35th International Electric Vehicle Symposium and Exhibition (EVS35)
Oslo, Norway, June 11-15, 2022

Zero-Emission road freight – an overview of a rapidly developing market

R.A.A. Kroon[1], S. Van der Wilt[2], H.A.M. Weken[3]

[1] *FIER Automotive & Mobility,*
rkroon@fier.net

[2] *FIER Automotive & Mobility,*
svanderwilt@fier.net

[3] *FIER Automotive & Mobility,*
harmweken@fier.net

Summary

Road freight transport causes disproportionately high amounts of GHG emissions, compared to other transport modalities. The implementation of zero emission trucks are a good solution for this issue. There are important developments with regards to zero-emission road freight, in terms of availability of vehicles, pricing, charging infrastructure, policies, etc.. In this paper these topics are researched to give a comprehensive overview of this rapidly developing market. Also the challenges for further uptake of the zero emission truck market are discussed, and potential solutions provided.

Keywords: Heavy-duty; Truck; Business Model; Policy; Energy network; Charging

1 Background and motivation

Global transportation systems have begun a shift to newer, cleaner technologies that will meet greenhouse gas (GHG) emission reduction and air quality improvement goals that governments have developed, or fleets have adopted for themselves. Though freight vehicles represent a relatively small percentage of on-road vehicles, emissions from freight account for a disproportionately high percentage of GHGs, harmful air pollutants, and noise. Zero-emission freight vehicles (ZEFVs) can match the current transportation system's capabilities while creating societal benefits by reducing the negative outcomes associated with diesel and gasoline consumption.

Although there are opportunities for replacing Internal Combustion Engine Vehicles (ICEV), the uptake of zero emission trucks is limited. There are several reasons for the limited uptake. These reasons differ between the stakeholders.

- In the transport sector there is a limited sense of urgency, and the knowledge of what is possible is also limited. Transport companies have indicated that they will wait until new developments will take place, where the technology is more mature and/or is not having an impact on their current way of doing business. Also the significant upfront investments are holding back. Since the profit margins in the sector are limited, the implementation is related to the willingness to pay from their customers. Organisations have also indicated that there is unclear governmental policy, with regards to restrictions and financial incentives.
- The vehicle producing industry has made significant progress with optimising the efficiency of diesel motors, and have invested in the supply chain and the production process. Since the new technology of electric drivetrains needs a different supply chain, more expensive components and a new production process, the cost price is high. The customers is not willing to pay this price. Also, the industry will need to come up with a different type of business model to ensure the revenue which is needed.
- The governmental organisations have set out challenging climate ambitions and targets. Most of these targets are however exceed the responsibility of the current administration. Stimulating desired market behaviour can be done with the right policy and incentives. Finding the right balance in incentives (carrot stick), to accelerate the uptake of zero emission trucks, is also considered as a challenge.

The authors have been involved in multiple studies and living labs related to ´making the road transport sector more sustainable´ since 2013. Several flagship project like eGLM [1], ZEBRH [2] and other have been initiated, developed and managed by the authors. In 2020, the authors presented the report ´Moving Zero-Emission Freight Toward Commercialization´ [3] which was prepared in cooperation with CALSTART for International ZEV Alliance.

2 Current market of electric road freight vehicles

The truck producing industry has seen some challenges in the last decades. The regulations on the emissions from the diesel engine increased, resulting in an evolution of these fossil fuelled engines. The engines produced less emission and were therefore environmental friendlier than their predecessors.

At this moment, the truck producing industry is facing an even bigger change. To build a zero emission vehicle, a complete new drivetrain needs to be implemented. The industry of truck production, including the complete supply chain, will change significantly.

2.1 Electric trucks

The complete automotive sector is facing the same challenge of producing more environmentally friendly vehicles. The passenger vehicle market is ahead of the truck market. Although the electric passenger vehicle market is not mature yet, it shows a significant growth in sales figures. This is due to the increased demand of the market, the availability of vehicle producers and the supporting measures of governments.

Currently, the truck market is behind the passenger vehicle market. The real start of the electric truck market started in the years 2010 – 2015 with pilot projects. These projects tested trucks that originally had a diesel engine but were converted to electric by replacing the drivetrain. This was done by the converting companies.

At his moment, the converters still play a role in the electric truck industry, but it is rapidly changing. The established OEMs are now producing some models with electric drivetrains, although not on a big scale yet. Figure 1 shows that the uptake has significantly increased since 2018 and continued in the years after. The number of BEV trucks is a lot higher than the PHEVs and H2 trucks.

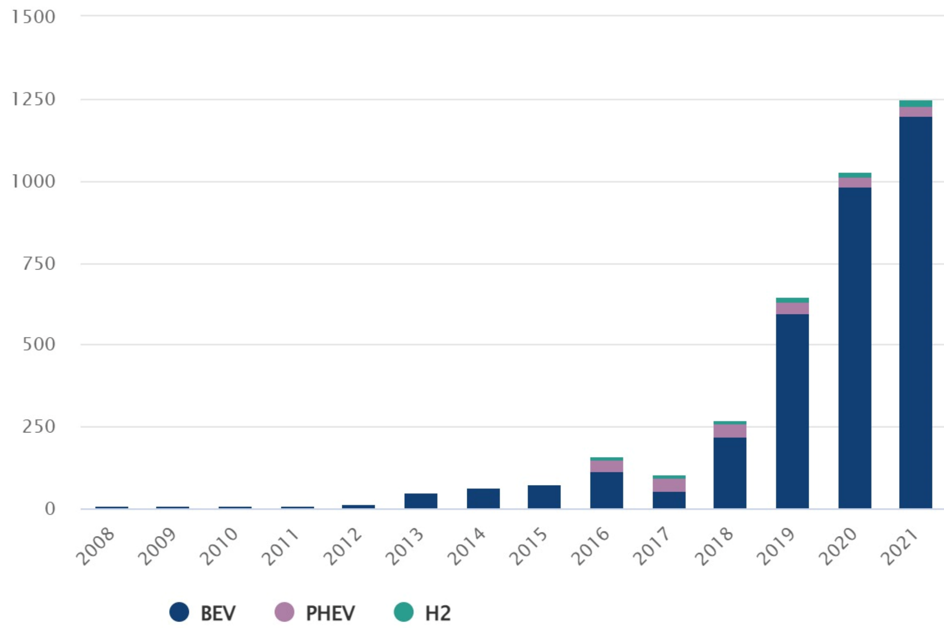

Figure 1: Total number of BEV, PHEV and H2 trucks - N2 and N3 in EU27. Source: EAFO

Although some OEMs are investigating the options of H2 drivetrains for trucks, the majority is currently focussing their strategy on BEV drivetrains.

The availability of BEV N2 and N3 trucks offered by OEMs is growing, but currently limited. Within the N2 market several OEMs like DAF, Mercedes-Benz, MAN, Renault, Volvo are offering trucks commercially. The N3 market is only offered by DAF. Volvo N3 type trucks are open to order, but not yet available now, similar as Renault.

The size of the battery, combined with the electric drivetrain efficiency, results in the range an electric vehicle provides. Since the drivetrain efficiency is not that different between the different electric truck manufacturers, the energy capacity of the battery has the most influence on the range of the vehicle. In terms of battery capacity, there is a variety of offerings. Most manufacturers offer different battery configurations. This is because the batteries have a significant impact on the costs and on the weight of the vehicle. Battery capacity in the N2 and N3 segments are between 185kWh and 540 kWh. The range with the largest battery, in this case produced by Volvo, claims to be 340km +.

2.2 Electric truck charging infrastructure

There are several technologies and methods to charge electric trucks. There are options to charge with an overhead pantograph, like is common for charging electric busses. Although some manufactures are testing with this technology, it is not a common solution for electric trucks. Neither is inductive charging a common solution. This technology could charge the vehicle (often from the ground) without direct physical contact with the charger. This type of charging is also being tested on a small scale. All the technologies mentioned above are quite promising, but not as mature as the current standard of cable charging.

Electric trucks are charged by either AC or DC charging. AC charging requires the truck to have an onboard charger, converting the AC current into DC current, which the battery needs for charging. An onboard charger is not necessary for DC charging. Where AC charging is quite common for passenger vehicles, it is less for electric trucks. DC charging is the standard and only a few manufactures offer the option of AC charging. This is because an onboard charger is costly and is limited in terms of charging speed. With bigger batteries, AC charging will take too long for the truck to be charged again. For smaller capacity batteries, it is however still a financially viable solution. This is because the costs of an AC charging points are lower and charging during a longer time when the truck is not being used (during the night for example) could suit the requirements.

DC chargers are currently available for trucks range between 11kW and 350kW. The lower powered chargers are usually used during a longer time when the truck is not being used. The higher powered chargers open new opportunities for the utilisation of the truck. By using so called High Power Chargers (HPCs), electric trucks can charge a significant amount of range in a limited time. This means these trucks can drive more kilometres per day. Current available trucks are limited to 150kW, with one exemption. DAF is offering a 250kW charging option for their electric CF. It is however expected that more OEMs will offer higher charging capacities soon.

Although the market of electric trucks is still young, there are already standards for charging which manufactures agreed on. For AC charging the Mennekes Type 2 plug is the standard. For DC charging the standard is the CCS plug. Also, with regards to communication protocols between the truck and the charger, there are agreed standard. Truck manufactures offer charging infrastructure with their trucks, but this could also be purchased elsewhere. Also multiple truck brands can use the same charging infrastructure, so there is no vendor lock-in.

At the moment the next phase of fast charging is being developed. This is the so-called Megawatt Charging System (MCS). It is specifically designed to charge trucks, boats and airplanes which are expected to have a larger capacity battery, and therefore also require fast charging solutions. The impact in the logistic planning will be significant since charging time will not hold back the further utilisation of the electric trucks. Long haul transport with electric trucks will become more viable than as well.

3 Challenges for large scale implementation of electric trucks

The market of electric road freight is rapidly developing, but there are some challenges which have an impact on the speed in which this is taking place. The main challenges are the economic feasibility of the implementation of electric transport, the optimalisation of the utilisation of the electric trucks and the needed energy availability on the energy grid.

3.1 Economic feasibility

To introduce and accelerate the uptake of an alternative technology which does not have a financial benefit over the predecessor, will always be challenging. This currently applies for the electric truck.

3.1.1 Purchase costs

The purchase cost of an electric truck is currently roughly three to four times the cost of a diesel equivalent. There are a couple of reasons for this. First of all, the production of battery electric trucks is not at the same level as the diesel versions. The supply chain of parts is not as mature on most levels. This applies to the electric drivetrain and the battery. The battery itself has the largest impact on the high purchase costs. Although battery prices are steadily going down, it is still by far the most expensive part of the electric truck. Also, the production itself is not optimised, which result in a labour-intensive process. OEMs spend a significant amount of time and effort in developing and testing the new drivetrain. These investments also impact the price.

There are developments noticeable where OEMs are increasing their production of electric trucks, which is to be seen in the purchase price. This is the effect of economies of scale, as seen by both Renault and Volvo electric trucks. It is expected that the effects of a more mature supply chain, batteries at a lower cost and an optimised production process, are also going to be seen at other OEMs in the near future.

There is not a real market of second-hand electric trucks yet. Therefore, it is not straight forward to calculate the expected residual value. There are however some expected developments to use as input for the calculation of the residual value. The electric truck is currently expensive due to the current battery prices. When these needed to be replaced in the future, the expected replacements costs are lower than the current price. The rest of the drivetrain has fewer moving parts. Therefore, it is expected that the electric drivetrain will have a longer life-expectancy than the diesel. Also, the application areas for diesel trucks are going to be more limited, due to low- and/or zero-emission zones. This has its effect on the expected residual value of both the diesel truck, as well as on the electric truck.

3.1.2 Operational cost

The operational cost of a diesel truck and an electric truck have the same components. These are the energy costs, service & maintenance costs, road tax and insurance costs. Although these are same components, the calculation method differs significantly.

The energy cost of a diesel truck, is the price of diesel multiplied by the average fuel consumption. For an electric truck this is not only the purchase price of a kWh energy multiplied by the efficiency. Also the cost of the charging infrastructure needs to be taken in to account. Depending on the type of needed charging infrastructure, this could have a significant impact. A UFC could for example have a positive impact in the numbers of potential driven kilometres a day, but could cost € 200.000 to purchase and install. If this charger is than used for only one truck, the costs of energy will be relatively high.

The 'service and maintenance market' of electric trucks is not as mature as for the diesel trucks. The process of service and maintenance is theoretically relatively simple for electric trucks. However, mechanics need to be trained differently, the spare parts are different, and there is not a lot of track record to use for calculating the service and maintenance costs. This currently results in equal or higher service and maintenance prices for electric trucks compared to diesel trucks. It is also expected that the service and maintenance costs of the electric trucks are going down in the future, due to the maturing of the market.

3.1.3 Future developments

In order to calculate the effect of these expected future developments in terms of purchase costs, the residual value and the operational cost, the Total Cost of Ownership (TCO) can be calculated. Based on the expected developments, and the insight of multiple other studies, the following TCO comparison has been made.

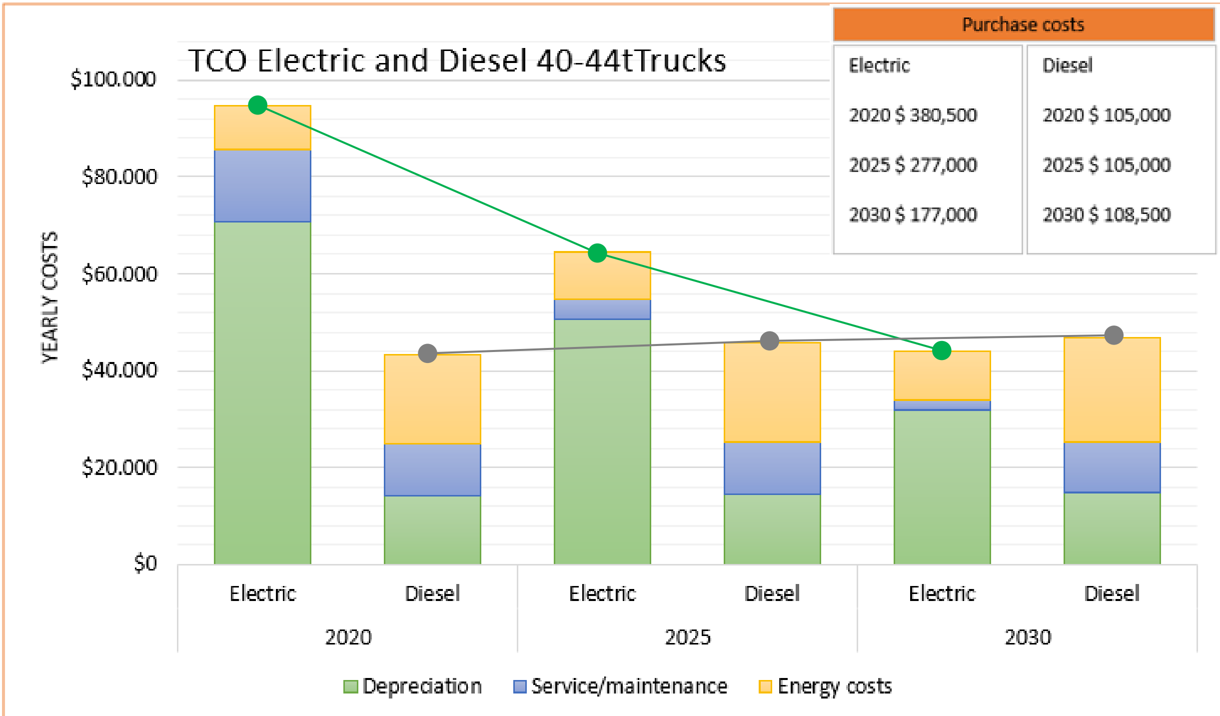

Figure 2: TCO comparison between electric and diesel truck

The effect of the lower depreciation of the electric truck, as well as the lower operational costs, result in an improving TCO calculation. For the heavy 40 / 44 ton truck, it is expected that before 2030 they will be TCO neutral. For lighter vehicles, it is expected that this TCO neutrality will happen even sooner. The calculation is not taking in to account any financial / taxation impact of governmental incentives.

3.2 Operational utilisation

Electric trucks and diesel trucks have different characteristics. Most often the battery of the electric truck needs to be recharged sooner, than a diesel tank needs to filled-up again. And with the current status of charging technology, it takes longer to charge as well. However, if planned in a smart way, the electric truck already has the potential of achieving a high level of deployability. It is about the combination of the route planning, the electric truck capabilities and the charging infrastructure.

The planning of the routes is crucial for the deployment of an electric truck. It is impossible to plan longer trips than there is range in the battery, when there is no opportunity and/or time to charge. Most often the deployment in plannable routes works best for electric trucks. The capabilities of the trucks can then be used in the most optimal way.

It is important to take in mind the location and the duration of the stops. This has an impact on the choice of type and speed of the charging infrastructure.

3.3 Electricity grid

There are innumerable amounts of studies about the energy transition. Not only the freight transport sector is going to use electric energy. Also, other modes of transport are increasingly going to use the energy grid network. It is also to be expected that industry and households will consume more electric energy in the future. On the other hand, local energy production is growing as well. The amount of PV installations, but also other sources add energy to the network. These developments create a higher demand, and create an imbalance on the energy grid network.

Installing and using charging infrastructure for electric trucks could have an effect on the grid connection. It depends on the current grid connection, the options to increase the contract and/or upgrade the grid connection, and of course the expected charging needs. It is likely that a grid connection needs to be upgraded if the current connection is relatively small, and there is a need to charge a larger number of trucks and/or implement (multiple) fast chargers. The costs and the duration could have a significant impact. In some cases, it is not even possible to upgrade the connection, due to limitations on the grid.

Smart charging could have a positive impact. If it fits in the planning, smart charging could be used to lower or postpone certain charging sessions from specific trucks. This way, it could be possible to 'peak shave' the energy demand, to stay under a threshold. Stationary batteries could also be added to the charging system in order to charge when there is a surplus of energy, and to discharge when there is a need for energy.

The expected growth of the number of electric trucks and the needed electric energy is not in line with the available energy in the local grids. Upgrading of these networks, and the increase of production of clean energy, could slow down the uptake of electric trucks. Smart charging and stationary batteries will become part of the solution.

4 The impact of governmental incentives

One of the reasons why the market of electric freight transport is growing, is because also governmental organisations are encouraging this. Both in terms of CO2 production, as well as hazardous emissions, there is a lot to gain in freight transport. This motivates the governmental organisations to discourage conventional diesel trucks to be used, and encourage the use of electric trucks.

4.1 National governments

From a national level, governments are able to adjust the financial systems to encourage en discourage certain 'behaviour'. This can for example be done by purchase subsidies and or taxation differences. The Dutch government encourages the purchase of electric trucks by giving a tax advantage (MIA). Also, they have recently followed the example of the German government to implement a purchase subsidy. However, in Germany the purchase subsidy is significantly higher. In Switzerland there is no purchase subsidy for electric vehicles.

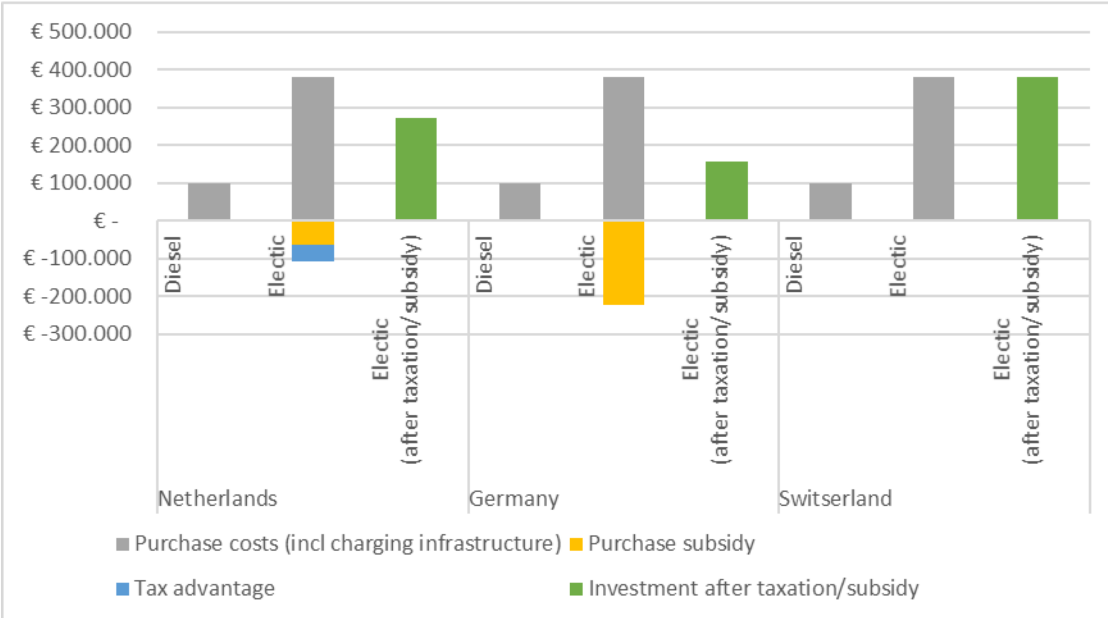

Figure 3. Example calculation of purchase cost of diesel and electric trucks, including governmental incentives for Netherlands, Germany and Switzerland.

In figure 3 an example calculation is to be seen, where the effect of different governmental incentives are taken in to account of the purchase cost of diesel and electric trucks. The example calculation is done to compare the purchase cost of a 40/44 ton truck. In the Netherlands there is a small tax advantage and purchase subsidy to be seen. This results in a difference in purchase price, where the electric truck is € 173.550 more expensive. The effect of the higher German purchase price subsidy is resulting in a € 56.000 purchase price difference, where also the electric truck is still more expensive. In Switzerland there is no purchase incentive for electric trucks, resulting in € 280.000 difference.

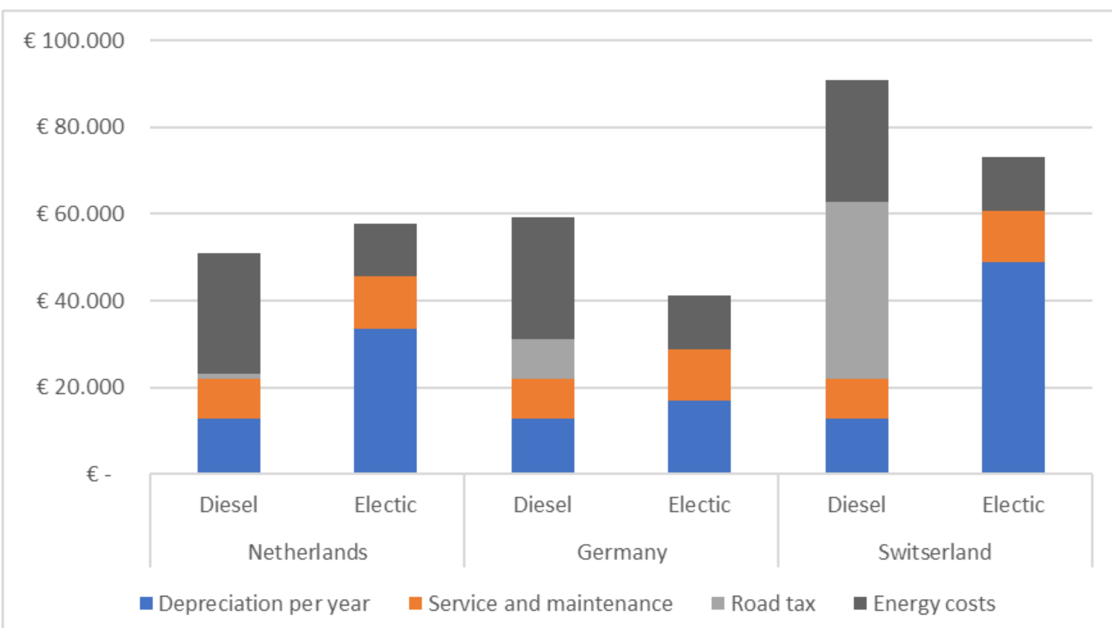

Figure 4. Example calculation of TCO of diesel and electric trucks, including governmental incentives for Netherlands, Germany and Switzerland.

In the example TCO calculation shown above, the depreciation is calculated with a 10% residual value for all trucks, and a depreciation time of 7 years. It is expected that for now, the electric trucks will have a slightly higher service and maintenance costs, but is the same for all countries within this calculation. The expected costs are calculated with a yearly milage of 50.000 km (which is reasonable for an electric truck).

Based on the above, the effect of the different incentives is shown per country. For example, in the Netherlands, the road tax exemption for electric trucks doesn't make a significant impact. Mainly due to the lower energy cost, the difference is limited to € 7.000 per year. In Germany the lower difference in purchase cost has an effect on the depreciation. Also, the Maut (road tax) plays a more significant role. The total effect is that an electric truck is about €18.000 cheaper per year. In Switzerland there is no purchase incentive for electric trucks, but the high road tax had a significant effect on the yearly TCO, resulting in an advantage for the electric truck of € 18.000.

4.2 Regional and local governments

Regional and local governments are also able to encourage the use of electric trucks. This can be done by, for example, (planning the) implementation of low and zero emission zones. This has a significant impact on (older) conventional diesel trucks, which will not be allowed within certain zones. If deliveries need to be made within a zero emission zone, there is no need to compare the business case of a diesel and an electric truck, since the diesel is not even considered as an option.

This indirectly also has a financial effect. Even if a zero emission zone is going to be implemented in a couple of years, it has an effect on the purchase of a diesel truck. The depreciation time could be shortened, because this truck will need to be replaced before the effectiveness of the zero emission zone. Also, the residual value could be lower, since other companies will then also not be able to use the truck within these zones.

Depending on the type of transport process, there will be different solutions. City hubs, where the inbound (and sometimes outbound) flows of a city are combined, could be a solution. Long haul trucks make the delivery to a city hub, where freight can be combined and distributed throughout the city with zero emission vehicles. It could also be that city delivery is done from multiple regional distribution centres (DC's). Delivery to and between DC's can be done with a long haul trucks, and the city delivery with zero emission vehicles.

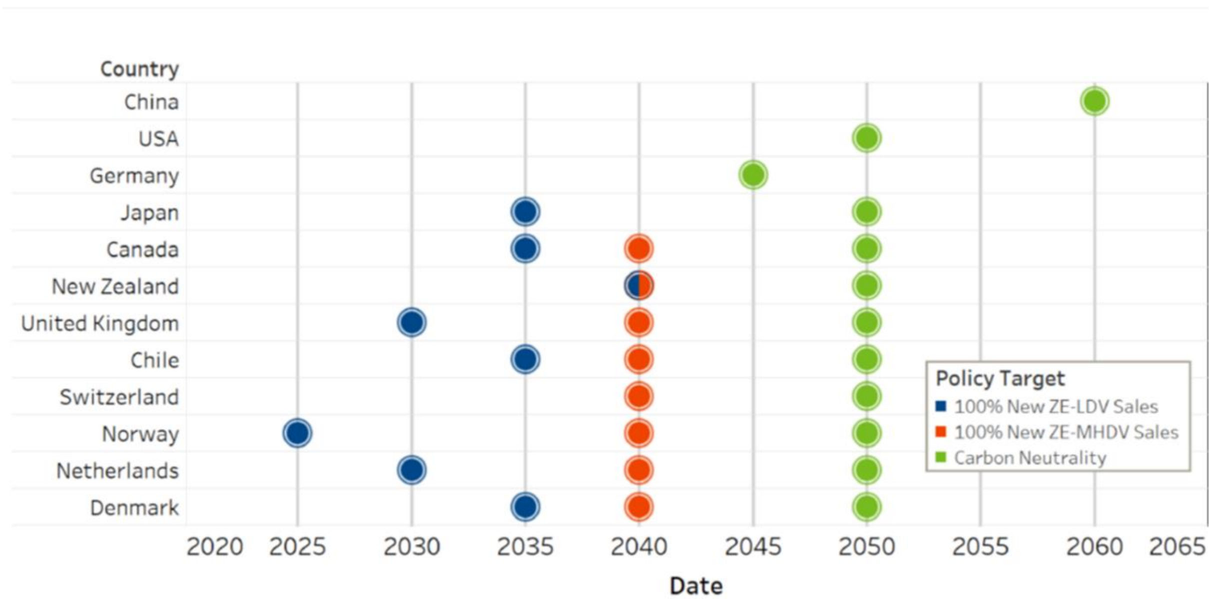

Figure 5. Example Countries prioritize Light-Duty Vehicles, Heavy-Duty is next phase. Source: Global Commercial Vehicle Drive to Zero (2022)

As to be seen in figure 5, different countries have got a different policy target for zero emission freight vehicles. Frontrunner countries are the United Kingdom, Norway and The Netherlands, with the ambition of 100% zero emission light duty vehicles (ZE-LDV) sales in 2025 and 2030. It is also interesting to see that most countries prioritise on ZE-LDV, and have zero emission medium and heavy duty vehicles (ZE-MHDV) in the next phase.

5 Conclusion

Both in terms of CO2 production, as well as hazardous emissions, there is a lot to gain in the road freight transport. Therefore electric trucks will play an important role. It is important to ensure a accelerated uptake of these vehicles, since the current uptake is limited. It means that the different challenges from the different stakeholders will need to be addressed.

It is to be seen that the OEMs are offering more electric freight vehicles, now also in the medium and heavy duty (N2 and N3) category. Although there is still a lot to gain, the first modest steps towards a more mature market are being made. Technically the vehicles improve in terms of capabilities and reliability. This is crucial for the speed of the uptake of the zero emissions vehicles.

Currently, there is already a decent standardisation of charging, both in hardware as well as in software. For a lot of applications the current technology is sufficient. Also the developments with regards to charging are promising. The new standards with regards to faster charging are going to optimise the deployability of electric trucks as well as open the opportunities for long-haul transport.

Ultra Fast Charging and/or charging a larger number electric trucks simultaneously, result in a strong demand of the electricity grid, which might not be possible everywhere due to the limitations of the local electricity grid. Due to the expected uptake of electric trucks, this will have a significant impact on the local electricity grids. The grid operators will probably not be able to keep up with the demand in certain areas. This will result in a slower uptake of electric freight distribution. It is therefore important to know what the expected growth of demand will be, and to assure that the capacity of the electricity network is timely upgraded. Next to upgrading the grid itself, there are other solutions. Local energy production, smart charging and stationary batteries are going to play an important as well. These technologies will need to further mature.

Currently the electric trucks are more expensive than their diesel equivalents, and although operational costs are often lower, the TCO is still negative. It is expected to change due to several market developments. Before 2030 the TCO of a N3 category electric trucks could be lower than diesel, for lighter vehicles this might even be sooner. For the meantime, there is no financial advantage for an electric truck, when there are no financial incentives from governmental organisations.

But to stimulate the use of electric trucks, different are countries applying different financial incentives. These lower the cost of electric trucks. The financial support is needed to overcome the number of disadvantages, like the limited range and the charging time. The effect of zero emission zones within cities will also have an positive impact on the uptake of electric vehicles.

In general, there is a lack of knowledge and a limited sense of urgency in the transport sector about the implementation of zero emission trucks. A good and reliable information source with relevant and comprehensive information would support transport companies in the decision making process.

Acknowledgments

The authors would like to thank Mr. C. Façanha (CALSTART) for his contribution.

References

[1] eGLM, Interreg project with 5 44ton full electric semi-trucks (FRAMO)- www.eglm.eu

[2] ZEBRH, DKTI project with 12 full electric trucks (DAF and Renault) https://www.rvo.nl/initiatieven/dkti-tenders/zebrh-zero-emissie-binnenstedelijke-regio%E2%80%99s-%E2%80%93-vol-elektrische-hybride-trucks

[3] R. Kroon, H. Weken, F. Jousma, D. Welch and C. Façanha - ´Moving Zero-Emission Freight Toward Commercialization’, https://www.fier.net/movingzeroemissionfreight/

Presenter Biography

Harm Weken is since 1995 managing Partner of FIER Automotive, a business development company in the international automotive sector, with a focus on sustainable and electric mobility. Harm is co-founder and co-owner of GoodMoovs.com, the largest all electric business-to-business car sharing program in the Netherlands and part of a EU network of electric car sharing programs.

Moreover Harm, supports electric mobility initiatives and the academic sector as board member, advisory council member and in scientific reviewing committees at universities and electric mobility foundations, in Europe and abroad.

The core of the work of Harm and his company FIER, is (EU and national) project initiation and business development in electric mobility for private companies, public authorities and consortia. During recent years, the focus has been on: Stimulating electric vehicle (EV) uptake in fleet; Effectiveness of national EV incentives and policies; Stimulating electric trucks in distribution and inner-city freight and; Electric car sharing and smart charging infrastructure.

After graduating from Fontys Universities (Eindhoven, the Netherlands) in Automotive Management, Rob has developed himself as an experienced project manager in the field of sustainable mobility and transport. He is working as a project manager/consultant at FIER Automotive since 2011. At FIER, Rob is involved in different (national and international) projects, mainly focusing on overall project management and his role as an EV / e-truck expert. Next to that, he is also involved in tasks like conducting research studies, workshop leader, communication and dissemination, et cetera. Due to the involvement in multiple EU projects and other business development projects, Rob has built experience, knowledge and an interesting network in the field of electric/sustainable mobility.