It includes driving on an existing logistics network, on a daily. regional-national, long-haul profile for 3 months.
The vehicle: The vehicle is a 6x2 44-ton tractor + semi-trailer combination vehicle. It will be a FCEV.
The route: The route consists of a round trip between Vienna and Graz in Austria. This is followed by a general parcel distribution in the area surrounding Vienna. The total distance covered in the day is 600-700 km.
USP: The USP of this use case is the operation of an FCEV heavy-duty vehicle in a regional, national, long-haul (VECTO equivalent) mission profile.

The reference vehicle is one which is driving on a similar route but is a DAF 50 ton tractor semi-trailer with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.15 Use case 7.6.3 Ford – P&G

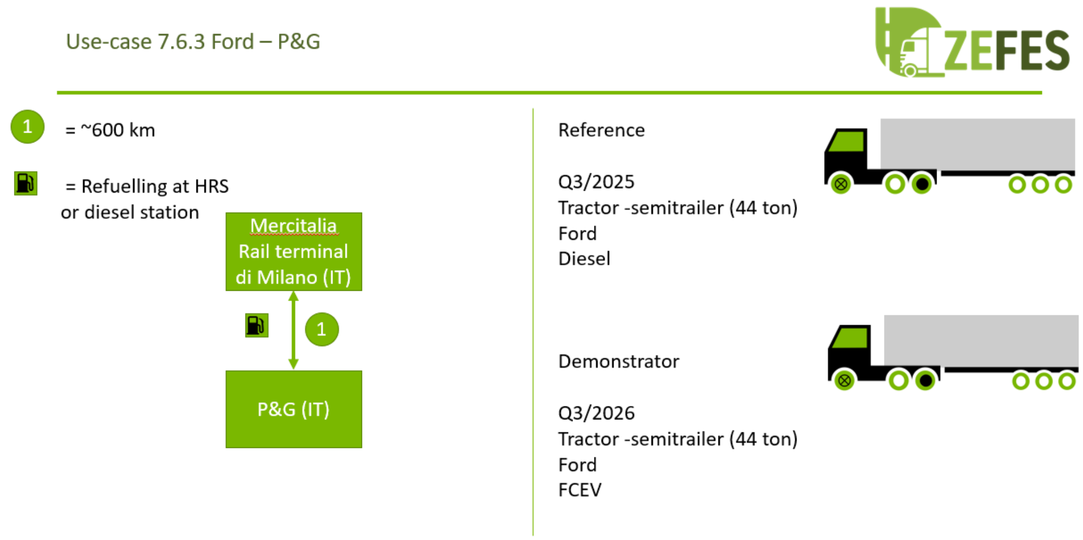


Figure 2.19 Use case 7.6.3. Ford - P&G

The Use case 7.6.3 is a Ford use case where P&G acts as the stakeholder. It includes driving in a national, multimodal flow, long-haul profile for 3 months.
The vehicle: The vehicle is a 6x2 44-ton tractor + semi-trailer combination. It will be a FCEV.
The route: The route consists of about 600 km trip from the Mercitalia Rail terminal di Milano in Italy to the P&G office in Vescovo, Italy. The route goes through a mountainous terrain with the use of tunnels.
USP: The USP of this use case is the operation of an FCEV heavy-duty vehicle in a hilly, national, long-haul (VECTO equivalent) mission profile.

The reference vehicle is assumed to be the same as the demonstrator vehicle with a diesel powertrain running on the same route as the demonstrator. The final description of the use-cases will be published in D7.1 in the project.

2.3.16 Overview of all the use cases

The use cases are summarized in the following table. The reference vehicle in the table is the current choice of the reference vehicle and the expected reference vehicle is the best case scenario of a reference vehicle. The latter would help in making a more sound comparison to the demonstrator vehicle.

Table 2.33 Summary of the use cases

Name	Origin - Destination	Total Distance [km]	Duration	USP	Demonstrator Vehicle	Reference Vehicle	Expected reference vehicle

7.2.1 Volvo - OVA, APG	Gothenurg (SE) - Hofors (SE)	1000 km round-trip, 5x per week	12 months	EMS1 in long haul transportation	6x2 64 ton FCEV EMS1	Unknown	6x2 64 ton diesel EMS1
7.2.2 Volvo - SLI	Gothenburg (SE) - Gent (B)	1300 km	12 months	vehicle in cross-border, multimodal operation with a single driver	Plan A: 6x2 64 ton BEV EMS2 Plan B: 6x2 44 ton BEV tractor + semi-trailer	Unknown	Plan A: 64 ton diesel EMS2 Plan B: 44 ton diesel tractor + semi-trailer
7.2.3 Volvo - P&G	Amiens (FR) - Zeebrugge (B)	550 km round-trip	6 months	demonstration of a duo-trailer of a BEV with remote dolly operation at the terminal in Dourges	Part 1: 6x2 64 ton BEV EMS2 Part 2: 6x2 44 ton BEV tractor + semi-trailer	Unknown	Part 1: 6x2 64 diesel ton EMS2 Part 2: 6x2 44 ton diesel tractor + semi-trailer
7.2.3 Volvo - PRI	Le Boulou (FR) - Halmstad (SE)	1200 km	6 months	demonstration of a BEV tractor + semitrailer with 2 drivers for 1200 km daily	6x2 44 ton BEV tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer	6x2 44 ton diesel tractor + semi-trailer
7.2.4 Volvo - DPD	Aichach (DE) - Oirschot (NL)	700 km	6 months	demonstration 3 swap bodies and the e-powertrain within each vehicle unit.	6x2 48 ton BEV rigid truck with a dolly and E-trailer	6x2 48 ton diesel tractor semi-trailer	6x2 48 ton diesel rigid truck with a dolly and E-trailer
7.3.1 Scania -SLI	Sodertalje (SE) - Zwolle (NL)	1325 km	6 months	Cross-border multimodal operation of a fully electric vehicle	4x2 44 ton BEV tractor + semi-trailer	4x2 40 ton diesel tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer

7.3.2 Scania -VET, GRU	Austria - Italy	680 km round-trip	6 months	100% green transportation on an international corridor with an FCEV powertrain vehicle	4x2 44 ton FCEV tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer
7.3.3 Scania - PRI, IDI, MIC, GSS, CM	Huelva (ES) - Le Boulou (FR)	1300 km round-trip	6 months	direct comparison of a FCEV and a BEV on an identical route	Vehicle 1: 4x2 44 ton BEV tractor + semi-trailer Vehicle 2: 4x2 44 ton FCEV tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer
7.3.4 Scania - GSS	Heilbronn (DE) - Martorell (ES)	Part 1: 600 km round-trip Part 2: 550 km round-trip	Part 1: 3 months Part 2: 3 months	operation of a BEV low-liner with battery on the low-liner semi-trailer and charging on the rail wagon	Part 1: 4x2 44 ton BEV tractor + (low-liner) semi-trailer Part 2: 4x2 44 ton BEV (low-liner) EMS2	Unknown	Part 1: 4x2 44 ton diesel tractor + (low-liner) semi-trailer Part 2: 4x2 44 ton diesel (low-liner) EMS2
7.4.1 Renault - MIC	Blanzy (FR) - Blavozy (FR)	250 km	3-6 months	evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin	6x2 44 ton BEV tractor + semi-trailer	Unknown	6x2 44 ton diesel tractor + semi-trailer
7.4.2 Renault - Renault	Blainville-sur-Orne (FR) - Venissieux (FR)	700 km	3 months	evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin	6x2 44 ton BEV tractor + semi-trailer	Unknown	6x2 44 ton diesel tractor + semi-trailer

7.4.3 Renault - DPD	Veenendaal (NL) - Vilvoorde (B) - Veenendaal (NL) - Rotterdam (NL) - Veenendaal (NL)	675 km	6 months	1. Evaluation of the impact of electrification of vehicles on the prototype tyres from Michelin 2. Evaluate the feasibility of a traditional full round trip cross border logistics parcel route in 2 different vehicle configurations	Configuration 1: 6x2 44 ton BEV tractor + semi-trailer Configuration 2: 6x2 44 ton BEV EMS1	Configuration 1: 6x2 44 ton LNG tractor + semi-trailer Configuration 2: 6x2 44 ton LNG EMS1	Configuration 1: 6x2 44 ton diesel tractor + semi-trailer Configuration 2: 6x2 44 ton diesel EMS1
7.6.1 Ford - EKO	Kocaeli (TR) - Istanbul Pendik Ports (TR)	70 km, 3 round trips, 500 km total	2-3 months	operation of an FCEV heavy-duty vehicle in a non-EU country	6x2 44 ton FCEV tractor + semi-trailer	4x2 44 ton diesel tractor + semi-trailer	6x2 44 ton diesel tractor + semi-trailer
7.6.2 Ford - GBW	Vienna (AT) - Graz (AT)	600 - 700 km	3 months	operation of an heavy-duty FCEV in a regional, national, long haul VECTO mission profile	6x2 44 ton FCEV tractor + semi-trailer	4x2 50 ton diesel tractor + semi-trailer	6x2 44 ton diesel tractor + semi-trailer
7.6.3 Ford - P&G	Mercitalia Rail terminal di Milano (IT) - P&G (IT)	600 km	3 months	operation of an heavy-duty FCEV in a hilly national long haul VECTO mission profile	6x2 44 ton FCEV tractor + semi-trailer	Unknown	6x2 44 ton diesel tractor + semi-trailer

2.4 Innovations

Reference vehicles will be compared to demonstration vehicles, but the demonstration vehicles shall also be compared to demonstration vehicles with ZEFES innovations. Here we list the ZEFES innovations that will be assessed.

Flexible and modular vehicle platform for both BEV and FCEV

Flexible and modular vehicle platforms are made for all vehicles that use batteries and/or fuel cells. This has obvious benefits in terms of scale and time-to-market for new models. Part of the project is the physical implementation of specific powertrain components, subsystems, their improved control systems, and energy and thermal management systems. During the project, the optimal configurations of the modular powertrains are determined. This includes the right choice of components and the best strategies. The key ZEFES innovations per OEM are listed below:

- **BEV** truck that has 82% energy efficiency and **FCEV** that has 44 % energy efficiency

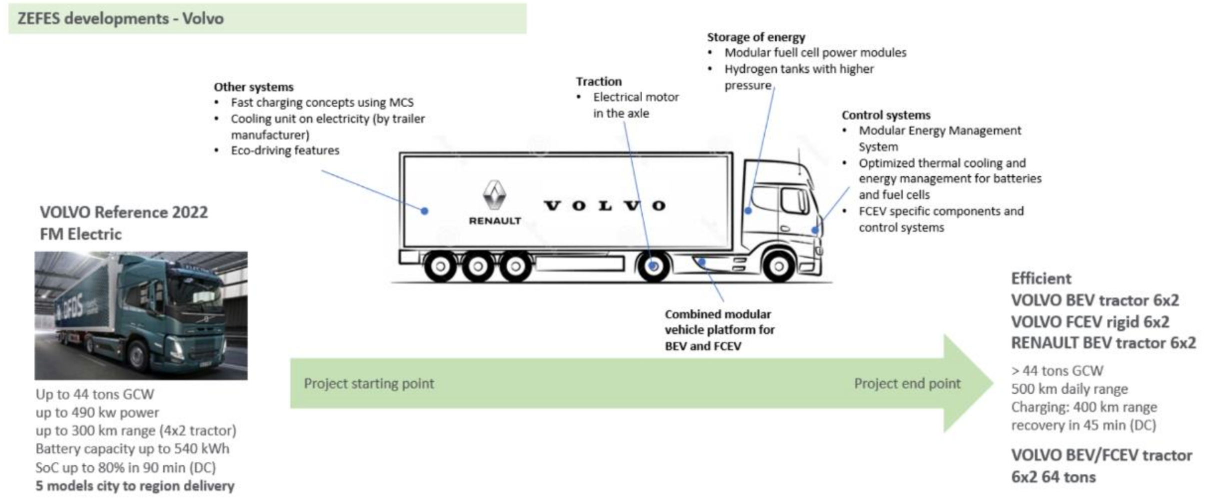


Figure 2.20 Volvo and Renault truck innovations [Source: Consortium Agreement document]

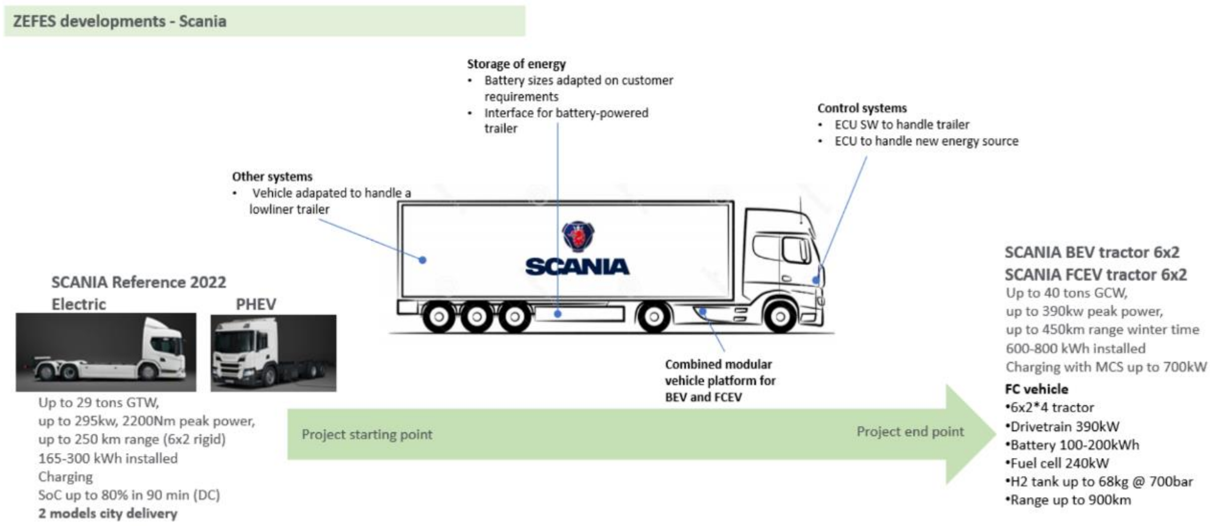


Figure 2.21 Scania truck innovations [Source: Consortium Agreement document]

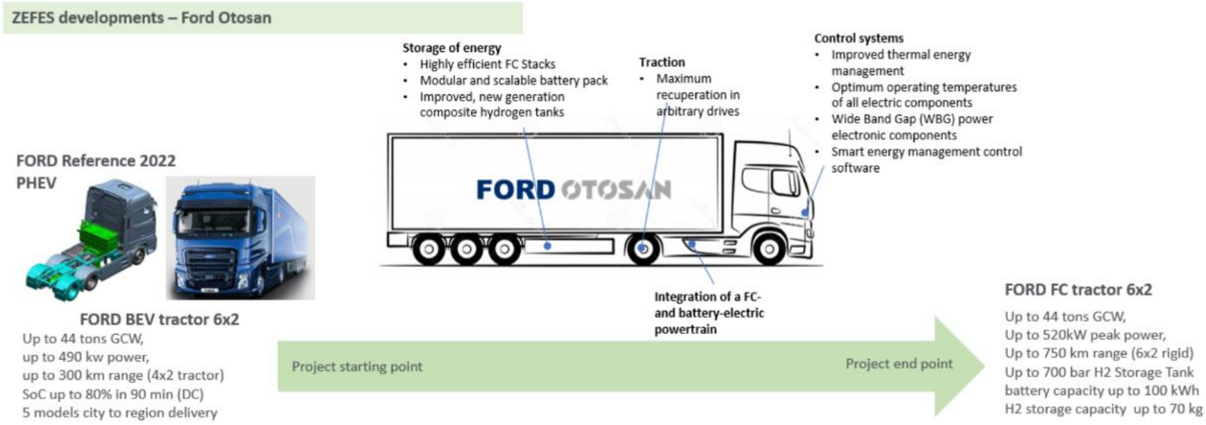


Figure 2.22 Ford truck innovations [Source: Consortium Agreement document]

- Battery trailer (B-trailer)
  In addition to the innovations in the field of the E-trailer, part of the project is also the development of a trailer in which only batteries are included without e-axles on the trailer (B-trailer). The energy stored in the B-trailer will be transferred to the prime mover and used for the propulsion of the prime mover. This means that a high-power coupling will be fitted between the trailer and prime mover, which requires extra attention concerning safety. The prime mover can be a BE or FCE powertrain. Part of the project is the development and optimization of the interfaces (hardware and software).
  A new design of a modular battery housing is created, which is adaptable to the needed capacity for the range extension. The housing needs to fit in (ultra) low-deck trailers and a standard height (container) trailer will be considered. From the housing, the cable connection to the towing vehicle must be realized safely. The batteries in the trailer will have the possibility to recharge by plug-in on the road.

- E-trailer (trailer with electric drivetrain) and/or E-dolly (dolly with electric motor and small battery)
  The earlier AEROFLEX project demonstrated the fundamental potential for improvement in the use of electrically powered vehicles. However, it also showed the need to verify the knowledge gained in real situations and missions. The findings from the previous project have also led, amongst other things, to improved axle concepts, requirements for the control models, and the electrical and driving dynamics application models of the E-trailer.

  In ZEFES, an improved mechanical design for an E-trailer will be developed. The core of the work will be the housing of the required battery capacity, the implementation of a new generation of e-drive control units and the use of the latest generation of e-axles. The e-drive control takes over the control of the electric drive in conjunction with energy consumption management. In addition, the existing braking and stability control systems have to be integrated into E-trailers and an external charging option for the battery will be implemented. The trailer can thus contribute to the traction power independently or in combination with the towing vehicle. A connection is required for the E-trailer to control the powertrain in the combination of the prime mover and trailer. Interoperable interfaces to the modular E-trailer will be implemented and deployed, including a new interface to the IoT and VCU (hardware) communication units to the E-trailer (e.g. extra CAN), enabling the extra hybrid mode with E-trailer via software (to provide the reference power to the E-trailer control unit) and then verification of the prime mover-E-trailer communication protocol system. The mechanical interfaces with the E-trailer will be also upgraded.

Another step of the project is the implementation of the aerodynamic components. In addition, new design concepts that were examined in AEROFLEX (trailer front edge fairing and trailer diffuser) will be integrated into the new E-trailer, and their business potential will be examined. Finally, the new E-trailer should be assembled, tested and homologated for the various demonstrations with truck solutions.

- Improve HVAC system

  Thermal management is generally a collection of effectively independent heating and cooling systems (for the battery, for the fuel cell, the PEMD, the cabin, and for the payload) plus their control. Part of the project is the development of an improved thermal management system with higher efficiency and increased capacity to enable higher GCW, bigger battery packs and faster charging. Part of the improvements is a bigger capacity and lower energy use of fans which could be achieved by the use of bigger components. Additionally, HVAC systems will be improved to optimize the heat exchange between the vehicle system and cabin, e.g. with a heat pump system.

  Furthermore, energy management systems in the VCU will be improved, by adding eco-driving and eco-comfort strategies. Also "model-predictive energy management control" will be implemented, which is software used to enable an optimal energy split between FC and battery system. Next to that, powertrain control will be adapted to minimize the consumption of H_2 (kg/km) over the mission profile and to optimize the lifetime of the FC system. Here, the deployment of the control system will be as a new hybrid mode with battery in the trailer via master/slave control concept.

<u>Michelin tyres (e-tyres)</u>

The new powertrain concepts of ZEFES are distributing the load and torque amongst the vehicle axles differently when compared to regular, ICE powertrains. This will have a significant impact on the operating conditions of the tyres. On the pulling unit, a combination of higher loads (to accommodate, e.g., extra battery weight) is expected, coupled, on the drive axle, with higher driving torques and significantly more braking torque (to regenerate energy). The new concepts of the trailers will also require higher load capacity. In addition, electrified axles (E-trailer or dolly) will imply a new driving torque and braking torque on the trailer tyres. In ZEFES, Michelin will make new tyres for the e-drive axles, available for the demonstrations in real-world missions (WP7) to validate that the expected durability reductions without compromising the rolling resistance performance (and thus the vehicle keeping the expected daily range).

<u>Fast charger improves efficiency 80% efficiency) and capable of adding 400km in 45 minutes</u>

The project will develop interoperable hardware and software for the use of the Megawatt Charging System (MCS) further, based on earlier developments in this field. Two concepts will be developed: a "Multiport MCS" (with different power levels greater than 1MW and with MCS interface and CCS interface) and a "Mobile and Interoperable MCS" which makes it possible to be used in different demonstrations. The systems will be interoperable between the OEMs. Next to that, continuous synchronizations for interoperability are needed, especially regarding the communication between the charger and the vehicle. The interoperable MCS system with optimized interfaces (HW, SW and communications) is developed, together with modular and SiC power electronics modules. The advanced control system layers of the MCS will be developed allowing optimal operating efficiency at a wide battery SoC window with reduced footprint during the charging process. Thanks to the developed interoperable MCS interfaces, the MCS will be compatible with all BEVs that are used in the project. The partners of the project will collaborate towards the development and standardization of the MCS.

<u>Logistics tool</u>

The logistics tool will improve work by increasing logistics efficiency to achieve energy savings during operational scenarios. It will create an end-to-end transportation model for heavy-duty, zero-emission vehicles (HD ZEV) within supply chain processes, addressing parameters such as load efficiency, capacity usage and driving, charging and resting time limitations. The tool will demonstrate integrated mission planning under the constraints of range limitations, electric and hydrogen recharging schemes. It will synchronize trip characteristics with vehicle specifications and cargo, requiring a new set-up of an interconnected transport planning and management system that provides connectivity to battery status and availability of charging capacity on the route. Additionally, it will harmonize loading and unloading processes among different stakeholders, challenging existing legacy systems and moving towards a more resilient and connected supply chain.

Not all innovations will be demonstrated in all use cases. To make explicit what innovation is planned to be demonstrated in which use case, Figure 2.23 gives the expected overview.
Note: The use of the battery trailer in the use cases is unclear at this point. Therefore, none of the use case is marked as such in the table above.

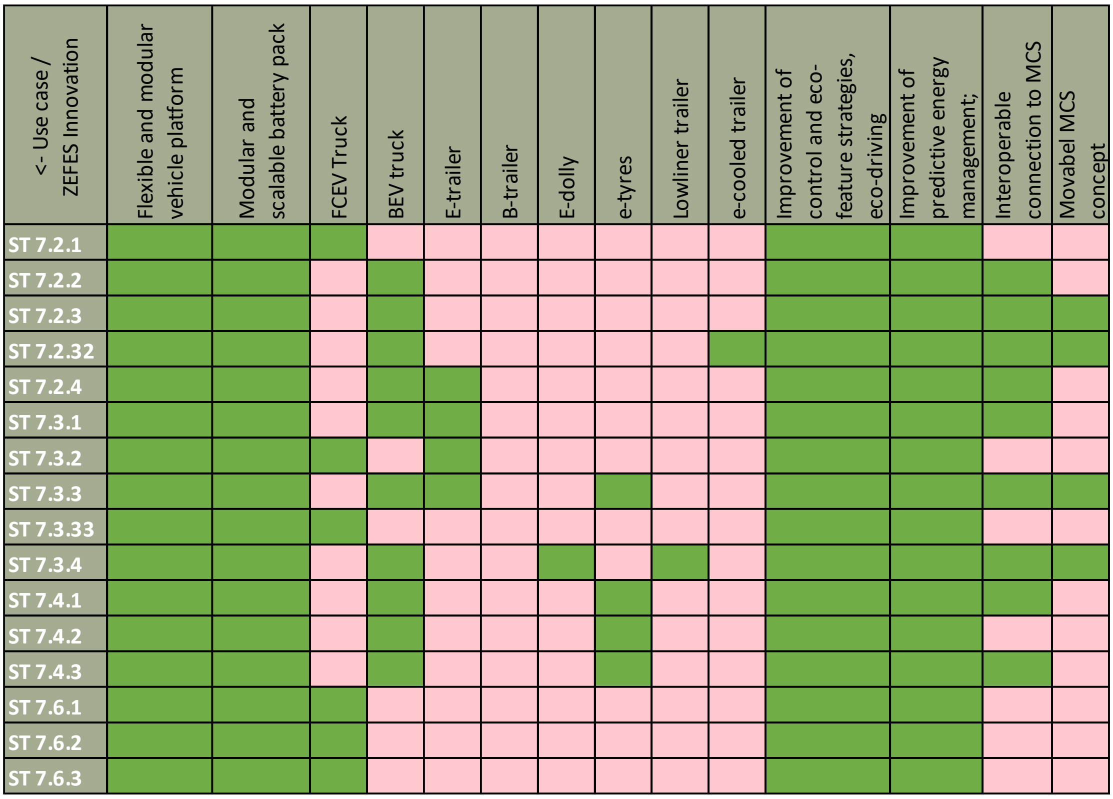


Figure 2.23 Innovations in Use cases (Green – use case contains innovation; Red – use case do not contain innovation)

2.5 Conclusion

This chapter explored the boundary conditions from other work packages, to the assessment framework and the analyses done with this framework. Table 2.34 summarizes the main conclusions from the work and links the different parts together:

- The requirements describe the expected and required functionality of the assessment framework;
- The KPI column refers to the chapter that describes how the results should be measured and calculated;
- The use cases show to what use cases the requirements are linked;
- The column chapter/reference finally looks forward how the requirements are met by the assessment framework in Chapter 3 and the data requirements in Chapter 4..

This table can be seen as a verification of the assessment framework in the sense that it meets the functional requirements, there are KPIs linked to the requirements and there are use cases defined to assess these KPI and it is clear what data needs to be logged to do so.

Table 2.34 Requirements to the assessment framework.

Group	Requirements	KPI	Use cases	Chapter/reference
Vehicle platform and trailer configurations	The assessment framework should enable the evaluation of battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV). The assessment framework should enable the evaluation of e-dolly, E-trailer and B-trailer. The assessment framework should enable the evaluation of all combinations in all use cases.	2.2.1 Powertrain KPI 2.2.3 Vehicle KPI	All	3.2.2 Vehicle powertrains. 3.2.3 Innovations. 3.3.1.1 Technical assessment of FCEV and BEV with distributed powertrains. 4.3 Vehicle specifications
Efficiency improvements	The assessment framework should enable the calculation of energy consumption in kWh; The assessment framework should	2.2.1 Powertrain KPI	All	3.3.1.1 Technical assessment of FCEV and BEV with distributed powertrains

	enable the calculation of travel distance in kilometres; The assessment framework should enable the calculation of travel time in hours; The assessment framework should enable the calculation of refuelling/charging time in hours; The assessment framework should allow for the simulation of Battery Electric and Fuel Cell Electric drivetrains and vehicles.			
Typical European long-haul road transport operations on TEN-T corridors	The assessment matrix should consist of selected use cases for typical long-haul road transport in Europe, representing at least major goods categories and applications. The assessment framework should allow for simulation of use cases that cannot be demonstrated on the road but represent a significant share of total long-haul heavy-duty logistics	2.2.5 Logistic KPI	All	2.3 Use cases
Real traffic and conditions evaluation	The assessment framework should be calibrated with reference and demonstrator test results; The assessment framework should be	N/A	All (except B-trailer UC)	4.1 Data-requirements reference tests 4.2 Demonstration tests

	validated with reference and demonstrator test results.			
Charging (MCS) and H_2 refuelling infrastructure	The assessment framework should be capable of accounting for the time needed for refuelling/charging; The assessment framework should be capable of accommodating the varying energy intake requirements during charging or refuelling sessions for different vehicle types.	2.2.4 Infrastructure KPI	7.2.2; 7.2.3-1; 7.2.3-2; 7.3.1; 7.3.3; 7.3.4-1 7.4.1 7.4.3	3.3.1.2 Charging and H2 refuelling infrastructure 3.3.1.1 Technical assessment of FCEV and BEV with distributed powertrains
Realistic simulations	The sensitivity analysis should include a variation of traffic conditions. The sensitivity analysis should include variations in weather conditions. The sensitivity analysis should include variations in road conditions. The sensitivity analysis should include variations in vehicle characteristics.		all	3.2.1 Use case simulation and . 3.3.1.1 Technical assessment of FCEV and BEV with distributed powertrains.
2ZERO Partnership requirements	The assessment framework should enable the calculation of energy intensivist in kWh/tkm; The assessment framework should enable the calculation of greenhouse gas	2.2.1 Powertrain KPI	all	Section 3.3.1 - Use-case evaluation

	(GHG) emissions per kilometre [g/km];			
E-tyres evaluation	The assessment framework should consider the tyre model and its impact on energy consumption.; The assessment framework should enable simulations with different tyres;	2.2.2 Tyre KPI	case 7.3.3; 7.4.1; 7.4.2; 7.4.3	3.3.1.5 Evaluation of Tyres

3 The assessment framework

In this chapter, the assessment framework is described. The assessment framework used in the AEROFLEX project is used as a basis and described briefly in Section 3.1. In Section 3.2 the main differences between the technical assessment in AEROFLEX and the foreseen use-case evaluation and impact assessment in ZEFES are highlighted, emphasizing what should be added to meet the requirements listed in Section 2.5. Section 3.3 includes a functional description of the assessment framework for ZEFES and finally, Section 3.4 concludes how the proposed assessment framework meets said requirements.

3.1 The ZEFES assessment framework in context of AEROFLEX

The AEROFLEX assessment framework is described in [1]. The functional description of the technical assessment carried out in the AEROFLEX project is summarized as follows:

To assess the efficiency improvement potential of AEROFLEX innovations in typical European long-haul road operations, building on the reference and demonstrator test results, using realistic simulations, and providing input to the impact assessment of the EU freight transport and book of recommendations.

To perform this technical assessment, the assessment framework has been designed in such a way that it enables:

calculating the energy efficiency for any given vehicle, equipped with any given AEROFLEX innovation or combination of innovations, used in any given transport application.

The AEROFLEX assessment framework is thus designed to perform simulations of use cases, defined as a set of trips, performed with a default vehicle and compared to a vehicle that is equipped with innovations. The reason why this approach was chosen is because the AEROFLEX innovations were only demonstrated on a single round trip, on a limited set of vehicle configurations and with a limited set of variations of the innovations. To analyze the potential fuel efficiency improvements on different use cases, varying in, e.g., location, cargo type, road geography and vehicle configuration an extended simulation program was needed to cover a variety of use cases. The use cases were defined together with logistic companies to reflect real-world scenarios.

For the simulation of use cases a stepwise approach is used that is summarized in Figure 3.1. In the figure the inputs are shown in blue, the calculation methods in green and the results in yellow. Each block is summarized in the sections below in order to analyze their applicability to the ZEFES project.

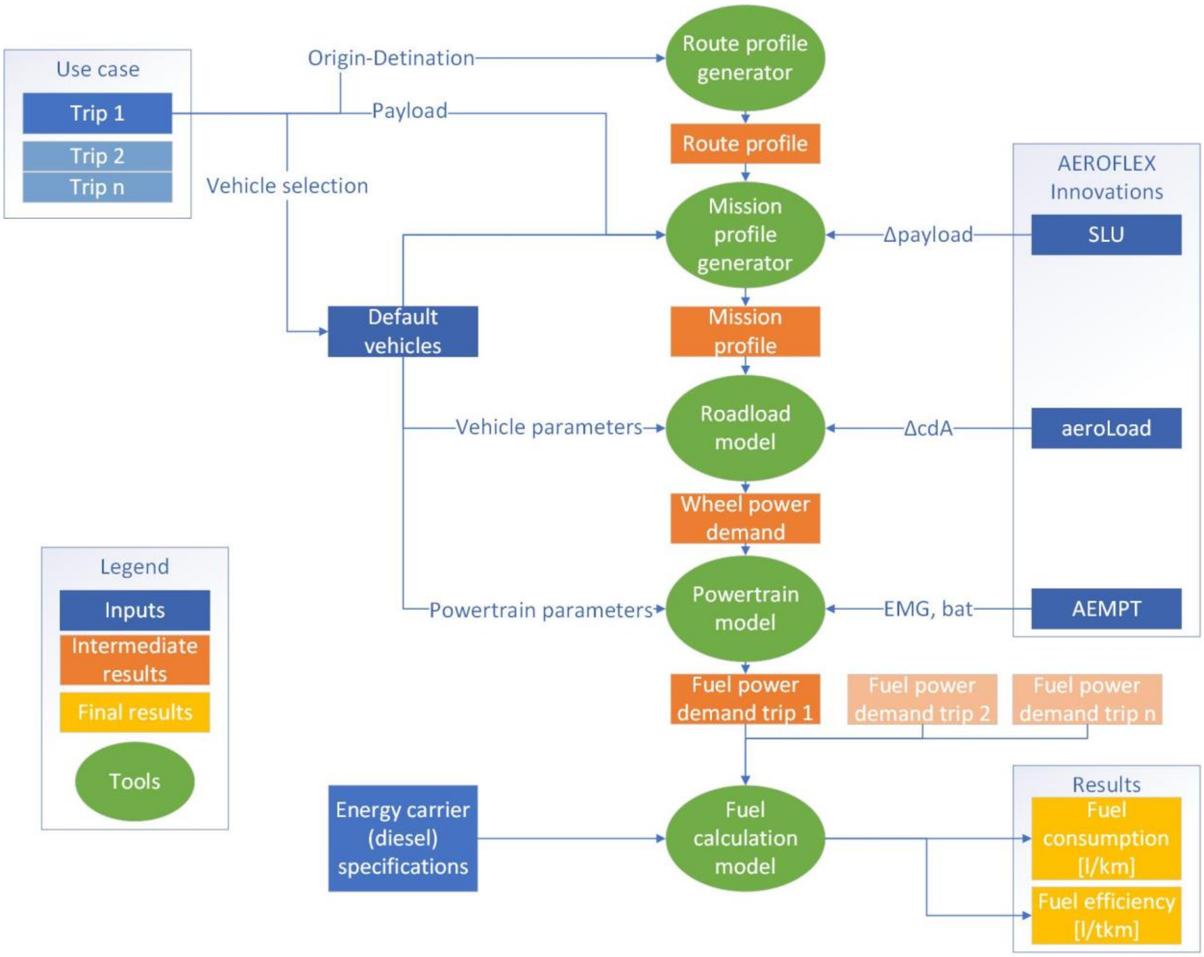


Figure 3.1 Stepwise approach used for the assessment of a use case in AEROFLEX (Source: [1])

3.1.1 Inputs to the framework

In AEROFLEX, each use case was defined as a set of trips. Each trip consists of an origin, a destination and a payload (in kg). The payload can vary from trip to trip due to loading and unloading. Each use case is performed by a default vehicle which defines the vehicle and powertrain parameters. Three types of AEROFLEX innovations can be analyzed by changing the input parameters of the models. Each by influencing either the powertrain, the payload or the aerodynamics of the vehicle.

3.1.2 Tools

The Route Profile Generator (RPG) converts the origin and destination to a route profile; a distance-based profile of the route including elevation and speed limits. The Mission Profile Generator (MPG) converts this to a mission profile; a time-based profile including road slope and vehicle speed. The road load model calculates the power at the wheels from the mission profile. The powertrain model calculates the power demand from the fuel. This is finally converted to fuel consumption (in litre/km) and fuel efficiency (litre/tkm) based on the energy carrier specifications. In the case of AEROFLEX this was by default diesel fuel.

3.1.3 Outputs

The output of the modeling is the total fuel consumption and fuel efficiency for a given trip with a given vehicle. In the reporting, only the relative difference between the default vehicle and different (combinations of) AEROFLEX innovations have been reported.

3.2 Differences between AEROFLEX and ZEFES assessment

In this chapter the main differences between the ZEFES assessment framework and the AEROFLEX assessment framework are listed. Based on these differences, the tools that need to be developed, additional to the existing assessment framework, will be identified.

3.2.1 Use case simulation and use-case evaluation

In the AEROFLEX project, all use cases were simulated as the reference and demonstrator vehicles were only tested on a test track and a single designated route. In the ZEFES project, the reference vehicles and demonstrator vehicles will be used in daily operation in all of the use cases and, therefore, gather large amounts of real-world test data. However, a simulation framework is still required to make fair comparisons between vehicle configurations and between use cases to account for external influences such as weather and traffic.

3.2.2 Vehicle powertrains

The first and most important difference between the projects is that AEROFLEX considers vehicles with a diesel powertrain and ZEFES considers BEV or FCEV, using Diesel and LNG only as a reference. This means that the assessment framework should include powertrain models to calculate the energy efficiency of these powertrains. The final results will not be fuel consumption and fuel efficiency but energy consumption and energy efficiency, not only of the demo BEV/FCEV vehicles but also of the ICE reference vehicles.

3.2.3 Innovations

The innovations, as discussed in Section 2.4, are recapped here, and specific considerations regarding their integration in the assessment framework are considered. One of the main innovations in ZEFES is the **E-trailer (or B-trailer)**. These are important to consider in detail, because the interplay between the E-trailer and the main power source in the pulling vehicle has an effect on not only the energy consumption but also the state of charge (SOC) of the main battery and thus the range of the vehicle. This was not the case for the diesel vehicles as the regenerative braking only influenced the fuel consumption and could be calculated separately and added at the end of the simulation. For ZEFES, a modular approach is needed where the energy consumption of the main battery depends on the contribution of the power source in the trailer(s).

E-tyres might possess a different rolling resistance. Therefore, the effect of this change on the energy-consumption KPI’s should be quantified through simulation.

Logistic tooling is developed in WP4 mainly to help logistic companies in utilizing the ZE vehicles in their fleet and operations. The assessment framework should include methods to assess if and how these tools meet the requirements set by the logistic companies that will utilize them.

In order to quantify the effect of **fast charging concepts** on the KPI's, the energy use during charging, i.e. charging efficiency, should be included to account for these innovations.

3.2.4 Logistic implications

In the AEROFLEX use cases a reference (diesel) vehicle was replaced by a demonstrator vehicle with a different fuel consumption but other than that the same capabilities. For ZEFES the reference vehicles are replaced by demonstrator vehicles that have considerably different capabilities than the reference vehicle. The demonstrator vehicles expected to have to stop more frequently and for longer in order to charge or refuel. This means that the user of the vehicle may have to adapt its logistic processes to fit the new vehicles. In order to do this properly, the assessment framework should include methods to compare these capabilities between the reference and demonstrator vehicles.

The need for charging and refuelling and the time it takes to charge and refuel should be included in the analyses. This should be linked to the (mandatory) rest times of the driver, as regulated in Regulation (EC) No 561/2006, to see if it fits or that the driver should stop longer than was the case without the charging activities.

Operators will change the way they plan their vehicle operations. Operator behavior and the way they plan their vehicle operations should be analyzed in order to see if and how they change their behaviour (in the sense that vehicles might drive shorter routes or ZE vehicles are only used for specific routes).

3.2.5 Upscaling potential

The upscaling potential or penetration rate, is calculated by looking at the current state of the art vehicles and comparing them to vehicles created in the project. Based on the requirements to the vehicles (i.e. what work they should be able to do for what cost) the potential uptake can be calculated. In the AEROFLEX project, the fuel efficiency, calculated with the assessment framework, was used as input to the calculation of the uptake potential, but the calculation itself was done by a different partner in a different work package and was carried out separately from the use-case evaluation. In short, the upscaling potential was not part of the assessment framework. In ZEFES, the upscaling potential is part of the assessment framework.

3.3 Overall assessment framework ZEFES

This chapter describes the ZEFES assessment framework. As the assessment framework is based on the AEROFLEX assessment framework, only those tools that are added to this framework will be described in this chapter. Table 3.1 compares the different parts of the assessment framework on two scale levels, the first being the number of vehicles analyzed (single use case versus fleet level) and the second on a temporal scale (current versus future).

Table 3.1 Comparison between the different analyses in WP8. The vertical axis shows the scale of the analysis and the horizontal axis shows the timing of the analysis.

	Current situation	Future situation
Use case	Use-case evaluation	Life-Cycle Analysis (LCA)
Fleet	Impact assessment	Upscaling potential

The use-case evaluation includes a direct comparison between the current situation, where a reference vehicle is used, and a future situation, where the demonstrator is used. The LCA (see chapter 3.3.2) focuses on single use cases as well, but instead of looking at a few months of data, the analysis includes the complete lifetime of the vehicles. The impact assessment extrapolates the results from the use-case evaluation to fleet level to calculate the impacts on a larger scale level. Finally, the upscaling potential generates fleet-level results and places them on a timeline towards the future.

In summary, the following questions are answered by the different analyses:

- **Use-case evaluation:** What is the effect of replacing the reference vehicle with a demonstration vehicle in a particular use case?
- **Life-cycle analysis:** What is the environmental impact over the lifetime of a demonstrator vehicle, given that it is used in a particular use case?
- **Impact assessment:** What would be the societal impact if all heavy-duty long-haul road transport in Europe were to be performed by ZEFES demonstrator vehicles?
- **Upscaling potential:** How will the penetration rate of long-haul heavy-duty ZEVs develop in the coming years, based on the results from the use-case evaluation and impact assessment?

The following sections continue to give a functional description of the different parts of the assessment framework.

3.3.1 Use-case evaluation

In the use-case (UC) evaluation, the effect of introducing the demonstrator vehicle in each particular use case will be studied and quantified. The changes in KPI's, with special focus on the powertrain KPI's such as energy intensity in kWh/t.km and GHG emissions per kilometre [g/km], will be studied. Six different assessments are performed:

1) Technical assessment of the demonstrator vehicles based on received vehicle data as described in Section 3.3.1.1;
2) Assessment of the charging and/or refuelling infrastructure as described in Section 3.3.1.2;
3) ZEFES-developed logistic tooling will be assessed as described in Section 3.3.1.3;
4) End user experiences are evaluated by using interviews and questionnaires as described in Section 3.3.1.4;
5) Assessment of the new driven tyres are described in Section 3.3.1.5;

6) Finally, the analysis of traffic flows and operator behaviour are assessed and is described in Section 3.3.1.6.

3.3.1.1 Technical assessment of FCEV and BEV with distributed powertrains

The predominant change in the demonstrator vehicles compared to the reference vehicles is the switch from a vehicle with an ICE powertrain to either a BEV or FCEV. Additionally, the ZEFES vehicles can be equipped with an e-trailer, b-trailer or e-cooled trailer or can drive with a different vehicle configuration than the reference vehicle. Assessment of the reference vehicles is the first step. By using the received reference data, as described in Section 4.1, the relevant KPIs can be determined for every UC. These will be described in D8.2.

Once the data from the demonstrator vehicles, detailed in Section 4.2, becomes available, the KPIs can again be calculated for the demonstration vehicles and compared these to the same KPIs for the reference vehicles. Due to the various conditions under which the vehicles are measured, a spread in energy consumption is expected due to different vehicle payloads, traffic, and ambient conditions. In these cases, statistical analyses and histograms will serve to identify correlations and assess the statistical distributions of the KPI-values. In order to investigate specific dependencies, binning the data can enable a comparison of KPIs under equivalent conditions. Where the direct comparison of the KPIs remains challenging, the Vehicle Simulation Framework will be employed. This framework is described below and allows the reference and demonstrator vehicle to be compared in simulation under the same conditions, thereby resulting in a fair comparison of the technology to be assessed. Also, if a breakdown is required of the effect of individual innovations, such as an E-trailer or B-trailer, the vehicle simulation framework can be used.

Vehicle Simulation Framework for BEV & FCEV

The Truck Vehicle Simulation Framework for both BEV and FCEV is introduced. The simulation framework is MATLAB/Simulink-based and relies on the TNO ADVANCE [6] simulation environment, as shown in Figure 32. The use of this software enables the use of modular vehicle and powertrain models, where different vehicle combinations (e.g. tractor-trailer, EMS1 or 2) can easily be evaluated

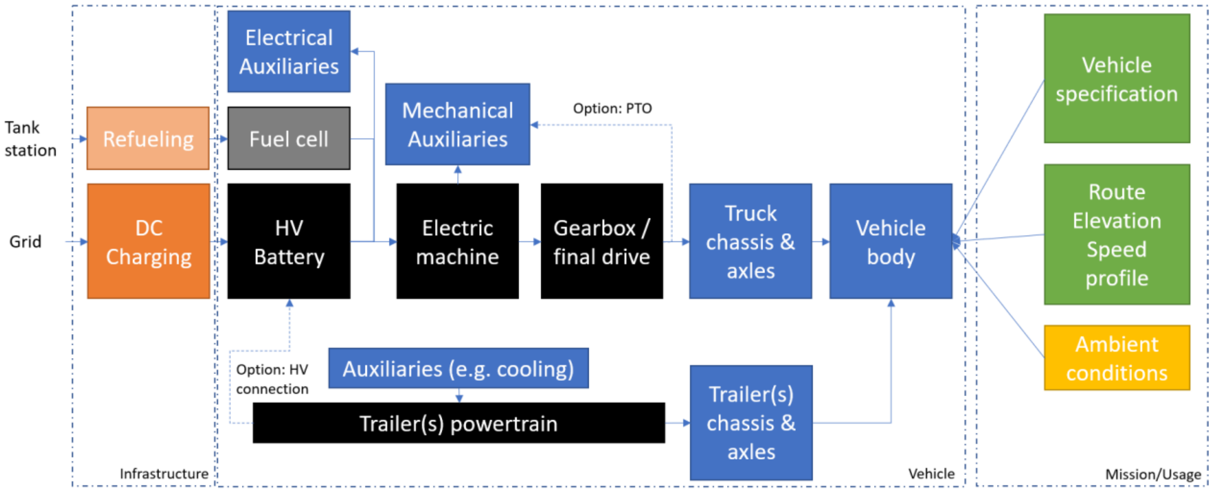


Figure 32 Schematic overview of the power flow within an electric truck. Refuelling + Fuel Cell is optional depending whether the vehicle is FCEV or BEV.

for different routes by parameterization only. This framework enables the automatic evaluation and validation of multiple vehicle configurations, thereby increasing the robustness of the method. Furthermore, the use of TNO ADVANCE allows for modelling of the various control algorithms present in a vehicle, that control for instance the power split between Fuel Cell and HV Battery, or between B-trailer battery and HV-battery. Considering the large number of use cases in the ZEFES project and the large amount of trips that will be measured during real-world operation, the simulation framework should facilitate fast and automated analysis of large numbers of trips, possible under different road etc. conditions.
A schematic overview of the Truck Simulation Framework for both BEV and FCEV is presented in Figure 32. The energy flow starts at the infrastructure, where the efficiency of either the DC charger or the hydrogen refuelling station is taken into account in the simulation. Next, the power flow inside the vehicle is modelled, where the efficiencies of all the physical powertrain components are considered. This includes a component model of the HV Battery, Fuel Cell, Electric Machines but also gearbox, final drives and lumped electrical/mechanical auxiliaries. Note the optional HV interconnection with the powertrain of the trailer (B-trailer only). The E-trailer powertrain (with/without a cooled body) is similarly modelled as the BEV truck, e.g. individual powertrain component models, such as an electric machine, gearbox/final drive and auxiliaries (e.g. cooling). The modular vehicle body allows for the various vehicle configurations as part of the UCs and is subject to a target speed profile, which is a result of the Route Profile Generator (RPG) described in Section 3.1.2. The RPG is extended here to provide the locations and properties of refuelling and charging stations. Additionally, the TNO ADVANCE vehicle simulation model allows for varying payloads, charge/refuelling events and stop/break events to closely simulate a 24-hour real-world operation per simulation event.
To enable these vehicle simulations several inputs are required, such asincluding vehicle specifications. The most important are the vehicle specifications of powertrain component properties, as described in Section 4.1.1. These, together with the measurement data are used to parametrize the model and calibrate the efficiency maps that represent the various components as described in Figure 32. Where direct parametrization from specifications is not possible, parameters are fitted based on the measurements or based on engineering judgment alternatively. An additional challenge is here that, compared to the simulation framework employed in AEROFLEX, where dedicated vehicle measurements were available, the ZEFES simulation framework will have to be parametrized on the real-world measurements performed for both the reference and the demonstration vehicles. To model the “infrastructure” (e.g. charger locations/properties, refueling and road infrastructure, data will be taken from publicly available databases such as H2-Stations.eu – European Hydrogen Refuelling Stations Availability System and TENtec Interactive Map Viewer (europa.eu).

3.3.1.2 Charging and H_2 refuelling infrastructure

The success of the ZEFES project will rely on the existence of a reliable, well-performing, accessible, and widespread network of charging and refuelling stations. The assessment framework for the charging and hydrogen refuelling infrastructure will focus on evaluating live data and comparing it to the expected performance. We will collect data from both the vehicles and the infrastructure to assess their interaction and determine if the expected performance is being delivered. For hydrogen

and MCS, we will examine the available infrastructure and its accessibility. This data will be incorporated into the simulation framework to evaluate performance under different infrastructure deployment levels.
The infrastructure will be assessed considering real-world use and the capabilities of the trucks. Consequently, some calculated values related to infrastructure performance may differ from specifications. To achieve our evaluation objectives, we will gather data directly from the charging and refuelling infrastructure. The focus will be on interaction with ZEFES vehicles, as their performance will fully utilize the infrastructure.

Inputs: The data should be retrieved directly from the infrastructure or provided by the Infrastructure CPOs. Data that cannot be retrieved directly needs to be gathered by the driver through logging into a logbook.
Tools and Methods: Charger and H_2 refuelling infrastructure partners will provide models that can be used in the assessment framework to simulate the infrastructure for other use cases.
By analyzing this data, we aim to assess the effectiveness and efficiency of the infrastructure in supporting the ZE-HDV logistics operations, ensuring it meets the required performance standards in real-world conditions.

3.3.1.3 Evaluation of digital and fleet management tools

In the ZEFES project digital and fleet management tools (a buying decision tool, a mission planning tool, a fleet management tool for deploying mixed fleets, a digital twin tool and a predictive maintenance tool) are developed to provide an answer to relevant questions of truck end users and to help the integration of ZE trucks in fleets, to optimise logistical task assignments considering routes, infrastructure and refueling/recharging opportunities, and to develop predictive maintenance strategies including deployment of diagnostic and prognostic techniques.

ZEFES will assess the technical and practical performance of the tools and analyse their applicability in different logistic use cases by means of meetings and workshops with transportation companies and logistics users for each tool, so as to receive feedback on the tool's development and needs. Also, logistic companies that operate ZEFES use cases will be invited to participate and provide a qualitative assessment of the useability of the tools based on their experiences.

3.3.1.4 User interview end-user experience evaluation

In addition to the assessment of the KPIs mentioned in Section 2.2, the execution of ZEFES use cases will be also qualitatively assessed. Consortium partner ALICE will conduct interviews as part of Task 8.3, "Use-case evaluation of all relevant stakeholders", to evaluate the driving experience and the impact of electrification on logistics. The main goal is to determine whether objectives 2 (demonstrate MCS and HRS for ZE-HDVs along corridors), 3 (provide digital and fleet management tools specifically for HD ZEVs, fleet integration with remote operational optimisation of vehicle performance) and 4 (demonstrate missions on cross-border, TEN-T corridors, fulfilling the requirements for range and payload, and comparing the deployability of BEVs and FCEVs for different mission profiles) of the ZEFES project are met, beyond the parameters that can be measured. In addition, it will be checked if the ZEFES project was capable of fulfilling the needs and requirements of the stakeholders defined in D1.5, “Supply chain needs”.

ALICE will prepare a structured interview template in collaboration with the project partners for each stakeholder group involved. Also, the applicability of other evaluation formats, such as online surveys, will be assessed. The insights from the interviews will be published in D8.3, “Use-case evaluation”.

3.3.1.5 Evaluation of tyres

The goal is to evaluate the impact of the electrification of truck vehicles (BEV and FCEV) on the wear, tread depth and energy consumption performance of Drive prototype tyres (315/70 R22.5 XM901) compared to the market reference 315/70R22.5 X MULTI D. To achieve this objective, three key deliverables will be required:

a) Field placement of tyre on electric vehicles (4*2 and 6*2 BEVs designed by Renault Trucks ; 4*2 BEV designed by Scania; 6x2*4 FCEV designed by Scania) compared to diesel vehicles (4*2)) on different use cases in real conditions in Europe:

- Comparison between Scania BEV, Scania FCEV and a diesel vehicles between 2 Primafrio sites (South of Spain/French border); 6 months of driving; 1300 km per day. This is further described in Use case 7.3.3 in Section 0.
- Comparison between Renault Trucks BEVs and a Renault Trucks Diesel vehicle operated by:
    - Renault Trucks between 2 Renault Trucks sites in France; 3 months of driving; 700 km per day; use on motorways. This is further described in Use case 7.4.2 in Section 2.3.11.
    - Michelin, between 2 Michelin factories (Montceau-Les-MinesLe Puy-en-Velay); 3 months of driving; 500 km of daily travel; use on hilly national roads. This is further described in Use case 7.4.1 in Section 2.3.10.
    - DPD in 2 different configurations [T+ST; T+ST+ST] between the Netherlands and Belgium; 6 months of driving; 625 km per day; mixed use between motorway and expressways. This is further described in Use case 7.4.3 in Section 2.3.12.

b) Follow-up of the field placements by a Michelin survey technician, who will carry out regular measurements of the evolution of the tread depth of the Drive prototype tyres and regular identification of the number and type of wear/irregular wear/aggression patterns. This data will then be post-processed by a tyre performance expert to consolidate the wear kinetics of these tyres in order to conclude on their wear performance, irregular wear and resistance to aggression.

c) Capture and analysis of usage data by a Michelin analyst, intended to enrich the analysis of wear, irregular wear and resistance to aggression performance previously described. This usage data will mainly be captured by telematics boxes installed on the vehicles and using the vehicles' CAN-bus:

- GPS position, longitudinal and lateral accelerations, ambient temperature: data obtained by telematic boxes.
- Wheel speeds and vehicle reference speeds, engine torque and Rotations Per Minute (RPM), gear ratio, braking forces per axle, battery state of charge and electrical energy consumption: data can be retrieved via connection to the vehicle's CAN-bus.
- Tyre pressure: data obtained from the TPMS installed on the wheel.

- Other data: history of the position of the tyres on the vehicle (information from the driver); total weight of the vehicle; weight per axle (data from vehicle manufacturers).

3.3.1.6 Analysis of traffic flows and operator behaviour

For a selection of 10 use cases, detailed data from the trucks will be retrieved, analysed and interpreted. It is assumed that for the running use cases, this data can be made available by the involved OEMs. Once the data can be processed, it will be analysed in several ways. We will investigate amongst others types of trips (city logistics, national logistics and cross-country logistics), the length of trips, the energy consumption of driving and auxiliaries, the range of the vehicle type of charging (slow, fast) and charging time and operation time per type of operation (driving, charging, idling, not being used). These analyses will be made to get a better understanding of the energy use of the truck, the charging process, the state of charge and the uncertainties and difficulties related to the charging strategy of heavy-duty electric trucks.

The analysis will also be done qualitatively, which includes interviews with fleet operators, planners and/or drivers. The idea to interview fleet operators and planners is to understand the challenges faced when planning the logistics operations for a BE or FCE trucks as compared to conventional vehicles. The idea of interviewing drivers is to understand the behaviour of the vehicle and the learning curve for the drivers, planners and fleet operators when compared to a conventional vehicle. We will investigate especially the difference between the planning of the electric trucks and the realisation in logistics operation and the reasons for the differences. By making these kinds of comparisons, we will learn from practice about the issues, problems and uncertainties related to operating heavy-duty electric trucks.

The quantitative and qualitative analysis would also help understand not only the issues around electric driving but also around the charging of the vehicles (charging locations, required detours to go to charging locations, charging time, performance of charging locations, availability of charging locations, available reservation systems, overall charging strategy etc.).).

Based on the analyses, insights will be gained about the operation of heavy-duty electric trucks and related problems and issues. Together with the logistics companies, solutions will be elaborated and tested right away if feasible on short notice. Based on the data analyses, the impact of the solutions will be further analysed.

As the use of heavy-duty electric trucks is still in the early phase of the full transition towards ZE driving, transport companies do operate electric trucks but in many cases with small numbers. They operate 1 or 2 trucks to get a better understanding of the performance. This leads to the situation that the transport companies will be able to take shortcuts for problems that occur or that are expected. However, once these companies are further in the transition and when they will have many electric trucks, it is not realistic they can still take these shortcuts. We will take this into account by not only analysing the current situation based on the data and the interviews but by also already elaborating and exploring scenarios for these future situations.

Deliverable 8.3 will include findings on the data analysis and the experience of the logistics companies in running the BEV and FCEV. It will also include possible solutions concerning their use and operations for the logistics service providers.

3.3.2 LCA

The Life Cycle Assessment (LCA) to be completed within the ZEFES project will build upon the methodologies, datasets and findings of a previous Ricardo study for DG CLIMA, “Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA”[3], and updates to this framework and datasets made by Ricardo since this study. The assessment of the environmental impact of the complete lifecycle of the ZEFES vehicles will be compared to the baseline ICE vehicle technologies over the tested duty cycles. The methodologies and results will also be reviewed through comparisons to methodologies and analysis results of other studies including the previous DG CLIMA study, TranSensusLCA and 2ZERO, and methods that will be developed (a) by the UNECE Informal Working Group on Automotive-LCA , (b) for/by DG CLIMA as part of the proposed provisions to the HDV CO_2 regulations (and existing requirements for LDVs in the CO_2 regulations for these). Through this analysis, refinements to assumptions and datasets included in the models will be made as far as is feasible. These will comprise characterization of the vehicles based on improved data on the real-world energy consumption performance of HDVs for new/alternative powertrain types, sizing/specification of components and range requirements, sensitivities to climatic impacts on energy consumption and emissions, the impact of vehicle maintenance between the different powertrain types and practical impact into refueling and recharging infrastructure aspects.

The approach to be used has been developed from the DG CLIMA study and follows the general method outlined in the ILCD handbook[4]. The main reference flow will be tonne-km (tkm) for goods transported. The analyzed scope includes all relevant processes directly related to the use of transport vehicles. The methodological boundary thus encompasses the whole life cycle of the vehicles themselves, from manufacturing and fuel and electricity production to the use phase and the end-of-life.

The main impact category included in the analysis will be climate change and will calculate greenhouse gas emissions GWP100 (Global Warming Potential of the greenhouse gases over 100 years) in CO_2eq., and we will also provide results for the Cumulative Energy Demand (CED) indicator (as a measure of lifecycle primary energy efficiency, split into renewable and non-renewable components). This choice of impact categories/indicators is determined by climate change being perceived as the single most important impact category, the critical importance of energy-efficiency as part of the framework for tackling climate change, and the robustness of datasets included in the initial donor DG CLIMA models for commercial vehicles.

Background LCI (Lifecycle Inventory) data includes the main datasets obtained from existing Ricardo LCI datasets (source Ecoinvent/GREET) for key materials, activities and energy carriers that are not

[3] Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA, Nik Hill et al, Ricardo

[4] International Reference Life Cycle Data System (ILCD) Handbook, JRC IES

directly calculated in this project. Electricity generation mix/composition will be based on EU energy system modelling scenarios, updated as far as feasible to the latest projections of the future supply mix under currently implemented policy. Similarly, the projected supply mix of hydrogen will also be considered, also factoring in EU rules on additionality for green hydrogen supply. The LCA method applied to liquid and gaseous fuels is a “Well-to-Tank” (WTT) approach plus exhaust emissions (TTW). We will also include an assessment of the potential impacts of fugitive emissions of hydrogen across the lifecycle, and the most recent scientific evidence on its significance as a greenhouse gas .

Input data from the ZEFES project will be used to refine the baseline LCA models of the ICE and electrified vehicles. Categories of input data comprise general vehicle specifications, vehicle unladen mass and composition, powertrain type and energy storage, energy consumption, vehicle activity, lifetime and spatial considerations.

The output of the study will be a Life Cycle Analysis report (deliverable 8.4) outlining the climate change impact of the vehicles in the ZEFES project including comparisons to benchmark vehicles and other studies.

3.3.3 Upscaling potential

The upscaling potential analyses the potential uptake of ZE heavy-duty vehicles in the total heavy-duty long haul logistics, now and in future years. The upscaling potential will be determined with the TEHUP (Techno-Economic Heavy-Duty Uptake) model [7].

What is the TEHUP model?
The TEHUP model analyzes the total cost of ownership (TCO) of heavy-duty trucks driving in the EU. It calculates the TCO for the following drivetrain configurations: diesel, battery-electric (BEV) and hydrogen-fuel cell-electric (FCEV). TCO is calculated for varying average daily mileages over the years from 2020 – 2040 (year of purchase). By comparing the TCO for varying daily mileages over time, insight is given into when and under what conditions zero-emission trucks become cheaper from a TCO perspective than diesel trucks. It is also used to calculate the techno-economic uptake potential of electric (or FCEV) vehicles.

The main goal of the TEHUP model is, therefore, the comparison between conventional drivetrain types (diesel) and zero-emission drivetrain types (BEV and FCEV).

The truck types currently considered in the TEHUP model are:

- Rigid 16 tons – urban delivery
- Articulated 40/44 tons – regional delivery
- Articulated 40/44 tons – long haul – **[relevant for ZEFES]**
- Articulated 40/44 tons – construction.

Outputs of the model
The results of the model are as follows:

- The below figure shows per year and average daily mileage bin (25km increments) which drivetrain configuration has the lowest TCO for the truck type: Articulated Long Haul.

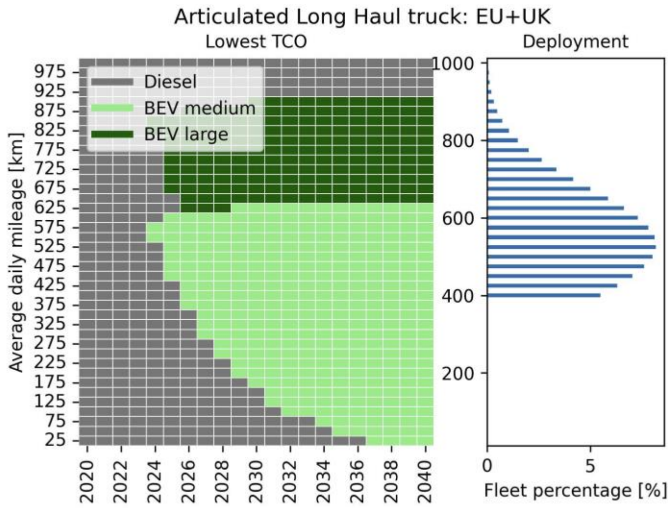


Figure 3.3 Example of per year and average daily mileage bin (25km increments) which drivetrain configuration has the lowest TCO for the truck type Articulated Long Haul

So, we can calculate per average daily mileage and per year of purchase the TCO of varying truck types and varying drivetrain types. If to consider the deployment distribution, it can calculate the techno-economic uptake potential (percentage of fleet for which ZE is the cheapest option) per year.

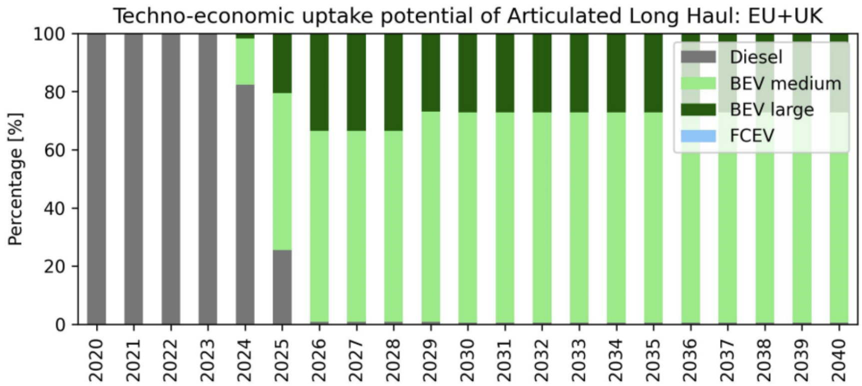


Figure 3.4 Example of techno-economic uptake potential of Articulated Long-Haul trucks

TEHUP model TCO calculation

The inputs to the TEHUP model would be aligned with the WP2 TCO model.

TCO consists of CAPEX (capital expenditures) and OPEX (operational expenditures).

$$CAPEX = purchase\ cost - residual\ value$$
$$residual\ value = purchase\ cost \cdot depreciation\ factor$$

$$OPEX = energy\ cost + maintenance\ cost + tolling\ cost$$

Tolling costs are optional in the TEHUP model. Other costs like labour, overheads and insurance costs as well as vehicle taxes are assumed to be the same for all drivetrain types and would, therefore, not affect the TCO comparison. Costs can be added if necessary.

TCO is calculated from the business perspective for a use period of 5 years (this can also be a societal perspective for a use period of 15 years).

Table 3.2 Inputs required/desired per use case [2] [3] [8] [5] [4] [9] [6] [10] [11].

	Drivetrain	Current/measured data	Nice to have
Deployment data	BEV or FCEV	Deployment data -> Average daily mileage and relative standard deviation Average payload with which is driven	Long-Haul freight fleet deployment distribution which ZEFES project attempts to represent. To say something about the larger scale, not just the use cases. Km-based payload distribution
Energy cost	BEV	Depot charging price (€/kWh) Opportunity charging price along corridor (€/kWh) Percentage of total kWh depot charged / opportunity charged	Depot and opportunity charging price projections 2025 – 2045 (€/kWh)
	FCEV	Hydrogen tanking price (€/kg)	Hydrogen tanking price projections 2025 – 2045 (€/kg)
Purchase costs	BEV	Purchase cost BEV truck	Share of costs attributed to battery. BEV truck purchase cost projection until 2040. Battery price projection (€/kWh) until 2040.
	FCEV	Purchase cost FCEV truck	Share of costs attributed to fuel cell system and battery. FCEV truck purchase cost projection until 2040. Fuel cell system price projection until 2040.
Depreciation	BEV or FCEV	Km-based depreciation factor. Year-based depreciation factor (over 5 years).	
	BEV	#EFCs until battery State of Health reaches 80%	Battery #EFC projections until 2040
	FCEV	Fuel cell #operating hours until end-of-life	Fuel cell #operating hours projections until 2040
Vehicle characteristics	BEV or FCEV	GCVW; empty weight tractor; empty weight trailer	
	BEV	Energy efficiency (kWh/km) Battery capacity (kWh) (gross capacity and net available)	Energy efficiency projection based on expected efficiency improvements (until 2040)

	FCEV	Energy efficiency (kWh/km or kg/km)	Energy efficiency projection based on expected efficiency improvements (until 2040)
Maintenance costs	BEV/FCEV	Average maintenance costs in €/km	Maintenance costs projections in €/km (until 2040)
Tolling costs (optional)	BEV/FCEV	Average tolling costs in €/km along the corridor	

If certain inputs are not attainable, current inputs of the TEHUP model will be used alternatively.

3.3.4 Impact assessment

As is mentioned in the Description of Work (DoW), the impact assessment "concerns the total environmental, societal and logistic impact of the project, the vehicles, components, infrastructure, tools and other innovations". The impact assessment combines the results from the use-case evaluation, the LCA and the upscaling potential, in order to calculate the total impact. In this chapter first, the combination of the three models is described. Then, the container concepts environmental, societal and logistic impact are narrowed to their usage in ZEFES to scope the analysis.

3.3.4.1 Extrapolation of results

In order to calculate the total impact of ZE vehicles in the impact assessment, the effects calculated on single vehicles in single use cases need to be extrapolated to a total. The total to be extrapolated to, in the ZEFES impact assessment, is the total ton.km shipped by heavy-duty long-haul vehicles in Europe:

- Total ton.km as reported by Eurostat for the European Union (EU-27)
- Heavy-duty transport is defined as vehicles with a permissible laden weight of >40 tons (Figure 3.6 Long-haul transport includes all trips with a distance of 300 km or more)
- Long-haul transport is defined as trips with a length of 300 km or more (Figure 3.6 Long-haul transport includes all trips with a distance of 300 km or more)

Road freight transport by maximum permissible laden weight of vehicle, 2022
(million tonne-kilometres)

	10.0 tonnes or less		10.1 - 20.0 tonnes		20.1 - 30.0 tonnes		30.1 - 40.0 tonnes		> 40.0 tonnes		Total	
		% of total		% of total		% of total		% of total		% of total		Growth rate of total tkm %
EU	4 878 p	0.3	308 817 p	16.1	97 782 p	5.1	1 034 911 p	53.9	473 861 p	24.7	1 920 249 p	0.0
Belgium	63	0.2	25 173	75.2	7 455	22.3	774	2.3	15	0.0	33 480	-7.4
Bulgaria	44	0.1	429	1.2	1 601	4.6	25 494	72.6	7 565	21.5	35 134	0.0
Czechia	698	1.1	3 992	6.1	3 132	4.8	2 953	4.5	55 019	83.6	65 794	3.2
Denmark	11	0.1	233	1.5	617	4.1	2 507	16.5	11 792	77.8	15 162	-1.2
Germany	356	0.1	8 605	2.8	18 407	6.1	242 477	79.8	34 102	11.2	303 948	-1.1
Estonia	9	0.2	62	1.4	123	2.7	33	0.7	4 313	95.0	4 540	-13.3
Ireland	216	1.7	278	2.2	851	6.9	1 965	15.9	9 054	73.2	12 364	-1.0
Greece	192	0.9	1 441	6.8	1 021	4.8	13 264	62.6	5 264	24.9	21 182	0.6
Spain	303	0.1	4 433	1.7	6 754	2.5	242 714	91.0	12 520	4.7	266 724	-1.3
France	28	0.0	110 453 p	63.7	6 100 p	3.5	1 721 p	1.0	55 051 p	31.8	173 353 p	-0.9
Croatia	30	0.2	342	2.5	434	3.2	436	3.2	12 416	90.9	13 659	0.2
Italy	141	0.1	128 934	85.3	19 483	12.9	2 255	1.5	286	0.2	151 100	4.2
Cyprus	40	4.2	140	14.8	53	5.6	316	33.3	399	42.1	949	29.8
Latvia	13	0.1	156	1.1	297	2.0	11 448	78.5	2 667	18.3	14 581	-3.5
Lithuania	17	0.0	2 635	4.9	4 684	8.7	41 901	77.9	4 535	8.4	53 773	-6.9
Luxembourg	1	0.0	62	0.8	29	0.4	165	2.2	7 097	96.5	7 353	6.5
Hungary	57	0.2	1 416	3.8	2 412	6.4	30 201	80.7	3 357	9.0	37 444	0.9
Malta (¹)	-	-	-	-	-	-	-	-	-	-	-	-
Netherlands	130	0.2	1 083	1.6	640	1.0	349	0.5	64 944	96.7	67 148	-4.4
Austria	29	0.1	700	2.6	1 633	6.1	1 994	7.4	22 474	83.8	26 830	-1.7
Poland	1 455	0.4	7 949	2.1	10 956	2.8	358 877	93.2	5 852	1.5	385 089	1.4
Portugal	137	0.4	584	1.8	1 403	4.4	28 749	89.7	1 166	3.6	32 039	0.0
Romania	76	0.1	7 560	11.7	4 831	7.5	11 597	18.0	40 289	62.6	64 353	4.0
Slovenia	32	0.1	339	1.4	551	2.3	6 307	25.9	17 078	70.3	24 308	-2.6
Slovakia	706	2.2	822	2.6	594	1.9	3 885	12.3	25 481	80.9	31 488	4.3
Finland	88	0.3	285	0.9	1 586	5.2	1 407	4.6	27 224	89.0	30 590	3.3
Sweden	5	0.0	708	1.5	2 133	4.5	1 122	2.3	43 897	91.7	47 865	0.8
Norway	12	0.0	724	3.0	2 622	10.7	302	1.2	20 768	85.0	24 428	8.3
Switzerland	50	0.4	287	2.2	255	2.0	10 138	78.1	2 259	17.4	12 988	2.3

(-) Not applicable
(p) Provisional
(¹) Data not available
Source: Eurostat (online data code: road_go_ta_mplw)

eurostat

Figure 3.5 Heavy-duty transport include all vehicles with a maximum permissible laden weight of ≥40 tons

Road freight transport by distance class, 2022
(million tonne-kilometres)

	Less than 150 km		From 150 to 299 km		From 300 to 999 km		1 000 km or more	
	2022	Growth rate 2021/2022	2022	Growth rate 2021/2022	2022	Growth rate 2021/2022	2022	Growth rate 2021/2022
		%		%		%		%
EU	402 086	-1.0	359 134	-1.2	788 067	0.8	364 606	0.2
Belgium	10 273	5.4	10 567	-15.6	16 527	-14.8	1 443	-3.1
Bulgaria	3 815	-1.2	3 656	-10.1	11 565	5.1	16 155	-0.5
Czechia	15 146	-0.9	11 498	2.9	23 848	7.6	15 406	0.9
Denmark	4 765	3.7	4 486	1.7	4 728	-8.2	1 184	-0.3
Germany	94 913	-1.2	77 069	-1.7	113 346	-0.9	8 017	9.4
Estonia	950	-3.1	906	-1.8	1 242	-16.8	1 415	-22.1
Ireland	5 481	1.0	4 116	-3.3	2 108	1.1	590	-10.5
Greece	5 922	-3.9	3 805	2.7	7 301	-2.8	4 158	12.9
Spain	43 463	-2.0	34 615	-1.6	120 923	-1.1	67 720	-0.9
France	45 138	-2.7	40 683	-0.7	84 128	0.0	3 409	2.4
Croatia	2 326	0.9	2 199	-2.5	5 819	-0.1	3 287	1.3
Italy	35 090	5.5	40 889	-1.9	63 576	5.7	11 542	16.4
Cyprus	889	30.7	36	50.0	4	33.3	20	-13.0
Latvia	2 820	-2.4	1 890	-5.0	3 941	-4.0	5 800	-3.2
Lithuania	1 776	-12.6	2 975	-14.1	21 666	-5.5	27 340	-6.7
Luxembourg	1 426	5.4	1 653	-1.4	3 835	9.6	439	17.4
Hungary	7 174	-6.3	7 110	-5.0	16 703	7.8	6 290	0.8
Malta (*)	-	-	-	-	-	-	-	-
Netherlands	28 280	-0.3	19 291	-4.9	15 789	-8.3	3 994	-15.9
Austria	10 336	-3.4	6 252	3.6	7 675	-1.3	1 755	-1.9
Poland	41 934	-5.1	51 825	4.5	173 327	3.5	118 021	-0.5
Portugal	4 491	1.4	3 402	-5.6	8 184	-2.5	15 956	2.1
Romania	7 974	7.3	6 538	9.8	24 127	0.5	25 712	5.1
Slovenia	2 276	1.8	2 082	-7.6	11 180	-5.0	8 732	0.9
Slovakia	3 925	-4.0	3 454	-2.2	11 599	5.3	12 458	8.3
Finland	7 151	-15.4	6 744	7.0	15 303	12.7	1 166	9.8
Sweden	14 352	7.0	11 393	-4.2	19 622	5.2	1 910	-35.4
Norway	8 658	16.8	4 538	1.0	8 968	9.1	1 907	26.6
Switzerland	8 565	2.6	2 770	1.7	1 301	-3.2	:	-

(:) Not available
(-) Not applicable
(*) Data not available (see chapter 'data sources')
Source: Eurostat (online data code: road_go_ta_dc)

eurostat

Figure 3.6 Long-haul transport includes all trips with a distance of 300 km or more

The use-case evaluation calculates effects of replacing a conventional vehicles with ZE-vehicles in individual use cases, the effects can thus be expressed as effect/ton.km.

The LCA continuous to extrapolate some of these effects to the total lifetime (and total kilometres driven) of these vehicles and thus indicates the km/vehicle.

The upscaling potential calculates the potential uptake of ZE vehicles, thus indicating the (maximum) projected % of ZE-vehicles in new sales per sight year.

The missing link to calculating the total effects is the number of newly sold vehicles per year. For this, the following Eurostat tables will be used:

- New lorries and their load capacity by permissible maximum gross weight (online data code: road_eqr_lorrit)
- New road tractors by type of motor energy (road_eqr_tracmot)

The total impact will be calculated by summing the impact of newly sold vehicles per year. The impact per year will be calculated as:

$$\begin{aligned} Total\_impact\_year\_i \\ &= Impact\_per\_ton.km\ (use\ case\ evaluation)\ *\ ton.km\_per\_vehicle\ (LCA) \\ &*\ uptake\_\%\ (upscaling\ potential)\ *\ new\ registrations\ *\ share\_heavy\_duty \\ &*\ share\_long\_haul \end{aligned}$$

3.3.4.2 Scoping the impacts

The **environmental impact** that is calculated in the ZEFES project include the total CO_2-emissions over the lifetime of the vehicles. A comparison will be made between a default scenario and a scenario where ZEFES innovations accelerate the uptake of ZE HD vehicles.

The **societal impact** is the impact of the ZEFES innovations on society. A major impact on society from the vehicles will be the demand for charging and fueling infrastructure. The societal impact assessment will include an analysis towards the needs for net capacity, charging locations and fueling locations on different locations, e.g. in urban areas, near rural roads, on national motorways and next to TEN-T corridors, based on current intensities (vehicles/hour) and estimated uptake of ZE-vehicles.

The **logistic impact** assessment focusses on the impacts of the ZEFES vehicles on the logistic operation. The use of ZE vehicles may change the operation because vehicles have a limited range, capacity and need more time for charging the battery. Further, several use cases include the use of larger vehicle configurations with more loading capacity. The analysis will include an assessment of the required size of the vehicle fleet in different scenarios. This will also have an effect on the required number of drivers.

3.4 Conclusion

The pervious chapter described the assessment framework to be used for the use-case evaluation and impact assessment of the ZEFES use cases. The final table from Chapter 2.5 shows how each requirement links to the chapters describing the assessment framework.

4 Inputs to the evaluation

The calculation of the KPI's listed in Section 2.2 requires data to be logged from the demonstrator vehicles. In addition, reference tests with conventional ICE vehicles will take place, which will also have to be monitored to allow for proper comparison to the ZEFES demonstrators. Reference tests are introduced in Section 4.1 and the relevant input data requirements and agreements with data-delivering parties are listed. Similarly, the data requirements of the demonstrator vehicles and the corresponding agreements are detailed in Section 4.2.

In order to compare the ZEFES demonstration vehicles to the state-of-the-art, reference tests will be performed. The reference tests concern the same routes as described in the use cases, see Section 2.3, but will be driven by conventional ICE vehicles, indicated as 'reference vehicles'. To enable a quantitative comparison between reference and demonstration vehicles, data will be logged from these reference vehicles. To enable logging of these signals, agreements with shippers operating the reference and demonstrator vehicles, and their OEMs are made. These agreements are summarized in each section for reference and demonstrator cases respectively.

4.1 Data-requirements reference tests

To monitor relevant KPI's and perform simulations using the simulation framework, monitoring of the reference vehicles is imperative. The monitored signals will be used both to perform statistical analyses as well as model-based analyses that in the end allow for comparisons between the ZEFES demonstrators and the reference vehicles. Signals are based on the Fleet Management System (FMS) [9] communication standard as developed by several ACEA members [1]. Dependent on the operator of the vehicle and corresponding OEM, the signals are monitored via the fleet management portals or via installed CAN sniffers.

*Table 4.1: List of required signals for the reference vehicles. **Bold** = must-have, black = nice-to-have.*

Channel	Frequency	Channel	Frequency
Date and time	s by s	**Trip fuel consumption**	trip
GPS location (LON/LAT)	s by s	**Tractor and trailer weights**	trip
Ambient temperature & pressure	s by s	Drive mode (D/N/R)	s by s
Accelerator & brake pedal positions	s by s	Cruise control active	s by s
Cabin temperature set point	s by s	Total Retarder Torque	s by s
Wheel-based vehicle speed	s by s	PTO state	s by s
Gear number	s by s	Trailer cooling system setpoint temperature (if any)	s by s
Engine speed	s by s	ECO mode active	s by s
Drive torque request	s by s	Indicator of pneumatic braking	s by s
Total engine torque (= torque pct + reference* + friction)	s by s		
Fuel rate	s by s		
Fuel level	s by s		

*reference value is a constant (in [Nm]) which differs per vehicle, and should be known to calculate total engine torque.

4.1.1 Vehicle specifications

In addition to the signals listed above, several vehicle metrics are required to be known in order to assess various KPI's or enable a model-based comparison of vehicles. To this end, the following vehicle specifications are sent to vehicle owners. Whilst it is unlikely to gather all specifications for all of the vehicles, the intention is to gather at least the must-have specifications for all reference vehicles. From these, many other information can be deduced.

*Table 4.2: List of requested vehicle specifications for the reference vehicles for both the truck (left) and the trailer (right). **Bold** = must-have, black = nice-to-have.*

Description TRUCK	Unit	Value
Brand	-	
Type	-	
Axle Configuration	-	
Cabin Type	-	
Tare Weight	kg	
Gross Combination Weight	kg	
Gross Vehicle Weight	kg	
Payload Capacity	kg	
Wheel Base (Axle distance)	m	
---- ICE details ----		
ICE Type	-	
# cylinders + configuration	-	
Fuel Tank capacity	litres	
AdBlue Tank capacity	litres	
Power Output	kW	
---- Powertrain details ----		
Gearbox type	-	
Final drive ratio	-	
Location of axle weight senor (which axle?)		
Licence Plate Number		
Country of registration (license plate)		
Tyre Size		
Tyre Types Per Axle (Brand, Type, RRC Label)		
Trace Of Maintenance and Software Versions		

Description TRAILER	Unit	Value
Brand	-	
Type	-	
Axle Configuration	-	
Tare Weight	kg	
Gross Trailer Weight	kg	
Payload Capacity	kg	
Total Length	m	
Length kingpin to first axle	m	
Cooled trailer volume (if available)	m	
Cooled trailer peak power (if available)	kW	
Licence Plate Number		
Country of registration (License plate)		
Tyre Size		
Tyre Types Per Axle (Brand, Type, RRC Label)		
Trace Of Maintenance and Software Versions		

4.1.2 Agreements reference tests

To enable remote logging of the reference vehicles, agreements are made with the shippers operating the vehicles and, in case the reference vehicles happens to be manufactured by a ZEFES partner, the relevant OEM. This effort is coordinated by RICARDO under the scope of Sub-task 7.1.6, with the assistance of TNO. Due to the relevance for the assessment framework, the results are summarized here in Table 4.3.

Table 4.3: List of the reference tests and the logging agreements made by RIC in collaboration with TNO per use case.

Use case	Ref. Test Period	Ref. OEM	Preliminary agreement with shipper and OEM
721 VOL-OVA	Q1/24	VOL	Log via VolvoConnect
722 VOL-VOL	Q1/24	VOL	Log via VolvoConnect
723-2 VOL-PRI	Q1/24	VOL	Log provided by shipper (PRI)
723-1 VOL-P&G	Q4/24	VOL	Log via VolvoConnect (tbc*)
724 VOL-DPD	Q2-3/24	VOL	Log via VolvoConnect
731 SCA-SCA	Q2-2/24	SCA	Log via MyScania
732 SCA-GRU	Q4/24-Q1/25	SCA	Log via MyScania + FHG FMS logger (1 veh)
733 SCA-PRI	Q2/25-Q3/25	tbc*	CAN-Log provided by shipper (PRI)
734-1 SCA-GSS	Q2/24	SCA	Log via MyScania
734-2 SCA-GSS	Q2/24-Q3/25	SCA	Log via MyScania
741 REN-MIC	Q2/24	tbc*	tbc*
742 REN-REN	Q3/24	tbc*	tbc*
743 REN-DPD	Q1/25	VOL	Log via Volvo Connect
761 FRD-EKO	Q3/24	FRD	CAN-log provided by shipper (EKO)
762 FRD-GBW	Q4/23-Q1/24	DAF**	FHG FMS logger
763 FRD-P&G	Q1/25	tbc*	tbc*

*tbc = to be confirmed, **not a ZEFES project partner

The right column of Table 4.3 lists the agreed method through which the data of the reference vehicles will be measured. Most use cases that drive either a Volvo or Renault reference vehicle, will be monitored through the VolvoConnect telemetry portal. For Scania vehicles, data will be provided through the MyScania portal. Thirdly, for vehicles where no telemetry service is directly available, such as in UC762 where the reference vehicle was not manufactured by a ZEFES partner, FHG will provide an FMS logging solution. This solution requires FHG hardware to be installed in the vehicle. UC732 will be logged both through MyScania and the FHG FMS logger enabling direct comparison of the two data sources and the possible effect in the changes in resolution and frequency on the results.

4.2 Demonstration tests

In the demonstration tests, the vehicle demonstrator vehicles, with FCEV and BEV powertrain, will be operated on the use-case routes. During this operation, certain vehicle-level signals will be logged to ensure calculation of the KPI’s and calibration of the models. In this section, these data requirements are listed in Section 4.2.1.

4.2.1 Data requirements

The assessment focusses mainly on the demonstrator vehicles, because these contain the ZEFES innovations. Therefore, the data requirements for the demonstration vehicles are more elaborate than those for the reference vehicles.

4.3 Vehicle specifications

The desired vehicle specifications are slightly different from those of the reference vehicles, mainly due to the electric powertrain. Depending on the exact type of vehicle, e.g. FCEV or BEV, and the attached trailer, e.g. E-trailer, the specifications are slightly extended. For a complete list of the vehicle specifications see Appendix A – Requested specifications of demonstrator vehicles.

4.4 Agreements

Already in the early stages of the project, arrangements are made how to obtain data from the demonstrator vehicles. This data-acquisition effort is mostly coordinated through WP4 Tasks 4.3 and 4.7. Since these arrangements are relevant to the assessment in WP8, the preliminary agreements with OEMs and shippers regarding the logging of the demonstrator vehicles are listed in Table 4.4. Note that, in contrast to the agreements related to the demonstration vehicles, only on-board logging devices are used. This ensures the temporal frequency of the received signals is high and there are no practical restriction on the number of CAN-signals that can be logged.

Table 4.4: Overview of the UC's and the currently agreed data logging solution for the demonstrators.

Use case	Demo Period	Agreement with shipper and OEM
721 VOL-OVA	03/25 - 02/26	Volvo logger into FHG Logger
722 VOL-VOL	03/25 - 02/26	Volvo logger into FHG Logger
723-2 VOL-PRI	03/25 - 08/26	Volvo logger into FHG Logger
723-1 VOL-P&G	10/25 - 03/26	Volvo logger into FHG Logger
724 VOL-DPD	03/25 - 02/26	Volvo logger into FHG Logger
731 SCA-SCA	03/25 - 08/25	FHG logger
732 SCA-GRU	10/25 - 03/26	FHG logger
733 SCA-PRI	06/26 - 11/26	FHG logger
734-1 SCA-GSS	03/25 - 08/25	FHG logger
734-2 SCA-GSS	10/25 - 03/26	FHG logger
741 REN-MIC	03/25 - 05/25	FHG logger
742 REN-REN	07/25 - 09/25	FHG logger
743 REN-DPD	11/25 - 03/26	FHG logger
761 FRD-EKO	07/25 - 09/25	FHG logger
762 FRD-GBW	11/25 - 01/26	FHG logger
763 FRD-P&G	03/26 - 05/26	FHG logger

In all of the use cases mentioned in the table above, data will be recorded by a logger from Fraunhofer.

5 Results & Discussion

5.1 Results

This deliverable concludes Task 8.1, the definition of an assessment framework. The result of the work performed in this task is an assessment framework to be used for the use-case evaluation and impact assessment. This guarantees that:

1. The use-case evaluation and impact assessment are in line with the questions posted in and boundary conditions set by WP1;
2. The right data will be gathered, directly from the start of the demonstration phase;
3. The results that will be calculated are presented in the right format to be used for project reporting and dissemination;
4. The right methods and models are developed in order to perform the evaluations and assessments in the limited time frame between the demonstrations and project end.

5.2 Contribution to project objectives

The assessment framework described in this deliverable contributes to the evaluation of the use cases and the impact assessment of the vehicles and innovations. Hereby, a contribution is made to Objective 4 and to Objective 6 in the ZEFES DoA.

Objective	Part	Contribution of assessment framework
4	Comparing the deploy-ability of BEVs and FCEVs for different mission profiles	The assessment framework allows for a fair comparison between FCEV and BEV vehicles with similar operating and external conditions, with a strong link to the real-world data from the use cases.
6	Analyse the effect on society	The LCA described in Chapter 3.3.2 allows for assessing the impact of the vehicles on the environment throughout the entire life of the vehicles.
6	Analyze the effect on energy efficiency	The assessment framework allows for a comparison in energy consumption and energy efficiency on a range of use cases.

5.3 Contribution to major project exploitable result

The deliverable contributes to two exploitable results:

1. It provides methods to gather knowledge about the real-world performance of ZE vehicles, technologies and tools in logistic use cases;
2. It defines tools to assess the real-world performance of ZE vehicles, technologies and tools in logistic use cases.

6 Conclusions and recommendations

The assessment framework presented in this document provides a blueprint for the use case evaluation and impact assessment. This blueprint is based on the available deliverables and status quo of the use cases and demonstrations. This blueprint is not set in stone as it is based on demonstrations of innovative vehicle concepts in real-world conditions. This means that unforeseen circumstances will inevitably lead to changes in the demonstrated use cases and data being gathered by these use cases. The assessment framework can handle these changes to a certain extent but to do so it depends on clear communication and transparency between the different work packages.

This is summarized by the following recommendations for further work in WP8:

1. Perform pilot assessments, based on provisional or simulated data, to inform the consortium and other stakeholders on the expected results and provide opportunities to provide input to these results.
2. Perform sanity checks on the generated data, right from the start of the demonstrations, in order to adjust data loggers and data interfaces in due time.
3. Cross-check the assumed properties of the use cases, vehicles, powertrains, innovations etc. with the respective OEMs, shippers and other suppliers.
4. Monitor the planning of the use case demonstrations and relate any changes to the results being created by the assessment framework.

7 Risks and interconnections

7.1 Risks or problems encountered

This section describes the risks we foresee for the assessment framework, the probability of them occurring and their effect and, most importantly, our solutions to counter them in case they occur.

Risk No.	What is the risk	Probability of risk occurrence[1]	Effect of risk[1]	Solutions to overcome the risk
WP8.1	If use cases are delayed the use case evaluation will also incur a delay.	1	1	Project extension needed; or a partly extension for the use cases that are delayed.
WP8.2	If use cases are cancelled or cannot be performed, the use-case evaluation cannot be performed.	2	2	In this case, we may consider simulating (part of) the use case in order to forecast its effects.
WP8.3	If data formats are different than expected, we may not be able to generate the results indicated in this report.	2	3	TNO will assess the data while it is being collected in order to prevent this risk from occurring.

[1)] Probability risk will occur: 1 = high, 2 = medium, 3 = Low

7.2 Interconnections with other deliverables

The table below shows how the assessment framework relates to other deliverables in the project.

Deliverable	Input/output	Status	Explanation
D1.1	Input	Submitted	Vehicle KPI input to KPI list
D1.2	Input	Submitted	Logistic KPI input to KPI list
D1.2	Output	Submitted	Requirements to datalogging on demonstrator vehicles
D4.1	Output	Submitted	Requirements to platform specification in relation to data interfaces
D4.3	Output	Submitted	Requirements from assessment framework to data platform and interface

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2	FRD	FORD OTOMOTIV SANAYI ANONIM SIRKETI
3	HYU	HYUNDAI MOTOR EUROPE TECHNICAL CENTER GMBH
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
9	ABB	ABB E-MOBILITY BV
9.1	ABP	ABB E-MOBILITY SPOLKA Z OGRANICZONAODPOWIEDZIALNOSCIA
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	PLASTIC OMNIUM NEW ENERGIES WELS GMBH
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
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
28	IDI	IDIADA AUTOMOTIVE TECHNOLOGY SA
29	TNO	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO
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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10 Appendix A – Requested specifications of demonstrator vehicles

Table 10.1: Overview of the to-be requested specifications of the demonstration vehicles (tractor/truck).

Specification TRAILER	Unit
Brand	-
Type	-
Axle Configuration	-
Tare Weight	kg
Gross Trailer Weight	kg
Payload Capacity	kg
Total Length	m
Length king pin to first axle	m
# of Electric Machines (EMs), and per EM: (E-trailer only)	-
EM Brand	-
EM Type	-
Rated Power EM (Cont.)	kW
Rated Power EM (Peak)	kW
Rated Torque EM (Cont.)	Nm
Rated Torque EM (Peak)	Nm
# of High Voltage (HV) Batteries, and per battery: (e/B-trailer only)	-
Battery Type (e.g. chemistry)	-
Total Battery Capacity	kWh
Useful Battery Capacity	kWh
Battery Nominal Voltage	V
Charging Power (slow)	kW
Charging Power (fast)	kW
Cooled trailer volume (if available)	m
Cooled trailer peak power (if available)	kW
Licence Plate Number	
Tyre Size	
Tyre Types Per Axle (Brand, Type, Energy Consumption Label)	
Trace Of Maintenance And Updates, Software Versions	

Table 10.2: Overview of the to-be requested specifications of the demonstration vehicles (trailer).

Specification TRUCK	**Unit**
Brand	-
Type	-
Axle Configuration	-
Cabin Type	-
Tare Weight	kg
Gross Combination Weight	kg
Gross Vehicle Weight	kg
Payload Capacity	kg
Wheelbase	m
# of Electric Machines (EMs), and per EM:	-
EM Brand	-
EM Type	-
Rated Power EM (Cont.)	kW
Rated Power EM (Peak)	kW
Rated Torque EM (Cont.)	Nm
Rated Torque EM (Peak)	Nm
# of High Voltage (HV) Batteries, and per battery:	-
Battery Type (e.g. chemistry)	-
Total Battery Capacity	kWh
Useful Battery Capacity	kWh
Battery Nominal Voltage	V
Charging Power (slow)	kW
Charging Power (fast)	kW
# of Fuel Cells (FCs) and per FC: (FCEV only)	-
Fuel Cell Brand	-
Fuel Cell Type	-
Total Fuel Cell Peak Power	kW
Fuel Cell idle Power	kW
Power Consumption of Auxiliary (e.g. compressor etc.)	kW
Number of FC Stacks	-
Number of fans per stack	-
On-Board Hydrogen Capacity	kg
Working Pressure H_2 Cylinders	bar
License Plate Number	
Country of registration (license plate)	
Tyre Size	
Tyre Types Per Axle (Brand, Type, Energy Consumption Label)	
Trace Of Maintenance And Updates, Software Versions	