7. CO_2 ABATEMENT COST

Facts about climate-friendly road freight transportation

What is the best strategy for realizing climate-friendly road freight transportation? Let's take a look at the facts.

If total cost of ownership (TCO) is the key metric for commercial haulage operations considering new technical solutions, then the cost involved in order to abate (i.e., decrease) emissions is what guides public policy.

The CO_2 abatement cost differs from TCO in important ways. While the latter looks solely at the aspects which are relevant to the owner of a heavy-duty vehicle (HDV), the abatement cost also adjusts for those aspects of TCO which are essentially transfers between the road freight sector and other parts of society. Examples of these are: how road usage is paid for, taxes/subsidies on vehicle purchases, or the level at which fuel prices are taxed. Adjusting such aspects can greatly influence TCO (and thereby affect how quickly a new technology is adopted), although the total cost to society will be the same.

By comparing the total societal costs of different technologies with the level of CO_2 reduction which can be achieved for each, **the abatement cost shows how cost effective each technology is at reducing CO_2. This metric is therefore the key factor in helping policy makers put limited public resources to best use for achieving their climate protection objectives.**

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Furthermore, by effectively filtering out many local aspects, such as fuel taxes, the abatement cost figure is more likely to be globally relevant than an individual TCO calculation. CO_2 abatement cost is not just therefore useful for guiding national decisions, rather also for understanding which solutions have the best global potential. It is therefore not surprising that, when a review of the scientific literature was implemented on alternative fuels and drives for heavy duty vehicles (HDVs), it found that 15 studies took this into consideration, and just two did not.[1]

Overhead catenary line (OCL)

That same study found that there was a great diversity in which technologies were considered in the various studies. It is however noteworthy that of the 1/3 of studies which included the OCL option, essentially all [2] of them concluded that OCL would be the most effective decarbonisation technology for heavy duty vehicules (HDVs).This is also what a major study by the Federation of German Industries found.[3] Just last year, Germany´s National Platform Future of Mobility (NPM)[4] estimated the expected CO_2 abatement cost in 2030 for HDVs heavier than 20 tons and it also found OCL to come out with the lowest cost.[5]

Battery electric vehicles (BEV)

The NPM estimate for the abatement cost of battery electric vehicles (BEV) was slightly higher than for OCL used by hybrid HDVs. That finding left open the possibility that a combination of BEV and OCL would therefore result in an even lower abatement cost: low-cost vehicles which are able to travel fully electrically along the core corridors, without losing time to charge, while also able to travel significant distances under electric power away from the core corridors. This would yield the maximum CO_2 savings and do so while being economical with savings in energy, resources and time.

Fuel cell electric vehicles (FCEV)

The NPM calculation also looked at the third technology-option for zero emission heavy road freight: fuel cell electric vehicles. According to the NPM report, FCEV provides a CO_2 reduction at nearly three times the cost of the alternatives using electricity directly (e.g., OCL).

The significance of this difference is well illustrated with an example calculation provided by the German federal ministry of environment: At a targeted reduction of 10m tons of CO_2 per year in Germany, this difference in CO_2 abatement cost amounts to an annual cost difference of 7bn EUR.[6]

Renewable fuels (RF)

Renewable fuels are sometimes excluded from CO_2-abatement reports, since it would not be a zero-emission solution. However, as it is a technology option which can decarbonise the existing vehicle fleet (and in 2030 and even 2050, it is still very likely that there will be HDVs in operation with combustion engines), this should not be excluded. A more serious aspect is the large amounts of energy needed to produce renewable e-fuels (refer to the earlier article on energy efficiency). Primarily for this reason, the BDI study mentioned above found RF to be one of the five most expensive measure for reducing CO_2 in the transport sector.

This was despite the Federation of German Industries assuming that the RF would mostly be made outside Europe using low-cost electricity. Scenarios where RF is made abroad are frequently preferred, arguing that a wind turbine in some places can generate much more energy than in others. The logic being that even with higher energy losses (both in generating e-fuels and by using it in combustion engines), the same wind turbine could generate similar amounts of usable energy for a HDV, as would be the case when the wind turbine is generating electricity used directly by a nearby HDV in a region without strong winds.

A key variable in order to evaluate such claims is the discount rate. It has been reported that the cost of capital for a wind farm project in Indonesia is twice that of a similar project in Germany.[7] So even though some places have better weather conditions for generating renewable electricity, that still does not automatically mean that electricity will be much cheaper than in places where the business environment makes a lower cost of capital possible.

However, that should not be the last word on RF. Because they are still likely to be expensive, it makes a lot of sense to focus on the use of RF to hybrids. Especially hybrids which drive a very large share of the mileage in electric mode, as would be the case with hybrid HDVs using OCL infrastructure.Conversely, when the OCL hybrids are not in electric mode, using RF helps ensure that CO_2 is eliminated from all the HDV's operations.

Some reports find that this combination, given a sufficiently large OCL network, would be the most cost-effective solution to decarbonise the road freight sector.[8] Although one should note that the OCL-BEV combination was not included in that study.

Conclusion

As the facts for each subject in this series have shown, there are strengths and weaknesses with each individual technology.
Given that these do not overlap, there should be especially high synergies in combinations of the different technologies.This, plus the urgency of the moment necessitating a multipronged approach, points to a future with a mix of the four technologies.
However, this does not imply agnosticism about their relative impact. It is unlikely that there will be an equal split between the technologies, as economic and practical concerns will lead to a greater role played by certain technologies.**The key for the future of road freight lies in understanding which combinations of technologies can achieve the greatest synergies.**

From this series' review of the public facts, it is clear that **electrification is very well placed to be at the core of the future road freight system**. **Due to its higher energy efficiency and associated lower abatement cost, it should be the preferred choice wherever it is practically possible. Furthermore, electrification is also the option available already now**.This applies both to vehicles (BEV) and infrastructure (OCL as well as high-power chargers, HPCs).
Based on the existing ecosystems of standards and suppliers, these can most easily be scaled up in the limited time which is left to achieve the climate goals.

Overhead contact line (OCL) is the most economically beneficial solution on the core motorways, where the volume of heavy goods vehicles justifies the installation of the infrastructure. It is compatible with all the other technologies and helps overcome their main obstacles for wider adoption e.g., lessens the need for large batteries, provides dynamic charging, and helps spread out the load on the grid, reduction of use of costly fuels as would be the case for FCEV and RF.

OCL is also technically feasible. Catenary is a technology which is already in global use, showing that no environmental barriers exist against its scaling up and explains why interest from around the world is strong. Due to the past five years of demonstration projects and field trials involving HDVs in commercial operations using OCL on public motorways, it has been possible to work with standardisation bodies such as CENELEC.

By setting standards for the OCL infrastructure as well as the interface between the vehicles and the OCL, the conditions have been created which will enable the broad electrification industry (with an annual global turnover of around 10 bn EUR) [9] to mobilise and support the rapid implementation of OCL.

OCL is also politically possible. As politicians are looking for solutions for achieving climate targets, including those for 2030, OCL provides an option which is available today and without needing any further technical breakthroughs. It does require the active cooperation of the owners and/or regulators of the motorways. In many cases around the world, these would be the same politicians who are looking for the cheapest and fastest way to decarbonise the road freight sector.

Battery electric HDVs are being launched by all major producers and they are well placed to become the dominant vehicle architecture. Initially these will be focused on urban areas and short distances, but with growing availability of charging infrastructure, operating ranges will be greatly extended. On less intensely used corridors, this is likely to be the exclusive domain of stationary chargers.
For the corridors, where lots of heavy-duty HDVs drive the main part of their journeys, a strong case can be made for why BEVs should want to make use of OCL infrastructure.[10]

Hydrogen is already a much-needed resource in different sectors today. Green hydrogen plays a negligible role so far. Substituting green hydrogen for the existing hydrogen which is produced (approx. 120m tons) will take a long time and require significant investments in renewable energy.
Even advocates for green hydrogen say it is at least 10-15 years away.[11] So as with any hydrogen solution, the case for fuel cell-powered electric vehicles, make the most sense „where other alternatives might not be feasible or have higher costs".[12] In the case of road freight, this means the missions where electrification is not economical (e.g., long range on roads with low traffic density in areas with poor grids – think of a HDV collecting timber deep in the forest) and where zero emission operations are needed. Furthermore, the infrastructure for green hydrogen production, hydrogen distribution and refueling is not available. The standard for refueling is still to be defined and has a direct impact on operational range, refueling speed, and time to market (35 MPa / 70 MPa / liquid).

In order to overcome these challenges, it would be essential for FCEV to be easily compatible with other technologies. Although FCEVs come with sizable batteries, their primary purpose is to buffer the energy from the fuel cells so that extra power can be achieved when accelerating or driving uphill.

The batteries are not meant to be the main source of onboard energy storage. Nor would FCEVs be able to make use of RF. However, if one wanted to scale FCEV today, relying on the only standardised solution for HDVs (35 MPa gaseous hydrogen), one could make a solid case for combining FCEV-OCL. 35 MPa is usually not considered suitable for long distance operation because of the highly voluminous tanks.

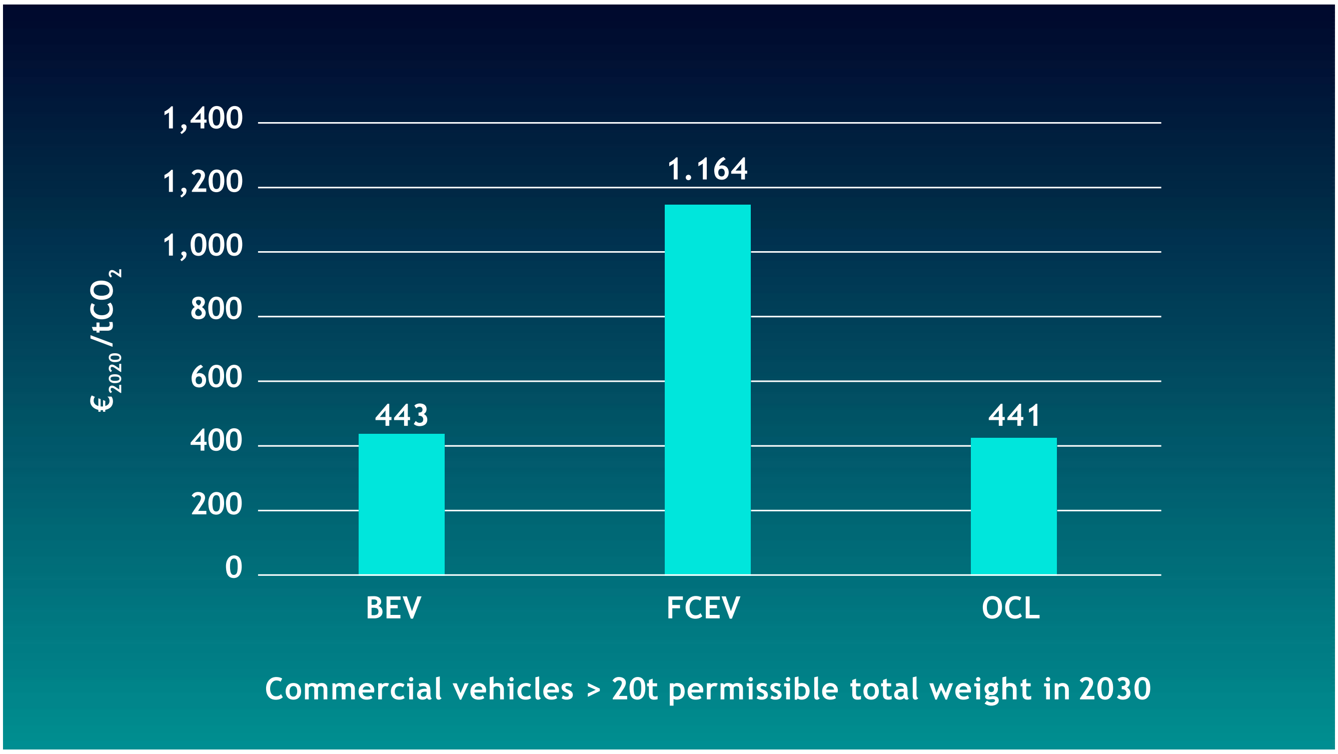
However, when combined with OCL, much smaller tanks are necessary, as most miles and especially most long-distance miles, can be powered via the OCL. As green hydrogen is likely to remain a more expensive fuel, OCL also helps ensure that it is only used where electrification isn't possible.

The future for e-fuels greatly depends on the prospect of achieving nearly limitless and super cheap electricity. As such, it represents a very optimistic view of the future.

As a precaution, in case this future does not materialize so easily, it makes sense to focus on the more energy efficient solutions, while developing RF as an addition to achieve decarbonisation of the combustion engine vehicles which may still be part of the future vehicle fleet. In this case too, it is worth mentioning that the use of RF in hybrids seems to make a lot of sense, especially in hybrids which can use the OCL to achieve most of their mileage in electric mode.

Just by looking at the ability of various technologies to be combined with the others, it is clear that the strongest synergies come from OCL. It therefore represents the lowest risk investment of all the aforementioned technologies, as it can most easily adapt and support whichever other technology makes the most progress in the coming years. Furthermore, due to its high efficiency in energy, resources and time savings, it is also the best suited technology to be combined with other technology trends in the road freight sector.

National Platform Future of Mobility - Total cost of ownership graph[13]



Sources

[1] The one exception (Ambel, C.C., 2017) is actually rather positive on catenary, so it is possible the authors simply misclassified it. To quote the main study (Page 5) "Creating *the right infrastructure. Battery electric, e-highway or hydrogen HDVs all require infrastructure to operate. Based on current knowledge, battery charging in cities and e-motorway infrastructure on motorways appear to be the most promising investments. A starting point would be to finance cross-border trials of e-motorway HGVs.*" In a later update, Ambel affirmed that "*Using direct charging - either catenary or battery electric - is the most energy efficient alternative*".

[2] https://www.sciencedirect.com/science/article/pii/S2352484719301167

[3] BDI Bundesverband der Deutschen Industrie (BDI). Klimapfade für Deutschland (2018): https://bdi.eu/publikation/news/klimapfade-fuer-deutschland/ Seite 54

[4] The NPM is a broad-based body set up by the federal cabinet to advise the federal transport ministry

[5] NPM Werkstattbericht https://www.plattform-zukunft-mobilitaet.de/wp-content/uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf

[6] Flasbarth https://www.eurotransport.de/artikel/staatssekretaer-flasbarth-zur-dekarbonisierung-wir-brauchen-den-klimafreundlichen-brummi-11178017.html

[7] https://www.economist.com/briefing/2021/06/12/the-bottlenecks-which-could-constrain-emission-cuts

[8] https://www.umweltbundesamt.de/publikationen/sensitivitaeten-zur-bewertung-der-kosten

[9] SCI Verkehr GmbH https://www.masstransitmag.com/rail/press-release/12408644/sci-verkehr-gmbh-new-study-railway-electrification-continues-to-grow-global-market-development-2018

[10] https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2021/BOLD_Truck_charging_discussion%20paper.pdf

[11] BMVI / Scheuer https://www.eurotransport.de/artikel/nicht-schnell-gruen-wasserstoff-nicht-konkurrenzfaehig-scheuer-verkehr-trans-port-erneuerbare-11183330.html

[12] EU Hydrogen Strategy https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0301&from=EN

[13] Source: https://www.plattform-zukunft-mobilitaet.de/wp-content/ uploads/2020/12/NPM_AG1_Werkstattbericht_Nfz.pdf page 20

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