National Transport Commission

Electric bus evaluation

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Acknowledgements

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A special thank you to all the Governments who participated in our targeted process and policy discussions and to the manufacturers Custom Denning and Volgren, and bus operators Kinetic, Transit Systems and ComfortDelGro Corporation who generously gave their time to discuss electric bus trials and tour onsite.

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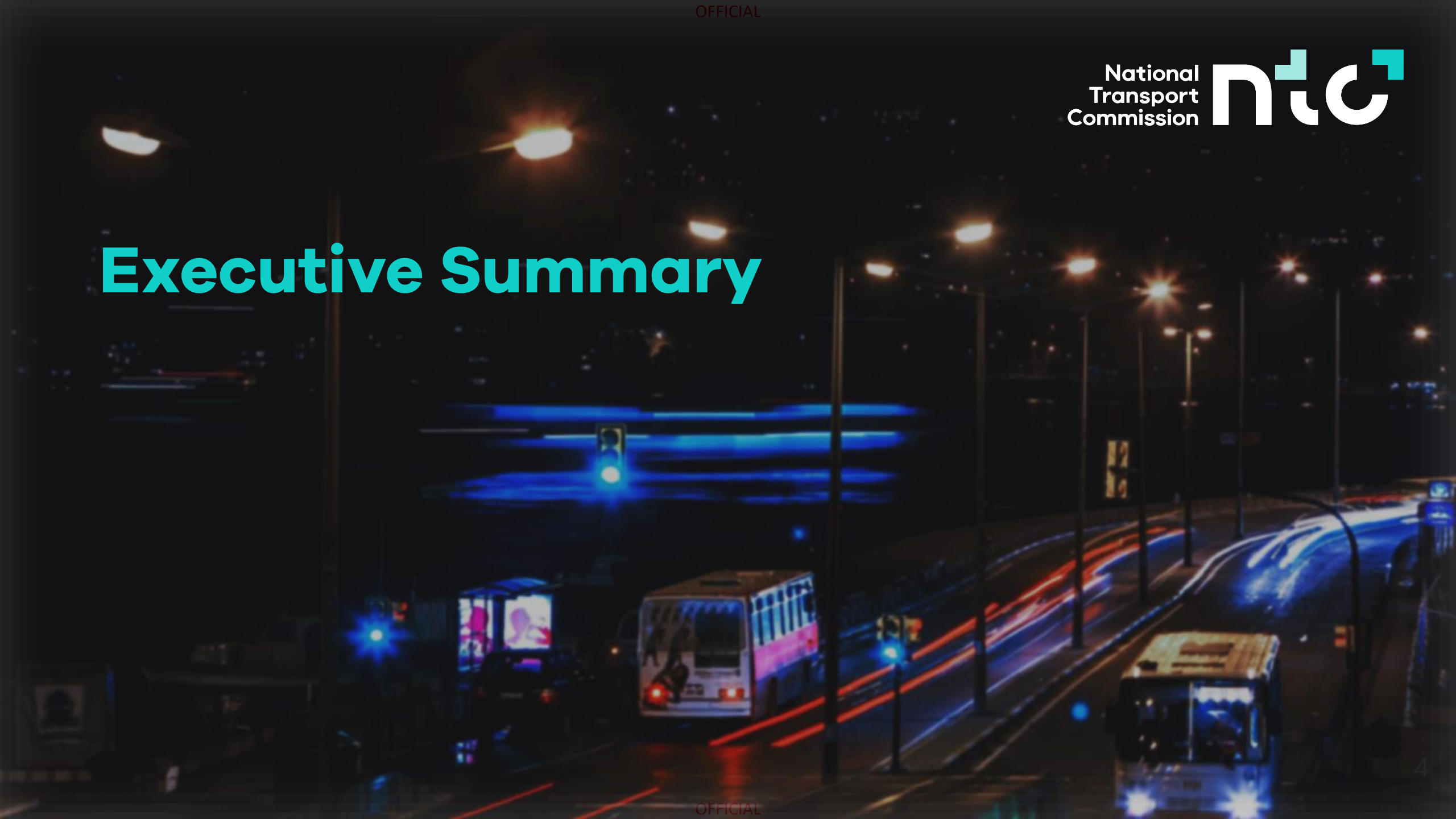


Executive Summary

Background

Jurisdictions across Australia have shown support for an electrified transport system. While States and Territories have various programs to increase the usage of zero emission (powered by renewable energy) buses over the coming years, their focus is on implementation. The NTC, as a national organisation, is uniquely placed to assist jurisdictions focused on delivery improve outcomes by sharing lessons learned.

Purpose

The purpose of this report is to provide and support Transport Ministers in future strategic decisions and investments in zero emission (electric) buses. As well as provide a summary of learnings on:

- The benefits, costs, and reported impacts of electric buses
- Possible ways to fund and finance electric bus services
- Regulatory frameworks incentivising the adoption of electric buses
- Challenges encountered in transitioning diesel bus fleets to electric buses
- Key steps governments and their agencies have taken to ensure success in adopting electric buses

Method and approach

Consultations sought the opinion of key transport agencies, local governments, operators, and suppliers working across the bus trials, operations, depot and electric supply development (for further information regarding the approach please refer to the Appendix). This allowed for a comprehensive discussion of the investment progression, the challenges and opportunities which the zero emission bus investment presents, and potential regulatory/ policy development to assist industry to drive the adoption of electric buses and develop the skills and growth in manufacturing.

Key factors that governments and their agencies have taken to ensure success

Australia is behind many other advanced and emerging economies in electric bus uptake. This is partly due to constrained supplies, a lack of national policy to encourage suppliers/ manufacturers to send more/ build more electric buses in Australia, and a shortage of high skilled electric bus workforce.

The number of electric buses is growing as jurisdictions trial electric bus technology. Jurisdictions that have progressed the furthest, have a defined timetable/ plan to achieve full electrification of their bus fleets.

The report identifies the key challenges and learnings identified through the consultations. The challenges encountered in transitioning bus fleets to zero emission buses can be managed through policy reform, planning, investment and upskilling and creating jobs. In summary, there are five key factors to ensure the successful of electric bus implementation:

1. **Develop regulatory frameworks and policy.** In Australia, clear targets have been established to achieve net zero emissions by 2050, including all future bus purchases to be electric. To accelerate uptake, the report also considers other regulatory reforms such as increasing vehicle dimension and axle loads, emission standards and national targets as well as charging infrastructure standards to assist the drive the adoption of electric buses.
2. **Funding programs and grants.** The high cost of an electric bus has in the past deterred the uptake of electric buses. Funding programs, grants, leasing models have been an important step in the uptake of electric buses. Advancing states in the uptake of electric buses have financial support from their local governments and green initiatives. The funding helps with the delivery of an electric bus network, upgrades to depots and the installation charging infrastructure.
3. **Planning for success.** To mitigate the risks and manage the transition, it is vital to have a scalable plan on how to deliver infrastructure in a least disruptive manner and securing energy supply infrastructure. The report lists several considerations including the type of technology considered, the charging infrastructure, the locations of charging equipment, energy supply and safety considerations.
4. **Invest in education, create jobs and grow manufacturing.** A push for electric buses is also a push for competitiveness, jobs and growth. The transition to electric buses presents an opportunity to upskill and develop new jobs in public transport, as well as help Australia transition to a cleaner, greener future as carbon emissions reduce and air quality improves.
5. **National coordination.** Lessons learned from countries with high uptake of electric buses have a developed national/ centralised plans covering national standards, and long-term strategic infrastructure planning. This includes setting emission standards and targets as well as charging infrastructure standards to ensure interoperability.

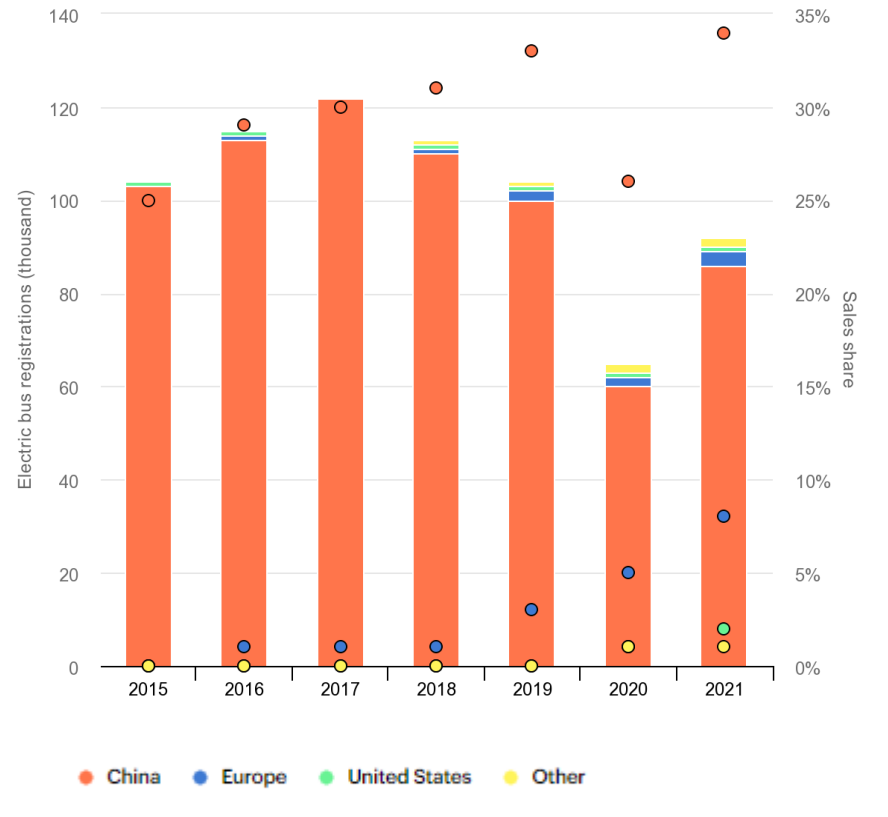
National Transport Commission

The state of play in Australia

The adoption of electric buses is growing globally

The adoption of electric buses in public transport is growing, with strong growth in Asia Pacific, America, and recent years Europe. China continues to dominates the market and deploys roughly 98 per cent of the electric buses in the world. The demand in Europe and America have increased and have recently accelerated their uptake in electric buses, with several countries and cities committing to having a fully electric bus fleet as part of their national decarbonisation strategies (refer to table below). Australia is behind many other advanced and emerging economies in electric bus uptake with only 0.2% bus^1 fleet and is slowly progressing as jurisdictions trial electric bus technology.

Electric bus registrations and sales shares by region, 2015-2021



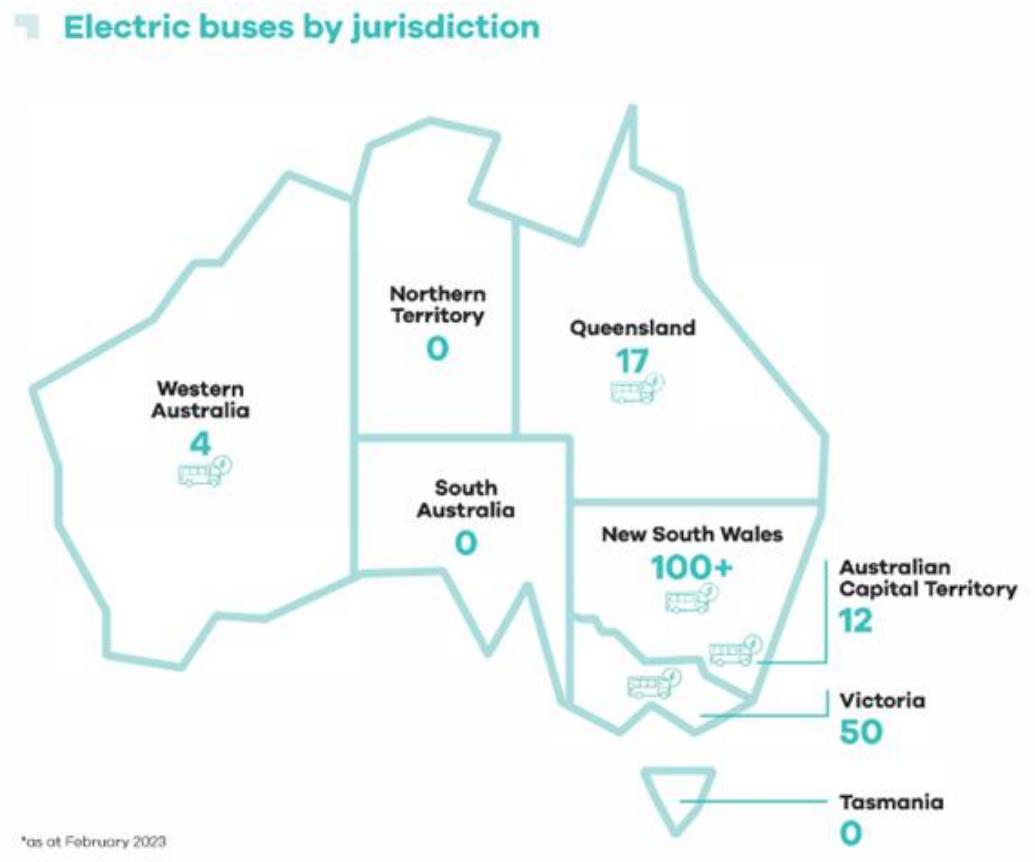
Source: Global EV Outlook 2022

Country/ City/ State	Target year (100% zero-emission bus fleet)	Source (publication year)
Denmark	2030	Climate and Air Plan (2018)
The Netherlands	2030	Mission Zero (2019)
New Zealand	2035	Government announcement (2021)
California (United States)	2040	Innovative Clean Transit (ICT) regulation (2018)
Austria	Not specified	Mobility Master Plan (2021)
Cape Verde	2050	Electric Mobility Policy Charter (2019)
Chile	Not specified	National Electromobility Strategy (2021)
Colombia	Not specified	National law on electromobility (2019)
Costa Rica	2050	Decarbonization Plan (2019)
California, Colorado, Connecticut, Hawaii, Maine, Maryland, Massachusetts, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, and the District of Columbia	Not specified	Memorandum of Understanding (2020)
Austria, Canada, Chile, Denmark, Finland, Luxembourg, Netherlands, New Zealand, Norway, Scotland, Switzerland, Turkey, United Kingdom, Uruguay, Wales	Not specified	Memorandum of Understanding (2021)

1. The Australia Institute, Stuck in the slow lane, Electrification of buses in Australia, February 2023

The state of play in Australia

Across Australia jurisdictions have shown support for an electrified transport system and are either planning for or committed to transition their bus fleets to zero emissions (electric buses powered by renewable energy), as part of state-based interim zero emission goals for 2030 and a broader national net zero emissions commitment goal for 2050. Jurisdictions that have progressed the furthest, have a defined timetable/ plan to achieve full electrification of their bus fleets. With the support of governments, many private operators have also invested and plan to fully transition their diesel fleet to electric.



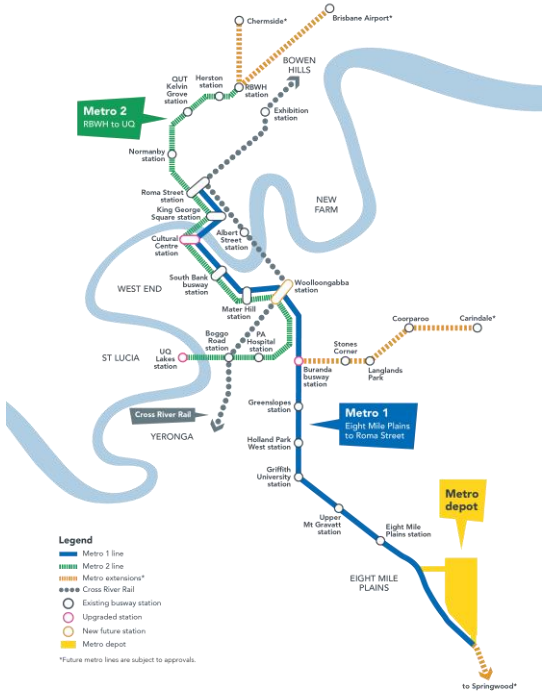
State	Government commitment
Australian Capital Territory	Electrify the entire bus fleet with a zero emissions public transport system by 2040
New South Wales	Electrify the entire fleet of over 8000 buses. The transition delivers on the NSW Government's commitment to achieve net zero emissions by 2050.
Northern Territory	The NT EV Strategy and Implementation Plan includes an action to investigate the feasibility of trialling low and zero emission buses in the NT urban fleet and this work is currently underway.
Queensland	From 2025 ageing diesel buses will be replaced with zero-emission buses. The government has vowed to build its next fleet of electric buses in Queensland. Some buses are currently being built on the Gold Coast and in Brisbane.
South Australia	Plan to trial two hydrogen fuel cell buses.
Tasmania	The Tasmanian Government has pledged to transition its entire fleet to battery-electric, plug-in hybrid and hydrogen vehicles by 2030. An initiative for emission-free buses is also underway to determine whether hydrogen or electricity is more appropriate.
Western Australia	Western Australia has committed $250 million. The $250 million program will deliver 130 new locally-built electric buses and charging infrastructure at key depots.
Victoria	From 2025 ageing diesel buses will be replaced with zero-emission buses. 4,000 public diesel buses will transition to zero emissions.

The state of play in Australia

The table below illustrates the programs and governments fundings in place to electrify infrastructure, upgrade depots and invest in electric buses.

State/ Territory	Program(s)	Funding	Bus ownership
Australian Capital Territory	The Zero-Emission Transition Plan for Transport Canberra outlines the pathway to achieve the ACT Government's ambition of zero-emission public transport system by 2040. The Plan will see the Government replace ageing diesel and CNG buses with battery electric buses powered with the ACT's 100% renewable electricity. This will be timed with plans for new bus depots with electric charging infrastructure to support the growing fleet of zero-emissions buses. Currently there are 12 electric buses (leased) on the road with 94 (battery) electric buses under procurement and expected delivery in the next three years. The procurement is released as three packages so that industry can offer solutions which incorporate both buses and charging infrastructure. Industry can bid for one, two or all three of the packages. The ACT Government has signed a contract with Vehicle Dealers International (VDI) to buy 90 Yutong 'E12' battery electric buses and is currently in negotiation with Custom Denning to procure four 'Element' battery electric buses including charging infrastructure.	The ACT Government will invest $26.3 million over three financial years to complete critical electrical infrastructure works to supply the depots with the energy required to house and charge up to 300 battery electric buses.	Transport Canberra buses are government owned, operated, managed and maintained. Transport Canberra directly employs all executive, administrative staff, bus drivers, transport officers and workshop mechanics in its bus operations. The ACT Government owns the bus fleet and bus depots and is responsible for delivering public transport infrastructure including terminals and layovers.
New South Wales	The Government is operating Australia's largest Zero Emission Bus fleet, with more than 100 buses currently in service. Under the Zero Emission Buses Transition Plan, the transition will be complete in Greater Sydney by 2035, in Outer Metropolitan regions by 2040, and in Regional NSW by 2047. The first stage of the transition will begin in 2023 and will introduce 1,200 new electric buses for Greater Sydney customers by 2028. As part of the first stage, 11 existing bus depots will be upgraded to support the new fleet and a new bus depot will be built in Macquarie Park. The electric buses comprise from a range of approved manufacturers on TfNSW Bus Panel.	The NSW Government has an approved budget of $3 billion to fund the next stage of Zero Emission Buses (ZEBS) and new charging infrastructure. This investment includes : • $84 million to enable transition planning, including electrical grid upgrades at 11 bus depots. • $218.9 million over the next seven years to support the bus fleet move to zero emissions technology and the rollout plan which will prioritise sustainability and local manufacturing. • $25 million over three years for regional trials in new and emerging technologies, including hydrogen fuel cell electric buses.	Transport for NSW is responsible for regulating public and private bus services across the state. Transport for NSW set routes, fares, service levels, fleet specifications and customer service standards.

The state of play in Australia

State/ Territory	Program(s)	Funding	Bus ownership
Northern Territory	Under further assessment		Privately owned
Queensland	Electric buses were trialled between 2020 – 2022. The trial confirmed battery electric technology is suitable for the public transport network and will be charged by renewable energy. The program is in the planning stage, currently the Queensland government are: • consulting industry and other key stakeholders in early 2023 • considering how to develop a sustainable pipeline of local manufacturing • understanding the infrastructure required for a zero emission ecosystem • investigating other technologies such as hydrogen fuel cells for future stages • engaging with the community **Brisbane City Council** • Currently constructing an electric charging depot • four are electric buses and plans to increase to more than 60 late 2024. **Redlands City Council** • 17 electric buses under procurement. The buses will be made by Volgren at Eagle Farm. Each bus built will support five jobs. **Logan City Council** has also placed orders.	The new 17 electric buses (Redlands City Council) form part of the Government's almost $3.9 billion road and transport plan for Greater Brisbane over the next four years. 	Government and privately owned. Translink a division of the Department of Transport and Main Roads is responsible for buses across South East Queensland.
South Australia	The South Australian government has announced a two-year hydrogen bus trial. The trial includes two hydrogen fuel-cell buses set to be deployed on routes across Adelaide from late August 2023 at the Morphettville bus depot.		Government owned

The state of play in Australia

State/ Territory	Program(s)	Funding	Bus ownership
Tasmania	Tasmania is 100% self-sufficient in renewable electricity. The emissions-free electricity will be used to power the battery electric bused (BEB). The Tasmanian Government is also promoting the State as a major potential producer and exporter of green hydrogen. With funding provided by the Tasmanian Government, Metro's Fuel Cell Electric Bus (FCEB) trial will kick-start this emerging industry as Tasmania's first project using green hydrogen. Metro Tasmania's Zero Emission Bus (ZEB) trial consists of two sub-trials of different ZEB technologies. 1. Battery Electric Bus Trial (Launceston): Up to three Battery Electric Buses (BEBs) will operate on a wide range of existing Metro routes for two years, commencing in late 2023. 2. Fuel Cell Electric Bus Trial (Hobart): Up to three Fuel Cell Electric Buses (FCEBs) will operate on a wide range of existing Metro routes for three years, commencing in early 2024. Kinetic has two brand new fully electric buses into its Tasmanian network (part of the SkyBus service connecting passengers between Hobart Airport and the city).	The Tasmanian Government is funding the trial through Renewables, Climate and Future Industries Tasmania. The Tasmanian Government plan to achieve net zero emissions by 2030. The Tasmanian Government has allocated $6 million for Metro to conduct the BEB trial and approved up to $12.3 million from the Tasmanian Renewable Hydrogen Industry Development Funding Program to progress recommendations from an Industry Activation Study, which includes the FCEB trial. Metro has released a Request for Expressions of Interest for the supply of the buses and associated recharging and refuelling equipment, and specialist maintenance services. The Expressions of Interest period will close on 30 May 2022.	Government and private owned. Metro Tasmania Pty Ltd is a state owned company established in February 1998. The company trades as Metro and operates bus services in Hobart, Launceston and Burnie. We are the largest Tasmanian-owned public transport company. Kinetic hold a long-term contract and is the largest private company in Tasmania. In 2018 Kinetic launched the SkyBus at Hobart Airport. Since then, the company has added Redline Coaches, MerseyLink, Saintys, East Tamar and O'Driscoll Coaches to its network.
Western Australia	Four battery electric buses supplied by Volvo was rolled out in March 2022 in Joondalup as part of a larger trial. The trial vehicles was supplied by Volvo through its existing bus supply agreement, with the cost of a Volvo electric bus at the current Transperth specification estimated at $1 million per vehicle. As part of the rollout trial of battery electric buses, modifications have also been made to the Joondalup bus depot including the installation of a high-voltage electric vehicle charging system along with a 100kW solar power array connected to a large on-site battery storage system. Volvo has committed to producing any future electric buses locally at the Volgren facility in Malaga if the trial should be successful, supporting local jobs and apprenticeships. The first locally manufactured buses will be in use in 2024 - 2025 in the Perth CBD and Perth metropolitan region. 130 new electric buses will be built. This will create over 100 new jobs and more than 300 existing workers (diesel) will be upskilled and transition to new roles using the new technology.	In the 2022-23 Federal Budget, $125 million out of $670 million infrastructure budget for Western Australia, will go towards electric bus charging infrastructure, which will also be funded by the WA Government through the local manufacture of 130 new buses. The funding will help deliver a new electric bus network for Perth through upgrades to bus depots and the installation of appropriate charging infrastructure. Western Australia has committed $250 million. The $250 million program will deliver 130 new locally-built electric buses and charging infrastructure at key depots.	Government owned and privately operated. Transperth provides the Perth metropolitan region with bus services and partner with businesses to run the bus services. Partners include Swan Transit, Path Transit and Transdev.

The state of play in Australia

State/ Territory	Program(s)	Funding	Bus ownership
Victoria	The Victorian Government pledged all new buses from 2025 will be zero emissions. As part of the zero emissions bus trials, 6 Victorian bus companies have been selected to trial 2 hydrogen and 50 electric buses across existing routes in Melbourne. The first trial was in August 2022 the remainder of buses rolling out progressively over the next three years. From 2025 Victoria will transition roughly 4500 publicly contracted diesel buses to ZEBs. **Donric** • Donric has introduced 3 new electric buses on existing routes using solid-state lithium metal polymer (LMP) batteries rather than the more common lithium-ion batteries used in other electric vehicles. **ComfortDelGro Corporation Australia's (CDC)** • has commenced its Zero Emissions Bus in partnership with the Victorian Department of Transport and industry leaders. 8 electric buses on trial in Melbourne's south-eastern suburbs. • The trial will use Volvo-Volgren battery-electric buses in the eastern states following their successful rollout in Western Australia. • Under a green loan arrangement, CDC WILL replace 50 diesel buses with the Volvo Euro 6 hybrid vehicles, of which over 30 hybrid buses are already in operation. **Kinetic** • Over the next 3 years, the Victorian Government and Kinetic Melbourne will introduce 36 new Zero Emission Buses to the public transport network. The buses will be built in Victoria, creating more than 60 jobs. Kinetic will also replace 341 of the current fleet's 531 buses with zero or low emission vehicles over the 9.5-year franchise. **Ventura** • Working in partnership with the Victorian Department of Transport, one of the depots will be transformed to operate only Zero Emission Buses. • The electric bus depot will be charge 27 buses in Melbourne's north by early 2024 as part of the Victorian Government's Zero Emissions Bus Trial. • Ventura will install 15 charging units to power the electric buses at its converted depot, with its first 12 electric trial buses due to enter the network in early 2023. • By early 2024, all 27 electric buses will be operating on nine routes across the northern suburbs. **Seymour Passenger Services** • In regional Victoria 3 electric buses are on trial providing the first completely electric town bus network. **Latrobe Valley Bus Lines** • 1 electric bus trial	The Victorian Government has invested $20 million (2020-21 Victorian State Budget) to undertake research, planning and trials of zero emission bus technology. Learnings from the trials will be shared across manufacturers, operators, government and others to inform the procurement of only zero emission buses from 2025.	Government and Privately owned Most buses and depots are privately owned by bus operator and operate under state contracts. • Procurement of buses and depot infrastructure is operator-led with minimal specification • The state finances the assets via monthly payments over the asset's lifespan

NTC electric bus evaluation

The state of play in Australia

Net zero bus emissions is slowly progressing towards the broader national net zero emissions commitment goal for 2050

The uptake of electric buses and the reduction of emissions takes time and careful consideration. Countries and cities that have a high uptake of electric buses started their electric journey many years ago, with Shenzhen China the world's first and largest fully electric bus (around 17,000 buses) and taxi fleet electrified in 2017.

Shenzhen started its journey in 2009 and converted to a fully electric fleet in several stages. Shenzhen electrified its whole bus fleet over eight years from 2009 to 2017:

- a demonstration stage in 2009-2011
- small pilots from 2012-2015
- large-scale electrification from 2016-2017

Cities that have converted to fully electrification or close to full electrification have done so over a period of roughly 10 years, with significant funding from the government or government incentive programs.

In Australia, Governments are slowly progressing towards a net zero bus network. It is unlikely Governments will meet their interim net zero bus emissions goals by 2030 but can achieve net zero bus emissions by 2050. Consequently, those with aggressive plans have revised their initial targets and plans to achieve a sustainable transition.

Expediting projects to meet interim goals may not be feasible and could be risky for the following reasons:

- **Scaling up too quickly.** Electric buses will be prone to issues such as delays and cost overruns, as well as equipment failures.
- **High demand, high price.** If demand is expanded beyond the capacity of the supply chain, this will drive up the cost of infrastructure upgrades and the buses.
- **Redundancy cliff.** A surge in procurement could also result in a redundancy cliff edge as no buses will be required for years as the average life of a bus in Australia is around 15 – 20 years*.
- **Natural attrition is financially a better option.** A significant amount of energy is required to make buses. To minimise the impact of production and cost, it is recommended that we gradually transition to electric buses and replace old diesel buses at the end of their useful lives.
- A few governments have also investigated diesel to electric bus conversions. However, the conversions were not implemented as conversions are not economically viable and the latest technology would not be used. Electric buses are now lighter and can run further distances of up to 100-200km longer than the trial models.

Reaching Australia's pathway to net zero involves significant investment both in time and financial resources. Partnerships, Programs and commitments such as the Zero-Emission Government Fleet and Driving the Nation Program will also ensure the net zero bus emissions is on track for 2050.

The key risks to achieving net zero bus emissions targets

1. **The lack of national policy to encourage suppliers/ manufacturers to send more/ build more electric buses in Australia.** Local manufacturers have the capacity to increase their production significantly, however, are not willing to do so without confidence in the ongoing level of demand. Increasing capacity involves heavy investment in production facilities and increased labour. Without planned purchases and industry/ job security, it is unlikely manufacturers will scale up to increase production capacity.
2. **Skill shortages.** There is a shortage of on the ground expertise, including electrical engineers. If the charging equipment or an electric bus fails, it could take up to a month, if not longer to be resolved. In some cases, an engineer from overseas is required to fly out, review and fix the issue as there is a limited number of local knowledgeable engineers.
3. **Constrained supplies.** A procured electric bus can take up to 12 months to be built and delivered to Australia. Suppliers are prioritising the sell and supply of electric buses and equipment/ parts to larger demand markets such as Europe over Australia and delaying shipment. It is likely international purchases are required to achieve ambitious targets.
4. **Challenging depot and infrastructure upgrades.** Upgrading electricity transmission and distribution networks to cope with the increased demand imposed by charging significant numbers of buses is challenging. Depot infrastructure will need to be upgraded and expanded, as storing and charging electric buses requires additional space. In some cases, the depot will need to be relocated as upgrading the existing depot is not feasible. The electric supply may not be sufficient at the current depot to supply a fleet of buses or too close to residential homes or enough space to build dedicated electrical feeders or hydrogen generators to fully supply the fleet of electric buses with enough energy.

* Based on the life of diesel buses currently in operation, this may differ for electric buses

The state of play in Australia

Most electric buses in Australia are battery run, but it's too early to rule out hydrogen fuel cell buses

Hydrogen fuel cell buses refuel at a faster rate than battery electric buses. Medium to large scale hydrogen fuel cell bus deployments can be fully refuelled in around 8-10 minutes, compared to battery electric $buses$[1], which can take on average 3-5 hours if not longer (plug-in) charging at the depot. The biggest advantage of this technology is the longer range, allowing normal daily public transport bus operations with no intermediate refuelling stops. Despite the advantage, the number of hydrogen fuel cell buses in Australia is minimal. Unresolved issues around hydrogen production and supply have deterred the use and uptake of hydrogen fuel cell buses in past. Operators are not keen to purchase hydrogen fuel cell buses, as producing the fuel and charging hydrogen fuel cell buses is perceived as complicated and dangerous compared to fuelling battery run buses.

However, this view is likely to change in the coming years as the Australian Government invests in hydrogen charging infrastructure, and planned hydrogen fuel cell bus trials emerge. The Australian Government is currently partnering with states and territories to create a national green hydrogen highway refuelling $network$[2] on Australia's busiest freight routes. As the Australian Government support de-risks investments and kick-starts hydrogen transport uptake, and jurisdictions become familiar with the new technology, it is likely the number of hydrogen fuel cell buses will increase.

The uptake of hydrogen fuel cell buses is low as the supporting hydrogen supply chain is in its infancy. Hydrogen fuel cell bus trials have been delayed due to hydrogen tank supply issues and building the infrastructure to be able to charge the buses. In general, the costs to produce and operate hydrogen fuel cell buses is higher than costs to build and run electric battery buses. The price is roughly up to 20% higher than an equivalent battery electric bus.

The uptake world-wide is also low compared to the battery run buses. However, uptake is slowly increasing with many global cities and states announced or announcing the roll-out of hydrogen fuel cell fleets including California, USA, London, UK, Cologne and Frankfurt-Höchst Germany and Groeningen and Drenthe in the Netherlands. Hydrogen fuel trials are also emerging across Australia.

Australian hydrogen fuel cell bus trials

- **Melbourne, Victoria.** Multinational operator Transit systems has taken the lead and has brought learnings from their overseas operations to Australia. Transit systems operate ten hydrogen fuel cell buses in London. Transit systems plan to deploy two hydrogen fuel cell buses in the western suburbs in Melbourne. There has been delays in starting the project due to hydrogen tank supply issues and is now expected to operate from June 2023.
- **Central Coast, New South Wales.** The first hydrogen fuel cell bus in NSW, started late 2022 in Central Coast. The project is a partnership with the Department of Planning and Environment, local bus manufacturer ARCC, Central Coast operator Red Bus, and Origin Energy.
- TfNSW has noted hydrogen charging issues. The original contractor to build the hydrogen charging facility withdrew from the program, as there was difficulty in charging the bus. The trial hydrogen fuel cell bus is now charged by a portable hydrogen charger. The trial continues and other charging mechanisms will be investigated.
- **Hobart, Tasmania.** In 2021, the Tasmanian Government completed the hydrogen industry activation study. The study identified buses as a potential user of hydrogen. An allocation of up to $12.3 million will support the trail from the Tasmanian Renewable Hydrogen Industry Development Funding Program. Foton Mobility Distribution (FMD), will supply the three buses to Metro Tasmania in 2024 and run the trial in Hobart for three years. FMD brings more than 12 years of experience with hydrogen as a vehicle fuel.
- **Morphettville, South Australia.** In August 2023, the South Australia Government launched a two-year hydrogen bus trial. Bus operator Torrens Transit will begin testing of the two Foton Hydrogen Fuel Cell Buses in collaboration with Foton Mobility, BOC gases and H2H Energy.

1. Please refer to the Appendix for further information on the different electric bus types. This includes electric buses that are battery run or fuelled by hydrogen fuel.
2. The Australian Government is working with states and territories to help decarbonise heavy transport. Driving the Nation Fund hydrogen highways initiative will provide up to $10 million to all jurisdictions on a matched basis (up to $80 million total) to help industry fleets acquire heavy hydrogen fuel cell vehicles and construct renewable hydrogen refuelling stations, located on major freight routes across Australia.

National Transport Commission

Learnings and insights

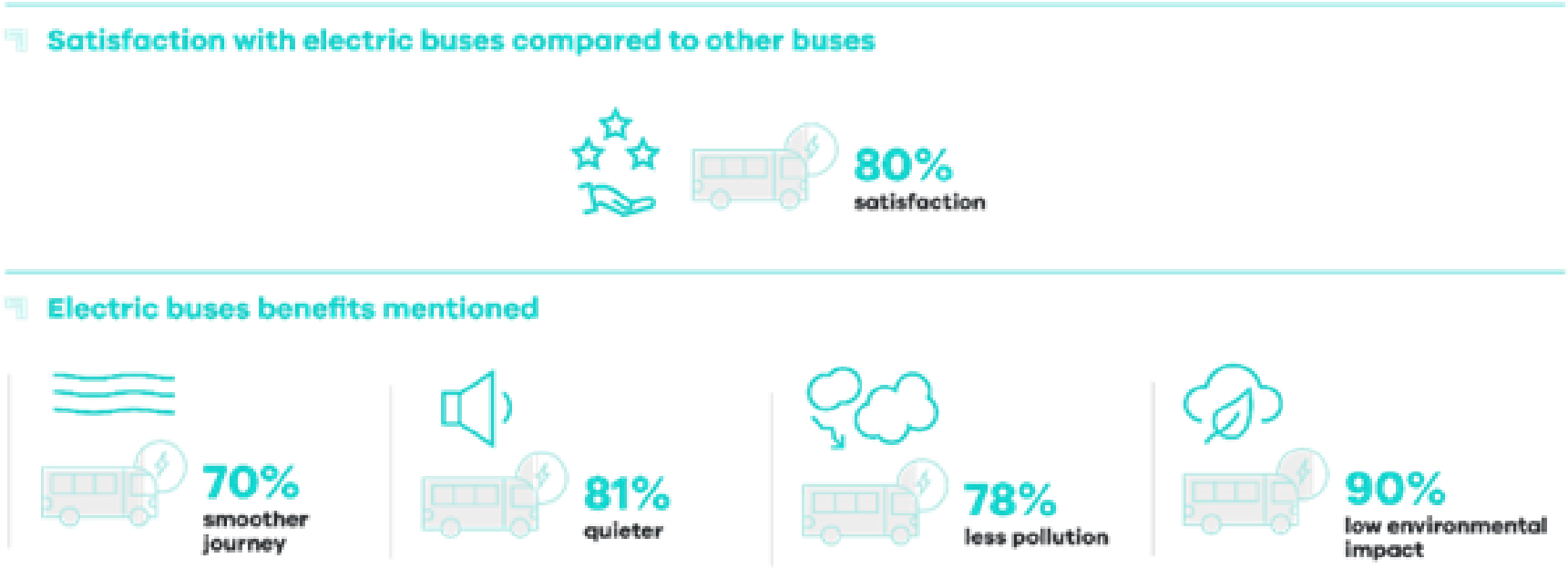
Source Zenobe

The benefits, costs, and reported impacts of electric buses

Strong public and industry support for working towards net zero

Jurisdictions across Australia have shown support for an electrified transport system and the full electrification of bus fleets is a widely popular policy option amongst Australians. According to the Climate of the Nation 2021 report, three in four Australians support the electrification of state bus fleets by 2023[1].

In NSW, interviews were conducted with electric bus customers, drivers, residents and businesses on common electric bus routes to understand public sentiment. The results from the survey suggested strong satisfaction with electric buses and likelihood for increased bus patronage/use.



Source: Transport for NSW

1. Quicke (2021) Climate of the Nation, https://australiainstitute.org.au/report/climate-of-the-nation-2021

The benefits, costs, and reported impacts of electric buses

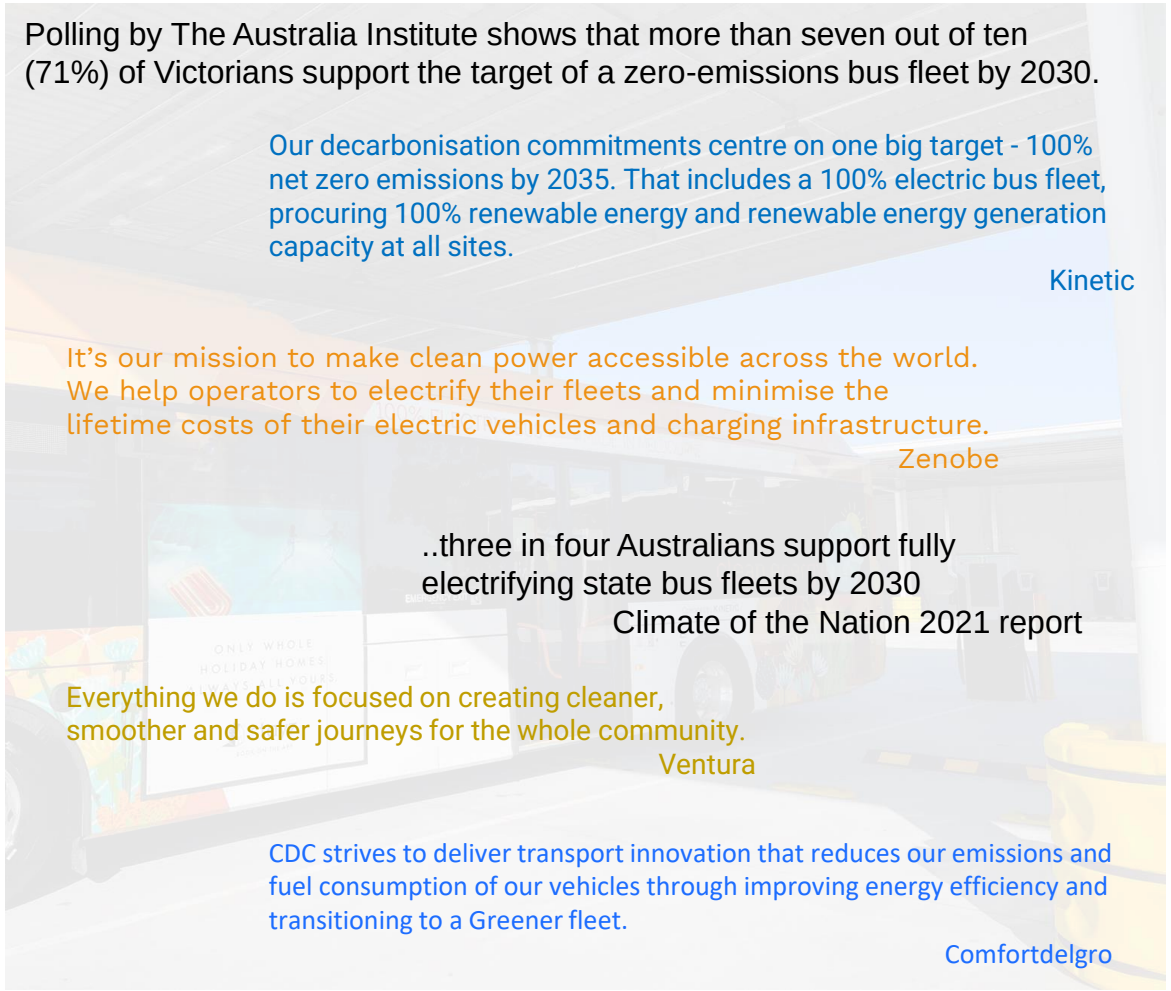
Strong public and industry support for working towards net zero continued

Several jurisdictions have committed to transition their bus fleets to zero-emission (buses powered by renewables), as part of state-based interim zero emission goals for 2030 and a broader national net zero emissions commitment goal for 2050.

- The New South Wales Government has pledged to electrify their entire fleet of over 8000 buses. Under the Zero Emission Buses Transition Plan, the first stage of the transition will begin in 2023 and be completed by 2047.
- From 2025, the Victorian and the Queensland Government, buses requiring replacement, will be replaced with zero-emission buses.
- The Australian Capital Territory Government is targeting an entire zero emissions bus fleet (public transport system) by 2040.

Where trials have taken place, the view is shared by the bus operators and suppliers in Australia. The bus operators are committed to bringing more electric buses onboard and are looking to procure/ fuel the buses with 100% renewable energy. Depots are currently being upgraded to supply the electric buses with renewable energy.

Governments and the industry are working together to reduce greenhouse gas emissions, bringing us closer to our zero emission goals. Where governments have assisted operators i.e. with paid electricity supply/ energy rate $prices$[1] the uptake of electric buses has been higher.



1. The renewal energy rate quoted for a bus operator was five times the current contract rate. With Government intervention, the bus operator was able to use the same low energy rate utilised by rail.

The benefits, costs, and reported impacts of electric buses

The cost of an electric vehicle is approx. two times greater than a diesel equivalent

An electric bus is approximately twice as much as its conventual diesel equivalent. As technology improves and the number of electric buses grows globally, the differential between diesel and electric buses will fall. The cost varies by electric type (battery or hydrogen fuel type), sizing (articulated, double decker, length size etc) and whether the bus was bought overseas or built here in Australia. A standard diesel bus roughly costs $550k whilst an electric bus is around $1m. Prices are falling as a result of more electric models and greater competition.

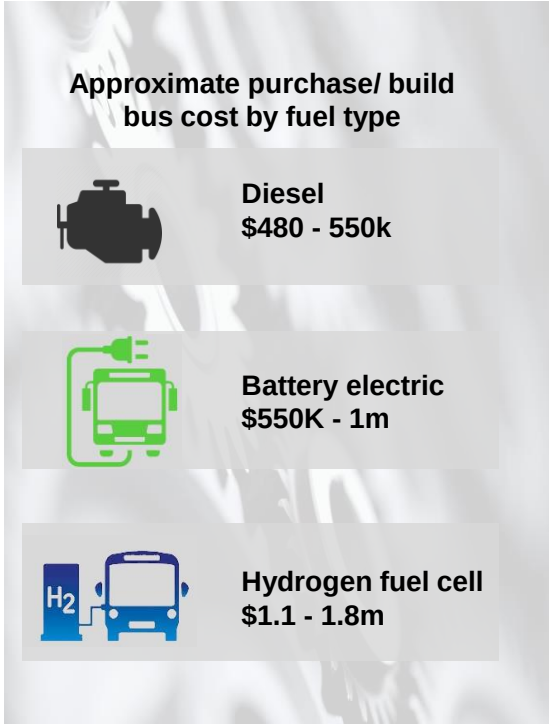
The difference in the initial purchase price compared to its diesel equivalent could be paid back through operational savings

Based on the trials to date, electric buses are likely to be cheaper to run, especially with the increasing cost of fuel, and lower maintenance costs. Electric buses are stable and cost less to maintain as they have fewer parts than their diesel counterparts, their braking systems also last longer, and they do not require oil changes. As the difference in the initial purchase price falls between diesel and electric buses, the difference could be paid back over the $lifetime$[1] of the bus. Based on the running trials and international operator experience, there is consensus that overall, the total cost of owning an electric bus is $cheaper$[2] and a superior option as it meets also the zero emission targets with no greenhouse gas emissions emitted from the tailpipe. In addition, with the development of smart tools, performance of fleet operation has also improved, as high flexibility in scheduling of electric bus fleets and high energy savings are made due to developed eco-driving, eco-charging and eco-comfort applications.

Currently, more electric buses are required to run the same diesel bus route, however this is not the case with the newer technologies and buses

Current trial buses cover roughly 280kms on a single charge. The trial buses in Australia were only used on specific routes with shorter operating distances. The short distances makes bus operations less flexible, however technology is rapidly improving.

There are bus routes that are 400kms long. The long routes require more buses to effectively cover the same route and timetable. With the trial technology operators can cover approximately 60% of their routes (if all buses were to be replaced today with the trial electric buses without any opportunity/ satellite charges). However, technologies have improved substantially in recent years. With the newer electric bus models and operational planning that balances the charging schedule to ensure that the route frequency is not affected, operators are now able to cover all the routes with the same number of electric buses as their diesel counterparts.



1. A typical lifetime of a diesel bus is between 15-20 years. Note the asset life is lower in other countries. In China it's roughly 5 - 8 years. Batteries are expected to last around 8 years, and in most cases with warranty. Early trials indicate batteries performing higher i.e. less deterioration than expected. At this stage, it is unknown whether the asset life of an electric bus is the same as diesel or whether it will be shorter or kept longer in operation.
2. Excludes the cost to build renewable energy sources, upgrade bus depots and install electric charging units

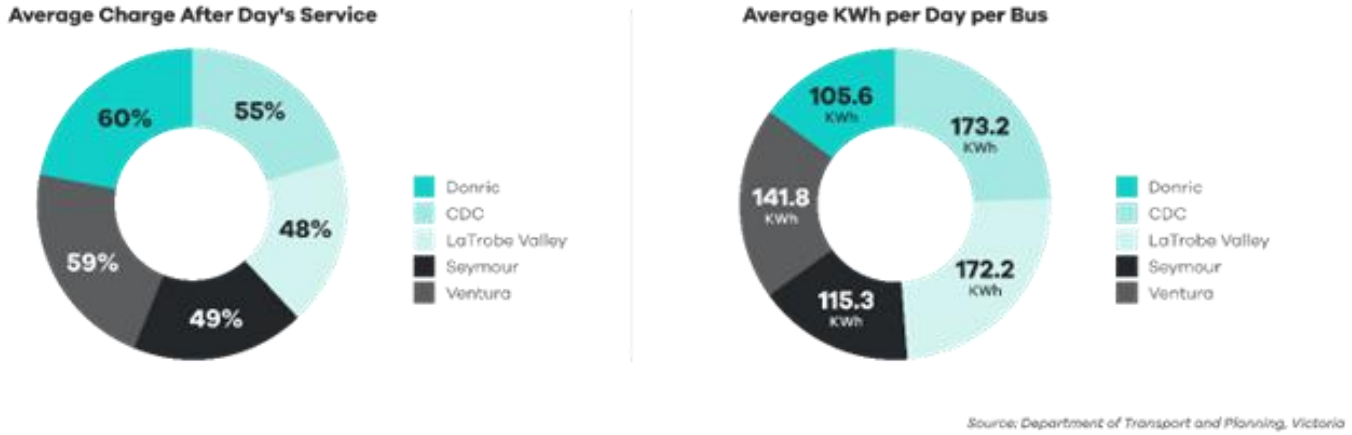
The benefits, costs, and reported impacts of electric buses

Currently, more electric buses are required to run the same diesel bus route, however this is not the case with the newer technologies and buses, continue

As technology rapidly progresses with newer electric buses now covering 400 – 500 kms on a single charge as well as the potential of building satellite or opportunity charges there is no longer the need for additional buses. As such, some jurisdictions have included longer running distance capable buses as part of their latest procurement specifications or included opportunity charging in their trials. Based on current trials, governments have also noted bus trial routes are comfortably covered with plenty of battery life remaining. Battery power and the rate or lack of battery life has performed greater than expected, with lower decline/ deterioration results.

Victorian trial results, March 2023

To date, the Victorian trial results indicate that the operators are covering their current passenger bus routes comfortably with remaining battery charge at the end of the day. The remaining battery charge for ComfortDelGro, despite the number of kilometres covered is particularly high due to offsite/ opportunity charging at Monash University.



Source: Department of Transport and Planning, Victoria

Notes:

- The operators are using less energy than anticipated, due to
  - Low distances at CDC and Donric.
  - Energy regeneration from braking.
  - New vehicles have better performance.
- *Seymour did not record KWh

The benefits, costs, and reported impacts of electric buses

Environmental benefits include reduced noise pollution, better air quality and reduced carbon emissions

Transport makes up 19%[1] of Australia's emissions, and public transport is one of the biggest contributors to co2. Buses make up 0.5%[2] of Australia's registered vehicles, and account for up to 6% of key air pollutants and produce roughly 1.4m tonnes of carbon dioxide (CO2) equivalent pollution each year. Diesel buses are responsible for disproportionately large amount of the air pollution in *cities*[3]. As Australia transitions diesel buses to electric, CO2 and other pollutants including nitrogen oxides, particulate matter, and toxic air emissions will significantly reduce, as electric buses emit zero emissions from the tailpipe while operating. Electric buses are better for the environment and as a result of less pollutants in the air will reduce community health impacts and save the health care costs on transport-related health illness due to air pollution (particularly tailpipe emissions). As well as work towards meeting shared climate goals by providing clean, reliable, safe, and affordable mobility solutions to the public.

In NSW, it's estimated that 7,700 tonnes of toxic exhaust particulate matter will be eliminated over 30 years.

Jurisdiction	Bus emissions and expected emission reductions
ACT	Emissions from transport are expected to create over 60% of the ACT's emissions by 2020, emissions from Transport Canberra buses account for 2-3% of these emissions but over 50% of ACT Government emissions. The ACT has committed to reducing emissions by 50-60% by 2025 from 1990 levels in order to reach its ultimate goal of 100% zero-emissions by 2045. This equates to a 17 per cent to 25 per cent reduction in emissions between 2020 and 2025. The Climate Change Strategy sets a zero-government emissions target of 2040 with an interim 2025 target of 33 per cent on 2020 (which represents the higher end of the 17-33 per cent reduction target).
NSW	Transport for New South Wales' (TfNSW) public bus fleet consists of approximately 8,300 diesel-powered vehicles. With the transition of Sydney's trains to green energy in late 2021, buses account for 78% of TfNSW's total emissions, and approximately 3% of NSW's total CO2 emissions. Transport's transition to zero emission buses is key to achieving NSW Government targets of a 50 per cent carbon reduction by 2030 and Net Zero emissions by 2050. By 2050, bus fleet is expected to transition fully to zero emission electric buses. It's estimated the carbon emissions will be reduced by 509,000 tonnes a year. This is the same amount of carbon emissions generated annually by more than 391,000 new cars in Sydney.

Environmental outcomes summary: Greater Sydney Stage 1

Environmental benefits

Reduced pollution

112,472 tonnes of annual carbon emissions eliminated

Renewable electricity benefits

Using **77 gigawatt hours of electricity per year** supplied by renewable sources primarily in NSW, supporting generation from **115,000 solar panels**

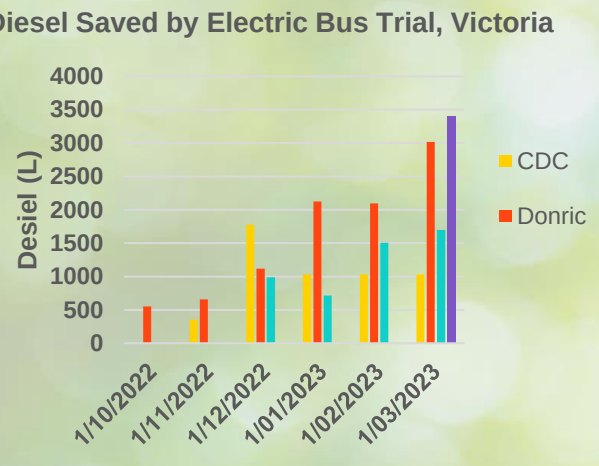
1. DCCEEW, 2022: https://www.dcceew.gov.au/energy/transport#:~:text=In%202022%20our%20transport%20sector,source%20of%20emissions%20by%202030.
2. The Australia Institute, Stuck in the slow lane, Electrification of buses in Australia, February 2023
3. BTRE (2005) Health impacts of transport emissions in Australia: Economic costs, https://www.bitre.gov.au/sites/default/files/wp_063.pdf

The benefits, costs, and reported impacts of electric buses

Environmental benefits include reduced noise pollution, better air quality and reduced carbon emissions continued

Diesel buses are loud. Noise pollution is also reduced as electric buses are up to 20 $dB(A)$[1] quieter than their diesel bus equivalent. Customers have noted the quieter, smoother and more comfortable bus journeys. The new buses are so much quieter that at low speeds, some operators and governments have considered or already installed devices emitting artificial sounds to the bus as a safety precaution to prevent accidents, and ensure that distracted passengers or visually impaired individuals are aware of approaching electric buses.

Jurisdiction	Bus emissions and expected emission reductions
QLD	Transport emissions in Queensland account for about 14 per cent of total emissions. The South East Queensland diesel bus fleet emits over 12,000t of CO2 a month. Queensland Government aims to reduce bus fleet emissions by 50% by 2030 and 80% by 2035.
SA	Transit Systems estimates that approximately 90 tonnes of CO2 emissions will be saved per year at a minimum through the trial, with the buses adding to Transit Systems' fleet of sustainable transport solutions that includes an electric depot, 60 electric buses and two hydrogen vehicles.
VIC	Transport is the second-largest source of emissions in Victoria. In 2019 it accounted for 25 per cent (22.7 Mt CO2-e) of the state's emissions. Transitioning to electric buses will reduce emissions. In 2021-22 bus services in Victoria travelled over 155 million scheduled kilometres. At an average bus emission rate of 1.35 kg/km this would equate to reducing emissions by 209,250 tonnes of $CO2$[2].
WA	Transport is the third-largest source of emissions in Western Australia and contributes about 15 MtCO2-e or 16 per cent of emissions in 2019. The four trial buses in Joondalup is estimated to have carried more than 250,000 passengers in the first 12 months and covered more than 140,000km, saving approximately 230 tonnes of carbon dioxide emissions in the $process$[3].



Approximately 24.3t CO_2 was saved in Mar-23 in the Victorian electric bus trials and approximately 61.2t CO_2 for ZEB Trial to date.

Source: Department of Transport and Planning, Victoria

1. The Australia Institute, Stuck in the slow lane, Electrification of buses in Australia, February 2023
2. https://www.sydney.edu.au/content/dam/corporate/documents/business-school/research/itls/zero-emission-electric-and-hydrogen-buses.pdf, September 2021
3. WA government: https://www.wa.gov.au/government/media-statements/McGowan-Labor-Government/Bus-fleet-goes-electric-with-%24125-million-State-investment-20230423

The benefits, costs, and reported impacts of electric buses

Strengthening the zero-emission future and messaging

With strong public support, the adoption of electric buses in public transport is growing. Jurisdictions can further drive and raise awareness in zero-emission buses in the community, with some Jurisdictions having already several initiatives and organisations in providing opportunities for the community to learn more about zero-emission buses and have their say. Below are some examples of initiatives across Australia:

- **Noosa EV Expo, QLD:** In 2018, not-for-profit community group Zero Emissions Noosa held its first ever Noosa EV Expo. The event showcases the world of electric vehicles and allows the public to speak with electric vehicle owners and suppliers.
- **Eventure, Canberra, ACT:** In 2022, the ACT Branch of the Australian Electric Vehicle Association (AEVA) organised the Eventure event. The event was intended to be informative as well as enjoyable and participants were able to trial and experience the electric vehicles. The program aimed to highlight the importance of electrified travel in driving down greenhouse emissions, and other emissions which impact public health.
- **Better Buses for Melbourne's West Campaign, Victoria:** Maribyrnong City Council has added its voice to a campaign to see better buses that are more frequent, connected and environmentally friendly rolled out in the municipality to increase public transport use, reduce emissions, and improve health and well-being. The Better Buses for Melbourne's West Campaign was launched by Friends of the Earth in 2021.
- **Brisbane Metro Information Centre:** The centre located in the city offers an immersive experience for all visitors, featuring state-of-the-art technology in the virtual reality and augmented reality zones, a life-size model of the metro's front passenger compartment and an opportunity to connect with members from the Brisbane Metro team. Any feedback and comments will be collected.
- **Zero Emission Buses Design Poll, 2023:** The public are involved and can choose their favourite bus design concept. Final designs may vary but the public has the opportunity to guide the choice that will be seen every day on Victorian roads.

Zero Emission Buses Design Poll, Victoria

Source: Public Transport Victoria

The Victorian public can vote on their favourite design. There are 3 designs to choose from: Concept 1 - Empowering ideas, Concept 2 – Accelerating, Concept 3 - Clean journeys. Votes close in March 2024.

Above is Concept 3 – Clean journeys. This organic and earthy concept represents a bright future ahead for our planet, with public transport powered by clean energy.

The benefits, costs, and reported impacts of electric buses

Strengthening the zero-emission future and messaging, continued

The messaging can also be included on the buses. In California, USA a regular annual contest allows students to design the bus (see case study).

The contests have been used for advertising, sales and promotional purposes that include regional media coverage. It has been well received from the public and has generated interests in clean energy and the services and programs at Sunline Transit Agency.

Case Study

Sunline Transit Agency promoting its alternative fuel buses

Jasmine Khaligov's 1st place bus design
Source: Sunline Transit Agency

Each year, the Sunline Transit Agency has an Annual Student Art Contest.

The contest is a way to educate the public on advantages of clean energy and the public transport system.

The program is a great way to advertise and promote working towards net zero, which involves the community. A simple yet an effective way to promote public awareness of clean energy and the public transport system.

Ways used to fund and finance zero emission bus services

One of the greatest barriers to electric bus take up has been the high purchase price and cost of charging infrastructure. Funding programs, grants, leasing models have been an important step in the uptake of electric buses. However, what works in one jurisdiction may not in another due to the different contractual bus agreements, ownership and capital available, as well as how willing the owner is to take on new technology and operational risk.

In jurisdictions where the bus ownership sits with the private sector, we've noted the international operators have leveraged their experience, knowledge and contacts to drive a diesel-free bus fleet in Australia. Jurisdictions have gained insight from the international players (leased programs and private operators) in Australia and their strategies incorporates insights learnt from overseas to help the transition to net zero emission buses smoother. This includes a broader knowledge and access to bus models, batteries and understanding of charging infrastructure. More could be done to assist with infrastructure, and this will be covered in the following section in "challenges encountered in transitioning bus fleets to zero emission buses".

Ways to fund electric buses and infrastructure

Funding programs, grants, leasing models have been an important step in the uptake of electric buses. Advancing states in the uptake of electric buses have financial support from their local governments and green initiatives. There are 3 main models of finance:

Grants and partnerships

Grants and partnerships are a great way to start the investment in electric buses. Jurisdictions that own the buses, have highlighted that partnering with the right organisation with experience in the electric bus industry is a key element to success. There are many invaluable lessons that can be learnt from private companies, especially if they have electric buses in operation overseas.

The tables "Partnerships" and "Grants and funding programs" lists some of the partnerships and grants in place in Australia.

Bus ownership in Australia

State/ Territory	Bus ownership
Australian Capital Territory	Government owned
New South Wales	Government and privately owned. Transport for NSW is responsible for regulating public and private bus services across the state.
Northern Territory	Privately owned in the NT with the Department of Infrastructure, Planning and Logistics regulating public bus services.
Queensland	Government and privately owned. Translink a division of the Department of Transport and Main Roads is responsible for buses across South East Queensland.
South Australia	Government owned
Tasmania	Government and privately owned. The largest state owned public transport company Metro Tasmania Pty Ltd trades as Metro and operates bus services in Hobart, Launceston and Burnie.
Western Australia	Government owned and privately operated with government specifications in the contract. There is a 10 year (5 + 5 years) bus agreement with a chassis and body builder supplier.
Victoria	Mostly privately owned. Procurement of buses and depot infrastructure is operator-led with minimal specification. The state finances the assets via monthly payments over the asset's lifespan. Victoria Government has access rights at the end of the contract.

Ways used to fund and finance zero emission bus services

Partnerships

Partnerships offer an opportunity to draw on the expertise and experience from the private sector and industry to improve safety, set standards, and grow the industry and skills in electric buses. Partnerships and potential partnerships include:

- **Transport and Energy Sector.** A fleet of electric buses require a vast source of energy. This presents opportunities to partner with electricity organisations to help manage the increasing loads on the energy grid and potentially allow operators to upload excess energy during the day (i.e. solar power) to the grid. The new relationships will present opportunities for to reduce costs, generate new sources of revenue, share solutions and better meet the energy needs of the future economy.
- **The Tasmanian Government has partnered with the Blue Economy Cooperative Research Centre (BECRC).** The BECRC's project to deliver an Offshore Renewable Energy Systems Program is focused on continuing Tasmania's production of low cost, reliable and clean energy – with green hydrogen a part of this innovation.
- **TSA has partnered with CDC, Volvo, ENGIE, Volgren, and Monash University** in a trial of eight battery electric buses at the Oakleigh Depot in the southeast of Melbourne. The Route 601 is one of Melbourne's busiest and most frequent bus services. Trialling battery electric buses on this route will build understanding of the customer and operational impacts on a high-frequency, high-capacity service. The trial also includes bus charging infrastructure, installed at Monash University Bus Interchange to test the concept of on-route charging to maintain the range of vehicles and better understand operational needs and requirements.

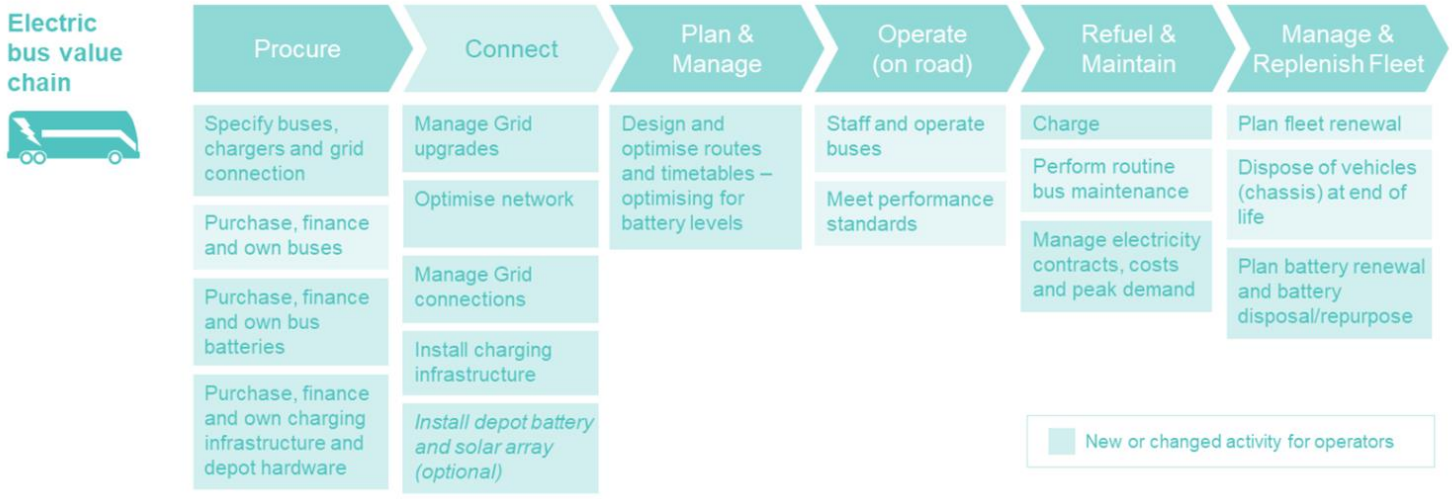
Grants and funding programs

Below lists a few of the grans and funding programs across Australia.

Fund/ Grant	Description
Renewable Hydrogen Commercialisation Pathways Fund (CPF)	The Renewable Hydrogen Commercialisation Pathways Fund (CPF) provided grant funding for capital works projects that support the building of hydrogen pilots, trials, and demonstrations. An example of grant funding includes the Manufacturing and Commercialisation of Hydrogen Buses project (an award of AUD$1,800,000). The project will develop two hydrogen fuel cell electric buses in the Melbourne suburb of Dandenong South. The buses will be trialled and tested prior to deployment to bus operators for trial use on the Australian public transport system. It is anticipated that commissioning activities of the completed buses will be undertaken by the end of the second quarter of 2024.
Tasmanian Renewable Hydrogen Industry Development Fund	The Tasmanian Government has conditionally approved up to $12.3 million from its Tasmanian Renewable Hydrogen Industry Development Fund to progress recommendations from the Tasmanian Renewable Hydrogen Industry Activation Study, including a trial of two or three hydrogen buses by Metro Tasmania.
Driving the Nation Program	Announced in 2022, the Government's Driving the Nation Fund provides $500 million to invest in cheaper and cleaner transport. This funding builds on the former 'Future Fuels Fund' (established in 2020), targeting support for business fleets, new technologies for heavy and long-distance vehicles, public charging and hydrogen refuelling stations and smart charging.
Australian Made Battery Plan	Under the Australian Made Battery plan jobs and wealth will be created as batteries are manufactured batteries onshore. The Australian Government will invest up to $100 million in equity injection into an Australian-Made Battery Precinct in Queensland. There are an estimated 34,700 jobs and $7.4 $billion$[1] in value to be made in Australia from battery technology and industries.

1. Accenture, Future Charge, Building Australia's Battery Industries, June 2021

Ways used to fund and finance zero emission bus services



Source: Zenobe

There are different leasing/ service models:

- **Full end-to-end service** – this includes design and planning, project management, smart charging, operational guarantees, battery replacement and recycle
- **Build and design** – including connection to grid
- **Operational guarantee**
- **Battery** – smart charging, guarantee, second life and recycling facilities

Leasing model

The initial cost of an electric bus is high and has in the past deterred the uptake of electric buses. The new technology risk and costs lifecycle risk can be outsourced for a price. Electric buses have been leased from $governments$[1] or organisations such as Zenobe that specialise in fleet electrification. The key advantage is the leaser takes on the following risks:

- High capital requirements for upfront costs and battery replacement
- Insufficient power supply both to and within the depot to support service delivery
- Unpredictable operational costs due to new technology and energy market volatility

Since the leasing period equals the total life of the buses, this arrangement turns the high-cost procurement into more manageable annual rental/lease payments. In addition, operators could return batteries to the manufacturer for recycling and disposal and sell the bus body for scrappage or metal recycling to reduce costs further and recycle the materials when the bus operator takes ownership of the buses after the leasing period is over.

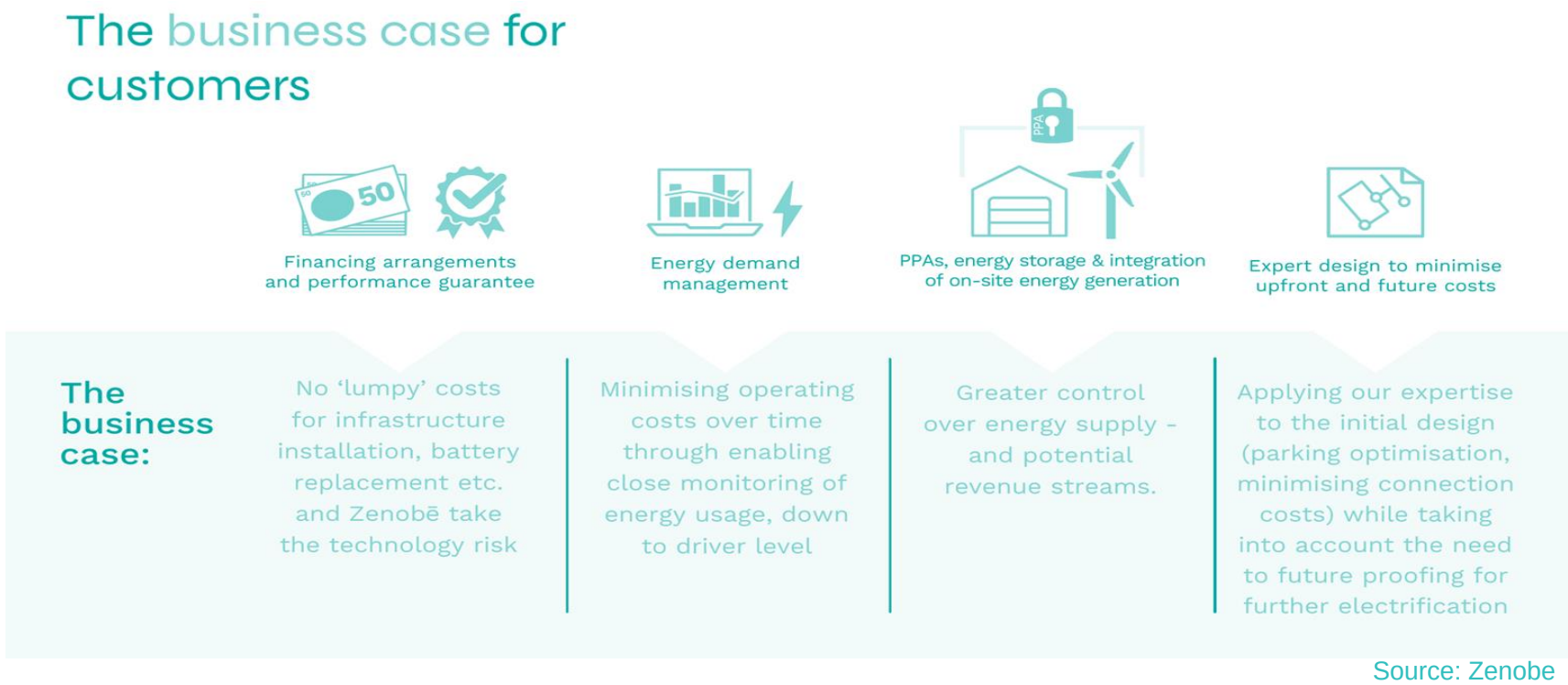
1. Government bought electric buses are leased to the bus operators through contractual operating bus leases/ contracts

Ways used to fund and finance zero emission bus services

Outright ownership

The leasing model is great for new operators with little or no experience in electric bus fleets. Once governments or operators are comfortable, have a sound understanding of the electric bus operations and are willing to take on the risks with new technology, buying the electric buses and installing the infrastructure, the risks can be considered and weighed. Governments and operators currently on leasing programs are considering or have decided to procure future electric buses outright. Infrastructure design and build, as well as service operations, charging optimisation and battery replacement and recycling services are still being considered and likely to continue to be outsourced.

Sample of the services offered by private organisations that specialise in assisting operators and governments in fleet electrification.



Source: Zenobe

Regulatory frameworks and policies incentivising the adoption of electric buses

Reducing emissions are key driving forces in adoption of electric buses

Policies supportive of reducing emissions and pollution are driving the adoption of electric buses worldwide. Governments and the private sector are investing in electric vehicles, with programs and groups such as *Drive to Zero*[1], *EV100*[2], *the Clean Bus Europe Platform Project*[3], and Zero Emission *Rapiddeployment Accelerator*[4] are assisting in the acceleration for zero emission buses. In partnership with the Netherlands government, Drive to Zero co-leads the Global Memorandum of Understanding (MOU) on zero-emission medium- and heavy-duty vehicles, where countries commit to working together to enable 100% zero-emission new truck and bus sales by 2040 with an interim goal of 30% zero-emission vehicle sales by 2030, to facilitate achievement of net-zero carbon emissions by 2050.

Many countries and cities have set targets for 100% public transport vehicles to be purchased as zero emissions, set zero emissions zones, and implement emissions standards for heavy vehicles. CO2 emission standards for heavy vehicles are expected to promote electric bus adoption. In Europe, the *European Union Clean Vehicles Directive*[5] sets national procurement targets of zero emissions public buses. Similar targets set by the jurisdictions has seen an update in electric buses and will continue to grow until the fleet is 100% electric.

Countries that have seen significant progress have implemented policies to curb pollution, set electric vehicle targets as well as set emissions standards. Examples include:

- **China:** VI-a emissions standards for new urban heavy vehicles took effect in 2020, followed by standards for remaining heavy vehicles in July 2021. In July 2023, China introduced VI-b emissions standards that establish more stringent testing requirements and monitoring systems.
- The release of the 14th FYP for Green Transportation by the Ministry of Transport sets an ambition for all new electric vehicles to account for 72% of national urban public transport (including buses). Regional policies for Shanghai, Ningxia and Guangdong have set targets for 96%, 45% and 100%, respectively, for all new buses to be electric by 2025.
- **European:** As a part of the *European Green Deal*[6], the CO2 emissions performance standard for heavy vehicles requires reducing specific CO2 emissions of regulated segments of medium- and heavy-duty trucks by 15% by 2025 and 30% by 2030, on average, relative to their 2019-2020 level. The proposed revision of the regulation extends its scope to other vehicle categories (such as buses) and includes targets for 2035 and 2040.
- **Norway:** Norway has a *target*[7] of 100% of new heavy vehicles, 75% of new long-distance buses and 50% of new trucks sold to be zero emissions by 2030. These targets are supported by a subsidy scheme and a fuel tax imposed on heavy vehicles of approximately EUR 200[8] per tonne of CO2.
- **Chile**: In January 2022, Chile set a target for 100%[9] of public transport buses, sold to be zero emissions by 2035 and by 2045 for intercity buses.

For further information and examples refer to the Electric bus registrations and sales shares by region, 2015-2021 graph and targets table in the State of Play.

1. Drive to ZeroTM program and campaign aims to accelerate the growth of global zero-emission (ZE) commercial vehicle space, with the aim of ZE technology becoming commercially competitive by 2025 and dominant by 2040 in specific vehicle segments and regions.
2. The EV100 Initiative brings together over 100 companies in 80 markets committed to making electric transport the new normal by 2030. This equates to 4.8 million vehicles switched to EVs and chargers installed in 6500 locations by 2030.
3. An initiative under the EU Commission: https://cleanbusplatform.eu/about/the-platform
4. The ZEBRA project, co-led by ICCT and C-40, was launched in 2019 with the aim of supporting the transition to zero-emission buses in leading Latin American cities. https://www.c40.org/what-we-do/scaling-up-climate-action/transportation/zero-emission-rapid-deployment-accelerator-zebra-partnership/
5. European Commission, https://transport.ec.europa.eu/transport-themes/clean-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en
6. https://eur-lex.europa.eu/eli/reg/2019/1242/oj
7. Norwegian Ministry of Transport and Communications, National Transport Plan 2018-2029
8. Fridstrøm, L. The Norwegian Vehicle Electrification Policy and Its Implicit Price of Carbon. Sustainability 2021, 13, 1346. https://doi.org/10.3390/su13031346
9. Ministry of Energy, National Electromobility Strategy, January 2022: https://biblioteca.digital.gob.cl/handle/123456789/3773

Regulatory frameworks and policies incentivising the adoption of electric buses

Charging standardisation will incentivise private investment to stay ahead of growing demand for the electric buses

There are arrange of bus types, battery and charger supplies. However, there is lack of technology standardisation, resulting in compatibility charging failures in trials and potential inoperability bus charging between Jurisdictions and same state operators. Failures include:

- Lack of compatibility with the battery technology
- Charger handshake issues (software and hardware might not be compatible)
- Different technologies used by jurisdictions means buses cannot move between states, or the workforce is restricted to certain jurisdictions

Failure to standardise could result in safety concerns and failing electric buses. Standards need to be common, and across Australia without being over subscriptive. Too much standardisation could negatively impact a technology that is still in its infancy. Each design decision has positives and drawbacks regarding technological design complexity, capital and operational cost.

Standardisation is recommended to ensure interoperability and encourage manufacturers to supply greater number of competitive models. It could bring economic benefits to operators as operators are able to charge buses from different manufacturers at the same charging point, without binding the operator to one solution or supplier. The standard charging will provide flexibility and operation optimisation possibilities to the operator as more operational choices are available. It will also allow and have a positive effect on the resale value of vehicles.

Non-standard design options for bus parts will help bus manufacturers develop innovative systems while also keeping buses light and efficient. One manufacturer has already designed a lighter chassis to counter the heavier batteries, so that electric buses are lighter and comparable to other fuelled buses. Innovative manufacturers and electric bus parts suppliers will have a crucial role to play in the electric mass transportation future.

ASSURED

Learnings can be gained from the $ASSURED$[1] project, an EU-initiative, developed and tested innovative solutions from 2017 – 2022 to support the standardisation and interoperability of electric vehicles charging. It enabled operators to mix and match different brands of vehicles and chargers in Europe, which makes their integration into the public transport network more flexible and, therefore, cheaper.

In 2019, the ASSURED Consortium released an interoperability report enabling the testing of interoperability and conformance, ultimately supporting the large scale uptake of electric bus fleets. The report has since been updated and released in 2021[1]. The ASSURED 1.1 Interoperability Reference can be used as a reference document by relevant standardisation committees or organisations that are aiming at achieving interoperability for automated connection device (ACD)-based charging solutions (namely infrastructure-mounted, roof-mounted, and floor-mounted ACDs) of electric buses.

The document starts with a general introduction to the work (Chapter 1). The standards referenced in ASSURED project are summarised in Chapter 2. Chapter 3, 4, and 5 include definitions and specifications of the three ACD-based charging solutions used in ASSURED where the solution differs from the referenced standards with additional clarifications if deemed necessary.

1. https://assured-project.eu/
2. https://assured-project.eu/storage/files/d44-assured-11-interoperability-reference-pdf.pdf

Challenges encountered in transitioning bus fleets to zero emission buses

Australian heavy vehicle dimension requirements cost the industry

An electric bus built for Australia costs more than an electric bus built for most other countries, for two main reasons:

1. **Right hand drive:** The chassis structure/ parts made in Europe are left hand drive designed. The structure can be designed so that the steering wheel is in the right place, however often further alterations are needed. An example is the side door entrance where passengers exit the bus. The outer structure is designed for left hand drives so often trunk space is where the door exit should be and the structure hasn't considered all changes for left hand traffic.
2. **Prescribed heavy vehicle dimensions and axle load limits:**

a) The width limit for heavy vehicles is 2.5 $meters$[1], whilst in Europe the maximum width is 2.6 $meters$[2]. The out of the box $Hess$[3] bus body kits is larger than width limit for Australia. The imported kits needs to be tailored to the Australian standards and market, resulting in higher body costs for Australia.

b) A single steer axle on a complying bus is 6.5t[4]. The maximum axle loads In Europe are 10t for a single axle and 11.5t for a driven axle.

It is unlikely, Australia would change the traffic driving side, however the prescribed heavy vehicle width dimensions and axle loads could be considered for change and increased to match international standards. The current maximum dimensions and axle load limits of heavy vehicles are impeding the market uptake of new technologies and limit the available models suitable for the Australian market.

Electric buses tend to be heavier than their diesel counterparts, as a result the payload or number of passengers per bus is less. Increasing the axle loads will alleviate this constraint. The impact is recognised in Europe and the EU have provided increases in operating mass allowances for zero emission buses and coaches of up to 2.5 tonne per bus type since 2015 (axle limits above the current Australian limits).

Increasing the heavy vehicle width to 2.55 meters and axle loads, will make it easier for manufacturers to supply not only additional electric bus models already available in other markets, but also additional heavy vehicles models that meet the $Euro\ VI$[5] requirements. Making changes to the bus dimensions specifically for the Australian Market is costly. An operator estimated a change in reform, increasing heavy vehicle dimensions and axle load limits reform could save the government/ operator up to $100K per bus, as more models and $knocked-down$[6] models are available. If a local government orders 100 buses per year, the local government could potentially save $10m per year.

1. Currently the width limit for heavy vehicles is 2.5 as set out under the Heavy Vehicle (Mass, Dimension and Loading) National Regulation 2013 (the Regulation). The dimension are currently under review. In October 2021, the Australian Government agreed, subject to the outcome of a separate regulatory impact analysis, to allow trucks and trailers up to 2.55m wide.
2. As per the 'Weights and dimensions' Directive of 1996 which sets maximum vehicle dimensions and weights for national and international road transport in the EU.
3. Carrosserie HESS AG manufactures bus kits for its customers. These kits are imported and then assembled on reaching their destination. The bus kits are used to build public bus bodies globally.
4. NHVR, General Mass Limits, https://www.nhvr.gov.au/files/201602-0114-general-mass-limits.pdf
5. On 13 October 2022, the Minister for Infrastructure, Transport, Regional Development and Local Government announced a new ADR 80/04 based on the Euro VI (Stage C) requirements will be phased in for newly approved heavy vehicle models supplied from 1 November 2024 and existing heavy vehicle models still being provided to the Australian market on or after 1 November 2025. Axle load increases is currently under review. ADR 80/04 includes zero emission vehicles (battery electric and hydrogen fuel cell vehicles), which means any mass concession provided to Euro VI diesel vehicles will also be provided to ZEVs. Consideration of the longer-term regulatory barriers for zero emission vehicles, including higher masses than those sought under Euro VI is not included in the ADR 80/04.
6. Knock-down (KD) models are production methods where a product is partially disassembled into its major components or subassemblies before being shipped or delivered to the final assembly location / market.

Challenges encountered in transitioning bus fleets to zero emission buses

Local content requirements vs cost and economies of scale

Local content requirements indirectly protect Australian bus body builders from overseas competition, but this protection has a cost in terms of a higher cost of electric buses due to reduced competition, and the opportunity cost of resources diverted to the protected sector from unprotected sectors of the economy.

This applies whether local content rules are applied at a national level or sub-national level. Applying local content rules at a state/territory level in Australia involves the risk of fragmenting the industry, and is likely to be a barrier to the desire to achieve a viable domestic manufacturing industry that is capable of producing a sufficient number of buses to achieve the desired transition at reasonable cost.

Australian manufacturers believe that a change in the dimension regulations will open the market to international competitors. As a result, domestic manufacturers will be crippled and may no longer exist. With a change in regulation, manufacturers believe companies are unlikely to invest and are not able to compete against internationals as in Australia the costs of labour and materials are high, and further state preferences/ regulations add additional costs.

A possible solution to expedite the number of electric buses, is to remove dimension and axel load limit barriers so more could be easily procured internationally as the number of electric vehicle models and market is larger.

Alternatively, this could be achieved through national strategy or national coordination. Local manufacturers have the capacity to significantly increase the number of buses in production. However, they need to be incentivised with long tern strategies/ contracts in place to ensure long term security and growth in the industry.

Australia cannot compete on price alone against international manufactures such as China as Australian manufacturers are too small to achieve the economies of scale of larger manufacturers. Australian manufacturers also typically face higher labour and materials costs. Manufacturers such as BYD, Yutong, Anhui Ankai continue to dominate the electric bus supply market, as they produce hundreds of electric buses a day and have also developed a wide range of models at lower prices due to availability of parts and components at cheaper rates.

A possible solution to retain local content, but still benefit from reformed prescribed heavy vehicle dimensions, is for governments to mandate the percentage of local content per bus. In Victoria 60% (dollar value) of the bus must be locally made. The percentage might not work in smaller jurisdictions as the economies of scale are smaller. However, if jurisdictions work together and coordinate the build, this could benefit all states and territories. Already, the Victorian and Queensland governments are working together to have buses built in Queensland.

If jurisdiction procurement policies for the purchasing of buses for public transport contracts are heavily weighted towards local content, the local market will be protected, including also suppliers for seats, electronic bus equipment and bus door manufacturing. However, this protection comes at the cost of higher procurement costs.

The Bus Industry Confederation (BIC) are in favour of increasing dimensions and axle loads. BIC are seeking ADR changes to allow for wider 2.55 m buses and understand the implications it may have to local manufacturing. To alleviate the impact and support the potential dimension and axle changes, the BIC council have requested that the BIC Executive pursue a program to develop an industry approved process for the calculation of local content for the various components used within the bus manufacturing industry. BIC^1 state “this would be intended to assist the State Government Procurement Bodies with the voracity of the local content claims put forward by suppliers during tendering and assessment processes”.

1. BIC, Dimensions and Mass for Low and Zero Emissions Buses and Coaches, February 2023

Challenges encountered in transitioning bus fleets to zero emission buses

Local content audits

The requirements and definition of local content is not the same in each jurisdictions. Without local content audits, international organisations can bring in $knocked - down$[1] models, and charge jurisdictions and operators it's cost with a margin to meet local content dollar requirements. Dollar only requirements will only achieve more expensive buses without the benefits such as creating and retaining jobs, and circular economic job developments (see local content and protecting jobs section for more details). By scrutinizing the local content, a comprehensive understanding of the supply chain's local involvement and the origin of materials and parts can be achieved.

The $Industry\ Capability\ Network\ Victoria$[2] (ICN) data collection system is a good working example, to validate local content figures and ensures suppliers and manufacturers are investing locally and growing the local market. The system highlights the percentage of local investment and percentage of local content in products. If local content is mandated, we recommend adopting a similar assessment to the ICN process. The adoption of a consistent methodology for calculating local content eliminates discrepancies between different states or manufacturers.

ICN Assessment process

The ICN assessment process for local content involves the following steps:

1. **Component Level Breakdown:** Each component of the bus undergoes evaluation to determine the extent of importation and local value added to the cost and sales price. This meticulous analysis encompasses over 1500 parts in a single bus.
2. **Labour Component:** All costs associated with labour activities related to the product are meticulously evaluated to determine their impact on the local content.
3. **Overheads and Margins:** The variance between cost and price is considered an integral part of the local content assessment, ensuring a comprehensive evaluation of the value added at each stage of production.

The transparent local content assessment offers several benefits, including:

1. **Fair Assessment of Supply Chain and Materials/Parts Source:** By scrutinizing the local content assessment, a comprehensive understanding of the supply chain's local involvement and the origin of materials and parts can be achieved.
2. **Criteria Standardization:** The adoption of a consistent methodology for calculating local content eliminates discrepancies between different states or manufacturers.
3. **Transparent Procurement Processes:** Local content assessments enhance the transparency of procurement processes. By providing clear and verifiable information about the local content, the assessment allows for fair and open competition among suppliers, promoting efficiency and integrity in procurement practices.
4. **Enhance Local Supply Chain Opportunities:** By highlighting the level of local involvement at each stage of production, businesses and government entities can identify and capitalize on potential areas for local sourcing and collaboration.

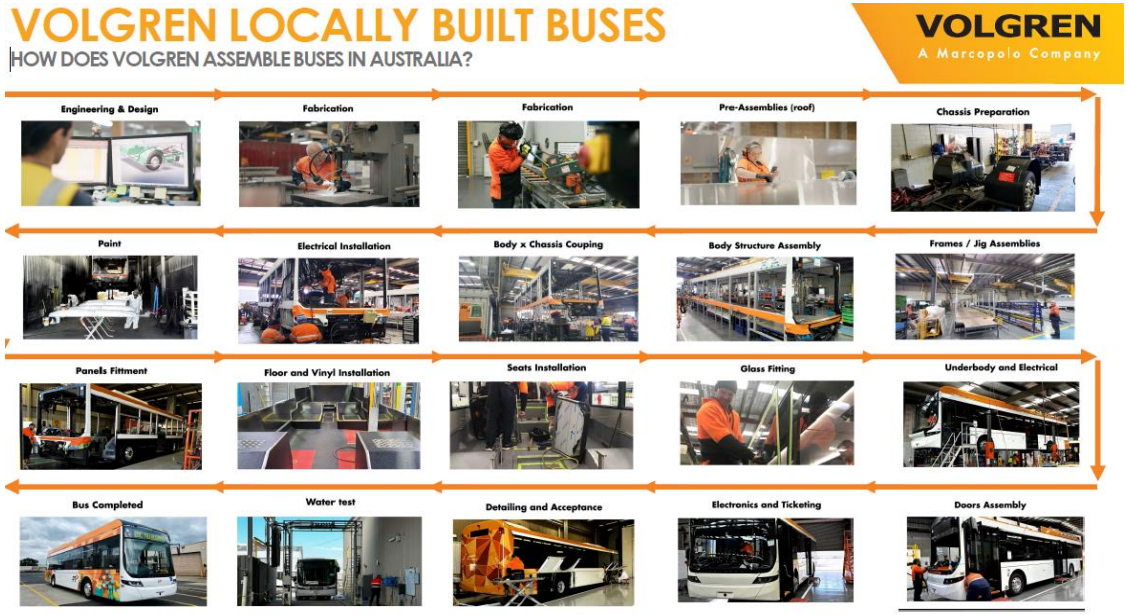
1. Knock-down (KD) models are production methods where a product is partially disassembled into its major components or subassemblies before being shipped or delivered to the final assembly location / market. The purpose of using KD models is to facilitate exports, transportation, reduce costs (including labour at destination), and optimize logistics, especially when dealing with large or bulky products, such as buses. In bus manufacturing, the usual KD / assembly models are: CBU (Completely Built Unit), CKD (Completely Knocked-Down), PKD (Partially Knocked-Down), SKD (Semi Knocked-Down) and DKD (Drivable Knocked-Down)
2. The ICN is a not-for-profit organisation supporting industry development. ICN provides end-to-end assistance and practical advice on applying Local Jobs First and manages the Victorian Management Centre (VMC). The VMC is an online system hosted by ICN and used by agencies and suppliers to register and report on Local Jobs First projects. It also manages reporting for the Social Procurement Framework.

Challenges encountered in transitioning bus fleets to zero emission buses

Local content and protecting jobs

Approximately 5 jobs per bus is $retained$[1] when a bus is built in Australia.

Bringing in $knocked - down$[2] buses into Australia will impact local jobs. One manufacturer believes that approximately 85% of the jobs will be exported to the country where the buses are built and roughly 100+ local suppliers will be negatively impacted.



Local content and jobs

The benefits to the economy include:

1. **Job Creation:** Facilities require a skilled workforce, providing employment opportunities for individuals with various levels of education and training.
2. **Circular Economic Development:** When manufacturing is concentrated locally, it can create a ripple effect, generating additional economic activities and increasing opportunities for the local supply chain.
3. **Response Times:** Local manufacturing enables faster response times to market demands.
4. **Quality Control:** Proximity to the manufacturing facility allows for better oversight, reducing the risks associated with long and complex supply chains.
5. **Innovation and Collaboration:** Manufacturers can work closely with research institutions, universities, and other companies in the region to exchange knowledge, share best practices, and drive technological advancements.

1. National Institute of Economic and Industry Research (NIEIR), The Economic Benefits of Local Bus Manufacture commissioned by the Bus Association Victoria (Bus VIC), 2015. The report was referenced by Bus VIC in its submission to Victoria's Future Industries.
2. Knock-down (KD) models are production methods where a product is partially disassembled into its major components or subassemblies before being shipped or delivered to the final assembly location / market. The purpose of using KD models is to facilitate exports, transportation, reduce costs (including labour at destination), and optimize logistics, especially when dealing with large or bulky products, such as buses. In bus manufacturing, the usual KD / assembly models are: CBU (Completely Built Unit), CKD (Completely Knocked-Down), PKD (Partially Knocked-Down), SKD (Semi Knocked-Down) and DKD (Drivable Knocked-Down)

Challenges encountered in transitioning bus fleets to zero emission buses

National coordination and sustained growth in the electric bus industry

A national approach and plan is recommended. Having a manufacturer in each state is possible, but it will be at a price to the Australian economy.

Manufacturers need to have certainty and several buses on order to break even. Their once reliant income from diesel bus builds have halted, and the number of electric bus orders are not yet in the same magnitude with no incoming or little long term future orders established. Australian manufacturers have the capability to expand production and increase the number of electric buses built per year but require certainty for the number of future buses ordered, so that plants, equipment and supplies can be ordered, and jobs created are sustained.

Planned purchases and builds will incentivise private investment to stay ahead of growing demand for the electric buses and potentially find new and innovative designs suitable for the Australian market and potentially abroad. Custom Denning for example has lighten their electric bus body and chassis design, so that the extra weight of the electric engine does not impact the passenger load. Custom Denning also plan to grow their export market and currently have 3 electric buses on order to the UK.

Australian manufacturers have the capability to grow and seek steady purchase orders and support to enable growth in the industry and job creation and retention.

It is also worth noting the importance of economies of scale. There has also been some incidences where international part suppliers will no longer ship to Australia or delayed shipment as priority has been given to high demand shipments in Europe. In 2021, battery demand for medium- and heavy-duty trucks and two/three-wheelers, increased by 65%[1]. The high demand meant a battery supplier has stopped shipping to Australia as the demand is too low and has prioritise supply to countries with high demand. As the demand for batteries sores, costs increase, as the demand for key metals used to produce the batteries surge in price.

To keep up-to-date with the demand and support domestic production, many governments globally have industrial strategies in place aimed in creating and expanding their prominence and within integrated supply chains. They have identified battery and EV manufacturing to be strategic sectors and look to support domestic production.

According to IEA[1], China's largest share of global EV battery production capacity in the world (77%) is a direct result of over a decade of government policies that support the industry. Korea, which accounts for 5% of global production capacity, along with Japan, at 4%, have recently launched large funding packages to bolster the competitiveness of their battery and EV industries.

Stimulating and sustaining growth in the industry will provide benefits such as:

- Create new and upskill jobs
- Grow local sustainable industries such as asset disposal and recycling
- Expand network of registered electric bus training authorities. This also includes skills development in zero emissions technology

Opportunity to create and develop jobs, wealth and skills in Australia

Governments are looking at options to develop the electric bus industry to drive economic growth, improve and create a highly skilled workforce, and develop sustainable and better environment. The transition to electric buses presents the opportunity to develop new jobs and skills in Australia across the supply chain, from manufacturing through to maintenance. New skills will be needed to support the rollout of electric buses.

There is currently a shortage in skilled labour and knowledge about smart charging capability. Any failures in the charging equipment or electric buses, may take several days if not weeks for the specialised technician to fly from overseas to review and fix the issue. There is a limited number of skilled technicians and organisations are starting to send employees abroad to train on the new technologies. Growing the industry and investing locally in education will levitate the shortage of skilled labour.

1. IEA, Global EV outlook 2022, Securing supplies for an electric future

Challenges encountered in transitioning bus fleets to zero emission buses

Opportunity to create and develop jobs, wealth and skills in Australia continued

This presents the opportunity to boost manufacturing and stimulate advances in related technologies in Australia. Australia has the mineral resources and capital to manufacture vital electric bus components such as electric batteries to assist in the transition to electric vehicles locally and abroad. Governments are investing to grow the labour force and skills, below are examples of supporting federal and local plans:

- **Australian made battery plan:** Under the Australian Made Battery plan jobs and wealth will be created as batteries are manufactured batteries onshore. The Australian Government will invest up to $100 million in equity injection into an Australian-Made Battery Precinct in Queensland. There are an estimated 34,700 jobs and $7.4 $billion$[1] in value to be made in Australia from battery technology and industries.
- **Queensland Resources Industry Development Plan**: Queensland will build on our existing manufacturing capability and further support manufacturing of ZEV technologies and component parts. This includes developing a battery manufacturing and recycling industry as part of the draft Queensland Resources Industry Development Plan.
- **Heavy Plant Centre of Excellence at Acacia Ridge:** With funding from the Queensland Government, TAFE Queensland has opened the Heavy Plant Centre of Excellence at Acacia Ridge. The new centre will provide training for the electric, hybrid and autonomous vehicle industry, using new machinery that produces lower emissions.
- **Future Battery Industry Strategy:** Western Australia Government deliver actions outlined in the Future Battery Industry Strategy to support Western Australia becoming a leading producer and exporter of future battery materials, technologies and expertise.
- **The Hydrogen Jobs Plan:** The Plan will deliver significant benefits for South Australia, including lower electricity prices for business and industry, thousands of new jobs for South Australians, and unlocking the development of a $20 billion pipeline of renewable energy projects.
- **Development of a local battery recycling industry:** Western Australia has ambitious targets that require 75 per cent of waste generated in Western Australia to be reused or recycled by 2030. Electric bus batteries can be repurposed for use as home or other stationary energy batteries, significantly extending their lifetime and value.
- **NSW Government's Renewable Manufacturing Fund.** The NSW government will invest $550 million. The fund aims to boost locally manufactured content for renewable energy and electric vehicles, which could include assembly of component manufacturing for electric vehicles.
- **Low-Carbon Manufacturing Grant Program:** The Government's Low-Carbon Manufacturing Grant Program will help Victorian manufacturers compete globally for renewable energy components, powering the state's transition to net zero and creating new jobs. Internships supported by the Government's Digital Jobs for Manufacturing program will help train, support and prepare 300 Victorian workers transition to new jobs that will be created as part of the state's push to net zero.
- **The New Energy Apprenticeships program** will create 10,000 new energy apprentices and the New Energy Skills program will help Australia's workforce to transition to a new economy by developing resources to support the uptake of existing training packages and provide mentoring support to apprentices in clean energy related jobs.

There is also the potential to grow wealth and skill in Australia through foreign investment. An example of this, is the Electric bus developer Ebusco. Ebusco has chosen Melbourne for its Asia Pacific operational headquarters creating new jobs and supporting the Victorian Government's Climate Change Strategy. The company is considering future manufacturing opportunities in Victoria and is currently working with Deakin University to develop composite materials and aerospace technologies to make its vehicles. Attracting foreign investment to set up and invest in Australia is also an opportunity to create highly skilled jobs and economic growth in electric buses.

1. Accenture, Future Charge, Building Australia's Battery Industries, June 2021

Challenges encountered in transitioning bus fleets to zero emission buses

The lack of accessible charging/ refuelling infrastructure is significantly impacting the uptake of electric buses

Jurisdictions reported the top barrier to uptake in electric buses is the lack of accessible charging/ refuelling infrastructure for both battery and hydrogen fuel cell buses. The cost to set up the infrastructure is high with challenging factors such as space limitations, locational suitability, electrics access and sourcing hydrogen, whilst minimising the interruptions to current passenger routes. On top of this, how to decarbonise the electricity system to achieve net zero targets.

The deployment of charging infrastructure is vital to enabling ZEV adoption, and countries that have the highest electric bus deployments, also have the largest charging networks. Governments have invested significant funding to electric vehicle charging infrastructure.

To ensure the longevity and sustainability of the charging infrastructure and future demands, the following key areas should be considered:

- Standardisation (charging equipment and emissions)
- improved charge point performance
- broader locational coverage (including rural areas)
- flexibility for installing technological advances like high power chargers
- Deployment of smart charging and smart grid technologies
- Electric supply guarantees

The lack of accessible charging/ refuelling infrastructure is significantly impacting the uptake of electric buses, continued

In general, the cheapest and most convenient option is to charge electric buses at the depot. However, updating existing depots may not always be possible or the best solution for numerous reasons. The location of the existing depot may not be suitable as there isn't enough space, there isn't enough electric capacity to charge an entire fleet of buses, or in some incidences the operator may not be able to afford to update the charging infrastructure, especially in rural and remote areas where the operator may only own one to two buses for school runs.

Satellite or opportunity charging is a potential solution for long routes, rural regions or where upgrading depots or a lack of depots that can reach enough electric supply is limited or difficult

The simplest solution to tackle long routes is to add more buses or change the route. This however may not be most economical solution or practical. Certainly, traditional routes are not that easy to change, and require long public consultations. Alternatively, buses with long roues maybe best using destination or on route/ interval charging, instead or in addition to depot charging. The charging technology has significantly advanced in the last few years and pantographs are now being considered in some Jurisdictions. The trials in Brisbane or promising and pantograph (destination) charging is likely to increase. Interval charging is great for electrifying long stretches, but the disadvantage is that the window for charging is short, meaning high charging power is required. This is expensive and requires major electrical infrastructure.

Rural operators may also consider community chargers. Governments are currently considering community charges at public owned grounds such as local councils. Monash University is trialling an opportunity charger at its campus. The charger could be used by various bus operators in that vicinity. Community charging may be better suited to remote/rural operations where it does not make sense to spend a large amount to upgrade small depots for a small number of buses.

Challenges encountered in transitioning bus fleets to zero emission buses

Electric buses require more space than their diesel equivalent

Currently electric buses take up more space in the depot than their diesel equivalent, as space is required to add the charging units to power up the buses. In addition, some depots require fire breaks to reduce the fire risks.

- **Charging infrastructure:** Approximately 1.5m of extra space is required between a charging (plugin) unit and bus. This may decrease depending on the design of the charging infrastructure and charging operations. Not all buses will require a full charge or need to be charged simultaneously. Smart charging, can minimise the charging time, alleviating any peak loads, thus potentially saving energy costs and spacing as buses are charged through a rotation.
- The charging unit may also change. Most chargers in Australia can charge up to two buses, with two arms. However, a charging terminal could potentially increase the number of charges to charge more buses. In 2016, Shenzhen piloted the 'network charging concept' with compact design of one charging terminal having several charging plugs/chargers so that up to four buses can charge at the same time. If for example 4 buses are charged at the same time, each bus receives ¼ of the power output, increasing the average charging time per bus. Although it takes longer time to charge, the advantage of this arrangement is that there are fewer charging units taking less space, and reduces the need to move buses at nighttime, which saves labour cost.
- Space could be also saved if the battery is charged at the top through pantograph charging $systems$[1] or through opportunity charging (could be charged on the bus route). However, these alternative charging mechanisms of course leads to other challenges such as location suitability the availability of significant energy supply to supply the rapid charging used by pantographs.

- **Fire precautions:** There are currently no prescribed national fire standards or safety procedures. Some depots have fire space gaps between groups of electric buses or plan to have an empty space for buses that are on fire. It is extremely difficult to put out the fire, once an electric bus is alit. Significant water supplies is required. Some operators believe it's better to let the bus to burn and move it to protect the other assets, especially other electric buses in harm's way.

"There are currently no national standards addressing fire safety requirements in the built environment (including in multi-storey car parks) in view of both the increasing number of EVs and EV charging infrastructure… Clear national guidance on evidence-based best practice for fire safety measurements addressing increasing number of EVs and chargers should be developed." ***– JET Charge***

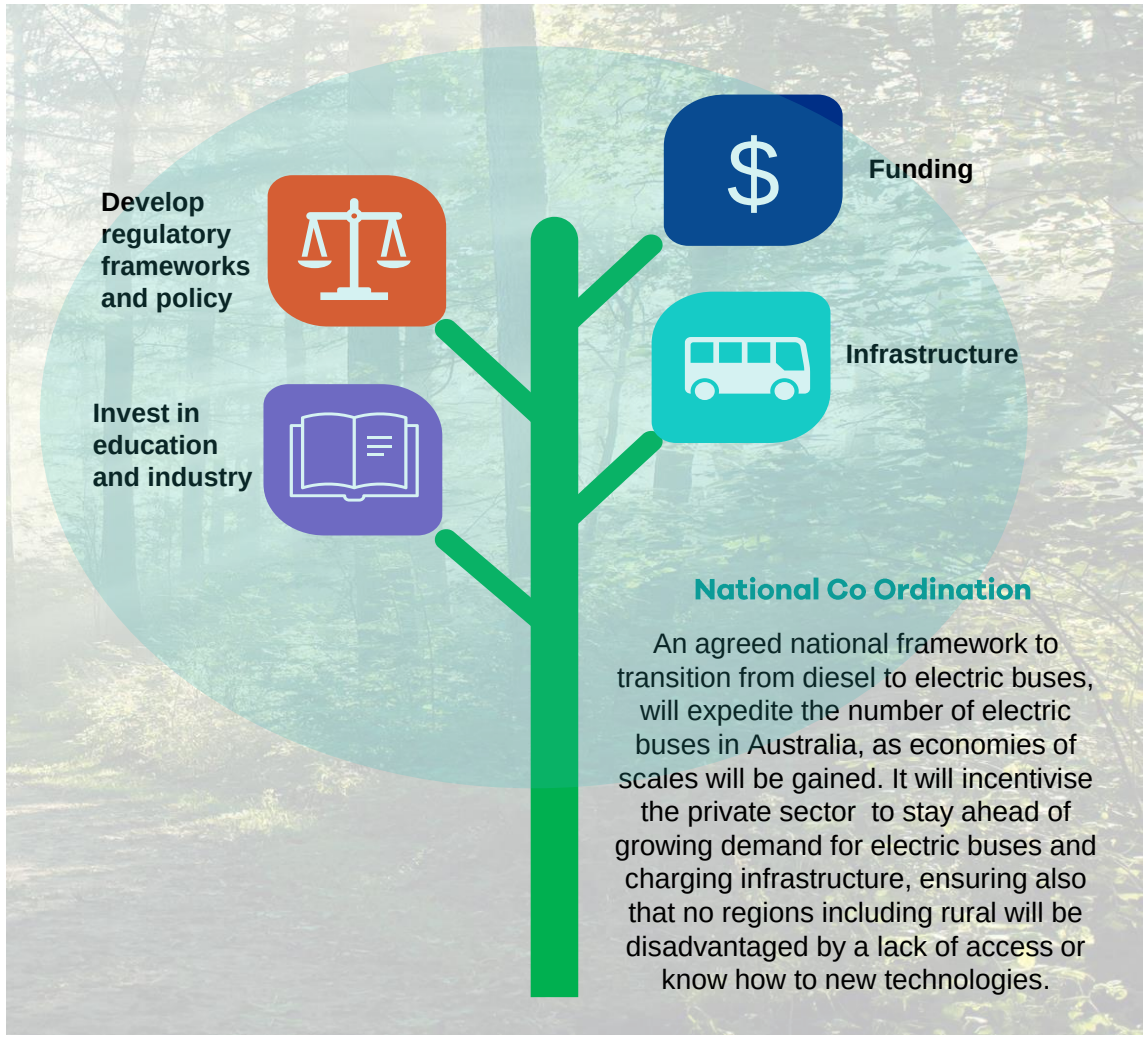
1. Pantograph xxx. The technology is ideal for bus routes with tight, continuous schedules and is often located at bus stops or terminals.

National Transport Commission

Key steps to ensure success

Source Zenobe

Key steps that governments and their agencies have taken to ensure success



Australians want clean vehicles for a better climate, and as technology improves and becomes cheaper to run, the uptake of electric buses grows. Jurisdictions across Australia have shown support for an electrified transport system and are trialling the electric bus technology with a few routes operating on road and taking passengers.

There is still work to do to reach Australia's pathway to net zero. The encountered challenges mentioned in the "Challenges encountered in transitioning bus fleets to zero emission buses" section can be managed through policy reform, planning, investment and upskilling and creating jobs. The recommendations differs between each jurisdiction as the recommendations depends on the ownership, capital available and future strategies of each jurisdiction, as well as whether national coordination is considered. As costs of electric buses and infrastructure and energy supply issues dissipate, its likely Australia will meet the net zero emission goals by 2050.

In summary, there are five key steps to ensure the uptake of electric bus success:

1. **Develop regulatory frameworks and policy to assist industry to drive the adoption of electric buses**

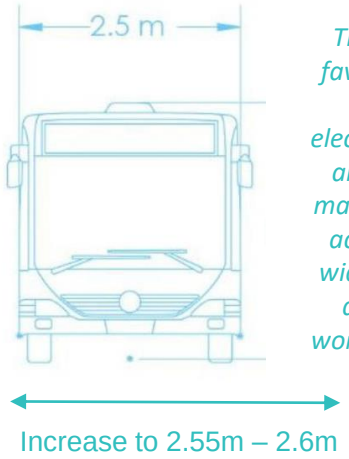
To reach net zero emissions by 2050 requires integration of the electric buses in power systems, decarbonisation of electricity generation, deployment of recharging infrastructure and manufacturing of sustainable batteries. Lessons can be learned from countries with a high uptake of electric buses. These governments have developed regulatory frameworks and policies such as future public transport vehicles to be purchased as zero emissions and implement emissions standards for heavy vehicles.

In Australia, clear targets have been established to achieve net zero emissions by 2050, including all future bus purchases to be electric. In order to accelerate the number of electric buses, it is recommended governments also review emission and national target settings as well as charging infrastructure standards to assist the drive the adoption of electric buses.

Key steps that governments and their agencies have taken to ensure success

Below summaries the key regulatory frameworks and policies mentioned earlier in the evaluation to assist industry to drive the adoption of electric buses:

- **Standardisation.** Governments can specify the technical specifications for vehicles and charging infrastructure. Having clear specifications, will allow the private sector to invest and plan for growing demand and ensure that the investment to build buses and infrastructure meet legislative and performance requirements, as well as ensure a return on investment. Where the Government owns the buses, it will also allow greater buying power on the specified bulk number of buses.
- Where the electric buses and depots are owned by the private sector, specifications can be added to the operational contracts, or a selection of certain buses can be purchased from a preselected/ verified Government list. Note however preselected lists may help small family operators who do not have the experience or knowledge to purchase electric buses, however for large, especially more experienced multinational operators they may already have arrangements in place which are cost effective.
- **Increasing the heavy vehicle dimensions and axle load limits.** Increasing the bus width dimensions and axle loads to match international standards will open the market to a greater number of bus models and makes. The current maximum dimensions and axle load limits of heavy vehicles are impeding the market uptake of new technologies and limiting the available models suitable for the Australian market.
- Increasing the heavy vehicle width to 2.55 meters and to match EU^1 axle mass limits, will make it easier for manufacturers to supply models available in other markets without making additional changes specifically for the Australian Market. Many suppliers outside the European Union supply buses that meet EU requirements.
- **Reducing emissions are key driving forces in adoption of electric buses.** Reducing emissions and pollution supportive policies are driving the adoption of electric buses worldwide. Many countries and cities have set targets for 100% public transport vehicles to be purchased as zero emissions and implement emissions standards for heavy vehicles. CO2 emission standards for heavy vehicles are expected to promote electric bus adoption. In Europe, the $European\ Union\ Clean\ Vehicles\ Directive^2$ sets national procurement targets of zero emissions public buses. Similar targets set by the jurisdictions has seen an update in electric buses and will continue to grow until the fleet is 100% electric. Countries that have seen significant progress have implemented policies to curb pollution, set electric vehicle targets as well as set emissions standards.



The Bus Industry Confederation (BIC) are in favour of the increase in dimensions and axle load increases. With the introduction of electric buses, buses are becoming heavier. BIC argues "the combinations of increased axle mass limits and low floor accessible passenger access needed is leading to a general use of wider independent front suspension systems" and continue to argue that the axle limits worked for diesel buses, but not on the heavier zero emission buses.

1. Regulations (EU): 2015/718, 2015/719 and 2019/1242 - all major international chassis and complete bus suppliers comply with the EU market requirements (irrespective of country origin)
2. European Commission, https://transport.ec.europa.eu/transport-themes/clean-transport/clean-and-energy-efficient-vehicles/clean-vehicles-directive_en

Key steps that governments and their agencies have taken to ensure success

2. Funding programs and grants to support the public transport industry

Many businesses in the public transport sector have had to face immense operational and financial difficulties in the last years, due to the Covid pandemic. That and the initial high cost of an electric bus has in the past deterred the uptake of electric buses. Funding programs, grants, leasing models have been an important step in the uptake of electric buses. Advancing states in the uptake of electric buses have financial support from their local governments and green initiatives. Governments have invested millions if not billions over the next years to assist in the delivery in electric buses and build critical electrical infrastructure/ depots to supply energy to the buses.

Whether the buses are state or publicly owned, the funding will help deliver a new electric bus network, upgrades to depots and the installation of appropriate charging infrastructure. Funded trials will also help assist in the correct procurement/ installation of materials required to build an effective zero-emissions bus network.

3. Planning is key to a successful infrastructure upgrading

Planning and building the depot and energy infrastructure required to support a zero-emission fleet is critical to enabling the transition. However, Jurisdictions and private operators have highlighted that providing charging infrastructure is also one of the biggest challenges to electrification and has slowed the progress of electric bus transition. Especially as the upgrade in infrastructure and fleet of buses also need to be delivered without disruption or little disruption to passenger routes. Any delays and disruptions to the routes, may incur penalties for the operators.

Upgrading a depot and investing in electric buses is also costly and time consuming and is by no means an easy task. Depending on whether there is sufficient electrical supply, dedicated feeders, bore work, proximity to residential homes, the number of electric buses requiring charging, an existing depot may not be feasible or economically viable for an upgrade and a new location is required adding to the cost of investing in an already high upfront investment cost.

Funding programs and grants in Australia

Jurisdictions that are further along have received government support and funding.

- The ACT Government will invest $26.3 million over three financial years to complete critical electrical infrastructure works to supply the depots with the energy required to house and charge up to 300 battery electric buses.
- The NSW Government has an approved budget of $3 billion to fund the next stage of Zero Emission Buses (ZEBS) and new charging infrastructure.
- The Tasmanian Government has allocated $6 million for Metro to conduct the BEB trial and approved up to $12.3 million from the Tasmanian Renewable Hydrogen Industry Development Funding Program to progress recommendations from an Industry Activation Study, which includes the FCEB trial.
- The WA Government will invest $125 million towards electric bus charging infrastructure and $80 million for the buses, $50 million for the facility and $120 million for the depot upgrades and required infrastructure.
- The Victorian Government has invested $20 million (2020-21 Victorian State Budget) to undertake research, planning and trials of zero emission bus technology. Learnings from the trials will be shared across manufacturers, operators, government and others to inform the procurement of only zero emission buses from 2025.

Key steps that governments and their agencies have taken to ensure success

3. Planning is key to a successful infrastructure upgrading, continued

To mitigate the risks and manage the transition, operators and Jurisdictions are progressing in tranches. The first tranche usually starting small is generally to test the electric bus and infrastructure charging types to inform future larger scale purchases. However, it is important to note, the initial tranches and selection of trial location/ depot upgrade is a site that could potentially replace all diesel buses in its vicinity to electric. One operator mentioned, one of its learnings would have been to consider a larger scale and longer-term investments than the initial trial bus numbers and routes. Charging one-to-three buses is very different to charging an entire fleet. Planning on a larger scale would have saved time, effort and costs. Transitioning overtime, will also require Jurisdictions to plan how the existing depots will accommodate the changing mix of diesel, electric and potentially hydrogen buses until net zero emissions is reached. Having a scalable plan on how to deliver infrastructure in a least disruptive manner and securing energy supply infrastructure is key to a successful transition.

Infrastructure considerations include:

Existing depots. It is important to validate that the existing depot can be upgraded to electrify the bus fleet for todays and future electric demand. It is also important to clarifying to suppliers what the owner needs and not be sold the technology they have. The owner needs to consider the following:

Location, Location, Location

Where possible it would best to utilise the existing depot and minimse the disruption to bus routes and times. Viability questions include:

1. Is the ground suitable for upgrading the depot? What's in the ground and above ground? Are there old tanks, buildings that need to be removed? If so, how much will this add cost to the project?
2. Where is the nearest substation? How much energy can the substations produce and can this power the fleet of buses?
3. Is the depot near or by residential areas? If so, are there any potential impacts to the neighbouring residential areas?
4. Has noise pollution been considered? At one depot, the solar battery software had been upgraded changing the speed of the fan used to cool the unit down. The increased speed, also cause the fan to emit an extremely loud noise waking up residents. The speed had to be reduced so residents were not disturbed.
5. What are the alternative solutions or land areas? i.e. build on green land, collocate with other public transport means, opportunity charging etc.
6. Where is the charging infrastructure (depot, destination charging, on route) best utilised? Are community charging points (potentially in remote areas where it's not viable for the operator to build charging facilities) required?
7. Can the charging facility be collocated for example with hydrogen, diesel or natural gas fuels?

Energy Capacity

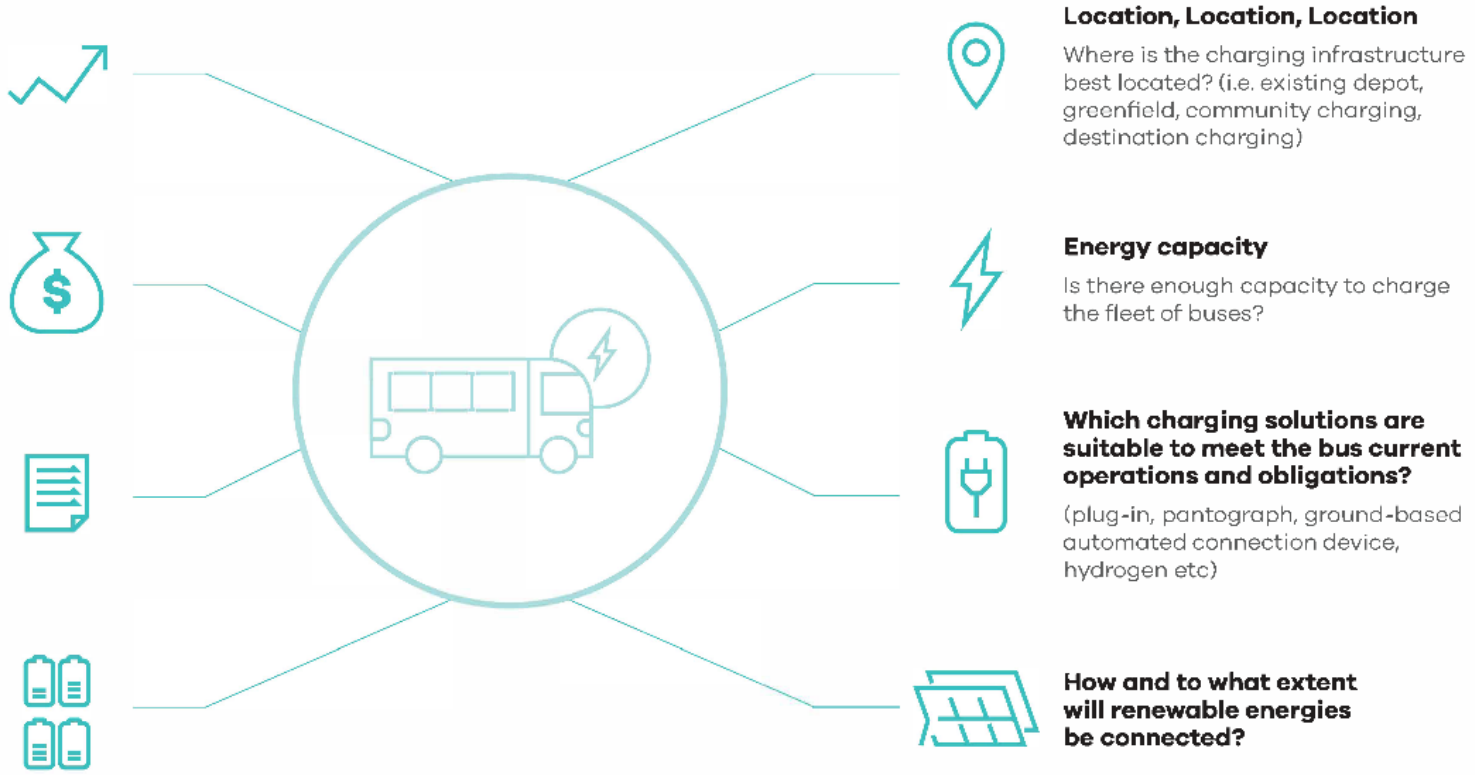
Charging a fleet of buses requires significant charging capacity. A lot of energy at a large scale is needed to fuel an entire electric bus fleet. With increasing costs of electricity provided by the grid, what alternative sources of energy is best.

The operator should consider:

8. Which energy source (solar, hydrogen, etc) is best suited?
9. Is the supply of equipment readily available? For example, how many solar panels are required to fuel the fleet and is there enough space for the panels and energy storage?
10. Do you require a dedicated electric feeder to fuel the fleet?
11. Peak loads are expensive, can the energy charging be managed?

Key steps that governments and their agencies have taken to ensure success

Key charging infrastructure considerations



Is it scalable with the growth of electric buses?

Energy and fleet optimisation

How to keep electricity bills low (smart charging). When is it off peak and can peak loads be managed?

What safety precautions have been considered? Is further training required?

Can the batteries be recycled? How can the battery storage be optimised?

Location, Location, Location

Where is the charging infrastructure best located? (i.e. existing depot, greenfield, community charging, destination charging)

Energy capacity

Is there enough capacity to charge the fleet of buses?

Which charging solutions are suitable to meet the bus current operations and obligations?

(plug-in, pantograph, ground-based automated connection device, hydrogen etc)

How and to what extent will renewable energies be connected?

Key steps that governments and their agencies have taken to ensure success

12. What are the optimal charging times, and off-peak electric costs?
13. Is there enough spacing between charges?
14. Are the charges at the back of the bus, on the side or on top? If the electric bus has external mirrors, please check the height of charging units as the chargers tend to knock the mirrors if charging is carried out on the side or alternatively you can consider having the charger at the back of the bus.
15. Is there a backup system if a charger (pantograph charger) fails or if there is an electric blackout?

Safety precautions

Very few electric buses worldwide have caught on fire and its believed battery electric vehicles are less likely compared to their internal combustion engine $counterparts^{1}$ to ignite. Although unlikely, electric vehicle fires are hard to fight. In Paris, it took 30^{2} firefighters to put out the Bluebus 5SE electric bus fire in April 2022. It is not clear what causes the electric bus failures and as a new technology it difficult to obtain reliable and independent statistics. It is suspected that the major source of ignition is caused by charging-induced overheating of components. According to EV Firesafe, only 19% of 125 $investigated^{3}$ EV fires were unanimously traceable back to a failure of the battery.

Questions to consider:

16. Are there any safety charger precautions? i.e. precautions to prevent bus from knocking equipment – i.e. line guidelines, metal stoppers to prevent bus backing into the chargers, etc.
17. Have you contacted the local fire station to understand their processes and recommendations?
18. What fire precautions are in place? Do you require fire safety gaps or empty space if an electric bus is on fire? Is there a protocol to recall all the electric buses if one ignites?
19. Is there sufficient water to put out an electrical fire? Are there water limitations?

Based on Sustainable bus, there are 4 key steps in reducing electric vehicle $fires^{4}$:

1. **Equipment barriers.** Equipment bought at the lowest price might cause issues in the long run, with further availability and safety concerns. Invest in technology suitable for the Jurisdictions environment and meets safety checks and regulations.
2. **Construction measures.** Bring in a dedicated electric vehicle fire risk experts into the depot design and construction process. An increased awareness for sharing experiences about, circumstances of and reasons for past incidents will hopefully also lead to a continuous improvement process in the industry – this demands a willingness to share lessons-learned.
3. **Human factors.** Operators must understand the electric assets and keep to date with regular training and maintenance of the buses. This includes bus driver training (including how to charge bus) and continuous education, as well as regular bus maintenance.
4. **Proper management and due use of an asset.** Permanent knowledge of battery safety and quality status, indications about preventive lifetime and risk optimization potentials and suitable early-warning systems of batteries, vehicles and infrastructure must and will become standard, given the virtually nonexistence of visual or other battery checks. A well-managed portfolio will also reduce fire and operational insurance costs and have a substantial lifetime and total cost of ownership impact. It is becoming common for operators to demand periodical asset portfolio quality reports from the original equipment manufacturer – a step into the right direction.

1. AutoinsuranceEZ 2022: based on car comparisons https://www.autoinsuranceez.com/gas-vs-electric-car-fires/
2. https://insideevs.com/news/583324/paris-suspends-149-bollore-electric-buses-after-two-fires/
3. https://www.evfiresafe.com/ev-fire-global-timeline
4. Based on the recommendations provided by Sustainable Bus 2022: https://www.sustainable-bus.com/news/london-fire-electric-buses-recalled/

Key steps that governments and their agencies have taken to ensure success

Changing the traditional charging landscape. Not all existing depots can be electrified. There may be spacing issues as often charging and energy storage require more space than their diesel counterparts or for example a limited energy supply/ electric capacity to electrify an entire fleet. As a result, new locations or new charging practices may need to be considered.

New sites could potentially be co-located with other Government owned resources such as other electrified public transport modes or opportunity chargers at council sites.

As the range and capacity of battery-electric buses and charging equipment improves, Jurisdictions could consider other means of charging such as on-route charging or rapid pantograph chargers. Depending on the location, these other charging options maybe better more suited to resolve the current shortage of charging infrastructure.

In some cases, the Government doesn't own the depots and financially it's not viable for owners to upgrade the depot to enable electrification of the fleet. This has certainly been the case in rural regions. A few Jurisdictions are investigating the feasibility of opportunity charging in rural towns as most rural operators are small in size and are often run by "mums and dads". They do not have the capacity to fund and install electric charging equipment, often on farmlands. In these situations, it may be best to consider opportunity charges on government grounds for multiple operators to use.

Opportunity charging and on route charging may also need to be considered if there is limited land suitable to build zero emission powered depots or safety concerns as depots are too close to residential homes. Opportunity charging and on route charging can potentially help build system redundancy and optimise assets by extending their route length, keeping batteries optimised and reducing dead running for charging purposes.

Understanding the charging schedule. Charging a fleet of buses requires significant charging capacity. A lot of energy at a large scale is needed to fuel an entire electric bus fleet. Smart charging and distributed renewable energy may assist in reducing the demand from the grid.

Pantograph Charging, Hess

Pantographs can be used for on route charging due to their rapid charging capacity. Brisbane Metro are currently trialling the technology.

Understanding the charging schedule continued. Ensuring the fleet has enough power to run all their routes without overloading the sub power stations/ electric supply, as well as optimising economically the usage can be difficult. Most buses are charged at night during the off-peak grid electricity times. This is especially challenging if the depot is using solar powered energy, batteries need to be installed to keep the daytime charge, as majority of charging happens when buses are not in operation at night.

Fortunately, electric buses and the charging equipment can include smart charging software. Smart charging technology can improve the management of zero emission buses and reduce pressure on the power grid and utilisation of alternative energy sources such as solar. Having a smart charging system in place will future proof bus depots, transit/ opportunity charging to be capable of powering an entirely electric fleet, real-time energy monitoring and communicate directly with the energy provider's assets.

Key steps that governments and their agencies have taken to ensure success

Ensuring the electric capacity

It is recommended that electricity demand research is carried out to ensure the increasing demand for electricity is met and guaranteed supply. This includes understanding the long-term infrastructure upgrades and demands to handle new loads required by heavy vehicles and other competing heavy electricity usages such as essential loads of electricity such as electrified heating.

In addition, to ease the pressure on power grids, smarter and more co-ordinated charging control measures could be established early to help reduce the cost of new infrastructure. Smart tools used to optimise fleet operation, charging and energy storage, can achieve significant cost reductions and increased efficiency of the charging.

Is it scalable with the growth of electric buses?

- **Energy supply.** Network upgrades are expensive and requires long term planning by electricity suppliers. Based on the trials in metro cities, installing power cables to substations can cost bus operators roughly $1m per meter. As the number of battery run electric buses are deployed, the demand for electricity will also increase. Charging one or two buses maybe within the current capacity of the substations. However, as we move to charge an entire fleet of buses the current substation may require an upgraded, which would lead to notably higher costs.
- The question is, can the network handle the increase of electricity demand to charge an entire fleet as well as other competing demands and uses such as charging light vehicles, households switching to electric heating from gas, appliances and other plug-in technologies compete for the same power. It won't be easy to plan and upgrade the distribution to ensure capacity for metro, rural and remote areas.

Is it scalable with the growth of electric buses? continued

- Distributed renewable (solar) capacity at charging stations can help alleviate the grid infrastructure costs required to connect these stations to the grid, as well as maximising the use of the network (smart charging). Maximising the use of the network will help and can be more cost-effective than upgrading assets to serve peak periods that occur for relatively short periods over the day.
- **Diversify technology.** It's also recommended that a mixture of fleet technology is considered, such as including the use of hydrogen fuel cell buses. In California, Sunline Transit Agency has invested in hydrogen fuel cell buses as electricity supply is not stable, with the occasional blackouts in the cities. With a mix fleet in Australia, the network will not be locked into one technology as technology improves. There is still no strong evidence that either battery run, or hydrogen fuel cell buses is better than the other. The uptake of hydrogen fuel cell buses globally is increasing and as the technology improves, it may be better suited in areas of Australia.
- **Interoperability.** As mentioned earlier, standardisation of charging technology and infrastructure will make scaling up electric buses easier and interoperable. It will enable operators to mix and match different brands of vehicles and chargers, which makes their integration into the public transport network more flexible and, cheaper.

Key steps that governments and their agencies have taken to ensure success

4. Invest in education, create jobs and grow manufacturing

A push for electric buses is also a push for competitiveness, jobs and growth. There is currently a shortage in skilled labour and knowledge about smart charging capability. The transition to electric buses presents an opportunity to upskill and develop new jobs in public transport, as well as help Australia transition to a cleaner, greener future as carbon emissions reduce and air quality improves.

Governments are looking at options to develop the electric bus industry to drive economic growth, improve and create a highly skilled workforce, and develop sustainable and better environment. Governments have invested in growing the labour force and skills with federal and local support investing millions in local and national programs to upskill, create new roles and grow the industry, as well as meet the needs of local customers. This includes developing and making electric batteries for electric vehicles and developing renewable energies such as clean hydrogen for the use of zero emission buses.

Wealth and skills in Australia can also be grown through foreign investment. An example of this, is the Electric bus developer Ebusco. Ebusco has chosen Melbourne for its Asia Pacific operational headquarters creating new jobs and supporting the Victorian Government's Climate Change Strategy. The company is considering future manufacturing opportunities in Victoria and is currently working with Deakin University to develop composite materials and aerospace technologies to make its vehicles. Attracting foreign investment to set up and invest in Australia is also an opportunity to create highly skilled jobs and economic growth in electric buses.

Key steps that governments and their agencies have taken to ensure success

5. National Coordination

To keep up-to-date with the demand and support domestic production of electric vehicles, many governments globally have industrial strategies in place aimed in creating and expanding their prominence and within integrated supply chains. Governments, including Australia, have identified battery and electric vehicle manufacturing to be strategic sectors and look to support domestic production.

Australia has the opportunity to boost manufacturing and accelerate uptake in electric buses. Especially as Australia has the mineral resources and capital to manufacture vital electric bus components such as electric batteries to assist in the transition to electric vehicles locally and abroad. More than half of the world's lithium is produced in Australia and is one of the top producers of nickel globally. Both vital elements required to make electric batteries.

Lessons learned from countries with high uptake of electric buses have a developed national/ centralised plan covering national standards, and long-term strategic infrastructure planning. This includes national policies and regulations such as emission and charging infrastructure standards, as well as nationally recognised/ certified skills.

However, unlike many of the high electric bus uptake countries Australia is a federation and will need to consider how investment in the industry reaches the nation and sufficiently covers each jurisdiction. Not only to ensure electric buses reaches all points in Australia, currently none in the Northern Territory and most remote and rural areas, but also allows Australia to compete in the production of electric buses/ batteries globally. In order to do this, economies of scale and standards is vital to enable interoperability, creating nationally recognised credentials to address skills shortages by attracting a more diverse workforce and provide support to manufacturers and suppliers to grow and meet demand. A national plan and coordinated approach is recommended.

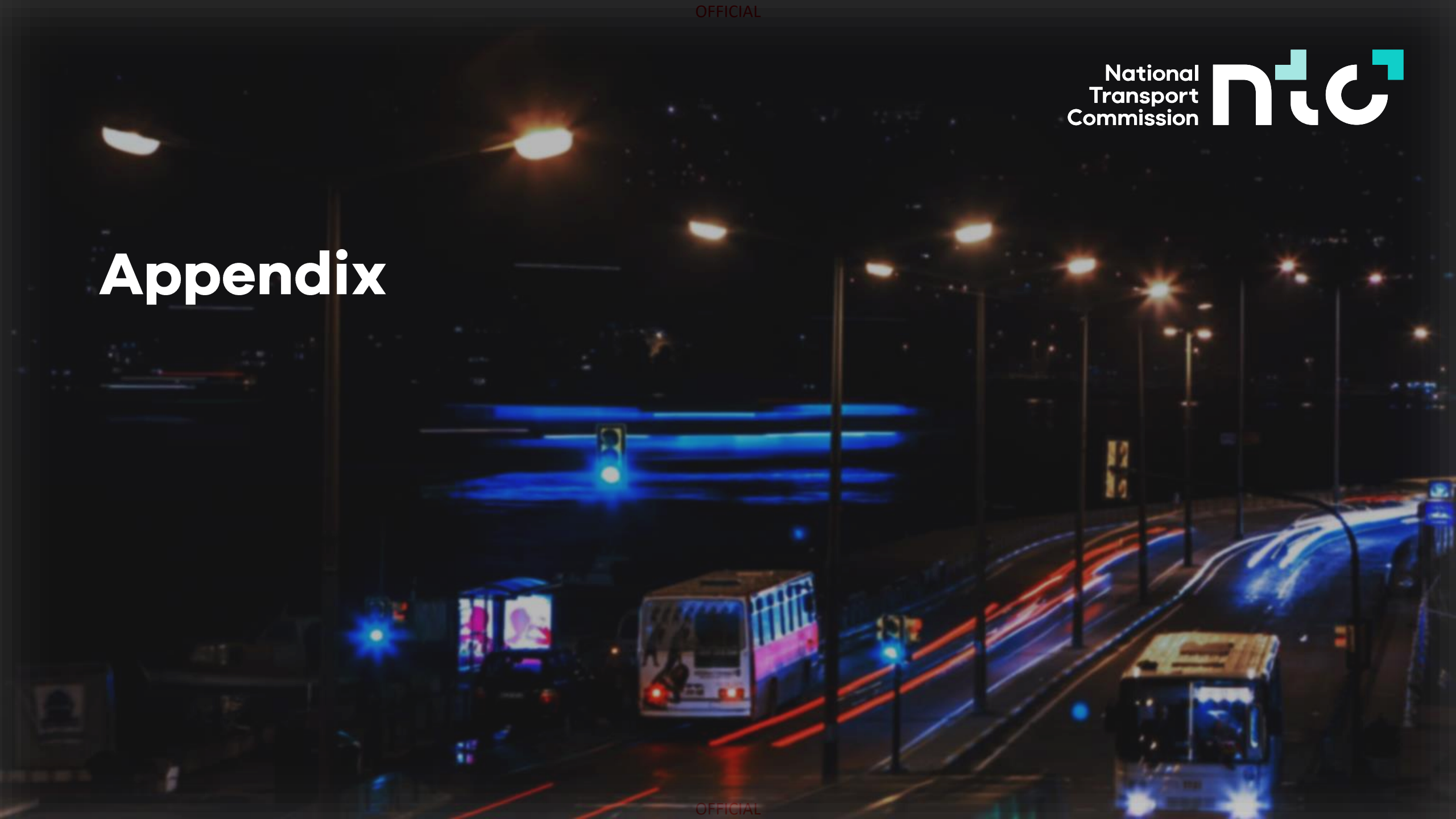
Lessons learned from major ZEV markets demonstrate that the lack of strategic infrastructure development either by central government planning or incentivised by policy mechanisms, along with insufficient co-ordination across key players, e.g. various government entities, utilities, building operators and charge point providers, tends to lead to infrastructure concentrated in certain areas (often lacking in remote regions).

Experience in more mature EV markets also demonstrates that access to property and grid connections, along with supporting building regulations, interoperability standards and efficient permitting can ease infrastructure development.

IEA, Global EV Outlook 2022

National Transport Commission

Appendix



About the evaluation

Purpose of the review

The NTC should play a stronger role in evaluating the outcomes of national transport reforms, in particular whether economic and safety benefits were achieved and to what extent. This would allow Ministers to determine the need for further actions and reforms. Transport Ministers should also periodically invite the NTC to suggest reforms for evaluation. Suggestions identified by stakeholders during this review could be considered as part of this process. [emphasis added]

NTC Statutory review, April 2022

The National Transport Commission (NTC) undertook this evaluation to identify and report on learnings from adopters of electric buses, as part of the NTC's evaluation plan and evaluation framework as recommended in the NTC Statutory Review 2022. The intention is to provide and support Transport Ministers in future strategic decisions and investments in zero-emission (electric) buses.

This includes identifying learnings and advice on:

- The benefits, costs, and reported impacts of electric buses
- Possible ways to fund and finance electric bus services
- Regulatory frameworks incentivising the adoption of electric buses
- Challenges encountered in transitioning diesel bus fleets to electric buses
- Key steps governments and their agencies have taken to ensure success in adopting electric buses

What are zero-emission electric buses?

A zero-emissions bus does not emit greenhouse gas emissions from the tailpipe and is fuelled by renewable energy. This paper examines the adoption of electric buses including:

Battery electric buses: Most electric buses in Australia are battery run. Battery electric buses operate solely on electricity and are usually charged overnight. In other words, they have no ICE, fuel cell or fuel tank and derive all their power from their battery packs. Battery electric buses use electric motors and motor controllers for propulsion instead of internal combustion engines.

Hydrogen fuel cell electric buses: There are currently a few hydrogen fuel cell electric buses being trailed in Australia. Fuel cell hydrogen buses use electric energy produced through an electrochemical reaction both for the powertrain and for a support battery charging. Energy stored in the batteries adds additional power in demanding situations like a rapid acceleration or gradients. Hydrogen is pumped into the bus's tank like traditional fuels.

A bus that does not use liquid petroleum-based fuels such as petrol, diesel or other fuel blends, or gaseous fuels such as liquefied petroleum gas (LPG, liquefied natural gas (LNG) and compressed natural gas (CNG)); and does not emit greenhouse gas emissions from its exhaust pipe.

National Transport Commission

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