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EXECUTIVE SUMMARY

In order to optimise European investments in R&I projects in the field of transport and logistics, BOOSTLOG carries out a thorough evaluation process of concluded Research and Innovation (R&I) projects financed with EU-funds.

This evaluation is conducted from the perspective of different key domains of transport and logistics (T&L), (defined by BOOSTLOG as “Logistics clouds”) to identify R&I gaps in T&L and prioritise the needs to be addressed in future research programmes, thus contributing to develop an innovation ecosystem for the logistics sector that also contributes to the EU policy objectives.

The present deliverable focuses on “Efficient and zero-emission freight transport”, showing the main results and impacts derived from European-funded projects on this area. The BOOSTLOG project maps more than 160 EU-funded R&I projects, from the FP5 to H2020. This deliverable has selected 8 projects regarding ‘Efficient and zero-emission logistics’ and two projects focusing on the correct reporting of emissions related to T&L (Figure 1).



Figure 1. Selected project discussed in this Cloud Report. All projects are finished, except H2Haul.



1 The BOOSTLOG project and scope of the deliverable

1.1 The BOOSTLOG project

Freight transport and logistics is facing critical challenges to address climate change, ensure supply chains are well functioning and people is served with required type of goods and services. In particular, cope with the expected growth of freight transportation and transition to zero emission logistics up to 2030 requires collaboration speeding up innovation.

The transport sector is the only sector where CO₂ emissions are still rising (See Section 2.1). BOOSTLOG's vision is transforming European freight transport and logistics R&I ecosystem to perform optimally by boosting impact generation out of R&I investment contributing to i) EU policy objectives towards climate neutrality, pollution, congestion and noise reduction, free movement of goods, internal security, digital transformation of logistics chains and data sharing logistics ecosystems and ii) *Companies* sustainability and competitiveness generating value for society.

In order to do so, BOOSTLOG has identified **4 main areas of action**: i) **increase visibility and support valorisation** of R&I project Results, Outcomes and Implementation Cases in the freight transport and logistics field ii) develop and implement **valorisation strategies and guidelines** to speed up the technological and organisational innovation uptake, including the creation of the Innovation Marketplace and issue recommendations to increase impact of R&I public funding, iii) Define high potential & priority **R&I gaps** to make efficient uses of R&I investments and iv) Strengthen R&I impacts **communication** and **Stakeholders engagement** in the innovation process.

In the framework of the first of those actions, BOOSTLOG has mapped and assessed more than 160 EU-funded R&I since FP5 in different freight transport and logistics domains (i.e., the Logistics Clouds), so as to develop 8 comprehensive and industry actionable reports (i.e., Cloud reports). 6 cloud reports have already been published focusing on i) Coordination & collaboration ii) Urban logistics, iii) Logistics nodes, iv) Freight and logistics data sharing, v) Logistics network and, vi) Physical internet. This document is the 7th (vii) cloud report focusing on efficient and zero-emission logistics/freight transport. The last cloud report (viii) will focus on digitalisation. These reports will be later complemented by deliverables on valorisation strategies and guidelines for public R&I uptake (WP3), an innovation marketplace for R&I uptake (D3.3) and the identification of high-priority and potential R&I gaps that need to be prioritized in future R&I actions targeting policymakers (WP4).

1.2 Scope of this deliverable

The scope of this report was decided by the task coordinators, consulted by the BOOSTLOG consortium. Defining the scope was mainly influenced by i) whether it lay within the scope of BOOSTLOG ii) how well the report complements the other 7 cloud reports iii) the availability of relevant R&I projects to be covered with this topic and, (iv) the time and resources available to conduct the report. Based on these factors, additional demarcation was made.

This cloud report will complement the other 7 cloud reports by focusing on **greenhouse gas (GHG) emissions in freight transport**. This includes i) **monitoring and reporting on GHG emissions in freight transport** ii) **developing and implementing efficient solutions for freight transport**, that **directly or indirectly decrease GHG emissions** and, iii) **developing and implementing zero-emission freight transport solutions**.



Monitoring and reporting on GHG emissions in freight transport

The report will cover a broad perspective including the full life cycle, i.e., GHG emissions related to the production of vehicles and energy, and to tailpipe GHG emissions. Several freight transport modes are included, enabling a comparison between different transport modes.

Developing and implementing energy efficient solutions for freight transport

The report will cover efficient solutions related to trucks categorised in EU as vehicle types N2 and N3, i.e., trucks that are 3.5 tonnes or heavier. Lighter trucks (N1) are covered in the cloud report Urban Logistics. Refused trucks are also excluded, since their operation is very different from heavy-duty road trucks. Other transport modes are not covered in this report CCAM projects are not covered in this report since they will be included in the cloud report on Digitalisation. Other projects that are within scope are those focusing on the improvement affecting the overall energy efficiency of the truck and/or the freight transport system, excluding those that only focus on one element such as tyres. Solutions focusing on human behaviour such as eco-driving are also included.

Developing and implementing zero-emission freight transport solutions

The project defines zero-emission vehicles as vehicles with zero tailpipe emissions, not taking into account emissions from production or the emission to produce the energy source used as fuel. These emissions will however be taken into account in projects with the main focus on emissions reporting. The report includes the development and implementation of electric and hydrogen heavy-duty trucks and the supporting infrastructure. Hybrid drive line technologies for heavy-duty trucks will not be part of the scope, although the report will acknowledge some of the projects covering this topic. Biofuels or Renewable Fuels from Non-Biological Origin (RFNBO), with the exception of hydrogen, will not be assessed in this report as the technology to use these fuels in internal combustion engines (ICE) is available and no impact on the logistic operation is expected. Figure 2 below summarizes what will be in scope and what is out of scope in this report.

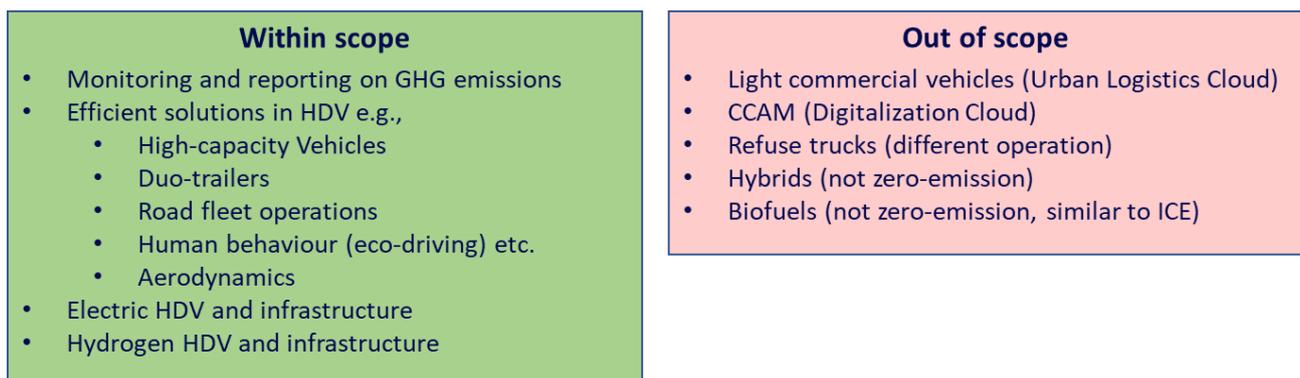


Figure 2. Scope definition for Cloud Report VII “Monitoring and implementing efficient and zero-emission freight transport”.



1.3 Methodology

These *cloud reports* include a brief highlight of the main Challenges, past and current specific **pain points** in a given Cloud, key R&I results, that have resulted in Outcomes and key milestones achieved such as Implementation Cases, establishing causal links between the EU R&I funding and innovation supporting the seamless integration and harmonization of transport modes, the more efficient management of physical information and financial flows, reducing negative impacts, such as carbon emission and congestion, ensuring free and seamless movement of goods and enhancing digital transformation.

This report contains clear actionable items, such as cases on how to implement the Outcomes or build on the Implementation Cases for the Cloud 'Monitoring and implementing efficient and zero-emission freight transport'.

The **methodology** to develop this report is shown in Figure 3. First, BOOSTLOG analyses the EU R&I results to identify **key outcomes**. The Outcomes are then analysed based on the achieved Technical Readiness Level (TRL) of the project results and further development. The **organizations** with most frequent participation in projects, for each Cloud, are mapped, as well as **individual people** from those organizations participating in the projects considered (i.e., notably our "experts").

Semi-structured interviews (see Annex I) have been undertaken with the experts (a list of the experts can be also be found in Annex I), to validate the outcomes and gather additional missing information that are relevant to the scope of the analysis, as well as to investigate which Outcomes have rolled out into **Implementation cases** (i.e. they have been implemented and adopted by the freight transport and logistics stakeholders).

The survey results have been the primary input for a BOOSTLOG cloud report, and it is complemented with desk research carried out on most relevant projects deliverables and communications, market/sector current practice analysis and the market solutions implemented and adopted including examples of Implementation Cases.

The first release of a report is submitted to the experts to get their feedback. Additionally, a complementary discussion is done in an online cloud-related working session (workshop) for final validation of the report. The final (validated) report will be presented in a webinar, where the ALICE members and other relevant influencing stakeholders are invited as BOOSTLOG partners networks.

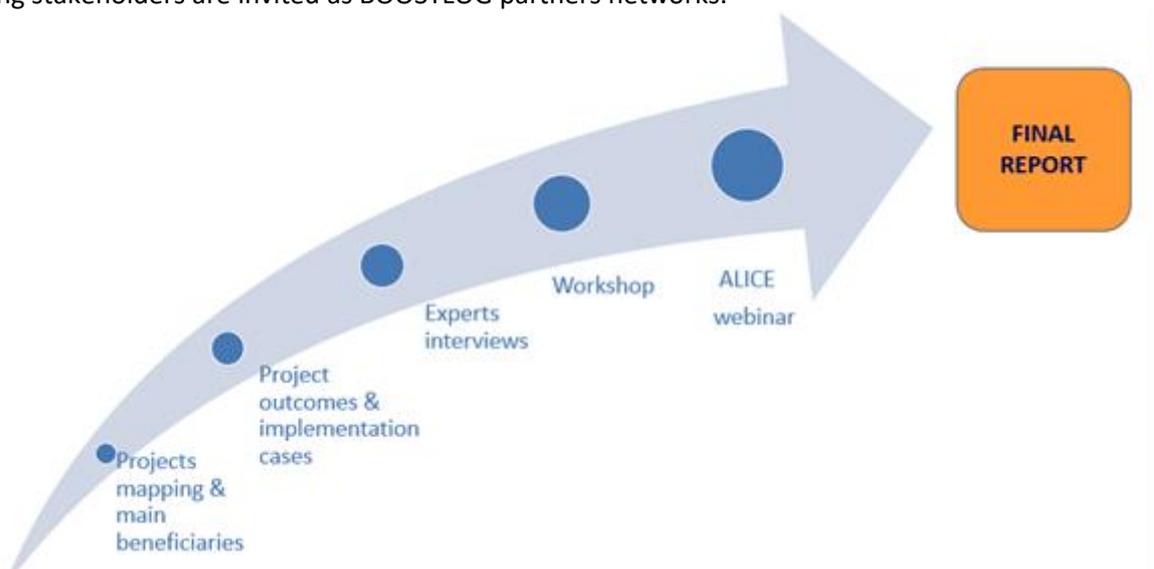


Figure 3. Methodology for the development of a BOOSTLOG cloud report



2 Why Efficient and Zero-emission freight transport

2.1 Introduction

The Paris Agreement, adopted in 2015, set a target to limit the rise in mean global temperature to well below 2 °C (3.6 °F) above pre-industrial levels, and preferably limit the increase to 1.5 °C¹. Reaching the more ambitious goal of 1.5 °C is appreciated to require that GHG emissions are reduced by 45% by 2030 and reach net zero by 2050. Under the European Climate Law, the European Union (EU) is committed to reducing its GHG emissions by a minimum of 55% by 2030, compared to the levels in 1990, with the ultimate goal of achieving climate neutrality by 2050.

It is appreciated that transport is responsible for about a quarter of the EU's total GHG emissions. However, until recent initiatives, CountEmissions EU, there has not been any common framework to calculate and report transport-related GHG emissions.

The road freight sector, and especially the heavy-duty sector, has increased its CO₂ emissions factor by 5,5% (2019) compared to the levels in 2000. This is mainly due to an increase in activity, e.g., transporting goods with heavy-duty vehicles increased by 31% in the same period. Meanwhile, the increase in activity transporting goods by rail and inland waterways was only 5% combined. Rail and inland waterways are much more efficient modes of transport to carry goods compared to road transport, having an intensity of one-sixth, and one-quarter respectively, compared to heavy goods vehicles.

Shifting logistics operations from heavy-duty road transport to rail and inland waterways has huge potential to decrease CO₂ emissions in the logistics sector. However, this shift is operationally challenging and there are benefits of using road transport, such as flexibility, that the other modes have not been able to compete with.

The logistics sector is still highly reliant on road transport and heavy-duty vehicles, and serious actions must be taken to both decarbonise and make road transport more efficient. This transition is already happening, led and supported by several legislative actions from the EC, such as the Revision of the CO₂ emission standards for Heavy-Duty Vehicles (HDV)², the Renewable Energy Directive II (RED II)³, Emissions Trading System 2 (ETS 2)⁴, c, and The alternative fuels infrastructure regulation (AFIR)⁵.

2.2 What is emission monitoring and reporting?

Just as important as adopting mitigation measures, companies must become better at identifying the actual emissions reduction potential of these measures, and be better at gauging the cost-efficiency of the solutions they ultimately use. For example, liquid natural gas (LNG) trucks receive financial benefits in some Member States in the EU, but actually show little to no climate benefit⁶. LNG trucks are still touted as climate-friendly by trucking operators. What could have caused the confusion in this case? Two possible factors, as illustrated by the Figure 4 below, are i) the neglect of other GHG besides CO₂ and ii) the neglect of upstream emissions

¹ The Paris Agreement, 2015, <https://unfccc.int/process-and-meetings/the-paris-agreement>

² https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_763

³ https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en

⁴ https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-2-buildings-road-transport-and-additional-sectors_en

⁵ https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1867

⁶ Oeko-Institut e.V. & ICCT, 2020: <https://www.oeko.de/en/up-to-date/2020/lng-trucks-not-an-option-for-climate-protection>



caused by the production of the fuels. This and other challenges have made the topic of emissions calculation a lot more important in actually mitigating climate change.

Transport emission calculation is typically shorthand for a lifecycle assessment of the operational emissions from transport activity. The scope of what is included is dependent on the purpose of the calculation and the requirements set by the industry, standards or legislation. For instance, the lifecycle assessment could include the emissions from the vehicle lifecycle (i.e. materials processing, vehicle production, logistics, and end-of-life method). Similarly, the GHG Protocol differentiates between Scope 1 and Scope 3, when it comes to fuel combustion. Scope 1 only includes tailpipe emissions, while the upstream emissions fall under Scope 3 Category 3. For the logistics sector, a standardized methodology is required as well that fulfils the needs of the industry and can be applied in the industry.

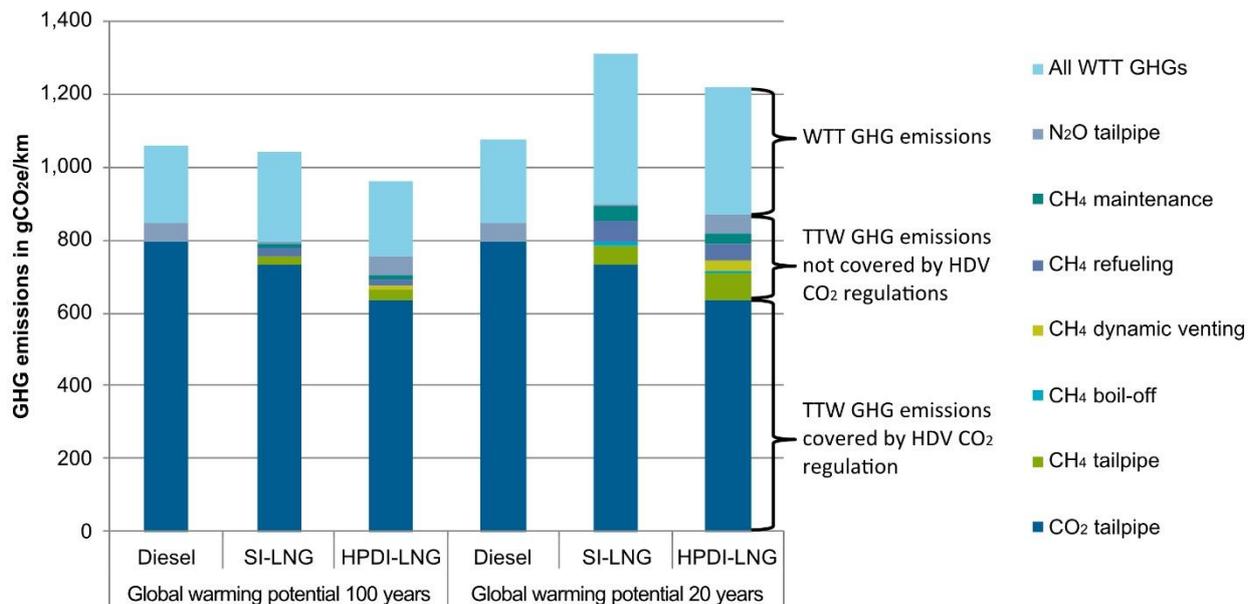


Figure 4. The emitted Green House Gasses (GHG, gCO₂/km) for diesel and LNG burned in a spark ignition (SI) engine and a high-pressure direct injection (HPDI) engine on a 100 and 20 years scale. It is clear that the CO₂ tailpipe emissions are not only emissions, also other GHG (NO_x and CH₄) need be taken into account, just as the venting and boil-off of CH₄⁷

Some of the purposes are listed below.

- **Monitor progress and mitigate emissions.** Companies may use a widely accepted methodology to calculate the emissions within their own transport chains, whether conducted by their own fleet or outsourced. Based on which, especially if they calculated the emissions with sufficient granularity, they would be able to create a mitigation plan. As the transport system is still predominantly dependent on fossil fuels, reducing emissions was synonymous with reducing fuel combustion, which served as an economic motivation for businesses.

⁷ <https://www.oeko.de/fileadmin/oekodoc/LNG-in-trucks.pdf>



- **Evaluation of emission reduction projects.** Evaluating emission reduction projects, whether conducted internally, within the value chain⁸, or purchased through carbon offsetting programs, require a standardized methodology to increase transparency and trust.
- **Sustainability reporting.** Many organizations carry out voluntary sustainability reporting according to the GHG Protocol. These may be published in their own (annual) sustainability reports, or through initiatives such as the Carbon Disclosure Project or the Science Based Target Initiative.
- **Legislative requirements.** While a significant portion of companies already report their emissions voluntarily, many, especially smaller organizations, do not. Further, many may not include emissions from transport, which often falls under Scope 3 reporting⁹. However, the legislative landscape is changing with the EU's Corporate Sustainability Reporting Directive (CSRD), which came into effect early 2023, and the US Securities and Exchange Commission proposal for climate-related disclosures. Notably, the EC has proposed the CountEmissionsEU legislation, which focuses specifically on standardizing the emissions calculation and reporting in the transport sector.

In the logistics sector, the de facto standard is the ISO 14083 "Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations", which launched in March 2023, as well as the industry standard GLEC Framework¹⁰ on which the ISO 14083 was based on. The GLEC Framework itself was developed to align with the GHG Protocol – a broad cross-sector framework for calculating and reporting emissions from economic activity. Some of the principles that unique to the GLEC Framework are presented below.

- The system boundary encompasses all transport operations by all freight modes (e.g., road, rail, pipeline), as well as the hubs (e.g., distribution centers or maritime ports) that precede, follow or link them together (International Organization for Standardization, 2023).

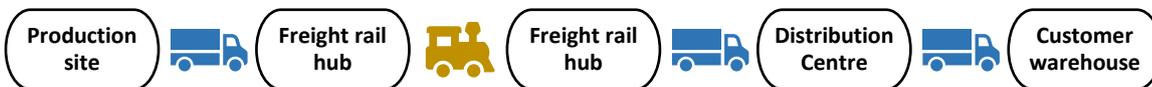


Figure 5. Example how the scope of calculation covers the full transport chain

- The emissions calculation takes a full energy lifecycle perspective, or the well-to-wheel (WTW), that takes both the well-to-tank (WTT) and the tank-to-wheel (TTW) stages. The WTT incorporates all the emissions from producing, storing, processing, and distributing of the energy-carrier (both fuel and electricity), while the TTW incorporates all the emissions from the operations of the vehicle or hub. While alternative energy carriers often had zero (or compensated) TTW emissions, the WTT emissions varied significantly depending on the type of fuel, production process, and feedstock.
- Emissions allocation to customers or shipments were based on transport activity, not using currency as a functional indicator. For instance, emissions in a road transport trip were allocated based on an indicator of transport activity calculated based on the weight of the shipment and transport distance.

⁸ Smart Freight Centre. 2023. "Voluntary Market Based Measures Framework for Logistics Emissions Accounting and Reporting." <https://www.flexmail.eu/f-902b8a2dc48f0681>.

⁹ Smart Freight Centre and CDP. 2020. "Closing the Logistics Emissions Disclosure Gap: An Analysis of Emissions Disclosure to CDP by Corporations Worldwide."

¹⁰ Global Logistics Emissions Council (GLEC): <https://www.smartfreightcentre.org/en/our-programs/global-logistics-emissions-council/>



These principles, while broad, allow for companies to at the very least, get better at monitoring their own climate change impact. There are other aspects that could be included that have been identified, which would allow companies to more accurately understand its impact, not just from the vehicle operations but also from the manufacturing of vehicles and transport infrastructure, the emissions from digital infrastructure, and the emissions from packaging. Besides these activities, there are also other types of emissions that cause climate change but through different means, such as the short-lived climate pollutants or the impact of water vapour from aviation emissions.

2.3 What is efficient freight transport?

There are several definitions for efficiency in (freight) transportation partly depending on what is meant by efficiency and also efficiency at what level, e.g., from a logistics operator point of view or from a road authority? It is worth highlighting some of the different perspectives before mentioning what will be the main focus of this report.

Transportation efficiency in society

This definition, used by e.g., the Swedish Transport Administration and the Swedish Energy Agency, takes a broader perspective and defines "*A society where the transportation system is used more resource-efficiently and where actions and actors are based on the perspective of primarily improving the accessibility within the transportation system*". Some of the proposed measures to increase transportation efficiency are actions that reduce the number of vehicle movements, measures to better utilize the infrastructure through, for example, deliveries at times other than during rush hours, and measures to reduce emissions and noise from vehicles.

Examples of indicators that are relevant to increasing transportation efficiency are i) time precision, a physical shipment or delivery takes place within specified timeframes ii) arrives at the right location iii) in the right condition, iv) provided with the right services to conduct the shipment/delivery v) optimizing the use of current infrastructure vi) while minimizing the wear and tear of roads vii) reducing noise emissions and emissions of harmful substances (such as GHG) viii) not contributing to traffic accidents etc. Furthermore, additional indicators such as i) resilience, by having alternative transport solutions available in the case of (un)foreseeable disruptions in society, ii) reducing the harm of the transport system on biodiversity and protected land and iii) that the execution of transportation does not significantly contribute to actual or perceived barriers for the rest of society, can also be included.

This definition, with examples of measures and indicators, showcases that increasing transportation efficiency in society is a complex process connected to many factors such as traffic safety, health and land protection. However, this perspective on transportation efficiency has also been criticised by several actors in the transport sector. One of the criticisms is that transportation should be able to increase, but the overall emissions and other negative effects of transportation should be reduced.

Energy efficiency in (freight) transport

Energy efficiency in transport is defined by the European Environment Agency as i) the energy intensity of passenger and freight transport, i.e. energy consumption per unit of transport activity (MJ/passenger-km and MJ/tonne-km), and by mode and, ii) the fuel efficiency of new cars and of the total cars fleet i.e. fuel use per km (litre/100 km) or (kWh/km). Increasing energy efficiency in freight transport are measure used to reduce the energy used per transport unit, in this case, tonne-km.

Trucks, including heavy-duty trucks, consume significantly more energy per tonne-km than rail or ship transport. However, as mentioned earlier, shifting operations from heavy-duty road transport to rail and inland waterways is challenging, and in many cases not realistic to do in the short term. There is a need to make heavy-duty trucks and HD fleets more energy-efficient. There are several promising solutions, some of them covered in other Cloud reports, such as Physical Internet, digital solutions, and potentially cooperative, connected and automated mobility (CCAM) solutions. Other solutions, such as the technical improvements of



the vehicles to increase the payload (e.g., High-capacity transport) and to improve the driveline and aerodynamics, solutions contributing to route optimisation of vehicles and fleets, and human behaviour factors, e.g., solutions enabling more efficient driving (e.g., eco-driving), will be included in this report.

Energy efficiency and reduction of GHG emissions

There is a clear correlation between energy and GHG emissions: less energy used usually means less GHG emissions are emitted, if all the other factors are the same. This is also true for zero-emission vehicles since zero-emission only refers to pipeline emissions. Increased efficiency is hence needed, no matter if zero-emission vehicles are used or not. However, zero-emission vehicles such as electric trucks, do impose new opportunities and challenges to become more energy-efficient, compared to ICE trucks. This means that insights made on e.g., route optimizations, eco-driving in ICE trucks etc. cannot simply be fully transferred to electric trucks without any adaptations.



2.4 What is zero-emission freight transport?

ACEA (2022) appreciates that there are approximately 6,2 million trucks (N2 and N3), of which the majority are run on diesel. Only 0,5% of all new trucks sold today are electrically chargeable (battery electric, plug-in hybrid) which accounts for 0,2% of all the trucks on the road in the EU. Only 0.1% have a full zero-emission powertrain¹¹.

Zero-emission freight transport includes in this report trucks with electrified powertrains. with two technologies, battery electric and hydrogen fuel cell electric, which are being or will be demonstrated in several European R&I projects, will be discussed further in this Cloud Report.

The use of biofuels, such as Hydrotreated Vegetable Oil (HVO) and biomethane can lead to a reduction in GHG emissions, especially Tank-To-Wheel (TTW) emissions. Nevertheless, as explained in Section 1.2, we will not assess biofuels, as their implementation can be done by conventional ICE and will not have an impact on the logistic operations.

Both zero-emission truck technologies have an electric motor instead of an ICE. They also have high power components and battery packs installed in between the axles and under the fifth wheel. However, the total battery capacity of the Battery electric heavy-duty road vehicles (BE-HDV) will be higher than the FCE-HDV. The main difference between BE-HDV and FCE-HDV is that fuel cell packs and hydrogen storage vessels are also mounted on a FCE-HDV. Mostly, the fuel cell packs are mounted in between the axles and the hydrogen storage vessels at the back of the drivers' cabin.

First of all, the energy source of both should be chosen wisely. Depending on the energy source the WTW emissions could be even worse than conventional ICE technology. The JEC study shows that with electricity from wind energy emission, a emission reduction can be attained for both battery and fuel cell electric technology¹². Nevertheless, when the electricity is produced from a coal-fired gas plant, there is no positive effect on the overall emissions.

BE-HDV will be used for missions with a relatively shorter distance. The commercial battery electric trucks now available have a range up to 300km. Battery electric trucks with a range of up to 700km are under development. Hydrogen could be a solution for use cases where a minimal fuelling time is of importance or electric grid restrictions are in play. The current fuel cell trucks (in demonstration phase) with a working pressure of 350 bar have a driving range of around 400km. Further increase of the driving range up to 700km is expected, when 700 bar technology is implemented. Next to the technical specification, the actual market uptake of zero-emission trucks is also dependent on policy framework. ACEA states that the registrations of zero-emission vehicles (BEV, FCEV) have accelerated from 692 (in 2019) to 1,239 (in 2020) and >2,500 in 2022¹³.

Also, the availability of the infrastructure to fuel and charge the trucks need to be considered to assess the readiness to implement zero-emission trucks. The new Alternative Fuels Infrastructure Regulation (AFIR) sets mandatory deployment targets for both electric recharging and hydrogen refuelling infrastructure for the road sector¹⁴.

We see that existing and new companies are bringing the regulation in practice. One example of a joint venture is Milence (Daimler Trucks, the TRATON GROUP and Volvo Group). The joint venture is committed to build and

¹¹ <https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2023.pdf>

¹² https://joint-research-centre.ec.europa.eu/welcome-jec-website_en
https://publications.jrc.ec.europa.eu/repository/bitstream/JRC121213/jec_wtw_v5_121213_final.pdf

¹³ https://www.acea.auto/files/Fact-sheet-CO2_standards_for_heavy_duty_vehicles.pdf

¹⁴ https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1867



operate 1700 high-capacity public charging points by 2027 in Europe¹⁵. Amazon developed an open-source tool CHALET, that can identify priority locations for charging infrastructure across Europe¹⁶.

Diesel truck

A diesel truck has a driving range of at least 1000 kilometre, some versions have a fuel tank up to 1200 liter and can drive more than 4000 km on one refuelling. The high energy density of diesel, in both mass and volume, make it an ideal energy carrier, which can be stored on the truck in a compact way, without affecting the payload. In addition, with high capacity pumps the truck can be refuelled in minutes. All these aspects, the long driving range, compact fuel storage, fast refuelling time and full payload available, make the diesel truck a solution for all missions. Unfortunately, not the same amount of energy can be stored on zero-emission trucks in the form of electricity or hydrogen, since the current storage methods are less volume dense. In addition, the energy flow of charging or refuelling is significantly smaller than fuelling a diesel. This leads to more time needed to charge or fuel and lower driving ranges for zero-emission trucks. There currently is no one zero-emission truck solution that can do all missions.

Battery electric trucks

The availability of battery electric vehicles is increasing rapidly. All European truck manufacturers have either already started or are about to start series production of their new zero emission trucks. The driving range and loading capacity of BE trucks are limited in comparison to diesel trucks. The heavy battery pack is the main reason for this¹⁷.

BE-HDV vehicles will be charged at DC/DC chargers. At the moment 350 kW chargers are commonly being built, also for the passenger market. However, it is not sure that trucks will be capable to use the chargers intended for the passenger market, due to height, weight and turning circle restrictions. A trend to megawatt charging systems (MCS) for freight transport applications is visible.

The charging power will depend on the logistic use case. Overnight charging at a relatively low power will be possible for some use cases, while for others charging time needs to be minimized to achieve optimal logistic operations and opportunity charging with MCS is the way to go. With the current technology charging time will vary between hours to half an hour, depending on charging power, battery size and the battery state of charge starting value.

Currently, European R&I project are trying to identify the main corridor and hubs where the charging infrastructure needs to be installed, plus specifying the power and amount of chargers. AFIR provides an initial planning but needs refinement (e.g. upscaling of chargers, emerging charging technologies). To achieve a more sophisticated planning for infrastructure, the energy need for logistics needs to be mapped. The energy need is related to the truck specifications, optimal route, the resting period for drivers, traffic and weather conditions etc. This can be done by for example building innovative Digital Twins (DT) and adopting planning and fleet management systems.

Overall, the battery electric powertrain will have a high efficiency, especially when looking from TTW and WTT perspective. For BE trucks the renewable energy can be transported by the grid and charged to the vehicle without any further conversion to a molecule, grid losses and losses by (fast) charging should be accounted for. The order of magnitude of these losses are estimated to be between 10% and 15%. In the vehicle itself

¹⁵ <https://milence.com/about/>

¹⁶ <https://www.aboutamazon.eu/news/job-creation-and-investment/amazon-boosts-european-charging-infrastructure-planning-with-new-technology>

¹⁷ https://www.acea.auto/files/Getting_ZeroEmissionTrucks_on_the_road.pdf



there will be losses due to DC/AC conversion and overall engine and transmission losses, with a total loss of around 10%. In total **the efficiency will be around 75 to 80%**. This energy efficiency is the main benefit of BE trucks, it is significantly more efficient than diesel trucks, meaning that less primary energy will be needed to power BE trucks. At the moment, the main barriers for BE truck implementation are still limited capabilities to fulfil long distance missions, uncertainty about availability of sufficient (MW) charging infrastructure and the uncertainty about how its implementation will affect the logistic operation.

Fuel cell electric vehicles

At this moment, European Tier I Truck OEMs do not have fuel cell electric hydrogen trucks in their portfolio. Only the Hyundai Xcient FC is on the market¹⁸. Nevertheless, several demonstration projects are ongoing.

If we look to the hydrogen pathway, water or steam can be transformed to hydrogen and oxygen by electrolysis. Current efficiencies of water electrolysis are ranging between 70 to 80%, you than need to take into account the efficiencies of the hydrogen transport, storage and fuelling. In the vehicles itself you have a fuel cell (70 to 80% efficient) and again the needed DC/AC conversion and engine and transmission losses. In total **the efficiency of the full chain** is estimated to be around **25 to 30%**.

The driving range of a FCE trucks is determined by the amount of hydrogen that can be stored on the vehicle, which on its turn is depending on the state of the hydrogen and the working pressure. Currently, there are two working pressures seen as standard: 350 and 700 bar. 700 bar is the standard of passenger vehicles, while busses, refuse trucks and the already in Europe demonstrated trucks have a working pressure of 350 bar. Trucks with a working pressure of 700 bar are still under development and will be first demonstrated in the ongoing H2Haul project (Section 4.4 for more information).

Some Truck OEMs are also looking into liquid hydrogen. Liquifying hydrogen will demand energy (8-13 kWh/kg), however transporting liquid hydrogen is more efficient than gaseous one due to the higher energy density. Also, the design of the liquid hydrogen refuelling station is expected to have a smaller footprint and be more cost-effective than hydrogen in gas form. Liquid hydrogen vessels are also cylindrical shaped and could be placed between the axles, which is beneficial for the truck design and capabilities. Daimler is the only European truck manufacturer that is demonstrating liquid hydrogen for trucks.

FCE trucks working on gaseous hydrogen are refuelled at hydrogen refuelling station (HRS). Most of the current HRS are working following the cascade principle. A cascade HRS consists of 4 or 5 parts. The first part is the hydrogen supply for the station. The hydrogen can be delivered by tube trailers, pipeline or it can be produced on site by electrolysis. The second part is the hydrogen storage, the third part is hydrogen compression, the forth part is cooling (which is at this moment not mandatory for heavy-duty HRS at 350 bar) and the last part is the dispenser for refuelling. The storage and compressor should be designed in such way that the refuelling demand, expressed in total amount of hydrogen refuelled during a day combined with the peak demand at a certain moment during the day, can be met. Cooling is mandatory for 700 bar stations, since cooling is necessary to prevent the hydrogen storage vessels in the vehicle to overheat.

At the moment, barriers for 700 bar truck refuelling are:

- Development and standardisation of components that can withstand hydrogen at 700 bar and are safe to be mounted on a driving vehicle
- Development and standardisation of components for high flow (at least 120 g/s) hydrogen refuelling stations with a fuelling capacity of more than 40 kg at once
- Development of a refuelling protocol for 700 bar trucks (PRHYDE project¹⁹)

¹⁸ https://www.acea.auto/files/Getting_ZeroEmissionTrucks_on_the_road.pdf

¹⁹ <https://cordis.europa.eu/project/id/874997>



The main benefit of FCE-HDV is its charging time. It is expected that fuelling a FCE-truck will be less than 20 minutes. The main barriers for widespread deployment are its low WTW energy efficiency and the absence of green hydrogen in sufficient quantities at feasible price.

2.5 Expected positive impacts

In this section the expected positive impacts on logistics related to 'monitoring and implementing efficient and zero-emission freight transport' are given. We will not focus on emission monitoring and reporting, as there will be no direct impact on logistics.

As stated in before the main goals for **efficient** freight is to increase the transport capacity and the fuel efficiency. We identified three action areas for more research in efficient freight transport.

Aerodynamics

Improvement of the aerodynamics of trucks and trailers impacts the fuel consumption significantly. A positive impact on the environment, the energy consumption and the transport cost will be the result.

Load efficiency

The load efficiency can be improved in many ways design of trailer, improve the logistic process, integrating Physical internet (Cloud Report VI), high capacity vehicles (EMS)... These improvements will have a positive impact on transport cost, emission reduction and congestion.

Eco driving electric driveline

The driving behaviour impacts fuel consumption, therefore eco-driving is investigated in several R&I projects. However, changes in eco-driving rules are expected when the driveline of the trucks becomes electric, and regenerative braking is possible, which should be assessed further. When implemented, a positive impact on transport costs, energy consumption and emissions is expected.

The shift to **zero-emission road transport** is done to lower the emissions. Nevertheless, since the capabilities of a zero-emission trucks are different than for a diesel truck the impact of the implementation will not have an unambiguous positive impact. We therefore also define action areas for zero-emission trucks that need further research and innovations.

Zero emission Truck and trailers

Currently, battery electric trucks are commercially available. Hydrogen trucks with a combustion engine or a fuel cell are being demonstrated at small scale in R&I projects. Nevertheless, their capabilities differ from diesel trucks – less driving range, more time needed to charge/fuel – so further research to improve the capabilities and mature the technology are needed.

In addition to the trucks, we should also include innovations in trailers. At this moment, cooled trailers or trailers with a tailgate use energy generated by the diesel engine. If we want full zero-emission truck-trailer combinations innovations to electrify the trailer will be needed.

The implementation of zero-emission trucks and trailers will have a positive impact on the environment. However, due to the higher investment cost and different capabilities compared to the current technologies, we expect that the cost will be higher and the capacity will decrease. Further research to develop the next, improved generation of zero-emission trucks and trailers.

The development of new generations of zero-emission trucks and trailers will have positive impact on emissions, energy consumption and overall transport efficiency and cost.

Charging and fuelling infrastructure

The success of the implementation of zero-emission truck-trailer combination is strongly depending on the availability of charging and fuelling infrastructure. Next to availability, the concept and capabilities of both will



improve. New charging concepts, such as Megawatt Charging System (MCS), dynamic charging and electric road systems (ERS) are emerging. While HRS with a daily capacity of 6 tonnes and 700 bar refuelling for trucks are in development.

On the short term, the development of new concepts for charging and fuelling will not have a positive impact on logistics itself but will make zero-emission trucks more deployable. On the longer term, trucks will contribute to vehicle-to-grid charging and storage, which can provide cost benefits for the combined energy-transport system²⁰.

Fleet integration and route optimisation

Since the capabilities of zero-emission trucks differ from diesel trucks adaptations in planning, dispatching and route selection are expected. New software that is able to take into account the limitations and opportunities of zero-emission trucks is needed. The software will have a positive impact on capacity utilisation, the overall cost, improve the energy utilisation and the transport efficiency. It will also improve the data quality and the means of communication from and with the vehicles, which is an important topic for the further digitalisation of logistics.

Ecosystem building

Although currently the cost to operate of zero-emission trucks does not reach diesel parity, it is expected to reach this level in the near future for battery-electric trucks, hydrogen technology will be later²¹. Ecosystem building to reach economy of scale is crucial. In addition, further assessment of innovative business models like (pay-per-use, Transport as a Service) is necessary, as the end customer may be willing to pay more for zero-emission transport.

Legislation

Legislation is the main driver for the implementation of zero-emission trucks. Until now, the zero-emission road transport ecosystem is not mature, further legislative incentives will be needed. This also includes the adaptation of technical regulations and making national legislation more uniform.

Digitalisation

Digitalisation of logistics is necessary to achieve further improvements. Currently, the concept of V2X, communication with the vehicle (both truck and trailer) with something else, is a concept in development that will be needed to ease the implementation of zero-emission trucks and CCAM. Concepts as bidirectional charging, route optimisation using GPS data, fleet management with the remaining driving range of zero-emission trucks as input, V2G communication during charging and communication with HRS to improve the refuelling, are only possible when the vehicles can communicate and share qualitative, well-defined data to infrastructure or the cloud. Definition of parameters and how to measure and communicate them across the whole industry are necessary.

²⁰ Gaete-Morales, C., Jöhrens, J., Heining, F., & Schill, W. P. (2023). Power sector effects of alternative options for electrifying heavy-duty vehicles: go electric, and charge smartly. <https://arxiv.org/abs/2303.16629>

²¹ The potential of e-fuels for heavy duty road transport in the Netherlands, TNO 2023 R10213 https://uploads-ssl.webflow.com/6144857e3aac5ad07ebf212f/63e6520e75c09309becdc952_2023_TNO_smartport_e-fuels%20for%20road%20transport.pdf



Table 1: Action areas for efficient and zero-emission freight transport and expected impacts

Action area	Expected impacts					
	Decreased environmental impact (including, but not limited to reduction of noise)	Improved capacity utilisation of barge, train and truck	Decreased cost of transport & overall logistics	Improve energy consumption	Increase transport efficiency	Data quality and communication
Aerodynamics	x		x	x		
Load efficiency	x	x	x		x	
Eco driving electric driveline	x		x	x		
Zero emission Truck and trailers	x	x		x		x
Charging and fuelling infrastructure	x					
Fleet integration and route optimisation	x	x	x	x	x	x
Ecosystem building	x	x	x	x	x	x
Digitalisation		x	x	x	x	x



2.6 Barriers and guidelines

In the previous section the expected positive impacts are described of the identified action areas. We also mentioned some of challenges and barriers that need to be overcome. In this section, we will give a structured overview of the challenges, barriers and their solution

Table 2 Barriers hindering efficient and zero-emission logistics

Monitoring and reporting emissions		
Challenges / Action areas	Barriers	Solutions
Increase the uptake of the ISO 14083 standard in industry	Lack of awareness or training	Activate via non-profits and green freight programs
	Lack of motivation to implement	Apply pressure through legislation or financial markets
Improve the quality of the calculations	Lack of ease to capture fuel consumption data	Tools to automate data collection (e.g., fuel consumption data collected through connected vehicle telematics based on ISO 23795)
	Carriers are not motivated to share the data	Make it a contractual obligation
	Difficult and inconvenient to examine all published data	Implement an assurance scheme and make it mandatory for all reporting
	Lack of consensus on how to produce energy emission factors	Mobilize the LCA database producers to harmonize the approach.
Expand the scope to holistically capture climate change impact	Lack of consensus on what other types of impacts to be included, such as from digitalization or packaging.	High-level discussion with climate change scientific community
	Lack of established emission factors for many types of climate change impacts beyond carbon dioxide emissions (e.g. black carbon, aviation water vapor)	Mobilize the LCA database producers and scientific community.
Monitoring and implementing efficient freight transport		
Challenges / Action areas	Barriers	Solutions



Aerodynamics	The risk of aerodynamic additions breaking off or being not adjustable anymore, impacts the application negatively	The durability of aerodynamic additions and their adjustability need to be improved, so the risk of a negative business case is minimised
Load efficiency	High capacity vehicles, like EMS, can not be deployed in international missions	Legal support on national level is necessary, until the European directive on 'Weight and dimensions' is voted and offer a solution
	Regulative framework for innovative trailer design is missing	The regulative frameworks is drafted and innovative concepts to improve load efficiency and trailer electrification are made possible.
Eco-driving electric driveline	Unsure that eco-driving guidelines still apply for trucks with electric driveline	A project to assess how regenerative braking of the engine and e-axles can be incorporated in eco-driving guidelines can be conducted.
	Change driving behaviour to drive more eco-friendly	Awareness campaigns, apps/services to support eco-driving should be developed so the integration of eco-driving is not an extra burden for the driver.
Route optimisation for trucks with an electric driveline	Location of infrastructure is not defined	Currently, infrastructure is accomplished on a project basis. More research is needed to define the corridors and hubs where infrastructure can be build. Digital twins that take into account logistic operation and planning, grid availability, truck capabilities... could help with defining suitable locations
	The real energy consumption of zero-emission trucks is unknown	Demonstration project for different use cases under varying conditions (routes, weather...) are needed to determine what the energy



		consumption of zero-emission trucks in real life is
	Renewable energy, in the form of electricity and hydrogen, is not always easily available, plus at an acceptable price	More renewable energy sources should be implemented in the European energy grid. The import of renewable energy should be further investigated. Business scenarios on how diesel parity can be met in the future needs to be done.
Monitoring and implementing zero-emission freight transport		
Challenges / Action areas	Barriers	Solutions
Capabilities and availability zero emission trucks and trailers	Hydrogen truck with fuel cell technology are not commercial available.	Further research to develop mature fuel cell technology is needed.
	Capabilities of the zero-emission truck trailer combination are insufficient to fulfill certain use cases.	Further development of the zero-emission trucks and trailers technically. Development of modular solutions, which can be adapted to the use case.
Charging and fuelling infrastructure	There are no large-scale investments in infrastructure, since the zero-emission truck market is just starting scaling up.	AFIR regulations instruct that both charging and hydrogen infrastructure is built along the European TEN-T network.
		Joint ventures and ecosystem building is happening. Front runners are working together. Nevertheless, this is mostly done on a project basis, while further upscaling is needed.
		Sharing of assets can have a positive aspect on TCO
Legislation	Regulative framework to operate zero-emission trucks is missing.	Clear legislation that makes it possible for zero-emission trucks to do cross-border, multimodal transport and enter all logistic nodes is necessary.



3 Analysis of current market practices and trends

3.1 Overview

ALICE has published the ‘Roadmap toward Zero Emission Logistics 2050²². The roadmap has defined a framework for a decarbonisation roadmap, consisting of identified solution areas, stakeholder groups and transition management measures where stakeholders need to collaborate over time. This framework has been applied by businesses and other innovation developers to advance zero emission logistics.

This chapter provides a compilation of market practices which can be considered as “innovative” in the sense that they contribute to further development of Efficient and zero-emission logistics. Such practices encompass

- Innovations already in place,
- Innovations under development in dedicated projects or research programs,
- Rules, guidelines and technical documentations that pave the way for subsequent application of innovative market practices

We see in Table 3 that for some defined action areas market practices and trends are missing. We did not find any projects or initiatives that looked into eco-driving for truck with electric drive trains. Currently, eco-driving training are focussing on diesel truck driving. We believe that concepts like regenerative braking will have an effect on eco-driving rules and training.

Table 3 Current Market practices related to the action areas of ‘Efficient and zero-emission logistics’

Action area	Efficient and zero-emission freight transport	
	Efficient Logistics	Zero emission logistics
Aerodynamics	Truck and trailer design	
Load efficiency	Trailer design, Light weight trailers, High capacity combinations	
Eco-driving electric driveline	(Trainings of drivers)	
Zero emission Truck and trailers		Electrification of trucks and trailers, Retrofitting existing trucks
Charging and fuelling infrastructure		AFIR, CEF
Fleet integration and route optimisation		Digital twin (ZEFES, EMPOWER, ESCALATE)
Digitalisation	V2X communication	Bidirectional charging

3.2 Market practices: efficient freight transport

Impactful Legislation

²² <https://www.etp-logistics.eu/wp-content/uploads/2019/12/Alice-Zero-Emissions-Logistics-2050-Roadmap-WEB.pdf>



Currently an update of the 'Weight and dimensions directive' ([Council Directive 96/53/ECEN](#)) is proposed on 11 July 2023. The update was not voted when this Cloud Report has been completed, we therefore advise you to check for any changes.

The directive and its amendments allow for deviations from the authorised weights of vehicles and vehicle combinations, so alternative powertrains (including zero-emission), aerodynamic improvements and intermodal transport operations can be carried out. The latest version aims to address four barriers: i) the regulative framework for zero-emission trucks and energy saving devices, ii) facilitate intermodal operations, iii) clear rules to use longer and heavier vehicle combinations in cross border activities and iv) more effective and efficient enforcement of the rules.

The following derogations regarding zero-emission vehicle combinations are mentioned in the revision:

- depending on the weight of the zero-emission vehicle combination a derogation of 2 (36 tonnes) or 4 (40-44 tonnes) tonnes is granted
- the weight of the zero-emission truck itself can deviate with a maximum of 2 tonnes.
- the weight on the driving axle of a zero-emission truck can be 12.5 tonnes
- the length of the truck can be extended with 90 cm to install zero-emission technology or improve aerodynamics, energy efficiency or safety.

Overall, the proposed derogation can help to compensate for the load capacity losses due to the weight of zero-emission technology and the extra length can be used to implement hydrogen technology in a safe and more optimal way.

Aerodynamics and minimizing rolling resistance

Overcoming resistance, both air and rolling resistance can improve fuel efficiency significantly. All truck OEMs are working on durable solutions to improve aerodynamics, which is reducing air resistance. One of the key elements to improve aerodynamics is to delay flow separation and keep the air layer as long as possible in parallel to the vehicle. Once the flow detaches a wake is created, which results in a pressure drag, minimising and delaying flow separation, and minimises pressure drag and energy loss. The impact of small gaps and splits on the flow separation is important, therefore new seals have been placed to cover small gaps and splits, especially the ones at the vehicle's front cover. improvements could be filling the void of the footstep box, wider wheels and mudguards to create more alignment, new mirror design²³ or even replacement by cameras. Next to less drag, the replacement of mirrors, can increase safety due to a larger field of vision and improved vision at night²⁴.

According to the EU regulations²⁵, truck manufacturers in EU countries can extend the front of vehicles by up to 90 cm and trailers can be extended with 50cm, on the condition that the loading capacity is not increased. Also the extension at the back should be able to retract or fold (manual or automated), so the vehicle does follow sizing regulations when standing still.

The rolling resistance can be improved by tyre innovations.

Trailer design

²³<https://www.volvotrucks.com/en-en/news-stories/stories/2022/apr/the-new-aerodynamic-improvements-to-the-volvo-fh-how-it-was-done.html>

²⁴ <https://www.orlaco.com/mirroreya-trucks>

²⁵ <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019R1892>



In practice, 60% of the goods in trailers are palletized, which means that volume not optimal used in some cases. Innovative trailer designs as double decking²⁶ are brought on the market. In the TRANSFORMERS and AEROFLEX, other innovations like aerodynamic shape²⁷, loading optimisation tools and optimised connection to a loading dock so one pallet more can be loaded, were established and are being brought to the market. These projects have shown that there are still low hanging fruit innovations in terms of trailer design. Light weight trailers are the main innovation for mass-limited missions^{28,29}.

In addition, some trailer manufacturers and European R&I projects are investigating the electrification of trailers (cooling and tailgate), by e.g. implementing solar panels in the trailers roof³⁰. Also, the integration of regenerative energy axles with cloud technology and the implementation of batteries on the trailer are investigated (cfr. ZEFES project)³¹.

High Capacity Combinations – European Modular System

An example of a high capacity combination is the European Modular System (EMS). EMS allows the combination of existing loading units (so-called modules) into longer and possibly heavier vehicles combinations, which can be used on some parts of the road network³². National authorities can allow vehicle combinations that are longer the 16.5 meters (maximum length defined in Europe) and can exceed the weight of 40 tonnes. The fact that national authorities are granting permissions, is the main limitation to bring EMS in practice. Currently, the national legislation is not uniform and cross-border operations are not possible. The proposed 'Weight and Dimensions' directive aims to ease the use of EMS by making cross-border operations possible. Nevertheless, this directive is not voted yet and not into force.

EMS can be divided in EMS1, consisting of combinations of trucks, dolly's, trailers and swap body's with a total length not exceeding 25.25 meter, and EMS2, also called duo-trailer or super eco combi, where to semi-trailers can be combined, exceeding the length of EMS1. Overall, both EMS concepts improves road freight transport efficiency and reduces its environmental impact.

EMS is complementary to other modes, especially EMS2, since standard semi-trailers are used. The smaller trailers used in EMS1 combinations do not use the slots on boats and trains optimally. All interviewees mentioning EMS, stated that EMS should not be seen as a competitor to other modes of transport, it is complementary and it is spurring innovation in related modes, such as rail, benefitting consumers³³.

3.3 Market practices: zero-emission freight transport

Impactful Legislation

²⁶ <https://www.krone-trailer.com/en/news/detail/aus-der-praxis-fuer-die-praxis-vorstellung-des-vario-line>

²⁷ <https://www.cargobull.com/en/-/media/project/scb-sites/scb-global-site/media-center-en/test-report-scs-ecoflex.pdf>

²⁸ <https://www.cargobull.com/en/products/curtainsider/curtainsider-semi-trailer/x-light>

²⁹ <https://www.compositesworld.com/articles/recycled-carbon-fiber-for-lower-priced-lightweight-in-heavy-trucks>

³⁰ <https://cordis.europa.eu/article/id/421568-smart-solar-solution-delivers-cleaner-mobility-on-the-road>

³¹ https://www.cargobull.com/en/press/2023/typgenehmigung_skoe_cool

³² <https://www.acea.auto/fact/european-modular-system/>

³³ <https://www.acea.auto/fact/european-modular-system/>



The European Commission is committed to reduce its CO₂ emission as stated in Section 2.1. Since road transport is a significant contributor, with 6% of the total emissions, the Regulation on CO₂ emissions standards for heavy-duty vehicles was implemented and states that a reduction with 15% needs to be reached by 2025 and 30% by 2030³⁴. In 2023, the Commission proposed to raise the ambition even more and go for a reduction of 45% by 2030 and by 2040 a reduction of 90%. These new targets need to be voted.

Low emission zones are implemented in more than 250 European cities to achieve better air quality. These zones also apply for heavy duty transport for urban deliveries. Transport companies are therefore implementing zero-emissions trucks³⁵.

³⁴ https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en

³⁵ <https://breytner.com/#zero-emission>



Battery electric and fuel cell electric vehicles

Battery electric trucks are commercially available. All European manufacturers are taking orders for battery electric trucks^{36,37,38}. They have sold more than 4000 truck in the last 12 months in Europe³⁹. The first fleets of battery electric are emerging in Europe^{40,41}. Most studies agree that battery electric trucks will be **cost-competitive with diesel trucks in the near future** for certain use cases⁴².

Fuel cell electric hydrogen trucks are not commercially available. Only in Switzerland a fleet of hydrogen trucks is operational. Hyundai wants to bring 1600 FC Xcient trucks on the Swiss road by 2025⁴³. In 2020 the first units arrived. A pay-per-use system was applied together with H2Energy. One of the HRS developed in the H2Haul project is also used to refuel the Hyundai trucks. Currently, there should be 47 trucks in operations. Reasons why the trucks are implemented slower than previous planned, are the limited availability of green hydrogen and the energy crisis which has led to higher prices, which putted pressure on the economic viability of the implementation of FCE-HDV. However, Hyundai and H2Energy state that the partners will continue the project. Overall, it is not expected that fuel cell electric trucks will be competitive in the near future. One reason is that green hydrogen is not available, and certainly not at an acceptable price.

Retrofitting of existing trucks and hydrogen combustion engines

Several companies are specialising in retrofitting of diesel truck to battery electric, fuel cell electric hydrogen or even hydrogen combustion engine propelled trucks⁴⁴.

Hydrogen can not only be used in fuel cells, it can also be combusted in ICE. The use of a combustion engine has some advantages compared to fuel cell electric. The driveline of combustion engines is known, is more robust and has a longer lifetime than the existing fuel cells. Also, the quality of the hydrogen does not need to be fuel cell quality. Hydrogen combustion engines are seen as a complementary zero-emission option⁴⁵. However, a major drawback is that they emit NOx . In addition, they have the same drawback of other hydrogen solutions (low efficiency and lack of supply of green hydrogen).

Route and mission planning optimisations

We see that with the emerging of zero-emission truck, the interest in route and mission planning optimisation is again rising. Previous the planning of a ICE fleet took only into consideration of following missions characteristics: distance, volume or weight payload, time and the overall utilisation of the

³⁶<https://www.volvotrucks.com/en-en/news-stories/press-releases/2023/mar/volvo-delivers-20-electric-trucks-to-dfds-in-gothenburg.html>

³⁷ <https://www.scania.com/ph/en/home/about-scania/newsroom/news/2023/Scania-secures-significant-truck-order-in-the-UK.html>

³⁸<https://press.mantruckandbus.com/corporate/already-more-than-500-order-enquiries-man-to-launch-electric-truck-for-long-distance-transport-in-2024/>

³⁹ Webinar ALICE – Decarbonizing Road Freight Transport vehicles roadmap

⁴⁰ <https://www.primafrio.com/grupo-primafrio-incorpora-a-su-flota-15-camiones-volvo-fh-electric/>

⁴¹ <https://bett.cenex.co.uk/bett-learning>

⁴²https://www.transportenvironment.org/wp-content/uploads/2022/10/202210_TNO_-_techno_economic_uptake_potential_of_zero_emission_trucks_in_Europe.pdf

⁴³ <https://hyundai-hm.com/en/2022/10/21/statement-concerning-hyundai-hydrogen-mobility-business-case-in-switzerland/>

⁴⁴ <https://cordis.europa.eu/article/id/442780-retrofitted-zero-emission-trucks-to-hit-the-road-in-2023>

⁴⁵ https://www.transportenvironment.org/wp-content/uploads/2023/04/202304_HDV_CO2_position_paper_final.pdf



fleet. When zero-emission trucks come into play, also charging or more regular hydrogen refuellings should be taken into account, together with the reduced driving range compared to diesel trucks.

In addition, the driving range of both technologies can be affected by the weather conditions. The fuelling of gaseous hydrogen will be more optimal at colder conditions, since the mass of hydrogen refuelled is inverse correlated to ambient temperature. Battery technology will work more efficient in environments at ambient temperature. All these variables, even degeneration of the fuel cell and battery capacity, should be taken into account in future planning and dispatching software that can calculate the optimal route for a mission. Currently, R&I projects (ESCALATE, EMPOWER and ZEFES) are working on digital twins, which can be the basis of these software. Another aspect of route optimisation that should be taken into account is the availability of infrastructure.

Penalties Truck OEMs

Most truck OEMs are investing in ZERO-EMISSION TRUCKS, since heavy penalties will be applied if their fleet does not meet the CO₂ target (set to 15% emission reduction by 2025 and 30% by 2030⁴⁶, stricter targets are proposed). The current penalties are set at €4,250 per g CO₂/t·km in 2025 and €6,800 per gCO₂/t·km in 2030. The penalties are already in force, even when the targets are missed by 1g CO₂/t·km. Currently, the penalties only apply on truck OEMs, not to other stakeholders in the transport and logistics value chain⁴⁷.

Infrastructure

The market developments of infrastructure are defined of what is technological feasible and what is implied by regulation.

Electric charging at a power of 350kW is available with CCS technology. However, this amount of power is not enough to charge a battery electric truck fast. It will take a hour to recharge the current trucks, and the upcoming truck with greater battery capacity, will take multiple hours to charge. Therefore we see the development of ultra-fast charging, MCS, charging at megawatt⁴⁸. With this technology the future truck will be recharged in less than an hour. Also, bidirectional charging is in development for passenger cars⁴⁹, and will be for trucks. Finally, pilots are being held in several countries with dynamic charging technology, with overhead lines and induction charging^{50,51,52}.

Also, the HRS technology is evolving. HRS with a working pressure of 350 bar for trucks and other vehicles are available. The first ones were built for buses (JIVE project) or other applications than trucks. Hydrogen fuel cell electric trucks with a working pressure of 350 bar have been demonstrated in national and regional R&I (H2Share). Now, the switch to 700 bar is made, with as main reason to increase the mass of hydrogen on the truck and the driving range. In the H2Haul project a first 700 bar HRS for trucks was built. Others are in development. Also, the daily refuelling capacity of the station is increasing to tonnes of hydrogen per day.

The implementation of the infrastructure is currently is not economically straightforward. Therefore, regulation and funding schemes is an important driver for investments. The AFIR sets targets for recharging and hydrogen refuelling infrastructure for the road sector, for shore-side electricity supply in maritime and inland waterway ports, and for electricity supply to stationary aircraft. In this way, a

⁴⁶ https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en

⁴⁷ https://www.acea.auto/files/Fact-sheet-CO2_standards_for_heavy_duty_vehicles.pdf

⁴⁸ <https://hochleistungsladen-lkw.de/hola-en/project/>

⁴⁹ <https://cordis.europa.eu/project/id/101056934>

⁵⁰ <https://cordis.europa.eu/project/id/774833>

⁵¹ <https://press.siemens.com/global/en/feature/ehighway-solutions-electrified-road-freight-transport>

⁵² https://www.transportenvironment.org/wp-content/uploads/2021/07/2020_02_RechargeEU_trucks_paper.pdf



minimal amount of infrastructure will be available in Europe, enabling the use of zero-emission trucks. In addition, the regulations also state best practices for user experience, price transparency and payment options at the station and coherent customer information across the EU⁵³.

The regulations states that for zero-emission trucks dedicated recharging stations need to be deployed every 60 km along the TEN-T core network. The minimum power output must be 350 kW. On the larger TEN-T comprehensive network every 100 km dedicated charging equipment should be available. Just as, infrastructure for overnight charging at parking areas an in urban nodes for delivery vehicles. The coverage of the complete network should be completed by 2030.

In addition, AFIR states that HRS that can both serve zero-emission trucks and lorries must be deployed every 200 km along the TEN-T core network and all urban nodes by 2030, to ensure a sufficiently dense network.

Funding to achieve these charging stations and HRS can be achieved through the Connecting Europe Facility (CEF) program. The CEF transport call already selected more than 60 project across Europe for funding. When this Cloud Report was written only one remaining cut-off date existed to apply for CEF Transport, under the existing rules. It is expected that a new series of calls will be published in the future, however changes in application rules are expected.

Vehicle Energy Consumption Calculation Tool (VECTO) for trucks and trailers

The European Commission developed in close collaboration with stakeholders the VECTO tool, which is a simulation software that can be used measure the CO₂ emissions and fuel consumption of heavy-duty vehicles (GVW above 3500kg) for specific loads, fuels and mission profiles (e.g., long haul, regional delivery, urban delivery, etc.) in a reliable and cost-effective way. Input for the simulation tool are the relevant vehicle components⁵⁴. Since 1 January 2019, the tool is mandatory for new trucks under certain vehicle categories. From 2024 onwards, trailers will also be certified. Bonus factors for trailers will be steering axles and lightweight running gear⁵⁵.

Past European projects

In this paragraph we mention some finished project about hybrid powertrain demonstrations and electric vehicles and infrastructure for urban conditions. We decided that these projects are not in scope. Nevertheless, a lot of innovations were established in these project that helped to develop current zero-emission truck technology. At the time of the hybrid powertrain projects, the technology for full electric trucks with high payloads was not available. Therefore we mention them in this chapter.

EcoChamp

EcoChamp⁵⁶ aimed to achieve efficient, compact, low-weight, robust and cost-effective **hybrid powertrains** for both passenger cars and commercial vehicles (buses, medium and heavy-duty trucks) with increased functionality, improved performance, comfort, safety and emissions below Euro 6 or VI, all proven under real driving conditions. The project was ongoing between 2015 and 2018, financed under H2020, and included 26 partners representing the European automotive industry OEMs (EUCAR), suppliers (CLEPA), ESPs and universities (EARPA) including members of ERTRAC and EGVA. The call expected an impact to deliver demonstrator vehicles that achieve a 20% powertrain efficiency

⁵³ https://ec.europa.eu/commission/presscorner/detail/en/ip_23_1867

⁵⁴ https://climate.ec.europa.eu/eu-action/transport-emissions/road-transport-reducing-co2-emissions-vehicles/reducing-co2-emissions-heavy-duty-vehicles_en

⁵⁵ <https://newsroom-en.bpw.de/pressreleases/eu-requires-climate-friendly-trailers-from-2024-onwards-bpw-products-fulfil-the-requirements-for-vec-to-certification-of-trailers-3216797>

⁵⁶ <https://cordis.europa.eu/project/id/653468>



improvement and 20% powertrain weight and volume reductions with respect to the 'best in class' full hybrid vehicles on the market in 2013, whilst having a maximum 10% cost premium over the conventional model upon which the demonstrators are based. Five demonstrators were conducted in EcoChamp including two demonstrators with trucks, one delivery truck, IVECO Daily Hybrid, 7.5 tonnes and one long-haul truck, DAF XF Long Haulage Hybrid Truck.

The result of the assessment was positive with the delivery truck with a 30% increased powertrain efficiency compared to Daily Diesel, and a decrease in powertrain mass (-27%) and volume (-36%) compared to Daily Electric, and with noxious emissions reaching Euro VI. The long-haul truck almost met the aimed target for powertrain efficiency with a 17% increase compared to DAF XF Diesel, and a decrease in powertrain mass (-17%) and volume (-13%) compared to a DAF XF (reference from FP7 project Convenient since no hybrid long haul truck was available in the market).

ORCA

Orca, **Optimised Real-world Cost-Competitive Modular Hybrid Architecture** for Heavy Duty Vehicles, aimed to design a clear and greener yet affordable hybrid drivetrain for heavy-duty vehicles^{57,58}. The project was ongoing between 2016-2021, financed under H2020, and included 10 partners from 6 different European Members States representing all requested competencies in the field of powertrain optimization for Heavy- Duty vehicles. The consortium comprises OEMs with IVECO-ALTRA, CRF and VOLVO (also members of EUCAR, suppliers VSCM, BOSCH and BLUWAYS, leading Engineering and Technology Companies/organizations and Universities with TNO, FRAUNHOFER, and VUB (EARPA). The majority are also active members of ERTRAC and EGVA. The objective of Orca was to:

- Reduce the Total Cost of Ownership (TCO) to the same diesel vehicle TCO level, targeting over 10% system cost premium reduction compared to actual IVECO hybrid bus and VOLVO conventional truck with the same performances, same functionalities and operative cost, and also targeting up to 10% rechargeable energy storage (RES) lifetime/energy throughput improvement.
- Improve the hybrid powertrain efficiency up to 5% compared to actual IVECO hybrid bus and conventional truck through optimized RES selection & sizing and by improving the energy and ICE management.
- Reduce the fuel consumption by 40% compared to an equivalent conventional HD vehicle (bus & truck).
- Downsize the ICE by at least 50% compared to actual IVECO hybrid bus and VOLVO conventional truck.
- Improve the electric range from 10km to 30km by adding the PHEV capabilities and optimising the RES capacity.
- Case study assessment to replace a diesel engine by a CNG engine for future heavy-duty vehicles.

One of the results of the project was developing a Volvo distribution hybrid truck with an extended full-electric range from 10 km to 30 km, improving the performance of batteries in terms of power and energy density as well as cost-enabling vehicle platforms with increased energy storage that facilitate further electric range, and sizing the internal combustion engine towards more average operation rather than the peak-power vehicle requirement benefits fuel efficiency and emission reduction. The vehicle was equipped with innovative plug-in hybrid electric vehicle (PHEV) rechargeable energy storage (RES) systems, designed specifically for vehicle application. It featured an improved range for operation in low-emission zones using advanced control systems.

ASSURED

⁵⁷ <https://cordis.europa.eu/project/id/724087>

⁵⁸ <https://h2020-orca.eu/>



Assured aimed at boosting the electrification of **urban commercial vehicles** and their integration with high-power **fast-charging infrastructure** and evaluating several infrastructures in different cities across Europe⁵⁹. The project was ongoing between 2017 – 2022 and included 39 partners from 12 different EU Member States.

The main goal was to charge different vehicles using the same infrastructure, making ASSURED innovative in this approach since this would be the first time a project set out to test the interoperability of the charging solutions applied. If successful, this would help reduce costs and support the standardisation of the elements of the infrastructure. Assured tested six public transport buses, two garbage trucks, one delivery truck, and one light commercial delivery vehicle with automatic fast charging, which meant that there was no human interaction during the charging process. The charging solutions tested by the project included different types of pantographs, plug-ins and wireless charging.

Some of the main results of the project were i) better understanding of the effects on battery ageing and lifetime due to fast charging, ii) effects on electric grids due to the installation of high-power chargers (up to 600 kW), iii) a common standard, laying out the guidelines for the interoperable operation of HD vehicles with chargers, iv) test results from interoperability, v) results from use cases and demonstrations of the vehicles in cities, and vi) a simulation tool to complement all the above, basically a virtual platform for anyone wanting to use the ASSURED solution.

CONVENIENT

Within the CONVENIENT project a suite of innovative energy-saving solutions were developed to achieve a 30% reduction target regarding the fuel consumption of long-haul heavy duty trucks⁶⁰. Three major EU truck manufacturers (IVECO, VOLVO and DAF) built 3 trucks, together with 19 project partners (research and suppliers). The aim was to demonstrate and validate the fuel-saving capabilities of technologies like: hybrid transmission, electrified auxiliaries, aerodynamics⁶¹, photovoltaic solar roof for truck and semitrailer and more.

Current European projects

NextEtruck

The NextEtruck project aims to play a pioneering role in the decarbonisation of vehicle fleets, with the focus on medium-duty trucks, and accelerating sustainable market replenishment, by bringing zero-electric medium freight haulage into practice. Some of the main objectives are: 10% improvement of overall efficiency, efficient sizing of the components based on the use case by using a digital twin, fast charging and fleet integration of the zero-emission trucks.

Again, lowering emissions is one of the main reasons for this project. Medium-duty trucks are responsible for about 25% of transport industry emissions and in Europe a fleet of 1.1 million medium-duty trucks is present. So changing this segment of vehicles to zero-emission can have a substantial impact on emissions.

Three pilot sites will be developed in the project, in three cities: Istanbul (Turkey), Utrecht (Netherlands), and Barcelona (Spain). Two electric trucks (built by TVV and Ford OTOSAN) and one electric refuse truck (built by IRIZAR) will be demonstrated. The DC chargers

⁵⁹ <https://cordis.europa.eu/project/id/769850>

⁶⁰ <https://cordis.europa.eu/project/id/312314/reporting>

⁶¹ <https://www.2zeroemission.eu/wp-content/uploads/2018/02/04-CONVENIENT-IVECO.pdf>



will be provided by JEMA and ABB (Panion). Overall a driving range of at least 200 km will be demonstrated.

The refuse truck will be demonstrated in Barcelona. Electric vehicles can help to protect the historic city centre. The impact on noise will be assessed.

In Istanbul, a truck from Ford OTOSAN will be demonstrated for six months on urban and intercity roads. The pilot will address, among other things, tailored eco-routing strategies with real-time mission, load and charging planning.

The last demonstration will be done in Utrecht. From 2025 Utrecht will have a Low Emission Zone and only zero-emission trucks will be allowed to enter the city to deliver goods. Therefore, the demonstration will give insights in how it can be done

The project is ongoing and the demonstrations will start in 2025.

H2Accelerate

H2Accelerate is a Horizon2020 project that aims to deploy hydrogen trucks with fuel cell technology and the related fuelling infrastructure at large scale in Europe⁶². The consortium exists of hydrogen infrastructure players (Linde, OMV, Shell and Total Energies) and truck manufacturers (Daimler truck, IVECO and VOLVO). The first phase will be the deployment of 150 trucks in Europe and more than 20 high capacity HRS. The roll-out will be done at carefully selected locations and clusters. The second phase will focus on the coverage of the major European corridors, reaching volume manufacturing of more than thousand trucks yearly.

Projects selected under HORIZON-CL5-2022-D5-01-08

Modular multi-powertrain zero-emission systems for HDV (BEV and FCEV) for efficient and economic operation (2ZERO)

Three projects were selected under this call: ESCALATE, EMPOWER and ZEFES. They all focus on technical objectives like scalable, modular powertrains, improved efficiency of the energy/thermal management, a load capacity of not less than 90%, improved fuel cell operations... In combination with the development of tools to integrate the ZERO-EMISSION TRUCKS in existing fleet, digital twin development and scenarios to achieve price reduction resulting from economies of scale. All projects are part of the AEVETO cluster. The project call can be found online⁶³.

ESCALATE

The ESCALATE project aims to demonstrate zero-emission long-haul applications with a driving range of more than 800 km without refuelling or recharging. A daily operation that covers at least 500 km is targeted⁶⁴.

The three targeted innovation areas are:

- Standardized well-designed, cost effective modular and scalable multi-powertrain components;

⁶² <https://h2accelerate.eu/>

⁶³ https://cordis.europa.eu/programme/id/HORIZON_HORIZON-CL5-2022-D5-01-08/en

⁶⁴ <https://www.escalate-eu.com/>



- Fast Fuelling & Grid-friendly charging solutions; and
- Digital Twin (DT) & AI-based management tools considering capacity, availability, speed, and nature of the charging infrastructures as well as the fleet structures

The ultimate goal is to develop a business model for three types of zero-emission trucks with innovative modular building blocks.

Five pilots, five digital twins and five TCO case studies will be conducted during the project. Special attention will be given to the environmental impact via the project TranSensusLCA. The pilots will demonstrate regional and cross-border logistics during a 24 month demonstration under real-world conditions and more than 500 000 km will be driven.

The project will also showcase 3 pioneering infrastructure pilots: a mobile HRS, a green-fix multi-fuel station and a 1 MW fast charger⁶⁵.

EMPOWER

The objective of the EMPOWER project is to deliver two modular zero-emission trucks, with a GVW of at least 40 tons for the truck-trailer combinations⁶⁶. Two demonstrations will be done with a FCE-HDV (range of 750 km unfuelled) and BE-HDV (400 km uncharged) from IVECO. The vehicles will be demonstrated in 5 long-haul and regional distribution use-cases, including cross-border corridors.

Other innovations will be a highly reliable fuel cell system, optimised thermal and energy management, digital twin models of the demonstrations, fleet management systems and optimised routing.

ZEFES

During ZEFES 9 long-haul truck configuration (3 BEV and 6 FCEV) will be deployed in various use cases covering important TEN-T corridors in Europe⁶⁷. In addition, innovations in trailers and megawatt charging systems will be demonstrated. The demonstrations also include multi-modal, cross-border use cases and in total more than 2 million kilometres will be driven. The vehicle combinations will be demonstrated in 15 use case, for at least 6 months per use case. Daily routes up to 1300 km will be showcased together with a digital twin and fleet integration tools. A description of all the use cases and the truck trailer combinations can be found on the project website⁶⁸. The use cases will be done from the north of Europe, to the south. In Sweden/Norway a VOLVO hydrogen fuel cell truck will be demonstrated, to check if fuel cell technology is less restricted than battery technology in a cold environment. The other hydrogen trucks will be demonstrated in the Alpine region and in an use case in Spain where the technology will be directly compared to battery electric. We expect that in Spain, both technologies will be pushed to their limits. Since both technologies will be pushed to their limits in warm weather conditions (cooling of batteries and lower gas density at higher temperatures).

⁶⁵ <https://www.etp-logistics.eu/wp-content/uploads/2023/05/1-ESCALATE-Transport-and-Logistic-Fair-11-May-2023.pdf>

⁶⁶ <https://www.ait.ac.at/en/news-events/single-view/detail/7610?cHash=36ff38b1736d0e1e681f20646748f2eb>

⁶⁷ <https://zefes.eu/>

⁶⁸ https://zefes.eu/wp-content/uploads/sites/9/2023/06/ZEFES_D1.2-NeedsRequirements_PUB_FINAL_website_.pdf



3.4 Market practices: emission reporting

Currently, in the market there are two important standards that have been produced, relevant to the logistics sector. The ISO 14083:2022 “Greenhouse gases — Quantification and reporting of greenhouse gas emissions arising from transport chain operations” provides a general framework for emissions calculations. Since it was only launched March 2023, much of the industry is ‘practically’ only using the industry standard GLEC Framework (2019) “Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting. Version 2.0”, although there are not significant differences between both standards. The second important formal standard that is the upcoming EN 17837:2023 “Postal Services - Parcel Delivery Environmental Footprint - Methodology for calculation and declaration of GHG emissions and air pollutants of parcel logistics delivery services”⁶⁹, which can be understood as the application of the ISO 14083 to the distribution of goods in a parcel delivery service, “namely the collection and delivery rounds, the trunking and the operations due to processing and the physical handling of parcels”.

Both of these standards are currently not mandatory to be adopted in internal calculation or for reporting purposes. They are aligned with the GHG Protocol, which is in turn used in the industry for sustainability reporting, submission to Science Based Targets, or Carbon Disclosure Project. However, the CountEmissionsEU proposal has adopted the CEN ISO 14083 (which is the ISO 14083 transposed to the European Committee for Standardization) as the standard to be used for transport emissions calculations for the instances applicable under the proposed legislation. The applicability of the proposed legislation is under a “binding opt-in” system, i.e., only for those that calculate and disclose GHG emissions data of transport services. In other words, if the data is not disclosed, the company does not need to use this. Other aspects have been included in the proposal, including management and verification of fuel emission factor and emission intensity data by the European Environment Agency (EEA), as well as other rules on communication and transparency, the use of certified calculation tools and the assurance scheme. The legislation strengthens the impact that the ISO 14083 standard can bring to the industry and climate change goals by enforcing the uniformity and increasing the trustworthiness of the emissions disclosure. Other regulations that are soon to be passed or come into effect that may use this framework are the Corporate Sustainability Reporting Directive (CSRD), the SEC proposal for scope 3 emissions, and the Streamlined Energy and Carbon Reporting (SECR), and even proposals for Unfair Commercial Practices Directive (UCPD). This is to increase the prominence of climate impact and risks in the financial sector, as well as to reduce greenwashing practices. This could see a large number of organizations being required to use the calculation framework to fulfill different legislative requirements in the coming years. For instance, the expected number of companies that the CSRD will initially apply to are 49,000 large or listed companies in the EU⁷⁰. SMEs will also eventually fall under CSRD requirements. While only some of the companies will be required to disclose their freight transport emissions, this will nevertheless be a significant increase in organizations that will apply the calculation framework.

It is important to note that just like the standard for the parcel sector, different sectors, whether differentiated by transport or economic activity have found the need to develop supplementary guidance (or industry standards) specific to their use case. These methodologies are aligned with the GLEC Framework. Some examples include the Clean Cargo methods⁷¹, Calculating GHG transport and

⁶⁹ <https://standards.iteh.ai/catalog/standards/cen/1ecb279f-4529-486b-9342-fb4d463ee666/pren-17837>

⁷⁰ <https://www.bsr.org/en/blog/what-business-needs-to-know-eu-corporate-sustainability-reporting-directive>

⁷¹ <https://www.smartfreightcentre.org/en/skills/library/clean-cargo-emissions-calculation-method/>



logistics emissions for the European Chemical Industry⁷², and Ro-Ro GHG Emissions Accounting Guidance⁷³. These are voluntarily adopted within a certain sector as pushed by the relevant trade association. The bodies that regulate and are very influential in the aviation and maritime sector are also adopting calculation methods that align well with the GLEC Framework. These are global initiatives that have the potential to expand the scope of application around the world.

Another trend in this space is the need for a standardized emissions accounting system to enable an emerging lever of transport decarbonization, that is the book-and-claim of low emissions transport solutions. The idea behind this is that a company would like to pay for the right to claim lower emissions in their emissions disclosures than is actually carried out within their transport chain, especially that which falls under their Scope 3 operations. Depending on the type of system, the lower emissions profile could be taken from a fuel provider or a carrier carrying out the low emission transport operation. In each case, the emissions profile associated with the fuel or operation is separated from the actual physical fuel or operations, and is sold to a buyer. This is an emerging practice, which is offered by a couple of carriers and fuel suppliers.

3rd party marketplaces and tools to support this type of transaction, typically called carbon insets, are cropping up and provide services to verify and book the claims (e.g. CarbonLeap and 123Carbon). However, to enable a transparent transaction, i.e., to avoid double counting, and to provide an accurate estimation of the amount of low emission transport 'credits' that can be claimed, a fair and transparent emissions calculation framework will need to be adopted by all parties involved. These typically would follow the calculation methods used in the GLEC Framework.

While the ISO 14083 standard has been released, there has been movement to also ensure that other countries and continents are enabled to use them. SFC China will be launching a GLEC Framework specifically for implementation in China. Similar initiatives are being launched by SFC in India and East Africa. While the groundwork of defining energy emission factors and emission intensities that represent the region's transport operations still needs to be done, what is hopeful is that the awareness of the importance of carrying this out is growing globally.

⁷² <https://cefic.org/media-corner/newsroom/updated-guidance-available-to-support-the-chemical-sector-further-reduce-its-environmental-impact-of-freight-transportation/>

⁷³ <https://www.smartfreightcentre.org/en/about-sfc/news/driving-decarbonization-in-shipping-smart-freight-centre-and-ecg-publish-the-first-ever-methodology-harmonizing-emissions-accounting-in-the-ro-ro-segment/>

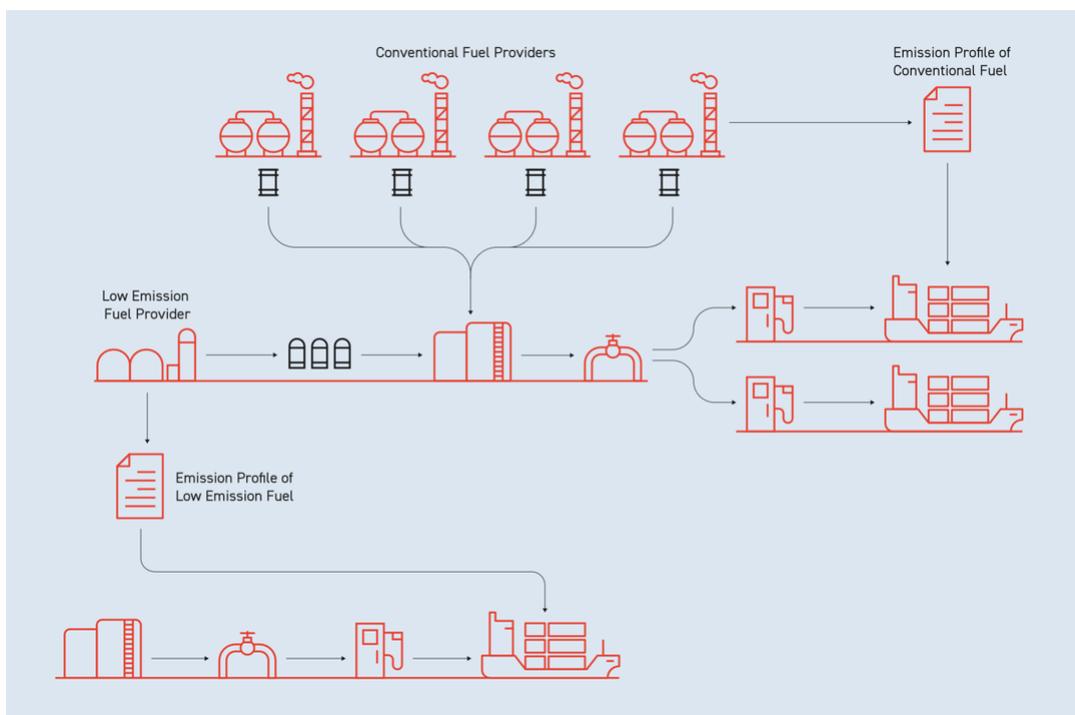


Figure 6. A book and claim chain of custody model (Smart Freight Centre, 2023)



Table 4 Summary of market status

Current	Short term	Medium to long term
ISO14083, GLEC v2 (voluntary for sustainability reporting and target setting.)	CountEmissionsEU proposal adopts CEN ISO 14083 (binding opt-in) EN 17837 launched end 2023.	Other regulations CSRD, SEC Scope 3 emission, SECR, UCPD likely to adopt. CSRD: now large/listed EU companies --> SMEs
Sectoral guidance and defaults aligned with standards (Clean Cargo methods, GHG emissions calculations for the European Chemical Industry, and Ro-Ro GHG Emissions Accounting Guidance)	More sectoral guidance as driven by industry. Regional guidance driven by different markets (China, India, East Africa). Book and Claim framework adoption (uncertain)	



4 Projects to improve Efficient and Zero-emission logistics

4.1 Identification and selection of relevant R&I projects

The selection of projects was performed within a three-step project mapping (see Figure 3). The aim of this exercise was to identify those R&I projects that shall be incorporated into the subsequent work steps of this Cloud Report. In practical terms, the almost 300 projects of the overall R&I project list were filtered according to following criteria:

- Step 1 (initial mapping): the titles and other entries of the project list were screened for relevant keywords and classifications, such as “zero-emission”, “efficient logistics”, “aerodynamics”, “transport emissions” or “load efficiency”. Additionally, the summaries of the projects were checked for these keywords. In total, 16 projects have been identified to be tackled within the next step. Sources used were CORDIS, TRIMIS and the project’s website, if still existing.
- Step 2 (relevance mapping): all projects of the R&I project list had received a relevance assessment (“high”, “medium”, “low”), referring to the general significance for the Cloud Reports. Basically, only projects with “high” relevance were further considered. After this work step, 11 projects remained.
- Step 3 (content mapping): in the final step, the content of the 8 projects was analysed in detail. More specifically, the project documentations were checked regarding
 - Compliance with the identified action areas and expected impacts (see Table 1);
 - Consideration in one of the other Cloud Reports. Generally, this was no exclusion criterion; however, it should be ensured that the projects were properly allocated to the Cloud Reports according to their content focus

As a result, the mapping exercise led to the identification of 8 projects relevant for this Cloud Report (see Table 5). The characteristics of efficient transport also imply a high likeliness of overlapping with projects and specific outcomes tackled by other Cloud Reports (Urban mobility, Physical internet, logistics networks...). Also, the strict scope of this Cloud Report led a lower number of selected projects, since only project with demonstration are selected. In addition, project on zero-emission trucks are just starting and are therefore not selected. Therefore, the low number of identified projects is understandable and plausible.

4.2 Overview on the selected projects

A visualisation of the projects is given in Figure 7. Three projects of the 7th European Framework were selected, two on efficient and zero-emission transport and one on emission reporting. UDRIVE focus on naturalistic driving behaviour, which can be used as an input for eco-driving. TRANSFORMERS demonstrated trailer innovations, for both loading efficiency and electric drive train. In COFRET the GLEC framework (methodology to calculate the greenhouse gas emissions from freight transport activity) was developed.

Five projects of Horizon 2020 were selected, four on efficient and zero-emission transport and one on emission reporting. AEROFLEX is the successor of TRANSFORMERS and focussed on the efficiency gains by aerodynamic adaptations. ENSEMBLE demonstrated multibrand platooning and Modales focussed on eco-driving. H2Haul is the only selected project that is still ongoing. It will demonstrate 16 fuel cell electric trucks at the related fuelling infrastructure. LEARN is the successor of COFRET and wanted to test the GLEC framework in real life and elevate it from an industry standard to an international standard.



More detailed project descriptions can be found in Section 4.4.

Table 5: Overview of the selected projects, the related program, coordinator and period.

Acronym	Name on CORDIS web page	Program	Coordinator	Period
UDRIVE	eUropean naturalistic Driving and Riding for Infrastructure & Vehicle safety and Environment	FP7-SST-2012-RTD-1	STICHTING WETENSCHAPPELIJK ONDERZOEK VERKEERSVEILIGHEID (SWOV)	10/2012-06/2017
TRANSFORMERS	Configurable and Adaptable Trucks and Trailers for Optimal Transport Efficiency	FP7-SST-2013-RTD-1	VOLVO TECHNOLOGY AB	09/2013-08/2017
AEROFLEX	Aerodynamic and Flexible Trucks for Next Generation of Long Distance Road Transport	H2020-GV-2017	MAN TRUCK & BUS SE	10/2017-09/2021
ENSEMBLE	ENabling Safe Multi-Brand platooning for Europe	H2020-ART-2016-2017	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK (TNO)	06/2018-03/2022
MODALES	MOdify Drivers' behaviour to Adapt for Lower EmissionS	H2020-MG-2018-2019-2020	EUROPEAN ROAD TRANSPORT TELEMATICS IMPLEMENTATION COORDINATION ORGANISATION - INTELLIGENT TRANSPORT SYSTEMS & SERVICES EUROPE	09/2019-05/2023
H2Haul	Hydrogen fuel cell trucks for heavy-duty, zero emission logistics	H2020-JTI-FCH-2018-1	ELEMENT ENERGY LIMITED	02/2019-01/2024
COFRET	Carbon footprint of freight transport	FP7-SST-2010-RTD-1	DEUTSCHES ZENTRUM FUR LUFT-UND RAUMFAHRT EV (DLR)	06/2011-11/2014
LEARN	Logistics Emission Accounting and Reduction Network	H2020-MG-2016-2017	STICHTING SMART FREIGHT CENTRE (SFC)	10/2016-03/2019



Figure 7. Eight projects were selected, 6 regarding Efficient and zero-emission freight transport and 2 regarding emission reporting.

Project results and outcomes must of course also be mirrored against the received funding, since this consists of public money. In this respect, (R&I) projects are obliged to return adequate benefits to the society that feeds them. The 8 selected projects consumed more than 63 million EUR of funding altogether.

In a next step, the organisations with the highest level of involvement in the selected 8 projects were identified. The main criteria were frequency of participation in the projects as well as their role as provider of substantial results or as a project coordinator. These organisations are important for



understanding and monitoring projects' outcomes as well as the implementation cases derived from them. Specifically, they form the basis for the selection of the interview partners. As Figure 8 visualises, 12 organisations were revealed as particularly involved in European research projects in the area of 'Monitoring and implementing Efficient and zero-emission freight transport'. Most of them are truck or trailer manufacturers, research institutes or associations.

We want to stress out that many more project partners contribute to the project results. The implementation of innovations in logistics is difficult, since the whole value chain (shipper, carrier, OEMs, suppliers, authorities, infrastructure...) is strongly interlinked. Innovations by one stakeholder group affects the other. One example for this is the transition to zero-emission trucks. To achieve this, all stakeholders will need to adjust their operations profoundly and it can only be a success when the stakeholders communicate and work together.

It was identified that projects benefit from a strong advisory board/stakeholder group with members from the full logistics value chain. We therefore want to address that mapping only funded partners, does not give a complete picture of the stakeholders that contributed to the project. Unfunded stakeholder group members should get recognition for their contributions to R&I project.

Especially, truck end-users (carriers) and shippers are underrepresented as partner in the assessed, finished R&I projects. In all finished project, P&G was the only funded shipper. Luckily, we see a change in the newly started projects, were shippers and truck end-users are funded partners.

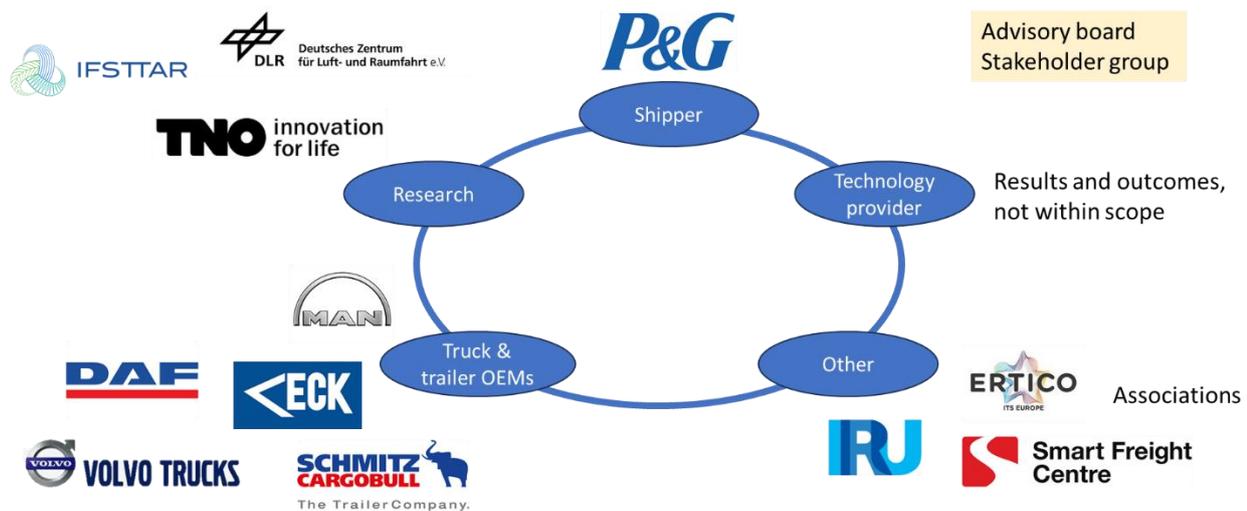


Figure 8. Overview of the main stakeholder groups in European R&I projects and the involved companies. We want to stress the importance of strong advisory boards or stakeholder group involvement. Unfunded partners can impact the project significantly and their contribution should be acknowledged more.



4.3 Expected impacts of the selected projects

In the Table 6 the expected impacts for Table 6 are repeated together with related KPIs and the projects who worked on the topic.

Table 6 Expected impacts of the selected projects

Expected impacts	KPIs	Projects
Decreased environmental impact (including, reduction of noise)	GHG emissions/Unit of transport Energy consumption/Unit of transport	TRANSFORMERS, AEROFLEX, H2Haul
Improved capacity utilisation of barge, train and truck	Increase the load capacity of trailers	TRANSFORMERS, AEROFLEX
Decreased cost of transport & overall logistics	Decrease the fuel consumption	TRANSFORMERS, AEROFLEX, UDRIVE, Modales
	Less driver costs	ENSEMBLE
Improve energy consumption	Electrify the drive train Regenerative technology	TRANSFORMERS, AEROFLEX
Increase transport efficiency	Compatibility with high capacity vehicles and other transport modes	TRANSFORMERS, AEROFLEX, ENSEMBLE
Data quality and communication	Connected, cooperative vehicles, V2X, infrastructure	ENSEMBLE
		H2Haul



4.4 Description of the selected projects

UDRIVE

The UDRIVE project aimed to increase the understanding of road user behaviour by systematically studying road user behaviour in real-life conditions. The project was funded by FP7, between 2012 and 2017, with a consortium consisting of 19 partners, representing a good balance between different EU regions, and between expertise in the various research areas. UDRIVE focused on two aspects: the identification of relevant measures to improve road safety, and on the identification of promising approaches for reducing harmful emissions and fuel consumption to make road traffic more sustainable. The project **conducted a large-scale naturalistic driving study**, with participants using their own vehicles, allowing them to drive their cars, trucks and scooters naturally. The project used a specially designed data acquisition system connected to seven or eight unobtrusive cameras installed throughout the vehicle. Each vehicle was also equipped with a smart camera capable of automatically identifying nearby objects, such as cars, trucks and pedestrians.

UDRIVE generated several types of results including technical developments, the UDRIVE database and new behavioural insights. The results relevant to the cloud report were mainly related to eco-driving with the analysis showcasing velocity distributions across drivers and speed limits, the effect of driving styles on eco-driving and the potential effects of eco-driving. One of the insights was that the analysis reinforced the conclusion that energy is being wasted by drivers in the approach to and passage through curves by lack of anticipation of the need to slow down and therefore by over-harsh deceleration. Behaviours regarding gear-changing, braking and speed choice were especially relevant as drivers showed large variations in those behaviours with associated substantial variations in CO₂ emissions. Recommendations for new measures include enforcement of speed limits with the aim to reduce energy use, regulating the use of in-vehicle systems that contribute to eco-driving, further awareness campaigns promoting the use of vehicles with gear shift indicators and automatic engine shutdown systems, promoting driving in the highest gear, and giving feedback to drivers about their eco-driving 'scores'. Another category of measures is the design of road infrastructure that supports eco-driving (e.g., grade-separated intersections, improved network design, improved traffic light algorithms including communication with vehicles). Traffic management strategies can be adapted to achieve smoother driving (less stop-and-go traffic). And in the longer term, automation of the driving task offers possibilities for programming the vehicles to drive eco-friendly.

TRANSFORMERS

Within the TRANSFORMERS project the aim was to reduce the energy consumption with 25% per tonne.km goods transported in real world scenarios, to achieve this, the project assessed four innovations:

- a trailer designed for increased load capacity
- mission planning and adaptation to allow an optimised journey for each vehicle combination
- a vehicle that can transform to achieve improved aerodynamics based on the mission
- 'Hybrid-on-Demand' (HoD) electric driveline

In total 13 project partners have worked together to apply a holistic view on aerodynamics improvements of the tractor-trailer combination. Since a trailer is not always filled to the brim with goods (mass limited missions, goods that cannot be stacked...), a trailer could change shape and alter the volume available for payload without compromising its loading efficiency. The trailer changes include curved front bulk head, side skirts, boat tail and 4-segments lowerable roof (See figure 9).

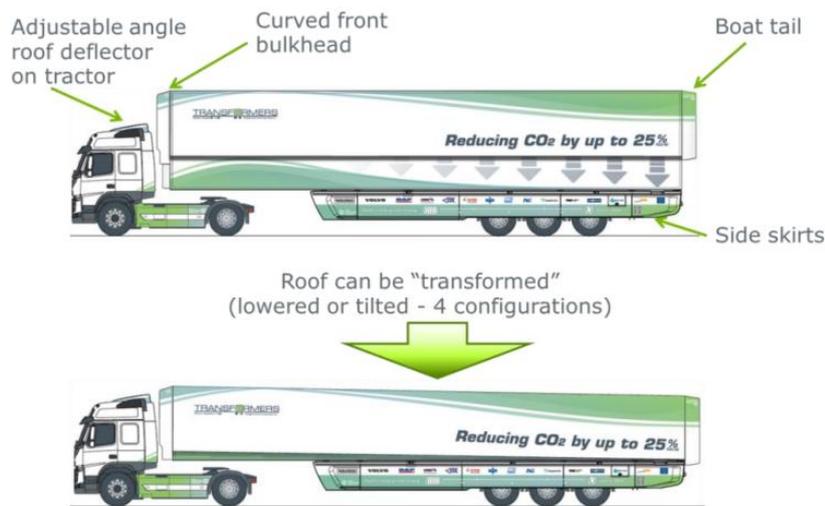


Figure 9. The adjustments in trailer design implemented the TRANSFORMER project

The demonstrator test results showed that the Hybrid-on-Demand system could result in a fuel consumption (%/ton·km) reduction of 3 to 5%, and even more in urban heavy traffic and steep elevation changes. The aerodynamic features could result in a 14% drag reduction (at 90km/h constant speed), which relate to fuel reduction of 8%. During the product a reduction of 6.5% was demonstrated, without optimised side skirts and bulkhead, so the 8% should be feasible. The improvements in loading efficiency can have the biggest impact. The use of a double floor, could lead to 10 extra pallets increase, which with the project assumption of an original cargo payload of 15 tonnes, leads to an energy use reduction up to 17% per t.km. When all TRANSFORMERS innovations are combined, a reduction in energy use per t.km of goods transported of more than 25% can be achieved for almost all mission profiles at average payload (15t).

AEROFLEX

The goal of AEROFLEX was to optimize future freight transport and multimodal transport chains, to lower the emissions and increase the transport efficiency⁷⁴. Therefore flexible and adaptable vehicles and loading units with optimized aerodynamics were developed. Together with a 'hybrid' power train (ICE engine and electrified powertrain in trailer). In addition, intelligent access policies, efficient use of road infrastructure and safety systems were investigated.

The main objectives were:

- Characterize the European freight transport market for 2040
- develop new concepts and technologies resulting in adaptable trucks with a reduced drag,
- improved safety, comfort, cost efficiency and multimodal transport
- demonstrate potential of truck aerodynamics and energy management improvements
- associated impact assessments
- drafting of recommendations for revising standards and legislative frameworks to allow the new aerodynamic and flexible vehicle concepts on the road
- achieve an efficiency improvement up to 33 % in long haulage road transport.

⁷⁴ <https://aeroflex-project.eu/>



The outcomes of the project were: i) the result of the future market study, ii) the demonstration of two EMS combinations, of which one is focussing on efficiency improvement (advanced energy management powertrain, AEMPT) and the other on aerodynamic improvements (aerodynamic features for the complete vehicle (AFCV), iii) an electric, remote controlled dolly, iv) demonstration of multimodal.

The project consisted out of two demonstrators, both EMS combinations. The first combination was a EMS 1 (60t) combination, a 6x2 rigid truck combined with a e-dolly (Smart Power Dolly) (and a semitrailer (originally developed in the TRANSFORMERS project). The demonstrator vehicle and a reference vehicle were subject to various on-road tests to demonstrate, validate and analyse the potential of the AEMPT concept to save fuel and decrease CO₂ emissions under real-world conditions. When the fuel consumption, expressed in both L/km and L/t·km, was compared between the EMS1 combination with and without AEMPT a significant fuel usage reduction was found. The absolute value of the reduction was related to the use case, however reductions between 2% and 10% were found on a L/km basis.

The second demonstrator was a EMS 2 combination, a 4x2 tractor-semitrailer –dolly – semitrailer (from the TRANSFORMER project). This combination was demonstrated with and without aerodynamic features. Simulations and wind tunnel tests showed that a reduction in drag of 17 to 27% could be expected.

Other innovations that were demonstrated were Smart Loading Units (SLU), smart power dolly (remote controlled) that can help manoeuvre EMS trailers.

The main conclusion for AEROFLEX was that EMS is a positive evolution for both the transport efficiency as the for emission reduction. EMS is compatible with other transport modes.

ENSEMBLE

ENSEMBLE demonstrated 'multi-brand' platooning to improve fuel economy, traffic safety and transport capacity. A platoon of seven trucks from different brands has been demonstrated under real life conditions, across national borders. The project started in 2018 and lasted for 4 years. The main technical outcomes of the project are collaborative AEBS system and the demonstration of multi-brand platooning. The ENSEMBLE project led to ISO/DIS 4272 Truck platooning systems (TPS).

In the first year of ENSEMBLE, acceptance criteria, a reference and the specifications were determined. During the second and third year, the reference designs was implemented on the trucks and an impact assessment was made for several criteria. Finally, in the last year, the multi-brand platoons were tested on a test track and on international public roads.

Platoons are small truck convoys, that are partly automated. Commonly, the first truck has a driver, while the other truck are driverless and follow the first truck (see figure 10). The potential of platooning can be huge, since around 14% of the total distance driven by trucks could be part of a platoon. Nevertheless, highway entrances and exits and inserting of another truck within in the platoon can impact and limit the applicability of platooning. Platooning could have beneficial results on traffic flow, however there was no clear positive impact found on fuel consumption and emissions and for other road users.

Overall, the investments related to make a truck platoon-ready was found to be less that 5k€ or less, and cost savings where on average about 3% or more, indicating that there could be a market. However, due to an inept road network configuration and a short life cycle of a commercial truck, the market uptake is almost none. In addition, (international) regulation is missing for platoon service providers.

Platooning is a promising concept, nevertheless due to technical and regulatory limits it is not applied yet. The further development and integration of platooning is now seen as a part of Cooperative, Connected and Automated Mobility (CCAM).



Figure 10. The multi-brand platoon with seven trucks demonstrated during the ENSEMBLE project

MODALES

Modales was developed to substantially reduce air pollution from all types of on-road vehicles by encouraging the adoption of low-emission driving behavior and proper maintenance choice. The project ran from 2019 to 2023 and included 16 partners, from 10 European countries and 2 international partners, representing research institutes and universities, vehicle component manufacturers, ITS- and road transport sector, legal and policy consultants etc.

The aim of Modales was to:

- (1) Understand the nature of driving behaviour with respect to vehicle emissions, by validating variables for driver behaviour and their variability (e.g. speed, road condition etc),
- (2) Correlate driving behaviour variability with real powertrain, brake and tyre emissions, by developing mathematical equations defining powertrain, brake and tyre emissions as a function of driving behaviour,
- (3) Propose and validate real-time driver assistance smartphone app for low emission driving,
- (4) Promote low-emission oriented driving via training courses and an awareness campaign
- (5) Assess the real effectiveness of on-board diagnostics (OBD) and technical inspections and investigate the legal situation of tampering in Europe, and
- (6) Assess the potential impact of diesel retrofits.

Results from Modales that are relevant to the Cloud report topic are mainly connected to gaining knowledge on eco-driving, and training drivers to drive more eco-friendly.

COFRET

The aim of COFRET was to develop methodologies and tools to calculate the greenhouse gas emissions from freight transport activity. One of the main objectives was to ensure that the methods would be used by the industry, hence during the grant agreement stage, after the project was formally awarded the grant, the



Project Officer (PO) from DG MOVE, requested that an Industry Advisory Board (IAB) be included and integrated into the project.

An important outcome of including the IAB in the project was that early in the project, after the work package that reviewed the state-of-the-practice, the IAB requested that the scope of the project be changed. The main reason was that the IAB identified the real implementation barrier was the lack of standardisation of in the market. The different methods and tools, such as Smartway, from ADEME, and the European EN 16258, were used for different reasons by different actors. One single standard that harmonized the different approaches was needed, rather than an additional method and tool.

After negotiation between the partners, the IAB and the PO, the scope of COFRET was changed towards standardising the methodology for calculating GHG emissions in freight transport.

The main results, the COFRET methodology, led to what is now commonly referred to as the **GLEC Framework**, which is the harmonized methodology for calculating emissions from freight transport chain.

Project Deliverables:

- Existing methods and tools for calculation of carbon footprint of transport and logistics, Deliverable D 2.1, COFRET project (Carbon Footprint of Freight Transport), Auvinen, H., Mäkelä, K., Lischke, A., Burmeister, A., de Ree, D., Ton, J., 2011
- Methodologies for emission calculations — Best practices, implications and future needs, Deliverable D 2.4, COFRET project (Carbon Footprint of Freight Transport), Auvinen, H., Mäkelä, K., Gjerde Johansen, B., Ruesch, M., 2012
- Assessment and typology of existing CO2 calculation tools and methodologies, Deliverable D 3.1, COFRET project (Carbon Footprint of Freight Transport), de Ree, D., Ton, J., Davydenko, I., Chen, M., Kiel, J., Auvinen, H., Mäkelä, K., 2012
- Gap analysis, Deliverable D 3.2, COFRET project (Carbon Footprint of Freight Transport), Kiel, J., Auvinen, H., Bohne, S., Davydenko, I., Diekmann, D., Krietsch, F., 2014
- Suggestions and recommendations towards global harmonisation of carbon footprint calculation principles and comparable reporting, Deliverable D 3.3, COFRET project (Carbon Footprint of Freight Transport), Davydenko, I., Tavasszy, L., Ehrler, V., Lewis, A., 2014

For further exploitation, the **International Workshop Agreement**⁷⁵ proposing the harmonized methodology was also issued.

At the last months of the COFRET project the Smart Freight Centre (SFC) was founded by Sophie Punte in Amsterdam. The aim of the organization was to establish an organization focused on reducing freight emissions at a global level, in collaboration with more regional or national green freight programs. The coordinator and several leading partners of the COFRET consortium, and the IAB together with the PO discussed the possibility of using SFC in its post-project exploitation, namely by housing the GLEC methodology and the IAB. When this happened, SFC took on the role of promoting the GLEC methodology and developing it further, while the COFRET IAB became the founding members of the GLEC Advisory Council – composed entirely of members in the logistics industry.

The end of COFRET marked the start of the global standardization of freight transport emissions calculation led by the Smart Freight Centre. With this new aim and the GLEC Framework, the next test was carried out in the LEARN project.

⁷⁵ International Organization for Standardization. International Harmonized Method(s) for a Coherent Quantification of CO2 Emissions of Freight Transport. (2015). (<https://www.iso.org/obp/ui/#iso:std:iso:iwa:16:ed-1:v1:en>)



LEARN

While the COFRET had a strong research purpose, that is to create the harmonized methodology, the LEARN had a socialization purpose.

The industry needed to see the credibility of the GLEC Framework in order to be widely accepted. The European Commission needed to emphasize the legitimacy of the standard in order to cement its position in legislation.

Thus, the two main objectives were as follows:

1. Test the methodology in real-world situations together with the industry.
2. Elevate the GLEC Framework from an industry standard to an international standard, namely an ISO standard.

The project was a Community Support Action. The main actions were engagement with the key stakeholders who were calculating emissions in freight transport, and to carry out pilots of the GLEC Framework in real-world situations. Besides industry actors, the project reached out to other programs, which had developed their own approach, which at the time were primarily Green Freight Programs. Some examples, were ADEME (France), Smartways (US), Ecostars and the Low Emission Reduction Scheme (UK), Lean and Green (NL) and Clean Cargo (BSR).

To expand the reach in Europe, the consortium worked closely with ALICE ETP-LOGISTICS.

In addition, the consortium prepared the way for engagement with the ISO Committee, by preparing a proposal for the ISO 14083. Andrea Schoen from DB Schenker, supported by Verena Ehler (DLR) and Alan Lewis (SFC) led the proposal to the ISO Committee, which showed the industry support to the initiative. The funding for Alan Lewis to eventually become project manager for the ISO Working Group was crowdfunded from the industry partners.

Some of the results and outcomes of the project include

- GLEC Framework v2
- Roadmap towards Zero-emission logistics
- Start of the ISO 14083 process
- The LEARN final conference provided

The project provided SFC with more legitimacy as a non-profit organization to advocate the harmonized emissions calculation to the industry, including the resources to provide and expand its technical competence and services.

H2Haul

The H2Haul project wants to validate the ability of FCE-HDV to provide zero-emission mobility for heavy-duty applications and will lay the foundations for the commercialisation of FCE-HDV⁷⁶.

The H2Haul project aims at developing and deploying 16 FCE-HDV. The vehicles will be deployed in four countries: Belgium, France, Germany and Switzerland. Two types of trucks will be demonstrated: 26 tonnes rigid truck and 44 tons truck-trailer combination in a variety of use cases.

In addition, three hydrogen refuelling stations for trucks will be built within H2Haul. Air Liquide developed a new high-capacity hydrogen refuelling station at a working pressure of 700 bar, the first of its kind in Europe. Two other stations, in Belgium and Switzerland, were built with project support. The two HRS built in Germany are subsidized by other programs.

⁷⁶ <https://www.h2haul.eu/>



Figure 11. The first HRS at 700 bar designed for trucks is developed in the H2Haul project⁷⁷.

At this moment, the 3 subsidized HRS are operational and the newly developed FCE-HDV will be demonstrated from the end of 2023. Currently the stations are providing hydrogen to vehicles developed in other R&I projects, like Waterstofregio2.0 and HyAMMED⁷⁸.

⁷⁷ <https://www.h2haul.eu/air-liquide-and-iveco-group-reaffirm-their-commitment-to-hydrogen-at-the-inauguration-of-the-first-high-pressure-hydrogen-station-for-long-haul-trucks-in-europe/>

⁷⁸ <https://techsnooper.io/air-liquide-va-ouvrir-a-fos-sur-mer-la-premiere-station-hydrogene-pour-poids-lourds-deurope/>



5 Implementation cases

5.1 Overview on Outcomes and Implementation cases

As stated before, BOOSTLOG aims at establishing causal links between the public R&I funding and deployment of results in the market; such links can be created through projects' Outcomes and Implementation cases. Within the BOOSTLOG project, Outcomes are primarily understood as products, services or solutions for business applications aiming at addressing Pain Points and other value-added results potentially impacting the market (by creating it or transform it), the company's operations as well as policies and regulation.

Implementation Cases are considered as outcomes where research results have been further developed and have been deployed as commercial solutions, have generated a new market or have contributed to new policies.

In the scope of the present report, all outcomes from the 8 identified projects in the area of "Efficient and zero-emission freight transport and emission reporting" have been identified and analysed with respect to their grade of implementation. It is distinguished between (1) outcomes which have been implemented in a real-life environment and which are still in operation today or further used/developed in other commercial framework – the so-called "Implementation cases", (2) outcomes which have been demonstrated during the project and/or implemented afterwards in a real-life environment, but disrupted or stopped meanwhile, and (3) outcomes, which have not yet been demonstrated or deployed in real-life operation.

In total, 23 Outcomes have been identified, thereof 4 implementation cases (= category 1), 7 demonstrations and/or temporary implementations (= category 2) and 11 outcomes without any implementation.

Acronym	Implementation case	Demonstration and/or temporary implementation	Outcome without implementation
UDRIVE			- Naturalistic driving behaviour study - Insights in parameters eco-driving
TRANSFORMERS	- Homologated trailer with improved loading capacity and aerodynamics. Ready for market uptake	- Pulling e-dolly (regulation and homologation ongoing) - remote controlled yard operations with e-dolly - e-trailer (trailer with battery pack)	- Key insights European transport market - My PUZZLE - Freight study 2040
AEROFLEX	- E-axle with regenerative braking		
ENSEMBLE		- Multi-brand platoon	- ISO/DIS 4272 Truck platooning systems (TPS) - Collaborative AEBs
Modales		- Low-emission driving app	- Methodology to optimise the driving of automated vehicles - Training eco-driving
H2Haul	- Hydrogen refuelling stations for trucks	- 16 fuel cell electric hydrogen trucks	
COFRET			- COFRET methodology - ISO International Workshop Agreement
LEARN	GLEC Framework ISO 14083 CountEmissionsEU	Methodology applied in case studies.	



5.2 Implementation cases

Four of the selected R&I projects led to implementation cases. The COFRET project led to the development GLEC Framework, which is adapted in the CountEmissionsEU proposal and a ISO standard for emission reporting. The TRANSFORMERS and AEROFLEX resulted in the development of an e-axle with regenerative braking and an innovative trailer with improved load efficiency and aerodynamics. The last implementation case is found in the H2Haul project, where the first European 700 bar HRS for trucks was developed in.

5.2.1. COFRET

Smart Freight Centre was founded during the last year of the COFRET project and has been instrumental in the past decade to develop and promote the GLEC Framework in the logistics sector, to develop it into an ISO standard, as well as to be adopted in the CountEmissionsEU proposal on transport emissions calculation and reporting. There were a couple of opportunities that came together to allow SFC to create impact based off COFRET's project results. However, this was only possible since COFRET was successful in creating results with high impact.

Some of the main reasons that COFRET was successful were:

- **The topic addressed a relevant industry question at the time.** Besides the growing environmental interest, companies were also interested in accurately calculating fuel consumption along the transport chain for financial reasons. Fuel prices were high, and the industry was still reeling from the financial crisis of 2007-2009.
- **A visionary and invested project officer from the EC.** The assigned project officer was from DG MOVE and was thus interested and knowledgeable about the transport sector rather than having a focus on research. This steered the project outcomes towards what was practical rather than what was purely academic. He only finalized the consortium grant agreement, if a strong industry advisory group was part of the project. Hence, from the beginning the project had an industry-orientation, which made the final project results high-impact for the industry.
- **Strong and engaged industry advisory board.** The project benefitted from a strong and active advisory board consisting of members of leading industry actors, such as IKEA, Scania, DB Schenker, UPS, etc. Their involvement and commitment throughout the project were crucial in guiding the project's direction, making decisions, and ensuring alignment with industry needs, i.e., to develop something that can be really used by the group it was created for. The board remained open to new members, which signaled that other industry actors were always invited to contribute to the project.
- **Permission to change grant agreement and project direction midway.** The industry advisory board wanted a shift from developing a new methodology and tool towards a harmonization of existing methods through a common framework. The project officer supported these changes to be made in the grant agreement midway during the project, which included changes with respect to timeline and budget.
- **Collaboration with DG MOVE.** The collaboration and support from two individuals in DG MOVE, , contributed significantly to the project's success, and paved the way for the follow-up EU project, LEARN. Their involvement and backing demonstrated a strong commitment from the EU side, fostering a positive environment for the project's development and for post-project uptake.
- **Industry-led ambition to standardize emissions accounting.** While what the industry wanted was an ISO norm, this could not be accomplished directly within the COFRET project due to lack of time and resources. Hence, the decision was made to produce an International Workshop Agreement, which is a "a workshop mechanism outside of ISO committee structures, following a procedure that ensures the broadest range of relevant interested parties worldwide have the opportunity to participate, and are approved by consensus amongst the individual participants in the workshops." (<https://www.iso.org/deliverables-all.html#IWA>, Accessed 31.07.2023) The IWA served in this case as



a precursor to a full-fledged ISO norm. The result, codified in an industry-approved medium, such as the IWA, sent a strong signal for relevance compared to the other, often academic, publications that were created in the project.

- **Consortium and project coordinator that rose to the occasion.** The COFRET project would not have been feasible without a strong and dynamic project coordinator, as well as the consortium partners that were willing and agile to adapt to the changing needs of the project.

In short, the individuals in the project took the initiative, in many cases, outside of the 'normal' expected effort to create lasting value from the project. From the researchers to the project officer; the industry to the public authorities; there was a concerted effort to produce what would be impactful to the industry, as expressed by the industry members themselves. Many of the same individuals would take this onwards through the GLEC, Smart Freight Centre, the LEARN project and to the ISO 14083 standard.

It could be considered that the rest of the journey from COFRET to ISO 14083 was due to its post-exploitation activities. As COFRET created the framework, the idea was to apply them in as many countries as possible. This led to Smart Freight Centre (SFC) that was still in its infancy that aimed at playing a role somewhat as a global green freight program, in alignment with and integrating with regional (e.g., Green Freight Asia) or national (e.g., Smartways) green freight programs.

COFRET contacted the founder of SFC and together with the industry advisory board, as well as DG MOVE, **made a plan to transition COFRET's framework and the industry advisory board to be hosted by SFC.** The industry advisory board became the Global Logistics Emission Council (GLEC) advisory board. The COFRET framework was reworked to become more practical in the form of the GLEC Framework publication, which provided reader-friendly (as opposed to expert-oriented) guidance into how emissions calculation should be applied.

Other milestones:

- The follow-up project LEARN, coordinated by SFC, exposed the GLEC Framework more intensively to the industry via the respective green freight programs and case studies. Close collaboration with other associations in the space, such as ALICE, played a crucial role in ensuring that the dissemination and communication activities were impactful.
- The start of the ISO working group hosted by the German norms association, DIN, led by the COFRET project coordinator also began. SFC led the work on logistics emissions calculation as project manager. The ISO 14083 was published April 2023.
- The CountEmissions EU proposal, published July 2023, will use the ISO 14083 as the calculation methodology. SFC continues to work closely with DG MOVE to support their initiative. Standardizing the fuel emission factor and intensity databases, the assurance scheme and the verification of tools, are key features that will ensure the proposal makes impactful change in the emissions reporting in the EU.

Once the CountEmissions EU proposal and the associated directives are in place, more work will need to be done to align actual implementation in the transport sector. Standardization is after all not about standardization of techniques, but standardization of the implementation of techniques. And more importantly, it is about applying the techniques to drive real-world lasting change for the sake of addressing humanity's greatest collective challenge, anthropogenic climate change.

5.2.2. TRANSFORMERS and AEROFLEX: Innovative trailer and e-axle

The consecutive projects TRANSFORMERS and AEROFLEX resulted in two implementation cases: and innovative trailer design and regenerative e-axle. The trailer designed by Van Eck Trailers in TRANSFORMERS is optimised for assignments where the trailer volume is not optimally used. The new trailer design increases the load capacity within the weight and dimensions regulations (valid at the time of the project). The trailer



had an adjustable, double floor system, which is adaptable per mission. The double floor is sectionalised, adjustable in height and the double floor can be put in place by a forklift during loading. The inner floor length of the trailer was increased by adjustments to the front bulkhead and at the trailer end, so an extra pallet would fit. In addition, the roof top can be lowered to achieve a more aerodynamic shape.

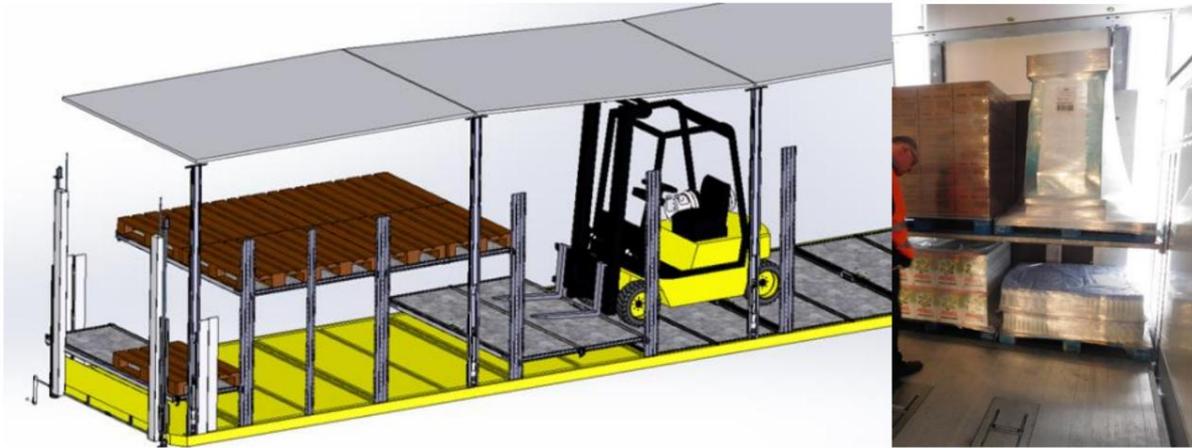


Figure 12. The innovative trailer with a moveable second floor, developed during the TRANSFORMERS and AEROFLEX project.

Further AEROFLEX adaptation on the trailer to make it compatible with other transport modes and high capacity are: i) compatibility with rail transport was proven, ii) dolly can be coupled to achieve EMS2, iii) more aerodynamic features were added and iv) cameras to estimate the cargo load were added⁷⁹. The cameras can give input to software (PUZZLE⁸⁰) that can optimize the loading of the trailer. A regenerative e-axle is implemented in the trailer and was proven successful in lowering the fuel consumption.

Now that the AEROFLEX project is finished, the trailer is homologated and will be brought on the market. The trailer is ready to be tested by interested logistic companies. We see the some of the innovations, like the tear shape and the regenerative e-axle also in commercial products of other trailer OEMs. Nevertheless, the trailer demonstrated in TRANSFORMERS and AEROFLEX is the first one were all the innovations (plus more) were in combined.

5.2.3. H2Haul: Hydrogen refuelling stations for trucks

The third implementation case that was identified were the hydrogen refuelling stations (HRS), designated to trucks, build during the H2Haul project. The station in Fos-sur-Mer (France) of Air Liquide is the first truck HRS with a working pressure of 700 bar. Currently, the mass flow of the station is restricted to mid flow (90 g/s), since hardware and fuelling protocols are missing. Nevertheless, we see that the hydrogen truck technology is making the shift of 350bar to 700bar, so more hydrogen can be stored on the truck and longer driving ranges are attainable.

This first demonstration is ground breaking and the development of it gave insights on missing hardware, fuelling protocols and regulative framework (also for the trucks).

⁷⁹ <https://www.vanecktrailers.com/nl/aeroflex-intensieveert-samenwerking-met-van-eck/>

⁸⁰ <https://demo.mypuzzle.de/aeroflex/>



5.3 Demonstrations and temporary implementations

As shown in Table 6, most outcomes of the selected 8 projects have proven their technical feasibility by demonstrations during the project lifetime. For logistics real “live” demonstrators of operation concepts are particularly relevant. Such demonstrators were performed successfully in TRANSFORMERS, AEROFLEX, ENSEMBLE, H2Haul and Modales. All these and other operation concepts worked well during the project and fulfilled their technical requirements.

6 Potential implementation paths

We end this Cloud Report with an overview of the identified potential implementation paths we should work on to make ‘Monitoring and implementing efficient and zero-emission freight transport’ a success. In addition some key factor for a successful project are given together with recommendations.

From the interviews and the analysis of the finished R&I projects, it became clear that future R&I projects about efficient and zero-emission freight transport should focus on 5 fields:

- Technical innovations
- Digitalisation
- Regulative framework
- Digital twin
- Emission reporting

Technical innovations comprehend the further development of the durability of aerodynamic improvement, trucks and trailers innovations and infrastructure. Further innovations in the capabilities of zero emission trucks (driving range, weight) will be key. Also, innovations in charging infrastructure (MCS, dynamic charging and ERS) and high capacity HRS will happen. R&I projects that lead to further upscaling and increased reliability of both zero emission trucks and their infrastructure are necessary.

In parallel to the technical R&I projects, the **regulative framework** needs to be updated, so the innovations can be demonstrated and implemented in real life operations. From the current assessment we learn that it takes time to adjust regulative framework and develop ISO norms. Therefore, the revision of regulative frameworks needs to start as early as possible. Extra legal support (especially on national level) would be beneficial.

The capabilities of zero-emission truck-trailer combinations are strongly linked to availability of infrastructure and how their operation is planned (use case dependent). **Digitalisation** and digital twins are necessary to assess the full potential of zero-emission trucks and support the implementation of these vehicles in fleet operation, which will be use case dependent. Tools to implement zero-emission truck in fleets and integrate charging and fuelling in the logistic operation are needed (route optimisation, booking of charging/fuelling slots...). Also connected vehicles that can communicate to other assets (V2X) will be needed. Special attention should be given to data quality and standardisation communication protocols.

Innovations will only be adopted in the logistic industry if there is a viable business case. R&I project should consider **ecosystem building** and explore scenarios to make the logistic innovations economically viable. Some of the logistic innovations are strongly dependent on the innovation in other industries. As an example, the sustainability of zero-emissions trucks is dependent of the decarbonisation status of the energy industry. Further research is needed to see how all industries can reach their sustainability goals.

It is expected that R&I projects on these topics will lead to implementation cases. We see that in the ongoing zero-emission truck projects (EMPOWER, ESCALATE, NextEtrucks and ZEFES), all topics are included in the project. Even digitalisation in an indirect way, since it is necessary to establish the digital twin.



As last we mention **emission reporting** as a possible implementation path. The finished project on emission reporting COFRET and LEARN have led to a real uptake of the industry. They even led to an initiative for a common framework to calculate and report transport-related greenhouse gas emissions (CountEmission EU). New R&I project on this topic funded by Horizon Europe⁸¹ are aiming to further improve the methodology and the data quality and are widening the scope.

In Figure 13 a visualisation of the potential implementation paths is given.

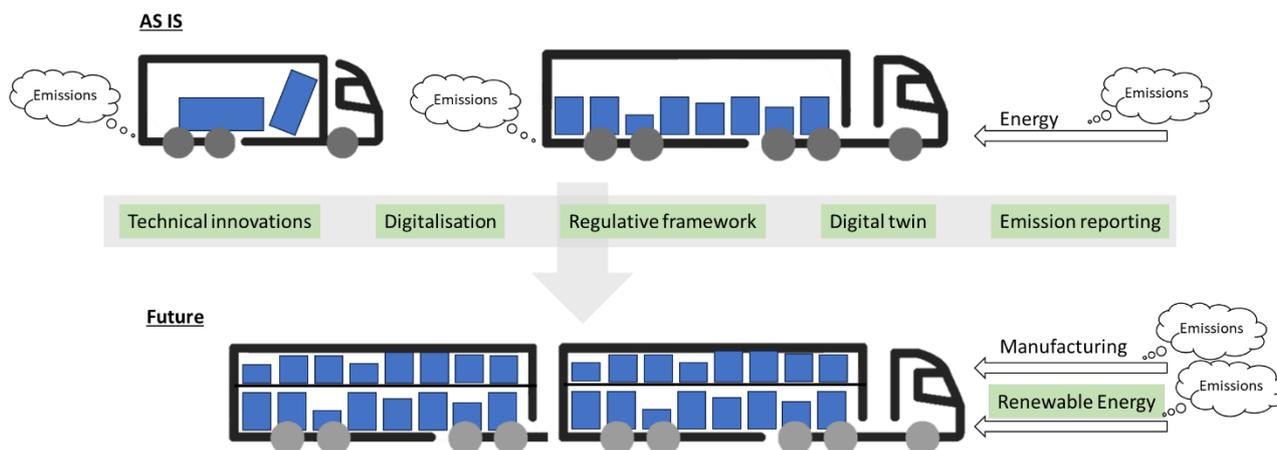


Figure 13. Visualisation of the five potential implementation pathways for 'Monitoring and implementing zero-emission freight transport'.

Overall, there can be three lessons learned from the finished projects to improve the quality of the project and its outcomes.

First of all, end users (shippers, carriers) should be active and empowered in the project. They should have at least a role as active stakeholder group member, but preferably they are funded partner. As end user, or the paying customer, they are the key for successful implementation of innovations.

The stakeholder group is also important for ecosystem building. In logistics the full value chain is interlinked, so communication between the different stakeholder groups and working together are key for successful implementation of innovations.

And as last one, we want to stress the importance of a project officer, that empowers and is willing to align with evolving needs of sector. Sometimes and adjustment of scope, even during the project, is the best thing to do. And this can only be done when the project officer is receptive for feedback from the project.

When evaluating potential implementation paths, it is also worth highlighting supporting factors for successful projects and implementations. The following factors are already published in an earlier Cloud Report, but would like to repeat them as they are general applicable.

The supporting factors can be allocated to four areas, (1) Composition of the consortium, (2) Topic/subject of the project, (3) Process of tendering/application/funding, and (4) Project execution and implementation of outcomes.

(1) Composition of the consortium

⁸¹ HORIZON-CL5-2023-D6-01-08: Future-proof GHG and environmental emissions factors for accounting emissions from transport and logistics operations



- Right mix of partners - involvement of real operating partners and the final end-user
 - Trust within consortium (complementary interests, advantages visible for all partners, partners knowing each other);
 - Same level of knowledge and “access” to the topic (skilled experts from the project partners involved in the project work);
 - Partner commitment - Sufficient efforts of partners investing in the project.
- (2) Topic/subject of the project
- Project/Solution must be economically viable;
 - Projects must be linked to real practice;
 - Project must consider European decision-making environment (entity and rules / priorities);
 - Focus on a fewer, but dedicated topics better than including everything.
- (3) Process of tendering/application/funding
- National projects often allow more efficient consortia (limited number of partners, complementary interests);
 - Flexibility for project design in application phase, focus on project result (e.g. demonstrator, product), NOT on tasks/work content.
- (4) Project execution and implementation of outcomes
- Rules in the grant agreement, if deployment does not happen to hand over IPRs e.g. to a “Implementation agency”;
 - Idea: dedicated consultant paid by EU for project documentation and administration (selected by the consortium); - Stronger commitment requested to exchange information – strong stakeholder board
 - Non-feasibility of a solution might be also an outcome.



Annex I – Semi-structured interview guide

Cloud Report: Efficient and zero-emission logistics

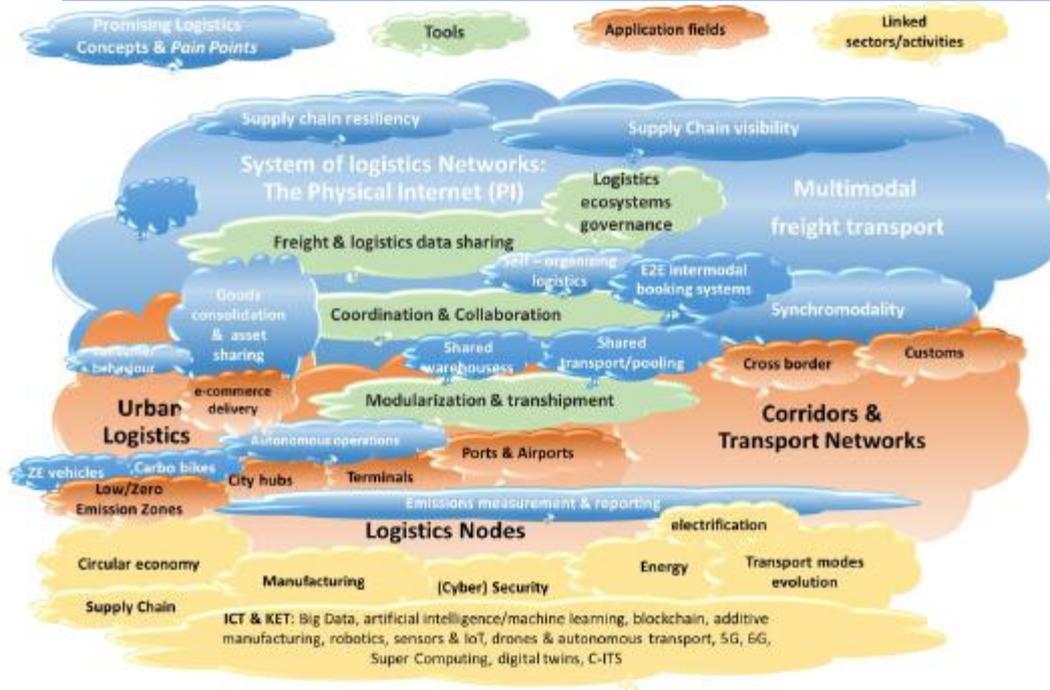
1. Project introduction

For more than two decades EU has invested in research and innovation (R&I) through various Framework Programmes, e.g. FP5 (1998-2002), FP6 (2002-2006), FP7 (2007-2013), and the ongoing HORIZON 2020 (2014 – 2020). This has contributed to the development of the logistics sector through the creation of new companies, implementation of concepts in practice and through science based regulation. The BOOSTLOG project aims to boost impact generated from future EU funded R&I projects to contribute to EU policy objectives, address societal challenges and increase EU's competitiveness. The project will map more than 160 projects funded by FP5, FP6, FP7 and Horizon 2020, and identify successful implementation cases into the market and regulations and will develop actionable reports on various subjects prioritized by stakeholders. The project will assess the impacts generated, identify gaps and priorities for future funding programmes.





2. Cloud and subclouds diagram



- Do you miss any important cloud/subcloud?

3. Most relevant projects in the cloud

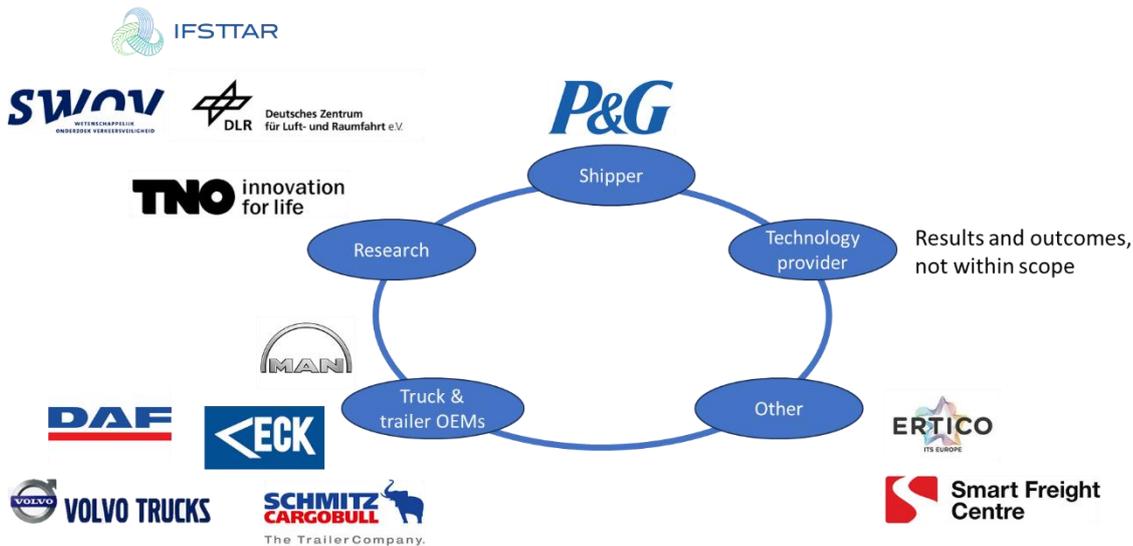
Efficient and zero-emission logistics

LCA emissions reporting

- Do you miss a relevant R&I project not included here?



4. Organizations with highest participation in relevant projects in the cloud



- Do you miss an important/relevant organization with good R&I results in this area?
- If yes? Which organizations and for which results? Who is the contact person?

5. Trends and societal drivers relevant/addressed for the Cloud

LIST of trends and societal drivers:

Climate change, electrification, emissions, (energy) efficiency **others**

- Do you agree with this list of External Factors?
- Which are for you the 2/3 most critical/relevant?

6. Relevant EU policies addressed

LIST of policies addressed by the cloud:

- **The European Green Deal**
 - **Fit for 55**
- **Economy that Works for People**
- **Promoting our European way of life**
- **A Europe fit for the digital age**
- Which other policies you know are also relevant?
- Which is the EU policy this area has a greater impact?

7. Project participation of your organization per Cloud

- Have your organization participated in other relevant projects? Which ones? Could you share some information references?
- Which are the most Relevant/Key R&I results project deliverables for each project? Could you share them with us?
- Which have been the key partners on those projects à Generating results/outcomes and after project implementation?
- Overall, which is your conclusion on the projects in terms of:
 - Progress made
 - Level of adoption of results
 - Which have been for you the 2/3 key barriers for adoption?



- Which would you think is the best (or best 2 projects) and why?

8. Project Outcomes

- Do you have any outcome out of these projects in this field?
- If a research center, is it your ambition to transfer/implement the Knowledge?
 - How your organization address that?
 - Through Market agreements on Knowledge Transfer to Companies.
 - Spin offs
 - Other
- What is the main barrier to reach the market you faced:
 - Financing for further development.
 - Finding right (industry) partners
 - Value proposition towards customers.
 - Business models.
 - Other?
- Do you have outcomes out of R&I projects in other BOOSTLOG CLOUDS?

9. Implementation Cases

- Do you know any Implementation Cases out of these projects?
- If yes, which entity was the R&I/Outcome owner and which entity was the Innovation Seeker.
- Would you like ALICE/BOOSTLOG to promote the Implementation Case?

10. Final comments

- How could we improve the interviews?
- Would you like to join a workshop in which we will share the aggregated results and discuss conclusions with your peers?
- Any further comment.



We would like to thank the experts the we have interviewed and helped us to determine the project outcomes and implementation cases.

Table 7: List of interviewees, their organisation and the project they have worked on

Name	Project	Organisation
Sergio Barbarino	TRANSFORMERS	P&G
Business developer	H2Haul	DATS 24 (Colruyt Group)
Ton Bertens	AEROFLEX, TRANSFORMERS, (ZEFES)	Van Eck Trailers
Verena Ehrler	COFRET, LEARN	DLR
Marika Hoedemaeker	UDRIVE	TNO
Ben Kraaijenhagen	AEROFLEX, TRANSFORMERS, ENSEMBLE, (ZEFES)	(former) MAN
Alan Lewis	COFRET, LEARN	Smart Freight Center
Paul Mentink	AEROFLEX, (ZEFES, NextETruck)	TNO
Sophie Punte	COFRET, LEARN	Smart Freight Center
Mats Rosenquist	ENSEMBLE, AEROFLEX, TRANSFORMERS, (ZEFES)	VOLVO
Isabelle Schnell-Lortet	ENSEMBLE	VOLVO
Cor Van der Zweep	AEROFLEX, TRANSFORMERS	UNIRESEARCH
Dehlia Willemsen	ENSEMBLE	TNO
Andrew Winder	MODALES	ERTICO
Ted Zotos	MODALES	IRU