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

ZEFES - Deliverable report

D1.5 Supply Chain Needs

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Publishable Summary

In Deliverable 1.5, the finalized Supply Chain Needs and Requirements are published together with the methodology on how they were derived, followed by the main insights gathered from the survey and interviews with all stakeholders of the zero-emission heavy-duty road transport ecosystem.

Chapter 2 defines the ecosystem and the stakeholders during the process of gathering needs and requirement. It became clear that the ecosystem is more than just the trucks that will be electrified. Since the energy carrier will change from diesel to hydrogen or electricity stored in batteries, the full energy supply chain will need to change. Therefore, Charging Point Operators (CPO) and Hydrogen Refuelling Station (HRS) operators as stakeholders are identified. Next to the flow of energy, the flow of goods, logistics itself, will be impacted by ZE-HDV capabilities. Shorter driving ranges and restricted payloads compared to diesel trucks change logistics planning and routing needs. The impacts on the driver should also be assessed further. A visualisation of the ecosystem is given in Figure 1.

The **overall approach to derive the needs and requirements** is described in **Chapter 3**. A first bundle of needs and requirements was gathered in interviews and a survey. Next, an interactive validation session in real-life was organized.

In **Chapter 4 the outcome of the ZEFES survey and the interviews** is given. The main take-aways per stakeholder group are the following: <u>Shippers and truck end-users</u> want to learn, but the impact on costs and logistics operations hampers large scale implementation. <u>Logistics site owners or operators</u> want to install infrastructure at logistics hubs if it does not endanger business continuity. The installation of the infrastructure will be limited by the power connection of the site. <u>Truck OEMs</u> have commercial BE-HDV in their portfolio, but FCE-HDV technology is not as developed as BE-HDV and not ready for commercial deployment. It should not be forgotten that <u>trailers also need to be electrified</u>, especially conditioned trailers (reefers) and trailers with a tailgate. This means that the trailers need to be getting electricity from the ZE-HDV, impacting the driving range, or have their own battery that could be charged by a regenerative axle (e-axle) or from the grid. <u>Infrastructure manufacturers and operators</u> state that developing infrastructure takes years, due to permitting and securing the power connection. Also, the increase of hydrogen working pressure to 700bar will impact the HRS design drastically. Finally, route optimisation for ZE-HDV is again a research field that <u>logistics software providers</u> are looking into, just like software to book time slots at infrastructure locations to charge and fuel.

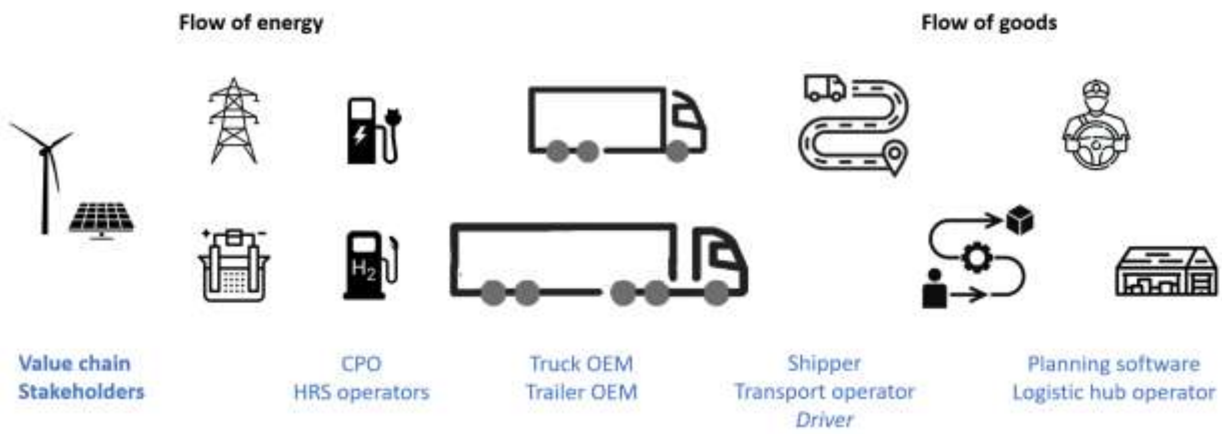

Figure 1: The stakeholders of the ZE-HDV ecosystem that were approached to gather needs and requirements

Chapter 5 reflects the feedback gathered at the **SHG workshop**. The input led to the definition of 64 needs and requirements divided over 6 categories: (i) truck-trailer technology, (ii) integration in the logistics operation, (iii) social acceptance: safety and sustainability, (iv) legal barriers, (v) infrastructure and (vi) viable business case. The list of the final needs and requirements can be found in **Appendix I.**
The final conclusions can be found in **Chapter 6**; we structured them in such a way that relations and interdependencies between the different stakeholders can be seen. The interdependencies suggest that the whole zero-emission ecosystem needs to collaborate and move as a whole to make zero-emission trucks and their infrastructure a reality.
<u>The logistics use case that needs to be electrified can be seen as the start, the centre of the interdependencies</u>. The logistics use case is defined by several parameters, such as: route, mileage, payload, specification of the cargo (ADR, temperature-controlled goods, etc.), and delivery time.
The shippers and transport operators want to be able to define the capabilities of ZE-HDVs needed based on the logistics mission they will perform (buying decision tool). The truck end-users also stated that interoperability between ZE-HDVs and the available charging and fuelling infrastructure is one of their main concerns (even more than reducing emissions), so charging/fuelling is possible at every available location and the flexibility of operation is maximised. In addition to the buying decision tool, truck end-users are also requesting a fleet management system (FMS) that can integrate ZE-HDVs in existing fleet operation, considering their different capabilities compared to diesel trucks.
Truck and trailer OEMs want to learn from the truck operators what exactly are the needed ZE-HDV capabilities, so the customer can be convinced to buy ZE-HDVs instead of diesel trucks. This knowledge about realistic implementation scenarios is also important to determine (production) scale-up scenarios and should be based on real operational data of ZE-HDV fleets. There will be no one-solution-fits-all ZE-HDV, as ZE-HDVs with different, modular designs (e.g. different battery sizes) will be brought on the market. Additionally, trailers will be electrified, and their implementation and charging should also be organised.
Operators of infrastructure (CPOs or HRS operators) want to learn what the demand profile will be (location and daily power charged/mass refuelled) and how the profile will change during the day and in the coming years. Since ZE-HDVs and infrastructure technology are still evolving, investing in state-of-the-art infrastructure technology can be seen as a risk, as it could be useless for the new generations of trucks. Nevertheless, the investments is need today, so smart concepts that increase the compatibility with future ZE-HDV are necessary, e. g. the modular expansion of charging locations with CCS 350 kW with more chargers and even MCS, based on the expected future demand and technology evolution. Infrastructure operators are also requesting a reservation platform or booking app, where truck operators can book a time slot to charge or fuel their truck. In this way, the infrastructure operators can better predict the actual demand and optimise the operation and business case of the station.
ZEFES addresses three tools or apps: a buying decision tool, a fleet management system for fleets with mixed power trains, and a booking app for charging or fuelling slots. Companies that develop **logistics planning software** are therefore an important stakeholder. They want to gather more insights in how routes can be optimized for ZE-HDV and are requesting connected ZE-HDV, so the vehicle parameters like locations and State of Charge (SOC) are communicated directly to the logistics planning software.
Lastly, the **operators of logistics hubs** are willing to install infrastructure on their site. Nevertheless, they want to get more insights into future demand: how much will be charged at logistics hubs, and how much at commercial stations? The installation and operation of the infrastructure should not hamper the business continuity of the site. In addition, the power connection of logistics hubs is

limited, which will have an impact on what can be installed and make charging at these sites challenging.

All these interdependent needs and requirements are visualised in Figure 2. Most of them can be seen as bilateral advantages and are even connected to multiple stakeholders. Most of the needs and requirements stated in APPENDIX I can also be connected to this summary.

Value chain Stakeholders / **Interdependencies**	Shipper Transport operator	Truck OEM Trailer OEM	CPO HRS operators	Planning software Logistic hub operator
Shipper Transport operator	**Logistic use case**	**Selection HDV technology**	**Interoperability**	**Integration tools for mixed fleet (FMS)**
Truck OEM Trailer OEM	**HDV capabilities**	**Implementation scenario, scale-up**	**Trailer charging, acces and parking**	**Real operational truck data**
CPO HRS operators	**Infrastructure capabilities, demand**	**Compatibility**	**Evolving technology**	**Reservation platform**
Planning software Logistic hub operator	**Logistic planning Routing**	**Connected vehicles**	**Limited power connection hubs**	**Business continuity Energy management**

Figure 2: Summary table of the identified needs and requirements and the interdependencies between the needs and requirements of the different stakeholders. The logistics use case is seen as the starting point.

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Abbreviations and Definitions

Abbreviation	Explanation
BE-HDV	Battery Electric Heavy-Duty Vehicle
BEV	Battery Electric Vehicle
CCS	Combined Charging System
CPO	Charging Point Operator
D	Dolly
DT	Digital Twin
DTP	Digital Twin Platform
e-D	Electric dolly
EMS	European Modular System, HDV carrying standardised loading units for intermodal freight transport
e-ST	Electric semi-trailer
FCE-HDV	Fuel Cell Electric Heavy-Duty Vehicle
FCEV	Fuel Cell Electric Vehicle
FMS	Fleet management system
GCW	Gross Combination Weight
HDV	Heavy-Duty Vehicle
HRS	Hydrogen Refuelling Station
ICE	Internal Combustion Engine
ISO	Interchangeable container as defined in the ISO-Norm 668
MCS	Megawatt Charging System
OEM	Original Equipment Manufacturer
R	Rigid unit
Reefer	Loading unit to transport temperature-controlled cargo
SOC	State Of Charge, applicable for both BE-HDV and FCE-HDV
ST	Semi-trailer
SWAP	Interchangeable container accommodating Euro-pallets for road and rail transport
SHG	Stakeholder group
T	Tractor unit
TCO	Total Cost of Ownership
tkm	Tonne kilometres
TR	Trailer
USP	Unique Selling Proposition (uniqueness of ZEFES use cases)
VECTO	Vehicle Energy Consumption Calculation Tool
vkm	Vehicle kilometres
WPL	Work Package Leader within ZEFES project
ZE-HDV	Zero tailpipe Emission Heavy-Duty Vehicles
ZEV	Zero tailpipe Emission Vehicle
	Abbreviations of project partners, see chapter 8 acknowledgement

1. Introduction

In this deliverable the outcomes of the ZEFES survey is discussed, interviews with companies in the ZE ecosystem, and the final workshop with the ZEFES consortium and SHG in detail.

Chapter 2 defines the ecosystem and the stakeholders. The overall approach to derive the needs and requirements is written out in **Chapter 3**. **Chapters 4** and **5** describe the outcomes of the ZEFES survey, the interviews, and the SHG workshop. The final list of identified needs and requirements can be found in **Chapter 6**, and in the final **Chapter 7** a concluding table with the interdependencies and needed future collaboration between the stakeholders is shown.

2. Definition of the Ecosystem

How the ZE-HDV ecosystem is defined is already explained in detail in D1.3. In the figure below the defined ecosystem is shown and briefly repeat the description, so this deliverable can stand on its own. The ZE-HDV ecosystem is defined around two flows: one of goods and one of energy (Figure 1 above and Figure 3 below). The flow of goods is fulfilled by the collaboration of shippers, transport operators (driver), and logistics site operators. The process can be done by additional companies, these three roles are defined for simplicity.

ZE-HDV, trailers and planning software are required to transport the goods. So, the companies that produce them (truck and trailer OEMs and day-planning/dispatching software providers) are also in the ecosystem.

The trucks need to be supplied with energy, so a second flow, the energy flow is linked. The stakeholders identified for this flow are the infrastructure manufacturers and operators (both charging and hydrogen refuelling stations (HRS)). It was decided not to consider energy production itself and energy transport.

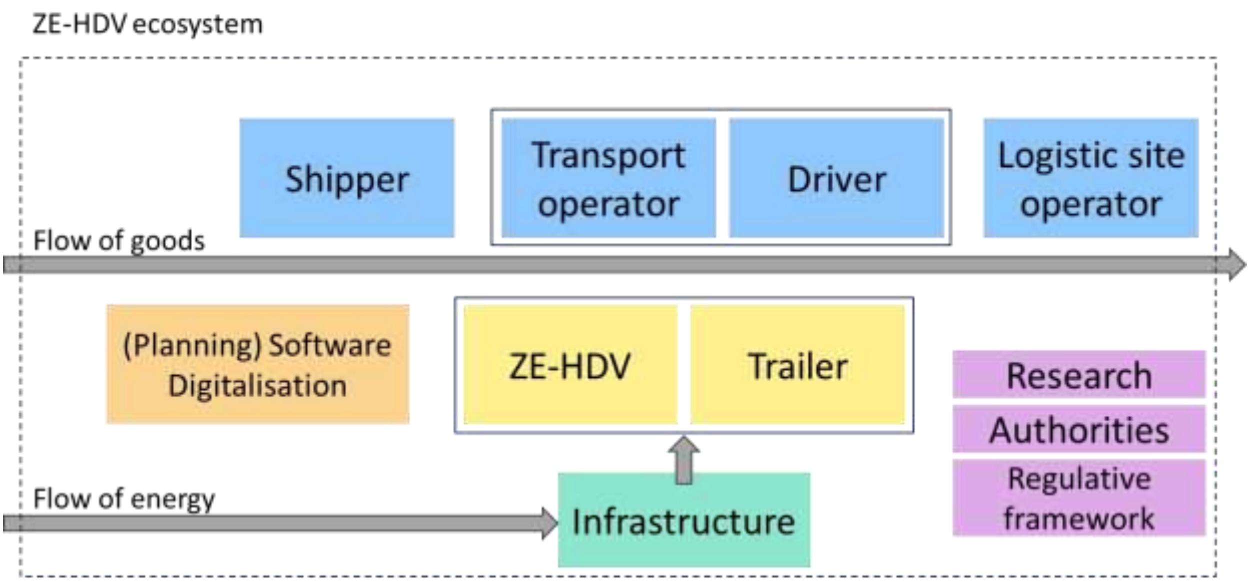


Figure 3: Stakeholders of the ZE-HDV ecosystem

3. Overall approach to gather input

This section addresses the procedure to derive the needs and requirements and the applied methodology to compose the online survey, the interviews, and the final validation workshop. The methodology is already explained in detail in D1.3 but is repeated to achieve a stand-alone deliverable.

As stated earlier, input was gathered in three ways: by a survey, interviews, and a final interactive validation workshop (Figure 4). The survey was filled in by 43 respondents, more than 10 interviews were conducted in combination with explaining the content of the ZEFES project, and more than 100 people attended the final validation workshop (Figure 5).

After the definition of the stakeholders, we decided to develop different surveys for each stakeholder group, since they all have different views on zero-emission road transport as well as different needs and requirements. The survey questions are based on insights of the ZEFES partners, combined with insights from the interviews with logistics companies. All survey questions, organised by stakeholder group, can be found in D1.3 APPENDIX I.

Once the questions were defined, the online survey was built (using Gravity Forms software) and published publicly on the ALICE website. Interested respondents from the ZEFES project partners and ALICE members were asked to fill in the survey by personal mail. We also asked to publish the link to the ZEFES survey in relevant newsletters to attract respondents. We aimed for qualitative responses rather than a high number of respondents. At the end of the survey period, 43 respondents filled out the survey.

Most of the interviews were bilateral, which means that the ZEFES project and objectives were presented together with gathering the needs and requirements of the relevant company. Logistics companies and the infrastructure operators were targeted.

The first responses to the survey and the interviews led to a preliminary list of needs and requirements, which was published in D1.3. the identified needs and requirements are divided into six categories: (i) truck-trailer technology, (ii) integration in the logistic operation, (iii) social acceptance: safety and sustainability, (iv) legal barriers, (v) infrastructure, and (vi) viable business case.

Figure 4: Input for the needs and requirements list was asked by a survey, interview and an interactive, live workshop

In a third step, the survey answers collected so far and the preliminary list of needs and requirements were validated during the ZEFES Symposium of 25th of October, in Session I 'Supply chain needs'. The list with needs and requirements was shared with the participants prior to the event, so they had time to formulate feedback. The Session consisted of three parts. First, a presentation with the preliminary survey results and secondly a panel discussion with representatives from logistics companies that have already implemented at least one zero-emission HDV in their operations were organised. A question from each of the six identified categories was discussed during the panel. Figure 5 shows a picture from the panel discussion.
Following the panel discussion, the final part, an interactive poster session, allowed participants to respond to the identified needs and requirements per topic. The identified needs and requirements were printed on posters, and the workshop participants provided comments on post-its. A picture of one of the topic posters and the gathered feedback can be seen in Figure 5. All gathered feedback can be found in Chapter 5. Finally, we asked for input by mail from all members of the stakeholder group, including those who could not participate in the workshop.

Figure 5: Pictures from the panel discussion about needs and requirements and one of the posters used during the interactive validation workshop.

4. Interviews with logistics companies and CPOs insights

As stated in Chapter 3, the interviews focussed on logistics companies and infrastructure operators. Some qualitative findings – focused on the themes of uncertainty, compatibility, and (infrastructure) availability - will be discussed in this Chapter.

Uncertainty

The interviews revealed that uncertainty about the availability of infrastructure was a recurring topic by **logistics companies**. Most of them were able to assess the capabilities of commercial zero-emission trucks and decide whether it was a match with their logistics operations, but they stated their **concern about the absence of charging and fuelling stations**.

This is confirmed by conversations with both charging point operators (CPOs) and HRS operators, who admit that their current focus lies on the passenger market and not yet on the heavy duty market. This is changing, as the heavy duty market is evolving faster than anticipated due to a combination of technological change, purchasing incentives, and regulatory pressure.[1] In addition, the demand from trucks is an order of magnitude greater per vehicle compared to a passenger car. One truck charging/fuelling is approximately equal to ten passenger cars. This has an impact on the needed infrastructure capabilities and changes the business model drastically.

Despite the lack of infrastructure especially designed for ZE-HDV, ZE-HDV are entering the market, and HDV operators are using chargers for passenger cars (CCS for cars is compatible with BE-HDV, the CCS2 plug for 350 kW charging is installed on both), even if the charger location is not designed for HDVs. HDV accessibility can be limited due to the roof, turning circle, and length of the vehicle (especially as a trailer combination), but also because the concrete surfaces of the locations are not designed to withstand the weight of HDVs and their trailers.

Compatibility

Unfortunately, **a HRS for cars is not compatible with (all) FCE-HDV**. The pressure standard for hydrogen cars is 700 bar, while 350 bar is the common working pressure for the FCE-HDV currently in operation and demonstration. FCE-HDVs with a working pressure of 700 bar are under development and will be demonstrated in ongoing R&I projects, like ZEFES and H2Haul.

But the same working pressure is not enough to be compatible. The mass flow to refuel cars is limited to 60 g/s maximum, and the average refuelling mass flow is lower. In the near future, an increase of the mass flow to 90 g/s is expected, making so called mid-flow refuelling available. When the correct fuelling nozzle is installed on the vehicle, both passenger cars and trucks could be refuelled. KPIs for refuelling speed by the U.S. Department of Energy (DoE, US) are 60 kg in 10 minutes (100 g/s) by 2030 and 60 kg in 6 minutes (167 g/s) by 2050. These target filling rates are higher than what is technically feasible now. A solution could be that two refuelling nozzles are connected to the vehicle, as two mid-flow nozzles could lead to a filling rate of more than 100 g/s. Using a nozzle that is both compatible with cars and HDV is also beneficial for HRS operators, because the same HRS could serve a wider range of clients and could in turn improve the business model.

In addition, the amount of hydrogen refuelled at once is different between cars and HDVs. A car refuelling takes around 5 kg, while masses of up to 80 kg will be needed for HDVs. Due to this difference in mass refuelled, the HRS design will need to change hydrogen storage or compression capacity, or even both.

Availability

The availability of infrastructure is top of mind with logistic companies, as operating ZE-HDV will lead to significantly more charging or fuelling events. The current diesel trucks are commonly refuelled once per week. Due to the high energy density of diesel and the ease of fuelling (pumping) a liquid at ambient conditions, the energy fuelled and fuelling time of a diesel truck are unmatched by ZE-HDVs (Table 1). The main goal of logistics companies is to integrate the (daily) charging or fuelling event in the logistic operations. In general, drivers need to take a rest of 45 min after 4.5 hours of driving, which could be used for refuelling or recharging. Table 1 shows that with current combinations of energy storage on the vehicle and charging or refuelling speed, one ZE-HDV refuelling or recharging per day

[1] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/preparing-the-world-for-zero-emission-trucks

during the driver's resting time could be sufficient, as the daily driving mileage is estimated to be around 300 km.

Table 1: Comparison of the different HDV fuels in terms of energy fuelled, fuelling time and related driving range.

	Energy content	Amount fuelled of energy carrier	Total Energy fuelled	Energizing rate	Time to fuel	Fuelling power	Fuel consumption during driving	Driving range
Diesel	36,9 MJ/L	min 600 L	22.14 GJ	120 L/min	5.0 min	73.80 MW	0.28 L/km	2143 km
H2 350 bar	120 MJ/kg	40 kg	4.80 GJ	80 g/s	8.3 min	9.60 MW	0,09 kg/km	444 km
H2 700 bar	120 MJ/kg	70 kg	8.40 GJ	80 g/s	14.6 min	9.60 MW	0,09 kg/km	778 km
350 kW charger		400 kWh	1.44 GJ	0.35 MW	68.6 min	0.35 MW	1,3 kWh/km	308 km
1 MW charger		400 kWh	1.44 GJ	1.00 MW	24 min	1.00 MW	1,3 kWh/km	308 km
350 kW charger		700 kWh	2.52 GJ	0.35 MW	120 min	0.35 MW	1,3 kWh/km	538 km
1 MW charger		700 kWh	2.52 GJ	1.00 MW	42 min	1.00 MW	1,3 kWh/km	538 km

5. Survey results

This Chapter will look closer at the gathered survey results. In addition to a list of needs and requirements it is to derive levels of importance for different stakeholders.

When the survey was closed, 43 respondents had filled in the survey. Most of them where truck end-users, which was expected as this was the main target audience. Overall, all stakeholders are represented. An overview of the distribution of responses by stakeholder category can be found in Table 2. Some of the respondents identified as multiple stakeholders, which explains why the sum of all stakeholder responses in Table 2 does not equal 43.

The survey also asked about levels of expertise of the respondents. Most of the respondents see themselves as experts or competent in their field; only 5% of the respondents identified as novice.

A geographical distribution is included of the respondents to make sure that all of Europe was covered. Fifteen of the respondents stated that they operate throughout Europe.

Table 2: Stakeholder category that the survey respondents assigned their company to.

	Number of respondents	Share of respondents (%)
Truck end-user: road transport operator (with or without own fleet) or logistics service provider	13	30
Shipper	6	14
Logistic site owner or operator	9	21
Truck OEM	6	14
Trailer manufacturer	2	5
Renewable fuel infrastructure manufacturer (hydrogen)	2	5
Renewable fuel infrastructure manufacturer (fast charging)	3	7
Renewable fuel infrastructure operator (hydrogen)	3	7
Renewable fuel infrastructure operator (fast charging)	4	9
Policy maker	3	7
Road, traffic or type approval authority	4	9

Researcher	9	21

Table 3: Level of expertise the survey respondents assigned themselves

Level of expertise	%
an expert	24
Competent	44
an advanced beginner	17
a novice	5

5.1. Methodology

The methodology of the survey can be found in more detail in D1.3. We repeat some of the methods and the survey boundaries and definitions to facilitate the reader's understanding of the shown responses.

Survey boundaries and definitions

We define zero-emission heavy-duty vehicles as **vehicles that have an electrical powertrain and a GCW of 40+ tons**. ZE-HDVs could be battery electric and fuel cell electric trucks. Hydrogen is assumed as fuel for the fuel cell electric trucks, as other Renewable Fuels from Non Biological Origin (RFNBO) suitable for fuel cell technology, like ammonia and methanol, are still in the research phase.

The survey will not include vehicles with an internal combustion engine. We acknowledge that a significant reduction in greenhouse gasses (GHG) can be achieved by using biofuels and RFNBO as fuel for an internal combustion engine (ICE) truck, but this technology is beyond the scope of the ZEFES project.

The focus will be on trucks which can complete a mission independent from road infrastructure. The possibility to charge while driving, e.g., e-highways with charging by catenary infrastructure or photo-voltaic panels on the truck and/or trailer, is not considered in this survey.

It is assumed that all energy (in the form of electricity or hydrogen) provided to the truck is renewable.

We are aware that the zero-emission transport discussion is also about energy efficiency, life cycle assessment (LCA), import of energy, additionality, etc. Nevertheless, the focus of this survey is on the implementation of innovative trucks, not the full energy transition.

Statements

Statements are used to derive the opinion of the respondents on some topics, for example reasons to buy/not buy ZE-HDVs. The respondents can indicate whether they agree or disagree. Other options are 'not relevant' or 'I don't know'. The answers give insights to the current market status and can be used to derive needs and requirements to improve the implementation of ZE-HDV.

MoSCoW-method

The relevance of certain predefined needs and requirements will be checked by the MoSCoW-method. The MoSCoW-method can be used to prioritize the needs and requirements.[2] The acronym MoSCoW stands for four categories:

[2] https://www.productplan.com/glossary/moscow-prioritization/

M	Must have	Mandatory need or requirement
S	Should have	Important need or requirement that is not vital, but has a significant added value
C	Could have	Nice to have need or requirement, that will have a small impact when not implemented
W	Would have	Needs and requirements that are not a priority

We applied the method to assess the importance of some capabilities or services related to ZE-HDV and their related infrastructure. By selecting one of the categories, the respondent can indicate the importance of the capability or service.

5.2. Shipper

Six shippers filled in the survey, with two of them owning trucks. All of them are interested in shipping goods by ZE-HDV (n=6, 100%). Nevertheless, only fifty percent of the respondents were willing to adjust their logistics operation to implement ZE-HDV, and only 33.3% of respondents were willing to pay more for ZE-HDV transport. It can be concluded that flexible, reliable ZE-HDVs with adequate mileage are needed to convince shippers to switch to zero-emission transport. The adequate mileage is dependent of the logistics use case and varies with it. In addition, the cost should be comparable to transport with diesel trucks.

Also, it was asked if they were considering other options to lower their emissions. Multimodal transport is an emission-reduction option that is investigated by 83% of the respondents, while the implementation of biofuels is investigated by 67% of the respondents (Figure 6).

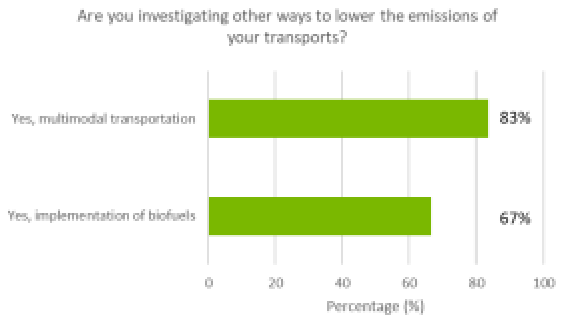


Figure 6: Shippers are also looking to other options to lower their transport emissions.

Lastly, it was asked why the shippers are interested in zero-emission transport (Table 4). The two main reasons that emerged were: we want to learn from practice (100%, n=6), and we want to lower our emissions (100%, n=6). Responses about other possible reasons, like demand from clients, broader delivery windows and locations (Low Emission Zones) are less straightforward. Trust in the new technology is also not a given. Nevertheless, one of the respondents commented that trust should or will improve in the future with the increasing experience of driving ZE-HDV.

Table 4: Statements on why shippers would be interested in implementing ZE-HDV

	n	Agree	Disagree	Not relevant
We are interested in shipping by ZE-HDV, since we want **to learn from practice**	6	**100**	0,0	0,0
We are interested in shipping by ZE-HDV, since our clients are requesting transport by ZE-HDV	5	60,0	20,0	20,0
We are interested in shipping by ZE-HDV, since ZE-HDV have the advantage that they can enter certain Low Emission Zones for last mile delivery.	6	50,0	16,7	33,3
We are interested in shipping by ZE-HDV, since ZE-HDV have the advantage that they are quieter (less noise), which can positively impact delivery time windows	6	83,3	0,0	16,7
We are interested in shipping by ZE-HDV, since we want **to lower our emissions**	6	**100**	0,0	0,0
We are interested in shipping by ZE-HDV, since we trust the ZE-HDV technologies and expect the goods to be delivered on time.	6	50,0	0,0	50,0

5.3. Truck end-user

The survey of the truck end-user was filled in by 13 respondents and consisted of three parts. In the first part, the nature of the logistics operation was queried. Secondly, the truck end-user was asked if they have already purchased or demonstrated a ZE-HDV. Depending on their answer, the reasons why they are or are not implementing ZE-HDVs were assessed. In the third part, more information about the needed infrastructure was asked from the respondents that are already implementing zero-emission trucks.

5.3.1. Logistics operation

All the truck-end users that responded are operating trucks with a GVW greater than 16 tonnes (Figure 7), which is what we aimed for. They are using a variety of heavy-duty vehicles (Figure 9), like rigid trucks, semi-tractors (4x2, 6x2) and even high-capacity vehicles, which can be EMS 1 or 2, for example.

Also, the missions they are conducting are in line with the defined survey boundaries (Figure 8). The respondents are doing a variety of logistics missions, ranging from regional missions with a mileage below 400 km to international long-haul missions (expected to be longer than 700 km one way). Within the ZEFES project different trailer types (standard, low liner, temperature conditioned trailer – reefer) will be demonstrated. Luckily, the respondents are operating all those trailer types (Figure 10). The respondents specified other trailers they are operating as container carriers, curtainsiders, bulkers, and tankers.

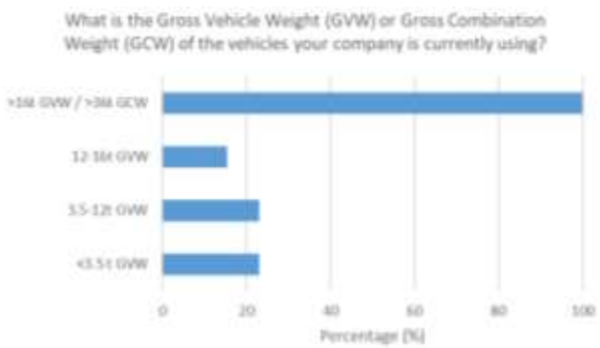


Figure 7: The survey respondents are driving with HDV (GCW > 16 tonnes)

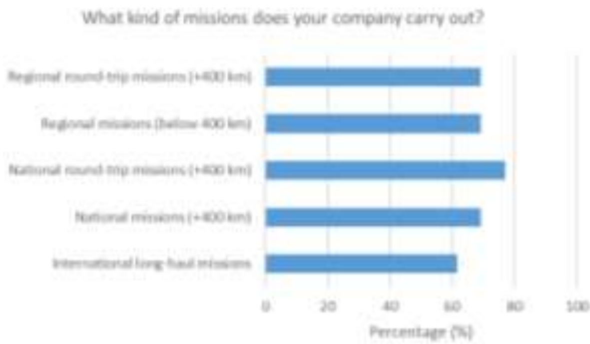


Figure 8: A broad range of use cases are done by the respondents

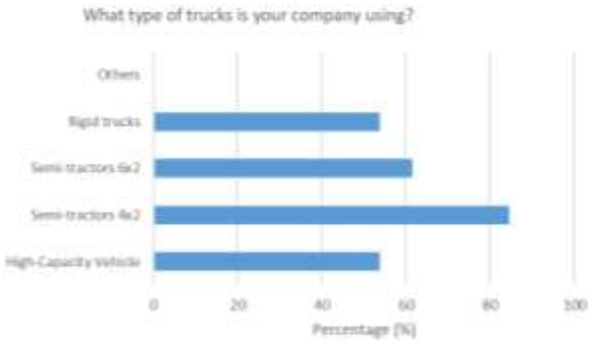


Figure 9: The survey respondents are operating all relevant HDV classes.

Figure 10: The survey respondents are operating all relevant trailer types.

Next to specifying the vehicles used by logistics companies and categorizing the use case by driving range, we also asked them if they were considering other options to lower their emissions. We asked if they were considering replacing diesel with less CO_2 intensive fuels or even changing their logistics operations so they would better suite the capabilities of ZE-HDV.

Biofuels like Hydrotreated Vegetable Oil (HVO) and biomethane are seen as interesting options to lower emissions by the respondents who do not have experience with ZE-HDV. Also, hydrogen combustion engines seem interesting technology from the viewpoint of the truck end-user. One of the respondents commented that BE- and FCE-HDV are the future of zero-emission transport, but that they are evaluating all alternative solutions to lower emissions.

On the second question, about **altering logistics operations**, almost halve of the respondents decided to comment, mostly to provide nuances to their answers. The comments express that changes will be **cost driven and dependent on the use case**. **The changes are also expected to have a limited extent, as several fixed parameters (drivers resting time, location of the hubs…) need to be taken into account.** In addition, transport operators are dependent on the decisions their clients, the shippers, make. They also state that operating a mix of technologies (BE-HDV for city deliveries and regional logistics and FCE-HDV for long haul, international transport) is already a change compared with only diesel truck operations today and that operating vehicles with greater GCW (EMS) is also a possibility.

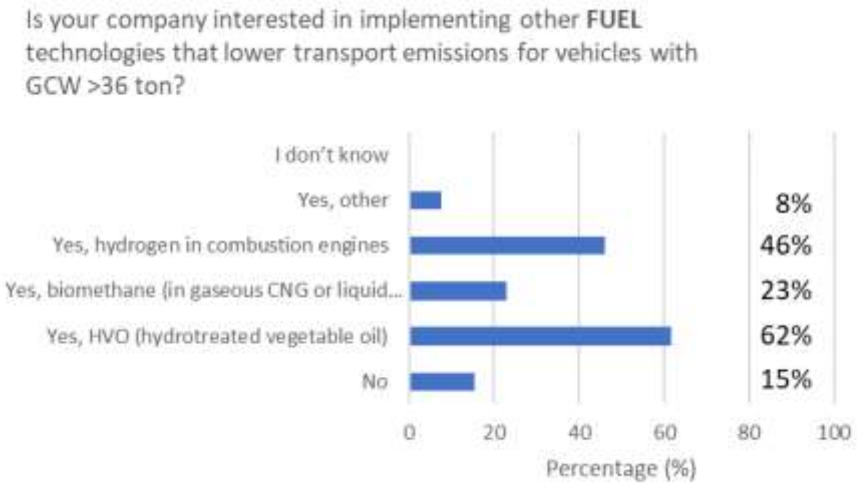


Figure 11: 85% of the Truck-operators are considering other low-carbon fuel options

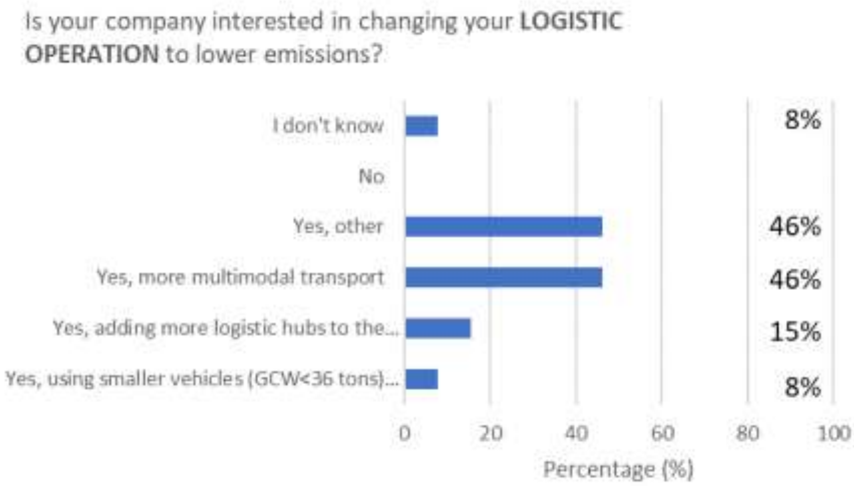


Figure 12: Most of the logistic companies are considering changing their logistic operation to lower emissions, but they will try to limit the extent.

Of the proposed options to achieve lower emissions by changing logistic operations, more multimodal transport is the main answer. More logistics hubs and smaller vehicles are not seen as a commonly expected change.

5.3.2. ZE-HDV

After the more general questions about their logistics operations, the respondents were asked to give their opinion on statements related to possible reasons whether to implement ZE-HDV in their logistics operations. The number of participants were too low to be able to perform a qualitative analysis of the answers. Nevertheless, it is to see that the presented answers as a qualitative representation of logistics companies.

First, we asked the respondents if their company had a clear sustainability strategy or emission reduction target, focussed on the HDV operation. 77% of the respondents answered positively. Most of the targets were expressed as a percentage reduction in a certain timeframe and were in line with the European reduction targets.[3]

Currently ZE-HDV cost more than diesel, but 77% of respondents will still purchase a ZE-HDV despite the higher costs. We also asked what type of incentive (or discouragements for fossil fuels) would help the implementation of ZE-HDV (Table 5). A majority of respondents thinks that CAPEX subsidies for both trucks and infrastructure will have a positive effect. Other incentives that convinced most respondents are exemptions of (road) taxes, additional taxes related to CO2 emissions, and OPEX subsidies.

Table 5: Type of incentives (or discouragements for fossil fuels) that the respondents would find be helpful to implement ZE-HDV.

CAPEX subsidies for trucks	84,6%
CAPEX subsidies for infrastructure	76,9%

[3] At the time of writing this deliverable, there was still a 30% emission reduction target for HDVs: https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en#regulation-on-co%E2%82%82-emission-standards-for-heavy-duty-vehicles

Exemption (road) taxes	69,2%
Additional taxes related to CO2 emissions	69,2%
OPEX subsidies since renewable electricity or H2 cost more	61,5%
Non-financial benefits (like priority lanes)	23,1%

Four of the respondents did not purchase or demonstrate a ZE-HDV vehicle yet. When asked for possible reasons to not invest in BE-HDV, the long charging time and missing incentives to invest in charging infrastructure were cited. Nevertheless, the respondents agreed that BE-HDV are commercially available and that the BE-HDV can be combined with the trailers they are using. They also agree that the fleet management system will not be a limiting factor. The full analysis of the statements about BE-HDV and why they are not purchasing them yet, can be found in Table 6.
In addition, the majority of the respondents who had no experience with ZE-HDV agrees that payload restriction will not be a problem for BE-HDV, just like they expect the vehicles to be safe, socially accepted and will lead to actual emission reductions. The answers for the other statements are quite dispersed. We believe this is due to the low number of respondents and the differences between the operations of the companies, which could lead to different needs and requirements as well as different opinions.
The same survey questions were also asked for FCE-HDV (Table 7). Three of the respondents decided to fill them in. Nevertheless, after examining the inputs, the quality of the responses was assessed to be low. The majority of the answers was '*I don't know*', which was set as the default answer. The fact that the Truck operator respondents kept the default answer indicates that knowledge about FCE-HDV and their capabilities is lower compared to the knowledge about BE-HDV.
The difference in knowledge about both technologies can be explained by one of the answers, that FCE-HDV are not commercially available and therefore the technical aspects are less accessible for the general public. It also stands out that two of the respondents indicate that the fuelling time will not be a problem, as this is generally seen as one of the advantages of FCE-HDV.

Seven of the respondents answered that they are purchasing or have purchased or demonstrated a ZE-HDV vehicle. In total, the respondents are driving or have purchased **226 ZE-HDV** (GCW>36 tonnes) with the amount of ZE-HDV ranging from 1 to 125 per respondents. Only one respondent is implementing both BE-HDV and FCE-HDV. Seven respondents are implementing BE-HDV and one only FCE-HDV.

The main reasons to do this: **they want to learn** (n=8, 100%). In addition, the majority of the respondents states that they have the in-house resources to procure suitable ZE-HDV. In addition, the majority agrees that there **is a positive business case for ZE-HDV, but that diesel trucks are still cheaper**. Also, **reducing emissions** is seen as one of the main reasons to implement ZE-HDV.
The companies have invested in ZE-HDV, but that does not mean that the ZE-HDV fit their needs and requirements. On the question whether there are enough ZE-HDV commercially available, the answer was split. 85.7% of the respondents stated that the driving range of the available ZE-HDV is insufficient and that the current vehicles cannot be deployed in almost all missions. The majority also agrees that the transport capacity of ZE-HDV is limited and the charging and fuelling infrastructure at the needed power or pressure is missing. They also state that charging BE-HDV takes too long.

Table 6: Feedback on possible reasons to not implement BE-HDV from the viewpoint of the Truck end-user with no experience operating ZE-HDV.

We don't invest in BE-HDV because:	n	Agree	Disagree	Not important	I don't know
BE-HDV are not commercially available.	4	0,0	**100**	0,0	0,0
BE-HDV cannot be deployed in enough missions.	4	50,0	25,0	25,0	0,0
Driving range is too low	4	50,0	50,0	0,0	0,0
Payload is restricted	4	25,0	**75,0**	0,0	0,0
Charging time is too long	3	**66,7**	0,0	0,0	33,3
A fleet management system that can account for the potential benefits and limitations of the BE-HDV is non-existing.	4	0,0	**100**	0,0	0,0
Incentives to invest in BE-HDV are missing	4	25,0	50,0	0,0	25,0
Commercial charging infrastructure is missing	4	50,0	25,0	25,0	0,0
Incentives to invest in charging infrastructure are missing	4	**75,0**	25,0	0,0	0,0
It is currently impossible to calculate TCO and business cases since data is missing (maintenance cost, availability numbers, capacity prognosis, lifetime, residual value…)	4	25,0	50,0	25,0	0,0
The uncertainty on future (energy) prices is too high to decide now.	4	25,0	50,0	25,0	0,0
The uncertainty on future technology improvements is too high to decide now.	4	25,0	50,0	25,0	0,0
There is no positive business case for BE-HDV.	4	50,0	50,0	0,0	0,0
There is a positive business case for BE-HDV, however the TCO of BE-HDV is higher than ICE-HDV.	4	25,0	25,0	0,0	**50,0**
The CAPEX investment in a BE-HDV is too high.	4	50,0	0,0	25,0	25,0
BE-HDV cannot be combined with the trailer type we use.	4	0,0	**100**	0,0	0,0
We don't implement BE-HDV due to safety aspects (high voltage, fire hazard…)	4	0,0	**75,0**	0,0	25,0
We do not implement BE-HDV due to social acceptance aspects (environmental impact of battery production and recycle)	4	0,0	**75,0**	0,0	25,0
It is unclear whether BE-HDV will lead to an actual emission reduction (GHG and PM).	4	0,0	**75,0**	0,0	25,0
Our company does not have the knowledge or resources to procure suitable BE-HDV	4	25,0	50,0	0,0	25,0
Renewable electricity is not available at an acceptable price.	4	0,0	50,0	0,0	**50,0**
There is no legislation forcing us to implement BE-HDV.	4	25,0	25,0	25,0	25,0
The legislative framework to drive with BE-HDV is missing (uncertain if allowed to cross borders, use tunnels, transport ADR goods…).	4	25,0	50,0	0,0	25,0
The BE-HDV are not equipped with the necessary driver comfort equipment (type of cabin, heated seats…)	4	0,0	**75,0**	0,0	25,0
It is unclear what the impact will be on the logistic operation (overall capacity loss?)	4	50,0	25,0	25,0	0,0
BE-HDV is new technology, which we do not trust enough (risk of breakdowns is not mitigated enough).	4	25,0	**75,0**	0,0	0,0
The impact of weather conditions on the performance of BE-HDV is not known	4	0,0	**100**	0,0	0,0

Table 7: Feedback on possible reasons to not implement FCE-HDV from the viewpoint of the Truck end-user with no experience operating ZE-HDV.

We don't invest in FCE-HDV because:	n	Agree	Disagree	Not important	I don't know
FCE-HDV are not commercially available.	3	**66,7**	33,3	0,0	0,0
FCE-HDV cannot be deployed in enough missions.	3	33,3	33,3	0,0	33,3
Driving range is too low	3	0,0	33,3	0,0	**66,7**
Payload is restricted	3	0,0	33,3	0,0	**66,7**
Fuelling time is too long	3	0,0	**66,7**	0,0	33,3
A fleet management system that can account for the potential benefits and limitations of the FCE-HDV is non-existing.	3	0,0	33,3	0,0	66,7
Incentives to invest in FCE-HDV are missing	3	33,3	33,3	0,0	33,3
Commercial HRS are missing	3	33,3	33,3	0,0	33,3
Incentives to invest in HRS are missing	3	0,0	33,3	0,0	**66,7**
It is currently impossible to calculate TCO and business cases since data is missing (maintenance cost, availability numbers, capacity prognosis, lifetime, residual value…)	3	**66,7**	0,0	0,0	33,3
The uncertainty on future (hydrogen) prices is too high to decide now.	3	33,3	33,3	0,0	33,3
The uncertainty on future technology improvements is too high to decide now.	3	33,3	33,3	0,0	33,3
There is no positive business case for FCE-HDV.	3	66,7	33,3	0,0	0,0
There is a positive business case for FCE-HDV, however the TCO of FCE-HDV is higher than ICE-HDV.	3	0,0	33,3	0,0	**66,7**
The CAPEX investment in a FCE-HDV is too high.	3	0,0	33,3	0,0	**66,7**
FCE-HDV cannot be combined with the trailer type we use	3	0,0	33,3	0,0	**66,7**
We do not implement due to safety aspects (fire hazard, high voltage…).	3	33,3	0,0	0,0	**66,7**
We do not implement due to social acceptance aspects (impact of hydrogen production, impact of battery production and recycle…)	3	33,3	0,0	0,0	**66,7**
It is unclear whether the FCE-HDV will lead to an actual emission reduction (GHG and PM).	3	33,3	0,0	0,0	**66,7**
Our company does not have the knowledge or resources to select suitable FCE-HDV.	3	33,3	0,0	0,0	**66,7**
Green hydrogen is not available.	3	33,3	0,0	0,0	**66,7**
There is no legislation forcing us to implement FCE-HDV.	3	33,3	0,0	0,0	**66,7**
The legislative framework to drive with FCE-HDV is missing (uncertain if allowed to cross borders, use tunnels…)	3	0,0	0,0	0,0	**100,0**
The FCE-HDV are not equipped with the necessary driver comfort equipment (type of cabin, heated seats…)	3	0,0	0,0	0,0	**100,0**
It is unclear what the impact will be on the logistic operation (overall capacity loss?)	3	0,0	0,0	0,0	**100,0**
FCE-HDV is new technology, which we do not trust enough (risk of breakdowns is not mitigated enough).	3	0,0	0,0	0,0	**100,0**
The impact of weather conditions on the performance of FCE-HDV is not known	3	0,0	0,0	0,0	**100,0**

Table 8: Feedback on possible reasons to implement ZE-HDV from the viewpoint of the Truck end-user with experience operating ZE-HDV

We are investing in ZE-HDV, since:	**n**	**Agree**	**Disagree**	**Not relevant**	**I don't know**
We want to learn	8	**100,0**	0,0	0,0	0,0
Sufficient ZE-HDV are commercially available	8	37,5	50,0	12,5	0,0
ZE-HDV can be deployed in almost all missions	8	12,5	**87,5**	0,0	0,0
Driving range is sufficient	8	12,5	**87,5**	0,0	0,0
We want to be able to enter Low Emission Zones	8	62,5	12,5	25,0	0,0
ZE-HDV are more silent and could be used for night deliveries	8	50,0	25,0	12,5	12,5
Transport capacity is not restricted	8	12,5	75,0	12,5	0,0
Charging time is not too long	8	0,0	**87,5**	12,5	0,0
Hydrogen refuelling time is not too long	8	12,5	50,0	25,0	12,5
ZE-HDV can be combined with the trailer type we use	8	37,5	50,0	12,5	0,0
Sufficient charging and fuelling infrastructure is available, at the pressure or power we want.	8	12,5	**87,5**	0,0	0,0
There are sufficient incentives to invest in ZE-HDV	8	12,5	**87,5**	0,0	0,0
The CAPEX investment of ZE-HDV is acceptable.	8	0,0	87,5	0,0	12,5
The TCO of ZE-HDV can be calculated (residual value, lifetime... are known)	8	37,5	62,5	0,0	0,0
The TCO of ZE-HDV is acceptable	8	25,0	**75,0**	0,0	0,0
There is a positive business case for operating ZE-HDV.	8	50,0	50,0	0,0	0,0
There is a positive business case for ZE-HDV, however the TCO of ZE-HDV is higher than ICE-HDV.	8	62,5	25,0	12,5	0,0
It is safe to operate BE-HDV (battery)	8	50,0	0,0	37,5	12,5
It is safe to operate FCE-HDV (hydrogen)	8	25,0	0,0	**50,0**	25,0
It is societal accepted to operate ZE-HDV	8	75,0	0,0	12,5	12,5
We have the knowledge and resources to procure suitable ZE-HDV	8	**87,5**	12,5	0,0	0,0
The ZE-HDV are equipped with the necessary driver comfort equipment (type of cabin, heated seats…)	8	50,0	12,5	25,0	12,5
Renewable electricity is available at an acceptable price.	8	37,5	62,5	0,0	0,0
Green hydrogen is available	8	12,5	37,5	25,0	25,0
The risk of ZE-HDV breakdowns is mitigated, we trust the technology	8	25,0	62,5	0,0	12,5
The risk of infrastructure breakdowns is mitigated, we trust the technology	8	12,5	75,0	0,0	12,5
Fleet management software that can integrate ZE-HDV in a fleet is available.	8	25,0	75,0	0,0	0,0
We want to lower our emissions (GHG and PM).	8	**75,0**	12,5	0,0	12,5
The legislative framework is not restricting the deployment of ZE-HDV (crossing of borders, multimodal missions, transporting ADR goods...).	8	37,5	12,5	25,0	25,0
Legislation is forcing us to implement ZE-HDV	8	25,0	62,5	12,5	0,0
The impact of weather conditions on the performance of ZE-HDV is known	8	12,5	**75,0**	0,0	12,5

CAPEX investment in ZE-HDV is seen as too high, and there are not enough incentives to invest in ZE-HDV

Opinions are divided on whether the TCO can be calculated.

A difference with the respondents that did not implement ZE-HDV yet can be found on the topic of fleet management software. While the respondents without experience expect the fleet management software to be available, 71.4% of respondents with experience state that such software is not available. Some more detailed feedback from the interviews was received.

- BE-HDV integration needs special attention, they do not have the capabilities of diesel trucks

- Dedicated planning, done by people hand-picking the missions for the BE-HDV is needed, because no fleet management software that can handle fleets with mixed power trains is available.
- Difference between what they expected from the theoretical assessment and real-life operations. The impact of weather (cold temperatures + wind) is sometimes underestimated.

One of the questions was to rank how the BE-HDV must be optimised. The top three ways to optimise are lowest TCO, lowest CAPEX, and longest driving range. These answers are expected as they are all important parameters to reach a viable business model (TCO and CAPEX) in an industry with low profit margins. The driving range is also the perfect parameter to express the flexibility of the BE-HDV.

Table 9: Prioritisation based on the survey responses on how the BE-HDV must be optimised, from the truck operators' point of view. The ranking by seven respondents is given, together with the sum of all rankings. The lower the total, the more important the characteristic is perceived.

BE-HDV characteristics	R1	R2	R3	R4	R5	R6	R7	Total
Lowest total cost of ownership (TCO)	4	2	2	1	2	1	5	**17**
Lowest investment cost (CAPEX)	3	3	4	2	1	2	6	**21**
Longest driving range	6	1	3	3	3	4	3	**23**
Reliability	1	5	7	4	4	11	1	**33**
Lowest energy consumption (includes efficiencies, aerodynamics, HVAC…)	10	7	6	5	6	3	2	**39**
Lifetime of the BE-HDV	8	4	10	6	5	5	7	**45**
Compatible with different types of trailers	2	6	5	7	9	8	9	**46**
Max payload weight	5	8	8	9	10	6	4	**50**
Max payload volume	7	9	9	8	11	7	8	**59**
Length and weight of the truck	11	11	1	10	7	9	10	**59**
Driver comfort equipment (type of cabin, heated chairs	9	10	11	11	8	10	11	**70**

5.3.3. Infrastructure

In the last part, the respondents were asked about the infrastructure.
They were asked to rate some needs and requirements by importance, using the MoSCoW-method. Again, we see a difference between the number of people that filled in the BE-HDV (8) and the FCE-HDV survey (2). This demonstrates again that the implementation and knowledge of FCE-HDV is less than BE-HDV. Knowledge levels are even so low that it may not be possible to derive reliable survey results.
If we look to the results for the BE-HDV, the main conclusions are the following:

- Renewable energy is preferred, but not seen as a must for the majority of the respondents
- The same is true for communication between the vehicle and the charger. It is preferred, but not seen as a must
- Interoperability is key. One plug that fits all is what the majority of the respondents wants. We should learn from the standardization for passenger cars (Chademo/CCS)
- Bidirectional charging is not a must for the truck operators
- MCS is seen as a 'should' have
- Half of the respondents see the possibility to reserve a charging slot as a must have
- The majority of respondents sees a power connection for the trailer as a 'could' have; however, from the interviews plus the survey results for the trailer OEMs, we see that there will be a need for trailer power connection when the reefers are electrified.

Table 10: Results of the MoSCoW analysis about the BE-HDV infrastructure from the viewpoint of the truck end-users.

MOSCOW BE-HDV	n	**Must have**	**Should have**	**Could have**	**Would have**	**Not relevant**
The BE-HDV can be easily connected to the charging infrastructure (length cable, automatic grounding, galvanic isolation…)	8	**75,0**	25,0	0,0	0,0	0,0
Possibility to charge BE-HDV on the right- and lefthand side of the truck.	8	25,0	25,0	**37,5**	12,5	0,0
The connection between BE-HDV and charger is standardised (one plug fits all)	8	**87,5**	0,0	12,5	0,0	0,0
Charging station is adjusted to the turning cycle of long trucks-trailer combinations (high capacity vehicles)	8	50,0	25,0	25,0	0,0	0,0
Renewable electricity is available	8	**37,5**	**62,5**	0,0	0,0	0,0
Megawatt Charging System (>900MW) is available	8	**37,5**	**50,0**	12,5	0,0	0,0
CCS (350 kW) and MCS (>900MW) are available at the same station (price can differ between them, option to opportunity charge at a lower price when time is not the limiting factor)	8	12,5	**37,5**	**37,5**	12,5	0,0
Variable electricity prices related to the charging power (kW)	8	12,5	12,5	**75,0**	0,0	0,0
Variable charging prices related to time of the day (charging during peak demand is more expensive)	8	12,5	25,0	37,5	25,0	0,0
Communication between charger and the BE-HDV to optimize charging locally (power and time)	8	**25,0**	**62,5**	12,5	0,0	0,0
Vehicle to grid (V2G) communication to optimize charging at grid level	8	25,0	25,0	50,0	0,0	0,0
Bidirectional charging for (local) grid support services (peak managing, energy storage…)	8	0,0	37,5	25,0	25,0	12,5
Pay by credit card or pay per use over digital platform	8	**50,0**	**50,0**	0,0	0,0	0,0
Reservation of timeslot to charge (no waiting at the charger)	8	**50,0**	**25,0**	12,5	0,0	12,5
Unambiguous pricing displayed	8	50,0	25,0	25,0	0,0	0,0
Automated charging (connection between BE-HDV and infrastructure and payment is made without interaction of the driver)	8	0,0	37,5	37,5	25,0	0,0
Amenities for truck drivers	8	37,5	25,0	12,5	12,5	12,5
Small footprint of the infrastructure (both in area and in weight)	8	25,0	50,0	25,0	0,0	0,0
Long term (hours) parking available (possibility for depot charging)	8	50,0	25,0	25,0	0,0	0,0
Power connection for conditioned trailer or e-trailers is available	8	25,0	12,5	**62,5**	0,0	0,0

Only two of the respondents filled in the MoSCoW-questions for FCE-HDV. This number is too low to derive conclusions. Nevertheless, we have decided to show the gathered results in Table 11 but will not discuss them further.

Table 11: MoSCoW-method results for FCE-HDV infrastructure from the viewpoint of the truck operator

MOSCOW BE-HDV	n	Must have	Should have	Could have	Would have	Not relevant
Ease of handling: length hose is sufficient.	2	50	50	0	0	0
Ease of handling: no nozzle frozen onto FCE-HDV	2	50	0	0	0	50
Possible to refuel FCE-HDV with H2 receptacles on the right and lefthand side of the truck.	2	50	50	0	0	0
High refuelling speed = fast refuelling time (at least 120 g/s)	2	50	0	50	0	0
Green hydrogen is available	2	100	0	0	0	0
700 bar hydrogen is available	2	50	0	0	50	0
700 bar and 350 bar are available (price and refuelling rate can differ between them due to technical reasons. 350 bar could be less expensive per kilogram H2, however the total mass refuelled will be less, which results in smaller driving range)	2	50	50	0	0	0
Variable hydrogen prices related to pressure fuelled (350 and 700 bar)	2	0	100	0	0	0
Variable hydrogen prices related to time of the day (fuelling during peak demand is more expensive)	2	0	0	50	50	0
Achieve State of Charge (degree of filling) above 95%	2	50	0	50	0	0
Capable to refuel 70 kg of hydrogen at once (related to driving range of ± 700 km)	2	50	0	0	50	0
Communication with the FCE-HDV to optimize fuelling (mass and time)	2	50	50	0	0	0
Pay by credit card or automated payment by online platform	2	50	0	0	50	0
Reservation of timeslot to fuel (no waiting at the pump)	2	50	50	0	0	0
Unambiguous pricing displayed	2	100	0	0	0	0
Estimation of the amount of hydrogen that can be refuelled (mass) is displayed before start of refuelling	2	50	50	0	0	0
Automated fuelling (nozzle is connected by robot arm)	2	0	0	0	100	0
Adjusted to turning cycle of longer truck-trailer combinations (high capacity vehicles)	2	50	0	0	50	0
Amenities for truck drivers	2	0	50	0	50	0
Power connection for conditioned trailers or e-trailers is available	2	0	100	0	0	0

5.4. Logistics site owner or operator

We received 8 responses from logistic site owners or operators. Only two of them identified solely as logistic hub owner or operator; the others also identify as truck owner, shipper and even infrastructure operator.

On average, the logistic site owner/operator manages 29 sites, which are visited daily by 1078 trucks (average). The number of visiting trucks is strongly dependent on the size of the logistics hubs. Ports can receive more than 5000 trucks, while smaller logistics sites only get around 100 trucks passing by. Six of the respondents stated that they have charging or hydrogen fuelling infrastructure installed on their sites. Three of them have both charging and fuelling infrastructure, one has only a HRS, and two only charging. All the respondents are planning to install additional charging infrastructure on their sites by 2028, while only half of them (n=4) are also planning to install (additional) HRS.

We asked if the clients (visiting truck drivers or shippers that deliver goods to the sites) of the logistics hub owner/operators are requesting infrastructure. Only one respondent states that clients are not requesting infrastructure, and one of the respondents was not sure about the answer, but the other six respondents state that clients are requesting charging infrastructure. Also, HRS are requested by the clients at the sites of 4 of the respondents.

It can be concluded that infrastructure, both charging and HRS, will be installed (or existing infrastructure will be extended) at logistic hubs by 2028. Also, external visitors and clients of the logistic hubs are requesting it.

More insight into the reason why or why not logistics hubs operators are installing infrastructure can be found in Table 12. They want to be more sustainable, ready for the future, and trust the infrastructure technology.

The presence of renewable energy production assets can help to ease the installation of infrastructure (especially when grid connection is limited) and can help to improve the renewable share of the energy provided by the infrastructure. Therefore the respondents are asked if they have solar panels or wind turbines installed at their premises. Only one of the respondents did not have renewable energy production assets installed. All others had solar panels installed, and two respondents even had wind turbines.

We also explicitly asked the respondents whether the grid connection of the logistic sites will limit the number of chargers and charging power that could be installed. Five of the respondents answered that it will be a limited factor in the future, and the other three answered it is already a limiting factor today for their daily operations.

It can be concluded that the power connection of logistics sites is already limiting the installation of infrastructure in some cases, and it will definitely be a restriction in the future.

The importance of charging infrastructure characteristics was asked with a ranking question. The respondents were asked to rank the charging infrastructure characteristics from important to less important. The results can be found in Table 12. The respondents found varying requirements important, but overall **reliability, low CAPEX and OPEX, high energy efficiency and a small footprint** seem important. Maximal charging power, lifetime and user comfort were given lesser importance.

Table 12: Reasons to invest in ZE infrastructure at logistic hubs, assessed by logistic hub operators

We installed infrastructure at our logistics sites, since	n	Agree	Disagree	I don't know
we wanted to learn	8	62,5	25,0	12,5
the clients were requesting it	7	57,1	28,6	14,3
we want to be ready for the future	7	85,7	0,0	14,3
there is a business case for charging or fuelling ZE-HDV at logistic sites	7	57,1	28,6	14,3
we found it an opportunity to use the existing, financial incentives to install the infrastructure	6	66,7	16,7	16,7
will be legally obligated in the future	6	33,3	50,0	16,7
we trust the current technology.	7	85,7	0,0	14,3
we want to be more sustainable	8	87,5	0,0	12,5

Table 13: Answer to: Prioritisation based on the survey responses on how the requirements for the needed charging infrastructure must be optimised, from the viewpoint of the logistic hub operator. The ranking by eight respondents is given, together with the sum of all rankings. The lower the total, the more important the characteristic is perceived. The maximal charging power, lifetime and user comfort are seen as the least important requirement of charging infrastructure at a logistic hub.

BE-HDV characteristics	R1	R2	R3	R4	R5	R6	R7	R8	TOTAL
Reliability	2	3	7	4	2	4	3	4	**29**
Lowest investment cost (CAPEX)	3	2	3	2	7	6	4	3	**30**
Lowest total cost of ownership (TCO)	4	1	5	8	8	3	1	1	**31**
Highest energy efficiency	1	4	6	5	3	2	5	5	**31**
Smallest footprint	6	6	4	3	1	8	2	2	**32**
Maximal charging power	8	5	1	1	4	1	8	8	**36**
Lifetime	5	7	2	7	6	7	6	6	**46**
User comfort	7	8	8	6	5	5	7	7	**53**

We also ask the respondents to rank characteristics of the HRS with lowering importance. In this way we know how the HRS should be optimised to their needs. The five respondents placed **lowest hydrogen price, lowest CAPEX and smallest footprint and safety perimeter** in their top three of most important HRS characteristics. The full list can be found in Table 13.

Table 15 and 16 show the results of the MoSCoW analysis. We received a range of answers about the charging infrastructure. Nevertheless, they agree that the impact on the logistics operation should be minimal and that the plug should be easy to handle and standardised. For the other statements no majority was found for any of the possible answers. The MoSCoW questions for the HRS were only answered by three of the respondents.

Table 14: Answers to: 'Rank the following requirements for the needed HRS from most important to less important by dragging.' The HRS should be optimised to achieve the lowest hydrogen price.

Characteristic of the HRS	R1	R2	R3	R4	R5	Total
Lowest hydrogen price	1	1	1	6	3	**12**
Lowest investment cost (CAPEX)	2	4	4	2	2	**14**
Smallest footprint and safety perimeter	4	2	2	3	4	**15**
Lowest total cost of ownership (TCO)	3	12	5	1	1	**22**
Highest energy efficiency hydrogen conditioning (compression and cooling)	5	10	3	8	5	**31**
Lifetime	7	8	6	4	6	**31**
Reliability	6	9	7	9	7	**38**
Multiple operating pressures	11	5	11	5	9	**41**
Refuelling of more than one truck at once	8	3	12	7	11	**41**
Mass of total hydrogen refuelled at once	9	11	9	11	8	**48**
Unlimited back-2-back refuelling	10	13	8	12	10	**53**
User comfort	12	7	10	13	12	**54**
State of Charge above 95%	13	6	13	10	13	**55**

Table 15: Results for the MoSCoW assessment for BE-HDV charging infrastructure from the viewpoint of the logistic hub operator or owner

MOSCOW BE-HDV charging infrastructure	n	Must have	Should have	Could have	Would have	Not relevant
The plug is easy to handle and, the length of cable is sufficient	8	**62,5**	0,0	12,5	0,0	25,0
The plug is standardized	8	**62,5**	12,5	0,0	0,0	25,0
Renewable energy is produced (partly) locally on site	8	12,5	**50,0**	0,0	12,5	25,0
Renewable energy can be bought on the market at an acceptable price	8	37,5	37,5	0,0	0,0	25,0
A booking tool for the clients is available, so the usage rate can be predicted and is known	8	12,5	37,5	25,0	0,0	25,0
A payment and billing tool for the clients is available	8	**50,0**	12,5	0,0	12,5	25,0
Incentives to install charging equipment	8	25,0	25,0	12,5	0,0	37,5
Electrical grid reinforcement	8	50,0	25,0	0,0	0,0	25,0
Stationary energy storage (battery)	8	25,0	37,5	12,5	0,0	25,0
An energy management system to achieve optimal charging at the lowest price (i.e. by avoidance of peaks)	8	37,5	25,0	12,5	0,0	25,0
Vehicle-2-Grid communication to achieve optimal charging	8	37,5	12,5	12,5	12,5	25,0
Bidirectional charging	8	25,0	0,0	25,0	12,5	37,5
Amenities for truck drivers	8	**50,0**	12,5	0,0	0,0	37,5
The footprint of the charging infrastructure is minimal (both in area as in mass)	8	37,5	25,0	12,5	0,0	25,0
The installation is done without impact on the logistic activities	8	**75,0**	0,0	0,0	0,0	25,0
Long term (hours) parking available (possibility for depot charging)	8	37,5	0,0	25,0	12,5	25,0
Megawatt Charging System (>900MW) is available	8	37,5	12,5	0,0	12,5	37,5
CCS (350 kW) and MCS (>900MW) available at the same station (price can differ between them, so option to opportunity charge at a lower price when time is not the limiting factor)	8	25,0	12,5	25,0	12,5	25,0
Power connection for conditioned trailers or e-trailers available	8	37,5	12,5	12,5	12,5	25,0

Table 16: Results for the MoSCoW assessment for BE-HDV charging infrastructure from the viewpoint of the logistics hub operator or owner

MOSCOW BE-HDV charging infrastructure	n	Must have	Should have	Could have	Would have	Not relevant
The length of the hose is adequate and easy to handle.	3	33,3	33,3	0,0	0,0	33,3
The nozzle is easy to connect and disconnect and cannot freeze onto FCE-HDV (-20 to -40°C cooled hydrogen)	3	33,3	33,3	0,0	0,0	33,3
High refuelling speed = fast refuelling time (at least 120 g/s)	3	**66,7**	0,0	0,0	0,0	33,3
It is possible to refuel FCE-HDV on the right and lefthand side of the truck.	3	33,3	0,0	66,7	0,0	0,0
Green hydrogen is available	3	**66,7**	33,3	0,0	0,0	0,0
700 bar hydrogen is available	3	33,3	33,3	0,0	0,0	33,3
700 bar and 350 bar available (price and refuelling rate can differ between them due to technical reasons. 350 bar could be less expensive per kilogram H2; however, the total mass will be less, which results in smaller driving range)	3	33,3	0,0	0,0	33,3	33,3
Variable hydrogen prices related to pressure fuelled (350 and 700 bar)	3	0,0	0,0	0,0	66,7	33,3
Variable hydrogen prices related to time of the day (peak demand or not)	3	0,0	33,3	0,0	66,7	0,0
Achieve State of Charge (degree of filling) above 95%	3	33,3	66,7	0,0	0,0	0,0
Capable to refuel 70 kg of hydrogen at once (related to driving range of ±700 km)	3	**66,7**	33,3	0,0	0,0	0,0
Communication with the FCE-HDV to optimize fuelling (mass and time)	3	**66,7**	0,0	33,3	0,0	0,0
Pay by credit card or pay per use over digital platform	3	**66,7**	33,3	0,0	0,0	0,0
Reservation of timeslot to fuel (no waiting at the pump for the client)	3	33,3	33,3	0,0	33,3	0,0
Unambiguous pricing displayed	3	**66,7**	0,0	0,0	0,0	33,3
Adjusted to turning cycle of longer truck-trailer combinations	3	**100**	0,0	0,0	0,0	0,0
Amenities for truck drivers	3	33,3	33,3	33,3	0,0	0,0
Footprint and safety perimeter is minimised by the design of the HRS	3	**100**	0,0	0,0	0,0	0,0
Hydrogen mass on site is below the SEVESO limit.	3	**66,7**	33,3	0,0	0,0	0,0

5.5. Truck OEM

The truck OEM survey was filled in by five respondents, representing some of the main European manufacturers. Unfortunately, only three of the respondents filled in all questions. All truck OEMs state that they are working on battery electric and gaseous hydrogen fuel cell electric trucks. One of the respondents states that they are working on a fuel cell electric truck powered by liquid hydrogen, and four of the respondents are developing a truck with a hydrogen combustion engine.

Only two of the respondents state that they have a commercial BE-HDV (GCW>36 tons) on the market at the moment, but all of them state that this will be the case by 2026 at the latest.

The energy content of the battery will range between 380 and 780 kWh, and most of the respondents indicate that the energy content will increase in the future. A majority of the respondents (n=3) also agrees that trucks with variable battery sizes will be brought on the market and the battery technology will change (n=4).

The respondents were not able to give a clear answer if and when vehicle-2-grid communication and bidirectional charging will be available. However, the majority agreed that the trucks will be compatible with all trailer types and that weight regulations are restricting the BE-HDV specifications.

We asked the truck OEMs to give their opinion on reasons why BE-HDV and FCE-HDV can or cannot be commercially deployed. The statements and the answers of the Truck OEMs are given in Table 17. Please remark that for BE-HDV, the 3 main respondents are overall positive. Only on the question if they are aware of the needs of the end-users the majority disagreed (n=2). While for FCE-HDV, none of them answered positively on most of the questions.

Overall, the feedback for the FCE-HDV is that the technology is not as developed as BE-HDV, and not ready for commercial deployment. One of the respondents raised the concern that the advantages of FCE-HDV regarding range and refill time is shrinking with the progress of batteries and MCS. However, hydrogen could still play a role in countries where the electrical grid strengthening for the energy transition is lagging behind. Together with some use-cases where costs matters less than up-time.

Table 17: Answers to statements about the readiness of BE-HDV and FCE-HDV to be commercially deployed from the viewpoint of the truck OEMs.

BE-HDV can be commercially deployed, since	**n**	**Agree**	**disagree**	**I don't know**	**NR**
all components are available and standardised	3	66,7	33,3	0,0	0,0
BE-HDV can be commercially deployed, since the lifetime of components is adequate	3	66,7	0,0	0,0	33,3
the maintenance of the BE-HDV can be organized by the existing dealer network in their workshops.	3	**100**	0,0	0,0	0,0
enough trained technicians are available to maintain the BE-HDV.	3	**100**	0,0	0,0	0,0
the homologation process is clear and standardized.	3	33,3	0,0	33,3	33,3
BE-HDV can be deployed in intermodal missions.	3	100	0,0	0,0	0,0
BE-HDV can be deployed in in international missions.	3	33,3	33,3	33,3	0,0
the risks related to BE-HDV (high voltage, fire hazard…) can be technically mitigated	3	66,7	0,0	0,0	33,3
the needs of the end-users are clear, and the characteristics of the electric truck are adjusted to them	3	33,3	**66,7**	0,0	0,0
FCE-HDV can be commercially deployed, since	**n**	**Agree**	**disagree**	**I don't know**	**NR**
all components are available and standardised	3	0,0	100	0,0	0,0
the lifetime of components is adequate	3	0,0	66,7	0,0	33,3
the maintenance of the FCE-HDV can be organized by the existing dealer network in their workshops.	3	0,0	**100**	0,0	0,0
enough trained technicians are available to maintain the FCE-HDV	3	0,0	**100**	0,0	0,0
the homologation process is clear and standardized	3	0,0	66,7	33,3	0,0
FCE-HDV can be deployed in intermodal missions	3	33,3	66,7	0,0	0,0
FCE-HDV can be deployed in international missions	3	33,3	66,7	0,0	0,0
the risks related to FCE-HDV (high voltage, fire hazard…) can be technically mitigated	3	0,0	0,0	66,7	33,3
the needs of the end-users are clear and the characteristics of the FCE-HDV are adjusted to them.	3	33,3	66,7	0,0	0,0

Table 18: MoSCoW truck OEMs

MOSCOW BE-HDV	**n**	**Must have**	**Should have**	**Could have**	**Would have**	**Not relevant**
The BE-HDV can be easily connected to the charging infrastructure (length cable, automatic grounding, galvanic isolation…)	3	**100**	0,0	0,0	0,0	0,0
Charging is started automatically	3	0,0	33,3	**66,7**	0,0	0,0
Possibility to charge BE-HDV on the right- and lefthand side of the truck.	3	33,3	0,0	33,3	33,3	0,0
The connection between BE-HDV and charger is standardised (one plug fits all)	3	**66,7**	33,3	0,0	0,0	0,0

Charging station is adjusted to the turning cycle of long trucks-trailer combinations (high capacity vehicles)	3	**66,7**	33,3	0,0	0,0	0,0
Renewable electricity is available at an acceptable price	3	33,3	33,3	33,3	0,0	0,0
Megawatt Charging System (>900MW) is available	3	**66,7**	33,3	0,0	0,0	0,0
CCS (350 kW) and MCS (>900MW) available at the same station (price can differ between them, so option to opportunity charge at a lower price when time is not the limiting factor)	3	33,3	33,3	33,3	0,0	0,0
Variable electricity prices related to the charging power (kW)	3	0,0	**66,7**	0,0	33,3	0,0
Variable charging prices related to time of the day (charging during peak demand is more expensive)	3	0,0	**66,7**	0,0	33,3	0,0
Communication between charger and the BE-HDV to optimize charging locally (power and time)	3	**66,7**	0,0	33,3	0,0	0,0
Vehicle to grid (V2G) communication to optimize charging at grid level	3	33,3	33,3	33,3	0,0	0,0
Bidirectional charging for (local) grid support services (peak managing, energy storage…)	3	0,0	**66,7**	33,3	0,0	0,0
Pay by credit card or pay per use over digital platform	3	66,7	33,3	0,0	0,0	0,0
Reservation of timeslot to charge (no waiting at the charger)	3	33,3	66,7	0,0	0,0	0,0
Automated charging (connection between BE-HDV and infrastructure is made without interaction of the driver)	3	0,0	66,7	0,0	33,3	0,0
Small footprint (both in area and in weight)	3	0,0	66,7	0,0	33,3	0,0
Amenities for truck drivers	3	33,3	33,3	33,3	0,0	0,0
Long term (hours) parking available (possibility for depot charging)	3	33,3	66,7	0,0	0,0	0,0
Power connection for conditioned trailers or e-trailers available	3	0,0	33,3	33,3	33,3	0,0

MOSCOW FCE-HDV	n	Must have	Should have	Could have	Would have	Not relevant
The length of the hose is adequate and easy to handle.	2	**100**	0,0	0,0	0,0	0,0
The nozzle is easy to connect and disconnect and cannot freeze onto FCE-HDV (-20 to -40°C cooled hydrogen)	2	**100**	0,0	0,0	0,0	0,0
Cooling of the hydrogen	2	**100**	0,0	0,0	0,0	0,0
Possible to refuel FCE-HDV on the right and lefthand side of the truck.	2	0,0	100	0,0	0,0	0,0
High refuelling speed = fast refuelling time (at least 120 g/s)	2	0,0	100	0,0	0,0	0,0
Green hydrogen is available	2	50,0	50,0	0,0	0,0	0,0
700 bar hydrogen is available	2	**100**	0,0	0,0	0,0	0,0
700 bar and 350 bar available (price and refuelling rate can differ between them due to technical reasons. 350 bar could be less expensive per kilogram H2, however the total mass refuelled will be less, which results in smaller driving range)	2	0,0	50,0	0,0	50,0	0,0
Variable hydrogen prices related to pressure fuelled (350 and 700 bar)	2	0,0	50,0	0,0	50,0	0,0
Variable hydrogen prices related to time of the day (fuelling during peak demand is more expensive)	2	0,0	100	0,0	0,0	0,0
Achieve State of Charge (degree of filling) above 95%	2	0,0	100	0,0	0,0	0,0
Capable to refuel 70 kg of hydrogen at once (related to driving range of ±700 km)	2	50,0	0,0	50,0	0,0	0,0
(IR) Communication with the ZE-HDV to optimize fuelling (mass and time)	2	50,0	0,0	50,0	0,0	0,0
Refuelling protocols are available	2	50,0	0,0	50,0	0,0	0,0
Pay by credit card or pay per use over digital platform	2	50,0	50,0	0,0	0,0	0,0
Reservation of timeslot to fuel (no waiting at the pump)	2	0,0	100	0,0	0,0	0,0
Automated fuelling (nozzle is connected by robot arm)	2	0,0	50,0	50,0	0,0	0,0
Adjusted to turning cycle of longer truck-trailer combinations	2	0,0	100	0,0	0,0	0,0
Amenities for truck drivers	2	50,0	50,0	0,0	0,0	0,0

5.6. Trailer manufacturer

Two respondents filled in the ‘trailer manufacturer or leasing’ survey. One of the respondents also identifies as truck end-user and owns +100k trailers and is probably a leasing firm. The other respondent owns six trailers and identifies only as a trailer manufacturer. Both companies manufacture standard trailers and reefers (cooled trailers).

Both companies confirm that their clients are demanding zero-emission solutions for conditioned trailers (reefers) or trailers with an electrical tailgate. They are also developing or demonstrating e-trailers or e-dolly's (defined as a trailer/dolly with at least an integrated battery).

When asked which trailer technologies will be implemented in the future, they agree on the following:

- An e-axle for regenerative braking together with battery on the trailer (no connection to the ZE-HDV)
- PV panels integrated on the trailer roof combined with a battery on the trailer
- Only a battery that can be charged from the grid.

There was no consensus on the innovation 'Battery on the trailer connected with ZE-HDV to increase the driving range', as a high-power connection between trailer and truck is a safety challenge.

The respondents also made use of the opportunity to make some comments. One of the respondents said that: 'Payload and costs are key for the success of the e-trailers business case. E-trailers will continue to be a 'nice to have' while these two bottlenecks are not solved. Please note that costs are not just the cost of purchasing the equipment; it is also end of life residual value.'

The second respondent stated that they are working on electrified reefers and trailers that can enlarge the driving range by integrating e-axles and batteries. The electrification of tailgates is also investigated.

Table 19: Trailer OEMs - statements

		Agree	**disagree**
We are developing e-trailers and e-dolly's, since we want to learn.	2	**100**	0,0
We are developing e-trailers and e-dolly's, since clients are requesting it.	2	**100**	0,0
We are developing e-trailers and e-dolly's, since it lowers the emissions	2	50,0	50,0
We are developing e-trailers and e-dolly's, since it is more energy efficient than the current technologies	2	50,0	50,0
We are developing e-trailers and e-dolly's, since there is a business case for e-trailer and e-dolly's	2	50,0	50,0
We are developing e-trailers and e-dolly's, since it can extent the driving range when combined with ZE-HDV	2	50,0	50,0

5.7. Infrastructure manufacturer and operator

The survey was filled in by seven infrastructure operators and five manufacturers. Because of the low response numbers on the online survey, we focussed on meetings and interviews with infrastructure operators, where we also discussed potential collaboration for the ZEFES use case demonstrations.
In this section we discuss the findings for both charging infrastructure and hydrogen refuelling stations (HRS).

Charging

The CPOs admit that there are currently not that many charging stations compatible with trucks. The focus of most of the CPOs lies on passenger cars. Some of the interviewed CPOs admit that their CCS charging points (150-350KW) are used by trucks, even if the accessibility and the stability of the subsurface is not designed for truck-trailer combinations.
Most of the CPOs say that the technology, station design and business model for truck charging differs fundamentally with passenger cars charging. The CPOs that made the decision to also invest in truck charging focus on **secured parking for trucks only** with at least CCS available for now and the option to upgrade to MCS when the technology is ready.
Locations that combine both charging for trucks and passenger cars are seen as a less viable option, because it is expected that charging will take longer than diesel fuelling today. Charging will be aligned more with the resting times of drivers, and during their resting times, drivers want to stall their truck-trailer combination safe, away from other types of road users. Also, passenger cars drivers are not fond of sharing infrastructure with trucks due to safety reasons. Currently most conventional gas station operators try to split the flow of passenger cars and trucks when the available footprint allows it, and this trend can be seen also for charging locations.
They also state that the aim should be to create a viable business model and should learn the following lessons from the infrastructure development for passenger cars:

- **Aim for a uniform plug**: the CHAdeMO and CCS1/ CCS2 system competition led to a legacy car fleet and infrastructure that is used suboptimally.
- **Avoid underusage of the infrastructure.** The business case of charging infrastructure is strongly linked to its usage rate (the more energy charged, the lower the cost related to the CAPEX investment per unit charged). A decent usage rate from the beginning is crucial for a viable business case.
- **Know the demand a day before.** Charging for passenger cars is based on a first-come-first-serve principle. Operators do not know beforehand if somebody comes to charge and how much. Passenger car charging at a commercial charging location is still mostly opportunity charging. Operators get some insights from historic usage data.
  Nevertheless, due to the higher investments needed for truck charging infrastructure this will not work. CPOs focusing on trucks are all working with a **reservation platform**, where truck operators can book their charging spot. This is beneficial for both sides; the truck driver is sure of a spot and that the charger will be available, and the CPO knows that there will be demand and can place an order on the day-ahead energy market.

Other barriers that were mentioned by the CPOs are further innovations in charging technology, short-term concessions, and limited grid connection.
Expected **further innovations in charging technology** also lead to an uncertain climate for investment decisions. Currently, the CCS at 350kW seems a standardised solution that can be installed and used now. However, innovations increasing the voltage (to 600V) and increasing the power beyond 1 MW are expected, so that current investments could be updated. The focus should lie on installations that

can be modular and expanded with increasing demand while being adapted to new power electronics standards in a technically and economically viable way. Most of the CPOs see MCS as the technology the market is moving to. There were some concerns about the future need for MCS, especially when autonomous logistics will be possible or changes in the drivers resting regulation happen and more time to charge will be available, thus cancelling the need for MCS.

Another limitation for commercial charging hubs are **the concessions** of the current (highway) stations. The duration of the concessions determines the budget for investments. Short concessions (less than 10 years) hamper the installation of charging infrastructure, as the guaranteed payback period is too short to be profitable.

The main factor that defines the attractiveness of a location for truck charging **is the existing or future power connection**. Green fields with a sufficient power connection (possible up to 25MW) are the wish of every CPO. Currently the timeline of projects is determined by the power connection and the time needed to get the grid connection approval from the DSO (local, low-voltage distribution to the end-users) and maybe the TSO (long-distance, high-voltage transmission) for some corridors. Upgrades of the electricity grid take time. It is possible that the current gas station locations are not suitable as charging locations due to grid limitations. Grid limitations at the logistic hub level is already discussed in Section 5.4 and is also identified as the main barrier for charging infrastructure implementation.

HRS

The current state of the art of HRS for trucks is 700 bar and a filling rate of 90 g/s (Chapter 4, Interview results). The first truck HRS with these specifications is built in the H2Haul project and is operational. Other 700 bar HRS for trucks are in the development phase.

It is clear that 700 bar will also **become the standard for hydrogen trucks.** Doubling the operating pressure will lead to more mass on the HDV, increasing its driving range up to 700km. The main advantages of 700 bar hydrogen HDV would then be the mileage and the faster refuelling time (Table 1). As stated in Section 5.5, FCE-HDV are still in the development phase, whether they are 350 bar or 700 bar. Hydrogen trucks are still special vehicles built on commission and not at commercial scale, as some battery truck models are today.

Besides trucks, there are still barriers to overcome before the 700 bar HRS technology for trucks will be implemented at large scale. First, 700 bar HRS for passenger cars are not designed to be used by trucks. Thus, **the current network of HRS for passenger cars** is **not compatible with HDV**. Passenger cars HRS are designed to deliver a certain amount of hydrogen at once, which is around 5 kilograms, the maximal mass fuel cell electric passenger cars can store in their tank. In addition to the mass delivered per refuelling, the stations are designed for a certain refuelling profile, which is characterised by the daily total amount of hydrogen that will be refuelled and the peak demand (amount of back-to-back refuelling). Some passenger car HRS are already designed to be able to continuously fuel cars.

Looking at truck refuelling, the amount of hydrogen that should be refuelled at once would lie between 50 to 80 kg, an increase with an order of magnitude. Also, if the total daily capacity of Truck HRS is estimated to be around 6000 kg per day, then they could cater to around 100 trucks per day, the same amount as for commercial gas stations for trucks now. This means that the capabilities of the HRS should increase drastically, which will affect the CAPEX, layout, and design of the HRS. Currently HRS are mostly designed to work by the cascade refuelling principle, and their capability is defined by the compressor capacity and the local storage of hydrogen at high pressure. Increasing the throughput of hydrogen in a technically and economically viable way will only be possible when there are innovations in hydrogen compression, storage, and hydrogen transport or local hydrogen production. Even HRS designs working with liquid hydrogen could be a solution.

Another discussion point is the fuelling speed. The refuelling speed for passenger cars is currently set at a maximum of 60 g/s (in reality an average fuelling speed of 40 g/s is attained), this is too slow to achieve the worldwide milestones set out on HD fuelling by the US Department of Energy (60 kg in 10 minutes by 2030 and 60 kg in 6 minutes by 2050).

As stated before, the Air Liquide station in Fos-sur-Mer has a maximum fuelling rate of 90 g/s as it uses a prototype of the mid flow nozzle (H70_F90) and refuelling protocol which will be compatible with both cars and trucks. It is believed that when HRS are equipped with two mid flow nozzles, they can fuel two passenger cars with one nozzle each or fuel trucks quickly with both nozzles connected to the same truck. This technology is ready to be deployed and is believed to keep the development costs of high throughput HRS in check as they can cater to both types of vehicles. Higher flow nozzles are under development.

In conclusion, the standard for truck refuelling at 700 bar is not ready. The suitable hardware is developed but not implemented at large scale yet, further standardisation of the hardware and fuelling protocols is needed. Also unifying the fuelling nozzle to mid-flow for both passenger cars and HDV could be beneficial for the business case as the economic viability is also dependent on the utilisation rate (cfr. charging infrastructure).

We decided to forego an extensive analysis on **the availability of (green) hydrogen, but it is a main barrier for implementation.**

We also want to state some barriers that are currently identified with the operational 350 bar stations and trucks:

- **Green hydrogen availability**: there is no mature market for green hydrogen, as long as the price is too high for market uptake. Import of large quantities of green hydrogen in the form of NH3 is seen as a possible solution. However, the ammonia needs to be cracked to hydrogen, plus hydrogen liquefaction to purify the obtained hydrogen is needed, affecting the energy efficiency of the total process negatively.
- **Availability of tube trailers to transport the hydrogen to the HRS**: at the moment hydrogen is mostly delivered by tube trailer to the HRS, but a shortage of tube trailers (due to delayed delivery of new ones, or contamination) can affect the availability of the HRS. In the future hydrogen pipelines could be used for hydrogen distribution, but their feasibility is still in the research phase.
- **Hydrogen quality**: for FCE-HDV the hydrogen should be fuel-cell grade quality. For hydrogen trucks with a combustion engine, the quality could be lower. In addition, when the hydrogen is cooled (up to -40°C in the current passenger car HRS, no standard for the HDV HRS defined yet) water contamination could block the heat exchanger of the cooling unit, making the HRS unusable. Therefore, hydrogen quality is important for both the truck and the HRS availability.
- **Permitting and procurement:** permitting of a HRS can take some time due to strict safety regulations and related safety perimeters. We are in favor of all necessary safety measures, but currently local regulations are not uniform, and the impact of the SEVESO regulation, which is applicable when five tons of hydrogen are stored on site, is unsure. Since the technology is still in development, procurement is not straightforward.

5.8. Research

Nine respondents filled in the survey for researchers. Almost all respondents were working in the industry, and no university researchers filled in the survey. The topics that the respondents researched are broad: from a hydrogen combustion engine and cryogenic hydrogen storage, studies on logistics and intermodal transport, to optimal routing, BE-HDV and conductive charging.

The main lessons learned and identified *needs and requirements* from the research stakeholder respondents are in line with the responses of the other stakeholder groups.

- The numbers of vehicles are still too limited to achieve economies of scale
- Need for transparency regarding alternative drive train solutions
- Need for real tests in standard business conditions to assess if current HDVs can be considered a sustainable solution. Involving multiple countries and multiple business models in logistics and freight transport.
- Need to include related processes to be electrified. Besides transport, loading and unloading consumes energy.
- In addition to ZE-HDV, there is still a need towards a modal shift.
- The need to develop charging and refueling infrastructure and maybe new concepts, combined with renewable hydrogen production
- It is interesting to see whether these super heavy (cargo load) and long ZE vehicles really reach the market and what their range will be
- Need for policy support
- Massive European call for proposals involving all stakeholders

When asked for future zero-emission truck technologies, the respondents answered:

- Powertrains that are robust for contaminants in the hydrogen fuel. Hydrogen storage systems that combine high pressure and cryogenic hydrogen.
- Battery electric, other sustainable engine technology, certainly not hydrogen due to fundamental flaws in energy, loss along the chain of fuel supply.
- Battery vehicle for short distance due to regulations by city governments
- Dynamic charging to enable long-haul logistics
- If we compare other HDVs almost ten years ago, when allowed in Finland, the newer fleet took its market share very quickly. Maybe something similar will happen here, when the market is ready. ZE- HDV integration could happen quickly.

Data and research that is missing according to the research respondents:

- Hydrogen engine development. Materials that are suitable for the combination of high stress and cryogenic temperatures.
- Cheap, clean, powerful batteries in all areas
- Regulations in the electricity grids, unified grids like in Denmark, we need less bureaucracy and regulations
- Is there any current call for proposals in any European country on that? Everything is in its infancy and needs massive R&D investment at all levels and for all logistics business models, including construction, reefer food etc.
- holistic view on energy demand for loading, transport and unloading as well as for special devices such as refrigerators
- Standardization will be required to scale-up.

We asked if the researchers wanted to propose some literature. The main answer of the respondents was that the research published in scientific papers is too slow. They proposed industry-led research reports, published by organisations with strong industrial ties (ICCT, ACEA, Fraunhofer, etc.).

6. Input Stakeholder Group Workshop at IDIADA

During the Stakeholder Group meeting at IDIADA, Spain, a workshop was held to present the preliminary survey results. In addition, a panel discussion was held, followed by an interactive validation workshop where the needs and requirements per category were discussed.

Prior to the workshop, we divided the identified needs and requirements into six categories: (i) truck-trailer technology, (ii) integration in the logistic operation, (iii) social acceptance: safety and sustainability, (iv) legal barriers, (v) infrastructure and (vi) viable business case. The full list of needs and requirements can be found in APPENDIX I, together with a description of the current state of the market. In a next step, the needs and requirements will be converted into KPIs. This will be done in collaboration with WP8 – Use-case evaluation, impact assessment and LCA.

6.1. Truck-trailer technology

You can find the gathered feedback in Figure 13. Most of the feedback targeted the first requirement: *T1 truck-trailer combination should be seen as one asset*.

This requirement was stated, as the capabilities and needs of the truck and trailer should be combined to assess whether a mission is possible from an energy perspective. Concerns were raised whether the trailer must be seen as a part of the energy equation. Making the mission completion dependent on the trailer will render logistics operations more complex and less flexible. Adding the trailer to the energy equation also means that the trailer needs to have a battery. Electrified trailers are more expensive than regular ones. Some logistic operators have more trailers than trucks. The higher cost and amount of trailers makes it more challenging to invest in a full fleet of electrified trailers with battery. A battery pack in the trailer was not seen as a solution to improve the logistics flexibility or the charging time by the workshop participants.

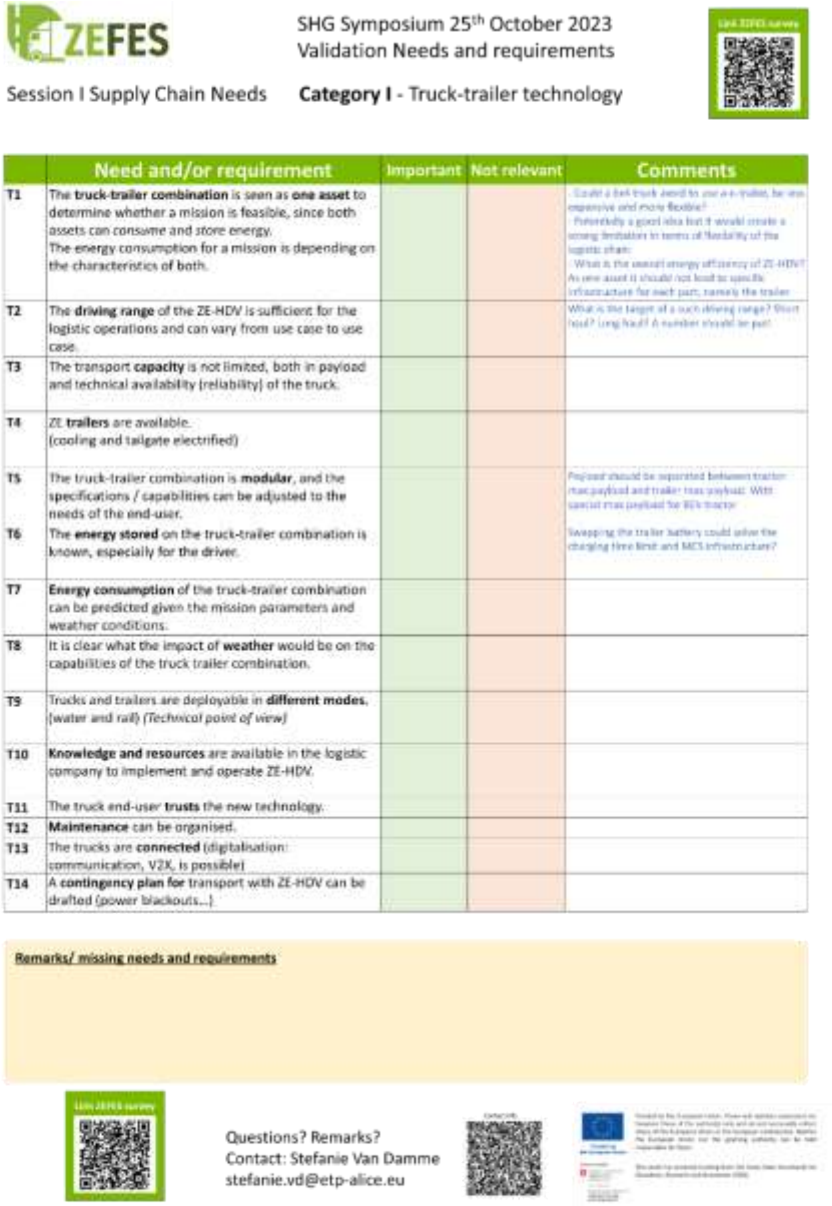
The feedback on the second requirement T2, was more a question: 'what should the mileage of a ZE-HDV be?' The answer is that the mileage needed will depend on the use case for the truck. We see that truck OEMs are considering bringing BE-HDV with a variable battery pack size on the market. We will evolve from a one-solution fits all (the diesel truck) to fleets existing of a mixture of vehicles with different capabilities and powertrains.

Another comment pointed out that regulations for payload definition should be defined in more detail, maybe on the level of tractor and trailer separately. Now the total weight of the tractor-trailer combination is limited as the weight that can be put on the axles of the combination. The weight of the powertrain technology (battery pack, hydrogen vessels…) has an impact on the net payload that can be transported with the ZE-HDV, and this should be clearly communicated to the end-user.

The need to assess other options to energize the HDV was mentioned as well (battery swapping).

Conclusion: Identified needs and requirements during workshop Truck-trailer technology

- The effect of energy storage on the trailer on the flexibility of logistics operations is not clear. It can be an improvement in terms of mileage but can create less flexibility in dispatching, as an investment in a fleet of e-trailers is not expected due to higher CAPEX.
- **It should be clear what the impact of the ZE powertrain capabilities is on the net payload (new need and requirement).**



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Category I - Truck-trailer technology

	Need and/or requirement	Important	Not relevant	Comments
T1	The **truck-trailer combination** is seen as **one asset** to determine whether a mission is feasible, since both assets can consume and store energy. The energy consumption for a mission is depending on the characteristics of both.			- Could a [illegible] truck avoid to use a e-trailer, be less expensive and more flexible? - Potentially a good idea but it would create a strong limitation in terms of flexibility of the logistic chain - What is the overall energy efficiency of ZE-HDV? As one asset it should not lead to specific infrastructure for each part, namely the trailer
T2	The **driving range** of the ZE-HDV is sufficient for the logistic operations and can vary from use case to use case.			What is the target of a such driving range? Short haul? Long haul? A number should be put
T3	The transport **capacity** is not limited, both in payload and technical availability (reliability) of the truck.			
T4	ZE **trailers** are available. (cooling and tailgate electrified)			
T5	The truck-trailer combination is **modular**, and the specifications / capabilities can be adjusted to the needs of the end-user.			Payload should be separated between tractor max payload and trailer max payload. With special max payload for [illegible] tractor
T6	The **energy stored** on the truck-trailer combination is known, especially for the driver.			Swapping the trailer battery could solve the charging time limit and MCS infrastructure?
T7	**Energy consumption** of the truck-trailer combination can be predicted given the mission parameters and weather conditions.			
T8	It is clear what the impact of **weather** would be on the capabilities of the truck trailer combination.			
T9	Trucks and trailers are deployable in **different modes**. (water and rail) *(Technical point of view)*			
T10	**Knowledge and resources** are available in the logistic company to implement and operate ZE-HDV.			
T11	The truck end-user **trusts** the new technology.			
T12	**Maintenance** can be organised.			
T13	The trucks are **connected** (digitalisation: communication, V2X, is possible)			
T14	A **contingency plan for** transport with ZE-HDV can be drafted (power blackouts…)			

Remarks/ missing needs and requirements

Questions? Remarks?
Contact: Stefanie Van Damme
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Figure 13: Feedback gathered on the first Category: Truck-trailer technology

6.2. Integration in the logistics operation

Most of the gathered remarks are already discussed in this document. Nevertheless, we want to emphasize that questions were raised over the feasibility to charge during the 45 minutes driver breaks. Some are doubting the feasibility of charging during breaks, as drivers could be doing other tasks, such as loading/unloading or administrative tasks. It is also not clear that infrastructure will be available in the locations where drivers will take their break.

Conclusion: Identified needs and requirements during workshop Integration in logistic operation

- It needs to be clear that the charging can be done during the drivers breaks.

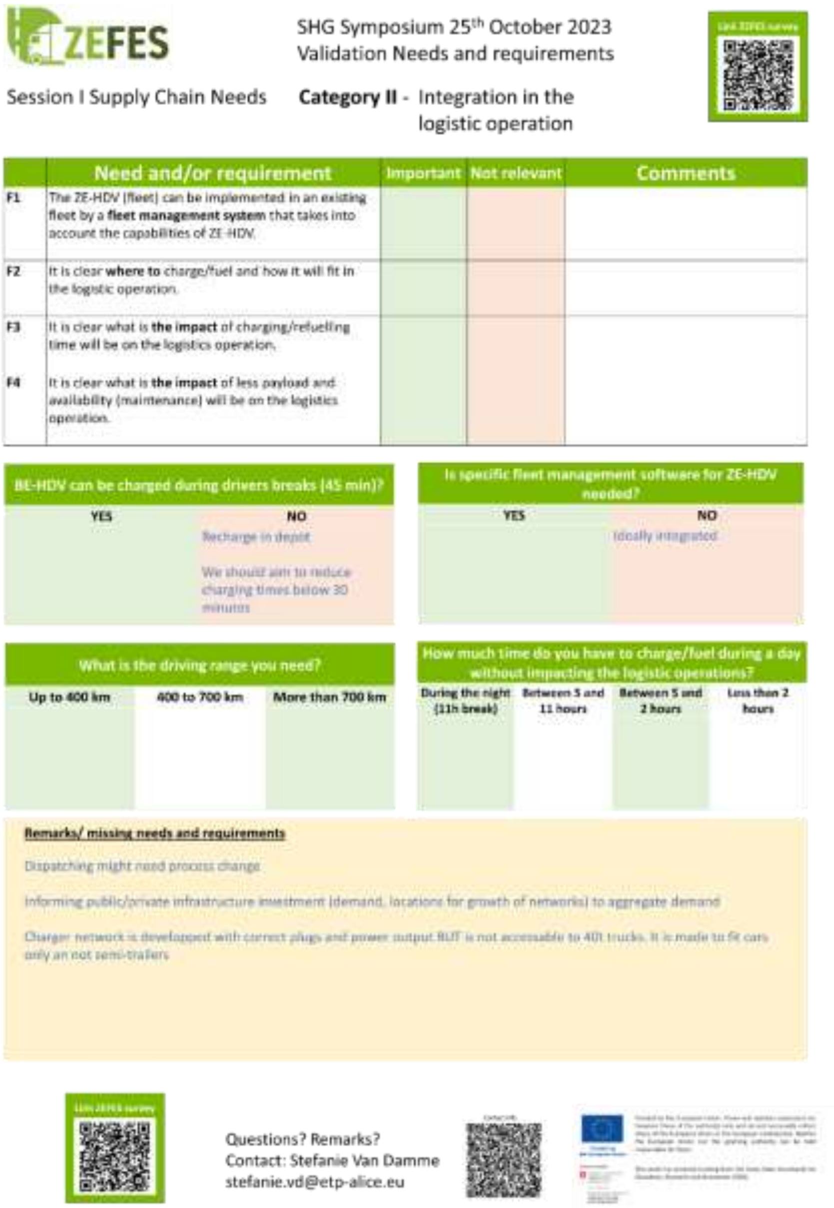

Figure 14: Feedback gathered on the second Category: Integration in the logistic operation

6.3. Social acceptance: safety and sustainability

Social acceptance mean two things: driver acceptance mostly in terms of safety and reliability and acceptance of society that ZE-HDV will lead to more sustainable transport.

The feedback on the social acceptance topic shows that there is a need to define needs and requirement about technical learnings of truck drivers (proving the ZE-HDV are safe and reliable) and define how to communicate the learnings to the general public.

In addition, sustainability should be looked at in a broader way. Circular economy was mentioned in the workshop, as the sustainability of the battery supply chain from a LCA point of view, not only focussing on the CO_2 balance calculated well to wheel. It was also suggested to define a need or requirement about the competitiveness of the European industry and value creation in the ZE-HDV market.

Conclusion: Identified needs and requirements during workshop Social acceptance

- Circular economy and LCA assessment on the sustainability are needed. Well to wheel analysis of the CO_2 emissions is not sufficient. At best, the full logistics chain can be assessed. The findings should be communicated to the public.
- The driver and the public need to be informed by the learnings about the safety and technical reliability of ZE-HDV.

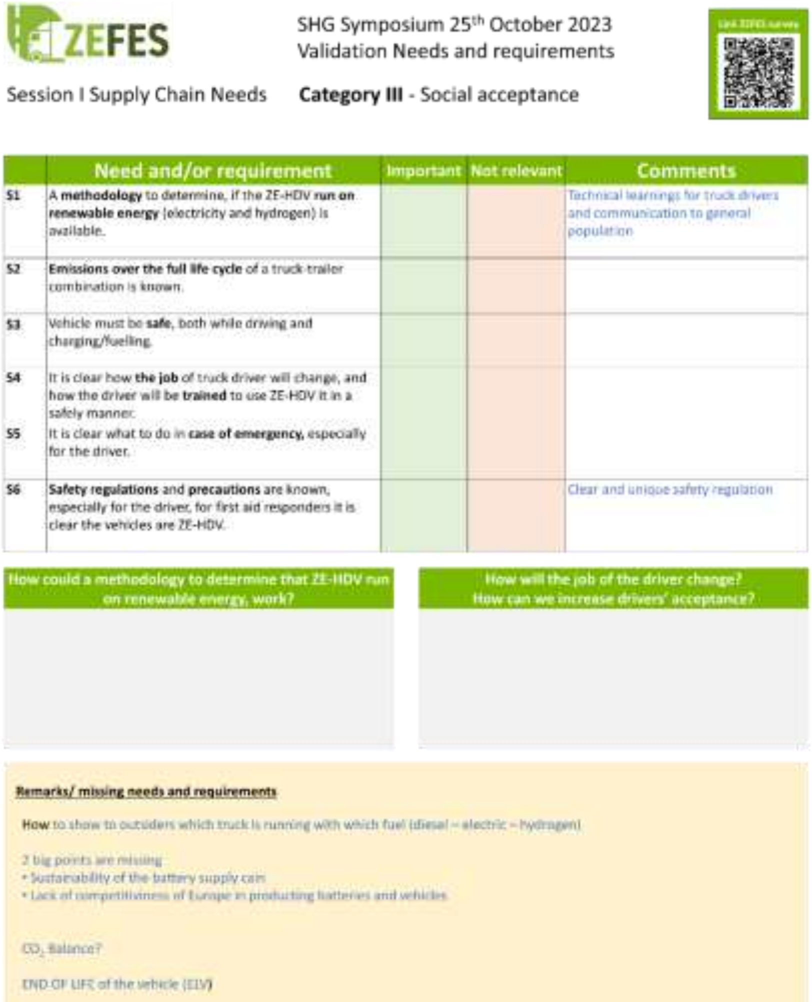

Figure 15: Feedback gathered on the third Category: Social acceptance.

6.4. Infrastructure

Two posters about infrastructure were prepared for the workshop, since we wanted to adress two audiences: one focussing on the needs of the infrastructure and logistics hubs operators, and one focussing on the needs and requirements for truck end-users.

The main need of the infrastructure operators is to define the optimal location for the infrastructure and what will be the demand in the near future. CPOs are developing sites for HDV charging, and they say that the power connnection is one of the main characteristics to select a suitable site. If the grid connection is not present, the time to develop the project will be years. Also, the possibility for partnerships is an important reason to prefer a location. Having a business case from the start is seen as a ‘nice’ to have. The decision to invest in a location depends on demand, power connection, and land availability. CPOs see a reservation or booking app as an asset.

Conclusion: Identified needs and requirements during workshop Infrastructure operator and logistic hub operator

- Optimal locations for chargers need to be found in terms of both power connection and future demand
- Need for booking app
- Need for back-up infrastructure
- Need to identify who is investing, and map the infrastructure especially built for ZE-HDV.

Figure 16: Feedback gathered on the fourth Category: Infrastructure operator and Logistic operator.

In Figure 17, the feedback on the infrastructure for the truck end-users is given. Again, providing basic knowledge to the truck end-users and shippers is stated as a need. The availability of the infrastructure is seen as the most important requiremen, especially at the right time and location. The end-user expects a uniform connection to the truck (interoperability). Driver amenities and overnight parking are seen as less important needs and requirements. The end-users know that the electricity grid and power connection can be a limiting factor. Some of the workshop participants believe there is a need for MCS. In addition to charging infrastructure for trailers, the respondents also stated that procedures to charge EMS combinations without decoupling need to be determined.

The hydrogen quality is also a concern for some of the respondents and how the hydrogen quality will be checked in a fast and reliable way.

The efficiency of the infrastructure system should also be known. The truck end-user is interested to know what the power losses are between the location where the electricity consumption is measured and the actual energy in the ZE-HDV. Once the infrastructure is available, the efficiency of the infrastructure will be an important decision maker for the CPO. A method to define the efficiency of both charging and HRS on the system level should be defined, so a comparison and further improvements can be quantified.

Conclusion: Identified needs and requirements during workshop Infrastructure viewpoint truck end-user

- Methodology to define the efficiency of a charger on the system level
- The full vehicle combination needs to be able to charge; this means that multiple power connections could be needed.

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Session I Supply Chain Needs — **Category IV** – Infrastructure Truck end-user

	Need and/or requirement	Important	Not relevant	Comments
I1	Charging or fuelling infrastructure is **available**.	xx		Right connection and capacity of the grid
I2	Charging or fuelling a ZE-HDV should be **easy and safe.**	x		
I3	**Driver amenities** are available at charging stations and HRS.	Not always		
I4	**Charging** can be combined with **overnight** parking.	Not always		
I5	Charging / fuelling infrastructure available at the **right location.**	xx		Key, and in the right time and at the right (declared) speed
I6	Charging / fuelling infrastructure available at the **right power/pressure.**	x		Key, need MCS
I7	**Waiting time** at the charging station/HRS is minimal (not only waiting time during refuelling or charging, but also waiting time to get a charger/refuelling nozzle).	x		Bookable
I8	**Availability and reliability** of the infrastructure is high.	x		= electricity grid and power available
I9	The charging station/HRS is **accessible** by truck-trailer combination.	x		
I10	Charging infrastructure for **trailers** is available.	x		How to charge EMS without decoupling -> possible to charge the 3 vehicles
I11	The charger/refuelling infrastructure is capable of fuelling/charging the wanted **amount of energy.**	x		
I12	Connected ZE-HDV, **V2X communication.**			Nice to have
I13	**Unambiguous pricing displayed** or communicated at the charging and refuelling stations (AFIR ✓).	x		
I14	At charging and fuelling stations can be **paid with conventional means** (credit card, pay per use over digital platform) (AFIR ✓).	x		Not currently possible in all countries – in France not possible with conventional paymayment
I15	**Quality** and origin (green, grey, pink) **of the hydrogen should be fuel cell grade.**			Who will check the quality?

Remarks/ missing needs and requirements

Different charging interface for trailer possible. Define which will be used in each UC

Deployment flexibility and scalability

Infrastructure should be discussed at the site level, not at the individual charger -truck

Standardized requirements for deployment in EU (grid +safety)

Infrastructure should be integrated in a different way to the grid, taking into account that many chargers need to be operated at one site

Efficiency should be defined as a system for the grid connection point and inlet

Basic knowledge – what should users and shippers need to know

Figure 17: Feedback gathered on the fourth Category: Truck end-user

6.5. Viable business case

The earlier identified needs and requirements B5 to B7 were seen as important. Incentives for infrastructure should also be limited in time. This could be added to B4.

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Session I Supply Chain Needs — **Category V** – Viable business case

Link ZEFES survey

	Need and/or requirement	Important	Not relevant	Comments
B1	The **TCO** of ZE-HDV can be calculated.			
B2	Assessment of **new business models for ZE-HDV** is needed			
B3	Realistic scenarios to reach **economies of scale** are drafted and defined in time			
B4	**Incentives** to invest in **ZE-HDV** are available.			But limited in time
B5	The **emission reduction** can be monetized.	x		Regulation on book & claim system
B6	Renewable electricity and hydrogen should be **affordable** for logistic companies.	x		
B7	**Incentives** for charging and fuelling **infrastructure** are available.	x		Strong incentives to charge in DAY time -> solar surplus
B8	The **TCO** can be calculated for the **infrastructure** (viable business case).			
B9	**New business model to operate infrastructure** are assessed.			Combine ZE-HDV with autonomous applications (CCAM)

Can the TCO of ZE-HDV be calculated?	
YES	NO
	x

What is missing to calculate the TCO?

How could the zero-emission aspect be monetized? How do we convince the end-costumer?

Example of ETS in Germany, where charging reimburses through ETS licenses

Taks breaks for BEVs as incentives

What is the link with ETS for road?

Remarks/ missing needs and requirements

It's practical impossible to build a generic and credible TCO. It changes a lot for different use cases. The most reliable thing is to create a guideline to follow

Battery standardisation could be a way to reduce TCO, open innovation, enable solutions like swapping.

Figure 18: Feedback gathered on the fifth Category: Viable business case

6.6. Legal barriers

Legal Barriers need and requirement are defined open, so a lot will fall under it. Within the ZEFES project more detailed gaps in the legislative and regulative framework are already defined. The validation session is used to check if a perspective is missing.

The attendees to the workshop mentioned

- Cross-border logistics
- Fragmentation of national and EU legislation
- Adapting rest times regulations or other social legislation
- Access regulations (low emissions zones and city environment)
- Special permit for longer vehicles
- Limitations due to safety regulations: we identified within ZEFES that ZE-HDV could not enter tunnels, ferries, ADR trailers

Figure 19: Feedback gathered on the sixth Category – Legal barriers

7. Conclusions

One of the main conclusions from the identification of the needs and requirements of all ZE-HDV ecosystem stakeholders is that the ecosystem is characterized by interdependencies. In Figure 20, a visualization of interdependencies of the main stakeholders is shown and explained in more detail in Table 20. Due to the interdependencies, the ZE-HDV ecosystem needs a transition as a whole.

In the future ZE-HDV vehicles must be able to be integrated in fleet operation.

The shipper and transport operator want to be able to define the capabilities of ZE-HDVs needed based on the logistics missions it will perform (buying decision tool). The truck end-users also stated that interoperability between ZE-HDVs and the available charging and fuelling infrastructure is one of their main concerns (even more than reducing emissions), so charging/fuelling is possible at every available location and the flexibility of operation is maximised. In addition to the buying decision tool, truck end-users are also requesting a fleet management system (FMS) that can integrate ZE-HDVs in existing fleet operations, taking into account the different capabilities compared to diesel trucks.

Truck and trailer OEMs want to learn from the truck operators what exactly are the needed ZE-HDV capabilities, so the customer can be convinced to buy ZE-HDVs instead of diesel trucks. This knowledge about realistic implementation scenarios is also important to determine (production) scale-up scenarios and should be based on real operational data of ZE-HDV fleets. There will be no one-solution-fits-all ZE-HD. ZE-HDV with different, modular designs (e.g. different battery sizes) will be brought on the market. Additionally, trailers will be electrified, and their implementation and charging should also be organised.

Operators of infrastructure (CPOs or HRS operators) want to learn what the demand profile will be (location and daily power charged/mass refuelled) and how the profile will change during the day and in the coming years. Since ZE-HDVs and infrastructure technology are still evolving, investing in current state of the art infrastructure technology can be seen as a risk, as it could be useless for new generations of trucks. Nevertheless, there is a need for investments today, so smart concepts that increase the compatibility with future ZE-HDV are necessary, e. g. the modular expansion of charging locations with CCS 350 kW with more chargers and even MCS, based on the expected future demand and technology evolution. Infrastructure operators are also requesting a reservation platform or booking app, where truck operators can book a time slot to charge or fuel their truck. In this way, the infrastructure operators can predict the actual demand in a better way and optimise the operation and business case of the station.

In ZEFES there are three tools or apps: a buying decision tool, a fleet management system for fleets with mixed powertrains, and a booking app for charging or fuelling slots. Companies that develop **logistics planning software** are therefore an important stakeholder. They want to gather more insights into how routes can be optimized for ZE-HDV and are requesting connected ZE-HDV, so the vehicle parameters like locations and State of Charge (SOC) is communicated directly to the logistics planning software.

Lastly, the **operators of logistics hubs** are willing to install infrastructure on their site. Nevertheless, they want to get more insights into future demand: how much will be charged at logistics hubs, and how much at commercial stations? The installation and operation of the infrastructure should not hamper the business continuity of the site. In addition, the power connection of logistic hubs is limited, which will have an impact on what can be installed and make charging at logistics sites challenging.

All these interdependent needs and requirements are visualised in Figure 2. Most of them can be seen as bilateral advantages and are even connected to multiple stakeholders. Most of the needs and requirements stated in APPENDIX I can also be connected to this summary.

In Table 20, the main learning from the ZEFES survey per stakeholder group is summarized.

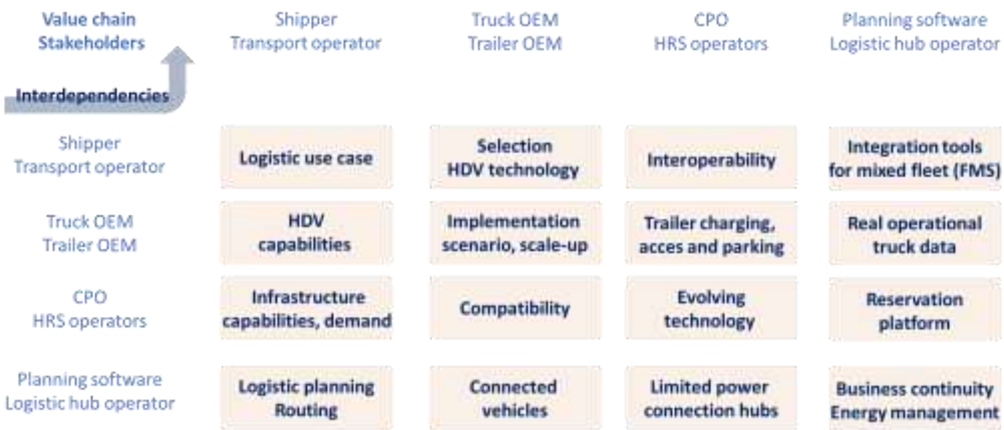

Figure 20: Visualisation of the interdependencies between the ZE-HDV value chain stakeholders.

Table 20: Main take-aways per stake-holder group from the ZEFES survey

Stakeholder group	**Statement from the ZEFES survey**
Shipper and Truck end-user	Shippers and transport operators are interested in ZE-HDV, they want to learn, but the impact on costs and logistic operation hampers large scale implementation
Logistic site owner or operator	Infrastructure will be installed at logistic hubs, if it does not hamper business continuity. It will be limited by the power connection.
Truck OEM	FCE-HDV technology is not as developed as BE-HDV, and not ready for commercial deployment.
Trailer manufacturer	Clients are demanding zero emissions solutions for conditioned trailers (reefers) or trailers with an electrical tailgate.
Infrastructure manufacturer and operator	Secured truck parking with MCS takes years to develop due to grid connection
	Raising the working pressure from 350 to 700 bar impacts the HRS design drastically, not all needed hardware and protocols are available.
Planning software	Route optimisation is again a research field.

Table 21: Conclusions summary

Needs and requirements per stakeholder group and the interdependencies between stakeholder groups.					
	Shipper **Transport operator**	**Truck OEM** **Trailer OEM**	**CPO** **HRS operator**	**Planning software**	**Logistics hub operator**
Shipper **Transport operator**	Logistics use case The mission profiles that need to be carried out by an ZE-HDV fleet is the starting point, as it defines the ZE-HDV capabilities and the logistics operation	Selection HDV technology The end-user wants to be able to select a HDV that matches the logistic needs and carry out mission profiles (buying tool).	Interoperability The end-users want ZE-HDVs and infrastructure that are interoperable, to maximise the flexibility. End-users spread the risk, operate different brands, but different brands should be able to be implemented in the same way.	Tools to integrate mixed fleet Truck operators are already operating different truck brands and trailer concepts, but integrating HDV with different powertrains will be new.	Charging at logistics hub Depot charging will be important in the future, but the feasibility is not clear.
Truck OEM **Trailer OEM**	HDV capabilities The capabilities should be based on the end-users needs	Implementation scenario, scale-up Understanding how the market will evolve is crucial.	Charging of the full vehicle combinations More than one power plug could be needed	Real operational truck data Simulations alone are not enough.	
CPO **HRS operator**	Infrastructure capabilities Are requested by the end-users Demand profiles by the CPOs	Compatibility ZE-HDV and infrastructure should be compatible	Evolving technology leads to investment risk	Reservation platform	
Planning software	Logistics planning Routing	Connected vehicles			
Logistic hub operator			Limited power connection of hubs		Business continuity Energy management

8. Risks and interconnections

8.1. Risks/problems encountered

No risks were identified with a link to this report and the respective activities performed by the project partners. The focus of this deliverable is procedures and methodology and gathering final results to validate the quality of the methodology. Special attention was needed in contacting the relevant profiles to participate in the survey where experts in the field and a representative sample of the ecosystem was required in identifying the users' needs and requirements for the scope of the ZEFES project. Moreover, the partners' needs and requirements need to be fully understood and translated at a technical level during the project. This deliverable is the first document translating user needs and requirements into technical needs. We are aware that the stated needs and requirements and their technical translation are not a static given and can evolve in time with evolving truck and infrastructure technology and logistic operations.

8.2. Interconnections with other deliverables

A close alignment with the rest of the Work Package 1 tasks and the Work Packages 2, 3, 4, 7, and 8 has already resulted in addressing topics, user needs and requirements at an early stage in the ZEFES project. This report is going to provide input into the different project activities such as the digital twinning platform (WP4) and the preparation and piloting of the trucks. The evaluation of the pilots will reflect the needs and requirements set by transport operators and other stakeholders representing the whole supply chain (shippers, OEMs, charging and refuelling etc.) with the objective of giving feedback to the industry on the advantages and limitations of BEVs and FCEVs. All final results and analysis of the user needs and requirements survey will be presented, and the final business cases will be further detailed in the final report of WP1. The needs and requirements of this report will be translated into technical requirements and implemented in WP2, 3, 4, 5, 6, then demonstrated in WP7 and assessed in WP8 (Assessment of requirements on use-case level in D8.3, LCA in D8.4, (societal) impact assessment in D8.5).

9. Acknowledgement

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Project partners:

#	Partner short name	Partner Full Name
1	VUB	VRIJE UNIVERSITEIT BRUSSEL
2	FRD	FORD OTOMOTIV SANAYI ANONIM SIRKETI
3	KAE	KASSBOHRER FAHRZEUGWERKE GMBH
4	REN	RENAULT TRUCKS SAS
5	SCA	SCANIA CV AB
6	VET	VAN ECK TRAILERS BV
7	VOL	VOLVO TECHNOLOGY AB
8	ABB	ABB E-MOBILITY BV
8.1	ABP	ABB E-MOBILITY SPOLKA Z OGRANICZONAODPOWIEDZIALNOSCIA
9	AVL	AVL LIST GMBH
10	CM	SOCIEDAD ESPANOLA DE CARBUROS METALICOS SA
10.1	APG	AIR PRODUCTS GMBH
11	HEPL	HITACHI ENERGY POLAND SPOLKA Z OGRANICZONA ODPOWIEDZIALNOSCIA
12	MIC	MANUFACTURE FRANCAISE DES PNEUMATIQUES MICHELIN
13	POW	PLASTIC OMNIUM NEW ENERGIES WELS GMBH
14	RIC-CZ	RICARDO PRAGUE S.R.O.
14.1	RIC-DE	RICARDO GMBH
15	UNR	UNIRESEARCH BV
16	ZF	ZF CV SYSTEMS HANNOVER GMBH
17	ALI	ALLIANCE FOR LOGISTICS INNOVATION THROUGH COLLABORATION IN EUROPE
18	DPD	DPD (NEDERLAND) B.V.
19	COL	ETABLISSEMENTEN FRANZ COLRUYT NV
20	GRU	GRUBER LOGISTICS S.P.A.
21	GBW	GEBRUEDER WEISS GESELLSCHAFT M.B.H.
22	PG	PROCTER & GAMBLE SERVICES COMPANY NV
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22.2	PGA	PROCTER & GAMBLE AMIENS
23	PRI	PRIMAFRIO CORPORACION, S.A.
24	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

APPENDIX I – List of final identified 'Needs and requirements'

The Needs and requirements are divided into six categories. This is the final, updated version. We give the identified 'Need or/and requirement' and the status quo.

(i) truck-trailer technology: the truck-trailer combination is technically able to do the mission		
	Need or/and requirement	**Status quo / questions / more details**
T1	**Truck-trailer combination** is seen as **one asset** to determine whether a mission is feasible, since both assets can *consume* and *store* energy. The energy consumption for a mission is depending on the characteristics of both.	- A diesel truck can be combined with all types of trailers, can be refuelled in minutes and can drive more than 1000 km at once. Its capabilities are not limiting the logistic operations, it is a 'one-solution-fits all'. - A ZE-HDV should provide energy to some trailer types (cooling / tailgate), therefore the energy balance should be made over the truck-trailer combination. - This 'Need or/and requirement' is more an assumption - In planning and dispatching software, the capabilities and needs of the combination must be taken into account (link F1). - The effect of energy storage on the trailer on the logistic flexibility is not clear. It can be an improvement in terms of mileage but can create less flexibility in dispatching as an investment in a fleet of e-trailers is not expected due to higher CAPEX investments.
T2	**Driving range** ZE-HDV is sufficient for the logistic operations of a transport company (can varies from use case to use case).	- Required driving range depends on the use cases. More than 750km driving range is a common request (cfr. Interviews and survey responses) - Driving range is not only dependent on the energy stored on the vehicle, but on the overall efficiency of the drive train and HVAC system, the payload, the route followed…
T3	**Transport capacity** is not limited, both in payload and availability of the truck	- What will be the impact on payload and availability when a ZE-HDV is used? - Less payload due to weight of the battery pack and hydrogen skid - More charging and refuelling time = less time to drive = less availability - Will you need more trucks to do the same work?
T4	**ZE trailers** are available (cooling and tailgate electrified)	- Trailer manufacturers are developing ZE trailers, and the first models are commercially available

T5	The truck-trailer combination is **modular**, and the specifications / capabilities can be adjusted to the needs of the end-user	- Diesel truck can be applied in all use cases, this is not expected for ZE-HDV (limited driving range/payload) - Will the market evolve to a customized truck, whose characteristics are defined by the missions it will do? - Will a range of trucks models with varying capabilities and CAPEX investments be available?
T6	**The energy stored** on the truck-trailer combination is known by the driver can be predicted	- The characteristics of the components and energy vector are more depending on the weather (batteries, hydrogen storage), which means that the energy storage can alter from day to day, and therefore also the driving range - Drivers are not familiar with the concept of State of Charge (for both H2 and batteries). - FCE-HDV: energy is stored in a battery, plus the mass of hydrogen on the truck, how can it be converted to one, understandable parameter. - Is stating the expected driving range enough?
T7	**Energy consumption** of the truck-trailer combination can be predicted.	- An electric driveline is more energy-efficient than an ICE, however the characteristics of the components and the energy vector are more dependent on the weather (batteries, hydrogen storage), which means that the energy consumption can alter. - Also impact of regenerative braking and unplanned events - Will truck end-user be able to work with the variability in energy consumption throughout the year and type of mission.
T8	It is clear what the impact of **weather** would be on the capabilities of the truck trailer combination	Linked to T6 and T7
T9	Trucks and trailers are deployable in **different modes** (water and rail) *(Technical point of view)*	- Charging equipment for trailer preconditioning or for (slow) charging is available on ferry or train - The dimension of the ZE-HDV is appropriate for multi-modal transport -
T10	**Knowledge and resources available** in the logistic company to implement and operate ZE-HDV	- The transport operator can select and procure a suitable ZE-HDV option for its operations - The transport operator knows how to implement the ZE-HDV in the fleet - The transport operator can derive which missions are feasible with the ZE-HDV - The transport operator can assess the need for infrastructure - The transport operator is capable of calculating the TCO of ZE-HDV - The transport operator can organize maintenance - Drivers are trained, know the safety precautions specific for ZE-HDV, know how to refuel/charge and know what to do when an ZE-HDV breaks down
T11	The truck end-user **trusts** the new technology	- The end-user believes that the technology is safe - High availability of the truck-trailer combination, low downtime, is achieved during operations

T12	**Maintenance** can be organised	- The truck OEM organizes a network of dealers that can do the maintenance work, as it is now for conventional trucks
T13	The trucks are **connected** (digitalisation, communication – V2X is possible)	- The driving range of ZE-HDV is smaller and therefore significantly more charging/refuelling will be needed. - Communication with the dispatching/planning software will be needed to check whether charging/fuelling is necessary to fulfill the mission - Communication with infrastructure will be necessary to optimize the charging/fuelling
T14	A **contingency plan** can be drafted	- Some logistic companies have a contingency plan for disruptive events (e.g. oil crisis during the 1970s). - How can ZE-HDV be made more resilient to disruptive events (e.g. blackout of the power grid)?
T15	**It should be clear what the impact of the ZE power-train capabilities is on the net payload**	- The weight and dimension directive is under revision - How is the payload impacted when you operate a ZE-HDV? - And what could be the impact on payload of electrified trailers?

(ii) integration in the logistic operation: can ZE-HDV be integrated in logistic (fleet) operation?		
	Need or/and requirement	**Status quo**
F1	The ZE-HDV (fleet) can be implemented in an existing fleet by an **fleet management system** that takes the into account the capabilities of ZE-HDV	- Both for dispatching / day planning - Does the implementation strategy differ in relation to the share of ZE-HDV in the fleet?
F2	It is clear **where to** charge/fuel and how it will fit in the logistic operation	- Link to **Infrastructure** - Charging and fueling locations are missing - Booking time slots to charge - It needs to be cleared out if driver breaks can be used for charging
F3	It is clear what is **the impact** of charging/refuelling time will be on the logistics operation	- The time to charge/fuel without impacting logistic operations is limited. Some respondents of the survey stated to have only 1 hour per day to charge/fuel - It is unclear whether charging during the break of the driver will be practical feasible

F4	It is clear what is **the impact** of less payload and availability (maintenance time) will be on the logistics operation	- Not only the charging/fueling time will limit the deployability, also less payload and breakdowns will affect the operation

(iii) Social acceptance: is it safe and sustainable to use ZE-HDV		
	Need or/and requirement	**Status quo**
S1	A **methodology** to determine, if the ZE-HDV run on **renewable energy** (electricity and hydrogen) is available	- The emission reduction achieved by transitioning current fleet to an electric fleet (if market ready) with current energy mix in certain countries (e.g., Germany, Poland) would be very limited (less than 30%). Not all electricity on the grid is renewable - Most hydrogen is made from fossil fuels, less than 2% is made by electrolysis. Furthermore, the electricity used for electrolysis should be renewable.
S2	Emission over the **full life cycle** of a truck-trailer combination is known	- GLEC framework, CountEmissionEU - Shift from well-to-wheel analysis to full Life Cycle Analysis (LCA) approach - Transensus LCA project
S3	Vehicle has to be **safe,** both while driving and charging	- Special attention needs to be given to fire safety and education/research on how the fire can be extinguished. - The time that a truck can charge is limited and depends on the use case of the truck. Every opportunity to charge a BE-HDV should be taken. This means that for international, multiple-day missions the BE-HDV should be able to charge during the night, also when the driver is in the vehicle.
S4	It is clear how the **job of truck driver** will change, and the driver will be trained to do it in a safely manner	- Link with **T10**
S5	It is clear what to do in case of emergency.	- Drivers, first aid responders… are trained

S6	Safety regulations and precautions are known	- It is clear where battery and hydrogen trucks can drive, charge/fuel and park (underground, inside…) and if some precautions are necessary. - Link with **Legal barriers**
S7	Knowledge is transferred	- The driver and the public should be educated with learning about the safety, technical reliability and sustainability of ZE-HDV.

(iv) Infrastructure: will ZE-HDV be able to refuel or charge?		
	Need or/and requirement	**Status quo**
VIEW Truck end-user		
I1	Charging or fuelling infrastructure is **available.**	- Currently the availability of charging and fuelling infrastructure is a bottleneck. The current network is not sufficient - Logistic operations are delaying the implementation of ZE-HDV due to the uncertainty about the infrastructure
I2	Charging or fuelling a ZE-HDV should be **easy and safe.**	- manual action is easy to do, only one action to connect - clear manual - clear instructions in case of emergency - easy to pay
I3	**Driver amenities** are available at charging stations and HRS	- shops, restaurants, sanitary facilities… as it is now
I4	**Charging** can be combined with **overnight** parking	- charging during the 11-hour break should be feasible (at relatively lower power)
I5	Charging / fuelling infrastructure available at the **right location**	- the infrastructure is available at logistic hubs (ports, distribution centre, terminals…) and the corridor (highway) itself
I6	Charging / fuelling infrastructure available at the **right power/pressure**	- It is expected that the needs of the customer will differ in relation to the use cases the customer is fulfilling. - (International) long haul use cases will expect opportunity charging during the driver break of 45 min, while other use cases could use overnight low power charging

		- Time available for charging defines the power needed. Maybe optimization is possible when available charging time can be communicated to the infrastructure, for both truck end-user as infrastructure operator.
I7	**Waiting time** at the charging station/HRS is minimal (not waiting time during refuelling or charging, but waiting time to get a charger/refuelling nozzle)	- enough chargers or fuelling nozzles should be available to meet peak demand - Link with **F2** – charging infrastructure can be booked. So the *load/capacity factor* of the infrastructure is known, which is also beneficial for the operator.
I8	**Availability and reliability** of the infrastructure is high	- Downtime should be minimal. Truck end-users are counting on infrastructure to work. There will be no/few alternatives during the start of the implementation. When infrastructure is down, the risk exists that ZE-HDV get stalled.
I9	The charging station/HRS is **accessible** by truck-trailer combination	- the location should be able to accommodate truck-trailer combinations. Taking into account turning radius, height of roof, strong floor, separated from passenger cars (safety), separated from conventional fuels: otherwise, stricter regulations (e.g., ATEX) - This includes EMS combinations
I10	Charging infrastructure for **trailers** is available	- Especially valid for cooled trailers where preconditioning is needed. Cooling with the ZE-HDV will affect the driving range.
I11	The charger/refuelling infrastructure is capable of fuelling/charging the wanted **amount of energy**	- This is especially important for HRS: an HRS should be able to refuel until a SOC above 95%. - This means that at peak demand (maximum back-2-back refuelling), the HRS (at 700 bar) is still capable of providing +75 kg of hydrogen - The compression capacity and local H2 storage of the HRS should be designed in such way that the demand can be met
I12	Connected ZE-HDV, **V2X communication**	- charging infrastructure: there is communication between vehicle and charger - HRS: vehicle can communicate temperature and pressure via infrared communication to the HRS, however more optimal fuelling would be possible if there are feedback loops, and more variable fuelling (update fuelling protocols is investigated cfr. PRHYDE)
I13	**Unambiguous pricing displayed** or communicated at the charging and refuelling stations	- Is stated in the AFIR regulation, but is not always the case for older infrastructure - Do we expect varying prices during the day? Will charging at peak moments be more expensive?

I14	At charging and fuelling stations can be **paid with conventional means** (credit card, pay per use over digital platform)	- Is stated in the AFIR regulation, but is for older infrastructure not always the case
I15	**Quality of the hydrogen** should be fuel cell grade	- Hydrogen from electrolysis is on paper fuel cell quality and has a superior quality compared to H2 from steam methane reforming. However, contamination along the way can happen (tube trailer, HRS). Common contaminants are water (should not be a real problem for the fuel cell, but if you cool down to -20/-40°C things get blocked by ice), nitrogen, oil and lubricants from the compressor (compressor should be engineered to minimize the risk). These contaminants can damage the fuel cell. - Currently a paper of the supplier says that the quality is ok, no obligation to do test
VIEW infrastructure operator		
I18	The need for charging/fuelling infrastructure is clear (location + demand). An expected daily consumption profile is available.	- Charging/HRS infrastructure operators will only invest in a location when enough demand is expected. - Charging/HRS operators need more insights on which are the important corridors and how the demand will increase in time - the business case for infrastructure is strongly dependent on the usage. - High capacity factor (usage rate) will lead to a better business case, and possibly lower prices for the end customer - the design of the infrastructure is optimal when based on the actual demand profile - Modularity in infrastructure design will be key
I19	It is economically feasible to operate the infrastructure	- Price of hydrogen / electricity should cover the molecule/energy price, operational costs and CAPEX depreciation; however, it should be a price that the logistic operators are willing to pay. - Need for a booking app
I20	It is technically feasible to operate the infrastructure	- All hardware is available and reliable (HRS 700 bar and MCS, no monopoly) - Maintenance can be organized - All protocols and software are available - Can the charging power be adaptable?
I21	**Suitable land slots** are available	- for both HRS and charging stations the location impacts the economic viability - at corridor/hub for enough demand

		- Charging: sufficient power connection - HRS: source of green hydrogen, supply by tube trailer or pipeline, power connection
I22	The infrastructure can be expanded in a **modular** way	- The capacity of the infrastructure should grow together with the demand (ZE-HDV fleet size) - Investments spread in time are better for the infrastructure business case - modularity can improve the reliability/availability
I23	Optimisation of charging/fuelling both technical and financial	- V2X can be used to optimize the charging from the view of the end-user = as fast as possible, but V2X can also be used to optimise the charging from operators' point of view (energy management) - Optimization of HRS operation should also be feasible. So the cost of compression and cooling is minimized. When hydrogen is produced on site, energy management can be beneficial.
I24	Quality of hydrogen can be tested fast and in an easy way	- Contaminants should be detected fast, otherwise the fuel cells of your clients can be affected. - Inline, continuous detection would be best option, but technically not feasible and expensive - sampling can be done, but limited laboratories that offer this service (+expensive)
I25	Reliable GREEN hydrogen supply to the HRS Reliable renewable energy supply to the charging infrastructure	- hydrogen can be supplied to the HRS by tube trailer or pipeline (for both on and off-site production). - you can only attain a high availability for the HRS as the supply is reliable - e.g., Swiss demonstration Hyundai was affected by a shortage of renewable hydrogen/tube trailers - Renewable energy is more available, but still a small share of the market.
I26	Booking app	- A booking app will help the infrastructure operator to define the demand, which could have a positive effect on the business case - The ZE-HDV end-user is certain of the availability of the infrastructure
VIEW logistic site operator that wants to install infrastructure on its own sites		
I27	Minimal impact of installation of infrastructure on logistic operations	- When infrastructure is installed on logistic site, the impact of the installation itself should be minimal, in combination with a small footprint

I28	Minimal impact of operation of infrastructure on logistic operations	- Space will need to be allocated to charging vehicles. Are there enough parking spaces available?

(v) Viable business case: without it, there will be no implementation of ZE-HDV.		
	Need or/and requirement	Status quo
B1	**TCO** of ZE-HDV can be calculated	- Fleet ownerships is very fragmented with most of the owners with fleets below 10 trucks therefore, investing in these trucks is very risky particularly with a questionable business model - It is unclear what the CAPEX, yearly mileage, capacity, fuel/energy cost, lifetime, residual value, funding, insurance, maintenance cost will be… In its uncertain how the market evolves (vehicles and energy)
B2	Assessment of **new business models for ZE-HDV**	- New business models as pay per use, transport as a service (TaaS), mutualization/sharing of assets are emerging
B3	Realistic scenarios to reach **economies of scale** are drafted and defined in time	- Logistic companies have sustainability targets. Will the market mature fast enough?
B4	Incentives to invest in ZE-HDV and related infrastructure are available but are limited in time.	- Discouragements for fossil fuels - Maut throughout Europe known
B5	The **emission reduction** can be monetized	- Advantages both in kind (entrance low emission zones) and financial could help to implement ZE-HDV. - Are the clients/shippers willing to pay more for zero-emission transport - Difficult to justify a premium cost to customers when using electric trucks - Trust in emissions reduction reporting and pricing
B6	Renewable electricity and hydrogen should be affordable for logistic companies	
B7	Incentives for charging and fuelling infrastructure	

B8	TCO / business case can be calculated for the infrastructure	- all the necessary parameters are known
B9	New business model to operate infrastructure are assessed	- How does Pay per use, TaaS affect the way you finance infrastructure - joint ventures of front runners

(vi) Legal barriers: can logistic companies use the ZE-HDV as they want without legal barriers?		
	Need or/and requirement	Status quo/ questions
L1	Innovative technologies (trucks and infrastructure) can be implemented since a regulative framework exists	- Directive, authorities and local permitting governments provide a clear regulative framework. At the moment this can be missing. - Fast chargers and HRS are relatively new technologies, and a standardized permitting procedure is not available in all countries. The technology is unknown by local authorities, which can affect the permit request - Can battery electric truck be on ferries? All transport modes are accessible for ZE-HDV - Can you drive with hydrogen in a low emission zone or a tunnel? All roads are accessible for ZE-HDV

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