
# Auckland's Low Emission Bus Roadmap

December 2018

# Contents

# About AT and our Sustainability Framework

**Auckland Transport's role as a transport provider and mobility integrator is rapidly evolving to meet and anticipate fast-paced changes in how people in successful cities want and need to travel. We play an active role in shaping a growing, vibrant Auckland with more sustainable and networked modes of transport, and in integrating the diverse new ways our customers will be more mobile.**

The Auckland Transport Alignment Project (ATAP) aligns central and local government priorities for land transport. These priorities include:

- Encouraging mode shift from cars to public transport, walking and cycling
- The adoption of low emission vehicles
- Meeting our wider environmental commitments such as the Paris Agreement and the C40 Fossil-Fuel-Free Streets Declaration.

A focus of Auckland Transport's Sustainability Framework is low emission transport choices, which mitigate climate change, improve air quality and reduce the city's reliance on fossil fuels. One of the framework's key actions is to develop a Low Emission Bus Roadmap. AT's Statement of Intent 2019-2021 commits to development of this roadmap in the 2018/19 year. Our customers are overwhelmingly with us on this journey – the majority of over 18,000 submissions on the Regional Land Transport Plan 2018-2028 agreed that transport's impact on the environment is a key challenge.

The Low Emission Bus Roadmap presents a baseline for transition of the Auckland bus fleet to a low emission fleet, with key milestones at 2020, 2025 and 2040. The baseline will be updated and reviewed regularly as technology advances and costs reduce. Current barriers to a transition to a low emission bus fleet are identified for development by AT and its partners.



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# 0.1 Executive summary

**The pathway to cleaner air for Auckland by eliminating diesel buses from the city's roads.**

**This Low Emission Bus Roadmap is a baseline thought piece and tactical document that outlines the pathway to transition Auckland's bus fleet to zero emissions by 2040. The roadmap reviews the policy and bus market context, assessment of bus technology and fleet options and associated benefits, costs and challenges for this transition. It also outlines next steps.**

In Auckland, diesel vehicles are estimated to be responsible for 81% of all vehicle-related air pollution health costs, estimated at $466 million annually.

In November 2017, the Mayor of Auckland joined 11 other cities in signing the C40 Fossil-Fuel-Free Streets Declaration. The declaration commits Auckland to buying only zero emission buses from 2025 and ensuring a major area of the city is zero emission by 2030.

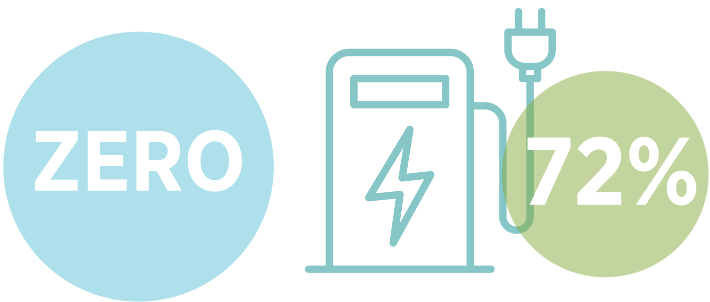
**In the context of these commitments, AT is targeting a full zero emission bus fleet by 2040.**

Approximately 1,300 diesel buses are in operation in Auckland, with variable fleet sizes, Euro standards and deck configurations. Full conversion of Auckland's bus fleet to zero emission vehicles will reduce life cycle greenhouse gas emissions (GHG) from buses by 72%, and eliminate the tail-pipe emissions of the various oxides of nitrogen (NOx) and particulate matter (PM). This result would deliver significant benefits to the environment as well as to the health of the local population. Over 20 cities globally have made policy commitments to stop purchasing diesel buses and have zero emission bus targets. In 2017, only 10% of the global bus stock operated as low emission vehicles but given the pace of international development and deployment of electric bus technology – in terms of both technical capability and commercialisation – AT's long-term vision for a full zero emission bus fleet by 2040 is thought to be achievable.

## Life cycle analysis and trial of options

We have worked with the Low Carbon Vehicle Partnership (LowCVP) in the UK as we progressed to developing this Low Emission Bus Roadmap. Life cycle evaluation of the range of low and zero emission bus technologies and fuels shows that battery electric buses (BEV or e-bus) will deliver significantly lower GHG emissions compared to conventional diesel buses, benefiting from New Zealand's renewable electricity grid. BEVs

tail-pipe emissions of nitrogen oxides (NOx) and particulate matter (PM)




less life cycle greenhouse gas emissions (GHG) from electric buses have a 65% share of the global low emission bus market and are the most commonly adopted technology. From 2018, AT is trialling two e-buses on the City LINK service, with positive results in terms of service reliability, customer feedback and operational savings.

The preferred strategic option for implementing the replacement programme of zero emission buses (ZEV) is for bus operators to purchase the vehicles and AT to specify for all contracts that from 2025 new buses for end-of-life replacements and fleet growth must be zero emission vehicle-only. This option meets the C40 commitment for zero emission-only purchases from 2025. To achieve 100% ZEV before 2040 under the preferred strategic option, and to reduce the risk of operators being stranded with diesel buses, AT would specify – and advise bus operators early – that all remaining diesel buses (~18% of total fleet) must be removed from service by 2040 and replaced with ZEV. This will allow bus operators to plan their replacement ahead of the 2040 deadline. A 2025 start date enables Auckland to benefit from further technology developments in the interim and gives AT more time to prepare the necessary infrastructure. This will be reviewed and updated as part of the next roadmap update.

The roadmap also recommends a 'quick win' opportunity for the City LINK service to be run by fully electric buses from November 2020 when a new service contract is due to start.

### Challenges to reaching the 2040 goal

There are challenges ahead. Transitioning Auckland's bus fleet involves high capital outlay and set-up costs, although the capital costs of both e-buses and lithium ion batteries is expected to fall as battery technology improves and market competitiveness increases (see Figure 01). The wide variety of bus makes, models and ages, makes retrofitting existing buses with battery electric or plug-in hybrid propulsion expensive. Some questions remain about service longevity of the batteries and their 'green' bottom line across their life cycle.

### Finance issues

Support for further trials may come from a combination of the Energy Efficiency and Conservation Authority's (EECA) Low Emission Vehicle Contestable Fund and AT. The total operating costs of e-buses should reduce over time, as the increased Peak Vehicle Requirement (PVR) contract rate due to higher capital costs will be offset by the lower operational in-service km rate.

## Next steps with this roadmap

Given its early stage and iterative nature, the next steps with the roadmap are to adopt and progress its principles and:

- Establish a national Low Emission Bus Working Group of industry stakeholders to influence national policy including fiscal incentives, growing the market, and facilitating supply chains
- Continue to collaborate with international organisations such as C40 and other New Zealand cities to share learning
- Continue to undertake trials and demonstrations.

The roadmap will be refined and updated on a 12-18 month basis as further market information becomes available, technology advances and outcomes of further trials are confirmed.

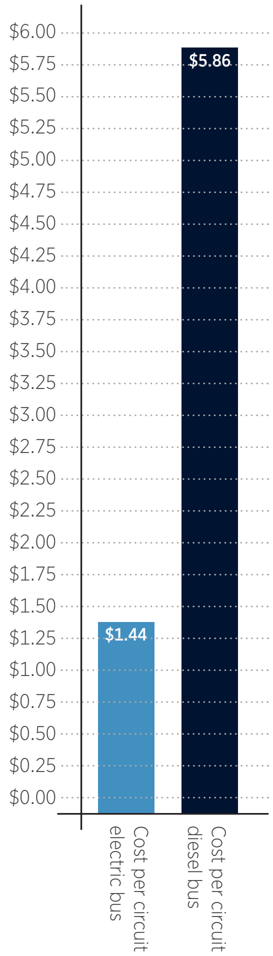
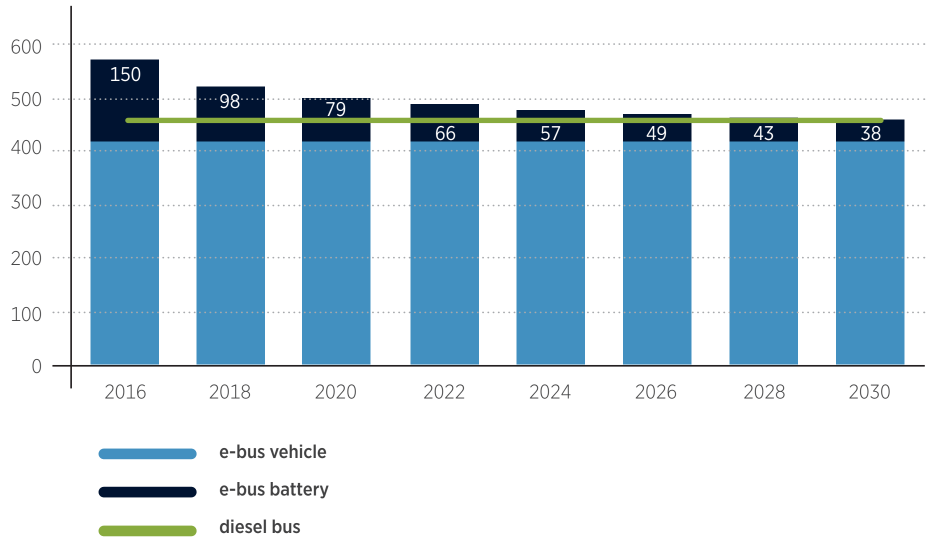



Figure 1: The capital cost of electric buses (shown below in thousand USD) is predicted to reach parity with diesel buses by 2030 as the cost of batteries falls. Capital costs are offset by reduced operating costs, as shown (left) in the 2018 trial of two e-buses on Auckland's City LINK.




Source: Bloomberg New Energy Finance. Notes: e-bus with a 250kWh battery, initial battery price at $600/kWh.

## Timeline to 2040

Figure 2 identifies some key decision and intervention points on the timeline to 2040 for a full low emission bus fleet.

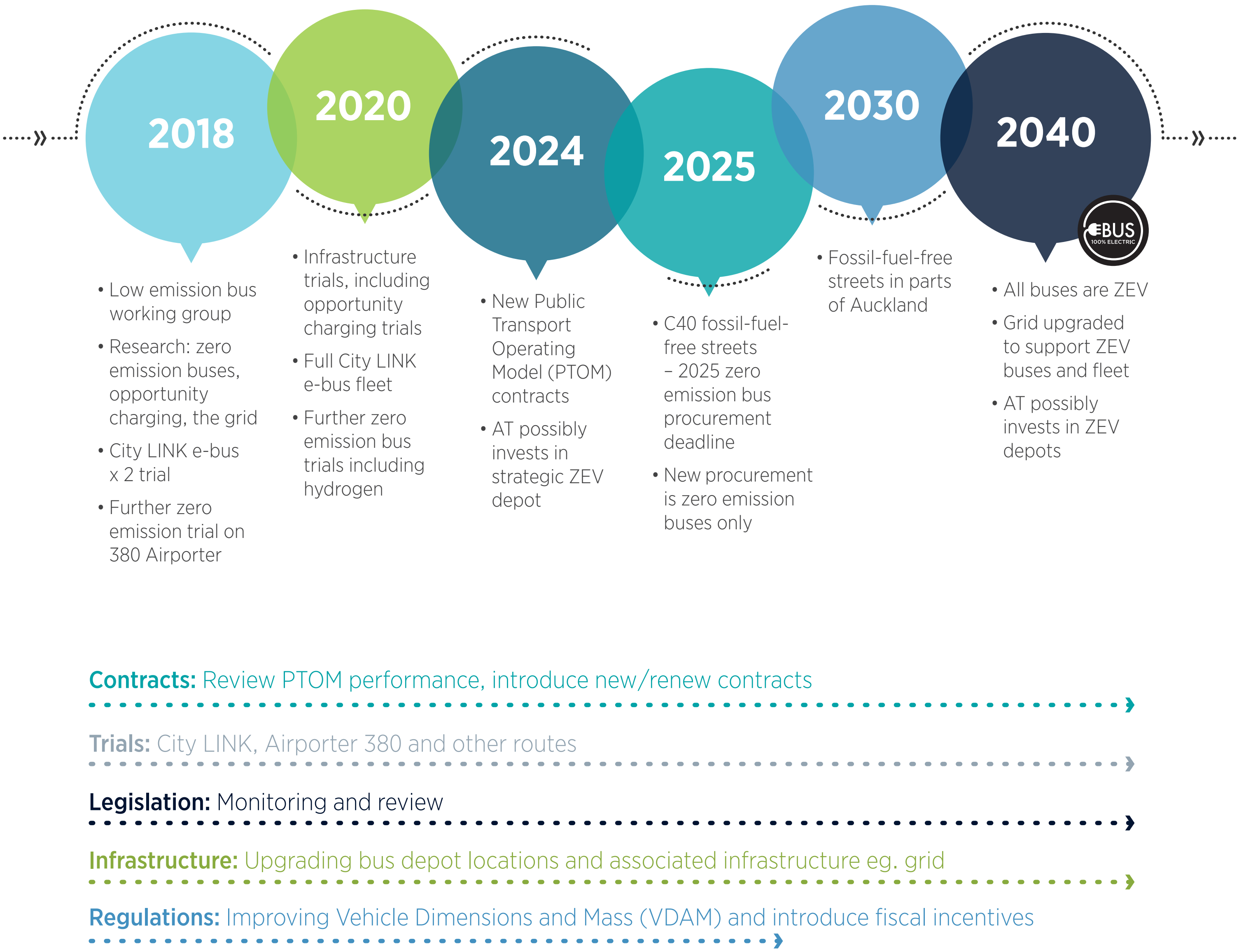



Figure 2: Timeline for implementing Auckland's Low Emission Bus Roadmap.


# 1.0 Introduction

**This Low Emission Bus Roadmap was initially developed as a thought piece in partnership with the Low Carbon Vehicle Partnership (LowCVP) in the UK and Transport Research Laboratory (TRL) Limited. Their final report of January 2018 assessed the challenges and opportunities inherent to Auckland's context, and the range of potential low emission options for the city's bus fleet. Alongside this report, AT has investigated a set of potential implementation and indicative funding scenarios to identify preferred options and pathways to a full low or zero emission fleet by 2040.**

Auckland Transport's Low Emission Bus Roadmap 2018:

- Outlines the strategic context, including policy and opportunities
- Identifies the research, trials and demonstrations of new technologies being undertaken
- Identifies the barriers that need to be resolved in order to fully electrify Auckland's bus fleet over the next two decades
- Analyses and evaluates the range of low emission bus technologies and fuels
- Estimates the total cost of ownership of new technologies
- Assesses the potential implementation and financing options
- Identifies next steps to be taken.

## 1.1 Recommendations

The LowCVP and TRL Low Emission Bus Roadmap report made a series of recommendations that we have reviewed and further refined as follows:

1. AT targets a full zero emission bus fleet by 2040.
2. All buses in Auckland are to be procured as zero emission vehicles from 2025 at the latest and preferably earlier, subject to refined cost/benefit analysis and verification (obtained through trials and further information) that the price differential between zero emission and diesel buses has reduced as forecast:
    a. For single-deck buses – Auckland transitions to a battery electric new bus solution from 2025 replacing diesel fleet at the end-of-life and as new fleet will be required for annual growth and new contracts, and takes into account overnight depot charging and on-route 'opportunity' charging. A possible future hydrogen fuel cell technology may also be used.
    b. For double-deck buses – as for single-deck buses, but recognising zero emission capable, large double deck vehicles are still developing and a slower uptake may be required for all new contracts from the start of 2025. A possible future technology could be electric buses fitted with hydrogen fuel cells.
3. The trial and demonstration of new technologies has been invaluable in other cities and this approach is recommended strongly in Auckland. Demonstration trials should include:
    a. Battery electric buses (single and double-deck) with depot and on-route charging (rapid plug-in charging, inductive and pantograph)

   b. Hydrogen electric trials (incorporating hydrogen supply)
   c. Retrofitting of existing Euro 5 diesel buses with electric and/or hydrogen fuel cell technology.

These trials will guide local and national policy development and validate roadmap recommendations.

4. A 'quick win' start on a larger-scale trial of the City LINK electric bus service from November 2020 when the current bus contract for that route is renewed.
5. As part of the iterative review of the roadmap, undertake a detailed assessment of all Auckland bus routes for BEVs and charging infrastructure deployment, and current fleet replacement life cycles.
6. Assess the practical and cost impact of a large electric bus fleet deployment on Auckland's electricity supply grid.
7. Establish a Low Emission Bus Working Group, to include a range of public and private national regulatory, operational and supply stakeholders.
8. Continue to engage with international organisations such as the C40 Low Emission Vehicle Network to help expand knowledge and understanding of the deployment of low emission buses.
9. Collaborate with other cities in New Zealand to increase influence on central Government policies, to share learning and to cooperate with vehicle procurement.
10. To support long-term sustainability and reduce the end-of-life environmental impacts of zero emission buses, engage with central Government and the automotive industry put measures in place for the re-use and recycling of lithium batteries.

## 1.2 Challenges to the 2040 goal

A number of important barriers have been identified in the LowCVP and TRL report, and are set out below. Some of these will need to be resolved in order to electrify AT's bus fleet fully over the next two decades:

### Regulatory and financial

1. Weight restrictions imposed by Vehicle Dimensions and Mass (VDAM) regulations are presently restricting adoption and capacity of some battery electric buses, both for single and double-deck vehicles.
2. High upfront capital costs of battery electric buses and retrofit low emission technologies.
3. The high set-up cost of electric charging infrastructure, including upgrade of the power distribution network to accommodate overnight charging loads at most or all depots and wider implications for the electricity industry; and potential requirement for roadside 'opportunity' charging infrastructure, which could de-limit the number of routes BEVs can operate on.
4. Potential for high renewal cost of batteries, as longevity in service remains uncertain.

5. The lack of national fiscal incentives to support the development of a low emission bus market in New Zealand.

### Low emission bus market

6. The wide variety of bus makes, models and ages of AT's contracted bus fleet could make any retrofitting of battery electric or hydrogen fuel cell electric buses expensive.

7. Lack of established supply chains and after-market support. An added challenge is that bus manufacturers do not currently produce three-axle battery electric buses, and three-axle double deck electric buses are only in the early stages of development.

8. Lack of procurement and ownership models for low emission buses, charging/refuelling infrastructure and depots to retain competition between bus operators.

9. Alternative hydrogen fuel cell technology is not yet developed in New Zealand and requires third-party hydrogen production and infrastructure.

10. Questions remain as to the 'green' bottom line of batteries across their whole life cycle and hydrogen fuel.

### Bus operators' perspectives

11. Bus operators' lack of confidence in new low-emission bus technologies, being uncertain of their performance.

# 2.0 National and regional policy frameworks

**The Low Emission Bus Roadmap has been developed in the context of recent national and regional policies and frameworks.**

## 2.1 Climate change and air quality

Experience around the world reveals that Government policy has played an instrumental role in helping to stimulate the market for low emission buses and associated infrastructure.

Policies include:

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

New Zealand is a part of international climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Paris Agreement. New Zealand ratified the Paris Agreement in 2016 setting a target to reduce GHG emissions to 30% below 1990 levels by 2030.

There is now a greater focus by the Government on climate change, which includes an Independent Climate Change Commission, a Zero Carbon Act, and a potential national target of zero carbon by 2050.

New Zealand benefits from a diverse range of energy sources, with abundant fossil fuel and renewable energy resources. Eighty percent of this country's energy is derived from renewable energy. The very low carbon intensity of electrical power in New Zealand makes the electrification of transport particularly attractive. Currently there are no coal-fired power plants in the South Island. Hydroelectric power is the dominant form of electricity generation, with wind and solar beginning to contribute more to the energy mix. The North Island's electricity generation is much more diverse, including natural gas, oil, hydroelectric, geothermal, coal and wind. All petroleum products for transport use are imported. This means that there are energy security benefits in moving away from fossil-fuelled transport.

New Zealand has adopted the Vehicle Exhaust Emissions Regulations, aimed at reducing road transport air pollution emissions. These currently require new heavy-duty vehicles, including urban buses, to meet the Euro 5 standard as a minimum. Auckland's current fleet is operated by a range of diesel Euro 3 to Euro 6 standard buses. (See figure 6 on page 21.)

## 2.2 Electric vehicle programme

A package of measures was announced by the previous Government in 2016 aimed at increasing uptake of electric vehicles. Examples of the measures are listed below; it is important to highlight that these are focussed primarily on light duty vehicles (mainly cars):

a. A target to double the number of electric vehicles in New Zealand every year to reach approximately 64,000 by 2021.

b. Extending the Road User Charge (RUC) exemption on light electric vehicles until they make up 2% of the light vehicle fleet.

c. A new RUC exemption for heavy electric vehicles until they make up 2% of the heavy vehicle fleet.

d. Government agencies are co-ordinating activities to support the development and roll-out of public charging infrastructure including providing information and guidance.

e. A Low-Emission Vehicle Contestable Fund of up to NZ$6 million per year to encourage and support innovative low-emission vehicle projects (administered by EECA).

## 2.3 Auckland policy framework

Auckland Council's sustainability objectives focus on reducing greenhouse gas and air pollution emissions and lowering reliance on fossil fuels. Aligned with these objectives is the ambition to expand the adoption of low emission vehicles and to reduce car use through greater adoption of sustainable modes of transport. Key plans that support these aims and objectives include:

- The Auckland Plan
- Low Carbon Auckland
- The City Centre Master Plan
- AT's Sustainability Framework.

Auckland Council has a statutory obligation to meet national emission standards for air quality. Over recent years concentrations of air pollutants such as fine particulate matter (PM10), nitrogen dioxide (NOx) and sulphur dioxide ($SO_2$) have stabilised in Auckland. However, heavily trafficked areas of the city centre can experience higher emission concentrations and breach air quality targets.

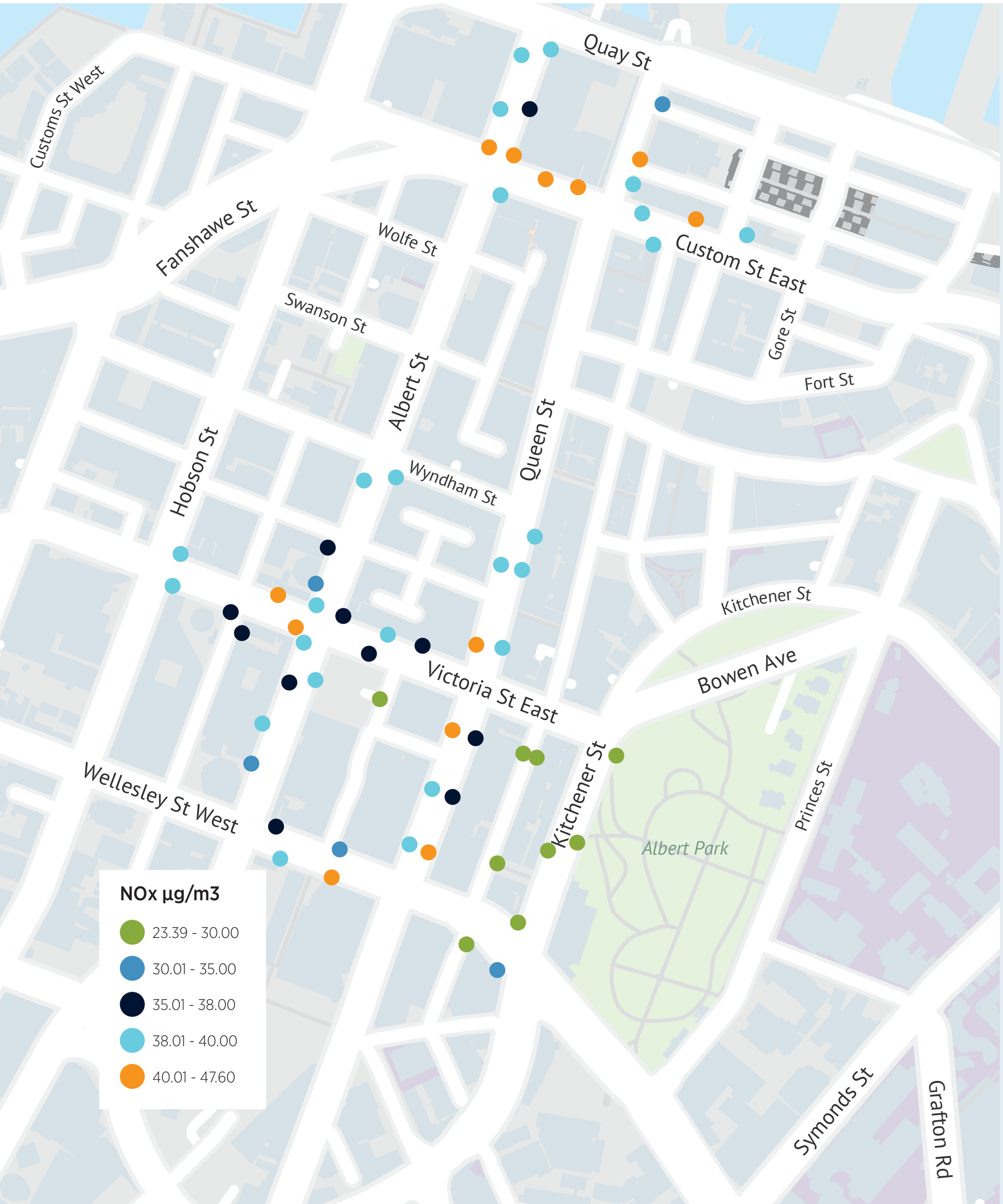



Figure 3: Auckland road transport emissions profile, including city centre air quality hotspots.

The orange dots represents locations where weekly concentrations of NOx exceed the proposed annual Auckland Ambient Air Quality Standards (AAAQS) and the World Health Organisation (WHO) standards of 40µg/m³.

These air quality hotspots are largely clustered around major road intersections and busy bus routes, which coincide with areas of high pedestrian traffic areas.

Therefore, we are concentrating on urban routes first. City LINK has the highest profile and operates in areas of highest public exposure, hence our 2018 trial area. Ideally we are seeking to initially focus our cleanest buses in areas with the highest numbers of people.


# 3.0 Strategic context

**An assessment of the current Auckland bus fleet profile has been undertaken and its contribution to environmental impacts in the city and region.**

## 3.1 International context – uptake of battery electric buses

In 2017, there were over 340,000 low emission vehicles operating (~10% of global bus stock) with a large proportion in China (~75% of the clean bus market).

Battery electric buses have a 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.

A technology to watch or to trial early will be hydrogen fuel cell. Other parts of the world are in the early trial stages with favourable results, however costs remain high for implementation.

## 3.2 Auckland context – environment and health impacts

A review of the main sources of $CO_2$, NOx and PM10 (particulate matter) emissions in Auckland shows that road transport is the largest source of greenhouse gas emissions and accounts for 34.8% of emissions.

Cars are responsible for the highest road transport GHG (24%), with commerical vehicles being the next largest emission source (11%). This highlights the importance of encouraging Aucklanders to make the shift from private vehicles to sustainable public transport.

Continuing health research has revealed that persistent exposure to relatively low levels of air pollution can contribute to or exacerbate health problems. These include respiratory

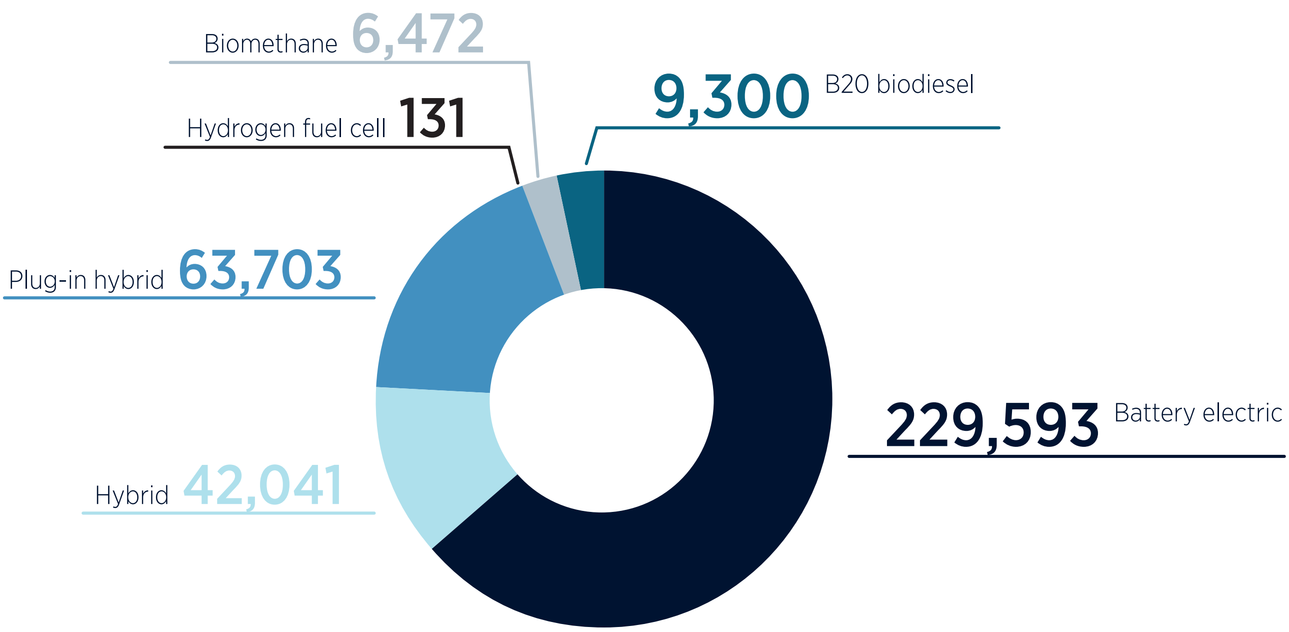



Figure 2: Global technology share of the low emission bus market.

National and regional funding is still available in Europe, US, China, and Canada to support zero emission capable buses and EV charging infrastructure, to help reduce high capital costs. For example, £100m ($197.5m) has been put aside in the UK alone for bus subsidy grants between FY 17/18 and 20/21. In 2017, this equated to 326 low emission (mostly electric or hybrid electric) buses in the UK.

Europe has far more aggressive targets for greenhouse gas emission-free city centres, with penalties/charges for not complying.

C40 CITIES CLIMATE LEADERSHIP GROUP

More than 20 cities globally have made policy commitments to stop purchasing diesel buses and have zero emission bus targets. London will have a total zero emission bus fleet by 2037. Twelve major cities **including Auckland**, signed the C40 Fossil-Fuel-Free Streets Declaration in 2017 which:

- Pledges to buy **only zero-emission buses from 2025**
- Ensure the major area of their city is zero emission by 2030.

Wellington (Tranzit) - 10 fully electric double deckers were rolled out in Wellington in July 2018, with another 22 to be added by 2021. They will operate on main arterial roads between the suburbs of Island Bay and Churton Park. These buses are two-axle and only have a similar capacity as AT's three-axle single-deck buses.

Christchurch (Red Bus) – Have ordered three single-deck fully electric buses identical to the ones AT is running on the City LINK).

Figure 4: The international and New Zealand context.

and cardiovascular conditions and reduced life expectancy. Children are particularly at risk with exposure to air pollution causing asthma. Nearly 130 Aucklanders die prematurely every year due to pollution emitted from motor vehicles 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, with the annual 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.

The LowCVP report shows that in the New Zealand context, BEVs will deliver significantly lower GHG emissions over their whole life cycle compared to conventional diesel buses, benefiting from this country's renewable electricity grid. The complete conversion of AT's diesel bus fleet to e-buses will result in a life cycle greenhouse gas emission reduction of 72%, and eliminate the tail-pipe emissions of the various oxides of nitrogen (NOx) and particulate matter (PM), bringing about significant benefits to the environment and to the health of the local population.

**Auckland's Greenhouse Gas (GHG) Emissions**

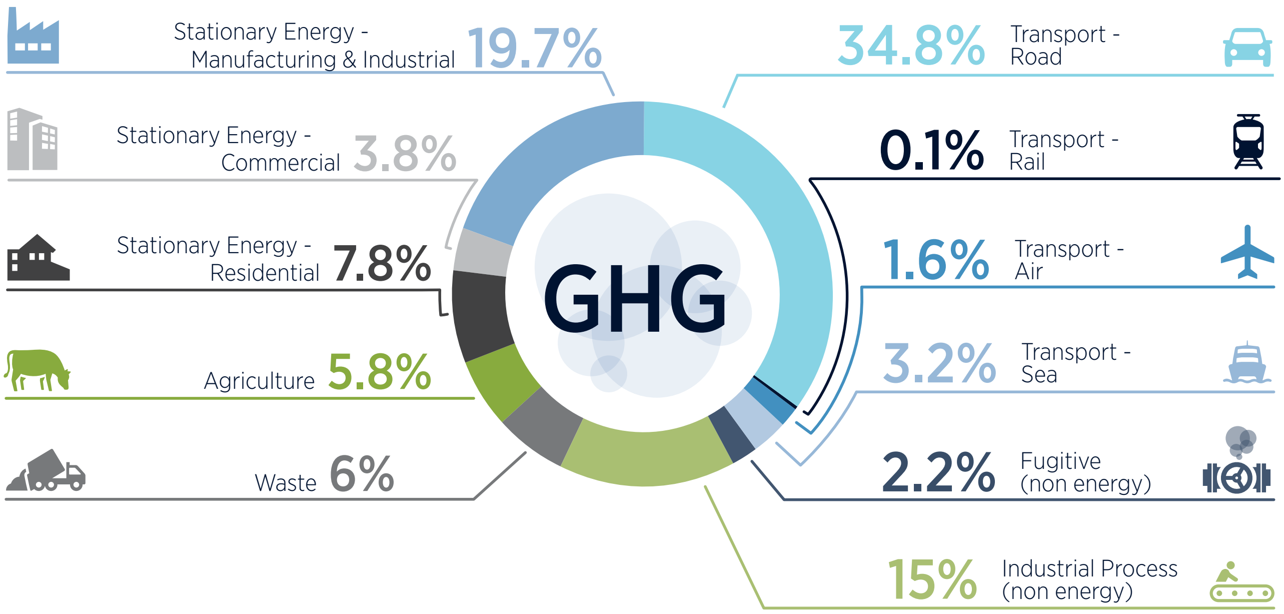



Figure 5: Auckland's $CO_2$e emissions profile (2014). (Source Auckland Plan).

We commissioned Emission Impossible Ltd to estimate the social benefits of progressively moving to an e-bus fleet in Auckland. Figures in Table 1 are derived by comparing emissions from e-buses to emissions from Euro standard 6 diesel buses, and capture all the relevant emissions: $CO_2$ equivalent, PM10, NOx, CO, HC and noise.

## 3.3 Auckland context – the city's bus fleet

Auckland's buses are privately owned. AT contracts all its urban and school bus services to 10 bus operators. There are currently 94 routes, using approximately 1,300 diesel buses. The fleet size varies considerably between operators, with NZ Bus running over 500 buses, while some smaller operators have fewer than 100 buses each.

Of the current fleet, 477 buses are more than 10 years old. Some of Auckland's bus operators are running Euro 6 diesel buses, replacing older diesel buses, with a total of 196 in operation. A breakdown of the fleet composition by Euro standard in 2018 is shown in figure 6.

At present 91 buses are double-deck, with a further 98 double-deck buses on order for delivery before the end of 2018. The number of double-deck and extra-large single-deck buses will increase in the future. Buses in the current fleet range from ~11m to 13.5m, and include both two and three-axle vehicles. Auckland bus operators have strong links with European bus manufacturers, with many purchasing models from ADL, Volvo, MAN and Scania.

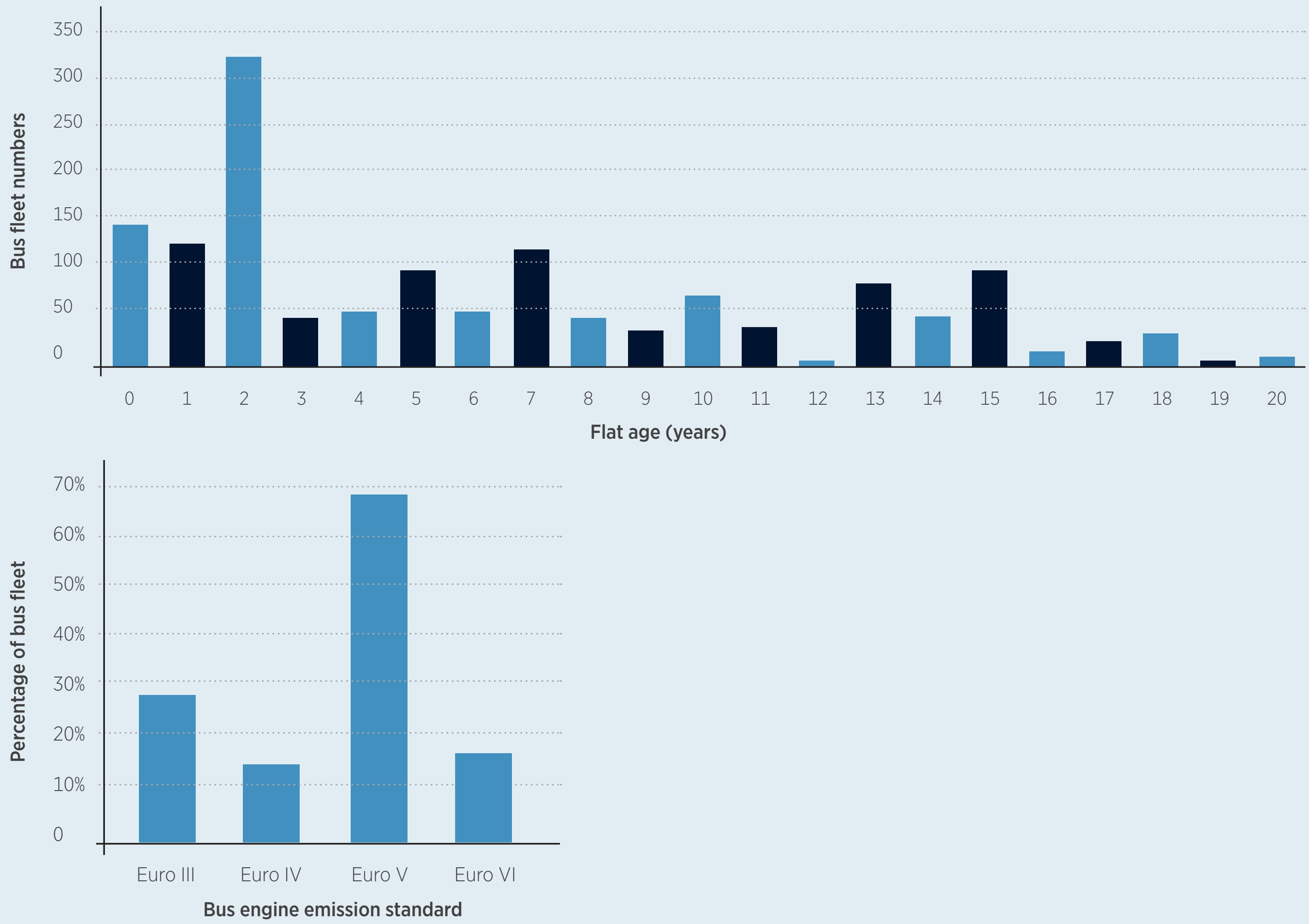
Urban bus fleet must not exceed an average age of 10 years, in line with requirements under AT's Public Transport Operating Model (PTOM) contracts, however the maximum permitted age can be up to 20 years. Routes

| Social benefits | Cumulative values (2017 values - $millions) | Net Present Value of cumulative benefits |
|---|---|---|
| Air emissions reductions | $104.6 | $41.9 |
| Noise reductions | $36.7 | $14.7 |
| **Total benefits** | **$141.3** | **$56.7** |

Table 1: Total benefits over 23 years from the progressive move to a low emission bus fleet in Auckland.

will be re-tendered through the 2020s in several batches in line with recently issued new PTOM contracts. This essentially defines the timescale over which the requirements for new technologies can be procured (unless a separate scenario is selected, e.g. fast-tracking deployment), as the specifications for fleet will need to be included in route tenders.

**Figure 6: Auckland's fleet by age in years and composition of Euro standards**




# 4.0 Developing the Low Emission Bus Roadmap

**To migrate over time to a more renewable, greener technology, AT 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 options

The Low Emission Bus Roadmap report was based primarily on life cycle analysis and looks 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):** similar to 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:** is a 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.
- **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 'early adopter' demonstration phase across the world and is subsidised heavily by governments.

BEVs offer the best all-round opportunities, however HFC buses may be a potential future solution for longer range requirements and larger fleet, subject to third-party hydrogen production and infrastructure development. There is an emerging opportunity to trial HFC buses with Ports of Auckland.

## 4.2 Roadmap methodology

Based on the rate of adoption of different low emission buses globally, and AT's requirements, the Low Emission Bus Roadmap report recommended a low emission bus technology roadmap be developed, accompanied by key actions we should take to achieve a zero emission bus fleet by 2040.

The methodology involved evaluating each low emission bus technology and fuel against a set of criteria in terms of suitability for AT's fleet and operational considerations. The methodology included:

- Baseline data gathering
- Low emission bus technology appraisal (including bus route modelling of three typical urban bus routes: 973, City LINK and Inner LINK)
- Low emission bus technology and fuel comparison
- Low Emission Bus Roadmap development.

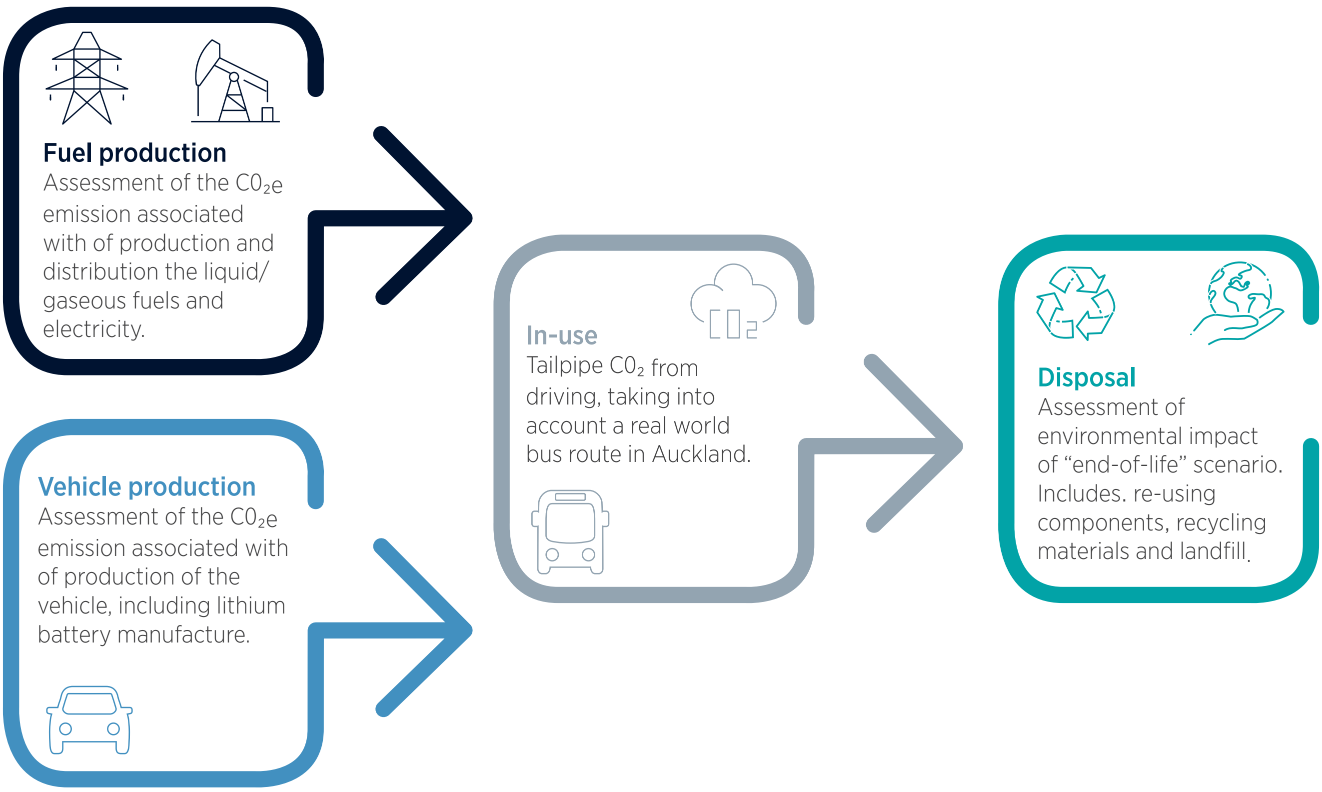



Figure 6: Life cycle analysis methodology.


# 5.0 Assessment of early trials and strategic options

**An early e-bus trial has commenced on the City LINK bus route, which is already provided inputs to the low emission roadmap.**

## 5.1 City LINK e-bus trial early results

Auckland Transport is working in partnership with NZ Bus to operate two electric buses for an initial six-month trial on the City LINK service.

After arrival in Auckland in February 2018 the vehicles underwent all NZ compliance testing and were delivered to NZ Bus in April for final preparations, including driver training, installation of ticketing, safety equipment and charger units, and AT branding.

The trial began in service during May 2018 and the vehicles are performing well, with combined vehicle availability at 84%. The confidence of operators to fully use the vehicles is growing and customer feedback is positive. Initial data indicates that, despite an unresolved issue with installing the charging units (see Appendix 1 for further detail) the chargers are functioning sufficiently to enable the vehicles to easily complete a full day of operations on the City LINK service. The buses on average are using 60-64% of their battery power for a full day's work.

Each bus and charger cost $840,000 and were purchased with a $500,000 contribution from EECA's contestable fund. Early results show overall operational savings (18 June - 2 Sept) of $5,759 from the two buses, which travelled a combined 9,785km in this period.

Figure 8 demonstrates lower in-service costs per kilometre, per hour and per circuit for trial

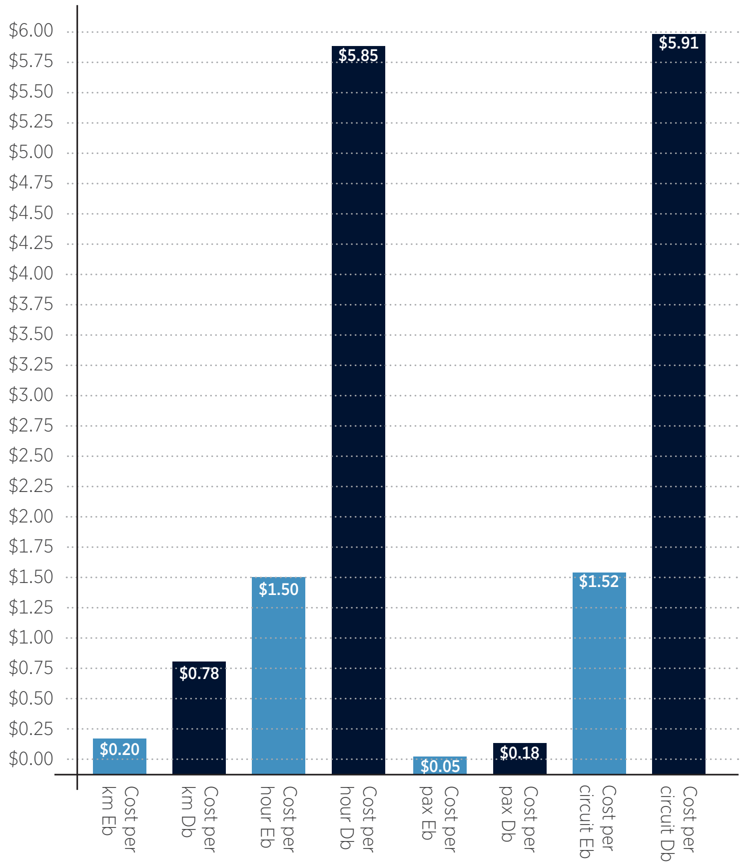



Figure 8: Comparative operating costs of diesel vs electric six-month trial on the City LINK e-bus 305 in 2018, data from 18 June to 2 September.

e-bus 305 as compared with diesel buses. (Bus 304 produced similar results – see Appendix 1.) These lower operating costs are expected to reduce the Total Cost of Ownership of electric buses and offset high capital costs. Further trials will enable total cost of ownership comparisons with diesel fleets. This early data is further discussed in option E below.

The trial project aligns with this roadmap and is already informing future legislative requirements and implementation strategy. A further e-bus trial is being developed for the 380 Airporter service and potentially the 309 service. This trial will partner with a different bus manufacturer and slightly different technology, charging station and bus specification.

Further trials are necessary for different vehicle types, to complete a broader understanding.

## 5.2 Assessing transition and ownership options

Five strategic options for the transition to low emission buses in the Auckland fleet have been identified and are outlined below. We have assessed the merits of each approach, and recommend moving to BEVs from 2025 by AT specifying that new buses for end-of-life replacements and fleet growth are BEV-only for all contracts from the start of 2025. All options were carefully considered. They included scenarios with different rate of transition to zero emission fleet and start dates. The rate of transition from diesel to zero emission fleet is seen on figure 8.

We recommend that bus operators purchase the electric buses (as they do now for diesel buses). AT does not require capital to purchase fleet, and fleet costs are incorporated into contract rates, or Peak

| Recommended option | Benefits | Disadvantages |
|---|---|---|
| No ZEV contract requirement until end of 2024<br><br>Then all new contracts progressively from start 2025 specify bus replacements and growth as ZEV-only, with early indication from AT o this requirement from 2020 | • Meets Mayoral commitment to buy only ZEV from start of 2025<br>• Later start maximises benefits of technology development, reduced capital cost of vehicles and cheaper future replacement batteries<br>• Ability to implement City LINK fleet contract (opportunity) as bigger scale trial of a ZEV-fleet and assess its impact on depot charging and grid<br>• More time to prepare for infrastructure and to plan fleet change<br>• Gives AT more time initially to consider and procure depots and implement large-scale charging infrastructure upgrades (not in RLTP)<br>• Nearer to 2030 capital cost per bus parity, with estimated total operating cost parity or savings forecast from 2025 | • Operators purchasing small numbers of electric buses for patronage growth likely to be more expensive (discounting for bulk purchase not modelled)<br>• Achievement of 100% ZEV passes beyond 2040 unless AT specify all remaining diesel fleet to be replaced by 2040 |

Table 2: Benefits and disadvantages of preferred implementation option.

Vehicle Requirement (PVR) variations rates.

We also recommend a ‘quick win’ opportunity for the City LINK service to be full BEV operation from November 2020 when a new service contract starts.

Options A – D were also assessed with the option of AT purchasing the e-bus fleet and leasing to bus operators. The financing option for these scenarios provides the ability to negotiate bulk procurement discounts, and achieve consistent fleet and charging infrastructure. It also provides an ability to re-use batteries for other AT applications. However, these scenarios require 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 are not recommended.

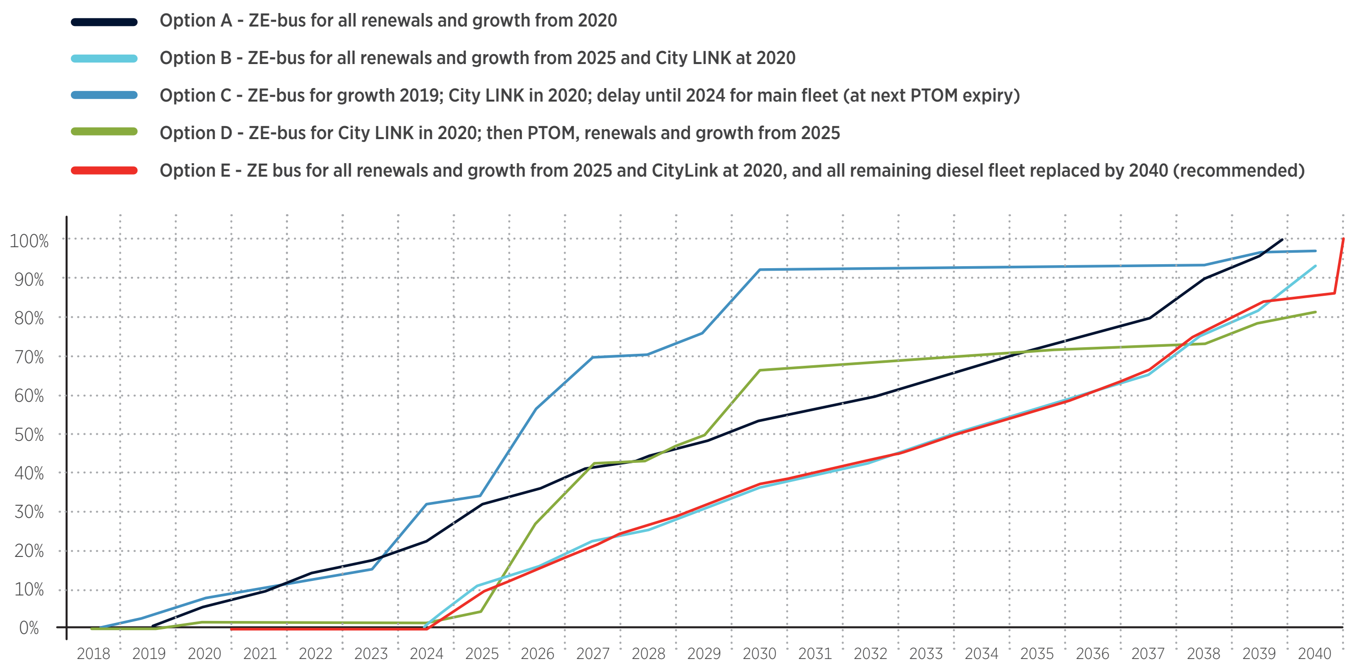


Figure 9: Annual increase in percentage of fleet ZEV under options A to E.

| Recommended option - financing | Benefits | Disadvantages |
|---|---|---|
| Bus operators purchase electric buses | AT does not require capital to purchase fleet<br>Fleet costs incorporated into contract rates (or PVR variations rate)<br>While ZEV purchase price remains higher than diesel the lower Total Cost of Ownership (TOC) should limit the impact on contract rates | Variety of buses that may affect interoperability and charging infrastructure<br>Risk of higher contract costs due to higher premium for ZEVs<br>No bulk procurement discounts<br>Operational challenges with ZEV across many routes |

Table 3: Benefits and disadvantages of financing the recommended option.


# 6.0 Cost assumptions and impacts

**There are three significant categories of cost to consider: capital (vehicles and infrastructure); operational (energy and maintenance); and battery renewal.**

## 6.1 Capital costs

The premium on the purchase price of e-buses is heavily influenced by the cost of batteries. The expected falling costs of battery production and increased normality of their use have been used to base future costs of low emission buses. As Figure 10 demonstrates, e-bus prices are predicted to reach parity with diesel buses by 2030.

## 6.2 Operational, maintenance and renewal costs

Operational costs are detailed in Appendix 3: Assumptions. In summary, analysis shows that relative energy costs favour electric over diesel, and maintenance costs from e-buses with fewer moving engine parts than a combustion engine are likely to be around $2,000 less per bus per year. The additional cost of upgrades to the power distribution grid and depot

### European e-bus and diesel bus upfront price forecast (US$000)

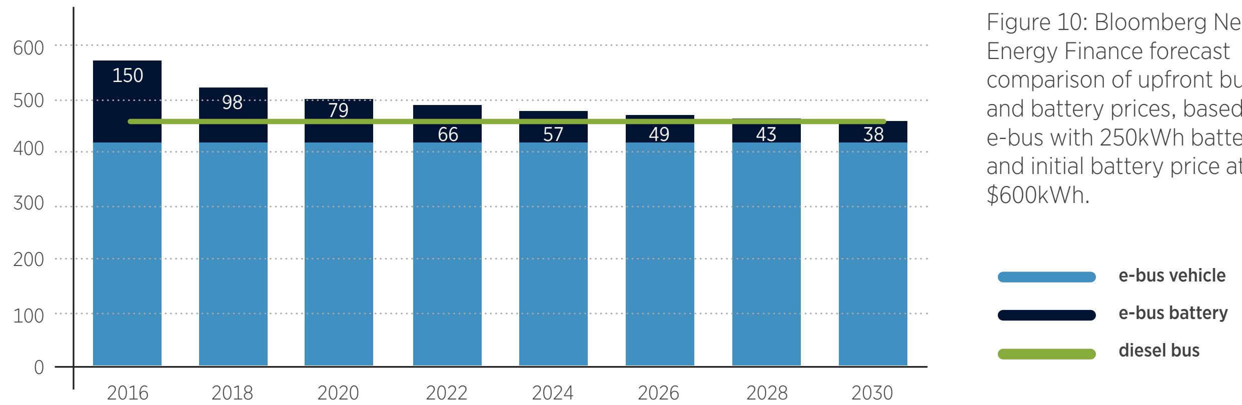
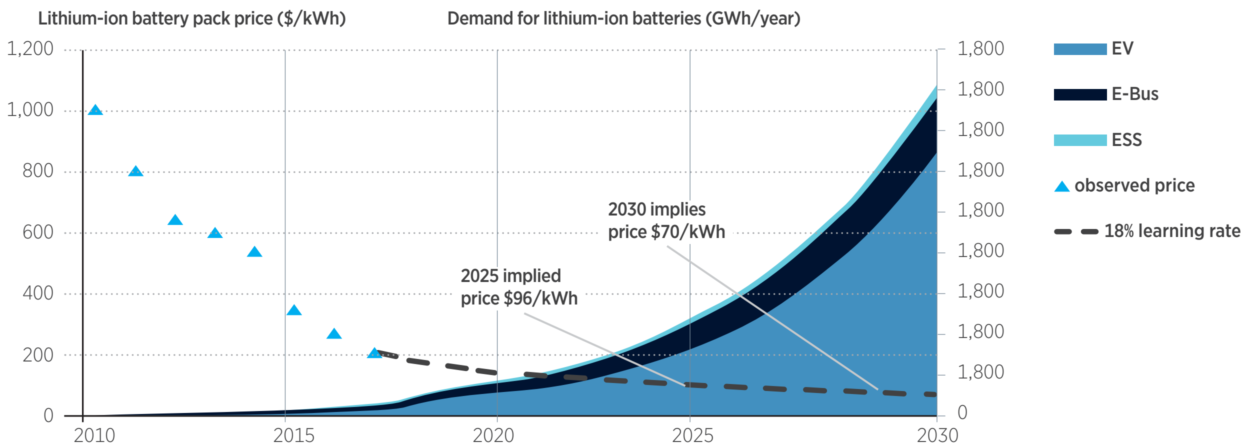



Figure 10: Bloomberg New Energy Finance forecast comparison of upfront bus and battery prices, based on e-bus with 250kWh battery and initial battery price at $600kWh.

### Lithium-ion battery pack price forecast (US$)



upgrades is estimated at between $30-$60 million. Further assessments and studies are underway to better understand these costs.

Any increased investment in fleet from 2020 is likely to cause increases in the tendered prices of future PTOM contract rounds with PVR rates. Changed requirements for the vehicles to be used on contracted services within the life of current contracts would trigger variations in payments to operators. The change in costs will be passed on to AT in the form of higher contract tender prices, but may be negotiated down due to lower in-service kilometre rates. The savings from transition to zero emisson fleet are expected to be fully realised by AT in contract prices from 2040 with a net NPV benefits of $152m over the period 2025 to 2040 based on contract PVR rates on par with diesel fleet and fleet growth of 3% to cater for patronage growth. Should the average PVR rates be higher for zero emission fleet than current PVR rates, the net NPV benefits over that period could reduce down to $95m. All other assumptions are explained in Appendix 3: Assumptions.

Appendix 3 discusses end-of-life options. E-bus batteries are assumed to reach their end of life after seven years and to have 80% capacity left. This residual capacity and the predicted falling prices for new batteries will make used batteries attractive for other users or applications.

## Transitional fleet vs diesel fleet: costs and net savings

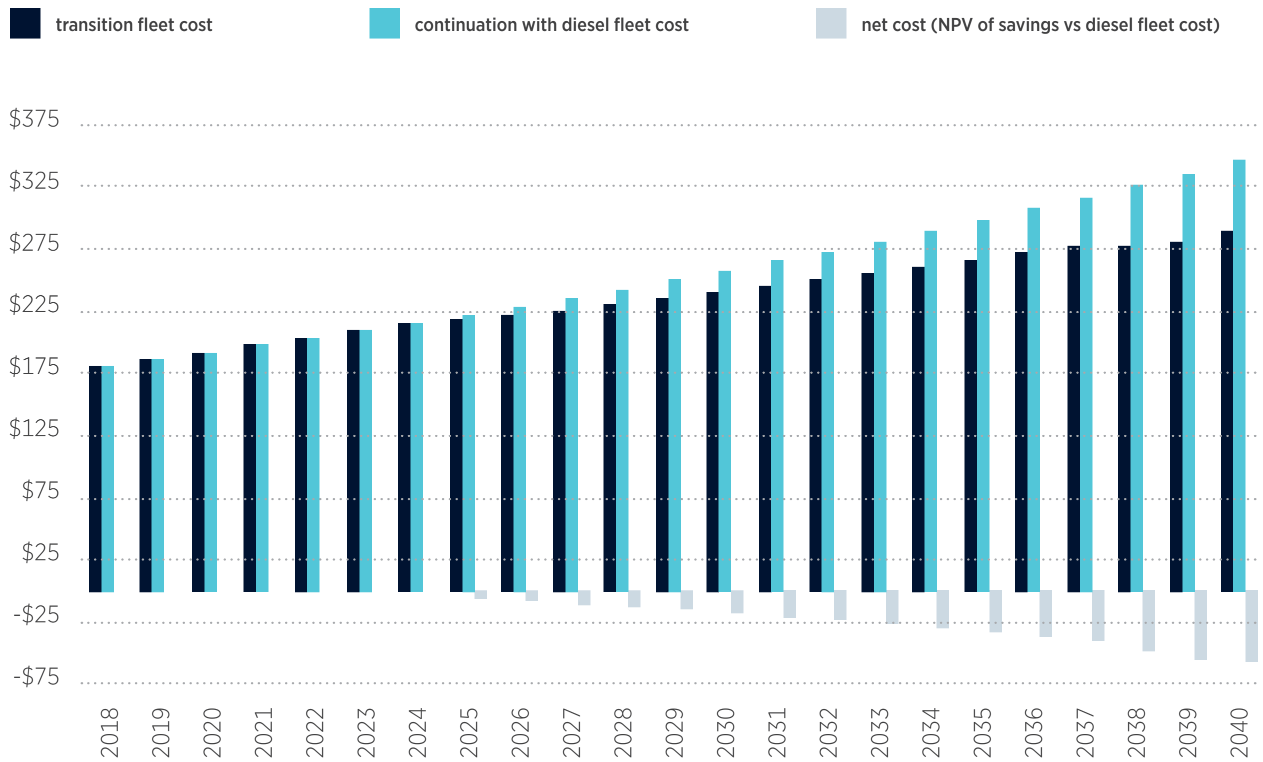



Figure 11: Likely impact on costs incurred under preferred option.

# 7.0 Financing options

**Multiple financing options have been considered for achieving the transition to low 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 2024 (Option E with opportunity to specify BEV for City LINK from November 2020) through contracted rates in service contracts. New contract variation rates to be agreed for ZEVs.

Future contracts could be funded through the current model of farebox revenue supplemented by AT and NZ Transport Agency funding for operational expenditure for bus service delivery. These contracts could incorporate an agreed schedule for fleet transition from diesel to zero emission propulsion (under Option E at the end of their useful 20-year life and before 2040) with agreed variation rates for PVR and in-service km costs that would account for the anticipated future reductions over time of acquisition and operation of zero emission buses.

The cost-benefit analysis will change as battery technology improves and market competitiveness increases, therefore regular review is necessary for accuracy of future cost modelling which will impact the necessary funding.


# 8.0 Next steps

## The following five steps have been indentified to progress our commitments.

1. Adopt and progress the Low Emission Bus Roadmap principles as a baseline transition with continuing 12-18 month updates to base level scenario cost/ benefit and net present value (NPV).
2. A 'quick win' start on a larger-scale trial of the City LINK electric bus service from November 2020 when the current bus contract for that route is renewed.
3. Continue to undertake trials and demonstrations of ZEVs and their associated infrastructure (subject to budget and availability). Seek funding from EECA from their LEV contestable fund. Proposed options include:
   - Further electric bus trials from other manufacturers
   - Hydrogen electric trials (incorporating hydrogen supply)
   - 'Opportunity' charging bus trials
   - Trial re-power of diesel bus to electric using proven technology.
4. Collaborate with C40:
   - Work with the Mayor's office to develop the Fossil-Fuel-Free Declaration programme and the financial implications of procuring electric buses from 2025 onwards.
   - Undertake research into the impacts of e-buses on the grid across Auckland; and the financial implications.
   - Use the C40 network to learn lessons and to benchmark with other cities about the adoption of low-emission buses.
5. Set up a national Low Emission Bus Working Group to break down the barriers to adopting low-emission buses in Auckland and New Zealand. Given the early stage and iterative nature of the roadmap, AT is intending in late 2018 to establish and lead a Low Emission Bus Working Group. This group is open to 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
- Influencing national policy
- Disseminating outcomes of demonstration trials and assessments.

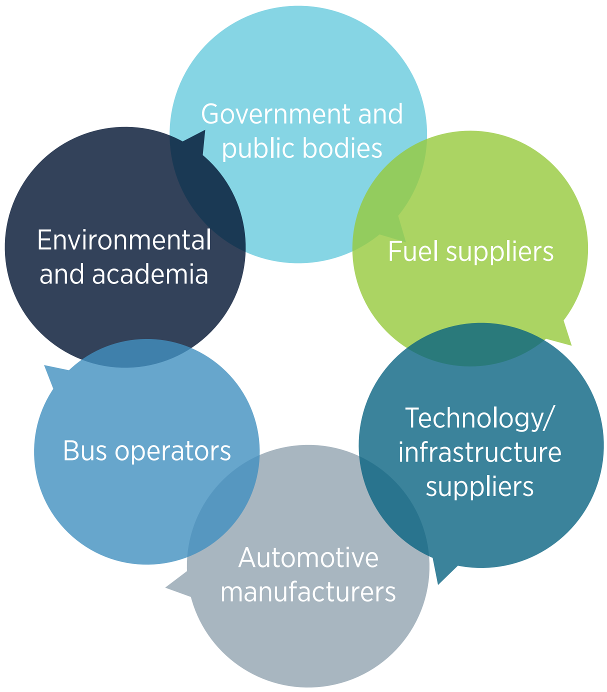



Figure 12: Proposed membership of the Low Emission Bus Working Group.

# Glossary

| Acronym | Description |
|---|---|
| BEV | Battery Electric Vehicle (also known as E-Bus) |
| 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 |

# Appendices

## Appendix 1: City LINK e-bus trial data

### Background

Two electric buses arrived in late February 2018. The vehicles underwent all NZ compliance testing and are registered with the NZ Transport Agency. The buses are operating on a weight permit issued by NZTA, and AT have speed-limited them to 70km/h (in agreement with NZTA). The vehicles have been leased to NZ Bus for a nominal fee of $1 for the six-month trial period. The cost of operating the vehicles during the trial will be covered mostly by NZ Bus, but AT will be continuing to insure the vehicles and will cover maintenance costs.

An agreement is in place with NZ Bus to operate the vehicles for an initial six-month period on the City LINK service, being up to (19) circuits over an 18-hour period. This route was chosen for air quality issues, public exposure, length of route, changes in topography, and close proximity of the depot to the route and to AT head office.

The vehicles were delivered fully-charged to the NZ Bus depot on 9 April, at which time final preparations were made to put the vehicles into service. This included:

- Acceptance of vehicles by drivers' committee
- Driver training
- Maintenance staff training
- Installation of HOP, CCTV, and RT equipment
- AT Metro branding
- Installation of depot charger units.

### Vehicle implementation

With regard to driver training and operations, there were no significant differences introducing the vehicles into the NZ Bus fleet compared to a conventional diesel vehicle. Drivers were however given additional training on regenerative braking.

NZ Bus are not undertaking any chassis related repairs or maintenance to these vehicles as ADL are undertaking these requirements for the trial period and beyond.

ZEV buses as standard would likely require a slightly different commissioning process.

The installation of the charging interfaces has been somewhat problematic, due to NZ requirements for 'Type B' RCDs to be installed.

Initially the RCDs tripped regularly, but software changes to the vehicle have reduced these events dramatically. A filter has been fitted to the incoming power supply on one interface, and to date this unit has had no 'tripping' events. Once proven, the remaining interface will be fitted with same filter. While the Type B requirement is currently unique to NZ, it will likely become a European standard in ~2019. The sensitivity of the device does provide a high level of reassurance in regard to the electrical safety of the vehicles on a daily basis.

## Data collection

The following figures are based on data collected between 18 June and 2 September 2018.

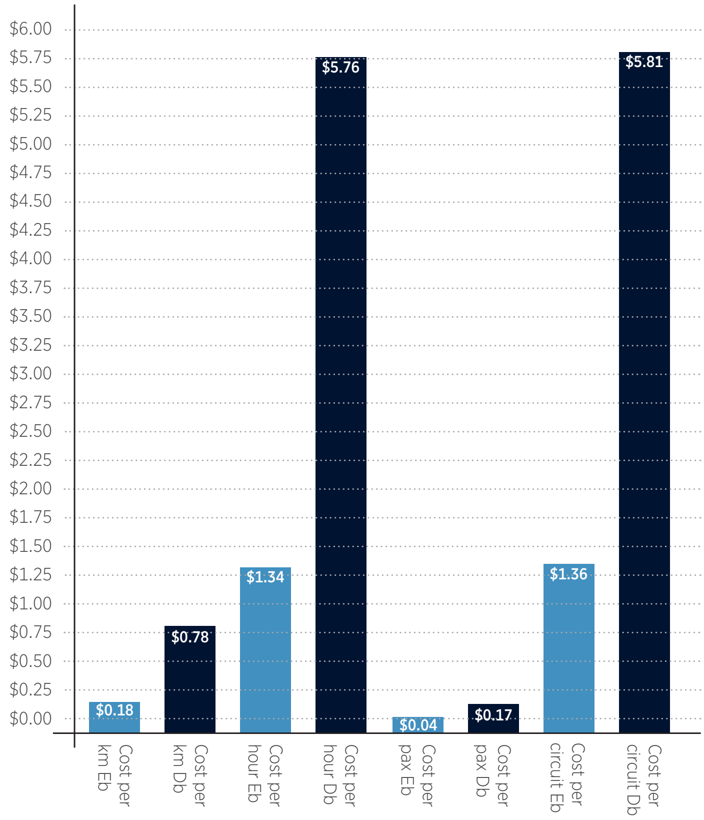
| | |
|---|---|
| Power cost | $0.17 per kWh |
| Road User Charge | $0.278 per kilometre |
| Combined diesel and Add Blue cost | $1.44 per litre |
| Fuel consumption of comparable diesel bus | 0.35 litres per kilometre |

The kWh/km rate currently being measured would translate to a range of circa 265km using 90% of battery capacity. The measured saving per kilometre in energy and Road User Charge is approximately $0.59/km, which is within 5% of the saving used in the LEV Roadmap model. To date the availability of both vehicles has been 84%.

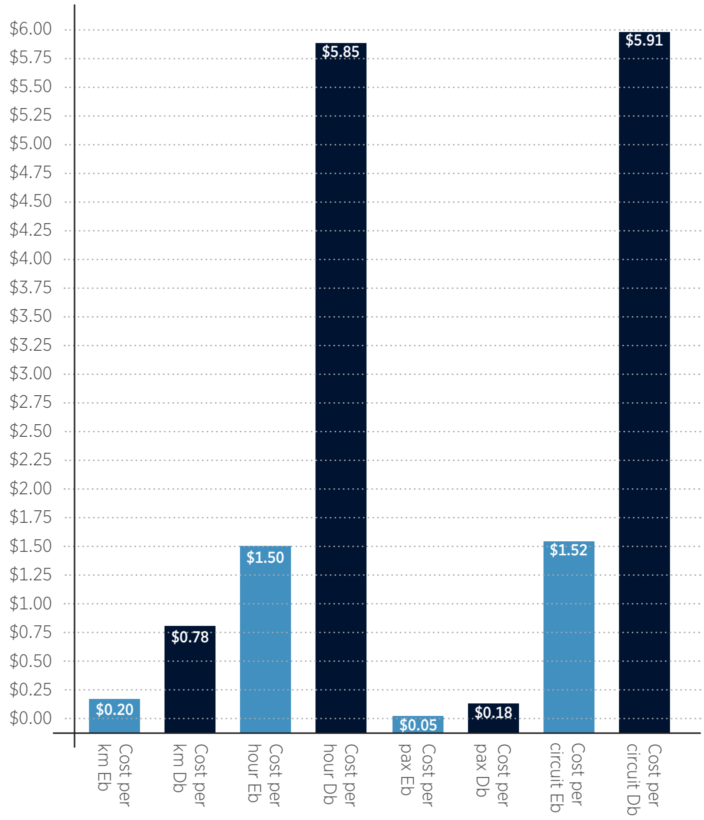
| Statistic | Bus 304 | Bus 305 |
|---|---|---|
| Total km | 4,030 km | 5,755 km |
| Total operational hours | 547 hours | 770 hours |
| Total passengers | 18,794 pax | 25,3267 pax |
| Total power consumption | 4,321 kWh | 6,810 kWh |
| Average kWh/km | 1.07 kWh/km | 1.18 kWh/km |
| Average kWh/h | 7.89 kWh/hour | 8.85 kWh/hour |
| Average kWh/pax | 0.23 kWh/pax | 0.27 kWh/pax |
| Overall operational saving | $2,416.90 | $3,342.54 |

## Comparative costs

The following graphs show the comparative costs between the electric and diesel buses:




### Comparative Costs Bus 304




### Comparative Costs Bus 305

## Appendix 2: Assessment of implementation and funding options

### Implementation options not recommended

| Option | Pros | Cons | Meets C40 Commitment |
|---|---|---|---|
| A. AT to specify ZE-bus for: all bus renewals and bus growth from 2020 onwards | Potentially shortest time to meet C40 commitment of 100% ZEV<br>Smooth capital cost profile<br>Gradual increase in ZE-fleet across network enables operator learning-curve at reduced risk<br>Allows time to prepare depots for greater fleet numbers | Purchasing small numbers of electric vehicles for patronage growth likely to be more expensive (discounting for bulk purchase not modelled)<br>Some fleets will contain few electric vehicles for a long time. More difficult to introduce initial charging infrastructure<br>High risk of increasing operators' write-off costs of 'stranded assets': operators may want buy-back guarantees from AT if their contracts are not extended<br>Requiring ZE-bus for fleet replacements from 2020 will require variations to existing contracts | Yes |
| B. AT to specify ZE-bus for: City LINK contract in 2020 and for all bus renewals and bus growth from 2025 | Later start maximises benefits of technology development, reduced capital cost of vehicles and cheaper future replacement batteries<br>Ability to run bigger trial of a ZE-fleet and its impact on depot charging and grid<br>More time to prepare for infrastructure and to plan fleet change<br>Smooth capital cost profile | As A | Yes |

| Option | Pros | Cons | Meets C40 Commitment |
|---|---|---|---|
| C. AT to specify ZE-bus for: City LINK in 2020; growth vehicles from 2019; full ZE-bus fleet under each new PTOM contract from 2023/24 (start of 2nd round). Operator fleet renewals at operator's choice – modelled as diesel. | Unit by unit introduction makes planning of large-scale charging infrastructure easier and introduction of electric vehicles quicker overall<br><br>Likely to be greater buying power as bulk purchasing for large contracts | Some fleets will contain few electric vehicles for a long time as replacements can be diesel before PTOM renewal. Difficult to introduce initial charging infrastructure<br><br>As A ref. variations to require ZE-buses for renewals<br><br>As A ref. write-off costs, but at lower risk | Yes |
| D. AT to specify ZE-bus for: City LINK in 2020; full ZE-bus fleet for each new PTOM contract from 2023/24 (start of 2nd round); any remaining fleet renewals and growth from 2025 | As C but: gives AT more time initially to consider and procure depots and implement large-scale charging infrastructure upgrades (not in RLTP) | As C, plus:<br><br>Purchasing diesel vehicles as replacements will be problematic with operators - may want buy-back guarantees from AT if their contracts are not extended and they have nowhere to cascade diesel buses – however this might encourage earlier take-up of ZEV<br><br>Achievement of 100% ZEV passes beyond 2040 | No |

## Funding options not recommended

| Option | Benefits | Disadvantages |
|---|---|---|
| 1. AT purchase ZEV fleet and lease to bus operators | • Ability to negotiate bulk procurement discounts<br>• Consistent fleet and charging infrastructure<br>• Ability to re-use batteries for other AT applications | • High capital cost outlay (not in RLTP)<br>• Continuing cost of fleet replacement |
| 2. Bus operators lease buses from bus manufacturer | • No capital required from operators nor AT<br>• Easy upgrades to newer fleet at the end of life / term of lease | • Higher Opex<br>• Lease costs may be high<br>• No established ZEV leasing system<br>• Variety of buses that may affect interoperability and charging infrastructure |
| 3. Bus operators buy buses but lease batteries | • Lower up-front costs for buses<br>• Batteries replaced at end of life (when only 80% of initial capacity is reached)<br>• Battery owner responsible for re-use or disposal | • With lower prices over time this model may not be sustainable (see price forecast)<br>• Leasing companies may keep batteries running to 60% of initial capacity reducing range<br>• There are no norms and standards for battery disposal / recycling<br>• No ability to use old batteries for other purpose in AT or public transport<br>• Variety of buses that may affect interoperability and charging infrastructure |

## Appendix 3: Assumptions

The recommended option is estimated to deliver total of $152 million over the period of 2025 to 2040 in savings compared to operating diesel fleet, ranging from an annual NPV of $4.3m in 2025 to $56m in 2040 (refer to page 31). The assumptions made in financial modeling are explained below.

### Capital cost of infrastructure

Each operator of electric vehicles must provide for the recharging of their on-board batteries using appropriate depot equipment. It is highly likely that the electrical power supply network into many depots will have insufficient capacity for the electrical load placed on it by the simultaneous recharging of multiple heavy BEVs. It is possible that as well as the secondary grid, in some parts of Auckland the primary grid might require enhancement. These requirements could impose significant capital costs on the programme (estimated at $30-60 million) at or near the outset. Further, should the potential for opportunity charging be taken forward (perhaps in order to be able to use shorter-ranged, smaller and therefore lighter-weight buses; or to reduce the power demand of overnight charging of long-range batteries) there would be further capital investment required in roadside charging equipment.

A study was completed (with the support of C40) into the impact on Auckland's power distribution network which provided greater knowledge on these questions and provided the estimate mentioned above.

There is no cost built into the model on a per-vehicle basis to account for additional infrastructure. This can be refined as more information becomes available.

### Energy costs and savings

The analysis undertaken has modelled the energy requirements to operate the planned network, and assessed the consumption of diesel and the kWh of electricity needed. It has not attempted to predict and account for future changes to the efficiency of either fuel type.

The relative costs of energy between diesel and BEV buses balance in favour of electrical power. The cost of diesel is anticipated to rise in coming years as the fuel type is discouraged further by a national programme promoting sustainable vehicles. The model does not attempt to account for this cost rise as it remains unknown.

A significant cost that will take effect in direct relation to operations is the renewal of the batteries that each bus must carry. The in-service longevity of batteries for the propulsion of heavy vehicles is uncertain as sufficient experience has not yet been gained globally. The financial modelling carried out has assessed battery replacement cycles set at a calendar life of 10 years when they are expected to retain 80% of their capacity. It is anticipated that over time, battery technology will extend the life of each new battery and reduce the capital cost of it; however this remains an unknown and is not accounted for in the analysis. As the use of lithium-ion batteries becomes more commonplace, the anticipated effect on the price of their supply can be seen in the chart in section 6.1 Capital costs.

## Maintenance savings

Maintenance of battery electric propulsion systems will require a different skill-set for depot staff; however, all other bus systems would likely remain similar to today. During the transition from diesel to electric power the number of maintenance staff across all operators is likely remain reasonably constant following an initial increase in electrical technicians.

Electrically propelled vehicles have fewer moving parts, no engine, gearbox nor liquid fuel system. Maintenance costs for BEVs are anticipated to be lower than the equivalent diesel vehicles. This is modelled as a saving of $2,000 per bus per year.

## Road User Charges

Road User Charges (RUCs) are applied to the diesel bus fleet but are subject to an exemption in favour of electric vehicles. This is planned at present to continue until 2028 at which point RUCs could be applied to E-Buses as well; whether on an equal basis or with a declining degree of preference afforded to E-Buses. The model therefore disregards RUCs beyond 2028 as the same cost could apply to all buses and would cease to be a differential in the cost model.

## Sustainability

Electric car and bus manufacturers had planned initially to recycle batteries once they were removed from EVs; however, the batteries still have sufficient capacity left to be used for second-life applications, especially as they retain up to 80% capacity after an estimated 10 years in bus use. The predicted falling prices for new batteries (see figure 10) will make used batteries attractive for other users or applications. It is predicted that the demand for stationary storage will increase four times between 2018 and 2025 to 20GWh while the amount of used BEV batteries available will increase from 0GWh in 2018 to 11GWh in 2025.[3]


The second life applications could provide additional sustainability and resilience benefits to Auckland Transport and Auckland Council. The pros and cons of using “End of Life’ LEV batteries have been assessed with two stages where they are can be used in second life applications before potentially being recycled. The table below demonstrates the considered possibilities.

| Option | Benefits | Disadvantages |
| --- | --- | --- |
| **A. Second-life applications**<br>• Use in chargers at depots<br>• Deploy to PT facilities to store solar power (if batteries owned by AT)<br>• Sell as alternative power storage for telecom towers and similar applications (if batteries owned by AT) | • Improve grid performance during peak times for bus charging<br>• Ability to create more power back-up in case of emergencies / power cuts<br>• Lower energy use if combined, especially with use of solar power<br>• Additional revenue to recover some initial costs<br>• Demand for used batteries expected to grow (see table below) – could help to boost residual LEV values | • Technical modifications required to depot chargers<br>• Some technical modifications and associated costs to use batteries as backup<br>• Cost of installing solar panels and connections at bus facilities |
| **B. Recycling of batteries after second-life** | • Clean environment and less polluted landfills<br>• Revenue source from cobalt and metals contained in batteries due rising commodity prices<br>• Ability to include responsibility for collection and recycling | • Limited (if any) recycling capability in NZ<br>• Does not produce material of high enough purity to be re-used in battery manufacturing |

3. Electric Buses in Cities: Driving Towards Cleaner Air and Lower $CO_2$ March 29, 2018. On behalf of: Financing Sustainable Cities Initiative, C40 Cities, World Resources Institute and Citi Foundation.

## Social benefits

Based on a study commissioned from Emission Impossible, the estimated social benefits of moving progressively to an electric bus fleet in Auckland (based on a model developed for Greater Wellington's recent bus tender round, which was reviewed and approved by NZTA) consistent with the preferred option E outlined above, reflect the estimated value to society of reducing harms. In this case the benefit would be reduced air and noise pollution when comparing emissions from LEV buses to emissions from Euro 6 standard diesel buses.

The estimate captures benefits from reducing all key relevant vehicle emissions: $CO_2$ equivalent, PM10, NOx, CO, HC and noise. The total cumulative value of social benefits through these externalities is $141.3 million, with an NPV of $56.7 million. These are made up of:

1. Engine emissions reductions ($104.6 million cumulative value and NPV of $41.9 million in total savings over the period from 2025 to 2040)
2. Noise reductions ($36.7 million cumulative value and NPV of $14.7 million of cumulative savings over that period).

### ETS sensitivity

The Emissions Trading Scheme (ETS) includes a charge on diesel of 7c per litre. The model takes the middle of the range for the two scenarios included in the Productivity Commission report[4] – 31c and 61c/litre diesel (targeting Net Zero Carbon) in 2050, and applies a linear increase from today to those levels.

The potential impacts on the wider transport network from the projected ETS price (greater modal shift, quicker light EV uptake) has not been considered as part of the ETS sensitivity analysis tabled below. The ETS costing below requires further work to confirm total costs as detailed information is not yet established for (e.g.) exact technology type, volume discount, depot upgrades, grid upgrades, replacement cycles, one-off costs, procurement and operational model alternatives including impact of any LRT introduction (*). The diesel figure in the table below won't be affected by changes in diesel costs as it is based on current contracted km rates, which are fixed (**).

| *Scenario | *Cost of transitional fleet ($m) | **Cost of continuation with diesel ($m) | *Indicative cost saving ($m) per annum | *Indicative NPV saving ($m) over period 2025-2040 |
|---|---|---|---|---|
| A. Base: 'Carbon Tax' for Emissions Trading Scheme set at basic Productivity Commission levels | $289 | $345 | $56 | $152 |
| B. Alternative: ETS set at 'Net Zero' levels | $285 | $345 | $60 | $163 |
| C. Sensitivity: no ETS charge on diesel | $292 | $345 | $53 | $143 |

4. New Zealand Productivity Commission (2018). Low-emissions economy: Final report. P144. Available from www.productivity.govt.nz/low-emissions

## Costs sensitivity

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

| Variables and Assumptions | | | | |
|---|---|---|---|---|
| **PVR cost (average PTOM unit agreement PVR rate)** | **SB** | **LB** | **XLB** | **LBDD** |
| Zero emission PVR rate premium | 0% | 0% | 0% | 0% |
| **Fuel consumption** | | | | |
| Electric (kWh/km) | 0.9 | 1.1 | 1.3 | 1.6 |
| Diesel (litres/km) | 0.3 | 0.35 | 0.455 | 0.55 |
| Average kms per annum | 50,000 | 50,000 | 50,000 | 50,000 |
| Average Road User Charge (RUC) for diesel bus per km | $0.142 | $0.278 | $0.278 | $0.372 |
| Maintenance savings per annum (electric bus) | $2,000.00 | $2,000.00 | $2,000.00 | $2,000.00 |
| Ave Diesel bus cents per km rate (cpk) 2018 | $1.25 | $1.68 | $2.25 | $2.08 |
| End of exemptions from Road User Charge (RUC) for electric bus | 2028 | | | |
| **Fuel costs** | | | | |
| Electric (kWh) | $0.170 | | | |
| Diesel (per litre) | $1.4841 | | | |
| Add blue % (per litre of diesel) | 2.12% | | | |
| AdBlue (per litre) | $0.62 | | | |
| Diesel combined fuel (per litre) | $1.50 | | | |
| **Net Present Value Calculations** | | | | |
| NPV discount factor | 6% | | | |
| Excludes NZTA indexation* | | | | |

* It is unknown at this stage what NZTA indexation rate will apply to contracts with zero emission buses. Current rate include costs associated with operating diesel fleet.

The impact on costs by premium for LEV, RUC exemptions and diesel price have been tested at three different scenarios as seen in the table below.

| Variable | *Cost of transitional fleet ($m) | **Cost of continuation with diesel ($m) | *Indicative cost saving ($m) per annum | *Indicative NPV saving ($m) in 2025-2040 |
|---|---|---|---|---|
| **Base:** PVR premium for ZEV is 0% | $289 | **$345 | $56 | $152 |
| **Sensitivity 1:** premium 20% | $310 | **$345 | $35 | $95 |
| **Sensitivity 2:** premium 40% | $331 | **$345 | $14 | $39 |
| **Base:** RUC exemption to 2028 | $289 | **$345 | $56 | $152 |
| **Sensitivity 3:** RUC exemption continues past 2040 | $274 | **$345 | $71 | $191 |
| **Sensitivity 4:** no RUC exemption | $298 | **$345 | $47 | $127 |
| **Base:** Diesel price $1.48/litre | $289 | **$345 | $56 | $152 |
| **Sensitivity 5:** Diesel price $1.30/litre | $296 | **$345 | $49 | $133 |
| **Sensitivity 6:** Diesel price $1.66/litre | $282 | **$345 | $63 | $170 |

*This costing requires further work to confirm total costs as detailed information is not yet established for (e.g.) exact technology type, volume discount, depot upgrades, grid upgrades, replacement cycles, one-off costs, procurement and operational model alternatives including impact of any LRT introduction

**The continuation with diesel figure used is insensitive to fuel price costs as it is based on current contracted km rates which are fixed. The saving modelled is based on the relative energy costs of diesel vs electric propulsion, and realisable as a change to a LEV fleet would require changes to km rates.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