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 Eco System

ZEFES - Deliverable report

D1.4 Supply Chain Mapping

Funded by the European Union

Deliverable No.	ZEFES D1.4	
Related WP	1	
Deliverable Title	Supply Chain Mapping	
Deliverable Date	2023-09-30	
Deliverable Type	REPORT	
Dissemination level	Public (PU)	
Author(s)	Marcel Huschebeck (PTV) Ben Kraaijenhagen (VUB)	
Checked by	Name WP leader PTV	2023-09-22
Reviewed by (if applicable)	Kai König (ABB) Stefanie van Damme (ALICE) Adrian Valverde (PRIMA)	2023-09-27
Approved by	Omar Hegazy (VUB) – Project coordinator	2023-10-06
Status	Final	2023-10-09

Publishable summary

WP 1 addresses the needs and requirements of logistics stakeholders on Battery Electric Heavy Duty Vehicles (BEV) and Fuel Cell Heavy Duty Vehicles (FCEV). Long-haul BEVs and FCEVs need to become more affordable and reliable, more energy efficient, with a longer range per single charge, and a reduced charging time to meet the user's needs. Next to those, there is a real need to take zero emission long-haul goods transport in Europe to the next level by executing real-world demonstrations of BEVs and FCEVs spread all over Europe to operate in complex transport supply chains.

D1.4 addresses the analysis of different real-life truck and intermodal operations as integrated part of industry supply chains and analyses the transformation process from Internal Combustion Engines (ICE) to Battery Electric and Fuel Cell Electric engine technologies.

Approach is to model and simulate transport and logistics operations of the different use cases and to assess and compare key indicator between ICE and BEV or FCEV alternatives. This will be done in order to derive the needs and requirements for the demonstration set up prior to the implementation. Operational limitations, especially related to electric charging and hydrogen fuelling infrastructure can be analysed and research questions to develop and implement demonstrator can be defined. With regards to supply chain operations crucial questions will be addressed such as

- Can single trips be executed within a daily trip operation, in line with driving and resting regulations
- Can charging be matched with breaks during driving and resting time
- Are charging and hydrogen fueling stations available along best routes
- Are BEV and FCEV economically competitive with present diesel metrics

Within ZEFES supply chain operations the stakeholder group priorities the following key performance indicators as crucial:

- Lead time of transport operations, preferably in daily operations
- Cost per trip
- Energy use and emissions of transport operations

A consistent methodology in line with energy and emission reporting standards (ISO 16258 and ISO 14083) has been developed and applied over the 15 ZEFES pilot cases. A supply chain mapping is made by comparing operations parameters and metrics as performed by diesel, BEV and/or FCEV trucks. The results are structured in a common reporting format providing a concise overview on the key parameters and metrics of the single pilot operations in supply chain context.

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1 Introduction

WP 1 addresses the needs and requirements of logistics stakeholders on Battery Electric Heavy-Duty Vehicles (BEV) and Fuel Cell Heavy Duty Vehicles (FCEV). Long-haul BEVs and FCEVs need to become more affordable and reliable, more energy efficient, with a longer range per single charge, and a reduced charging time to meet the user's needs. Next to those, there is a real need to take zero emission long-haul goods transport in Europe to the next level by executing real-world demonstrations of BEVs and FCEVs spread all over Europe to operate in complex transport supply chains.

D1.4 addresses the analysis of different real-life truck and intermodal operations as integrated part of industry supply chains and analyses the transformation process from Internal Combustion Engines (ICE) to Battery Electric and Fuel Cell Electric engine technologies.

Approach is to model and simulate transport and logistics operations of the different use cases and to assess and compare key indicator between ICE and BEV or FCEV alternatives. This will be done in order to derive the needs and requirements for the demonstration set up prior to the implementation. Operational limitations, especially related to electric charging and hydrogen fuelling infrastructure can be analysed and research questions to develop and implement demonstrator can be defined. With regards to supply chain operations crucial questions will be addressed such as

- Can single trips be executed within a daily trip operation, in line with driving and resting regulations
- Can charging be matched with breaks during driving and resting time
- Are charging and hydrogen fueling stations available along best routes
- Are BEV and FCEV economically competitive with present diesel metrics

D1.4 is structured that a common methodology is developed to analyse the different ZEFES use cases by means of a comparative analysis of ICE against BEV and/or FCEV operations. An individual trip analysis will be made followed by a comparative analysis of key performance indictors: energy needs per trip, cost comparison per trip and CO2 emission per trip. Within chapter 2, a detailed overview on the methodology is given while chapter 3 provides a detailed assessment of the 15 ZEFES use cases. Results are consolidated in a structured data sheet.

2 Methods and core part of the report

Chapter 2 will work out the methodology used to execute a comparative analysis. The overall structuring of the analysis is described in chapter 2.1.

2.1 Overall assessment structuring

To perform a supply chain mapping an extensive analysis will be made consisting of

- Technical specification of the technology deployed and its characteristics in terms of energy use and logistics operations
- Analysis of the corridor routing and related parameters and derivations on logistics operations
- Additional arising parameters such as the number of drivers, as from infrastructure usage and the energy needs
- Any additional arising effect to be taken into consideration
- Calculation of the specific parameters to compare supply chain operations by means of KPI

All results have been complied in a data sheet as shown below:

Dats Sheet UC1: <<include use case identifier>>				
Vehicles & trip: <<include detailed description of the technology used and the trip classification>>				
<<<include detailed transport route>>	Trip Parameters <<include parameter as from routing>>			
	Trip length: Driving time: Rest&Service: Charging time:		Total Travel Diesel: Total Travel BEV: Total Travel FCEV	
Additional Settings: <<include additional setting parameters and calculated trip energy use>>				
Number of Drivers Maut diesel truck Maut Toll BEV		Fuel per trip Energy BEV Energy H2		
Additional information: <<include any additional information related to the trip operation and requirements>>				
Performance comparison				
<<include overview on energy need>>	<<include overview on cost comparison>>	<<include overview on CO2 assessment>>		

Table 1: ZEFES data sheet template

2.2 Truck routing and corridor parametrizing

To derive the truck route per ZEFES use case PTV Map&Guide software has been used. The online truck route planning software automatically considers vehicle restrictions, time windows, traffic information, and driving and rest times, resulting in routes adjusted for trucks and commercial vehicles. The truck routing software also calculates infrastructure tolls per country.

Figure 1: Screenshot route planning Map&Guide

Accurate parameters on the driving time, driving and resting breaks during the journey as well service time at the sending and receiving can be derived from PTV Map&Guide.

For BEV routing PTV EV Truck Route Planner has been used. The EV Truck Route Planner is a specialised software tool including:

- Comprehensive catalogue of Truck & Van EVs (Electric Vehicles) in Europe
- Realistic consumption calculation
- Innovative EV truck routing and planning algorithms
- Consideration of relevant vehicle-specific restrictions
- Consideration of driving behaviour, elevations, temperature, and wind influences

Figure 2: Screenshot route planning EV Route Planner

2.3 KPI and calculations

Within ZEFES supply chain operations the stakeholder group priorities the following key performance indicators as crucial:

- Lead time of transport operations, preferably in daily operations
- Cost per trip
- Energy use and emissions of transport operations

Within the following chapters a more detailed overview on the methodology background is provided

2.3.1 Lead Time assessment

The lead time indicator is composed of the following parameters:

- Actual driving time of the truck
- Driving and resting time as provided by regulations
- Service time related to handling operations, this can be loading and unloading or truck positioning
- For BEV vehicles additional charging time

In principle trucks can be operated continuously while drivers have to operate under the regime of driving and resting time regulation (REGULATION (EC) No 561/2006). Key parts of the regulation state that:

- Daily driving period shall not exceed 9 hours, with an exemption of twice a week when it can be extended to 10 hours.
- Total weekly driving time may not exceed 56 hours and the total fortnightly driving time may not exceed 90 hours.
- Breaks of at least 45 minutes (separable into 15 minutes followed by 30 minutes) should be taken after 4 ½ hours at the latest.

A time frame for one driver of 9 hours maximum 10 hours driving with at least 45min break after 4 ½ hours driving. (Electric) Charging time can principally be matched with break times as long as they are planned.

Within the D1.4 assessment all routes have been analysed in terms of

- Identifying the best route for heavy duty trucks from origin to destination
- Analyse trip time and derive needs for journey breaks and driving compliance
- For charging time the energy need as well as the availability of charging stations along the corridor have been taken into account (for BEV https://map.electromaps.com/; for FCEV https://h2.live/)

Using the PTV Map&Guide tool national Maut tolls are included as far as available. Additional CO2 surcharges as to be introduced in Germany in 2023 are also considered.

2.3.2 Energy consumption calculation

The specific energy consumption has been calculated to enable a comparison of operational energy needs of different drive technologies, namely diesel powered ICE, BEV and FCEV. In order to be consistent, a Tank To Wheel (TTW) methodology has been applied while the emission calculation is considering the energy production and follows a WTW approach.

Truck energy consumption is included using measured average fuel consumption of 40t trucks and EMS trucks on European corridors (in various loading states). Measurements were made in the AEROFLEX project. If measured average data is not available, default data as provided by truck profiles in Map&Guide have been used. The approach is in line with the CEN 16258 standard. Recuperation for BEV for FCEV is not taken into account at this stage. This will be included in the data collection in WP7 and evaluation of WP8.

For BEV, energy consumption calculated based on EV Truck Route planner calculation taking into account elevation parameters (TTW). Calculation is based on existing truck profiles and characteristics as provided by different OEMs. For D1.4 truck profiles for Volvo/Renault, Scania and Ford have been used. For e-Trailer profile data from Trailer dynamics have been used.

FCEV sources truck profile data as provided by the OEMs have been used. Average energy consumption per kg hydrogen has been used and if not available calculated. Conversion rates have been applied 1 kg hydrogen heating value of 33,3 kwh (used for FC drive). For consistency reasons cross metric calculations have been made on the specific energy needs as well as on the physical losses related to the drive engines.

2.3.3 Emission calculation

2.3.3.1 CO2 emission factors ICE

Fuel emission factors for road transport follow the ISO 14083 standard as provided and updated by the Smart Freight Center. CO2 emissions are included as CO2 equivalents (CO2e) as provided by the ISO 14083 standard and updated by Smart Freight Center report “Fuel Emission Factors in ISO 14083 A brief description of the derivation of emission factors” in July 2023. CO2 Emissions are reported on a Well to Wheel (WTW) basis taking the total GHG emissions (including energy production) into account. For consistency reasons emission factors are transposed into kwh, considering 0,343 kg CO2e/kwh for diesel propelled ICE. Optionally, emission factors for HVO/HEF
A (SAF) (50 % rapeseed, 50 % used cooking oil) has been included as full renewable solutions. Following the ISO 14083 emission standards 0,097 kg CO2e/kwh are considered for HVO.

2.3.3.2 Emission factors for BEV

CO2 emission factors vary from country to country and depends on the mix of energy sources for electric power production made accessible via the power grid. Thus, are equivalent standard emission factor for WTW CO2 calculation is not available. Furthermore, electric power can be produced locally on completely renewable basis and primarily used to charge electric trucks at site. For the assessment of WP1 an average EU electricity factor is used as provided by the ISO 14083 update of Smart Freight Center. For consistency reasons this was transposed into kwh, considering 0,349 kg CO2e/kwh. For fully green renewable energy production a value of 0,006 kg CO2e/kwh is included (in line with wind power production)

2.3.3.3 Emission factors FCEV

Hydrogen is produced from various sources. Mainly, there is made difference between grey, blue and green hydrogen:

- Grey hydrogen: This production form is based on steam reforming of natural gas (Steam Methane Reforming – SMR). This form is well approved and used for industrial hydrogen production for chemical and oil industries.

- Blue hydrogen: In order to reduce CO2 emissions during the steam reforming process the resulting CO2 will be captured and stored (Carbon Capture and Storage CCS). Estimation suggest that about 60 to 70% of the CO2 emissions from the reforming process can be captured.
- Green hydrogen: Hydrogen that is produced by electrolysis using electric power. The electric energy used can only be covered by renewable energy sources, such as wind or solar power.

CO2 equivalent emission factors for hydrogen are provided by the ISO 14083 for gey hydrogen (steam reforming from natural gas) with 0,579 kg CO2e/kwh (WTW). For blue and green hydrogen consistent standard figures are not available. German Umweltbundesamt provided a study in 2022 provided a consistent comparison between grey, blue and green hydrogen resulting in 0,486 kg CO2e/kwh for grey hydrogen, 0,371 kg CO2/kwh for blue hydrogen and 0,108 kg CO2e/kwh for green hydrogen. For consistency reasons the calculated emissions factors from the Umweltbundesamt are used within ZEFES D1.4 taking into account that these are at the lower end.

3 Results & Discussion

Within chapter 3 the methodology described will be applied to each ZEFES use case. The mapping made is to:

- Define realistic routing options
- Complete a data sheet per use case

3.1 Results

3.1.1 Use case 1: FCEV Gothenburg to Hofors

A Swedish shipper will contract a carrier to operate the vehicle (R+ST 24m @ 64 GCW) for 12 months on an existing flow to carry steel scrap from Gothenburg-SE to Hofors-SE and in the opposite direction carry steel collies. The truck is to complete up to five return trips per week resulting in a total distance of ca. 4800 km/week.

Trip classification	Single trip
Distance	477 km
#Drivers	1
Driving time	8:45 h
Driving & Resting	0:45 h
Road Tolls	Eur 0

Table 2: Route metrics Gothenburg to Hofors

A single trip of 477 km and driving time of 8:45h with one resting break in the area of Örebro. For the FCEV operation a similar trip layout is considered than for diesel. An additional fuelling stop might be needed. There is a fuelling station available in Mariestad.

The trip metrics are shown in the data sheet below:

Dats Sheet UC1: FCEV on Gotheburg – Hofors:

Vehicles & trip

- FCEV VOLVO, capacity of 58 kg hydrogen
- Rigid 6x2 with Standard Swedish trailer in duo configuration (24m length and max 64t GW)
- Single Trip A
- No Dolly

	Trip Parameters

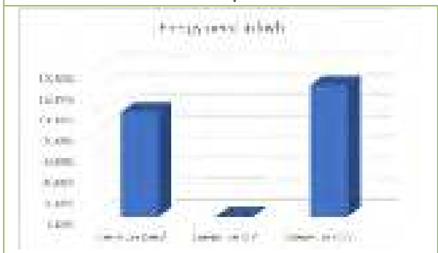
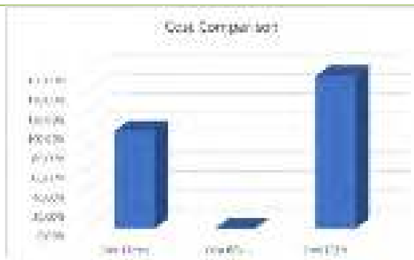
	Trip length: Driving time: Rest&Service: Charging time:	480 km 8:45h 0:45	Total Travel Diesel: Total Travel BEV: Total Travel FCEV	9:30 9:30
Additional Settings				
Number of Drivers Maut diesel truck Maut BEV	1	Fuel per trip Energy BEV Energy H2	208 l 77 kg	2038 kwh 2564 kwh
Additional information: • Fueling on-trip would be possible at Hynion stations (Gothenburg and Sandviken), additional possibilities on shippers' site would be welcome • Additional on-trip fueling would be needed. A H2 fueling station is available in Mariestad				
Performance comparison				
				

Table 3: Data sheet Gotheburg to Hofors

Overall, the energy need (TTW) for FCEV is higher than diesel (+25%). Cost is about 50% higher due to the relative high hydrogen costs in Sweden (compared to other EU countries H2 prices are quite low). CO2 emissions of FCEV are higher for grey (+78%), blue (+36%) and lower for green hydrogen (-65%). Comparing with HVO fuelling for diesel trucks even green hydrogen does not show better emission metrics.

3.1.2 UC2: BEV Gothenburg to Gent

The Swedish shipper will operate the vehicle (T+ST @ 44 GCW) or (T+ST+D+ST @ 64t GCW) for 12 months serving the existing automotive parts supply chain between 2 factories in Gothenburg-SE and Gent-BE. The cargo is volume limited. Scandlines operates the ferry connection Puttgarden to Rodby, giving the opportunity of charging of the vehicle during ferry operation or at the terminal. The route length is 1250km.

	Trip classification	Single trip
	Distance	472 km
	#Drivers	1
	Driving time	6:45 h
	Driving & Resting	0:45 h
	Maut	170 Eur

Table 4: Route metrics Gothenburg to Rödby

A resting break needs to be made in the area of Copenhagen. After the journey continues to Rödby where a ferry with 45 min transit time will be reached.

For the journey Fehmarn to Gent 2 additional breaks including a resting time of 11 hours is needed.

Trip classification	Distance	#Drivers	Driving time	Driving & Resting	Maut
Single trip	670 km	1	10:00 h	1:30 h	127 Eur

Table 5: Route metrics Fehmarn to Gent

The corresponding BEV routing has been made using the PTV EV Routeplanner.

Table 6: EV Route planning Gotenburg to Gent

Charging stops are needed in the Malmö area, Rödby and Bremen area. Partly, this can be matched with the break times. Since a 11 hours break is also needed charging with lower capacity can take place during this time. The following structure is considered for the corridor:

	km	driving time	Energy in kwh	Resting	Charge time CCS	Total time
Got - Malmö	274	04:00	400	00:45	01:30	05:30
Malmö - Rödby	199	03:00	202			03:00
Ferry				00:45	01:00	01:00
Break				11:00		11:00
Fehmarn-Bremen	284	03:30	324		01:00	04:30
Bremen-Venlo	283	03:30	326	00:45	01:00	04:30
Venlo-Gent	195	03:00	252		01:00	04:00
	1235	17:00	1504	13:15	05:30	33:30

Table 7: Route breaking and charging stops Gothenburg to Gent

The trip metrics are shown in the data sheet below:

Dats Sheet UC2: Gothenburg – Gent

Vehicles & trip

- BEV Volvo FM, Capacity of 540 kwh
- Tractor with standard trailer and / or duo std trailers, recommended eTrailer
- Single trip A-C

Trip Parameters

Trip length:	1235 km	Total Travel Diesel:	30:30 h
Driving time:	18:00 h	Total Travel BEV:	33:30h
Rest&Service:	13:15 h	Total Travel FCEV	
Charging time:	5:30		

Additional Settings

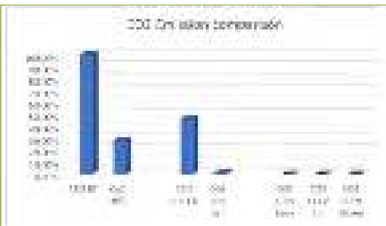
<table>
<tr><td>Number of Drivers
Maut diesel truck
Maut BEV</td><td>1
424 Euro
170 Euro</td><td>Fuel per trip
Energy BEV
Energy H2</td><td>310 l</td><td>3028 kwh
1504 kwh</td></tr>
<tr><td colspan="5">Additional information:
eTrailer battery capacity up to 500kWh? Used summing up to 1000 kwh battery capacity?
Charging possibilities (Helsingborg (Vol), Hamburg (ZEFES), Lippstadt and Rhynen (HoLa) and Asten
CO2 charges and Maut exemption included for German leg. Max. tariffs are used for duo trailer Maut charges.</td></tr>
<tr><td colspan="5">Performance comparison</td></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td></td></tr>
</table>

Table 8: Data sheet Gothenburg to Gent

Overall, energy use of BEV is significantly lower (-55%) to diesel trucks. Along the corridor BEV are commercially at an even level to diesel cost metrics due to the extra CO2 Maut charge in Germany. CO2 emissions are -54% lower for BEV to diesel (using EU average CO2eq).

3.1.3 UC 3: BEV Amiens to Zeebrugge

A global shipper will contract carriers to operate the vehicle (T+ST @ 44 GCW) for 6 months, as tractor + duo container-trailer (T+ST+D+ST @ 64t GCW), to transport 45ft containers with hazardous goods between a factory in Amiens-FR via the multimodal terminal Dourges-FR to the multimodal terminal Zeebrugge-BE, a roundtrip of 550km daily. The Vehicle drives (T+ST+D+ST) from Amiens to Dourges. At the terminal Dourges, the dolly will decouple from the vehicle. The T+ST will continue to Zeebrugge (cross border). The D+ST will operate at terminal and D will be charged. When the T+ST comes back from Zeebrugge, it will continue again as T+ST+D+ST back to Amiens.

Trip classification	Round trip
Distance	472 km
#Drivers	1
Driving time	7:00 h
Driving & Resting	0:45 h
Maut	70 Eur

Table 9: Route metrics Amiens to Zeebrugge

For a daily round trip of the diesel operation one break of 45 min is needed. It is considered that this break will be done during the delivery in Zeebrugge.

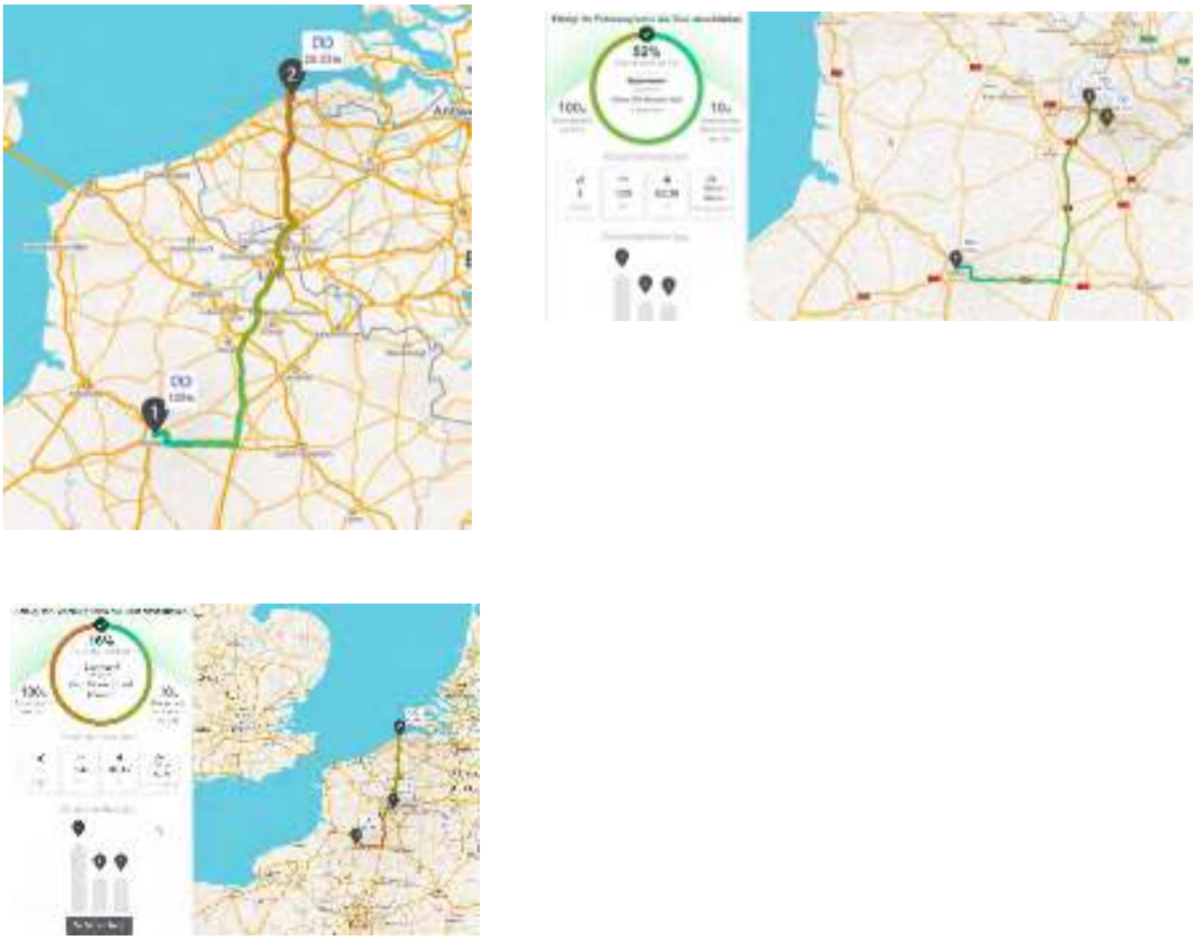


Table 10: EV route planning Amiens to Zeebrugge

Within the one trailer configuration the total energy need per round trip is amounting to 606 kwh while for a duo trailer operation 1130 kwh would be needed. In the present setting a charging at Zeebrugge for a single trailer operation would be needed. For a duo trailer operation 2 charging stops would be needed. In this case two stop in Dourges would be needed.

The trip metrics are shown in the data sheet below:

Dats Sheet UC3: Amiens Zeebrugge

Vehicle & trip

- BEV Volvo FM, battery capacity of 540 kwh
- Standard ISO container trailer, single configuration and duo (max 64t GW)
- Daily round trip
- eDolly AEROFLEX (VET/FHG)

Trip Parameters

Trip length:	472 km	Total Travel Diesel:	8:30 h
Driving time:	7:00 h	Total Travel BEV:	8:30
Rest&Service:	1:30 h	Total Travel FCEV	
Charging time:	1:00 h		

Additional Settings

Number of Drivers	1	Fuel per trip	251 l (Duo)	2460 kwh
Maut diesel truck	71 Euro	Energy BEV		1130 kwh
Maut BEV	71 Euro	Energy H2		

Additional information:

- onsite charging possible at shippers location. Additional on trip charging needed at Zeebrugge. For duo trailer operation in Dourges
- e-Dolly operation in Dourges

Performance comparison

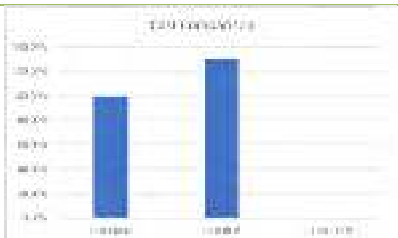


Table 11: Data sheet Amiens to Zeebrugge

Overall, energy use for BEV are significantly lower than diesel (-55%). BEV show higher cost metrics than diesel operations while CO_2 emissions are lower (-53%).

3.1.4 UC4: BEV Dudelange to Halmstad

A Spanish shipper will operate the vehicle (T+ST @ 44 GCW) for 6 months on an existing route of temperature-controlled goods from the CFL Multimodal Terminal in Dudelange-LU to Lidl Halmstad-SE, taking the ferry from Travermünde-DE to Malmö-SE, 1200km, a 2 driver operation. Drivers and e-reefers are owned by the shipper. The e-reefer is equipped with an e-axle, a battery, and an e-cooling for the cargo. UIC/CFL Intermodal take care of the transport by rail (Le Boulou (FR) to Dudelange (LU)) and the charging of the trailer batteries during the train operation.

Trip classification	Single trip
Distance	722 km
#Drivers	2
Driving time	10:00 h
Driving & Resting	0:00 h
Maut	258 Eur (incl. CO2-Charge)

Trip classification	Single trip
Distance	147 km
#Drivers	2
Driving time	2:30 h
Driving & Resting	0:00 h
Maut	Eur

Table 12: Route metrics Dudelange Halmstad

Due to the 2 driver operations no overnight resting break is needed. The ferry link from Travemünde to Malmö takes 10 hours. A total journey time of 22:30 hours is possible as to provide a A to B service.

	km	driving time	Energy in kwh	Resting	Charge time CCS	Total time
Dudel – Wuppertal	277	04:00	410		01:30	05:30
Wupper – Hamburg	292	04:00	410		01:30	05:30
Hamburg -Travemünde	187	02:00	240			02:00

Ferry		10:00				10:00
Helslingborg -Halmstad	141	02:00	179			02:00
	897	22:00	1239		3:00:00	25:00:00

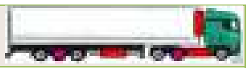
Table 13: Route breaking and charging stops Dudelange to Halmstad

Table 14: EV Route planning Dudelange to Halmstad

Two charging stops would be needed for the journey Dudelange to Travemünde. For the final leg an additional charging either on the ferry or before/after would be necessary.

The trip metrics are shown in the data sheet below:

Dats Sheet UC4: Dudelange to Halmstad



Vehicles & trip

- BEV Volvo FM, battery capacity 540 kwh
- E-Reefer trailer and Reefer trailer both SCB
- A to B single trip

Trip Parameters

Trip length:	870 km	Total Travel Diesel:	22:30
Driving time:	12:00 h	Total Travel BEV:	25:00
Rest&Service:	0:00 h	Total Travel FCEV	
Charging time:	3:30 h		

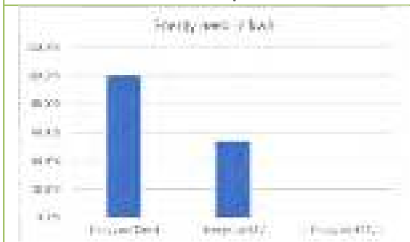
Additional Settings

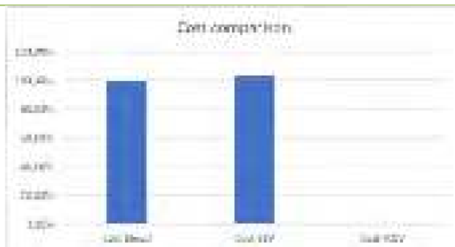
Number of Drivers Maut diesel truck Maut BEV	2 258 Euro 0	Fuel per trip Energy BEV Energy H2	260 l	2548 kwh 1240 kwh

Additional Information:

- Trip include 10 hours ferry Travemünde - Trelleborg / Malmö
- Cost calculation include Maut exemption BEV and CO2 surcharge in Germany on Diesel
- Charging possibilities in Dudelange (CFL), Wuppertal (ZEFES), Lipperland and Rhynern (HoLa), Hamburg (ZEFES) and Helsingborg (VOL)

Performance comparison





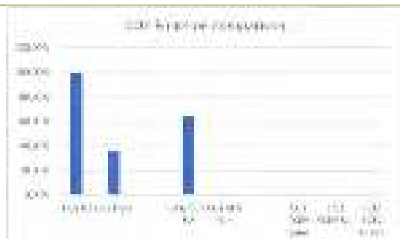


Table 15: Data sheet Dudelange to Halmstad

Overall, energy consumption of BEV to diesel is significantly lower (-51%). Commercially BEV to diesel corridors are at the same metrics due to the CO2 Maut charges in Germany. CO2 metrics show less emissions for BEV (-50%)

3.1.5 UC5: BEV Munich to Eindhoven

A Dutch shipper will operate the vehicle (R+eD+eT @ 48 GCW) for 6 months on a daily Rhine-Alpine corridor to transport parcels from Munich area-DE to Eindhoven area-NL, a round trip with a length of 675km demonstrating the vehicles capability of 750km. The vehicle configuration is a BEV with an e-dolly and an e-trailer equipped with a BDF frame to transport swap bodies.

Trip classification	Single trip
Distance	724 km
#Drivers	2
Driving time	9:30 h
Driving & Resting	0:00 h
Maut	252 Eur (incl. CO2 Maut Germany)

Table 16: Route metrics Munich to Eindhoven

The total trip distance would make a 2 driver setup necessary. With 2 drivers, only breaks for changing the drivers are needed, no additional resting time.

	km	driving time	Energy in kwh	Resting	Charge time MCS	Total time
Munich-Wiesbaden	426	06:00	783		01:00	07:00
Wiesb-Eindhoven	315	04:30	580			04:30
	741	10:30	1362		1:00:00	11:30:00

Table 17: Route breaking and charging stops Munich to Eindhoven

For the BEV routing a charging stop in Wiesbaden area would be necessary. The requirement would be a MCS charging since trailer and tractor would be needed to recharge at limited time scale.

Table 18: EV route planning Munich to Eindhoven

The trip metrics are shown in the data sheet below:

Dats Sheet UC5: Munich Eindhoven

Vehicles & trip

- BEV Volvo FM, battery capacity 540 kwh
- German SWAP-BDF trailer 14,9m, with e-propulsion and dolly
- Daily single trip

Trip Parameters

Trip length:	746 km	Total Travel Diesel:	09:30 h
Driving time:	9:30 h	Total Travel BEV:	11:00 h
Rest&Service:	0:00 h	Total Travel FCEV	
Charging time:	1:30 h		

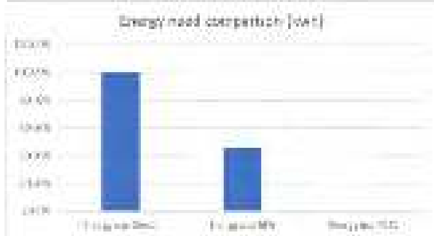
Additional Settings

Number of Drivers	2	Fuel per trip	305 l	2989 kwh
Maut diesel truck	668 Euro	Energy BEV		1373 kwh
Maut BEV	0 Euro	Energy H2		

Additional information:

- eTrailer used extending battery capacity to 1000 kwh
- Maut exemption for BEV and CO2 surcharge for diesel is considered for Germany
- Megawatt Charging possibilities in Asten, Neuss (DPD), Wonnegau, Dasing

Performance comparison



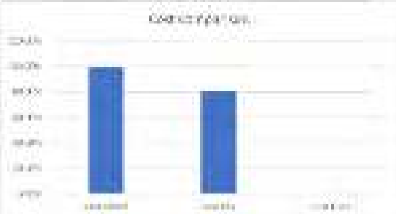


Table 19: Data sheet Munich to Eindhoven

Overall, the energy needs compared to diesel are significantly lower (-49%). Cost are a comparable levels due to German Maut regulations. CO2 emissions are 48% lower for BEV than diesel (average EU CO2 eq for electric power).

3.1.6 UC6: BEV Sodertalje to Zwolle

A Swedish shipper will operate the vehicle (T+ST @ 44 GCW) for 6 months on an existing transport flow of automotive components from Sodertalje to Zwolle and back. The return flow to Sodertalje is limited amount of goods. The round trip is a forward and return trips of 1325km single. The e-trailer operates as a range extender. Scandlines will ensure charging on the ferry Puttgarden / Rodby or in the terminal. USP, Battery in semi-trailer as “range extender”

Trip classification	Single trip
Distance	784 km
#Drivers	2
Driving time	11:00 h
Driving & Resting	1:30 h
Maut	168 Eur

Trip classification	Single trip
Distance	489 km
#Drivers	2
Driving time	8:00 h
Driving & Resting	0:45 h
Maut	152 Eur (incl. German CO2 Maut)

Table 20: Route metrics Sodertalje to Zwolle

Total trip distance with diesel truck is 1275 km. A ferry from Rödby to Fehmarn is taking 45 min transit time. A total travel time of 19 hours is possible. Breaks for driver changes would be necessary. An A to B service is possible.

Table 21: EV route planning Sodertalje to Zwolle

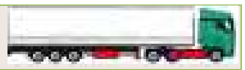
For BEV routing an e-Trailer of 500 kwh battery capacity is taken into account. A charging stop in the area of Helsingborg is necessary as well as in Rodby (on ferry or before /after). With the extended driving range a total trip time of 20:30 can be achieved making a A to B service possible.

	km	driving time	Energy in kwh	Resting	Charge time MCS	Total time
Soder-Helsingborg	522	07:00	612		01:00	08:00
Malmö-Rödby	266	03:45	390		00:45	04:30
Ferry		01:00				01:00
Putt-Zwolle	480	07:00	698			07:00
	1268	18:45	1700	0:00:00	01:45	20:30:00

Table 22: Route breaking and charging stops Sodertalje to Zwolle

The trip metrics are shown in the data sheet below:

Dats Sheet UC6: Sodertalje - Zwolle



Vehicles & trip

- BEV Scania, battery capacity 540 kwh
- Standard trailer, recommended e-trailer with e-propulsion
- A-B Single trip

Trip Parameters

Trip length:	1290 km	Total Travel	21:30 h
Driving time:	20:00 h	Diesel:	23:45 h
Rest&Service:	1:30 h	Total Travel BEV:	
Charging time:	3:45 h	Total Travel FCEV	

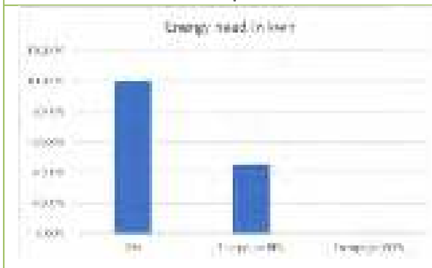
Additional Settings

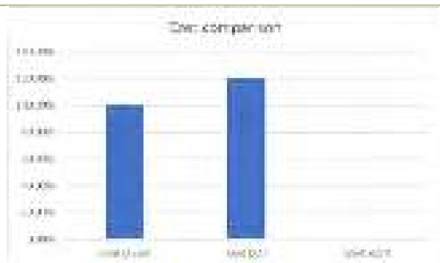
Number of Drivers	1	Fuel per trip	380 l	3724 kwh
Maut diesel truck	334 Euro	Energy BEV		1710 kwh
Maut BEV	140 Euro	Energy H2		

Additional information:

- eTrailer enlarge battery capacity to 1000 kwh
- Maut exemption for BEV and CO2 surcharge for Diesel Maut included
- Charging at Scania CCS stations in Chassiporten, Copenhagen and Zwolle. MCS in Jönköping and Hamburg
- Using Volvo MCS in Helsingborg would be recommended

Performance comparison





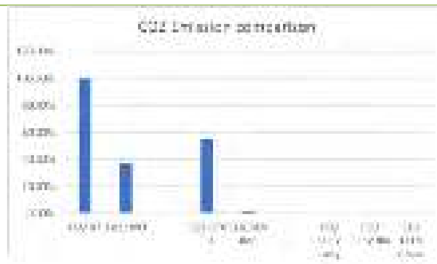


Table 23: Data sheet Sodertalje to Zwolle

Overall, energy consumption shows lower metrics for BEV to diesel (-54%). BEV might operate at slightly higher cost parameters than diesel. CO2 emissions show lower (-53%) based on average EU CO2eq. for electric power.

3.1.7 UC7: FCEV Brenner: Trento to Heinfels

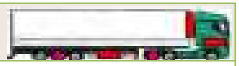
An Italian shipper will run the vehicle (T+ST @ 44 GCW) for 6-month-period across the Brenner Pass complying temperature-controlled goods to evaluate the performance of the vehicle into a real-life environment. The round trip covers a daily distance of about 680 km using a hydrogen station (certified green hydrogen) along the Brenner corridor. The fixed route links approximately Brixen to the road intersection between the Brenner Corridor (Highway A22) and the Highway A4. The operator has the possibility to choose different destination different days to probe the performance of the vehicle.

Trip classification	Round trip
Distance	350 km
#Drivers	1
Driving time	6:00 h
Driving & Resting	0:45 h
Maut	15 Eur

Table 24: Route metrics Trento to Heinfels

The trip metrics are shown in the data sheet below:

Dats Sheet UC7: Trento-Heinfels



Vehicles & trip:

- FCEV Scania, capacity 58kg H2
- E-Reefer trailer and Reefer trailer both KRONE
- Daily round trip

Trip Parameters:

Trip length:	352 km	Total Travel Diesel:	7:30 h
Driving time:	6:00 h	Total Travel BEV:	
Rest&Service:	1:00 h	Total Travel FCEV	7:30 h
Charging time:			

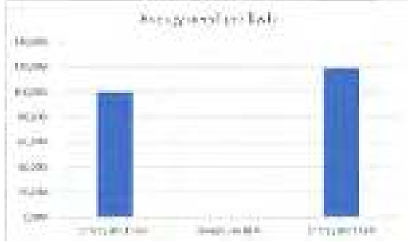
Additional Settings

Number of Drivers	1	Fuel per trip	105 l	1029 kwh
Maut diesel truck	15	Energy BEV		
Maut BEV		Energy H2	35 kg	1165 kwh

Additional Information:

- At both destinations, the truck will collect / deliver cargo at a number of stops. Daily trip length close to 600km.

Performance comparison



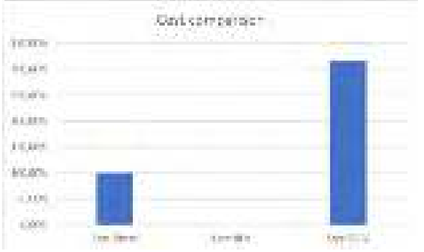


Table 25: Data sheet Trento to Heinfels

Overall, FCEV do not show advantages in energy consumption to diesel operations. Costs are significantly higher due to high H2 costs in Austria and Italy. CO2 emissions are higher for FCEV when using grey and blue hydrogen. Reductions in CO2 emissions can be achieved by using green hydrogen (-62%). HVO might be a better alternative in terms of CO2 emissions.

3.1.8 UC8: BEV and FCEV Huelva to Le Boulou

A Spanish shipper will operate both vehicles BEV and FCEV vehicles (T+ST @ 44 GCW) for 6 months on the existing route of temperature-controlled goods from Huelva to the multimodal terminal, Le Boulou France. Drivers and e-reefers are owned by the shipper. The e-reefer is equipped with an e-axle, a battery, and an e-cooling for the cargo. UIC/CFL Intermodal take care of the transport by rail (Le Boulou (FR) to Dudelange (LU)) and the charging of the trailer batteries during the train operation. The final destination for the e-reefers is Halmstad, Sweden. (See also demonstration 3).

Trip classification	Single trip
Distance	1367 km
#Drivers	2
Driving time	18:30 h
Driving & Resting	0:00 h
Maut	Eur

Table 26: Route metrics Huelva to Le Boulou

Two drivers setup enables a 18:30 driving time. Breaks for driver changes would be necessary. An A to B service is possible in this set up.

The BEV routing would need for 4 charging stops. The routing was based in CCS charging systems summing up to 6 hours additional charging time. If MCS charging would be available the charging time could be reduced. The usage of e-Trailers for range extension would further reduce the charging time. For FCEV an additional fueling stop would be needed.

The BEV routing is shown below.

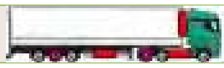
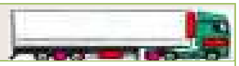
	km	driving time	Energy in kwh	Resting	Charge time CCS	Total time
Huelva-Le Pena/Malaga	269	03:45	404		01:30	05:15
Le Pena - Murcia	374	04:30	501		01:30	06:00
Murcia – Valencia	228	03:15	300		01:30	04:45
Valencia - Tarragona	258	03:30	326		01:30	05:00
Tarragona – Le Boulou	259	03:30	352			03:30
	1388	18:30	1883	0:00:00	06:00	24:30:00

Table 27: Route breaking and charging stops Huelva to Le Boulou

Table 28: EV route planning Huelva to Le Boulou

The trip metrics are shown in the data sheet below:

Dats Sheet UC1: Huelva-Le Boulou

Vehicles &trip:

- BEV Scania, battery capacity of 540 kwh
- FCEV Scania, fueling capacity of 58 kg H2
- E-Reefer trailer and Reefer trailer both SCB

Trip Parameters

Trip length:	1380 km	Total Travel Diesel:	19:30h
Driving time:	18:30 h	Total Travel BEV:	24:30h
Rest&Service:	1:00 h	Total Travel FCEV	19:30h
Charging time:	6:00 h		

Additional Settings

Number of Drivers	2	Fuel per trip	388 l	3800 kwh
Maut diesel truck		Energy BEV		1883 kwh
Maut BEV		Energy H2	130 kg	4329 kwh

Additional information:

- BEV route need to change due to limited charging possibility at reference route (via Madrid, Zaragoza) resulting is 80 km longer distance -> PRI plans to invest in charging points at their depots along coast route to Valencia
- Need to use e-trailer (even on alternative route) to extend range
- Almost no possibility to fuel hydrogen in Spain
- MCS chargers are available at Primafrio depots in Lepe/Huelva and Murcia. Along the route MCS are available in Malaga, Valencia, Tarragona and Le Boulou
- Hydrogen fuel stations are available in Lepe, Murcia, Tarragona and Le Boulou

Performance comparison



Table 29: Data sheet Huelva to Le Boulou

Overall, energy consumption for BEV is at lowest compared to diesel and FCEV. Cost metrics show that BEV are about 20% higher and FCEV 60% higher than diesel. CO2 emissions are 49% lower for BEV, FCEV show lower CO2 emissions for green hydrogen (-65%).

3.1.9 UC9: BEV Martorell to Le Boulou and Dudelange to Heilbronn

A Spanish shipper and Carrier will operate the vehicle (T+ST @44 GCW) for 3 months in Germany on an existing transport flow of automotive goods between Heilbronn-DE to Dudelange-LU, a round trip of 600km. Next the shipper will operate the vehicle for 3 months in Spain on this existing transport flow of automotive goods from Le Boulou-FR to SEAT Martorell-ES as tractor and duo semi-trailer combination (T+ST+D+ST @ 64t GCW), a round trip of 550km.

Trip classification	Round trip
Distance	364 km
#Drivers	1
Driving time	5:20 h
Driving & Resting	0:45 h
Maut	Eur

Table 30: Route metrics Martorell to Le Boulou

The routeing Martorell to Le Boulou will be operated in a duo trailer configuration. Daily break time can take place at the terminal or the shipper location.

Trip classification	Round trip
Distance	582 km
#Drivers	1
Driving time	8:00 h
Driving & Resting	1:00 h
Maut	200 Eur (incl. German Maut sceme)

Table 31: Route metrics Dudelange to Heilbronn

The round trip Dudelange to Heilbronn can be done within a one day driver period. Break times at the shipper or terminal location care considered.

Table 32: EV Route planning Martorell to Le Boulou

The duo trailer combination has an energy need of 440 kwh per leg resulting in a charging at shipper location or at the terminal. Given MCS chargers are available at both ends this, would enable a recharging during the break times.

Table 33: EV Route planning Dudelange to Heilbronn

The single trailer operation from Dudelange to Heilbronn would enable a complete operation without on-trip charging. Charging can take place at the shippers location or in the terminal. There is a need for MCS charging to keep driving time limitations.

The trip metrics are shown in the data sheet below:

Dats Sheet UC9-1: Martorell-Le Boulou

Vehicles & trip:

- BEV, Scania Low Liner, battery capacity 540 kwh
- Low Liner trailer in duo configuration (max 64 t GW)
- Dolly

Trip Parameters

Trip length:	364 km	Total Travel Diesel:	6:30h
Driving time:	5:30 h	Total Travel BEV:	7:30h
Rest&Service:	0:45 h	Total Travel FCEV	
Charging time:	1:30		

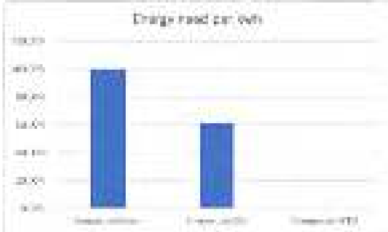
Additional Settings

Number of Drivers	1	Fuel per trip	194 l	1901 kwh
Maut diesel truck		Energy BEV		871 kwh
Maut BEV		Energy H2		

Additional Information:

- Singel trip considered per day
- Charging at shippers site might be possible (CCS), MCS on trip charging might be possible at Le Boulou

Performance comparison



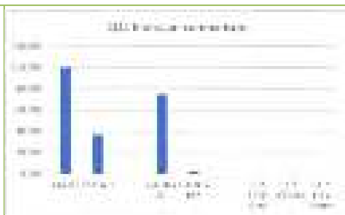


Table 34: Data sheet Martorell to Le Boulou

Overall, energy consumption on this trip is lower for BEV (-55%) to diesel. BEV show higher cost metrics to diesel. CO2 emissions are again lower for BEV to diesel (-53%)

Dats Sheet UC9-2: Dudelange-Heilbronn

Vehicle & trip:

- BEV Scania Low Liner, battery capacity 540 kwh
- Low Liner trailer
- Daily single trip

Trip Parameters

Trip length:	527 km	Total Travel Diesel:	8:00h
Driving time:	8:00h	Total Travel BEV:	9:30h
Rest&Service:	0:45 h	Total Travel FCEV	
Charging time:	1:30 h		

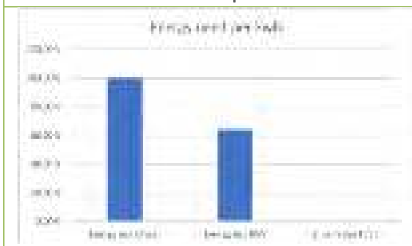
Additional Settings

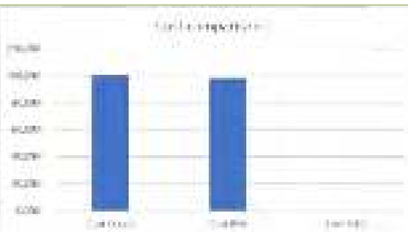
Number of Drivers Maut diesel truck Maut BEV	1 200 Euro (incl. CO2 Charge)	Fuel per trip Energy BEV Energy H2	86 l	840 kwh 398 kwh

Additional Information:

- Singel trip considered per day
- MCS Charging at Dudelange terminal site and at shipper location in Heilbron (CCS), on trip charging might be needed (at limit)

Performance comparison





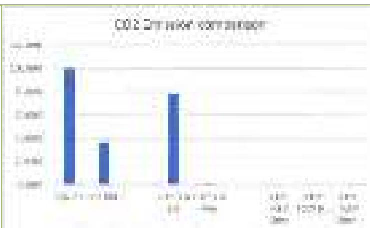


Table 35: Data sheet Dudelange to Heilbronn

Overall, energy consumption of BEV is 54% lower than diesel. The cost metrics for BEV and diesel show that both operate at the same level. CO_2 emissions are 53% lower for BEV than diesel.

3.1.10UC10: BEV Blanzy to Blavozy

A French shipper will start to operate the vehicle (T+ST @ 44t GCW) for 3 to 6 months on an existing plant-to-plant flow, a 500km daily shuttle of semi-finished products on hilly national roads (Blanzy (71)– Blavozy (43)). MICHELIN evaluate the impact of electrification on tires performances (wear, Rolling Resistance) for a Drive prototype tires (315/70R22.5 XM901 – market maturity 2027) improved in wear resistance vs rolling resistance compromise in comparison to current market tyres reference 315/70R22.5 XMD. The assessment of electrification impact on tyre wear performance will be made.

	Trip classification	Round trip
	Distance	478 km
	#Drivers	1
	Driving time	8:00 h
	Driving & Resting	1:00 h
	Maut	Eur

Table 36: Route metrics Blanzy to Blavozy

A daily round trip of 3:30 driving time allows for breaks at each end of the shipper locations.
For the BEV operations the trip characteristics are at the energy capacity limits of the vehicle profile. Charging can be made at the shippers' location keeping the daily driving time limitations.

Table 37: EV route planning Blanzy to Blavozy

The trip metrics are shown in the data sheet below:

Dats Sheet UC10: Blanzy – Blavozy 

Vehicles & trip:

- BEV Renault, battery capacity 540 kwh, equipped with Michelin e-tires
- Standard trailer
- Daily single trip

Trip Parameters

Trip length:	480 km	Total Travel Diesel:	8:45 h
Driving time:	8:00 h	Total Travel BEV:	9:00 h
Rest&Service:	0:45 h	Total Travel FCEV	
Charging time:	1:00		

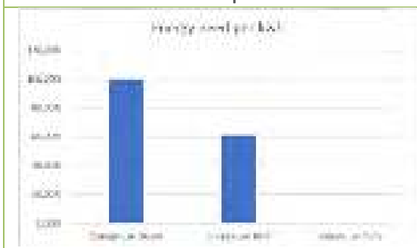
Additional Settings

Number of Drivers	1	Fuel per trip	141 l	1381 kwh
Maut diesel truck		Energy BEV		840 kwh
Maut BEV		Energy H2		

Additional Information:

- Megawatt charging possible in Andrezieu, CCS in Blanzy. On-trip charging might be needed matching with driver break regulations

Performance comparison



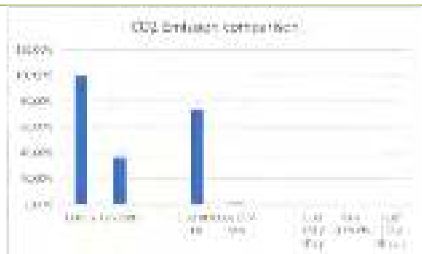


Table 38: Data sheet Blanzy to Blavozy

Overall, energy consumption of BEV is lower compared to diesel (-40%). Cost metrics are higher for BEV than diesel while CO2 emissions are considerably lower for BEV (-39%).

3.1.11 UC11: BEV Blainville sur Orne to Bourg en Bresse

A second French shipper will operate the vehicle for 3-6 months on an existing automotive logistic flow, delivering cabs (Blainville sur Orne – 14) to assembly plant warehouse (Bourg en Bresse – 01), a daily distance of 700 km mainly on French highways. Pending on the logistic operator, goods are going through warehouse closed to each plant before sequenced deliveries.

Trip classification	Single trip
Distance	676 km
#Drivers	2
Driving time	9:30 h
Driving & Resting	0:45 h
Maut	152 Eur

Table 39: Route metrics Blainville sur Orne to Bourg en Bresse

Based on the trip length a 2 driver equipment might be necessary. In this setting a daily round trip might even be possible or a daily shuttle service.

	Km	driving time	Energy in kwh	Resting	Charge time CCS	Total time
Blainville-Nemours	320	04:30	465	00:45	01:30	06:00
Nemours - Bourg en Bresse	352	04:45	511			04:30
	672	09:15	976	00:45	01:30	10:30

Table 40: Route breaking and charging stops Blainville sur Orne to Bourg en Bresse

Table 41: EV route planning Blainville sur Orne to Bourg en Bresse

The routing might be feasible with one interim charging. A stop in Nemours provides the possibility for a MCS, however this station is located are the range limits. Possibly an additional charging stop might be needed.

The trip metrics are shown in the data sheet below:

Dats Sheet UC11:Blainville – Bourg en Bresse

Vehicle & trip

- BEV Renault, battery capacity of 540 kwh, equipped with Michelin e-tires
- Standard trailer
- Round trip over 3 days

Trip Parameters

Trip length:	680 km	Total Travel Diesel:	09:30 h
Driving time:	9:30h	Total Travel BEV:	10:30 h
Rest&Service:	0:00h	Total Travel FCEV	
Charging time:	1:30h		

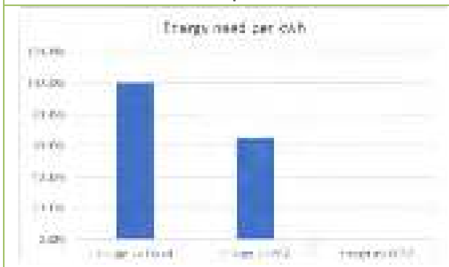
Additional Settings

Number of Drivers	1	Fuel per trip	200 l	1963 kwh
Maut diesel truck	152 Euro	Energy BEV		1176 kwh
Maut BEV	152 Euro	Energy H2		

Additional Information:

- MCS charging at Balinville and Bourg-en-Bresse is possible. On-trip in Nemours (south Paris) to keep drive&rest timing

Performance comparison



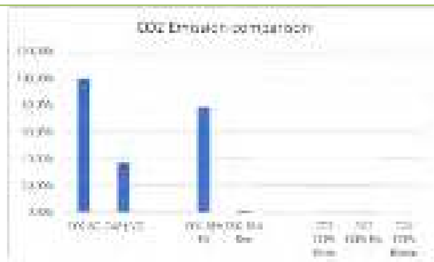


Table 42: Data sheet Blainville sur Orne to Bourg en Bresse

Overall, energy needs for BEV are 47% lower than diesel. Commercial metrics show 20% higher costs. CO_2 emissions are 45% lower for BEV to diesel.

3.1.12 UC12: BEV Veenendaal, Rotterdam, Brussels

A Dutch shipper will contract a carrier to operate the vehicle for 6 months in 2 different configurations as tractor and semi-trailer (T+ST @ 44t GCW) and as tractor and semi-trailer and trailer (T+ST+TR EMS @ 44t GCW) on an existing parcel logistic flow from Veenendaal (NL) to Rotterdam area and Brussels area. A daily distance of 575+100 km (single trailer operation plus, modular trailer configuration). One vehicle in 2 configurations in a traditional full round trip cross border logistics parcel route, equipped with the new designed Michelin tires for ZE-HDV. Charging aligned with drive / rest time schedule and critical time slots at depots.

	**Trip classification**	**Round trip**
	Distance	442 km
	#Drivers	1
	Driving time	6:45 h
	Driving & Resting	0:45 h
	Maut	35 Eur

Table 43: Route metrics Veenendaal, Rotterdam, Brussels

One charging stop in Brussels area is necessary and might be combined with breaking times.

Table 44: EV route planning Veenendaal, Rotterdam, Brussels

The trip metrics are shown in the data sheet below:

Dats Sheet UC12:Veendaal -Rotterdam-Brussels

Vehicles & trip

- BEV Renault, capacity 540 kwh
- Standard trailer, single and in trailer combination (max 44t GW)
- Multi-stop daily round trip

Trip Parameters

Trip length:	442 km	Total Travel Diesel:	7:30h
Driving time:	6:45 h	Total Travel BEV:	7:30h
Rest&Service:	0:45 h	Total Travel FCEV	
Charging time:	0:45 h		

Additional Settings

Number of Drivers	1	Fuel per trip	130 l	1276 kwh
Maut diesel truck	35 Euro	Energy BEV		480 kwh
Maut BEV	35 Euro	Energy H2		

Additional information:

- Retail trip considered not fully loaded with 25t. In this case round trip without charging might be possible
- MCS charging in Berle en Rodenrijs (Volvo) and Puurs

Performance comparison

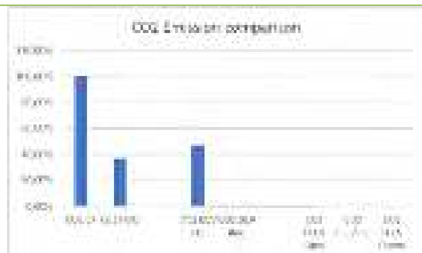


Table 45: Data sheet Veenendaal, Rotterdam, Brussels

Overall, the use of energy of BEV compared to diesel is significantly lower (-55%). Cost metrics show higher cost parameters for BEV to diesel. CO2 emissions a lower by 54%.

3.1.13 UC13: FCEV Kocaeli to Pendik

A turkey's shipper will start the operation for 2 months with the vehicle (T+ST @ 44 GCW) on a regional-national long-haul route between a factory in Kocaeli Plant and the Istanbul Pendik Ports, daily 3 round trips ca. 500km transporting vehicle production parts.

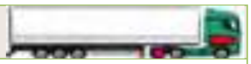
Trip classification	Round trip
Distance	456 km
#Drivers	1
Driving time	9:00 h
Driving & Resting	0:45 h
Maut	Eur

Table 46: Route metrics Kocaeli to Pendik

A local round trip of 160 km and 3 hours driving time, each. The trip is executed in a shuttle operation between plant and port area. For the FCEV operation one fuelling is necessary at shippers location.

The trip metrics are shown in the data sheet below:

Dats Sheet UC13: Kocaeli – Pendik



Vehicle & trip

- FCEV Ford, capacity of 58 kg hydrogen
- Standard trailer
- 3 Daily round trips

Trip Parameters

Trip length:	456 km	Total Travel Diesel:	09:45h
Driving time:	9:00h	Total Travel BEV:	
Rest&Service:	0:45h	Total Travel FCEV	09:45h
Charging time:			

Additional Settings

Number of Drivers	1	Fuel per trip	134 l	1316 kwh
Maut diesel truck		Energy BEV		
Maut BEV		Energy H2	45 kg	1498 kwh

Additional information:

- Driving and service time might exceed travel time regulations, possibly only 2 round trips are possible
- Charging at shipper site would be needed

Performance comparison

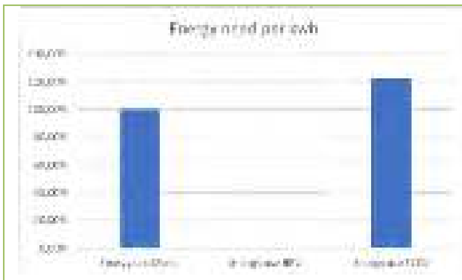
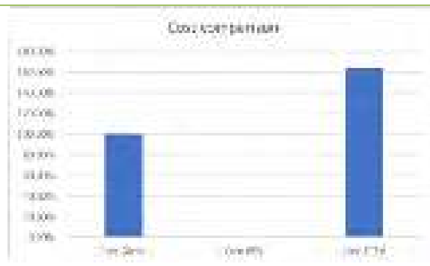
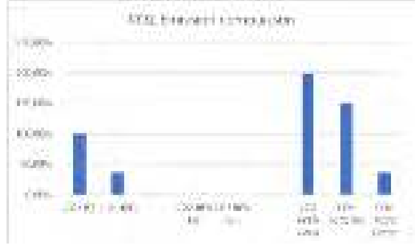




Table 47: Data sheet Kocaeli to Pendik

Overall, FCEV show higher metrics on energy consumption (+14%). Costs are significantly higher to diesel operation (+64%). Grey and blue hydrogen usage show higher emission metrics on CO2 emissions. Green hydrogen has less CO2 emissions to diesel operations (-65%).

3.1.14 UC14: FCEV Linz, Graz, Vienna

An Austrian shipper will contract carriers for 3 Months to operate the vehicle (T+ST @ 44 GCW) in a logistics network of a daily regional-national long-haul profile for parcel distribution, daily ca. 600km. USP, FCEV vehicle operating in a regional / national long-haul mission profile.

Trip classification	Round trip
Distance	596 km
#Drivers	1
Driving time	8:45 h
Driving & Resting	0:45 h
Maut	263 Eur

Table 48: Route metrics Linz, Graz, Vienna

One day round trip of 8:45 hours driving time and one break in the area of Graz is necessary for execution. FCEV would require an additional refuelling in the area of Graz (in Graz, a hydrogen fueling station is available).

The trip metrics are shown in the data sheet below:

Dats Sheet UC14: Linz – Graz - Vienna

Vehicles & trip

- FCEV Volvo, capacity of 58 kg hydrogen
- Standard trailer
- Daily round trip

Trip Parameters

Trip length:	596 km	Total Travel Diesel:	9:45 h
Driving time:	8:45 h	Total Travel BEV:	
Rest&Service:	1:00 h	Total Travel FCEV	9:45 h
Charging time:			

Additional Settings

Number of Drivers	1	Fuel per trip	193 l	1887 kwh
Maut diesel truck	262	Energy BEV		
Maut BEV	262	Energy H2	63 kg	2097 kwh

Additional information

- High H2 cost in Austria of 27 Euro per kg

Performance comparison

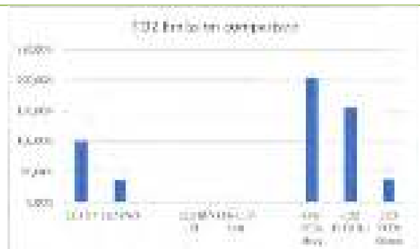


Table 49: Data sheet Linz, Graz, Vienna

The energy use of FCEV is 10% higher than diesel. Due to the high hydrogen prices in Austria, a commercial comparison shows significantly higher cost metrics for FCEV. Grey and blue hydrogen usage would additionally result in higher CO2 emissions. Green hydrogen could reduce CO2 emissions by 65%.

3.1.15 UC 15: FCEV Milan to Pomezia

A global shipper will contract carriers to operate the vehicle, (T+ST @ 44 GCW, ST is a 45ft container-trailer) in a national multimodal flow long-haul profile of partly dangerous goods on mountainous terrain and with the use of tunnels, daily ca. 660 km for 3 months.

Trip classification	Single trip
Distance	621 km
#Drivers	1
Driving time	8:45 h
Driving & Resting	0:45 h
Maut	85 Eur

Table 50: Route metrics Milan to Pomezia

A single day trip with one driving break in the area of Firenze. For FCEV an on-trip refueling would need to be made. Presently hydrogen fuelling stations in Italy are rare. Possibilities are available only in the Grecciano/Livorno area. However, this would lead to a detour and longer trip time compared to the diesel route. Since trip metrics are already at the limit a further detour would exceed the daily driving restrictions and making a two driver setup necessary.

Dats Sheet UC15:Milan - Pomezia

Vehicles & trip

- FCEV Ford, capacity of 58 kg hydrogen
- Standard ISO container trailer
- Single daily trip

Trip Parameters

Trip length:	612 km	Total Travel Diesel:	9:45h
Driving time:	8:45h	Total Travel BEV:	
Rest&Service:	1:00h	Total Travel FCEV	10:00h
Charging time:			

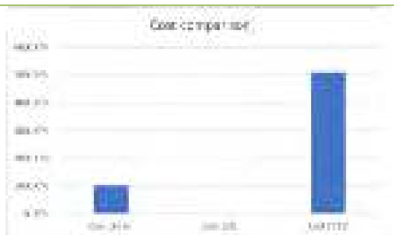
Additional Settings

Number of Drivers	1	Fuel per trip	206 l	2021 kwh
Maut diesel truck	85	Energy BEV		
Maut BEV		Energy H2	68 kg	2274 kwh

Additional information

- No charging possibilities along the corridor available
- Hydrogen fueling station in Grecciano/Livorno, detour of 30 min.

Performance comparison



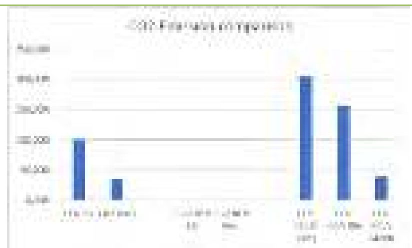


Table 51: Data sheet Milan to Pomezia

Energy use of FCEV is higher to diesel operations (+12%). Cost metrics show no commercially viable alternative to diesel operations due to high hydrogen prices in Italy. Green hydrogen has the potential to reduce CO_2 emissions along the corridor by 65%.

3.2 Contribution to project (linked) Objectives

D1.4 contributes to the ZEFES objectives:

- Providing initial analysis on the pilot demonstration performance parameters. Improvements in the design and set up can be defined. D1.4 will be the basis for WP7
- Requirements on the performance assessment will be used to design battery capacity as well as charging needs for the technical development in WP2 and 3. The need for eTrailers on specific corridors has been identified and would need to be taken into account.
- Requirements for the digital twin development in WP4 has been identified. Approaches for the decision support and optimization has been identified and needs and requirements provided.
- D1.4 approach could be taken up by WP8 activities on the pilot assessment. Parameters and performance indicators might serve as base line.

D1.4 provides a crucial contribution to key objectives, especially:

- Design requirements to improve modular BEV and FCEV vehicles in terms of battery capacity or modular systems
- The needs for megawatt charging systems within supply chain operations
- Needs and requirements to better design dedicated digital tool and services for BEV and FCEV
- Provide valuable contributions to design and set up successful demonstrators fulfilling the requirements for range and payload, and comparing the deployability of BEVs and FCEVs for different mission profiles

4 Conclusion and Recommendation

With regards to needs and requirements the following can be summarised:

Topic	Needs
Trip	• Route planning may not lead to longer and slower routes for BEV or FCEV compared to diesel • Route optimization need to be in line with driving and resting time regulations, including charging activities • Energy consumption to be integrated in trip planning to find charging and fueling possibilities • Additional parameters, e.g. energy prices, safe and secure parking to be included • Dynamic route planning needs to consider various parameters integrating weather data, traffic situation, time windows matching eco driving considerations • Eco route profiles maximizing energy savings (recuperation modes) • Energy and emission calculations should be consistent with ISO 16258 and ISO 14083. Need to extent the standards for BEV and FCEV
Charging & Fuelling	• Location identification for MCS and CCS on-trip charging • MCS and H2 technology (open) on trip fueling network • Access and slot booking to minimize time for charging operations • Accessibility data (weight, height, and dimensions) for trucks
Vehicles	• CAPEX: purchasing prices for BEV and FCEV significantly to be reduced to become competitive • OPEX: Electric energy and hydrogen prices need to be reduced to become competitive. High variations in on-trip charging • Price harmonization across Europe (H2 and electricity) • Minimum battery capacity should be around 600 kWh (to be safe within the 4,5 hours driving range)
Infrastructure & Policy	• Maut and CO2 prices can be decisive for business case. Need to include in trip planning • Accessibility to infrastructure e.g., hydrogen in tunnels and cities, BEV on ferries • Data availability e.g., mapping, tracking and tracing

Table 52: Consolidated needs and requirements

5 Risks and interconnections

5.1 Interconnections with other deliverables

D1.4 is considered as a further specification of the use cases in D1.2. The results of D1.4 are considered complementary to D1.3. The results will be further detailed in D1.5. D1.4 will be the basis for WP 7 activities and taken up for D7.1. The results will be used in WP8 for setting up the evaluation framework and included in D8.1.

6 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:

#	Partner short name	Partner Full Name
1	VUB	VRIJE UNIVERSITEIT BRUSSEL
2	FRD	FORD OTOMOTIV SANAYI ANONIM SIRKETI
4	KAE	KASSBOHRER FAHRZEUGWERKE GMBH
5	REN	RENAULT TRUCKS SAS
6	SCA	SCANIA CV AB
7	VET	VAN ECK TRAILERS BV
8	VOL	VOLVO TECHNOLOGY AB
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
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17	ZF	ZF CV SYSTEMS HANNOVER GMBH
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19	DPD	DPD (NEDERLAND) B.V.
20	COL	ETABLISSEMENTEN FRANZ COLRUYT NV
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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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