Policies to incentivise the uptake of zero-emission trucks

Prepared for the Ministry of Transport

12 May 2022

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Acknowledgements

We would like to thank those individuals from the following organisations who've variously provided much useful information and reviewed earlier drafts of this paper: Ministry of Transport, Waka Kotahi, EECA, Inland Revenue, Electricity Authority, The ICCT, Calstart, Hiringa, Spartan Finance, Sustainable Business Council, Zenobe, Fuso New Zealand, Motor Truck Distributors, Scania New Zealand, CharIN Asia, ChargeNet

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In a nutshell – the one-page summary

From a whole-of-New-Zealand 'public' perspective, zero emission vehicle (ZEV) trucks are starting to reach total-cost-of-ownership (TCO) parity with internal combustion engine vehicles (ICEVs) for some use requirements. As truck manufacturers increasingly role out ZEV models and battery costs continue to reduce, ZEV trucks (particularly BEVs[1]) will soon become lower TCO options for most use requirements.

However, several significant barriers means that they are likely to remain higher-TCO options from a private truck owner's perspective for many years:

- The high-capex-low-opex profile of ZEV trucks doesn't fit with the freight terms and financing arrangements which are built around the low-capex-high-opex profile of ICEV trucks.
  - This will be exacerbated for countries who don't put in place measures to overcome barriers, as manufacturers will use price to allocate scarce global ZEV truck supply to those countries who do implement such measures
- ICEV trucks don't pay the full global warming and human health costs of their exhaust emissions
- There is inadequate public recharging/refuelling infrastructure for ZEV trucks
- Electricity tariffs for recharging trucks are higher than the underlying cost of supply
- Sub-optimal approaches for recovering electricity network upgrades triggered by a consumer installing depot charging are inefficiently deterring these 'first movers'
- RUC and VDAM rules and categorisations are disadvantaging ZEV trucks in many instances

This multi-causal set of barriers to cost-effective ZEV truck update needs multiple initiatives to rectify:

- A supplier obligation in the form of a ZEV mandate that requires a minimum proportion of trucks sold to be ZEVs
- Financial purchaser incentives in the form of accelerated depreciation on ZEVs, plus a discount on the purchase price. Fairness considerations should drive decisions on whether discounts are funded via fees on ICEV trucks (a so-called feebate mechanism), or by broader levies (eg, on RUC) or from general taxation.
- Jointly funding (in conjunction with private investment) a comprehensive network of truck-scale public BEV chargers and FCEV refuelling stations. This is already underway for FCEV stations, but has yet to be initiated for BEV truck chargers. Analysis shows the costs of under-investing in public BEV charging infrastructure far outweigh the potential costs of over-investing.
- Introducing a fund to address poor electricity network upgrade cost allocation outcomes for depot charging installations. This should be an interim measure until the Electricity Authority and Commerce Commission introduce more fit-for-purpose standard arrangements.
- Removing artificial barriers from RUC and VDAM rules
- Ensuring carbon prices reach 1.5-degrees-consistent levels (something in MfE's purview)
- Moving to more cost-reflective electricity prices (the Electricity Authority's purview)
- Introducing ZEV mandates for procurement of some government truck services (eg, rubbish collection), and expanding ZEV truck demonstration projects

[1] BEV trucks are projected to be materially lower cost options than hydrogen fuel cell electric vehicle (FCEV) trucks for almost all NZ truck use cases on an ongoing basis.

Executive Summary

Zero-emission vehicle (ZEV) trucks represent a major opportunity to reduce emissions and achieve lower-cost freight outcomes

Although trucks account for only 3.5% of vehicles on New Zealand's roads, their greater weight and much longer daily travel distances means they account for 25% of road vehicle fuel consumption and carbon emissions. Given that road transport is New Zealand's biggest source of energy-related carbon emissions, decarbonisation of the trucking sector is therefore essential if we are to meet our greenhouse reduction requirements.

Having initially focussed their development resources on producing ZEVs for the Light fleet (cars, utes, vans, etc), vehicle manufacturers are now starting to produce ZEV trucks in the form of battery electric vehicles (BEVs) and hydrogen fuel cell electric vehicles (FCEVs). Although the capital cost of ZEV trucks is currently two to four times higher than their internal combustion engine vehicle (ICEV) equivalents – higher for FCEVs than BEVs, and a much higher ratio than for Light vehicles – the fact that trucks travel much further each year than Light vehicles means that the fuel savings from ZEV trucks are proportionately much greater.

As ZEV truck manufacturing starts to achieve the scale economies that Light ZEV manufacturing is starting to enjoy, and as battery costs and performance continue to rapidly improve, the capital costs of ZEV trucks are projected to follow the same trajectory of rapid cost reductions as Light ZEVs. This reduction in capital costs means that, *from a whole-of-New-Zealand perspective including the benefit of avoided emissions*, they will soon become lower-cost freight options than ICEV trucks. This point of total-cost-of-ownership (TCO) parity from a 'public' perspective is already being reached for some trucking use cases, and will rapidly encompass all use cases as ZEV truck capital costs decline – an evaluation which is consistent with analyses in other major truck markets. This transition to achieving lower TCO than ICEV trucks is happening faster for BEV trucks than FCEV trucks, with BEV trucks projected to be significantly lower TCO options than FCEV trucks on an ongoing basis for the vast majority of truck requirements in New Zealand. This cost differential is predominantly due to the costs of using green hydrogen[2] produced from renewable electricity being significantly greater than the costs of using the renewable electricity to charge BEV trucks directly.

Although there are relatively few ZEV truck models available for purchase today, within three to four years, countries that have put in place arrangements to facilitate the uptake of ZEV trucks should have a much larger, and growing, range of ZEV truck models to choose from (particularly BEV trucks), and start to enjoy the significant economic and environmental benefits they offer.

Recognising both the scale of trucking sector emissions, and the opportunities for lower-cost freight outcomes from the use of ZEV trucks, New Zealand recently joined 14 other countries in signing a Memorandum of Understanding committing to 30% ZEV uptake for heavy vehicles (trucks and buses) by 2030, and 100% by 2040. Commitments made by some leading truck manufacturers are even stronger than these adoption rates, with several global truck manufacturers proposing that over half their sales will be ZEVs by 2030.

[2] 'Green' hydrogen is produced via splitting water using electrolysis powered by renewable electricity, resulting in zero CO_2 emissions. 'Brown' hydrogen is produced by steam methane reforming of natural gas. This causes a lot of CO_2 emissions in its production, making the total fuel process more emissions-intensive than burning the natural gas directly. 'Blue' hydrogen is the same as brown hydrogen with the addition of carbon capture and storage (CCS) to capture most (but not all) of the CO_2 emissions from the production process.

Significant barriers to ZEV truck uptake are frustrating good outcomes

Although ZEV trucks are becoming lower-cost freight options from a public perspective, the presence of significant barriers and externalities means that from a *private* truck-owner's perspective the TCO and practicality of ZEV trucks is still materially worse than for ICEV trucks.

Key barriers include:

i) The high-capex-low-opex cost profile of ZEVs being inconsistent with the predominant freight contracting terms and financing arrangements which have been built around the low-capex-high-opex cost profile of ICEVs. This is further exacerbated by:

   (1) Current low global supply. If New Zealand doesn't have ZEV truck policies of equivalent strength as jurisdictions such as Europe and America, manufacturers will not allocate scarce ZEV truck supply to New Zealand, or will require higher prices to sell into the New Zealand market.

   (2) Private truck owners generally discounting future costs and benefits by significantly greater amounts than cost-benefit evaluations from a public good perspective. This works against ZEVs with their high up-front cost vs low lifetime operating cost value proposition.

   (3) Major uncertainty over the residual value of ZEV trucks that will be achieved when the first owner decides to sell them on as second-hand (typically after approximately five years).

ii) ICEV trucks not facing the full global warming and human health costs of their emissions

iii) Current lack of public recharging/refuelling infrastructure for ZEV trucks

   (1) There is almost no large-capacity charging infrastructure for BEV trucks at New Zealand's public EV stations. Even though the majority of charging for BEV trucks will be undertaken from low cost overnight 'depot charging' at business premises, public charging facilities are a crucial complementary re-charging element to enable a BEV truck to undertake a wide range of journey profiles as required.

   (2) Hydrogen refuelling stations for FCEV trucks are in early stages of installation, but with a plan for widespread deployment over the next five or so years.

iv) Non-cost-reflective electricity supply arrangements, resulting in:

   (1) BEV truck owners paying more for depot charging, and green hydrogen producers paying more to generate hydrogen from electricity, than the underlying costs of electricity supply.

   (2) Inappropriately high charges if the installation of depot chargers for BEVs, or public BEV charging/ FCEV fuelling stations happens to trigger a local network upgrade. This so-called 'first-mover disadvantage' issue is emerging as a growing problem overseas and in New Zealand as decarbonisation through electrification gathers pace.[3]

v) Weight limits and axle configuration for road-user charge (RUC) categories causing an artificial barrier to the uptake of ZEVs which currently[4] weigh more than ICEVs due to their batteries/fuel

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[3] First-mover disadvantage (FMD) refers to a situation where a consumer whose demand increase happens to trigger a network upgrade is charged for a significant proportion of this upgrade, even though it will provide extra capacity for many additional subsequent consumers. FMD can inefficiently cause the initial consumer not to proceed with their demand increase.

[4] Continuing rapid improvements in battery technology, particularly energy densities, means this weight barrier is projected to disappear within 10 to 15 years.

cell drive train.[5] Together with New Zealand's Vehicle Dimension and Mass (VDAM) Rules, these constrain the use of globally standard truck configurations.

A suite of eight key policy measures is urgently required to deliver good truck sector outcomes

Due to the multi-faceted nature of the barriers facing ZEV truck uptake, a range of different policy measures are required: If one barrier isn't adequately addressed, other policies to address other barriers will be much less effective.

Eight key policy mechanisms are required:

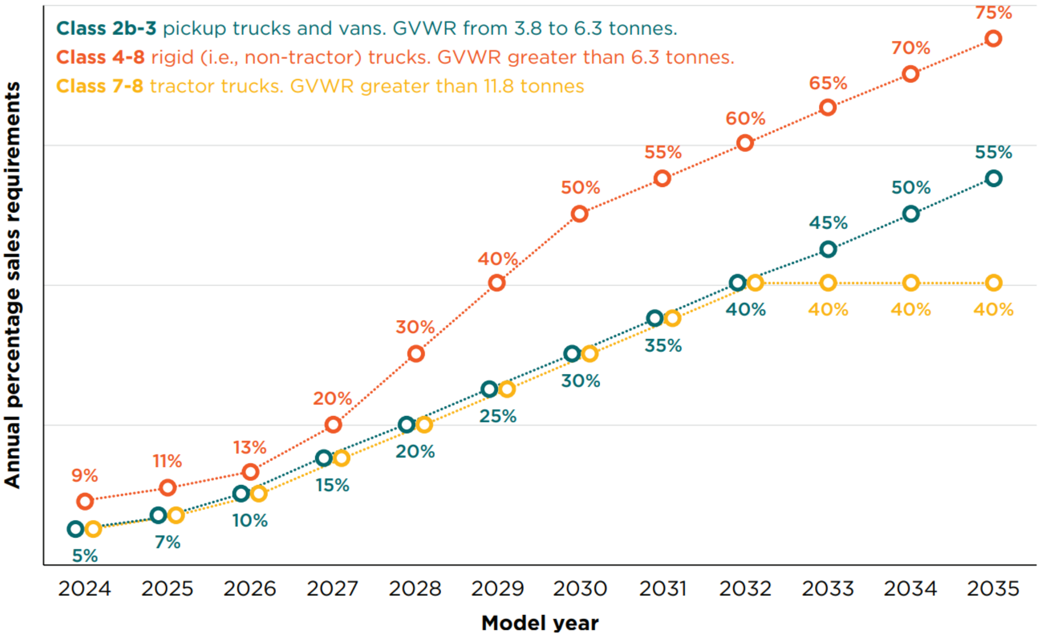
- Five are truck-sector specific, and fall within the purview of the Ministry of Transport
- Three are economy-wide policy measures that will not just affect ICEV vs ZEV uptake decisions, but also fossil-vs-renewable technology choices across the wider economy. These policies fall within the purview of other government agencies.

The five key truck-sector specific policy measures are:

1) Introducing a ZEV mandate on truck suppliers

As they have already done for light vehicles, the majority of international markets in Europe, America, and Asia have introduced obligations on truck suppliers as a key plank in their ZEV truck uptake toolset. Such supplier obligations involve a (progressively strengthening) target for uptake of zero- or low-emission vehicles, backed with penalties if a target is not met. The target is either direct (requiring a growing proportion of ZEVs each year, as is the case in California) or indirect (requiring the reduction of average CO_2 emissions across the new fleet, with ZEVs one way for a supplier to achieve them).

Figure 1: Example of a ZEV Truck Mandate enacted in California:



[5] The effect of this barrier is somewhat muted today because ZEV trucks are currently exempt from RUC charges, but will start to face them from 2025. As 2025 gets closer, the effect of this barrier grows stronger.

A supplier obligation of some form is considered essential for New Zealand as:

- the effect of other countries' supplier obligations means that New Zealand will face higher truck prices without its own obligation of similar strength[6];
- supplier obligations help eliminate the potential for any financial incentives for truck purchasers being 'captured' by truck suppliers by artificially raising their ex-subsidy price; and
- manufacturers will give priority to New Zealand when determining where to allocate the finite volumes of ZEV trucks over the next decade.

The type of obligation which is most appropriate for New Zealand's truck market is a direct ZEV mandate: expressing the target in the form of a minimum percentage of truck sales that must be ZEVs. An indirect obligation – a fleet CO_2 emissions standard – is not appropriate for New Zealand's truck sector given that the lack of necessary testing data means it would take a long time, and cost a lot, to develop.[7] Other measures will be needed to help reduce CO_2 emissions from those diesel trucks which continue to be purchased. (Also noting that a fleet CO_2 standard wouldn't incentivise most of the measures to reduce truck diesel emissions). Resurrecting the Waka Kotahi / EECA heavy vehicle fuel efficiency initiative would be a valuable means of achieving this.

This situation of a ZEV mandate being most appropriate contrasts with the Light vehicle sector where, because of a combination of factors – sufficient New Zealand-specific vehicle data is available[8], there are more Light vehicle imports each year (approximately 300,000 compared to 8,000 for the heavy fleet), and light vehicle loads and uses are reasonably homogenous – it was cost-effective to develop a Light fleet CO_2 emissions standard as the Clean Car Standard[9].

Further, unlike for the light fleet where low-emission vehicles in the form of plug-in-hybrid and hybrid vehicles are commonly available and affordable options to help lower fleet emissions in the short term, these technologies are not widely available for the truck fleet. Hybrid trucks can offer helpful fuel economy savings, especially in urban stop-start traffic, however only zero emission vehicles provide decarbonisation with the necessary pace to achieve our climate goals – particularly as truck manufacturers appear to be focussing on ZEVs rather than hybrids.

2) Financial incentives for truck purchasers

Solely relying on supplier obligations without addressing the barriers to ZEV truck uptake will make New Zealand a risky place for truck suppliers to operate. Given our small size, this could result in many of them exiting the New Zealand market. Supplier obligations and financial incentives for purchasers work in unison, in that obligations send very clear market direction signals and discourage price inflation, while targeted and timebound purchaser incentives enable the earlier introduction of obligations by accelerating cost parity for truck purchasers between a ZEV truck and its diesel counterpart.[10]

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[6] This dynamic arises because of the current scarce global supply of ZEV trucks relative to global demand. In order to allocate scarce ZEV truck supply to markets without supplier obligations, truck suppliers will increase the price for sales in such non-obligation markets in order to achieve a similar margin as selling ZEV trucks into markets with supplier obligations.

[7] This difficulty is compounded by the need for a sophisticated multitude of targets to appropriately accommodate the diversity of truck sizes, weights, and uses. There is also significant variation around load weight on fuel economy, and difficulty in measuring this.

[8] Light vehicle importers have been required to provide vehicle fuel consumption information since 2008.

[9] Enacted through the Land Transport (Clean Vehicles) Amendment Act 2022, refer www.legislation.govt.nz

[10] Purchaser incentives help align the TCO for truck purchasers with the public TCO of New Zealand – noting that the presence of emissions externalities, non-cost-reflective electricity pricing, freight terms being set up for the low-capex-high-opex profile of diesel trucks, and higher private sector discount rates, means that ZEV trucks which are lower TCO from a public perspective are higher from a private truck owner's perspective.

Although the economy-wide measures around 1.5-degrees-consistent-emissions pricing and improved electricity supply arrangements (measures (6) to (8) below) should eventually deliver the most significant TCO incentive to ZEV truck purchasers, they may take a long time to achieve full cost-reflectivity. Further, even if such cost-reflectivity were to happen overnight, and even with widespread use of leasing, the barriers relating to ZEVs high-capex-low-opex cost structure in a freight sector geared around low-capex-high-opex trucks, coupled with the significant uncertainty over ZEV trucks' residual value, mean that rates of ZEV uptake would still be significantly below least-cost-optimal levels for many years. Accordingly, additional financial incentives for purchasers will be required.

For a given level of public funding, much higher rates of ZEV uptake are achieved from giving support via a mechanism which affects the relative up-front purchase price of ZEVs and ICEVs, rather than one which affects the lifetime operating cost of ZEVs and ICEVs (eg, RUC discounts on ZEVs). Two types of purchase-price support mechanisms are recommended.

a. Allowing accelerated depreciation for ZEV trucks

Allowing accelerated depreciation for ZEV trucks will significantly help a truck operator in a market where freight terms are based around ICEV cost structures. However, this is a relatively low-cost option from a public finance perspective – being 'just' the interest cost the government incurs in funding postponed tax receipts from truck operators.

Faster depreciation rates for ZEV trucks may emerge from Inland Revenue's regular operational reviews of depreciation rates for different assets, with the fact that ZEV trucks are rapidly evolving and have uncertain residual values likely pointing to faster depreciation rates being justified. However, if such an operational review doesn't result in ZEV trucks having materially lower depreciation rates justified for 'accounting' reasons, accelerated depreciation for ZEV trucks could be justified on broader climate (and human health) policy grounds. This could require primary legislation (amending the Income Tax act) to put into effect.

Given the significant potential benefits from ZEV trucks having accelerated depreciation, it is recommended that MoT work with IRD to determine whether, and how best, to implement such a mechanism.

b. Introducing a subsidy scheme for ZEV truck purchases

Accelerated depreciation is unlikely to be sufficient to deliver the required rates of ZEV truck uptake. An additional financial incentive on ZEV truck purchasers in the form of a discount on the purchase price is likely to be required. Such mechanisms have successfully been introduced in places such as California and many European countries.

Because the purchase prices of ZEVs are forecast to reduce as the technology matures, the level of discount required can therefore reduce – and be phased out completely when ZEVs reach purchase price parity with ICEVs.

As well as determining the appropriate level for such a subsidy, one of the key design choices is the source of funding:

- General taxation;
- Operational levies on vehicles generally (eg, an addition to petrol excise duty, or road user charges); or
- Fees on the sale of ICEVs, as part of so-called 'feebate' mechanisms.

The source of funding which is likely to deliver the least economically distortive outcomes is from levying fees on sales of ICEV trucks. This 'feebate' approach is the structure used for the Clean Car Discount scheme for Light vehicles.[11]

If there are sufficient ZEV truck models available to meet truck purchaser's requirements, a feebate approach is also arguably fairer than raising funds from taxpayers generally or all road users generally. However, if some truck users don't have adequate ZEV models available to meet their requirements when they need to purchase a truck, this mechanism is arguably unfair. Any mechanism which is widely perceived to be unfair is likely to engender significant opposition, jeopardising its introduction and durability. Given that there are more truck use requirements than there are Light vehicle requirements, and given truck manufacturers are at an earlier stage of transition to ZEV models than Light vehicle manufacturers, it is likely that there could be material numbers of truck use cases for which a ZEV model is not available for the next five or so years. Further, there is greater opportunity for truck operators to pass-on some proportion of the higher costs faced by ICEV trucks to end consumers, resulting in similar long-term distributional impacts as funding via general taxation.

Because of this dynamic, there may be merit in ZEV truck subsidies being funded by a broader levy base than would be achieved via a feebate. Because the number of ZEV trucks entering New Zealand is much smaller than Light vehicles, the capital spent on truck purchases each year is less than 10% of that spent on Light vehicles. Accordingly, such a broader levy would have a much smaller impact on general taxation or RUC rates than if this funding approach were used for Light vehicles.

3) Rapid investment in public BEV truck charging stations

Lack of public ZEV charging/fuelling stations is a major impediment to ZEV uptake. Due to the 'chicken-and-egg' barrier[12] facing ZEV station development, this requires public funding and coordination – at least until the initial phase of achieving sufficient geographic coverage has been achieved. BEV and FCEVs each need to be separately supported, because they rely on different energy carriers: electricity and hydrogen.

- BEVs can predominantly charge cheaply overnight at depots, given electricity is ubiquitous, and trucks typically park at depots idle for many hours overnight. However, as with the Light fleet which predominantly charges overnight at homes, there is still an important role for public fast charging infrastructure for BEV trucks:
  i. It builds confidence for both vehicle distributors and buyers, and helps fleets to trial electric trucks ahead of installing depot charging, which will accelerate adoption;
  ii. It provides a backup for fleets if they run low on electricity when away from base (eg, if undertaking a longer-than-usual journey), which will ensure productivity
  iii. It enables BEV trucks to make longer distance trips, expanding the scenarios where BEV trucks can replace diesel.

  Some BEV trucks can both recharge, as well as support battery swapping. This is currently being trialled with support from EECA. However, battery pack design for swapping and swapping infrastructure is proprietary to each truck manufacturer. Depending on market demand, it is possible that public EV charging facilities could also offer private battery swap facilities for certain truck marques in the future. However, having multiple brands of battery swap facilities (Battery-as-a-Service) would become very expensive as so much capital would be involved having additional battery packs of different designs available at different locations should a swap

[11] Refer www.nzta.govt.nz/cleancar

[12] Potential private investors in ZEV stations are unwilling to invest until sufficient ZEV vehicles are on the roads, but potential ZEV owners are unwilling to purchase ZEVs until there are sufficient ZEV stations available.

be needed. The standardisation of heavy vehicle battery pack designs is not under consideration.

- FCEVs cannot refuel without dedicated hydrogen infrastructure, so are totally reliant on their installation.

The current state of public recharging/refuelling for ZEV trucks is different between FCEVs and BEVs:

- In response to a private sector initiative, the Government is contributing a $11M loan and $5M grant towards four FCEV re-fuelling stations from 2022, with a further 20 geographically spread locations across New Zealand by 2026 planned by the private sector. Refer www.hiringa.co.nz
- No funding has yet been requested for an equivalent private sector-initiated plan for BEV truck recharging stations. Consequently, no material public BEV truck charging facilities exist.[13]

The following immediate actions are recommended to address this situation:

1. Government invites private sector to install public BEV fast charging for trucks, and indicates co-funding available.
2. Government updates EECA funding rules and Waka Kotahi guidelines that new public Light BEV fast charging stations can *also* be used by small-to-medium sized trucks (and cars with trailers), by providing sufficient physical space for at least one medium truck per station.
3. Update Waka Kotahi guidelines to support the BEV megawatt-charging-standard once available in the international market.
4. By middle of the decade, government and private sector have installed a minimum nationwide network infrastructure for ZEV trucks, based on current and future need. (Currently underway for hydrogen stations however not started yet for electric charging stations)

Investing in a BEV truck charging network of equivalent geographic coverage to the FCEV stations is a technology neutral policy that will enable New Zealand to take advantage of whichever truck technology (BEV or FCEV) is cheapest.

The net-benefit of a rapid public BEV truck station roll-out is projected to be large because:

- There is already pent-up demand for BEV truck stations, and there is a large asymmetry between investing in ZEV stations too early versus too late.
- The majority of capital invested in BEV truck stations can be re-deployed for Light BEV charging if required – ie, there is very little risk of wasted capital in BEV truck stations.
- Only a small number of BEV stations are needed to support large numbers of BEV trucks, because public stations are complemented by significant numbers of private chargers installed at depots. This keeps public investment cost low on a per-vehicle basis.
- The economics of BEVs for the majority of truck use cases appear materially superior to FCEVs – a fact reflected in the significantly greater global variety of BEV models and associated sales across all truck classes compared to FCEVs. (Refer sections 6 and 7 of main report).
- As hydrogen stations are likely to have strong electricity connections to perform on-site electrolysis, they can also provide BEV charging. On-site battery storage or hydrogen as a buffer can be used where this is cheaper than high-capacity grid connections.

[13] Although some of the 300 kW charging points being rolled-out for the Light fleet have the electrical capacity to charge medium trucks (roughly <20 t vehicles), the vast majority do not have the physical space to accommodate such trucks. No MW-scale charging facilities exist to enable charging of the heaviest truck categories (approx. > 20t).

4) Developing a scheme to provide public funding to cover some local electricity network upgrade costs triggered by installation of BEV chargers or FCEV electrolyser stations

The first-best option to address this issue would be to reform the approach electricity networks take to recovering network upgrade costs. (Option (8) in the economy-wide policy measures below). As this may take years to put into effect, an interim policy measure to guarantee public funding to cover some proportion of the costs of any network upgrade cost allocation (subject to suitable public-benefit tests) should help significantly overcome this barrier. This could also cover installation costs of depot charging. Eligibility should be offered as a grant that is more accessible than currently provided by EECA's low-emissions transport fund (LETF), which is currently contestable.

5) Removing the artificial barrier to ZEV uptake from the current RUC and VDAM specifications

The first-best solution would be to reform RUCs and VDAM in a way which didn't have such 'band boundary' issues and encourage non-standard vehicle configurations, and instead more appropriately reflected factors such as the extent to which truck weight drives roading costs.

Until such reform is implemented, New Zealand should follow jurisdictions such as Europe and California in introducing temporary exemptions which allow heavy-duty ZEVs to exceed class weight limits by certain amounts.

The three key economy-wide policy measures are:

6) Ensuring carbon prices charged on fossil fuels reach '1.5-degrees-consistent' levels

Although carbon prices in the New Zealand Emissions Trading Scheme (NZ ETS) have recently risen significantly ($75/$_{tCO2}$ at time of writing), they are substantially below the $250/t$CO_2$ (in $2020) that the Climate Change Commission indicated would be necessary by 2050 to achieve our net-zero emissions target. Further, given that most countries' estimates of the carbon price required to limit global warming to no more than 1.5˚C are substantially higher than $250/t$CO_2$, this New Zealand net-zero-by-50 target is likely to be inconsistent with the level of action (and the prices required) to meet our Paris commitment to take action to limit global warming to 1.5˚C.

The design of the NZ ETS falls under the purview of the Ministry for the Environment which is currently undertaking a major review of key elements – in particular the inclusion of Forestry in the ETS – to ensure that prices are at levels which deliver required outcomes for New Zealand.

7) Reforming electricity tariffs to make them cost-reflective

Recovering a greater proportion of the costs of supply through fixed charges or similar, and ensuring variable tariffs differentiate between peak and off-peak periods, should result in BEVs paying much lower (and more cost-reflective) prices for charging their vehicles, particularly overnight.

The Electricity Authority is currently engaged in working to reform electricity network prices, with such reformed network prices likely to flow through to more cost-reflective retail prices.

8) Reforming the approach for the cost-recovery of local network upgrade triggered by individual consumer investments

The Electricity Authority and Commerce Commission can help standardise networks' approaches for recovering the costs of local network upgrades triggered by individual connected-parties' investments. Approaches which recognise the once-in-a-generation change occurring from electrification of fossil activities across the whole economy should help eliminate the 'first mover disadvantage' dynamic which is frustrating electrification initiatives in many sectors.

A range of supplementary policy measures could further improve rates of ZEV uptake

Supplementary measures which could improve the effectiveness of the key policy measures include:

- Priority or exclusive ZEV road access arrangements. For example, introducing zero-emission zones in certain urban areas or differentiated toll road rates. Local government can already impose outright restriction zones but differentiated entry costs would rely on developing new legislation.
- Improving the emissions regulations on non-CO_2 exhaust emissions by adopting Euro VI now and the stricter upcoming Euro VII harmful emissions standard in the second half of this decade.
- Expanding the funding of ZEV truck demonstration projects to improve sector knowledge about the opportunities (and issues) associated with ZEVs
- Introducing ZEV requirements for government procurements of some trucking services (eg, for waste management services, or other freight services). This approach appears to already be working well to stimulate the uptake of zero emission public transport buses, prompted by a government policy mandating all new public transport buses be ZEVs from 2025.

1 Introduction

Road transport is New Zealand's largest, and fastest growing, energy-related greenhouse gas emitting sector. Trucks[14] are the fastest growing source of these road transport emissions, rising from 11% of road transport emissions in 1990 to 25% in 2019. Under current policies, emissions from the trucking sector are projected to continue rising for many years.

Decarbonisation of the trucking sector is therefore going to be a critical component of New Zealand's measures to meet its greenhouse gas reduction commitments.

Recognising this, New Zealand recently joined 14 other countries in signing an international truck and bus decarbonisation commitment. This commitment – in the form of a Memorandum of Understanding on Zero-Emission Medium- and Heavy-Duty Vehicles[15] - commits New Zealand and the 14 other signatory countries to achieve 30% ZEV new truck and bus sales by 2030 and 100% by 2040.

This paper considers what policy measures are likely to be best at delivering a level of ZEV truck uptake that meets New Zealand's needs:

- Section 2 outlines the current barriers facing ZEV uptake
- Section 3 analyses the issues and options for the various policy measures that could overcome such barriers
- Section 4 pulls together a summary set of recommended policies

The analysis on the barriers to ZEV uptake and measures to overcome such barriers has been developed within the context of the New Zealand trucking sector, and the current and expected future state of global ZEV truck development. Detailed analysis on these issues is set out in a set of appendicised sections:

- Section 5 sets out analysis on the New Zealand trucking sector. The key take-aways are:
  - Although trucks are small in number (accounting for approximately 3.5% of vehicles on the road), they travel further each year than Light vehicles and are significantly heavier, meaning they account for 25% of road fleet fuel consumption and carbon emissions
  - This dynamic is also reflected *within* the trucking sector. Our analysis of MoT data shows that the heaviest category of trucks (>20 tonnes) only account for approximately 31% of all truck numbers but, due to travelling the furthest distance and weighing more, account for approximately 80% of trucking fuel consumption and carbon emissions
  - Most New Zealand truck trips are for relatively short distances:
    - Data for recent years shows that more than 60% of all trips were under 100 km, and nearly 85% were under 200 km. Only 3.1% of truck trips were over 400 km and 1.4% over 500 km.
    - New Zealand's geography means that truck trip distances are considerably shorter than most overseas continental countries. For example, on a tonne.km basis, 38% of European truck trips were over 400 km, whereas only 4.5% of New Zealand truck trips were over 400 km.
  - The implication of this is that, for the majority of applications, depot charging will provide the basis for almost all energy needs. This is because BEV trucks capable of 200km already exist,

[14] 'Trucks' are defined in this report as road vehicles over >3.5 tonnes, other than buses. Road vehicles <3.5 tonnes are defined as the 'Light fleet'.
[15] https://globaldrivetozero.org/mou-nations/

and are expected to achieve 400km by the middle of the decade. Strategically placed public charging stations can provide backup and range extension without productivity loss.

  - This also has an implication that hydrogen may only play a minor role in the New Zealand context. This is because hydrogen trucks cost significantly more to purchase and to operate, and because New Zealand does not have the continental-scale long routes that can favour hydrogen trucks in international markets.

- Section 6 sets out the current and projected future state of ZEV truck economics based on analysis of international ZEV truck developments and the specific New Zealand context. The key take-aways are:
  - As international OEMs start to produce ZEV trucks in scale, and as battery prices and performance continue to significantly improve, ZEV trucks will overtake ICEV trucks as lower total-cost-of-ownership (TCO) vehicles for most use requirements from a whole-of-New-Zealand 'public' perspective, likely this decade.
  - However, from a private truck owner perspective, the presence of externalities and other barriers (detailed in section 2) means that ZEV trucks are still many years away from being cost-effective
  - Both battery electric vehicle (BEV) and hydrogen fuel-cell electric vehicles (FCEVs) are projected to become lower TCO options than ICEVs. However, more rapid development of BEV trucks by global manufacturers indicates that BEVs will overtake ICEVs several years earlier than FCEVs from a cost-effectiveness basis, with it also being likely that BEVs will remain lower cost options than FCEVs for the vast majority of New Zealand's trucking requirements.
- Section 7 presents a brief review of overseas countries' and truck manufacturers' ZEV developments. The key take-aways are:
  - An increasing number of countries, including those covering the world's largest truck markets, are putting in place a range of policy measures to overcome the barriers facing ZEV truck uptake.
  - Global truck manufacturers are increasingly committing to ZEV trucks:
    - Almost all traditional ICEV truck manufacturers have committed to significant future ZEV sales, often outstripping countries' policy commitments. For example, the average of European truck manufacturers 2030 ZEV sales commitments is 43% - higher than the current 30% stated ambition of EU countries.
    - Several traditional ICEV truck manufacturers have committed to not producing any new ICEV models within a few years. For example, Scania has committed to no new ICEV models being produced after 2025.

Lastly, it should be noted that the scope of this paper is only to consider measures to improve ZEV uptake for trucks. Its purpose is not to consider:

- the extent of, and possible means to achieve, additional decarbonisation that could be achieved from mode-shifting (eg, from road freight to rail or coastal shipping), vehicle operational efficiency measures (at a vehicle or fleet management level), or the use of biofuels – although section 8 in the appendices details how decarbonisation through biofuels inter-relates with decarbonisation through ZEV uptake.
- measures to incentivise ZEV uptake for the Light fleet or buses, as these vehicle types already have a more comprehensive policy framework already in place.

This report has been developed through a mix of original analysis by the authors, discussions with and/or early-draft reviews by individuals in a range of organisations[16], plus extensive literature review drawing on the documents detailed in Section 9 in the appendices.

Box 1: A note on acronyms

ICEV = Internal combustion engine (ICE) vehicle powered by a liquid fuel. (Petrol, diesel, or a biofuel/e-fuel).

ZEV = Zero-emission vehicle, not powered by an ICE.

EV = Electric vehicle, where the motive power comes from an electric motor. BEVs, PHEVs, and FCEVs are all EVs.

BEV = Battery electric vehicle. A fully-electric vehicle relying on an externally-charged battery as the primary source of energy.

PHEV = Plug-in hybrid electric vehicle. An EV which also has an ICE to provide ancillary power to extend the range of the vehicle if required.

FCEV = hydrogen fuel cell electric vehicle. A vehicle relying on hydrogen stored on-board which is converted to electricity in a fuel cell to charge a battery which then drives an electric motor.

OEM = Original Equipment Manufacturer. Companies such as Volvo, Scania, Ford, Tesla, etc, who manufacture vehicles.

[16] Ministry of Transport, Waka Kotahi, EECA, Inland Revenue, Electricity Authority, The ICCT, Calstart, Hiringa, Spartan Finance, Sustainable Business Council, Zenobe, Fuso New Zealand, Motor Truck Distributors, Scania New Zealand, CharIN Asia, ChargeNet

2 What barriers affect the uptake of ZEV trucks?

Barriers affecting the uptake of ZEV trucks can be grouped into five main areas:

1) ***Infant technology barriers***, including:
   a) ZEVs having a high-capex-low-opex cost profile in a freight industry whose terms of trade and financing arrangements are currently based on ICEV trucks which have a low-capex-high-opex cost profile
   b) Current limited model choice and price premium in early stages of technology uptake. New Zealand's small size and right-hand drive (RHD) configuration, exacerbates this barrier as suppliers will tend to focus initially on the bigger markets.
   c) Lack of sector knowledge about ZEVs, and uncertainty about their residual value for resale
2) ***Emissions externalities*** – particularly, ICEV owners not facing the full global warming and human health costs of their tailpipe emissions
3) ***Lack of ZEV public charging/fuelling stations***
4) ***Non-cost-reflective electricity supply arrangements***, including
   a) Tariff structures not reflecting the underlying costs of supply at different times
   b) Inappropriate network cost-recovery arrangements if installation of chargers at truck owners' premises trigger electricity network upgrades.
5) ***Legacy regulatory barriers***, where rules and regulations that were appropriate for the status quo technology are inadvertently inappropriate for the new technology.

Each of these barriers is briefly detailed in this section.

2.1 Infant technology barriers

There can be specific barriers facing new technologies in the initial stages of their introduction due to lack of sector knowledge about the new technology, and institutional arrangements which have been designed around the legacy technology but are inappropriate for the new technology.

Currently ZEV trucks face the same general issues common to most new technologies associated with relatively limited model choice and relatively high purchase costs in the early years of a technology's development. The small size, and right-hand-drive nature of New Zealand's market can exacerbate such issues. These barriers will naturally diminish as the technology develops, but, in conjunction with the 'status quo bias' consumer behavioural barrier detailed in section 2.1.1 below, they can result in rates of technology uptake which are lower than would be cost-effective from a national perspective.

A key specific issue for ZEV trucks is due to their having a high-capex-low-opex cost profile in a freight industry whose terms of trade and financing arrangements are based on ICEV trucks which have a low-capex-high-opex cost profile:

- Even though a ZEV truck may be lower cost on a lifetime TCO basis, the high-capex-low-opex value proposition of ZEVs presents a challenging cash-flow dynamic for truck operators in the first few years of a truck's operation where freight rates and contract terms are based on a model which assumes the low-capex-high-opex cost structure of diesel trucks. This may be particularly challenging for SMEs (single truck owner-operators or those with a small number of trucks) if their small size hinders their access to capital relative to large truck operators.

- The newness of the technology is giving rise to significant uncertainty in truck owners' (and truck financiers') minds over ZEV trucks' residual value at time of resale. This is causing them to discount residual value, further exacerbating the high-capex-low-opex issue for ZEVs.
- Truck purchasers are likely to discount the future value of fuel and CO_2 cost savings from choosing a ZEV by a greater amount than the value government would ascribe when it considers the cost-benefit from a whole-of-NZ perspective. This is because
  - truck owners use higher effective discount rates for considering future costs and benefits than government does for considering national costs and benefits. The 'short-termism' consumer behavioural barrier detailed in section 2.1.1 below can exacerbate this factor.
  - future CO_2 and electricity prices are relatively uncertain, causing truck operators to discount future savings which rely on such prices more heavily than if there was absolute certainty as to their future values.

There is also little or no knowledge within the trucking industry about how best to operate BEV trucks in terms of managing routes in conjunction with the currently more-limited range of BEV trucks to ensure the balance between depot and public charging is optimised. There can also be significant (and often misplaced) 'range anxiety' over whether BEV trucks will have adequate ranges to meet requirements.

Similarly, there is limited knowledge around BEV and FCEV truck maintenance requirements, cost of replacement parts (including mid-life replacement of batteries)[17], nor good appreciation of the scale of maintenance cost savings that in particular, BEVs, being mechanically simpler, offer.

Lastly, there can be incentives on the status quo industry to oppose the new industry. In the case of trucks, given that the maintenance cost of BEV trucks is 70-75% of ICEV trucks, the parts and servicing industry stands to ultimately lose 25% to 30% of its business (and associated workforce) due to the much greater reliability and significantly reduced maintenance requirements of BEV trucks compared to diesel trucks.[18] It is therefore perhaps no surprise that, internationally, many of the objections (and, at times, misinformation) around ZEV truck uptake and policies to support such uptake have come from the legacy diesel truck supply sector.

2.1.1 Consumer behavioural barriers exacerbate infant technology barriers

For most of the 20th century, 'classical' economics was based on models which assumed that decision-makers responded entirely rationally to price signals when making decisions about what goods and services to purchase.

However, a growing body of evidence that consumers often make decisions with higher-cost outcomes resulted in the discipline of 'behavioural' economics emerging. This branch of economics has demonstrated that cognitive biases can result in individuals making poor choices.

[17] Although mid-life replacement of batteries is a material issue for BEVs, FCEVs also contain large rechargeable batteries (approximately one-fifth or one-quarter of the size of a BEV). In addition, the fuel-cell that converts hydrogen gas into electricity also has a finite duty cycle and itself represents a costly replacement. As such, both BEVs and PHEVs face an unclear long term ownership cost profile until such time as technology and ownership experience matures. While diesel trucks also undergo expensive engine rebuilds on a periodic basis, the cost and timeframe for that is predictable.

[18] The maintenance savings from FCEV trucks are less as they are more complex than BEV trucks (noting that FCEVs are essentially BEVs with smaller batteries plus the hydrogen fuel tank and fuel cell).

In relation to ZEV-uptake, two key cognitive biases are relevant:

- 'Short-termism' or 'time-inconsistency', whereby individuals place undue weight on short-term costs and benefits relative to longer-term costs and benefits. This acts against ZEVs whose value proposition is higher up-front capital costs in return for lower long-term operating costs.
- 'Status quo bias', whereby individuals faced with needing to choose between an unfamiliar 'new' option or a familiar 'old' option, will tend to revert to the old option. This is particularly where evaluating the options requires relatively complex calculations or needing to make predictions about future changes in the relative costs of the new and old options. This exactly reflects the evaluation between a ZEV and an ICEV where purchasers need to consider potential future electricity or hydrogen prices, future oil and carbon prices, future maintenance costs, and future resale values for the ZEV and ICEV vehicles.

The extent of these cognitive biases in relation to ZEV purchase decisions will likely vary between decision-makers. For individuals or businesses who have expertise in financial modelling the effect of these biases is likely to be smaller than in situations where such individuals or businesses do not have any expertise in financial analysis.

2.2 Emissions externalities

Externalities arise when the parties undertaking an action do not face the full costs of their actions. The principal area where this occurs in relation to trucks are ICEV owners not facing the global warming and human health costs of their tailpipe emissions.

2.2.1 Global warming

CO_2 emissions from ICEVs are the largest single source of New Zealand's energy-related greenhouse emissions. At the time of writing this paper, the New Zealand emissions trading scheme is resulting in carbon prices of approximately \$75/tCO_2. This adds approximately 23 cents (incl. GST) to a litre of diesel, representing approximately 10% of diesel prices at the time of writing this paper (approximately \$2.35/litre retail).

The Climate Change Commission's (CCC) modelling indicates that actions consistent with a marginal abatement cost of \$258/tCO_2 (in \$2021) will be needed by 2050 for New Zealand to bring its emissions of long-lived gases (ie, all greenhouse gases other than biogenic methane) to net-zero levels by that time. \$258/tCO_2 is almost 3.5 times the current price of carbon in the ETS.

The Treasury has recommended that this CCC trajectory of emissions values to 2050 be used as a central 'shadow price' to evaluate the costs and benefits of policies which alter greenhouse emissions.[19]

However, even this 'NZ-net-zero-by-50' trajectory of emissions reduction could be inconsistent with the level of action required to limit warming to 1.5˚C, and '1.5-degrees-consistent' action could require significantly greater and faster emissions reductions. As a point of comparison, a recent review of shadow carbon price projections produced by other international governments and agencies showed that the median 2050 price of projections consistent with 1.5-degrees-consistent action was approximately NZ\$500/tCO_2. If carbon prices were at this level today, diesel prices would rise to \$3.65/litre (incl. GST).

[19] See Appendix 5 in https://www.treasury.govt.nz/sites/default/files/2021-09/cbax-guide-sep21.pdf

2.2.2 Human health

The 2012 '*Updated Health & Air Pollution in New Zealand study*' commissioned by the Ministry of Transport indicated that New Zealand incurs over $1bn a year in respiratory health costs associated with road transport.

An update to this study is due in 2022 and is expected to show even greater health costs are resulting from transport pollution in New Zealand.[20] The authors of the health study (Emissions Impossible) state that as most of the transport pollution costs come from nitrous oxides (NOx) from diesel combustion, most of this health harm will be removed by the shift to BEVs or FCEVs. The positive effects of regenerative braking have not been quantified but are expected to reduce particulates associated from brake pad wear, which again reduces health costs.

That said, a significant proportion of health costs are from particulates associated with worn tyres and road dust, meaning they will continue to cause respiratory health costs, even with ZEVs.

Overall, the authors of the health study estimate a ZEV truck is likely to produce about two-thirds less social costs than a diesel truck meeting Euro VI emissions standards, and only a few percent of the costs of an average Euro V or earlier truck currently on our roads.

It is worth noting there is a strong geographic element to these respiratory health costs in that they occur almost entirely due to travel along urban roads adjacent to where people live and work. Open road travel causes little respiratory health impacts.

It is also worth noting that ICEVs have an impact on truck drivers' health through stress from ICEV engine noise and vibration – something that doesn't happen with ZEVs.

2.3 Lack of ZEV charging/fuelling infrastructure

The development of public charging and fuelling stations for ZEVs faces the classic 'chicken and egg' barrier facing new technologies:

- Potential private investors in public ZEV charging and fuelling stations will be unwilling to make such investments unless they have reasonable confidence there will be sufficient demand for them.
- However, potential purchasers of ZEVs will be unwilling to make such purchases unless there are already sufficient public charging and fuelling stations in place to meet their needs. This has been demonstrated with numerous studies showing that 'range anxiety' (ie, the fear of running out of electricity or hydrogen before reaching a charging or fuelling station, given the currently lower ranges of ZEVs compared to ICEVs) is a significant deterrent to potential purchasers of ZEVs, and that investment in public charging/fuelling stations is a pre-requisite for ZEV uptake.
  - In the case of BEV trucks, even though most will charge at their base, typically overnight, and have a battery size which allows a full day's duty on a single charge, public charging infrastructure provides confidence that a truck can still operate if additional duties or exceptional trips are required, or for trucks that have variable schedules, or if it is not charged due to error. Lack of public charging infrastructure risks loss of income to the truck operator. In addition, some inter-regional trucks will need to be charged during the day's operation, and in some cases to allow longer journeys to be undertaken. This is likely to be needed where the driver takes their mandatory rest break.
  - In the case of FCEV trucks, this public infrastructure barrier is even stronger, as these are almost totally dependent on the development of public hydrogen fuelling stations as it is

[20] When published, the HAPINZ 3 report will be available from www.transport.govt.nz/vehicle-emissions/

much less likely that hydrogen fuelling facilities will be developed at private business premises.

The current state of public ZEV truck infrastructure development is quite different between hydrogen fuelling for FCEVs and BEV charging stations in New Zealand:

- For FCEVs, a private sector initiated initiative has resulted in $16m of public money being allocated to start the development of a hydrogen re-fuelling network, and a relatively detailed development plan has been developed.[21] When completed, this network will address re-fuelling coverage as a barrier to FCEV truck uptake.
- No funding has yet been requested for an equivalent private sector-initiated plan for BEV truck recharging stations. Consequently, no material public BEV truck charging facilities exist.[22] Without additional policy measures such as a ZEV mandate (see section 3.1 later) to help de-risk investment, there seems to be little prospect of a privately funded MW-scale charging network. Even with such a mandate it is likely that some public funding will be required – particularly given the asymmetry between under- and over-investment in public charging networks (as detailed further on page 45, later).

This current New Zealand state contrasts with major markets such as Europe, which is planning for public truck BEV charging infrastructure to be at least as developed as for hydrogen re-fuelling stations by the middle of the decade.[23] As Europe's ZEV truck charging and refuelling infrastructure is rolled out it will make Europe a relatively more attractive place for ZEV trucks, increasing ZEV truck demand. Given tight global supply relative to demand, this will tend to increase the price at which truck manufacturers will supply trucks to non-European locations.

The current relative situation between New Zealand's FCEV refuelling and BEV charging infrastructure for trucks also contrasts with the analysis set out in the appendicised sections 6.3 and 7.2 which shows that:

- BEVs are emerging as significantly more cost effective than FCEVs for the vast majority of global trucking use cases – and an even greater proportion of New Zealand use cases
- global truck manufacturers are producing a greater variety of, and selling significantly more, BEV models than FCEV models, with some major truck manufacturers deciding to only head down the BEV route.

It is understood that this current disparity between FCEV refuelling and BEV charging stations for trucks is not as a result of a conscious decision by government, but more a result of government responding to the immediate demands of the two ZEV automotive segments:

- BEV suppliers have focussed initially on the light fleet, as that is where the greatest volumes are, and where the greatest immediate need for charging infrastructure is.
- In contrast, hydrogen refuelling stations can satisfy both light and heavy FCEVs if they are designed to deliver hydrogen at both 70 MPa to light vehicles and 35 MPa to heavy vehicles.

[21] https://www.hiringa.co.nz/hydrogen-fuelling-network

[22] Although some of the 50-300 kW charging points being rolled-out for the Light fleet have the electrical capacity to charge medium trucks (roughly <20 t vehicles), the vast majority do not have the physical space to accommodate such trucks. No MW-scale charging facilities exist to enable charging of the heaviest truck categories (approx. > 20t).

[23] Europe's Alternative Fuels Infrastructure Regulation (AFIR) specifies minimum levels of BEV charging and FCEV refuelling stations along Europe's highways and within urban areas. These minimum levels are specified both in terms of geographical spacing along highways, as well as power output, with different requirements for light duty vehicles (cars and vans) and heavy-duty vehicles (trucks).

Despite this disparity in truck refuelling infrastructure not having been a deliberate outcome, the fact that it has occurred means New Zealand now risks some combination of:

- skewing ZEV truck investment towards a technology (FCEVs) which appears to be significantly more expensive than the alternative (BEVs); and
- delaying BEV truck uptake, and suffering higher environmental and economic costs as a consequence.

2.4 Non-cost-reflective electricity supply arrangements

2.4.1 Tariff structures not reflecting the underlying costs of supply at different times

There are a lot of costs associated with electricity supply that aren't driven by the volume of demand (kWh or peak kW), but by factors such as the number and geographical disposition of consumers. Our analysis indicates that approximately half of network costs and all of retail & metering costs are not driven by demand. However, most of these costs which aren't driven by demand are currently recovered by demand-based tariffs ($/kWh or $/kW). This is causing inefficient outcomes as it increases the effective cost to a consumer of choosing an electric appliance (such as a heat pump or EV) rather than a fossil version (such as a gas heater or ICEV).

In addition, for those electricity supply costs which are driven by demand, a significant proportion of such costs are driven by a relatively small number of peak periods – typically mornings and evenings during winter. The demand-driven costs of supply outside of these times can be an order of magnitude lower. However, currently, most $/kWh tariffs, including those for commercial consumers, are 'flat' within the day (ie, the same price day and night), and many peak-demand based $/kW tariffs for commercial consumers are based on the individual consumer's 'anytime' peak demand rather than demand during the system's 'coincident' peak demand. These non-cost-reflective tariff structures

- make it much more expensive than it should be for vehicle owners charging their vehicles overnight – the period when the vast majority will anyway be stationary. This will tend to suppress the rates of ZEV uptake that would otherwise occur.
- don't disincentivise EV owning businesses from avoiding charging their vehicles during peak periods in the evening.

2.4.2 'First mover disadvantage' from electricity network upgrade cost-recovery approaches

In some cases, installing chargers at a truck depot will push the total demand from all electricity consumers in the area above the capacity of the local distribution network, thereby triggering an electricity network upgrade. Installing an electrolyser at a green hydrogen re-fuelling station can also trigger the need for an electricity network upgrade.

Practices vary between distribution networks as to how much of any such upgrade cost the party triggering the upgrade will bear (noting that the upgrade typically results in increased capacity being made available that can be used to accommodate growth in electricity demand from other electricity consumers), and whether they must pay up front (typically through a "capital contribution").

If cost allocation and recovery settings are too unfavourable for the party seeking to install the electricity consumption equipment (in this case a depot charger or electrolyser), this can deter installation altogether. This can lead to inefficient outcomes such as:

- Truck operators choosing ICEVs rather than BEVs, even though BEVs would be lower cost from a public cost-benefit perspective

- Truck fleet operators choosing to incrementally install chargers (and associated transformer and switchboard gear) as and when they replace old ICEVs with new BEVs, rather than capture the economies of scale of a large one-off depot charger installation which will allow for increasing BEV truck numbers;
- Electrolysers facing inefficiently high network pricing, giving rise to inefficiently high hydrogen production prices and subsequent deterrent of truck operators considering purchasing FCEV trucks.
- Deterring a network upgrade that would efficiently provide anticipatory capacity to support future demand growth – something that is increasingly likely as decarbonisation-through-electrification takes hold through the economy.

This dynamic of inappropriate cost allocation to parties triggering a network upgrade is commonly referred to as the 'first mover disadvantage' (FMD) problem.

It is not just a problem facing electrification of the transport sector, but also other parts of the economy including electrification of industrial process heat.

Further exacerbating this issue is the current lack of transparency about the available capacity at different points in a network. This makes it difficult to optimise the location and timely roll-out of public charging stations and new truck depots installing charging infrastructure. In other countries, such as the UK, maps identifying where there is spare network capacity available are produced by local electricity networks.

2.5 Legacy regulatory barriers

Legacy regulatory barriers are where rules and regulations that were appropriate for the status quo technology are inadvertently inappropriate for the new technology.

2.5.1 RUC categorisations should not disadvantage ZEVs compared to diesel trucks

New Zealand charges distance-based Road User Charges (RUCs) on all vehicles other than petrol, though electric vehicles are currently exempt (until March 2024 for light, and until December 2025 for heavy.) Therefore, diesel and hydrogen fuelled trucks pay Road User Charges today.

However, there are distortions that should be ideally fixed and these need to be identified and addressed through the review of Road User Charges that is occurring over 2022-2024[24].

The purpose of the charges are to recover the costs imposed by the vehicles in terms of road maintenance.

While RUC itself is fit for purpose, the most significant legacy regulatory barrier RUC imposes on ZEVs is the method of categorising trucks. This categorisation is based on a mix of truck body configuration (eg, number of axles) combined with gross vehicle mass (GVM), with the GVM being defined in a relatively small number of bands.

GVM is the weight of the vehicle plus its maximum payload. Therefore, RUC charges are based on the maximum that a truck *could* carry, rather than its unladen or actual laden weight. RUC costs increase with GVM band, and decrease as axles are added to a vehicle (or trailer), with weight per axle broadly correlating with changes in road damage.

The weight categorisation bands were developed in an environment where all trucks were ICEVs.

The categorisations can disadvantage ZEVs where they operate close to or at full payload. As batteries in ZEVs make them heavier than diesel trucks when unladen, this either reduces available payload to maintain the same GVM and RUC operational cost, or, to preserve payload, would

[24] https://www.transport.govt.nz/consultations/road-user-charges-consultation

increase the GVM which, depending on where they sit on a RUC band, *may* tip a vehicle into the next higher RUC weight band and so increase operational costs. Increasing GVM on a truck can involve significant engineering changes.

2.5.2 Width, axle, and mass limits and price incentives should be reviewed

Width, length, and axle weight limits in New Zealand are prescribed by the Vehicle Dimension and Mass (VDAM) Rule. They pose a number of issues for ZEV trucks, and which interplay with RUC.

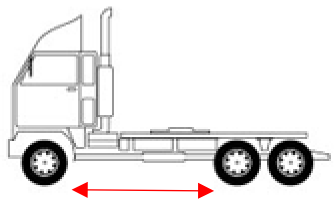
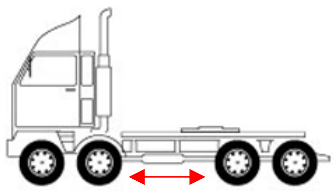
For example, above 18 tonnes, a four-axle truck (RUC type 14) pays barely more[25] than a three-axle truck (RUC type 6) but under VDAM have an allowance of four more tonnes payload. This makes four axle diesel trucks a unique freight standard for heavy loads in New Zealand whereas three axles are common internationally for the same task.

Another example is that prime movers (the tractor units that tow semi trailers), which are already short, are encouraged to add axles through both RUC and VDAM rules. However, this will limit space for batteries for ZEV trucks.

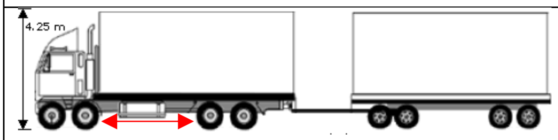
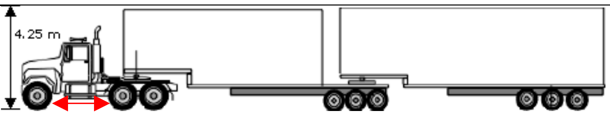
Such examples illustrate barriers on manufacturers to supply ZEV trucks to New Zealand, because of reduced space for batteries and/or also because they have to provide a non-standard or less common specification to New Zealand.

The Sustainable Business Council has said that *"restrictions (e.g., length restrictions) on the type of heavy vehicles that can be bought into New Zealand … are a barrier to low-carbon heavy vehicle uptake. A change to allow longer vehicles could incentivise low-emissions heavy-freight vehicles into New Zealand faster."*[26]

Visual summary:

<table>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Prime movers tow semi trailers. The more axles on the prime mover, the less length and thus space there is for batteries and other equipment necessary for ZEV trucks. (Above).

Trucks, either used indepedently, or when pulling a semi-trailer or trailer, have a longer wheel base than a prime mover, so space constraints are less prounced. Still, if domestic rules mean our trucks don't follow international specification norms, this can can impede ZEV truck supply.

(Below left truck has more space for batteries, than the primer mover below right).</td></tr>
<tr><td></td><td></td></tr>
</table>

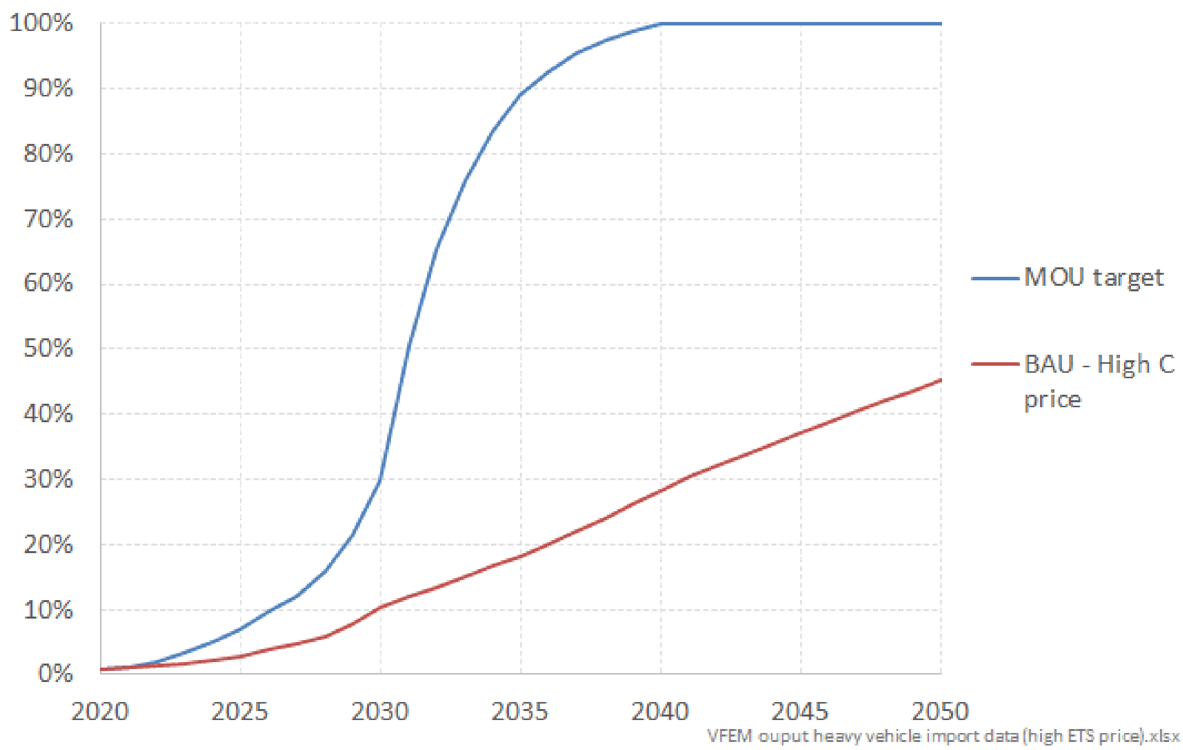
[25] https://www.nzta.govt.nz/vehicles/road-user-charges/ruc-rates-and-transaction-fees/

2.6 ZEV truck uptake is likely to be substantially less than required if barriers are not addressed

Due to the above market barriers, the rates of uptake of ZEV trucks will be significantly below an optimal level of uptake, and also below the rates of uptake required to meet our recently-signed international truck decarbonisation commitment.

To illustrate this, Figure 2 shows MOT's projection of the rate of ZEV truck and bus uptake under current policy settings ('BAU') under a high carbon price path, and compares this with the rates of uptake implicit in meeting the MOU commitment.

Figure 2: Comparison of projected rates of ZEV truck and bus uptake under current policy settings with the MOU target



As can be seen, even if carbon prices reach high levels[27] the projected rate of uptake of ZEV trucks and buses falls well short of the MOU targets.

Consistent with this, several manufacturers who were contacted during the process of developing this paper said that, although they were bringing new ZEV truck models to market internationally over the next four years, they might not make them available for the New Zealand market unless a comprehensive ZEV truck policy was developed and in place.

It is worth noting that while other countries are seeking to achieve at least the levels of ZEV truck uptake indicated in the MOU target, the per-truck emissions reductions achieved in these markets – while very large – is likely to be generally less than in New Zealand. This is because of New Zealand's very high level of current renewable electricity generation[28], and access to relatively low-cost additional renewables. This makes New Zealand one of the lowest-cost places to deploy ZEV trucks to reduce carbon emissions.

[27] The high carbon price path used for the MOT modelling reaches $270/tCO2 by 2050, which is 8% higher than the Climate Change Commission's carbon price projection in its Demonstration Path

[28] Currently 80% with a government target of getting close to 100% by 2030.

3 What policy measures are likely to be best at delivering a cost-effective uptake of ZEV trucks?

As set out in section 7.1, overseas governments have implemented a range of different policy instruments to overcome the barriers facing ZEV truck uptake. This section draws upon such experience, plus undertakes specific additional analysis, to review the issues and options for these different instruments in the New Zealand context.

Based on overseas experience, there are five policies which are considered 'core' mechanisms, in that they have the most significant effect on rates of ZEV truck uptake:

1) Obligations on truck suppliers
2) Financial incentives for ZEV truck owners
3) Public funding of ZEV charging/fuelling infrastructure
4) Correcting ICEV emissions externalities
5) Improving electricity supply pricing approaches

The issues and sub-options associated with each of these policy mechanisms are addressed in some detail in this report.

There are also a range of 'supplementary' mechanisms which can improve the effectiveness of these core mechanisms but are considered less essential:

- Priority or exclusive ZEV road access arrangements
- Non-CO_2 emissions regulations and measures
- Public funding of ZEV demonstration projects and information provision
- Government procurement

These supplementary mechanisms are set out in lesser detail.

Section 4 then draws the analysis together to present a summary recommendation of the package of policy mechanisms which will best meet New Zealand's ZEV truck needs.

3.1 Supplier obligations

This family of mechanisms incentivises suppliers to achieve greater sales of ZEVs by setting targets for suppliers to achieve, with penalties for falling short of a target.

Internationally for Light vehicles, obligations on vehicle manufacturers were found to be crucial to incentivising them to start producing ZEV models. Solely relying on financial incentives on purchasers was found to be insufficient incentive on vehicle manufacturers to invest the significant resources required to start to shift away from ICEV production (where all their development capital and most of their production capital was sunk, and therefore incremental ICEV production was very profitable) to ZEV manufacturing where significant amounts of new capital would be required.

There are two main approaches for achieving these outcomes:

- Fleet CO_2 emissions standards
- ZEV sales mandates ('ZEV mandates')

3.1.1 Key characteristics of fleet CO_2 emissions standards and ZEV mandates

Fleet CO_2 emissions standards

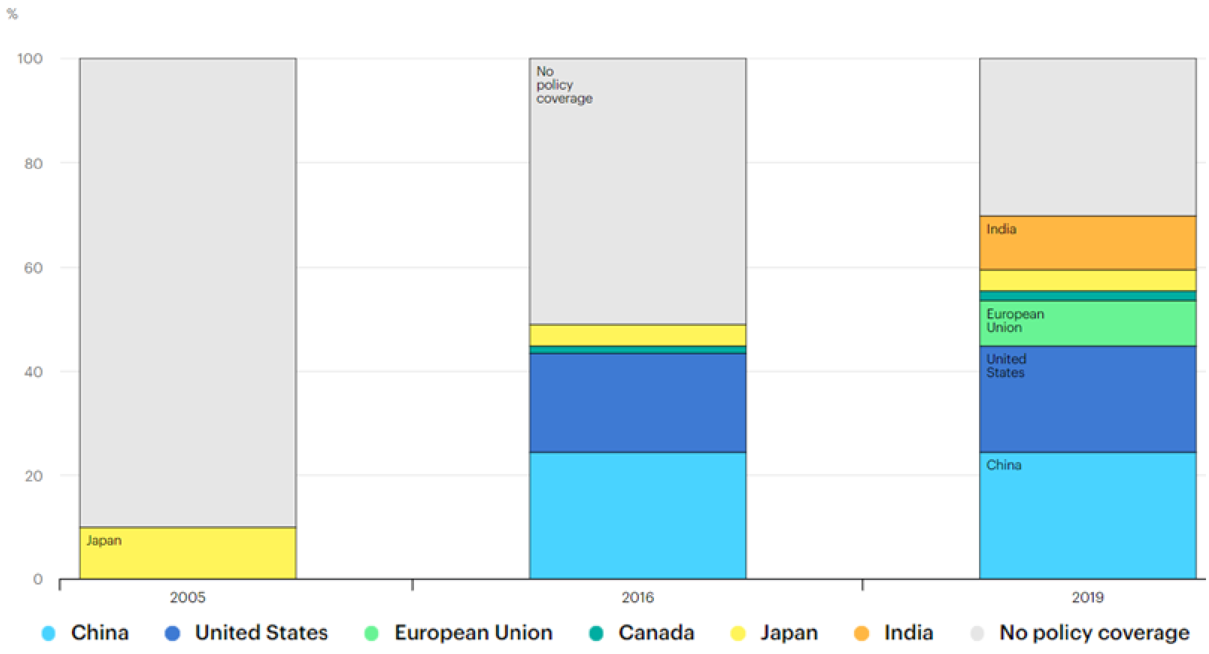
This mechanism has already been introduced in New Zealand for Light vehicles as the 'Clean Car Standard' (CCS),[29] and is a widely used international approach to incentivise ZEV uptake.

Under a fleet emissions standard, if the average emissions of all vehicles supplied by a vehicle supplier is above a pre-determined standard (expressed in gCO_2/km for the CCS) it will pay a penalty on every vehicle supplied – being the difference between the average emissions across all the vehicles and the standard, multiplied by a penalty (expressed in \$/gCO_2/km for the CCS).

The intention is to provide incentives on suppliers to alter their sales mix toward lower emission vehicles (both ZEVs and higher-efficiency ICEVs) and improve their technology over time. Typically, including in the New Zealand CCS, fleet emissions standards get more stringent over time to incentivise ever-improving rates of ZEV uptake. By expressing the standard as a weighted average across a fleet rather on a per vehicle basis, this gives suppliers flexibility to import both low and high-emitting vehicles so long as the average across all the vehicles meets the target. This flexibility is designed to facilitate overall lower cost outcomes.

Figure 3 shows that, by 2019, approximately 75% of heavy-duty vehicles sales around the world are in countries which have adopted fuel economy or CO_2 standards.

Figure 3: Heavy-duty vehicle sales in countries with adopted fuel economy (and/or GHG/CO2) standards, 2005-2019



Source: https://www.iea.org/data-and-statistics/charts/heavy-duty-vehicle-sales-in-countries-with-adopted-fuel-economy-and-or-ghg-co2-standards-2005-2019

ZEV sales mandates

This approach simply requires that a minimum percentage of trucks sold be ZEVs. Failure of a supplier to meet the target results in a financial penalty per non-ZEV truck sold below the target.

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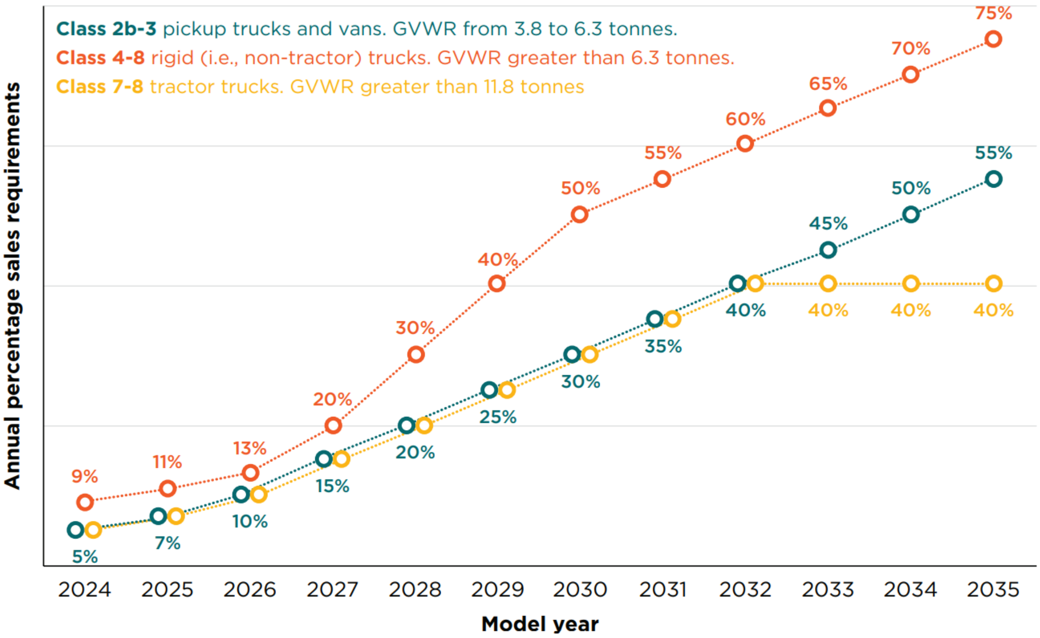
[29] This was enacted through the Land Transport (Clean Vehicles) Amendment Act in 2022 (https://www.legislation.govt.nz/act/public/2022/0002/latest/whole.html), with targets commencing from January 2023. This Act also enables a Light vehicle ZEV Mandate to be introduced later through regulation.

While a growing number of jurisdictions (including New Zealand) have made policy commitments to achieving certain ZEV sales targets for trucks, to-date, the only jurisdiction to *legislate* a supplier sales target with penalties for non-compliance is California with its Advanced Clean Trucks Regulation, although Canada has recently announced that it too is going to introduce a ZEV mandate mechanism.

As illustrated in Figure 4, the Californian requirement differs by truck type and the % requirement grows over time.

Figure 4: California Advanced Clean Trucks Regulation ZEV sales percentage schedule by vehicle group and model year



It is also worth noting that the Californian governor has made an Executive Order that "It shall be a further goal of the State that 100 percent of medium- and heavy-duty vehicles in the State be zero-emission by 2045 for all operations where feasible and by 2035 for drayage trucks". As that applies to all trucks on the road in the state, not just truck sales in those years, the Regulation is planned to be amended with stronger targets.[30]

The recent Canadian Government statement is that it will develop a ZEV mandate that will require 100 percent medium- and heavy-duty vehicle sales to be ZEVs by 2040 for a subset of vehicle types based on feasibility, with interim 2030 regulated sales requirements that would vary for different vehicle categories based on feasibility, and explore interim targets for the mid-2020s.[31]

3.1.2 Comparison of fleet emissions standards and ZEV mandates

Both mechanisms should incentivise the uptake of ZEVs. The key differences between them are:

- Fleet emissions standards are more complex to administer than ZEV mandates
- Fleet emissions standards could potentially also incentivise uptake of more efficient ICEVs, whereas ZEV mandates provide no such incentive

With regards to complexity, fleet emissions standards require measurement of each vehicle model's emissions efficiency to determine its gCO_2/km performance.

[30] https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf
[31] https://www.canada.ca/en/environment-climate-change/news/2022/03/2030-emissions-reduction-plan--canadas-next-steps-for-clean-air-and-a-strong-economy.html

For the CCS, New Zealand has piggy-backed off international testing regimes. A similar approach would likely be required if a truck fleet emissions standard was to be introduced – for example adopting the European vehicle energy consumption calculation tool (VECTO) testing results – as developing our own testing regime would be very costly. However, there are significant logistical hurdles to overcome:

- There would need to be a legislative requirement on suppliers to provide such data, and for the data to be of a significantly more detailed basis than that which is currently voluntarily supplied by industry
- Only the European testing regime is sufficiently well developed to enable this analysis. However, New Zealand also gets trucks from other markets which may not have European test results. This would require arrangements to be developed to address such situations.
- Approximately 30% of trucks entering the New Zealand fleet are second-hand from overseas, almost all of which originate from Japan. Japan has tested CO_2 emissions of trucks and regulated their reductions since 2005, the first country in the world to do so[32]. Therefore, emissions data associated to Japanese trucks could be used to investigate for relevance to New Zealand. However, there could be challenges in aligning Japanese testing to be coherent with European testing.

  As an aside, as truck sales inside Japan and Europe must achieve lower average emissions each year, this implies there emission reductions could be achieved from reducing the average age of used import trucks to New Zealand, or, requiring newer standards that achieve a similar outcome (New Zealand still accepts used vehicles imported meeting the very old Euro IV standard, so requiring used vehicles to achieve the newer Euro VI standard could reduce CO_2 reductions and bring health benefits).

For trucks there is an added complication in that the fuel-efficiency of a truck also depends significantly on the duty it is required to undertake – in particular, the body type that is added to the chassis here including whether this is refrigerated, the weight of freight it carries, whether it is towing a trailer, and (to a lesser extent) the type of travel it undertakes. There can be significant variation in these parameters, with consequent significant variation in fuel consumption.[33] This variation in fuel consumption outcomes is much greater than the average variation in load on a passenger car.

To address this, the fleet emissions standard for trucks in Europe is expressed in terms of gCO_2/tkm (ie, emissions per *tonne* kilometre).[34] This requires the measurement and assigning of an emissions efficiency value to a particular truck model to be based as a weighted average of different assumed 'mission profiles' which have differing payloads and distances. Different truck types (differentiated by factors such as truck weight, rigid vs tractor configuration, axle configuration, cab types, and engine power) have different assumed mission profiles. This raises potential issues as the shorter daily distances travelled by trucks in New Zealand (what we class as long-distance is more like medium-distance on European scales) mean that the mission profile mix for some classes of truck –

[32] https://theicct.org/wp-content/uploads/2021/06/Japan_HDV_FE_Phase_2_20190129.pdf

[33] For example, a study of real world fuel consumption and CO_2 in New Zealand in 2019 showed the upper bound for urban delivery could be 390 g CO_2/tkm (increased over time due to decreased load), while for long haul the emission intensity could be 105 g CO_2/tkm. See: https://www.knowledgehub.transport.govt.nz/assets/TKH-Uploads/TKC-2019/Real-world-fuel-economy-of-heavy-trucks.pdf

[34] There is also the potential for the standard to be expressed as gCO2/m3km which takes into account the volume of goods a truck can transport. The European Union considered this option, but decided to choose gCO2/tkm as it was felt that, on balance, weight was a more appropriate factor to account for variance in fuel efficiency.

potentially the largest trucks – will not be closely reflective of 'average' New Zealand truck types and journeys.

In addition, there are inherent issues with these testing regimes, as there is increasing evidence that the real-world fuel use and CO_2 emissions of vehicles are generally significantly higher than those measured in these idealised test regimes. Further, hybrid and PHEV vehicles have even greater deviations from actual and test efficiencies, creating specific issues for regimes trying to incentivise the uptake of low-emissions vehicles.

Several fleet emissions standards implemented overseas have also introduced arrangements to increase the incentive for the uptake of ZEVs including:

- The use of 'super-credits', whereby a ZEV would count as more than one vehicle for the purpose of calculating the fleet-weighted average emissions of a supplier. For example, in the EU scheme a ZEV truck counts as two vehicles in the early years of the scheme.
- Relaxing the fleet emissions standard a supplier needs to achieve if the % of ZEV vehicle sales exceeds a benchmark. Generally, this approach has limits on the extent to which an emissions standard can be relaxed due to ZEV uptake.

In contrast, a target in a ZEV mandate is easy to specify and measure. The only potential complication is the treatment of plug-in hybrid electric vehicles (PHEVs). However, even this is relatively easily addressed by specifying that a PHEV truck would count as 'x'% of a ZEV truck.

Offsetting this increased complexity of fleet emissions standards, is the fact that these can incentivise the uptake of more efficient ICEVs, whereas a ZEV mandate could not. If there is significant potential for additional emissions- and cost-reduction gains to be made (on top of incentivising ZEV uptake) by incentivising a shift to more-efficient ICEVs, the increased complexity of a fleet emissions standard could be justified. However, if the potential is relatively small, or could be achieved through other means, the complexity is unlikely to be justified.

In this respect, a recent European report identified that if only the most efficient ICEV models were chosen by truck purchasers, a 6% improvement could be achieved in the average efficiency of ICEVs entering the truck fleet in any one year.[35]

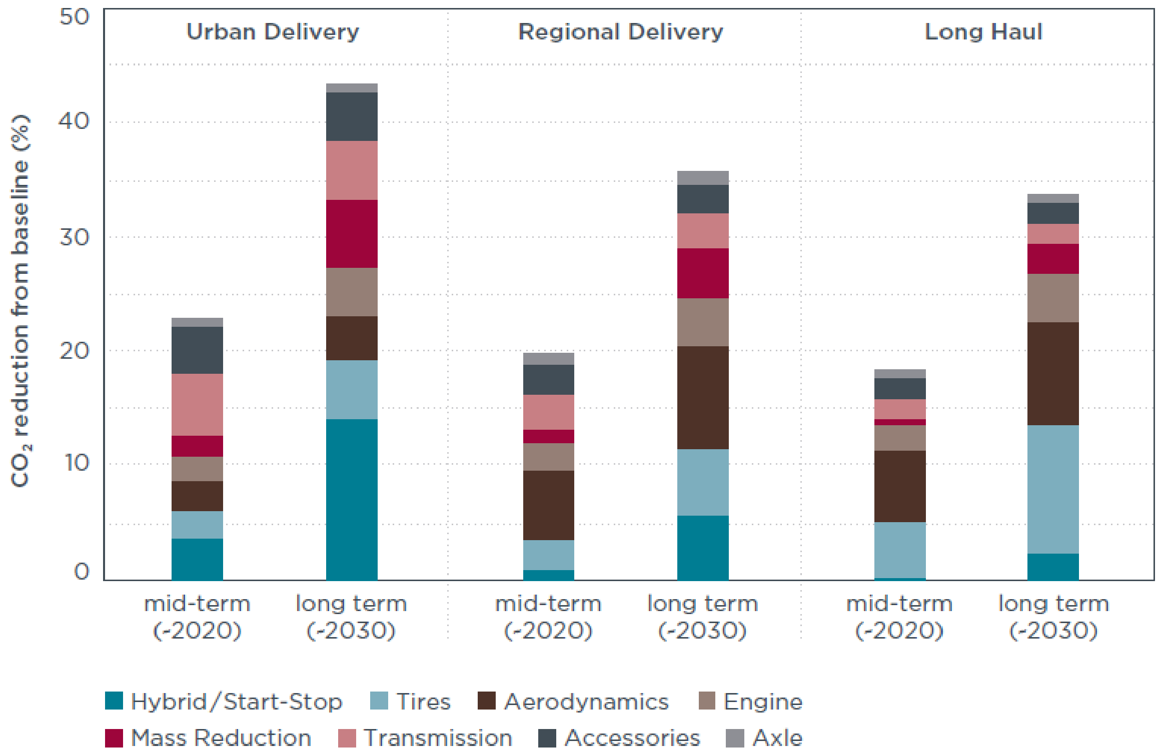
While at first sight this 6% potential reduction seems large, there are several other factors which mean that the achievable amount which can solely be attributable to a fleet emissions standard is likely to be materially less:

- It is unlikely that a shift to the absolute most efficient ICEV model in every class could be achieved. Rather, a general shift towards the more efficient half of vehicle efficiencies could probably be practicable;
- As ZEV uptake starts to take effect, the relative importance of improving ICEV efficiencies starts to decline. For example, following this example of 6% savings being achieved by shifting to the most efficient ICEV model across all 100% of ICEV purchases, this same saving can be achieved by having 6% uptake of ZEVs;
- Incentivising the development of progressively more efficient ICEVs only makes sense if ICEVs are going to be a technology which OEMs are going to continue to devote development funding towards. However, an increasing number of truck manufacturers are announcing plans to progressively move away from ICEV manufacture to ZEV manufacture, and are consequently significantly reducing the amount of R&D funding for ICEV models and instead allocating this to ZEV R&D.

[35] "*Easy ride: Why the EU truck CO_2 targets are unfit for the 2020s*", Transport & Environment, October 2021

- A study by The ICCT showed that reducing carbon emissions from diesel trucks in Europe relies on a wide range of factors, not just improved engines, and that there are notable differences between urban and long haul solutions. For instance, reducing mass and hybrid/stop-start technology helps significantly in urban environments whereas aerodynamics and low rolling resistance tyres play a comparatively larger role at highway speeds, both of which are unrelated to the engine technology. This shows that a policy designed to reduce emissions in diesel trucks either would need to focus primarily on engine-technology, and is limited in benefit, or, encapsulates a wide variety of emission reduction solutions including differences between urban and long haul use, which would be very complex.

Potential CO2 reductions forecast on European diesel trucks from a 2017 baseline:



Source: https://theicct.org/publication/fuel-efficiency-technology-in-european-heavy-duty-vehicles-baseline-and-potential-for-the-2020-2030-timeframe/

It should also be noted that a range of other measures can also make significant improvements to the fuel efficiency and/or carbon emissions of ICEV trucks. For example:

- improving driver behaviour with regards to safer driving techniques also significantly improves the fuel efficiency of such driving
- better fleet management
- technologies to improve the efficiency of vehicles (low running resistance tyres, improved aerodynamics, stop-start anti-idling)
- adopting tougher exhaust emissions standards
- using biofuels.

However, crucially, these (apart from stop-start anti-idling) can't be incentivised through a fleet CO_2 emissions standard, and require other policy measures. For example, the Waka Kotahi and Energy Efficiency & Conservation Authority (EECA) has done a lot of work to help improve the operation of trucks to improve their fuel efficiency, and improving the exhaust emissions of ICEVs requires additional instruments – such as adopting the Euro VI and subsequent emissions regulations – see section 3.7.2)

Lastly, we note that New Zealand does not require fuel consumption, CO_2 emission, or related information on heavy vehicles entering New Zealand to be reported into the motor vehicle register[36]. This information is provided on a voluntary basis and is therefore incomplete and inconsistent. We recommend that irrespective of the policy choices made, the government should make providing such vehicle data a requirement, so that the emissions profile of the fleet can be better assessed over time, and so that it can inform later policy decisions.

3.1.3 Key design issues

Categorisation into different truck types

Both mechanisms will likely need to differentiate between different truck types:

- Both mechanisms will need such differentiation if it is likely that there will be variance between truck types for the achievable rate of ZEV uptake over time (eg, out to 2040). For example, if lighter trucks are expected to be able to move to ZEV models earlier than heavier trucks, this will need to be factored into the calculations of the appropriate targets to set.
- A fleet emissions standard will also need such differentiation if the travel-weighted mix of truck types is expected to change in the future due to underlying changes in the demand for freight services. For example, over the last couple of decades, the proportion of overall truck travel undertaken by the heaviest category of trucks has increased, thereby altering the average gCO_2/tkm for the overall truck fleet.

Given that both such factors appear likely, it would appear sensible to have categorisations. Not having such categorisations in situations where the above factors apply, risks inappropriate incentivisation of uptake of vehicles which are not least-cost. On the other hand, the greater the number of categorisations, the more complex a scheme is to administer.

One option for a basis for categorisation is to use the categories used for setting RUC rates as this is a well-established categorisation framework. Some of these RUC categories could be grouped together for the purposes of supplier obligations if achievable rates of ZEV uptake are projected to be broadly similar between categories or if there are unlikely to be shifts in the proportions of vehicles between categories. Grouping RUC categories into a smaller number of supplier obligation categories would be desirable from a practicability perspective.

Alternatively, existing New Zealand vehicle classification definitions could be used. These split goods vehicles into three groups by GVM ('NA' up to 3.5 tonnes; 'NB' up to 12 tonnes; 'NC' above 12 tonnes).

At the very least, if any such legislation encompasses buses, the significantly different rates of ZEV uptake between buses and trucks to-date would suggest that ZEV targets differentiate between buses and trucks. Within trucks, it may be possible to have only two or three truck categories, as is the case in the example of California.

Care needs to be taken with a ZEV uptake target to ensure that perverse incentives don't arise due to boundary effects. For example, if there is a higher % ZEV target in a lighter truck category than in a heavier category, truck suppliers may be incentivised to persuade purchasers to purchase an ICEV truck in the heavier category rather than a ZEV truck in the lighter category. Preventing such potential outcomes will require a mix of:

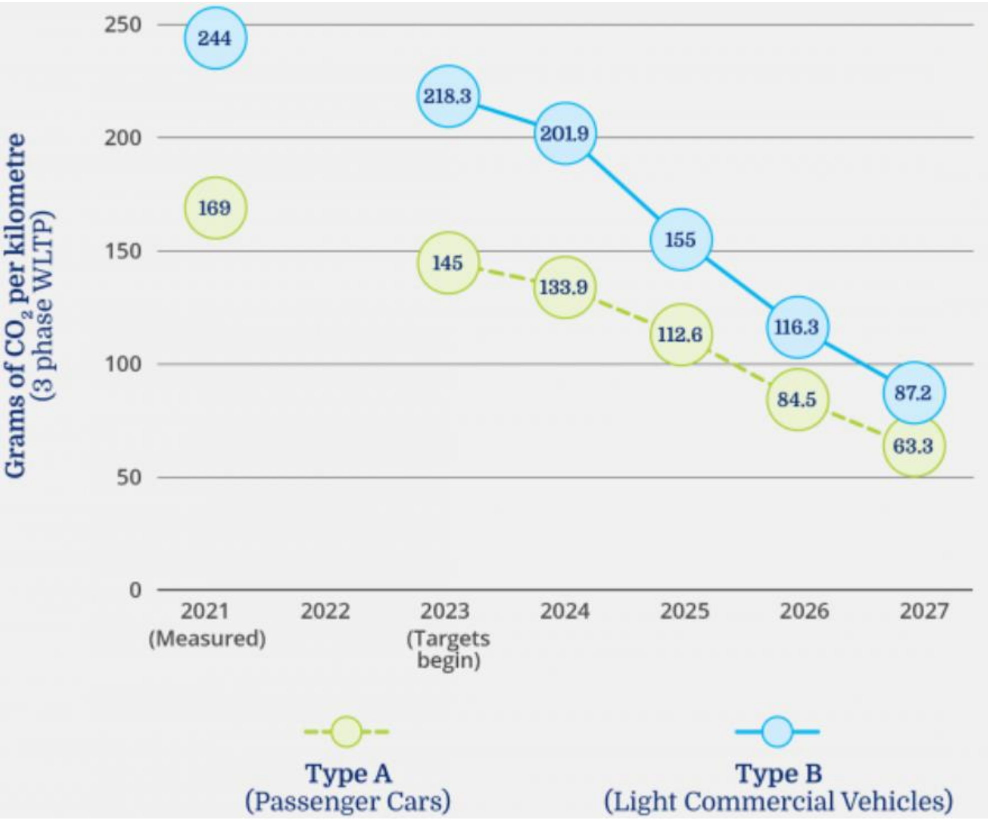
[36] Reporting of CO_2 emissions information is only required on vehicles with a gross vehicle mass of 3,500 kg or less. https://www.nzta.govt.nz/resources/rules/vehicle-efficiency-and-emissions-data-2022/

- Good analytics when setting the initial targets to ensure they are of similar ambition across the truck categories;
- Purchase price incentive mechanisms (detailed in section 3.2 below) to help de-risk suppliers' ability to meet a ZEV obligation; and
- A process which allows for regular review of targets to ensure they are appropriate in the light of changing costs or other factors.

What level to set the targets, and how often should they be reviewed?

Both ZEV uptake targets and fleet emissions standards have targets which require progressively greater levels of ZEV uptake over time. Ever-stricter standards is a common feature of such mechanisms, internationally. For example, as shown previously in Figure 4, the Californian ZEV targets for non-tractor trucks with GVWR>6.3 tonnes start at 9% of sales in 2024 and rise to 75% of sales by 2035. Likewise, as shown in Figure 5 below, the fleet emissions standard for New Zealand's CCS gets stricter over time.

Figure 5: New Zealand clean car standard targets



In setting a target for future years it will be necessary to undertake analysis which demonstrates that the target is not only achievable given projections of likely ZEV vehicle availability and cost, but also meets broader government targets including CO_2 emissions and specific truck-related ZEV commitments such as the MoU on Zero-Emission Medium- and Heavy-Duty Vehicles.

Such analysis should be complemented by comparison with key external points of reference including ZEV mandates and commitments by overseas jurisdictions and truck manufacturers, such as those outlined in section 7.

Because New Zealand has committed via the MoU to 30% ZEV truck and bus sales by 2030 and 100% by 2040, it would seem appropriate that at the very least, the targets for ZEV truck and bus uptake be set to the MoU targets for those years, with additional analysis required to determine an appropriate 'uptake trajectory' between those years (eg, straight line, 's-curve', or something else).

If analysis such as that set out in section 6 identifies that even faster rates of uptake would be desirable from the point of view of achieving lower-cost outcomes, then it would be appropriate for the targets to reflect this.

As the rate of ZEV uptake is currently progressing at a much faster rate for buses than trucks, the consequent required rate of ZEV truck uptake can be reduced to meet a given overall truck + bus target. Given MoT projected numbers of truck and bus entry in 2030, if ZEV bus uptake hits 100% at that point (which looks very likely based on current rates of uptake and the government's policy that it will only fund zero emission public transport buses beyond 2025[37]) then the required level of ZEV truck uptake would only need to be 23% to meet an overall 30% ZEV uptake target.

As time progresses, assumptions about future conditions (eg, future rates of reduction in ZEV purchase costs, or carbon prices) may turn out to be too high or too low. It would therefore be appropriate to have arrangements whereby targets can be reviewed in the light of the most recent information and adjusted as appropriate. It is suggested that such reviews occurring every three to five years will strike the right balance between being:

- too frequent (and thus adding too much administrative overhead, and giving insufficient certainty to suppliers for planning purposes);
- too infrequent (which could result in targets which turn out to be materially different to least-cost outcomes for New Zealand).

Banking, borrowing, and trading

The timeframe for a truck manufacturer to bring out a new model is of the order of five to eight years. Given differences in the timing of truck developments between manufacturers, in any given year in any given truck segment, some manufacturers may be bringing out a new model while the newest model from other manufacturers may be several years old.

It is therefore likely that some manufacturers may have models which are better suited to meeting a segment target in a given year than other manufacturers, but this relative suitability may change from year-to-year as manufacturers' model mixes change.

To accommodate this, most fleet emissions standards and the Californian ZEV target have the ability for over-performance in one year to be 'banked' and used to offset potential under-performance in future years. Likewise, under-performance in a year which can't be offset by previous years' over-performance may have the penalty postponed pending potential over-performance in future years. This is known as 'borrowing'. Typically, there are time limits on how long this under-or over-performance can be borrowed or banked. For example, in the New Zealand CCS borrowing underachievement of one year is permitted until 2025, and banking overachievement is supported with credits lasting up to three years.

Banking and borrowing – subject to appropriate time limits – are important mechanisms to help suppliers manage their risks in meeting obligations. Generally, allowing suppliers to appropriately manage risk will benefit consumers as suppliers will feel less need to manage some of their risk by adding a risk premium to sales prices or, in the extreme, deciding to exit the New Zealand market altogether. Given greater uncertainties over truck ZEV development, it may be appropriate to have longer allowable periods for borrowing / banking than the one/three year limits in the CCS.

[37] https://www.transport.govt.nz/area-of-interest/environment-and-climate-change/public-transport-decarbonisation/

Not having such flexibility mechanisms would make managing targets harder for vehicle suppliers. This increased supplier risk would likely either result in higher prices to consumers or some vehicle suppliers exiting the New Zealand market (which is very small by international standards). Alternatively, the risk to suppliers from not having flexibility mechanisms could be addressed from having lower supplier targets. However, this would result in New Zealand not gaining the benefits of higher ZEV uptake and increased risk of not meeting its international commitments.

Most schemes also allow for trading between suppliers, although this needs careful design to prevent gaming. This allows for a supplier which has over-performed to sell some of this over-performance to an under-performing supplier to be used to offset the penalty it would otherwise incur. Such trading needn't be through a formal mechanism built into the policy as occurs in some jurisdictions, but could be achieved through a series of bilateral deals with only reporting requirements to meet compliance with the policy mechanism. This 'behind the scenes' approach is much lower cost to administer, and is used for the CCS.

The ability to have trading is also an important mechanism to help suppliers manage their risks. Additionally, trading also provides important revenue streams for vehicle manufacturers who solely supply ZEV vehicles, and for whom supplier targets would otherwise provide no benefit.

How to treat Used vehicles entering the New Zealand market

In 2020, 30% of trucks entering New Zealand were 'Used' – ie, second-hand from countries such as Japan and other right-hand drive markets.

Given that the average age of these Used trucks entering New Zealand in 2020 was 9.4 years old and ZEV trucks are only just starting to come on the market for some truck categories (and still a few years away for other categories), it would not be appropriate to expect the same rates of ZEV uptake for New trucks as for Used trucks.

This is illustrated by import figures. To date, only one used electric truck has been imported to New Zealand. This compares to about 4 new electric trucks entering New Zealand each month during 2021. Over 10,500 diesel trucks (new and used) entered New Zealand that year.[38]

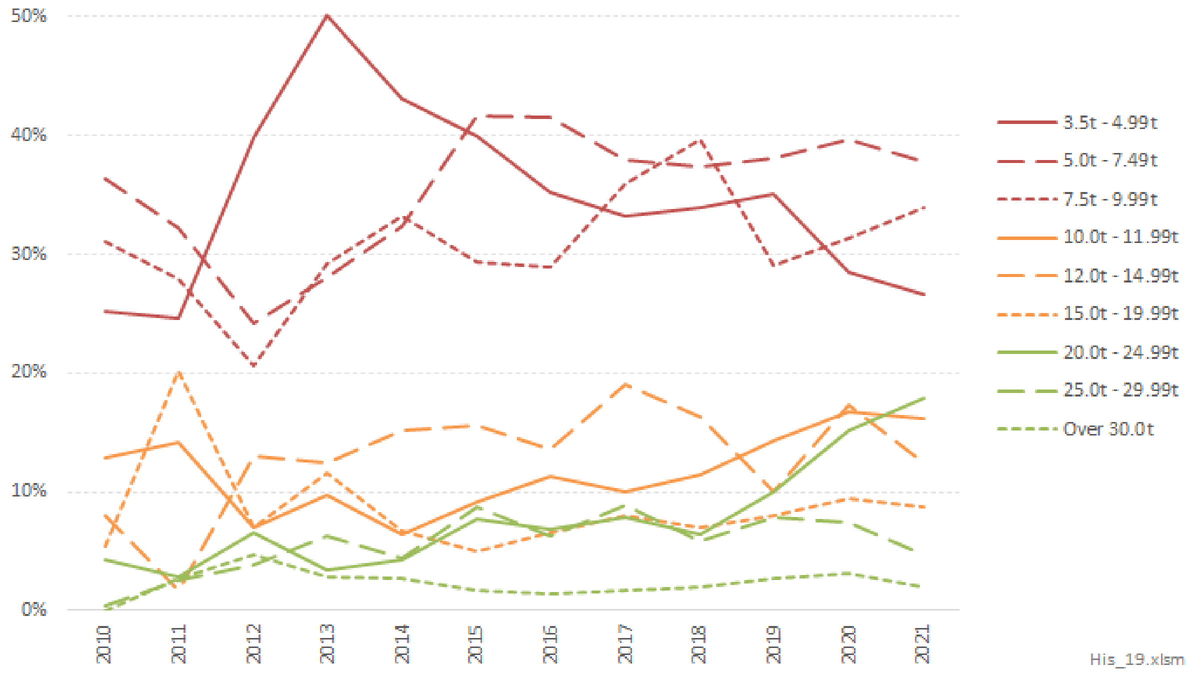
One option to address this would be to have separate targets for New and Used trucks. However, this may have the undesired effect of incentivising greater proportions of (more emissions-intensive) Used trucks entering the market. This risk may be tempered by the fact that most freight sector operators will only buy new trucks, and many owner-operators contracting freight services will have requirements in their contracts to have trucks less than a certain age.

A more appropriate approach could be to specify a whole-fleet target (ie, combined New and Used), but that the process of setting targets will have accounted for the proportions of New and Used, and the feasibility of ZEV rates of uptake for each category. Such an approach could also take account of future changing proportions of New and Used if the analysis identified that a greater proportion of New trucks would deliver lower-cost outcomes for New Zealand given expectations on truck, fuel and carbon prices.

It may also be necessary to split such whole fleet targets by truck type given that the proportion of Used trucks entering New Zealand varies significantly by weight band – as illustrated by Figure 6.

[38] https://www.transport.govt.nz/statistics-and-insights/fleet-statistics

Figure 6: Proportion of heavy vehicles entering New Zealand which are Used[39]



As can be seen, the vast majority of Used truck imports are for small size trucks. (Note: It is difficult to draw conclusions as to whether the changes in other categories seen in 2020 and 2021 are reflective of underlying trends because there is a general pandemic-related drop in truck purchases in those years).

To estimate the scale of this issue from an emissions perspective, analysis was undertaken which combined the estimated split of fuel consumption shown in Figure 13 with the split of entry of Used vehicles shown in Figure 6 and with analysis of the likely lifetime vkt of trucks of different ages. This indicated that, of the fleet of trucks entering in 2021, the lifetime emissions of those which are Used would account for just under 5% of the lifetime emissions from all trucks entering in 2021.

This analysis suggests that setting a whole-fleet target (ie, covering New + Used) would be the most appropriate approach, using analysis which assumes the same proportion of New and Used in future years.

3.1.4 Fleet purchase obligations

For the sake of completeness, it is worth noting that some jurisdictions have implemented an obligation approach on fleet *owners*. This has been implemented for buses in the EU, California, and the Netherlands. However, the only jurisdiction which is proposing to implement it for trucks is California with the (yet-to-be-implemented) Advanced Clean Fleets regulation.

This approach is not considered suitable for trucks in New Zealand due to the high proportion of owner-operators and small fleets in the freight sector. Over 80% of trucks in New Zealand are in fleets of 10 or fewer vehicles. That said, there may be opportunities for industry-led approaches such as voluntary targets pioneered by the likes of the Sustainable Business Council.

The government's policy to only fund new zero emission buses by 2025 has created a *de-facto* fleet purchase obligation on public transport buses. However, the tourism/private coach sector may need separate consideration (and is out of scope for this paper).

[39] Statistics taken from https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/

3.2 Financial incentives for ZEV truck owners

Whereas supplier obligations work by introducing a financial penalty 'stick' on suppliers if they fail to sell a target level of ZEVs, financial incentives for truck owners work by offering financial 'carrots' to purchasers of ZEVs.

Various financial incentive schemes have been introduced by international jurisdictions to incentivise the uptake of ZEVs for both the Light and trucking fleets. Often the precise design has reflected the specific circumstances of the country, particularly its tax regime.

This section details the various different types of scheme, and assesses their relatively suitability for incentivising the uptake of ZEV trucks in New Zealand.

3.2.1 Up-front purchase price incentives or operating cost incentives?

A key distinction between different types of purchaser incentive schemes, is whether such an incentive is given

- in the form of an altered relative *purchase price* of low- and high-emission vehicles (eg, by offering a discount on the sales price of a ZEV); or
- through altering the relative *operating costs* of the two types of vehicles (eg, by imposing an emissions charge on diesel prices, or exempting ZEVs from some proportion of ongoing roading charges).

Given that externalities associated with the use of ICEVs (both global warming and human health externalities) are the principal reason for wanting to drive the uptake of ZLEVs, it may seem appropriate to incentivise such uptake through an operating cost incentive such as an emissions levy on diesel.

However, there are two key reasons why solely incentivising rates of ZEV uptake through adding emissions costs to diesel prices would be less appropriate than using mechanisms which altered the relative purchase price of high- and low-emissions vehicles.

Firstly, potential purchasers have far greater certainty of the financial effect of a purchase price incentive than they do for operating cost incentives. This is because operating cost incentives face potential price uncertainty (eg, future levels of emissions prices) and the potential risk of future policy changes which may remove or reduce the effect of an operating cost incentive.

Combined with the fact that truck operators tend to use far greater effective discount rates for evaluating purchase decisions than government does for evaluating technology options, this will result in purchasers significantly discounting the value of such operating cost incentives. As a result, an up-front purchase price incentive will deliver greater levels of ZEV uptake than an operating cost incentive with an equivalent financial value (in present value terms).

Secondly, rapidly introducing emissions pricing at emissions-cost-reflective levels[40] will have some adverse equity consequences, especially for smaller businesses. While truck owners who anyway need to purchase a new vehicle in the near future can respond to these altered prices and purchase ZEV options, it wouldn't be cost-effective for truck owners who have recently bought a new ICEV to sell that and switch to a ZEV. This is arguably unfair for this latter group of truck owners.

There is an additional social dimension for passenger vehicles in that the least-wealthy car and van owners will most likely continue to have ICEVs the longest (due to this group being less able to buy

[40] We define cost-reflectivity as the level of carbon pricing necessary to deliver sufficient action to limit global warming to no more than 1.5˚C – the target which New Zealand and most other countries have signed up to under the Paris agreement. As set out in section 2.2.1, such levels are estimated to be substantially higher than current prices in the New Zealand Emissions Trading Scheme.

newer vehicles). Applying an emissions tax to petrol and diesel will therefore have regressive outcomes. This has flow-on consequences for the ability to add a cost of carbon into the diesel purchased by trucks: Even if it was deemed acceptable to impose emissions-cost-reflective prices on petrol and diesel for commercial vans and trucks, social policy considerations for passenger vehicles may constrain the ability to have such prices on petroleum fuels.

Taken together, altering the relative purchase price of ZEVs and ICEVs is considered to be much more cost-effective at altering rates of ZEV uptake than altering their relative operating costs, and much more practicably achievable.

On the flip side, concerns have been raised in the past that purchase price incentives in the form of subsidies are more easily 'captured' by vehicle suppliers who will simply raise their ex-subsidy price. While this can be a significant issue, section 4 sets out that this need not occur if a purchase price incentive is *combined* with a supplier obligation which removes this potential incentive on suppliers to capture some proportion of the subsidy.

Further, while properly designed purchase price incentives (ie, in combination with supplier obligations) are considered to be more effective at positively influencing rates of ZEV uptake than operating cost incentives, it should be noted that New Zealand already has

- a carbon price applying to petroleum through operation of the NZ ETS – albeit, as section 2.2.1 details, at levels materially below those required for '1.5-degrees-consistent' action.
- other operating cost incentive mechanisms such as differential RUC rates which alter the relative usage costs of high- and low-emissions trucks.

While these usage-based incentive mechanisms do not obviate the need for purchase-price incentive mechanisms, their effect needs to be considered when setting appropriate purchase price incentive levels: If the current and expected future level of such operating cost incentives is high, the required level of purchase price incentive to deliver a desired level of ZEV uptake will be lower than if such operating cost incentives are low.

Section 3.2.2 below details the options for purchase price incentive mechanisms, then section 3.2.3 details the options for operating cost incentive mechanisms.

3.2.2 Options for purchase price incentive mechanisms

Numerous overseas jurisdictions have incentivised the cost-effective uptake of ZEVs through purchase price subsidy mechanisms of one form or another.

The wide variety of approaches can be boiled-down to three main categories of purchase price incentive mechanism:

- Allowing accelerated tax depreciation on vehicle capital costs
- An explicit purchase price subsidy
- A residual value guarantee scheme

Each of these is described below.

Accelerated tax depreciation

When a capital item is purchased, its capital value is depreciated for tax purposes over a set number of years. The amount being depreciated in a year is deducted from a company's earnings for that year, thereby reducing the amount of tax needing to be paid in that year.

Accelerating the depreciation of ZEVs relative to ICEVs – for example depreciating a ZEV truck over four years, rather than eight – would reduce the tax the ZEV truck operator would need to pay in those initial four years, but increase the amount it would need to pay in the subsequent four years.

This can be a valuable support mechanism from the point of view of a ZEV truck operator, as it better aligns the cashflow profile of a high-capex-low-opex ZEV with the freight rates and terms that have been developed on the basis of the low-capex-high-opex cost profile of ICEVs.

The cost to the taxpayer of such a mechanism is relatively low given that it is 'just' the interest cost of the government financing the postponed tax receipts.

It is possible that faster depreciation rates for ZEV trucks could emerge from the Inland Revenue Department's (IRD) own periodic operational reviews of rates for different asset types. The fact that ZEV trucks are currently rapidly evolving technologies with unclear residual values means that such a review may find that faster depreciation rates are justified.

However, if a strict assessment of appropriate ZEV truck depreciation rates does not yield a materially accelerated rate, then further acceleration, known as 'depreciation loading'[41] could be justified on broader climate and human health policy grounds. This may require primary legislation to put into effect.

An explicit purchase price subsidy

These mechanisms alter the up-front purchase price that truck owners need to pay. A variety of approaches have been used around the world to achieve this.

- waiving sales taxes (eg, GST) or other purchase-related fees (eg, initial registration fees) for ZEVs
- an explicit subsidy on the sales price of ZEVs, with various mechanisms for how the money is transferred. (For example, California operates a voucher scheme, whereas other jurisdictions operate schemes where the vehicle retailer needs to apply for the funding on each vehicle sold)
- mechanisms which reduce the price of ZEVs with such subsidies funded by increasing the purchase price of ICEVs. These so-called 'feebate' or 'bonus-malus' schemes have been used very successfully in various European countries to incentivise zero- and low-emission Light vehicle uptake. It is also the form of mechanism behind the recently introduced Clean Car Discount in New Zealand.

At the end of the day, for a given level of change in the relative purchase price of ZEVs and ICEVs, there should be little difference between the approaches on the effect on the uptake of ZEVs.

The main difference is the source of funding for the ZEV purchase price subsidies.

- Waiving sales taxes will be funded from taxpayers, generally
- Waiving transport specific purchase-related fees (eg, initial registration fees) will tend to be funded by ICEV owners, generally
- Explicit subsides on ZEV sales purchases can either be funded from general taxation or, if they were to be funded by receipts on fuel excise duty and RUC, would be funded by ICEV owners, generally
- Feebate mechanisms will, by their very nature, be funded by purchasers of ICEV trucks

From an economic efficiency perspective, feebate mechanisms are likely to be the least distortive, and arguably better internalise the externalities which ZEV subsidies are seeking to reflect.

[41] New Zealand offered 20% depreciation loading as an incentive to encourage New Zealand businesses to invest in new capital equipment until 2010. Refer https://www.taxtechnical.ird.govt.nz/en/new-legislation/act-articles/taxation-budget-measures-act-2010/changes-to-depreciation-loading

However, there can be differences in the perception of the 'fairness' of the different mechanisms, and subsequent public acceptability:

- Using general taxation to fund subsidies for ZEV truck owners is arguably less fair than mechanisms where funding for 'clean' vehicles comes from owners of 'dirty' vehicles. However, because the amounts of funding required for ZEV truck subsidies is relatively small compared to general taxation, the effect on individual taxpayers is unlikely to be material.
- In contrast, the effect of a feebate on purchasers of ICEVs will be more substantial. This can lead to this group being vocal in their opposition – particularly if they have limited ZEV choices to meet their needs when they come to make a truck purchase. It is also arguably unfair if there are no ZEV truck models available to meet a truck purchaser's particular use requirements – something that is likely to occur during the early stages of such a mechanism while ZEV trucks are still in their relative infancy.

Lastly, in terms of mechanics, if funding is to come from ICEV owners (either from a feebate mechanism, or from using hypothecated taxes (fuel excise duty, RUC, etc), arrangements will need to be made so that over- or under-spend in a year due to rates of ZEV uptake being different to that predicted can be balanced by sources of general taxation funds. This ability to balance funding requirements has been implemented for the Clean Car Discount scheme.[42] Another mechanism to manage this issue is from a pre-funded scheme such as California's voucher scheme. This pre-allocates funds in rounds, and allocates funding within a round on a 'first-come-first-served' basis.

While it is beyond the scope of this document to propose dollar amounts for fees or rebates, an illustration of the principles at play can be provided. For example, a fee on a diesel truck should not be less than $5,000, as that is approximately the maximum fee under the New Zealand's current *light vehicle* feebate policy. A flat fee of that amount could fund rebates of $100,000 on heavy ZEVs until such time as they constituted about 5% of the sales mix.

To prevent over subsidisation, particularly on vans and smaller trucks, rebates should be capped to a maximum percentage of the actual purchase price of a vehicle. As of early 2022, merely ~ 0.2% of truck sales are zero emission, so reaching 5% (about 400 vehicles per year) constitutes significant progress from current adoption rates.

Overseas examples of purchase price incentives include:

- Plug-in grant scheme in the UK. This grant will fund 20% of the purchase price of a ZEV truck, up to £16k (≈ NZ$32k) for <12t trucks and up to £25k (≈ NZ$50k) for >12t trucks. These amounts thus reimburse only a small proportion of the cost premium.
- Californian Hybrid and Zero-Emission Truck and Bus Voucher Incentive scheme. This gives vouchers for ZEVs ranging from US$45k (≈NZ$65k) for a Class 3 vehicle, up to US$120k (≈NZ$175k) for a class 8 vehicle. Additional % modifiers are given if the vehicle is to operate within a disadvantaged community, or is for public transport or school buses.
- A number of European countries offer truck subsidies. For example, Germany offered a federal grant of up to €40k (≈NZ$65k) on zero emission trucks, recently reduced to a €15k (≈NZ$24k) grant only available for scrapping an old truck at the same time.

A residual value guarantee scheme

As set out in section 2.1, one of the issues facing ZEVs is that there is significant uncertainty over the residual value that a first purchaser will be able to receive from selling the vehicle on the second-

[42] For example, at the start of the CCD scheme the New Zealand government provided approximately $300 million dollars for the purpose of managing cashflow timing differences. Over the course of this decade, this taxpayer funded pool is to be repaid to the crown via charges imposed on high emitting vehicles.

hand market after they have initially used it. Typically, such first purchasers sell-on their trucks when they reach four to eight years of age.

This uncertainty is causing potential ZEV purchasers to significantly discount this potential future residual value, thereby significantly increasing the effective capital cost of ZEVs.

Governments could help address this through putting in place arrangements which under-write this residual value (RV) risk: A government-backed institution (eg, NZ Green Investment Finance) would work with financing institutions to agree a certain level of RV for ZEV trucks – or potentially specific components of the trucks such as the batteries. If the outturn RV were to be lower than this the government would fund the difference to the financial institution. Such an arrangement would substantially de-risk the funding proposition for the financial institution allowing lower financing rates and reduced TCO for truck operators.

In many respects, government has already taken on this RV risk for the financing of ZEV buses given that government (central or local) is the ultimate funder of most public transport bus services. Indeed, this is arguably one reason why the electrification of buses has proceeded at a much faster rate than the electrification of trucks, and even light vehicles.

This under-writing of RV risk is essentially a form of 'first loss protection': a financial product in the securitisation and insurance industries which insulates lenders from a pre-defined amount of financial loss due to a specified risk – in this case RV being lower than anticipated.

Such a mechanism has potential advantages in that it could be a low-cost way of funding ZEV uptake. For example, if ZEVs hold their value, the cost to the New Zealand taxpayer could be close to zero[43] as there would be no need to fund an RV shortfall.

The main issue seems to be practicability in terms of developing systems and processes whereby a future market price for second-hand ZEVs (or just the batteries) could be reasonably determined and used as a basis for any such RV shortfall payments. Given the very small size of New Zealand's truck market, this may prove challenging.

3.2.3 Options for operating cost incentives

Operating cost incentives work by reducing the relative ongoing operating costs of ZEVs compared to ICEVs. The expectation of these lower relative lifetime operating costs should influence purchasers of vehicles such that they are more likely to purchase ZEVs than they would otherwise.

However, as already mentioned, operating cost incentives are considered less effective in influencing vehicle purchaser decisions than an equivalent amount of financial support (as represented by the present value of the lifetime operating cost incentive) given as a purchase price incentive. This is due to individuals having less certainty over the future level of such an incentive – or even whether the incentive may be withdrawn – combined with the higher effective discount rates that private truck owners use than government does for evaluating different technology options.

Before disregarding operating cost incentives completely, it is worth distinguishing between two fundamental types of such incentives:

- Subsidies to ZEVs in the form of avoiding all or some of a charge whose purpose is to fund an underlying service (eg, road user charges, or annual vehicle registration charges)

[43] Although no RV 'balancing' payments would need to be paid, the cost of administering such a mechanism would need to be funded.

- Altering charges to make them more cost-reflective and internalise externalities. Eg, adding emissions levies on petroleum fuels, or altering electricity prices to make them more cost-reflective.

Because of the reduced effectiveness of operating cost incentives compared to purchase price incentives, the first category of subsidy (ie, avoiding a charge whose purpose is to fund a service) is not considered best practice for incentivising cost-effective ZEV uptake. However, at the moment New Zealand does have such a subsidy in the form of the RUC exemption for electric vehicles (but not hydrogen fuel cell vehicles) which is due to expire for trucks at the end of 2025. Removing this operating cost subsidy is considered appropriate but only if it is immediately replaced with a purchase price subsidy whose value is at least as equivalent (noting a small allowance for weight should be provided, see Section 2.5). Removing the RUC subsidy mechanism before a replacement is put in place can damage consumer sentiment and unnecessarily stall ZEV uptake for a while.

In contrast, altering charges to make them more cost-reflective to remove externalities is considered appropriate. As such, as set out in section 3.4, it is recommended that petroleum fuels move to have the full emission costs included, and electricity prices are restructured such that consumers pay the 'true' underlying costs of charging an electric vehicle. That said, demand for fuels is very price inelastic and price rises are regressive to owner of light vehicles; there are also likely to be political constraints on the speed at which such charges can move to such cost-reflectivity.

Further, because of the infant technology barriers facing ZEVs set out in section 2.1, even if diesel and electricity prices were fully cost reflective, it would still be appropriate to have additional purchase price incentives in order to deliver optimal rates of ZEV uptake.

The government is currently conducting a review of RUC in terms of how it might be used to charge for greenhouse gas emissions and other factors beyond damage to the roads (like noise pollution and congestion), and how *light* Electric Vehicles (EVs) owners can transition into paying RUC when the exemption for EVs ends in March 2024[44].

3.3 Public funding of ZEV charging/fuelling infrastructure

Significant uptake of ZEV trucks will require significant investment in charging/fuelling infrastructure:

- Investment in *public* EV charging or hydrogen re-fuelling stations
- Investment in *private* EV charging facilities in business premises – often referred to as 'depot' charging

3.3.1 Development of public charging/fuelling stations – 'ZEV stations'

Why is public funding of ZEV stations required?

As previously set out in section 2.3, the development of public ZEV charging/fuelling stations (hereafter referred to as 'ZEV stations') faces the classic 'chicken and egg' barrier facing new technologies:

- Potential private investors in ZEV stations will be unwilling to make such investments unless they have reasonable confidence there will be sufficient demand for them.
- However, potential purchasers of ZEVs will be unwilling to make such purchases unless there are already sufficient public ZEV stations in place to meet their needs.

Public funding of these public ZEV stations is required to break this impasse to enable the cost-effective uptake of ZEVs.

[44] https://www.transport.govt.nz/consultations/road-user-charges-consultation

For example, In Europe, the EU has identified insufficient charging/fuelling infrastructure as a key barrier to ZEV uptake, and also concluded that Supplier Sales Obligations and Purchaser Incentives will be insufficient measures without also ensuring there is sufficient ZEV fuelling infrastructure.

It is therefore developing a regulation on the deployment of "alternative fuels infrastructure" which requires EU Member States to put in place measures to ensure that minimum targets for public EV charging and hydrogen fuelling stations are met.[45]

An overview of the European proposal, and a submission from the European Automobile Manufacturers Association is shown below. Electric charging stations for highways are expected every 60km on Europe's tier one highways, at power levels shown below. This illustrates both the development of the European regulatory planning as well as the even stronger demand from industry for public EV charging:

Figure 7: European Alternative Fuels Infrastructure Regulation overview for heavy-duty vehicles

ELECTRIC CHARGING INFRASTRUCTURE

	COMMISSION PROPOSAL			NEEDED IN REALITY			
TEN-T core network	31 Dec 2025	31 Dec 2030	31 Dec 2035	1 July 2025	1 July 2027	1 July 2030	1 July 2035
Power output per recharging pool	≥1,400kW	≥3,500kW		≥5,000kW		≥6,500kW	
Number/power of recharging stations	1 x 350kW	2 x 350kW		4 x 350kW 4 x 800kW		4 x 1,200kW	
TEN-T comprehensive network	31 Dec 2025	31 Dec 2030	31 Dec 2035	1 July 2025	1 July 2027	1 July 2030	1 July 2035
Power output per recharging pool		≥1,400kW	≥3,500kW		≥1,400kW	≥3,000kW	≥5,000k
Number/power of recharging stations		1 x 350kW	2 x 350kW		2 x 350kW	2 x 800kW	2 x 1,200kW
Safe and secure parking areas	31 Dec 2025	31 Dec 2030	31 Dec 2035	1 July 2025	1 July 2027	1 July 2030	1 July 2035
		1 x 100kW		4 x 100kW			
Urban nodes	31 Dec 2025	31 Dec 2030	31 Dec 2035	1 July 2025	1 July 2027	1 July 2030	1 July 2035
Aggregated power output	≥600kW	≥1,200kW				≥1,600kW	
Individual power output	≥150kW	≥150kW				All ≥150kW + 2 x 350kW	

HYDROGEN REFUELLING STATIONS

- Set intermediate target for 2025, matching the ambitious roll out of fuel-cell electric trucks from 2024 onwards
- Not more than 300km between publicly accessible refuelling stations for liquid hydrogen by 1 January 2027

LNG AND CNG FILLING STATIONS

- Appropriate number of public LNG and CNG refuelling points should be put in place as soon as possible

Zero-emission trucks are beginning to hit the road in large numbers. However, suitable (public) infrastructure is still missing almost completely – this is something the Alternative Fuels Infrastructure Regulation (AFIR) needs to address urgently.

The **technical specifications and requirements** of charging and refuelling infrastructure for battery and fuel-cell electric heavy-duty vehicles are **completely different from those for cars**.

Particularly with respect to:

- Locations of charging and refuelling stations
- Space requirements
- Minimum power output levels

AFIR KEY RECOMMENDATIONS

- Increase the level of total power output requirements per recharging pool / station on the TEN-T core network
- Increase the number of charging stations available at truck parking areas
- Increase the level of total power output requirements for charging pools at urban nodes
- Speed up the deployment of hydrogen refuelling stations and lower the maximum distance between liquid hydrogen stations

Source: https://www.acea.auto/files/fact_sheet_AFIR_heavy-duty_vehicles.pdf

It should be noted that the European regulation of truck charging every 60 km on tier one highways is greater than the Waka Kotahi guidelines for charging infrastructure for light vehicles in New Zealand of one charging station every 75 km on state highways. Further consideration of an appropriate density for New Zealand conditions should be given, and is beyond the scope of this report.

The first stage of development of public ZEV stations is to develop sufficient geographic coverage such that potential ZEV drivers will not be in a situation where they are close to running out of fuel and are unable to refuel. While stations can be operated and part funded by the private sector, the first stage of development requires significant public funding support, as it is the stage where the chicken-and-egg dynamic is most significant. It also requires central coordination, to ensure that sufficient coverage is achieved. A mixture of similar amounts of private and public investment have rapidly achieved more than 97% coverage of charging every 75 km on the highway roading network for light vehicles.

[45] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021PC0559

Once sufficient geographic *coverage* of public ZEV stations has been achieved, further investment to increase the *capacity* of refuelling stations to meet growing demand is more amenable to being privately-funded. However, given the significant uncertainty over rates of ZEV uptake and the asymmetry identified in the following sub-section, this is still an area where public funding will continue to be required, for example to ensure system resilience – although potentially with a lower ratio of public to private finance.

What are the risks of investing too much or too little in ZEV stations?

Because the transition to ZEVs has to happen, with the only uncertainty being over the pace of this transition – plus or minus 5 or so years for rates of ZEV uptake – this significantly alters the risk profile for investing in public ZEV stations:

- Over-investment should be absorbed by ZEV uptake within three to five years – ie, the consequence is capital being invested in ZEV stations a few years too early, but ultimately proving useful.
- In contrast, under-investment will frustrate ZEV uptake causing purchasers to choose ICEVs rather than ZEVs, which will then spend the next 15 to 20 years on New Zealand's roads – ie, the consequence is irreversible costly investment in the wrong capital assets.

A recent study by Concept Consulting[46] used the ENZ model used by the Climate Change Commission (CCC) for setting its carbon budgets. This model includes a ZEV uptake forecasting tool, and an associated projection of the amount of public ZEV charging infrastructure required to support such uptake.

The study took the CCC's Demonstration Path projection as a base, and then ran the model with a two-year delay in Light EV uptake relative to this base but then transitioning to the Demonstration Path uptake pattern by 2035. The present value out to 2050 of all vehicle costs (capital purchase and maintenance, petroleum fuel, electricity, and emissions) for this delayed pattern of uptake was compared with the present value of vehicle costs for the Demonstration Path. This gives the cost of Light EV uptake being delayed by two years up until to the transition year.

This was compared with the cost of bringing forward public Light EV charging investments by two years (again up to the transition year) compared to the charger investment pattern in the Demonstration Path.

The analysis demonstrated that the costs of Light EV uptake being delayed by two years were approximately 25 times greater than the costs of public EV charging infrastructure happening two years earlier than required.

The considerations are slightly more complicated for public ZEV truck stations because, while there is near universal agreement that BEVs will be the most cost-effective ZEV option for Light vehicles, there is less consensus for trucks between BEVs and FCEVs. Thus, although the analysis in section 6 shows that BEVs are increasingly emerging as the lowest cost trucking solutions for the vast majority of trucking use cases in New Zealand (including for the longer-distance, heavy weight categories), there is still some residual debate as to whether FCEVs may be better suited for some use cases.

Given this residual debate and uncertainty, the question arises as to whether it would be better for NZ to wait and only invest in trucking ZEV stations for the technology that has clearly emerged as the

[46] "*Shifting gear – How New Zealand can accelerate the uptake of low emission vehicles. Report 3: Electric vehicle charging infrastructure*". December 2021, Concept Consulting

'winner'. However, there are a number of factors to suggest this would deliver poor outcomes for New Zealand:

- The scale of asymmetry between over and under-investment in ZEV stations is such that it would still be cost-effective to back 'both horses' early, even if one proves to be the wrong horse.

  Thus, the effect of rolling out both technologies' ZEV stations would be to roughly double the cost of the early roll-out of ZEV stations. However, given the scale of benefit from not frustrating the uptake of ZEV trucks, this doubling of early ZEV station costs would still be cost-effective.

  Investing in both ZEV station technologies also preserves the technology agnostic approach which should ideally be applied to the vast majority of policy interventions to prevent government's inadvertently 'picking losers'.

- There is already a sufficient level of commitment from truck suppliers for both BEV and FCEV trucks to justify a minimum geographical coverage for both technologies.

  In this respect it is important to note that suppliers have indicated (in discussions for this study) that further commitments will be heavily dependent on whether sufficient public ZEV stations will be committed to by the government.

- In the case of high-capacity BEV stations for the heaviest category of trucks, there is far less risk of wasted capital investment if FCEVs do emerge as the dominant technology for trucks.

  This is because the majority of investment in BEV charging stations is the electrical infrastructure. This can be re-allocated to meet the rapidly growing demand for public charging for Light EVs – noting that there is no material residual debate as to whether FCEVs may emerge as the dominant option for the Light fleet.

- Waiting a few more years makes achievement of our commitment of 30% ZEV sales by 2030 much less likely, as national ZEV station coverage will likely be required by approximately 2025 for such a target to be met.

The current truck ZEV station funding approach is risky

While $16m of public money has been allocated to the development of hydrogen fuelling stations for FCEV trucks and a detailed hydrogen re-fuelling station development plan has been developed (see https://www.hiringa.co.nz/hydrogen-fuelling-network), no money has yet been allocated, nor a plan yet developed, for the development of either BEV charging stations for small to medium sized trucks (<20t), nor higher-capacity (megawatt) BEV charging stations needed for the heaviest category of trucks (>20t) which account of over 70% of truck fuel consumption.[47]

This contrasts with major overseas trucking markets in Europe, America, and China, where development of BEV charging stations for heavy trucks has been identified as an urgent priority, with plans being drawn up and funding allocated.

For New Zealand to only focus on one ZEV truck technology risks some combination of delayed uptake of cost-effective ZEVs or locking-in a technology that turns out to be higher cost.

To rectify this will require the rapid development of a BEV truck charging development plan and public funding commitment that is at least of the scale already provided for hydrogen fuelling stations.

[47] The increasing roll-out of high-capacity 300 kW charging stations to allow high-power charging of high-end Light vehicles will, once sufficient coverage has been reached and provided they are developed with adequate truck parking and manoeuvring space, be ideal for medium trucks of less than 20 tonnes.

How much public charging infrastructure may be required?

As noted above, $16m government funding is already granted for four hydrogen re-fuelling stations to be developed by Hiringa Energy, with 20 more stations planned by 2026. Hiringa estimates that by 2026 their hydrogen re-fuelling network will provide coverage for about 95% of long-distance heavy freight routes in the North Island and 82% of the South Island.[48]

To estimate the potential scale of investment for high-capacity truck BEV stations, analysis was undertaken using the ENZ model for a scenario where the share of ZEV trucks entering New Zealand is to reach 30% by 2030 and 100% by 2040.

This revealed that the pattern of investment will involve a significant 'hump' of investment during the middle of this decade to provide geographical coverage, but then the level of investment required will tail off for many years, as the numbers of chargers to provide adequate coverage will largely satisfy the capacity requirements of trucks. This contrasts with the Light fleet where significant ongoing investment will be required to meet capacity growth beyond the initial geographic coverage phase of investment.

This is because there are far fewer trucks than light vehicles: over 96% of the road fleet are Light vehicles, 2.5% are trucks under 20 tonnes, and 1% are trucks over 20 tonnes. It is also likely that a smaller number of sites will be required to deliver sufficient geographic coverage for trucks than for Light vehicles. This is due to a combination of truck routes being far less widely geographically dispersed than Light vehicle routes, and truck battery ranges being much greater than the first -generation Light EV ranges that dictated the initial coverage requirements for the Light fleet.

In addition, trucks have other characteristics which mean that the amount of public charging stations required per 1,000 vehicles is going to be less than for Light vehicles:

- trucks generally travel more consistent distances each day enabling batteries to be better-sized to enable a full day's travel on an overnight charge
- trucks don't have the same pattern of unusual peak public charger demand days that Light vehicles do associated with public holidays.
- freight trucks generally have regular depot stops each day for loading/unloading, making the development of top-up depot charging more cost-effective
- a very high proportion of freight trucks utilise overnight depots, whereas there are some 15% of households who don't have access to at-home charging for their Light vehicles overnight.

To get a feel for the scale of potential truck charger investment required, if it is assumed that only 35% of the number of Light charger sites are required to provide geographical coverage for <20 tonne trucks, and 20% of the number of Light sites are required to provide geographical coverage for >20 tonne trucks, we estimate that approximately $60m will need to be invested from now through to the middle years of this decade to provide sufficient coverage for the BEV truck fleet[49] – 55% of this for the >20 tonne MW-scale chargers.[50] If half of this amount were to come from government funding (as has been the case for the Light charger coverage roll-out) this amounts to $30m.

However, it should be appreciated that there is some margin of error in these estimates.

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[48] https://www.futurenetzero.com/2020/08/12/new-zealand-backs-hydrogen-fuelling-network-with-20m-funding/

[49] This assumes 115 medium capacity charging stations (approx. 300 kW) for the <20 tonne fleet, and 65 MW-scale high capacity charging stations for the >20 tonne fleet.

[50] It should be noted these 35% and 20% numbers are subject to material uncertainty. Work will continue during the course of this year to develop better estimates of the scale of truck charger investment requires.

To begin with, EECA funding rules and Waka Kotahi guidelines should be updated so that new public Light BEV fast charging stations can also be used by small-to-medium sized trucks (and cars with trailers), by providing sufficient physical space for at least one large charging bay per station. This provides a very low risk and low cost way to begin support BEV trucks now.

Where will ZEV stations be required?

In addition to ZEV stations at locations on the main highway network to cater for long-distance trips to/from cities or ports, ZEV stations will be needed within urban centres for charging urban delivery trucks in the main urban centres. This is for the 'metro floater' trucks that have no fixed routes to regular depots and can see some days with route distances of 200-250 km or more. Such facilities could also be used by Light commercial electric vehicles such as couriers and taxis. These Light vehicles undertake very long daily distances, and thus are responsible for a significant proportion of Light fleet fuel and emissions.

Another option for urban truck ZEV stations is to share infrastructure at electric bus depots. Bus depots use their charging infrastructure overnight when electric trucks will be using their own depots. However, when buses are operating during the day, this infrastructure could be utilised by urban trucks for top-up charging, paying for this service.

Developing 'density-based' ZEV station requirements in addition to distance-based geographic coverage requirements has already happened for Light vehicles in an increasing number of international jurisdictions.

For the highway-based ZEV stations, these will ideally be located at the places where truck drivers anyway take their regulated rest breaks, and which also provide other facilities such as toilets and purchase of food and drink. This could be a combination of 50-300 kW chargers and MW chargers.

What standards may be required for BEV charging?

Waka Kotahi NZTA has produced guidelines for the types of EV charging connectors to be used in New Zealand.

The majority of international OEMs planning heavy electric trucks are looking to deploy the forthcoming MegaWatt Charging System (MCS) in their vehicles, allowing charging at rates between 600 kW and 4 MW. MCS is a sister-standard to the CCS2 connectors already included in Waka Kotahi's guidelines. It is expected that heavy electric trucks will have both a CCS2 port for depot charging and an MCS port for highway charging. The CCS2 port can also be used to charge the trucks at public DC charging stations for light vehicles if there is sufficient space.

We recommend that Waka Kotahi includes the MCS connector in its guidelines as soon as this is available commercially to create certainty for vehicle OEMS and electric vehicle supply equipment (EVSE) providers. The high power level of MCS will rely on additional considerations around safety and skills for those maintaining both the charging equipment and vehicles.

Are there other charging/fuelling technologies which may emerge?

Other emerging charging technologies for electric trucks, such as catenary (overhead wire) and dynamic induction charging from the roadway are unlikely to be cost-effective and practical here due to our geography and predominance of single-lane highways. Overseas, the likes of catenary technology are generally only being regarded as feasible options for the very largest, very long-distance trans-continental highways to support 'road-train' type movement of freight – freight journeys which do not exist in New Zealand.

Some truck manufacturers are starting to offer battery-swap technology, including in New Zealand. As the battery pack geometry and swapping mechanisms are proprietary to each truck OEM, the battery-swap stations cannot be considered as public infrastructure (and thus potentially warranting public funding), unless an interoperable standard for battery-swap technology is developed in the future. This is similar to the position that has been taken where governments have not supported the roll out of proprietary light vehicle charging networks, for example Tesla's charging infrastructure network which can only be used by Tesla cars (in most countries).

3.3.2 Funding EV charging facilities in business premises

As well as public charging infrastructure, electric trucks will also require investment in charging facilities at their business premises or depots. This is to enable the low-cost overnight charging that is expected to meet the majority of BEV trucks fuel needs, plus potentially some within-day top-ups while trucks are loading/unloading for days when the total trip distance is expected to be greater than the battery range.

There is not the same 'chicken-and-egg' barrier facing investment in these depot chargers, as a business owner investing in a BEV truck knows they will need to invest in charging facilities at their depot.

Nonetheless, government financial support for some depot charging investments can help overcome infant technology barriers in the early stages of BEV truck uptake. This is currently the case through some parties receiving co-funding via the Low Emissions Transport Fund administered by EECA on a contestable basis. Until a critical mass of BEV trucks has emerged, the eligibility for depot charging installations should be expanded to be accessible to all fleet operators meeting a certain set of criteria, rather than being provided upon contestability.

Once a critical mass of BEV trucks has emerged and there is more widespread familiarity within the industry about BEV charging, the need for government funding should largely be reduced – although potentially continued as part of an overall package of purchase price incentive support.

The main exception relates to issues around costs incurred if installation of chargers happens to trigger the need for a local electricity network upgrade. As detailed in section 2.4.2, inappropriate network cost recovery approaches in many cases is resulting in 'first mover disadvantage' which is deterring some potential purchasers of BEV trucks.

The first-best solution to this issue would be for electricity networks to standardise on an appropriate approach for recovering such local network upgrade costs. However, this could take many years to develop. In the interim, it is recommended that a specific fund be developed which would help cover some or all of the 'capital contribution' costs that BEV truck owners may be being asked to fund if their installations trigger local network upgrades.

Fleets of trucks are likely to switch to BEVs gradually as replacement vehicles are needed. However, it would be significantly more costly to implement charging infrastructure for a depot gradually than to do this as a one-time investment, particularly considering the one-off costs of transformer upgrades, switchboard upgrades and cable trenching. Fleet operators will be reluctant to invest in depot-wide charging infrastructure ahead of BEV truck uptake in their fleets, creating a further barrier which may need to be overcome by specific funding.

3.4 Making electricity pricing cost-reflective

Both types of ZEV use electricity, so non-cost-reflective electricity charging approaches can act as a significant barrier in both cases, whether it be electricity charging approaches for BEV chargers at a depot or public station, or electricity charging for an electrolyser station producing hydrogen for FCEV fuelling.

3.4.1 Electricity tariff design

As set out in section 2.4.1, the predominant over-variablisation of electricity supply costs in tariffs (ie, recovering costs through $/kWh charges rather than fixed $/day charges), coupled with inadequate signalling of the variation in supply costs between peak and off-peak times, is resulting in ZEV truck owners facing higher charges for recharging their vehicles than the underlying costs of supplying such vehicles.

Moving to more cost-reflective tariffs which have a higher proportion of costs recovered through fixed charges and which have better signalling of peak/off-peak cost differentials (eg, time-of-use tariffs) would deliver better outcomes for both the transport and electricity sector.

The Electricity Authority is currently engaged in working to reform electricity network prices. It is likely that improved electricity network prices will flow-through to improved retail prices to end consumers.

3.4.2 Network upgrades

Section 2.4.2 details how the cost-allocation and recovery practices by some networks for the costs associated with a network upgrade can inefficiently affect technology uptake – whether it be the installation of chargers at a truck depot or the installation of electrolysers at a hydrogen re-fuelling station.

Recognising this 'first mover disadvantage' (FMD) barrier, some jurisdictions such as California [51] have changed legislation such that customers no longer have to pay an up-front contribution to network upgrades in order to install public EV charging or private EV depot charging infrastructure.

In New Zealand, the Electricity Authority and Transpower have considered FMD as part of their recent transmission pricing methodology work, with wide industry support for measures to mitigate (or eliminate) the problem. There has been less industry or regulatory attention on FMD within distribution networks, where each network determines its own pricing and capital contribution settings. We understand that the Electricity Authority is aware of the FMD issue at the distribution level, and staff are planning to initiate a workstream to address the issue.

3.5 Addressing emissions externalities

As set out in section 2.2, under-pricing of costs arising from ICEV exhaust emissions, including global warming from CO_2 emissions and human health costs from non-CO_2 emissions, are adversely affecting the uptake of ZEVs relative to ICEVs.

The principal mechanism in New Zealand for reflecting the costs of carbon emissions from ICEV trucks is the New Zealand Emissions Trading Scheme and the consequent increase in the price of diesel. As detailed in section 2.2.1, it is likely that the price in the NZ ETS is below the level of price associated with '1.5-degrees-consistent' action.

It is beyond the scope of this paper to consider issues around the design of the NZ ETS. However, to the extent that prices in the ETS remain below '1.5-degrees-consistent' levels, there will continue to be a need for other mechanisms to support ZEV truck uptake – even if the capital cost of ZEVs falls close to those of ICEVs.

The human health cost of exhaust emissions could potentially also be reflected in some adder on diesel prices. However, given the highly locational nature of such health costs, this may be less effective and appropriate than other measures, such as:

- Introducing a locational and time-of-use element to RUC charging which also distinguishes by fuel

[51] In 2021, the California Public Utilities Commission approved new rules to ensure utilities provide "utility-side make-ready" infrastructure to support electric vehicle (EV) charging without oncharging installation costs to the first mover, through . https://www.nrdc.org/experts/miles-muller/ca-approves-new-rules-support-ev-charging-infrastructure

- Introducing zero-emission zones in cities (as detailed in section 3.7.1 below)
- Introducing stricter limits on allowable exhaust emissions for vehicles entering New Zealand (as detailed in section 3.7.2 below)

Again, to the extent that the above measures aren't introduced, it would be appropriate to continue to have additional mechanisms to support ZEV uptake.

3.6 Altering RUC and VDAM settings to remove inadvertent ZEV barriers

As set out in section 2.5, the current settings for RUC and VDAM can introduce barriers to the uptake of ZEVs:

- Weight categorisations for RUCs creating 'boundary' issues that inefficiently penalise ZEVs
- The VDAM rules creating length constraints on the configuration of trucks which limits the ability to add batteries, or which encourage axle configurations which are internationally non-standard.

In the long term, the best way to resolve this would be to change RUC categories to a continuous formula, or to shift to a higher quantity of categories that have smaller price steps between them. Doing so however could result in all ZEVs being paying a premium than diesel trucks for the same freight task, where trucks operate close to or at their GVM limit. This is reasonable in terms of paying for road damage though creates a disincentive to ZEV trucks.

In the short term (to support FCEVs now and BEV trucks when the exemption expires), for the purposes of paying RUC, the weight bands on ZEVs could be set one tonne higher, to offset for the battery weight. This would remove operational cost disadvantage compared to diesel trucks, and would be less disruptive to the revenues and impacts on the diesel fleet. While this means ZEVs would not pay for their full road maintenance, it would mean they pay very close to doing so. This is similar to how other jurisdictions have tackled related issues; for example, the California legislature allows alternative fuel vehicles a 2,000-pound (900 kg) exemption to vehicle class weight limits and the European Union has implemented a 2 tonne class weight limit exemption for ZEV technologies, though the very top class maximum limit is not raised.[52]

With regards to VDAM rules, the government and industry should review how this tension between ZEV trucks, RUC, and VDAM rules can be better managed, to ensure that they don't inadvertently create incentives for non-standard vehicle configurations.

3.7 Supplementary policy mechanisms

3.7.1 Priority or exclusive ZEV road access arrangements

Some overseas jurisdictions have incentivised ZEV uptake through granting such vehicles exclusive access to certain parts of the roading infrastructure.

ZEV zones are the principal example, whereby only ZEV vehicles can enter such a zone – typically central city areas. As well as incentivising ZEV vehicles to deliver climate benefits, such approaches also internalise other externalities in terms of:

- human respiratory health, in that ICEV tailpipe emissions causing respiratory damage are heavily concentrated in dense urban areas
- noise pollution, noting that electric trucks are significantly quieter than ICEV trucks (which will become an increasing issue where other climate change/transport policies such as urban densification see more people living in city centres).

Another type of ZEV zone implemented overseas is exempting electric trucks from night-time urban truck curfews. The purpose of such curfews is to mitigate the community impacts of vehicle noise and emissions, however electric trucks are much quieter and do not produce emissions. Relaxing such curfews could deliver additional productivity benefits as evidenced by the experience of some curfews being relaxed due to the impacts of COVID-19 on the supply chain. A New South Wales government review of the suspension of curfews for COVID-19 reported benefits from out of hours deliveries included improved productivity and efficiency, flexibility to respond to surges in demand, reliability for consumers, fewer visible heavy vehicles at peak times and improvements to road safety.

For these reasons ZEV zones, including electric vehicle truck exemptions, would appear to have considerable merit. Auckland has proposed a Zero Emission Area for the Queen Street Valley[53], but its implementation may require legislative changes depending on the scheme design. Legislation to allow zero emission areas should be progressed by government. Other exclusive ZEV road access arrangements include:

- Exclusive ZEV truck access to some motorway slipways
- Exclusive ZEV loading zones in urban centres
- Reduced rate or exclusion from paying road tolls or congestion charges

3.7.2 Non-CO_2 tailpipe emissions regulations

Standards such as the Euro VI emissions standard mandate certain maximum levels of tailpipe emissions for gases and particulates which are harmful to human health. New Zealand currently requires the Euro V standard for heavy vehicles, a generation behind where most developed countries sit.

While there is no direct correlation between implementing stricter standards regulating emissions harmful to health and reducing CO_2 emissions, there is an indirect correlation. Advances in diesel engine fuel efficiency and vehicle design which reduce CO_2 emissions are implemented by OEMs in tandem with the leading human health emissions standards.

Truck distributors in New Zealand have informed the Ministry of Transport in 2022 about measured CO_2 reductions in the order of up to 10-20% by moving from Euro V to VI, stating this occurs as a result of better overall engine design and because Euro VI trucks require higher consumption rates of AdBlue Diesel Exhaust Fluid to reduce harmful emissions and that as the relative proportion of diesel consumed reduces, so does CO_2.

By implementing Euro VI emissions standards, ICEVs with the latest technology, including the latest CO_2 emissions reductions technologies will be encouraged here.

Euro VI in Europe also requires testing of heavy vehicles in their fleet, to ensure vehicles in service continue to conform to the emissions levels for several years after their entry. If New Zealand adopts in service conformity testing, then CO_2 and harmful emissions levels will be better maintained.

Towards the middle of the decade, Europe is expected to enact even tougher non-CO_2 regulations in the form of Euro VII. The details of this proposal are expected be proposed by the EU Commission during 2022[54]. The United States Environmental Protection Agency is likewise expected to announce tougher emission limits on U.S. trucks to come into force around 2026[55]. Drafts to date reveal

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1. [53] https://www.aucklandccmp.co.nz/access-for-everyone-a4e/zero-emissions-area-zea/

[54] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12313-European-vehicle-emissions-standards-Euro-7-for-cars-vans-lorries-and-buses_en

[55] https://www.epa.gov/regulations-emissions-vehicles-and-engines/clean-trucks-plan

emission limits that will be challenging to achieve with traditional diesel engines[56], and if they proceed, could encourage hybrid and zero-emission technology adoption[57]. If New Zealand follows Europe and the United States in adopting these post-Euro VI regulations later this decade, this could provide the dual benefit of ensuring the very best diesel engines where they remain purchased, while at the same time encouraging the supply of zero emission trucks.

3.7.3 Public funding of ZEV demonstration projects and information provision

Demonstration projects and information provision can help overcome the consumer behavioural barriers to new technology. EECA has been providing up to $5 million per year demonstration project funding through the Low Emission Vehicles Contestable Fund for five years towards electric cars, buses trucks and public charging infrastructure. This has now been replaced by the $25 million per year Low Emission Transport Fund, which also covers the marine and aviation sectors.

At the conclusion of the Low Emission Vehicles Contestable Fund, a total of $6,450,000 had been allocated to 21 BEV truck projects and 1 hydrogen fuel cell truck project.

Outside of the Contestable Fund, EECA has provided $16 million co-funding from Crown funds for the development of a public hydrogen charging network.

EECA has published a number of case studies based on the demonstration BEV truck projects it has funded. Further dissemination of the information gained through the projects is occurring through conferences and industry publications.

There is potential to increase the provision of information on zero emission trucks through both the EECA GenLess website and the Waka Kotahi NZTA website. For example, the heavy vehicle selection pages of both these websites do not mention zero emission trucks, including the Waka Kotahi guide to heavy vehicle selection[58]. Funding could be made available to include information on zero emission trucks through these sources and through Waka Kotahi programmes targeted at heavy fleet operators such as Safe and Fuel Efficient Driving (SAFED)[59].

3.7.4 Government procurement

Overseas, policies requiring government procurement of Light ZEVs for the fleet of vehicles owned by central and local governments have been very successful at incentivising cost-effective uptake of ZLEVs. Not only do such policies deliver increased ZEV vehicles in their own right, but they increase rates of ZEV uptake of privately-owned vehicles. This is because they help drive the technology along the uptake curve, helping establish ZEV supply chains and associated infrastructure, and increasing wider familiarity with the technology.

Such policies have also been very successful with buses, including in New Zealand.

Central and local government doesn't own the same proportion of trucks as it does of light vehicles and buses. However, it does contract for services which require trucks. For example, rubbish collection, road building, as well as general freight deliveries. This raises opportunities for such contracting to favour parties who will deliver a specified percentage of such services through ZLEVs. As an example, Lower Hutt City Council will have a complete electric rubbish collection service by 2024.

[56] https://theicct.org/sites/default/files/eu-commission-euro-7-and-VI-may2021.pdf

[57] www.acea.auto/files/ACEA_Position_Paper-Views_on_proposals_for_Euro_7_emission_standard.pdf

[58] https://www.nzta.govt.nz/resources/heavy-vehicle-selection-guide/heavy-vehicle-selection-guide.html

[59] https://www.nzta.govt.nz/commercial-driving/commercial-safety/safe-and-fuel-efficient-driving-new-zealand-safed-nz/

4 Which policies are likely to be best at incentivising ZEV uptake?

All of the above policy mechanisms to incentivise ZEV uptake have merit to varying degrees. This begs the question: Which one should be chosen, or should several mechanisms be implemented together?

Due to the multi-faceted nature of the barriers facing ZEV truck uptake, a range of different policy measures are required: If one barrier isn't adequately addressed, other policies to address other barriers will be much less effective.

Eight key policy mechanisms are required:

- Five are truck-sector specific, and fall within the purview of the Ministry of Transport
- Three are economy-wide policy measures that will not just affect ICEV vs ZEV uptake decisions, but also fossil-vs-renewable technology choices across the wider economy. These policies fall within the purview of other government agencies.

The five key truck-sector specific policy measures are:

1) Introducing a ZEV mandate on truck suppliers

A supplier obligation of some form is considered essential for New Zealand as:

- the effect of other countries' supplier obligations means that New Zealand will face higher truck prices without its own obligation of similar strength[60];
- supplier obligations help eliminate the potential for any financial incentives for truck purchasers being 'captured' by truck suppliers by artificially raising their ex-subsidy price; and
- manufacturers will give priority to New Zealand when determining where to allocate the finite volumes of ZEV trucks over the next decade.

The type of obligation which is most appropriate for New Zealand's truck market is a direct ZEV mandate: expressing the target in the form of a minimum percentage of truck sales that must be ZEVs. An indirect obligation – a fleet CO_2 emissions standard – is not appropriate for New Zealand's truck sector given that the lack of necessary testing data means it would take a long time, and cost a lot, to develop.[61] Other measures will be needed to help reduce CO_2 emissions from those diesel trucks which continue to be purchased. (Also noting that a fleet CO_2 standard wouldn't incentivise most of the measures to reduce truck diesel emissions). Resurrecting the Waka Kotahi / EECA heavy vehicle fuel efficiency initiative would be a valuable means of achieving this.

This situation of a ZEV mandate being most appropriate contrasts with the Light vehicle sector where, because of a combination of factors – sufficient New Zealand-specific vehicle data is available[62], there are more Light vehicle imports each year (approximately 300,000 compared to 8,000 for the heavy fleet), and light vehicle loads and uses are reasonably homogenous – it was cost-effective to develop a Light fleet CO_2 emissions standard as the Clean Car Standard[63].

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[60] This dynamic arises because of the current scarce global supply of ZEV trucks relative to global demand. In order to allocate scarce ZEV truck supply to markets without supplier obligations, truck suppliers will increase the price for sales in such non-obligation markets in order to achieve a similar margin as selling ZEV trucks into markets with supplier obligations.

[61] This difficulty is compounded by the need for a sophisticated multitude of targets to appropriately accommodate the diversity of truck sizes, weights, and uses. There is also significant variation around load weight on fuel economy, and difficulty in measuring this.

[62] Light vehicle importers have been required to provide vehicle fuel consumption information since 2008.

[63] Enacted through the Land Transport (Clean Vehicles) Amendment Act 2022, refer www.legislation.govt.nz

Further, unlike for the light fleet where low-emission vehicles in the form of plug-in-hybrid and hybrid vehicles are commonly available and affordable options to help lower fleet emissions in the short term, these technologies are not widely available for the truck fleet. Hybrid trucks can offer helpful fuel economy savings, especially in urban stop-start traffic, however only zero emission vehicles provide decarbonisation with the necessary pace to achieve our climate goals – particularly as truck manufacturers appear to be focussing on ZEVs rather than hybrids.

2) Financial incentives for truck purchasers

Solely relying on supplier obligations without addressing the barriers to ZEV truck uptake will make New Zealand a risky place for truck suppliers to operate. Given our small size, this could result in many of them exiting the New Zealand market. Supplier obligations and financial incentives for purchasers work in unison, in that obligations send very clear market direction signals and discourage price inflation, while targeted and timebound purchaser incentives enable the earlier introduction of obligations by accelerating cost parity for truck purchasers between a ZEV truck and its diesel counterpart.[64]

Although the economy-wide measures around 1.5-degrees-consistent-emissions pricing and improved electricity supply arrangements (measures (6) to (8) below) should eventually deliver the most significant TCO incentive to ZEV truck purchasers, they may take a long time to achieve full cost-reflectivity. Further, even if such cost-reflectivity were to happen overnight, and even with widespread use of leasing, the barriers relating to ZEVs high-capex-low-opex cost structure in a freight sector geared around low-capex-high-opex trucks, coupled with the significant uncertainty over ZEV trucks' residual value, mean that rates of ZEV uptake would still be significantly below least-cost-optimal levels for many years. Accordingly, additional financial incentives for purchasers will be required.

For a given level of public funding, much higher rates of ZEV uptake are achieved from giving support via a mechanism which affects the relative up-front purchase price of ZEVs and ICEVs, rather than one which affects the lifetime operating cost of ZEVs and ICEVs (eg, RUC discounts on ZEVs). Two types of purchase-price support mechanisms are recommended.

a. Allowing accelerated depreciation for ZEV trucks

Allowing accelerated depreciation for ZEV trucks will significantly help a truck operator in a market where freight terms are based around ICEV cost structures. However, this is a relatively low-cost option from a public finance perspective – being 'just' the interest cost the government incurs in funding postponed tax receipts from truck operators.

Faster depreciation rates for ZEV trucks may emerge from Inland Revenue's regular operational reviews of depreciation rates for different assets, with the fact that ZEV trucks are rapidly evolving and have uncertain residual values likely pointing to faster depreciation rates being justified. However, if such an operational review doesn't result in ZEV trucks having materially lower depreciation rates justified for 'accounting' reasons, accelerated depreciation for ZEV trucks could be justified on broader climate (and human health) policy grounds. This could require primary legislation (amending the Income Tax act) to put into effect.

Given the significant potential benefits from ZEV trucks having accelerated depreciation, it is recommended that MoT work with IRD to determine whether, and how best, to implement such a mechanism.

[64] Purchaser incentives help align the TCO for truck purchasers with the public TCO of New Zealand – noting that the presence of emissions externalities, non-cost-reflective electricity pricing, freight terms being set up for the low-capex-high-opex profile of diesel trucks, and higher private sector discount rates, means that ZEV trucks which are lower TCO from a public perspective are higher from a private truck owner's perspective.

b. Introducing a subsidy scheme for ZEV truck purchases

Accelerated depreciation is unlikely to be sufficient to deliver the required rates of ZEV truck uptake. An additional financial incentive on ZEV truck purchasers in the form of a discount on the purchase price is likely to be required. Such mechanisms have successfully been introduced in places such as California and many European countries.

Because the purchase prices of ZEVs are forecast to reduce as the technology matures, the level of discount required can therefore reduce – and be phased out completely when ZEVs reach purchase price parity with ICEVs.

As well as determining the appropriate level for such a subsidy, one of the key design choices is the source of funding:

- General taxation;
- Operational levies on vehicles generally (eg, an addition to petrol excise duty, or road user charges); or
- Fees on the sale of ICEVs, as part of so-called 'feebate' mechanisms.

The source of funding which is likely to deliver the least economically distortive outcomes is from levying fees on sales of ICEV trucks. This 'feebate' approach is the structure used for the Clean Car Discount scheme for Light vehicles.[65]

If there are sufficient ZEV truck models available to meet truck purchaser's requirements, a feebate approach is also arguably fairer than raising funds from taxpayers generally or all road users generally. However, if some truck users don't have adequate ZEV models available to meet their requirements when they need to purchase a truck, this mechanism is arguably unfair. Any mechanism which is widely perceived to be unfair is likely to engender significant opposition, jeopardising its introduction and durability. Given that there are more truck use requirements than there are Light vehicle requirements, and given truck manufacturers are at an earlier stage of transition to ZEV models than Light vehicle manufacturers, it is likely that there could be material numbers of truck use cases for which a ZEV model is not available for the next five or so years. Further, there is greater opportunity for truck operators to pass-on some proportion of the higher costs faced by ICEV trucks to end consumers, resulting in similar long-term distributional impacts as funding via general taxation.

Because of this dynamic, there may be merit in ZEV truck subsidies being funded by a broader levy base than would be achieved via a feebate. Because the number of ZEV trucks entering New Zealand is much smaller than Light vehicles, the capital spent on truck purchases each year is less than 10% of that spent on Light vehicles. Accordingly, such a broader levy would have a much smaller impact on general taxation or RUC rates than if this funding approach were used for Light vehicles.

3) Rapid investment in public BEV truck charging stations

The current lack of public truck ZEV charging/fuelling stations is a major impediment to ZEV truck uptake. The following immediate actions are recommended:

1. Government invites private sector to install public BEV fast charging for trucks, and indicates co-funding available.
2. Government updates EECA funding rules and Waka Kotahi guidelines that new public Light BEV fast charging stations can *also* be used by small-to-medium sized trucks (and cars with trailers), by providing sufficient physical space for at least one medium truck per station.

[65] Refer www.nzta.govt.nz/cleancar

3. Update Waka Kotahi guidelines to support the BEV megawatt-charging-standard once available in the international market.
4. By middle of the decade, government and private sector have installed a minimum nationwide network infrastructure for ZEV trucks, based on current and future need. (Currently underway for hydrogen stations however not started yet for electric charging stations)

Investing in a BEV truck charging network of equivalent geographic coverage to the FCEV stations is a technology neutral policy that will enable New Zealand to take advantage of whichever truck technology (BEV or FCEV) is cheapest.

The net-benefit of a rapid public BEV truck station roll-out is projected to be large because:

- There is already pent-up demand for BEV truck stations, and there is a large asymmetry between investing in ZEV stations too early versus too late;
- The majority of capital invested in BEV truck stations can be re-deployed for Light BEV charging if required – ie, there is very little risk of wasted capital in BEV truck stations; .
- Only a small number of BEV stations are needed to support large numbers of BEV trucks, because public stations are complemented by significant numbers of private chargers installed at depots. This keeps public investment cost low on a per-vehicle basis.
- The economics of BEVs for the majority of truck use cases appear materially superior to FCEVs – a fact reflected in the significantly greater global variety of BEV models and associated sales across all truck classes compared to FCEVs. (Refer sections 6 and 7 of main report).
- As hydrogen stations are likely to have strong electricity connections to perform on-site electrolysis, they can also provide BEV charging. On-site battery storage or hydrogen as a buffer can be used where this is cheaper than high-capacity grid connections.

4) Developing a scheme to provide public funding to cover some local electricity network upgrade costs triggered by installation of BEV chargers or FCEV electrolyser stations

The first-best option to address this issue would be to reform the approach electricity networks take to recovering network upgrade costs. (Option (8) in the economy-wide policy measures below). As this may take years to put into effect, an interim policy measure to guarantee public funding to cover some proportion of the costs of any network upgrade cost allocation (subject to suitable public-benefit tests) should help significantly overcome this barrier. This could also cover installation costs of depot charging. Eligibility should be offered as a grant that is more accessible than currently provided by EECA's low-emissions transport fund (LETF), which is currently contestable.

5) Removing the artificial barrier to ZEV uptake from the current RUC and VDAM specifications

The first-best solution would be to reform RUCs and VDAM in a way which didn't have such 'band boundary' issues and encourage non-standard vehicle configurations, and instead more appropriately reflected factors such as the extent to which truck weight drives roading costs.

Until such reform is implemented, New Zealand should follow jurisdictions such as Europe and California in introducing temporary exemptions which allow heavy-duty ZEVs to exceed class weight limits by certain amounts.

The three key economy-wide policy measures are:

6) Ensuring carbon prices charged on fossil fuels reach '1.5-degrees-consistent' levels

Although carbon prices in the New Zealand Emissions Trading Scheme (NZ ETS) have recently risen significantly ($75/$_{tCO_2}$ at time of writing), they are substantially below the $250/t$CO_2$ (in $2020) that the Climate Change Commission indicated would be necessary by 2050 to achieve our net-zero emissions target. Further, given that most countries' estimates of the carbon price required to limit global warming to no more than 1.5˚C are substantially higher than $250/t$CO_2$, this New Zealand net-zero-by-50 target is likely to be inconsistent with the level of action (and the prices required) to meet our Paris commitment to take action to limit global warming to 1.5˚C.

The design of the NZ ETS falls under the purview of the Ministry for the Environment which is currently undertaking a major review of key elements – in particular the inclusion of Forestry in the ETS – to ensure that prices are at levels which deliver required outcomes for New Zealand.

7) Reforming electricity tariffs to make them cost-reflective

Recovering a greater proportion of the costs of supply through fixed charges or similar, and ensuring variable tariffs differentiate between peak and off-peak periods, should result in BEVs paying much lower (and more cost-reflective) prices for charging their vehicles, particularly overnight.

The Electricity Authority is currently engaged in working to reform electricity network prices, with such reformed network prices likely to flow through to more cost-reflective retail prices.

8) Reforming the approach for the cost-recovery of local network upgrade triggered by individual consumer investments

The Electricity Authority and Commerce Commission can help standardise networks' approaches for recovering the costs of local network upgrades triggered by individual connected-parties' investments. Approaches which recognise the once-in-a-generation change occurring from electrification of fossil activities across the whole economy should help eliminate the 'first mover disadvantage' dynamic which is frustrating electrification initiatives in many sectors.

A range of supplementary policy measures could further improve rates of ZEV uptake

Supplementary measures which could improve the effectiveness of the key policy measures include:

- Priority or exclusive ZEV road access arrangements. For example, introducing zero-emission zones in certain urban areas or differentiated toll road rates. Local government can already impose outright restriction zones but differentiated entry costs would rely on developing new legislation.
- Improving the emissions regulations on non-CO_2 exhaust emissions by adopting Euro VI now and the stricter upcoming Euro VII harmful emissions standard in the second half of this decade.
- Expanding the funding of ZEV truck demonstration projects to improve sector knowledge about the opportunities (and issues) associated with ZEVs
- Introducing ZEV requirements for government procurements of some trucking services (eg, for waste management services, or other freight services). This approach appears to already be working well to stimulate the uptake of zero emission public transport buses, prompted by a government policy mandating all new public transport buses be ZEVs from 2025.

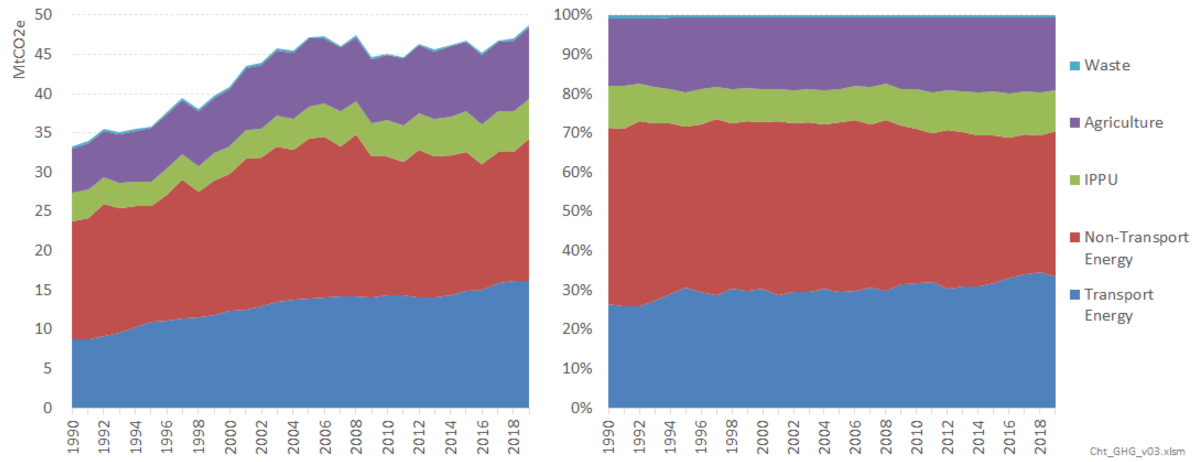
APPENDICISED SECTIONS

5 Trucks in the New Zealand context

5.1 Trucks account for a large (and growing) proportion of New Zealand's emissions

New Zealand has a greenhouse gas reduction target of achieving net-zero long-lived gases (everything except biogenic methane) by 2050. However, as Figure 8 below shows, New Zealand's long-lived gases have been growing at a steady rate from 1990 to 2019, with transport accounting for a disproportionate amount of this growth.

Figure 8: New Zealand's long-lived greenhouse gas emissions from 1990 to 2019



Source: Concept analysis of MfE data

Road transport accounts for the lion's share of these transport emissions, accounting for almost 91% in 2019.

As Figure 6 and Figure 10 below shows, trucks account for a very small number of vehicles on New Zealand's roads (approximately 3.5%) but, because of their heavier weight and because they travel much further each year, trucks account for a much greater proportion of road transport emissions (approximately 25%), and the growth in trucks has been a significant driver of the growth in road transport emissions.

Figure 9: Vehicle numbers from 2000 to 2019 (,000)

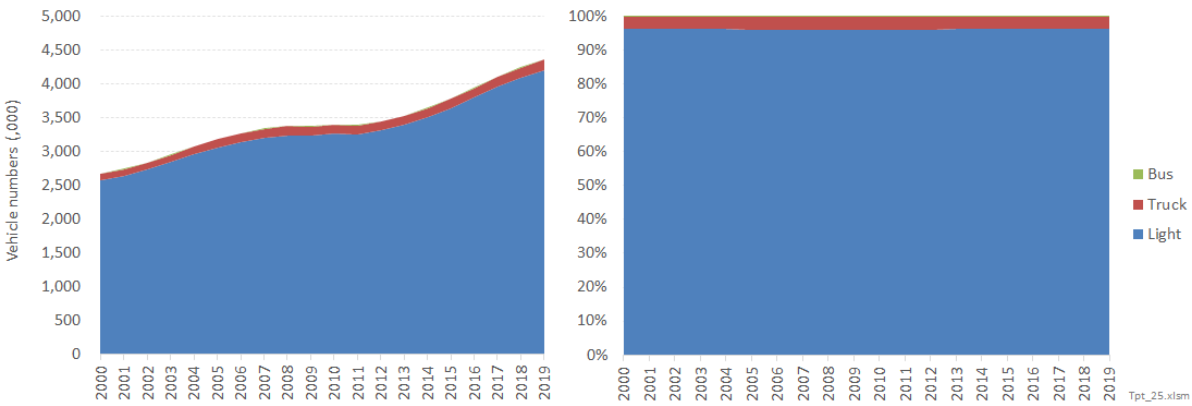
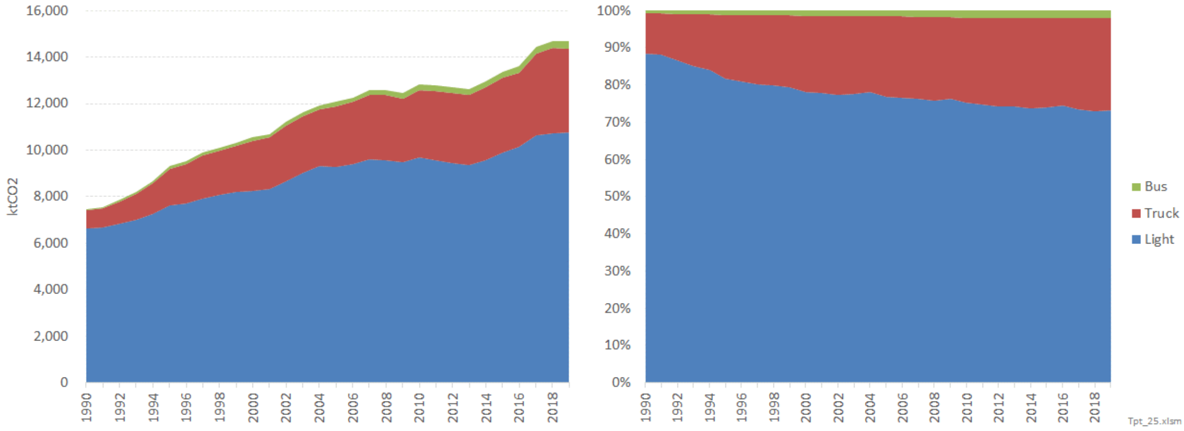


Figure 10: Road transport emissions from 1990 to 2019 (ktCO₂e)

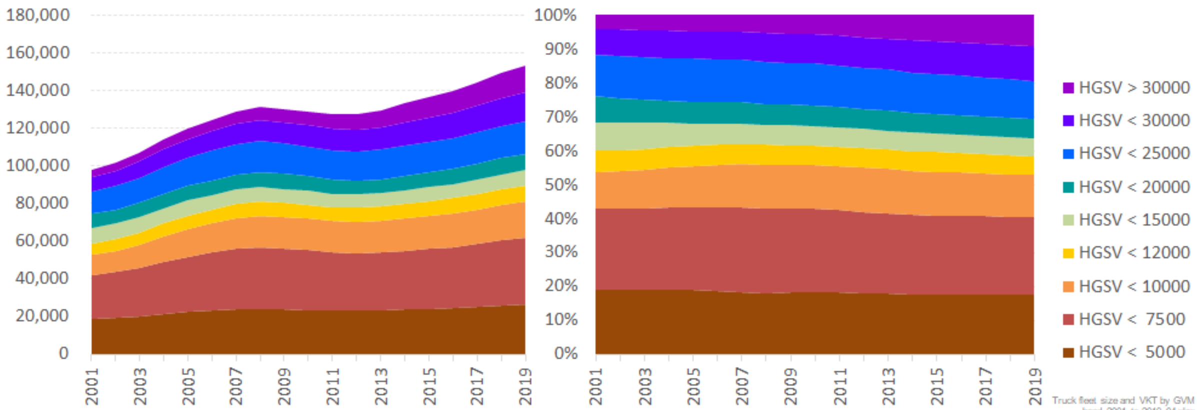


Source: Concept analysis of MBIE data

5.2 The heaviest category of trucks account for the greatest proportion of emissions

Digging deeper into the different types of trucks, Figure 11 to Figure 13 show that, although the heaviest trucks are a small proportion of the overall numbers of trucks on New Zealand's roads, because they travel much further distances and weigh a lot more, they account for the vast majority of fuel consumption (and hence emissions) for the trucking fleet. Thus, the heaviest category of trucks (>20 tonnes) only account for approximately 31% of all truck numbers but account for approximately 80% of trucking fuel consumption and carbon emissions. Further, the heaviest truck categories have been growing the fastest.

Figure 11: Split of number of vehicles by truck weight category[66]



[66] The truck weights are in kg. Hence, 'HGSV<5000' = trucks less than 5 tonnes.

Figure 12: Split of total vkt by truck weight category (bn km)

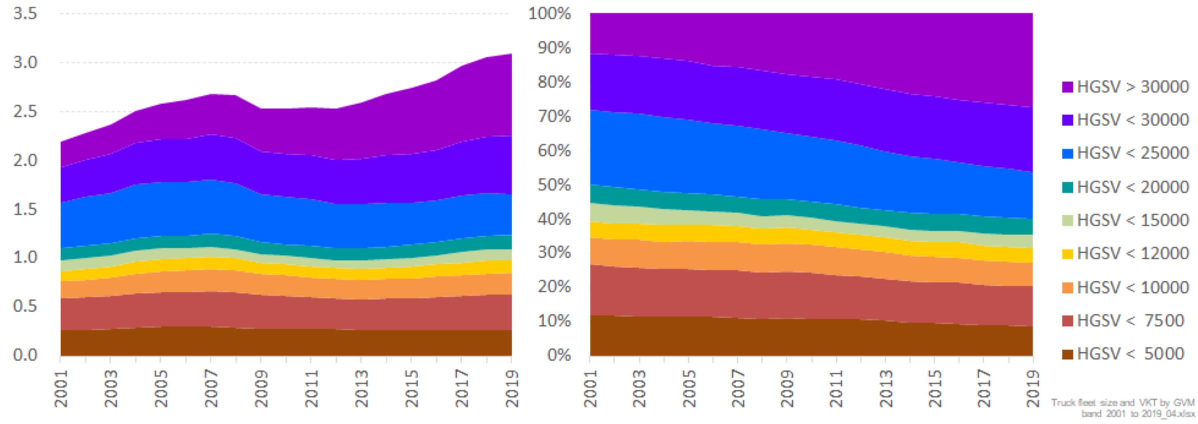
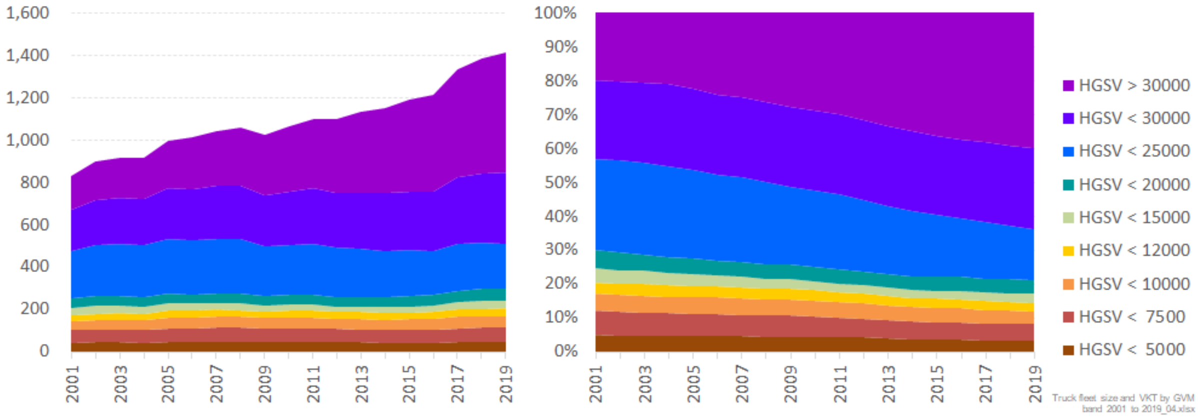


Figure 13: Split of total diesel consumption by truck weight category (l x 10^6)



Source: Concept analysis of MoT data

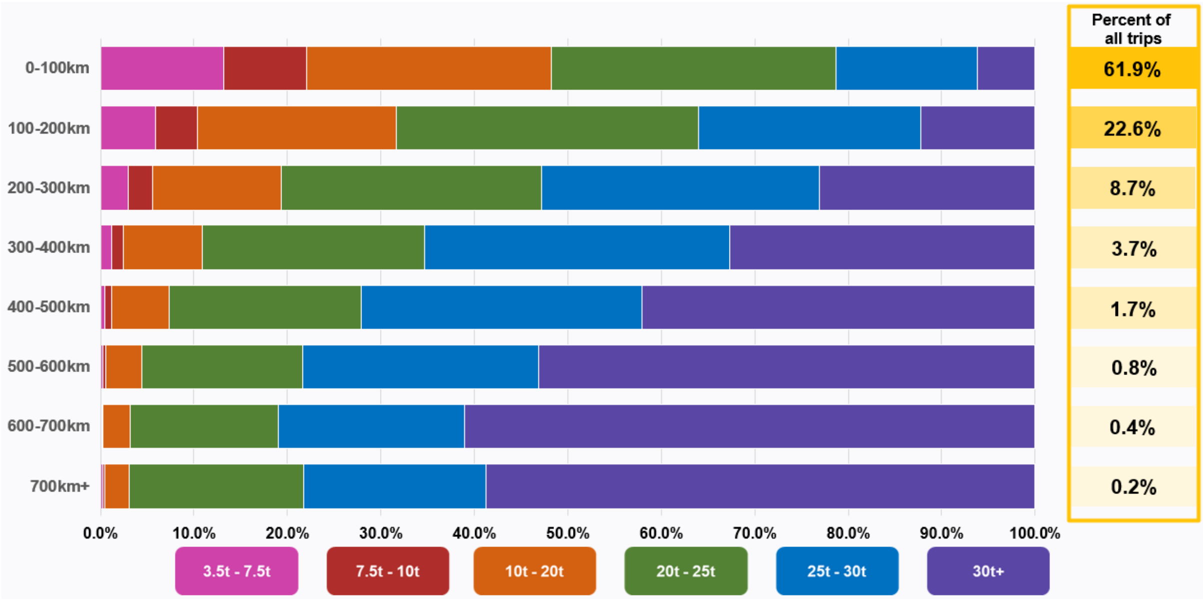
5.3 Most New Zealand truck journeys are for relatively short distances

As shown in Figure 14, analysis of telematics data from EROAD for Ara Ake[67] shows that more than 60% of all truck trips[68] were under 100 km, and nearly 85% were under 200 km. Only 3.1% of truck trips were over 400 km and 1.4% over 500 km.

[67] https://www.araake.co.nz/insights/ldhf-phase-two/

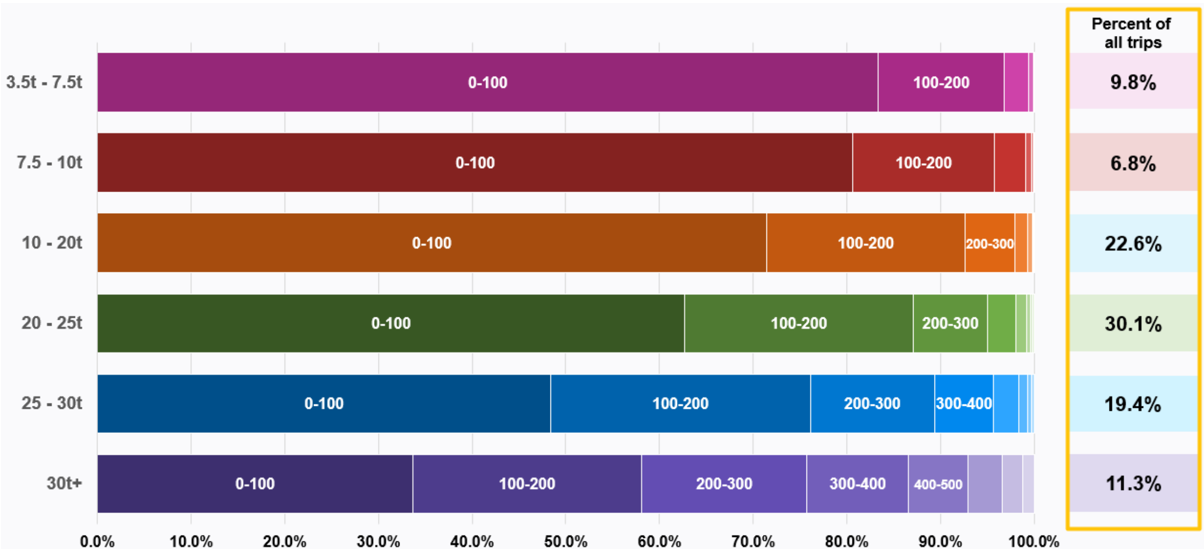
[68] A 'trip' is a journey from one destination to another. A day's travel can be comprised of multiple trips.

Figure 14: Freight vehicle trips by distance, for different vehicle weight bands



As shown in Figure 15, even for the heaviest trucks (30 tonnes+), only 7% of trips were longer than 500 km, as shown in the chart below.

Figure 15: Freight vehicle trips within each weight band by distance



On a day's driving basis (noting that a day's travel is often comprised of multiple trips, with breaks in between), Figure 16 shows a very similar picture, with the significant majority of daily distances being less than 500 km.

Figure 16: Percent of average annual day's driving within a distance band by weight band

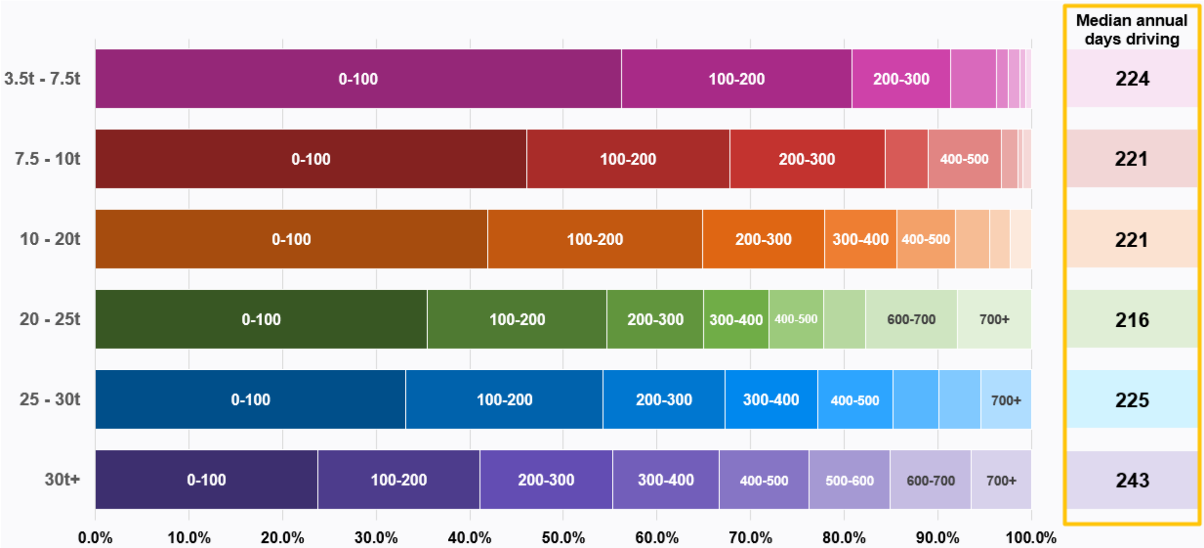
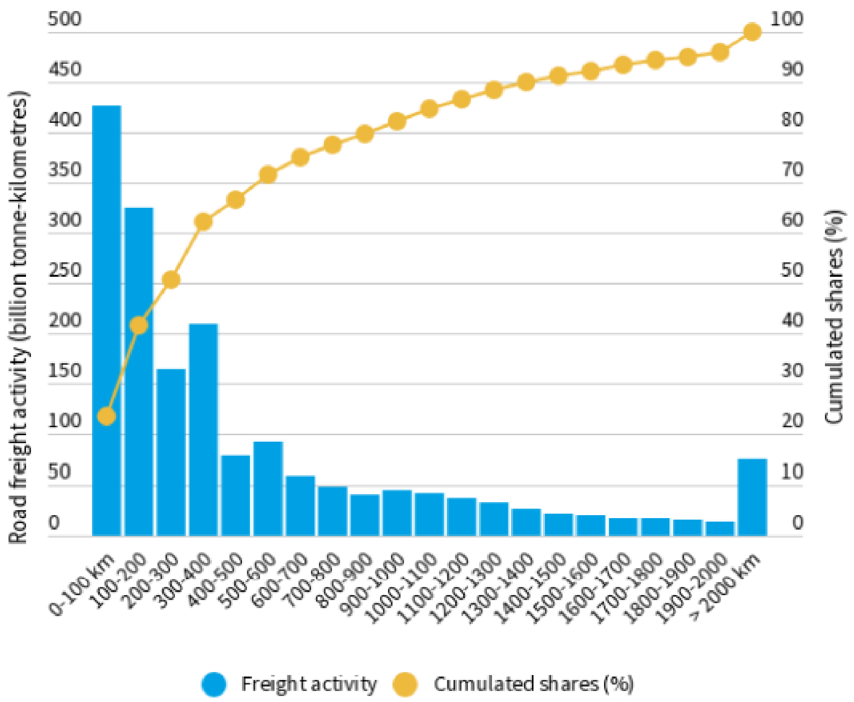


Figure 17 shows a similar distribution of truck distances for Europe. This shows that, on a tonne.km basis, 38% of trips were over 400 km. This compares with an estimate that only 4.5% of trips in New Zealand were over 400 km on a tonne.km basis.[69] This predominantly much shorter trip distance in New Zealand compared to Europe is a function of our island geography and disposition of our main urban centres. (You run out of road once you travel much beyond 600km on each island!).

Figure 17: Distribution of road freight activity across trip distances[70]



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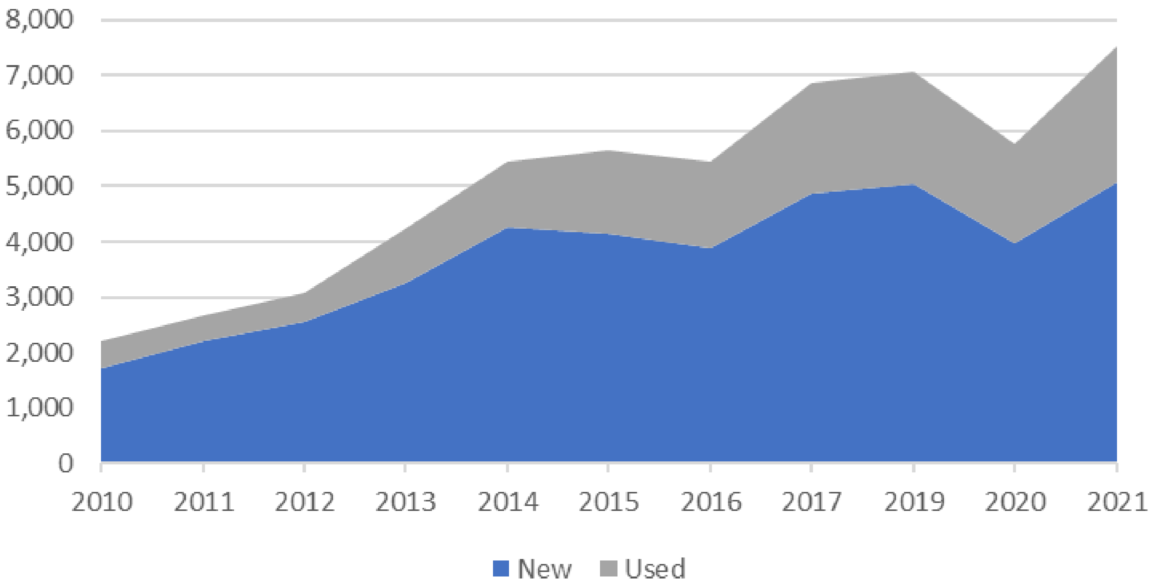
[69] The data in Figure 14 was converted into a tonne.km basis to enable a like-for-like comparison with the European data.
[70] Source: "Flicking the switch on truck charging", Transport & Environment, January 2022

5.4 What type of trucks are entering New Zealand, and who owns them?

New Zealand registered around 7,500 trucks and heavy vans in 2021, of which approximately one third are used imports. The annual first registrations of trucks and heavy vans entering the fleet new and as used imports over time is illustrated in Figure 18, based on MOT data[71]. This is comparable to countries with similar geography and population, such as Norway and Sweden, which each had annual sales of around 7,000 heavy vehicles per year in 2020[72].

Over the last decade, the average annual rate of growth of used import trucks has averaged 37% per year, higher than the average annual rate of growth of new trucks at around 25% per year.

Figure 18: Annual registrations of trucks and vans

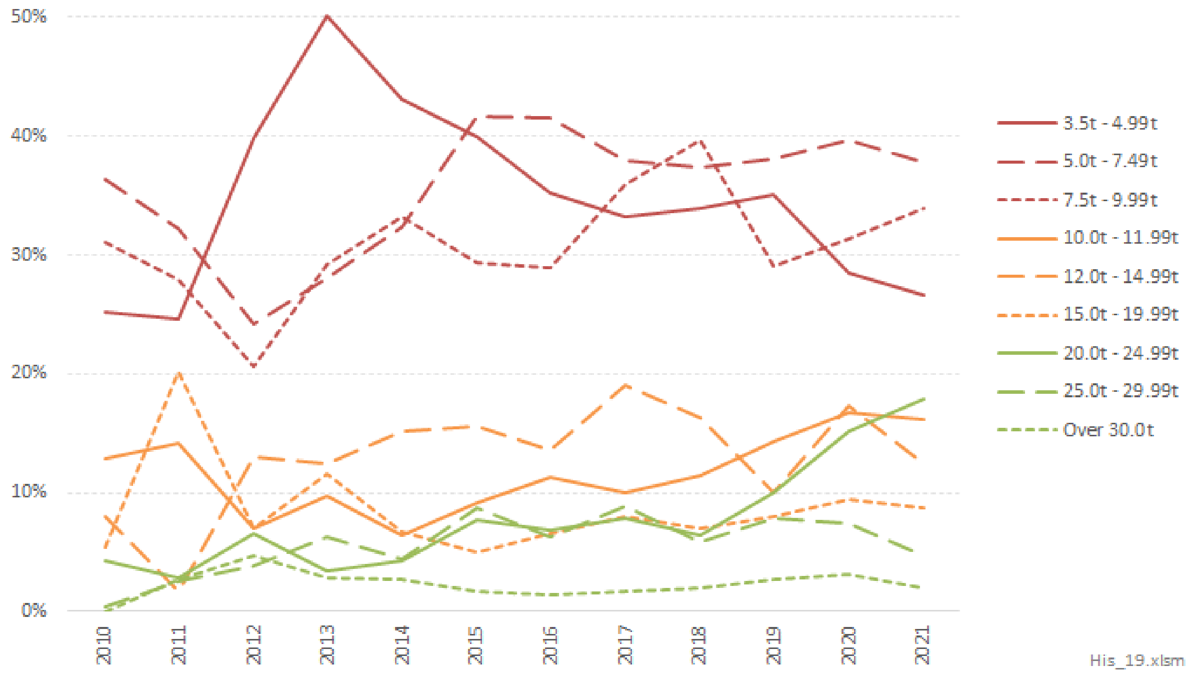


The growth in the number of heavy freight vehicles registered echoes predictions from the World Economic Forum of that the growth of eCommerce alone will increase the number of freight vehicles in the top 100 cities globally by 34% over the period 2019-2030 (base case scenario). It is also likely to reflect both population and economic growth (GDP)[73] over the same period in New Zealand.

[71] https://www.transport.govt.nz/statistics-and-insights/fleet-statistics/new-insight-sheet-page-2/
[72] https://theicct.org/publication/zevtc-effective-policies-dec2021/
[73] https://www.anz.co.nz/content/dam/anzconz/documents/economics-and-market-research/2022/ANZ-Truckometer-20220209.pdf

As illustrated in Figure 19 below, the majority of Used vehicles are for the lighter truck classes

Figure 19: Proportion of heavy vehicles entering New Zealand which are Used



In terms of truck ownership, more than 55% of heavy vehicles in the road freight industry operate as a single owner-operator or part of a small fleet (five or fewer vehicles).[74]

Many trucks are owned and operated by individuals and organisations not primarily involved in road freight, including, tradespeople, developers, contractors, local councils, manufacturers, and utilities[75].

5.5 New Zealand has several 'tail winds' to make us an attractive place for ZEV uptake

The low average trip distance undertaken by New Zealand trucks will make us a good candidate for early adoption of ZEV truck models as we will not need the higher expense of ZEV truck models that can travel very long distances.

Our highly renewable and relatively low-cost electricity grid will deliver greater emissions savings from ZEV truck uptake than countries who have higher proportions of fossil generation.

And, because we don't have a domestic manufacturing industry to protect, we also have a vehicle regulatory regime which is relatively open, enabling us to accept vehicle standards from many markets, thereby making us a more attractive place for potential suppliers.

[74] https://www.transport.govt.nz//assets/Uploads/Paper/Green-Freight-Strategic-Working-Paper_FINAL-May-2020.pdf

[75] https://www.transporting.nz/about-our-industry/new-zealands-truck-fleet

6 ZEV trucks are rapidly emerging as lower-cost solutions

6.1 The current high purchase price of ZEV trucks is projected to fall significantly

ZEV trucks currently cost significantly more to purchase than ICEV trucks: Approximately 2-3 times more expensive for BEV trucks and 3-4 times more expensive for FCEV trucks.[76] Some of this higher cost is due to inherently higher costs of certain components – particularly the batteries in BEVs and FCEVs[77], plus the fuel cell and hydrogen storage tanks in FCEVs.

However, a significant factor behind the currently high cost of ZEV trucks is that, to-date, they have yet to be produced in dedicated mass-production factories. Thus, the only ZEV truck models being produced are relatively small numbers of what are essentially demonstration models, often based on re-configuring a diesel model.

In large part this is due to vehicle manufacturers having concentrated their available development capital on the higher volume (and higher margin) Light vehicle segments – the results of which are being seen in large number of ZEV light vehicle models being produced at rapidly declining costs. However, vehicle manufacturers are now starting to turn their attention to developing ZEV truck manufacturing facilities, with an increasing number of ZEV truck models being released and in the pipeline – as detailed in section 7.2 below.

ZEV truck models are now starting to be produced in scale in dedicated manufacturing plant, and are expected to follow the same trajectory of rapid improvements in cost and performance that Light BEVs have been enjoying. For Light BEVs, the rate of improvement is such that TCO parity has already been achieved for most Light vehicle uses, and purchase price parity is expected to be achieved by around 2026 to 2028 with BEVs costing less than ICEVs beyond that point. This ability for BEVs to cost less than ICEVs is because, although the batteries are currently relatively expensive, the rest of the vehicle (in terms of drive train, electronics, assembly, etc.) costs significantly less.

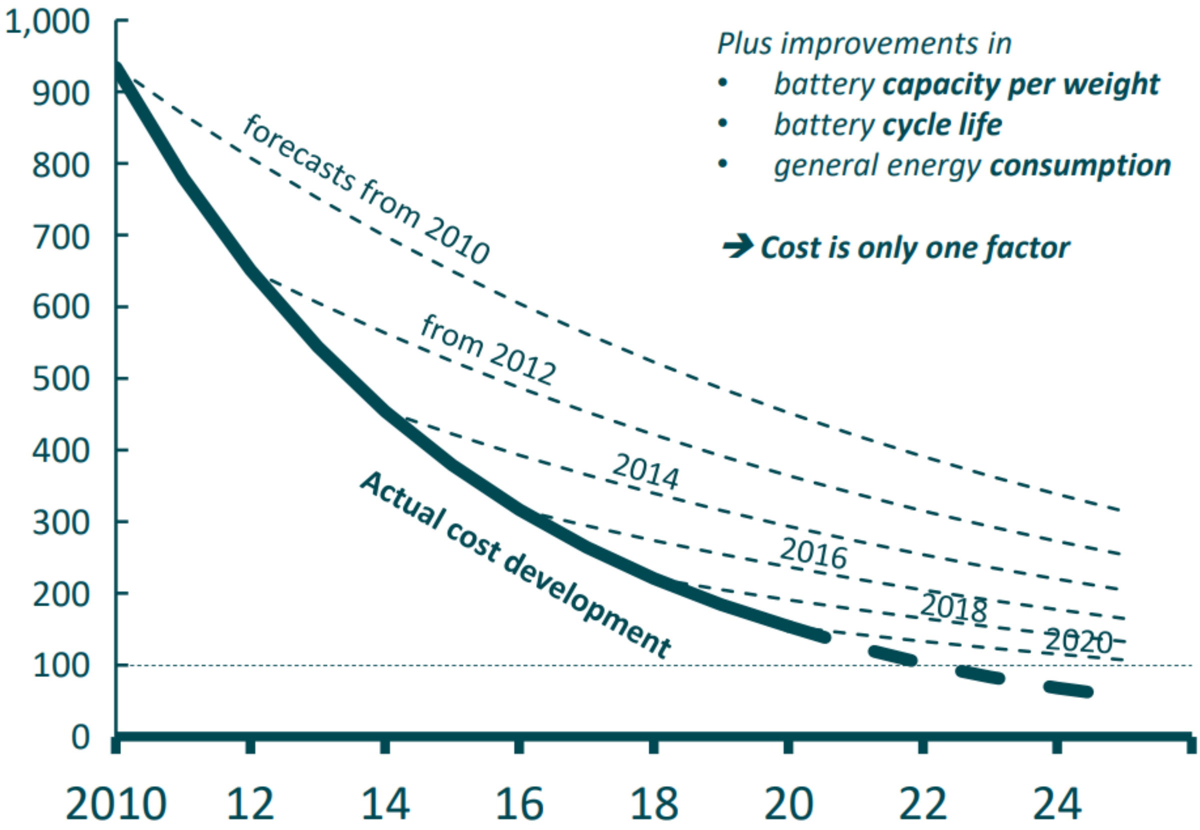
For example, in mid-2021 Bloomberg New Energy Finance (BNEF)[78] estimated that by 2025 the non-battery costs of a Light BEV will cost 72% of the non-battery costs of a Light ICEV, falling to 61% by 2030. When the cost of BEV batteries are added, this resulted in the projected purchase price of BEVs being 10% more than ICEVs in 2025 but, due to continued falling battery prices, 14% *less* than ICEVs in 2030.

Trucks are several years behind Light BEVs in terms of developing scale manufacturing facilities. But they are catching up fast as indicated by the increasing number of announcements of ZEV truck models that are coming to market.

Trucks also have a relative purchase price disadvantage in that they require proportionately more batteries than Light vehicles due to their higher per-km energy requirements associated with carrying heavy loads. However, the ongoing rate of battery cost reductions is such that this disadvantage is getting rapidly less. Figure 20 below, taken from a May 2021 investor presentation by TRATON (one of the world's largest truck manufacturers), illustrates how quickly battery costs have fallen and how this rate of fall has been approximately 2.5 times faster than predicted.

[76] Estimates based on various discussions with truck manufacturers.
[77] FCEVs also have batteries, albeit these are approximately 1/4 to 1/3 the size of the BEV battery. Batteries in a FCEV provide an additional, flexible response to the truck's power demand and (like BEVs) also capture energy from regenerative braking.
[78] "Hitting the EV inflection point", BloombergNEF, May 2021

Figure 20: Battery pack cost (EUR/kWh)[79]



Note: 100EUR equates to approximately US$115

Figure 20 also highlights that cost per kWh storage is not the only factor to have improved: battery energy density, cycle life, and efficiency of operation have all significantly improved. As set out in section 6.2, the improvement in battery energy density has been particularly beneficial for the (relatively few) truck categories where the heavier weight of batteries has been an issue.

Further, the fact that trucks are driven much further during their lifetime than Light vehicles means that the fuel and maintenance savings for BEVs relative to ICEVs are proportionately much greater for trucks than for Light vehicles. This significantly counteracts the purchase price disadvantage to the extent that trucks are likely to overtake Light vehicles in terms of the extent to which BEV TCOs are lower than ICEV TCOs.

6.2 BEV trucks will soon be lower TCO options than ICEVs

To illustrate the overall effect of this, we have developed an example of the economics of a >30t tractor unit – the heaviest category of truck which travels the longest distances, carries the most weight, and consequently is responsible for the greatest amount of fuel consumption. A diesel ICEV heavy truck costs approximately $250k. In contrast, a BEV truck currently costs two to three times that amount. However, as truck manufacturers start to produce BEV trucks in dedicated production facilities (rather than re-tooling ICEV trucks to have BEV options), significant economies are expected.

If BEV truck manufacturing can reach scale economies such that the non-battery cost of a BEV truck can be 72% of that of an ICE truck (ie, the same as the projected ratio for Light BEVs for 2025) then the non-battery cost of a BEV truck equivalent to a >30t $250k ICEV truck will be $180k. For a heavy BEV fuel efficiency of 135 kWh/100km and a range of 600 km, this gives rise to a need for an

[79] Source: "DEEP DIVE E-MOBILITY – THE TRATON PERSPECTIVE", TRATON Group, May 2021

810 kWh battery. At BNEF's projected 2030 battery prices of US$60/kWh[80] (approx. $86/kWh) this results in a battery cost component of $70k. This gives an overall price of $250k – ie, purchase price parity.

It is not known when BEV trucks will reach this point of scale manufacturing economies but, given the rate at which truck manufacturers are starting to produce BEV models (set out in section 7.2 below) and the increasingly stringent ZEV truck policies being implemented by major truck markets such as Europe, California, and China (set out in section 7.1 below), it seems likely that purchase price parity will be reached at some point between 2030 and 2040.

Further, 600 km range is likely to be in excess of what is required for most truck uses in New Zealand given the relatively small size of each of our islands. Thus, as illustrated in section 5.3, for this heaviest weight category:

- approximately 50% of truck *driving days* are for less than 250 km, and only 24% are for more than 500 km
- approximately 50% of truck *trips* are for less than 150 km, and only 7% are for more than 500 km.

And, as also set out in section 5.3, for lighter truck weight categories the average distance travelled in a day and per trip falls significantly. Given this travel pattern, it is likely that New Zealand truck operators will tend to purchase BEV trucks with smaller (cheaper) batteries, and use the back-stop of within-day public charging or depot charging (eg, when unloading at a destination) to top-up for those days when travel is longer than normal.

In addition, even before purchase price parity is reached, over the lifetime of the truck on New Zealand roads we are already very close to reaching TCO-parity for BEV trucks from a *public* cost-benefit basis. Using the ENZ model developed for the Climate Change Commission, we have estimated that the present value of whole-of-life fuel, carbon and maintenance costs for a >30t ICEV truck entering New Zealand in 2022 will be be $925k, $220k, and $115k, respectively, whereas for an equivalent BEV truck they are estimated to be $490k, $0k, and $90k.[81] In total, the lifetime operating costs of a heavy BEV truck entering New Zealand in 2020 are estimated to be $685k less than of an ICEV truck. And for a truck entering in 2030, the relative carbon savings of BEV trucks will likely grow as the Climate Change Commission is projecting that carbon prices will need to steadily increase from 2020 through to 2050 and beyond in order to meet our emissions-reduction requirements.

Given the current estimated 2-3 times purchase price premium of BEV trucks relative to ICEV trucks, this analysis indicates that heavy BEV trucks are already very close to being lower TCO options than ICEV trucks from a public perspective. With the likelihood of very significant purchase price cost reductions as scale manufacturing starts to be achieved and battery prices continue to reduce, we estimate that they will be lower TCO options on a public-benefit basis before 2025.

However, from a private truck-owner perspective, the barriers detailed in section 2 mean that BEV trucks are further away from being cost-effective.

This analysis is consistent with other analyses undertaken by overseas agencies. For example, a November 2021 study by the ICCT[82], did a detailed bottom-up analysis of the TCO of the heaviest

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[80] BNEF project battery prices to fall from US$137/kWh in 2020 to US$60/kWh by 2029.

[81] These estimates are from a public cost-benefit perspective (ie, over the whole life a vehicle is expected to be on New Zealand roads, ignoring taxes, and fully cost-reflective supply costs of diesel or electricity). Other assumptions are: lifetime vkt of 1.8 million km, US$60/bbl oil prices, carbon prices following the CCC's demonstration path trajectory.

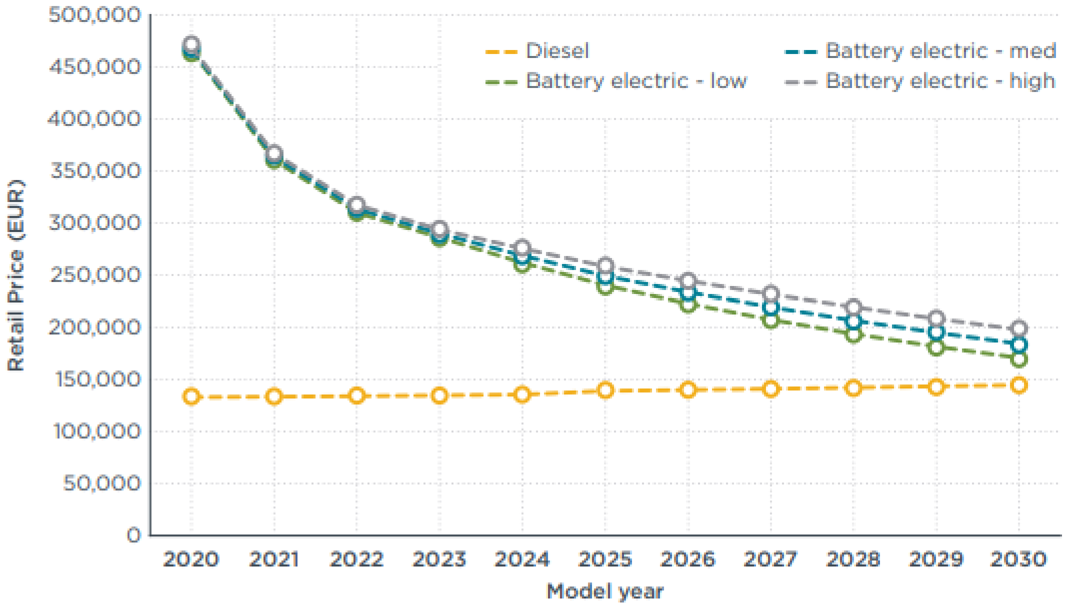
[82] "*Total cost of ownership for tractor-trailers in Europe: Battery electric versus diesel*", The ICCT, November 2021

category of trucks (40 tonne GVM for diesel, 42 tonne for BEV) carrying a range of payloads (19.3 tonnes down to 2.6 tonnes) for daily distances of 500 km.

With the projected reduction in BEV purchase costs shown in Figure 21, ICCT estimated the TCO of BEV trucks from a truck owner's perspective is projected to drop below that of ICEV trucks between 2024 and 2029 – with the variance being between different European countries due to differences in electricity and diesel prices, road tolls, and currently implemented policy measures to support BEVs.

When the externality costs of CO_2 were added to the TCO evaluation, the time when TCO parity is achieved drops to 2022. ie, from a public benefit perspective, heavy BEV trucks were projected to be already cost-effective.

Figure 21: Projected European heavy tractor-trailer purchase prices[83]



Another study by Lawrence Berkley Laboratories in March 2021 came to a very similar conclusion, including that a battery cost reduction from US$135 to US$60 per kWh from 2020 to 2030 would provide electric trucks with a 40% TCO improvement over diesel.[84]

6.3 FCEV trucks appear further away from cost-effectiveness

Relative to BEVs, FCEVs have both advantages and disadvantages.

There are three main potential advantages:

- ***FCEVs have longer ranges and faster re-fuelling times***. This utility for long distance trucks is the current main advantage for FCEVs. However, this advantage is significantly reducing due to several factors:
  - the rapid improvement in battery costs means that BEV trucks are starting to become available whose ranges satisfy the vast majority of New Zealand's daily operating distances.
  - the development of MW-scale chargers allows for fast top-ups of BEV trucks for those days when journeys are longer than average. In this it should be noted that top-ups can occur during scheduled stops, and that top-ups do not need to completely fill the battery but

[83] "*Total cost of ownership for tractor-trailers in Europe: Battery electric versus diesel*", The ICCT, November 2021

[84] "*Why Regional and Long-Haul Trucks are Primed for Electrification Now*", LBL, March 2021, https://eta-publications.lbl.gov/publications/why-regional-and-long-haul-trucks-are

instead add enough to enable the rest of the day's trips to be undertaken before completely re-charging overnight at the truck depot.

These developments mean that BEVs are emerging internationally as practical options for even the heaviest category of long distance trucks.

- ***FCEVs weigh less due to the relatively heavy weight of batteries***. FCEVs contain batteries, adding weight to the truck (about the same amount as found in a passenger EV, see Section 7), which may influence payload. However, BEV trucks have much more substantial batteries (four to five times the amount of a FCEV) and this can noticeably reduce payload. For the very heaviest category of trucks an extra tonne of batteries means one less tonne of freight to be carried. This is a key advantage in the current generation of ZEVs. However, this advantage is also significantly limited and reducing due to a couple of factors:

  – the majority of trucks are *volume-constrained* for their purpose, not *weight-constrained*. [85]

  – even for truck uses which are weight-constrained, rapid and continuing improvements in battery energy densities is significantly reducing the extent of this BEV disadvantage – to the point where it is projected to be largely irrelevant for heavy trucks by the end of the decade.[86]

  That said, there are some current regulatory barriers in terms of how RUCs are charged which can create some weight penalties, even for small and medium BEV trucks. Section 2.5.1 addresses this further.

- ***Hydrogen can be stored which allows production of hydrogen to be focussed more towards periods of low electricity prices***. This potential advantage is relatively small in New Zealand given our hydro-dominated power system which results in low-price periods occurring predominantly in summer and with significant year-to-year variance – factors which require storage capacities of many months of storage (or more) to take advantage of. Hydrogen storage capacities of this scale are not cost-effective. Further, the predominant lower overnight electricity prices can be taken advantage of just as much by BEVs as hydrogen production for FCEVs.

Offsetting these potential FCEV advantages, are a number of disadvantages relative to BEVs:

- ***Their current purchase prices are approximately 33% to 50% more expensive than BEVs***, as indicated on page 66 above. Over time, this cost differential may reduce if international FCEV uptake is fast and FCEV's move down their learning curve. However, if international BEV truck uptake is faster, FCEV's may not catch up.

- ***Their fuel costs are considerably greater***, as three times as much renewable electricity is needed to produce hydrogen to power a FCEV compared to the amount of renewable electricity required to power a BEV, plus the capital cost of an electrolyser and any transport costs of the hydrogen fuel needs to be taken into account.

- ***Their maintenance costs are greater than a BEV***, given that they need the same electric motor as a BEV but additionally need a fuel cell and hydrogen storage tank. FCEVs also contain significant lithium-ion batteries (refer list of models in Section 7). Both these batteries and the fuel cell will require replacement at intervals during the life of the truck.

Taking all the relative advantages and disadvantages of FCEVs together, and the extent to which these advantages and disadvantages are getting greater or smaller, the use-cases where FCEVs are considered potentially more cost-effective than BEVs are the very long-distance journeys which can

[85] "*Why Regional and Long-Haul Trucks are Primed for Electrification Now*", LBL, March 2021, https://eta-publications.lbl.gov/publications/why-regional-and-long-haul-trucks-are

[86] https://www.transportenvironment.org/discover/why-the-future-of-long-haul-trucking-is-electric/

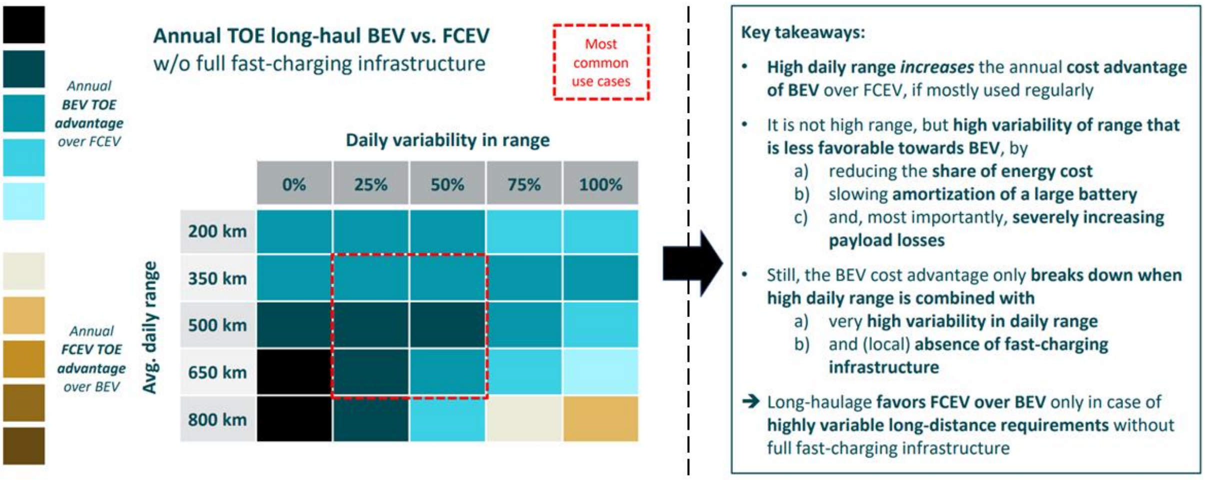
represent a significant proportion of t.km in America, Europe, Australia, and China, but which are essentially non-existent in New Zealand due to our geography.

For example, a recent ICCT report[87] estimates that the threshold daily distance for heavy trucks above which FCEVs could become cost-effective relative to BEVS is 650 miles (1,050 km). However, as section 5.3 illustrates, only 0.2% of truck trips in New Zealand are greater than 700km with an even smaller proportion being greater than 1,000km.

Figure 22 shows the evaluation by truck manufacturer, TRATON (which includes the Scania and MAN brands), of the relative advantage of BEVs and FCEVs for different use cases in the European market. Again, their evaluation is that there will only be a very small number of use cases and combination of circumstances where FCEVs will have a TCO advantage:

- Very long daily distances; and
- Very large daily variability in range (noting that their evaluation is that BEVs are strongly more cost effective for extreme long distances which are done regularly every day); and
- No fast-charging infrastructure for BEVs. If fast charging exists for BEVs, even this FCEV-favourable use case segment is removed.

Figure 22: Relative advantage of BEV versus FCEV for different truck use cases[88]



TRATON's conclusion is that BEVs will be the mainstream truck technology across all major applications, including long-haul, but that FCEVs could be more cost-effective for certain niche applications.

As section 7.2 sets out, this assessment of the relative cost-effectiveness of BEV and FCEV trucks appears to be reflected in the fact that global truck manufacturers are starting to produce a much greater range, and selling significantly more, BEV models than FCEV models. This is for all weight categories, including the heaviest categories for long-distance duties.

However, it should be appreciated that there remains a diversity of views on this issue. Thus while some OEMs have decided to head completely down the BEV route[89] and some initially FCEV-only

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[87] "*Infrastructure to support a 100% zero-emission tractor-trailer fleet in the United States by 2040*", ICCT
[88] Source: "DEEP DIVE E-MOBILITY – THE TRATON PERSPECTIVE", TRATON Group, May 2021
[89] For example, see this statement from last year from the heavy truck manufacturer Scania:

> *"Scania's aim is to be the leader in the shift towards a sustainable transport system. Battery electric vehicles will be the main tool to drive this shift and to enable decarbonised transport solutions with better transport economy to customers.*

OEMs have started to produce BEV models (eg, Nikola), other OEMs such as Hyundai have made a significant investment in FCEV technology and continue to produce and promote such models.

The rapid development of electric solutions for heavy-duty vehicles includes the fast advancement of battery technology in respect of energy storage capacity per kg. Charging time, charging cycles and economics per kg are improving rapidly. This means these solutions will become more cost effective, primarily in repetitive and predictable applications. They will gradually overtake Scania's industry-leading fossil and biofuel powered solutions in most transport applications.

Scania has invested in hydrogen technologies and is currently the only heavy-duty vehicle manufacturer with vehicles in operations with customers. The engineers have gained valuable insights from these early tests and efforts will continue. However, going forward the use of hydrogen for such applications will be limited since three times as much renewable electricity is needed to power a hydrogen truck compared to a battery electric truck. A great deal of energy is namely lost in the production, distribution, and conversion back to electricity.

Repair and maintenance also need to be considered. The cost for a hydrogen vehicle will be higher than for a battery electric vehicle as its systems are more complex, such as an extensive air- and cooling system. Furthermore, hydrogen is a volatile gas which requires more maintenance to ensure safety."
https://www.scania.com/group/en/home/newsroom/news/2021/Scanias-commitment-to-battery-electric-vehicles.html

7 An increasing number of countries and manufacturers are moving to ZEV trucks

7.1 Country policies

Recognising the significant environmental (and increasingly economic) benefits of ZEV trucks, a growing number of countries and jurisdictions are making commitments to significantly accelerate the rate of uptake of ZEV trucks – with some also committing to complete phase-out of ICEVs within the next couple of decades.

In 2021 during COP26, fifteen countries including New Zealand signed a Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles, in which countries commit to working together to enable 100% zero-emission new truck and bus sales by 2040 with an interim goal of 30% zero-emission vehicle sales by 2030, to facilitate achievement of net-zero carbon emissions by 2050.

- Austria
- Canada
- Chile
- Denmark
- Finland
- Luxembourg
- Netherlands
- New Zealand
- Norway
- Scotland
- Switzerland
- Turkey
- United Kingdom
- Uruguay
- Wales

As set out in detail in section 2 of this report, there are significant barriers to the cost-effective uptake of ZEV trucks. Recognising this, most of these countries are implementing policies to enable these ZEV uptake targets to be achieved. A summary of policies used in key jurisdictions internationally to accelerate the uptake of ZEV trucks is given in Table 1 below.

Table 1: Summary of international policies to facilitate ZEV truck uptake[90]

Policy	Jurisdiction							
	California	China	EU	Japan	South Korea	UK	USA	Canada
Heavy ICEV phase out target	2045					2040		2040
CO_2 standard	Yes	Yes	Yes	Yes		Yes	Yes	Yes
ZEV sales mandate	Yes							Yes
Purchase incentives	Yes	Yes	In Netherlands, France, Germany, Spain, Sweden	Yes	Yes	Yes	Yes	Yes
Tax exemption		Yes	In France	Yes				
In-use incentives	Yes		In Germany		Yes			
Infrastructure strategy	Yes		Yes	Yes	Yes			
Public infrastructure funding	Yes	Yes	In Sweden	Yes				
Private infrastructure funding	Yes	Yes	Yes	Yes	Yes		Yes	
Fleet purchase requirements	Yes	Yes	Yes		Yes			

One key take-away from Table 1 is that most jurisdictions are using a suite of policies to address the different barriers facing ZEV uptake.

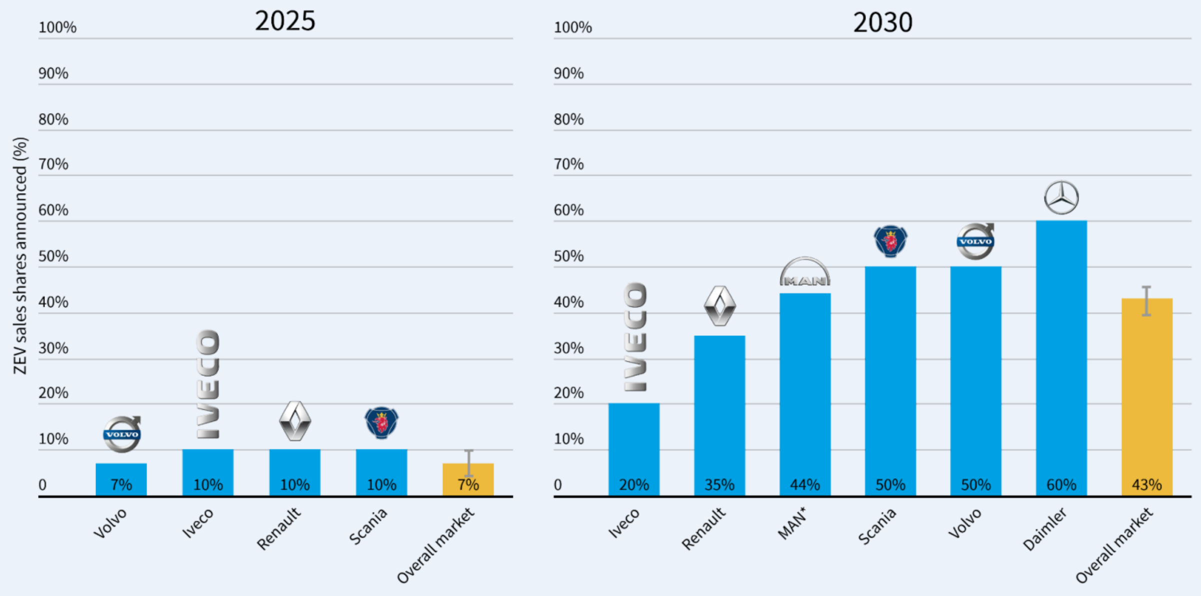
7.2 Manufacturers

Truck manufacturers are following countries in terms of committing to ZEV trucks.

For example, as Figure 23 below shows, European manufacturers have collectively committed to achieving a minimum 43% of truck sales being ZEVs by 2030 – a huge increase from the 2% level achieved in 2020, and greater than Europe's current 30% target.

[90] Based on https://theicct.org/publication/zevtc-effective-policies-dec2021/

Figure 23: Announced European truck makers ZEV voluntary sales commitments[91]



Indeed, the scale of commitments from truck manufacturers is starting to overtake that of countries' commitments, resulting in calls from stakeholders such as the ICCT to increase the level of these policy commitments.

This commitment from manufacturers is being reflected in an increasing number of ZEV trucks being brought to market.

The International Energy Agency provides data on the number of Battery Electric, Plug-In Hybrid Electric and Fuel Cell Electric trucks on the roads globally[92]. As at the end of 2020, there were over 30,000 BEV trucks, 200 PHEV trucks and 3,000 FCEV trucks. The majority of electric trucks deployed are in China.

Table 2 shows a snapshot of what ZEV trucks are available internationally today, distinguishing between BEV and FCEV models.

Table 2: ZEV trucks and heavy vans available internationally

Excludes retrofits on other OEM cab chassis. List as at February 2022 and may not be complete (particularly Chinese manufactured trucks). Tesla has widely announced their "Tesla Semi". This is not noted in the table below because though it will soon enter production, it is not currently available.

ZEV make and model	GVM, tonnes	Battery,[93] kWh	H_2 fuel cell, kW	Range, km	Configuration	Status in NZ (May 2022)
BEVs						
BYD 8TT[94]	47	409		200	Tractor: 6x2	Not available
BYD 6F[95]	11	221		200	Rigid: 4x2	Not available

[91] Source: "*Easy Ride: why the EU truck CO_2 targets are unfit for the 2020s*", Nov-2021, Transport & Environment
[92] https://www.iea.org/reports/global-ev-outlook-2021
[93] Traction battery in BEV, auxiliary battery in FCEV
[94] https://californiahvip.org/wp-content/uploads/2020/09/2019-BYD-8TT-Cut-Sheet-190306.pdf
[95] https://californiahvip.org/vehicles/byd-6f-cab-forward-truck/

ZEV make and model	GVM, tonnes	Battery,[93] kWh	H_2 fuel cell, kW	Range, km	Configuration	Status in NZ (May 2022)
DAF CF Electric[96]	29 or 37	350		220 or 250	Rigid: 6x2 Tractor: 4x2	Not available
DAF LF Electric	19	282		280	Rigid: 4x2	Not available
Freightliner eCascadia[97]	37	475		400	Tractor: 6x2, 6x4	Not available
Freightliner eM2[98]	11 - 15	315		370	Rigid 4x2	Not available
Fuso eCanter[99]	6 or 7.5	81		150	Rigid 4x2	Available
Kenworth T680E[100]	25 and 37	396		240	Rigid: 6x4 Tractor: 4x2, 6x4	Not available
Kenworth K270E / K370E[101]	11 and 15	141 and 282		160 and 320	Rigid: 4x2	Not available
Lion 8T[102]	37	653		418	Tractor: 6x2	Not available
Lion 6	11	252		320	Rigid: 4x2	Not available
MAN e-TGM[103]	26	185		190	Rigid: 6x2	Not available
Mercedes-Benz eSprinter2[104]	4 and 5					Not available
Mercedes-Benz eActros[105]	Up to 27	336 or 448		300 or 400	Rigid: 4x2, 6x2	Not available
Peterbilt 579EV[106]	36	396		240	Tractor: 6x2, 6x4	Not available
Peterbilt 220EV	11 or 15	141 or 282		160 or 320	Rigid: 4x2	Not available
Renault D ZE[107]	16 or 26	200 - 395		120-300	Rigid: 4x2, 6x2	Not available

[96] https://www.daf.com/en/about-daf/sustainability/alternative-fuels-and-drivelines/battery-electric-vehicles
[97] https://freightliner.com/trucks/ecascadia/
[98] https://freightliner.com/trucks/em2/
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[103] https://www.man.eu/de/en/truck/all-models/the-man-etgm/etgm.html
[104] eSprinter1 van is available in NZ but is a light van, eSprinter2 has heavy van options which are not available in NZ https://www.mercedes-benz.co.nz/vans/en/sprinter
[105] https://www.mercedes-benz-trucks.com/en_GB/emobility/world/our-offer/eactros-and-services.html
[106] https://www.peterbilt.com/resources-support/manuals-brochures
[107] https://www.renault-trucks.co.uk/product/renault-trucks-d-all-electric

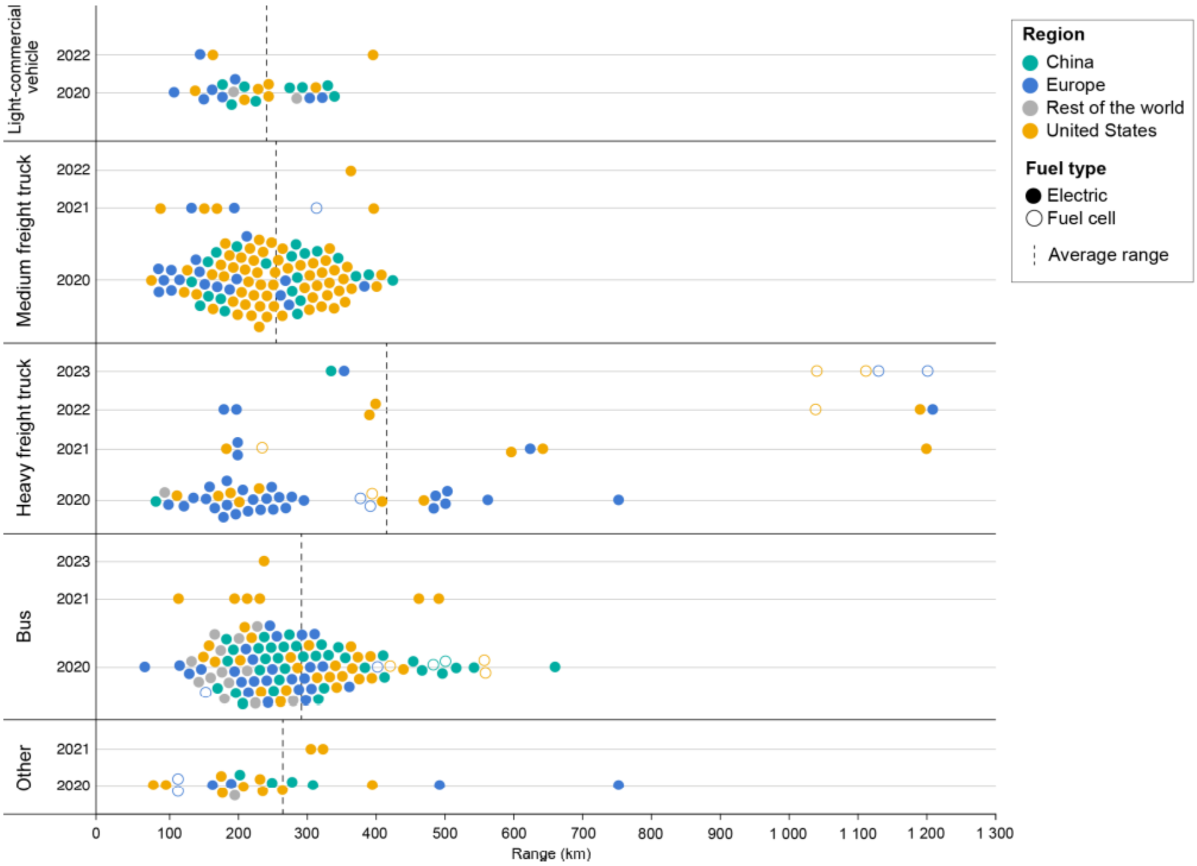
ZEV make and model	GVM, tonnes	Battery,[93] kWh	H_2 fuel cell, kW	Range, km	Configuration	Status in NZ (May 2022)
Scania[108] P series	Up to 27	165 or 300		250	Rigid: 4x2, 6x2, 6x2*4	Available mid 2022
Volvo FE Electric[109]	Up to 27	200 or 265		200	Rigid 4x2, 4x6	Orders likely from late 2022
Volvo FH Electric	Up to 44	180 - 540		300	Tractor: 4×2, 6×2, 6x4Rigid: 4×2, 6×2, 6×4, 8×2, 8×4	Orders likely from late 2023
Volvo FL Electric	Up to 16	200 - 395		300	Rigid 4x2	Orders likely from late 2022
Volvo FM Electric	Up to 44	180 - 540		380	Tractor: 4×2, 6×2, 6x4Rigid: 4×2, 6×2, 6×4, 8×2, 8×4	Orders likely from late 2023
Volvo VNR Electric	15 to 37	375 or 565		560	Rigid: 4x2,6x2 Tractor: 4x2, 6x2, 6x4	Not available
XCMG E100[110]	4.5			180	Rigid: 4x2	Available
XCMG E300	10			-	Rigid: 4x2	Available
XCMG E700 Battery swap	50	282		-	Rigid: 8x4 Tractor: 6x4	Available
XCMG XGE90	90	422		-	6x4 dump truck	Available
XCMG TFT125	49	350		-	6x4 dump truck	Available
FCEVs						
Hyundai Xcient Fuel Cell[111]	18 or 36	72	180	400	Rigid: 4x2 / plus trailer	Trials in 2022
Hyzon Hymax-450[112]	Up to 70	140	240	650	Tractor: 6x2	Available
Hyzon Hymax-GSL		140	60	200	Rigid: Side-load rubbish truck	Available
XCMG E700 Hydrogen FCEV	49	100	Not stated	400	Tractor: 6x4	Available

108 https://www.scania.com/nz/en/home/products-and-services/trucks/our-range/scania-battery-electric-truck.html
109 https://www.volvotrucks.com/en-en/trucks/alternative-fuels/electric-trucks.html
110 https://etrucks.co.nz/
111 https://www.hyundai.co.nz/trucks/xcient/fuel-cell
112 https://hyzonmotors.com/wp-content/uploads/2021/10/Hyzon-HyMax-450-HyMax-GSL-update-251021.pdf

From the situation a few years ago of being essentially a demonstration technology, Table 2 shows that a range of ZEV models are now available from most major truck manufacturers and spanning a wide range of truck uses, including long-range heavy-duty applications. Of the 32 ZEV models available 28 are BEVs and 4 are FCEVs. When sub-options of different model weights and battery sizes are included, there are 48 models, of which 45 are BEVs and 5 are FCEVs.

Figure 24 below from the IEA (now a year out of date) illustrates the type, size and driving range of heavy vehicles in the market today and announced for delivery through to 2023.

Figure 24: Current and announced zero-emission HDV models by segment, release year and powertrain in major markets, 2020-2023[113] [114]



With reference to section 5.3 previously, the average 250 km range of current medium duty trucks is greater than over 95% of trips undertaken by <20t vehicles in New Zealand, and greater than 80% of daily driving days for such vehicles.

Some models of heavy ZEV trucks available today have a range of up to 500 km. Truck drivers in New Zealand can only drive for a maximum of 5.5 hours before they must take a half hour rest break by regulation, meaning that they will be required to stop before the 500 km range limitation is met. They then have the potential to recharge during this half-hour mandatory rest period if suitable charging facilities are available.

Other key take-aways from Figure 24 include:

[113] https://www.iea.org/reports/global-ev-outlook-2021

[114] For regularly updated research on product range growth refer https://globaldrivetozero.org/tools/zeti-analytics/

- Very long-range (>1,000km) heavy freight trucks are being produced in both BEV and FCEV models
- There are significantly greater BEV models being produced than FCEV models across all commercial vehicle types, with FCEV models largely limited to heavy freight and buses.

A few OEMs are already offering electric trucks in New Zealand today, with others planning to bring BEV models in, at least on a trial basis, during 2022. As at January 2022 there were 144 electric trucks and heavy cargo vans registered in New Zealand (of which 58 are heavy cargo vans).

Fuso New Zealand is offering the eCanter truck, with 21 trucks deployed or about to be deployed. Fuso's parent company, Daimler, has eActros 25 tonne and eCascadia 40 tonne trucks operating in extensive trials in fleets internationally.

Two other global OEMs contacted for this study, Scania and Volvo, have indicated that they will have OEM battery electric trucks operating with customers in New Zealand during 2022, including heavy-duty trucks.

Chinese manufacturer, XCMG, is selling a variety of different models of battery electric truck here today, including two battery swap trucks (6x4 and 8x4), a 40-tonne mining truck and a 90-tonne mining dump truck. It is also offering a 6x4 hydrogen fuel cell truck.

Major OEM Hyundai and international hydrogen fuel cell vehicle specialist company Hyzon both offer hydrogen FCEV trucks here. New Zealand is the third country in the world to be demonstrating the Hyundai's fuel cell trucks. Hyzon has signed an agreement with hydrogen fuel provider Hiringa to supply up to 1,500 fuel cell trucks by 2026.

Both Isuzu and Waste Management have facilities and experience in the conversion of diesel trucks to battery electric operation in New Zealand, using imported technology from companies such as SEA Electric and Emoss.

The global OEMs with battery electric and hydrogen FCEV truck models all indicate that government policies are needed to help them secure supply for New Zealand.

Looking forward, there are expected to be an increasing number of ZEV truck models developed and released internationally. Concurrently, with some manufacturers indicating they will no longer produce new ICEV models after a certain date, there will be progressively fewer ICEV models available. Europe's seven largest commercial truck makers – DAF, Daimler, Ford, Iveco, MAN, Scania and Volvo, have jointly agreed to end the sale of diesel-engine trucks by 2040[115] , provided government policies to support the transition are in place.

[115] Pledge is here https://www.acea.auto/uploads/press_releases_files/ACEA_CV_CEOs-PIK_joint_statement.pdf and depends on suitable policies being implemented by government.

8 Biofuels and e-fuels

Another potential decarbonisation route for heavy freight is to continue with ICEV trucks, but change the fuel from petroleum diesel to a zero or low-emissions 'drop-in' fuel. Such drop-in fuels are chemically identical to existing petroleum fuels but produced either as:

- Biofuels using biomass (eg, from pulp logs) processed in a bio-refinery
- E-fuels made through combining carbon dioxide extracted from the atmosphere with hydrogen created from the electrolysis of water

In addition, partial decarbonisation of diesel can be achieved by blending conventional fatty-acid methyl ester (FAME) biodiesel with diesel fuel. However, there are limits to the amount of FAME which can be blended before affecting most diesel engines.

In theory, it is possible that these bio/e-fuels could be lower cost routes for decarbonising trucking than ZEVs. However, while not the focus of this paper, our provisional analysis indicates that ZEVs are likely to be lower cost than drop-in-fuels for road vehicles.[116] This is because:

- as set out in section 6, BEVs are projected to be lower cost options than diesel trucks from a public perspective during this decade;
- analysis of the economics of biofuels suggests that, if the marginal feedstock for a bio-refinery is pulp logs that would otherwise be exported, then if pulp log and oil prices are similar to recent levels (NZ$120/m3 and US$75/bbl, respectively) the carbon price required for bio-diesel to be cheaper than fossil-diesel is over NZ$400/t$CO_2$.
- The energy conversion losses of running a vehicle on e-fuels are even greater than running a FCEV on hydrogen – noting that both options use renewable electricity as the primary energy source. Given that these conversion losses are the key reason why BEVs are projected to be lower cost options than FCEVs, it follows that BEVs are also likely to be lower cost options than e-fuels.

It is also worth noting that drop-in fuels still have the same exhaust emissions as petroleum fuels, and thus the same human health impacts from ICEVs operating within towns and cities.

However drop-in fuels can help decarbonise harder-to-electrify use cases (particularly shipping and aviation), and help address decarbonisation of the existing fleet of trucks until they are eventually replaced by ZEVs.

[116] For the hard-to-electrify sectors of international aviation and shipping, drop-in fuels are likely to be lower-cost options than battery-electric planes or ships.

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