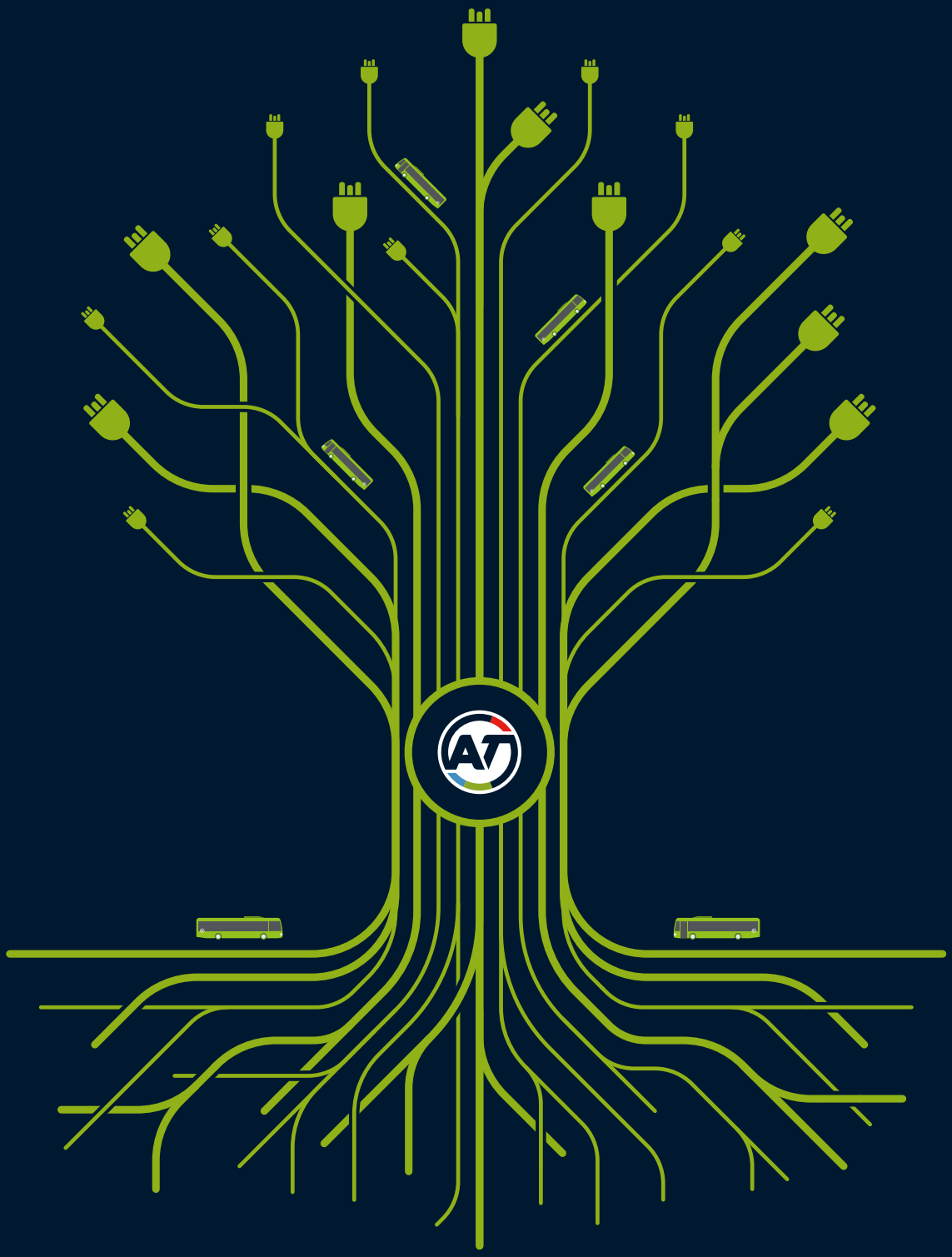
Auckland's

LOW EMISSION BUS ROADMAP



VERSION 2.0

October 2020

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 Transport's role as a transport provider is rapidly evolving to meet fast-paced changes in how people want and need to travel. We play an active role in shaping a growing, vibrant Auckland by working together to deliver safe, innovative, and sustainable modes of transport for a beautiful city.

Like many others, Auckland Transport is focused on understanding our impact on the climate and ensuring sustainability is embedded in the ways that we build, operate, and maintain the transport network. As part of our Sustainability Strategy, we are committed to providing low emission transport choices, which will reduce greenhouse gas emissions, improve air quality, and reduce the city's reliance on fossil fuels.

In our latest greenhouse gas emission inventory, operation of the bus fleet accounted for 93,200 tonnes of CO2e. This is the largest source of greenhouse gas emissions in Auckland Transport's operational carbon footprint. Delivering the Low Emissions Bus Roadmap is one of the most impactful actions Auckland Transport can take to reduce greenhouse gas emissions.

The Low Emission Bus Roadmap presents a baseline for transitioning the bus fleet to lower emissions, with key milestones at 2020, 2025, and 2030. It supports the C40 Fossil Fuel Free Streets Declaration, signed by Mayor Phil Goff at the Together4Climate event in Paris, which commits Auckland to procuring zero-emission buses from 2025 onward. The Low Emission Bus Roadmap will be updated and reviewed regularly as technology advances and pricing structures change, among other industry trends.

Transitioning the bus fleet does not come without its challenges however. There is an array of developing technology choices, complex operating models for the bus fleet, and requirements for supporting infrastructure. We look forward to working with our partners and stakeholders to overcome these challenges and deliver a low emission transport network for all of Auckland.

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Figure 1: Auckland's low emission bus roadmap

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 37.6% of the region's emissions profile[1]. We recognise that diesel vehicles, including buses, contribute to serious health implications and social impacts.

Diesel vehicles are estimated to be responsible for 81% of all vehicle-related air pollution health costs, valued at $466 million annually. With over 1,300 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 Low Emission Bus Roadmap **AT.govt.nz/media/1980070/low-emissions-bus-roadmap-dec-2018.pdf** The Roadmap is a tactical document that outlines the pathway to transition Auckland Transport's bus fleet to zero-emissions by 2040. It also delivers on our commitment to the C40 Fossil-Fuel-Free Streets Declaration signed by the Mayor of Auckland in 2017. The declaration commits Auckland to procuring zero-emission buses from 2025 onward and ensuring that designated areas of the city centre reach zero-emissions by 2030.

Auckland Transport uses a large bus fleet consisting of variable vehicle ages, sizes and Euro standards operated under contract by private bus companies who own the fleet. It was important for the Roadmap to provide context on the complex policy and operating conditions. The Roadmap also reviewed recent trends in the wider bus market, including options for technology and charging infrastructure, implementation models, and financing.

1. Auckland Council 19 December Briefing to the Climate Change Commission based on 2016 data

In 2019, Auckland Transport undertook a greenhouse gas emissions inventory, which revealed that operation of the bus fleet is the largest source of operational carbon in our organisation[2]. In the Financial Year 2017-2018, buses were responsible for 85 per cent of Auckland Transport's total greenhouse gas emissions, emitting over 93,200 tonnes of CO2e.

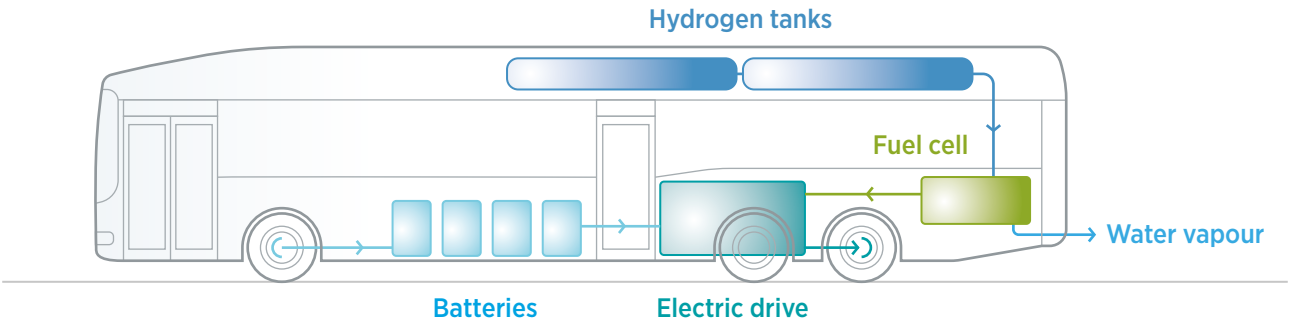
Therefore, delivering the Low Emissions Bus Roadmap is critical, as the transition to a low emission fleet will be the single greatest contribution required to achieve our aspirations for a zero-carbon future by 2050.

Trialing Low Emission Technology

Since the establishment of the Low Emissions Bus Roadmap, Auckland Transport has continued to explore technology options and has conducted several trials with low emission bus vehicles.

With battery electric buses (BEVs) being the technology of choice for many jurisdictions (estimated to have 65 percent of the global low emission market share), Auckland Transport initiated an electric bus trial in 2018 with three vehicles on several routes across Auckland. The electric buses serviced the City LINK, Inner LINK, 380 Airporter, and route 309. All the trials have delivered positive results in terms of service reliability, customer feedback, and operational savings.

2. **The FY 2017-2018 Greenhouse Gas Emissions Inventory for Auckland Transport did not include emissions as a result of asset construction or road corridor maintenance.



The trials also confirmed battery electric buses reduce greenhouse gas emissions significantly compared to conventional diesel buses. With a national grid largely sourced from renewables, the trials could achieve on average between an 85 and 90 percent reduction in greenhouse gas emissions. Furthermore, the electric buses proved that they were more than capable of completing a day's service on a single charge, which is an important finding that helps reduce range anxiety faced by private bus operators.

Auckland Transport has also partnered with Ports of Auckland to establish a hydrogen bus trial. Auckland Transport has commissioned a hydrogen bus to be built in New Zealand while Ports of Auckland establish a hydrogen refueling plant. This trial is expected to start in December 2020 and will demonstrate the potential of an alternative low emission technology that could help us reach our vision for a zero-emission future.

Engaging our Stakeholders

The Low Emission Bus Roadmap addressed various implementation scenarios to achieve our vision of a zero-emission bus fleet. The preferred option was for Auckland Transport to continue with the model where bus operators purchase vehicles and Auckland Transport utilise contract specifications to stipulate that new buses for end-of-life replacements and fleet growth must be zero-emission from 2025 onward. This option requires strong relationships with the entire supply chain, from bus operators to technology/infrastructure suppliers, to manufacturers. Auckland Transport has signaled to operators the objectives of the Roadmap and is cognisant of the challenges around high upfront capital costs, the possibility of stranded assets and completely new ways of doing business.

In July 2019, Auckland Transport convened key industry stakeholders at the Low Emission Bus Forum. 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 Low Emission Bus Working Group, which brings stakeholders together on a regular basis to address the challenges and opportunities that lie ahead.

Accelerating our transition

The achievement of a full zero-emission fleet by 2040 has been challenged by the Auckland Transport Board. Given the pace of international development and deployment of low emission bus technology, Auckland Transport's vision for a full zero-emission bus fleet by 2040 and the potential to transition earlier is thought to be achievable.

Since the establishment of the first Roadmap, Auckland Transport has successfully contracted the entire City LINK service to be fully electric by November 2020, and a new

Airport LINK service from Manukau Bus Station via Puhinui Station to the Airport to be also operated by fully electric buses from January 2021. We have also agreed to procure Waiheke bus services with eight electric buses from November 2020 with additional electric buses to be introduced to the fleet progressively replacing the existing diesel fleet.

However, an accelerated transition is not without its challenges. These range from operators lacking confidence in the long-term performance of electric buses, high upfront capital costs for new buses, limited configurations and sizes available for the New Zealand market with unique axle weight limits for bus, electricity network upgrades necessary to enable bus charging and short contracts resulting in higher contract costs.

In order to understand these challenges better while creating solutions, Auckland Transport has procured two additional trial battery electric extra-large buses with a three-axle configuration to test the design and performance of high capacity electric buses in New Zealand in partnership with Auckland bus operators. It has agreed a Memorandum of Understanding with Vector Limited to undertake a detailed study of electricity requirements by battery electric bus fleet, assess the required investment in the electricity network to fully electrify the bus fleet in Auckland and identify opportunities to reduce costs through innovation.

After conducting a detailed modelling of the costs, greenhouse gas emissions and social benefits, Auckland Transport has updated the previously endorsed Option E and developed an alternative Option F to accelerate our mission to have a zero-emission bus fleet. The following options have been considered:

Option 1: Default zero-emission by 2040 (Option E updated comparison to a continued diesel fleet)

- No diesel fleet procurement from 2025; full fleet transition to low emission (zero-emissions by tail pipe) by 2040; continued new services / fleet intervention by AT to 2025
- Reduces carbon emissions by 0.8 million tonnes and down to 33.3% in 2040 (in 2030 it increases emissions by 1% compared to the 2019 level)
- Estimated to deliver net social benefits of $75 million over 20 years ($28 million discounted).
- Estimated to deliver net cost savings of $49 million over 20 years ($10m discounted).
- Requires additional funding of $9 million ($3 million discounted) for transitioning the remaining 12% of diesel fleet (250 buses) in 2040 (cost / benefit of last 250 buses has not been modelled)

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

- No diesel procurement from 2025 with earlier target subject to funding; full fleet transition by 2030
- Reduces carbon emissions by 1.8 million tonnes and down to 11.7% in 2030 compared to the 2019 level of 93,200 tonnes (100%); in 2040 emissions will be down to 15.2% compared to the 2019 level
- Delivers cumulative social benefits of $166 million ($72 million discounted).
- Enables fleet transition agreements to progressively introduce zero-emission buses from 2022

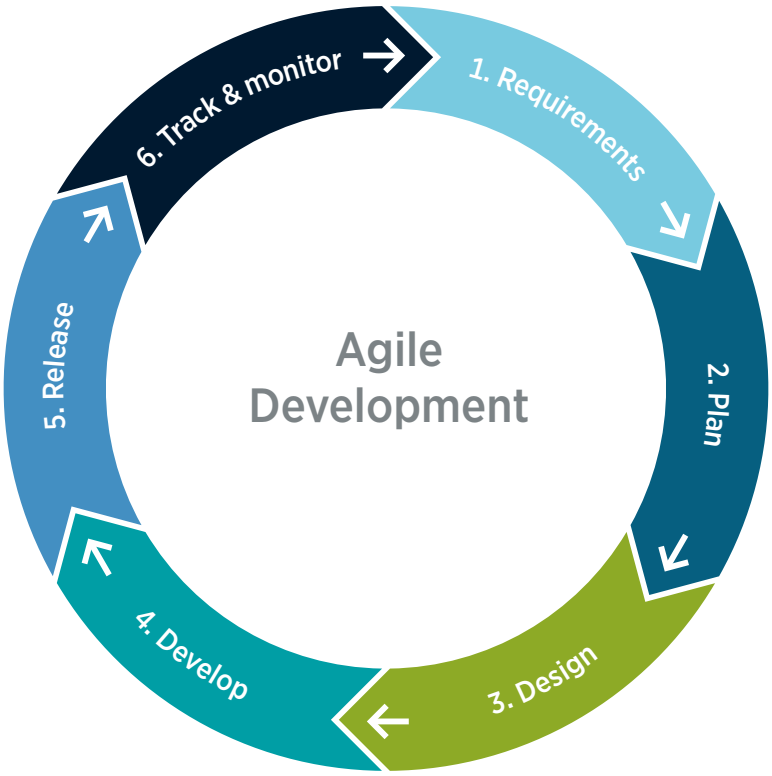
- Requires additional funding of $350 million ($177 million discounted) over 20-year period due to the earlier transition within a shorter delivery timeframe
- Estimated to cost an additional $164 million ($103 million discounted) for bus services between 2020 and 2030 when transition would be completed (compared to the diesel fleet).

Both options are proposed to be implemented using variations and extensions of the existing bus service contracts and new contract tenders. Both options also require bus operators' confidence in technology and incentives to adopt zero-emission fleet and upgrades of the electricity network. Developing the supply chain to lower the cost of electric buses and innovation to reduce costs of bus charging infrastructure is also required under both options.

Recommendation

It is recommended to seek funding as part of the upcoming Regional Land Transport Plan (RLTP) funding prioritisation to potentially accelerate the transition to zero-emission bus fleet, targeting 2030 for completion (Option 2), with further regular reviews every 12-18 months as more information becomes available from the market, learnings from AT trials and implementation of e-buses over the next two to four years incorporating technology updates, impacts of innovation in bus charging, pavement maintenance costs and financing options.

Faster electrification of urban buses will significantly improve climate and social benefits. It will reduce greenhouse gas emissions by 1.8 million tonnes and improve air quality on Auckland streets delivering cumulative social benefits of $166 million compared to the diesel fleet. It will ensure Auckland Transport meets its commitment to have zero emission fleet by 2040 and Auckland's C40 Cities commitment to create fossil fuel free streets in the city centre by 2030 and align with Auckland's Climate Action Plan to transition to low emission transport by 2030. It will also provide contingency time to mitigate any risks associated with large capacity electric buses yet to be manufactured and tested in New Zealand. It is estimated that an additional $164 million of funding ($103 million discounted) over the ten years to 2030 will be required with an annual increase of 0.8% in 2021, 1% in 2022, 1.7% in 2023 during



the three-year RLTP funding update, and up to 6.1% in 2026 and 4.9% in 2030 compared to diesel fleet based on current assumptions described in Appendix 2.

An all-electric bus fleet from 2030 will significantly contribute to achieving the objectives of Auckland's Climate Actions Framework and achieve a meaningful reduction of Auckland Transport's carbon footprint. The accelerated 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 fleet in our city.

Staying agile

The Low Emission Bus Roadmap will address challenges 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, future tenders for bus service contracts and early implementation 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, 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.

1.0 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.

Auckland Transport's Low Emission Bus Roadmap – Addendum: October 2020:

- Updates strategic context, including policy and opportunities
- Analyses the results of trials and demonstrations of new technologies
- 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 an accelerated transition.

1.1 Recommendations

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

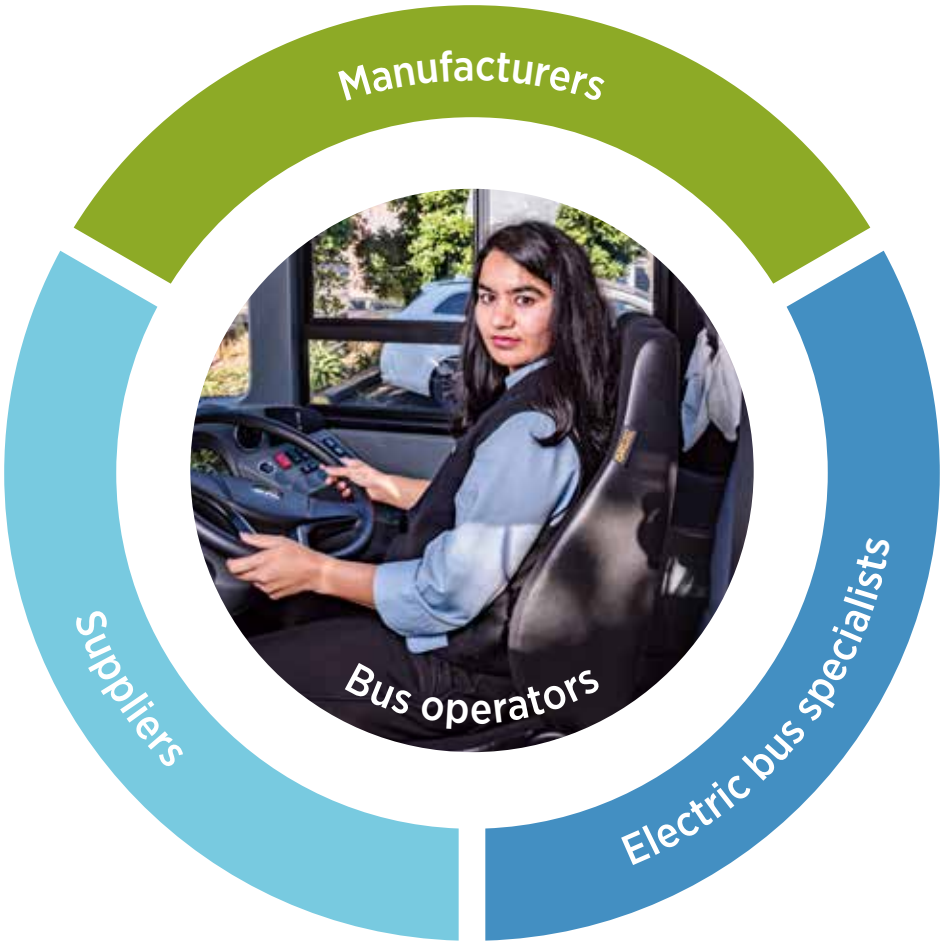
1. Accelerate the 2040 goal of transition to full zero-emission bus fleet and target completion by 2030.
2. All urban buses in Auckland are to be procured as zero-emission vehicles from 2025 onward with preference to advance this to 2020 subject to funding and specific approvals.
   a. All end-of-life single-deck diesel bus fleet and additional new fleet required for growth are transitioned to battery electric from 2020 onward under variation to existing service contracts. Hydrogen fuel cell technology may also be used as a zero-emission alternative, subject to a successful trial in partnership with Ports of Auckland and market developments.
   b. All new Public Transport Operating Model (PTOM) contracts are transitioned to battery electric or hydrogen bus fleet from 2022 onward. Consideration will be given to overnight depot charging and opportunity charging at interchanges. Due to fleet type or upgrades to charging infrastructure, Auckland Transport may agree fleet transition plans with bus operators to implement zero-emission fleet by 2025 under the new contracts.
   c. Double-deck buses and other high capacity buses transition to zero-emission from 2025 onward. Technology for these larger vehicles is still developing and therefore a slower uptake may be required. Auckland Transport will closely watch the market for future technology changes and work with bus operators to find the best solution. Future technology

could include electric buses fitted with hydrogen fuel cells and considers depot charging, plug-in opportunity charging, on-route flash , inductive charging on busways and dedicated bus rapid transit (BRT) corridors.

3. Building off the success of previous technology trials, additional demonstrations should include:
    a. Battery electric buses (extra-large three-axle single and double-deck) with depot charging
    b. Hydrogen fuel cell bus trials
    c. 'Opportunity' charging to assess plug-in charging at layovers
    d. Retrofit existing diesel buses with electric and/or hydrogen fuel cell technology
    e. Trial of inductive bus charging at depots to reduce the footprint required for plug-in chargers and to automate the bus charging process
    f. Investigate "opportunity" on-route flash charging or inductive charging for busways and BRT projects.
4. Collaborate with Vector to assess the practical and cost implications of a large-scale deployment of electric buses on Auckland's electricity network so they can plan their investments to support e-bus deployments at selected depots by the commencement dates for new bus service contracts.
5. Collaborate with Ports of Auckland, Auckland Council and the industry in the development of the hydrogen industry to reduce the cost of operating alternative hydrogen fuel cell (HFC) buses.
6. Continue to engage with international organisations such as C40 Cities and the Financing Sustainable Cities Initiative (FSCI) to help expand knowledge and share lessons learned on the transition to low emission buses.
7. 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.
8. 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.
9. 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.

1.2 Challenges for Accelerating the 2040 Goal

Several barriers were identified in the first version 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 "opportunity" plug-in charging infrastructure at bus layovers and on route flash charging, which could increase the number of routes battery electric buses could operate reliably that will require capital investment across Auckland Transport's bus network.
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 bus network, therefore it is only considered for 'flash' or inductive charging options on dedicated busways and new BRT projects with high capacity fleet.

5. High costs for renewing batteries over the life of the asset. 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 costs.

6. Short contract tenure during the transition period influences the cost of service delivery with zero-emission buses compared to diesel fleet. Longer term contracts under the 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.

8. Lack of regulations on a standard for bus charging affects future interoperability of EV bus fleet between contracts and main centers in New Zealand.

Low Emission Bus Market & Procurement

1. The low emission bus market has benefited from early bus trials and deployments during 2018 and 2019 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. The market has evolved with single deck standard two-axle battery electric buses now readily available for New Zealand from several bus manufacturers, with early deliveries for service contracts in Auckland expected from July 2020.

2. The wide variety of bus makes, models, and ages of Auckland Transport's contracted bus fleet 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 offer a cheaper alternative to new buses.

3. Three-axle double deck electric buses are still in the early stages of development with few manufacturers producing vehicles for other markets.

4. High capacity articulated and bi-articulated battery electric buses are now available internationally for BRT applications and can be considered for future projects.

5. 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 the depreciation of assets at depots.

6. 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.

7. Alternative low emission bus technologies like hydrogen fuel cell are not yet developed in New Zealand and require a third-party 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).

Operations

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. Due to a short time in depot for buses to be fully charged, additional buses may be needed to cover those that require re-charging.

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. On route fast charging i.e. 'flash' or indictive charging is considered for dedicated busways and BRT services.

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.

Influencing Bus Operators

1. Bus operators have low confidence in low emission bus technologies largely when it comes to performance. 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. Recent changes to the requirements for rest and meal breaks for bus drivers under the Employment Relations Amendment Act (ERAA), identified more buses would be needed to deliver current service levels. The reset of timetables in May 2020 Identified opportunities to restore some trips potentially affected by ERAA when new fleet is available. Auckland Transport is influencing operators to consider new battery electric buses for future service changes to meet capacity demands which will require additional buses.

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 following model has been used to influence bus operators along with education and encouragement, setting a base for empowering them to become early adopters of zero emission fleet and enforcing new fleet requirements through new contracts.

2.0 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. Auckland's current bus fleet includes range of Euro 3 to Euro 6 standard diesel buses.

With 82 per cent of New Zealand's electricity grid sourced from renewable energy sources, the country is well positioned to electrify transport. As the Government works toward 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 (currently under review)
- Extending the Road User Charge (RUC) exemption for electric vehicles until they make up 2 per cent of the light passenger fleet
- A new RUC exemption for electric vehicles until they make up 2 per cent of the heavy vehicle 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 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.

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. Alongside these 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:

- The Auckland Plan
- Auckland Climate Action Plan (replacing Low Carbon Auckland)
- The City Centre Master Plan

Auckland Council is also developing a sustainability strategy to meet national emission standards for air quality. Auckland Council runs an effective 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.

3.0 Strategic Context

In 2019, there were over 400,000 electric buses operating (approximately 10% of the global bus stock), with an estimated 98 percent of them in China.

3.1 International Context

Battery electric buses have 65% share of the global low emission bus market and are the most commonly adopted technology. Plug-in hybrid buses are the next most popular technology, serving 18% of the low-emission bus market. Hybrid buses have the third highest take up at 12%. Asia has the largest market share of battery electric, hybrid and plug-in hybrid buses.

There has been a significant swell in interest when it comes to hydrogen fuel cell technology with more than 400 hydrogen buses already operating in the United States, Europe and China and from the end of 2019 in Pau, France there will be a first BRT system in Europe running on hydrogen. Other parts of the world are in the early trial stages with favourable results, however costs remain high for implementation.

3.2 Auckland Context

Air Quality and Health

Road transport is the largest source of greenhouse gas emissions in Auckland, accounting for 37.6% 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. Nearly 130 Aucklanders die prematurely every year as result of vehicle pollution and 215,000 days are lost due to illness or poor health.

Diesel vehicles in Auckland are estimated to be responsible for 81% of all vehicle-related air pollution health costs, estimated at $466 million. 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 will result in a 72% reduction of life cycle greenhouse gas (GHG) emissions over the transition period from 2020 to 2040 compared to retaining diesel fleet and eliminate harmful tail-pipe emissions such as nitrogen and particulate matter.

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 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.

The same model updated with a 2018 baseline and with accelerated transition to zero-emission buses completed by 2030, indicates the social benefits improving by $18.7 million in cumulative value over the ten years of accelerated transition to zero-emission fleet – see table 1 below. The earlier transition also achieves higher social benefits of $71.7 million (discounted).

The figures in table 1 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 CO2e, PM10, NOx, CO, HC and noise.

Table 1: Total benefits from the progressive move to a low emission bus fleet in Auckland by 2030

Social benefits	Cumulative values (2018 values–$millions)	Net Present Value (2018 values–$millions)
Air emissions reductions	$123.4	$53.3
Noise reductions	$42.7	$18.5
Total benefits	**$166.0**	**$71.7**

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 September 2019, there were 1,352 diesel buses operating over 200 routes[4]. The fleet size varies considerably between operators, with some operators managing fleets over 500 while others have fewer than 100 buses each.

The current fleet composition includes 285 buses that are more than ten years old. Some bus operators have recently incorporated new Euro 6 diesel buses to replace older fleet or for new contracts, but only 207 Euro 6 buses

4 Including route variants but excluding school bus routes

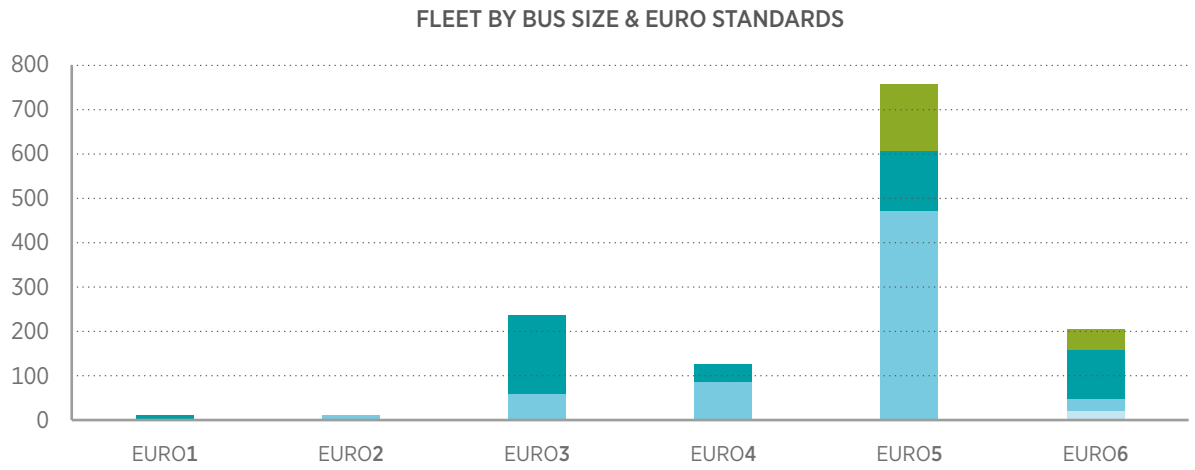


Table 3: Auckland Transport's contracted bus fleet profile in September 2019 by bus size and Euro standard.[5]

are currently in operation. The 2019 fleet composition included a variety of bus sizes and Euro standards, as depicted above:

Buses in the current fleet range in size from about 10m to 13.5m and include both two and three-axle vehicles. The double deck fleet has increased to 195 buses in two years. Furthermore, the numbers of double-deckers and extra-large single-deck buses will increase in the future to meet capacity demand. 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 and procurement process for more extra-large three-axle trial buses have generated interest from other bus manufacturers. Brands like BYD/ADL, Yutong, CRRC, Foton, BCI, Optare 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 or in collaboration with local bus builders like Global Bus Ventures (GBV) or Kiwi Bus Builders (KBB).

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. This provides an earlier opportunity to introduce battery electric buses to replace some age expiring buses between 2020 and 2025.

Current PTOM service contracts for all new routes implemented for the Auckland New Network will be re-tendered throughout the 2020s in several batches. This essentially defines the timescale over which the requirements for new technologies can be procured, fast-tracking deployment, as the specifications for fleet will need to be included in route tenders.

5. There are ten Euro 1 and 13 Euro 2 buses in Auckland Transport contracted fleet as Transitional or Contingency Fleet. These buses are only permitted on some school trips under fleet transition agreements with operators while other buses are being refurbished or new fleet has been ordered, and as a contingency fleet for special events and unplanned rail replacements.

4.0 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.

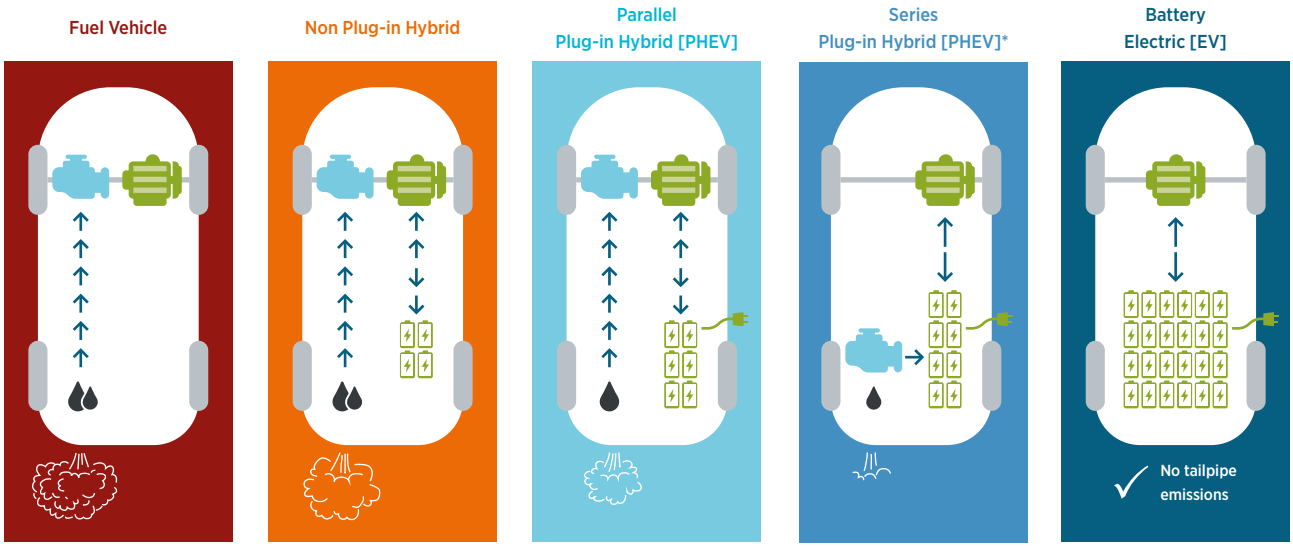
4.1 Assessment of technology options

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 feed-stocks which can be used in a conventional diesel engine. B20 (a blend of 20% biodiesel and fossil fuel) produced from sustainable waste feed-stocks was 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. Hydrogen fuel cell technology is also recommended as a solution for longer routes that battery electric may not be able to service. 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 will require a custom retrofit solution. A trial focused on newer and large capacity buses where new bus options within New Zealand regulations are not yet available, is proposed for retrofit trials.



- **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 refueling time (charge time), varies based on the battery size and charging 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, and those that charge at interchanges and layovers or on-route.
- **Hydrogen fuel cell** (HFC): HFC technology is immature and at demonstration 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 refueling time is similar to diesel. 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, when batteries will become harder to dispose of after their second life applications. There is a risk that batteries may become more expensive over time as precious minerals to produce them may be depleted or in short supply if the metals are not recovered through a recycling process. The investigation of hydrogen as a future fuel is important for the change in the way public transport buses will be powered in the later stages of this transition. AT's plans to trial hydrogen are aligned with the vision for

hydrogen in New Zealand proposed in a Green Paper released for consultation 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/). The cost and benefits of the transition to hydrogen technology on buses and the risk of increasing costs of batteries 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.

- **Retrofit:** Retrofit technology is in an early stage of development and large-scale applications are limited. Its operability is suitable for most routes in Auckland, but it may bring about VDAM challenges due to the weight. Retrofitted buses will 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 furthers 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[6] 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.

6 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.

5.0 Technology Trials

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)

Auckland Transport is working in partnership with bus operators to trial battery electric buses.

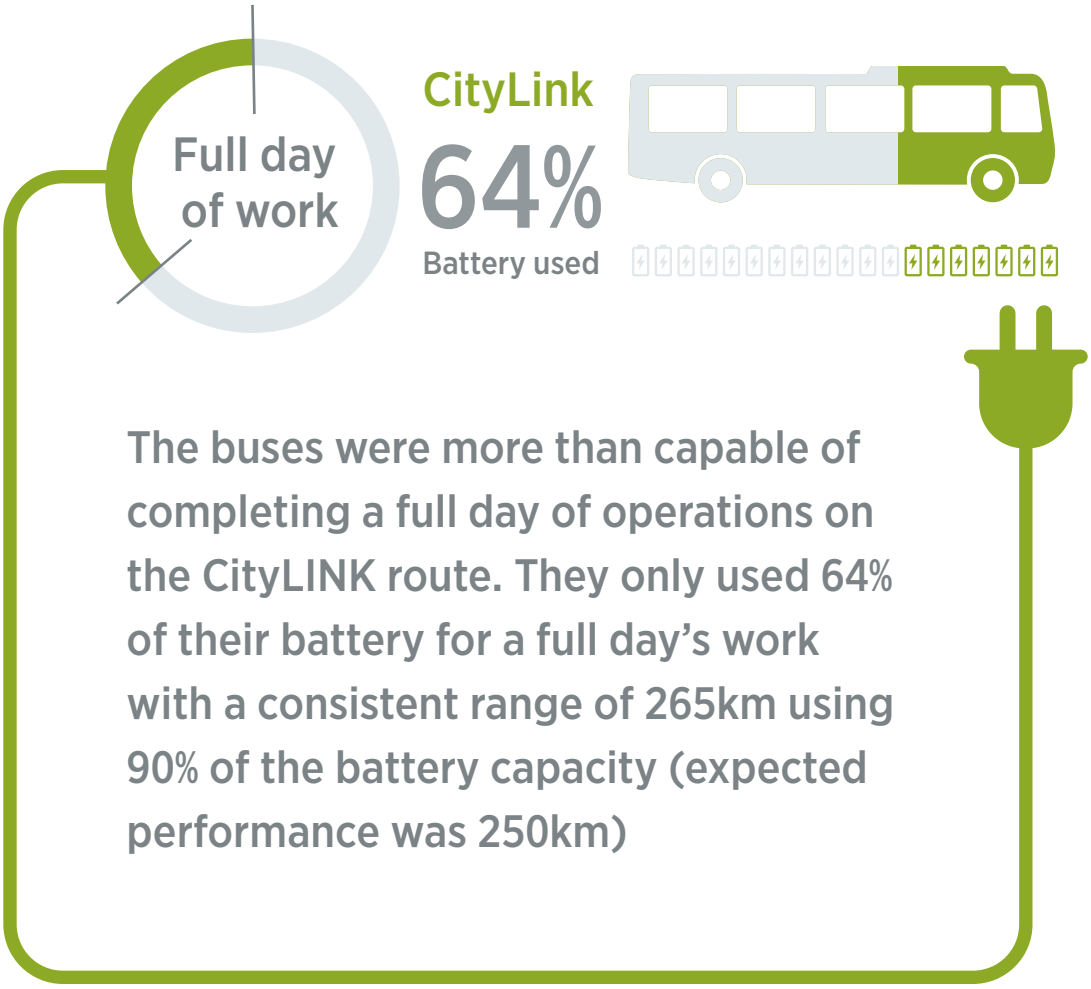
5.1 Electric Bus Trials

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.

Additional trials on other routes will allow Auckland Transport and bus operators to gather more local data on range and operating costs to inform future investment decisions. The positive results of trials confirmed that the City LINK route is the perfect candidate for a transition to a zero-emission fleet when the operating contract comes up for renewal in 2020. This will be the first fully “electrified contract” and will target emissions reduction and improvement of air quality in the city centre. The trials also enable the selection of



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)

appropriate solutions to implement an all new electric Airport LINK bus service from Manukau Bus Station via the new Puhinui Station to the airport.

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 from mid-2020. 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.

The trials also enable testing of the bus charging technology. ADL/BYD uses a two-plug system of 40kW per plug enabling slow charging overnight at depot. The charging time takes up to six hours. The Yutong bus 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 contribute to a better understanding of any issues and opportunities to improve design and processes.

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 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.

Over the course of 2020, Auckland Transport is planning to trial more two-axle e-buses from other manufacturers to encourage more market options and will test the first 'extra-large' battery electric buses in Auckland, and the first of its kind in the world, designed especially for New Zealand. These buses have three axles, compared to two used in standard large buses and can carry up to 78 passengers.

Auckland Transport has also been assessing hydrogen fuel cell (HFC) bus options and quotes have been obtained from global bus suppliers. Up to three HFC trial buses (single and double deck) are expected to be operational in 2020 and 2021. The first HFC bus will be built in Christchurch. It will be 13.5m long with three-axles and provide capacity for up to 78 passengers. Discussions are still underway to source suitable double deck HFC buses for more trials in 2021.

The hydrogen production plant and refueling station will be built by Ports of Auckland (POAL) in the third quarter of 2020. This station will provide the hydrogen fuel supply for Auckland Transport's trial HFC fleet.

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 retrofitting diesel 'extra-large' three-axle and double decker buses to electric using proven technology
- Trials of different charging infrastructure solutions
- Trial of inductive bus charging technology to reduce depot footprint required to park electric buses connected to plug-in chargers
- 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 is in discussions with the Ministry of Transport and Auckland Transport about the potential to support its use in heavy transport and buses.

6.0 Accelerating our transition to zero-emission

The transition to zero-emission fleet included consideration of ownership models for fleet and depots. However, 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. The depot ownership was to be considered as part of a depot strategy to be developed during the transition period.

6.1 Ownership Models

Fleet ownership

The current fleet provision under the PTOM has been recommended. 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 2018, Auckland Transport does not require capital to purchase fleet (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 and the International Association and Public Transport (UITP) 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), by the transit authorities and sub-leasing them to bus operators. Other regional councils in New Zealand and the Ministry of Transport have initiated discussions of alternative fleet procurement and ownership in New Zealand. Auckland Transport will further investigate the options.

Charging Infrastructure

The bus charging, associated depot infrastructure and electricity network upgrades were not included in the cost and benefits analysis of the transition to electric buses in the previous version of the Roadmap, but it was assumed that $32 million would be required to upgrade the electricity grid, based on a study completed by independent consulting firm Element Energy Limited. Later estimates were in the range of $30 million to $60 million.

Auckland Transport has since updated the cost and benefits of electrifying bus fleets. 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. 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 development of ‘charging as a service’ by Vector Energy Solutions has enabled the mitigation of some of the ownership issues, with Vector investing in the electricity network and depot infrastructure as an operational cost to the bus operator under lease arrangements. This leasing option mitigates some of the depot ownership challenges identified during the early planning to implement the first all-electric bus contracts for City LINK and Airport LINK services. However, this option transfers

the risks associated with the lease term to Auckland Transport. This results in higher bus charging costs due to the depreciation of the depot electricity network infrastructure being accelerated over the remaining term of the contract or depot lease instead of the end of the useful life of those assets, which for some electricity assets may be 20 years.

6.2 Transition Options

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 LEV 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.	• Meets Mayoral commitment to buy only zero-emission from start of 2025 • Later start maximises benefits of technology development, reduced capital cost of vehicles and cheaper future replacement batteries • 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 • More time to prepare for infrastructure and to plan fleet change • 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) • 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)

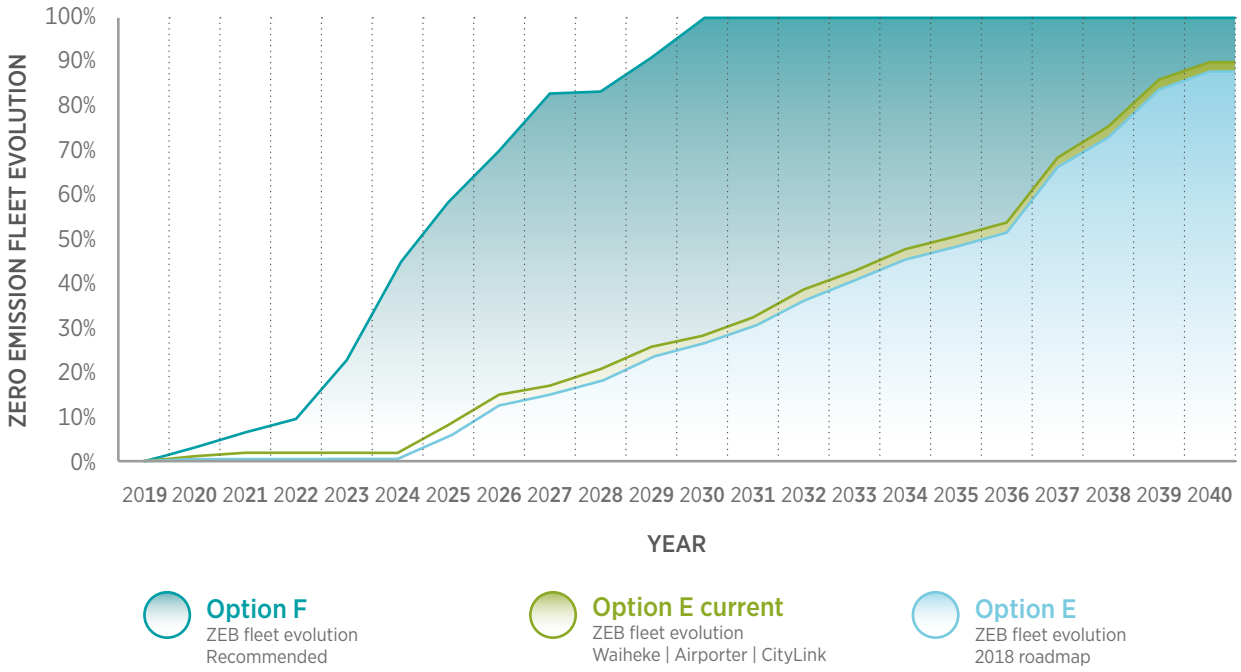


Figure 2: Comparison of transitions to zero-emission buses under Option E, current contractual commitments and accelerated transition under Option F[7].

Electrify faster

The current transition to zero-emission buses is tracking ahead of Option E endorsed by the Board in December 2018. With the Board's subsequent approvals to extend the City LINK contract with an all-electric bus fleet and to procure electric bus services for Waiheke Island and the new Airport LINK from Manukau via Puhinui Station, Auckland Transport has surpassed the targets of the original transition plan (Option E), as shown by the orange trendline in Figure 2. However, the red trendline in Figure 2 shows the significant opportunity to realise the environmental and social benefits sooner by electrifying the bus fleet faster. The accelerated transition will help overcome the challenges that Auckland Transport faces along the way to transition to zero emission buses and contribute to creating fossil free streets in major parts of the city center.

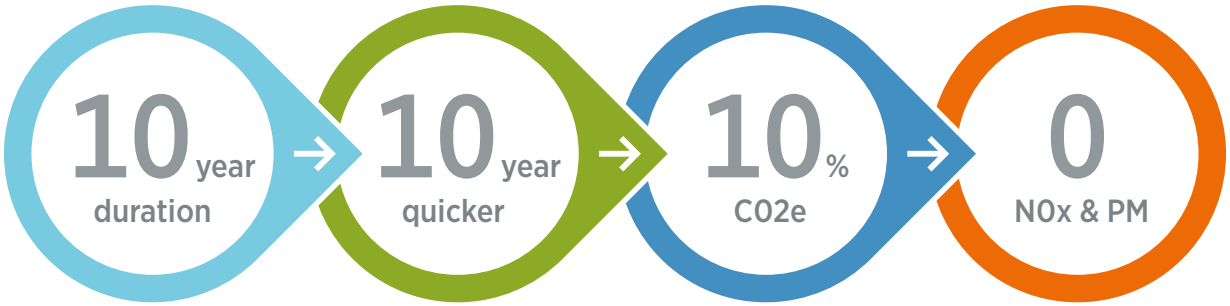
Based on the progress made in promoting the earlier adoption of low emission bus fleet in New Zealand and creating a supply chain able to support their operation, along with the evolution in battery and charging technology and updated cost and benefits (including social and environmental), faster electrification of buses under new Option F will complete the transition ten years earlier, over a ten year period and reduce carbon emissions down to almost 10 percent of expected CO2e in 2030 and zero nitrogen and particulate matter emissions from tail pipe.

Recommended OPTION F for faster transition

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

7 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.



Option F (2020)	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. All contracts from 2022 specify new fleet, replacements and growth as zero-emission only. All double decker and other high capacity electric or hydrogen buses transition to zero-emission from 2025.	• Meets Mayoral commitment to buy only zero-emission from start of 2025 and make major part of city center fossil fuel free by 2030 • Accelerated start maximises benefits of rapid technology development, stimulates supply chains to reduce capital cost of vehicles and brings forward cheaper future replacement batteries • Completes transition to zero-emissions (at tail pipe) 10 years earlier over 10 years period reducing carbon emissions down to about 10% 2030 CO2e. • Ability to implement more battery electric buses and fast track investments in depot charging and electricity network • 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).	• Operators purchasing small numbers of electric vehicles for growth likely to be more expensive (discounting for bulk purchase not modelled) • 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 • Regulators, electricity suppliers, manufacturers and key stakeholders have less time to transition to the new technology • 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)

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.[8]

8. 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.

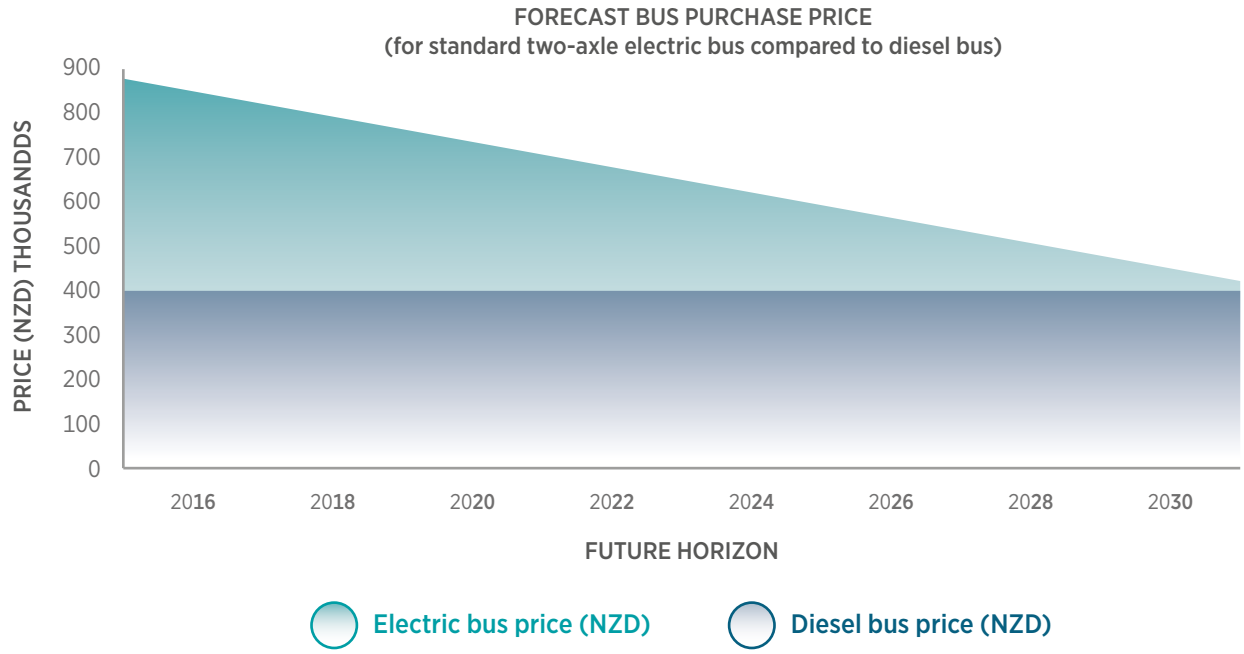


Figure 3: Forecast purchase price for standard two-axle electric bus compared to diesel bus.

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. Learnings from overseas markets indicate a small premium on e-buses will still exist in the future due to different technology. 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 modeling 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 policy statements and contractual requirements for future bus service contracts, to 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.[9] However, a more detailed grid study is underway using the international expertise recommended by the C40 network and their Technical Assistance Programme.

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) Auckland Transport and Vector are to collaborate to identify opportunities and mechanisms to reduce costs of bus charging infrastructure and reduce the predicted costs to run e-bus services.

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

The challenge for bus operators to overcome 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.

Therefore, 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 16% premium on the PVR rate for e-buses based on current cost assumptions, reducing to an 11% premium in 2030 and 6% 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 costs favour electric over diesel, and maintenance costs from electric buses with fewer moving engine parts than a combustion diesel engine with a Euro 6 emission standard are likely to be around $2,000 less per bus per year.

Battery renewal costs have not been modelled, as the renewal can vary from 6 to 12 years depending on the operating hours of the fleet, type of battery technology used and number of full recharge cycles. Additionally, bus manufacturers are developing different battery replacement plans. For the purpose of modelling future costs, it is assumed that buses will be new, and their batteries will last the duration of the contract. It will be expected that the cost of battery replacement/ refurbishment will be built into the PVR rate by the operator depending on the type of contract they operate.

The cost model does not include the replacement or rebuild costs of a diesel engine, and for comparative reasons the costs of battery renewal in electric buses have not been modelled either. However, it is noted that bus operators have concerns over the longevity of batteries in service and the future costs of their renewal. This is more related to the residual value of the buses at the end of contract or the cost of extending their life to maximise their permitted age under RUB in an economically viable way.

Impacts

Accelerated transition will achieve full transition to zero-emission buses by the end of 2030 without the additional arrangements to complete this transition envisaged in the 2018 Roadmap which did not include 250 buses. Figure 4 clearly demonstrates the positive impact on the progressive change in fleet evolution for Auckland Transport.

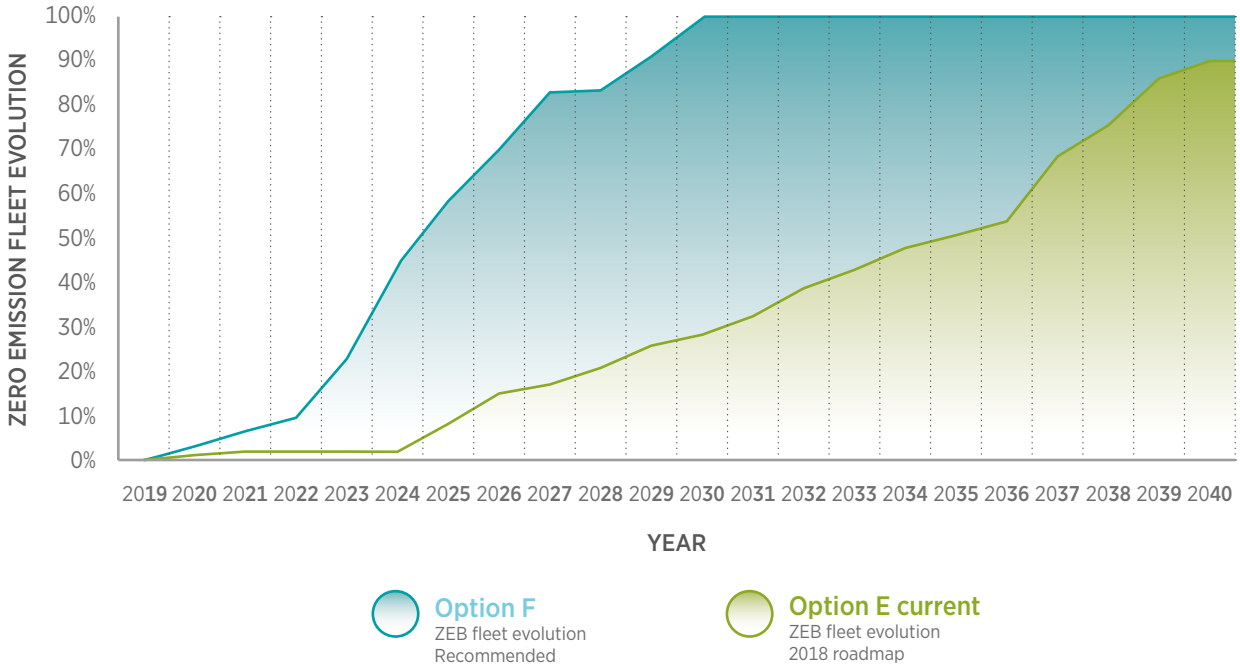


Figure 4: Fleet evolution in percentage of electric buses in AT fleet under Option F vs Option E

The additional benefit of an accelerated transition under Option F is a smaller carbon footprint with life cycle greenhouse gas emissions reduced by 1.8 million tonnes–down to 11.7 percent of expected CO2e in 2030 compared to 0.8 million tonnes less emissions during a 20-year transition and a 33.3 percent of predicted CO2e in 2040 if progressing with Option E. Both options compare emission levels from diesel fleet in 2019.

High level estimates based on data from e-bus trials indicate the following electricity demand from e-buses during transition under Option F compared to Option E.

The detailed study in collaboration with Vector will provide more precise 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 by 2023 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 F is expected to increase bus services costs by up to 4.9% in 2030 and 0.6% 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.

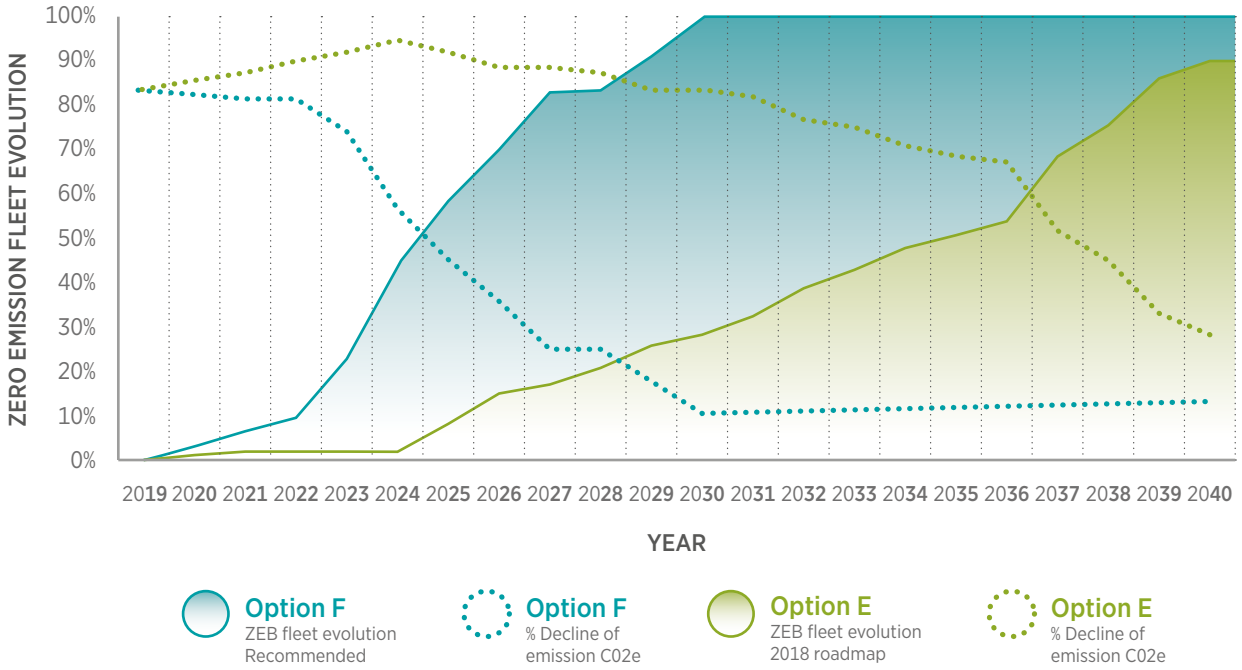


Figure 5: Emissions profiles for Option F compared to Option E based on e-bus fleet evolution

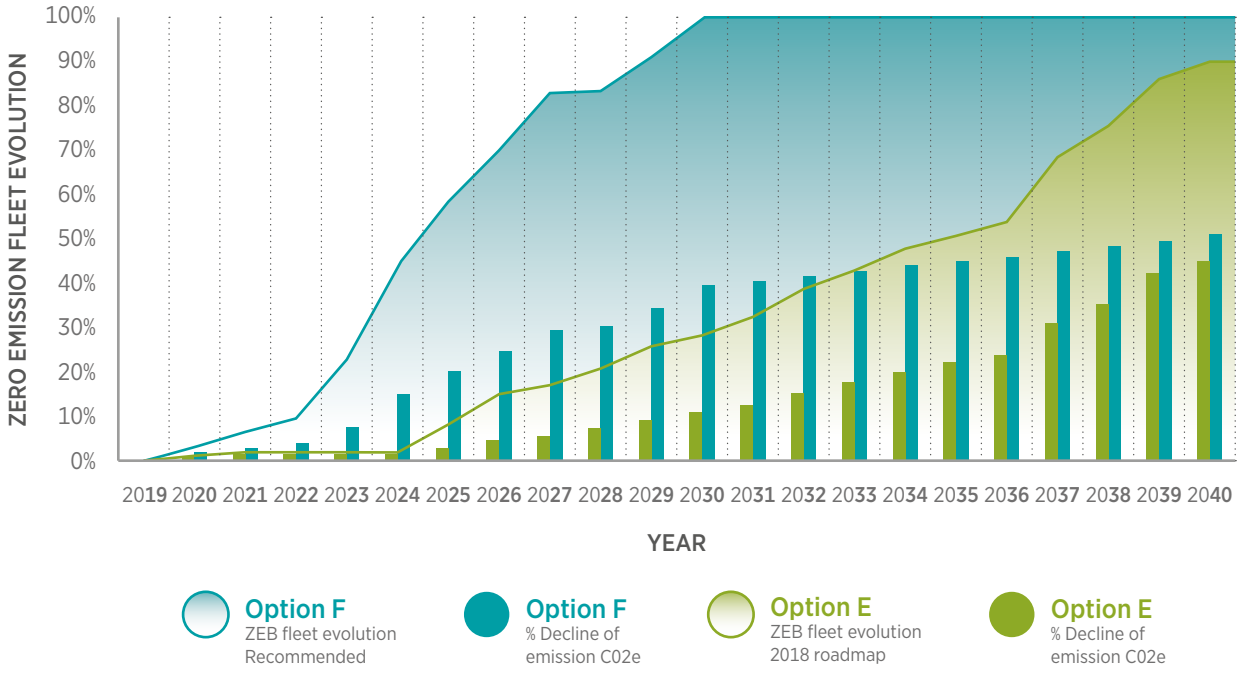


Figure 6: Estimated electricity demand from e-buses based on AT e-bus trials under Option E and Option F

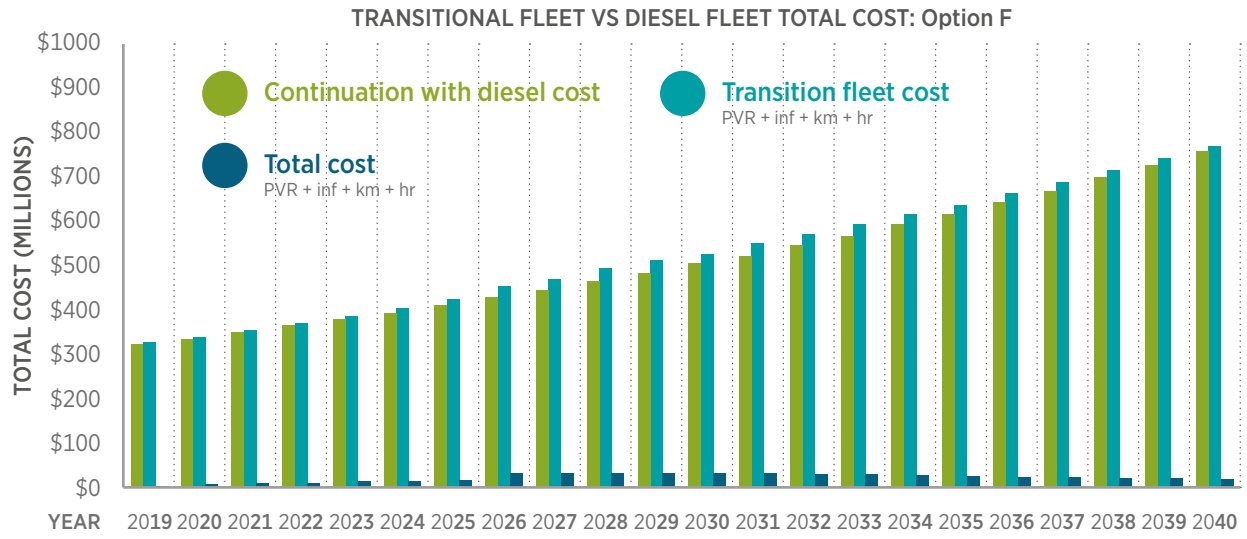


Figure 7: Total costs of bus services under Option F compared to continuing with diesel fleet (2.6% pax growth and 2% NZTA annual indexation applied)

Based on the updated information and forecasts, Option E is now expected to increase operating costs by up to 0.9% in 2030 and reduce costs compared to diesel fleet by 2.7% in 2040 but 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 impact on pavement has not yet been modelled, Auckland Transport has commenced a study to understand the impact of heavier battery electric buses on pavements and the associated cost of road maintenance or rehabilitation to improve their quality. These impacts will be provided with the next update of the Roadmap.

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.

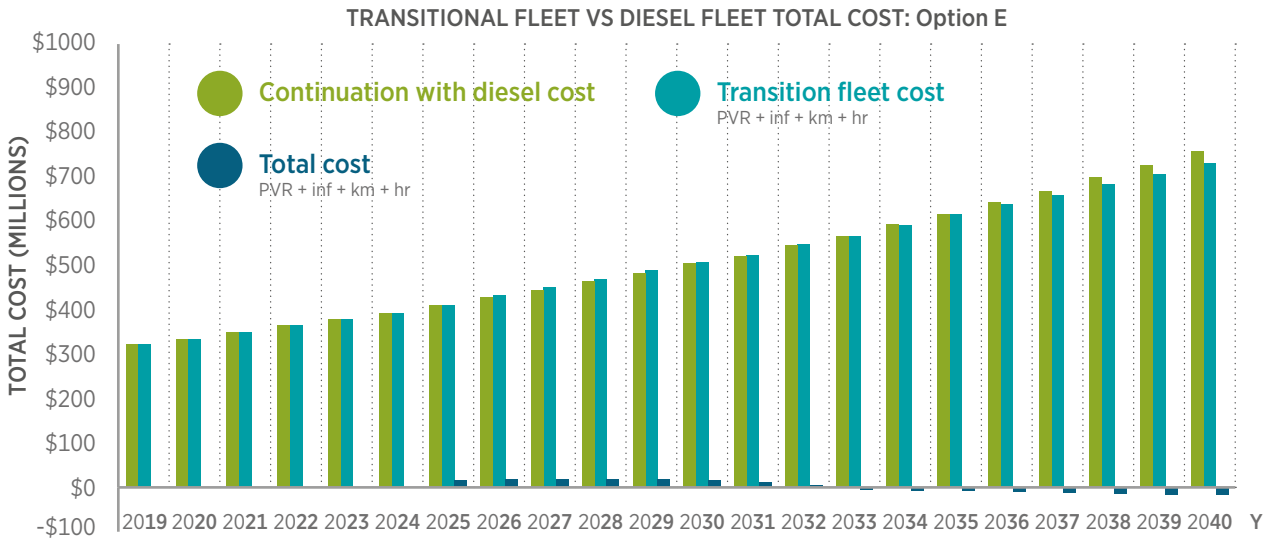


Figure 8: Total costs of bus services under Option E compared to continuing with diesel fleet (2.6% pax growth and 2% NZTA annual indexation applied)

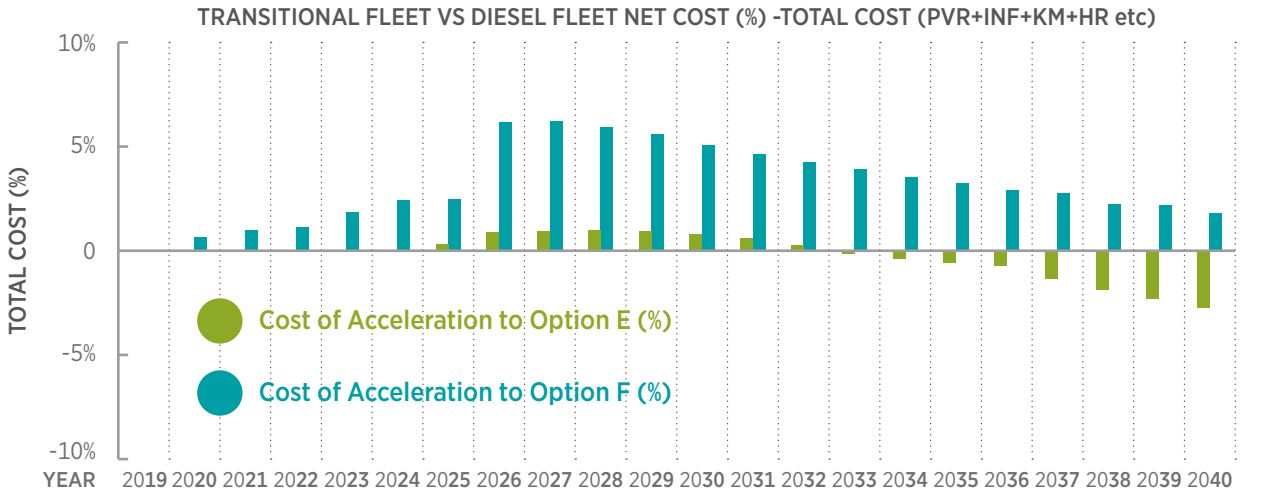


Figure 9: Percentage difference in total costs during transition period between Option F and Option E compared to continuing with diesel fleet

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 change into contracts and extend life of existing fleet. Such change could incorporate an agreed schedule for fleet transition from diesel to zero-emission propulsion (under Option F), 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 F; therefore, regular review is necessary for accuracy of future cost modelling which will impact the necessary funding.

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. Progress the Low Emission Bus Roadmap principles from a baseline transition endorsed in December 2018 and updated in September 2020 with continuing 12-18-month updates to the "Roadmap" base level scenario. These updates would be based on benefit/cost, technology updates and other impacts.
2. Implement e-buses on Waiheke Island from mid-2020 to progress transition from current diesel fleet on the Island under the new PTOM contract.
3. Implement a larger-scale trial of the City LINK e-bus service from November 2020 (when the current contract for that route is extended).
4. Implement a new Airport LINK service on route 38 with e-buses with a trial of opportunity plug-in charging at Manukau Bus Station from the start of 2021.
5. Continue to undertake trials and demonstrations of zero-emission buses and their associated infrastructure solutions (subject to budget and availability). Seek funding from EECA from their Low Emission Vehicle Contestable Fund. Proposed options include:
    - Further electric bus trials from other manufacturers
    - Hydrogen electric trials (incorporating hydrogen supply)
    - 'Opportunity' 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 charging for busways and BRT projects

6. 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 previously provided by Financing Sustainable Cities Initiative (FSCI) and it is expected to guide the infrastructure and financial planning supporting the deployment of buses.
7. Complete an assessment of impact of heavier battery electric buses on pavement wear and associated costs of road maintenance.
8. Lead and facilitate the Low Emission Bus Working Group to break down the barriers to adopting low-emission buses in Auckland and New Zealand and develop supporting infrastructure, technical assistance and financing models. This group includes local bus operators and a range of public and private stakeholders in deploying Auckland's Low Emission Bus Roadmap.

This group is tasked with:

- Growing the low emission bus market in Auckland (and NZ)
- Facilitating the development of supply chains and aftermarket support, technical assistance and financing models
- Understanding impacts related to charging infrastructure
- Disseminating outcomes of demonstration trials and assessments
- Influencing national policy.

9. Collaborate with C40:
   - Work with the Mayor's office to develop the Fossil-Fuel-Free Declaration programme including the development of Te Tāruke-ā-Tāwhiri: Auckland's Climate Action Framework, which outlines a series of required mitigation and resilience actions to limit global warming to within 1.5 degrees Celsius above pre-industrial levels, and understand the financial implications of accelerating the transition to buses with zero-emissions at the tail pipe from 2020.
   - Use the C40 network to learn lessons and to benchmark with other cities about the adoption of low-emission buses and accelerating transition.
10. Investigate 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.
11. Develop a depot strategy to increase competitiveness of tenders for future bus service contracts.
12. Consider investment in depot bus charging infrastructure to reduce the premium on contract rates.

Glossary

Acronym	Description
BEV	Battery Electric Vehicle (also known as E-Bus)
CO2e	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
PTOM	Public Transport Operating Model
PVR	Peak Vehicle Requirement
RCD	Residual Current Device
RUC	Road User Charges
VDAM	Vehicle Dimensions and Mass (NZ)
ZEV	Zero-Emission Vehicle

Appendix 1: Electric bus trial results

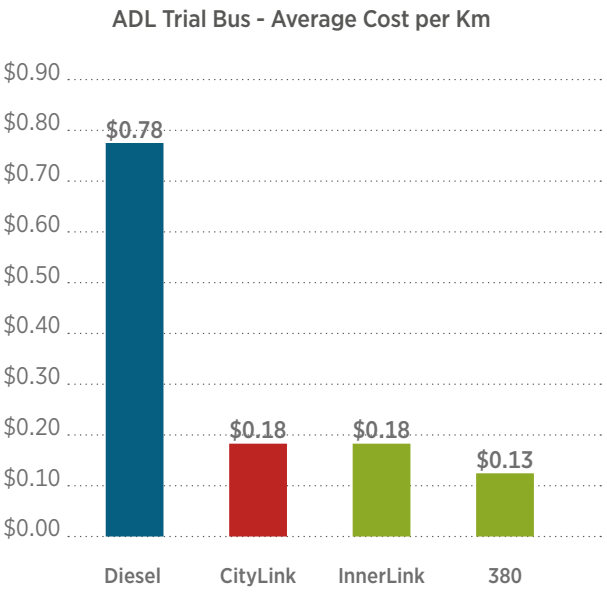
Data collection

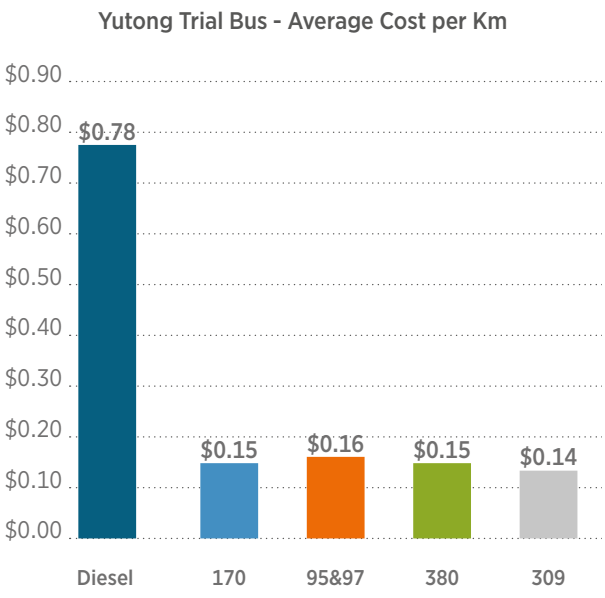
Data collection from three trial electric buses has continued to be relatively reliable, albeit with gaps where buses have not been fully utilised.

The base figures below have been used in calculations.

The following statistics are based on data collected up to 31 December 2019.

Power cost	$0.17 per kWh
Road user charge	$0.278 per kilometre
Combined diesel & add blue cost	$1.44 per litre
Fuel consumption of comparable diesel bus	0.35 litres per kilometre





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.

Appendix 2: Benefits & financial impacts

Assumptions

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

Notes and other assumptions

1. Based on "operator fleet data" and "PVR data" as at September 2019.
2. The electric bus premium is assumed to be 110% as at 2017, declining over 14 years to around 13% in 2031.
3. In-Service km rates are an average across all contracts with no weighting of rates across the range of unit agreements. 2019 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, Carbon Tax, Adblue and the remaining.
4. PVR rates are an average across all contracts with no weighting of rates across the range of unit agreements.
5. Diesel bus PVR rate is calculated based on the average of similar size bus PVR rates over different units excluding outliers. 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.
6. Assumed in-service hours are the same for electric as diesel. The 2019 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 2019 and is inflated with 2% NZTA indexation over time and used to forecast the "balance cost" over time. This is assumed to replace the remaining in-service hour cost over time.
7. Diesel price forecast is based on the Ministry of Transport's historical database. The discounted retail price of diesel excluding the ETS (Carbon Tax), is used to forecast the diesel price over time.
8. Provision of ETS on diesel fuel uses the current 6.675 cents per litre with 2% inflation included as base case. Provision of sensitivity analysis with alternative scenarios of 61C/L in 2050 (Net Zero), 31C/L in 2050 (Productivity Commission) and an average value of 46C/L in 2050 is included.
9. Retail electricity price forecast is based on Energy Link's assessment.
10. It is assumed that road user charges (RUC) applies to electric buses from the beginning of 2026 at the same as for diesel buses.
11. Patronage is based on AT HOP card data. Average patronage increases of 3.8% with lower bound 2.6% and Upper bound 4.8% with 95% Consumer Index (CI), is forecasted.
12. Considering spare capacity in the bus network, the bus capacity increase rate in the network is assumed to be less than the average rate of the increase in patronage. As such, lower bound bus capacity growth rate (2.6%) is considered in the model as the base case. Provision of sensitivity for 3.8% growth rate (same as average patronage growth rate) and 4.8% growth rate (same as upper bound patronage growth rate), is included.

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 emission PVR premium	Dynamic/reducing as per forecast			
Total Bus Contracts Costs in 2019	$320,832,355			
Fuel / Energy consumption (weighted average)				
Electric (kWh/km)	0.79	0.97	1.14	1.41
Diesel (litres/km)	0.3	0.35	0.455	0.55
Low inf Cost premium over e bus PVR	6%	6%	6%	6%
High inf Cost Premium over e bus PVR	16%	16%	16%	16%
Inf Cost_diesel_premium	$0.00	$0.00	$0.00	$0.00
Road user charge per km (diesel bus)	$0.142	$0.278	$0.278	$0.372
Electric (kWh/km)	0.79	0.97	1.14	1.41
Maintenance savings per annum (electric bus)	$2,000.00	$2,000.00	$2,000.00	$2,000.00
Diesel contract per km rate	$1.21	$1.67	$2.40	$2.46
RUC applies to zero emission bus	2026 onwards			
Fuel / Energy Costs				
Electric (kWh)	$0.170			
Diesel (per litre)	$1.40			
Add blue % (per litre of diesel)	2.12%			
Add blue (per litre)	$0.62			
Diesel combined fuel (per litre)–2019	$1.41			
NZTA indexation factor	2%			
NPV discount factor	6%			
Fleet retirement age	20 years			
Patronage				
Bus patronage (2019)	74,534,638			
Double-decker bus patronage (2019)	17,505,951			
Growth forecast for patronage	2.6% (lower bound)			

13. Annual Patronage Increase on DD routes over the rest of the city is considered to be the same for the base case. Provision of sensitivity for higher (0.5%,1%, 1.5%) patronage increase rate of DD routes over the rest of the city routes can be tested.

14. The useful life of buses is 20 years.

15. The infrastructure cost for electric bus PVR premium over e-bus PVR rate is assumed to be following a linear decreasing trend from 16% to 6 % 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.

16. It is assumed the PVR premium of diesel buses will remain constant (it does not change when new contracts are tendered).

17. 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.

18. Capacity unit of Small Bus, Large Bus and Double Decker is 51%,69% and 128% in comparison to the Extra-Large Bus.

19. 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).

20. Average annual kms (mileage) travelled by buses of all types is based on 2019 data and remains constant over time based on the current bus network. This excludes any increase in Network kms as new routes may be added in the future.

21. Option E assumes that 12% of the bus fleet (250), would need to be replaced with e-buses by the end of 2040 with no financial impact to AT. This would require contractual arrangements or rely on operators changing fleet voluntarily before that date

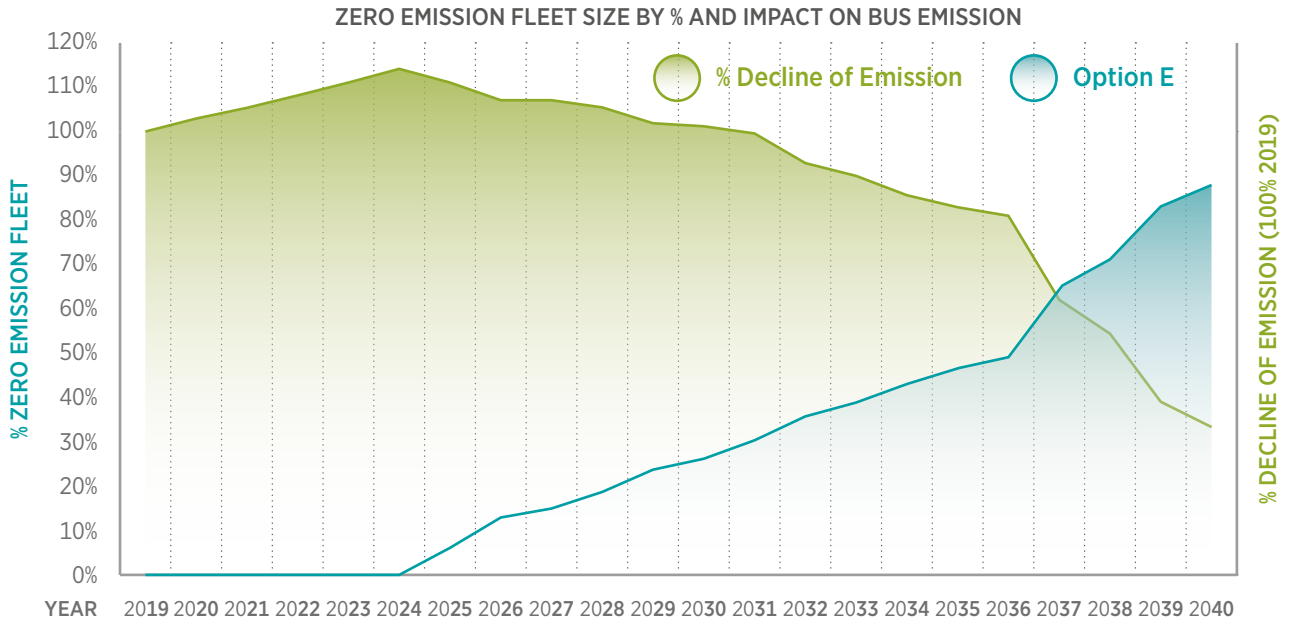
Benefits & Impacts

Option E

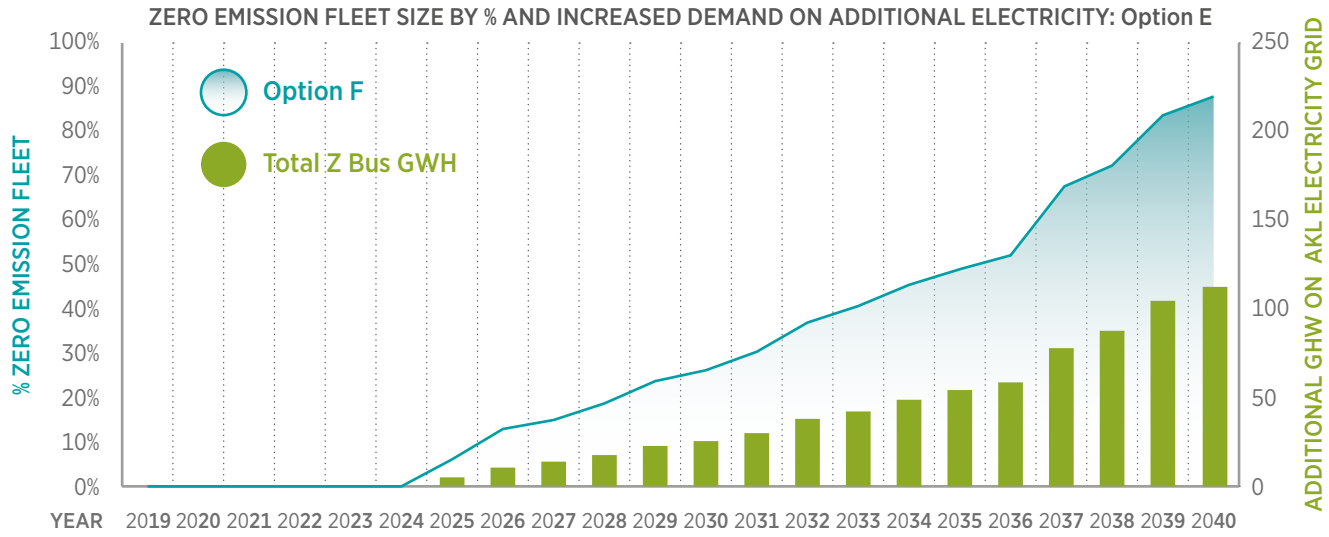
- The transition under Option E will reduce greenhouse gas emissions by 0.8 million tonnes[10] and down to 33.3% in 2040 (2030 it increases emissions by 1% compared 2019 level).
- The social benefits from the progressive move to a low emission bus fleet in Auckland by 2040 under Option E account for $75 million ($28 million discounted) of cumulative values over the years of transition based on a 2018 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 CO2e, PM10, NOx, CO, HC, and noise.

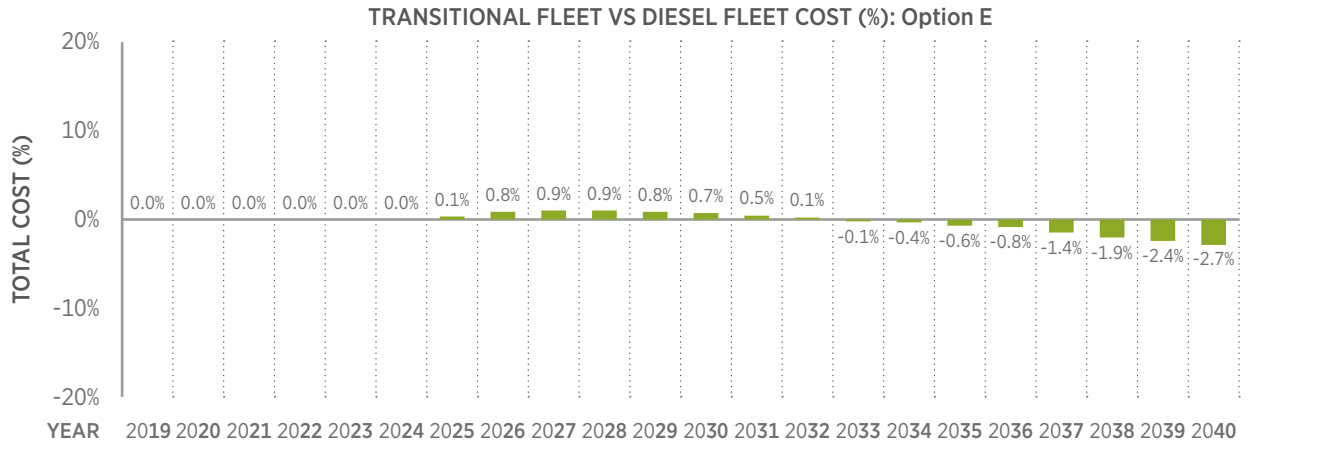
10 Cumulative value over the 20-year transition period compared to diesel fleet in 2019

Social benefits	Cumulative values	Net Present Value
(2018 values–$millions)		
Air emissions reductions	$56	$21
Noise reductions	$19	$7
Total benefits	$75	$28

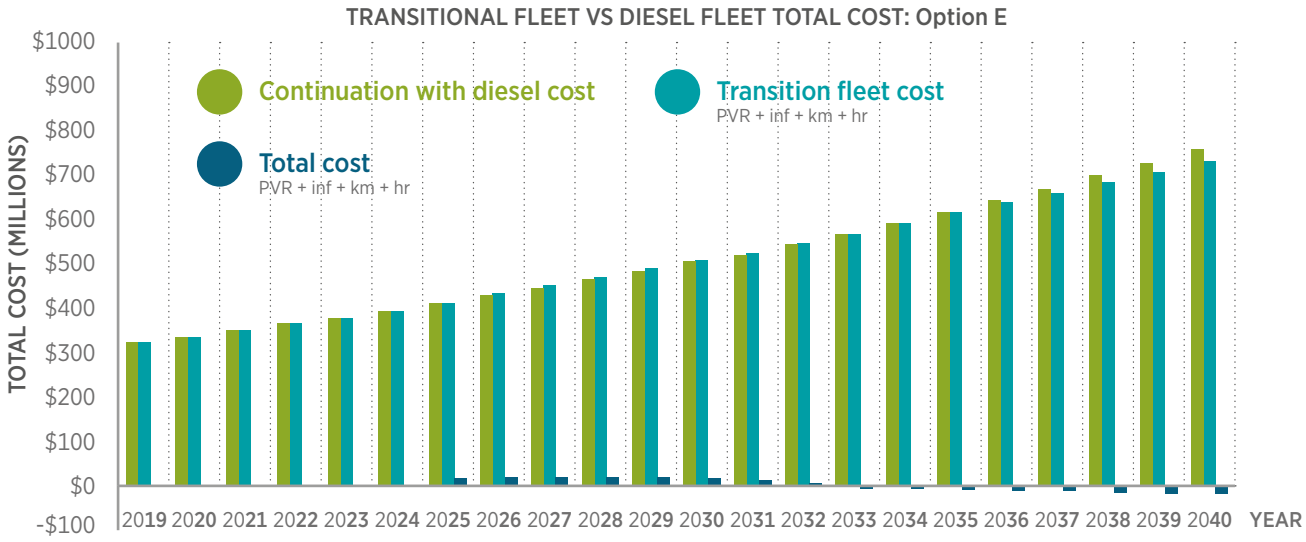


- The slower transition would delay the increase of electricity consumption by AT Metro buses and the required electricity network upgrades for bus depots.
- The updated net costs of transition under Option E increases operating costs by up to 0.9% compared to diesel fleet in 2030 and reduces costs by 2.7% in 2040.





- Predicted to deliver savings of $20.7 million (2.74%) in cost of bus services in 2040 compared to continuation with diesel fleet and cumulative savings of $49 million over 20 years.
- The Incremental benefit / cost ratio is very high (due to cumulative cost savings).

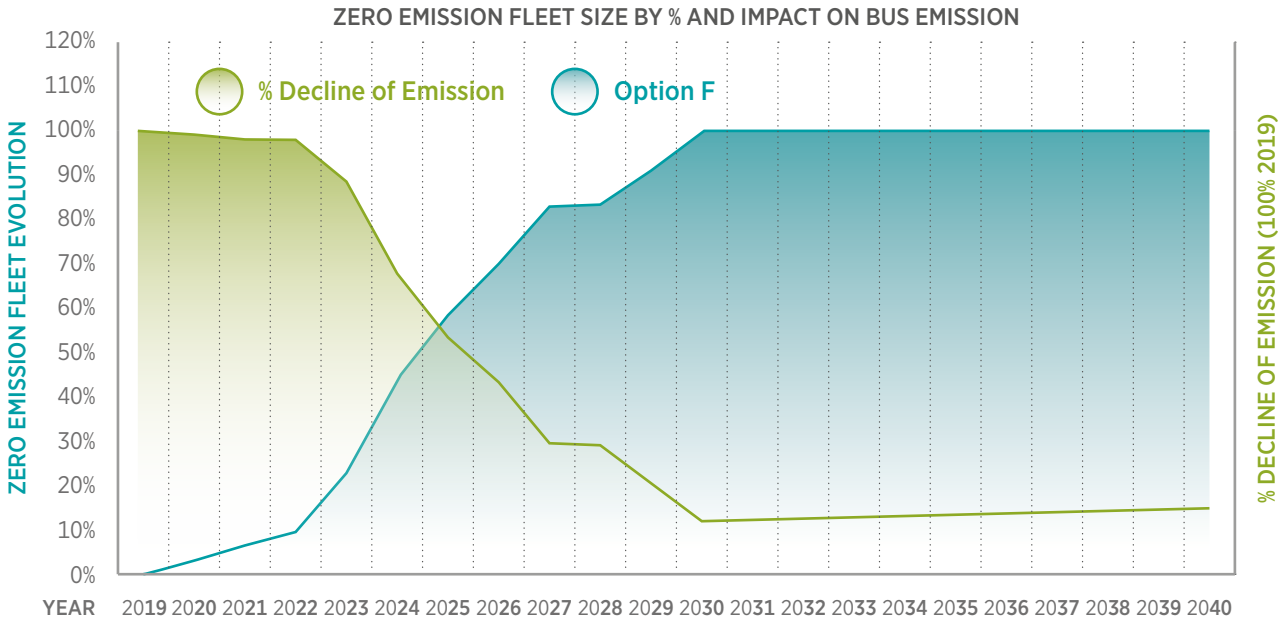


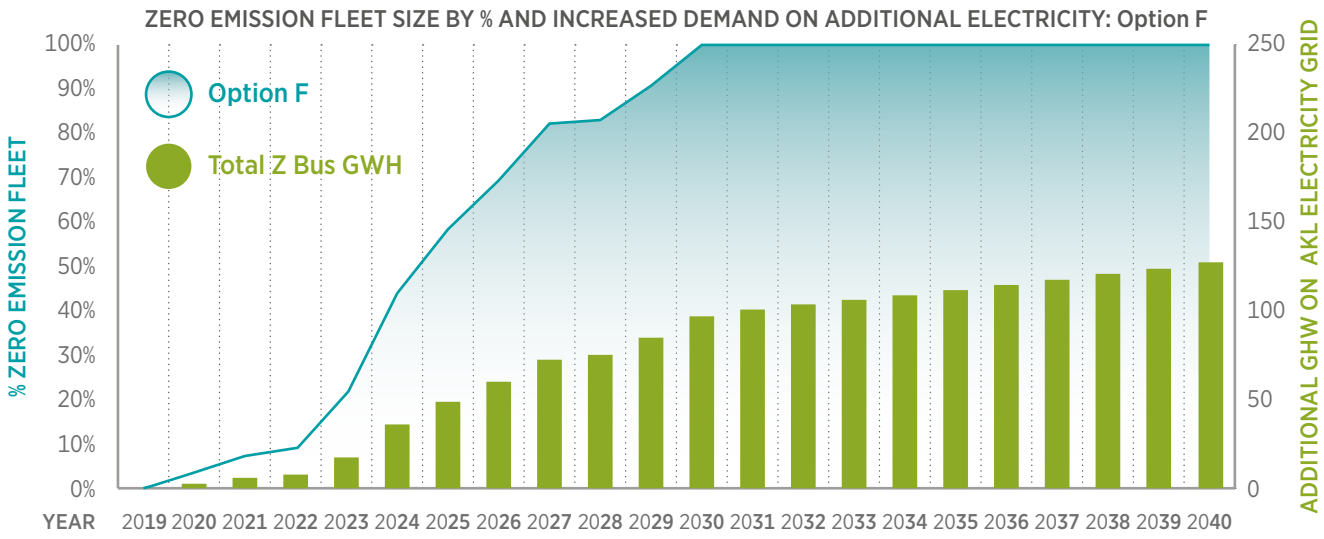
Option F

- Reduces carbon emissions by 1.8 million tonnes and down to 11.7% in 2030 (2040 emissions will be down to 15.2% as more e-buses due to growth will increase carbon emissions over time).
- The social benefits account for $166M of cumulative values over the years of transition and $71.7M of net present value based on a 2018 baseline 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 CO2e, PM10, NOx, CO, HC, and noise.

Social benefits	Cumulative values	Net Present Value
(2017 values–$millions)		
Air emissions reductions	$123.4	$53.3
Noise reductions	$42.7	$18.5
Total benefits	$166.0	$71.7

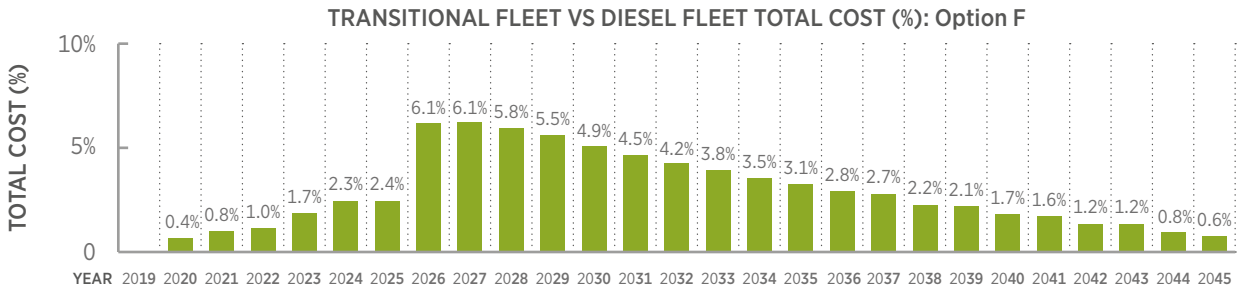
- The accelerated transition will bring forward higher electricity consumption by AT Metro buses and required electricity network upgrades for bus depots will need to be done sooner.
- The updated net costs of transition under Option F increases by up to 6.1% in 2027 compared to diesel fleet before it will reduce.
- Accelerated transition is expected to cost $164 million ($103.5 million discounted) over the ten years to 2030 with annual increases ranging from 1% in 2022 of up to 4.9% for bus services in 2030 when transition

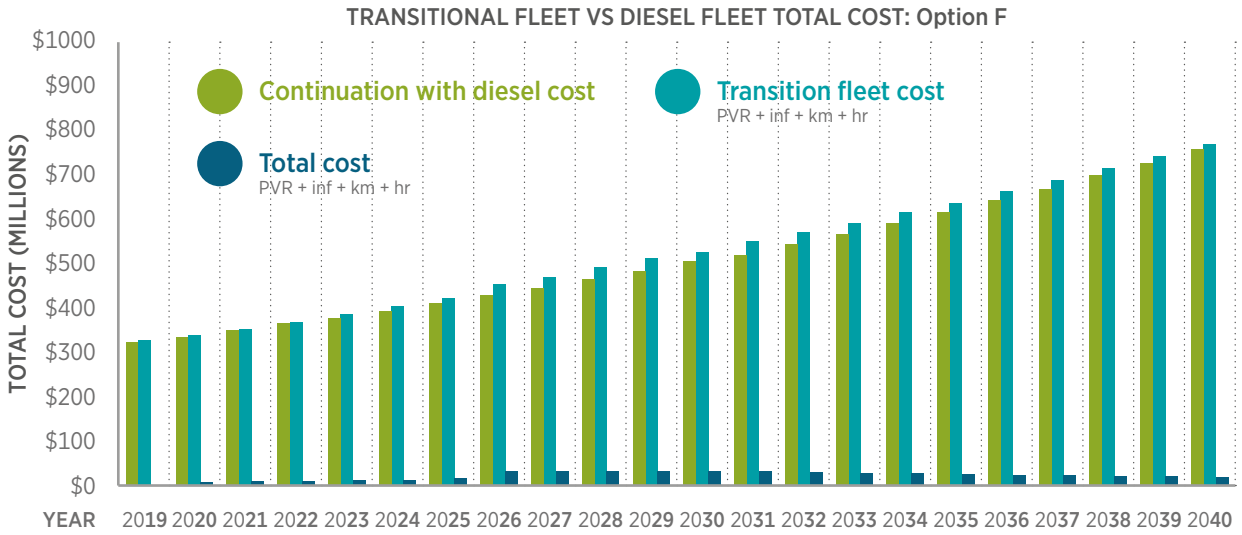




would be completed compared to the diesel fleet.

- Faster transition will have a cumulative cost of $350.1 million ($177.8 million discounted) over the 20-year period from 2020 to 2040 compared to retaining a diesel fleet. The incremental benefit / cost ratio is 0.4.





Sensitivities

Option E (2020 -2040)

Variable	Factor	Cumulative cost of transitional fleet ($m)	Cumulative cost of continuation with Diesel ($m)	Cumulative cost for transition to Zero Emission ($m)	Indicative discounted cost for transition to Zero Emission ($m)
Base: Maintenance savings p.a. (e-bus)	$2,000	4,551	4,532	19	11
Scenario 1	$5,000	4,546	4,532	14	9
Scenario 2	$10,000	4,538	4,532	6	4
Base: Growth forecast for patronage	2.6%	4,551	1,481	19	11
Scenario 3	3.8%	4,896	4,873	24	14
Scenario 4	4.8%	5,226	5,197	29	17
Base: Emission Tax Sensitivity	Current ETS (c6.67/l – c12.32/l in 2050)	4,551	4,532	19	11
Scenario 5	Productivity Commission (c31/l in 2050)	4,563	4,546	17	10
Scenario 6	Net Zero emissions (c61/l in 2050)	4,581	4,567	14	8

Option F (2020- 2030)

Variable	Factor	Cumulative cost of transitional fleet ($m)	Cumulative cost of continuation with Diesel ($m)	Cumulative cost for transition to Zero Emission ($m)	Indicative discounted cost for transition to Zero Emission ($m)
Base: Maintenance savings p.a. (e-bus)	$2,000	4,696	4,532	164	104
Scenario 1	$5,000	4,670	4,532	138	87
Scenario 2	$10,000	4,627	4,532	95	60
Base: Growth forecast for patronage	2.6%	4,696	4,532	164	104
Scenario 3	3.8%	5,064	4,873	191	121
Scenario 4	4.8%	5,414	5,197	216	138
Base: Emission Tax Sensitivity	Current ETS (c6.67/l – c12.32/l in 2050)	4,696	4,532	164	104
Scenario 5	Productivity Commission (c31/l in 2050)	4,700	4,546	154	98
Scenario 6	Net Zero emissions (c61/l in 2050)	4,707	4,567	140	89