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SUSTAINABLE MOBILITY

Lowering your emissions through innovation in transport and energy infrastructure

Energy transition in Luxembourg's logistic sector

Decarbonising Medium- and Heavy-Duty Vehicles

23rd May, 2023

Management summary

1. Commercial offer of Low and Zero Emission MHDVs in Luxembourg

ZEMDHV market development

Within the first chapter the developments in the market of ZE-MHDVs are examined and the different types of zero emission technologies are compared. Overall, there is a growing availability in the ZE-MHDV models manufactured by OEMs in all weight classes. The availability of FCEV is currently still very limited. Currently there over 41 different BEV models available, and OEMs are announcing more to come soon. Also, the range of these BEVs seems to grow steadily.

The expected developments in ZE-MHDV are that these trucks are going to be offered with a variety of battery sizes. Also, it is expected that the sizes of the batteries are increasing without a more negative impact on the payload due to improved battery technology. On average, purchase prices seem to be relatively stable compared to the development of the purchase prices of diesel trucks. It is expected that the purchase prices of BEV trucks will be lower in the future due to economies of scale, and further improved technology. The speed of fast charging is also increasing, with current models capable of charging at up to 250kW. Future technologies with charging speeds over 1MW are expected to be commercially available in 2024.

TCO

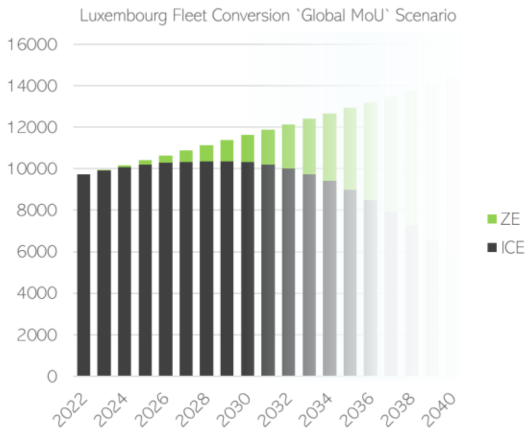
The Total Cost of Ownership (TCO) is a standardised calculation of running cost by unit. The calculations have been performed to understand how the different drivetrain technologies perform in terms of economics. For all segments, TCO parity between ICE and BEV is expected between 2025 and 2030, but a significant gap exists in 2022. For FCEV there is currently no expected TCO parity with either ICE or BEV, mainly due to the high purchase price as well as energy costs.

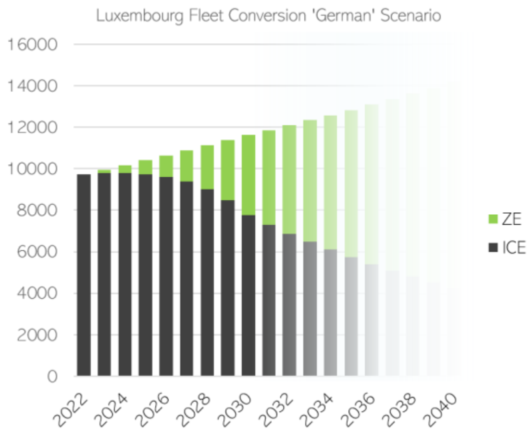
Energy price difference between electricity, diesel or hydrogen has a huge impact on the final TCO. The various scenarios of increasing or decreasing fuel prices are very important to consider and monitor, because the economic viability significantly depends on this factor.

Potential of decarbonisation and operational feasibility

As well as assessing the economic performance of ZE alternatives, the operational suitability of the different technologies for the Luxembourgish fleets needs to be considered. This mainly has to do with the size of the battery and the efficiency of the Battery Electric MHDV, as the range on one battery charge is limited. Most of the daily distances driven by trucks in Luxembourg can be achieved by BEV alternatives. The current ranges of BEV trucks are sufficient to cover these distances utilising a single (standard) charge (usually overnight). From a technical / operational point of view, the majority of N2 rigids and N3 rigids could easily be replaced by BEV alternatives without considering the complexity and the cost of fast charging during the day. For the N3 long haul trailer units, most of these vehicles are operating above the 300km daily which would require significant operational duty changes or high-powered fast charging to operate on BEV.

The decarbonisation potential in Luxembourg is indicated in 2 scenarios to estimate the speed of the energy transition for the road freight transport fleet in Luxembourg.





The German scenario is more progressive than the Drive to Zero Global MoU scenario. The phasing out of ICE trucks will take much longer in the Global MoU scenario, in turn reducing the energy transition of the logistic sector in Luxembourg.

Hydrogen logistics market size scenarios

The hydrogen demand scenarios calculated, show the potential ramp up of hydrogen trucks in line with ZE truck uptake commitments plus different possible levels of H2 truck adoption to 2030. We have considered just tractor trailer trucks with daily average mileages >400km as these are more likely to be unfeasible to operate as BEVs. Even in the high demand scenario, this results in a relatively low number of hydrogen stations by 2030.

Fleets travelling nationally, but undertaking high mileages are likely to favour rapid/opportunity charging of BEV trucks. This will help maximise the BEV asset and will provide lower total cost of ownership compared to hydrogen. The supporting data used in the development of the scenarios suggests that the majority of Luxembourg haulage is international.

Alternative fuelled MHDVs in the Luxembourg fleet

The truck sector is on a path to ZE technology, but true zero emission options, particularly for larger, high mileage vehicles, are not yet available on the market. To 2030, there are some alternative fuel options that could significantly reduce the emissions of the Luxembourg truck fleet.

The simplest option is HVO as this is a drop-in fuel which can be used in standard vehicles offering WTW emission reductions of over 90%, albeit at a price premium. High biodiesel blends also offer emission reduction but is only likely to be taken up in niche applications by some fleets as the organic nature of the fuel makes fuel management problematic. CNG will not assist in emission reduction unless biomethane is used. H2 ICE may play a role from 2025 onwards, but this will depend on the availability of hydrogen and proof from real-world trials that H2 ICE engines offer better NOx and PM emission performance than Euro VI and Euro VII diesel. Any fiscal policy aimed towards the alternatives mentioned above (biomethane and HVO) may generate short term CO2e emission savings however these will remove focus from ZE options. This decade of incentives in ZE trucks is likely to be a critical factor (learning on use, operations, infrastructure, maintenance, supply chain set-up, skills) to allow successful adoption when costs reduce ready for mass market adoption.

2. Review of European financial aid schemes and recommendations for Luxembourg

In recent years many EU countries have developed state funded financial aid schemes for sustainable vehicles and infrastructure, such as purchase and tax incentives. This chapter gives an overview of the financial aid schemes implemented and an assessment in terms of their effectiveness.

Publicly financed incentives have proven to be an effective catalyst and temporary fix for the initially higher purchase prices of electric vehicles whilst production volumes are increasing to eventually bring prices down. They can kick-start and accelerate road freight's zero emission transition, a sector driven by both technological and economic considerations.

Financial incentives - One-time benefits

Since most of the countries in this study have limited purchase tax on freight vehicles, it is not a significant steering mechanism for policy makers to change the purchase cost and therefore the TCO. An increase to the purchase tax of non-ZE trucks can be considered, but a one-time benefit via a purchase subsidy is more common. Considering the dynamics of the Luxembourg truck fleet (internationally orientated) the impact of ZE kms will also be applicable outside Luxembourg's borders. Purchase subsidies for chargers should also be considered, as they are inseparably linked with ZE trucks and do impact operator CAPEX.

Since the purchase subsidy for ZE trucks is arguably the most evident type of incentive, the study analysed these incentive systems in multiple countries in depth to provide incentive design recommendations. Generally, countries design their ZE MHDV subsidies as either covering a percentage point difference between the purchase price of a new ZE MHDV and a diesel truck or as a fixed per-vehicle sum. Austria, Germany, and France have the most generous programs in place covering 65% and 80% of the difference in vehicle price between a ZE MHDV compared to the diesel, thereby making an appealing case for hauliers to transition and eventually benefit from the more attractive TCO of a ZE MHDV. These countries support hauliers with the maximum aid allowed per-vehicle under EU state aid rules, which is 40%. Most other European countries cover between 20%-60% of the cost difference between ZE MHDVs and conventional diesel trucks.

Most member states offer insufficient compensation, either in terms of the per-vehicle spending or the program's overall budget. Long application cycles with heavy administrative processes as reported in Germany and France inhibit SMEs from making use of the funding and transitioning. For them, uncertainty of the timeline and administrative resources pose a bigger burden.

About the process of the recommended state aid for Luxembourg, we advise a one-stage application process, with multiple (2-3) application rounds per year. It should be a competitive application process, where applicants are ranked, based on the selection criteria, discussed in detail in the report.

Financial incentives - Recurring benefits

Implementing a differentiated policy with regards to road tax and/or toll for ZE trucks is the most obvious incentive. When the incentive of lowering or exempting ZE trucks from road tax is only applicable for Luxembourg registered vehicles, the impact is limited. Since the number of non-Luxembourg registered trucks driving within or through Luxembourg represents 64% of total kilometers, it is wise to also include those vehicles. The implementation of a (kilometer-based) road toll, also applicable for non-Luxembourg registered trucks, could be a powerful incentive tool.

Facilitating public charging

To stimulate the uptake of ZE trucks a supportive network of Ultra-Fast Chargers is necessary. This network will also be a necessity for internationally operating trucks, either Luxembourg or non-Luxembourg registered. The proposed AFIR from the EC is the regulation for countries to create this type of network.

Other recommendations

Combine incentives for ZE trucks with disincentives for non-ZE trucks. Raising awareness and knowledge is crucial. The lack of understanding the possibilities often withholds uptake of new technologies. Providing knowledge and raising awareness of ZE options can be done by providing tools, organising events, or distributing 'knowledge vouchers' where selected consultancy firms can help the transport companies in investigating the opportunities, etc. The impact of Zero emissions zones can be significant, as it will impact all transport organisations who operate in these zero-emission zones. These zones are implemented by municipalities but should be supported (or even initiated) by the national government. Stimulate all ZE trucks (both BEV and FCEV). Aim to be technology neutral and focus on the ZE applications. On the other hand, it is smart to consider the effect on uptake of ZE-MHDVs per spend euro. Support favourable finance for ZE-trucks: Since the purchase price of ZE-trucks is significantly higher, it is expected that the transport companies will need support for low(er) interest loans.

1. Introduction

Medium and Heavy-duty diesel vehicles (MHDVs) contribute significantly to greenhouse gas emissions, pollution, and health impacts through their use of greenhouse gases. To reduce emissions, governments around the world are transitioning away from diesel MHDVs and toward zero emission MHDVs. In order to reduce the greenhouse gas emissions, it is necessary to shift from HDVs to alternative fuel-based vehicles.

To make this shift happen the Luxemburg government set up the Tripartite agreement in March 2022:

« Mise en place d'un futur régime d'aides en faveur de l'acquisition de véhicules propres: En complément du futur régime d'aides en faveur de l'installation d'infrastructures de charge (projet de loi déposé), le Gouvernement s'engage à mettre en place une aide incitant les entreprises à convertir progressivement leur flotte en véhicules (camionettes, camions) zéro carbone ».

Luxembourg's road freight sector, like all sectors of the economy, needs to reduce its carbon footprint over the next decade if it is to succeed in the energy transition. In Luxembourg, road freight transportation is an integral part of commercial, industrial, and logistical activities. It is essential to reduce CO2 emissions from road freight transport while maintaining the competitiveness of the companies involved, so that the government's CO_2 emissions targets can be reached.

Cenex and FIER were appointed in August 2022 to carry out a study to inform the transition of road freight towards zero CO2 emissions. The main objectives of the study are:

- The current and future (up to 2030) market availability for zero and low emission MHDVs;
- The cost performance of zero and low emission N2 and N3 alternatives to Internal Combustion Engine (ICE) technology, from a Total Cost of Ownership (TCO) perspective that includes costs for associated energy infrastructure provision;
- The potential need to design an aid scheme for N2 and N3 vehicles based on the above economic performance factors in addition to operational suitability;
- The need for charging and refuelling infrastructure to be deployed at a site-level (e.g. depots, warehouses, logistics sites, etc) to inform the planning of grid re-enforcement and/or hydrogen (H2) generation and distribution where required.

The study comprises four main work packages with specific outputs and this is reflected in the structure of the final report. Work Package 1 (WP1) examined the state of the market for low and zero emission MHDVs and their comparative running costs and uptake potential in Luxembourg. Outputs include:

- A custom database on low and zero emission MHDVs;
- A comparison of TCO of these vehicles versus ICE without subsidy;
- The number of existing vehicles that could be replaced by 2025 and 2030 and map of where uptake will happen by Canton;
- Alternatives to electrification examined for vehicles where this is not economically or technically feasible. Recommendation of whether H2 will be significant domestic solution and expected domestic demand.
- Additional analysis of CO2 and air pollution reduction benefits based on the expected uptake scenarios, not included in the original scope, which was agreed at project initiation. This can be found in section 4.3.

Work Package 2 examined the current range of financial aid incentive schemes available across European neighbours, with outputs including:

1. A review of EU-wide incentive schemes;
2. TCO outputs from WP1 adjusted using incentive schemes identified;
3. Best- and worst-case scenarios produced for MHDV decarbonisation along with TCO outputs for each incentive scheme;
4. A recommendation of the optimum state aid scheme for Luxembourg.

2. Commercial offer of Low and Zero Emission MHDVs in Luxembourg

2.1 Database of available and upcoming low and zero emission MHDVs

This work package examined developments in the market of low and zero emission MHDVs, compared the different types of low and zero emission technologies and provides a more detailed analysis of battery electric vehicle (BEV) availability. A more in-depth consideration of the applicability of these alternative technologies to the logistics sector is covered in section 4.

2.1.1 General overview of low- zero emissions technologies

Hybrid Electric Vehicle (HEV)

A hybrid vehicle has two power sources. For trucks, this is usually electrical motors powered by batteries and an internal combustion engine (ICE) powered by another fuel, such as diesel. The batteries are charged by using regenerative breaking, and/or by a generator connected to the ICE. Since most batteries on HEV's are relatively small, the zero-emission range is also small. For example, the 30 kWh in the Scania HEV has a zero-emission range of 17 km.

A HEV cannot be charged by a cable meaning the charging of the vehicle is heavily depended on the type of usage. The HEV technology will be most effective if there is more regenerative breaking possible, meaning lower speeds with more stop-and-go motions. Therefore, HEV technology can make a truck more fuel efficient and is capable of driving zero emission for short distances. Given the limited focus on HEV technology from OEMs, the HEV market is rather small.

Plug in Hybrid Vehicle (PHEV)

The plug-in hybrid electric vehicle (PHEV) is a HEV with the option of recharging the batteries by a charger. There are only a small number of PHEV trucks available on the market. The PHEV Scania truck has a bigger battery (90kWh) and a longer range (60km) compared to their HEV model. The idea is that the truck will keep the extended range of a diesel-powered truck but can run emission-free when needed. DAF have produced a PHEV and it is currently being tested in a pilot study. It is unknown if and when this PHEV will come in production.

Since PHEV trucks are also equipped with an ICE motor, they cannot be classified as an 100% zero emission vehicle. In addition, no standardised monitoring system exists to check if, for example within geo-fenced city centers, the truck is powered exclusively by electric motors, which makes it difficult for policymakers to include in low and zero emission transport regulations.

Biodiesel

The two most widely used biodiesel fuels are Fatty Methyl Ester (FAME) and Hydrotreated Vegetable Oil (HVO). FAME can be produced from vegetable oils, animal fats, or water cooking oils[1]. Almost all trucks can run on biodiesel.

Analysis by the European Commission shows that using FAME increases transport emissions by almost 4% compared to regular diesel. According to forecasts of biofuel demand provided by the EU Member States, as well as estimates of indirect land-use change emissions for different biofuel feedstocks, indirect land-use change is likely to contribute significant greenhouse gas emissions, which may offset some or all of the greenhouse gas emissions savings of individual biofuels. This is since nearly all biofuel production in 2020 was derived from crops that could also be grown for food[2].

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[1] https://www.etipbioenergy.eu/fact-sheets/fatty-acid-methyl-esters-fame-fact-sheet#:~:text=Rapeseed%2C%20sunflower%2C%20soybean%2C%20palm,simultaneously%20during%20the%20transesterification%20process.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32015L1513

Biofuels, which include bioethanol as well as biodiesel, are forecast to have lifecycle greenhouse gas emissions similar to or higher than fossil fuels - including indirect land use change (ILUC).[3] In conclusion, biofuels can only reduce emissions if they meet certain sustainability criteria, which is currently not yet the case.

CNG (Compressed Natural Gas) / LNG (Liquefied Natural Gas)

Trucks powered by gaseous fuels have been available for some time. LNG and CNG are derived from natural gas, with LNG being liquified at very low temperatures and CNG being compressed at high pressure. Scania, Volvo and Iveco offer trucks powered by these alternative fuels.

With regards to LNG, the CO_2 emissions are lower than in a diesel equivalent. However, according to T&E and Graz University of Technology, the well-to-wheel emissions from these trucks, looking at 20 years GWP (global warming potential) the LNG truck had higher emissions than the diesel truck (13.4% higher). Within the same research it was also identified that the LNG truck produces more particulate matter (PM) emissions.

In trucks, burning CNG emits greenhouse gases in the same range as best-in-class diesel equivalents.

FCEV (Fuel Cell Hydrogen Vehicle)

FCEVs use hydrogen to produce electricity with an onboard fuel cell. Some of the electricity is used right away and some is stored in a battery. Electricity generated by recapturing brake energy is also stored in the battery. A FCEV has a fuel cell stack, a compressed hydrogen storage tank, and a onboard battery pack to absorb peak engine loads[4]. Due to the high mass energy density of hydrogen, FCEVs are considered a solution to decarbonize transport.

The amount of energy needed for a fuel cell vehicle is double what is needed for a battery electric vehicle[5]. In conjunction with the roll-out of maturing renewable power generation technologies and capacities, costs of production for Green Hydrogen are expected to decrease markedly as manufacturing capacity for more efficient and cost-effective electrolysers grows.

The storage and transportation of hydrogen is more complex than that required for fossil fuels. This implies additional costs to consider for hydrogen fuel cells as a source of energy[6].

HICEV (Hydrogen Internal Combustion Engine Vehicle)

The HICEV uses a modified version of the conventional ICE. The absence of carbon in the fuel means that no CO_2 is produced, which eliminates the main GHG-emission of a conventional ICE. However, the HICEV can produce NOx. As such, HICEV are not considered zero emission.

Today, Hydrogen ICE trucks are in the development and demonstration phase with few vehicles available from low-volume providers. OEMs are exploring the technology, but introduction is highly dependent on future regulations.

The amount of energy needed for a HICEV is four times what is needed for a battery electric vehicle. This implies a much greater demand for additional renewable energy to produce the hydrogen needed for the same transport work.

Hydrogen is as clean as the electricity used to produce it. It is currently mainly produced from fossil fuels (methane gas reforming), with sustainable green hydrogen only a fraction of hydrogen produced today. The only sustainable and scalable way to produce hydrogen is to use 100% renewable electricity and, to ensure that the production of hydrogen and e-fuels does not displace the use of renewable electricity from other sectors[7].

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[3] https://www.transportenvironment.org/discover/biodiesel-increasing-eu-transport-emissions-4-instead-cutting-co2/

4 https://www.transportenvironment.org/wp-content/uploads/2021/07/2020_06_TE_comparison_hydrogen_battery_electric_trucks_methodology.pdf

5 https://www.transportenvironment.org/challenges/energy/hydrogen-efuels/

6 https://www.twi-global.com/technical-knowledge/faqs/what-are-the-pros-and-cons-of-hydrogen-fuel-cells

7 https://www.transportenvironment.org/challenges/energy/hydrogen-efuels/

BEV

Battery Electric Vehicles (BEVs) use battery packs to power electric motors for their propulsion. The most common way of charging is by a cable, although alternatives are being investigated. BEV technology is being offered by the majority of truck manufacturers, with the majority of existing and new OEMs making public statements stating it as their primary zero emission propulsion solution. Also from a Technology Readiness Level (TRL), BEV is ahead of other ZE alternatives.

Like FCEV, the source of the energy is of critical importance to any associated emission reduction. The use of renewable electricity accelerates the reduction of greenhouse gas emissions from road transport and improves the carbon footprint of an electrified vehicle.

One of the main challenges for BEV is availability and speed of charging infrastructure. It is expected that the majority of BEV MHDVs will charge at depot locations, but there will also be a need for the roll out of high powered public charging to support operational distances greater than those capable with existing battery capacities.

Comparison of zero- emission technologies

This table gives a general overview comparison of CO2 intensity and air quality. FCEV and BEV are the two zero-emission technologies in the table, with almost similar advantages and disadvantages. Both technologies are further discussed and analysed in the database.

Emissions	**Bio/synfuel**	**Hydrogen internal combustion engines (H2-ICE)**	**Hydrogen (H2) fuel cell**	**Battery electric**
CO2 intensity	CO2 intensity depends on source of biomass/carbon	Zero/minimal CO2 if using green/blue H2	Zero/minimal CO2 if using green/blue H2	Zero/minimal CO2 if using green energy
Air Quality	NOx1 and particulate matter emissions similar to diesel	No significant Nox emissions with SCR aftertreatment	Zero emissions	Zero emissions

Variations across categories High performance, Medium-high, Medium-low, Low performance

Figure 1. Comparison of the Four zero-emissions technologies, well-to-wheel – source McKinsey updated by FIER[8]

[8] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-hydrogen-combustion-engines-can-contribute-to-zero-emissions

2.1.2 Database of BEV, FCEV and PHEV MHDV options

A collection of vehicle information has been gathered from existing databases such as Low Emission Commercial Vehicle Finder and the European Alternative Fuel Observatory (EAFO), and the internal databases of vehicles compiled by FIER and Cenex through their extensive work in this sector. The resulting database has been verified with truck dealerships and contains the most up-to-date information available.

In the truck industry standardised information is not commonly available, due to the large number of options and adjustments offered. Where models are yet to be released some of the information is sometimes missing or unclear. For the full database, please see the excel file.

	Source	General Info									Availability					Range and efficiency		
	Info source	Company	Brand name	Drivetrain	OEM/ Retrofit	GTW in ton (max)	Weight Self	Chassis	Axles	Photos	Available in Market? Year	Price (Euro)	Price (Euro) (max)	Availeble since (year)	Available from (Only if it's not yet in the market)	Range as specified by manu. In km (if applicable smallest batter	Range as specified by manu. In km . Max (if applicable biggest batter	Avg. consumption in km/ kwh or (km/100kg)
2		Bollinger	B4	BEV	OEM	7.2		CAB			N		40000			160	320	
2		BPW	Bax	BEV	OEM	7,49					N					130	200	1,82
2		BYD	6F + 6F ER	BEV	OEM	11,6												
1		DAF	CF FAN Electric	BEV	OEM	29		Rigid	6x2	https://www.daf.com/	Y						250	1,43
1		DAF	CF FT	BEV	OEM	37		Tractor	4x2		Y						220	1,43
1		DAF	LF	BEV	OEM	19		Rigid	4x2	https://www.daf.nl/-	Y						280	1,43
1		DAF	CF Hybrid Innovation	PHEV	OEM	36		Tractor	4x2		N						50	
1		DAF	XD Elecric	BEV	OEM	28		Tractor	4x2		N				2023	200	500	
2		Dennis Eagle	eCollect	BEV	OEM	26		Rigid	3 axles		Y							
2		E-Force One	EF18	BEV	Retrofit	44	18				Y						450	1,25
2		E-Force One	EF26	BEV	Retrofit	44	26				Y						450	1,25
2		Electra Commercial	Deliver-E	BEV	Repower	7,5		Tractor	4x2		N							
2		Electra Commercial	Deliver-E	BEV	Repower	7,5		Tractor	4x2		N							
2		Electra Commercial	Deliver-E	BEV	Repower	11		Tractor	4x2		N							
2		Electra Commercial	Deliver-E	BEV	Repower	11		Tractor	4x2		N							

Figure 2. Example overview of database of low en zero emissions MHDVs

A comparison of OEM BEV trucks is presented below in two subgroups based on their chassis: Rigids and Tractor units.

Rigids

In this market several OEM truck manufacturers offer BEV-trucks including DAF, MAN, FUSO, Mercedes-Benz, Renault, Scania, and Volvo. The Gross Train Weight (GTW) or maximum permitted combined mass of the vehicle and attached trailer. of the available models varies from 7.5 to 64 tons. There are batteries of various capacities (gross) ranging from 83KWh to 624kWh which can travel from 100 kms up to 560 kms.

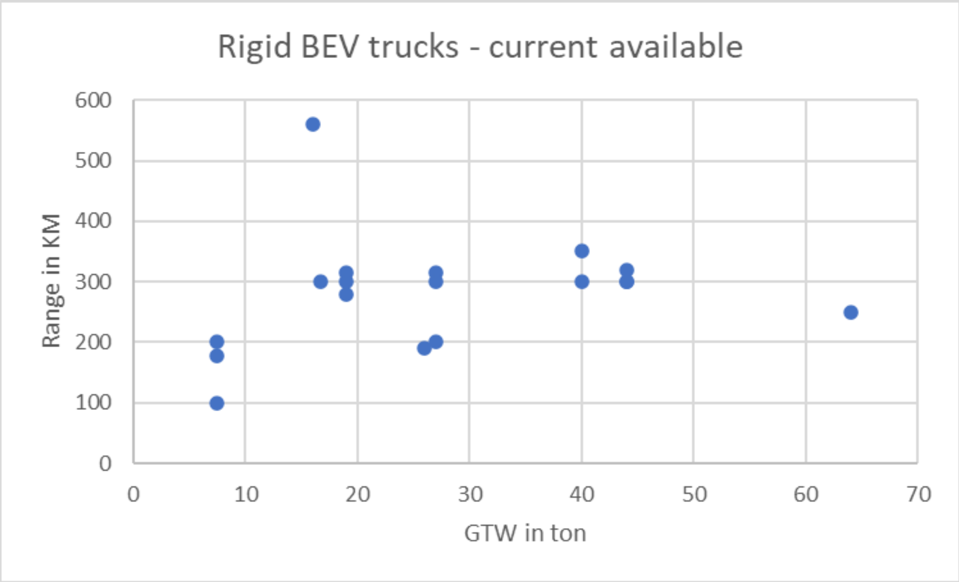

Figure 3. Overview of Rigid BEV trucks comparing GTW and Range in KMs

OEMS are offering BEV rigid trucks in all weight classes. Except for a couple of examples, most of these vehicles are able to drive over 200km on one battery charge, with a small number capable of between 400 and 560 kms.

Another development worth noting is that some OEMs are offering different battery sizes to meet the demand of their customers. This effects the cost price of the truck, the cargo weight and the available range.

Tractor units

OEM companies including Mercedes, Scania, Volvo offer tractor units.

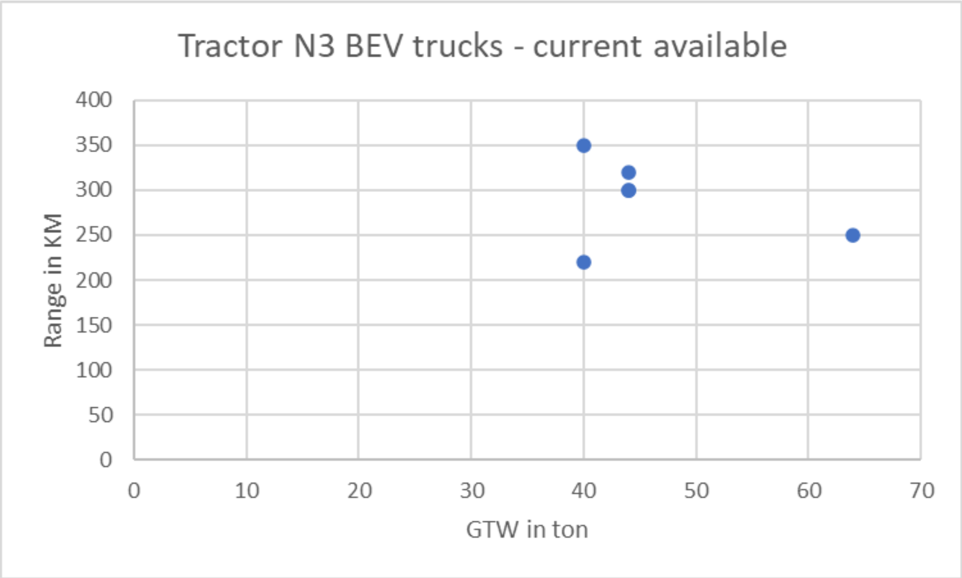

Figure 4. Overview of N3 BEV tractors comparing GTW and Range in KMs

The figure shows the relation between range and GTW of BEV OEM tractor units in the market. As presented in the figure all of the models have a weight between 40 and 64 tons. There is no truck with a range under 220km.

Range overview of currently available e-trucks

Summarizing the range of current available e-trucks is shown below in the graph. There is an additional split between the N2 rigid and N3 rigids.

Figure 5. Range of current available e-trucks (per category)

2.1.3 Expected trends in ZE MHDV development 2025 – 2030

ZE truck manufacturing is undergoing rapid development. Although truck manufacturers are offering BEVs, (P)HEVs and FCEVs, the majority are currently focussing on the more mature BEV technology. Accordingly, in the near term this ZE technology seems to be emerging as the preferred choice for truck propulsion. Technical breakthroughs with regards to other type of ZE technologies may change this.

While truck manufacturers are often not clear about their technology roadmap or availability timeframes, there are some discernible trends:

- Trucks are going to be offered with a variety of battery sizes and drive trains;
- The sizes of the batteries are increasing without a more negative impact on the payload due to improved battery technology;
- On average, purchase prices seem to be relatively stable compared to the development of the purchase prices of diesel trucks. It is expected that the purchase prices of BEV trucks will be lower in the future due to economies of scale, and further improved technology (see TCO calculations in section 2;
- Charging is gradually evolving from AC to DC, which results in a lighter and cheaper truck, but creates the need for dedicated DC truck chargers.
- The speed of fast charging is also increasing, with current models capable of charging at upto 250kW. Future technologies with charging speeds over 1MW are expected to be commercially available in 2024.

2.2 Total Cost of Ownership (TCO) assessment and technology roadmaps

The starting point of assessing the viability of alternatively fuelled vehicles is to understand how different drivetrain technologies perform in terms of the economics of their operation. This is expressed in terms of their Total Cost of Ownership (TCO), which is a standardised calculation of running cost by unit of distance. A comprehensive overview of TCO comparisons between BEVs, FCEV and Diesel MHDVs has been created for this study. Our starting point was to understand the TCO without accounting for governmental incentives, and thus the calculations in this section do not include any purchase subsidies or taxes, road taxes or tolls.

To calculate the purchase cost, the capital expense (CAPEX) of trucks and charging infrastructure has been collected. The expected residual (or resale) value is calculated based on existing research (CENEX, FIER and external) and includes potential second life applications of components (e.g., batteries used for stationary energy storage). In a recent study, the battery estimated residual value for second-life applications is assumed to be 15% of the battery original cost (ICCT 2021[9])

For the operating expense (OPEX) calculation the energy costs (renewable energy and fuel, grid connection fees), cost for service, repairs, and maintenance, and insurance costs were used. Next to the TCO assessments of the current technologies, the future TCO values for 2025 and 2030 are also estimated.
A comprehensive Excel file has been developed showing purchase price figures and TCO comparisons between different powertrain types for 2022, 2025 and 2030.

2.2.1 Luxembourg MHDV sector analysis

The analysis of the Total Cost of Ownership (TCO) structure began by formulating use cases to enable the examination of a representative sample. This was accomplished by utilizing a comprehensive excel file containing all currently operational trucks in Luxembourg, and an extensive research database

9 https://theicct.org/sites/default/files/publications/TCO-BETs-Europe-white-paper-v4-nov21.pdf

provided by the Transport Ministry from the database of the national registration authority (SNCA - “société nationale de circulation automobile”). This database consisted of approximately 11,000 N2 and N3 vehicles, which were subjected to cleaning and variable manipulation to classify the share of main vehicle types. It is important to note that during the cleaning process, around 10% of the vehicles were excluded from the analyses due to different reasons, such as insufficient information or the inability to determine the exact type of vehicle. These vehicles were subsequently removed from the database, and their usage in the analysis was not possible. Therefore, the final number of vehicles that remained in the database was 9730.

As a result, we produced the distribution of N2 Rigids, N3 Rigids and N3 long-haul vehicles (tractor-trailer units) which became the base for multiple calculations, including the daily mileages, the structure of the fleet, and estimated total mileage of the home fleet. Amongst other, the average yearly mileage has been calculated. This was crucial to understand the Luxembourg fleet, and to make realistic and applicable calculations. The daily mileages determine the applicability of alternative fuel technologies. The routes which can be covered by one charge or one refuelling is a key indicator. We used this data to overlay with the availability of a BEV and FCEV models.

To create the figures for the average daily mileages, we calculated the average daily mileage of all trucks in the database. To produce this data, the first registration date, the date of last technical inspection, and the vehicle mileage was used. The difference of the technical inspection date and the date of registry was expressed in form of days, and the total mileage was divided with this figure. To factor the operational time, we consider 250 operational days for urban and regional delivery trucks, and 300 operational days for long-haul ones. Based on these calculations, the following figures are created. Databases were shared by the client, sourced from data.public.lu (https://data.public.lu/fr/datasets/limites-administratives-du-grand-duche-de-luxembourg/ , https://data.public.lu/fr/datasets/registre-national-des-localites-et-des-rues/). As a result, the daily mileages for the three use case categories were determined, and new variables were introduced to the database.

2.2.2 Calculation methodology

Use cases: For the comparative overview of the TCOs, ‘typical’ use-cases were defined that involve urban delivery with N2 rigid trucks (7,5 – 12 tons): regional delivery with N3 rigid trucks (26-32 tons); and long-distance transport with N3 long haul trailer units (40-44 tons).

Drive train technology: In the calculations, Diesel, BEV, and FCEV powertrain types are compared. Low emission trucks are also explained in separate chapter – ‘Alternative Options Roadmap’.

Expected term of ownership is assumed to be 5 years. The experience with professional operators is that the ownership duration of the first owner us usually around 5 years.

Usage patterns: The three use cases each have a different average daily mileage. This is based on the true mileage made by the vehicle category in Luxembourg. This means that the urban delivery use case involves 65 km, regional delivery 128 km and the N3 long haul trailer unit 418 km daily mileages. For both the N2 and the N3 rigid use case, 250 operating days per year have been assumed, with 300 for the N3 long haul tractor trailer unit. It is the experience with professional operators that N2 and N3 rigids are often used less intensively than the long-haul tractor trailer units.

Energy costs: The energy costs used in the calculation are coming from different sources which are linked in the excel file. The diesel prices are coming from the European Commission[10], electricity used for depot charging is coming from GlobalPetrolPrices[11] and the public ultra-fast charger prices from ICCT[12]. The future prices of the diesel and electricity are expected to increase by 3% yearly, also according to ICCT.

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[10] https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin_en
[11] https://www.globalpetrolprices.com/electricity_prices/
[12] https://theicct.org/sites/default/files/publications/TCO-BETs-Europe-white-paper-v4-nov21.pdf

Within the calculation, due to the higher millage of the N3 tractor units, 20% of charging is expected to be at public chargers. The average cost of public charging with a 350kW charger is included in the calculation.

H2 prices: the current price of hydrogen is based on the average European pump price ex VAT[13], , although it is worth noting that this is not necessarily green hydrogen. Looking at the future it is expected that green hydrogen availability will increase as the REPowerEU plan aims for 20 million tonnes in 2030[14]. The price for green hydrogen is therefore expected to decrease, the values for 2025 and 2030 are based on multiple research papers and models[15,16].

The developments of energy costs is a very volatile, especially indicated by recent macro-economic developments. The global energy transition towards electricity will also result in a potential of energy scarcity. These and other developments can have an influence on the availability and pricing of fuels/electricity. The sources we used for the TCO calculation with regards to the expected price developments are strong, but there are many scenarios thinkable which lead to different outcomes. There is a diesel / energy price sensitivity analyses in this chapter, where the impact of changes is indicated

Vehicle specifications: For the average consumption the sources of ICCT and Panteia are used for both diesel and electricity. There are no developments of improvement of consumption figures applied, as they are expected to be not significant. The improved average consumption of the FCEV is applied (source Roland Berger).

Purchase costs and depreciation: Multiple sources have been used to determine the purchase price and the residual value. Where possible, the residual value of the battery / H2 drive train is calculated separately of the rest of the truck. Sources which are used are Panteia, ICCT, ITF, T&E and Roland Berger.

Tires and Maintenance: tires costs are not expected to vary between different drivetrains, maintenance costs are a more complex issue. These costs are usually based on historical experience of the wear and tear of components and their chance of breakage, the cost of these components, and the labor rate to replace them. There is already extensive experience with these costs for diesel trucks, but limited experience for electric and hydrogen trucks. Also, the cost of components are relatively expensive and a limited amount of mechanics are certified to work on these trucks. These market conditions are currently contributing to cost estimates higher than diesel trucks. This is also based on practical experience with OEM BEV truck pilot projects. There is also anecdotal evidence that OEMs are offering lower maintenance charges but are raising purchase prices to compensate. A potential reason is that existing purchase subsidies are based on the purchase price of the ZE truck, encouraging “frontloading”. Because of the reasons mentioned above, and because limited other external information is available, the prices in the calculation are not changed for future scenarios.

Charging infrastructure costs: These costs are adjusted to the expected need of charging infrastructure. This only applies for BEV trucks, since it is expected that both diesel and FCEV trucks refuel at public stations. For the N2 rigid for urban delivery, a 22kW charger is used in the calculation. For both N3 categories a 50kW charger is used for the calculation. Depreciation and maintenance costs are considered in the total cost for charging infrastructure. The potential cost of grid connection reinforcements are not included in the calculation. This is because of it is possible that these costs are non-existing, when the current grid connection is sufficient. It could also be, that costs are applicable. In that case it heavily depends on the situation how high the costs are. Therefore it should be noted that the non-negligible potential costs should be considered in every individual situation, but is too complex to include in this calculation.

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13 H2.live

14 https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

15 https://www.itf-oecd.org/decarbonising-europes-trucks-minimise-cost-uncertainty

16 https://theicct.org/publication/fuels-eu-onsite-hydro-cost-feb22/

2.2.3 Rigid truck (N2) for urban distribution

The urban delivery category represents only 7% of the fleet of Luxembourg but due to likely operation in more densely populated areas, zero emission options are preferred. The average daily mileage of this category in Luxembourg is **65km.** This makes the BEV disadvantage of having a lower range less relevant. TCO parity is expected between 2025 and 2030 for the Diesel and the BEV, but in 2022 there is still a significant disadvantage (22%) in TCO for the BEV.

The expected TCO of a FCEV is more than 4 times of the diesel in 2022. Although there is a significant expected TCO drop in the years of 2025 and 2030, the FCEV TCO will still be much higher than a Diesel or BEV. The potential operational advantages of a FCEV will not be relevant for the use case of urban delivery and is therefore not considered to be a viable economic or operational alternative.

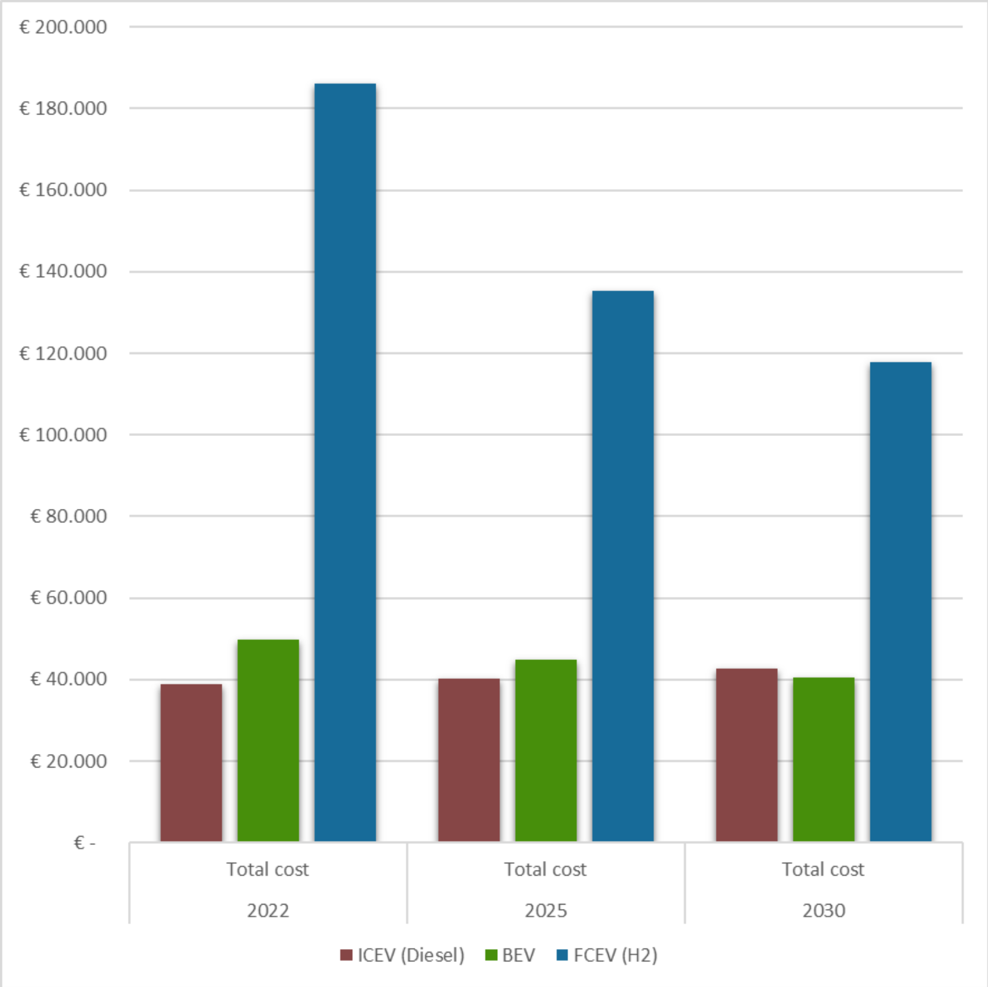


Figure 6: TCO comparison of Rigid trucks (N2) for urban distribution with different drivetrain technologies and different years

In the attachment of the report the details behind the TCO calculations are to be found

2.2.4 Rigid truck (N3) for regional distribution

The regional delivery category with N3 rigids represents 33% of the Luxembourg truck fleet. The average daily mileage is **128km**, which is within the range of the average BEV model in this category.

Like in the urban delivery category, TCO parity is expected between 2025 and 2030 for the Diesel and the BEV. In 2022 the TCO difference is still 16%.

The TCO for a FCEV is expected to drop from more than 2 times the TCO of a diesel, to only 10% more in 2030. The TCO will still be higher than the BEV in 2030, and based on the average mileage of this category, there will be limited need for FCEV as the range of BEVs will in most cases be sufficient.

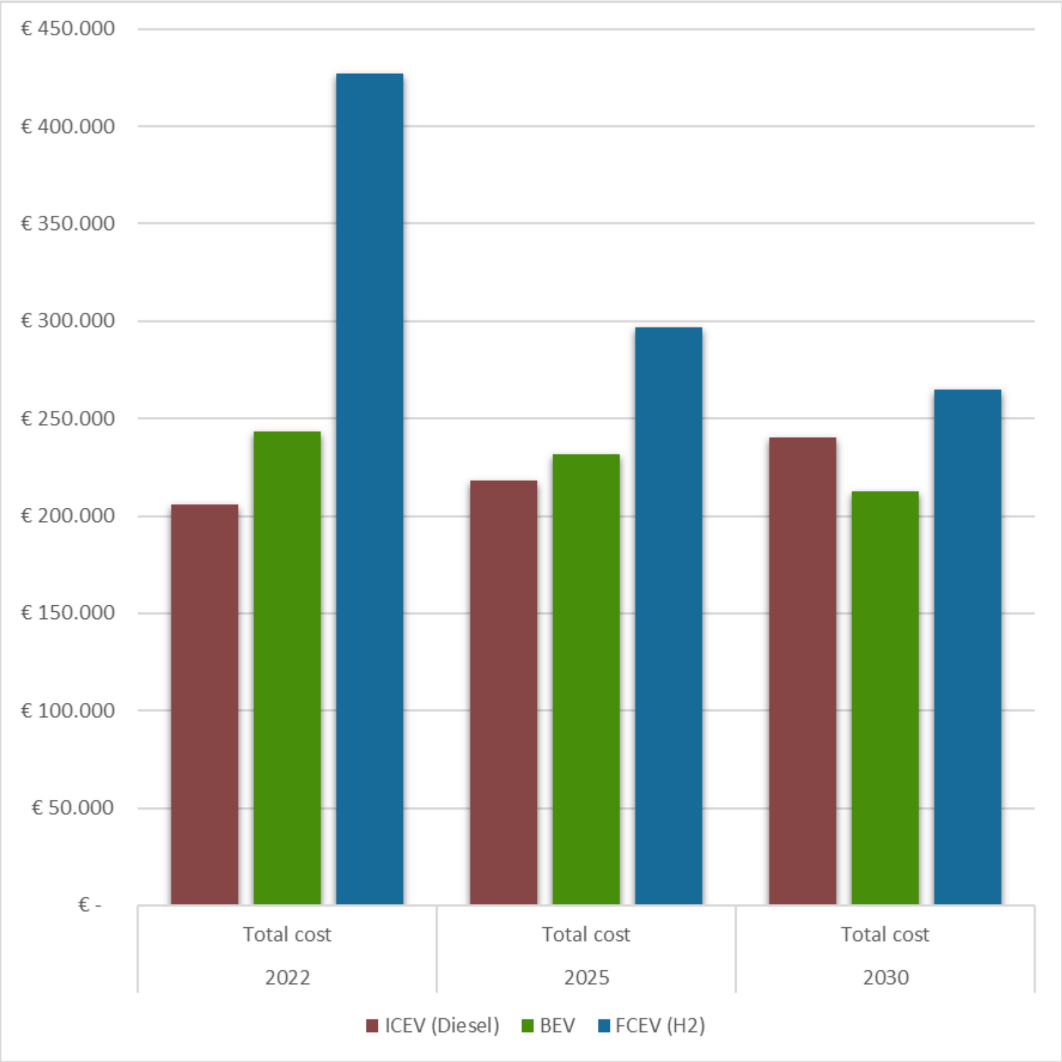


Figure 7: TCO comparison of Rigid trucks (N3) for regional distribution with different drivetrain technologies and different years

In the attachment of the report the details behind the TCO calculations are to be found

2.2.5 40t Tractor unit (N3) for long-haul transport

The majority (60%) of the Luxembourg truck fleet is represented by the tractor trailer category, and this category travels higher mileages compared to the other categories (**418km** on average).
Although there will be BEV trucks available in this category with a higher range than this average, the TCO calculations for the BEV include the higher cost of public charging (20% of the kWh charged are estimated to be at more expensive public chargers). The BEV TCO premium of approximately 36% in 2022 is significant, but it is expected that also between 2025 and 2030 TCO parity with diesel will be achieved.

TCO parity between diesel and FCEV is not expected to happen within the time scope of this study based on the variables used in this comparison. It is worth mentioning that the TCO disadvantage of a FCEV in the 40t tractor trailer category is larger than in the N3 Rigid category. This is because of the higher operational costs of a FCEV, and the higher mileage used in this tractor trailer TCO calculation. Depending on technical developments for the BEV and the FCEV, there may be an operational advantage for the FCEV that could positively impact the sales of these FCEVs.

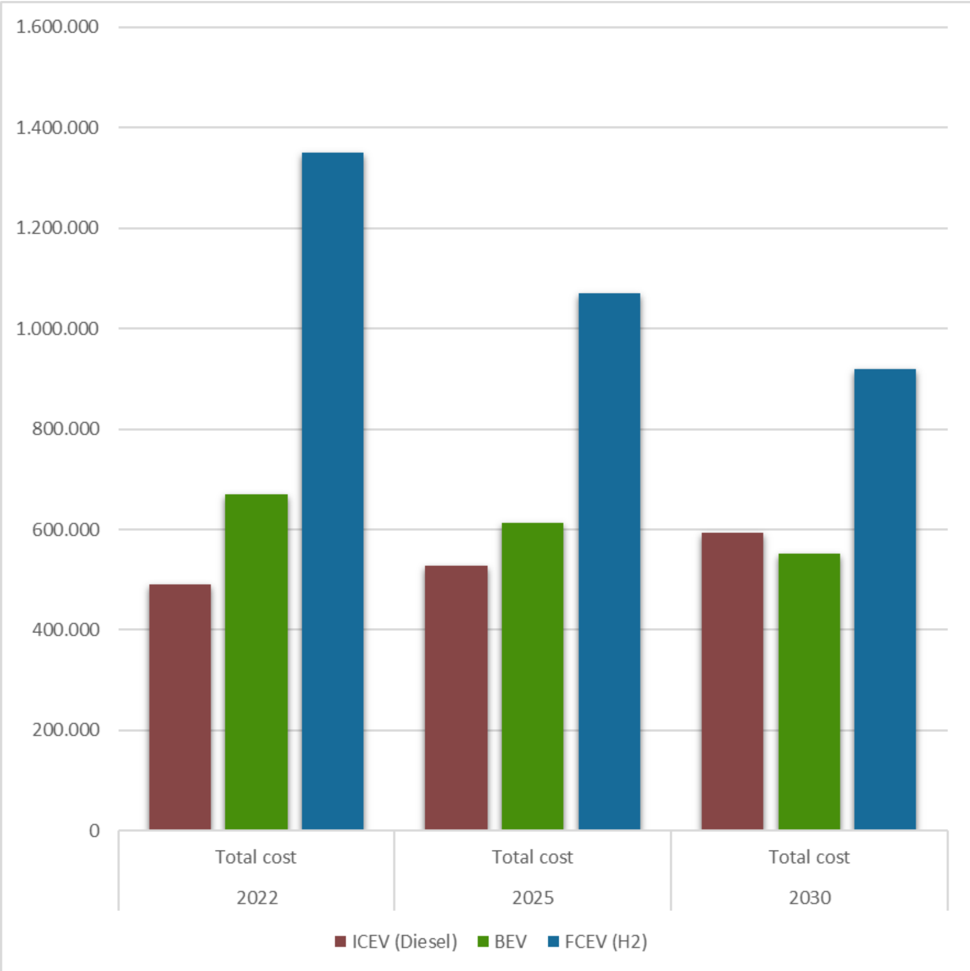


Figure 8: TCO comparison of 40t (N3) Tractors for long-haul transport with different drivetrain technologies and different years

In the attachment of the report the details behind the TCO calculations are to be found

2.2.6 Energy price sensitivity

Global energy prices have seen considerable fluctuation in recent years. As energy costs form a significant proportion of TCOs for both diesel and BEV trucks, we have analysed the effect of changes in these costs on TCO, based on a model without incentives applicable for the year 2022.

Impact on TCO difference (x €1.000)

Electricity price per kWh \ Diesel price per liter	€ 0,80	€ 1,00	€ 1,20	€ 1,40	€ 1,60	€ 1,80	€ 2,00	€ 2,20	€ 2,40	€ 2,60	€ 2,80	€ 3,00
€ 0,05	€ 16	€ 14	€ 13	€ 11	€ 10	€ 8	€ 6	€ 5	€ 3	€ 2	€ 0	-€ 1
€ 0,10	€ 17	€ 16	€ 14	€ 13	€ 11	€ 10	€ 8	€ 7	€ 5	€ 3	€ 2	€ 0
€ 0,15	€ 19	€ 17	€ 16	€ 14	€ 13	€ 11	€ 10	€ 8	€ 7	€ 5	€ 4	€ 2
€ 0,20	€ 21	€ 19	€ 18	€ 16	€ 14	€ 13	€ 11	€ 10	€ 8	€ 7	€ 5	€ 4
€ 0,25	€ 22	€ 21	€ 19	€ 18	€ 16	€ 14	€ 13	€ 11	€ 10	€ 8	€ 7	€ 5
€ 0,30	€ 24	€ 22	€ 21	€ 19	€ 18	€ 16	€ 15	€ 13	€ 11	€ 10	€ 8	€ 7
€ 0,35	€ 25	€ 24	€ 22	€ 21	€ 19	€ 18	€ 16	€ 15	€ 13	€ 12	€ 10	€ 8
€ 0,40	€ 27	€ 26	€ 24	€ 22	€ 21	€ 19	€ 18	€ 16	€ 15	€ 13	€ 12	€ 10
€ 0,45	€ 29	€ 27	€ 26	€ 24	€ 23	€ 21	€ 19	€ 18	€ 16	€ 15	€ 13	€ 12
€ 0,50	€ 30	€ 29	€ 27	€ 26	€ 24	€ 23	€ 21	€ 20	€ 18	€ 16	€ 15	€ 13
€ 0,55	€ 32	€ 30	€ 29	€ 27	€ 26	€ 24	€ 23	€ 21	€ 20	€ 18	€ 17	€ 15
€ 0,60	€ 34	€ 32	€ 31	€ 29	€ 27	€ 26	€ 24	€ 23	€ 21	€ 20	€ 18	€ 17
€ 0,65	€ 35	€ 34	€ 32	€ 31	€ 29	€ 27	€ 26	€ 24	€ 23	€ 21	€ 20	€ 18
€ 0,70	€ 37	€ 35	€ 34	€ 32	€ 31	€ 29	€ 28	€ 26	€ 24	€ 23	€ 21	€ 20
€ 0,75	€ 38	€ 37	€ 35	€ 34	€ 32	€ 31	€ 29	€ 28	€ 26	€ 25	€ 23	€ 21
€ 0,80	€ 40	€ 39	€ 37	€ 35	€ 34	€ 32	€ 31	€ 29	€ 28	€ 26	€ 25	€ 23
€ 0,85	€ 42	€ 40	€ 39	€ 37	€ 36	€ 34	€ 32	€ 31	€ 29	€ 28	€ 26	€ 25
€ 0,90	€ 43	€ 42	€ 40	€ 39	€ 37	€ 36	€ 34	€ 33	€ 31	€ 29	€ 28	€ 26

Figure 9: Heatmap. A sensitivity analyses for energy price vs diesel price for a N2 Rigid for Urban Delivery

Impact on TCO difference (x €1.000)

Electricity price per kWh \ Diesel price per liter	€ 0,80	€ 1,00	€ 1,20	€ 1,40	€ 1,60	€ 1,80	€ 2,00	€ 2,20	€ 2,40	€ 2,60	€ 2,80	€ 3,00
€ 0,05	€ 63	€ 54	€ 45	€ 36	€ 27	€ 18	€ 9	-€ 1	-€ 10	-€ 19	-€ 28	-€ 37
€ 0,10	€ 74	€ 65	€ 56	€ 47	€ 37	€ 28	€ 19	€ 10	€ 1	-€ 8	-€ 17	-€ 26
€ 0,15	€ 84	€ 75	€ 66	€ 57	€ 48	€ 39	€ 30	€ 21	€ 12	€ 2	-€ 7	-€ 16
€ 0,20	€ 95	€ 86	€ 77	€ 68	€ 59	€ 49	€ 40	€ 31	€ 22	€ 13	€ 4	-€ 5
€ 0,25	€ 106	€ 97	€ 87	€ 78	€ 69	€ 60	€ 51	€ 42	€ 33	€ 24	€ 14	€ 5
€ 0,30	€ 116	€ 107	€ 98	€ 89	€ 80	€ 71	€ 62	€ 52	€ 43	€ 34	€ 25	€ 16
€ 0,35	€ 127	€ 118	€ 109	€ 99	€ 90	€ 81	€ 72	€ 63	€ 54	€ 45	€ 36	€ 26
€ 0,40	€ 137	€ 128	€ 119	€ 110	€ 101	€ 92	€ 83	€ 74	€ 64	€ 55	€ 46	€ 37
€ 0,45	€ 148	€ 139	€ 130	€ 121	€ 112	€ 102	€ 93	€ 84	€ 75	€ 66	€ 57	€ 48
€ 0,50	€ 159	€ 149	€ 140	€ 131	€ 122	€ 113	€ 104	€ 95	€ 86	€ 76	€ 67	€ 58
€ 0,55	€ 169	€ 160	€ 151	€ 142	€ 133	€ 124	€ 114	€ 105	€ 96	€ 87	€ 78	€ 69
€ 0,60	€ 180	€ 171	€ 161	€ 152	€ 143	€ 134	€ 125	€ 116	€ 107	€ 98	€ 89	€ 79
€ 0,65	€ 190	€ 181	€ 172	€ 163	€ 154	€ 145	€ 136	€ 126	€ 117	€ 108	€ 99	€ 90
€ 0,70	€ 201	€ 192	€ 183	€ 174	€ 164	€ 155	€ 146	€ 137	€ 128	€ 119	€ 110	€ 101
€ 0,75	€ 211	€ 202	€ 193	€ 184	€ 175	€ 166	€ 157	€ 148	€ 139	€ 129	€ 120	€ 111
€ 0,80	€ 222	€ 213	€ 204	€ 195	€ 186	€ 176	€ 167	€ 158	€ 149	€ 140	€ 131	€ 122
€ 0,85	€ 233	€ 224	€ 214	€ 205	€ 196	€ 187	€ 178	€ 169	€ 160	€ 151	€ 141	€ 132
€ 0,90	€ 243	€ 234	€ 225	€ 216	€ 207	€ 198	€ 189	€ 179	€ 170	€ 161	€ 152	€ 143

Figure 10: Heatmap. A sensitivity analyses for energy price vs diesel price for a N3 Rigid for Reginal Delivery

Impact on TCO difference (x €1.000)

Electricity price per kWh	Diesel price per liter: € 0,80	€ 1,00	€ 1,20	€ 1,40	€ 1,60	€ 1,80	€ 2,00	€ 2,20	€ 2,40	€ 2,60	€ 2,80	€ 3,00
€ 0,05	€ 294	€ 255	€ 217	€ 178	€ 140	€ 101	€ 63	€ 24	-€ 14	-€ 53	-€ 91	-€ 130
€ 0,10	€ 335	€ 297	€ 258	€ 220	€ 181	€ 143	€ 104	€ 66	€ 27	-€ 11	-€ 50	-€ 88
€ 0,15	€ 377	€ 338	€ 300	€ 261	€ 223	€ 184	€ 146	€ 107	€ 69	€ 30	-€ 8	-€ 47
€ 0,20	€ 418	€ 379	€ 341	€ 302	€ 264	€ 225	€ 187	€ 148	€ 110	€ 71	€ 33	-€ 6
€ 0,25	€ 459	€ 421	€ 382	€ 344	€ 305	€ 267	€ 228	€ 190	€ 151	€ 113	€ 74	€ 36
€ 0,30	€ 501	€ 462	€ 424	€ 385	€ 347	€ 308	€ 270	€ 231	€ 193	€ 154	€ 116	€ 77
€ 0,35	€ 542	€ 504	€ 465	€ 427	€ 388	€ 350	€ 311	€ 273	€ 234	€ 196	€ 157	€ 119
€ 0,40	€ 583	€ 545	€ 506	€ 468	€ 429	€ 391	€ 352	€ 314	€ 275	€ 237	€ 198	€ 160
€ 0,45	€ 625	€ 586	€ 548	€ 509	€ 471	€ 432	€ 394	€ 355	€ 317	€ 278	€ 240	€ 201
€ 0,50	€ 666	€ 628	€ 589	€ 551	€ 512	€ 474	€ 435	€ 397	€ 358	€ 320	€ 281	€ 243
€ 0,55	€ 708	€ 669	€ 631	€ 592	€ 554	€ 515	€ 477	€ 438	€ 400	€ 361	€ 323	€ 284
€ 0,60	€ 749	€ 710	€ 672	€ 633	€ 595	€ 556	€ 518	€ 479	€ 441	€ 402	€ 364	€ 325
€ 0,65	€ 790	€ 752	€ 713	€ 675	€ 636	€ 598	€ 559	€ 521	€ 482	€ 444	€ 405	€ 367
€ 0,70	€ 832	€ 793	€ 755	€ 716	€ 678	€ 639	€ 601	€ 562	€ 524	€ 485	€ 447	€ 408
€ 0,75	€ 873	€ 835	€ 796	€ 758	€ 719	€ 681	€ 642	€ 604	€ 565	€ 527	€ 488	€ 450
€ 0,80	€ 914	€ 876	€ 837	€ 799	€ 760	€ 722	€ 684	€ 645	€ 607	€ 568	€ 530	€ 491
€ 0,85	€ 956	€ 917	€ 879	€ 840	€ 802	€ 763	€ 725	€ 686	€ 648	€ 609	€ 571	€ 532
€ 0,90	€ 997	€ 959	€ 920	€ 882	€ 843	€ 805	€ 766	€ 728	€ 689	€ 651	€ 612	€ 574

Figure 11: Heatmap. A sensitivity analyses for energy price vs diesel price for a Tractor unit (N3) for long-haul transport

In a "ceteris paribus" analysis, the figures above indicate the effect on the TCO. In these analyses only the price of the diesel / electricity costs is changed to compare the outcome of the TCO differences. These TCO differences are shown in the heatmap above. In the case where diesel is expensive, and electricity is cheap, the matrix shows a green negative number, showing the TCO advantage of the BEV over an ICE MHDV. The amount shown in the matrix must be multiplied by 1.000 to get to the overall (5 year) TCO difference.

Energy price difference between electricity, diesel or hydrogen has a huge impact on the final TCO. The various scenarios of increasing or decreasing fuel prices are very important to consider and monitor, because the economic viability significantly depends on this factor. Some countries also consider measures to introduce, by for instance capping the maximum price for depot charging.

2.2.7 TCO comparison between diesel and zero emission alternatives

BEV

In all segments, TCO parity is expected somewhere between 2025 and 2030, but a significant gap exists in 2022. This makes it significantly more expensive for transport companies to implement BEVs now.

For the average daily mileages in the urban and regional scenarios, most of the transport duties are within the range capabilities of current OEM BEV offerings. For the long-haul scenario, this proportion reduces due to higher average daily mileages. Although optimisation of the vehicle utilisation (e.g. through adapting the planning to let the BEV drive more kilometres within the battery range) is not considered in this TCO comparison, it is a crucial part of implementation of BEV trucks and could increase their applicability here.

FCEV

In all categories, the FCEV is not competitive with the TCO of diesel or BEV. The average mileage in the long-haul category (418km) could be challenging for a BEV, and slow (overnight) charging might not be sufficient. Especially in the cases where the MHDV drive more than the average mileage.
There could be an operational advantage for the FCEV in that case, depending on the availability, pricing and speed of fuelling stations and charging stations at strategic (publicly available) locations.

Conclusion

TCO parity does not guarantee an increased uptake of BEV versus diesel. Even when the TCO is similar, there are still some significant challenges for logistics operators to switch to BEV. This includes range, charging infrastructure and operational challenges which contribute to reducing the rate of uptake of BEV MHDVs.

2.3 Potential of decarbonisation and operational feasibility

2.3.1 Assessment of operational suitability

As well as assessing the economic performance of ZE alternatives, the operational suitability of the different technologies for the Luxembourgish fleets needs to be considered. This mainly has to do with the size of the battery and the efficiency of the BEV MHDV, as the range on one battery charge is limited. If there is a need for a higher daily mileage that exceeds the vehicle's range on a single charge, the complexity and cost of fast charging needs to be considered. We have analysed the data on the average daily mileages in Luxembourg to assess the potential of decarbonisation in terms of operational feasibility (considering limited range of BEV MHDVs). This is done, based on a comprehensive excel file consisting of all current operation trucks active in Luxembourg. To create the figures for the average daily mileages, we calculated the average daily mileage of all trucks in the database. To produce this data, the first registration date, the date of last technical inspection, and the vehicle mileage was used. The difference of the technical inspection date and the date of registry was expressed in form of days, and the total mileage was divided with this figure. To factor the operational time, we consider 250 operational days for urban and regional delivery trucks, and 300 operational days for long-haul ones. Based on these calculations, the following figures are created. Databases were shared by the client, from the SNCA database.

In the graph below the distribution of the daily mileages per truck type is shown.

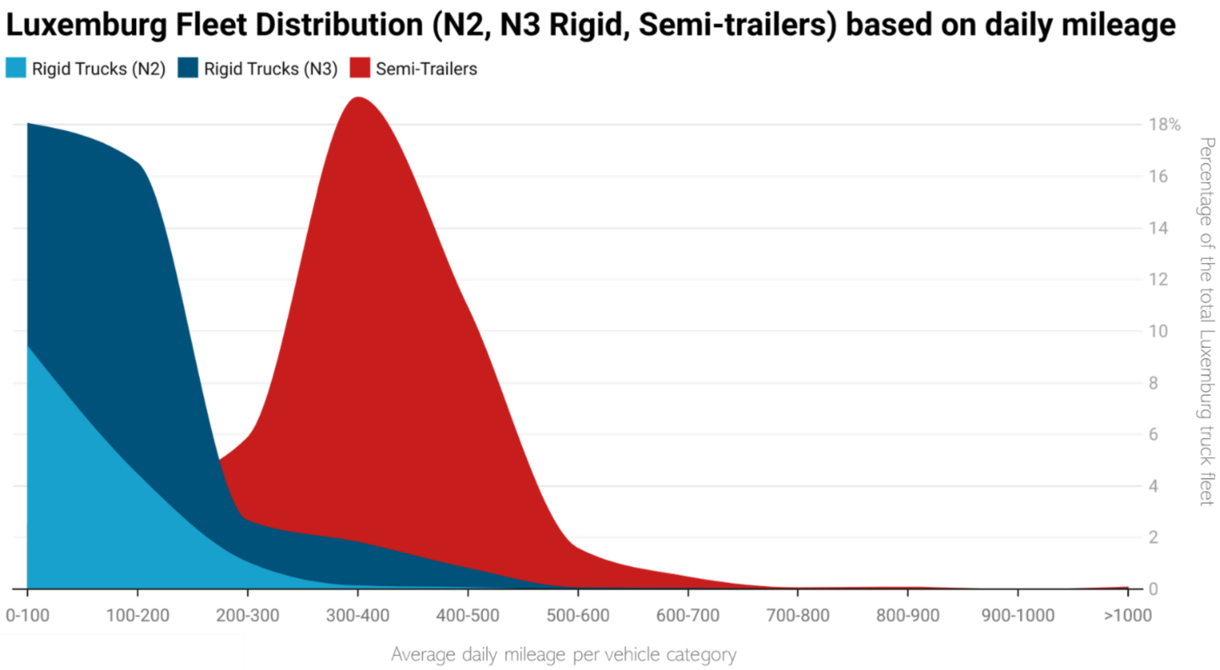


Figure 12: Luxembourg fleet distribution (N2 Rigids, N3 Rigids and N3 long haul trailer) based on daily mileage

In the graph it is clear to see that the majority of the N2 rigids and N3 rigids have an average daily mileage below 200km. Only 6% has a higher daily mileage than 300km. The N3 long haul trailers have a higher average daily mileage, but 70% is below 400 km.

Current low-hanging-fruit

Based in the graphs above, the majority of the daily distances driven by trucks in Luxembourg can achieved by BEV alternatives. The current ranges of BEV trucks are sufficient to cover these distances utilising a single (slow) charge (usually overnight). From a technical / operational point of view, the majority of N2 rigids and N3 rigids could easily be replaced by BEV alternatives without considering the complexity and the cost of fast charging during the day.

For the N3 long haul trailer units, the majority of these vehicles are operating above the 300km daily which would require significant operational duty changes or high-powered fast charging to operate on BEV.

Future technology

It is worth noting that the range of the BEVs and their charging speeds continue to improve. A (publicly available) fast charging network covering strategic locations is also a crucial facilitator for the uptake of BEV trucks.

The ZE technology most applicable for longer average daily mileages in the longer term will depend on the development of both BEV and Fuel Cell Electric Vehicle (FCEV) technologies, and the type of usage of those trucks.

N1 category

As an additional request, an overview of the N1 category was included in the report. As there is a large N1 fleet in Luxembourg, it has a large impact on the graph. It indicates a predominantly domestic, low mileage operation for this category.

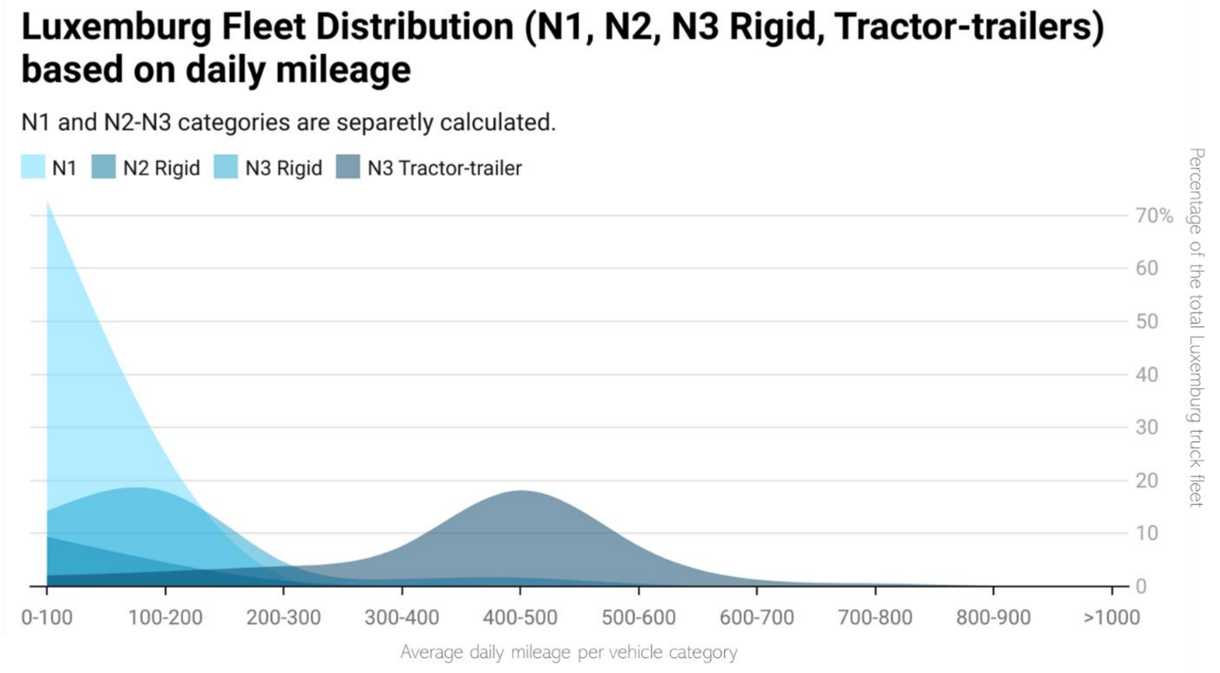


Figure 13: Luxembourg fleet distribution (N1, and N2-N3 vehicles) based on daily mileage

2.3.2 Decarbonisation potential of the MHDV fleet

Within this study there have been 2 scenarios applied to estimate the speed of the energy transition for the road freight transport fleet in Luxembourg.

Global MoU scenario

The first scenario is the MoU scenario from the program Global Drive to Zero. This MoU has been signed by the Luxembourg government and therefore can be considered as a base line / minimum target.

Based on the MoU ambitions/targets, the following graphs show the transition at a graduated growth curve. This expresses the expectation, that the rate of transition will be continuous, without any high peaks. The growth rate is based on the target of minimum 30% Zero Emission sales by 2030 and 100% Zero Emission <u>sales</u> by 2040. The assumptions[17] are that there is an annual fleet growth of net. 2% until 2030, then 1%. For the ICE MHDVs it assumes 6.5% fleet phase out per annum.

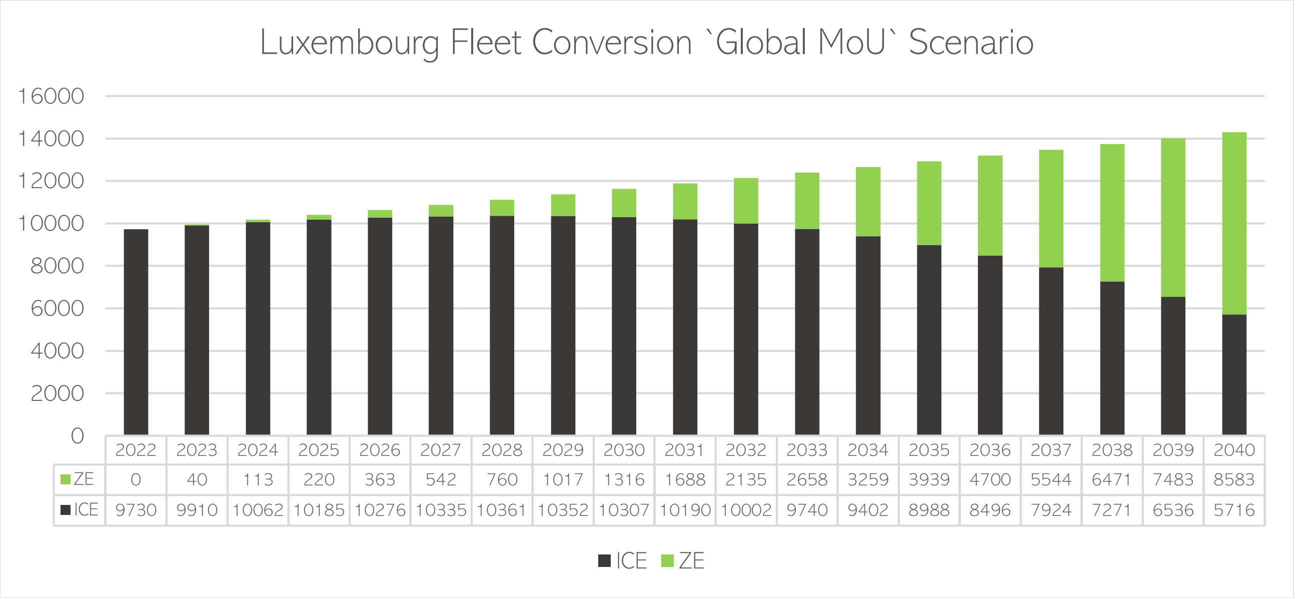


Figure 14: Luxembourg Fleet Conversion `Global MoU` Scenario

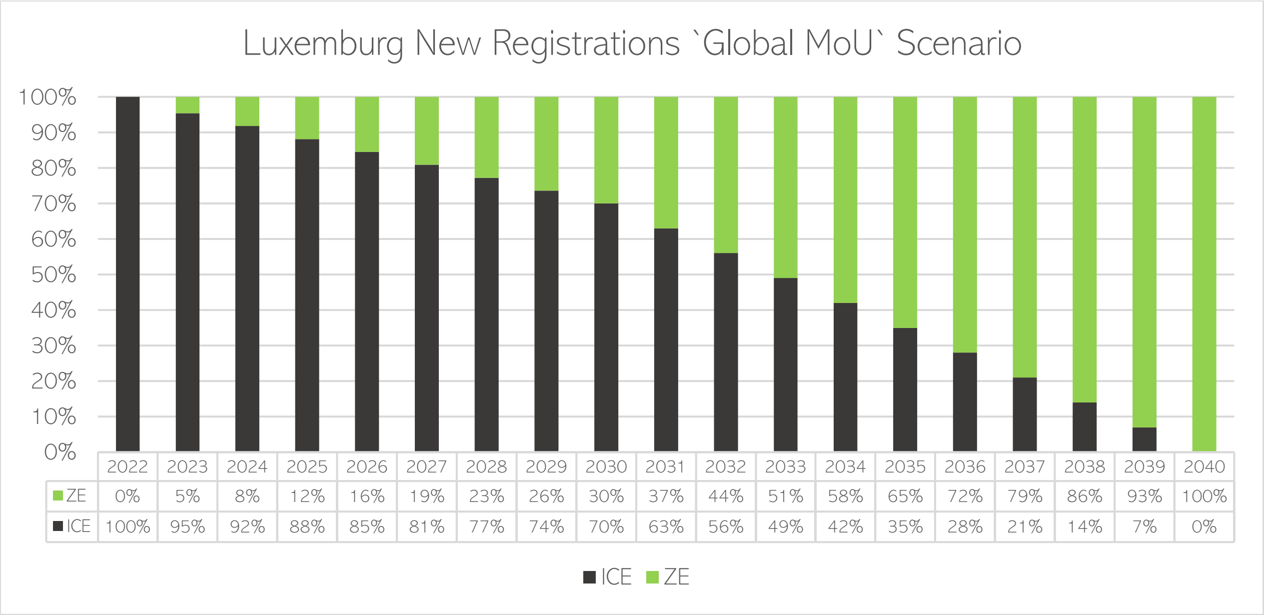


Figure 15: Luxembourg New registrations `Global MoU` Scenario

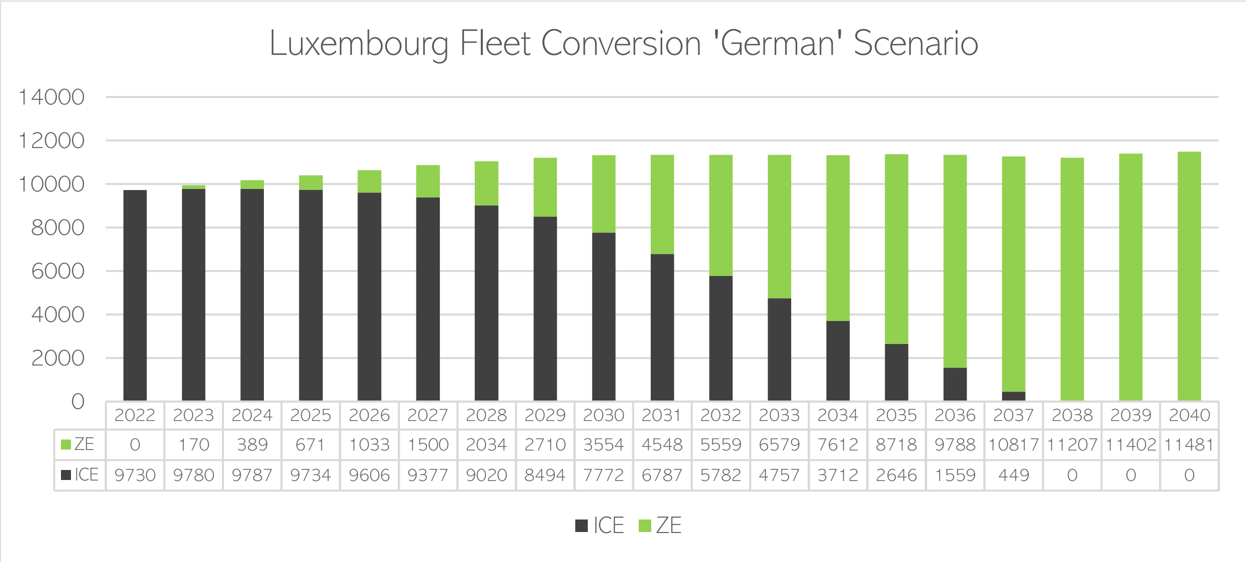
German scenario

The second scenario for the adoption curve applied to the Luxembourg fleet is based on the more ambitious German goals. This curve is based on a gradual growth rate (without any years where a significant change occurs, the growth of the ZE fleet is linear) towards the goal of 33% ZE fleet conversion in 2030. We estimate, that a 100% ZE registration in 2030 is needed to achieve that goal. This 100% ZE

17 For detailed assumptions made and background calculations, please consult the file “T1.3 Decarbonisation calculations.xlsx” in the annex.

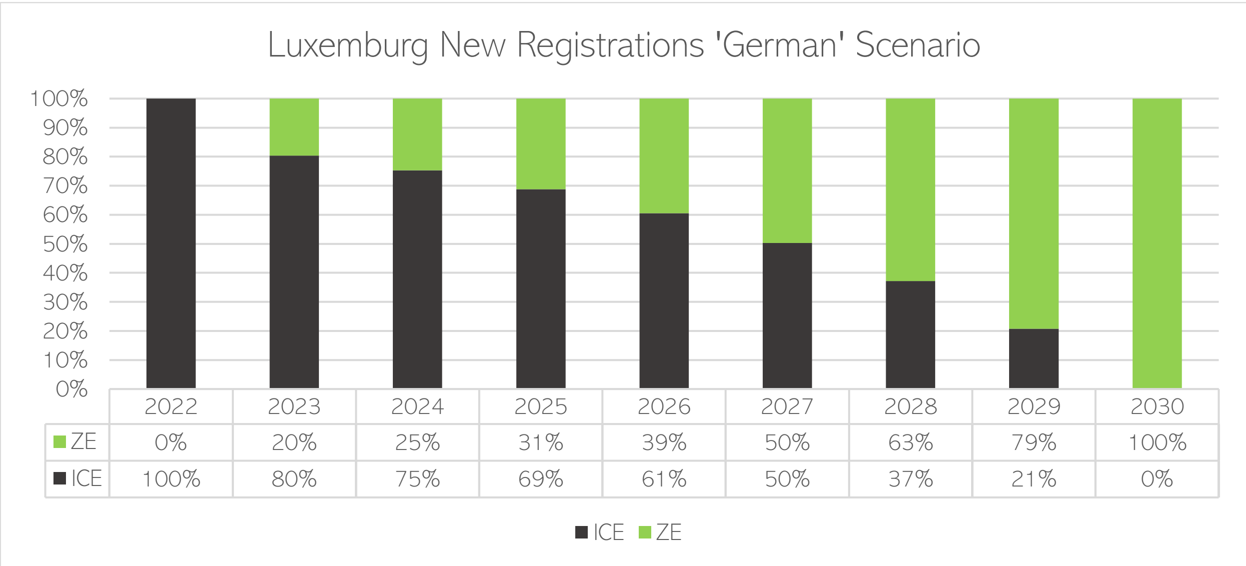
registration in 2030 is however not mentioned as a target by Germany, so that is an assumption in the model.

The following graphs are created under the assumption of an annual fleet growth net. 2% and a 6.5% phase out of ICE MHDV fleet per annum.



	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
ZE	0	170	389	671	1033	1500	2034	2710	3554	4548	5559	6579	7612	8718	9788	10817	11207	11402	11481
ICE	9730	9780	9787	9734	9606	9377	9020	8494	7772	6787	5782	4757	3712	2646	1559	449	0	0	0

Figure 16: Luxembourg Fleet Conversion `German` Scenario



	2022	2023	2024	2025	2026	2027	2028	2029	2030
ZE	0%	20%	25%	31%	39%	50%	63%	79%	100%
ICE	100%	80%	75%	69%	61%	50%	37%	21%	0%

Figure 17: Luxembourg New registrations ` German` Scenario

The German scenario is more progressive than the Drive to Zero Global MoU scenario. The phasing out of ICE trucks will take much longer in the Global MoU scenario, in turn reducing the energy transition of the logistic sector in Luxembourg.

Luxembourg trucks driving in Luxembourg or internationally

To provide a better context for the decarbonisation of the Luxembourg MHDV fleet, we analysed traffic movement in the country, and the traffic properties of vehicles registered in the country. The analysis showed that the traffic trends in those two aspects, is of significant difference to other neighbouring and other European countries.

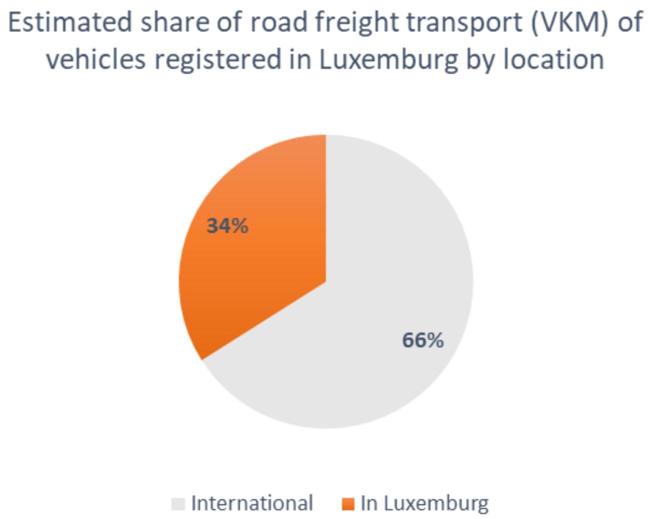


Figure 18: Estimated share of road freight transport (VKM) of vehicles registered in Luxemburg by locations

Source: Own analysis based on open data vehicle register

What this circle diagram shows is where Luxembourg registered MHDVs are driving. It is clear that these vehicles drive a significant percentage (66%) of their kilometres abroad/international. In other neighbouring countries, the percentage of MHDV driving within their own country is significantly more. When incentivising the sales of Luxembourg registered ZE trucks, a significant part of ZE kilometres driven by these incentivized trucks will be outside of Luxembourg.

Trucks driving in Luxembourg.

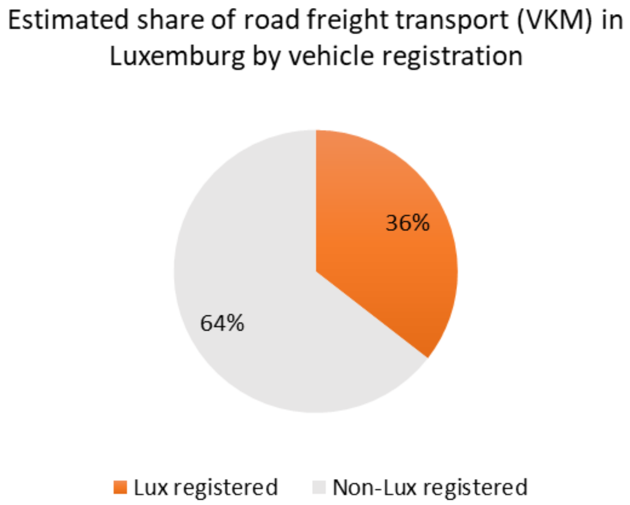


Figure 19: Estimated share of road freight transport (VKM) in Luxemburg by vehicle registration

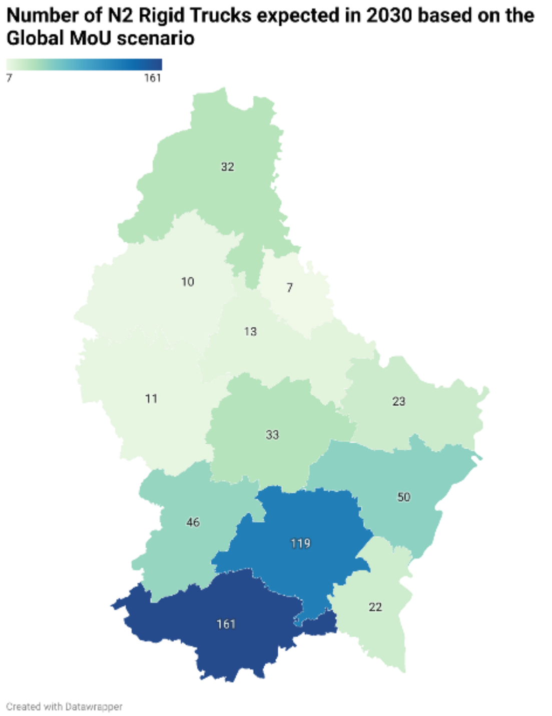
Source: own calculation based on Eurostat

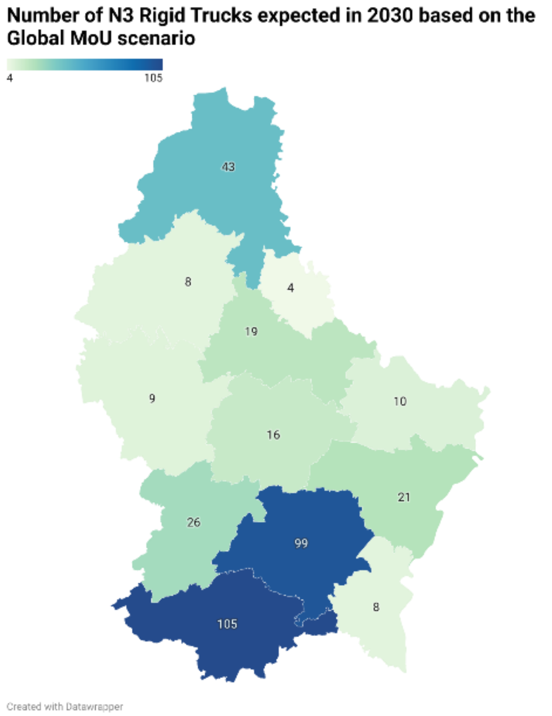
This circle diagram shows the MHDVs driving in and/or through Luxembourg. The majority (64%) of the vehicles are not Luxembourg registered vehicles, but vehicles registered in another country. This means that any financial aid applied to MHDVs purchased in Luxembourg will not directly impact on vehicles driving 64% of all MHDV kilometres domestically. Incentivising via operational costs will impact all the driving kilometres within Luxembourg. This is further discussed in the recommendations, by dividing measures based on their impact (home of foreign fleet).

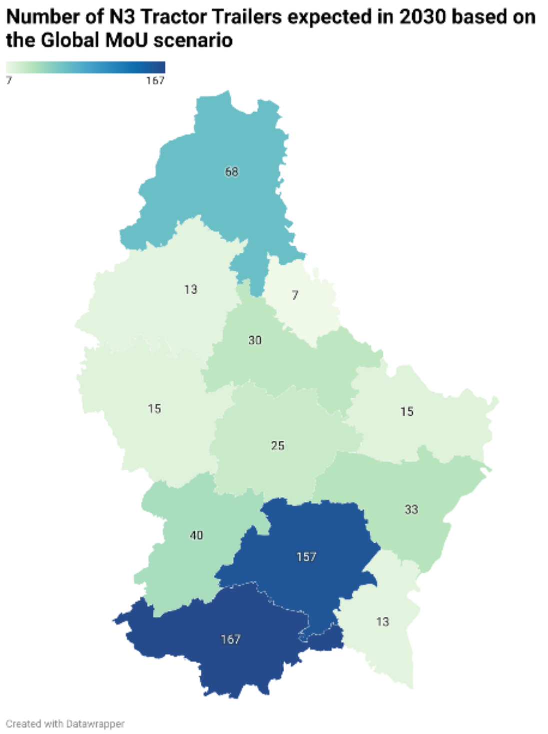
2.3.3 ZE MHDVs per canton

This section gives an overview of the expected number of ZE MHDVs registered across cantons in 2030, based on the two different scenarios (German and Global MoU). The base for the calculation is the overview of the in Luxembourg registered MHDVs. Based on the N2 rigid, N3 rigid and N3 Tractor Trailer units currently registered per canton, the expected growth scenarios are applied. Based on the input and predictions, the future number of different types of ZE MHDVs are visualized in form of Choropleth maps. In these maps, the darker the colour suggests higher predicted uptake of ZE MHDVs. Datapoints and calculations used for these maps are available in the attached file “T1.3 Decarbonisation calculations”.

Global MoU Scenario in 2030





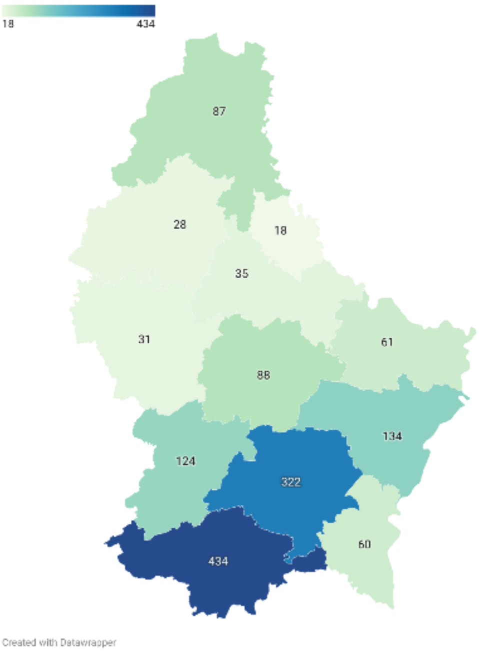


	N2 Rigid	N3 Rigid	N3 Tractor trailer	Total
CAPELLEN	46	26	29	**112**
CLERVAUX	32	43	49	**143**
DIEKIRCH	13	19	21	**61**
ECHTERNACH	23	10	11	**47**
ESCH-SUR-ALZETTE	161	105	121	**433**
GREVENMACHER	50	21	24	**104**
LUXEMBOURG	119	99	113	**375**
MERSCH	33	16	18	**74**
REDANGE	11	9	11	**36**
REMICH	22	8	10	**44**
VIANDEN	7	4	5	**17**
WILTZ	10	8	10	**32**
Total	**526**	**368**	**421**	**1316**

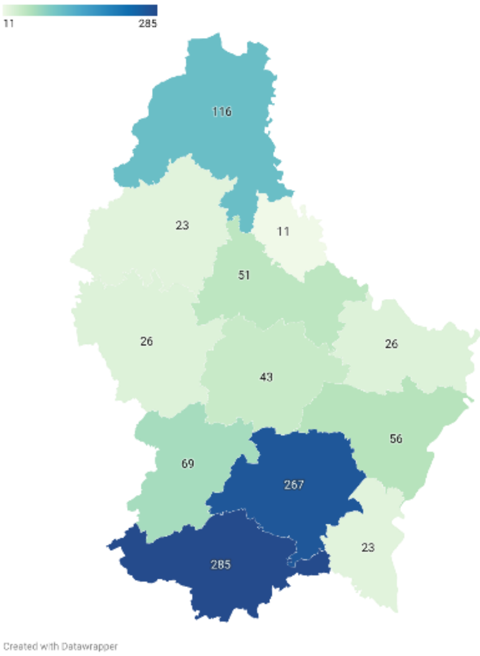
Figure 20: Number of ZE trucks expected per canton in 2030 at the Global MoU scenario

German Scenario in 2030

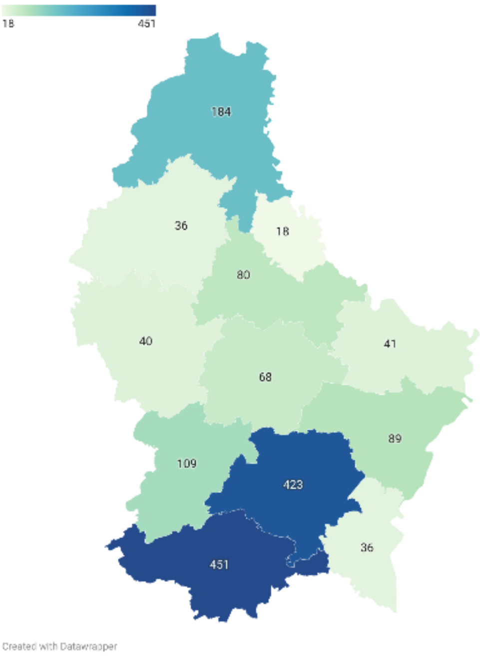
Number of N2 Rigid Trucks expected in 2030 based on the Germany scenario



Number of N3 Rigid Trucks expected in 2030 based on the Germany scenario



Number of N3 Tractor trailer Trucks expected in 2030 based on the Germany scenario



	N2 Rigid	N3 Rigid	N3 Tractor trailer	Total
CAPELLEN	124	69	109	**302**
CLERVAUX	87	116	184	**386**
DIEKIRCH	35	51	80	**166**
ECHTERNACH	61	26	41	**128**
ESCH-SUR-ALZETTE	434	285	451	**1170**
GREVENMACHER	134	56	89	**280**
LUXEMBOURG	322	267	423	**1012**
MERSCH	88	43	68	**199**
REDANGE	31	26	40	**97**
REMICH	60	23	36	**119**
VIANDEN	18	11	18	**47**
WILTZ	28	23	36	**87**
Total	**1421**	**995**	**1576**	**3992**

Figure 21: Number of ZE trucks expected per canton in 2030 at the German scenario

2.4 'Difficult to electrify' hydrogen logistics market size scenarios

Previous analysis shows that the daily mileage of the rigid truck fleet was generally low. 90% of N2 category daily mileages were below 200km and 90% of the N3 rigid daily mileages were below 300km. These mileages are expected to be within the mileage capabilities of EV trucks with the majority feasible to electrify given the correct charging regime.

Luxembourg truck fleet daily mileages that are greater than, or close to, the mileage capability of current BEV trucks have been taken forward for a hydrogen demand assessment.

The N3 long haul category showed around 65% of the daily mileages undertaken are greater than 400 km per day. The maximum range of current BEV tractor units is stated as ~500 km from manufacturers, therefore these vehicles may be more difficult to electrify – especially when considering day to day range variation requirements and the generally lower range of vehicles in winter. For this category it is therefore prudent to take a more cautious approach and determine the potential hydrogen demand for long haul tractor trailer logistics. Additionally, 66% of mileage from trucks registered in Luxembourg is international, therefore it is a reasonable assumption that much of the >400 km daily mileage vehicles travel internationally. If these trucks are travelling internationally then H2 also offers a faster and more convenient refuel. Analysing energy provision for truck travelling internationally was out of scope of this project.

2.4.1 Hydrogen Demand Scenarios

Given the uncertainties around future ZE vehicle uptake (particularly the availability, cost, and performance of hydrogen vehicles), forecasts of hydrogen vehicle and refuelling uptake numbers are at best highly speculative. To provide guidance on the potential future role of hydrogen fuelling in MDV transport in Luxembourg three potential demand scenarios for the possible uptake of hydrogen articulated trucks have been estimated. The same scenarios of EV uptake used here are used in the incentives analysis (with international travel out of scope of this study).

- **Low Scenario** - High power or MW EV charging is available for all fleets and, therefore, no H2 refuelling is required.
- **Medium** - Meeting the Global MoU target of 30% ZE vehicle sales by 2030, vehicles > 400 km (i.e., 65% of N3 fleet), 50% use of high power/MW charging, 66% of remaining H2 refuelling done internationally, with cost effective H2 available.
- **High** - Meeting the Global MoU target of 30% ZE vehicle sales by 2030, vehicles > 400 km (i.e., 65% of N3 fleet), 66% of H2 refuelling done internationally, with cost effective H2 available.

The chart below shows the number of hydrogen vehicles that would be deployed under both the medium and high H2 scenarios above, showing that by 2030 there could be up to 373 FCEV trucks compared to a total of 4,314 N3 tractor trailers currently registered in Luxembourg

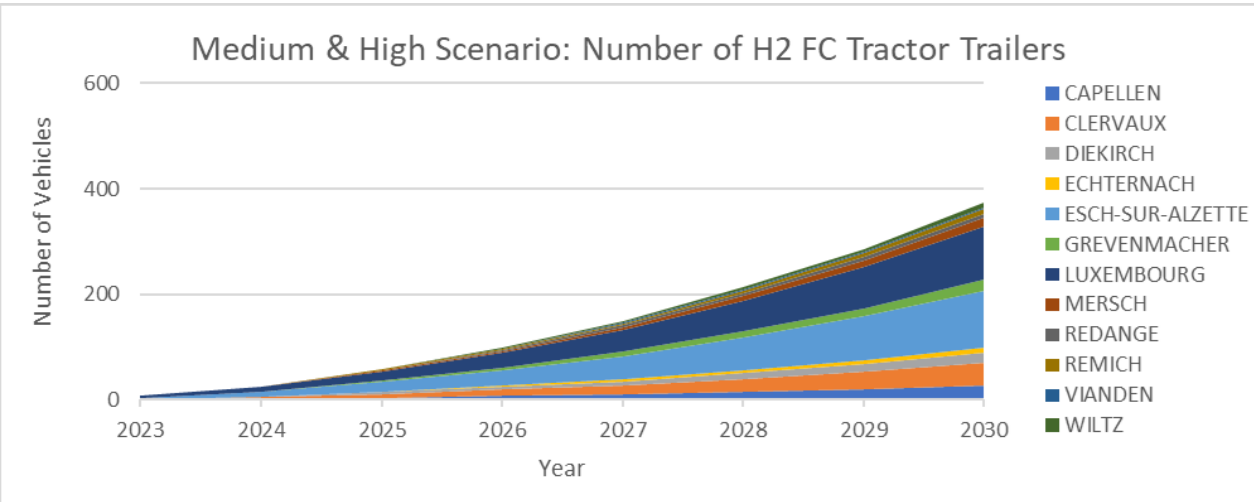


Figure 22: Medium & High Scenario: Number of H2 FC N3 Tractors per Canton

2.4.2 H2 Demand and Potential Station Requirement

The total hydrogen demand of the FCEV fleet was calculated using the average annual mileage for tractor trailer trucks undertaking >400km per days (125,000km) and the expected fuel consumption per km[18].

The table below shows the hydrogen demand (annual and daily) in both the Medium and High demand scenarios. Most modern hydrogen stations capable of serving medium and heavy-duty vehicles are specified to be capable of dispensing at least 1 tonne per day. Therefore, looking at the total demand we see that by 2030 there could be between 3 and 6 hydrogen stations in Luxembourg supplying between 690 tonnes to 1390 tonnes of hydrogen per annum for the most difficult to electrify sector of the Tractor Trailer fleet.

	2023	2025	2030
Medium Scenario: Annual Demand (t/annum)	19	140	690
Medium Scenario: Daily Demand (t/day)	0.1	0.6	2.8
High Scenario: Annual Demand (t/annum)	40	280	1390
High Scenario: Daily Demand (t/day)	0.2	1.1	5.5

Table 1: Medium & High Scenario of H2 demand

There is relatively little demand for hydrogen across the cantons until the H2 fleet grows towards the end of the decade. The main demand will then come from trucks registered in Esch-sur-Alzette, Luxembourg and Clervaux which could potentially each sustain at least one H2 station, although, as stated below, stations should be placed to maximise their strategic trucking network usage as well as national usage. Due to the relatively low demand, it is clear that any transition to hydrogen will need subsidies for refuelling stations to attract suppliers, at least to 2030 and potentially beyond.

2.4.3 Recommendations on applicability of FCEV and associated demand for H2

The hydrogen demand scenarios presented here show the potential ramp up of hydrogen trucks in line with ZE truck uptake commitments plus different possible levels of H2 truck adoption to 2030. We have considered just tractor trailer trucks with daily average mileages >400km as these are more likely to be unfeasible to operate as BEVs. Even in the high demand scenario outlined above, this results in a relatively low number of hydrogen stations by 2030.

Fleets travelling **nationally**, but undertaking high mileages are likely to favour rapid/opportunity charging of BEV trucks. This will help maximise the BEV asset and will provide lower total cost of ownership compared to hydrogen. The supporting data discussed in the previous section and used in the development of the scenarios suggests that the majority of Luxembourg haulage is international. Given that international travel is out of scope of this study, we recommend that the project steering committee should undertake additional work outside of this study on how potential Luxembourg hydrogen station locations are related to 1) the plans and requirements of strategic transnational trucking corridors, particularly the TEN-T networks, and on 2) hydrogen infrastructure plans in neighbouring countries, particularly in the light of the proposed requirements of the coming Alternative Fuels Infrastructure Regulation (AFIR). This planning work should ensure that stations are placed in locations to maximise interoperation with those in neighbouring countries, and therefore to maximise the usage of, and business case for, national hydrogen stations if they are deployed.

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18 0.13 km/kg (2025) reducing to 0.09 km/kg (2030). Based on reported ranges and hydrogen tank size. Efficiency gain of 27% in 2030 (taken from an ICCT report) and linearly interpolated from 2022.

3 Review of European financial aid schemes and recommendations for Luxembourg

This work package provides an overview of a selection of neighbouring European countries approaches to financial aid schemes for ZE truck purchases. Utilising this information and the national conditions in Luxembourg, different scenarios are calculated to illustrate how different schemes would alter the economic viability of ZE MDHVs. This is combined with analysis of state budget implications. We then set out an optimal policy recommendation, considering the European Union's state aid regulation and expected changes with the new GBER update.

Summary

In recent years many EU countries have developed state funded financial aid schemes for sustainable vehicles and infrastructure, such as purchase and tax incentives. These are matched at EU-level by the EU's fund for infrastructure (CEF). The adoption of the Recovery and Resilience Facility (RRF) to boost the European economy after the COVID-19 crisis opened the door for more EU countries to financially incentivise the sustainable transport transition or for countries with existing schemes to scale those up.[19] This chapter gives an overview of the financial aid schemes implemented and an assessment in terms of their effectiveness.

The European Union has supported commercial ZEV adoption with a variety of regulations and incentives. Its 2019 HDV CO_2 standards reward participating ZEV manufacturers for up to twice the credit allocation of a diesel-fuelled truck through 2024. This "super-credit" system will be replaced in 2025 with a benchmarking system that reduces the calculation of the manufacturer's average
specific CO_2 emissions once their ZEV sales share exceeds 2%. ZEV adoption is also supported by the Clean Vehicles Directive, which aggregates municipal vehicle purchases to national levels and establishes ZEV procurement targets for each member state in 2025 and 2030. The European Union also allows electric heavy-duty trucks to exceed class limits by 2 tonnes.[20]

On a national level, vehicle purchase incentives are the most used policy tool to incentivise the uptake of zero emission trucks after having been successfully deployed in the European car sector already. 16 European countries currently have such incentives in place. Publicly financed incentives have proven to be an effective catalyst and temporary fix for the initially higher purchase prices of electric cars whilst production volumes are increasing to eventually bring prices down. They can kick-start and accelerate road freight's zero emission transition, a sector driven by both technological and economic considerations. Whilst in the next few years incentives are needed as a bridging mechanism to finance capital intensive BEV MHDVs, any financial aid schemes should be phased out in the second half of the 2020s once scaling effects have secured affordable vehicles across all ranges. As the first work package results clearly show, after 2025 with TCO parity achieved and a wide range of available vehicle models will support full market viability of ZE trucks.

Overview of national financial aid schemes

In the next few years of market introduction, the investment cost (Capex) for a zero-emission vehicle will be high. These initially high investments can deter uptake in the freight sector due to its predominant composition of small and medium sized enterprises (SMEs). But, as evidenced by the TNO study,[21] savings on operating expenditures (Opex) such as lower fuel costs, repairs and road tolls will soon fully offset the capex over the lifetime of the truck, making the TCO of ZE MHDVs more favourable. A period of national demand-side policies such as purchase premiums to help hauliers bridge the cost difference

19 How to buy an electric truck: Public funding helps hauliers to deliver on zero emission road freight, Transport & Environment, 2022. November.

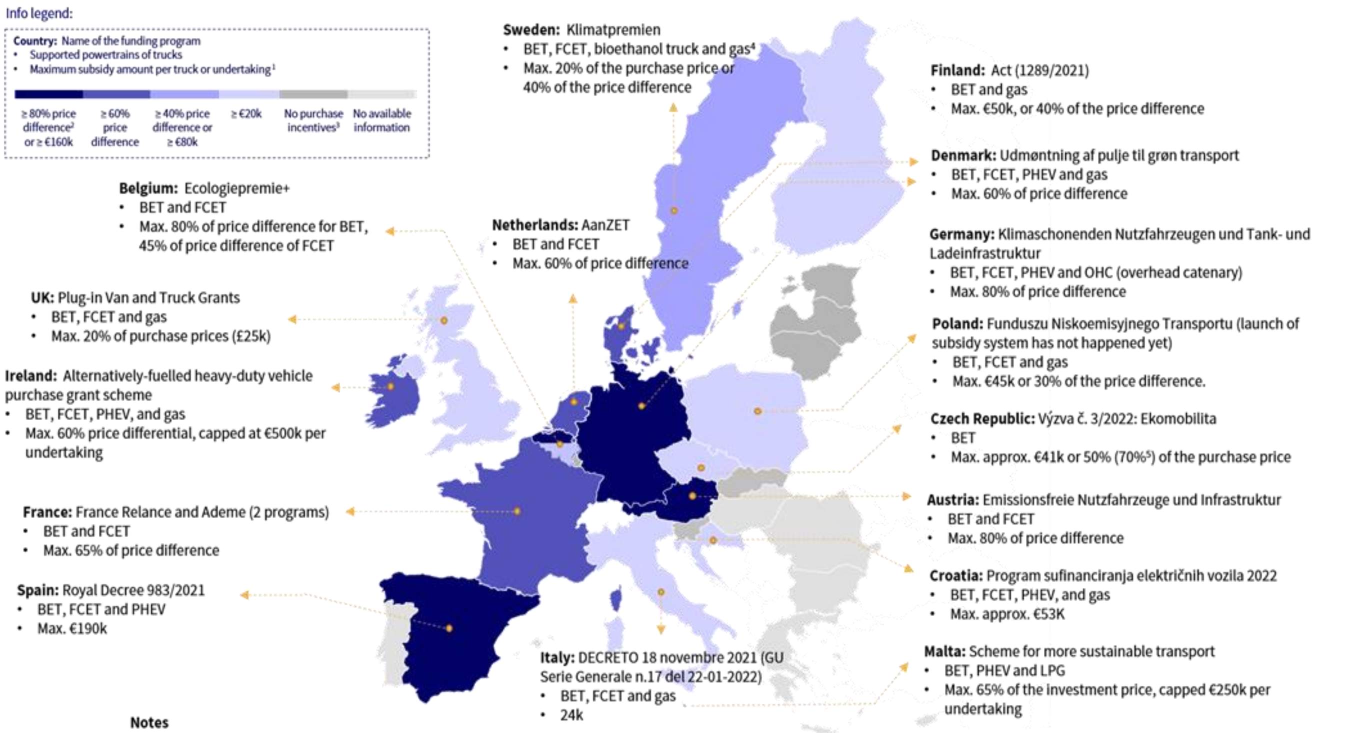
20https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment

21 TNO (2022). Techno-economic uptake potential of zero emission trucks in Europe.

between a ZE MHDV and diesel are needed. These financial incentives should be designed to adequately direct subsidies where they are most needed and most efficient to reduce emissions.

Nationally, the most used policy tools are vehicle purchase incentives. 16 European countries currently have incentives in place for the uptake of ZE MHDVs after successfully deploying similar schemes in the European car sector.

Generally, countries design their ZE MHDV subsidies as either covering a percentage point difference between the purchase price of a new ZE MHDV and a diesel truck (the AT, BE, DE, FR, IE, MT, NL, SE and UK schemes) or as a fixed per-vehicle sum (the CZ, ES, FI, IT and HR schemes). Austria, Germany and France have the most generous programs in place covering 65% and 80% of the difference in vehicle price between a ZE MHDV compared to the diesel, thereby making an appealing case for hauliers to transition and eventually benefit from the more attractive TCO of a ZE MHDV. These countries support hauliers with the maximum aid allowed per-vehicle under EU state aid rules, which is 40%. Most other European countries cover between 20%-60% (based on standardised percentage points for the incentive amounts of the different programs) of the cost difference between ZE MHDVs and conventional diesel trucks (CZ, FI, HR, IE, NL).



Notes

1. Average purchase prices (excl. VAT) for the different powertrains have been standardised, taking the percentages of the price difference as a baseline for all countries. The per-vehicle sums can be lower depending on truck weight and drivetrain.
2. The price difference refers to the difference in purchase price between the zero- or low- emission truck and its diesel equivalent.
3. Countries with no purchase incentives have been confirmed by the responsible ministries.
4. Gas-powered trucks use either liquified natural gas or compressed natural gas.
5. The subsidy cap can be increased by 20% through a scrappage program.

Figure 23: Map of national ZE MHDV funding programs across the EU+UK. Source: Transport & Environment (2022).

In terms of the drivetrain technologies, all the countries offer aid for battery electric and hydrogen trucks aside from Malta and the Czech Republic, who both focus solely on BEVs. Germany, Ireland, Malta and Spain also include plug-in vehicles. Sweden is the only country that supports vehicles running on biofuels, while Germany is the only country that includes overhead-catenary systems in its program. Few countries such as Ireland, Finland, Italy, Poland, and Sweden still incentivise in new fossil gas vehicles. Countries such as Spain and Denmark used to include so-called low-emission options such as gas trucks but have moved away from that inclusion and are now encouraging only truly zero emission trucks.

Country	Program	Per Vehicle	Type of Drivetrain	Total budget	Budget per ICE truck registered[22]	Running time
Austria	Emissionsfreie Nutzfahrzeuge und Infrastruktur	max. 80% of difference	BEV / H2	360 million €	4905 €	2022-2026
Belgium (Flanders)	Ecologipremier+	max. 80% of difference	BEV / H2	3 million / year	-	2022 – tbd
Denmark	Udmontning af pulje til gron transport	max. 60% of difference	BEV / H2	6,72 million €	159 €	2021-2022
France	France Relance and Ademe	max. 65% of difference (~100.000 €)	BEV / H2	165 million €	275 €	2021-2024
Finland	Regulation 1289 / 2021	50.000 €	BEV / natural gas	4 million €	42 €	2022
Germany	Klimaschonenden Nutzfahrzeugen & Tank- & Ladeinfrastruktur	max. 80% of difference (550.000 €)	BEV / H2 / PHET / OHC	5000 million €	5250 €	2021-2024
Italy	Ministerial decree (GU Serie Generale n.17 del 22-01-2022)	24.000 €	BEV / H2 / natural gas	30 million €	35,5 €	2021-2024
Netherlands	AanZET	max. 60% of difference (132.000 €)	BEV / H2	13,5 million €	86 €	2022-2026
Spain	Royal Decree 983/2021	max. 190.000 €	BEV / H2 / PHEV	150 million €	244 €	2020-2022
Sweden	Klimatpremien	20% of purchase price	BEV / H2 / natural gas	10,6 million €	125 €	2022-2024
United Kingdom	Plug-in Van and Truck Grants	max. 20% of vehicle (~28.000 €)	BEV / H2 / natural gas	1605 million €	2204 €	2022-2025

Table 2: Detailed overview of national ZE truck subsidies[23]

To elaborate further, the success of incentive programs designed to promote the adoption of electric trucks can be evaluated by measuring the number of electric trucks in use in a given country or region over time. However, as many of these programs are relatively new, there is currently limited usage data available to analyze. Without sufficient data, it is difficult to determine which incentive programs are most effective in driving the adoption of electric trucks.

In addition, there are several factors that can impact the adoption of electric trucks beyond just the presence of incentive programs. For example, the availability of charging infrastructure, the cost of the vehicles, and the range of the vehicles all play a role in determining whether or not a fleet operator

22 https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2022.pdf

23 Source: FIER, ACEA - https://www.acea.auto/files/ACEA-report-vehicles-in-use-europe-2022.pdf (2022) and T&E (2022)

chooses to adopt electric trucks. Therefore, it is important to consider all of these factors when evaluating the impact of incentive programs on the adoption of electric trucks. Overall, while incentive programs can be a valuable tool in promoting the adoption of electric trucks, it will take time and additional data to determine their true effectiveness.

Incentives for infrastructure

Convenient and affordable publicly accessible chargers will be increasingly important as BEVs scale up. To help address this, governments have provided support for EV charging infrastructure through measures such as direct investment to install publicly accessible chargers or incentives for EV owners to install charging points at home. In some places building codes may require new construction or substantial remodels to include charging points, for example in apartment blocks and retail establishments.

Charging infrastructure is a crucial part of the e-mobility transition for both passenger and freight transport. With increasing electric vehicle uptake, a wider expansion of private infrastructure will enlarge the existing public network as private charging point operators move into the heavy-duty field. Generally, member states support public, private and semi-private charging and refuelling hubs to varying degrees, either entirely publicly financed or through public-private co-financing agreements. Those include different charger types, ranging from public high power charging points to public and private overnight chargers.[24]

At EU level the Europe Union, the Alternative Fuel Infrastructure Directive (AFID) is the main measure guiding the roll-out of publicly accessible EV charging stations. EU members are required to set deployment targets for publicly accessible EV chargers for the decade to 2030, with an indicative ratio of 1 charger per 10 electric cars. The mandatory charging and refuelling targets for HDVs in the proposed Alternative Fuels Infrastructure Regulation (AFIR) as well as the corresponding AFIF funding instrument will ensure a basic HDV charging and refuelling network across Europe, making cross country and long-haul operations feasible by 2025. Today ZE MHDVs are mostly deployed in regional distribution, where charging at their logistics hubs is the most common and time-efficient approach. Besides AFIF, the EU-level also offers the Connecting Europe Facility (CEF), which aims to finance a Trans-European Network (TEN) in the transport, telecommunication and energy sectors. The programme was renewed under the EU's latest multiannual budget (MFF 2021-2027) with a total budget of €33.7 bn, with 77% (€25.8bn) available for transport projects. A large part of that (€18bn) will be spent in the first 3 years (2021-2023).

24 How to buy an electric truck: Public funding helps hauliers to deliver on zero emission road freight, Transport & Environment, 2022. november.

At national level, an interconnected European EV charging network also depends on the ambitions of individual countries. Leading countries such as Germany, France, Netherlands, Sweden and Italy have national policies and targets to encourage development that range from grants and fiscal incentives for installation of public and private chargers to free public charging in urban areas. Out of the 16 countries with a scheme of vehicle subsidies, only 12 also offer subsidies for recharging (BEV) and refuelling (FCEV) infrastructure with adequate power output for HDVs. That means charging stations with an output of at least 80kW for overnight charging, at least 150kW for opportunity charging and 350kW for a full recharge of BEVs. The most advanced schemes are currently in place in France, Germany, and Sweden with an offer to compensate between 60-100% of the infrastructure costs. Small cost contributions are available in Belgium, Croatia, Italy, and Poland.

Country	Program	Per Charger	Type of infrastructure	Running time
Austria	Emissionsfreie Nutzfahrzeuge und Infrastruktur	40% of costs (max. 30 000> kW	BEV / H2	2020-2026
Belgium (Flanders)	Ecologipremier+	30 % of costs (min. 50. kW)	BEV / H2	n/a
Denmark	Udmontning af pulje til gron transport	n/a	BEV / H2	2021-2024
France	Advenir	60% of costs (max. 960 000 € > 4000 KvA)	BEV	2021-2022
Finland	Decree under Act on Discretionary Government Transfers	n/a	BEV /H2/ natural gas	2022-2025
Germany	Klimaschonende Nutzf Nutzfahrzeugen & Tank- & Ladeinfrastruktur	80% of costs	BEV	2021-2024
Italy	Gazetta Ufficiale n.251	40% of costs (max. 75 000 € for > 100 kW)	BEV / H2 / natural gas	n/a
Sweden	Klimatklivet	40% of costs (for > 50 kW)	BEV	2020-2022
United Kingdom	none	none	none	none

Table 3: Detailed overview of national charging infrastructure subsidies[25]

25 Source: FIER

3.1 Country specific analyses

3.1.1 Austria[26]

The Austrian government which intends[27] to phase out diesel HDVs by 2030 for trucks with less than 18t and by 2035 for all other HDVs (Mobility Masterplan 2030)[28]. In its Recovery and Resilience plan (RRF[29]), Austria sets aside roughly €848,6 million for mobility initiatives.

The funding for MHDVs is called the *'Emission-free Commercial Vehicles and Infrastructure'* (ENIN) and it is hosted by the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology (BMK) and managed by the Austrian Research Promotion Agency (FFG).

Purchase subsidy

The first call targets Vans (N1), compensating 80% of the additional vehicle costs. Tendering started in the summer of 2022.. Each following year has a fixed budget of €50 million. A large proportion of that originates from Austria's recovery fund. A second call designated to trucks (N2 and N3) started in August 2022 with the promotion of the chassis and bodies if they save CO2. Electrically operated ancillary units, superstructures or associated devices (maximum one unit per purchased zero-emission commercial vehicle) are also subsidised. The purchase incentive is not a fixed lump-sum support but depends on a ranking based on the type of vehicle and infrastructure as well as its CO_2 emission saving potential. An initial 85 million euros will be awarded in the calls for proposals now launched. Applications can be submitted until 10 May 2023.

The funding will come partly from RRF - €35 million, a further €330 million will come from the national budget.

Other incentives

In Austria ZE MHDVs also have:

- Motor vehicle tax exemption;
- Infrastructure charge deduction;
- Road charge reduction.

Charging infrastructure

Austria's guideline document for enterprises transitioning to e-mobility details the subsidies per charger depending on their power output. For the necessary power output for trucks (above 80kW), a contribution of €30,000 is offered. The support for private charging points with the same output is slightly reduced at €20,000. The calls are published under the ENIN fund for infrastructure with a total of €35-50 million. The scheme is open for several years and contributes 40% to the net acquisition costs. One of the conditions to installing infrastructure is however the purchase of a BEV.

Country specific TCO tables

The following tables TCO tables are based on the TCO structure, introduced in section 2. They present the total cost of ownership structure of the ZE MHDVs in the selected use cases, in a 5-year period. The following cost components are used in the tables: Purchase subsidy, Registration tax, Truck Depreciation, Energy costs, Tires & Maintenance, Infrastructure maintenance, Infrastructure depreciation, Infrastructure subsidy, Motor vehicle tax, Infrastructure charge (road toll), External cost charge for noise and air pollution, External cost charge for CO2, Mandatory inspection.

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26 https://www.austriatech.at/assets/Uploads/Publikationen/PDFDateien/FactsFigures_2022_10_E.pdf

27 Mobilitätsmasterplan 2030 – Neuausrichtung des Mobilitätssektors.

28 https://www.klimafonds.gv.at/wp-content/uploads/sites/16/Leitfaden_E-Mobilitaet_Gewerbe_2021.pdf

29 https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/austrias-recovery-and-resilience-plan_en

Urban Delivery

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 14 907 €	
	Registration tax	195 €	195 €	- €
	Truck Depreciation	15 510 €	27 791 €	12 281 €
	Energy costs	14 646 €	7 529 €	- 7 117 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	2 500 €	2 500 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 035 €	- €
	Motor vehicle tax	930 €	- €	- 930 €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 148 €	6 007 €	- 2 141 €
Total costs		40 740 €	30 035 €	- 10 705 €

Table 4: TCO comparison Urban Delivery in Austria

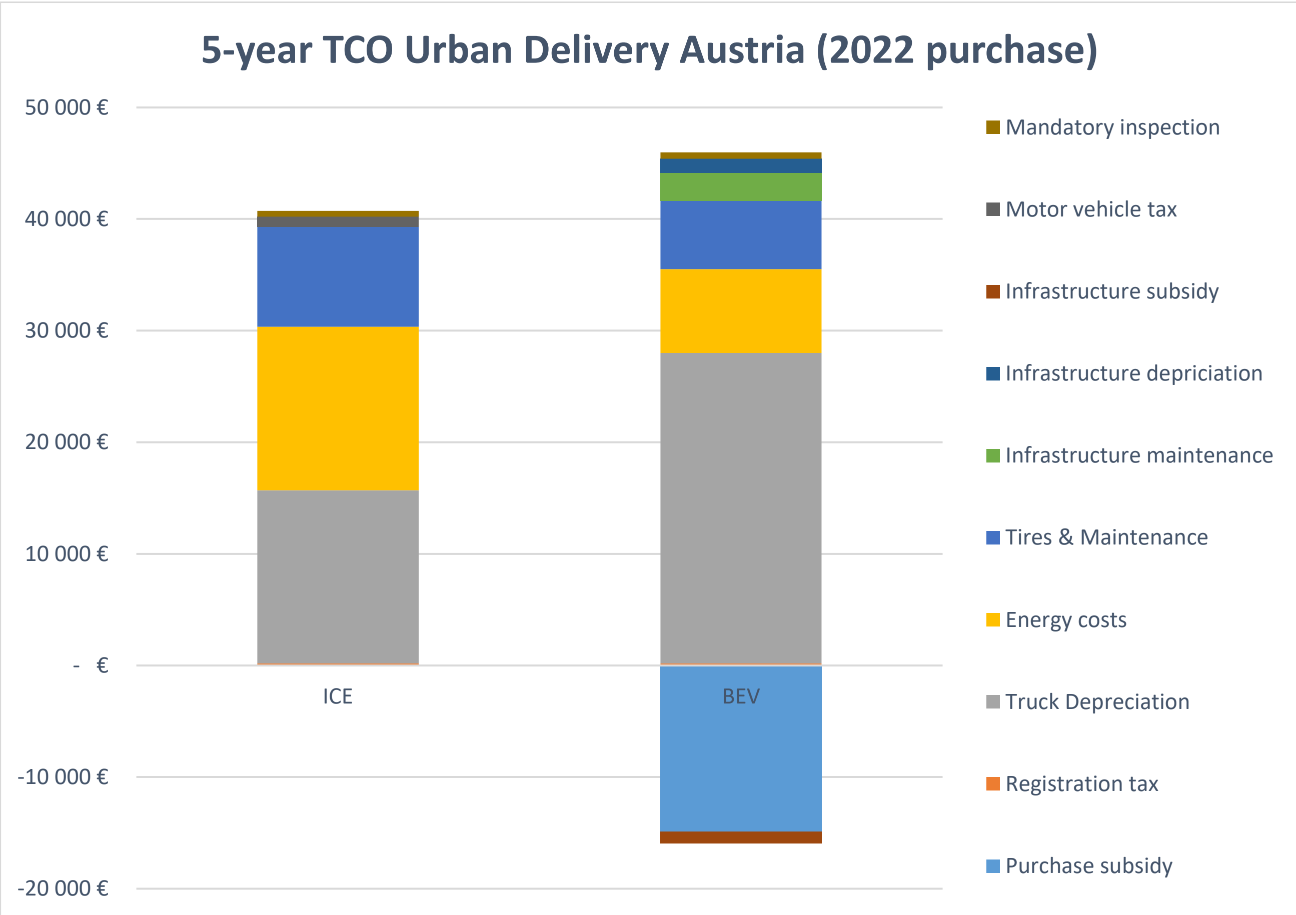

Figure 24: 5-year TCO Urban Delivery Austria (2022 purchase)

Regional Delivery

	Parameters	ICE	BEV	FCEV (H2)	Delta
5-year cost	Purchase subsidy	- €	-94 000 €	-214 000 €	
	Registration tax	195 €	195 €	195 €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €
	Energy costs	86 525 €	49 041 €	144 000 €	-37 484 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	-12 000 €	- €	
	Motor vehicle tax	4 800 €	- €	- €	-4 800 €
	Infrastructure charge	71 905 €	17 966 €	17 966 €	-53 939 €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	17 225 €	- €	- €	-17 225 €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €
Annual average		58 709 €	43 914 €		-14 795 €
Total costs		293 545 €	219 571 €	232 821 €	-73 974 €

Table 5: TCO comparison Regional Delivery in Austria

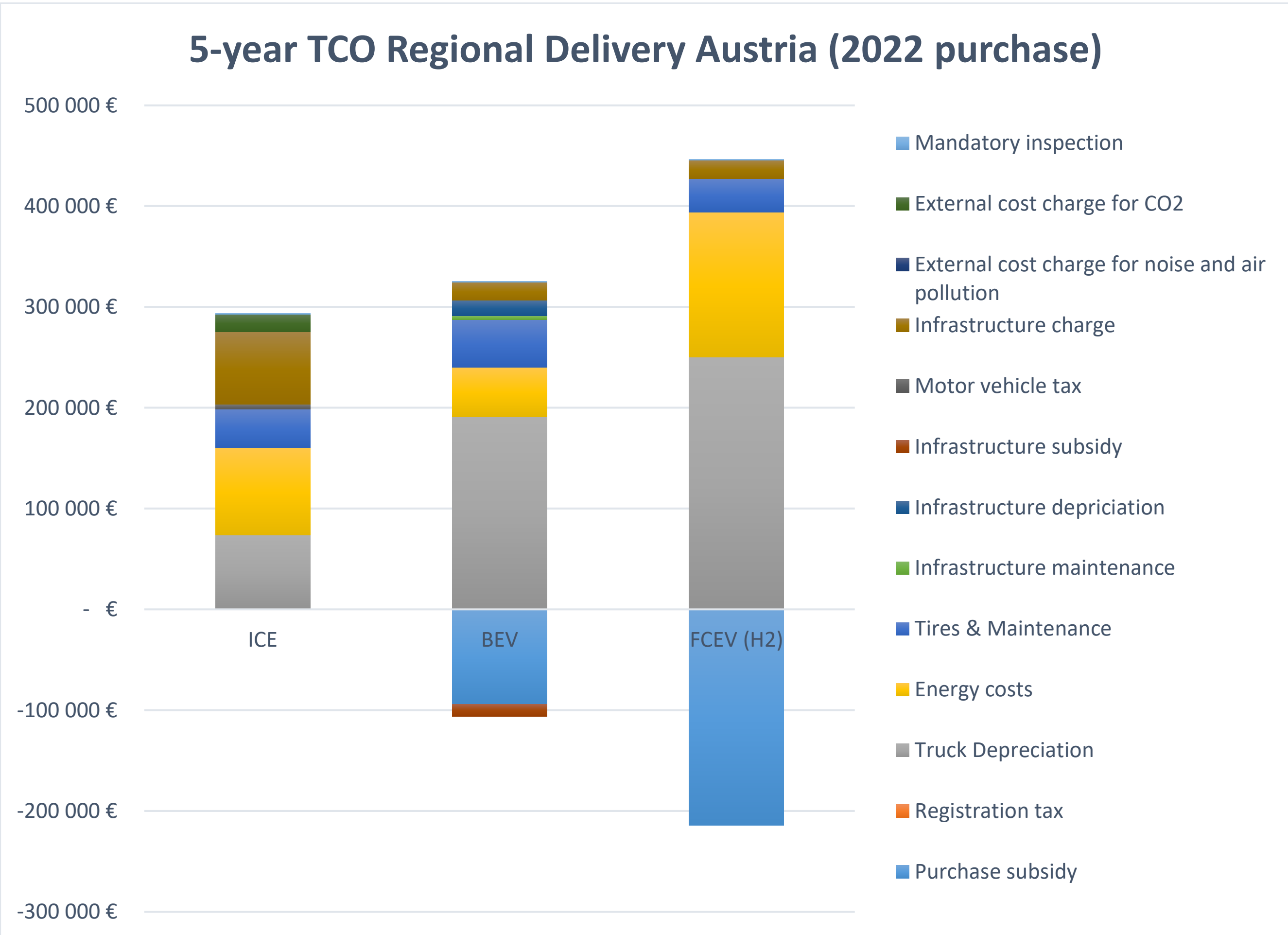

Figure 25: 5-year TCO Regional Delivery Austria (2022 purchase)

N3 Long Haul

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta BEV
	Purchase subsidy	- €	- 140 000 €	- 216 000 €	- 140 000 €
	Registration tax	195 €	195 €	195 €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	157 821 €
	Energy costs	369 503 €	396 482 €	815 100 €	26 978 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 12 000 €	- €	- 12 000 €
	Motor vehicle tax	4 800 €	- €	- €	- 4 800 €
	Infrastructure charge	314 928 €	78 687 €	78 687 €	- 236 241 €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	29 167 €	- €	- €	- 29 167 €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	104 €
Annual average		166 575 €	124 746 €	242 868 €	- 41 829 €
Total costs		832 877 €	623 732 €	1 214 338 €	- 209 145 €

Table 6: TCO comparison Long Haul in Austria

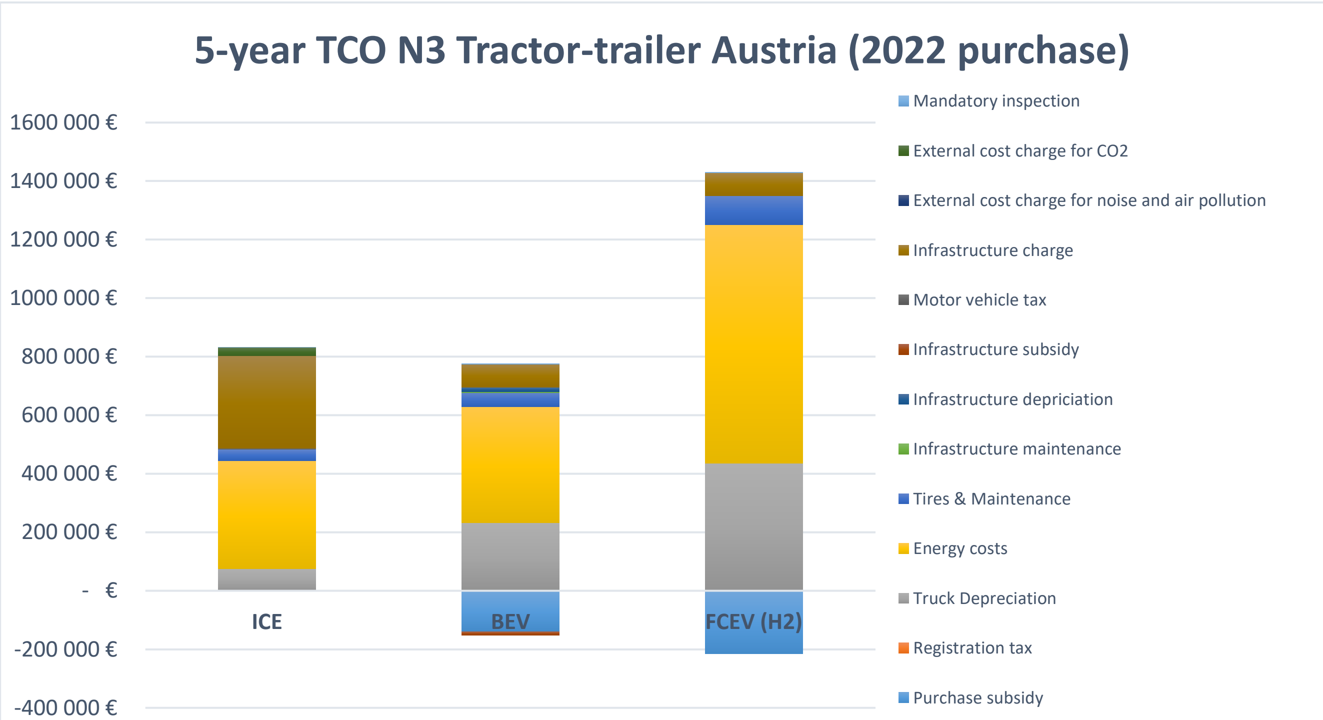

Figure 26: 5-year TCO Long Haul Austria (2022 purchase)

3.1.2 Belgium (Flanders)

Belgium only incentivizes fully decarbonized road freight solutions. A strong recommendation is given to maximize the use of renewable energy for both charging and hydrogen refueling infrastructure projects. There is strong and clear evidence that gas trucks are as bad for the climate as their diesel counterparts therefore Belgium (and Denmark) have already removed gas trucks from their financial aid schemes .

Purchase subsidy

An ecology premium is a financial contribution to companies that will make ecology investments in the Flemish Region. With the ecology premium, the Flemish government wants to encourage companies to organize their production process in an environmentally friendly and energy-efficient way, and is thereby paying part of the extra investment costs that such an investment entails.[30] In Belgium the total budget is relatively low with respectively €3 and €5 million, especially in comparison to the several hundred million that Germany or France have budgeted for investment. The programme contributed to soaring number of new BEV and PHEV truck in Belgium, resulting in 14 BEVs and 3 PHEVs at the end of 2022. The estimations show, that most of the vehicles, 13 has been registered in the fourth quarter (EAFO, ACEA).

A recent reform removed gas trucks from the support program, doubling support for electric trucks instead. Support is capped regarding company size (50% of the additional costs for small and medium-sized companies (<250 workers) and 40% for large enterprises) and total vehicle costs (40% for BEVs, 22.5% for FCEVs and €160,000 in total). Companies can have a maximum of 2 trucks funded.

The Wallonian government has had a fund in place from 2021 onwards. €5k is given per vehicle, with a maximum amount of €15K per company. The goal is to reduce energy consumption, noise and emissions and the scheme includes both vehicles and equipment.

Other incentives

In Belgium ZE MHDVs also have:

- Motor vehicle tax exemption
- 30% of charging infrastructure costs
- Exemption from external cost charge for CO2 from 2025 (€5.300 - € 9.600)

Charging infrastructure

The premium also enables the construction of recharging stations. Up to 30% of the costs can be compensated, as long as the power output is at least 50 kW and renewable energy is used. For a hydrogen refilling station 27% of its costs are reimbursed, with a cap of €2 million per fueling station.

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[30] GBER: Link1, Link2. Ministerial decree, Link3, Link4. Decree of the Flemish Government.

Urban Delivery

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 14 907 €	
	Registration tax	496 €	496 €	- €
	Truck Depreciation	15 510 €	27 791 €	12 281 €
	Energy costs	15 187 €	5 265 €	- 9 923 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 786 €	- €
	Motor vehicle tax	- €	- €	- €
	Mandatory inspection	255 €	255 €	- €
Annual average		8 077 €	5 118 €	- 2 959 €
Total costs		40 385 €	25 588 €	- 14 797 €

Table 7: TCO comparison Urban Delivery in Belgium (Flanders)

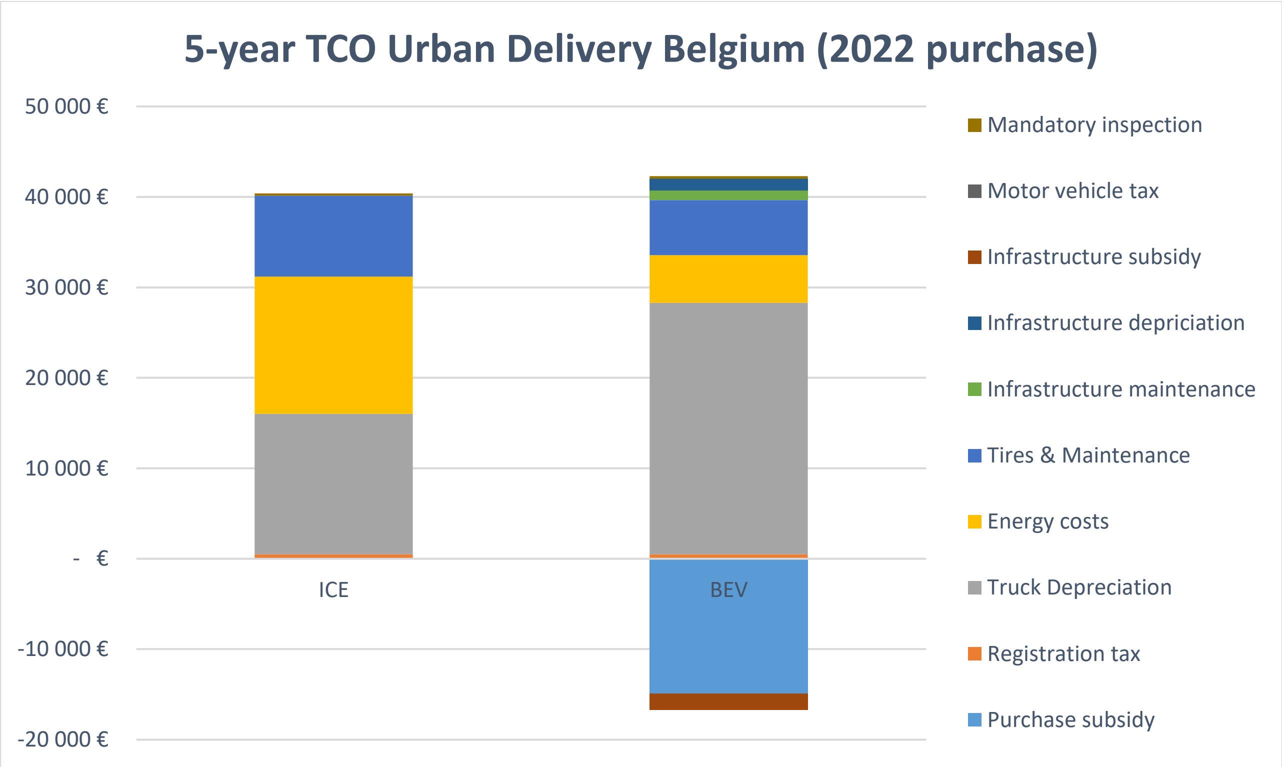

Figure 27: 5-year TCO Urban Delivery Belgium (2022 purchase)

Regional Delivery

	Parameters	ICE	BEV	FCEV (H2)	Delta
5-year cost	Purchase subsidy	- €	- 94 000 €	- 120 375 €	
	Registration tax	4 957 €	4 957 €	4 957 €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €
	Energy costs	89 721 €	34 289 €	144 000 €	- 55 432 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 9 000 €	- €	
	Motor vehicle tax	2 685 €	- €	- €	- 2 685 €
	Infrastructure charge	27 233 €	27 233 €	27 233 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	4 396 €	- €	- €	- 4 396 €
	Mandatory inspection	255 €	255 €	318 €	- €
Annual average		48 219 €	44 191 €	-	- 4 029 €
Total costs		241 097 €	220 954 €	339 358 €	- 20 143 €

Table 8: TCO comparison Regional Delivery in Belgium (Flanders)

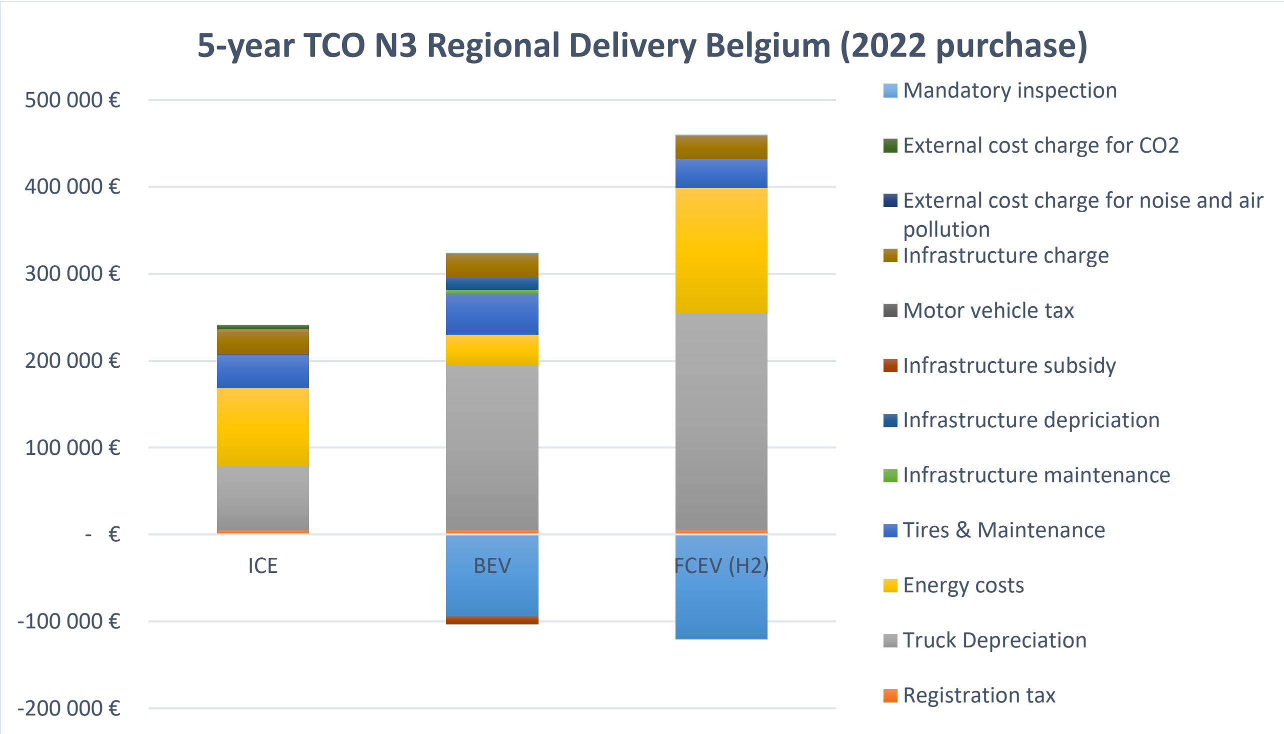

Figure 28: 5-year TCO Regional Delivery Belgium (2022 purchase)

Long Haul

	Parameters	ICE	BEV	FCEV (H2)	Delta BEV
5-year cost	Purchase subsidy	- €	- 140 000 €	- 200 250 €	- 140 000 €
	Registration tax	4 957 €	4 957 €	4 957 €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	157 821 €
	Energy costs	383 150 €	343 347 €	815 100 €	- 39 803 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 9 000 €	- €	- 9 000 €
	Motor vehicle tax	4 645 €	- €	- €	- 4 645 €
	Infrastructure charge	144 321 €	144 321 €	144 321 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	35 292 €	- €	- €	- 35 292 €
	Mandatory inspection	255 €	255 €	509 €	- €
Annual average		137 172 €	128 620 €	259 739 €	- 8 552 €
Total costs		685 860 €	643 100 €	1 298 697 €	- 42 760 €

Table 9: TCO comparison Long Haul in Belgium (Flanders)

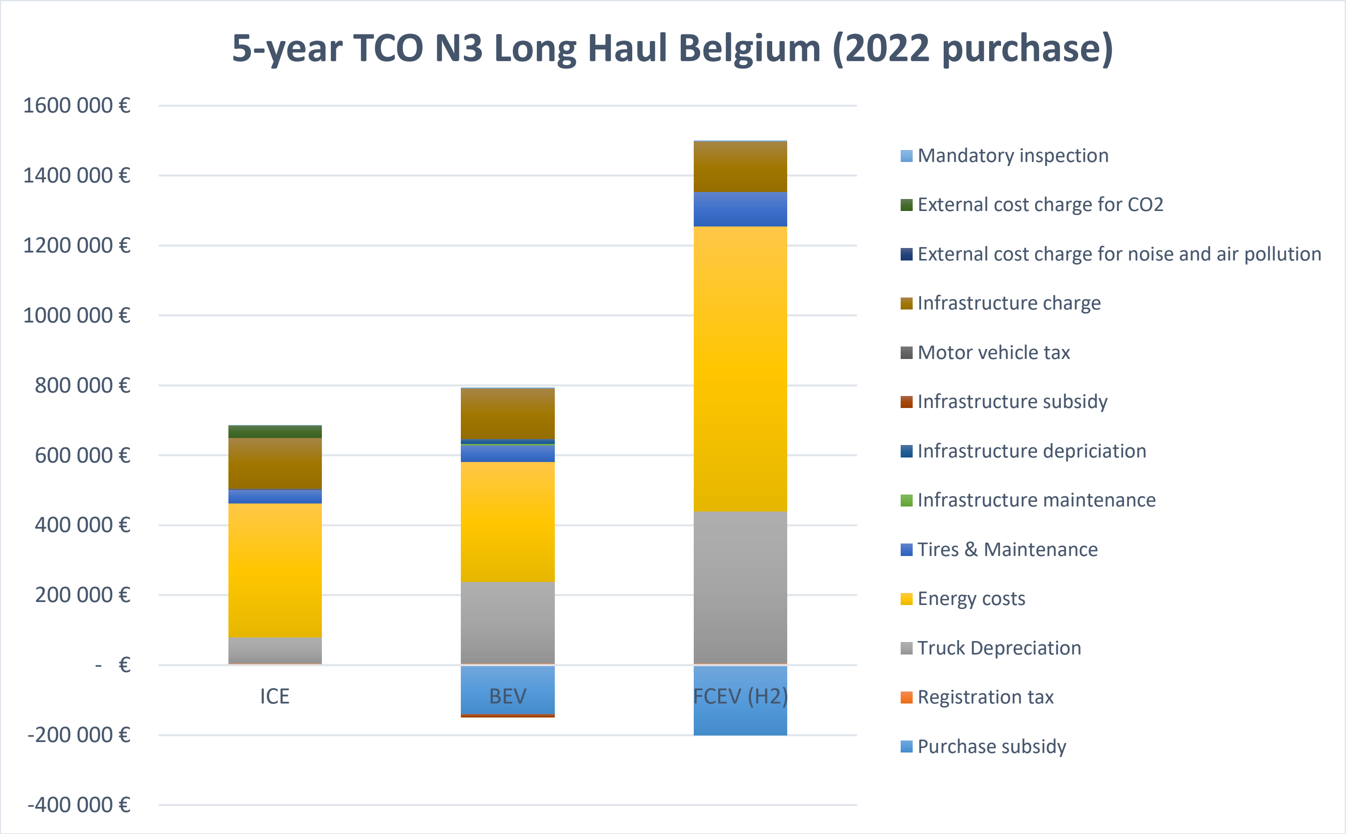

Figure 29: 5-year TCO Long Haul Belgium (2022 purchase)

3.1.3 France

Austria, Germany and France have the most generous schemes in place compensating the difference in vehicle price between a ZE MHDV compared to the diesel, thereby making an appealing case for hauliers to transition and eventually benefit from the more attractive TCO of a ZE MHDV. Despite this, the long application cycle with heavy administrative processes reported in France has inhibited SMEs from making use of the funding and transitioning.

Purchase subsidy

To enable rapid usage of zero emission vehicles in the transport sector France has put two subsidy schemes in place that can help hauliers. On the one hand, there is the a scheme entitled 'Ecology bonus' for trucks based on the Code de l'energie within the country's €100 million strong '*France Relance*' scheme [31]running until 2022[32]. The ecology bonus consists of a fixed amount per truck and is handled by Avere France, the national association for electromobility. The bonus compensates 40% of the purchase price of a battery electric or hydrogen-powered vehicle, with a maximum of €50,000 for a truck and €30,000 for a bus. The support can be combined with the depreciation scheme for 'heavy vehicles using clean energy', a super depreciation scheme resulting in a cost reduction of 7.5% of the purchase price, cumulatively capped at €100,000. The depreciation scheme was recently extended until the end of 2024.[29] As a result, the combination of the grants and the additional depreciation scheme can sum up to €100,000 per electric truck.

On the other hand the Ademe' Program with the first call recently closed. This scheme has a budget of €65 million and will run until 2024. The Ademe calls, as approved by the Ministerial Council for Development and Innovation in Transport, are eligible for individual companies as well as consortiums. Per enterprise, a limit of €15 million is introduced. Purchase incentives of €100,000 per truck under 26t and €150,000 per truck above 26t are planned.

Other incentives

In France ZE MHDVs also have:

- Road toll reductions (Does not apply truck tolls, or existing concessions exempt until renewed or substantially amended)
- Motor vehicle tax reduction (50 % for 26-32t rigid)
- Motor vehicle tax exemption (for 40t tractor)
- Super depreciation Scheme: cost reduction of 7.5% of the purchase price, cumulatively capped at €100,000

Charging infrastructure

With a €120 million budget, France funds private chargers in the 'Advenir' program. Since 2016 this has led to the construction of 45,000 private and public charging stations for passenger vehicles and the program has been renewed until the end of 2023. For HDV charging the aim is to develop 50 projects, leading to an initial total of 1,000 new charging points. 50% of their costs, with a max. 960k for a charging hub with 48 charging points and a minimum connection power of 4.000 kVA (~4MW), will be covered.

31 https://www.diplomatie.gouv.fr/en/french-foreign-policy/economic-diplomacy-foreign-trade/promoting-france-s-attractiveness/france-relance-recovery-plan-building-the-france-of-2030/

32 https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046848201

https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000046768377

Urban Delivery

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 12 112 €	
	Registration tax	336 €	336 €	- €
	Truck Depreciation	15 510 €	27 791 €	12 281 €
	Energy costs	15 253 €	5 265 €	- 9 988 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	2 500 €	2 500 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 553 €	- €
	Motor vehicle tax	- €	- €	- €
	Mandatory inspection	325 €	375 €	50 €
Annual average		8 072 €	5 998 €	- 2 074 €
Total costs		40 361 €	29 990 €	- 10 372 €

Table 10: TCO comparison Urban Delivery in France

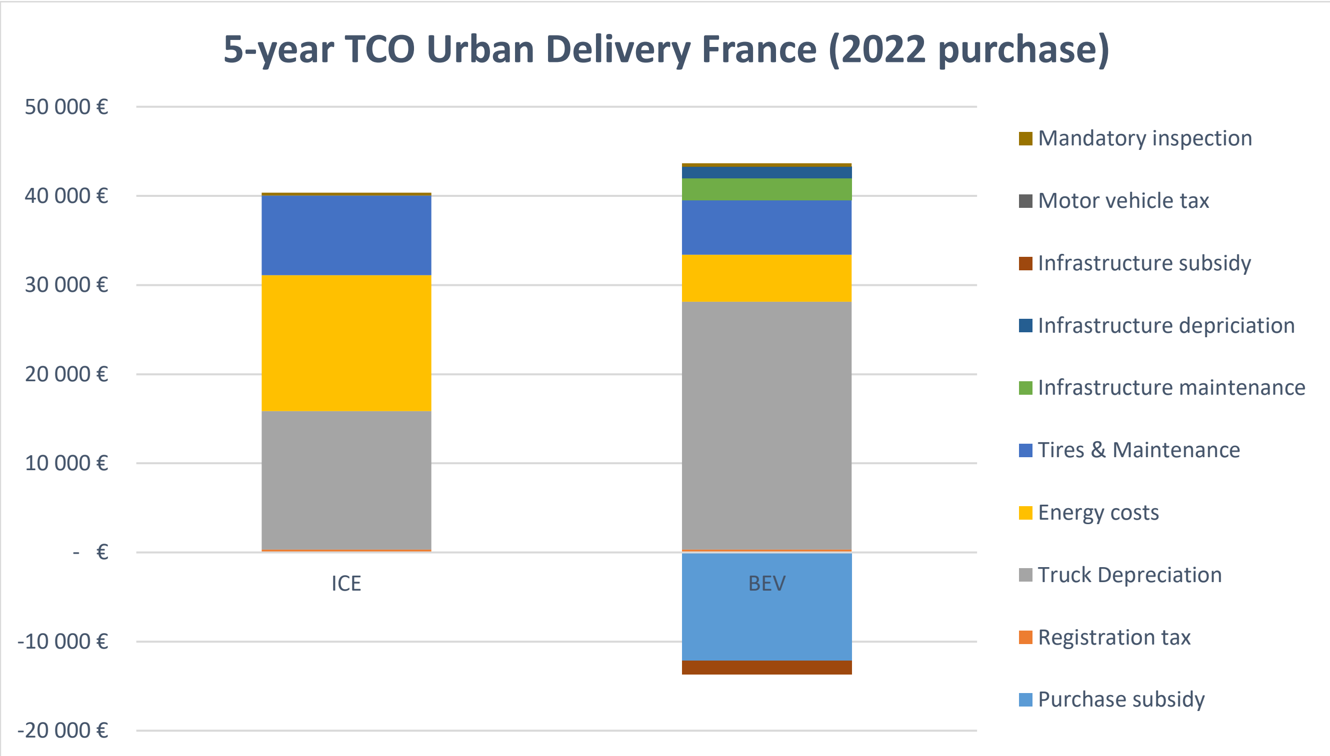

Figure 30: 5-year TCO Urban Delivery France (2022 purchase)

Regional Delivery

	Parameters	ICE	BEV	FCEV (H2)	Delta
5-year cost	Purchase subsidy	- €	- 68 750 €	- 80 000 €	
	Registration tax	51 €	51 €	51 €	- €
	Parafiscal charges	189 €	189 €	189 €	- €
	Truck Depreciation	73 472 €	190 821 €	250 000 €	117 348 €
	Energy costs	90 108 €	34 289 €	144 000 €	- 55 819 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 18 000 €	- €	
	Motor vehicle tax	3 140 €	1 820 €	1 820 €	- 1 320 €
	Infrastructure charge	45 013 €	45 013 €	45 013 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €
	Mandatory inspection	650 €	750 €	938 €	100 €
Annual average		50 173 €	50 516 €		344 €
Total costs		250 863 €	252 582 €	395 235 €	1 719 €

Table 11: TCO comparison Regional Delivery in France

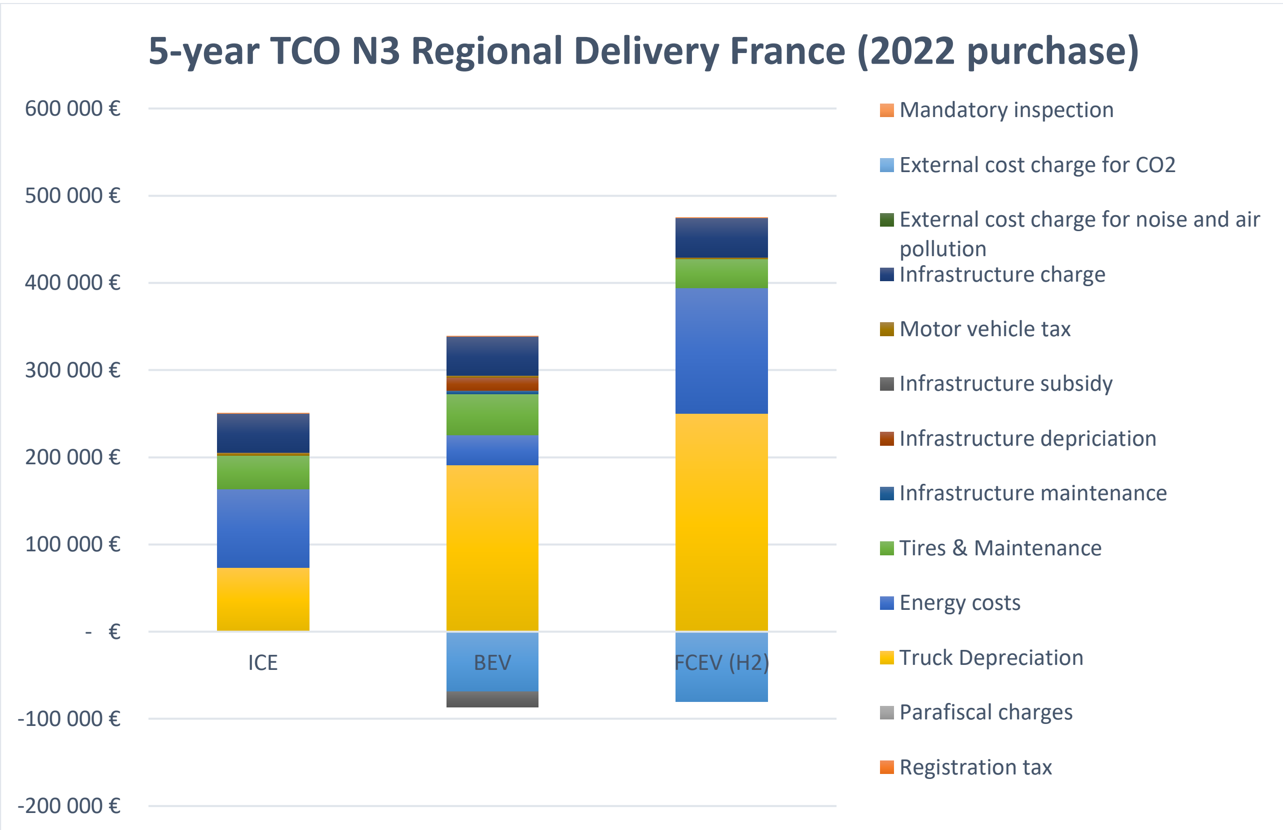

Figure 31: 5-year TCO Regional Delivery France (2022 purchase)

Long Haul

	Parameters	ICE	BEV	H2	Delta BEV
5-year cost	Purchase subsidy	- €	- 68 750 €	- 74 375 €	- 68 750 €
	Registration tax	51 €	51 €	51 €	- €
	Parafiscal charges	189 €	189 €	189 €	- €
	Truck Depreciation	77 778 €	183 984 €	250 105 €	106 206 €
	Capital allowance	- €	- 29 253 €	- 39 767 €	- 29 253 €
	Energy costs	420 486 €	314 558 €	720 781 €	- 105 928 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	3 348 €	- €	3 348 €
	Motor vehicle tax	3 140 €	- €	- €	- 3 140 €
	Infrastructure charge	236 576 €	236 576 €	236 576 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €
	Mandatory inspection	650 €	750 €	945 €	100 €
Annual average		155 422 €	141 570 €	238 597 €	- 13 852 €
Total costs		777 110 €	707 852 €	1 192 985 €	- 69 258 €

Table 12: TCO comparison Long Haul in France

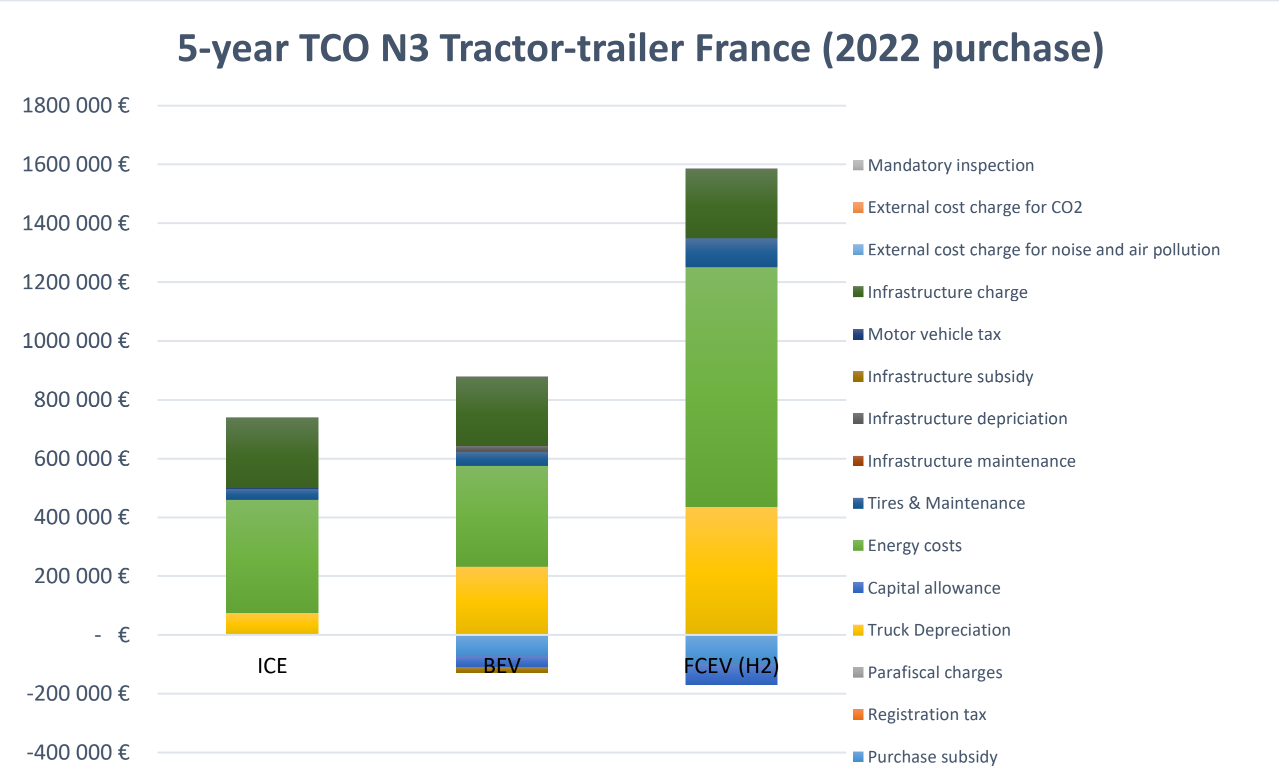

Figure 32: 5-year TCO Long Haul France (2022 purchase)

3.1.4 Germany

Germany is successfully bridging the investment gap between a diesel truck and a ZE MHDV by compensating up to 80% of the difference in costs. Germany have one of the most generous programs in place with 65% and 80% of the difference in vehicle price between a ZE MHDV compared to the diesel. Germany also includes plug-in vehicles and is the only country that includes overhead-catenary systems in its program.

Purchase subsidy

The German funding scheme takes the CO2 saving potential per invested euro into account. Only applications that save more CO2 than the lowest performing 50% of applicants are approved. Both investment cost and annual mileage are assessed, meaning that trucks with higher mileage are more likely to gain the subsidy. As these are also the trucks with the highest vehicle price, this differentiator steers funds towards where they are most needed.

'*Climate-friendly commercial vehicles and infrastructure*' (KsNI) entails incentives for heavy duty vehicles, their infrastructure and funding for feasibility studies. In this case the studies are geared to analyse the acquisition and operability of zero emission HDVs. [33]The fund addresses different focus points over the timespan of the program. Supporting the electrification of urban and regional distribution is the starting point, followed by battery trucks for long distances.

Three calls are published, each one running for a 12-month period. Elaborated by the transport ministry (BMDV), the first and second call focus on trucks (N1, N2 and N3), whilst the third one aims to enable the roll-out of zero emission vocational vehicles. The total budget for the three calls is 1,6 billion euro. Each allows the purchase of commercial vehicles with electric drive, plug-in hybrid, fuel-cell electric and overhead catenary systems (OHC). The calls compensate up to 80% of the price difference between a zero emission HDV and its Euro VI diesel equivalent. The fund further differentiates the per vehicle spending between drivetrain technologies.

Other incentives

In Germany ZE MHDVs have:

- Motor vehicle tax exemption;
- Infrastructure charge reduction;
- External cost charge for noise and air pollution reduction;
- Super depreciation scheme: cost reduction of 7.5% of the purchase price, cumulatively capped at €100,000;
- Road charge reduction.

Germany`s intention to support domestic manufacturing of trucks with incentives has been confirmed. The state aid scheme has no restriction on future operation, so companies registered in Germany, can easily apply for funding, which could attract Luxembourg companies to apply for funding in Germany.

33 https://www.klimafreundliche-nutzfahrzeuge.de/wp-content/uploads/2022/04/BAnz-AT-29.03.2022-B2.pdf

Charging infrastructure[34]

The coalition agreement of the current German government[35] maps out an ambitious path for electrifying vehicle fleets by 2030, aiming to build 1 million public charging stations across the country for private and commercial vehicles. It also released its proposal for a second '*Masterplan II*' for infrastructure this summer. The directive 'Publicly accessible charging infrastructure for electric vehicles in Germany was extended to the end of 2025 with the government's target of stationing 50,000 charging points with at least 20,000 of those being fast chargers for cars and trucks. For public and private actors, the fund for commercial fleets 'KsNI' refunds up to 80% of the costs of a charger and an additional maximum of €100.000 per charging location to connect charging hubs to the medium voltage grid. Additionally, the 'Masterplan for infrastructure II' promises a plan for a comprehensive roll out of a truck charging network across Germany.

	Kappungsgrenzen je Antriebstechnologie für Neufahrzeuge				**Kappungsgrenzen je Antriebs-technologie für umgerüstete Diesel-Fahrzeuge (Umrüstung)**	
EG-Fahrzeug-klasse und -zGG	**Batterie***	**Brennstoff-zelle****	**Oberleitungs-Verbrenner-Hybrid*****	**Plug-In-Hybrid**	**Batterie (Umrüstung)**	**Brennstoffzelle (Umrüstung)**
N1 ≤ 3,5 t	25.000 Euro	90.000 Euro	-	-	-	-
N2 > 3,5 t bis 12 t						
bis 7,5t	100.000 Euro	200.000 Euro	-	-	90.000 Euro	190.000 Euro
bis 12t	200.000 Euro	300.000 Euro	-	-	190.000 Euro	290.000 Euro
N3 > 12 t						
< 20 t	350.000 Euro	450.000 Euro	120.000 Euro	100.000 Euro	330.000 Euro	430.000 Euro
20 bis 30 t	400.000 Euro	500.000 Euro	170.000 Euro	150.000 Euro	380.000 Euro	480.000 Euro
> 30 t	450.000 Euro	550.000 Euro	220.000 Euro	200.000 Euro	420.000 Euro	520.000 Euro

*gilt für reine Batterieelektrofahrzeuge und Oberleitungs-Batterieelektrofahrzeuge (OL-Batterie) gemäß § 2 Nummer 2 EMoG
**gilt für reine Brennstoffzellenfahrzeuge und Oberleitungs-Brennstoffzellenfahrzeuge (OL-Brennstoffzelle) gemäß § 2 Nummer 4 EMoG
*** gilt nur für Oberleitungs-Verbrenner-Hybridfahrzeuge (OL-Verbrenner) gemäß § 2 Nummer 3 EMoG,
Hybridisierung mit Batterie beziehungsweise Brennstoffzelle gilt als reines Batterieelektro- beziehungsweise Brennstoffzellenfahrzeug

Table 13: Overview of German Purchase Subsidy scheme. Source: NOW GmbH (2022) – see attachment

34https://www.klimafreundliche-nutzfahrzeuge.de/wp-content/uploads/2021/08/Foerderaufruf_Teil1.pdf

35 https://bmdv.bund.de/SharedDocs/DE/Anlage/G/masterplan-ladeinfrastruktur.pdf?__blob=publicationFile

Urban Delivery

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 14 907 €	
	Registration tax	60 €	60 €	- €
	Truck Depreciation	15 510 €	27 791 €	12 281 €
	Energy costs	15 195 €	9 764 €	- 5 432 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 4 763 €	- €
	Motor vehicle tax	1 425 €	1 425 €	- €
	Mandatory inspection	325 €	375 €	50 €
Annual average		8 291 €	5 644 €	- 2 647 €
Total costs		41 453 €	28 220 €	- 13 233 €

Table 14: TCO comparison Urban Delivery in Germany

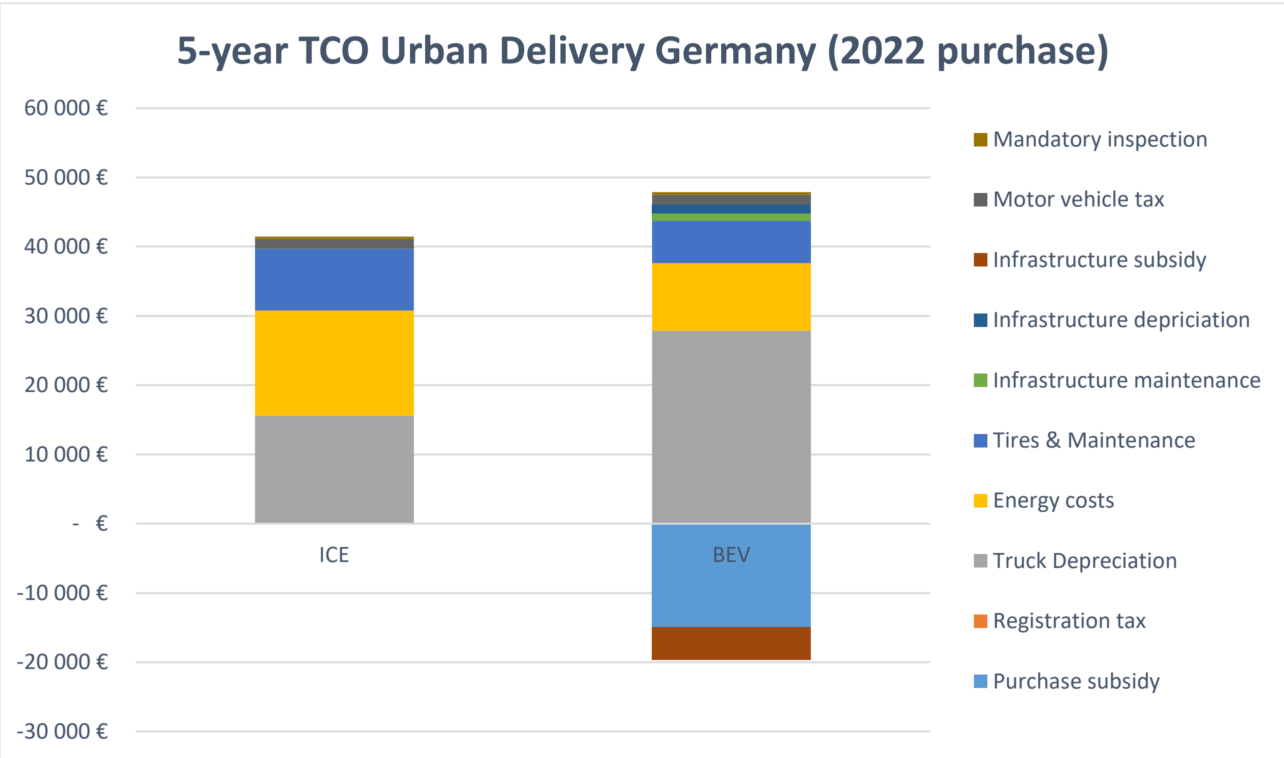

Figure 33: 5-year TCO Urban Delivery Germany (2022 purchase)

Regional Delivery

	Parameters	**ICE**	**BEV**	**FCEV (H2)**	**Delta**
5-year cost	Purchase subsidy	- €	- 94 000 €	- 214 000 €	
	Registration tax	60 €	60 €	60 €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €
	Energy costs	89 769 €	63 594 €	144 000 €	- 26 175 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 24 000 €	- €	
	Motor vehicle tax	9 305 €	- €	- €	- 9 305 €
	Infrastructure charge	29 309 €	- €	- €	- 29 309 €
	External cost charge for noise and air pollution	2 190 €	66 €	66 €	- 2 124 €
	External cost charge for CO2	5 231 €	- €	- €	- 5 231 €
	Mandatory inspection	650 €	750 €	938 €	100 €
Annual average		49 673 €	40 738 €		- 8 935 €
Total costs		248 365 €	203 691 €	214 289 €	- 44 675 €

Table 15: TCO comparison Regional Delivery in Germany

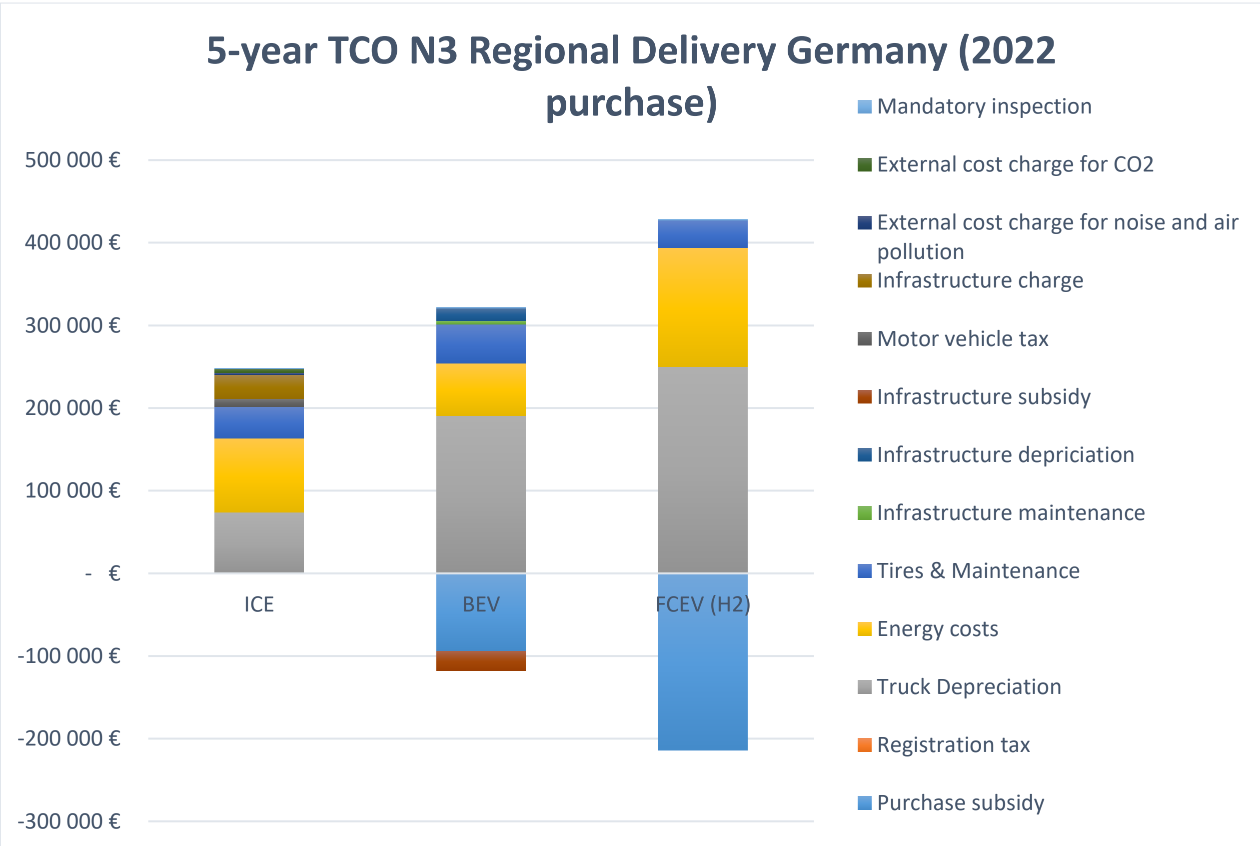

Figure 34: 5-year TCO Regional Delivery Germany (2022 purchase)

Long Haul

	Parameters	ICE	BEV	FCEV (H2)	Delta BEV
5 year cost	Purchase subsidy	- €	- 140 000 €	- 23 640 €	- 140 000 €
	Registration tax	60 €	60 €	60 €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	157 821 €
	Energy costs	383 357 €	448 898 €	815 100 €	65 541 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- 24 000 €	- €	- 24 000 €
	Motor vehicle tax	9 905 €	- €	- €	- 9 905 €
	Infrastructure charge	128 368 €	- €	11 €	- 128 368 €
	External cost charge for noise and air pollution	8 059 €	272 €	272 €	- 7 787 €
	External cost charge for CO2	19 251 €	- €	- €	- 19 251 €
	Mandatory inspection	650 €	750 €	1 500 €	100 €
Annual average		132 578 €	117 040 €	185 473 €	- 15 538 €
Total costs		662 891 €	585 201 €	927 363 €	- 77 690 €

Table 16: TCO comparison Long Haul in Germany

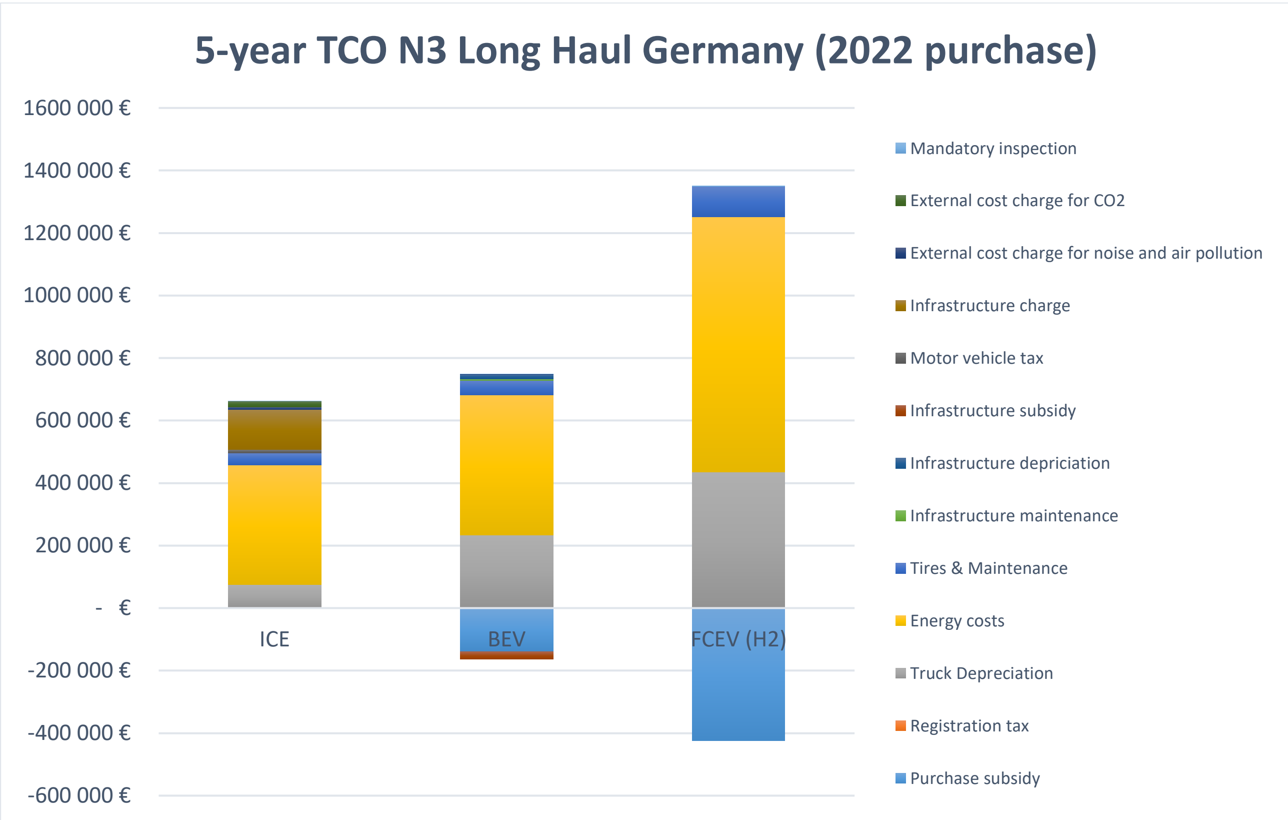

Figure 35: 5-year TCO Long Haul Germany (2022 purchase)

3.1.5 Netherlands[36]

The Netherlands has committed to a 30% share of new trucks and buses to be zero emission by 2030 and 100% by 2040, currently differentiating its subsidy amounts depending on the applicants company size or annual turnover. This allows the Dutch government to ensure larger aid sums flow to smaller companies with more limited financial capacities.

Purchase subsidy

AanZET'[37] ('Aanschaf Emissieloze Vrachtwagens') has a budget of €25 million to further the purchasing of ZE MHDVs. It was recently extended with the aim to register an additional 450 ZE MHDVs by the end of 2022. An additional €22.2 million is available for the purchase of construction trucks running on electricity or hydrogen or retrofitted from a former diesel engine. The AanZET is currently in consultation mode and will directly fund trailers and long-haul combinations, with differentiated support based on the applicant's company size. Whilst subsidies are capped at 40% of the vehicle costs on average, an extra boost is given to small companies (<10 employees) by increasing the cap to 60%. Companies can apply for subsidies from May 2022 onwards until 2027.

	Maximale steun op grond van EU-staatssteunkader					
	40% *(grote onderneming)*		50% *(middelgrote onderneming)*		60% *(kleine onderneming + non-profitinstelling)*	
Voertuig-categorie	Subsidie-percentage	Maximaal subsidie-bedrag	Subsidie-percentage	Maximaal subsidie-bedrag	Subsidie-percentage	Maximaal subsidie-bedrag
N2	12,5 %	€ 17.800	19,0 %	€ 26.800	25,0 %	€ 35.700
N3 Bakwagen	15,0 %	€ 43.600	21,5 %	€ 63.700	28,5 %	€ 84.000
N3 Trekker	20,0 %	€ 72.700	28,5 %	€ 102.300	37,0 %	€ 131.900

Table 17: Aanzet funding rates, based on company size and vehicle type[38]

Other incentives

In the Netherlands ZE MHDVs have:

- Motor vehicle tax exemption
- Exemption from external cost charge (from 2025, for noise and air pollution)
- Tax benefits for green investments

Charging infrastructure

The Netherlands currently installed a total of 96,473 charging points[39] for cars and vans across both public and semi-public areas[40]. 3,145 of those are fast charging points. However, the government currently has no funding program in place yet for HDV chargers and is exploring whether HDV charging infrastructure should receive financial assistance.

36 https://www.rijksoverheid.nl/documenten/kamerstukken/2021/12/14/regeling-aanschafsubsidie-zero-emissie-trucks-aanzet

37 https://www.rvo.nl/subsidies-financiering/aanzet

38 AanZET https://open.overheid.nl/documenten/ronl-61f2b232-cb07-4c25-908c-884c02edb594/pdf

39 https://www.rvo.nl/sites/default/files/2023-04/Statistics-Electric-Vehicles-and-Charging-in-The-Netherlands-up-to-and-including-February-2023.pdf

40 http://www.ieahev.org/news/annual-reports

Urban Delivery

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 4 006 €	
	Registration tax	52 €	52 €	- €
	Truck Depreciation	15 510 €	27 791 €	12 281 €
	Energy costs	15 081 €	9 550 €	- 5 531 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- €	- €
	Motor vehicle tax	1 600 €	1 600 €	- €
	Mandatory inspection	325 €	375 €	50 €
Annual average		8 301 €	8 767 €	466 €
Total costs		41 505 €	43 836 €	2 332 €

Table 18: TCO comparison Urban Delivery in Netherlands

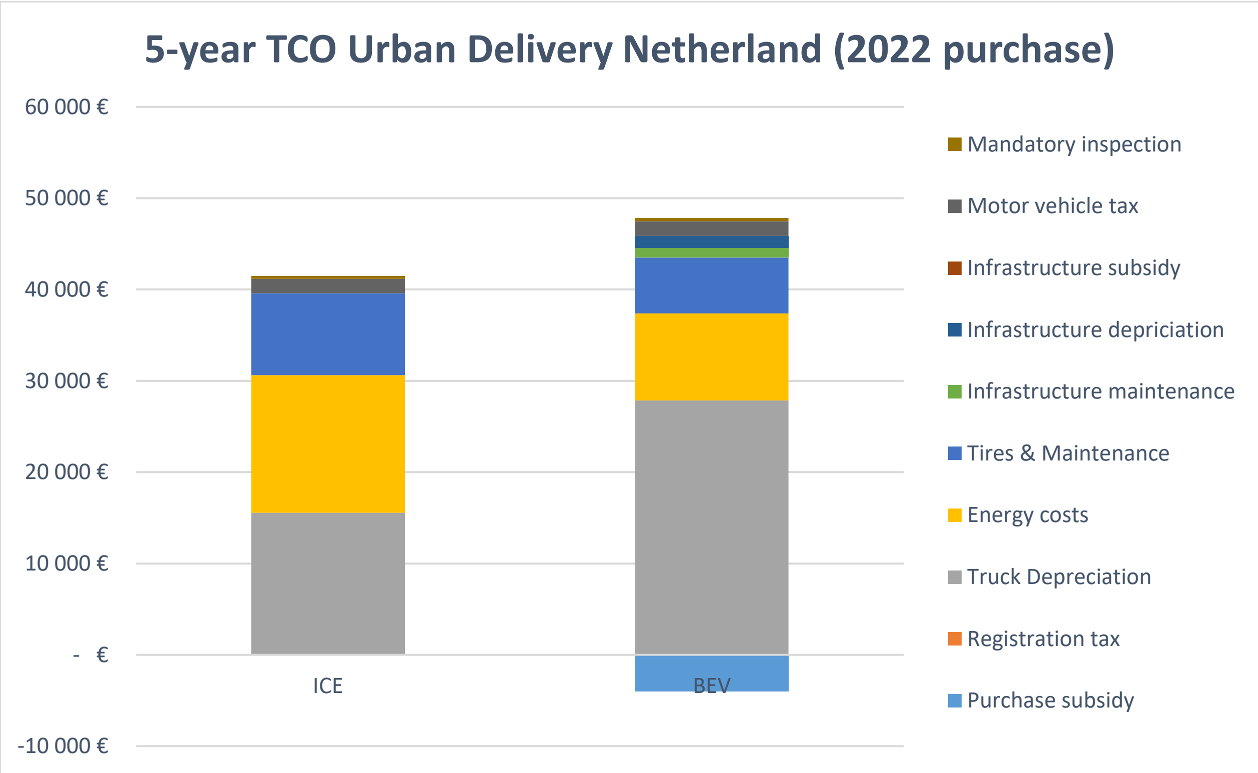

Figure 36: 5-year TCO Urban Delivery Netherlands (2022 purchase)

Regional Delivery

	Parameters	ICE	BEV	FCEV (H2)	Delta
5-year cost	Purchase subsidy	- €	- 33 488 €	- 76 238 €	- €
	Registration tax	52 €	52 €	52 €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €
	Energy costs	89 092 €	98 589 €	144 000 €	9 497 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- €	- €	- €
	Motor vehicle tax	3 200 €	- €	- €	- 3 200 €
	Infrastructure charge	6 505 €	5 529 €	5 529 €	- 976 €
	External cost charge for noise and air pollution	428 €	428 €	428 €	- €
	External cost charge for CO2	4 396 €	- €	- €	- 4 396 €
	Mandatory inspection	650 €	750 €	938 €	100 €
Annual average		43 235 €	65 816 €		22 582 €
Total costs		216 173 €	329 080 €	357 934 €	112 908 €

Table 19: TCO comparison Regional Delivery in Netherlands

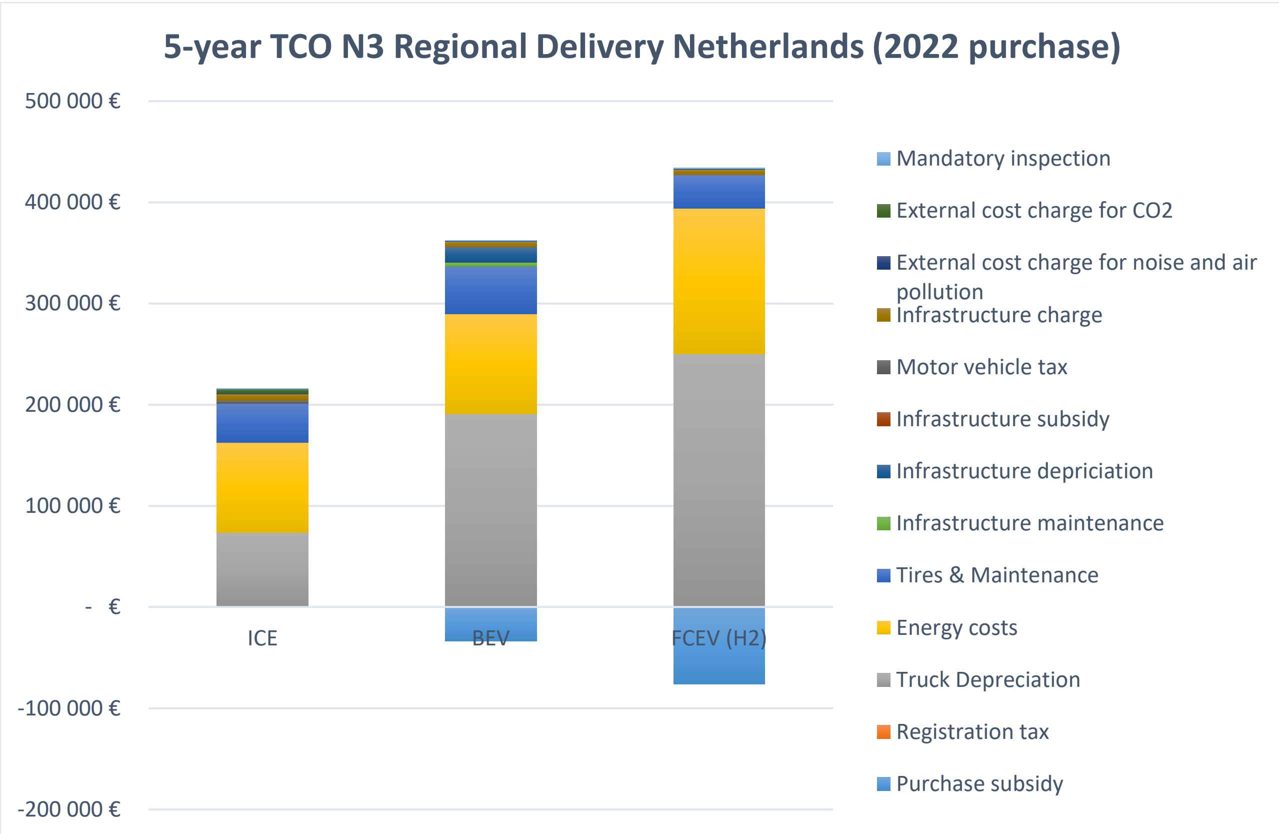

Figure 37: 5-year TCO Regional Delivery Netherlands (2022 purchase)

Long Haul

	Parameters	ICE	BEV	FCEV (H2)	Delta BEV
5-year cost	Purchase subsidy	- €	- 88 350 €	- 102 300 €	- 88 350 €
	Registration tax	52 €	52 €	52 €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	157 821 €
	Energy costs	380 462 €	443 872 €	815 100 €	63 410 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- €	- €	- €
	Motor vehicle tax	6 500 €	- €	- €	- 6 500 €
	Infrastructure charge	6 505 €	6 505 €	6 505 €	- €
	External cost charge for noise and air pollution	1 630 €	1 630 €	1 630 €	- €
	External cost charge for CO2	12 139 €	- €	- €	- 12 139 €
	Mandatory inspection	650 €	750 €	1 500 €	100 €
Annual average		104 236 €	132 736 €	251 309 €	28 500 €
Total cost		521 178 €	663 679 €	1 256 547 €	142 502 €

Table 20: TCO comparison Long Haul in Netherlands

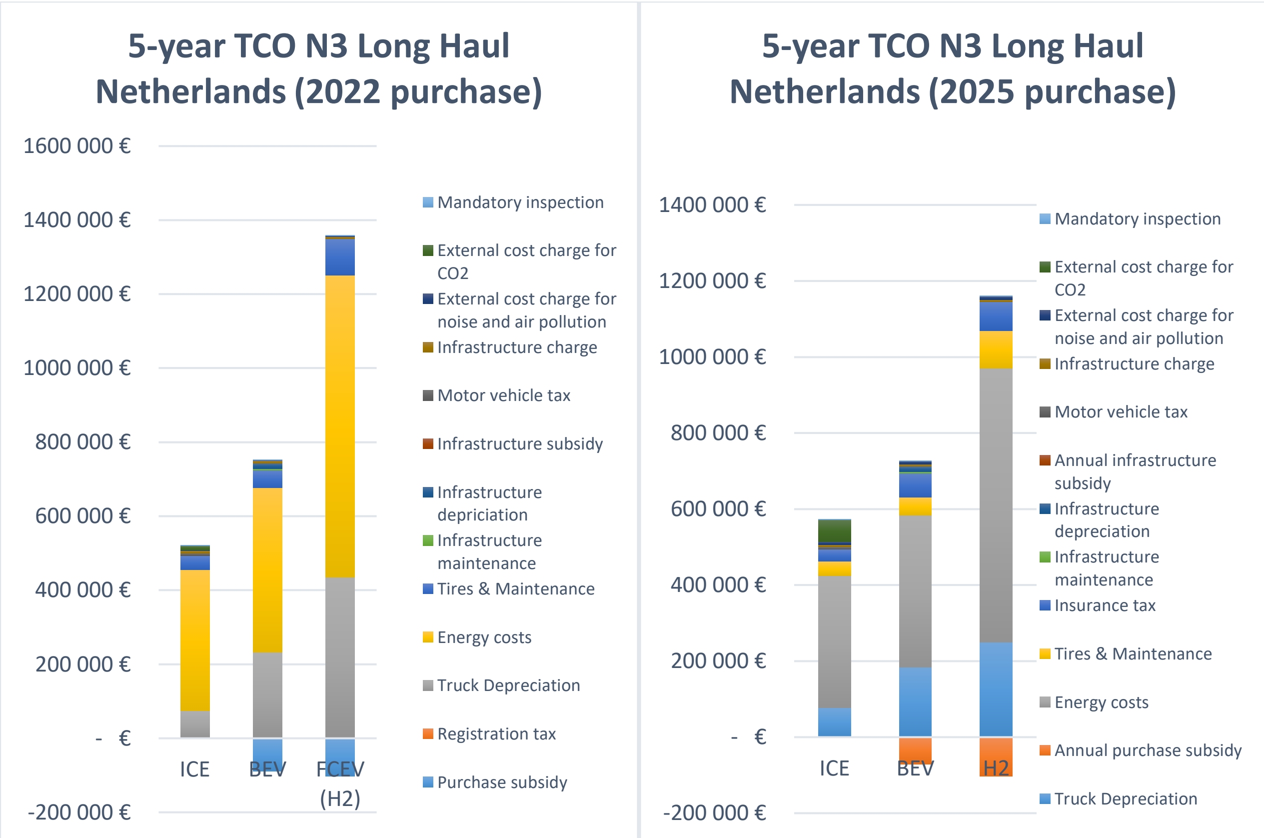

Figure 38: 5-year TCO Long Haul Netherlands (2022 purchase)

3.2 Conclusions of financial aid scheme comparison

There is no direct causal relation to be identified between the delta of TCO and the share of ZE trucks within the national fleet. The share of ZE trucks in a fleet has built up over several years, while the TCO is a momentary recording or ‘snapshot’.

There is however a difference between ZE fleet share in Netherlands, Germany, and Austria, where TCOs for BEVs are more favourable, and the lower scoring countries France, Belgium and Luxembourg. In Germany and Austria their incentives are the most effective in making the TCO of BEV more attractive. The high number of pilot projects in the Netherlands (which are funded on a project basis, so not included in the TCO calculation) might play a role in the higher fleet share. The low budget allocated to the incentive scheme in Belgium is suspected to account for the low amount of impact on fleet conversion.

	Urban Delivery	Regional Delivery	Long-haul	Fleet share
Netherlands	2 332 €	112 908 €	142 502 €	0,21%
Germany	- 13 233 €	- 44 675 €	- 77 690 €	0,18%
Austria	- 10 705 €	- 73 974 €	- 209 145 €	0,17%
France	- 10 372 €	1 719 €	13 214 €	0,02%
Belgium	- 14 797 €	- 20 143 €	- 42 760 €	0,02%
Luxembourg	11 896 €	136 369 €	163 366 €	0,01%

Table 21: TCO comparison between Diesel and BEV, including current ZE fleet share

- A positive amount means the BEV is more expensive than diesel
- A negative amount means the BEV is cheaper than diesel

Key observations

- Germany and the Netherlands are differentiating their subsidy amounts depending on the applicants’ company size or annual turnover. This allows these governments to ensure larger aid sums flow to smaller companies with more limited financial capacities.
- The German funding scheme takes the CO2 saving potential per invested euro into account. Only applications that save more CO2 than the lowest performing 50% of applicants are approved. Both investment cost and annual mileage are considered, meaning that trucks with high mileage are more likely to gain the subsidy. As these are also the trucks with the highest vehicle price, this differentiator steers funds towards where they are most needed.
- There are some EU examples (Malta and Croatia) where countries integrate scrappage into their funding schemes, increasing the support sum when the ZE MHDVs a one-on-one replacement of a diesel truck. This serves as an additional incentive to phase out diesel vehicles.

Conclusions

- Most member states offer insufficient compensation, either in terms of the per-vehicle spending or the program's overall budget. In the case of Belgium only about a dozen trucks can be funded with a budget of €3 million.
- There is strong and clear evidence that gas trucks are as bad for the climate as their diesel counterparts. Ireland, Finland, Italy, Poland, and Sweden should remove gas trucks from their funding programs immediately, as Denmark and Belgium have already done.
- Long application cycles with heavy administrative processes as reported in Germany and France inhibit SMEs from making use of the funding and transitioning. For them, uncertainty of the timeline and administrative resources pose a bigger burden. In Germany for example, a ZE MHDV purchase can only be made once the grant is approved, making the purchasing of a new truck a time-consuming process.[41]

41 Transport & Environment (2022)

3.3 Scenario building for potential Luxembourg financial aid scheme

In this section, we apply the current taxes and costs in Luxembourg to the TCO calculations. We collect information on the financial (company size) and business (key activities) attributes and check the profiles of them, including routes taken in Luxemburg and fleet characteristics (source data from Transport Ministry and companies). Existing use cases of the available and future technologies identified in section 1 will be matched. We build different scenarios (for 2025 and 2030) for each incentive approach to analyse the effect on TCO. The analysis calculates the proportion of trucks that are electric (for each truck category) in each year, for each scenario, and calculates the best and worst scenarios for fleet conversion. We the apply different types of purchase incentives and operational financial benefits at different levels. Per scenario, the total government costs / loss of tax income are assessed. This part of the report delivers the best- and worst-case scenarios for MHDV decarbonisation when financial aid schemes are applied. The best scenarios are interpreted in this report as state aid schemes which provide the highest amount of support per vehicle in a 5-year ownership period. This correlates with the approach in those countries that also have the highest uptake of ZE MHDVs in their fleets. Worst scenarios are those which provide little amount of financial support to the purchase and operation of ZE MHDVs, and correlate with lower uptake.

3.3.1 TCO calculations for Luxembourg (baseline scenario)

The first step in the scenario building, is the examination of the baseline scenario for the three use cases. This means that the 5-year ownership costs of the selected vehicles are calculated in Luxembourg. The first one is the urban deliver use case. Currently, considering a purchase at the end of 2022 (December), the 5-year TCO of the Battery Electric Truck (BEV) is 11.896 € more, in contrast to the Diesel equivalent. This originates mostly from the higher depreciation of the vehicle. FCEVs as ZE alternatives are not considered, due to their inapplicability to this use case. For the exact details of the calculations, please consult our excel sheet, attached to this report “Truck Country TCO combined_v1.xlsx”.

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- €	
	Registration tax	50 €	50 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- €	- €
	Motor vehicle tax	2 125 €	2 125 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 097 €	10 477 €	2 379 €
Total costs		40 487 €	52 383 €	11 896 €

Table 22: TCO calculations Urban Delivery for Luxembourg (baseline scenario)

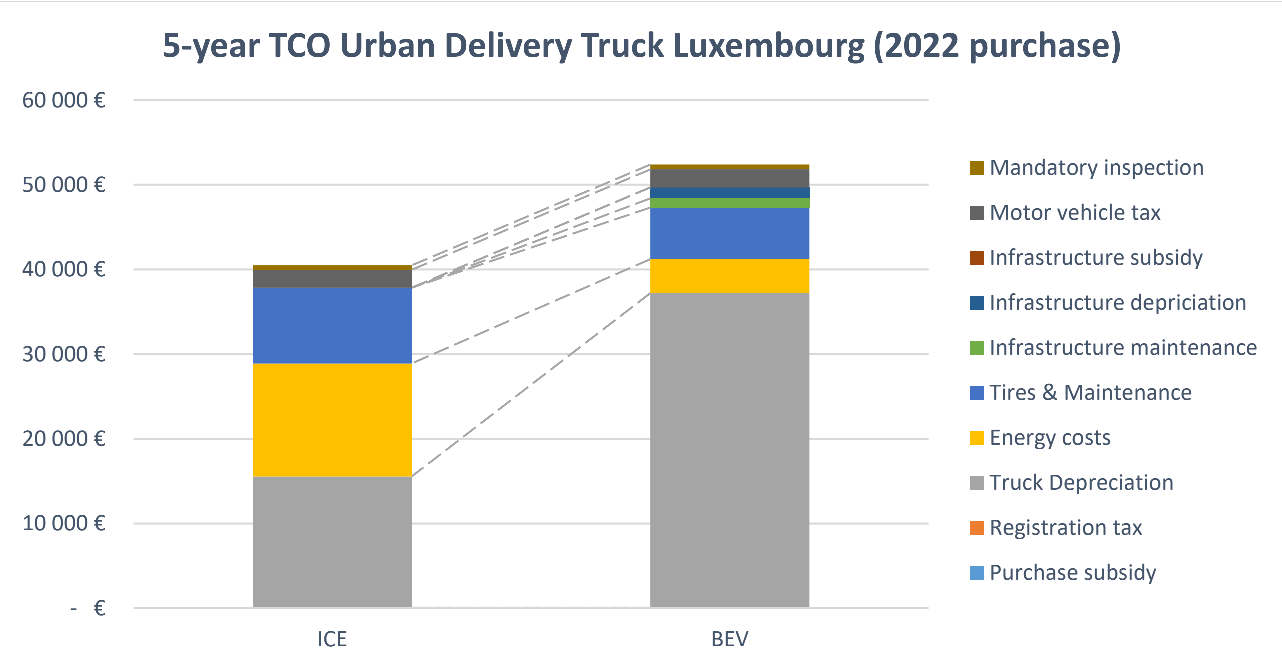

Figure 39: 5-year TCO Urban Delivery Luxembourg (2022 purchase)

The second use case is Regional Delivery, where FCEVs are also calculated. BEVs costs 136.369 € more than their diesel equivalents, while FCEVs 236.939 € respectively. This significant difference originates from the higher depreciation of the vehicles, the infrastructure costs for BEVs, and high H2 energy costs for the FCEVs.

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)
5-year cost	Purchase subsidy	- €	- €	- €	- €
	Registration tax	50 €	50 €	50 €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €
	Infrastructure subsidy	- €	- €	- €	- €
	Motor vehicle tax	1 825 €	1 825 €	1 825 €	- €
	Infrastructure charge	6 469 €	6 469 €	6 469 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €
Annual average		40 013 €	67 287 €	87 401 €	27 274 €
Total costs		200 065 €	336 435 €	437 004 €	136 369 €

Table 23: TCO calculations Regional Delivery for Luxembourg (baseline scenario)

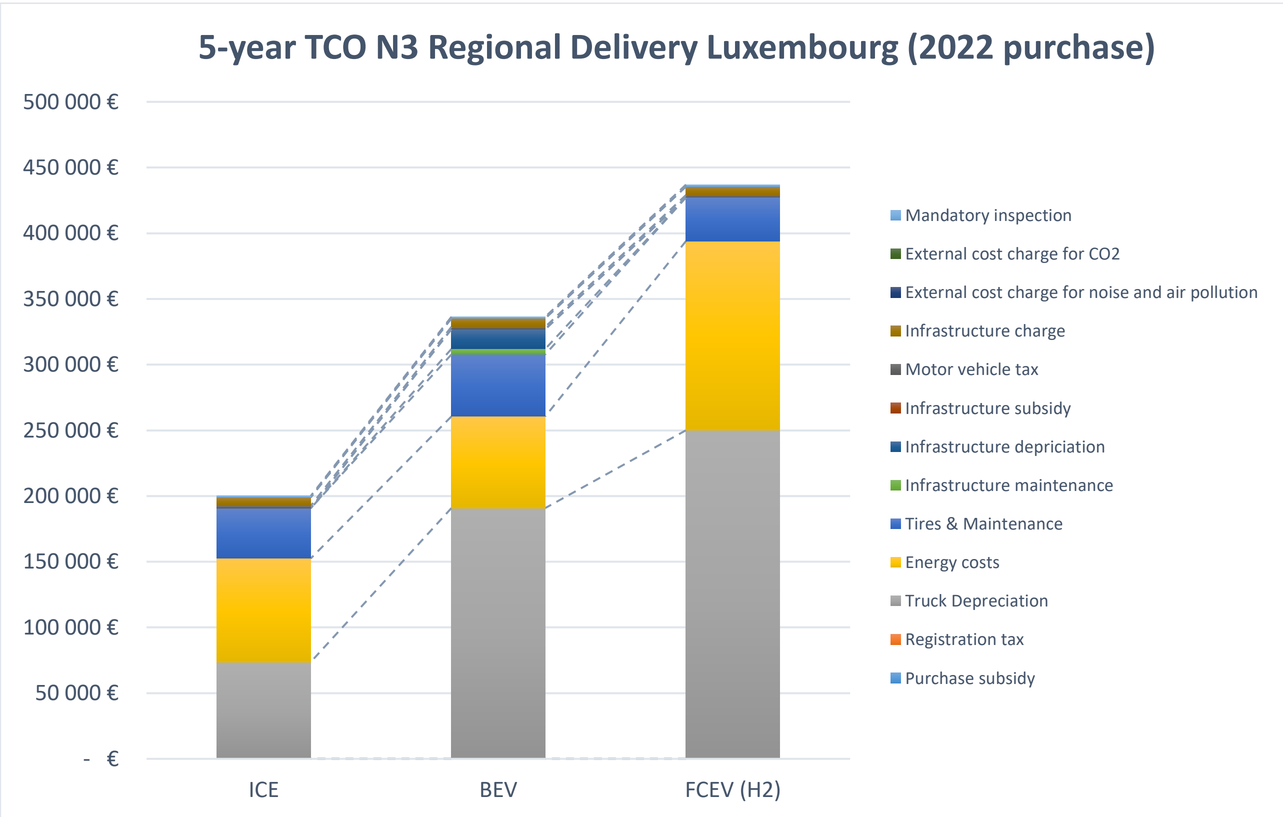

Figure 40: 5-year TCO Regional Delivery Luxembourg (2022 purchase)

The third use case concerns long haul trucks, where FCEVs are also calculated. BEVs costs 163.366 € more than their diesel equivalents, while FCEVs 900.546 € respectively. This significant difference originates from the higher depreciation of the vehicles, the infrastructure costs for BEVs, and high H2 energy costs for the FCEVs.

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
5-year cost	Purchase subsidy	- €	- €	- €	- €	- €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- €	- €	- €	- €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	8 749 €	8 749 €	8 749 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	1 252 €	104 €
Annual average		92 322 €	124 995 €	272 431 €	180 109 €	32 673 €
Total costs		461 609 €	624 974 €	1 362 154 €	900 546 €	163 366 €

Table 24: TCO calculations Long Haul for Luxembourg (baseline scenario)

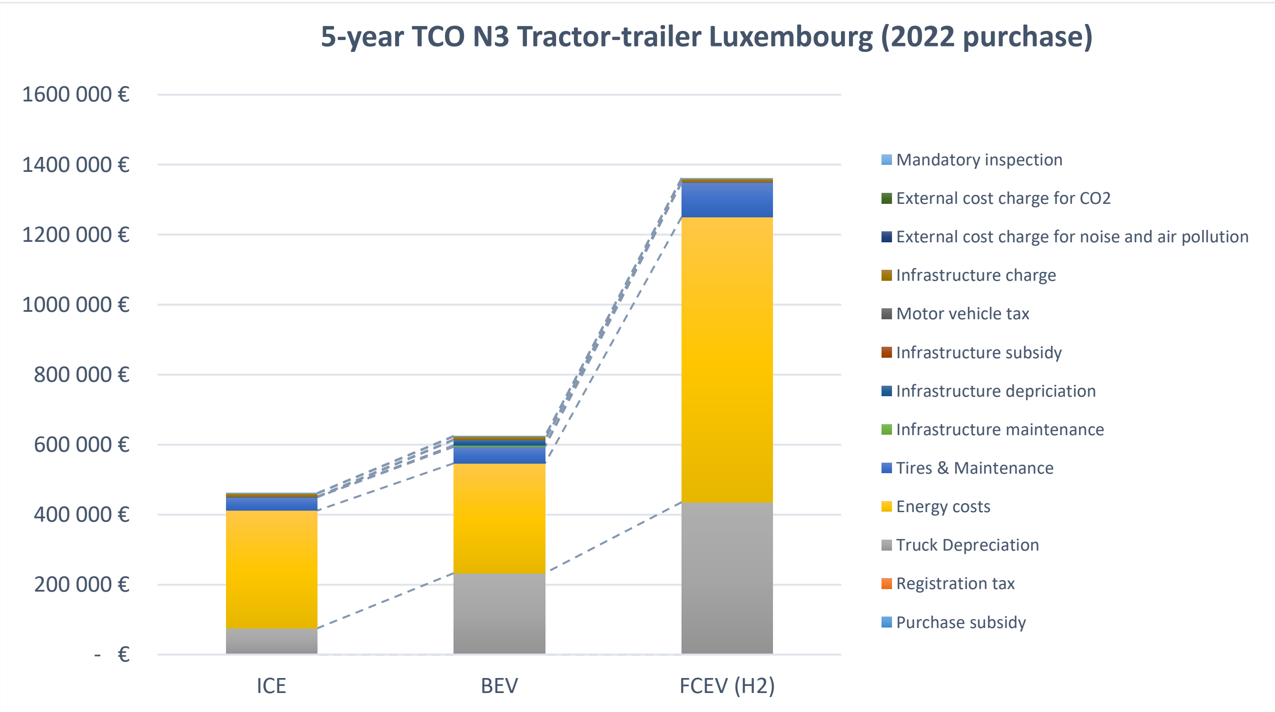

Figure 41: 5-year TCO Long Haul Luxembourg (2022 purchase)

3.3.2 TCO simulations for Luxembourg

The next paragraph simulates the effect of the five analysed countries' state aid environments and presents the results on the baseline 5-year TCO calculations of Luxembourg use cases. The parameters adapted to the local context in the simulation are Purchase subsidy, Registration tax, Infrastructure subsidy, Motor vehicle tax, Infrastructure charge, External cost charge for noise and air pollution and External cost charge for CO2. Parameters truck depreciation, energy costs, tires & maintenance, infrastructure maintenance, infrastructure depreciation and mandatory inspection costs were not altered.

Urban Delivery (9-12 Rigid Truck)

Luxembourg simulation Austria

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	- 14 907 €	- 14 907 €
	Registration tax	195 €	195 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 035 €	- 1 035 €
	Motor vehicle tax	930 €	- €	- 930 €
	Mandatory inspection	522 €	574 €	52 €
Annual average		7 887 €	6 892 €	- 995 €
Total costs		39 437 €	34 460 €	- 4 977 €

Table 25: Urban Delivery TCO differences, when Austian incentives are applied (2022)

Luxembourg simulation Belgium

5-year cost	Parameters	ICE	BEV	Delta
	Purchase subsidy	- €	- 14 907 €	- 14 907 €
	Registration tax	496 €	496 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 786 €	- 1 786 €
	Motor vehicle tax	- €	- €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		7 762 €	6 802 €	- 960 €
Total costs		38 808 €	34 011 €	- 4 798 €

Table 26: Urban Delivery TCO differences, when Belgium incentives are applied (2022)

Luxembourg simulation Netherlands

5-year cost	Parameters	ICE	BEV	Delta
	Purchase subsidy	- €	- 4 006 €	- 4 006 €
	Registration tax	52 €	52 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- €	- €
	Motor vehicle tax	1 600 €	1 600 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		7 993 €	9 571 €	1 578 €
Total costs		39 964 €	47 853 €	7 890 €

Table 27: Urban Delivery TCO differences, when Dutch incentives are applied (2022)

Luxembourg simulation France

5-year cost	Parameters	ICE	BEV	Delta
	Purchase subsidy	- €	- 12 112 €	- 12 112 €
	Registration tax	336 €	336 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 1 553 €	- 1 553 €
	Motor vehicle tax	- €	- €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		7 730 €	7 376 €	- 354 €
Total costs		38 648 €	36 879 €	- 1 769 €

Table 28: Urban Delivery TCO differences, when French incentives are applied (2022)

Luxembourg simulation Germany				
5-year cost	**Parameters**	**ICE**	**BEV**	**Delta**
	Purchase subsidy	- €	- 14 907 €	- 14 907 €
	Registration tax	60 €	60 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	- 9 333 €
	Tires & Maintenance	8 938 €	6 094 €	- 2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	- 4 763 €	- 4 763 €
	Motor vehicle tax	1 425 €	1 425 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		7 959 €	6 405 €	- 1 555 €
Total costs		39 797 €	32 023 €	- 7 775 €

Table 29: Urban Delivery TCO differences, when German incentives are applied (2022)

Examining the overall picture of the simulations in the five countries, it can be observed, that the 5-year TCO of both diesel and BEV trucks are lower, than the baseline scenario. The lower ICE vehicle amount is originating from the lower motor vehicle tax or registration tax in the selected countries. The lowest decrease is for the Netherlands, 4.520 €, due to relatively lower amount of purchase subsidy, and non-existent infrastructure subsidy schemes. The highest decrease is in Germany (-20.360 €), due to the high purchase subsidy and high infrastructure subsidy.

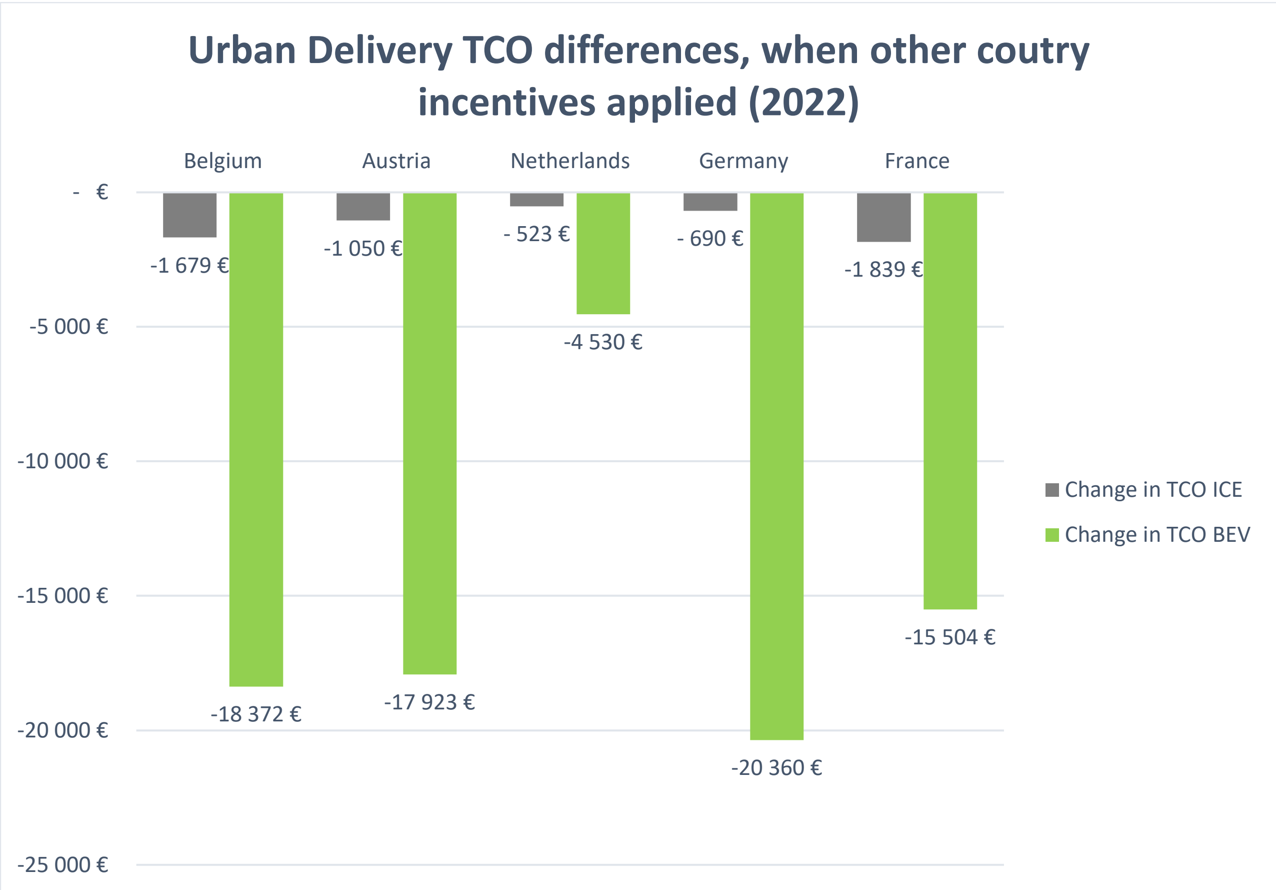

Figure 42: Urban Delivery TCO differences, when other coutry incentives applied (2022)

Regional Delivery (26-32 Rigid Truck)

Luxembourg simulation Belgium

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
5-year cost	Purchase subsidy	- €	- 94 000 €	- 120 375 €	- 94 000 €	- 120 375 €
	Registration tax	4 957 €	4 957 €	4 957 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	-5 015 €
	Infrastructure maintenance	- €	- €	- €	- €	- €
	Infrastructure depreciation	- €	- €	- €	- €	- €
	Infrastructure subsidy	- €	- 9 000 €	- €	- 9 000 €	- €
	Motor vehicle tax	2 685 €	- €	- €	- 2 685 €	- 2 685 €
	Infrastructure charge	27 233 €	27 233 €	27 233 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	4 396 €	- €	- €	- 4 396 €	- 4 396 €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		69 716 €	48 987 €		- 20 729 €	- 1 621 €
Total costs		348 580 €	244 935 €	340 474 €	- 103 646 €	- 8 106 €

Table 30: Regional Delivery TCO differences, when Belgium incentives are applied (2022)

Luxembourg simulation Netherlands

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
5-year cost	Purchase subsidy	- €	- 33 488 €	- 76 238 €	- 33 488 €	- 76 238 €
	Registration tax	52 €	52 €	52 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	-5 015 €
	Infrastructure maintenance	- €	- €	- €	- €	- €
	Infrastructure depreciation	- €	5 739 €	- €	5 739 €	- €
	Infrastructure subsidy	- €	- €	- €	- €	- €
	Motor vehicle tax	3 200 €	- €	- €	- 3 200 €	- 3 200 €
	Infrastructure charge	6 505 €	5 529 €	5 529 €	- 976 €	- 976 €
	External cost charge for noise and air pollution	428 €	428 €	428 €	- €	- €
	External cost charge for CO2	4 396 €	- €	- €	- 4 396 €	- 4 396 €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		41 260 €	37 059 €	71 686 €	- 4 202 €	30 426 €
Total costs		206 301 €	185 294 €	358 431 €	- 21 008 €	152 130 €

Table 31: Regional Delivery TCO differences, when Dutch incentives are applied (2022)

Luxembourg simulation Austria

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
5-year cost	Purchase subsidy	- €	- 94 000 €	- 214 000 €	- 94 000 €	- 214 000 €
	Registration tax	195 €	195 €	195 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 12 000 €	- €	- 12 000 €	- €
	Motor vehicle tax	4 800 €	- €	- €	- 4 800 €	- 4 800 €
	Infrastructure charge	71 905 €	17 966 €	17 966 €	- 53 939 €	- 53 939 €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	17 225 €	- €	- €	- 17 225 €	- 17 225 €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		57 169 €	48 050 €	46 564 €	- 9 119 €	- 10 605 €
Total costs		285 846 €	240 251 €	232 821 €	- 45 595 €	- 53 025 €

Table 32: Regional Delivery TCO differences, when Austrian incentives are applied (2022)

Luxembourg simulation Germany

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
5-year cost	Purchase subsidy	- €	- 94 000 €	- 214 000 €	- 94 000 €	- 214 000 €
	Registration tax	60 €	60 €	60 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 24 000 €	- €	- 24 000 €	- €
	Motor vehicle tax	9 305 €	- €	- €	- 9 305 €	- 9 305 €
	Infrastructure charge	29 309 €	- €	- €	- 29 309 €	- 29 309 €
	External cost charge for noise and air pollution	2 190 €	66 €	66 €	- 2 124 €	- 2 124 €
	External cost charge for CO2	5 231 €	- €	- €	- 5 231 €	- 5 231 €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		47 563 €	42 043 €	42 957 €	- 5 520 €	- 4 606 €
Total costs		237 816 €	210 216 €	214 786 €	- 27 600 €	- 23 030 €

Table 33: Regional Delivery TCO differences, when German incentives are applied (2022)

Luxembourg simulation France

	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
5-year cost	Purchase subsidy	- €	- 94 000 €	- 214 000 €	- 94 000 €	- 214 000 €
	Registration tax + parafiscal charges	240 €	240 €	240 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 18 000 €	- €	- 18 000 €	- €
	Motor vehicle tax	3 140 €	1 820 €	1 820 €	- 1 320 €	- 1 320 €
	Infrastructure charge	45 013 €	45 013 €	45 013 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		48 023 €	52 633 €	52 347 €	4 610 €	4 324 €
Total costs		240 114 €	263 163 €	261 733 €	23 049 €	21 618 €

Table 34: Regional Delivery TCO differences, when French incentives are applied (2022)

Examining the overall picture of the simulations in the five countries, it can be observed, that the 5-year TCO of diesel trucks are higher, while the BEVs and FCEVs are lower, than the baseline scenario. The higher diesel truck amount is originating from the higher road charges in the selected countries. Regarding the ZE changes, the lowest decrease is for the Netherlands, - 49.334 €, due to relatively lower amount of purchase subsidy, non-existent infrastructure subsidy schemes and insignificant road charges. The highest decrease is in Germany (- 126.218 €), due to the high purchase subsidy, high infrastructure subsidy and low road charges for ZE MHDVs.

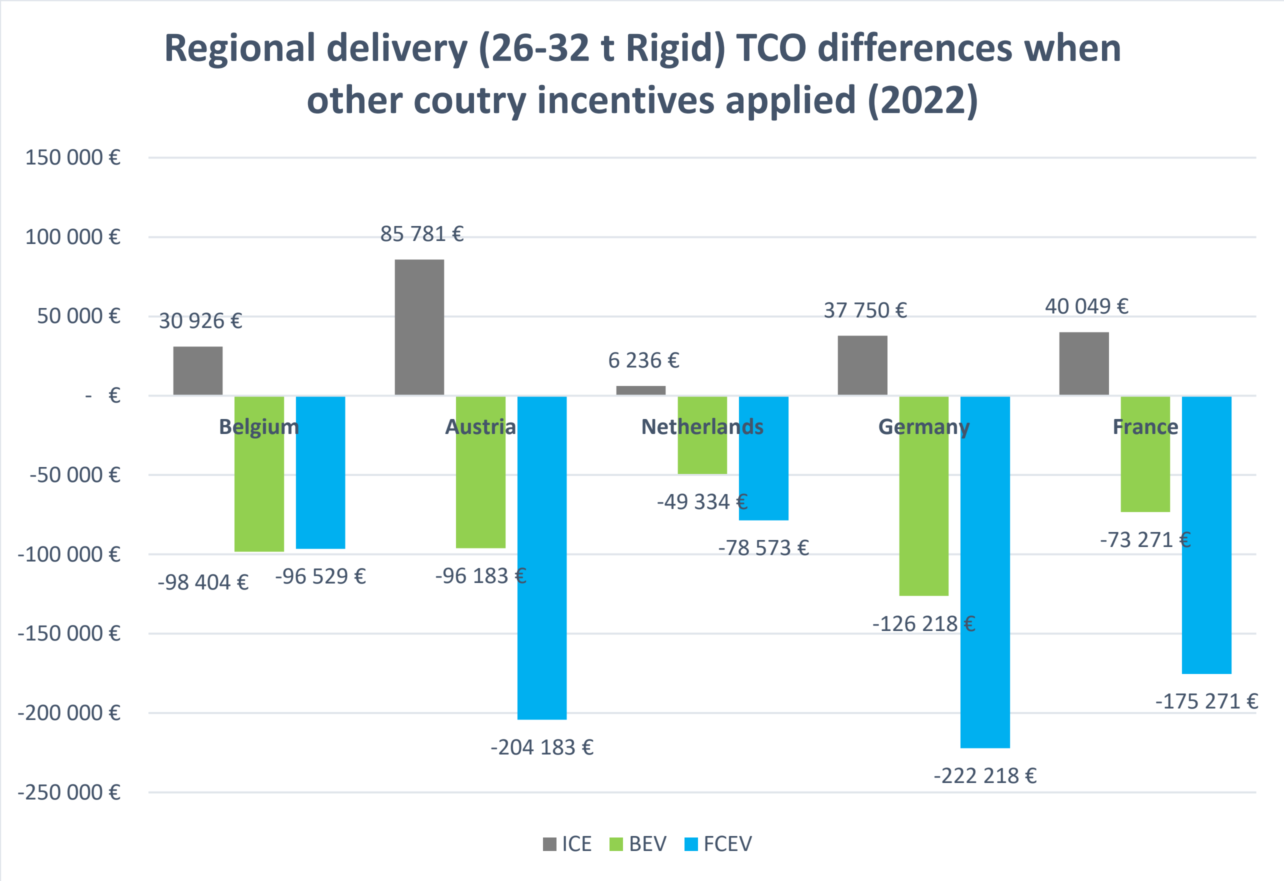

Figure 43: Regional delivery (26-32 t Rigid) TCO differences when other coutry incentives applied (2022)

Long haul (40 - 44 ton tractor trailer unit)

Luxembourg simulation Belgium

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
5-year cost	**Purchase subsidy**	- €	- 140 000 €	- 356 000 €	- 356 000 €	- 140 000 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 9 000 €	- €	- €	- 9 000 €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	144 321 €	144 321 €	144 321 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	35 292 €	- €	- €	- 35 292 €	- 35 292 €
	Mandatory inspection	255 €	255 €	509 €	255 €	- €
Annual average		126 337 €	122 131 €	227 988 €	101 651 €	- 4 206 €
Total costs		631 684 €	610 653 €	1 139 940 €	508 256 €	- 21 030 €

Table 35: Long Haul TCO differences, when Belgium incentives are applied (2022)

Luxembourg simulation Austria

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
5-year cost	**Purchase subsidy**	- €	- 140 000 €	- 356 000 €	- 356 000 €	- 140 000 €
	Registration tax	195 €	195 €	195 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 12 000 €	- €	- €	- 12 000 €
	Motor vehicle tax	4 800 €	- €	- €	- 4 800 €	- 4 800 €
	Infrastructure charge	314 928 €	78 687 €	78 687 €	- 236 241 €	- 236 241 €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	29 167 €	- €	- €	- 29 167 €	- 29 167 €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	1 252 €	104 €
Annual average		160 000 €	108 232 €	214 868 €	54 868 €	- 51 768 €
Total costs		800 000 €	541 158 €	1 074 338 €	274 338 €	- 258 842 €

Table 36: Long Haul TCO differences, when Austrian incentives are applied (2022)

Luxembourg simulation Netherlands

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
5-year cost	**Purchase subsidy**	- €	- 88 350 €	- 102 300 €	- 102 300 €	- 88 350 €
	Registration tax	52 €	52 €	52 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- €	- €	- €	- €
	Motor vehicle tax	6 500 €	- €	- €	- 6 500 €	- 6 500 €
	Infrastructure charge	6 505 €	6 505 €	6 505 €	- €	- €
	External cost charge for noise and air pollution	1 630 €	1 630 €	1 630 €	- €	- €
	External cost charge for CO2	12 139 €	- €	- €	- 12 139 €	- 12 139 €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	1 252 €	104 €
Annual average		95 547 €	106 822 €	251 468 €	155 921 €	11 275 €
Total costs		477 735 €	534 112 €	1 257 342 €	779 607 €	56 377 €

Table 37: Long Haul TCO differences, when Dutch incentives are applied (2022)

Luxembourg simulation Germany						
	Parameters	**ICE**	**BEV**	**FCEV (H2)**	**Delta H2**	**Delta BEV**
5-year cost	**Purchase subsidy**	- €	- 140 000 €	- 423 640 €	- 423 640 €	- 140 000 €
	Registration tax	60 €	60 €	60 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 24 000 €	- €	- €	- 24 000 €
	Motor vehicle tax	9 905 €	- €	- €	- 9 905 €	- 9 905 €
	Infrastructure charge	128 368 €	- €	11 €	- 128 357 €	- 128 368 €
	External cost charge for noise and air pollution	8 059 €	272 €	272 €	- 7 787 €	- 7 787 €
	External cost charge for CO2	19 251 €	- €	- €	- 19 251 €	- 19 251 €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	1 252 €	104 €
Annual average		123 311 €	90 122 €	185 632 €	62 321 €	- 33 189 €
Total costs		616 554 €	450 608 €	928 159 €	311 605 €	- 165 946 €

Table 38: Long Haul TCO differences, when German incentives are applied (2022)

Luxembourg simulation France						
	Parameters	**ICE**	**BEV**	**FCEV (H2)**	**Delta H2**	**Delta BEV**
5-year cost	**Purchase subsidy**	- €	- 73 250 €	- 100 000 €	- 100 000 €	- 73 250 €
	Registration tax + parafiscal charges	240 €	240 €	240 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 18 000 €	- €	- €	- 18 000 €
	Motor vehicle tax	3 140 €	- €	- €	- 3 140 €	- 3 140 €
	Infrastructure charge	236 576 €	236 576 €	236 576 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	2 295 €	1 252 €	104 €
Annual average		138 173 €	151 968 €	297 654 €	159 481 €	13 795 €
Total costs		690 865 €	759 841 €	1 488 271 €	797 406 €	68 976 €

Table 39: Long Haul TCO differences, when French incentives are applied (2022)

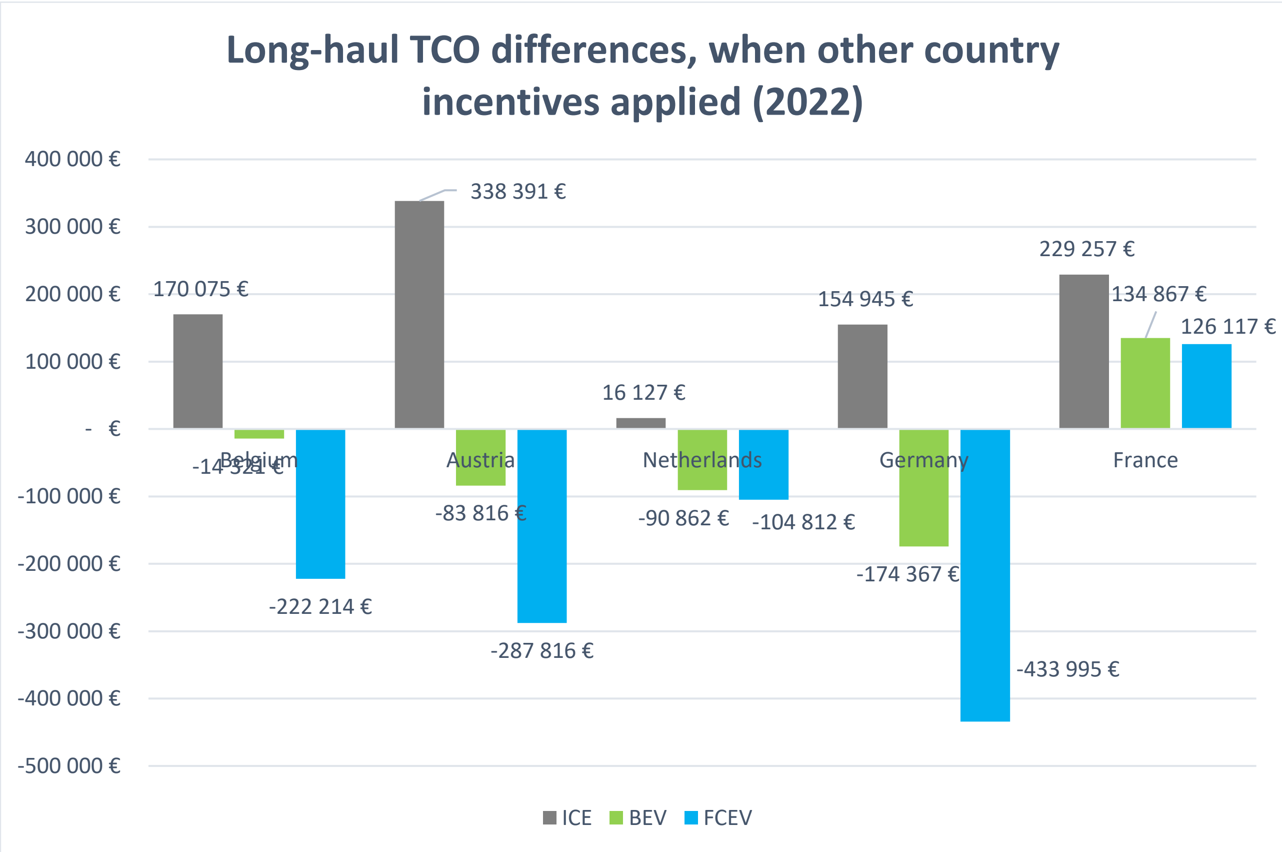

Figure 44: Long-haul TCO differences, when other country incentives applied (2022)

Examining the overall picture of the simulations in the five countries, it can be observed, that the 5-year TCO of diesel trucks are higher, while the BEVs and FCEVs are lower – except for France, than the baseline scenario. The higher diesel truck amount is originating from the higher road charges in the selected countries. Regarding the ZE changes, the lowest decrease is for Belgium (Flanders), - 14.321 €, due to the significant road charges, despite the purchase subsidy scheme. With parameters of France, BEVs and FCEVs are higher, despite their relatively high purchase subsidies and infrastructure subsidies. The reason for that is the high road charge for ZE MHDV. The highest decrease is in Germany (- 174.367 € BEV and – 433.995 € FCEV), due to the high purchase subsidy, high infrastructure subsidy and low road charges for ZETs.

Impact on public budget

In this section, we will calculate the total cost for the government, if the purchase subsidy and the infrastructure subsidy was introduced. The basis for the calculation is the subsidy per vehicle amount, and the number of vehicles forecasted to be registered annually, based on the scenarios of the Global MoU calculation, and the German scenario. The same funding rate is applied until 2025. Afterwards, the funding rate drops to 50% of the original one, and then decreases by 10% each year, until 2030. After 2030, no subsidy is calculated, due to the economic viability of the vehicles.

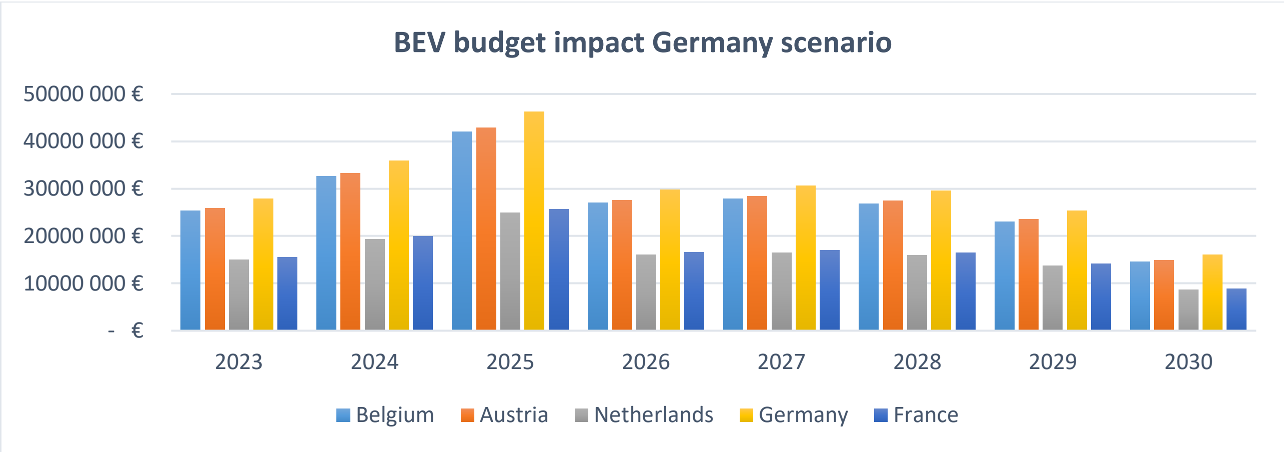

Figure 45: BEV budget impact Germany scenario

The first scenario is applying the German Zero Emission target, which is 30% ZE share in the national fleet, until 2030. Based on those predictions, overall, 3851 ZE truck would be supported by the state aid scheme, until 2030. This calculation assumes, that all ZETs are BEV, and there is a decreasing funding rate for purchase and infrastructure development starting from 2025.

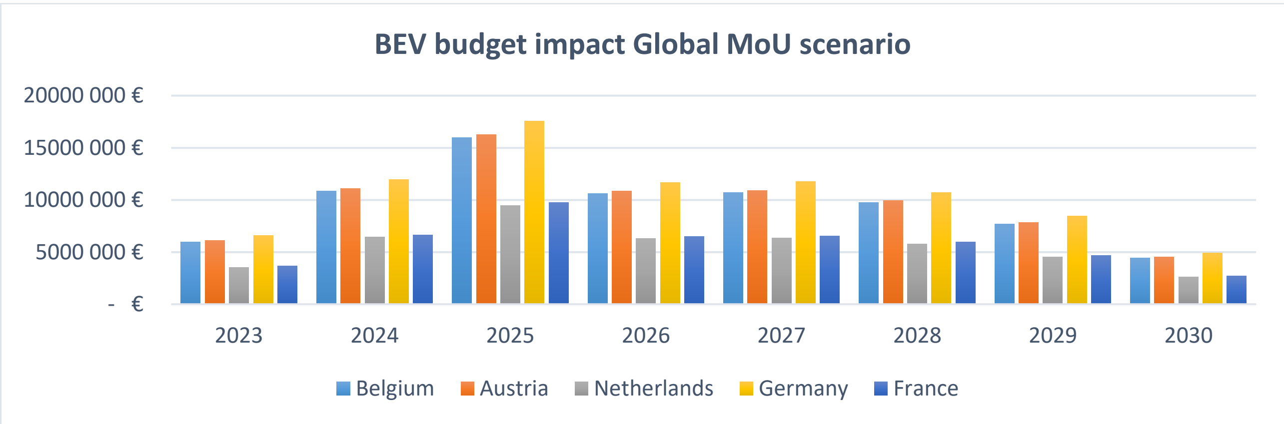

Figure 46: BEV budget impact Global MoU scenario

The second scenario is applying the Global MoU target, which is 30% ZE sales, until 2030, and 100% ZE sales until 2040. Based on those predictions, overall, 1316 ZE truck would be supported by the state aid scheme until 2030. This calculation assumes, that all ZETs are BEV, and there is a decreasing funding rate for purchase and infrastructure development starting from 2025.

3.4 Financial aid scheme recommendations for Luxembourg

Based on all the previous tasks, an analysis was conducted to formulate an optimal policy recommendation for Luxemburg in form of an aid scheme. We use principles for designing new incentive, considering the latest developments in European countries and research, for instance, ICCT's paper (adapted to MHDV usage). Different scenarios and conditions have been examined: vehicle type, size of company, size of fleet, sector of activity, cap of funding of company, aid intensity, tax credit/subsidy/call for projects, duration, and estimated impact. The General Block Exemption Regulation (GBER) was considered, and sensitivity analysis applied.

3.4.1 Design principles to formulate State Aid

There are various policy options to implement state aid support for the purchase of ZE MHDVs.

Policy	Implications
Phase-out targets	Establish phase-out targets for ZETs and HDVs, with emphasis on largest markets.
Regulations	Expand ZET regulations and continue to set stringent, long-term CO2 standards for Medium and Heavy-Duty Trucks that align with ZEV targets and transport decarbonization goals.
Fiscal incentives	Maintain purchase and in-use ZET incentives at least until cost parity (bonus/malus).
Charging / Refuelling infrastructure	Develop charging infrastructure action plans for ZETs in partnership with industry.
Consumer awareness / Fleet requirements	Adopt or expand fleet purchase requirements to government and private sector MHDV fleets.

ICCT`s study outlines four key principles of effective Zero Emission vehicle incentive design.

1) Move incentives up front to the vehicle purchase and make their value visible to dealers and prospective consumers.
2) Make the value of incentives crystal clear to consumers and dealers.
3) Ensure the incentives are available to the full target market.
4) Commit to durable incentives that allow manufacturers, dealers, public outreach campaigns, and consumers to rely on them for at least several years.

3.4.1 Overview of state aid options for ZE MHDV support

The following different incentives for stimulating ZE road freight transport have been identified during the research. Some of the incentives effect the home fleet, some the foreign fleet and some both. The effect of these incentives heavily depends on the existing local financial system and the type of operation, resulting in the true impact on TCO.

Measures / incentives	Home fleet	Foreign fleet	Explanation
Purchase subsidy	✓		A subsidy is given for the purchase of a ZE truck
Scrapping bonus	✓		Organisations which phase out an old polluting truck receives extra incentives
Charging infrastructure subsidy (depot)	✓	√	The purchase of non- or semi-public charging infrastructure is subsidised
Charging infrastructure programme (HPC)	✓	✓	The purchase of public charging infrastructure is subsidised
Capital allowance	✓		Enhanced tax relief for zero emission capital investment
Super depreciation	✓		Higher financial depreciation (for example more than 100%) for zero emission investments
Road infrastructure charge exemption	✓	√	Lowering or exempting ZE trucks from road infrastructure charge (flat annual fee)
Road tax exemption	✓	✓	Lowering or exempting ZE trucks from road tax (km-based fee)
Motor vehicle tax advantage	✓		General term for recurring operation tax.
Insurance tax exemption	✓		Lowering or exempting ZE trucks for tax on insurance

Table 40: Overview of state aid incentives for ZE MHDV support

The following disincentives for stimulating ZE road freight transport have been identified during the research.

Noise and air pollution charge (km)	✓	✓	Km based fee (implemented in Germany and Austria) with a lower rate for ZE vehicles
CO2 emission-based toll (km)	✓	✓	Km based fee (expected implantation in Germany in 2025 and Austria 2024). Could be dependent on location – different tolls apply to urban and sub-urban areas.
Registration tax (one-time, emission based)	✓		Taxation at the moment of registration of the vehicle
Vehicle tax (recurring, emission based)	✓		

Restricted VAT deductibility	(✓)		In some countries the VAT of vehicles is not automatically deductible
Zero emission landing zones	(✓)	(✓)	Priority treatment for ZE
Purchase requirements for companies	(✓)		XYZ % share of: Tonne-kilometres procured in a year is low / zero emission

(✓) Fully applicable
✓ Partly applicable

Table 41: Overview of state aid disincentives for ZE MHDV support

State Aid rules[42]

There are various aspects to consider regarding the use of state aid for financial aid schemes for zero- and low-emission road vehicles. This sub-section details the conditions affecting the need for state aid clearance.

<u>Instances in which the existence of State aid may be excluded:</u>

1) No economic activity
2) No State resources
3) No selectivity
4) No advantage
5) No effect on trade between Member States and no distortion of competition

<u>Instances in which there is no need to notify for State aid clearance, but other requirements may apply</u>

If a given investment meets the cumulative conditions of Article 107(1) TFEU and thus entails State aid, it may be considered compatible with the internal market and can be granted without notification in the following instances:

General Block Exemption Regulation (GBER)[43]

Measures supporting the acquisition of environmentally friendly vehicles are exempted from the notification obligation if the aid is granted in compliance with the conditions set out in Article 36 GBER on investment aid enabling undertakings to go beyond Union standards for environmental protection or to increase the level of environmental protection in the absence of Union standards. This provision allows investment aid of up to EUR 15 million per undertaking per project. The eligible costs shall be the extra investment costs compared to the costs of a reference (less environmentally friendly) investment that would credibly be carried out without the aid (thus generally a diesel or a petrol car/bus). No aid may be granted to comply with applicable Union standards. In case of retrofitting of vehicles, all relevant investment costs can be considered as eligible. The basic aid intensity of the differential is 40% and can be increased further by 20 percentage points and 10 percentage points if the beneficiary is a small or medium-sized enterprise, respectively.

Based on the requirements set out in the GBER instance, which does not require Members States to notify for State Aid clearance, the first recommendation considers these funding rates.

42 https://ec.europa.eu/competition/state_aid/what_is_new/template_RFF_premiums_acquisition_low_emission_vehicles.pdf

43 Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, OJ L 187, 26.6.2014, p. 1.

3.4.2 Financial incentives - One-time benefits

Since most of the countries in this study have limited **purchase tax** on freight vehicles, it is not a significant steering mechanism for policy makers to change the purchase cost and therefore the TCO. An increase to the purchase tax of non-ZE trucks can be considered, but a one-time benefit via a **purchase subsidy** is more common. Considering the dynamics of the Luxembourg truck fleet (internationally orientated) the impact of ZE kms will also be applicable outside Luxembourg's borders. Purchase subsidies for chargers should also be considered, as they are inseparably linked with ZE trucks and do impact operator CAPEX.

It is not expected that the market can or will go through the full energy transition in the short term. Therefore, it is wiser to focus first on the segments and type of operations where this transition is easier, the so called low-hanging-fruit, and not try to reach all segments at once. Although the incentives should be available for all segments, the state of the market is expected to favour investment in N2 rigids and N3 rigids early than other categories.

A **conversion bonus** for special vehicles (e.g., refuse collection vehicles) should be considered. These vehicles are often more expensive, and therefore have a longer depreciation and operation time. Also, not all special vehicle types are offered by OEMs, meaning a dependency on often more expensive vehicles, built in limited quantities by converters.

Including the eligibility of converters/retrofit vehicles will have a positive impact on the uptake of 'harder to electrify' segments, but the amount of complexity influences the organisational capacity of the funding program, according to German experience.

Design of purchase subsidy state aid scheme
Since the **purchase subsidy** for ZE trucks is arguably the most evident type of incentive, the study analysed these incentive systems in multiple countries in depth to provide the following incentive design recommendations:

About the process of the recommended state aid, we advise a one-stage application process, with multiple (2-3) application rounds per year. It should be a competitive application process, where applicants are ranked, based on the selection criteria, discussed below.

The eligible vehicle types should be focussed on two different types: road freight and special vehicles. Special vehicles are for instance construction vehicles, concrete mixer, grabbers.

Eligibility conditions: eligible applicants should be both private and public entities. The leasing and purchase of the vehicle are both acceptable options. To avoid that the purchased vehicles will be operated abroad, an obligation should be applied to the applicant companies – they should be settled at least 2 years in Luxembourg, with an option, that companies with longer establishment are ranked in front of those with only a few years operation. Furthermore, the selected companies need to be operated mostly in Luxembourg for the next 5 years, so it should not be sold abroad or operated abroad. In case of the funding rate, which does not require state aid exemption, discrimination of company size is unavoidable, so small and medium enterprises may receive a 20% and 10% premium respectively. The technological focus is recommended to be BEVs and FCEVs, the applicability of low emission vehicles (e.g., LNG) are not recommended due to the special composition of freight activities in Luxembourg; the low expected impact on the CO2 emission reduction[44]; natural gas infrastructure is very low in Luxembourg; trends in countries also show a diversion from such technologies in the funding programmes (e.g., Denmark, Belgium). OEMs and converters (retrofitting of vehicles) should both be eligible. Regarding vehicle size and type, N2 Rigids, N3 Rigids and N3 Long-hauls shall be acceptable.

44European Commission (2020). Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA. Link

Regarding the evaluation of applications, the following aspects needs to be considered:

- Competitive process, ranking applications
- Operational focus in urban, sub-urban journeys and regional delivery (↑)
- High mileage focus (↑)
- Conversion (scrapping) bonus for phasing out diesel trucks
- Conversion of vehicles: bad emission rate (↑), age (↑), overall CO2 (↑)
- Expected share of journeys (kms) in Luxembourg (↑)

Overall, the priorities in the subsidy award should be focusing on those vehicles, which are operating in, or in the proximity of urban areas, and the avoided emissions (CO2, NOx, etc.) are high. Therefore, the applicants should submit their planned routes and road freight activities for the purchased vehicles.

The cost difference between ICE and ZE (BEV or FCEV) in on average equal to € 250.000, which is calculated an average delta of the different vehicle types (N2 rigids, N3 rigids, N3 tractor trailer units) and fuel types (BEV, FCEV). The calculation for the differential average is as follows: [(117,000 + 175,000 + 267,000 + 445,000)/4] = [1,004,000/4] which is approximately €250,000. This indicates that for a 40% rate, the purchase subsidy would be €100,000 in 2023. Similarly, for a 60% rate, the purchase subsidy would be €200,000 in 2023.

2022 Costs	Urban Truck	Regional Truck	Tractor Trailer Truck
Typical GVW	7.5-16t	26-32t	44t
Typical cost BEV	€ 69 000	€ 250 000	€ 310 000
Typical cost FCEV	€ 240 000	€ 400 000	€ 580 000
Comparable diesel	€ 33 000	€ 132 250	€ 135 000

From 2026, we can expect the total cost of ownership (TCO) difference between battery electric, fuel cell electric, and diesel trucks to decrease sharply. This decrease in the TCO difference is primarily due to technological advancements in the electric vehicle industry, such as improvements in battery technology, charging infrastructure, and production processes, which are expected to lower the upfront costs of electric trucks. Additionally, as governments around the world continue to implement stricter emissions regulations and incentivize the adoption of zero-emission vehicles, the operating costs of diesel trucks are likely to increase. The hypothesis behind the sharp decrease in TCO difference starting in 2026 may be attributed to the fact that this is the year when the price of batteries is projected to reach a tipping point, making electric vehicles more affordable and cost-competitive with their diesel counterparts.

Figures in €	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
No. of new clean vehicles	+ 40	+ 73	+ 107	+ 143	+ 179	+ 218	+ 257	+ 299
Average additional cost	250.000	225.000	200.000	100.000	93.750	81.500	75.000	68.750
Fundig rate 40%	100.000	90.000	80.000	40.000	37.500	32.500	30.000	27.500
Estimated budget – if only Large Enterprises apply (**Min.**)	**4.000.000**	**6.570.000**	**8.560.000**	**5.720.000**	**6.712.500**	**7.085.000**	**7.710.000**	**8.222.500**
Funding rate 60%	150.000	135.000	120.000	60.000	56.250	48.900	45.000	41.250
Estimated budget - if demand is only from SMEs (**Max.**)	**6.000.000**	**9.855.000**	**12.840.000**	**8.580.000**	**10.068.750**	**10.627.500**	**11.565.000**	**12.333.750**

Funding rate

- Retail price difference-based funding model (cost of ZE truck – cost of diesel equivalent)
- Until GBER revision is in effect: 40% of total eligible costs (diesel and ZE difference) to be funded for vehicle purchase, 70% infrastructure, 40% feasibility study (de minimis funding). The investment aid of up to a theoretical maximum of **EUR 15 million per undertaking per project**. Considering size of the budget, the recommendation, is to maximize the number of companies involved in the programme, and not concentrate the subsidy to a handful of companies. Therefore, a vehicle per company limitations per annum could be a good option to maximize a distribution of funding among companies.
- When GBER revision is in effect: 80% of total costs to be funded for vehicle purchase, 50% infrastructure, 60% feasibility study.
- GBER suggestions: competitive bidding process based on above criteria and rates
- For conversion bonus: above 80% threshold (Up to 90%, in case of Zero Emission Vehicles)

Recommendation #1 (No need to notify for State aid clearance)

	Funding rate (% of difference)
Purchase subsidy	40%
Infrastructure subsidy	40%
Enterprise size[45]	**Funding rate**
Small	60%
Medium	50%
Large	40%

Table 42: Overview of recommended state aid funding rate percentage

Based on these funding rates, the impact on TCO in the three use cases are calculated.

Urban delivery

The first use case analysed is the Urban Delivery. A 5-year TCO is calculated for 3 company types: large enterprise, medium enterprise and small enterprise. This is the recommendation, which does not need state aid exemption. This calculation applies the funding rates presented in the table above (40% base rate, 10% premium for medium and 20% premium for small enterprises. Subsidy is based on the purchase price difference of BEV Trucks and an equivalent diesel truck.

Luxembourg simulation Recommendation (Large enterprise)

	Parameters	**ICE**	**BEV**	**Delta**
5-year cost	Purchase subsidy	- €	-14 400 €	-14 400 €
	Registration tax	50 €	50 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	-9 333 €
	Tires & Maintenance	8 938 €	6 094 €	-2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	-2 382 €	-2 382 €
	Motor vehicle tax	2 125 €	2 125 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 097 €	7 120 €	-977 €
Total costs		40 487 €	35 602 €	-4 886 €

Table 43: Luxembourg simulation Recommendation for Urban Delivery (Large enterprise)

45 https://single-market-economy.ec.europa.eu/smes/sme-definition_en

Luxembourg simulation Recommendation (Medium enterprise)

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	-18 000 €	-18 000 €
	Registration tax	50 €	50 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	-9 333 €
	Tires & Maintenance	8 938 €	6 094 €	-2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	-2 977 €	-2 977 €
	Motor vehicle tax	2 125 €	2 125 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 097 €	6 281 €	-1 816 €
Total costs		40 487 €	31 406 €	-9 081 €

Table 44: Luxembourg simulation Recommendation for Urban Delivery (Medium enterprise)

Luxembourg simulation Recommendation (Small enterprise)

	Parameters	ICE	BEV	Delta
5-year cost	Purchase subsidy	- €	-21 600 €	-21 600 €
	Registration tax	50 €	50 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	-9 333 €
	Tires & Maintenance	8 938 €	6 094 €	-2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	-3 572 €	-3 572 €
	Motor vehicle tax	2 125 €	2 125 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 097 €	5 442 €	-2 655 €
Total costs		40 487 €	27 211 €	-13 277 €

Table 45: Luxembourg simulation Recommendation for Urban Delivery (Small enterprise)

In the urban delivery use case, the proposed purchase subsidy and infrastructure subsidy scheme has a positive effect on the 5-year TCO of vehicles for all 3 company types. While for large enterprises, the TCO is 4.886 € more attractive, for small enterprises, up to 13.277 € advantage is achieved towards the BEVs, in contrast to diesel equivalent trucks.

Regional Delivery

Luxembourg simulation Recommendation (Large enterprise)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (FCEV)
	Purchase subsidy	- €	- 47 000 €	- 107 000 €	- 47 000 €	- 107 000 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 12 000 €	- €	- 12 000 €	- €
	Motor vehicle tax	1 825 €	1 825 €	1 825 €	- €	- €
	Infrastructure charge	6 469 €	6 469 €	6 469 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		40 013 €	55 487 €	66 001 €	15 474 €	25 988 €
Total costs		200 065 €	277 435 €	330 004 €	77 369 €	129 938 €

Table 46: Luxembourg simulation Recommendation for Regional Delivery (Large enterprise)

Luxembourg simulation Recommendation (Medium enterprise)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (FCEV)
	Purchase subsidy	- €	- 58 750 €	- 133 750 €	- 58 750 €	- 133 750 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 15 000 €	- €	- 15 000 €	- €
	Motor vehicle tax	1 825 €	1 825 €	1 825 €	- €	- €
	Infrastructure charge	6 469 €	6 469 €	6 469 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		40 013 €	52 537 €	60 651 €	12 524 €	20 638 €
Total costs		200 065 €	262 685 €	303 254 €	62 619 €	103 188 €

Table 47: Luxembourg simulation Recommendation for Regional Delivery (Medium enterprise)

Luxembourg simulation Recommendation (Small enterprise)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (H2)
	Purchase subsidy	- €	- 70 500 €	- 160 500 €	- 70 500 €	- 160 500 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 18 000 €	- €	- 18 000 €	- €
	Motor vehicle tax	1 825 €	1 825 €	1 825 €	- €	- €
	Infrastructure charge	6 469 €	6 469 €	6 469 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		40 013 €	49 587 €	55 301 €	9 574 €	15 288 €
Total costs		200 065 €	247 935 €	276 504 €	47 869 €	76 438 €

Table 48: Luxembourg simulation Recommendation for Regional Delivery (Small enterprise)

Long Haul

Luxembourg simulation Recommendation (Large enterprise)

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
5-year cost	Purchase subsidy	- €	- 70 000 €	- 178 000 €	- 178 000 €	- 70 000 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 12 000 €	- €	- €	- 12 000 €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	1 626 €	1 626 €	1 681 €	56 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	209 €	230 €	287 €	78 €	21 €
Annual average		90 730 €	106 987 €	235 016 €	144 285 €	16 256 €
Total costs		453 651 €	534 933 €	1 175 078 €	721 427 €	81 282 €

Table 49: Luxembourg simulation Recommendation for Long Haul (Large enterprise)

Luxembourg simulation Recommendation (Medium enterprise)

	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
	Purchase subsidy	- €	- 87 500 €	- 222 500 €	- 222 500 €	- 87 500 €
	Registration tax	4 957 €	4 957 €	4 957 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
5-year cost	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	-15 000 €	- €	- €	- 15 000 €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	8 749 €	8 749 €	8 749 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	391 €	104 €
Annual average		93 303 €	105 476 €	228 740 €	135 437 €	12 173 €
Total costs		466 516 €	527 381 €	1 143 700 €	677 185 €	60 866 €

Table 50: Luxembourg simulation Recommendation for Long Haul (Medium enterprise)

Luxembourg simulation Recommendation (Small enterprise)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
	Purchase subsidy	- €	- 105 000 €	- 267 000 €	- 267 000 €	- 105 000 €
	Registration tax	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Truck Depreciation	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Energy costs	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Tires & Maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure maintenance	- €	15 000 €	- €	- €	15 000 €
	Infrastructure depreciation	- €	- 12 000 €	- €	- €	- 12 000 €
	Infrastructure subsidy	- €	- 18 000 €	- €	- €	- 18 000 €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	8 749 €	8 749 €	8 749 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	391 €	104 €
Annual average		92 312 €	97 985 €	218 849 €	126 537 €	5 673 €
Total costs		461 559 €	489 924 €	1 094 243 €	632 685 €	28 366 €

Table 51: Luxembourg simulation Recommendation for Long Haul (Small enterprise)

In case of Long-haul delivery, BEV TCO differences are ranging between 28.366 € for small enterprises, to 81.282 € to large enterprises. FCEVs remain at a high level of difference, up to 721.427 € for large enterprises, therefore their economic viability is limited until cost components become reduced.

Recommendation #2 (Revised GBER scenario)

According to the latest draft of the GBER regulations on “clean vehicles” state investment aid for the acquisition of clean vehicles or zero-emission vehicles transport and for the retrofitting of vehicles to qualify as clean vehicles or as zero-emission vehicles shall be compatible with the internal market within the meaning of Article 107(3) of the Treaty and shall be exempted from the notification requirement of Article 108(3) of the Treaty. Aid shall be granted for the purchase or the leasing for a duration of at least **12 months** of clean vehicles powered **at least partially by electricity** or by **hydrogen or zero-emission vehicles** and for the **retrofitting** of vehicles allowing them to qualify as clean vehicles or zero-emission vehicles.

According to the latest draft of GBER regulations covering state aid for zero emission purchase subsidy, the eligible costs shall be:

- for investments consisting in the purchase of clean vehicles or zero-emission vehicles, the **extra costs of purchasing the clean vehicle or the zero-emission vehicle (retail price difference-based model)**;
- for investments consisting in the leasing of clean vehicles or zero-emission vehicles, the extra costs of leasing the clean vehicle or the zero-emission vehicle;
- for investments consisting in the retrofitting of vehicles allowing them to qualify as clean vehicles or zero-emission vehicles, the costs of the investment in the retrofitting.

Based on the foreseen revision, the aid shall be granted in a competitive bidding process, also the aid award shall be based on clear, transparent, and non-discriminatory eligibility and selection criteria. The ex post adjustments to the bidding process outcome (such as subsequent negotiations on bid results) shall be excluded, and the selection criteria used for ranking bids and, ultimately, for allocating the aid shall be based primarily on the contribution to the objectives of the measure put in direct or indirect relation with the aid amount requested by the applicant put in direct or indirect relation with the contribution to the objectives of the measure.

According to the latest draft of the revised GBER, if the requirements are met the aid intensity shall not exceed:

- 100 % of the eligible costs for the purchase or the leasing of zero-emission vehicles or the retrofitting of vehicles allowing them to qualify as zero-emission vehicles.
- 80 % of the eligible costs for the purchase or the leasing of clean vehicles, or of the retrofitting of vehicles allowing them to qualify as clean vehicles.

Urban Delivery

Luxembourg simulation Recommendation (80% Funding rate)

5-year cost	Parameters	ICE	BEV	Delta
	Purchase subsidy	- €	-28 800 €	-28 800 €
	Registration tax	50 €	50 €	- €
	Truck Depreciation	15 510 €	37 150 €	21 640 €
	Energy costs	13 343 €	4 010 €	-9 333 €
	Tires & Maintenance	8 938 €	6 094 €	-2 844 €
	Infrastructure maintenance	- €	1 087 €	1 087 €
	Infrastructure depreciation	- €	1 294 €	1 294 €
	Infrastructure subsidy	- €	-4 763 €	-4 763 €
	Motor vehicle tax	2 125 €	2 125 €	- €
	Mandatory inspection	522 €	574 €	52 €
Annual average		8 097 €	3 764 €	-4 333 €
Total costs		40 487 €	18 820 €	-21 667 €

Table 52: Luxembourg simulation Recommendation for Urban Delivery (at 80%)

Regional delivery

Luxembourg simulation Recommendation (80% rate)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta (BEV)	Delta (FCEV)
	Purchase subsidy	- €	- 94 000 €	- 214 000 €	- 94 000 €	- 214 000 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	73 611 €	190 821 €	250 000 €	117 209 €	176 389 €
	Energy costs	78 827 €	69 722 €	144 000 €	- 9 105 €	65 173 €
	Tires & Maintenance	38 240 €	47 150 €	33 225 €	8 910 €	- 5 015 €
	Infrastructure maintenance	- €	4 250 €	- €	4 250 €	- €
	Infrastructure depreciation	- €	15 000 €	- €	15 000 €	- €
	Infrastructure subsidy	- €	- 24 000 €	- €	- 24 000 €	- €
	Motor vehicle tax	1 825 €	1 825 €	1 825 €	- €	- €
	Infrastructure charge	6 469 €	6 469 €	6 469 €	- €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	1 043 €	1 148 €	1 435 €	104 €	391 €
Annual average		40 013 €	43 687 €	44 601 €	3 674 €	4 588 €
Total costs		200 065 €	218 435 €	223 004 €	18 369 €	22 938 €

Table 53: Luxembourg simulation Recommendation for Regional Delivery (at 80%)

Long haul

Luxembourg simulation Recommendation (80% Funding rate)

5-year cost	Parameters	ICE	BEV	FCEV (H2)	Delta H2	Delta BEV
	Purchase subsidy	- €	- 140 000 €	- 356 000 €	- 356 000 €	- 140 000 €
	Registration tax	50 €	50 €	50 €	- €	- €
	Truck Depreciation	75 000 €	232 821 €	435 580 €	360 580 €	157 821 €
	Energy costs	336 626 €	313 907 €	815 100 €	478 474 €	- 22 719 €
	Tires & Maintenance	38 240 €	47 150 €	98 480 €	60 240 €	8 910 €
	Infrastructure maintenance	- €	4 250 €	- €	- €	4 250 €
	Infrastructure depreciation	- €	15 000 €	- €	- €	15 000 €
	Infrastructure subsidy	- €	- 24 000 €	- €	- €	- 24 000 €
	Motor vehicle tax	1 900 €	1 900 €	1 900 €	- €	- €
	Infrastructure charge	1 626 €	1 626 €	1 681 €	56 €	- €
	External cost charge for noise and air pollution	- €	- €	- €	- €	- €
	External cost charge for CO2	- €	- €	- €	- €	- €
	Mandatory inspection	209 €	230 €	287 €	78 €	21 €
Annual average		90 730 €	90 587 €	199 416 €	108 685 €	- 144 €
Total costs		453 651 €	452 933 €	997 078 €	543 427 €	- 718 €

Table 54: Luxembourg simulation Recommendation for Long Haul (at 80%)

Overall, the priorities in the subsidy award should be focusing on those vehicles, which are operating in, or in the proximity of urban areas, and the avoided emissions (CO2, NOx, etc.) are high. Therefore, the applicants should submit their planned routes and road freight activities for the purchased vehicles.

The cost difference between ICE and ZE (BEV or FCEV) in on average equal to € 250.000, which is calculated an average delta of the different vehicle types (N2 rigids, N3 rigids, N3 tractor trailer units) and fuel types (BEV, FCEV). The calculation for the differential average is as follows: [(117,000 + 175,000 + 267,000 + 445,000)/4] = [1,004,000/4] which is approximately €250,000. This indicates that for a 40% rate, the purchase subsidy would be €100,000 in 2023. Similarly, for a 60% rate, the purchase subsidy would be €200,000 in 2023.

2022 Costs	Urban Truck	Regional Truck	Tractor Trailer Truck
Typical GVW	7.5-16t	26-32t	44t
Typical cost BEV	€ 69 000	€ 250 000	€ 310 000
Typical cost FCEV	€ 240 000	€ 400 000	€ 580 000
Comparable diesel	€ 33 000	€ 132 250	€ 135 000

From 2026, we can expect the total cost of ownership (TCO) difference between battery electric, fuel cell electric, and diesel trucks to decrease sharply. This decrease in the TCO difference is primarily due to technological advancements in the electric vehicle industry, such as improvements in battery technology, charging infrastructure, and production processes, which are expected to lower the upfront costs of electric trucks. Additionally, as governments around the world continue to implement stricter emissions regulations and incentivize the adoption of zero-emission vehicles, the operating costs of diesel trucks are likely to increase. The hypothesis behind the sharp decrease in TCO difference starting in 2026 may be attributed to the fact that this is the year when the price of batteries is projected to reach a tipping point, making electric vehicles more affordable and cost-competitive with their diesel counterparts.

Figures in €	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
No. of new clean vehicles	+ 40	+ 73	+ 107	+ 143	+ 179	+ 218	+ 257	+ 299
Average additional cost	250.000	225.000	200.000	100.000	93.750	81.500	75.000	68.750
Fundig rate 40%	100.000	90.000	80.000	40.000	37.500	32.500	30.000	27.500
Estimated budget – if only Large Enterprises apply (**Min.**)	**4.000.000**	**6.570.000**	**8.560.000**	**5.720.000**	**6.712.500**	**7.085.000**	**7.710.000**	**8.222.500**
Funding rate 60%	150.000	135.000	120.000	60.000	56.250	48.900	45.000	41.250
Estimated budget - if demand is only from SMEs (**Max.**)	**6.000.000**	**9.855.000**	**12.840.000**	**8.580.000**	**10.068.750**	**10.627.500**	**11.565.000**	**12.333.750**

In the following graphs, two different scenarios have been calculated to estimate total budgets of a potential purchase subsidy program. Both calculations are based on a funding rate starting at an average of € 100.000 per vehicle in 2023, which slowly decreases until 2025. From 2026 to 2030 it is expected a lower and decreasing funding rate is necessary to stimulate the purchase of ZE trucks. The two scenarios are based on the earlier discussed German and Global MoU uptake scenarios.

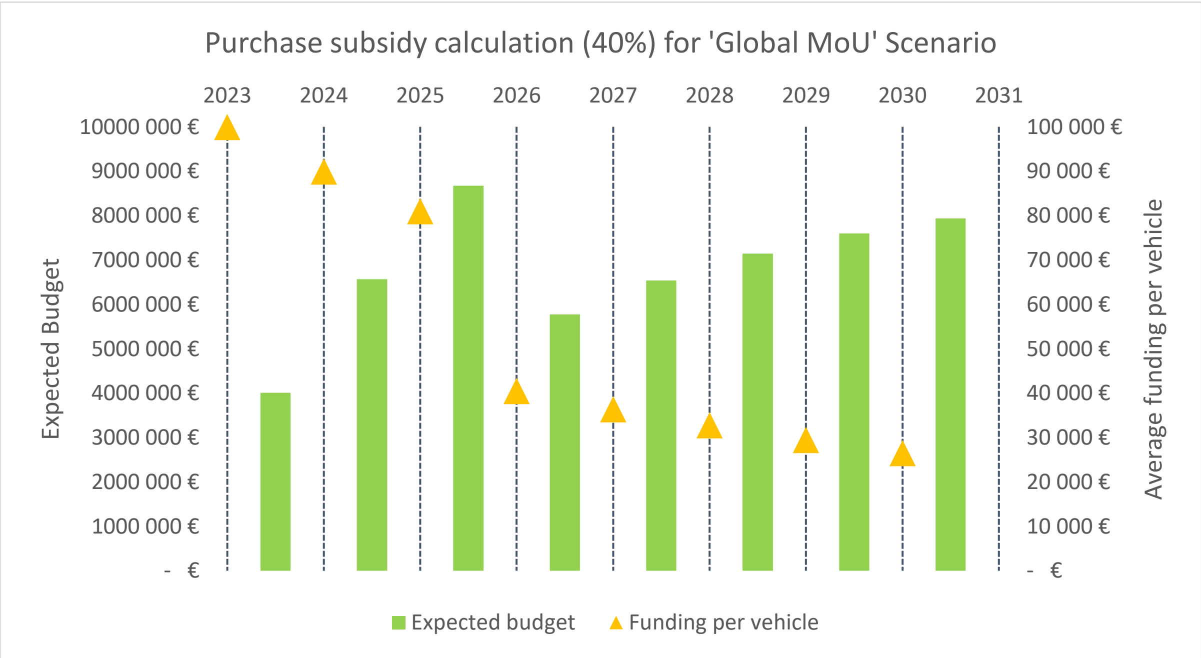

Figure 47: Purchase subsidy calculation (40%) for 'Global MoU' Scenario

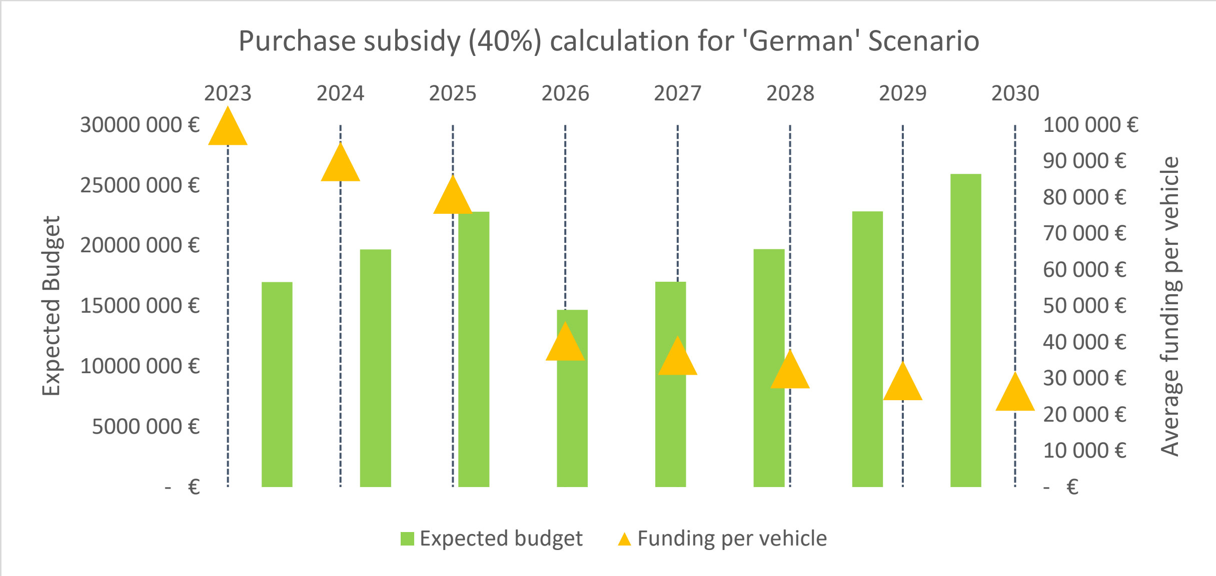

Figure 48: Purchase subsidy calculation (40%) for 'German' Scenario

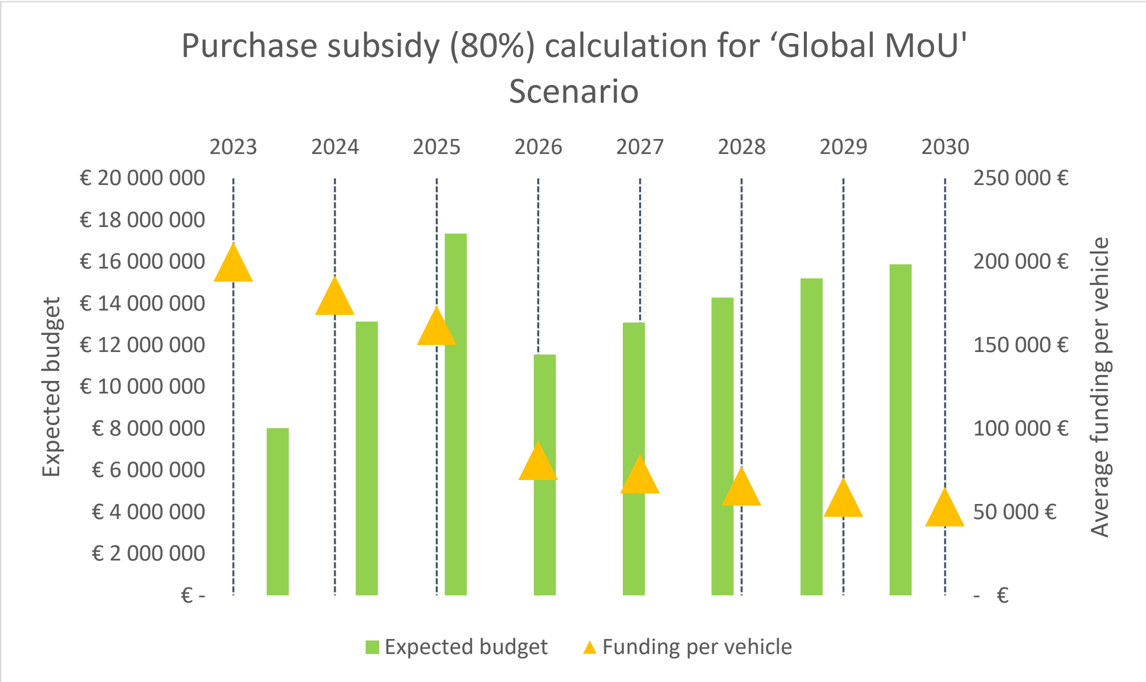

Figure 49: Purchase subsidy calculation (80%) for 'Global MoU' Scenario

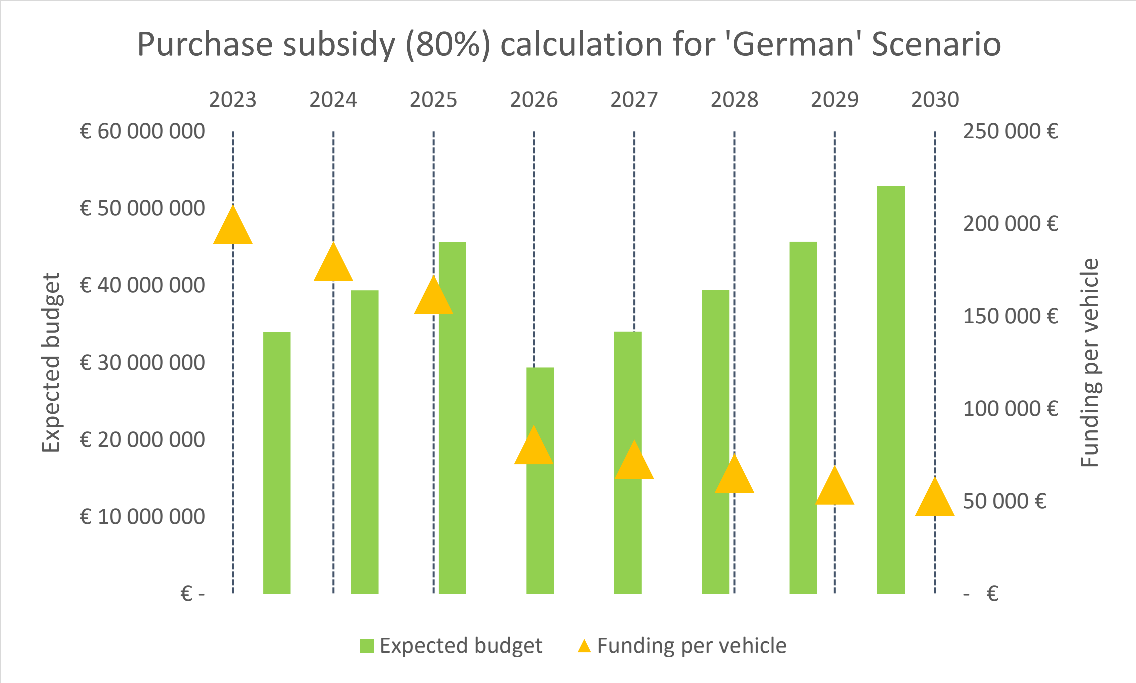

Figure 50: Purchase subsidy calculation (80%) for 'German' Scenario

3.4.3 Financial incentives - Recurring benefits

Implementing a differentiated policy with regards to road tax and/or toll for ZE trucks is the most obvious incentive. When the incentive of lowering or exempting ZE trucks from road tax is only applicable for Luxembourg registered vehicles, the impact is limited. Since the number of non-Luxembourg registered trucks driving within or through Luxembourg represents 64% of total kilometres, it is wise to also include those vehicles. The implementation of a (kilometer-based) road toll, also applicable for non-Luxembourg registered trucks, could be a powerful incentive tool. The impact of such a scheme would be maximized where the financial advantage is for ZE trucks has a significant impact on their TCO. The Directive (EU) 2022/362 amends the existing Toll Directive and foresees the end of the current user charges for trucks (Eurovignette) currently applicable in Luxembourg for March 2032 at the latest. Only kilometer-based road tolls can be applied from this date onwards. Therefore, Luxembourg will analyse to what extent such a road toll model for MHDV can be introduced.

3.4.4 Facilitating public charging

To stimulate the uptake of ZE trucks a supportive network of Ultra-Fast Chargers is necessary. This network will also be a necessity for internationally operating trucks, either Luxembourg or non-Luxembourg registered. The proposed AFIR from the EC is the regulation for countries to create this type of network. There are multiple ways to support the implementation of this charging network.

There are important developments with regards to the international high power trucks charging network(s) that are currently being rolled out. The current battery limitations which limits the daily mileage for (international) long haul, are (most likely) going to be solved by an international network of high power BEV MHDV chargers, along the Ten-T road network. Considering a ultra-fast charging network along the Ten-T corridor, the legal time limitations a truck driver is allowed to drive at a time (and therefore the stops that are needed), the larger batteries with higher ranges, also long haulage trucking becomes possible with BEV.

Therefore support from governmental organizations. At this moment, the countries within this study have no dedicated incentive scheme for the roll-out of a public available charging infrastructure. Most of these public charging hubs are supported by co-funding pilot projects, which would be our recommendation in any first phase. In a later phase a scheme for financial support via subsidy for the roll-out of public charging locations can be considered.

3.4.5. Overall/other recommendations

- **Combine incentives for ZE trucks with disincentives for non-ZE trucks:** The carrot- and stick approach has more impact compared to adding the effect from the individual incentives.
- **Raising awareness and knowledge is crucial:** The lack of understanding the possibilities often withholds uptake of new technologies. Providing knowledge and raising awareness of ZE options can be done by providing tools, organising events, or distributing 'knowledge vouchers' where selected consultancy firms can help the transport companies in investigating the opportunities, etc. An example of how the UK government funds fleet advice for HDVs is included in Appendix X.
- **Zero emissions zones:** The impact of this incentive can be significant, as it will impact all transport organisations who operate in these zero-emission zones. These zones are implemented by municipalities but should be supported (or even initiated) by the national government.
- **Slowly but steadily decrease level of incentives:** Start with incentives which create a significant impact, and slowly and steadily decease the level of incentives, making changes to a pre-agreed and communicated timescale. This way the market will slowly adapt, and this approach minimises risk of political fallout when subsidies are withdrawn.
- **Stimulate all ZE trucks (both BEV and FCEV):** Aim to be technology neutral and focus on the ZE applications. On the other hand, it is smart to consider the effect on uptake of ZE-MHDVs per spend euro.
- **Support favourable finance for ZE-trucks:** Since the purchase price of ZE-trucks is significantly higher, it is expected that the transport companies will need support for low(er) interest loans.

4 Alternatives to OEM Zero Emission Trucks

There are a number of alternative low emission fuel options available for consideration to decarbonise the Luxembourg commercial vehicle fleet. These options could be considered as transitional technologies to allow partial fleet decarbonisation to take place whilst ZE vehicles are maturing within the marketplace. The key characteristics of these fuels and vehicles and any operational implications are discussed below.

4.1 Vehicle and Alternative Fuel Introductions

4.1.1 Natural gas

Technology introduction: Natural gas (methane) powered vehicles run on either Compressed Natural Gas (CNG) or Liquified Natural Gas (LNG). A dedicated gas vehicle uses CNG or LNG in a spark ignited internal combustion engine similar to a petrol engine. Dual Fuel (diesel:gas) vehicles generally use a compression ignition engine and a blend of natural gas and diesel.

Whilst CNG and LNG are fossil fuels, biomethane is the renewable and sustainable form of methane. Biomethane is produced from organic waste and can be directly used in gas powered vehicles.

Technology availability: Gas vehicles are well-established worldwide, but their use in EU countries varies significantly depending on the established vehicle parc and policies of individual countries. N2 and N3 class vehicles are available from major OEMs.

Refuelling: CNG and LNG vehicles can be fuelled at public or dedicated depot-based refuelling stations. The initial investment cost of deploying a station of significant size and capability to serve a significant number of vehicles is high. The cost of fuel dispensed is highly dependent on station type and throughput, with publicly accessible high volume stations with a dedicated gas grid connection providing gas at the lowest cost.

In common with all alternative fuel types, a minimum network of refuelling stations is required for gas vehicles to promote vehicle uptake. Italy and Germany have the most natural gas stations, and the most gas vehicles, in Europe. The EU Alternative Fuels Infrastructure Directive (AFID) has mandated an appropriate number of urban CNG stations in each country by 2020 and CNG and LNG stations (spaced no more than 150 km) apart across the TEN-T core network by 2025.

4.1.2 Biodiesel

Technology introduction: Biodiesel, also known as FAME (Fatty Acid Methyl Esters), is a renewable fuel produced from vegetable crops or used cooking oil. It has similar properties to fossil fuel diesel and is already present in regular diesel purchased at public forecourts up to 7% blend (B7). High blend biodiesel usually contains at least 20% biodiesel. Common blend strengths are B20 (20% biodiesel), B30 (30% biodiesel) and B100 (100% biodiesel).

Technology availability: All diesel vehicles sold within the EU must be warranted to run on BS EN 590 diesel fuel, which can contain up to 7% biodiesel (B7). Many manufacturers design their vehicles to operate on higher biodiesel blends, normally up to a 30% blend (B30).

Truck manufacturers such as Mercedes, DAF, Scania, Dennis Eagle, and Volvo also warrant various blends up to B100 depending on vehicle model, although this generally requires a biodiesel conversion kit.

Refuelling: Biodiesel blends higher than B7 require dedicated onsite bunkering. Tanks need to be cleaned and maintained regularly. Due to issues with winter performance (gelling), blends above 30% often require heated tanks.

4.1.3 HVO

Technology introduction: Hydrotreated vegetable oil (HVO) is a fuel that is chemically similar to conventional fossil fuel diesel. It is classed as a ‘drop-in’ fuel, which means it can be substituted for conventional diesel with no impact on operational requirements. HVO can be produced from virgin vegetable oil, typically crude palm oil, and waste feedstock such as UCO and waste vegetable oils.

Technology availability: As HVO is a drop-in fuel its use has no impact on maintenance or warranty. All major truck OEMs approve 100% HVO for use in their vehicles provided the fuel meets European Standard EN15940. Sourcing fuel from reputable suppliers will ensure that HVO is renewable (i.e., produced from waste feedstocks).

Refuelling: HVO is not widely available from fuelling stations[46] and so dedicated onsite bunkering is normally required needed. Storage facilities are the same as those for diesel.

4.1.4 Retro-fit BEV

Technology introduction: While major manufacturers (OEMs) are working on dedicated BEV trucks, low volume technology developers have stepped in to address early market gaps for zero emission solutions by replacing diesel engines with battery electric drives in existing vehicle platforms (replacing a diesel engine with a lower emission drive is also known as repowering).

Technology availability: In some market niches where zero emission offers significant advantages (such as urban refuse collection vehicles), several developers are offering this technology. While this offers the purchaser first mover advantage, the products are inevitably les mature and reliable, and importantly have a significantly lower sales and service support base, than those from OEMs.

Refuelling: Retrofit/repowered BEVs are recharged in the same way as BEVs from major manufacturers

4.1.5 H2 ICE

Technology introduction: Internal combustion engines (ICE) are a long-established and mature technology. Burning hydrogen in an ICE is currently attracting considerable interest, particularly for heavy vehicles and construction machinery, as it has the potential for vehicle lower cost and earlier deployment than fuel cells. H2 ICE in trucks has the potential for 100% CO2e emissions savings (if renewable hydrogen is used) and potentially very low levels of NOx and PM if engines are further developed and calibrated.

Technology availability: No H2 ICE trucks are currently available in Europe. Major manufacturers such as Cummins and Bosch are actively pursuing the development of H2 ICE and the introduction of EU hydrogen combustion standards through the Hydrogen Engine Alliance.

Refuelling: Hydrogen ICE vehicles are fuelled with gaseous or liquid hydrogen in the same way as hydrogen fuel cell vehicles.

4.2 Alternative Options Roadmap

The roadmap below provides an outlook on the maturity of the relevant alternative fuels and drivetrains for commercial vehicles. The roadmap presents the fuels and technologies under the following conditions to 2030.

Trial & early-stage demonstration – this represents technologies which are new to market, often requiring financial support and deployed in low numbers to assess the performance of and prove the technology before wider deployment

Transition to main-stream technology – this represents technologies that are in series production but are not yet widely adopted in the marketplace. The technologies are still support by incentives to increase adoption

46 HVO is available from Bettembourg multimodal hub

Commercial/large-scale deployment – mature technology widely used in transport applications.

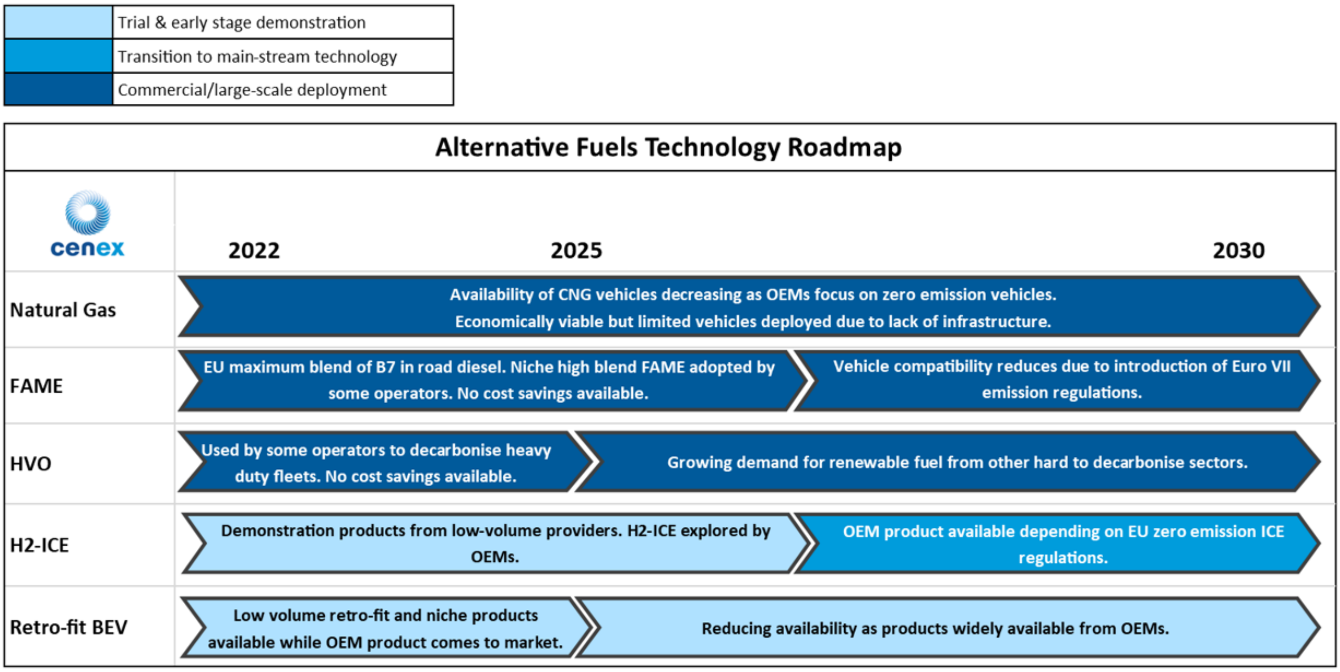

Figure 51: Alternative Fuels Technology Roadmap

The roadmap above shows the following:

Natural gas: Natural gas vehicles are a mature technology widely available from many OEMs. The number of natural gas vehicles available is likely to decline gradually from 2025 as manufacturers focus on developing and deploying ZE alternatives. At the time of writing only one publicly accessible CNG station remains in Luxembourg and is planned to close shortly, and there is also one private station of a public transport operator.

Biodiesel: All diesel vehicles will continue to be compatible with a maximum FAME biodiesel blend of 7%. Some operators looking to decarbonise their emissions will continue to operate higher blend biofuels (B20 and above) where higher blends are warranted for use in manufacturers' vehicles. We are likely to see a reduction in vehicle compatibility with higher blend biofuels when the Euro VII emissions regulation is introduced in 2027. This is because manufacturers will first design their vehicles to meet Euro VII regulations for the compliance date and then look to test and certify vehicles for higher blend biofuels as further development in future years.

HVO: HVO will continue to be supported by OEMs in Euro VI and also Euro VII products, with a growing number of operators turning to HVO as a decarbonisation route with relatively low barrier to entry. HVO is manufactured from limited feedstock and as such we expect a growing demand for the fuel from a range of hard-to-electrify areas. This may mean poor availability and higher costs for certified renewable HVO going forward past 2025.

H2-ICE: Hydrogen internal combustion engine vehicles will continue to be developed and used to demonstrate hydrogen propulsion. Proposals are being developed by the EU for a zero-emission combustion standard. If this is brought into regulation, then H2-ICE may gain significant traction and transition to a mainstream technology towards 2030.

Retro-fit BEV: Retro-fit solutions for ZE drivetrains and products from low volume manufacturers are likely to continue to be deployed to 2025 in niche applications and for early trials where OEM product is not yet available. As OEM trucks (rigid and artic) mature into the marketplace then these will dominate sales, with corresponding declining sales for retro-fit and low volume BEV providers. Although there will continue to be some low volume special purpose vehicle applications for retro-fit BEV.

4.2.1 Total Cost of Ownership

Work package 2 explained the purpose and design of the TCO for BEV, FCEV and Diesel. The same design and calculation methodology is used to create the TCO for the selected alternative fuels, i.e. using the same vehicle types and duty cycles. This allows for a direct comparison between the diesel and zero emission drivetrains and alternative fuelled drivetrains.. For each of the three vehicle categories the alternative fuel TCO is displayed, followed by the main points for each alternative technology.

Long Haul 40t Articulated Truck

Figure 52: Long Haul 40t Tractor

Regional 26t – 32t Rigid Truck

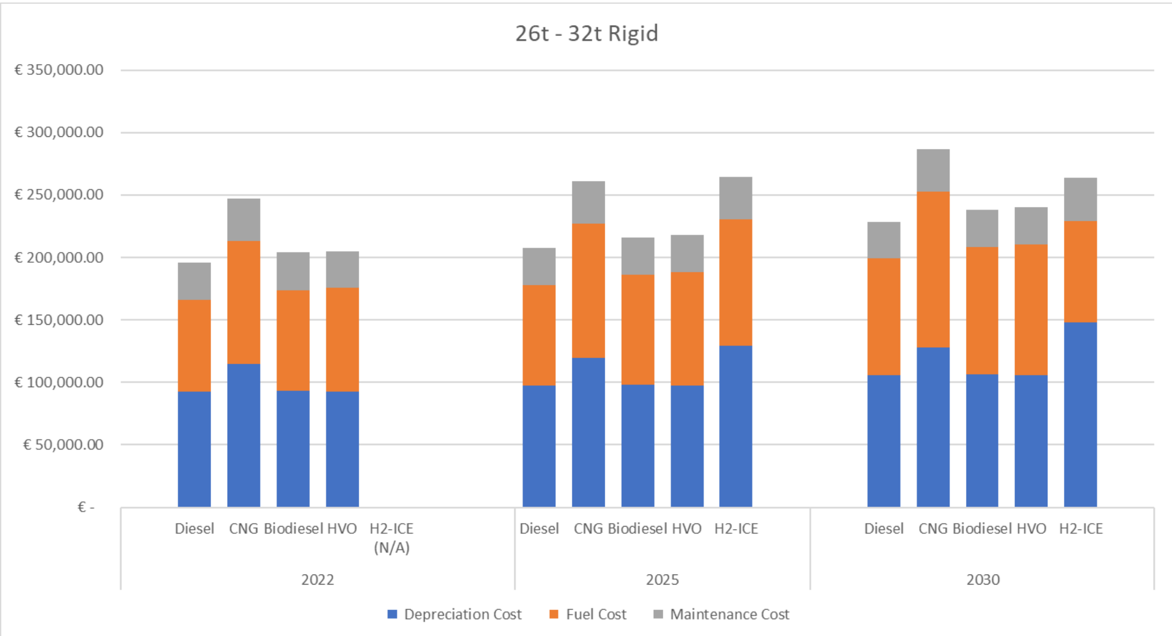

Figure 53: Regional Delivery Truck

Urban 7.5t – 12t Rigid Truck

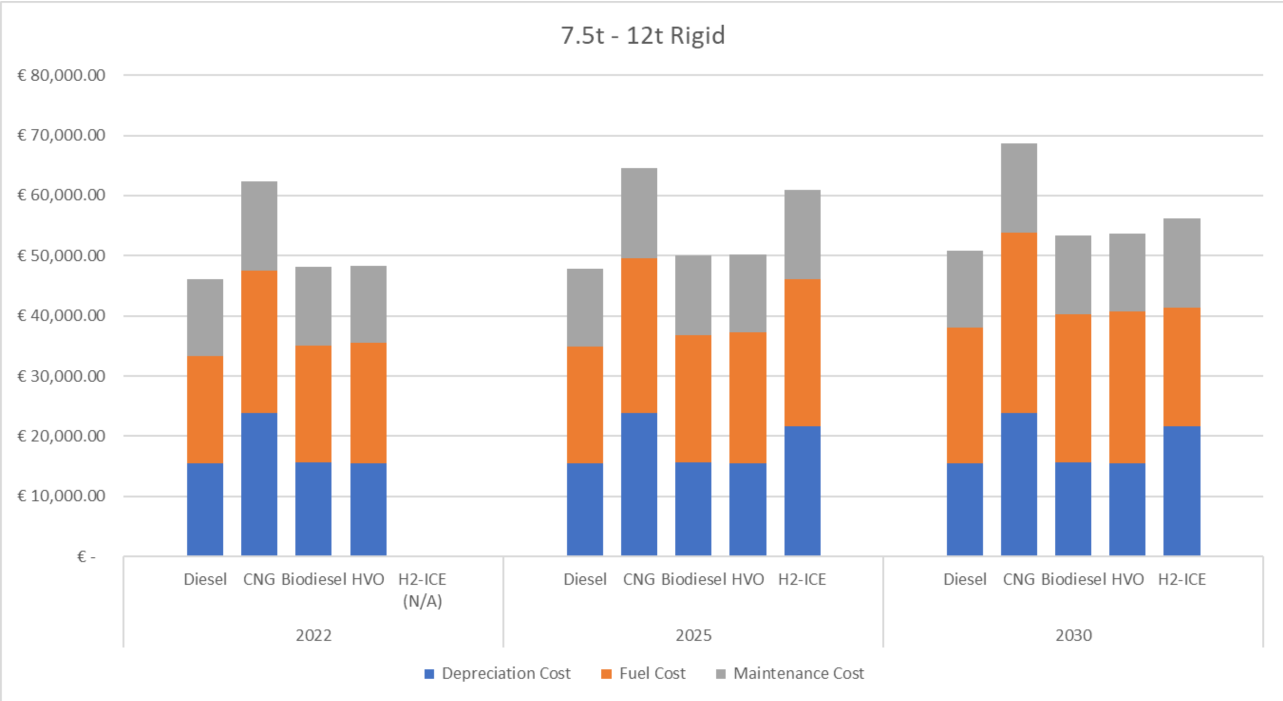

Figure 54: Urban Delivery Truck

The TCOs show that i) fuel costs are the main TCO component for the 40t and 7.5t – 12t trucks, while ii) purchasing costs are the main component for 26t – 32t trucks. This is caused by the relatively low mileages (and therefore fuel costs) for the 26t – 32t trucks relative to the high purchase costs.

Natural gas: CNG vehicles have a purchase cost premium compared to diesel, but fuel price dominates the TCO.

Biodiesel: Biodiesel trucks, and biodiesel itself, have a small purchase cost premium compared to diesel, and biodiesel blends are slightly more expensive per litre compared to pure fossil diesel. This leads to a slightly higher TCO compared to diesel.

HVO: HVO vehicles have no purchase cost premium compared to diesel as it is a drop-in fuel. HVO itself is more expensive per litre of fuel, leading to a higher TCO.

H2-ICE: There are no mass-produced OEM H2-ICE vehicles available in 2022. When H2-ICE vehicles do become available (here assumed to be from 2025 onwards), they are expected to have purchase cost premium of 40% compared to diesel vehicles. With the high prices for H2 at the pump, now and in the future, the TCO will become more competitive than CNG, but not compared with diesel, biodiesel or HVO.

4.2.2 Total Cost of Ownership Factors

For all technologies, except for H2-ICE (where technology development and production volumes will decrease purchase costs over time), the TCO increases over the years. This is because the rest of these technologies are proven concepts, with no significant expected cost savings in production or fuel in the coming years. Alternative fuel costs, except H2, are based on current prices in Europe and increased with 3% per year. For each technology the relevant factors used to calculate the TCO are described below.

Diesel: The diesel base case uses the same TCO as chapter 0, please refer to the explanation there.

Natural gas: Prices have been rising since 2021, with a peak in 2022 due to the war in Ukraine. The price of CNG is based on available CNG prices[47] in Europe, using the average value of 2022. It is

47 https://cngeurope.com/

expected that prices will remain high in coming years. An increase in price of 3% per year is used to estimate future prices. Based on recent events current and future prices are likely to be volatile and uncertain. It should be noted that if CNG were to revert to the pre-2021 costs then the operators of CNG Long-haul and Regional trucks would see a good TCO benefit.

The fuel economy of CNG vehicles is similar to diesel vehicles per unit[48,49] e.g. if a diesel truck has a fuel consumption of 0.3 l/km, a similar CNG truck will have a fuel consumption of 0.3 kg/km.

The retail price of CNG vehicles is based on the diesel base plus additional costs. These additional costs were determined by Cenex consultation with truck operators. It is assumed that the additional costs do not increase or decrease over time, decreasing the purchase cost relative to diesel in 2025 and 2030 as diesel trucks are expected to increase in price.

The percentage residual value of CNG vehicles is assumed to be comparable to diesel. This is because they are both proven technologies with an existing market. The maintenance costs for CNG vehicles are based on the diesel base plus an additional factor based on Cenex discussions with truck operators. It is assumed the additional factor does not change over the years.

Biodiesel: The price of B30 diesel is determined by using the average price in Belgium (where specific data were available in the public domain on the pricing of B30 blend) in 2022, the same 3% increase per year is assumed for future prices.

The fuel economy of biodiesel vehicles is assumed to be the same as diesel vehicles. The retail price of biodiesel vehicles is a small premium on top of diesel cost for a biodiesel conversion. The residual value of biodiesel vehicles is assumed to be comparable to diesel after 5 years. This because they are both proven technologies with an existing market. It is assumed this is true in the future. The maintenance costs for biodiesel vehicles are assumed to be slightly higher than diesel. It is assumed the additional factor does not change over the years.

HVO: The price of HVO is 10% to 15% higher than diesel[50], the same 3% increase per year is assumed for future prices.

The fuel economy of HVO vehicles is assumed to be the same as diesel vehicles. The retail price of HVO vehicles is the same as a diesel vehicle as diesel is a drop in fuel.

The residual value of biodiesel vehicles is assumed to be comparable to diesel after 5 years. This because an HVO vehicle is a diesel vehicle running on HVO. It is assumed this is true in the future. The maintenance costs of a vehicle running on HVO are assumed to be the same as a diesel vehicle.

H2-ICE: As described in the roadmaps, H2-ICE vehicles are in the demonstration phase. The factors used in the TCO assume an OEM H2-ICE model, that is also the reason there are no 2022 values.

The retail price of H2-ICE is uncertain as they are not yet commercially available. Based on the same source as the fuel economy it is assumed the retail price of H2-ICE is 40% higher than a comparative diesel vehicle. It is assumed that this factor does not change between 2025 and 2030.

As described earlier the current price of hydrogen is based on the average European pump price ex VAT[51], and that this is not necessarily green hydrogen. It is expected that green hydrogen availability will increase as the REPowerEU plan aims for 20 million tonnes in 2030[52]. The price for green hydrogen is therefore expected to decrease, with the values for 2025 and 2030 based on multiple research papers and models[53,54].

48 https://www.virginianaturalgas.com/business/natural-gas-vehicles/cng-vs-traditional-fueling.html

49 https://www.fleeteurope.com/en/new-energies/europe/features/10-reasons-why-cng-new-diesel?

50 https://hvofueluk.co.uk/blog/how-much-does-hvo-fuel-cost-compared-to-fossil-diesel/

51 H2.live

52 https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen_en

53 https://www.itf-oecd.org/decarbonising-europes-trucks-minimise-cost-uncertainty

54 https://theicct.org/publication/fuels-eu-onsite-hydro-cost-feb22/

H2-ICE vehicles are assumed to have a 5% better fuel efficiency than diesel, based on energy used[55]. e.g. if a diesel vehicle uses 100 MJ of energy a H2-ICE vehicle uses 95 MJ of energy. As H2 has a higher energy density compared to diesel this results in a fuel economy of 0.09 kg H2/km.

The residual value of H2-ICE vehicles is assumed to be comparable to diesel after 5 years. H2-ICE uses similar technology to regular ICE vehicles, which manufacturers expect to have similar aspects.

The maintenance costs for H2-ICE vehicles are based on the diesel base plus an additional factor. This factor is based on the same source as the fuel economy and retail price factor and is, like all factors for H2-ICE, uncertain. It is assumed the additional factor does not change over the years.

Alternatives – Role in the LU Fleet

The role of alternative technologies in the LU fleet are discussed following the emissions analysis in Section 0.

4.3 Emission Performance

The scope of this analysis is the Tank-To-Wheel (TTW), or Scope 1 emissions. TTW or Scope 1 emissions represent the amount of CO2e which is released from a vehicle's tailpipe when the fuel is burned. WTW or All Scope emissions are a more holistic method of looking at CO2e emissions and represent the amount of CO2e emitted during the fuel's life cycle. This includes the upstream emissions associated with fuel extraction, processing, transportation, and dispensing, as well as the emissions from final fuel combustion. Although the upstream emissions from fuel manufacture is not the reporting responsibility of the transport operator, WTW emissions are considered important by environmentally conscious fleets when making decisions on fuel and transport options.

Emissions are calculated using emission factors for each fuel type and truck type. The Luxembourg government provided the study team with their emission factors for diesel, HVO and standard biodiesel blend. Missing emissions were supplemented with UK emission factors for company reporting. This is a reasonable as only TTW emissions are considered, and therefore supply chain emissions are not factored.

The table entitled TTW CO2 Emissions Savings below shows the annual TTW emissions savings on the y-axis compared to an equivalent Euro VI diesel truck. Above the bars the savings percentage is shown, 100% being no TTW emissions. Emission savings are related to fuel use and therefore higher mileage vehicles save more emissions when converted to low or zero emission technologies. The exact values are also displayed in the table.

The table shows that all alternatives under consideration save emissions relative to diesel. Zero emission technologies (BEV and FCEV) produce 100% savings. TTW CO2e emission savings from HVO, a renewable fuel, are almost 100%. A B30 biodiesel blend, a common blend used by fleets, results in a ~30% CO2e saving. CNG vehicles give only a slight decrease in tailpipe emissions as they are often used in lower efficiency spark ignition engines. If biomethane (a sustainable version of natural gas) is used, then TTW emission savings would be close to 100%.

55 https://mobilitynotes.com/h2-ice-truck-cost-of-ownership-vs-diesel-and-fuel-cell-vehicles/

The graphs further show that the 40t tractors can save the most emissions per truck as they have the most intense drive cycle (long distances and worst fuel economy).

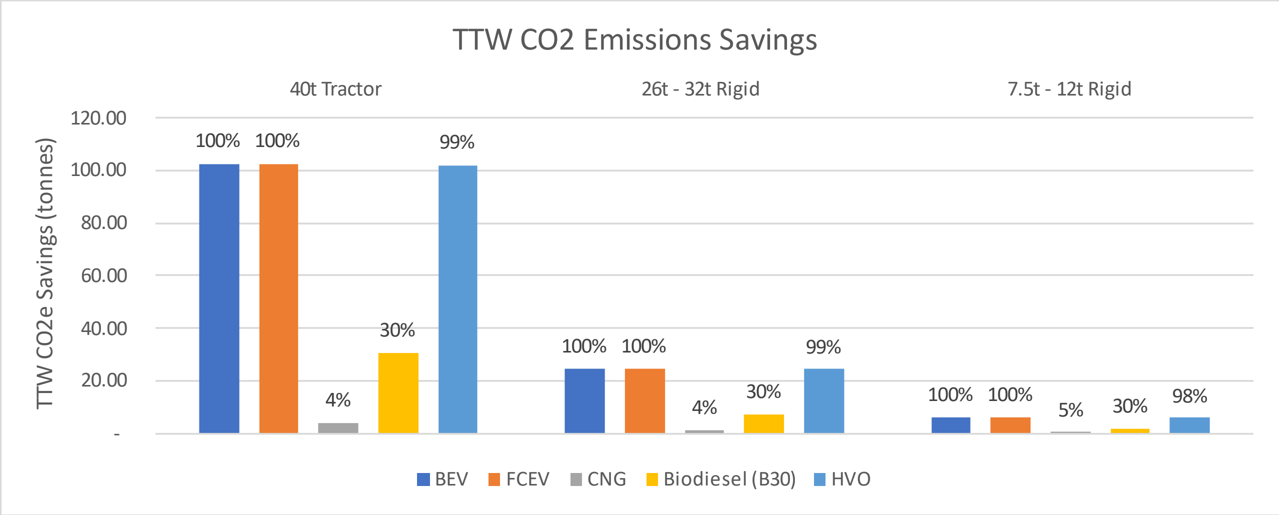

Figure 55: TTW CO2 Emission Savings

The NOx and PM emission saving graphs only show the emission savings for BEV and FCEV as no official emission factors for CNG, biodiesel or HVO exist; however all these vehicles meet Euro VI emission standards and can be considered as no worse than diesel. BEV and FCEV, as ZE vehicles, save 100%, or ~52 kgs NOx and 0.64 kgs of PM, per tractor trailer vehicle per annum.

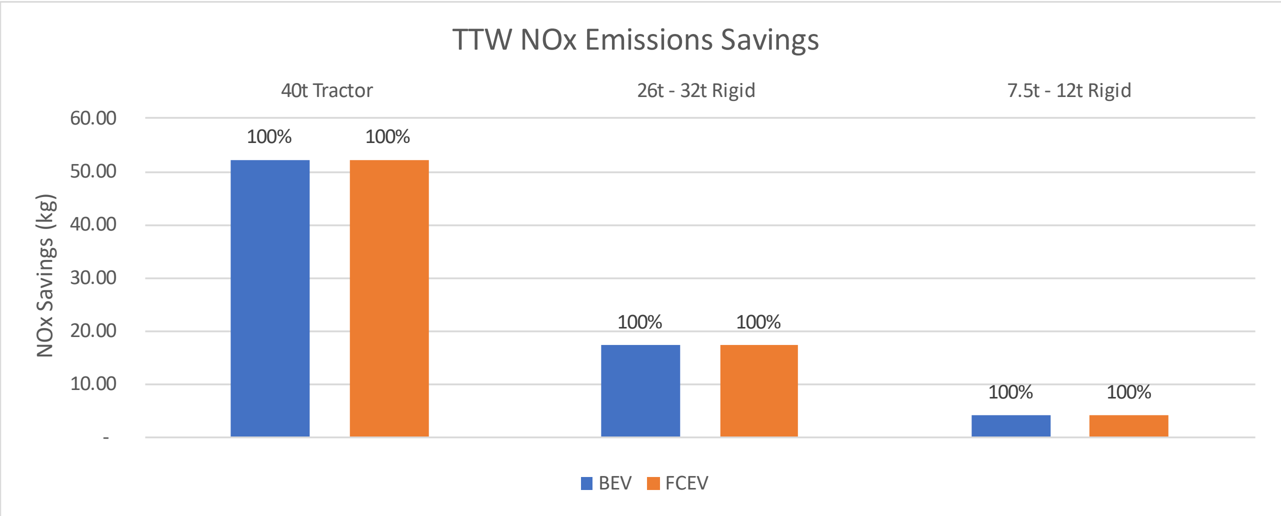

Figure 56: TTW NOx Emission Savings

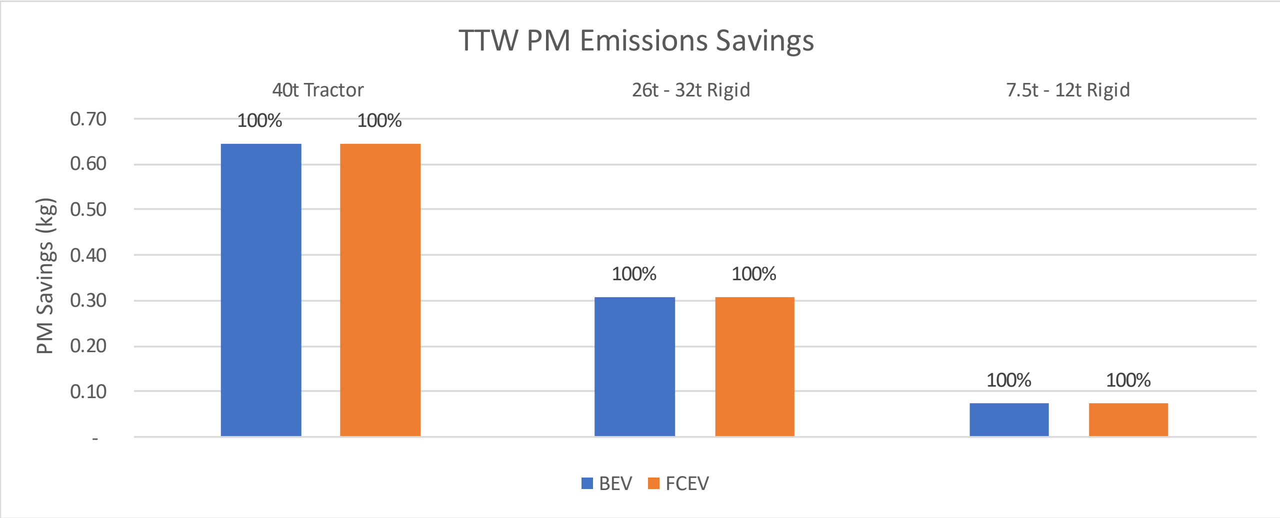

Figure 57: TTW PM Emission Savings

The table titled TTW CO2e Emissions shows the CO2e emissions per km for the different trucks and technologies. It shows that lighter truck types emit less CO2e, because they use less fuel per km.

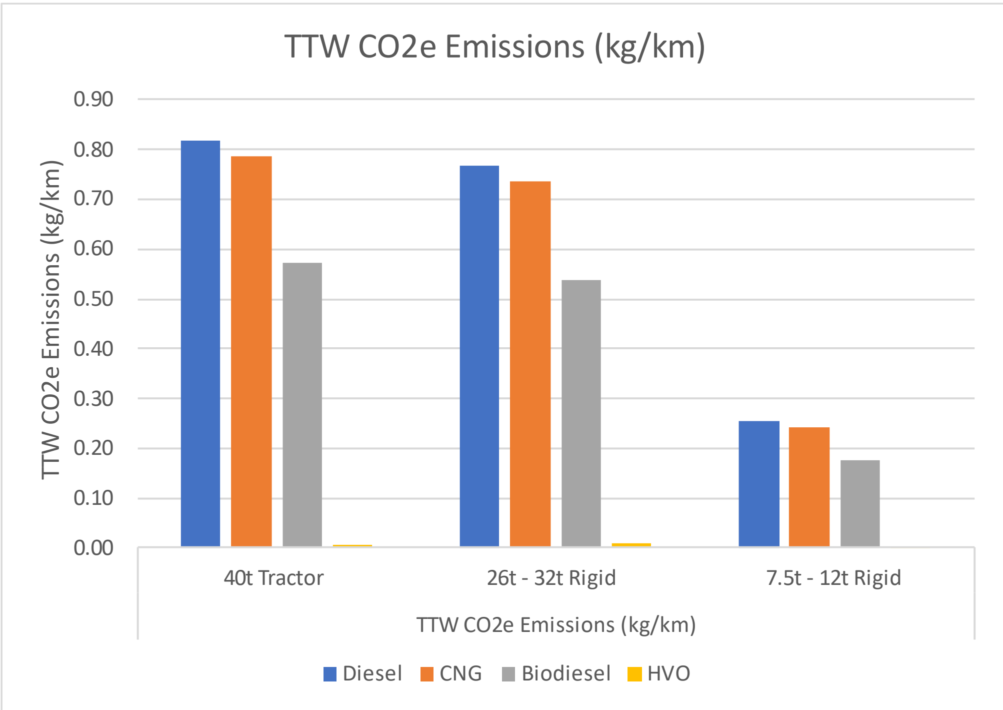

Figure 58: TTW CO2 Emissions in kg/km

The tables below show the emissions savings per annum and the CO2e emissions per km for all truck categories and technologies. CO2e emissions for BEV and FCEV are zero and therefore not listed.

		BEV	FCEV	CNG	Biodiesel (B30)	HVO
CO2 (T)	**40t Tractor**	102.57	102.57	3.89	30.77	101.75
	26t - 32t Rigid	24.54	24.54	0.99	7.36	24.30
	7.5t - 12t Rigid	5.95	5.95	0.28	1.78	5.85
NOx (kg)	**40t Tractor**	52.27	52.27	-	-	-
	26t - 32t Rigid	17.25	17.25	-	-	-
	7.5t - 12t Rigid	4.15	4.15	-	-	-
PM (kg)	**40t Tractor**	0.65	0.65	-	-	-
	26t - 32t Rigid	0.31	0.31	-	-	-
	7.5t - 12t Rigid	0.07	0.07	-	-	-

		Diesel	CNG	Biodiesel (B30)	HVO
CO2 (kg)	**40t Tractor**	0.82	0.79	0.57	0.01
	26t - 32t Rigid	0.77	0.74	0.54	0.01
	7.5t - 12t Rigid	0.25	0.24	0.18	0.004

Table 55: Emissions savings per annum and CO2e emissions per km for all truck categories and technologies

4.3.1 The role of alternative fuelled MHDVs in the Luxembourg fleet

The truck sector is on a path to ZE technology, but true zero emission options, particularly for larger, high mileage vehicles, are not yet available on the market. To 2030, there are some alternative fuel options that could significantly reduce the emissions of the Luxembourg truck fleet.

The simplest option is HVO as this is a drop-in fuel which can be used in standard vehicles offering WTW emission reductions of over 90%, albeit at a price premium. High biodiesel blends also offer emission reduction but is only likely to be taken up in niche applications by some fleets as the organic nature of the fuel makes fuel management problematic. CNG will not assist in emission reduction unless biomethane is used. H2 ICE may play a role from 2025 onwards, but this will depend on the availability of hydrogen and proof from real-world trials that H2 ICE engines offer better NOx and PM emission performance than Euro VI and Euro VII diesel.

The alternative fuels discussed above will require financial incentive packages to make them attractive. Fleet operators run on low margins in a competitive environment so long-term fiscal policy incentives with proven decarbonisation technologies will drive operators to adopt alternatives. Experience in the UK of biomethane uptake is instructive: the UK has a rapidly expanding biomethane sector and public infrastructure due to private investment in the network. Many UK fleets see good CO2 reduction potential for the next two vehicle replacement cycles through biomethane use before they will start to need to consider ZE truck options. However, any fiscal policy aimed towards the alternatives mentioned above (biomethane and HVO) may generate short term CO2e emission savings however these will remove focus from ZE options. This decade of incentives in ZE trucks is likely to be a critical factor (learning on use, operations, infrastructure, maintenance, supply chain set-up, skills) to allow successful adoption when costs reduce ready for mass market adoption.

Overview of figures and tables

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