New Zealand's experience of transitioning to a zero-emission public transport fleet – a research note

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L Thorwaldson, MRCagney, Auckland
A Knight, MRCagney, Hamilton

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Contracted research organisation – MRCagney (NZ) Ltd

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Waka Kotahi NZ Transport Agency
Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
NZTAresearch@nzta.govt.nz
www.nzta.govt.nz

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Abbreviations and acronyms

AUT	Auckland University of Technology
BEB	battery electric bus
EECA	Energy Efficiency and Conservation Authority
GBV	Global Bus Ventures
GHG	greenhouse gas
MoT	Te Manatū Waka Ministry of Transport
OECD	Organisation for Economic Co-operation and Development
PTA	public transport authority
PTAANZ	Public Transport Association Australia New Zealand
PTOM	Public Transport Operating Model
VDAM	vehicle dimensions and mass
WEBBCo	Wellington Electric Boat Building Company
ZEB	zero-emission bus

Contents

Executive summary

This research was commissioned by Waka Kotahi NZ Transport Agency to support public transport authorities (PTAs) and operators in New Zealand to transition to zero-emission public transport.

Transport accounts for 17% of New Zealand's greenhouse gas (GHG) emissions. Two important ways to reduce GHG emissions from transport are to reduce the overall amount of vehicle-kilometres travelled and to transition the private vehicle fleet away from the burning of fossil fuels for propulsion. Both approaches are essential to meeting our climate goals. Transitioning New Zealand's public transport fleet away from fossil fuels is more of a 'low-hanging fruit' compared to private vehicle fleet transition for several reasons:

- Public transport vehicles are typically in operation throughout the day and each vehicle drives many more kilometres than most private vehicles.
- Public transport use will grow through mode shift as other policies and projects change how we get around our cities.
- It is simpler to provide and manage a smaller number of large-vehicle charging facilities owned and operated by a few operators and/or PTAs than a large number of dispersed facilities shared by millions of private vehicle owners.

Government has mandated that no new diesel buses may be registered after 01 July 2025, working towards a goal of complete decarbonisation of the public transport fleet by 2035. To help this transition, the Energy Efficiency and Conservation Authority (EECA) has been providing grants to public transport operators who want to purchase zero-emission vehicles. Several public transport operators have already adopted zero-emission buses or ferries, but many more have yet to start the transition.

As part of its public transport design guidance, Waka Kotahi is collaborating with the Low Emission Bus Working Group to draft a topic paper about designing for battery electric buses, which should be available by early 2023.

This research note will complement the more technical public transport design guidance topic with knowledge and lessons learned from past and current zero-emission vehicle rollouts and trials across New Zealand. It has been derived through interviews with bus operators, PTAs and government authorities to gather a range of perspectives, challenges and opportunities.

What is zero-emission public transport?

This research explores the experiences of zero-emission public transport trials and programmes in New Zealand as of August 2022.

We define zero-emission public transport as any public transport vehicle with zero GHG emissions at the tailpipe. This currently covers three types of vehicles in New Zealand:

1. battery electric buses (BEBs)
2. hydrogen fuel cell buses
3. battery electric ferries.

This does not consider emissions from production of the electricity used to power the vehicle.

Methodology

The methods included:

- a brief document review of media and industry association articles published about zero-emission public transport trials in New Zealand

- open-ended interviews with public transport professionals to learn about public and staff reception of zero-emission vehicles, challenges, opportunities for the future and any other general findings or recommendations. Interviewees included:
  - six representatives from PTAs
  - five bus or ferry operators
  - two representatives from the Bus & Coach Association
  - two bus manufacturers
  - one representative from EECA.

Summary findings

There is now a relatively large amount of experience in zero-emission public transport among PTAs, operators and vehicle builders in New Zealand. This provides a good knowledge base for others to tap into when starting their decarbonisation journey. Most interviewees were very positive about their experiences and the future of zero-emission public transport in New Zealand. For example:

- Zero-emission public transport has been very well-received by the public and operators. Vehicles are quieter and have less vibration than conventional vehicles, which is pleasant for the public and a healthier working environment for drivers.
- Most interviewees were initially concerned about bus performance, battery life and/or range but generally found that the buses performed well. They reported that good forward planning paid off in getting the right vehicles for their needs. Wider industry concerns about range may be overstated due to media attention or outdated understanding of a rapidly changing technology.
- Options have expanded for buses that comply with vehicle dimensions and mass axle weight requirements.
- There has been good sharing of experience, buses and expertise between PTAs.
- Fuel costs for electric vehicles are generally lower than for diesel vehicles and not as affected by fuel price fluctuations.
- There has been a lot of enthusiasm to make this transition, and good partnerships have led to good outcomes, as highlighted by the comment below.

> *While we are still very early on in the journey, the commitment and enthusiasm to decarbonise the PT and ferry network shown by Auckland Council, Vector and other key stakeholders including ferry operators is refreshing and very collaborative.*
>
> *– Interviewee from Auckland Transport*

However, the transition is not without challenges or uncertainty. This research is intended to help other PTAs and operators plan for their zero-carbon transition with a clear understanding of the possible challenges and suggestions for tackling them.

The findings are split into three sections:

1. Challenges and possible solutions
2. Opportunities for the future
3. General findings and recommendations from interviewees.

Challenges and possible solutions

We have identified several types of challenges that have been faced by organisations transitioning zero-emission public transport, which are shown in Table ES.1 below. Some potential solutions that emerged from the interviews have been included.

Table ES.1 Summary of challenges and possible solutions for transitioning to zero-emission public transport

Challenge	Description	Solutions
Connection to power grid	The most common challenge raised by interviewees had to do with connecting to the electricity distribution network. These are the lines that distribute power across the city. The increased power draw from vehicle charging usually requires the distribution company (Vector, Powerco, etc) to upgrade their lines and/or transformers. This can be expensive, but the main challenge is scheduling the work. Distributors plan their upgrades years in advance and are reluctant to change those schedules. Interviewees reported a lack of urgency from power operators and delays of months or even years for getting the necessary upgrades so they could use their equipment to its full potential. This can have a major impact on decarbonisation progress.	• PTAs create a multi-year plan for which depots will be upgraded. • Coordination with distributor to align depot electrification plans with planned upgrades. • Cooperation between PTA and operator to persuade distributor.
Depot space constraints	BEBs with their charging infrastructure require approximately 20–25% more space in the depot than diesel buses. Many depots are already at capacity so electrification will require more depots. This can lead to increased operating costs due to more dead running time if new depots cannot be located as centrally as existing ones.	• PTAs may be better able to secure conveniently located depot space than operators. • Opportunity charging could reduce the amount of depot charging needed.
Service limitations and battery trade-offs	En-route charging infrastructure allows lighter batteries, which create less waste at end-of-life and allow more passengers within weight limits, but this restricts buses to routes where charging is available. Buses with larger batteries charged overnight can serve routes without charging infrastructure, but they are heavier, so they may not be able to take as many passengers or may have restrictions on what routes they service if overweight.	• Technology and bus designs are improving and may minimise this issue. • Some PTAs now specify no overweight buses. • Advanced planning of routes and future capacity needs is important for choosing a good mix of vehicles and charging (eg, aligning 10-minute opportunity charging with required driver rest breaks).
Communication to the public	Politicians or media releases may announce trials to the public without an understanding of how bus scheduling is conducted and why. One PTA interviewee reported that there were times during trials where incorrect information was given to the public about which routes the buses would serve. This type of misunderstanding could create public relations issues or require additional vehicles to meet public expectations.	• Ensure consistent and simple communications.

Challenge	Description	Solutions
Hydrogen-specific challenges	Hydrogen fuel cell vehicle technology is not as advanced as electric vehicle technology, so there has only been one trial of a hydrogen fuel cell in a bus in New Zealand to date. Hydrogen buses have the potential for greater range and faster fuelling than BEBs, but delays to fuel infrastructure have meant very slow fuelling. Hydrogen fuel cell technology requires purity of hydrogen at 99.999%, but electrolyser plants in New Zealand can only verify purity at 99.995%, which may affect warranties from fuel cell suppliers. Hydrogen fuel cell buses also have similar space and power supply requirements as BEBs.	• Ensure fuel supply infrastructure will be available before getting vehicle.
Ferry-specific challenges	The electric ferries designed thus far (one in Wellington and two in Auckland) require lighter hulls with less draft than conventional vessels. The builders used a lighter carbon composite hull construction to meet this need, rather than the more conventional aluminium. This reduces drag for greater range but has made the Wellington vessel more challenging to berth because it is more susceptible to wind and damage from hitting the wharf (electric ferries are not yet in operation in Auckland). It was reported that it performed better than diesel ferries outside of berthing. Future adopters may face different constraints where this design decision is not required. However, without others to compare against, it would be prudent to assume this as a baseline until proven otherwise. It should be noted that this was not listed as a major concern by the operator. Power supply issues for electric ferries are similar to those for BEBs.	• Plan for additional training time for skippers before putting in service. • Investigate potential for redesign of wharf fendering to protect the vessel.

Opportunities for the future

Interviewees gave professional opinions about possible changes within the industry in the future:

- **Technology will continue to improve**. Technology and bus designs have been improving rapidly such that some earlier issues (eg, overweight vehicles, lack of air conditioning) are no longer problematic. Depot space and weight/capacity/range issues are expected to improve over time. Concerns about range generally appear to be overstated.
- **Transfer of asset agreements and/or PTA ownership** for depots, vehicles and/or charging infrastructure in contracts would reduce risk for operators, which should reduce contract costs for the PTA. It may also allow more coordinated planning of power, depot and vehicle infrastructure by ensuring continuity of operation.
- Better **realising second life of batteries** (future stationary use of batteries after they have deteriorated to be unusable in vehicles) will improve financial and environmental outcomes. There is currently no cost credit given for second life of batteries. This should be explored and quantified as it may help reduce the costs of the buses.
- **More public information on the life expectancy of batteries** and on how to optimise the use of the batteries and monitor their state through the life of the batteries would give operators more accurate

depreciation rates for batteries. This could reduce costs, as annual costs are based on a relatively short life of the batteries to offset risk to the operator from incomplete information.

- **Automated monitoring** technology will continue to improve and help operators make better use of and extend the life of their assets.

General findings and recommendations from interviewees

The following general findings and recommendations from interviewees can help other organisations prepare for their decarbonisation journey.

- **High-level strategic coordination** is important.
  - Charging approach (en route or overnight) affects battery weight, cost, bus capacity and depot infrastructure requirements and capacity, but choice of charging approach depends on long-term strategic goals, including route permanence and network configuration, which depend on future patronage estimates.
  - The PTA should conduct a study of its network to identify locations that would suit en-route charging. Considerations include timetables, likelihood of installing charging in a residential area, ability for buses to return to the charger, and distance travelled before returning.
  - Planning depot locations and power needs ahead can make it easier to coordinate with power distribution companies for network upgrades.
- **Collaboration is essential.**
  - Power distribution companies can help PTAs plan for upgrades. Early engagement with distributors can reduce costs and avoid delays by aligning with planned works.
  - PTAs working with operators can help convince power distribution companies to prioritise upgrades as they may have more influence.
  - Information sharing between PTAs and operators builds trusted relationships and creates a positive feedback loop of information flow.
  - Inter-agency cooperation is beneficial for sharing experiences and tips. There seem to be a lot of perceptions of challenges that are either exaggerated or based on outdated information. It will be helpful to engage with people who have been actively involved in the transition of the fleet at other PTAs to sort fact from fiction.
- **PTAs can specify in tenders that operators must include a decarbonisation plan** over the course of their contract to ensure investment in the technology and a plan that best fits with the needs of the region.
- There is a need to be careful with funding to **ensure that operators are not subsidised into gaining an unfair competitive advantage** over other suppliers. Subsidies should include some buy back or agreement to transfer subsidised infrastructure to another operator if the incumbent does not win the next contract.
- Furthermore, many interviewees suggested that it could be useful for some PTAs to **include transfer of asset agreements in any future tender**. This helps operators offset the risk of stranded assets and allows for longer-term investments in vehicles and infrastructure.
- Interviewees suggested that **government could provide direction to power distribution companies to prioritise public transport** by:
  - prioritising infrastructure upgrades to depots
  - prioritising depots for reinstating power during outages, including specifying the minimum level of resilience of the network supplying the depot
  - ensuring that depots get first right of access to electricity for charging vehicles.

Abstract

Transport is one of the largest sources of greenhouse gas emissions and accounts for 17% of New Zealand's greenhouse gas emissions. Government has mandated that all new buses procured for public transport use after 01 July 2025 must have zero emissions at the tailpipe, working towards a goal of complete decarbonisation of the public transport fleet by 2035. Several public transport operators have already adopted zero-emission buses or ferries, but many more have yet to start the transition.

This research used direct interviews to gather first-hand experiences of bus operators, public transport authorities and government authorities who have been involved in zero-emission public transport transitions. The research note complements a more technical guidance document about designing for battery electric buses, which Waka Kotahi NZ Transport Agency will publish in early 2023 as part of its public transport design guidance. Together, these two documents will provide a useful resource for other public transport authorities and operators planning to transition to zero-emission public transport in New Zealand.

1 Introduction

This research was commissioned by Waka Kotahi NZ Transport Agency to support operators and public transport authorities (PTAs) in New Zealand to transition to zero-emission public transport. As part of its public transport design guidance, Waka Kotahi is collaborating with the Low Emission Bus Working Group to draft a topic paper on designing for battery electric buses (BEBs), which should be available by early 2023 (Waka Kotahi, 2022b). This research note will complement the more technical public transport design guidance topic paper with knowledge and lessons learned from past and current zero-emission vehicle rollouts and trials across New Zealand.

The purpose of this research was to focus on the experiences of public transport professionals in New Zealand. This research note does not include a full review of academic literature and international best practice. We have provided a high-level summary of several media and industry association articles that have been published about zero-emission public transport trials in New Zealand. This is also not a technical guidance or review of zero-emission public transport technologies.

This document is principally based on interviews with PTAs, operators, New Zealand vehicle manufacturers and other industry practitioners to gain insights into the challenges they faced in adopting low-emissions vehicles, and lessons learned. It is based on their experiences as of August 2022. The information contained is intended to provide a snapshot in time. Some of the challenges and opportunities may evolve as technology changes and these vehicles become more commonplace.

1.1 Structure of report

This report is divided into four parts:

1. The **Introduction** establishes the purpose of this work, sets out a definition for zero-emission public transport and lists relevant recent policy.
2. The **Methodology** chapter explains the approach we took to reviewing articles, engaging with the steering group and interviewing industry professionals.
3. The **Interviews with Public Transport Professionals** chapter explores the interviews we conducted with professionals who have first-hand experience with zero-emission public transport programmes.
4. The **Conclusions and Recommendations** bring together the findings of the interviews to draw conclusions on the challenges and opportunities for zero-emission public transport in New Zealand. Here we also highlight opportunities for PTAs, operators and government to speed up the transition to zero-emission public transport in New Zealand.

1.2 What is zero-emission public transport?

Over the lifetime of a vehicle, emissions result from mining of raw materials, production of the vehicle, transport of the vehicle to the customer, production of the 'fuel' (ie, production of electricity in the grid, production of diesel), tailpipe emissions from fuel use, maintenance, and end-of-life disposal.

For the purposes of this report, we define 'zero-emission public transport' as any public transport vehicle with zero greenhouse gas (GHG) emissions at the tailpipe – that is, fossil fuels are not burned onboard the vehicle. This currently covers three types of vehicles in New Zealand:

1. battery electric buses (BEBs)
2. hydrogen fuel cell buses
3. battery electric ferries.

A zero-emission public transport fleet is intended to eliminate or reduce the emissions from vehicle operation. Zero-emission public transport vehicles are generally considered to require less maintenance too, so they have fewer emissions related to this component of vehicle operation.

It is understood that the production of the electricity to power these vehicles may emit GHGs. However, electricity production is outside the control of PTAs and outside the scope of this research.

1.3 Policy and legislative landscape

Several recent announcements from Government are relevant to zero-emission public transport in New Zealand.

- By 2025, the Government will only allow zero-emission public transport buses to be purchased for public transport use. This commitment targets complete decarbonisation of the public transport bus fleet by 2035 (Te Manatū Waka Ministry of Transport [MoT], 2021).
- Government announced in January 2021 that they will support regional councils to achieve the above targets through a $50 million fund over 4 years. They will engage with the sector on how the $50 million fund is spent (MoT, 2021).
- The current road user charge exemption for heavy electric vehicles is being extended to after 2025 (Bus & Coach Association New Zealand, 2021a; Waka Kotahi, 2023).
- In August 2022, Cabinet agreed to replace the Public Transport Operating Model (PTOM) with the Sustainable Public Transport Framework (MoT, 2022). Relevant to this research is the reform that enables in-house delivery of public transport services (PTAs will be able to own assets and operate public transport services themselves).

1.4 Trials

Table 1.1 provides a summary of New Zealand zero-emission public transport trials and rollouts. As of mid-2022, there were 161 zero-emission buses deployed across four regions. By 2024 this is expected to be closer to 450 across 8 regions.

Table 1.1 Zero-emission PTOM bus fleet – as at July 2022 (Source: Compiled from council sources by Chris Vallyon, Waka Kotahi)

Region	Public transport bus fleet	Zero-emission buses (ZEBs) in service as at July 2022	% of fleet composed of ZEBs as at July 2022	New ZEBs estimated for 2023	Estimated ZEBs in service in 2024	Estimated % of fleet composed of ZEBs in 2024
Auckland	1,357	**38**	**3%**	162	200	**15%**
Wellington	475	**89**	**19%**	33	122	**26%**
Canterbury	260	**28**	**11%**	23	51	**20%**
Bay of Plenty	166	**5**	**3%**	0	5	**3%**
Waikato	107	**0**	**0%**	11	11	**10%**
Otago	98	**0**	**0%**	11	11	**11%**
Manawatū	44	**1**	**2%**	0	1	**2%**
Other regions	130	**0**	**0%**	17	17	**13%**
Total	**2,637**	**161**	**6%**	**287**	**448**	**17%**

2 Methodology

This research draws primarily from interviews with industry practitioners who have first-hand experience with zero-emission public transport programmes. We interviewed six representatives from PTAs, five bus or ferry operators, two representatives from the Bus & Coach Association, two bus manufacturers and one representative from the Energy Efficiency and Conservation Authority (EECA). Interviews were mostly one-on-one via videoconference calls, or group videoconference calls via the steering group. One bus operator preferred to provide a written response by email.

Interviews were open-ended discussions. Interviewees were told the purpose of the research and asked to recount their experiences and lessons learned for an audience of other PTAs or operators who are planning a transition to zero-emission public transport. A list of topics of interest was prepared in collaboration with the steering group beforehand. Interviewers guided the discussion to cover as many of these topics as possible.

On completion of the interviews, each one was analysed for its main themes. These themes were then collated and recurring themes grouped together.

Table 2.1 provides a list of the people who contributed their experiences and a brief summary of their organisation and zero-emission public transport rollout or trial.

Table 2.1 List of interviewees and organisation context

Organisation	Name – Interview method	Vehicle type	Summary
Auckland Transport	Darek Koper – Video call and steering group	BEB Hydrogen fuel cell bus Electric ferry	Conducted a trial with two BEBs in 2018 on the CityLink route. Put 31 more BEBs in service (CityLink, Waiheke, AirportLink) since the trial with 152 more to begin service soon. Trialled one hydrogen fuel cell bus on Botany-Britomart route. Has two electric ferries not yet in service.
Auckland Transport	James Aston – Video call	Electric ferry	Has two electric ferries not yet in service.
MoT (formerly employed by Auckland Transport)	Steve Zahorodny – Video call	(see Auckland Transport entries above)	(see Auckland Transport entries above)
Greater Wellington (via steering group)	Paul Blane – Steering group	BEB Electric ferry	Introduced 10 double decker BEBs in 2018. Has increased the number of BEBs in its fleet to 90 since. Has the first electric ferry in service as of early 2022.
Environment Canterbury	Sam Wilkes – Video call and steering group	BEB	Conducted a trial in 2019 with three buses. Now has 28 BEBs in operation in Christchurch.
Horizons Regional Council	Anonymous – Video call	BEB	Trialled one BEB in Palmerston North. Uses the BEB on several bus routes during morning and afternoon peak periods.

Organisation	Name – Interview method	Vehicle type	Summary
Public transport operator	Anonymous – Email	BEB	Anonymous
NZ Bus	Ian Gordon – Video call	BEB	Has 63 BEBs in operation in different places in New Zealand. Was the operator for the Auckland BEB trial in 2018.
Tranzit	James Howard – Video call	BEB	Operates BEBs for Greater Wellington Regional Council and was the operator for the Palmerston North BEB trial.
Ritchies	Warren Doel – Video call	BEB	Operated one of the first BEB trials in New Zealand for Environment Canterbury.
East by West Ferries	Mat Jonsson – Video call	Electric ferry	Operates ferry services in Wellington Harbour. Built and operate one of first electric ferries in the world to supplement fleet of two diesel boats.
Global Bus Ventures	Tim Duncan – Video call	BEB Hydrogen fuel cell bus	Builds New Zealand buses. Built BEBs for different operators/PTAs in New Zealand and a hydrogen fuel cell bus for Auckland Transport.
Kiwi Bus Builders	Richard Drummond – Video call	BEB	Builds New Zealand buses. Built BEBs for Tranzit to operate in Wellington and in Palmerston North.
EECA	Kii Small – Video call and steering group	N/A	Supplies funding for zero-emission public transport trials across New Zealand.
Bus & Coach Association (via steering group)	Ben McFadgen and Max Dickens – Steering group	N/A	Represents bus operators and builders in New Zealand.

2.1 Steering group

As part of the research process, we regularly engaged with a steering group consisting of representatives as per Table 2.2 below. The purpose of this steering group was to:

- gather insight and direction from those who had experience rolling out zero-emission vehicles, from both the operator and the authority side
- obtain feedback on the sort of information that would be useful for those who have yet to begin their roll outs.

The steering group also reviewed the report.

Table 2.2 Steering group members

Organisation	Name	Zero-emissions experience
Auckland Transport	Darek Koper	Auckland battery electric and hydrogen fuel cell bus rollouts
Bus & Coach Association	Ben McFadgen	Industry association
Bus & Coach Association	Max Dickens	Industry association
Environment Canterbury	Sam Wilkes	Christchurch BEB rollouts
EECA	Kii Small	Grants for zero-emission public transport trials
Greater Wellington	Paul Blane	Wellington BEB rollouts
MoT	Dominic Cowell-Smith	N/A
Northland Transport Alliance	Dean Mitchell	No current zero-emission public transport rollouts/trials
Waka Kotahi	Christine Moore	N/A
Waka Kotahi	Edward Wright	N/A
Waka Kotahi	Lorelei Schmitt	N/A

The steering group provided input on:

- confirming and refining interview topics/questions
- obtaining contacts to interview
- summarising and discussing interview findings
- providing information about upcoming changes and developments.

This helped to shape and refine the final report and expand our reach across New Zealand professionals.

3 Interviews with public transport professionals

This research draws primarily from interviews with industry practitioners who have first-hand experience with zero-emission public transport programmes. We conducted open-ended interviews with:

- six representatives from PTAs
- five bus or ferry operators
- two representatives from the Bus & Coach Association
- two bus manufacturers
- one representative from EECA.

Interviewees were asked to recount their experiences and lessons learned for an audience of other PTAs or operators who are planning a transition to zero-emission public transport fleets.

With such a large number of interviewees from different parts of the industry, we received diverse feedback. This section summarises this feedback into the following themes:

- Challenges during trials
- Anticipated challenges, improvements and opportunities for the future of transitioning to zero-emission public transport in New Zealand
- Lessons learnt and suggestions going forward
- Reception from staff and the public.

Under each theme the most commonly raised items are listed first. We have primarily focused on the challenges so that future adopters can consider these in advance. This approach risks overemphasising the challenges and making the transition to zero-emission public transport seem more formidable than it actually is. It's important to note that many of these issues will not be faced by everyone. Some are likely to be reduced or eliminated by technology, policy or process changes in the near future. We have identified where this is likely to be the case.

Future adopters of these technologies will also benefit from the experience of those who have already done it. There are many dedicated individuals and organisations such as the inter-agency Low Emission Bus Working Group, Waka Kotahi, EECA, and the Bus & Coach Association, among others, with resources and willingness to help.

We have generally indicated whether an issue or opinion was mentioned by multiple people or not and whether it came from a specific part of the industry (operator, public transport service provider, bus builder, etc). We have, for the most part, anonymised the responses as much as possible. The source organisation is sometimes obvious from the nature of the information, especially with Auckland Transport. In these cases we usually name the organisation, with the interviewee's permission.

3.1 Challenges during trials

Many interviewees faced challenges during the trials of their zero-emission vehicles due to the complexity of introducing the technology to operations. Two of the most frequently cited issues were coordinating with power companies for upgrading the power supply and contracting challenges. The challenges of coordinating with power companies and resulting delays for upgrading external infrastructure have a major impact on the ability of operators to electrify their fleet and/or make the most of their new internal infrastructure.

Other challenges were also discussed, as shown below.

The challenges are split across the following general types:

- Coordination and communication (including issues with power supply upgrades)
- Weight restrictions
- Service limitations and battery trade-offs
- Hydrogen-specific challenges
- Ferry-specific challenges.

3.1.1 Coordination and communication

Transitioning vehicle fleets requires coordination across multiple parties such as PTAs, road controlling authorities, operators, and energy suppliers. Many interviewees mentioned coordination challenges. Taken together, **these points suggest a need for a strategic lens to trials** – that is, they should be set up in a way that can be scaled efficiently by identifying the strategic routes/charging locations and coordinating with power companies well in advance to prioritise infrastructure.

3.1.1.1 Coordination with power supply (lines) companies for infrastructure upgrades

Both hydrogen fuel cell and electric buses and electric ferries require power infrastructure upgrades, which tend to have longer wait times than expected. This was a common theme across our interviews. Several operators and PTA members said that it’s relatively straightforward and quick to upgrade their sites, but very long lead times from lines companies to install transformers and upgrade the network to handle the increased load had caused significant delays in their rollouts.

> *We have a certain amount of capacity available to us, which is requiring a switchboard upgrade in order for us to get as much power as our charger can handle right now. By the time it’s done … will have been a two-year process [from] the ‘can we please request’ [through] design, build, implement, install a new switchboard, and it’s just inexplicably frustrating that no one has any kind of urgency ... From when our [vehicle] could have taken this extra charge [it] will have cost us $50,000 in diesel, and about 70,000 kilograms of carbon.*
>
> *– Operator*

> *We will say, ‘Right. We want to electrify this depot,’ and they will look at their map and say, ‘Well, we can’t deliver X [energy] to that depot for another five years – it’s in our plan to do it for five years. But, don’t worry, if you want to accelerate it, here’s the bill.’ And so, we have spent millions and millions of dollars getting lines companies to increase the capacity. If we order one MVA [megavolt ampere] transformer, we almost have to wait 12 months for it and we have to pay for it up front. And, concurrent to the production of that transformer, we’re hoping that the lines company is building up their HV [high voltage] network to our gate, so the transformer then links into an HV network that can cope and that takes years. And, you know, you speak to these companies and you are one of their customers – one of many – and of course they’re under huge pressure to increase the capacity, and you’re just a small itty bitty player, even though for you, it’s huge.*
>
> *And so, I find that for us it’s [a] very difficult financial structure for us to make or keep public transport as inexpensive as possible. And so, what we’ve learned to do is bring the regional councils into our planning, as well as there’s no point in us roaring ahead, electrifying [depots], if the Council aren’t in that tent, saying, ‘These are our priorities, this is where we want the lines companies to operate or prioritise. And we’re prepared to pay this amount of money for that to happen.’*
>
> *– Operator*

These operators and other interviewees highlighted the importance of building relationships. Alone, operators found it hard to get responses from power companies. However, when PTAs and operators coordinated efforts, they could prompt power companies into prioritising grid upgrades to depots.

> *They [the operator] reached out to our carrier. They got nothing back for ages and eventually we had to step in and basically blanket e-mail. I think there's about 10 contacts we had in our list. We just said, 'Spam them all with an e-mail and eventually one will respond' and I think that did something and got the wheel turning, but that still took ages to get the transformer and all the wiring done.*
>
> *– Public transport provider*

Building relationships with power companies means PTAs can know where grid upgrades will happen in advance and utilise this to build depots with charging infrastructure. One PTA interviewee suggested planning where depots need to be years in advance. This foresight allowed them to sync the upgrades they needed with power companies' upgrades to reduce delays in power grid changes.

3.1.1.2 Import and technology delays

Most interviewees had their zero-emission transition plans slowed by import delays. All these delays were thought to have been caused by the COVID-19 pandemic and the fallout from it.

For example, operators often had to wait for long periods of time to have buses sent from overseas, and bus builders had delays in parts being sent. Moreover, one operator found that brake certifications were hard to acquire during the trials as no one in New Zealand had the expertise to do that at the time.

3.1.1.3 Political and public communication

Politicians or media releases may announce trials to the public based on specific routes or locations without considering operational requirements. Saying that a particular route will be fully electric is a great way to raise the profile of fleet electrification but may not accurately reflect the details of a plan. Bus operators may spread their BEBs on multiple routes as the most efficient deployment to reduce diesel use and maximise their carbon emissions reductions. However, the media and politicians don't always understand how bus scheduling is conducted and why. One PTA interviewee reported that there were times during trials where incorrect information was given to the public, or assumptions were made by these parties about which routes the buses would serve. This type of misunderstanding could create public relations issues or require additional vehicles to meet public expectations.

3.1.2 Weight restrictions

Weight restrictions came up regularly in our interviews. Many of the early BEBs exceed vehicle dimensions and mass (VDAM) axle weight requirements, meaning they needed heavy vehicle permits. This restricts the routes they can serve because of weight restrictions on some streets and bridges. PTAs now have more options for buses that meet VDAM standards, but they should be aware of the challenges of overweight vehicles. PTAs should consider specifying weight limits in contracts or taking a proactive approach to engaging with the road controlling authority to ensure the streets that buses travel on can take heavy vehicles.

One PTA interviewee said their programme benefitted from an early partnership with territorial authorities to seek pre-approval for each route to know where there were problems on their networks that might not allow vehicles that exceed VDAM axle weight requirements. Given the growing availability of VDAM-compliant BEBs, this PTA will not accept overweight vehicles in any future contract.

3.1.3 Service limitations and battery trade-offs

The weight of batteries affects how many passengers a bus can carry within VDAM restrictions. Battery weight also affects range, which affects charging infrastructure needs. All of this has cost and feasibility implications.

Two interviewees discussed the trade-offs on battery size. En-route charging infrastructure means that the battery might be lighter. A lighter battery creates less waste at the end-of-life and allows a bus to carry more passengers within weight limits, but it restricts buses to using a particular route where opportunity charging is available. Buses using low-capacity batteries without en-route charging may require more 'dead running' (ie, running out-of-service, unavailable for passengers) to get back to charging stations or only provide service during peak hours. Buses using high-capacity batteries that are charged overnight can serve routes without charging infrastructure, but they are heavier so may not be able to take as many passengers or may have restrictions on what routes they service.

3.1.4 Hydrogen-specific challenges

Currently, the cost of hydrogen vehicles, when compared to fully electric, is much higher. This has led most early adopters to trial fully electric vehicles instead of hydrogen vehicles. However, Auckland has trialled one hydrogen fuel cell bus on one route, as shown in Figure 3.1. Some of our participants were involved with the hydrogen bus trial in Auckland.

Figure 3.1 Auckland's hydrogen fuel cell bus (Source: Global Bus Ventures)

Hydrogen fuel cell buses have some advantages over BEBs. They are lighter and have a better range, which makes them similar to diesel buses in that respect. However, some of the same challenges faced for BEBs also exist for hydrogen fuel cell buses.

First, power grid upgrades are still needed, with the same timing and cost challenges described above. Hydrogen was considered as a zero-emission option for ferries in Auckland. With the grid infrastructure upgrades that were needed, Auckland Transport chose to just build in charging infrastructure instead.

Like BEBs, hydrogen fuel cell buses need extra space in the depot compared to diesel buses, albeit not quite as much. This space is needed for the compressor and the refilling station.

The bus builder who was building a hydrogen fuel cell bus said the lack of access to international experts meant they had to upskill their staff to be able to build hydrogen fuel cell bus from scratch.

Figure 3.2 Interim hydrogen fuelling for Auckland's trial (Source: Bus & Coach Association)

The hydrogen fuel cell bus trial was also affected by coordination issues. Ports of Auckland was meant to get refuelling infrastructure built but there were huge delays, which has required refuelling from tanks on a trailer in the interim. This method increased refuelling time to four to six hours. Additionally, because hydrogen as a fuel is new for buses, regulation standards through WorkSafe were not available, causing barriers to trial the bus.

Hydrogen fuel cell technology requires purity of hydrogen at 99.999%, but electrolyser plants in New Zealand can only verify purity at 99.995%. If technology to verify purity is not available in New Zealand, this may affect warranties from overseas fuel cell suppliers.

3.1.5 Ferry-specific challenges

Ferries represent a big opportunity for decarbonisation. According to one interviewee from Auckland Transport, ferries carry only 6% of public transport trips in Auckland yet account for 20% of public transport GHG emissions.[1]

East by West Ferries was the first operator in New Zealand and the third in the world to trial an electric ferry. The lack of industry experience with this technology led to some unique challenges.

With no external or local companies to buy from, they had to set up a secondary company – Wellington Electric Boat Building Company (WEBBCo) – to build the ferry themselves.

[1] These figures are corroborated in an article by Greater Auckland (2022) (see https://www.greaterauckland.org.nz/2022/04/27/electric-ferries-for-auckland/).

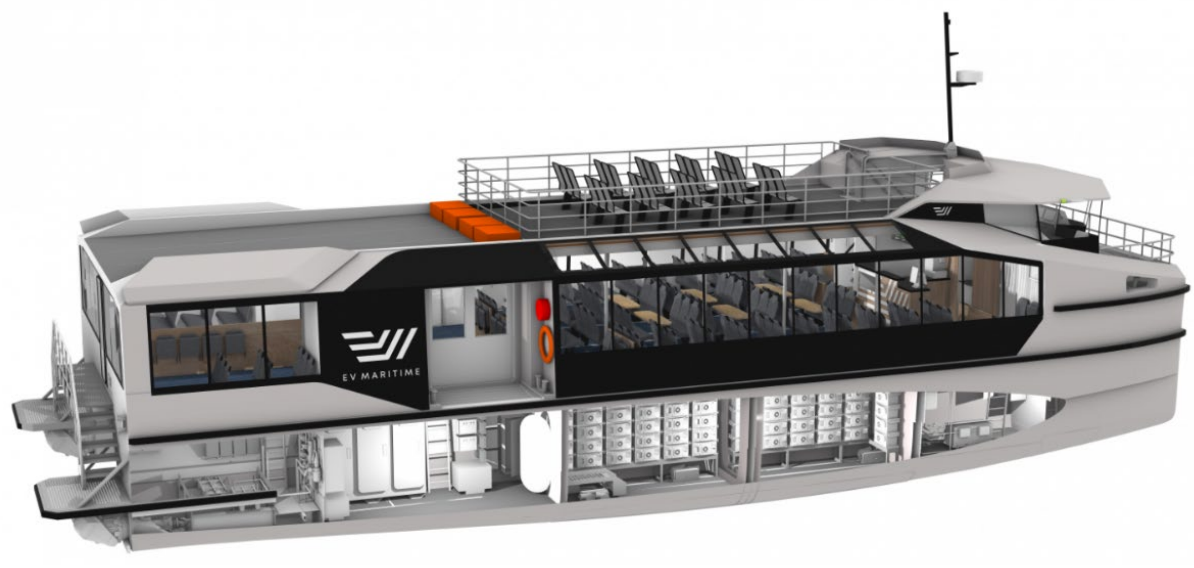
Insurance companies do not know a lot about electric ferry technology, so they do not have a framework for insuring them. The novelty of the technology meant they saw covering the boat as riskier, which led to higher insurance rates.

From an operational perspective, the electric ferry needs to be much lighter to reduce drag in the water. To achieve this lighter weight, WEBBCo and EV Maritime are constructing electric ferries using carbon-fibre instead of aluminium. This is better to operate in many conditions, but more care must be taken when berthing because the ferry is much more affected by wind and the lighter carbon-fibre construction cannot take as much impact. Future adopters may face different constraints where this design decision is not required. However, without others to compare, it would be prudent to assume this as a baseline until proven otherwise.

It should be noted that this was not listed as a major concern by the operator.

Auckland Transport is also in the process of electrifying their ferry fleet. Buses and trains have received a lot of attention and investment over the past two decades, which has led to huge growth. One interviewee from Auckland Transport noted that ferries have lagged behind, partly due to the contracting model. The current fleet hasn't seen much investment and has an average age of 19 years. The board of Auckland Transport has since approved the organisation to own the vessels in the future, either outright or rolling over from the operator at end of contract. Figure 3.3 shows an illustration of one of the electric ferries under construction by EV Maritime for Auckland Transport.

Figure 3.3 Illustration of one of the electric ferries under construction by EV Maritime for Auckland Transport (Source: Auckland Transport)



3.2 Anticipated challenges, improvements and opportunities for the future of transitioning to zero-emission public transport in New Zealand

Our research was primarily intended to get an understanding of the experiences of people who had rolled out zero-emission public transport. Most interviewees also provided some speculation about how technological advances and changes in the regulatory and financial landscape may affect public transport in the future.

We have included some of these predictions in this section. It is important to note that these are the opinions of individuals with varying experiences coming from specific parts of the industry. Some opinions may be influenced by business interests or points of view. We have made commentary and added our own insights where we felt necessary. We believe it is useful to include these opinions, but it should be noted that this is new, rapidly changing technology with a high level of uncertainty.

These predictions are split across the following sub-themes:

- Charging infrastructure/scheduling and depot space
- Power supply and costs
- Performance of electric vehicles
- Funding, ownership models and contracts
- Environmental impacts
- Staff requirements/vehicle maintenance
- Future technology.

3.2.1 Charging infrastructure and depot space

Installing the charging infrastructure required to service large electric fleets carries significant costs to PTAs and operators. Land acquisition, power infrastructure upgrades and chargers have been discussed as points of concern.

3.2.1.1 Depot space

Depot space was one of the main concerns that operators and PTAs raised for the future of electrification.

BEBs need more depot space than diesel buses because of the charging infrastructure, as shown in Figure 3.4.

Figure 3.4 Additional space is needed for charging infrastructure (Source: Environment Canterbury)

The amount of additional space needed will vary depending on the layout and technology used. Providing a range of space requirements for each technology is beyond the scope of this report. Several of our interviewees stated a figure of about 20–25% more space required and noted that many depots, especially more centrally located ones, are already very efficiently used. Regardless of the exact amount, more depot space will be needed to electrify the fleet. This could be a large cost, especially in central locations.

On-road charging has been identified as a potential way to counter bus depot size, but there are trade-offs. On-road charging can extend out-of-depot range and/or allow the use of lighter and cheaper buses, but it reduces flexibility for bus deployment because vehicles will need to be in specific routes where the chargers are located. Network design and operations plans also need to support appropriate pause times to coincide with when buses will be at the chargers. Chargers may not always be able to be installed at natural break points due to land use or infrastructure constraints.

3.2.1.2 Charging infrastructure

Installing the charging infrastructure to serve large electric fleets carries large costs to PTAs and operators. Forward planning of power requirements to future proof can reduce the need to dig twice. However, it needs to be balanced with an understanding of the permanence of that location as a depot because civil works can become a liability at the end of the land lease. Transfer of assets provisions in the contract can help offset this uncertainty.

> *Civil and electrical costs are massive – the moment we dig to install equipment, we tend to be filling the hole with money! The process is difficult and takes a massive amount of time and resource. The civil and electrical is often more expensive than the charging equipment itself! This money is in the ground and there is little to no resale value at the end of a contract. If anything there are ‘make good’ liabilities for operators at the end of a contract, as the landlords don’t want enduring easements and redundant infrastructure/civil works.*
>
> *– Operator*

PTAs and operators are both concerned about how they will fund the necessary investment to support the broader adoption of low-emission vehicles. Small councils are especially worried about the costs and are likely to be looking towards central government for funding.

3.2.1.3 Scheduling

One operator described some anticipated problems of having a large number of BEBs that charge at the same depot. They predicted a potential lack of chargers leading to a need to swap buses out over the course of the night. This is unlikely to become a challenge. It is possible to have more bus charging leads than chargers. A charger management system can control the charging through the night without the need to shift buses.

As part of the introduction of any number of BEBs, a charging plan should be drafted for both the PTA and operator to agree to that ensures an optimal allocation of the buses. The charging plan will ensure that there is sufficient charging capacity for the buses irrespective of the number of BEBs in service. Further to this, the PTA should be using emissions modelling to identify the routes/duties where the BEBs are to be operated and use the timetable process to manage this. This will be the basis around which the charging plan will be developed.

3.2.2 Power supply and costs

As more electric vehicles are added to public and private vehicle fleets, more energy will be demanded from the energy grid. One PTA is not worried as they have calculated they will have enough available power for their future fleet. Other PTAs are worried the limited power supply will cost them more by forcing specific charging times and lengthening the time to charge, which may impact operations.

One operator noted that local grid authorities operate control periods from 6 to 10 am and from 5 to 9 pm with massive penalties for encroaching on these times, which depend on weather and power network demands. But they need to charge from 6 pm to ensure full charging for all their vehicles. They were very concerned that as private electric vehicles become more widespread and electrical load/demand grows, these control periods will be extended and costs could skyrocket. For example, it would cost them an extra $130,000 per annum to charge eight buses through 12 control periods.

The project steering group noted that operators worry about not having enough power to meet contractual requirements. Price fluctuations are a big risk to operators because they plan out costs for a decade or more when bidding on contracts. Two potential solutions were raised by the group:

1. **PTAs negotiate energy supply agreements:** PTAs may be able to negotiate better energy supply agreements than individual operators. In some cases, the PTA will represent a larger user when taking into account energy used by water services and trains.
2. **Purchasing at wholesale rates:** Train services are able to purchase power at wholesale rates, whereas bus companies purchase at standard commercial retail rates, which involve a significant mark-up. PTAs or operators could see significant cost savings if they are able to adopt power supply agreements similar to rail.

3.2.3 Funding, ownership models and contracts

There were differing opinions about how the contracting process affects zero-emission vehicle uptake and competition.

3.2.3.1 Competition vs monopoly

The Public Transport Operating Model (PTOM) and other contract issues were seen by some to disincentivise early adoption of zero-emission vehicles because the high upfront costs of the technology make contracts more expensive. This may negatively affect operators who invest in zero-emission technology initially, as priced-based contract awards would favour those who retain or buy more diesel buses due to lower contractual costs. The concern is that this will result in more new diesel buses being added to the fleet, which will be operating for up to 20 years into the future.

Alternatively, some interviewees thought that early-adopting operators would have an unfair advantage due to the high costs of infrastructure creating a barrier to entry, risking a monopoly. Others viewed this simply as a feature of a competitive market – early adopters are taking a financial risk on uncertain technology, with the expectation that it will provide a competitive advantage. There is a lot of uncertainty about lifecycle costs (ie, How long do batteries really last?), which is challenging to price into a 9–12-year contract and creates financial risk for operators. The prospect of an advantage in the competitive market provides an incentive to take these risks and innovate.

The true outcome is likely to be some combination of these points. Initially, those who retain or buy more diesel buses may win some contracts due to lower contractual costs. However, there are national and local mandates to shift to zero-emission vehicles, meaning that many of the earlier adopters will be favoured in upcoming rounds. Operators who buy new diesel buses between now and 2025 may end up with stranded assets when they cease to be available for PTOM contracts in 2035, or sooner if legislation changes. There is also the risk that diesel prices will continue to rise in the future, which would offset the lower upfront cost of diesel vehicles. Transfer of asset provisions could help reduce contract prices by operators that use BEBs and make it more financially viable to replace diesel buses with BEBs mid-contract.

This balance of risk, innovation and reward is a feature of the competitive market. This could be more of an issue if government subsidises incumbents to build infrastructure without retaining the rights of transfer for that infrastructure.

One representative of a smaller PTA expressed concern that the limited funding for smaller PTAs means that early investment in charging infrastructure could restrict their ability to alter charging locations or types. There was a concern that being locked into early infrastructure investments means that the only operators with compatible bus technology will be able to win contracts. The steering group suggests that this depends on what smaller PTAs wants to achieve. They may be able to use slower charging technology initially and make larger investments as public transport services increase in the future. There is also now a common standard for charging, which should address this concern (Waka Kotahi, 2022a).

The benefits of requiring the option to transfer assets at the end of a contract were raised by several interviewees.

3.2.3.2 Funding of bus and infrastructure investment – operator, government or third party?

A related issue raised by our steering group is that the cost of infrastructure/buses on smaller PTOM units is very high. Recent changes to the contracting model have given PTAs more flexibility in how they tender public transport services regarding ownership and control over depot and vehicle assets.

One service provider is of the opinion that direct investment in depot infrastructure by PTAs would be beneficial in these cases because this would save on operator margins and PTAs are able to get finance cheaper. This could also give more flexibility to the timing of purchasing new vehicles to meet patronage growth. Operators need to depreciate over the contract lifetime so would not want to buy new buses in the latter part of the contract. This would not be an issue for third parties. The main issue is that this requires a different source of funding. If it's through the operator, it's classified as operating expenditure costs funding, which is a different bucket. Organising funding sources is the biggest challenge at the moment for this service provider. It was also noted by another service provider that some PTAs have trouble with debt ceilings, and more work will be needed to avoid that. They felt that money needs to come from central government to make it work.

There is also the trade-off between cost efficiency/return on investment for operators and network planning flexibility for PTAs. The need for operators to spread the cost of their investments over long contracts is exacerbated by more expensive vehicles (eg, BEBs). Longer contracts are less flexible for PTAs to make changes to the network or refresh contracts that are no longer meeting the needs of the city. Flexibility for iterative adjustments would be especially useful when using new technology to make sure demand is met.

One service provider noted that all their BEB deployments to date have been variations to an existing contract, but the next round of tenders will require operators to provide infrastructure because no funding is available for capital investments into third-party property (operators leasing depots from third parties) and the risks associated with investment into property that isn't owned by the operator or PTA. However, they are looking into alternatives for future rounds.

One interviewee from a smaller PTA noted that they do not have the money to go out and replace their fleet now, so they are including in their tenders a requirement that operators submit a plan for how they will transition to zero-emission vehicles over the course of the contract. This will put them in the position to be 100% zero-emission by 2035.

3.2.3.3 Effects of price assessments on contracting outcomes

Several interviewees raised concerns about how price is dealt with in contracting, which may favour operators to seek solutions with lower upfront costs. Favouring lower upfront costs can lead to adverse outcomes.

Less concern may be given to the sustainability of the battery packs being purchased – that is, no en-route charging is installed, leading to an abundance of heavier battery packs (cheaper), which one interviewee claimed was more wasteful at the end-of-life. This will be less of a concern as the second-life value of batteries as in-depot storage is realised. This will be more prevalent with ownership models that extend past contract timeframes.

3.2.4 Environmental impacts

Concerns were expressed that the transition may not be as environmentally friendly as intended.

One interviewee highlighted the need to ensure the power we're getting is from clean supplies. New Zealand has one of the highest proportions (75%) of electricity production by renewable sources in the Organisation for Economic Co-operation and Development (OECD).[2] However, this does not mean that additional energy demand from BEBs would be supplied by renewable resources. Most of the renewable production is hydroelectric, which requires supplementation from other sources (primarily fossil fuels) during dry periods. Hydroelectric is also baseline production. Marginal production during peaks is much more likely to be fossil fuel production, so charging during peaks is unlikely to be using renewables. As more of the private vehicle fleet electrifies, demand in off-peak periods will grow. This will flatten out the highly cyclical nature of demand, but this may require more continuous use of fossil-fuelled facilities like the Huntly Power Station unless/until significant additional renewables capacity is brought online. This is one of the reasons why emissions reduction plans need to focus on reducing private vehicle use, even if there is large-scale adoption of private electric vehicles.

While it is important to consider the power generation environmental impacts of catering for the increased demand, we shouldn't let this be a distraction from the importance of electrifying the fleet as this supports broader strategic goals of mode shift, which support a broader set of policy outcomes than just emissions reduction.

One service provider interviewee suggested that the industry is not currently realising the second-life value potential of old batteries but that this could change with changes to asset ownership models. There is currently no cost credit given for second-life use. If this value is quantified, it could reduce the lifecycle cost of buses and/or encourage the purchase of buses with more robust batteries planned for second life. More public information on the life expectancy of batteries and on how to optimise use and monitor their state through the life of the batteries could reduce costs. Annual costs are currently based on a relatively short life of the batteries to offset operator risk from lack of available information.

One interviewee believes that most operators have chosen to buy buses with large batteries that charge overnight, which is good for scheduling and not having to install en-route charging. However, larger batteries mean more waste each time they need to be replaced. They suggested that government should encourage avenues for en-route charging to reduce this impact. Some PTAs or third-party companies may choose to build opportunity charging hubs that can be used by any operator in locations where multiple routes come together.

3.2.5 Staff requirements/vehicle maintenance

Vehicles in public transport fleets need to be serviced. With a change in technology comes a change in the skills needed to be able to perform appropriate upkeep and to fix the vehicles when needed. Therefore, some operators want their staff to become certified to maintain the vehicles to avoid costs of external contractors and the opportunity cost of the buses being out of commission. However, one operator said that

[2] Seventy-five percent of production from 2017 to 2021 was from hydroelectric, geothermal or wind (Ministry of Business Innovation & Employment Hīkina Whakatutuki, 2022). Small scale distributed solar is not included.

finding courses for their staff members is proving difficult, so there was concern this would delay or complicate their transition.

Less familiarity with zero-emission technology could also lead to driver mishaps in operations such as running out of charge during a route. One operator specified that this issue is not related to the energy source, as the same thing could happen with diesel vehicles; it's more related to driver training and planning routes correctly. A public transport provider suggested that these planning challenges had to do with the uncertainty about energy use per kilometre due to differences in how this is advertised by bus manufacturers. This should be less of a challenge for future rollouts as domestic experience with different vehicles grows and can be drawn from.

3.2.6 Future technology

3.2.6.1 Reduced battery weight and power draw for air conditioning

A repeated theme from those we interviewed was an optimism for future iterations of zero-emission vehicles. From current trajectories, BEBs will likely reduce in weight and increase the range of batteries. If this trend continues, it will mean the same technology operators/PTAs can buy now will be cheaper in the future and the trade-offs between capacity, range and simplicity of charging may resolve themselves. Similarly, there is hope and evidence that air conditioning units will become more efficient over time, which will reduce power use.

3.2.6.2 Automated monitoring

Another hope for the future is on different types of automated monitoring. For example, driving and charging the batteries in a way to maintain good 'battery health' was entrusted to employees of operators during the trials. Leaving this monitoring to humans was manageable with singular buses, but concerns were raised about how well batteries could be maintained as the fleet grows. It was expected from one operator that this process will automate as software is further developed to monitor energy use to advise drivers what they need to do to take care of the battery. Similarly, software that records and models energy expenditure was discussed by multiple interviewees as having a role in future rollouts for planning routes, especially during the earlier stages of transitioning.

3.2.6.3 Hydrogen technology expectations

Hydrogen fuel cell technology is expected to become more readily available as it is developed further. One operator believed this development would improve the BEB technology through competition.

Hydrogen fuel cell vehicles are more expensive to trial than BEBs. One interviewee worried that incentivised trialling of electric battery-powered vehicles over hydrogen vehicles would snowball into a wider adoption of BEBs over hydrogen buses. However, another interviewee didn't think hydrogen buses were 'there' yet compared to electric vehicles so not ready for wider trials.

3.3 Lessons learnt and suggestions going forward

This final section brings together some of the broader lessons learned and suggestions from interviewees for future rollouts. Their responses split across the following general areas:

- Collaboration and outsourcing
- Planning
- Possible changes to ownership models.

3.3.1 Collaboration and outsourcing

Several interviewees found their transition to zero-emission vehicles worked better when there was cooperation and data sharing between organisations.

3.3.1.1 Power companies can help PTAs plan for upgrades

One public transport provider was able to team up with the local power company to understand more about the high voltage connections to each of their ferry terminals. They could then use this information to create cost estimates for a ferry procurement process. Another PTA regularly talks with the local power company to know where new grid connections are being developed, so they can consider if they want to build a depot there. This insight means they will not have to retroactively upgrade and connect to the power grid when they build new depots.

3.3.1.2 Information sharing between PTAs and operators builds trusted relationships

Collecting and sharing information proved to be key in establishing good working relationships with bus operators for one service provider. They shared all their internal trial data about fast chargers with bus operators, which prompted reciprocity. This collaboration became the ground for a trusting relationship, where both parties felt like they had a partner they could rely on during the transition.

3.3.1.3 PTAs may be more influential with power companies than operators alone

In more than one instance, PTAs helped operators by urging power companies to install transformers and upgrade the network to serve depots. Some operators expressed a perception that they are not considered as important to power companies as PTAs, so the extra pressure was thought to help move things along.

3.3.1.4 Inter-agency cooperation will benefit those who have not yet transitioned

Sharing information between PTAs has been an enormous help because different places have different insights to share from their experiences. This information sharing has been helpful between PTAs across New Zealand. Similarly, one operator found merit in collaborating with an overseas operator. This collaboration gave the New Zealand company an idea of their buses' energy use, which helped them plan their operations.

Smaller PTAs will benefit from the work early adopters have put into their programmes. For example, smaller PTAs have borrowed the buses purchased by larger PTAs to conduct their own trials and could use the connections established between the larger PTAs and bus manufacturers to trial buses.

The organisations that have already done, or are currently progressing, larger rollouts seem especially dedicated to helping others to adopt zero-emission public transport across New Zealand. Some PTAs have been developing processes and tools for other PTAs to use. For example, Auckland Transport has engaged KPMG to develop a model to predict cost of transition and funding requirements. This will be made available to other PTAs via the Transport Special Interest Group and Regional Software Holdings Limited, a council-controlled organisation created for cross-council collaboration. This will help PTAs predict how much money they'll need to transition.

Operators, PTAs, bus builders and other industry experts such as the Bus & Coach Association have formed the Low Emission Bus Working Group to share information and resources and to help others with their transition. Auckland Transport, Greater Wellington Regional Council and Environment Canterbury are members of the Zero-Emission Bus Government Roundtable Working Group, administered by the Public

Transport Association Australia New Zealand (PTAANZ)[3]. This group brings together New Zealand regional councils and Australian state governments to share resources.

Operators also found benefit consulting with one another. For example, one New Zealand company spent months talking to overseas operators to see how they modelled their average energy expenditure. This collaboration gave the New Zealand company an idea of the energy use of their buses, which helped them plan their own operations.

3.3.1.5 Outsourcing parts of the transition process has been helpful

One PTA required competing operators to come up with fleet transition plans as part of the bidding process instead of having to come up with a plan themselves or spend money on consultants. Another PTA paid consultants to come up with a power demand model based on vehicle design, battery specifications and charging requirements to assist their decision making in various parts of the transitioning process. They also employed some bus manufacturers to come up with bus designs to distribute the weight more evenly for New Zealand roads.

3.3.2 Planning

Several interviewees mentioned planning as an essential lesson for decision-makers.

What batteries are chosen, where to place the charging infrastructure and what type to invest in were cited as some of the biggest decisions that need to be planned. In fact, these decisions are all intertwined and together make up the bulk of the decisions that need to be planned. Having a long-term plan of a city's bus services, where and how large depots will be, and power supply capacity will help with planning what buses to get and what charging infrastructure to lay down.

Having only overnight chargers means the buses will likely have a heavier battery pack, which may restrict where they can go, or they may have to carry fewer passengers to meet weight restrictions. Overnight charging may add extra operating costs or complications to ensure all the buses are charged. Conversely, en-route charging infrastructure can also be expensive but allows for lighter battery packs. However, en-route charging can also 'lock' operators into routes, so having a long-term vision of where bus services will go may save time and money over time.

Charging infrastructure locations can reduce or increase the risk of dead running. If chargers are close to buses and batteries have enough capacity to reach them when they need to be charged, driver fees, opportunity costs, energy waste and wear on vehicles can be reduced. Therefore, choosing bus depots central to various bus routes or strategically placing en-route chargers is important.

One technical expert recommended working out how much energy an area will need over the long term. Having a future energy estimate helped the organisation they worked for place enough trench-laid ducting for future transformers when they were upgrading a depot's electricity grid. Cables can now be pulled through and connected to the transformers instead of unearthing infrastructure to do it. This foresight is likely to reduce time and costs when the fleet using that depot grows. This same expert also suggests making sure the correct technology is being installed for the short and long term. Their council spent a lot of time and money for extra civil works because they had to replace ducting that was too small.

In-house monitoring during the trials has also meant some operators have a better understanding of the energy outputs and, therefore, the range of the buses they will buy more of. For example, one operator has monitored their BEBs' performances in different terrains and in different seasons (with different use of air

[3] Formerly International Association of Public Transport Australia/New Zealand (UITPANZ)

conditioning/heating). Having done these trials already will mean they will be in a better position to know what routes they can serve with BEBs year-round, and how to schedule them.

For the earlier stages of transition, one service provider suggested figuring out which parts of the network and schedule create the most emissions to prioritise where to deploy zero-emission vehicles to maximise emissions reductions. This interviewee suggested figuring out where the most carbon or mileage is used by 'block' instead of route.

One PTA representative mentioned they consider where their depots need to be many years in advance. This foresight allows them to check with local power companies where there are expansion plans to decide where they want to put depots in.

3.3.3 Possible changes to ownership models

As discussed earlier, many interviewees raised concerns about contracting and ownership models. Some of our participants had suggestions to change the ownership models and tendering process to better suit transitioning to zero-emission technology.

One interviewee suggested that New Zealand would benefit from having a group of experts who could oversee and advise changes required over the course of contracts to assist operators and PTAs during the transition. Another suggested that they include 'quality' based metrics above cost considerations in contracts to ensure lifecycle environmental impacts are more heavily weighted.

Some interviewees suggested that PTAs could decide where depots are, where charging stations are installed, and pay for the upgrades to make it happen. PTA control means that whatever infrastructure is established will not need to be ripped out after the operator's lease on the depot land ends, and locations can match long-term bus service plans. However, one interviewee noted that council depot ownership could lead to the selling of depot land for other uses, which would push operations further out and lead to less efficient operations.

If PTAs provide 'buy back' options for electric vehicles, known as transferring assets provisions, this could benefit operators and PTAs. Operators will not have the risk of being unable to break even after buying zero-emission vehicles late into their contract. Additionally, PTAs could benefit because how much they pay in a contract is spread over the vehicles' lifespans instead of the upfront vehicle and infrastructure costs at the start of each contract period.

3.4 Reception from staff and the public

This section summarises how the electric vehicles were received by the public and staff. It is split up by vehicle type. The response has generally been positive for all vehicles.

3.4.1 Battery electric buses

Generally, the reception of BEBs was positive both from operators and the public. One operator said that drivers were 'hesitant' then 'pleasantly surprised' by the technology's capabilities and ease of operating. Drivers and passengers liked how quiet the buses were. Reduced noise and vibration are good for health and wellbeing. Drivers are especially affected by this because they spend so much time in the vehicles.

One operator noted that they were finding it difficult to retrain existing staff for electric vehicle maintenance (as it is 'extremely complex and dangerous work') and it was also difficult to recruit staff with such skills.

3.4.2 Auckland's hydrogen fuel cell bus trial

The first operators' initial reception of hydrogen technology was poor due to the delayed delivery of the refuelling infrastructure (discussed in section 3.1.4), but this challenge may be less likely in the future as the technology becomes more available and hydrogen supply chains develop in New Zealand.

3.4.3 Wellington electric ferry

According to our interviewee, customers enjoy riding in the electric ferry. The quiet engine 'comes as a surprise and then delight to many'. It isn't 'whisper quiet' but 'dead silent', which can feel like the boat is drifting unmoored until out of the speed restriction zone. He also mentioned a lot of positive feedback because the new build is 'pleasurable to sit in' but that this has as much to do with it being a new boat built to a high standard of presentation compared to older boats than being specifically related to the propulsion technology. The new electric ferry built by WEBBCo for East by West Ferries is shown in Figure 3.5.

Figure 3.5 Electric ferry built by WEBBCo for East by West Ferries (Source: East by West Ferries)

The skippers of the first ferry had a steeper learning curve to operate the boat than the operator expected as this boat has completely different challenges. This difference was attributed to the lightweight frame and much lower draft required to reduce drag. Light boats are more malleable to wind currents, which drastically alters the way drivers need to steer the ship and project power to speed and distance expectations. For the same reason, the skippers really enjoyed driving the ferry; the lightweight frame of the boat and the unexpected power behind the engine 'has delivered higher performance than other boats in the fleet'.

4 Conclusions and recommendations

There is now a relatively large amount of experience among PTAs, operators and vehicle builders in New Zealand. This will provide good opportunities for others who are starting the decarbonisation journey to learn and prepare. Most interviewees were very positive about their experiences and the future of zero-emission public transport in New Zealand. For example:

- Zero-emission public transport has been very well-received by the public and operators. Vehicles are quieter and have less vibration than conventional vehicles, which is pleasant for the public and a healthier working environment for drivers.
- Most interviewees were initially concerned about bus performance, battery life and/or range but generally found that the buses performed well. Good forward planning seems to have paid off in getting the right vehicles for the need. Wider industry concerns about range may be overstated due to media attention or outdated understanding of a rapidly changing technology.
- Options have expanded for BEBs that comply with VDAM axle weight requirements.
- There has been good sharing of experience, buses and expertise between PTAs.
- Fuel costs for electric vehicles are generally lower than for diesel vehicles and not as affected by fuel price fluctuations.
- There has been a lot of enthusiasm to make this transition, and good partnerships have led to good outcomes.

> *While we are still very early on in the journey, the commitment and enthusiasm to decarbonise the PT and ferry network shown by Auckland Council, Vector and other key stakeholders including ferry operators is refreshing and very collaborative.*
>
> *– Interviewee from Auckland Transport*

However, the transition is not without challenges or uncertainty. This research is intended to help other PTAs and operators plan for their zero-carbon transition with a clear understanding of the possible challenges and suggestions for tackling them.

The conclusions are split into three sections:

- Challenges and possible solutions
- Opportunities for the future
- General findings and recommendations from interviewees.

4.1 Challenges and possible solutions

We have identified several types of challenges that have been faced by organisations transitioning to zero-emission public transport. These challenges are shown in Table 4.1 along with some potential solutions that emerged from the interviews.

Table 4.1 Summary of challenges identified from the interviews and possible solutions for transitioning to zero-emission public transport

Challenge	Description	Solutions
Connection to power grid	The most common challenge raised by interviewees had to do with connecting to the electricity distribution network. These are the lines that distribute power across the city. The increased power draw from vehicle charging usually requires the distribution company (Vector, Powerco, etc) to upgrade their lines and/or transformers. This can be expensive, but the main challenge is scheduling the work. Distributors plan their upgrades years in advance and are reluctant to change those schedules. Interviewees reported a lack of urgency from power distributors and delays of months or even years for getting the necessary upgrades so they could use their equipment to its full potential. This can have a major impact on decarbonisation progress.	• Create a multi-year plan for which depots will be upgraded. • Coordination with distributor to align depot electrification plans with planned upgrades. • Cooperation between PTA and operator to persuade distributor.
Depot space constraints	BEBs with their charging infrastructure require approximately 20–25% more space in the depot than diesel buses. Many depots are already used to capacity, so electrification will require more depots. This can lead to increased operating costs due to more dead running time if new depots cannot be located as centrally as existing ones.	• PTAs may be better able to secure conveniently located depot space than operators. • Opportunity charging could reduce the amount of depot charging needed.
Service limitations and battery trade-offs	En-route charging infrastructure allows lighter batteries, which create less waste at end-of-life and allow more passengers within weight limits, but this restricts buses to routes where charging is available. Buses with larger batteries charged overnight can serve routes without charging infrastructure, but they are heavier, so they may not be able to take as many passengers or may have restrictions on what routes they service if overweight.	• Technology and bus designs are improving and may minimise this issue. • Some PTAs now specify no overweight buses. • Advanced planning of routes and future capacity needs is important for choosing a good mix of vehicles and charging (eg, aligning 10-min opportunity charging with required driver rest breaks).
Communication to the public	Politicians or media releases may announce trials to the public without an understanding of how bus scheduling is conducted and why. One PTA interviewee reported that there were times during trials where incorrect information was given to the public about which routes the buses would serve. This type of misunderstanding could create public relations issues or require additional vehicles to meet public expectations.	• Ensure consistent and simple communications.

Challenge	Description	Solutions
Hydrogen-specific challenges	Hydrogen fuel cell vehicle technology is not as advanced as electric vehicle technology, so there has only been one trial of a hydrogen fuel cell in a bus in New Zealand to date. Hydrogen buses have the potential for greater range and faster fuelling than BEBs, but delays to fuel infrastructure have meant very slow fuelling. Hydrogen fuel cell technology requires purity of hydrogen at 99.999%, but electrolyser plants in New Zealand can only verify purity at 99.995%, which may affect warranties from fuel cell suppliers. Hydrogen fuel cell buses also have similar space and power supply requirements as BEBs.	• Ensure fuel supply infrastructure will be available before getting vehicle.
Ferry-specific challenges	The electric ferries designed thus far (one in Wellington and two in Auckland) require lighter hulls with less draft than conventional vessels. The builders used lighter carbon composite hull construction to meet this need, rather than the more conventional aluminium. This reduces drag for greater range but has made the Wellington vessel more challenging to berth because it is more susceptible to wind and damage from hitting the wharf (Auckland electric ferries are not yet in operation). It was reported that it performed better than diesel ferries outside of berthing. Future adopters may face different constraints where this design decision is not required. However, without others to compare against, it would be prudent to assume this as a baseline until proven otherwise. It should be noted that this was not listed as a major concern by the operator. Power supply issues for electric ferries are similar to those for BEBs.	• Plan for additional training time for skippers before putting in service. • Investigate potential for redesign of wharf fendering to protect the vessel.

4.2 Opportunities for the future

Interviewees gave professional opinions about possible changes within the industry in the future:

- **Technology will continue to improve**. Technology and bus designs have been improving rapidly such that some earlier issues (eg, overweight vehicles, lack of air conditioning) are no longer problematic. Depot space and weight/capacity/range issues are expected to improve over time. Wider industry concerns about range may be overstated due to media attention or outdated understanding of a rapidly changing technology.
- **Transfer of asset agreements and/or PTA ownership** for depots, vehicles and/or charging infrastructure in contracts could reduce risk for operators, which should reduce contract costs for the PTA. It may also allow more coordinated planning of power, depot and vehicle infrastructure by ensuring continuity of operation.
- Better **realising second life of batteries** (future stationary use of batteries after they have deteriorated to be unusable in vehicles) will improve financial and environmental outcomes. There is currently no cost credit given for second life of batteries. This should be explored and quantified as it may help reduce the costs of the buses.

- **More public information on the life expectancy of batteries** and on how to optimise the use of the batteries and monitor their state through the life of the batteries would give operators more accurate depreciation rates for batteries. This could reduce costs as annual costs are based on a relatively short life of the batteries to offset risk to the operator from incomplete information.
- **Automated monitoring** technology will continue to improve and help operators make better use of and extend the life of their assets.

4.3 General findings and recommendations from interviewees

The following general findings and recommendations from interviewees can help other organisations prepare for their decarbonisation journey.

- **High-level strategic coordination is important.**
  - Charging approach (en route or overnight) affects battery weight, cost, bus capacity and depot infrastructure requirements and capacity, but choice of charging approach depends on long-term strategic goals, including route permanence and network configuration, which depend on future patronage estimates.
  - The PTA should conduct a study of its network to identify locations that would suit en-route charging. Considerations include timetables, likelihood of installing charging in a residential area, ability for buses to return to the charger, and distance travelled before returning.
  - Planning depot locations and power needs ahead can make it easier to coordinate with power distribution companies for network upgrades.
- **Collaboration is essential.**
  - Power distribution companies can help PTAs plan for upgrades. Early engagement with distributors can reduce costs and avoid delays by aligning with planned works.
  - PTAs working with operators can help convince power distribution companies to prioritise upgrades as they may have more influence.
  - Information sharing between PTAs and operators builds trusted relationships and creates a positive feedback loop of information flow.
  - Inter-agency cooperation is beneficial for sharing experiences and tips. There seem to be a lot of perceptions of challenges that are either exaggerated or based on outdated information. It will be helpful to engage with people who have been actively involved in the transition of the fleet at other PTAs to sort fact from fiction.
- **PTAs can specify in tenders that operators must include a decarbonisation plan** over the course of their contract to ensure investment in the technology and a plan that best fits with the needs of the region.
- There is a need to be careful with funding to **ensure that operators are not subsidised into gaining an unfair competitive advantage** over other suppliers. Subsidies should include some buy back or agreement to transfer subsidised infrastructure to another operator if the incumbent does not win the next contract.
- Furthermore, many interviewees suggested that it could be useful for some PTAs to **include transfer of asset agreements in any future tender**. This helps operators offset the risk of stranded assets and allows for longer-term investments in vehicles and infrastructure.

- Interviewees suggested that **government could provide direction to power distribution companies to prioritise public transport** by:
  - prioritising infrastructure upgrades to depots
  - prioritising depots for reinstating power during outages and specifying the level of resilience required
  - ensuring that depots get first right of access to electricity for charging vehicles.

Simon Hoyle, Southlight for WEBB

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Appendix A: Document review

Although this research did not include a full literature review, we completed a high-level review to find any documentation of New Zealand zero-emission public transport trials. The widespread adoption of zero-emission public transport vehicles is in its early stages, so there is a limited amount of New Zealand literature available. Research into zero-emission public transport has not previously been carried out as part of the research programme of Waka Kotahi or its predecessor Transit New Zealand.

Several media and industry association articles have been published about zero-emission public transport trials in New Zealand, but nowhere have they been synthesised and shared in one report. The following documents have been reviewed with key findings summarised below.

A.1 Vector/Auckland Transport PowerPoint

Auckland Transport engaged WSP to produce a report and tool to show the expected electrical demand per depot. This was then used to work with Vector to help understand the energy and infrastructure requirements. Vector used this information to:

- provide high-level costs and infrastructure requirements
- provide energy costs and charging times
- confirm the requirement that buses need to be charged during non-peak times to avoid surcharges and peak rates.

A.2 Trials

Table A.1 provides a summary of several New Zealand zero-emission public transport trials and rollouts described in the literature, including several profiles published in Bus & Coach Association New Zealand’s *Circular* magazine. The table includes details about the scale of the trial, date, location, organisations involved and some challenges that had been raised in the literature. This is not a comprehensive list of trials or rollouts that have been completed to date, and some of the challenges, especially for the older trials, may no longer be an issue. Many of these trials have since increased their fleets. In addition to those listed below, BEBs are also operating in Christchurch and Tauranga; one electric ferry is operating in Wellington, with more planned in Auckland; and additional BEBs are operating in Auckland and Wellington. See section 1.4 for more details of the number of zero-emission buses currently operating in each region and expected fleet growth through 2024.

Table A.1 Zero-emission public transport trial details

Trial details	Funding, ownership and operators	Bus specifications and distributor	Challenges	Other information	Reference
Route/s: Auckland CBD to outer city connector (Mahu City Express). One bus as of April 2021, progressively transitioning to a fully electric fleet.	Purchased by Mahu City Express and co-funded by EECA and the JW Group.	Luxury, BEB. Built by Chinese company Yutong.	The pandemic caused delays in importing the charger. Delays were caused waiting for permits due to large workloads at Waka Kotahi.	Mahu City Express employed the JW Group to conduct maintenance on their buses and help with rollout. Mahu City Express saw this as an asset. As a luxury service provider they had a marketing benefit from moving to zero emissions. They noted much lower maintenance costs.	Bus & Coach Association New Zealand (2021b)
Route/s: Number '70' in Auckland; Botany to Britomart via Panmure. One bus as of May 2021.	Auckland Transport commissioned the bus, and Howick and Eastern buses (Transdev) operated it.	Hydrogen fuel cell bus. Built and designed in New Zealand by Global Bus Ventures (GBV). The article suggests 30 kg of fuel gets the bus to a range of 400 km, but this is not confirmed. The fuel (30 kg) is stored in four tanks on the bus's roof, which feeds into the battery.	Due to the pandemic, GBV did not have access to overseas fuel cell manufacturers. Therefore, the company had to spend a lot of time upskilling themselves to build and maintain a hydrogen fuel cell bus. Tanks should take 10 minutes to refill. This was not possible because of a delay with the refuelling infrastructure. This is discussed in more detail in the interviews section of the report.	GBV built everything in New Zealand, which may be good for the New Zealand economy. As GBV is a New Zealand company, the bus was built to New Zealand standards, so special permits were not required.	Bus & Coach Association New Zealand (2021c)
Route/s: varied in Palmerston North. One bus in 2021.	Purchased and operated by Tranzit. Co-funded by EECA.	BEB. Charged once overnight and again during the middle of the day (off-peak). Average 220 km/day, with an operational time up to 10 hours/day.	No challenges were reported.	N/A	Internal documentation received by steering group

Trial details	Funding, ownership and operators	Bus specifications and distributor	Challenges	Other information	Reference
Route/s: multiple in Dunedin. One bus was trialled between 28 September and 29 October 2021. Purpose was to trial BEBs in the hilly Dunedin context.	Purchased and operated by GoBus for Otago Regional Council. Co-funded by EECA.	BEB. 35-seat, 2-axle Enviroline 200 bus. The bus was built in New Zealand to New Zealand weight standards by GBV. It was 3 tonnes lighter than standard BEBs purchased from overseas. The operators used a portable charger during the trial. Permanent charging infrastructure was not installed for the trial, therefore challenges regarding charging infrastructure were not covered.	Although the BEB was within New Zealand weight guidelines, it was too heavy to drive across four bridges in Dunedin. Fortunately, none of the routes GoBus operates on used the bridges. No other issues raised.	GoBus was worried about the range, how well the vehicles would perform on the hilly routes, and wider turning circles due to a wider wheelbase. None of these concerns manifested or caused issues; a full-day service only used 40–50% of the battery range. Buses performed well on the hills (partly due to regenerative breaking), and the drivers were able to mitigate the effects of the wheelbase through 'careful driver training and precise driving' (p. 43). GBV was able to 'provide detail on battery consumption relative to the Dunedin topography, and insight into other operational variables' (p. 44). This allowed GoBus to collect data on how well BEBs could work on hilly terrain. This trial had a large focus on educating and interacting with the public about the BEB. Outreach included an online survey, social media posts and free rides at the museum. Public response was positive.	Otago Regional Council Electric Bus Report (Documentation provided by steering group member)
Route/s: The fleet servicing Waiheke Island. Six buses at time of publication, with two more to join in December 2020.	Purchased by Fullers360 and operated by Waiheke Bus Company.	BEBs that carry 37 passengers each. 400 km range. Overnight charging. Distributor – not mentioned explicitly.	None mentioned.	The rest of the fleet (nine diesel buses) will be replaced by BEBs when they reach end-of-life.	Bus & Coach Association New Zealand (2020)

Trial details	Funding, ownership and operators	Bus specifications and distributor	Challenges	Other information	Reference
Route/s: varied within the Wellington context. 10 buses as of 2019.	Purchased and operated by Tranzit for Wellington Regional Council.	Double decker BEBs. Two axles, no air conditioning. Batteries have capacities between 109 and 161 kWh. 80-passenger capacity each. Fast chargers in different depots with plans to install en-route charging stations. The en-route chargers will (hopefully) increase the buses' ranges to 250 km per day, to be utilised for 20 hours per day. 120 km range currently; the buses were only deployed at peak times and/or short routes at time of report.	Grid capacity and planning charging times. At publication time, the capacity at the Rongotai Depot was at a maximum, but they believe they could double the number of BEBs that are charged there by staggering charging times. Having en-route bus charging locks in routes, or will incur costs to re-locate them in different areas.	The landscape will also be considered when choosing routes for the electric fleet to take advantage of regenerative braking.	Jake Roos Consulting Ltd (2019)

Trial details	Funding, ownership and operators	Bus specifications and distributor	Challenges	Other information	Reference
Route/s: Initially, just the CityLink service in Auckland for six months. Coverage expanded to the 380 Airporter and InnerLink. The third bus serviced the 380 Airporter and 309 routes. Two buses were lent to GoBus to trial in April 2018.	The first two were purchased by Auckland Transport and leased to NZ Bus to operate. NZ Bus paid for the operating costs, and Auckland Transport paid for insurance and maintenance costs. The third was lent to Auckland Transport.	BEBs. Overnight charging. Buses could complete a full day of service on one charge, so additional charging infrastructure wasn't needed. The first two buses were purchased from British distributer Alexander Dennis Limited. The third was borrowed from Yutong to trial. An overweight permit was needed for all of them.	The charging interfaces tripped regularly due to the New Zealand specific requirement to have type B residual current devices installed in electronics. One solution they found was installing additional software into the electric vehicle. This solution stopped tripping a lot of the time. Additionally, a filter was installed in one charging interface that stopped tripping events entirely. A 70 km/h limit was placed on the buses due to being overweight. This limit initially stopped them from being used on the 380 Airporter services. Permission was granted to increase max speed to 80 km/h. Bus driver shortage and limited training halted the use of the buses in the beginning.	No training beyond the standard training for any new bus was required of bus drivers except on regenerative braking. Operating costs for the BEBs were a lot less than for diesel buses.	Auckland Transport (2018, 2020)
Route/s: Bus for Auckland University of Technology (AUT) services in Auckland. One bus was delivered in March 2018 and put in service that year.	Purchased and operated by Tranzit. Co-funded by EECA. AUT was involved in the trial but did not co-fund.	BEB. Overnight charging. 35-seater bus. The body was built by Kiwi Bus Builders. The electric engine and chassis were built by Times Electric Group in China.	The compressor was louder than expected as a diesel engine usually drowns the sound out. This issue was fixed on later iterations of buses in Auckland (not on the AUT route). The trial faced challenges with the charging infrastructure; exact details were omitted.	A key finding was that the kW/km were difficult to predict as differences in driving create big variability for power consumption.	AUT (2018) and internal documentation received by steering group