# Auckland's Low Emission Bus Roadmap


**June 2023**
Version 3.0

# Sustainability at Auckland Transport

**Transport systems are a fundamental component and shaper of cities. They provide vital access for people, goods, and services which are the lifeblood of cities. They also have a significant impact on social, cultural, environmental, and economic outcomes.**

Auckland is a rapidly growing city. As it grows, the needs of the region and its inhabitants evolve and develop at an ever-increasing pace. As a key transport provider, Auckland Transport plays a critical role in helping to shape Auckland into a vibrant and inclusive city in a way that promotes safety, sustainability, and innovation across different modes of transport.

Auckland Transport has undertaken significant work to understand our impact on the environment and climate. Understanding this impact is the first stage of minimising our footprint and protecting our city. It is of paramount importance to us that sustainability is embedded into how we work, from the first concept discussions through to operating and maintaining the transport network. In line with our sustainability strategy, we are committed to providing low emission transport choices to reduce greenhouse gas emissions, improve air quality, and reduce Auckland's reliance on fossil fuels.

The operation of the Auckland Transport bus fleet accounted for 75,530 tonnes of $CO_2e$ in our 2021-2022 greenhouse gas emission inventory. This is the largest source of emissions from Auckland Transport's inventory, at 79% of the total emissions profile. Delivering the Low Emission Bus Roadmap (the "Roadmap") is one of the most impactful actions that Auckland Transport can take to reduce our greenhouse gas emissions.

The Low Emission Bus Roadmap provides a foundation for transitioning the bus fleet to low emissions with key milestones in 2021, 2025, and 2030. The original commitment to procure only zero-emission (at tailpipe) buses from 2025 onward was aligned with the C40 Fossil Fuel Free Streets Declaration, signed by Mayor Phil Goff at the Together4Climate event in Paris. However, since the 2020 version of this Roadmap was published, the decision was made to accelerate this milestone to procure only zero-emission buses as of July 2021. This document is a living document being regularly reviewed and updated as industry trends (such as technology advancements and pricing) evolve and there are more learnings from fleet and technology trials and early deployments.

There are challenges that come with transitioning the bus fleet to zero-emission (at tailpipe). It is a significant undertaking and there are many complex factors that impact the ability and speed at which it can be achieved. There is a wide variety of technology options, extensive supporting infrastructure required, and complex operating models of the bus fleet. We continue working with our stakeholders and partners to overcome these challenges and together deliver a low emission public transport network for all of Auckland.



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# Executive Summary

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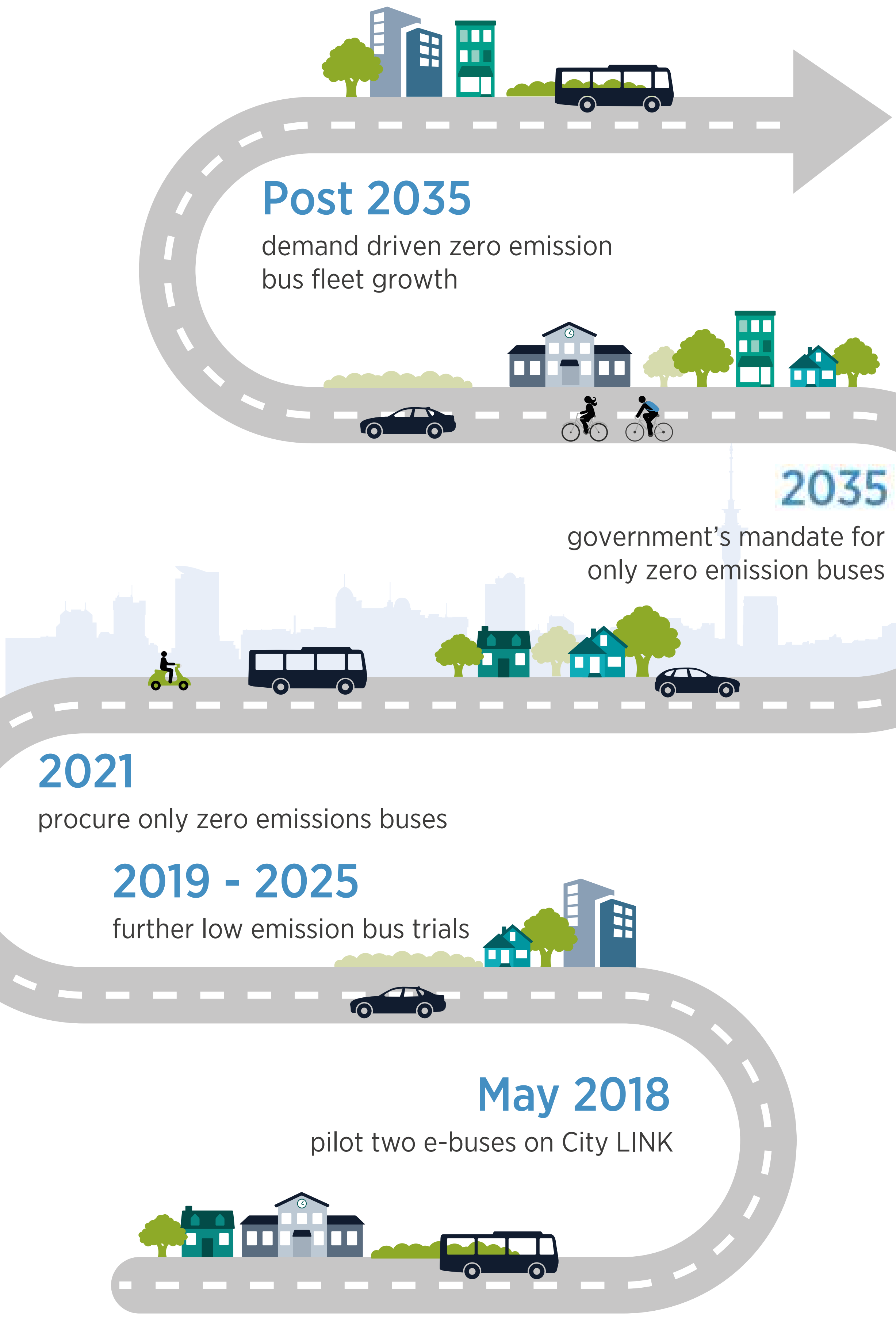


# Delivering on our Low Emission Vision Establishing the Low Emissions Bus Roadmap

**In Auckland, road transport emissions are the largest source of greenhouse gas emissions, comprising 33.3% of the region's emissions profile[1]. We recognise that diesel vehicles, including buses, contribute to serious health implications and social impacts.**

In Auckland, transport is estimated to be responsible for 81% of all anthropogenic air pollution health costs, valued at $763 million annually[2]. With over 1,350 diesel buses operating on Auckland Transport's public transport network, we needed a plan to transition to a low emission fleet for the health of our people and our planet.

In 2018, the Auckland Transport Board endorsed the first Low Emission Bus Roadmap. This was subsequently reviewed and updated in 2020. The Roadmap is a strategic document that outlines the plan and likely costs for transitioning Auckland Transport's bus fleet to zero-emissions (at tailpipe) by 2040. Since then, the plan to accelerate this transition was approved by the Auckland Transport Board in December 2020, now targeting a zero-emission fleet in 2030 (subject to funding).

Given the financial and logistical constraints to transitioning the entire bus fleet to zero-emission, including but not limited to higher upfront capital costs and risk of stranded assets, it is now proposed that the transition target is altered to be closer aligned to the Government mandated 2035. This allows for a more rapid transition than the originally targeted 2040, while mitigating some of the risks and challenges introduced by targeting 2030. This proposal is explained in greater detail in the subsequent paragraphs.

The Roadmap also delivers on our commitment to the C40 Fossil-Fuel-Free Streets Declaration signed by the Mayor of Auckland in 2017. This declaration committed Auckland to procuring only zero-emission buses from 2025 onward and ensuring that designated areas of the city centre are zero-emission by 2030. Auckland Transport has already achieved the milestone of only procuring zero-emission buses into the fleet as of July 2021.

Reducing road transport emissions is a key environmental priority for the Central Government. To give this effect, in February 2021 the Government announced a bus public transport decarbonisation policy mandating that only zero-emission public transport buses be purchased in New Zealand from 2025 (the 2025 Mandate); this supports a future target of decarbonising the nationwide public transport bus fleet by 2035.

The 2025 Mandate will apply to public transport buses registered for the first time in New Zealand from 1 July 2025. This will cover new and used buses that are imported to New Zealand and new buses manufactured or built in New Zealand. It will not cover buses that are already in the public transport bus fleet prior to 1 July 2025, even if they are transferred between regions or operators or refurbished.

The 2025 Mandate will apply to public transport buses and small passenger service vehicles used to deliver public transport services contracted by public transport authorities. The Government recognises that an earlier transition prior to this may be achieved by some councils, similar to the early transition adopted by Auckland Transport. It will not apply to vehicles used to deliver Total Mobility services, nor buses used for services contracted by the Ministry of Education.

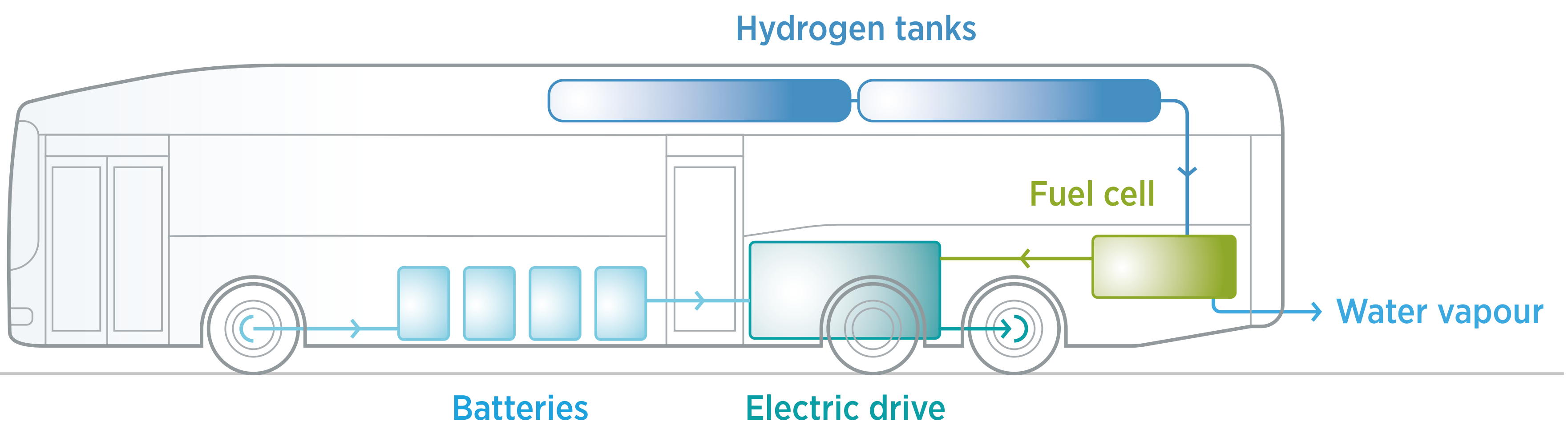
Auckland Transport bus services are operated under contract by private bus companies who own the vehicles. These vehicles vary in size, age, and Euro Standards for diesel buses and type of battery for the electric vehicles deployed already. It is critical that The Roadmap appreciates the complexity of these operating conditions. The Roadmap also reviews recent trends in the wider bus market, including options for technology and charging infrastructure, implementation models and financing.

Auckland Transport undertakes a regular greenhouse gas emissions inventory to track our progress towards reducing our emissions footprint. The inventory undertaken for financial year 2021-2022 highlighted that the bus fleet is responsible for 79% of our organisation's emissions, emitting 75,530 tonnes of $CO_2$e.

This emphasises how critical delivering the Low Emission Bus Roadmap continues to be for Auckland Transport. With the current bus fleet being responsible for majority of the organisation's emissions, transitioning the fleet to zero-emission is the most impactful action we can take towards achieving the Government's target of a zero-carbon future by 2050. Meeting the Government's target also helps ensure compliance with the SBT (science-based target) of 1.5 degrees Celsius by 2050 target set in the Paris Agreement, which New Zealand ratified in 2016.

[1] AXie, S (2022). Auckland's greenhouse gas inventory to 2019. Auckland Council technical report, TR2022/6

[2] HAPINZ 3.0 Report (2022)




**Trialing Low Emission Technology**

Since the establishment of the Low Emission Bus Roadmap, Auckland Transport has continued to explore technology options and has conducted several trials with zero-emission buses.

Battery electric buses (BEVs) are the preferred technology for many jurisdictions (estimated to have 65 percent of the global low emission market share). Because of this, Auckland Transport initiated electric bus trials in 2018 with three vehicles on several routes across Auckland. These electric buses serviced the City LINK, Inner LINK, 380 Airporter, and route 309. Since then, various other BEV trials have been conducted with different buses with different operators and routes.

All the trials to date have delivered positive results in terms of service reliability, customer feedback, and operational savings. This has given both Auckland Transport and our operators confidence that zero-emission vehicles are capable of performing the duties required of them in terms of range and customer experience, on a single charge and for lower operational costs per kilometer compared to diesel.

The trials also confidently confirmed that battery electric buses reduce greenhouse gas emissions significantly compared to conventional diesel buses.

In addition to trialling battery electric vehicles, a trial of a 3-axle hydrogen powered bus also commenced in July 2021. The bus was designed and built by Global Bus Ventures (GBV) in Christchurch and is currently being operated on route 70 by Howick and Eastern Buses (part of Transdev). This bus is being run in parallel to an electric and a diesel bus of similar configurations and will demonstrate the potential of an alternative technology to help us reach our zero-emission future.

**Engaging our Stakeholders**

The Low Emission Bus Roadmap considered various implementation scenarios to achieve our goal of a zero-emission fleet. Review of the Public Transport Operator Model (PTOM) and consultation led by the Ministry of Transport in 2021 considered feedback on public ownership of assets and bus depots. As a result of this the Ministry proposed a new Sustainable Public Transport Framework (SPTF). The SPTF proposes different ownership options for fleet and strategic public transport assets, including bus depots. It also considers an option where Public Transport Authorities (PTA), like Auckland Transport may also operate bus services. The option which is assessed in this Roadmap was to continue with our current operating model, in which operators purchase the vehicles. The scenarios assume that end of life replacements and any fleet growth under existing contracts must be zero-emission from July 2021, and that Auckland Transport utilises contract specifications to stipulate zero-emissions fleets or specific transition plans with bus operators for new contracts.

This option requires strong relationships with the entire supply chain, from bus operators to technology/infrastructure suppliers, to manufacturers. Auckland Transport has communicated the objectives of The Roadmap to bus operators and is cognisant of the challenges it poses for them. Predominantly, this transition requires high upfront capital costs and the possibility of stranded diesel assets. To help minimise potential challenges Auckland Transport actively collaborates with bus operators and key industry stakeholders following the initial Low Emission Bus Forum in July of 2019. This was an opportunity to discuss industry trends, tackle challenges, and share opportunities for collaboration and effective implementation. The outcome of the forum was the establishment of the Auckland Low Emission Bus Working Group, which brings stakeholders together on a regular basis to address the challenges and opportunities that lie ahead.

The Low Emission Bus Working Group (LEBWG) has been extended in 2020 to include representatives from the Ministry of Transport, Waka Kotahi NZ Transport Agency, other regional councils in New Zealand and the Bus and Coach Association, to work alongside industry experts from across New Zealand and Australia. The key focus areas of the Auckland Transport led LEBWG are technology adoption, infrastructure, regulatory framework and funding, and financing supporting New Zealand public transport authorities in achieving the Government's mandate. The future of the LEBWG is being reviewed in 2023 with barriers to earlier adoption of zero-emission buses (at tailpipe) now successfully removed and other frameworks and funding mechanisms now developing and available to implement zero emission buses in New Zealand.

**Accelerating our Transition**

The target of achieving of a full zero-emission fleet by 2040 was challenged in 2018 by the Auckland Transport Board. Given the pace of international development and deployment of low emission bus technology, the potential to achieve Auckland Transport's vision for a full zero-emission bus fleet earlier that 2040 was thought to be achievable. Consequently, in December 2020 the AT Board approved the decision to accelerate the fleet transition to zero-emission by 2030 (subject to funding). The Central Government has also set out their goal of zero-emission bus fleets by 2035 by announcing the Bus Public Transport Decarbonisation Policy in January 2021.

Since the establishment of the first Roadmap, Auckland Transport has successfully contracted the half of Waiheke bus fleet to electric from November 2020 with the remainder of the fleet to be replaced by electric buses progressively, as the current diesel fleet reaches end of life. The previous milestone to have all new buses procured as zero-emission from 2025 has also been accelerated and came into effect on 1 July 2021. There are now whole routes that are operated by fully electric fleets; the new Airport LINK service from Manukau Bus Station via Puhinui Station to the Airport, has been electric from January 2021, the City LINK service operating in city centre was electric since April 2021. Most recently, in November 2022, the Tamaki Link service transitioned to a fully electric fleet and 26 other electric buses were deployed to routes in Eastern Bays area of Auckland and more deployments are planned in 2023 adding over fifty more electric buses for passenger services

However, an accelerated transition is not without its challenges. These range from operators still lacking confidence in the long-term performance of electric buses across all sizes and configurations, high upfront capital costs for new buses, electricity network upgrades necessary to enable bus charging, and short contracts resulting in higher contract costs.

In order to address the limited configurations and sizes available for the New Zealand market with unique axle weight limits, and to better understand these challenges and actively find solutions, zero-emission bus trials are continuing. This includes vehicles ranging in differing battery electric and hydrogen fuel cell technology, and size and axle configurations. This has been done to test, in partnership with our bus operators, the different design and performance capabilities of various vehicles. Including the hydrogen bus, there are currently six zero-emission trial buses operating on the Auckland Transport network. The trials also include trials of different types of chargers at key bus interchanges and layovers to support the bus trials and to learn from the installations and to test the effectiveness of the plug-in top-up charging during bus drivers rest and meal breaks, which are now required under the Employment Relations Amendment Act.

In addition to these trials, Vector Limited was engaged under a Memorandum of Understanding (MoU) to participate in a detailed study of electricity requirements of battery electric bus fleet and assess the current electricity network and the network infrastructure upgrades that would be required for bus depots to achieve a fully electrified fleet. The study also identified opportunities to reduce costs through innovation and compatibility of charging systems with the Distributed Energy Resource Management System (DERMS) used by Vector to manage electricity network performance and available power. The early deployments of electric buses and depot upgrades in 2021 and 2022 provided opportunity to test the costs estimates from the study with the actual costs incurred in early depot upgrades.

After conducting a detailed modelling of the expected costs, greenhouse gas emissions and social benefits, and applying learnings from early deployments of battery electric buses and installations of charging infrastructure and high voltage connections to bus depots and interchanges, Auckland Transport has updated the endorsed in December 2020 Option F "Electrify Faster" to accelerate our mission to have a zero-emission bus fleet (from previous Option E "Electrify"), and developed an alternative and more affordable Option G aligning with Government's target to decarbonise public transport in New Zealand. Therefore, the following three options have been updated with current cost and benefits forecasts[2] and considered:

**Option 1:** Default zero-emission by 2040 (Option E updated comparison to a continued existing diesel fleet but with no more new diesel bus procurement from 2021)

- No diesel fleet procurement from July 2021; full fleet transition to low emission (zero- emissions by tail pipe) by 2040
- Reduces carbon emissions by 0.9 million tonnes
- Estimated to deliver net social benefits of $202.7 million over 19 years[3].
- Requires funding of $437 million ($176 million discounted) over 19-year period. Requires additional funding for transitioning the remaining 2.4% of diesel fleet (39 buses) in 2040 (cost / benefit of last 39 buses have not been modelled)

[2] The social costs of emissions from urban buses have been updated since the last version of the roadmap was published. The new cost factors are in line with HAPINZ 3.0 (2022). The NVP discount rate is calculated at 5.0% from NZ Treasury. Please see the Emission Methodology note at the end of the document for more details.

[3] Social benefits calculated against an all-diesel bus fleet where transition of older buses has been undertaken at the rate of Option E, to Euro 6 diesel vehicles

**Option 2:** Zero-emission by 2030 (Option F)

- No diesel procurement from July 2021; full fleet transition by 2030
- Reduces carbon emissions by 1.4 million tonnes
- Delivers cumulative social benefits of $901 million
- Enables fleet transition agreements to progressively introduce zero-emission buses from 2022
- Requires funding of $744 million ($300 million discounted) over 19-year period

**Option 3:** Zero-emission by 2035 (Option G)

- No diesel procurement from July 2021 with target aligned with Government's bus decarbonisation policy and expected funding to support transition; full fleet transition by 2035
- Reduces carbon emissions by 1.2 million tonnes
- Delivers cumulative social benefits of $694.5 million
- Enables fleet transition agreements to progressively introduce zero-emission buses from 2022
- Requires funding of $620 million ($289 million discounted) over 19-year period

All three options are assuming implementation using variations and extensions of the existing bus service contracts and new contract tenders. The three options also require upgrades of the electricity network and bus depots.

Developing the supply chain to lower the cost of electric buses and innovation to reduce costs of bus charging infrastructure and reduce the requirement for additional depot space is also required under the three options.

| Option: | E (Option 1) | G (Option3) | F (Option 2) |
|---|---|---|---|
| Cost to 2040 | $437m | $620m | $744m |
| Total $CO_2$ emission reduction: | 42% | 60% | 68% |
| Total NOx emission reduction: | 10% | 40% | 52% |
| Social costs benefits: | $203m | $695m | $901m |

Table 1 - Summary of costs and benefits of bus fleet decarbonisation options over 19 years

**Is the recommended trajectory aligning with science-based target (SBT) of 1.5 degree and 2 degree?**

It needs to be ensured that the proposed transition trajectory aligns with milestones for the Paris Agreements SBT (science-based targets) of 1.5 and 2 degrees Celsius (with a focus on achieving a 1.5-degree target) by 2050. These targets have been set to mitigate some of the most severe impacts of global warming and thus are an important consideration to align for Auckland Transport. While the end goal of being carbon neutral by 2050 remains consistent with the 2050 target set by the New Zealand Government, incorporating SBT-check into this roadmap provides a clear emissions reduction necessary for both short and long term. While by nature, the fleet transition rate is not linear, this SBT-check would help ensure whether the progress made is tracking well with the science requirement or not. This is demonstrated in Figure 1 overleaf.

Our calculations lead to a conclusion that option E does not meet the emissions reduction necessary for 1.5 degree and 2-degree requirement while both option G and F meet them. In addition, the SBT-check would help ensure that AT complies with Scope 3 emissions reduction requirement of NZ climate standard.

After going through the annual emissions trajectory of the recommended option G, that aims to transition to all buses to low emissions by 2035, the following targets seems appropriate considering the GHG emissions **baseline of 2021 Year** as overleaf.

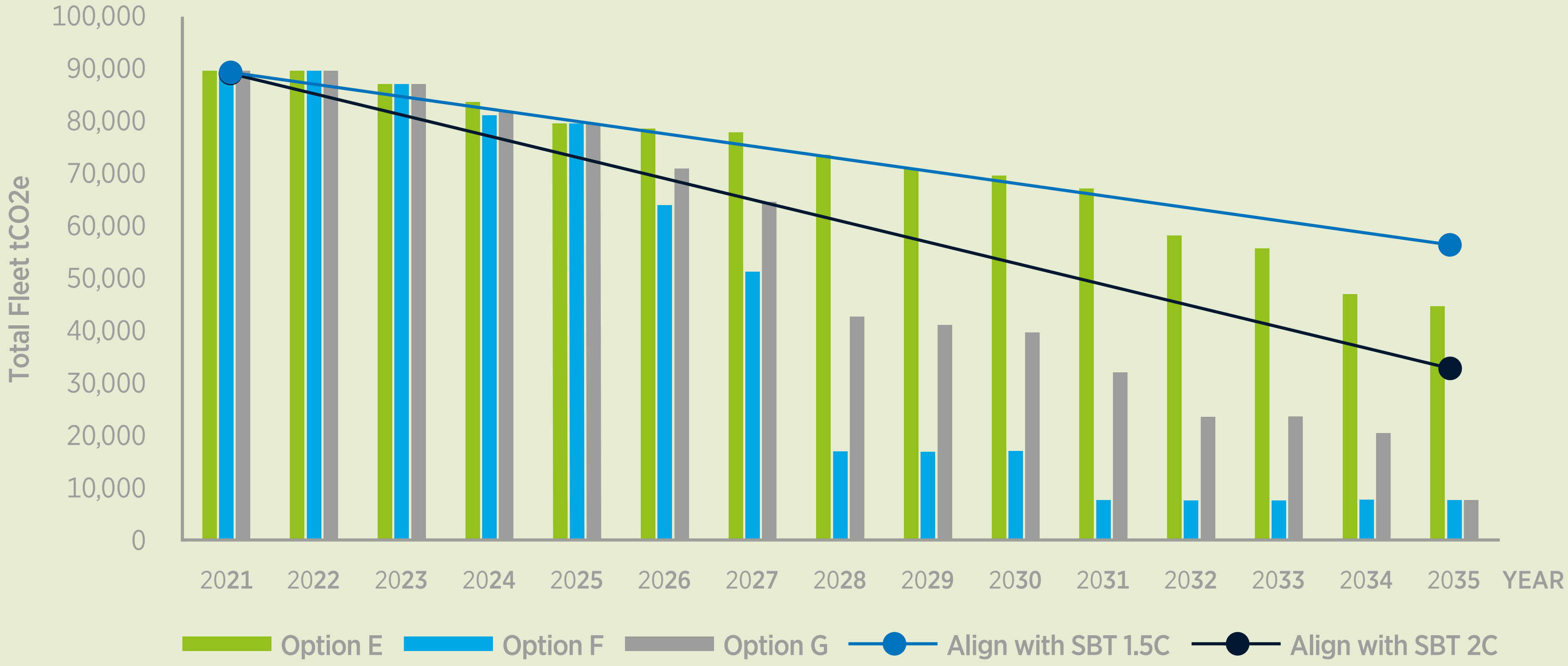



Figure 1 - Option Alignment with SBT Goals

### Targets

1. An interim target of reducing 64% GHG emissions by 2031 (of absolute baseline emissions). The interim time period to reach the target is 10 years from 2021.
2. A final target of reducing 91% GHG emissions by 2035 (of absolute baseline emissions). The time period is 14 years from 2021.

| **Year** | **Option G- Annual GHG absolute emissions trajectory, $tCO_2e$** | **Option G- Absolute annual GHG emissions reduction potential** (%) (of absolute baseline emissions) | **Proposed Target** | Period | |
|---|---|---|---|---|---|
| 2021 | **90,105** | | **Baseline** | | |
| 2022 | 89,889 | 0% | | 10 Years | 14 Years |
| 2023 | 87,365 | 3% | | | |
| 2024 | 82,921 | 8% | | | |
| 2025 | 78,773 | 13% | | | |
| 2026 | 71,435 | 21% | | | |
| 2027 | 65,256 | 28% | | | |
| 2028 | 42,690 | 53% | | | |
| 2029 | 41,423 | 54% | | | |
| 2030 | 39,674 | 56% | | | |
| 2031 | 32,017 | 64% | **Interim Target** | | |
| 2032 | 23,827 | 74% | | | |
| 2033 | 23,317 | 74% | | | |
| 2034 | 20,553 | 77% | | | |
| 2035 | 7,702 | 91% | **Final Target** | | |

### Notes

1. These targets are solely limited to the option G trajectory of the roadmap and have not yet considered any work/ aspiration/focus area related to TERP.
2. The emissions baseline/targets are based on annual absolute emissions aiming to contract the emissions over the proposed time period. The cumulative emissions reduction assessment is not considered for the target.

**Recommendation**

It is recommended to seek funding as part of the upcoming Regional Land Transport Plan (RLTP) funding prioritisation to continue accelerating the transition to zero-emission bus fleet taking into account impact on additional funding availability through the Climate Emergency Response Fund (CERF) and potential costs of stranded diesel assets, targeting 2035 for completion (Option 3). This will be reviewed regularly (every 18-24 months), as more information becomes available from the market, increased learnings from ongoing AT trials and further implementation of more electric buses over the next two to four years. This further implementation will have learnings regarding vehicle technology updates, innovation in bus charging, pavement maintenance costs and outcome of Road User Charges (RUC) review impacting costs of operating e-buses and financing options.

Electrification of urban buses aligning the completion of the transition to a zero-emission at tailpipe fleet with the Government's 2035 transition target will significantly improve climate and social benefits. It will reduce greenhouse gas emissions by 1.2 million tonnes and improve air quality on Auckland streets delivering cumulative social benefits of $694.5 million over period of 20 years compared to the diesel fleet. This will ensure compliance with the Government 2035 target for zero exhaust emission public transport buses and Auckland's C40 Cities commitment to create fossil fuel free streets in the city centre by 2030 (when all bus trips to city centre will be made by electric buses) and align with Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan's goals to reduce emissions by 2030. It will also provide a contingency period to mitigate any risks associated with stranded newer diesel buses procured by our operators for the PTOM contracts from 2016.

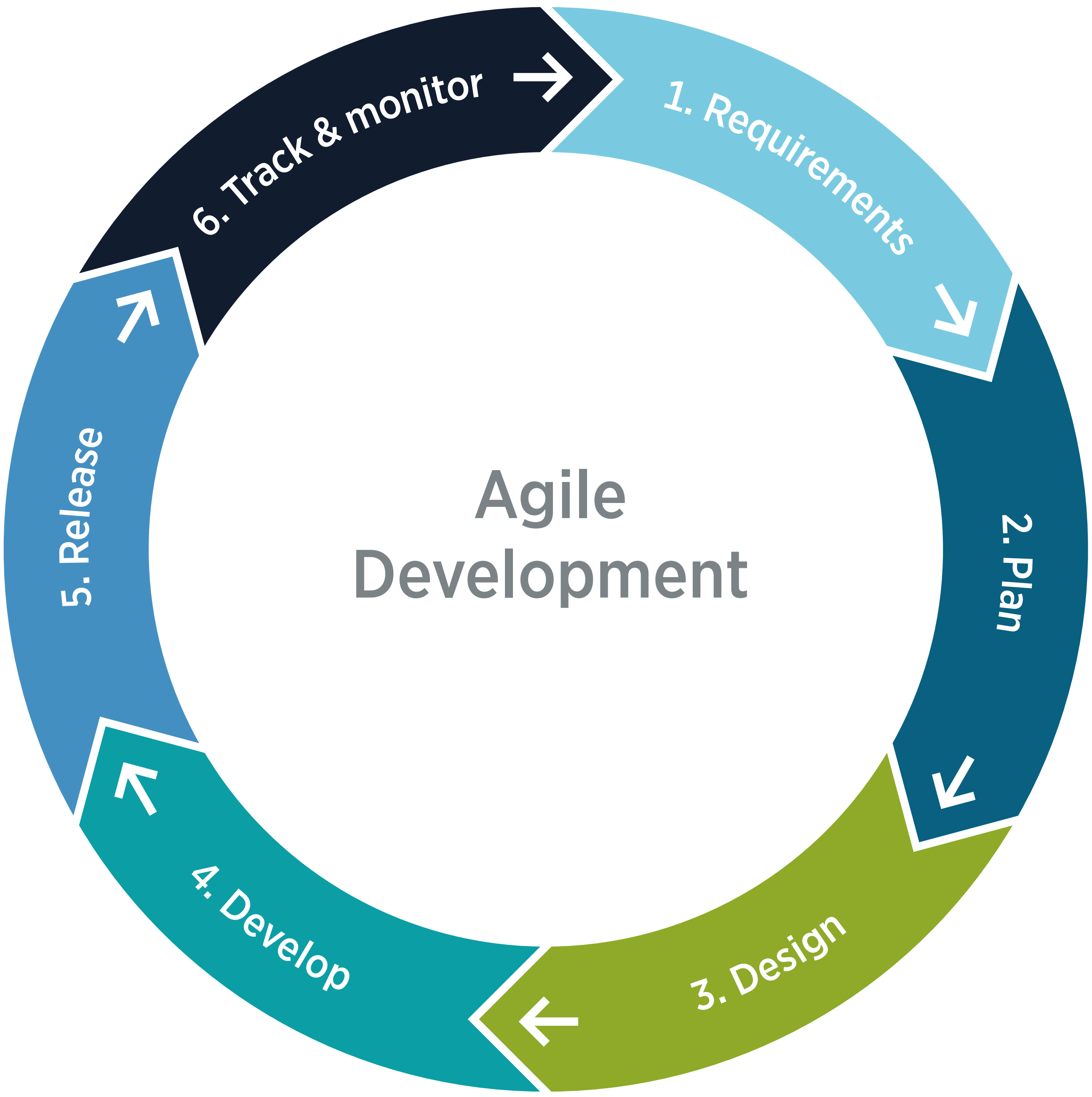
The updated Roadmap, targeting 2035 for full decarbonisation of bus services in Auckland, would mean that the emission reduction target for bus services of 1.2 million tonnes by 2040 is met, supporting the Paris Agreement science-based target of 1.5 degree Celsius. The interim absolute greenhouse gases (GHG) emissions reduction potential (of absolute baseline emissions) would be reached in 10 years, and the final target of reducing 91% GHG emissions by 2035. The revised target from the previous accelerated Roadmap approved by AT Board in 2020 provides options to address the funding concerns due to the economic impacts of Covid-19 pandemic, higher then accepted costs of charging infrastructure and battery replacements and impacts on bus operators due to stranded diesel bus assets. An all-electric bus fleet from 2035 will significantly contribute to achieving the objectives of Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan and achieve a meaningful reduction of Auckland Transport's carbon footprint. It will decarbonise bus public transport in Auckland and help achieve the Government's 2035 target for New Zealand. The accelerated start of the transition is aligned with Vector's plans to invest in the electricity network and in new innovative technology to improve the climate and reduce the cost of clean energy and charging of the EV fleets in our city.

**Staying Agile**

The Low Emission Bus Roadmap addresses challenges to decarbonising, while providing a set of principles to guide and progress transitioning to a zero-emission bus fleet. The Roadmap will continue to be refined and updated as technology advances, market trends change, and more evidence is gathered from trials. It will consider early deployments and future tenders for bus service contracts, as well as studies to understand the cost of electric bus charging and road maintenance impacted by heavier battery electric bus fleet.

Auckland Transport will also need to remain agile amongst a changing policy landscape. Auckland Transport, alongside the Low Emission Bus Working Group, or any subsequent forums, and Bus Decarbonisation Steering Group led by Waka Kotahi, will continue to monitor policy and industry trends as implementation of the Roadmap progresses.

We are committed to ensuring that we are aligned with our partners and stakeholders as we collectively work towards a zero-emission future for New Zealand.




# 1. Introduction

# 1. Introduction

**The Low Emission Bus Roadmap was initially developed as a thought piece in collaboration with the Low Carbon Vehicle Partnership (LowCVP) and TRL Limited who are leading transport research specialists from the United Kingdom. It outlined the challenges and opportunities applicable to the Auckland context and the range of low emission options for the city's bus fleet. Alongside this report, Auckland Transport investigated a set of implementation and indicative funding scenarios to identify preferred options for a zero-emission fleet by 2040 and updated it in October 2020 with accelerated transition and targeting completion by 2030.**

Auckland Transport's Low Emission Bus Roadmap – Addendum: June 2023:

- Updates strategic context, including policy and opportunities
- Analyses the results of trials and demonstrations of new technologies and learnings from early deployments
- Identifies barriers to implementation for an accelerated transition
- Updates the total cost of ownership of new technologies
- Reassess the implementation and financing options
- Identifies next steps to support the revised transition target (compared to the default option with the 2040 target and accelerated target of 2030).

## 1.1 Recommendations

The 2020 Low Emission Bus Roadmap made a series of recommendations that have been reviewed and refined. The Low Emission Bus Roadmap 2023 identifies the following new opportunities that would require additional prioritised funding:

1. Continue to accelerate the 2040 goal of transition to full zero-emission bus fleet and target completion by 2035.
2. Building on the success of previous technology trials, and continue with the additional demonstrations including:
    - 2.1. Battery electric buses (extra-large three-axle single and double-deck) with depot charging
    - 2.2. Further hydrogen fuel cell bus trials
    - 2.3. 'Top-up' charging to assess plug- in charging at layovers
    - 2.4. Retrofit existing diesel buses with electric and/or hydrogen fuel cell technology
    - 2.5. Trial of inductive bus charging at depots to reduce the footprint required for plug-in chargers and to automate the bus charging process
    - 2.6. Investigate "opportunity" on-route rapid charging or inductive charging for busways and BRT projects (opportunity charging refers to the practice of charging for short periods of time throughout the day – as the main/only way of charging the bus, while top-up means that fast charging is used as an addition to slow/overnight charging)
3. Collaborate with Vector to enable a large-scale deployment of electric buses on Auckland's electricity network at selected depots by the commencement dates for fleet replacements and new contracts, utilising the outcomes of the joint Grid Impact Study completed under MoU.
4. Collaborate with key stakeholders in the emerging hydrogen technology to develop the hydrogen industry in New Zealand and Auckland reducing the cost of operating alternative hydrogen fuel cell (HFC) buses.
5. Continue to engage with international organisations such as C40 Cities, the Financing Sustainable Cities Initiative (FSCI) and Public Transport Association in Australia and New Zealand (PTANZ)[4] to help expand knowledge and share lessons learned on the transition to low emission buses.
6. Continue to lead and facilitate the Low Emission Bus Working Group (established in 2019) to address barriers to accelerated transition to a zero-emission fleet in Auckland and New Zealand.
7. Contribute to the Bus Decarbonisation Steering Group led by Waka Kotahi and collaborate with other jurisdictions in New Zealand and with the Ministry of Transport, to influence central Government policies, share learnings, coordinate fleet procurement where feasible, and other options to accelerate the implementation of zero-emission buses.
8. Lobby central Government and the automotive industry to put measures in place for the re-use and recycling of lithium batteries to support long- term sustainability and reduce the end-of-life environmental impacts of zero-emission buses.

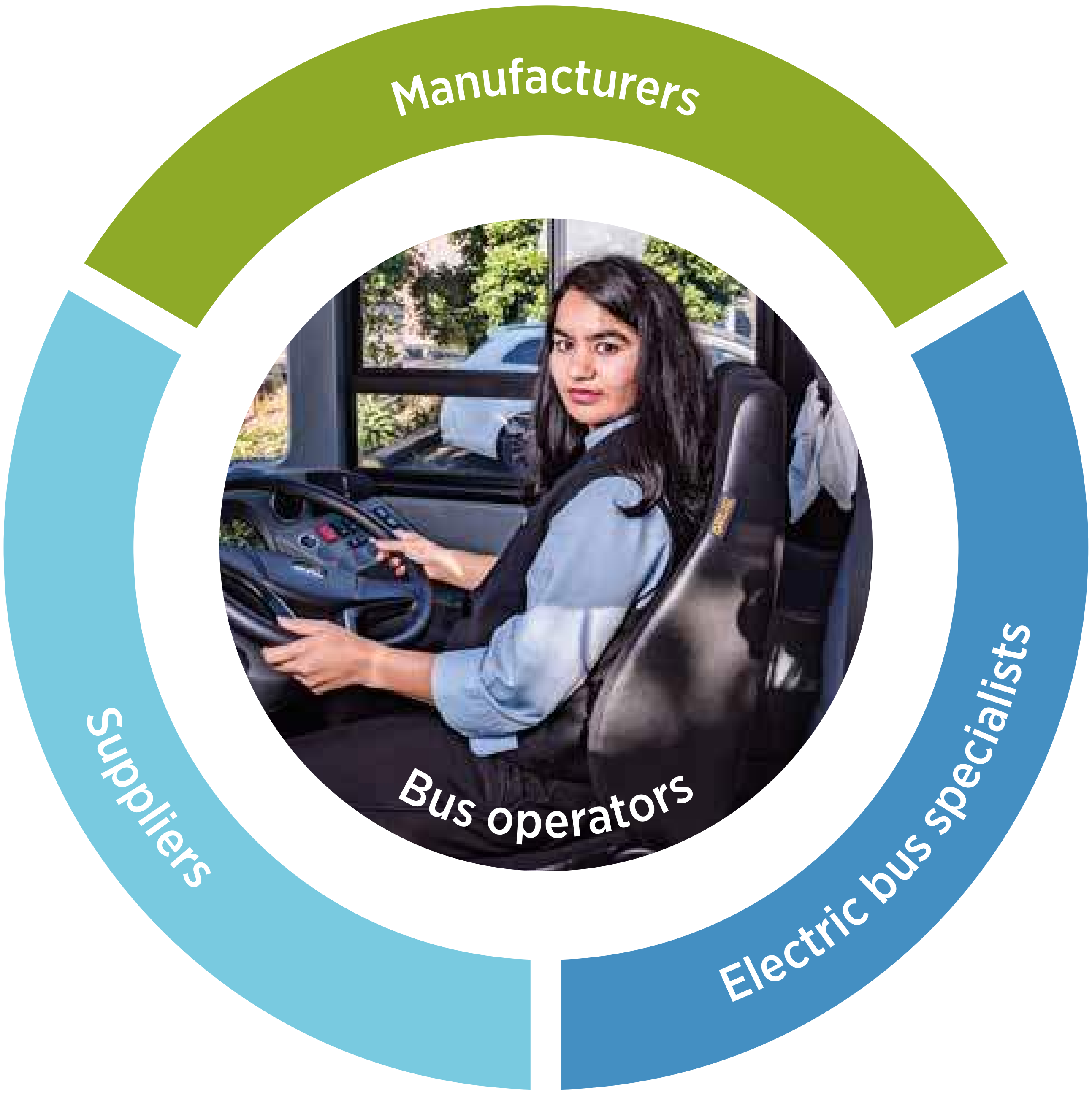
[4] PTAANZ is a new regional association following split from the International Association of Public Transport (UITP) branch for Australia and New Zealand.

## 1.2 Challenges for Accelerating the 2040 Goal

Several barriers were identified in the previous versions of the Roadmap and have since become a primary focus for Auckland Transport and the Low Emission Bus Working Group to address. These challenges are complex and diverse as well as essential to overcome in order to accelerate the transition to zero-emission buses.

**Regulatory and Financial**

1. High upfront capital costs for new battery electric buses and retrofits with low emission technologies.
2. High set-up costs for bus operators and utility companies (i.e., Vector), for electric charging infrastructure, including necessary upgrades to the electricity distribution network to manage overnight charging loads at bus depots and providing necessary resilience. There is also potential for "top-up" plug-in charging infrastructure at bus layovers and on route rapid charging, which could increase the number of routes battery electric buses could operate reliably without bigger and heavier battery packs but that will require capital investment across Auckland Transport's bus network. Auckland Transport is currently trialling deployment of plug-in top-up charging at several locations to support trial buses as well to test the top-up charging costs and utilisation.
3. Weight restrictions imposed by Vehicle Dimensions and Mass (VDAM) Rule are restricting the capacity of some battery electric buses, both for single and double- deck vehicles and slowing the adoption of zero-emission buses. Relaxing the weight restrictions or provision of over-weight special vehicle permits for electric buses on a large scale increases the risk of pavement damage and higher costs of resurfacing or road rehabilitations.
4. On route "opportunity" charging with pantographs could reduce the weight of buses and increase the hours of operation but is very expensive to install and maintain and presents consenting challenges across the geographically spread bus network in Auckland; therefore, pantograph charging is only considered on dedicated busways and new BRT projects with high-capacity fleet planned.
5. High costs for renewing batteries over the life of the bus assets. While battery longevity is improving, bus operators remain uncertain. This uncertainty affects the view of the total cost of ownership and residual value of the bus and batteries at the end of the vehicle's expected operational life and influences depreciation, ownership options and contract and have been added to the total cost of transition to zero-emissions fleet in this version of the Roadmap.
6. Short contract tenure during the transition period influences the cost of service operations with zero-emission buses compared to diesel fleet. Longer term contracts under the future Sustainable Public Transport Framework proposed by the Ministry of Transport to replace PTOM framework, or other contract incentives to guarantee EV bus fleet transfer would enable the reduction of Peak Vehicle Requirement (PVR) rates for e-buses and infrastructure through longer depreciation periods for assets.
7. Lack of national fiscal incentives to support the development of a low emission bus market in New Zealand beyond the current exemption from Road User Charges (RUC), which ends in December 2025.


Manufacturers
Electric bus specialists
Suppliers
Bus operators

**Low Emission Bus Market & Procurement**

1. The low emission bus market has benefited from early bus trials and deployments during 2018 through to 2022 in Auckland, Wellington and Christchurch, and from the zero-emissions commitment articulated to the supply chain at the Low Emission Bus Forum in July 2019 and following AT Board's approval of the accelerated Roadmap in December 2020. The market has evolved with single deck standard two-axle and three-axle battery electric buses now readily available for New Zealand from several bus manufacturers. The three-axle double deck electric buses are still in the early stages of development with few manufacturers producing vehicles for other markets. Auckland Transport is liaising with several players on the bus market to introduce 3-axle Double Decker buses for demonstrations and trials including new and retrofitted battery electric buses.
2. The wide variety of bus makes, models, and younger ages of some diesel buses procured for the first rounds of PTOM contracts in Auckland could make retrofitting to battery electric or hydrogen fuel cell buses expensive. More investigation and trials are required to better understand if this would be a viable option for some bus models, to mitigate the risk of stranded assets and potentially offer a cheaper alternative to new buses.
3. High capacity articulated and bi-articulated battery electric buses are now available internationally for BRT applications and can be considered for future projects with overnight depot charging and potentially with rapid charging on-route at key stations. Alternatively, these buses could be powered using hydrogen fuel cell technology as it is expected to mature, with more affordable green hydrogen produce at scale in New Zealand.
4. Procurement and ownership models for low emission buses are complex. Under the current procurement of bus services, bus operators must provide bus charging infrastructure and undertake necessary depot upgrades. Retaining market competition while tendering for bus services is challenging when operators' ownership or leases influence the cost of bus charging and depreciation of assets at depots. Auckland Transport is developing alternative options for depot assets ownership and control to test future models.
5. There are new ways to procure electric vehicles, charging equipment and maintenance services. Leasing options reduce the high upfront capital costs, mitigate the risk of high battery renewal costs or technological obsolescence, and provide time to develop bus operators' confidence in technology, but increase contract costs to AT.
6. In addition to the options outlined above, there are also opportunities to source chassis from international manufacturers and to retrofit existing diesel buses with electric drivetrains and batteries. These approaches can help to reduce costs and increase the availability of low emission buses in the New Zealand market. However, more research and development is needed to ensure that retrofitted buses meet safety and performance standards and can operate reliably in New Zealand conditions. As the low emission bus market continues to evolve, exploring a range of procurement and ownership models, technologies, and manufacturing options will be important to help achieve the goals of reducing emissions and improving public transportation.
7. Alternative low emission bus technologies like hydrogen fuel cell are not yet developed in New Zealand and require third-party 'green' hydrogen production and infrastructure.
8. There is still speculation around second life application of bus batteries to ensure a whole of life is sustainable over the long term and their end-of-life treatment (disposal or recycle).
9. The increased demand for electricity, both directly and indirectly via operators, as a result of low emission bus procurement and electrification of trains and ferries, will require a longer-term electricity supply strategy and procurement plan to ensure adequate and sustainable supply for the transportation sector in New Zealand.


### Operations

1. Operating all day bus services with a long span of service hours using battery electric fleet charged overnight at the depot, in some cases, may require more buses compared to operations using diesel fleet, heavier batteries reducing passenger capacity or use of alternative technology i.e., hydrogen fuel cell. The 2020 power demand study conducted in partnership with Vector and using WSP's battery lifecycle optimisation tool (BOLT) showed that 12% of bus services across Auckland will require such interventions with current technology.
2. Alternative opportunity charging on route with pantographs is not preferred on Auckland's streets due to a high cost of purchase, grid upgrades, construction and associated risk of consenting issues for pantograph installations. Additional fleet specifications and a limited interoperability affecting an efficient utilisation of buses on other routes, along with aging pantograph technology, also make this option less attractive. Auckland Transport remain focused on overnight depot charging. However, on route fast charging (i.e., rapid charging or inductive charging) is considered for dedicated busways and BRT services.
3. Operation and maintenance of electric buses require new skills and expertise. There are limited industry training courses and qualifications to promote the development of a new workforce and upskilling of existing mechanics and technicians to support the safe and reliable operation of electric bus fleet. Operators with early deployed buses rely on the original equipment manufacturer (OEM) to provide basic inductions and training. While Motor Industry Training Organisation (MITO) has developed formal training courses the existing diesel mechanics are not rushing to upgrade their qualifications and such a course will appeal to young and future electric vehicle technicians.

### Influencing Bus Operators

1. Bus operators generally have low confidence in low emission bus technologies regarding performance as batteries age and degrade. They are reluctant to purchase low emission vehicles without financial support and are seeking compensation to mitigate risks associated with the new technology, especially if required to transition to electric buses before the budgeted 20-year lifespan of the existing fleet expires, or on short-term service contracts.
2. Changes to the requirements for rest and meal breaks for bus drivers under the Employment Relations Amendment Act (ERAA), and final implementation of the changes to comply with ERAA identified more opportunities for plug-in charging at interchanges and bus layovers and Auckland Transport is actively exploring them and is deploying more trial sites in 2022. The reset of timetables in 2022 known as Network Recast is aiming at reducing bus drivers split shifts and will keep more buses operational throughout the day. This may require more plug-in charging at interchanges as less buses will be returning to depots during the day to top up batteries.
3. More zero-emission bus trials are planned with all bus operators to improve their confidence in technology, experience the operational benefits and identify challenges applicable to them while planning the transition. Bus trials enable bus operators' preparations to upgrade their depots with the required bus charging infrastructure.
4. Further trials of bus charging equipment and use of innovation will have the potential to reduce a depot footprint required to park and charge electric buses overnight.
5. Proposed trials of retrofitting existing diesel buses in collaboration with bus operators will potentially encourage them to transition to a zero-emission technology earlier, while maximizing the life of existing buses to their expected 20-year permitted use under the New Zealand Transport Agency's (NZTA) Requirements for Urban Buses (RUB).
6. The above model has been used to influence bus operators along with education and encouragement. This sets a base for empowering them to become early adopters of zero-emission fleet and enforcing new fleet requirements through new contracts.


# 2. National & Regional Policy Frameworks

# 2. National & Regional Policy Frameworks

**Experience from around the world reveals that Government policy continues to be instrumental in stimulating the market to transition to low emission buses.**

## 2.1 Climate Change and Air Quality

Policies include:

- Introducing subsidies and grants
- Allocating funding for demonstration trials of new technologies, and
- Setting vehicle emission targets.

In 2016, New Zealand ratified the Paris Agreement, a global effort to combat the effects of climate change by limiting the global average temperature increase to 1.5 degrees Celsius above pre-industrial levels.

The Government is focused on climate action and has established a Zero Carbon Act and an independent Climate Change Commission that will guide New Zealand to the goal of reducing net emissions of all greenhouse gases (except biogenic methane), to zero by 2050.

Furthermore, New Zealand has adopted the Vehicle Exhaust Emissions Regulations, which are aimed at reducing air pollution from road transport. The regulations require new heavy vehicles, including urban buses, to meet the Euro 5 standard as a minimum requirement.

In 2021, following lengthy consultation with all regional councils, the bus industry and other stakeholders, Waka Kotahi NZ Transport Agency published the new Requirements for Urban Bus (RUB) (https://www.nzta.govt.nz/resources/requirements-for-urban-buses/), which requires all new buses to be a minimum Euro 6 diesel engines with additional requirements for battery powers electric buses. Reducing road transport emissions is a key environmental priority for the government. Consequently, the RUB includes the Government mandate that only zero-emission public transport buses be purchased by 2025 (the 2025 Mandate); and this supports a future target of decarbonising the public transport bus fleet by 2035. A reduced emissions profile of the fleet could increase the proportion of customers who choose to use public transport, supporting mode shift to public transport.

With around 84% of New Zealand's electricity grid sourced from renewable energy sources, the country is well positioned to electrify transport. As the Government works towards achieving an electricity grid that is 90% renewable by 2025, electric vehicles will continue to be instrumental in achieving greenhouse gas emission reduction targets.

## 2.2 Electric Vehicle Programme

In 2016, the Ministry of Transport introduced a package of measures to increase the uptake of electric vehicles in New Zealand, primarily focused on the light passenger fleet. These included:

- A target to double the number of electric vehicles in New Zealand every year to reach approximately 64,000 by 2021 (as of May 2023 there are over 75 thousand battery electric vehicles registered in New Zealand, including over 20,000 PHEV )
- Extending the Road User Charge (RUC) exemption for electric vehicles until they make up 2 per cent of the light passenger fleet or until 31 December 2025, whichever comes first
- Government agencies are coordinating activities to support the development and deployment of public charging infrastructure, including providing information, guidance, and regulation for charging equipment
- A Low Emission Contestable Fund of up to NZ$6.5 million per year to encourage and support innovative low emission vehicle projects (administered by the Energy Efficiency and Conservation Authority)
- The Minister of Transport announced to the industry the Government's plan to establish a working group to enable faster adoption of zero-emission buses in New Zealand. This group has been disestablished in March 2020.
- Since Dec 2020 the Auckland Low Emission Bus Working Group has been externed to include all of New Zealand and the working group is represented at the New Zealand Public Transport Decarbonisation Steering Group chaired by Waka Kotahi NZ Transport Agency.
- More recently, in 2021 the Government introduced a Clean Car Standard for new and used light imported vehicles. The Low Emission Contestable fund has also been replaced with the Low Emission Transport Fund which makes available up to $25 million a year to support the demonstration and adoption of low emission transport (including infrastructure). Applications for this fund is split in two categories: demonstration of vehicles and technology and adoption of public charging infrastructure.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EBUS
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- In 2021, the Government announced the establishment of the Climate Emergency Response Fund (CERF) with an initial $4.5 billion 'down payment' for Aotearoa New Zealand's climate spending by recycling the proceeds of the Emissions Trading Scheme into a dedicated fund. In May 2022, the Government allocated in its 2022 budget a $41 million investment from CERF to support the decarbonisation of public transport through supporting Public Transport Authorities to deploy low- and zero-emissions buses. Applications for projects to be funded through this fund open in April 2023.

## 2.3 Auckland's Policy Landscape

Auckland Council's sustainability objectives focus on reducing greenhouse gas emissions and air pollution while reducing reliance on fossil fuels. This is reflected in Auckland Transport strategy documents such as the Auckland Transport Business Plan and 2019-2022 Statement of Intent. Alongside these sustainability objectives is the ambition to support the uptake of low emission vehicles and to support greater adoption of public transport and active modes. Key plans that support these objectives include:

- 2021/22- 2031/32 Government Statement on Land Transport
- The Auckland Plan 2050
- Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan (replacing Low Carbon Auckland)
- The City Centre Master Plan (revised in 2020)
- Waka Kotahi NZ Transport Agency Sustainability Action Plan 2020
- The Transport Emission Reduction Pathway (TERP) – adopted in August 2022

Auckland Council is also developing a sustainability strategy to meet national emission standards for air quality. Auckland Council runs a fixed monitoring network and promotes initiatives that will reduce emission sources. Over recent years, concentrations of air pollutants such as fine particulate matter (PM10), nitrogen dioxide (NO2), and sulphur dioxide (SO2) have stabilised in Auckland. However, heavily trafficked areas of the city centre can still experience higher NO2 concentrations and breach air quality targets.

The TERP is a key strategic document that will be used to guide planners and decision-makers during the development of future transport plans. It aims for five times the number of public transport trips taken – aided by a three-fold increase in the number of services on offer.


# 3. Strategic Context

# 3. Strategic Context

**In 2021, the global electric bus stock was 670 000. This represents about 4% of the global fleet[8].**

## 3.1 International Context

Battery electric buses have increased their share of the global low emission bus market from 65% in 2019 to almost 85% share and are the most commonly adopted technology. Plug-in hybrid buses are the next most popular technology, serving approximately 12% of the low-emission bus market. Hydrogen fuel cell buses have now registered their presence on the market with estimated 3% of the electric bus market.

The increase in interest in hydrogen fuel cell technology has remained steady, with about 5,250 hydrogen powered buses operating globally as of late 2022[6.] This is significant increase since the last Roadmap where this number was closer to 400, in 2019.

In Asia-Pacific, China is the largest manufacturer and consumer of e-buses in the world. The country's domestic demand has been supported by the national sales targets, favourable laws, supportive subsidies, and municipal air-quality targets. China is a key player in the electric bus market and is anticipated to sustain its dominance during the forecast period. In May 2020, more than 420,000 electric buses were in use in China, which amounts to about 99% of the global fleet.

## 3.2 Auckland Context

### Air Quality and Health

Road transport is the largest source of greenhouse gas emissions in Auckland, accounting for 33.3% of the region's emissions. Road transport emissions also contribute to poor air quality, contributing to undesirable health impacts.

Research has revealed that persistent exposure to even relatively low levels of air pollution can contribute to or exacerbate health problems. These include respiratory and cardiovascular conditions as well as the potential for a reduced life expectancy. Children are particularly at risk to poor air pollution which can cause asthma. Approximately 763 New Zealanders died prematurely in 2016 from vehicle related pollution[7].

In Auckland, transport is estimated to be responsible for 81% of all anthropogenic air pollution health costs, valued at $763 million annually[8]. Particulates from burning diesel are particularly hazardous and have been classified by the World Health Organisation as a carcinogen with no safe limit.

### Environment

Battery electric vehicles deliver a significant reduction in greenhouse gas emissions compared to conventional diesel buses, especially in New Zealand where the electricity grid contains a high mix of renewable sources. The complete conversion of Auckland Transport's diesel bus fleet to electric fleet by 2030 will result in an 68% reduction of life cycle greenhouse gas (GHG) emissions compared to retaining diesel fleet. Longer transition over the period from 2020 to 2040 would reduce GHG emissions by 42%. However, should transition by 2030 be not possible due to insufficient funding, achieving transition by 2035 in line with the Government's 2035 target would reduce GHG emissions by 60%. This conversion to electric fleets will also eliminate harmful tail-pipe emissions such as nitrogen and particulate matter.

[6] Fuel cell electric vehicles stock by region and by mode, 2020 – Charts – Data & Statistics - IEA
[7] HAPINZ 3 v2.0 (2022)
[8] IEA Global Electric Vehicle Outlook 2022

| NVP (2021) | Social Costs - Exhaust Air + GHG | Social Costs - Noise | Social Costs - Upstream GHG | Total | Benefits |
|---|---|---|---|---|---|
| Option E - 100% by 2040 | $1,805,092,390 | $73,395,731 | $18,907,591 | $1,897,395,712 | $202,726,650 |
| Option F - 100% by 2030 | $1,117,103,005 | $64,902,731 | $16,931,101 | $1,198,936,837 | $901,185,525 |
| Option G - 100% by 2035 | $1,320,242,770 | $67,811,538 | $17,556,452 | $1,405,610,761 | $694,511,601 |
| Option 0 - Diesel Baseline | $1,991,612,094 | $86,559,445 | $21,950,823 | $2,100,122,362 | |

Table 1 - Social Benefits from the Transition to Zero Emission at Tail Pipe Buses for Option E, Option F, and Option G.

**Social**

Emission Impossible Ltd was previously commissioned by Auckland Transport to study the social benefits of transitioning to a low emission bus fleet by 2040 based on the 2017 fleet profile. Their findings have been updated for the default Option E and show that the social benefits now account for $75 million ($28 million discounted) over the total period, based on a 2018 baseline. Details are provided in Appendix 2: Benefits and financial impacts.

This model has since been revised to reflect updated fleet numbers, as well as updated social costs of emissions from urban buses which were updated since the last version of the roadmap was published. The new cost factors are in line with HAPINZ version 3.0 (2022). The NVP discount rate is calculated at 5.0% from NZ Treasury.

The figures in table 1 of were derived by comparing emissions from electric buses to emissions from diesel buses. For the purpose of calculations, these have been assumed to enter the fleet at the transition rate of Option E and include $CO_2e$, PM2.5, NOx, SO2, CO, HC and noise pollution. Upstream GHG factors are based on published life cycle analyses for NZ fuels by Barber & Stenning (2021).

The updated benefits for Option (E) are $202.7m, Option 2 (F) would now deliver benefits of $902.2m, and the now recommended Option 3 (G) will be $694.5m

The social benefits only capture the replacement of diesel buses from urban bus services under contracts to Auckland Transport. If the replaced diesel buses from urban services are scrapped by bus operators or removed from Auckland, then the social benefits for Auckland would be greater. However, the diesel buses replaced by zero-emission fleet under Auckland Transport's Low Emission Bus Roadmap would likely still be on Auckland roads in other commercial capacities, therefore those benefits associated with their removal from all of Auckland's fleet are not included.

**Auckland Transport Bus Fleet**

Auckland Transport's buses are privately owned. Auckland Transport contracts all urban and school bus services to nine bus operators. As at March 2023, there were 1316 diesel buses and 78 low emission buses operating over 200 routes[9]. The fleet size varies considerably between operators, with some operators managing fleets over 500 while others have fewer than 100 buses each.

While as of July 2021, all new buses procured for Auckland Transport services must be zero emission vehicles there are still 502 buses in the fleet that are 10 years or older that are currently in operation.

[9] Including route variants but excluding school bus routes


9 bus operators
59,000,000km
annually
1350 buses
200 routes

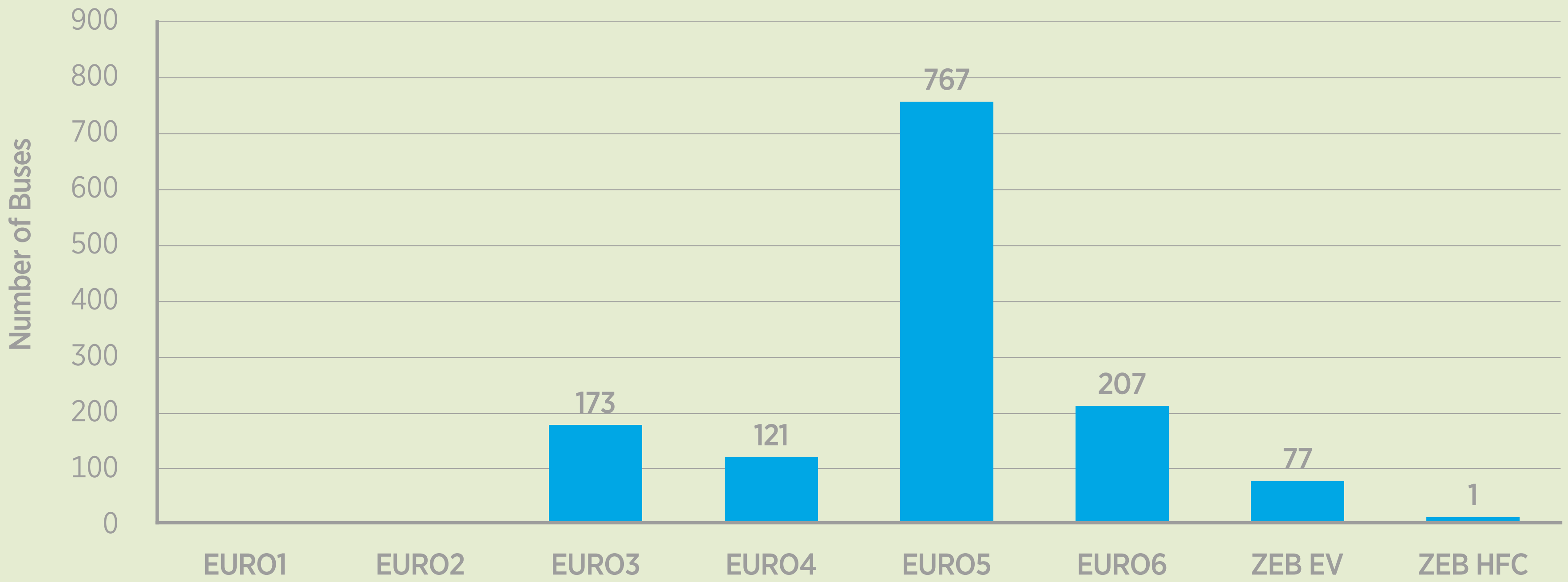



Table 3 - Auckland Transport's Contracted Bus Fleet Profile in April 2023 by Bus Emission Standard.

The 2023 fleet composition includes a variety of buses with emissions standards, as depicted above.

Buses in the current fleet range in size from about 8.5m to 13.5m and include both two and three-axle vehicles. The double deck fleet has stayed consistent at 195 vehicles since 2019 as the expected capacity demand has not increased due to COVID-19 pandemic reducing overall patronage. Their transition to an equivalent zero-emission option will require overcoming design challenges presented by the New Zealand Vehicle Dimension and Mass (VDAM) regulations. The challenges affect new bus manufacture and potential retrofitting with electric and hydrogen fuel cell (HFC) technology to mitigate the risk of stranded assets (new diesel fleet implemented in recent years). Auckland bus operators have strong links with European bus manufacturers, with many models purchased from ADL, Volvo, MAN and Scania.

The e-bus trials with procurement and implementation of extra-large three-axle trial buses by Auckland Transport from Global Bus Ventures (GBV), BYD/ADL and Yutong have generated interest from other bus manufacturers. Brands like CRRC, Foton, BCI, Optare, Hyzon and Hyundai are now interested in the New Zealand market to provide electric and hydrogen fuel cell buses of various sizes directly from their factories. In late 2022, new double deck three-axle zero-emission bus designs have been presented by GBV, ADL, Yutong and CRRC. In addition to GBV, there are also two other electric bus builders in New Zealand; Kiwi Bus Builders (KBB) and start-up Zemtec who are able to manufacture e-buses locally.

Bus operators' urban fleet must not exceed an average age of 10 years, in line with requirements under Auckland Transport's PTOM contracts, however the maximum permitted age can be up to 20 years.

Current PTOM service contracts will re-tendered from 2023 with implementation of new contracts expected by 2025.

# 4. Developing the Low Emission Bus Roadmap

# 4. Developing the Low Emission Bus Roadmap

**To migrate over time to a low emission technology, Auckland Transport needs to know what to migrate to and by when. We need an evidence base for investment in our bus fleet based on life cycle analysis.**

## 4.1 Assessment of Technology Options

The Low Emission Bus Roadmap Report in 2018 was based primarily on life cycle analysis and looked at the role of different low emission fuels and technologies in advancing Auckland's bus fleet to zero-emission by 2040 and the practical means to deliver this vision. The range of low emission bus technologies being deployed across the world are:

- Diesel hybrid: Series hybrid, the diesel engine only charges the battery, which then powers the electric motor; in parallel hybrid the powertrain can be switched between the diesel engine and the electric motor
- Plug-in hybrid (PHEV): Like a diesel hybrid, but with a larger battery that is charged from the electricity grid, enabling electric- only operation for part of a journey
- Battery-electric (BEV): Electric propulsion, powered solely by electricity stored in batteries
- Retrofit battery-electric and plug-in hybrid technologies: Conversion of existing diesel buses to low or zero-emission powertrain technologies
- Compressed natural gas (CNG): Spark- ignition engine powered by gas (natural gas or biomethane), with compressed gas stored on board the bus. Biomethane is a biofuel produced from organic waste
- Biodiesel: Biofuel produced from animal or vegetable oil feedstocks which can be used in a conventional diesel engine. B20 (a blend of 20% biodiesel and fossil fuel) produced from sustainable waste feedstocks were considered for this study
- Renewable Diesel (RD): Diesel refined from 100% renewable and sustainable raw materials of more than 10 different wastes & residues and various vegetable oils, it is colourless, odourless, and achieves cleaner burning in conventional diesel engines and reduces emissions and harmful irritants. Can be used as 100% fuel or a blend with no changes to engines and is being explored as a new interim alternative in this study
- Hydrogen Fuel Cell (HFC): Electric propulsion using a hydrogen fuel cell as its power source. Hydrogen fuel cell buses have been very lightly appraised in the study, since the technology is in the 'early adopter' demonstration phase across the world and is subsidised heavily by governments.

## 4.2 Recommended Technology Options

The Roadmap identifies battery electric technology as offering the best all round opportunities for most routes. Hydrogen fuel cell technology is also recommended as a solution for longer routes that battery electric may not be able to service. Hydrogen fuel cell buses may also be suitable for future Rapid Transit. Retrofitted diesel buses were identified as a solution to mitigate the risk of stranded assets for bus operators; however, Auckland's variety of bus makes and models could make this a costly option, as each make and model of a bus will require a custom retrofit solution. Auckland Transport is following closely the retrofit trial of double decker bus in Wellington and funded by EECA, and this could be solution for retrofit trials in Auckland where the operating environment is different, and if proven, could be used to repower newer double decker diesel buses.

- Battery electric: Battery electric technology is suitable for most routes in Auckland. It benefits from New Zealand's largely renewable electricity grid, cutting down the lifetime emissions. Battery electric vehicles have zero-emissions affecting air quality. The refuelling time (charge time) varies based on the battery size and charging type and infrastructure. Analysis has favoured off-peak, overnight charging at depot. There are two main variations of battery electric buses – those that charge only at the depot using plug cables, and those that charge at interchanges and layovers or on-route using pantograph or wireless charging.

  There are concerns with the environmental impacts of batteries no longer useful after their second life application. Battery Industry Group (BIG) has been set up by about 170 organisations. BIG's proposed solution is an innovative, 'circular' Product Stewardship scheme that will make sure we are taking responsibility for all large batteries, from the moment of arrival in New Zealand through a second or third life to the point of recycling at the end.

- Hydrogen fuel cell (HFC): HFC technology is developing but is immature and at trial stage at the time of the Roadmap. It has a similar ability to fulfil service requirements as a diesel bus. It benefits from New Zealand's largely renewable electricity grid, cutting down the lifetime emissions. An HFC's only tailpipe emission is water. The refuelling time is similar to diesel technology and takes between 10-15 minutes. At present, HFC buses have a significantly higher total cost of ownership than diesel buses. HFC buses are a more suitable alternative to e-buses to provide high-capacity large bus services that would otherwise require very large and heavy batteries. These batteries would in turn reduce the carrying capacity of those e-buses, as vehicle weight is limited by the VDAM rules. Initially, HFC buses will not be operationally cheaper than e-buses, but global studies suggest that hydrogen will be the main fuel to power public transport from 2030.

The cost of green hydrogen production in New Zealand needs to reduce significantly for HFC buses to become commercially viable. As hydrogen becomes cheaper the demand for HFC buses will lower the purchase price, reducing life cost of HFC bus. The investigation of hydrogen as a future fuel is important, particularly when looking at how public transport buses will be powered in the later stages of this transition (i.e., the routes that are more challenging to transition with current technology). AT is currently trialling a HFC bus. This trial is aligned with the vision for hydrogen in New Zealand articulated in a Green Paper consulted by the Ministry of Business, Innovation and Employment (https://www.mbie.govt. nz/have-your-say/a-vision-for-hydrogen- in-new-zealand-public-consultation/).

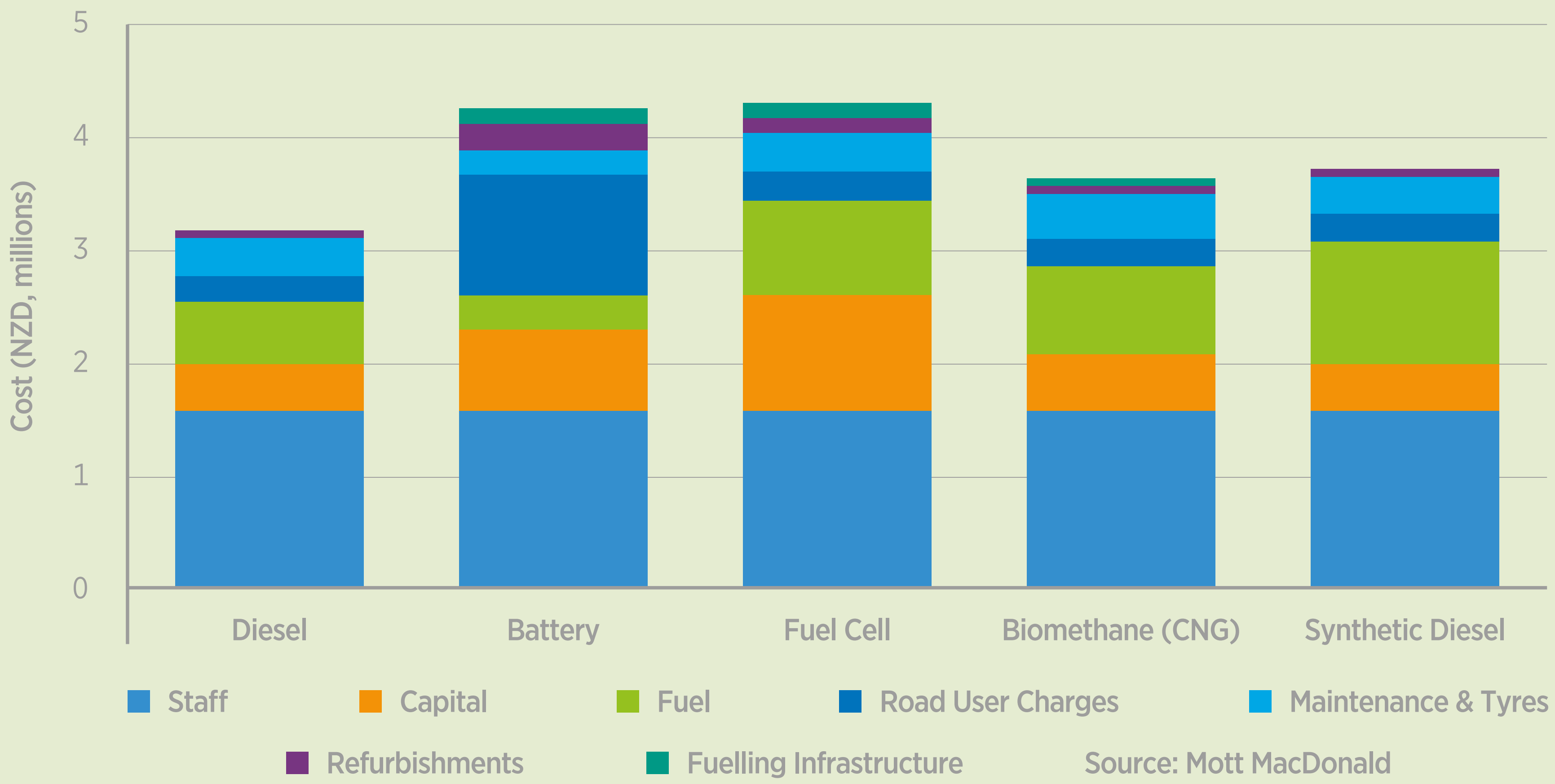



Figure 2 - Whole Life Costs of Buses with Different Type of Fuels and Technology (RUC Inclusive). Source Mott MacDonald.


The cost and benefits of the transition to hydrogen technology on buses have not been modelled in the Roadmap options and scenarios at this point. The Roadmap will be updated with those scenarios when more information is available from the HFC bus trial and learnings from other jurisdictions. Recent study done by KPMG and Mott McDonald for the Ministry of Transport compared the life costs of hydrogen fuel cell and battery electric buses against other fuels

- Retrofit: Retrofit technology is in an early stage of development and large-scale applications are limited. There is one trial underway in Wellington undertaken by Trazit Group and co-funded by EECA. Its operability is suitable for most routes, but it may bring about VDAM challenges due to the weight to enable longer range on single. Retrofitted buses will also require charging infrastructure. It also benefits from New Zealand's largely renewable electricity grid, cutting down the lifetime emissions. The total cost of ownership requires further analysis. The whole of life cycle $CO_2e$ is significantly better than diesel as are the air quality impacts. Its range is similar to battery electric buses and route dependent. The charge time is dependent on the model but is generally short (1-3 hours using DC[10] charging).

The above technologies were assessed amongst other low emission fleet options using international research, collaboration with the C40 network and the expertise from the Low Carbon Vehicle Partnership in the United Kingdom. They were discussed with the AT Board Customer Focus Committee in February 2018 and were endorsed as the preferred technology options by the Customer and Innovation Committee in July 2018. They were also endorsed in November 2020 by the Design and Delivery Committee and in December 2020 by AT Board.

[10] Direct Current (DC) charging is a fast charging system which transforms alternating current (AC) to direct current (DC) and sends this direct current directly from the external charging unit to the batteries on the bus.


# 5. Technology Trials

# 5. Technology Trials

**Auckland Transport is working in partnership with bus operators to trial zero-emission buses.**

## 5.1 Electric Bus Trials

In May 2018, Auckland Transport worked in partnership with bus operator NZ Bus to launch what started as a six-month trial of two electric buses. The vehicles serviced the City LINK route and performed exceptionally well.

The City LINK route was selected because the length and topography of the route was appropriate, it was near a bus depot, and it travelled through poor air quality zones with high public exposure.

There were operational savings of $10,900 from the two buses, which travelled a combined 17,400 km over the trial period.

It is expected that lower operating costs will reduce the total cost of ownership and offset high capital costs. Furthermore, the electric buses demonstrated an estimated emissions reduction of 160 tonnes of C02 over the course of six months.

With the success of the City LINK trial, Auckland Transport has experimented with alternate routes to challenge the technology and provide other bus operators with the opportunity to trial e-buses. In addition to the City LINK trial buses from BYD/ADL, a third electric bus (with slightly different technology), was acquired on loan from Yutong, a Chinese manufacturer. More trials are underway with the buses servicing the Inner LINK, Airporter 380 and 309 routes. Results from the trials are provided in Appendix 1.

In 2019 AT also trialled a demonstrator two-axle e-bus provided by Yutong. This bus was trialled along the BYD/ADL buses and tested on other routes and with different operators in Auckland.

In 2021 Auckland Transport with the co-funding from Waka Kotahi NZ Transport Agency and EECA have commenced trials of three-axle extra-large single decks battery electric buses and a hydrogen fuel cell bus.

There are currently six trial buses operating Auckland Transport bus services, with a variety of different operators. The data gained from these trials has been and will continue to be used to inform decisions regarding future investment. Of note, there is currently a trial underway of test the first 'extra-large' 3-axel hydrogen fuel cell in Auckland, and the first of its kind in the world, designed especially for New Zealand. The trial commenced in July 2021. The bus was designed and built by Global Bus Ventures (GBV) in Christchurch, New Zealand and is currently being operated on route 70 by Howick and Eastern by Transdev. This bus is being run in parallel to an electric and diesel bus of similar configurations and will demonstrate the potential of an alternative low emission technology to help us reach our zero-emission future.

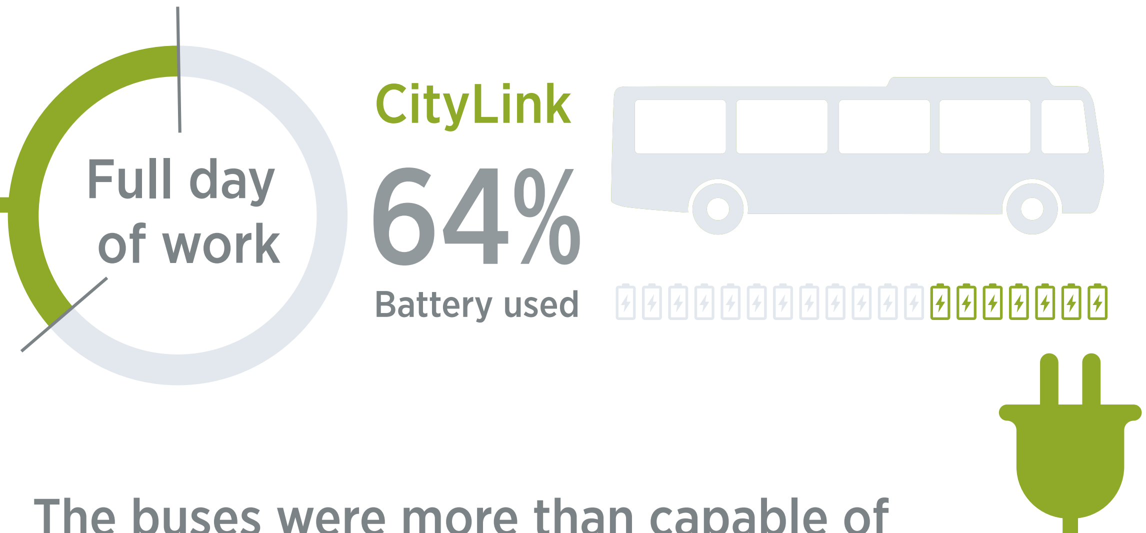
The confidence in the electric bus technology encouraged Fullers 360 subsidiary, Waiheke Bus Company, to purchase six BYD/ADL Enviro 200EV buses to operate them on behalf of Auckland Transport on Waiheke Island in November 2020. Two more electric buses were added to their fleet in February 2021. The remaining bus fleet on the island will transition to zero-emission buses, with seven more electric buses added to the fleet by the end of the contract.

Encouraged by the results from the trials, Auckland Transport launched the new Airport LINK service from Manukau Bus Station via Puhinui Station to the Airport also operated by fully electric buses from January 2021. In April 2021 the entire City LINK service has been transitioned to fully electric fleet from April 2021.

**CityLink Trial**

The bus model is a Enviro200EV from Alexander Dennis and BYD. Both buses are battery electric.

Each bus and charger cost $840,000 and were purchased by AT with funding support from Energy Efficiency and Conservation Authority ($500,000)




**The buses were more than capable of completing a full day of operations on the CityLINK route. They only used 64% of their battery for a full day's work with a consistent range of 265km using 90% of the battery capacity (expected performance was 250km)**

With the confidence gained from previous trials and global trends, the milestone to have all new buses procured as zero emission by 2025 has been accelerated and came into effect in July 2021.

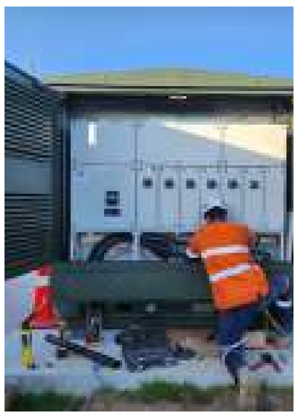
The trials also enable testing of the bus charging technology. The first ADL/BYD two-axle e-buses use a two-plug system of 40kW per plug enabling slow charging overnight at depot. The charging time takes up to six hours. The Yutong two-axle bus tested in 2019 uses a single plug design of 150kW per charge enabling fast charging between 1.5 hours to 4 hours depending on the power supply.

The initial depot set up and the transfer of trial e-buses between operators and routes contributed to a better understanding of any issues and opportunities to improve design and processes.

As a result of this testing, two 193kW chargers have been installed at Manukau Bus Station. These chargers are capable to charge buses using CCS/ CCS2 plug types with both AC (slow) and DC (fast) charging. The chargers can be used by different operators and enable on-charging of the electricity used to power specific buses using white sheet system. The white sheets allow pairing of buses with chargers so that the electricity use can be recorded.

These white sheet chargers have been crucial in helping operators charge their vehicles while undertaking trials of zero-emission buses, or while infrastructure upgrades to their own depots have been undertaken. This has increased the level of access to trial technology that some operators would have otherwise not had if the only option was to install chargers at their own depots.

Auckland Transport also installed AC and DC chargers at the Ti Rakau depot. This location will offer experience and learnings from using DERMS and inductive (wireless) chargers.



## 5.2 Future Trials

While the positive results from e-bus trials have influenced the supply chain and several global bus manufactures now offer single deck standard two-axle and three-axle battery electric buses for New Zealand operators, further trials are still necessary for different vehicle and route types to complete a broader understanding of technology and operational requirements and to overcome barriers to full adoption.

While promising, further trials of the hydrogen fuel cell bus are required to adequately test its performance capabilities and assess cost feasibility. The current hydrogen bus is 13.5m long with three-axles and provides capacity for up to 78 passengers. Discussions are underway to source more HFC buses for additional trials and pilots.

The hydrogen production plant and refuelling station originally proposed to be built by Ports of Auckland (POAL) in the third quarter of 2020 has now been undertaken by Obayashi Corporation. This station will provide the hydrogen fuel supply for Auckland Transport's trial HFC fleet. In the interim, the HFC bus has been refuelled using temporary refilling facility set up inside the port.

We will continue to undertake trials and demonstrations of zero-emission buses and their associated charging infrastructure with different bus operators and technology providers, and where possible maximise alternative funding streams such as from Energy Efficiency and Conservation Agency (EECA) and private capital.

Options include:

- Trial or demonstration of retrofitted diesel 'extra-large' three- axle and double decker buses to electric using proven technology
- Trials of different charging infrastructure solutions and type of chargers
- Trial of wireless inductive bus charging technology to reduce depot footprint required to park electric buses connected to plug-in chargers
- Other depot charging solutions to reduce impact on depot footprint and reduce manual connections of cabling and plugs
- Further assessment of 'opportunity' pantograph and inductive charging on route for busways and new BRT projects versus plug-in charging at depots and key stations/ layovers

As the transition is expected to take several years, other interim solutions to reduce the carbon footprint are being considered.

Auckland Transport is exploring the option to use renewable diesel with a low carbon emission factor and lower tail pipe emissions compared to conventional diesel. Renewable diesel is not yet available in New Zealand, but a global supplier, Neste, has completed discussions with the Ministry of Transport and Auckland Transport about the potential to support its use in heavy transport and buses and has signed a distribution agreement with Z Energy. Auckland Transport is considering a commercial pilot in partnership with Z Energy and with one of the contracted operators to use renewable diesel from Neste for newer diesel buses and assess if this solution could be used to reduce the risk of stranded bus assets for operators and still reduce greenhouse gas emissions. The trial is dependent on Z Energy receiving an approval from the Environmental Protection Authority to import the Neste 100 blend of renewal diesel product with a blend without palm oil.

# 6. Accelerating our Transition to Zero-emission

# 6. Accelerating our Transition to Zero-emission

**The transition to zero-emission fleet included consideration of ownership models for fleet and depots. In 2018 it was shown that the estimated costs of purchasing buses by Auckland Transport would require significant capital investment and was not recommended to the Board. Public Transport asset ownership was considered as part of public consultation in 2020 on the Public Transport Operating Model facilitated by Ministry of Transport and depot ownership has been identified as crucial enabler of the transition with the investment required in depot charging infrastructure. Auckland Transport 's depot strategy is being developed post this consultation.**

## 6.1 Ownership Models

### Fleet Ownership

The current fleet provision under the PTOM has been assumed, although mixed model is possible during the transition period. Bus operators will be responsible for purchasing and supplying electric buses for Auckland Transport contracts as they do currently for diesel buses. In the scenario endorsed by the Board in December 2020, Auckland Transport does not require capital to purchase fleet or charging infrastructure (except for trial purposes) and fleet costs are incorporated into contract rates, or Peak Vehicle Requirement (PVR) variation rates.

Since the development of the Roadmap, Auckland Transport has participated in the C40 Finance Academy and conferences organised by the Mass Transit on Clean Buses in Asia, the International Association and Public Transport (UITP) and Public Transport Association Australia New Zealand (PTAANZ), and have been exploring other ownership models used to accelerate the electrification of bus public transport. Such options include leasing buses and bus charging infrastructure from the original equipment manufacturers (OEM) or their consortiums with specialist leasing companies, by the transit authorities and sub-leasing them to bus operators. Other regional councils in New Zealand and the Ministry of Transport have considered alternative fleet procurement and ownership in New Zealand and at this point there is no clear direction form the Ministry regarding changes to the procurement model, however options exist for joint procurements between regional transport authorities and Auckland Transport. Auckland Transport will further investigate the options.

### Charging Infrastructure

The bus charging and associated depot infrastructure and electricity network upgrades were incorporated in the cost and benefits analysis of the transition to electric buses in the previous version of the Roadmap. Under the current PTOM contracts, the responsibility for bus charging infrastructure and upgrading the electricity network lies with bus operators. This means that electric buses, bus charging infrastructure and the operation of the fleet is procured in one single contract for bus services. Since the previous Roadmap was updated in October 2020, Auckland Transport has incorporated into the forecast costs the learnings from the trials and early deployments of electric buses, as well as the increasing cost of civil works and higher costs for new high voltage connections introduced in late 2021. The forecast now incorporates the costs of replacing batteries as these may increase the overall costs of transition if operators bid for contracts after 2030 with existing electric buses but with new batteries. The updated costs and benefits are discussed later in section 6.3.

The depots used by bus operators are either owned by bus operators, leased from other owners, or long-term head lease holders / investors. Therefore, the current depot ownership presents challenges in upgrading some depots with bus charging infrastructure. The availability of 'charging as a service' offered by many new zero emissions technology providers has enabled the mitigation of some of the ownership issues and capital investment requirements for bus operators. These options increase the operational cost to the bus operator under lease arrangements.

## 6.2 Transition Options

### 6.2.1 Electrify by 2040

In 2018, the Auckland Transport Board assessed five strategic options for the transition to low emission buses in Auckland. The board endorsed "Option E", which stipulates that as of 2025 all new buses for end-of-life replacements and fleet growth will be battery electric only for all contracts.

Options A – D were assessed with the scenario of Auckland Transport purchasing EV fleet and leasing it to bus operators. This scenario provides the ability to negotiate bulk procurement discounts and achieve consistent fleet and charging infrastructure. However, it requires a high capital cost outlay that is not in the Regional Land Transport Plan (RLTP) and would introduce a continuing cost of fleet replacement. Therefore, these options under such a scenario were not recommended.

| **Option E (2018)** | **Benefits** | **Disadvantages** |
|---|---|---|
| All contracts from start 2025 specify bus replacements and growth vehicles as zero-emission only. Option E - 1 | • Meets Mayoral commitment made in 2017 to buy only zero-emission from start of 2025<br>• Later start maximises benefits of technology development, reduced capital cost of vehicles and cheaper future replacement of batteries<br>• Ability to implement City LINK fleet contract (opportunity) as bigger scale trial of a LEV-fleet and assess its impact on depot charging and grid<br>• More time to prepare for infrastructure and to plan fleet change<br>• Gives AT more time initially to consider and procure depots and implement large-scale charging infrastructure upgrades (not in RLTP) | • Operators purchasing small numbers of electric vehicles for patronage growth likely to be more expensive (discounting for bulk purchase not modelled)<br>• Achievement of 100% LEV passes beyond 2040. It would require bus operators to voluntary, or by requirements added to future contracts, replace remaining diesel fleet (cost and benefits of replacing the remaining diesel fleet in 2040 were not modelled) |

### 6.2.2 Electrify faster by 2030

In December 2020, Auckland Transport Board approved the accelerated Roadmap targeting full transition to zero emission (at tailpipe) buses by 2030 starting from 2021, subject to funding.

Based on the funding available the Auckland Council approved the accelerated Roadmap with the Mayor's announcement that from 1 July 2021 all new buses procured for public transport services contracted by Auckland Transport must be zero-emissions.

The current transition to zero-emission buses is tracking in line with the accelerated Option F endorsed by the Board in December 2020. This delivered the City LINK contract with an all-electric bus fleet from April 2021, 8 electric buses in service for Waiheke Island the Airport LINK from Manukau via Puhinui Station. Most recently, in October 2022 the Tamaki Link service transitioned to a fully electric fleet.

Based on the progress made in promoting the earlier adoption of low emission bus fleet in New Zealand and creating a supply chain able to support their operation, along with the evolution in battery and charging technology and updated cost and benefits (including social and environmental), faster electrification of buses under the "Option F" will complete the transition ten years earlier. To align with this faster transition, in December 2021, Auckland Transport agreed with three operators to deploy 161 more electric buses between 2022 and 2025 with more discussions underway to deploy more, subject to funding.

| **Option F (2020)** | **Benefits** | **Disadvantages** |
|---|---|---|
| Option F will complete the transition ten years earlier – in 2030. | • Meets Mayoral commitment to buy only zero-emission from start of 2025 and make major part of city centre fossil fuel free by 2030<br>• Accelerated start maximises benefits of rapid technology development, stimulates supply chains to reduce capital cost of vehicles and brings forward cheaper future replacement batteries<br>• Ability to implement more battery electric buses and fast track investments in depot charging and electricity network | • Contract variation rates for electric buses under existing service contracts likely to stay high until end of term Auckland Transport may need to influence the market in order to achieve faster uptake of electric buses<br>• Regulators, electricity suppliers, manufacturers and key stakeholders have very limited time to transition to the new technology<br>• Auckland Transport will pay a premium during the initial procurement phase (increased demand for electric buses will aid in reducing the future cost of purchase fleet) |

### 6.2.3 Align with the government target of 2035

In February 2021, the Government announced a policy to decarbonise public transport buses in New Zealand starting from 2025 and completing this transition to zero emission buses by 2035. Due to the funding constraints that Auckland Transport and Auckland Council are facing exacerbated by the economic impact of COVID pandemic on fare revenue and other funding sources, and considering the higher costs of earlier deployments of electric buses then previously forecasted, Auckland Transport has developed a new "Option G". This option assumes continuing the accelerated transition from 2021 but proposes the completion of the transition by 2035 aligning with the government's 2035 target. This new option enables the extended use of modern low exhaust emissions diesel buses procured by bus operators for new PTOM contracts from 2017 and addresses their concerns about stranded assets, reduces the costs of new bus contracts with transition plans to replace existing modern diesel buses during the term of new contracts, and provides clarity about funding being provided from 2025 by the Government through the National Land Transport Fund (NLTF) and potentially CERF to cover the higher costs of bus service contracts when using zero emission buses.

| Option G (2023) | Benefits | Disadvantages |
|---|---|---|
| Work closely with operators to advocate for zero-emission buses in contracts for fleet replacement and growth vehicles from 2020 via contract variations.<br><br>All contracts from 2022 specify new fleet, replacements and growth as zero-emission only.<br><br>All double decker and other high capacity electric or hydrogen buses transition to zero-emission from 2025. | • Aligned with Government's bus decarbonisation policy and expected funding to support transition; full fleet transition by 2035<br>• Meets Mayoral commitment from 2017 to buy only zero-emission from start of 2025 and make major part of city centre fossil fuel free by 2030<br>• Accelerated start from July 2021, as per updated commitment, maximises benefits of rapid technology development, stimulates supply chains to reduce capital cost of vehicles and brings forward cheaper future replacement batteries<br>• Right balance between bus order sizes and grid upgrade requirements (discounting for bulk purchase not modelled)<br>• Ability to implement more battery electric buses and fast track investments in depot charging and electricity network<br>• Gives AT better understanding of requirements when considering the procurement of depots and implementing large-scale charging infrastructure upgrades at AT facilities (not in RLTP). | • Contract variation rates for electric buses under existing service contracts likely to stay high until end of term Auckland Transport may need to influence the market in order to achieve faster uptake of electric buses<br>• Auckland Transport may pay a premium during the initial procurement phase (increased demand for electric buses will aid in reducing the future cost of purchase fleet) |

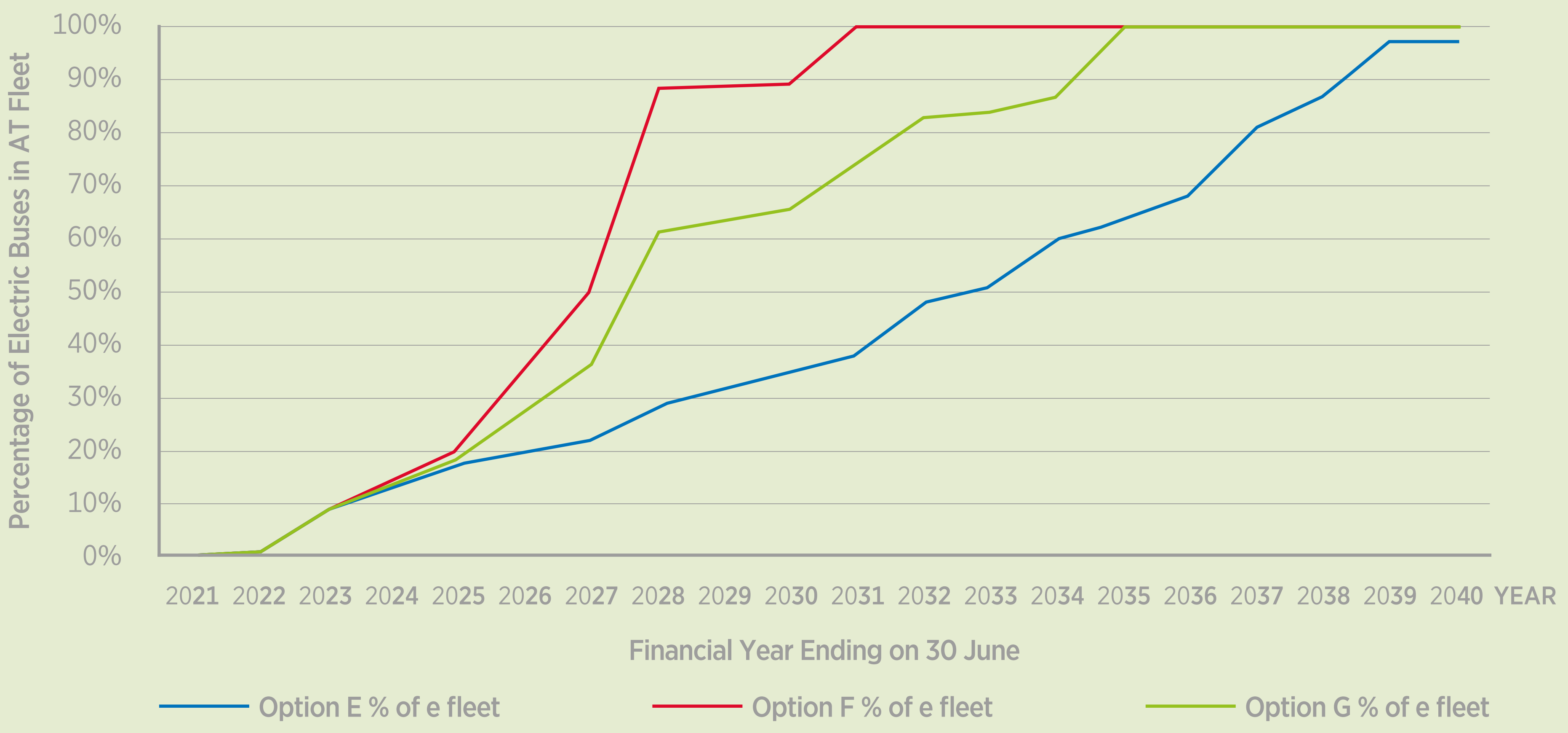



Figure 1 - Comparison of Transitions to Zero-Emission Buses under Option E, Option F, and Option G[11]

## 6.3 Cost Assumptions and Impacts

When considering the transition to zero-emissions, there are three significant categories of cost to consider: capital (vehicles and infrastructure), operation (energy and maintenance), and battery renewal. There is also a predicted increase in bus fleet due to patronage growth impacting the increase in the total cost of bus services under both options to transition from the current diesel fleet[12] .

[11] The transition under Option E assumed that the remaining 12% of diesel fleet in 2040 (250 buses) will be replaced by bus operators by the end 2040 voluntarily or via contractual arrangements to replace them by that date. The costs and benefits of transitioning the last 250 diesel buses in 2040 have not been modelled.
[12] Based on assumption of an average patronage growth of 2.6% on all bus services the fleet size will increase from 1,352 buses in 2019 to 2115 buses in 2040.

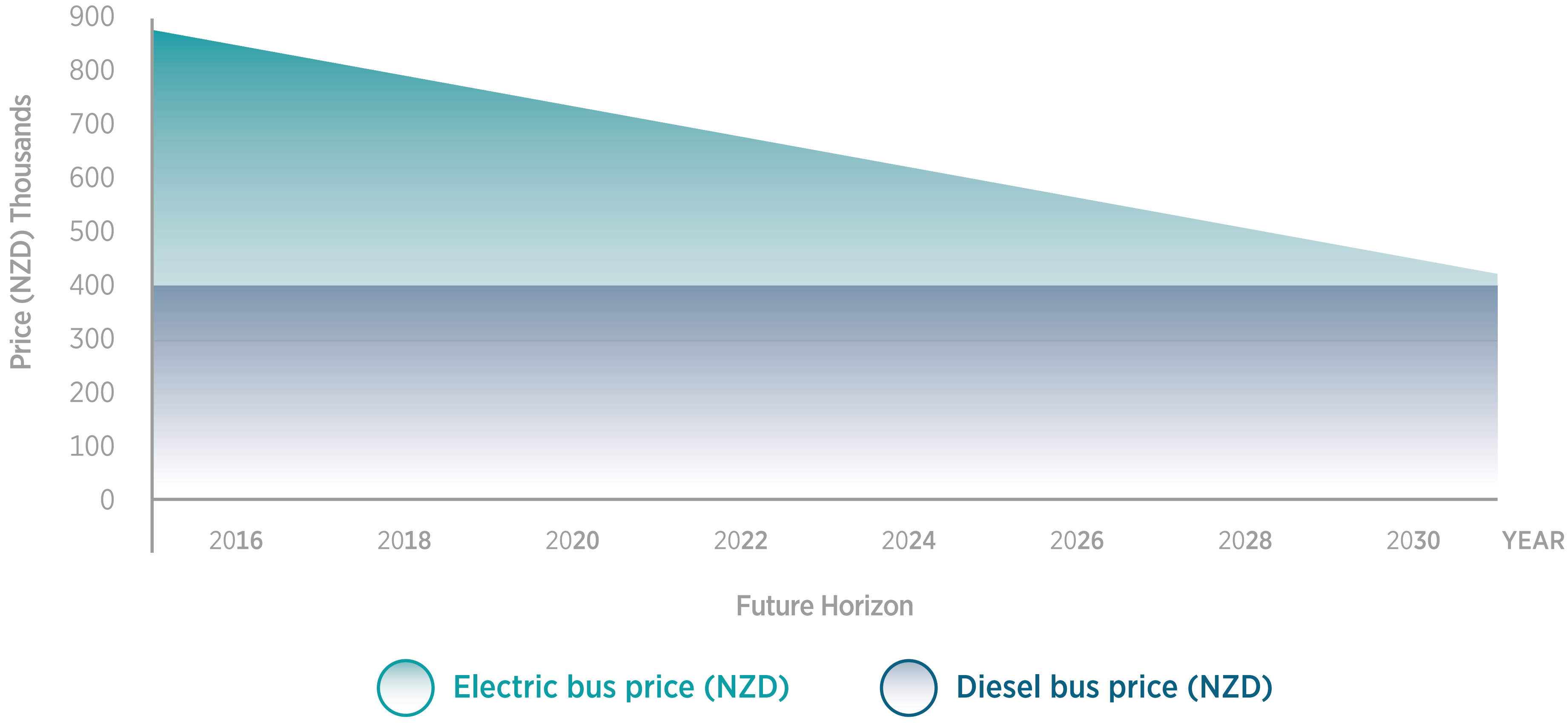



Table 3 - Forecast Purchase Price for Standard Two-Axle Electric Bus Compared to Diesel Bus.

**Capital: Vehicle and Infrastructure Costs**

The premium on the purchase price of electric buses is heavily influenced by the cost of batteries. The expected falling costs of battery production and an increased normality of their use forecasted by Bloomberg New Energy Finance, predict e-bus prices to reach parity with diesel buses by 2030. This forecast seen in figure 3 has been used to predict the future costs of standard low emission buses for New Zealand and updates the modelling of costs of transitioning to a zero-emission fleet.

However, for the purchase price of electric buses for the New Zealand market to follow the above forecast, a significant demand for new electric buses must be created by introducing policy statements and contractual requirements for future bus service contracts. This will attract suppliers keen to meet the unique New Zealand VDAM regulations and produce the fleet sizes and types needed to provide the required capacity in Auckland.

The additional cost of upgrades to the power distribution network and depot upgrades was estimated in 2018 to be between $30-$60 million[13]. Recent depot electrification projects allowed for better cost approximation – a regressive model has been adopted to reflect higher then assumed costs of the charging infrastructure in the first years, followed by a decline due to economies of scale (both regarding global charging infrastructure supply as well as lower unitary costs with larger depot upgrades).

Auckland Transport is working with Vector to better understand the electricity demands required to operate fully electrified bus fleets and bus charging infrastructure requirements for each of the bus depots and their associated costs, including the necessary investment in the electricity network.

Under the Memorandum of Understanding (MOU) between Auckland Transport and Vector, we are collaborating to identify opportunities and mechanisms to reduce costs of bus charging infrastructure and reduce the predicted costs to run e-bus services.

[13] Identified through a C40/AT joint-funded study on Auckland bus depots. June 2018.

The challenge for bus operators of high upfront capital costs of bus charging infrastructure can be partly mitigated by leasing such equipment and 'pay as you go' options through 'charging as a service' from Vector. However, this option introduces another premium on the PVR rates as the charging costs are passed through, increasing contract costs.

The higher PVR rates of new contracts (or contract variations for the electric bus fleet in other cases where zero-emission vehicles are introduced under existing contracts), are expected to be offset by lower in-service kilometre rates.

The overall funding requirements for bus charging infrastructure during the transition period are expected to be a 20% premium on the PVR rate for e-buses based on current cost assumptions, reducing to an 16% premium in 2030 and 14% in 2040; albeit the bus charging costs are expected to reduce compared to those modelled in the current cost benefit calculations through collaboration with Vector and the use of innovation. Alternative investment in depot infrastructure or other financial mechanisms may further reduce the premium added to PVR rates for e-buses and reduce the overall costs of transition.

**Operational: Maintenance & Renewal Costs**

Operational costs are detailed in Appendix 2: Benefits and financial impacts. In summary, analysis shows that relative energy and maintenance costs favour electric over diesel. With the fewer moving engine parts in electric buses compared to a combustion diesel engine with a Euro 6 emission standard, the maintenance costs are likely to be around $2,000 less per bus per year.

Battery renewal costs have been modelled and includes the residual value of the batteries considerations. This yields additional cost of $44m (option E) up to $89m (option F).

**Environmental and Social Impacts**

Transition aligned with Government bus decarbonisation target will achieve full transition to zero-emission buses by the end of 2035.

Figure 5 clearly demonstrates the positive impact on the progressive change in fleet evolution for Auckland Transport.

The additional benefit of the moderate transition under Option G is a smaller carbon footprint with life cycle greenhouse gas emissions reduced by 1.2 million tonnes. All options compare emission levels from diesel fleet in 2019.

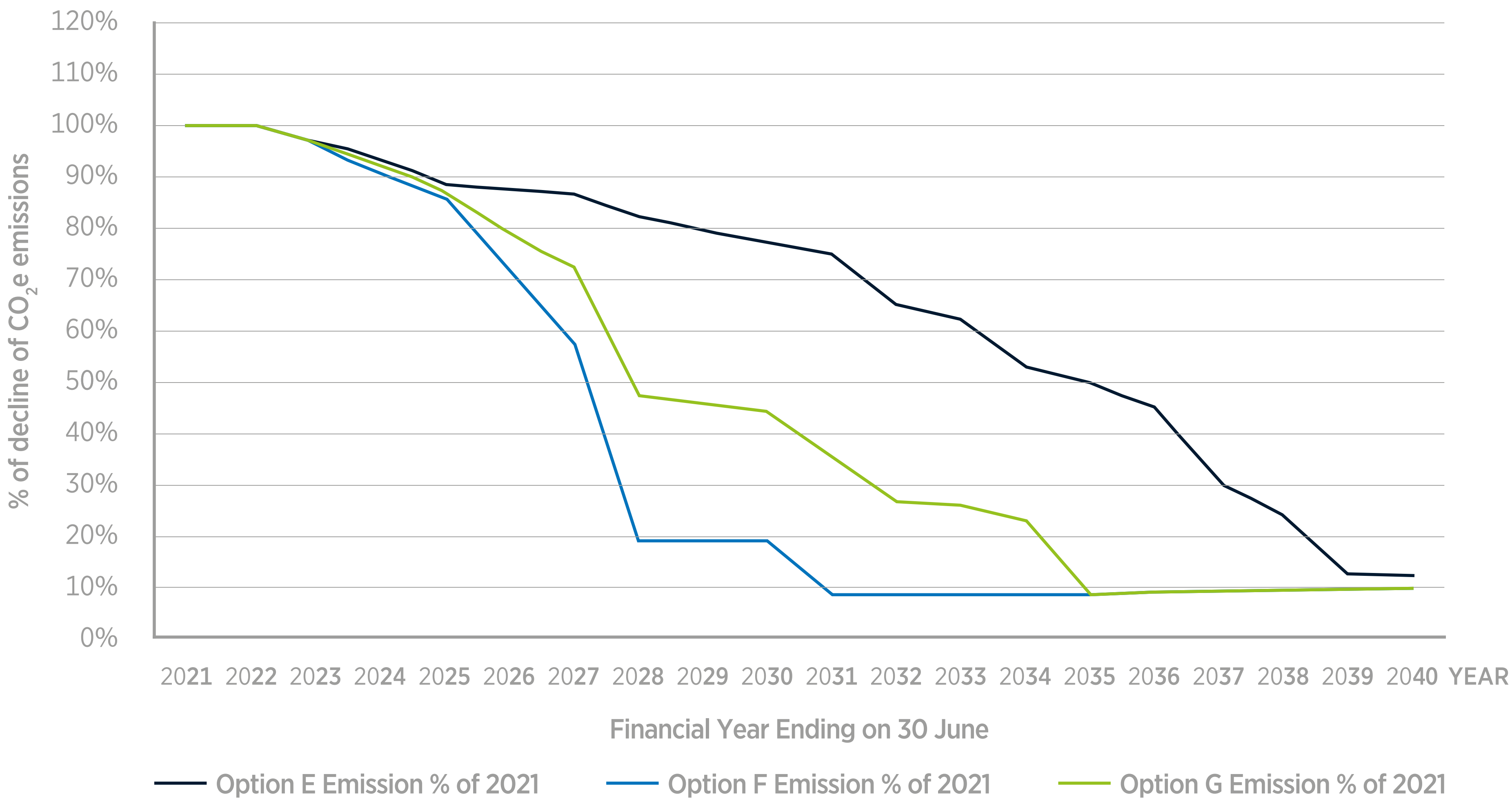



Figure 5 - Emissions Forecast for Option E, Option F, and Option G Based on E-Bus Fleet Evolution.

The detailed study in collaboration with Vector will provide more precise electricity demand information based on fleet type, route profiles, passenger loadings and operating hours. This information will inform the level of investment required to upgrade the electricity network and bus depots to support the accelerated transition to electric buses. Based on figure 6, significant investment in grid upgrades need to occur to support more e-buses implemented under new service contracts. This requirement will inform Vector's ten-year investment planning and prioritising of upgrades to depots where new e-bus contracts will be operating from and should deliver a lower cost of bus charging through innovation.

Below is the forecast of contract costs during the transition to e-buses as per the Roadmap. The forecast is accounting for 2 percent NZTA indexation (inflation adjustment).

Based on better understanding of all costs and an updated forecast, the recommended Option G is expected to increase bus services costs by up to 7.3% in 2030 and 8.5% in 2040 compared to diesel fleet but deliver significant environmental and social benefits. Figure 7 illustrates the trends in total cost bus services during transition to zero emission fleet by 2040.

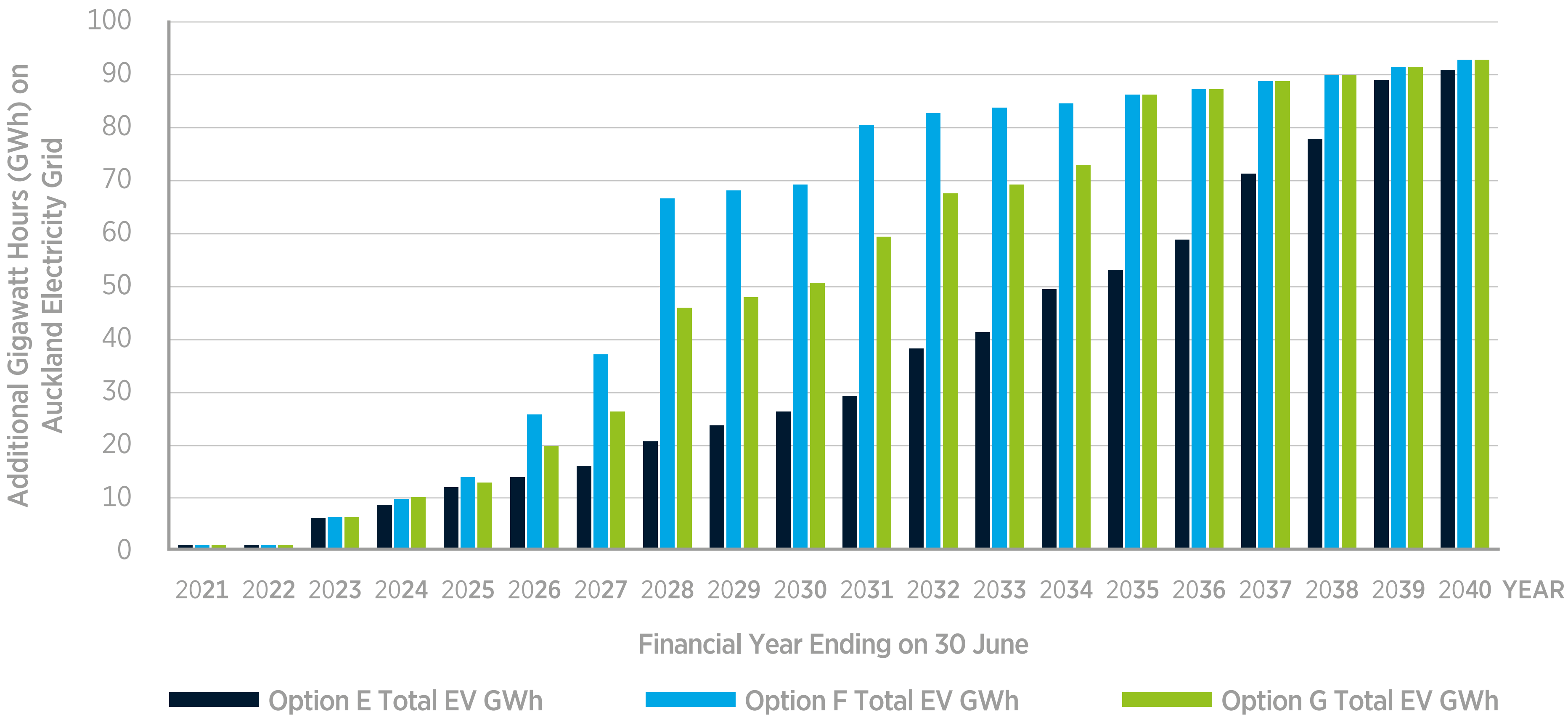



Figure 6 - Estimated Electricity Demand from E-Buses Based on AT E-Bus Trails

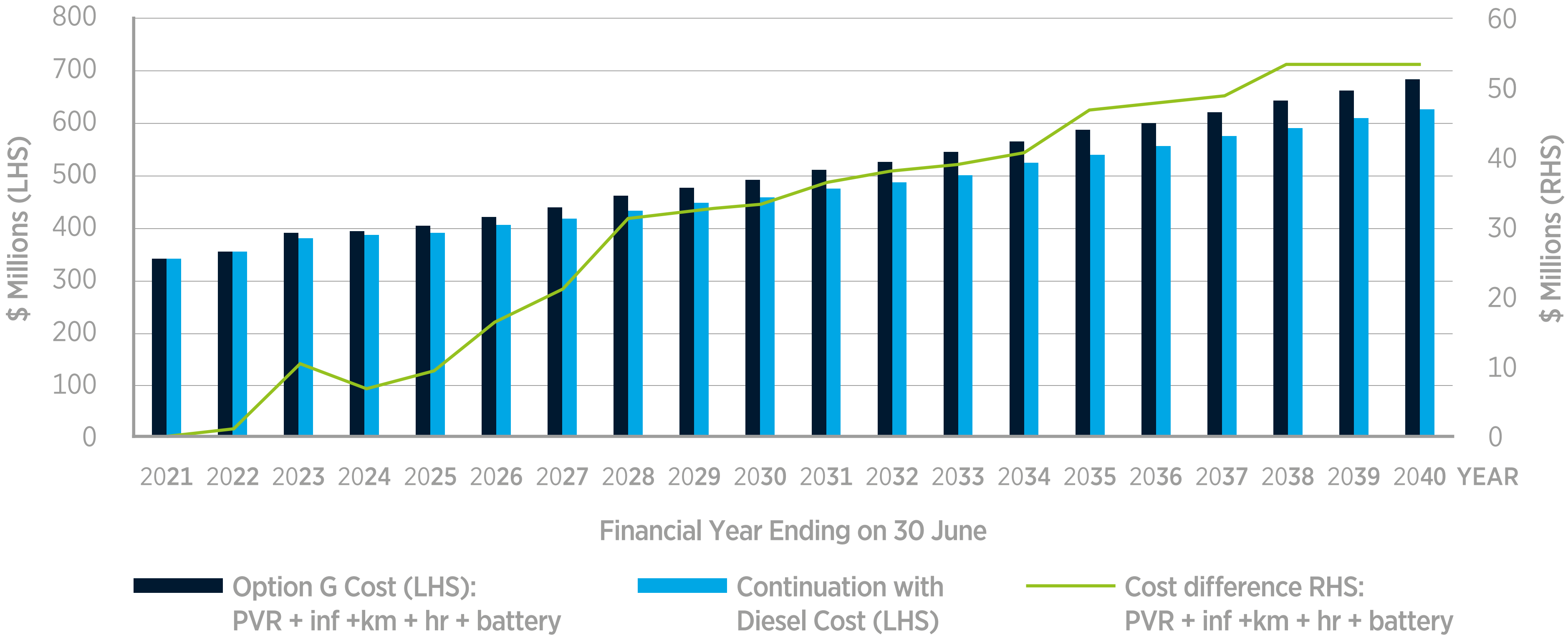
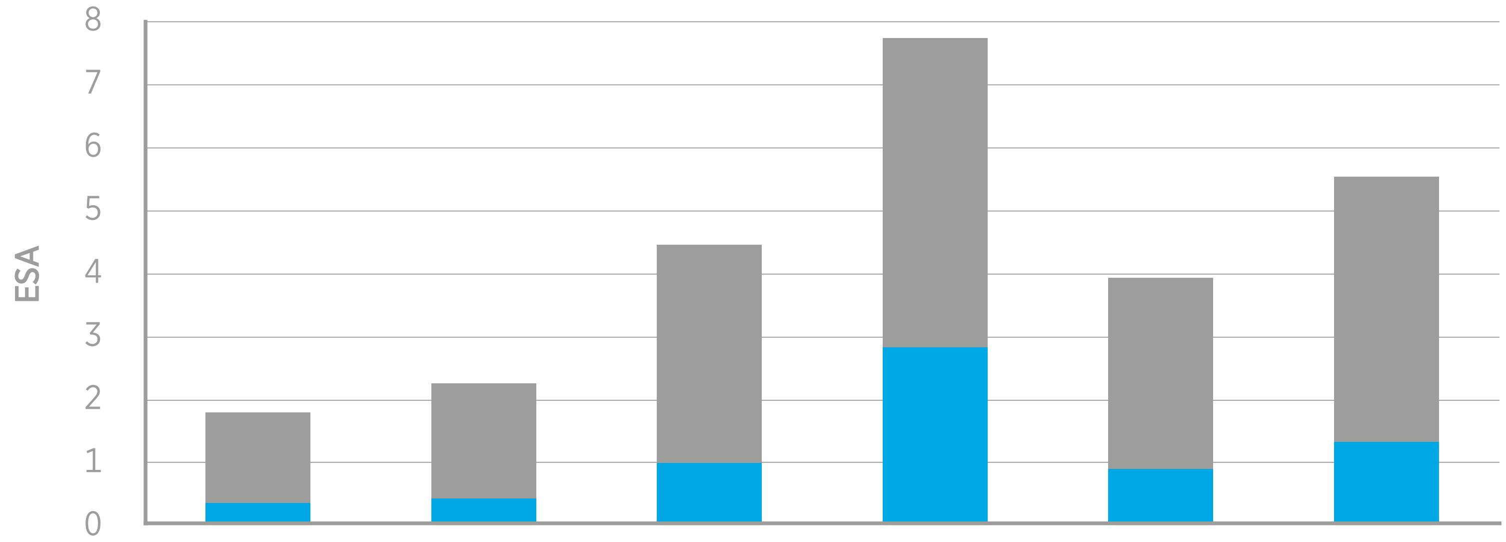



Figure 7 - Total Costs of Bus Services Under Option G Compared to Continuing with Diesel Fleet (1.5% Fleet Growth and 2% NZTA Annual Indexation Applied)

Based on the updated information and forecasts, Option E is now expected to increase operating costs by up to 4.5% in 2030 and by 6.9% in 2040 and achieve lower environmental and social benefits.

The heavier battery electric buses, if permitted to carry more passengers than allowed under the VDAM Rule, or if exempt from it to allow capacity on par with diesel buses, are expected to impact pavements. The alternative use of more battery electric buses to provide the same capacity as diesel fleet has potential for higher pavement costs, due to increased frequency of heavier electric buses across the bus network. While the full impact on pavements has not been modelled, Auckland Transport has conducted a case study on sample of bus routes to understand the impact of heavier battery electric buses on pavements and the associated cost of road maintenance or rehabilitation to improve their quality. This study identified that fully loaded electric single deck two-axle bus has the greatest amount of 'equivalent standard axle' (ESA) loading of all the electric bus configurations, despite having the least amount of total mass. This approach led to AT commissioning and trialling of three-axle battery electric buses to reduce the impact on road pavements while still providing good passenger carrying capacity to meet demand.




| | Diesel Single Deck 2 Axle | Diesel Single Deck 3 Axle | Diesel Double Deck 3 Axle | Electric Single Deck 2 Axle | Electric Single Deck 3 Axle | Electric Double Deck 3 Axle |
|---|---|---|---|---|---|---|
| Total Max ESA | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| + Passenger Mass | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| Empty Bus ESA | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |

Figure 8 - Pavement Impact Case Study Analysis

## 6.4 Financing Options

Multiple financing options have been considered for achieving the transition to zero-emission vehicles.

Funding for the replacement of the end-of-life diesel fleet may be provided to a bus operator replacing old diesel fleet before 2025 (Option E with implementing BEV for City LINK from November 2020). This funding to encourage and support innovative low emission vehicle projects was considered through a (potential) combination of EECA's Low Emission Vehicle Contestable Fund and additional funds from Auckland Transport and the New Zealand Transport Agency. Additional funds could pay for service delivery under existing contracts by means of new contract variation rates to be agreed for zero-emission buses.

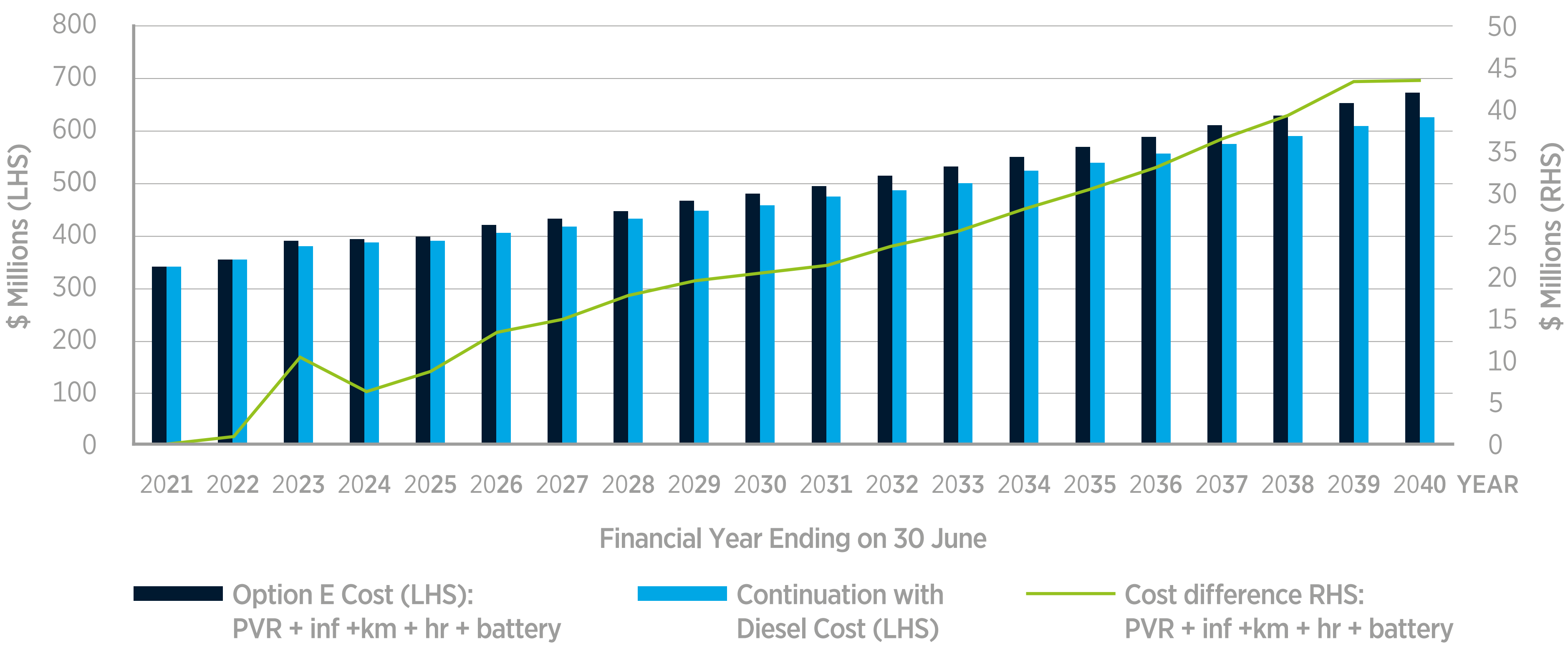



Figure 9 - Total Costs of Bus Services Under Option E Compared to Continuing with Diesel Fleet (1.5% PAX Growth and 2% NZTA Annual Indexation Applied)

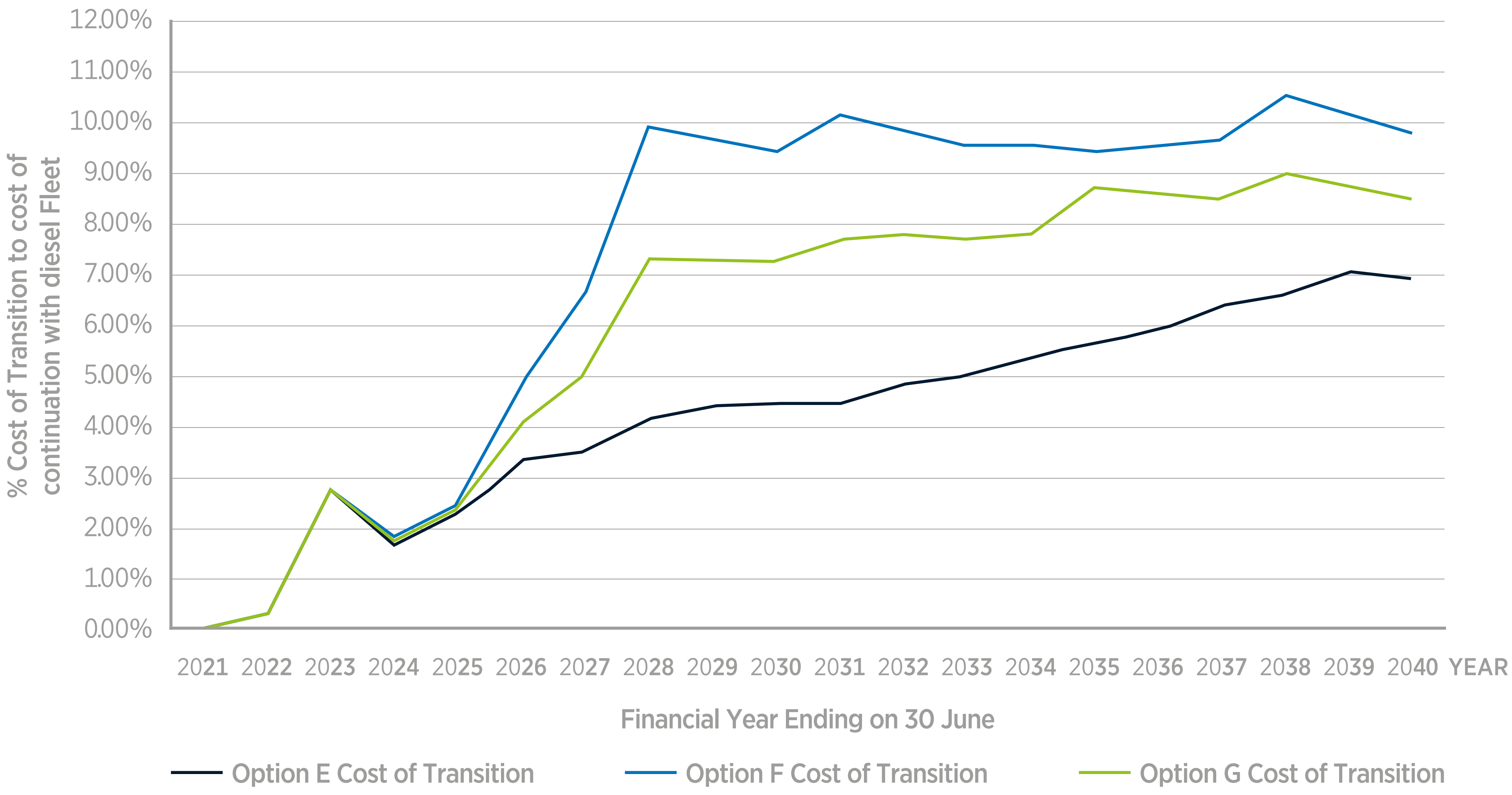



Figure 10 - Percentage Difference in Total Costs During Transition Period: Option E, Option F, and Option G Compared to Continuing with Diesel Fleet

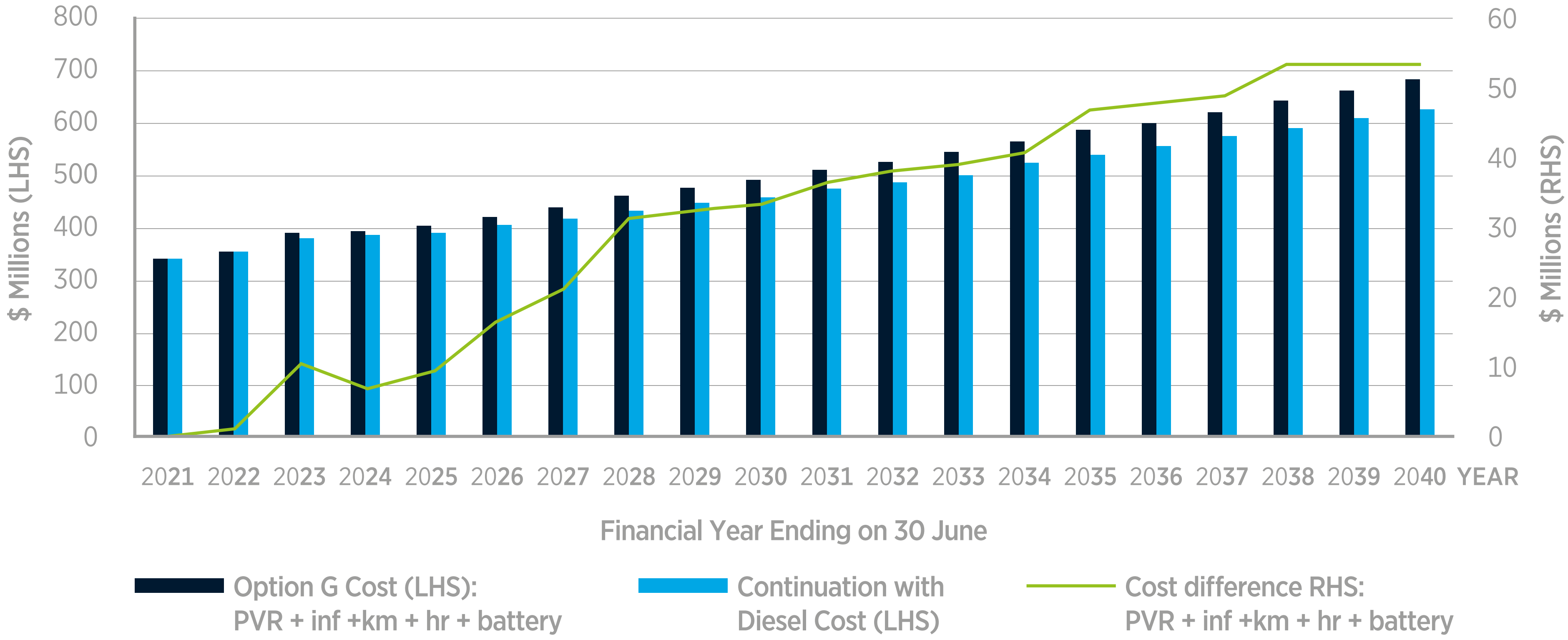



Figure 11 - Total Costs of Bus Services Under Option G Compared to Continuing with Diesel Fleet (1.5% PAX Growth and 2% NZTA Annual Indexation Applied)

Future bus service contracts are expected to be funded through the current model of farebox revenue supplemented by Auckland Transport and the New Zealand Transport Agency. To accelerate transition, these contracts will require increased funding. To reduce costs, AT could negotiate changes into contracts and extend life of existing fleet. Such change could incorporate an agreed schedule for fleet transition from diesel to zero-emission at tailpipe (under Option G), at the end of their useful 20-year life and before 2030.

However, to lower the costs, an agreement with operators would need to be reached on variation rates for PVR and variations to in-service km costs that would account for the anticipated future reductions over time of the acquisition and operation of battery electric buses.

The cost-benefit analysis will change as battery technology and the cost of bus charging improves and market competitiveness increases sooner with the accelerated transition under Option G; therefore, regular review is necessary for accuracy of future cost modelling which will provide more certainty when planning the necessary funding requirements for later stages of the transition.

Alternative finance packages tailored to suit different operators will empower bus operators to transition to zero-emission buses sooner and potentially reduce the costs to Auckland Transport. For example, these packages may include a guarantee to use zero-emission fleet beyond the expiry of contracts with bus operators to encourage purchases and potentially reduce contract costs through longer depreciation periods for buses and charging infrastructure.

# Next Steps

The following steps have been identified to progress our commitments to accelerate the transition to zero-emission fleet:

1. Continue to progress the transition from diesel buses to zero-emission (at tail-pipe) fleet.
2. Progress the Low Emission Bus Roadmap principles from a baseline transition with continuing 18-24-month updates to the "Roadmap" base level scenario and identifying alternative scenarios as opportunities arise. These updates would be based on benefit/cost, technology updates and other impacts.
3. Continue to undertake trials and demonstrations of zero-emission buses and their associated infrastructure solutions (subject to budget and availability). Seek funding from EECA through their Low Emission Vehicle Contestable Fund and Waka Kotahi (NZTA) through the Climate Emergency Response Fund (CERF). Proposed options include:
   - Further electric bus type trials from other manufacturers
   - Further hydrogen electric trials (incorporating hydrogen supply)
   - Top-up charging bus trials to assess plug-in charging at layovers
   - Trial of inductive bus charging at depots to reduce the footprint required for plug-in chargers and automate the bus charging process
   - Trial retrofit of diesel bus to electric using proven technology
   - Investigate "opportunity" on-route flash and/ or rapid charging for busways and future bus rapid transit (BRT) projects.
4. Collaborate with Vector to complete an in-depth feasibility study focused on the large-scale deployment of electric buses. This is the direct continuation of the technical assistance initially provided by Financing Sustainable Cities Initiative (FSCI) and expanded under MoU with Vector, and it is expected to guide the infrastructure and financial planning that will support more affordable deployment of buses.
5. Facilitate new low emission public transport forums following the success of the AT-led Low Emission Bus Working Group which succeeded in breaking down the barriers to adopting low-emission buses in Auckland and New Zealand and developed supporting infrastructure guidelines, provided technical assistance and explored alternative financing models.

   The new industry forums would focus on :
   - Facilitating the development of supply chains and aftermarket support, technical assistance and access to financing models
   - Understanding impacts related to charging infrastructure, lowering the costs of power connections and assuring the security of grid supply
   - Influencing regulatory changes to enable wider use of technology such as hydrogen fuel cells and adoption of new standards.
6. Collaborate with C40:
   - Continue to report on progress with transition to zero emission buses and use the C40 network to learn lessons and to benchmark with other cities about the adoption of low-emission buses and accelerating transition.
7. Continue assessing alternative fleet ownership options to accelerate transition to zero- emission buses, reduce costs and mitigate risk associated with battery renewal costs and second life applications.
8. Update depot strategy to better understand their impacts on competitiveness of tenders for future bus service contracts compared to cost and timeframes to acquire depots.
9. Continue assessing direct investment in depot bus charging infrastructure to reduce the premium on contract rates.

# Glossary

# Glossary

| Acronym | Description |
|---|---|
| BEV | Battery Electric Vehicle (also known as E-Bus) |
| $CO_2e$ | Carbon dioxide equivalent |
| EECA | Energy Efficiency and Conservation Authority |
| EV | Electric Vehicle |
| GHG | Greenhouse Gas |
| LEV | Low-Emission Vehicle |
| LowCVP | Low Carbon Vehicle Partnership |
| NZTA | New Zealand Transport Agency |
| NOx | Nitric oxide and nitrogen dioxide |
| PM | Particulate matter |
| PHEV | Plug-in Hybrid Electric Vehicle |
| PTOM | Public Transport Operating Model |
| PVR | Peak Vehicle Requirement |
| RCD | Residual Current Device |
| RUC | Road User Charges |
| RUB | Requirements for Urban Buses in New Zealand |
| VDAM | Vehicle Dimensions and Mass (NZ) |
| ZEV | Zero-Emission Vehicle |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# Appendix 1

# Appendix 1

## Data Collection

Data collection from trial electric buses has continued to be relatively reliable, albeit with gaps where buses have not been fully utilised.

The base figures below have been used in calculations.

The following statistics are based on data collected up to 31 December 2022.

| | |
|---|---|
| **Power cost** | $0.17 per kWh |
| **Road user charge** | $0.278 per kilometre |
| **Combined diesel & AdBlue cost** | $1.44 per litre |
| **Fuel consumption of comparable diesel bus** | 0.35 litres per kilometre |

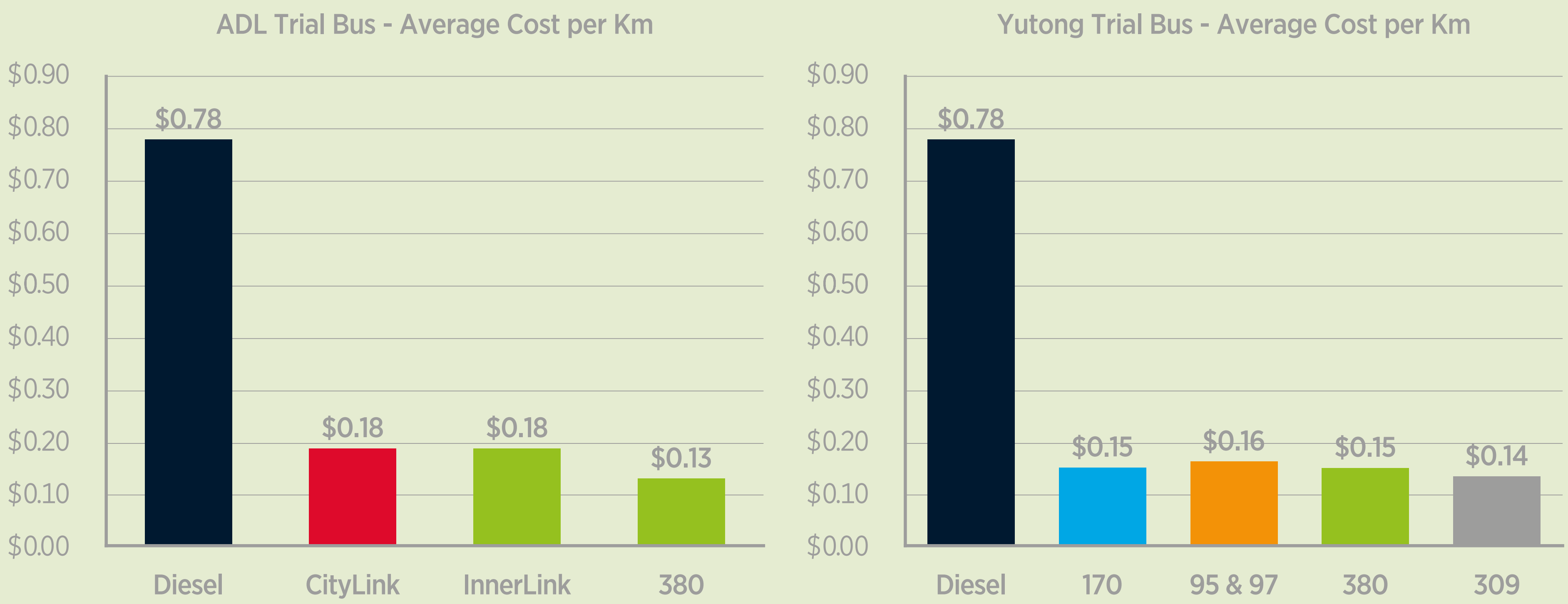


Figure 12 - Comparison of Cost per Km Using Different Vehicles and Routes

Overall, the results continue to be very positive with encouraging feedback from bus drivers and customers. Key findings were:

- ADL/BYD e-buses on City LINK, 380 Airporter and Inner LINK during the trial period achieved:
  - Actual range of up to 264kms on a single charge
  - 77 % lower operating costs compared to diesel buses on the City LINK circuit
  - 83 % lower operating costs on 380 Airporter service
  - 84 % less costs to operate the Inner LINK circuit
- Yutong e-bus on 380 Airporter and 309 routes during trial period achieved:
  - Actual range of up to 340 kms on a single charge
  - Using 90 % of battery capacity
  - 75 % lower operating costs

Key Issues included:

- The initial depot set up
  - Initial charging software on the ADL/ BYD buses caused tripping of Residual Current Devices (RCD) installed with the depot chargers. These issues have been overcome with software updates
  - Operation of the route 380 Airporter required the increase in the speed limit of an e-bus (NZTA permit limited the operating speed of ADL/BYD buses due to rollover limits) – the speed was increased to enable driving on motorways at safe speeds of up to 80 km/hour
- Bus software changes
  - The software update to change the speed limit on the ADL/ BYD bus caused issues with bus kneeling and prevented safe use of the e-bus in service but was quickly resolved
- Bus utilisation
  - Concerns over lower speeds of the ADL/BYD bus on motorways and door issues had initially limited the dispatching of the ADL/BYD bus for the 380 Airporter services. These issues have been resolved by a software fix and buses are well utilised;
  - General bus driver shortage and limited training affected the utilisation of e-buses at the early stages of the trial.

Between the period of March and October 2022, RMTS undertook a trial of a Foton BJ6123 single decker electric bus. The bus was operated on route 33 and charged at the Auckland Transport owned EV chargers at Manukau Bus Station.

The bus undertook an average of 10 trips (21km each) and usually had 25% battery life when sent to charge. Charging took around 2 hours on average.

Based on previously undertaken trials of a variety of different electric bus makes and models, this efficiency performance is positive. While the efficiency data tends to be within a similar range between the different buses, this is amongst those in the higher performing end of the spectrum.

It is important to note that many aspects may impact an electric vehicles performance, including but not limited to, driving style, topography and traffic profile of the route, and ambient air temperature.

While these trials are designed to test the vehicles in a variety of conditions, due to the above mentioned reasons, there is a limited dataset to confirm this is a representative of the long-term performance of the vehicle.

**Hydrogen Bus**

The Global Bus Ventures (GBV) Hydrogen bus is the first of its kind in New Zealand. This bespoke build was designed and built in Christchurch, New Zealand.

Components for this build were sourced either locally or globally, with the hydrogen fuel cell components being sourced from Ballard in Canada.

The GBV Hydrogen bus is a three-axle, 13.45 meter hydrogen/ battery electric single deck bus, with 47 seated positions and a total capacity of 78 passengers. The bus components are similar to an electric bus, but a smaller 45kWh battery is used to regulate the electricity generated from the hydrogen stored onboard.

A total of 30kgs of hydrogen is stored at 350bar and is stored in four separate tanks. This is converted to electricity to power the electric drivetrain for an estimated minimum driving range of 350kms.

AT and Howick & Eastern Buses (H&E) installed a new telematics recording device and worked with GBV to engineer a solution which could accurately measure and record the fuel usage over time.

Initial data has been retrieved from an onboard data logger, which derived the initial hydrogen use. This data suggests the vehicle is using an average of 8.44kgs of hydrogen per 100km, or 0.0844kgs per km.

Initial data from the telematics device has recorded hydrogen between 8.17kgs to 8.49kgs per km or 0.0817kg to 0.0849kgs per km. Ongoing fine-tuning of control unit allowed to reduce hydrogen consumption to 7 kgs per km/

The bus can hold a maximum of 30kgs of hydrogen but is currently unable to be filled with more than 22kgs of hydrogen due to limitations of the temporary refuelling system.

New Zealand regulation is under development for hydrogen refuelling, and largely relies on the Dangerous Goods Act.

Updating the current regulatory framework has interest from multiple government agencies and from the wider industry. AT is currently referring to international guidance (such as ECE79) as well as guidance from other government agencies and knowledge from industry professionals to follow best practice.

# Conclusion

The trials have provided much needed insight into the transition to zero-emission technology. The benefits of the technology is being investigated in a manner that allows for real-world experience to impact decisions made by AT and various stakeholders.

Questions surrounding preferred technologies or options are beginning to be answered. With information such as the cost per kilometre for hydrogen or electric vehicles, battery degradation, regulatory challenges, vehicle performance, driver feedback, and difficulties surrounding the adoption of different technologies being presented.

Initial results show that electric is outperforming hydrogen in certain applications as battery electric technology is further developed, is easier to implement and offers greater value for money. This is why initial zero-emission transition plans should adopt battery electric technology, while trials of alternative means such as synthetic diesel and hydrogen continue.

This new understanding should allow AT and Bus Operators to make informed decisions regarding the future. However, the installation of charging infrastructure on a large scale is yet to be undertaken and remains one of the chief concerns among Bus Operators.

The installation of fast chargers at Manukau Bus Station highlights the high cost of retrofitting the required electrical infrastructure to support fast charging. This, in combination with the Vector study which highlights 88% of AT's network can be supported with overnight depot charging, seems to suggest that on-route opportunity charging would not be beneficial for the majority of the network. Nevertheless, opportunity charging may be required for certain applications such as BRT, double decker buses or to add resiliency to the network.

Further installation of chargers (especially at the single depot that AT owns) is required to understand the economic implications and impact to depot land area of electrifying depots. The conversion costs and strategies used to decrease the expense would only be known after AT completes the redesign of the single bus depot it owns.

While the trials have provided much needed certainty in some respects, further analysis over a longer period is required to ensure the initial findings hold true in the long term.


# Appendix 2: Benefits & Financial Impacts

# Appendix 2: Benefits & Financial Impacts

## Assumptions

The table below shows the key variable and assumptions made when modelling future costs and benefits of the accelerated transition to zero emission fleet.

Notes and other assumptions

1. Based on "operator fleet data" as at May 2021. PVR data are developed in September 2022. This update impacts on all calculations associated with Options E, F and G.
2. The electric bus premium is assumed to be 118% as at 2017, declining to around 76% in 2030.
3. In-Service km rates are an average weighted on in service kms. 2021 in service km rate is decoupled to RUC, Carbon Tax, diesel, AdBlue and remaining. Diesel inflated based on historical trend. 2% NZTA inflation applies on RUC, AdBlue and the remaining. Carbon Tax is calculated from monetised benefit and cost manual of Waka Kotahi.
4. Diesel bus PVR rate is calculated based on the average of similar size bus PVR rates over different units. Following the Bloomberg's prediction of constant diesel bus prices in future (due to potential intelligence/technology upgrade), the same rate is applied over time.
5. Assumed in-service hours are the same for electric as diesel. The 2021 total cost of bus contracts are inclusive of PVR and in-service km cost, with the balance assumed as being the in-service hours cost, other overhead costs and operator profit margins. This remaining "balance cost" is assumed as a $/km rate for 2021 and is inflated with 2% NZTA indexation over time and used to forecast the "balance cost" (i.e., in service hour cost) over time.
6. Diesel price forecast is based on the weekly fuel price monitoring from Ministry of Business, Innovation & Employment. The discounted retail price of diesel excluding the ETS (Carbon Tax), is used to forecast the diesel price over time.
7. Provision of ETS on diesel fuel is calculated based on MBCM emission values.
8. Retail electricity price forecast is based on Energy Link's assessment.
9. It is assumed that road user charges (RUC) applies to electric buses from the beginning of 2026 at the same as for diesel buses.
10. Patronage is based on AT HOP card data moderated by PVR changes. Average patronage increase is forecasted to be 1.8% with a lower bound of 1.5% and an upper bound of 2.16%. Considering spare capacity in the bus network, bus capacity increase rate in the network is assumed to be less than average rate of increase in patronage. As such, lower bound bus capacity growth rate is used in the model as the base case. Provision of sensitivity for 1.8% growth rate (average patronage growth rate) and 2.2% growth rate (upper bound patronage growth rate) is included.
11. Annual Patronage Increase on DD routes over the rest of the city is considered to be the same for the base case.
12. The useful life of buses is 20 years.
13. The infrastructure cost for electric bus PVR premium over e-bus PVR rate is assumed to be following a linear decreasing trend from 21% to 14% p.a. (based on recently negotiated contracts rates and excluding one outlier). Initial upgrades of grid networks near to depots provides capacity to absorb subsequent demand for electricity for up to 50 e-buses before the capacity at that point saturates and may require a further upgrade. This leads to gradual decrease in infrastructure premium over time.
14. The maintenance savings of electric buses compared to diesel buses is assumed to be $2,000 per bus p.a. as the base case and provision for sensitivity is included for $5,000 and $10,000 per bus p.a.
15. Capacity unit of Small Bus, Large Bus and Double Decker is calculated as a percentage of average total capacity of all Extra Large Bus.
16. It is expected one e-bus PVR equals one diesel PVR. The model does not account for more e-buses that may be required to deliver high frequency services with longer operating hours and insufficient time to re-charge batteries overnight at depots, in which case, more e-buses would be required resulting in a higher PVR rate (to cover the cost of additional buses under the current PTOM contract mechanism).
17. Average annual kms (mileage) travelled by buses of all types is based on 2019 actual data. Not using the latest stats to minimise impact from COVID. It's assumed that the average mileage travelled by bus sizes remains constant over time based on current bus network. This exclude any increase in network kms as new routes may be added in the future.
18. Option E assumes that 2.4% of the bus fleet (39) would need to be replaced with e-bus by the end of 2040 with no financial impact to AT. This assessment would require contractual arrangements or rely on operators changing fleet voluntarily before that date.


Manukau
via Puhinui Stn
AIR
Metro
AirportLink
GB8905

| **Variables and Assumptions** | | | | |
|---|---|---|---|---|
| PVR Cost (Average PTOM PVR Rate) | Small Bus (SB) | Large Bus (LB) | Extra Large Bus (XLB) | Large Bus Double Decker (LBDD) |
| Zero Emissions PVR Premium | Dynamic/Reducing As Per Forecast | | | |
| Total Bus Contracts Costs in 2021 | $338,808,897 | | | |
| **Fuel/Energy Consumption (Weighted Average)** | | | | |
| Electric (kWh/km) | 0.87 | 0.97 | 0.97 | 1.38 |
| Diesel (Litres/km) | 0.36 | 0.40 | 0.40 | 0.57 |
| Low Infrastructure Cost Premuim Over E Bus PVR | 14% | 14% | 14% | 14% |
| High Infrastructure Cost Premuim Over E Bus PVR | 21% | 21% | 21% | 21% |
| Infrastructure Cost Diesel Bus Premium | 0 | 0 | 0 | 0 |
| Road User Charge Per km in 2021 (Diesel Bus) | $0.14 | $0.28 | $0.28 | $0.37 |
| Maintenance Savings Per Annum Electric Bus | $2,000 | $2,000 | $2,000 | $2,000 |
| Diesel Contract Per Km Rate | $1.12 | $1.49 | $1.75 | $1.99 |
| Ruc Applies To Zero Emission Bus | 2026 Onwards | | | |
| **Fuel/Energy Costs** | | | | |
| Electric ($ Per Kwh) | Periodical forecast | | | |
| Diesel ($ Per Litre) | Periodical forecast | | | |
| Add Blue % (Per Litre Of Diesel) | 2.12% | | | |
| Add Blue (Per Litre) | $0.62 | | | |
| Diesel Combined Fuel (Per Litre) In 2021 | $1.14 | | | |
| Nzta Indexation Factor | 2% | | | |
| Discount Factor | 6% | | | |
| Fleet Retirement Age | 20 years | | | |
| **Patronage** | | | | |
| Bus Patronage In 2019 | 73,050,000 | | | |
| Double Decker Bus Patronage In 2019 | 17,505,951 | | | |
| Growth Forecast For Patronage | 1.50% | | | |


# Benefits & Impacts

# Benefits & Impacts

## Option E

- The transition under Option E will reduce greenhouse gas emissions by 0.9 million tonnes[14] and down to 33.3% in 2040 (2030 it increases emissions by 1% compared 2019 level).
- The social benefits from the progressive move to a low emission bus fleet in Auckland by 2040 under Option E account for $202.7 million of cumulative values over the years of transition compared to a Euro 6 diesel baseline.
- Figures in the table below were derived by comparing emissions from electric buses to emissions from Euro Standard 6 diesel buses (which would be the alternative transition technology if zero-emission was not chosen) and include $CO_2e$, PM2.5, NOx, SO2, CO, HC and noise.
- The slower transition would delay the increase of electricity consumption by AT Metro buses and the required electricity network upgrades for bus depots.
- Requires funding of $437 million ($176 million discounted) over 19-year period
- Requires additional funding for transitioning the remaining 2,4% of diesel fleet (39 buses) in 2040 (cost / benefit of last 39 buses has not been modelled)
- The Incremental benefit / cost ratio is very high (due to cumulative cost savings).

| **Option E - 100% by 2040** | **NPV (2121$)** |
|---|---|
| Social Costs - Exhaust Air + GHG | $1,805,092,390 |
| Social Costs - Noise | $73,395,731 |
| Social Costs - Upstream GHG | $18,907,591 |
| | **$1,897,395,712** |
| **Benefits vs Option 0** | **$202,726,650** |

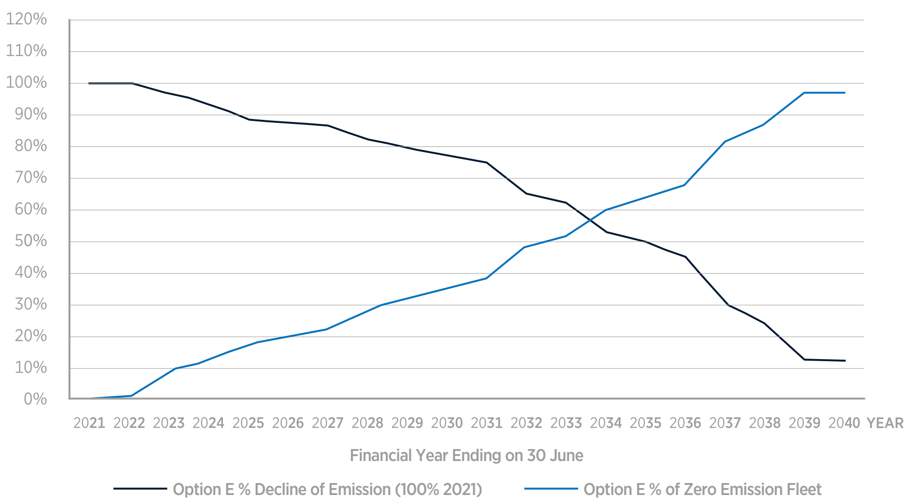


Figure 13 - Option E - Zero Emissions Fleet Size by % and Impact on Bus Emission

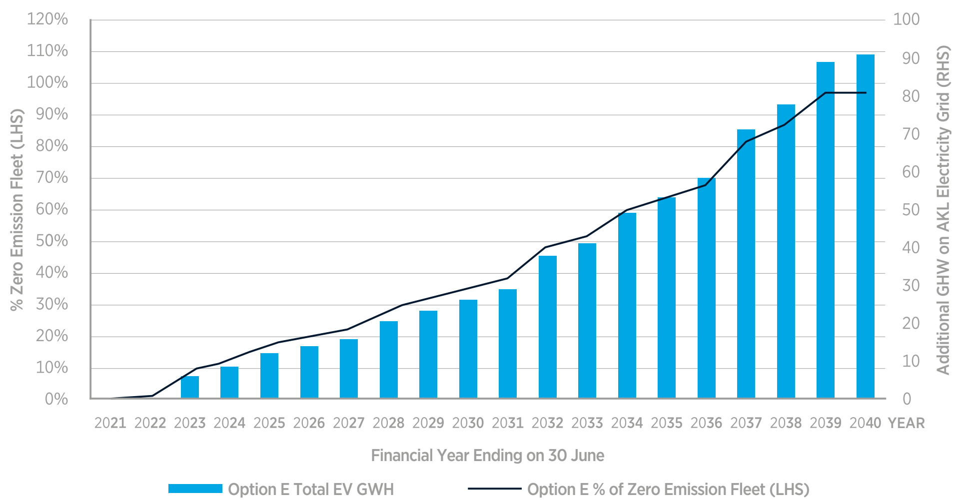


Figure 14 - Option E - Zero Emissions Fleet Impact on Electricity Demand

[14] Cumulative value over the 20-year transition period compared to diesel fleet in 2019

# Option F

- Reduces carbon emissions by 1.4 million tonnes.
- The social benefits account for $901.1 million of cumulative values over the years of transition comparing emissions from electric buses to emissions from Euro Standard 6 diesel buses (which would be the alternative transition technology if zero-emission was not chosen) and include $CO_2e$, PM2.5, NOx, SO2, CO, HC and noise.
- The accelerated transition will bring forward higher electricity consumption by AT Metro buses and required electricity network upgrades for bus depots will need to be done sooner.
- Requires funding of $744 million ($300 million discounted) over 19-year period due to the earlier transition within a shorter delivery time frame.

| **Option F - 100% by 2030** | **NPV (2021$)** |
|---|---|
| Social Costs - Exhaust Air + GHG | $1,117,103,005 |
| Social Costs - Noise | $64,902,731 |
| Social Costs - Upstream GHG | $16,931,101 |
| | **$1,198,936,837** |
| **Benefits vs Option 0** | **$901,185,524** |

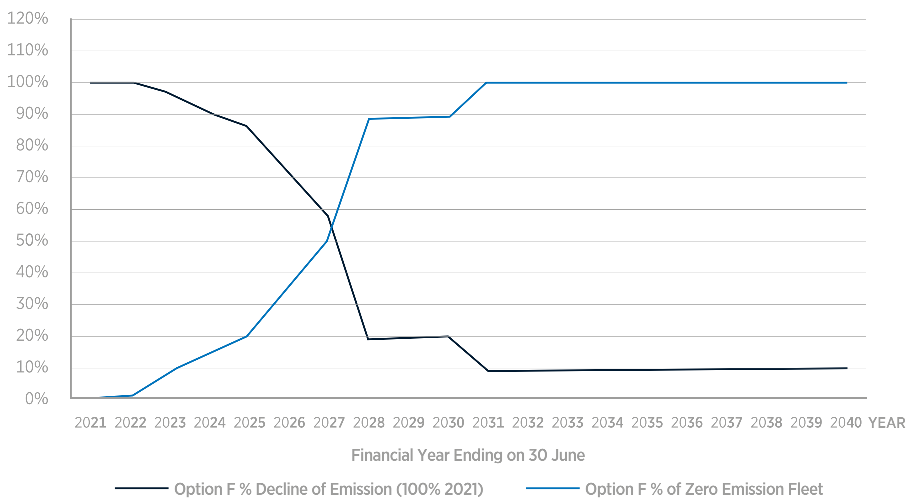


Figure 15 - Option F - Zero Emissions Fleet Size by % and Impact on Bus Emission

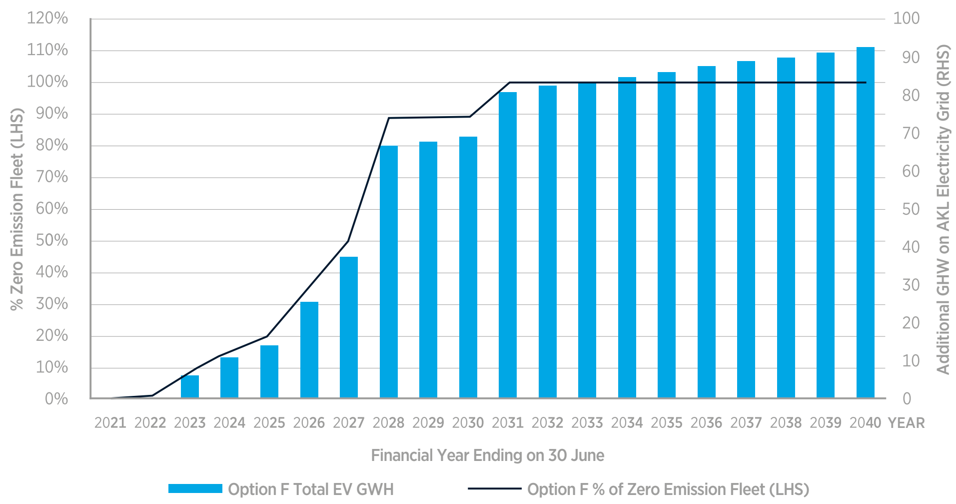


Figure 16 - Option F - Zero Emissions Fleet Impact on Electricity Demand

# Option G

- Reduces carbon emissions by 1.2 million tonnes.
- The social benefits account for $694.5 million of cumulative values over the years of transition comparing emissions from electric buses to emissions from Euro Standard 6 diesel buses (which would be the alternative transition technology if zero-emission was not chosen) and include $CO_2e$, PM2.5, NOx, SO2, CO, HC and noise.
- This option is a balance between the Option E and Option F allowing for more gradual but continuous fleet electrification and related funding requirements while still delivering significant environmental and social benefits.
- Requires additional funding of $620 million ($289 million discounted) over 19-year period due to the earlier transition within a shorter delivery time frame.
- Estimated to cost an additional $163 million ($105 million discounted) for bus services between 2020 and 2030 when transition would be completed (compared to the diesel fleet).

| **Option G - 100% by 2035** | **NPV (2021$)** |
|---|---|
| Social Costs - Exhaust Air + GHG | $1,320,242,770 |
| Social Costs - Noise | $67,811,538 |
| Social Costs - Upstream GHG | $17,556,452 |
| | **$1,405,610,761** |
| **Benefits vs Option 0** | **$694,511,601** |

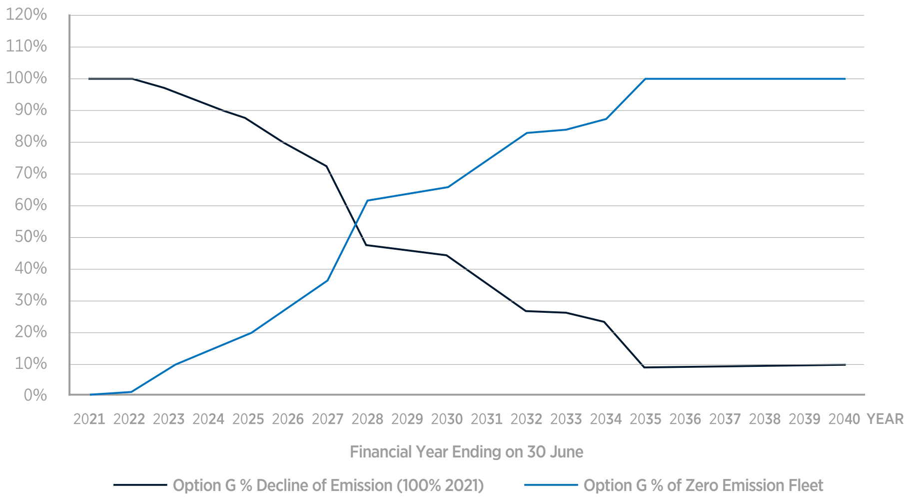


Figure 17 - Option G - Zero Emissions Fleet Size by % and Impact on Bus Emission

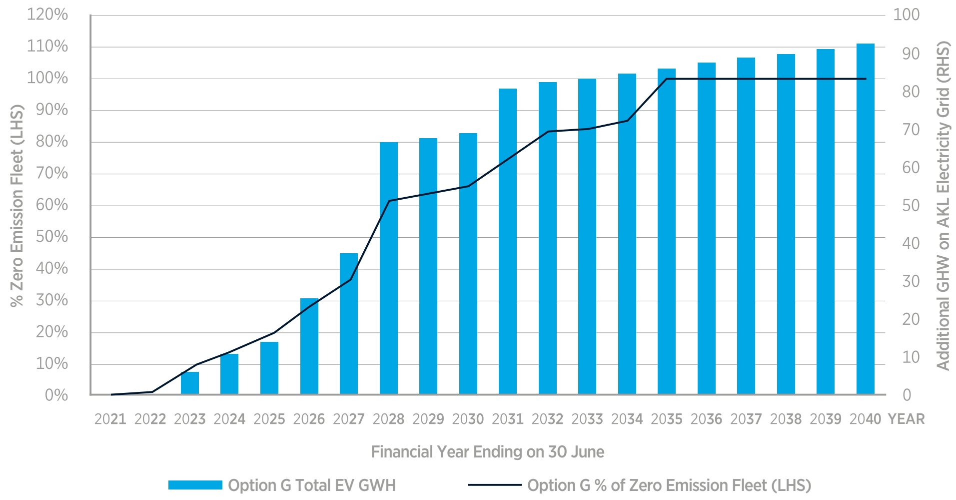


Figure 18 - Option F - Zero Emissions Fleet Impact on Electricity Demand


# Sensitivities

## Sensitivities

# Option G (2021-2035)

| Variable | Factor | Cumulative cost of transitional fleet ($m) | Cumulative cost of continuation with Diesel ($m) | Cumulative cost for transition to Zero Emission ($m) | Indicative discounted cost for transition to Zero Emission |
|---|---|---|---|---|---|
| Base: Maintenance savings p.a. (e-bus) | $2,000 | $6,880 | $6,526 | $354 | $195 |
| Scenario 1 | $5,000 | $6,849 | $6,526 | $323 | $179 |
| Scenario 2 | $10,000 | $6,797 | $6,526 | $271 | $151 |
| Base: Growth forecast for patronage | 1.50% | $6,880 | $6,526 | $354 | $195 |
| Scenario 3 | 2.20% | $7,072 | $6,703 | $369 | $203 |
| Scenario 4 | 1.80% | $6,966 | $6,606 | $361 | $199 |
| Scenario for Auckland's transport emissions reduction pathway | 8.45% | $9,357 | $8,819 | $538 | $288 |
| Base: Emission Tax Sensitivity | MBCM (c22/l in 2050) | $6,880 | $6,526 | $354 | $195 |
| Scenario 5 | Productivity Commission (c31/l in 2050) | $6,874 | $6,527 | $347 | $191 |
| Scenario 6 | Net Zero emission (c61/l in 2050) | $6,879 | $6,558 | $320 | $178 |

# Option F (2021-2030)

| Variable | Factor | Cumulative cost of transitional fleet ($m) | Cumulative cost of continuation with Diesel ($m) | Cumulative cost for transition to Zero Emission ($m) | Indicative discounted cost for transition to Zero Emission |
|---|---|---|---|---|---|
| Base: Maintenance savings p.a. (e-bus) | $2,000 | $4,207 | $4,002 | $205 | $124 |
| Scenario 1 | $5,000 | $4,191 | $4,002 | $189 | $114 |
| Scenario 2 | $10,000 | $4,164 | $4,002 | $161 | $98 |
| Base: Growth forecast for patronage | 1.50% | $4,207 | $4,002 | $205 | $124 |
| Scenario 3 | 2.20% | $4,255 | $4,045 | $210 | $127 |
| Scenario 4 | 1.80% | $4,228 | $4,021 | $207 | $125 |
| Scenario for Auckland's transport emissions reduction pathway | 8.45% | $4,755 | $4,497 | $258 | $155 |
| Base: Emission Tax Sensitivity | MBCM (c22/l in 2050) | $4,207 | $4,002 | $205 | $124 |
| Scenario 5 | Productivity Commission (c31/l in 2050) | $4,204 | $4,002 | $202 | $122 |
| Scenario 6 | Net Zero emission (c61/l in 2050) | $4,207 | $4,015 | $192 | $116 |


# Emission Reduction Methodology Note

# Emission Reduction Methodology Note

### What assessment (HAPINZ 3, 2 or MBCM) methodology to be considered for air pollution damage cost?

HAPINZ 3 is the outcome of the latest series of research conducted by Emissions Impossible (EI) published in March 22 for MoE, MoH, MoT and NZTA/WK. Research Report 696 Health and air pollution in New Zealand 2016 (HAPINZ 3.0) Volume 1: Findings and implications (nzta.govt.nz) and HAPINZ-3.0-Detailed-methodology.pdf (environment.govt.nz). However, HAPINZ 3 recommendation is yet to be embedded in the policy level update of NZTA/MoT (check current MBCM Section 3.3 page 57 Monetised benefits and costs manual v1.5 August 2021 (nzta.govt.nz)). For the bus roadmap, EI delivered the social cost/benefit model based on the HAPINZ 3 recommendation, the HAPINZ 3 is expected to be included in the new policy level update for air pollution social cost and benefit calculation.

### Why social cost/benefit is higher in this version of roadmap?

Our earlier roadmap considered following pollutants and the social damage cost for the calculation mostly in line with earlier version of HAPINZ. It scoped tail pipe gases as below but scoped out emissions due to brake, tyre, road dust, PM 2.5, upstream $CO_2e$ etc. The earlier social cost/benefit calculation assumed all our buses as EURO 6 rather than actual number of different Euro variations that might have different tail pipe emissions profile.

| Emission Type: | 2017 Value ($/t) |
|---|---|
| $CO_2$ | $66.52 |
| $PM_{10}$ | $467,790 |
| $NO_X$ | $16,623 |
| CO | $4.19 |
| HC | $1,329 |
| **Other** | **2017 Value (c/km)** |
| Noise | 2.83 |

Therefore, this time, we suggested EI to consider actual type of different Euro variations in the fleet rather than considering all Euro 6. Also, we have included the impact of brake/tyre wear and road dust (road tyre wear applies to Ebus as well). This help address some concerns raised in the past about Ebus being heavier are more dust pollutant producer in our roads. In addition, rather than constant $CO_2e$ price that we considered in our earlier roadmap, the current EI delivery considered shadow carbon price trajectory (from $63/t $CO_2e$ in 2021 to $201 in 2040) according to treasury centre forecast. EI also have added social cost associated to upstream (WTT) $CO_2e$ due to diesel and electricity in the calculation.

| | |
|---|---|
| $CO_2e$ | Carbon Dioxide equivalents (covering $CO_{2\text{-fuel}}$, $CO_{2\text{-lube}}$, CH4 and $N_2O$) |
| PM2.5 Exhaust | Particulate matter < 2.5 µm (exhaust only) |
| PM2.5 B,T & RD | Particulate matter < 2.5 µm (brake/tyre wear and road dust) |
| NOx | Oxides of Nitrogen |
| SO2 | Sulphur Dioxide |
| VOC | Hydrocarbons |
| CO | Carbon Monoxide |

Note: road/tyre wear still applies to EVs

Furthermore, we can see that the updated $/t cost of the pollutants (particularly PM and NOx) are significantly higher than what the old benefit model considered. This is why our social benefit value is significantly higher in this assessment compared to last roadmap.

| Pollutant | 2021-2040 Value ($/t) |
|---|---|
| $PM_{2.5}$ | $670,904 |
| $NO_X$ | $538,121 |
| SO2 | $39,310 |
| VOC | $1,544 |
| CO | $4.87 |
| **$CO_2$e by Yr** | **$63-201** |
| **Noise** | **$/km** |
| Diesel Bus | $0.09 |
| E Bus | $0.06 |

### Why GHG emissions trajectories presented in the document slightly differ?

EI calculated all pollutants (including $CO_2e$) based on average performance of bus @20 km/hr and average weight of the occupant 80 kg with average occupancy of 40%. AT, for internal consideration, including GHG Inventory, calculates $CO_2e$ emissions using different approach - one based on service km, dead service assumptions, network average fuel use consumption which we reckon is well recognised and being already verified by a third party. We decided to use our methodology to show the emissions reduction pathway for option E/F/G throughout the roadmap and to use EI calculations to present social benefits.

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Auckland Transport