PATREC

Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

iMOVE

Feasibility of Battery-electric Buses for Regional School Bus Services in Western Australia Final Report

June 2024

Feasibility of Battery-electric Buses for Regional School Bus Services in Western Australia Final Report

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Keywords

Electric buses; school bus service; EV charging; renewable energy

Version control

Final

Project No

iMOVE Project 6-019

Project steering committee

Steve Beyer – Department of Transport

Acknowledgment

This research was funded by PATREC and the iMOVE CRC and supported by the Cooperative Research Centres program, an Australian Government initiative.

Commissioning body

This research was commissioned by the Planning and Transport Research Centre (PATREC), a collaboration between the Government of Western Australia and local universities, constituted to conduct collaborative, applied research and teaching in support of policy in the connected spaces of transport and land use planning. The collaborating parties are: The University of Western Australia, Curtin University, Edith Cowan University, the Department of Transport, Main Roads Western Australia, Western Australian Planning Commission and the Western Australian Local Government Association.

Publisher

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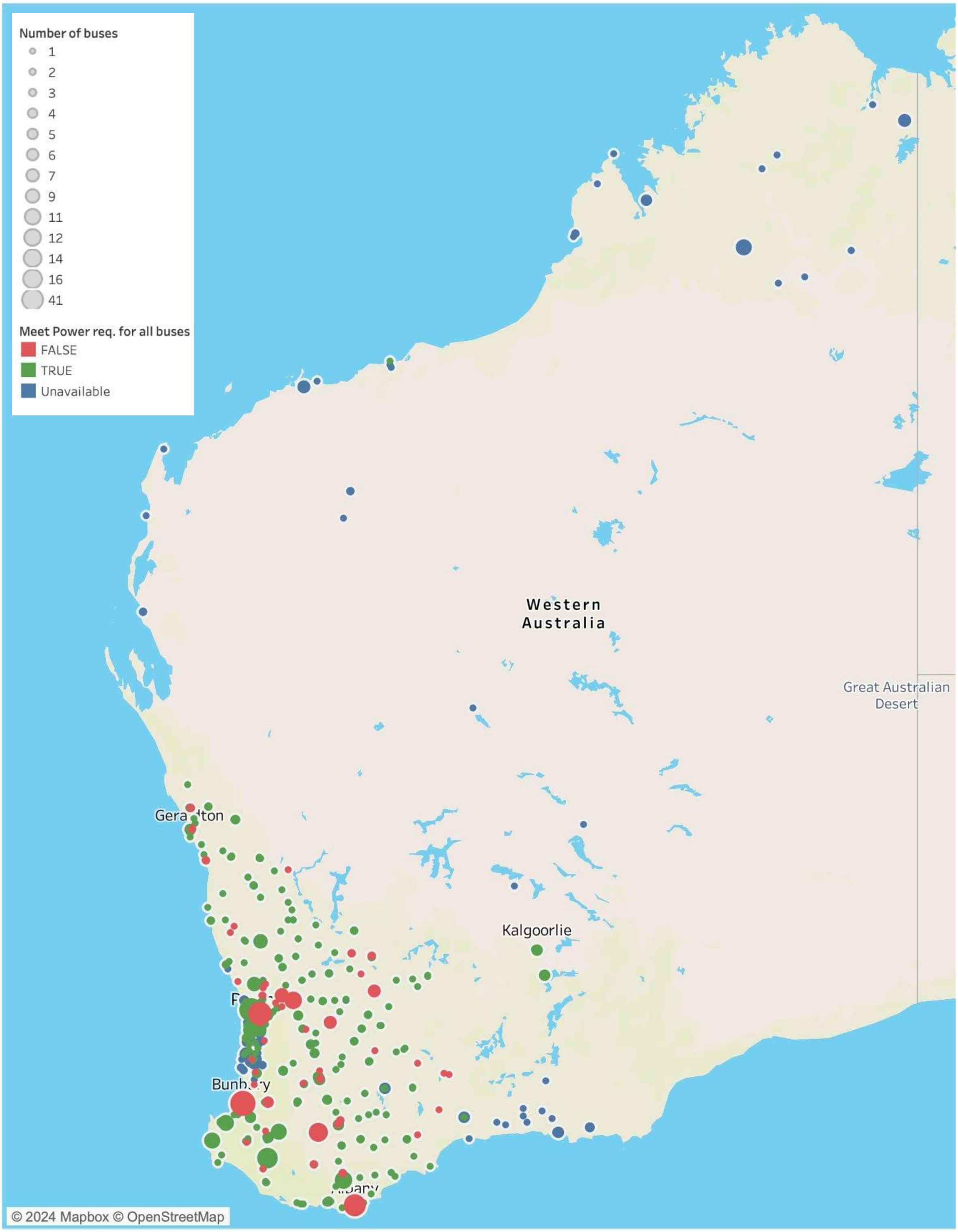
Executive Findings

1. **The introduction of electric school buses and corresponding charging stations is technically feasible and practical for all case studies investigated.**
2. At 73% of all 544 school bus depots (with 64% of all 935 school buses) in WA it will be possible to switch over to e-buses and charge them onsite without the need for a grid upgrade (or with a free upgrade).
3. For many of the sites with insufficient grid, charging will be possible at the corresponding schools. Only a small percentage of sites require either a grid upgrade or local generation (e.g. solar PV).
4. Every year WA school buses use 7.5 million liters of diesel, costing $15 million ($2/L) and producing 20,000 tons of CO_2.
5. A 100% electric school bus fleet in WA would require 34.7 GWh of electricity per year, generating around 14,800 tons of CO_2 in 2024 (a 26% GHG reduction relative to diesel).
6. E-bus emissions are expected to reduce to just 3,000 tons of CO_2 by 2030 (85% less than diesel) due to WA's emission reduction target for the grid.
7. In many locations, the lifetime economics of deploying and operating e-buses at today's prices is comparable to diesel buses – in several cases even lower. In addition, the cost of electric buses is expected to fall significantly over the next decade.
8. In our economic calculations we allowed for one full battery replacement after about 10 years of operation during the e-bus's 17 year contract time.
9. Mature e-bus solutions and charging systems are available in Australia in all categories and sizes.
10. **Making e-bus chargers available to the general public (residents and tourists) on weekends and school holidays will generate substantial income.**
11. Besides CO_2 emissions, diesel buses produce large amounts NO_x and PM emissions, which are known health hazards. More people die from vehicle emissions than in road accidents.

Map of School Bus Depots

The map[1] below shows all bus depot in WA. Sites with sufficient power to charge all e-buses are shown in green, those with insufficient power are red, those with unknown power levels are blue.



[1] Map created by Dr Kai Li Lim, The University of Queensland

Executive Summary

Driven by the need to reduce GHG emissions and improve air quality, this project investigates replacing diesel-powered school buses with electric buses in metro, regional, and remote WA.

It has been repeatedly demonstrated that electric buses work well in densely populated metro areas with strong electricity grids. However, it is often viewed as challenging to provide similar solutions for electric school buses (and other EVs) to some of WA's regional and remote areas. Many of WA's rural areas are supplied by very weak feeders that cannot support even a single 50 kW DC charger, while some areas have frequent power outages that would disrupt bus services.

We have considered different modes of operation and charging scenarios:

- Should each school bus return to the depot during the day, or should it stay at school? *This can mean a huge cost difference for long distance routes, such as Denmark-Albany by removing empty drives (dead-runs), and will significantly reduce CapEx (smaller bus battery and charger required) while cutting OpEx in half.*
- Does the bus need a depot, or can it stay at the school overnight? *If the school is close to the depot, then installing charging systems at the school will have a number of benefits, including independence of the bus operator.*
- Should the bus be charged at the depot, the school (or nearby facility) or both? *Emphasizing charging during the day will make most use of renewable energy. Schools have some of the best grid connections in WA's regional and remote areas. When charging at the depot and the school, a lower-cost smaller bus battery can be used.*
- Does the grid need to be upgraded or can charging be achieved by installing solar PV with backup generators?
  In cases where the grid is insufficient, either a grid upgrade or a solar PV with backup generation are the only two choices. Which one is more economical depends on the site.
- Can a school bus be charged directly from the grid, or does it require additional stationary batteries?
  Additional stationary batteries create significant additional cost, and in most cases offer only a small improvement for bus charging. However, they can prove economically attractive when chargers can be used for the general public outside of school days.

The following chapters contain a market analysis for electric school buses, charging stations and stationary battery storage options. We then look at the electricity grid situation in regional WA and present our custom web-based planning tool for electric school bus services.

The next chapter presents an economic model comparing e-bus operation to diesel bus operation, followed by discussing service issues for electric buses, including training of local motor mechanics as well as fly-in services, and a look at alternative zero emission technologies.

The final chapter comprises a number of case studies, where we look in greater detail at a number of depot locations and their bus routes and recommend one or more scenario solutions for e-bus operations and charging systems.

Overview

Western Australia's PTA operates:

- 935 diesel school buses,
- 544 locations, ranging from 1 to 41 buses per location,
- 429 schools serviced,
- 31.7 million km of combined travel per year,
- 7.5 million liters of diesel consumed per year,
- 375,000 liters of AdBlue consumed per year (5% of diesel),
- **20,000 tons of greenhouse gas emissions** (GHG)[23] generated per year,
- 87.5 tons of NO_x emissions and
- 1 ton of PM_{10} emissions generated (engine only);
  both NO_x and PM are known to be health hazards.

Transitioning step-by-step to a 100% electric bus fleet will change this to:

- 34.7 GWh (34.7 million kWh) electric energy required per year for bus charging,
- **14,800 tons of greenhouse gas emissions** (GHG) per year[4],
  a **26% reduction** (5,200 tons) of CO_2 emissions annually.

Noting that the WA government[5] has set an 80% emissions reduction target by 2030, which –if achieved– will result in an *additional* annual reduction of 12,000 tons of CO_2 emissions from the PTA school bus fleet by 2030, resulting in a total emission reduction of 85%. Once the grid is fully renewable, GHG emissions from charging the electric school buses will be zero (100% reduction).

"

Each of the 935 school buses has a contract time of 17 years, meaning on average 55 buses will be replaced annually.– There is no economic or technical barrier to transition to a 100% electric school bus fleet in WA.

Every new diesel bus purchased in 2024 will continue to pollute until the year 2041.

[2] Australian Transport, Emission conversion factors, https://www.atap.gov.au/parameter-values/road-transport/appendix-b-emission-conversion-factors; bus factors are 2.67 kg/l for CO_2 and 11.66 g/l for NOx.
[3] National Transport Commission, *Carbon Dioxide Emissions Intensity for New Australian Light Vehicles*, 2020, Aug. 2021 (2.67kg CO_2 per liter diesel)
[4] Electricity Maps, (427 g/kWh in 2023 for WA), https://app.electricitymaps.com/zone/AU-WA
[5] WA Today, Peter Kruijff, *WA government sets 80 per cent emissions reduction target by 2030 for state operations*, 23 June 2022

Disclaimer

We need to point out the following:

- Information provided by PTA on bus depots, routes and daily distances were supplied at the start of this project and may have changed in the meantime.
- Energy information was provided by Western Power, who note:
    - *This analysis does not provide a confirmation of capacity, all capacity indications are purely estimates. Detailed design assessment, which is a chargeable service, is essential to confirm any capacity.*
    - *In order to provide a high level analysis of almost 600 sites, various approximation and estimation methods have been employed. Chief of those is rhe use of nearest distance to identify upstream transformers.*
- *Capacity is fundamentally an estimate as electricity demand evolves over time and as capacity taken up by customers.*At sites where no energy information was provided, the available power levels had to be estimated by the authors.
- There is no reliable data on how e-bus and battery prices will develop over the next decades, but it is generally accepted that prices will continue to decline.

Acknowledgements

The authors would like to thank several agencies, companies and persons that were crucial in preparing this report We would like to thank the WA DoT, DoE, PTA (School Buse Services), and PATREC for their support and guidance throughout this report. We would like to thank Western Power and Horizon Power for supplying the power data used in creating this report and the numerous e-bus and charging station manufacturers and distributors to provide quotes. Further thanks go to Dr Kai Li Lim, St Baker Fellow at The University of Queensland, for preparing the overview map of school bus depots and Ms Vicky Chow at UWA for implementing the online e-bus planning tool. We further thank all bus operators and bus distributors for their valuable feedback and ideas, either through in-person interviews or online.

1. Introduction

This report has been commissioned by the WA Department of Transport and the Public Transport Authority (PTA) to assess the feasibility of replacing the diesel buses used as school buses in regional areas of Western Australia (WA) with electric buses. Assessing the feasibility of doing so involves gaining an understanding of both the technical viability, and the costs and benefits of replacing those diesel buses with electric buses. The assessment includes an analysis of the availability and cost of electric buses that would be suitable for use as school buses in regional areas of WA, the availability and cost of suitable electric bus charging equipment, the charging requirements, and the capacity of the electricity supply system.

It is useful to begin by outlining the context within which this assessment of the feasibility of replacing the diesel buses used as regional school buses in WA with electric buses is taking place.

1.1. The Global Context

The rate at which the electrification of road transport is occurring varies significantly from one country to another and from one vehicle type to another. To a very large degree, those differences reflect the differences in the motivations behind the policies that have been adopted and that are being implemented by governments to accelerate the take up of electric vehicles in their countries, regions, or cities. Those motivations include decarbonisation of road transport, improved local air quality and population health, reduced reliance on diesel imports, and industrial development.

The case for electrification of road transport varies significantly across vehicle categories. From an economic cost/benefit perspective, the three critical factors are the vehicle capital cost ($), the annual travel distance (km), and the vehicle's operational life (years). Whether it is economically viable or beneficial to electrify a particular vehicle category will therefore vary from one country to another and from one situation to another. In general, vehicle types for which the differences in the capital costs of internal combustion engine models and electric models are relatively small and that have relatively high lifetime mileages are likely to be the most attractive vehicle types for early electrification. Not only do many buses meet those criteria but once the other benefits are included, such as reduced operating and maintenance costs, the benefits of electrifying bus fleets are perceived as being relatively high. For that reason, buses are commonly the primary focus of many government transport electrification policies.

Electric buses are now dominating some global markets; a phenomenon that has been led by China and started with the launch of "One Thousand Vehicles in Ten Cities" National Energy-efficient and New Energy Vehicles demonstration project in 2009[1]. Since then, e-buses have outnumbered diesel buses and natural-gas buses to become the largest bus fleet. In 2022, 54,000 new electric buses were sold in China, representing 18% of total bus sales in China and about 85% of global electric bus sales[2]. However, the electrification of buses in China has not been without problems. A study published in 2019 found that the efficiency of the electric bus operations in China have been negatively affected by several factors, including: a mismatch between e-buses technical performance and the operation requirement (the electric bus model selected not being fit for purpose); insufficient planning of the charging infrastructure; and the lack of coordinated operation and charging schedules for e-buses[3].

[1] STIP Compass, https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives/2021%2Fdata%2FpolicyInitiatives%2F4813

[2] International Energy Agency (2023). Trends in electric heavy-duty vehicles. Global EV Outlook. Available online at https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-heavy-duty-vehicles

[3] Xue, L, Liu, D., Wei, W. and Peng Liu, P. (2019). Overcoming The Operational Challenges Of Electric Buses: Lessons Learnt From China. World Resources Institute. Available Online at https://wri.org.cn/en/research/overcoming-operational-challenges-electric-buses

The booms in the electrification of buses in Europe, North America, and India began later and at a slower rate than in China but are now rapidly gaining pace (Figure 1-1). Over the five-year period from 2017 to 2021, the sale of zero emission buses (ZEBs) increased over six-fold from 400 in 2016 to 2,500 in 2021. In 2021, fully electric powertrains represented 10% of new bus sales, representing an 85% increase in two years. The share of electric buses in the total city bus fleets was 22% in 2021, 30% in 2022, and is projected to be 37.5% in 2023[2]. In Finland, electric bus sales accounted for over 65% of all bus sales in 2022[4].

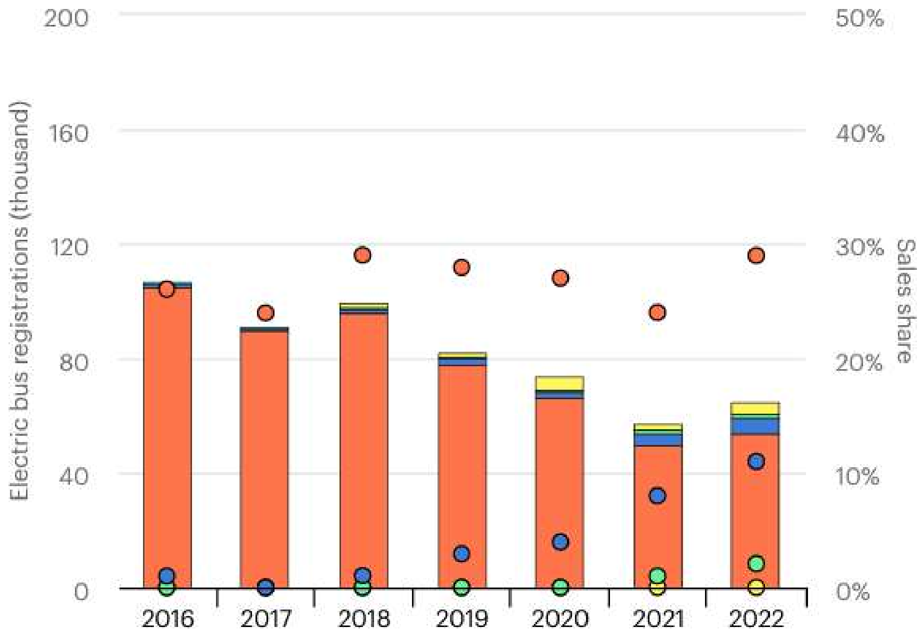


Figure 1-1 Electric bus registrations and sales share by region, 2015-2022[5].

One in-depth report on the global electric bus market predicted that the share of electric buses in the world bus fleet would reach 58% by 2030[6]. In 2022, around 220 electric heavy-duty vehicle models entered the market, bringing the total to over 800 models offered by well over 100 OEMs. Government ambitions with respect to electrifying buses is also growing. A total of 27 governments have pledged to achieve 100% ZEV bus sales by 2040[7].

The brief summary of the electrification of buses within a global context provided above focuses on those countries and regions in which the take-up rates of electric buses has been rapid. Before moving onto the Australian context, a couple of points need to be made by way of clarification or explanation. The first is to explain why the electrification of bus fleets has been led by China, Europe and the USA, which account for more than 90 percent of the world's electric vehicle fleet. In the case of China, the rapid electrification of buses has been the result of a concerted and coordinated effort on the part of both the Chinese national government and local governments. While improved urban air quality has been a major policy driver behind the electrification of buses in the country, it has not been the only one. As a result of bus electrification oil consumption in

[4] Mulholland, E and Rodríguez, F (2022). The rapid deployment of zero-emission buses in Europe. International Council on Clean Transportation. Available online at https://theicct.org/wp-content/uploads/2022/09/zero-emission-buses-europe-sept22.pdf

[5] International Energy Agency (2022). Global EV Outlook: Trends in Heavy Vehicles. https://www.iea.org/energy-system/transport/trucks-and-buses

[6] https://www.mordorintelligence.com/industry-reports/electric-bus-market

[7] International Energy Agency (2023). Trends in electric heavy-duty vehicles. Global EV Outlook. https://www.iea.org/reports/global-ev-outlook-2023/trends-in-electric-heavy-duty-vehicles

China was reduced by more than 200,000 barrels of oil per day while the amount of oil saved by all other EVs all around the world was only 40,000 barrels a day[8]. Industrial development has been another policy driver in China, the success of which is demonstrated by the fact that many of the electric buses now being sold in Europe, North America, Latin America, Australia, and New Zealand are Chinese brands.

In the cases of Europe and the USA, electric mobility is regarded by policy makers primarily as a means of decarbonising the transport sector. The strong policy focus on electric mobility is because many of the other decarbonisation policy options in Europe and the USA have already been exhausted. But industrial development is also a policy objective, particularly in the USA where generous federal grants are provided to produce new electric school buses and to convert diesel school buses to electric.

The second point that needs to be made is that most of the electric buses currently in use are urban or city public transit buses. The reason for that is simple. The case for electrification of buses is strongest for those buses that are used intensively. That is, buses that have high annual mileages. The greater the annual or lifetime bus mileage, the greater the accumulated reduction in operating and maintenance costs and, therefore, the shorter the payback period and the higher the return on investment. Another factor is that urban bus fleets are often owned by state or municipal governments, and governments are free to dictate the type of buses used in their public transport fleets[9]. In many cases, municipal governments do so to improve local urban air quality as health complications from poor air quality contribute to an estimated 7 to 8 million years of life lost annually[10,11]. National governments, on the other hand, electrify their bus fleets as a means of achieving their commitments to reducing GHG emissions, as buses account for a relatively high percentage of total road transport GHG emissions. At the global level, while heavy road vehicles (trucks and buses) represent less than 8% of road vehicles, they account for over 35% of direct CO_2 emissions from road transport[12].

1.2. The Australian Context

The adoption rate of electric vehicles in Australia has been relatively low, and it has been particularly low for heavy vehicles (trucks and buses). Rather than a dash to buying new zero-emissions buses, the approach has been to undertake pilot programs, to leverage global collaboration and research, to undertake local area trials and data analysis, and to explore funding options[13]. As is the case in most other countries, the initial focus of the state governments in relation to the electrification of bus fleets has been on public metro transport buses in their capital cities, as outlined below.

Queensland: The Queensland government commitment is for all new buses in its new TransLink funded buses used in SE Qld to be environmentally friendly by 2025 and across regional Queensland by 2030[14].

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8 Bucholtz, K. (2021). What's really driving the trend in e-vehicles? Your local electrical bus. https://www.weforum.org/agenda/2021/03/municipal-buses-lead-electrification-effort/

9 Bucholtz, K. (2021). What's really driving the trend in e-vehicles? Your local electrical bus. https://www.weforum.org/agenda/2021/03/municipal-buses-lead-electrification-effort/

10 https://blogs.worldbank.org/voices/developing-countries-e-mobility-revolution-closer-you-might-think

11 Briceno-Garmendia, C., Qiao, W. and Foster, V. (2022). The Economics of Electric Vehicles for Passenger Transportation. International Bank for Reconstruction and Development / The World Bank, Washington, D.C., USA. https://openknowledge.worldbank.org/server/api/core/bitstreams/4c73ad87-2972-44e3-942e-cd2e3bb32350/content

12 https://blogs.worldbank.org/voices/developing-countries-e-mobility-revolution-closer-you-might-think

13 https://www.busnews.com.au/inside-the-state-of-the-current-australian-electric-bus-industry

14 https://www.abc.net.au/news/2022-04-13/electric-buses-rolled-out-queensland-environment/100984570

Victoria: The Victorian government plans to add 36 zero emission buses to its public transport bus fleet over the next 3 years[15].

New South Wales. The NSW government has adopted a policy of transitioning the State's 8,000 plus diesel and natural gas public transport buses to zero emissions technology as part of its commitment to achieve net zero emissions by 2050. The program is to be delivered in stages to allow local industry time to prepare, and technology advancements to be assessed and adopted along the way. 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[16].

South Australia: The South Australian government is trialling two Foton FTH12 hydrogen fuel cell electric buses and is testing one battery electric bus, with a further five on order pending the results of the trial[17].

Tasmania: The Tasmanian government is undertaking a trial of four battery electric buses in Launceston and will commence a hydrogen fuel cell bus trial in Hobart in 2024[18].

Australian Capital Territory: The ACT government currently has a fleet of 16 electric buses and plans to add another 90 electric buses to its fleet over the next three years[19]. The government has an ambition of achieving a zero-emission public transport system by 2040[20].

The motivations behind these state and territory government initiatives have stemmed mainly from their commitments to reduce GHG emissions from their own operations, including from government owned enterprises. Reducing emissions from public transport services is an important component in achieving those commitments as the transport sector accounts for approximately 100 Mt $CO_{2\text{-}e}$ per year, about 20% of which result from heavy vehicle (truck and bus) use[21, 22]. The transport sector is the second largest source of greenhouse gas emissions and has the highest rate of growth of any sector in Australia. With no action, transport emissions are projected to continue growing to 2030 and are expected to reach 111 Mt $CO_{2\text{-}e}$ per year by 2030[23].

At the federal level, as a part of its Future Fuels and Vehicles Strategy the government established a $71.4 million Future Fuels Fund in 2020 aimed at supporting public charging infrastructure for battery electric vehicles, hydrogen fuel cell vehicles and biofuel technologies. In 2021, the funding amount was increased to $250 million[24]. While the primary purpose of the strategy was to reduce transport sector GHG emissions, a further motivation was to reduce reliance on imported diesel fuel. According to one of Australia's major bulk diesel suppliers, Australia is almost totally dependent on imported fuel"[25] and in 2022 imported 27,895 ML of diesel[26]

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[15] https://www.ptv.vic.gov.au/footer/about-ptv/improvements-and-projects/bus-and-coach/zero-emission-buses/

[16] https://www.transport.nsw.gov.au/projects/current-projects/zero-emission-buses.

[17] https://www.premier.sa.gov.au/media-releases/news-items/sa-accelerates-towards-zero-emission-public-transport-with-train-and-bus-trials

[18] https://www.metrotas.com.au/corporate/major-projects/zero-emission-bus-trial/

[19] https://www.act.gov.au/our-canberra/latest-news/2023/october/more-electric-buses-start-zapping-into-canberra

[20] https://electricvehiclecouncil.com.au/wp-content/uploads/2022/03/EVC-State-of-EVs-2022-4.pdf

[21] https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-gas-inventory-quarterly-update-march-2022#toc_2

[22] https://www.climatechangeauthority.gov.au/sites/default/files/2021-03/2021Fact%20sheet%20-%20Transport.pdf

[23] https://www.climatecouncil.org.au/resources/transport-emissions-and-climate-solutions/

[24] https://arena.gov.au/funding/future-fuels-fund/

[25] https://bulkfuel.com.au/news/where-does-australias-diesel-fuel-come-from

[26] Australian Petroleum Statistics 2022. Dept of Climate Change, Energy, the Environment and Water. https://www.energy.gov.au/publications/australian-petroleum-statistics-2022

1.3. The Western Australian Context

The WA government has adopted a goal of achieving net zero emissions by 2050. One strategy adopted by the WA government for achieving its emission reduction target has been to set a 2030 target for State Government emissions. The interim target that has been set is an ambitious 80% reduction relative to 2020 levels, which applies to emissions from all Government agencies across the State, including transport, health and education, and emissions generated by Government Trading Enterprises (GTEs)[27].

As a part of that commitment, PTA (Transperth) initiated a trial in February 2022 of four battery electric buses used as public transport buses on CAT route in Joondalup north of Perth. The next stage will involve purchasing 18 public transit electric buses and charging stations at Elizabeth Quay in the Perth CBD[28]. While the electric bus trials in Perth are one component of the WA government's climate action policies, surveys have found that the full electrification of bus fleets is a widely popular policy option amongst Australians. In 2021 the Australia Institute reported that three in four Australians support the electrification of state bus fleets by 2030[29].

1.4. Electrification of Regional School Buses

Most studies and trials of electric buses undertaken in Australia to date have focused on electrification of urban public transit buses. This study therefore represents a significant step forward in terms of bus electrification in WA and Australia. Assessing the feasibility of replacing diesel buses with electric buses used on regional school bus routes requires a far more in depth analysis of the various factors involved. Those factors include:

(i) The availability and cost of electric buses suitable for use as regional school buses.

While the number of city transit bus models available is quite large, the regional school bus services use different types of buses for which the number of available models is far more limited, and their costs are largely unknown.

(ii) The Minimum sizes and availability of suitable electric school bus charging stations.

The minimum sizes of the charging stations that would be required at each location will need to be calculated. The minimum sizes will vary from one location to another, and the availability of suitable charging stations will need to be assessed.

(iii) The capacity of the electricity supply system to supply the electricity required.

The buses as regional school buses are garaged in various locations spread throughout WA. The limitations of the electricity supply network at those locations in terms of the maximum capacity (kW) of a bus charging station that could be connected to the network need to be assessed. Connecting the required capacity of a charging station at a site could necessitate upgrading the electricity supply network, the details and the costs of which are unknown.

(iv) The electric school bus charging load and the impacts on peak electricity demand.

[27] https://www.wa.gov.au/service/environment/business-and-community-assistance/government-emissions-interim-target

[28] https://minister.infrastructure.gov.au/c-king/media-release/contract-awarded-perths-first-electric-bus-charging-station

[29] Quickie, A. (2021). Quicke (2021) Climate of the Nation: Tracking Australia's attitudes towards climate change and energy. The Australia Institute, Manuka, ACT. https://australiainstitute.org.au/report/climate-of-the-nation-2021

While the total amount of electricity required to charge the batteries of the school buses will not increase the load on the larger electricity supply networks by a significant amount, it could impact on the peak loads. The need to manage the timing of the charging to avoid negatively impacting on peak loads will need to be understood.

(iv) The Impacts of electric school bus charging on power quality

While the school bus charging loads are unlikely to result in the need for increased generation capacity, they could place unacceptable stress on local distribution transformers and feeders and could have negative impacts on power quality.

(v) Reductions in diesel use and in greenhouse gas emissions

The benefits of replacing diesel buses with electric buses include reductions in both diesel fuel use and in GHG emissions. The actual benefits will depend on the quantum of those reductions and will need to be calculated or at least estimated.

The following chapters of this report are used to study those factors in detail, and provide qualifications and quantifications with respect to regional and remote WA school bus electrification.

2. Electric Bus Charging Scenarios

With electric buses and EV charging technology readily available, the main concerns for operating an electric bus fleet are where to charge the buses, when to charge the buses, and where the required energy is supplied from. This has been considered especially challenging in WA's regional and remote areas where the electricity grid is in some cases is quite weak and rural feeders have a high number of outages per year.

We made the following assumptions:

- Each bus drives two school route runs daily of about two hours each (total of four hours).
- Additional charter drives are not considered in this analysis but can be catered for with a larger bus battery and charging infrastructure.
- Charging can occur for up to 14 hours per day (out of the theoretical max. of 20 hours) to avoid evening peak energy demand charging:
  - up to 5 hours between school runs from 9:30 to 14:30 and
  - up to 9 hours from 22:00 to 7:00.
- When the grid capacity is insufficient and on-site distributed renewable generation has to be used, it will be necessary to have a backup battery, diesel/petrol generator of sufficient size to produce the same on-site amount of energy over a 24-hour period.

2.1. When and Where to Charge

The mode of operation determines where the buses are parked during the day and night. However, there may be good reasons to change operations in the transition from diesel to electric buses. For example, it may be more beneficial to charge a bus at a location other than its current depot.

(a) Drive from depot to school twice a day

Most of the school buses are currently used to make two trips per day, from the bus depot or another place of overnight garaging to pick up students and then the school(s) and back to the depot in the morning, with largely the reverse in the afternoon. Each trip is taking a maximum of two hours. In the absence of any additional trips not funded by PTA, the school buses would be stationary at the depot or overnight parking place for 20 hours each weekday and for 24 hours on Saturday and Sunday, as well as during school holidays. This pattern of operation suggests charging at the depot, but buses could also be charged at other locations.

(b) Drive from depot to school once a day – leave bus at school over midday

In a number of cases there were long distances between the depot and the school(s). For these cases it would be beneficial to leave the bus at the school grounds during the middle of the day, if a suitable parking space was available. Many schools have excellent grid connections and already have some solar PV systems installed, which may not be fully utilised during the middle of the day. These could be used (and potentially be expanded) to provide additional renewable energy for charging.

If the bus for a long-distance route is left at the school in the middle of the day, it will also reduce the daily distance driven and consequently its energy requirements, as it does not have to return to the depot. Where this already occurs, bus drivers are able to use other suitable means of transportation around the town – often with a much smaller ecological and economic footprint.

In this scenario the bus can be charged from on-site generated renewable energy during the day at the school and – if necessary – also charge at the depot overnight. The overnight charge could be supplied either from the grid or from another on-site renewable energy generator (e.g. solar PV with stationary battery storage). If the bus gets charged twice per day (over midday at the school and overnight at the depot), then smaller and more cost-effective bus batteries and charging infrastructure can be used.

(c) Use school grounds as bus depot

If the school grounds can provide the space for secure daytime and overnight parking, the bus could operate from the school as its depot. This would mean that the bus would be charged from renewable energy during the day and from the grid overnight at the school. Schools often have large monitored parking areas, bus zones, and often their own school buses parked overnight.

2.2. Charging Scenarios

In the original project overview, we suggested classifying each school bus service into one of the following categories and to then explore a number of case studies in more detail.

(a) Daily energy demand can be met by direct grid connection.
(b) Daily energy demand cannot be met directly from the grid, but can be met from the grid over a 24-hour period when using suitable energy storage.
(c) Daily demand cannot currently be met from grid, but the location is suitable for a grid upgrade.
(d) Daily demand cannot currently be met from grid, but the location is suitable for connection of on-site renewable energy generation.
(e) Daily demand cannot currently be met completely from the grid, but the shortfall can be met by minimal use of an on-site petrol or diesel generator.
(f) Other cases with no obvious electrification solution.

Our project findings led to the following redefinitions of charging scenarios.

<u>(a) Direct Grid Charging</u>

Depots:

- The majority of school bus services fall into this category – 77% of all buses on the SWIS can be directly charged from the grid at their depot site.
- Even with a modest 15 kW single-phase connection[1], about 33% of all bus services can be slow-charged at their depots during their stationary periods. Charging can be undertaken by inexpensive AC chargers, which are easy to install and to replace.
- Higher powered DC chargers and larger bus batteries will be required in areas with expected grid outages.

Schools:

- For many of the 23% depot sites with insufficient power for e-bus charging in the SWIS, the corresponding schools do have sufficient power and can be used as charging sites.
- 97% of the schools selected for the case studies of this report have the capacity to install at least one 50 kW DC fast-charger without a grid upgrade.
- 92% of the schools can even support a 100 kW DC charger without a grid upgrade.
- Adding solar PV will not be necessary for these sites but remains highly desirable to further reduce the environmental footprint and to reduce the cost for e-bus charging.

Other:

- Only for a small number of sites in WA additional electricity is required from one of the methods described below – either to the depots or the schools.

[1] Western Power guarantees a minimum grid connection of 15kW for all rural residential dwellings Western Power, *New standard power supply allocation for the SWIS*, 3 April 2023, https://www.westernpower.com.au/news/new-standard-power-supply-allocation-for-the-swis/

(b) Grid Charging with Stationary Battery
Although this looks like a substantial improvement over scenario (a), adding a stationary battery offers only about 21%[2] more energy, as it accumulates additional energy only for the times the bus is driving. While only few cases fall into the category where it is necessary to use a stationary battery, there may be a high percentage of bus services for which operators would like to use a stationary battery for reasons of convenience or emergency. This could be because the bus could be charged in a much shorter time or because the bus could be charged from renewable energy generated at a location outside the bus depot.

(c) Adding Energy through Grid Upgrade
If the power supply at the charging premises is insufficient to meet the daily energy requirements of the school bus, then the choice is to either upgrade the network to the supply site or to add on-site renewable generation with a backup petrol or diesel generator (d)+(e). Our studies have shown that each school bus location has sufficient sub-station capacity to add the required charger for the school bus service, but this does not necessarily mean that the required power level is available at the specific bus or school premises without a distribution network upgrade to the site.

(d) +(e) Adding Energy through Renewables and Generator
The alternative to a grid upgrade (e.g. if it is too expensive or untimely), is to install on-site renewable generation using solar PV or small wind turbines. Each installation of renewables will require a matching backup generator to allow for extended periods of low solar radiation (such as high cloud cover) or days with low wind speeds. This means we can combine categories (d) and (e) into one. A detailed site-specific analysis will be required to decide if a grid upgrade or renewables with backup generator is the better option for a specific bus service.

(f) No Solution
According to our studies, every school bus service can be electrified, so category (f) ‘No Solution’ can be eliminated.

2.3. Community Benefits

While AC chargers are a low-cost solution, DC chargers and their connection to the electricity supply network can be expensive. If a decision is made to fund a DC charger, then the following scenarios may be considered, as they can provide a substantial benefit to the community at a marginally higher cost.

(a) Fast-charging for both School Bus and the Community
If the school building or another building in the town has a sufficient power connection for DC-fast charging or the space for a larger amount of solar PV plus battery backup, then a DC fast-charger could be installed for the school bus service. This could also be used by the community and by visitors to the town.

Modern DC chargers can charge several vehicles simultaneously through independent outlets (“kiosks”). One kiosk could be installed on the school grounds for charging the school bus, while another one could be installed in a charging bay outside school grounds and made available to members of the general public. School bus charging can be given priority via software in terms of reserved energy as well as preferred charging times. With sufficient power available, such an installation could benefit all residents of a town by facilitating the transition to electric vehicles, as well better destination charging services to visitors to the town. This is particularly suitable on weekends or school holidays when the DC chargers are not be required for school bus operations.

[2] Additional energy storage during 4 hours of driving minus 1 hour for fast-charging, so additional 3 hours versus standard 14 hours of charging

(b) Stationary Battery and Grid Stability
A stationary battery for e-bus charging can help in reducing the required power demand/connection as well as reducing e-bus charging times. Such a system could be of particular interest in remote locations that are supplied by a weak grid and experience a relatively high number of power outages per year. However, the stationary battery size required for such a service would need to be about ten times larger (and equivalently more expensive) than a buffer battery for an e-bus charger (e.g. 2 MWh versus 200 kWh). So, installing a buffer battery for rapid DC e-bus charging will have little community grid benefit. However, if Western Power or Horizon Power decided to install a stationary community battery, then this could very well be used for improving e-bus charging as well as general EV charging for the community.

2.4. Distributed Energy Generation

In some situations it will be either necessary or advantageous for the electricity used for charging the electric bus batteries to be supplied from sources other than from the local electricity supply network. In such cases, distributed generators[3] will be used to supply a portion of the electricity, while in other cases they may be used to supply all the electricity required. This chapter discusses the feasibility of using distributed generation to supply the electricity required for battery charging, with a primary focus on solar PV systems while also commenting on other distributed generation technology options that could be used for this purpose.

The use of distributed generation systems for charging the batteries of electric school buses is necessary when the capacity of the local electricity network is unable to supply the required electricity. Distributed generation systems reduce the stress on the network during peak demand periods. If the distributed or on-site energy generation systems used are renewable generators, their use would also reduce the amount of GHGs emitted. The distributed generation systems in most common use by far small-scale, mostly roof-mounted, solar PV systems, the investment in these systems being driven by both financial and environmental considerations. Depending on the electricity tariff at the bus charging site, the use of a distributed generator such as a solar PV system to charge the electric bus batteries may also reduce the costs of the electricity used for that purpose.

2.4.1. Grid-Connected Solar Photovoltaic Systems

Solar photovoltaic (PV) systems represent the most widely used on-site renewable electricity generation option. They can be used in practically every location throughout WA and in almost all cases, they would represent the lowest cost ($/kW installed and $/kWh produced) on-site energy generation option available.

The most common distributed solar PV system configuration is the grid-connected solar PV system as most electricity users are supplied from an electricity grid. In this type of system, the solar array is connected to the grid via solar inverter behind the customer's electricity meter (Figure 2-1). Any electricity generated by the solar PV system is used to meet the on-site instantaneous load and only if an excess amount of electricity generated by the solar PV system is the excess exported into the grid. During those periods when the amount of electricity produced by the solar PV system is insufficient to meet the site load, the additional electricity required to meet the site load is

[3] A distributed generator is a generator that is, or can be, connected to an electricity distribution system. They are therefore limited in capacity (kVA) to the capacity of the particular local distribution system to which they are connected.

imported from the grid. In this scenario, an electric school bus would be charged directly from the grid. The site load would be increased by the charging load, but a solar PV system would supply a portion of the electricity used to charge the electric bus batteries.

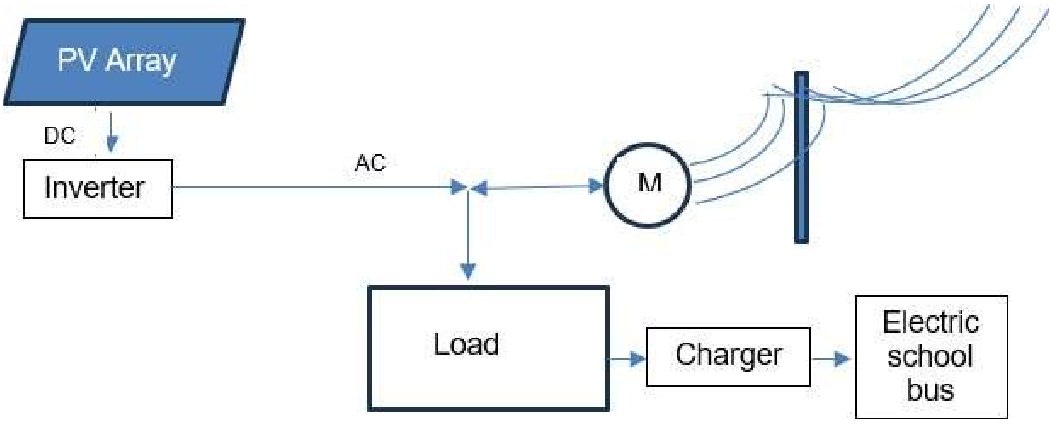

Figure 2-1 Grid-connected solar PV system.

GHG Emission Reductions

The GHG emission reductions achieved by replacing diesel buses with electric buses will depend on many factors, including the size of the bus (seating capacity), the route lengths, air conditioning loads, and the source of the electricity used for charging the batteries of the electric buses. Even charging electric buses using electricity supplied from any electricity supply network in WA will result in a reduction in emissions as their emission factors are relatively low. WA's average emission factor is below the Australian average, and only South Australia and Tasmania have lower emission factors than WA[4].

By how much the emissions will be reduced will depend on the emission factor of the electricity supplied from the grid that is used to charge the electric buses. In the case of the SWIS, the emission factor for the year 2022/23 was 0.51 kg CO_2-e/kWh. The Scope 2 emissions of diesel fuel are 2.71 kg CO_2-e/L. Using those figures in an example, if a diesel bus has a fuel consumption rate of 25 L/100 km, it would produce Scope 2 emissions of 67.75 kg CO_2-e per 100 km. If an electric bus has an energy consumption rate of 80 kWh/100 km and the electricity used for charging the batteries is supplied from the SWIS, the current Scope 2 emissions produced by the electric bus would be 40.8 kg CO_2-e/100 km. In this example, replacing the diesel bus with the electric bus would result in a reduction in GHG emissions of approximately 40%[5].

2.4.2. Off-Grid Solar Photovoltaic Systems

Historically, electricity in off-grid areas was supplied by diesel generators. At remote sites with large power demands, such as mining operations, they remain the dominant type of generation technology used. Solar PV systems started to be used alongside the diesel generators as a means of reducing diesel fuel use. As diesel prices increased and as the costs of solar PV systems and batteries declined, the design has been reversed and most systems currently being installed are

[4] Electricity Maps, https://app.electricitymaps.com/zone/AU-WA
[5] This quick calculation does not consider the electrical loses in battery charging and slightly overestimates the reduction in GHG emissions.

solar PV systems with battery energy storage that use the diesel generators as back-up only (*Figure 2-2*).

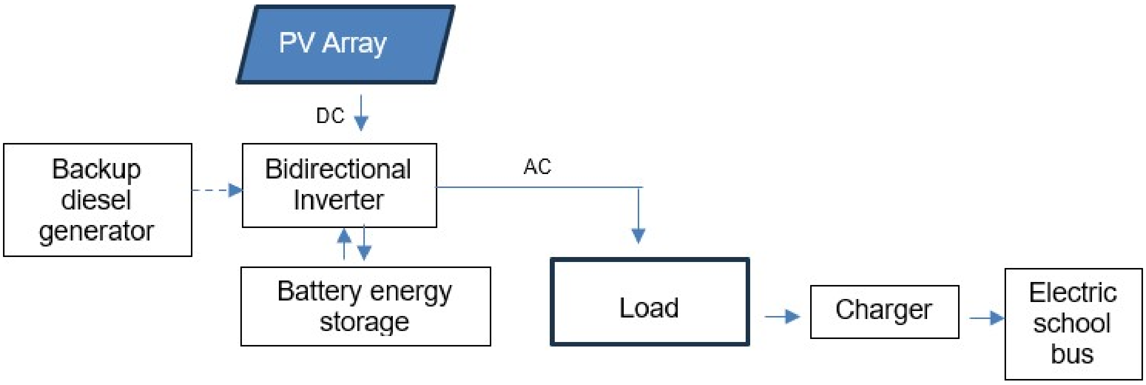

Figure 2-2 Stand-Alone Power System (SAPS).

Stand-alone power supply systems are able to supply electricity at a lower cost than the cost of electricity supplied from a grid taking into account the connection costs of connecting a site to the network. However, in WA if a site is already connected to the network, the tariff that the retailer charges for the electricity supplied from the grid will be lower than the cost of electricity produced using a stand-alone power supply system. This is because the former is cross-subsidised through WA's uniform tariff policy. Therefore, stand-alone power supply systems would be a viable option for charging electric school buses in only the very small number of cases in which the school bus garaging site is off grid. However, they may also be an option for sites currently connected to a network but for which the network upgrade costs would be high enough to justify the investment in a SAPS option.

A hybrid solution that is increasingly being installed is to have a SAPS system in combination with but separate to grid connection (Figure 2-3).

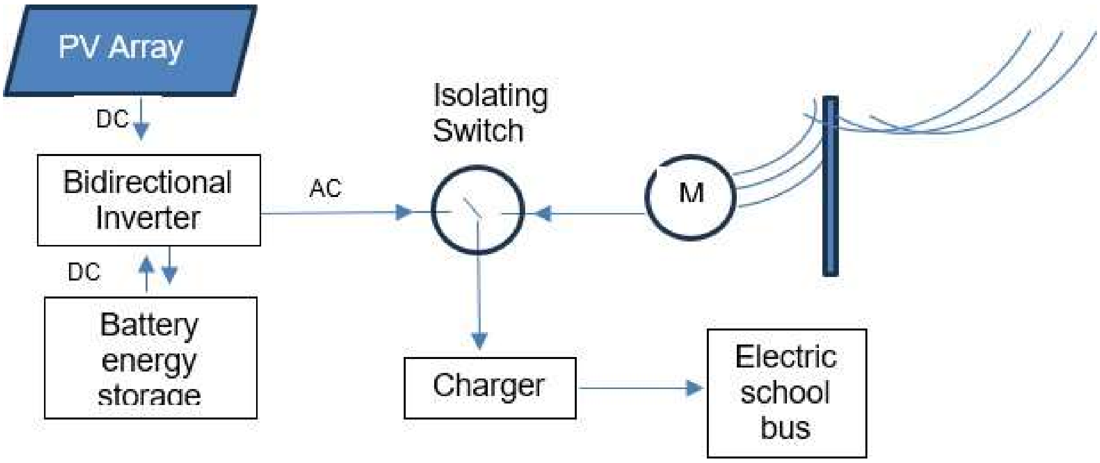

Figure 2-3 Hybrid 'either / or' power supply configuration.

The most common hybrid solution would consist of a solar PV system coupled with battery energy storage on the one side and the grid on the other. No backup generator would be required. Provided that the solar and battery energy storage system is not connected to the grid, no network connection application is required. This avoids costs and installation time delays.

3. Market Analysis Electric Buses

Electric buses used as school buses in regional and remote areas of WA need to be fit-for-purpose. Determining what models and makes of electric bus models currently being manufactured would be suitable for use as school buses in regional WA is not a straightforward task as electric buses manufacturers tend not to provide sufficient information in their marketing to be able to tell whether the electric bus model meets the Australian design standards. Therefore, identifying electric buses that would potentially be suitable for use as school buses requires a broad search for all electric bus manufacturers, and then using the information provided by each manufacturer to ascertain whether any of the electric bus models that they produce would be suitable for use as school buses.

This chapter is divided into three sections. The first section summarises a wide-ranging search of electric buses currently being manufactured in the world and attempts to identify those that may be suitable for use as school buses in regional WA. The second section focuses on electric buses currently available on the Australian market that are or could be used as school buses. The third section is used to discuss the costs of electric school buses.

3.1. Global Search

The first step in the analysis involved using a high-level global search for companies that currently build electric buses. Fourteen sources of information (Table 3-1) were used to identify electric bus manufacturing companies.

Table 3-1 Sources used for global search of companies that produce electric buses.

Source number	Source details
1	List of European electric bus manufacturers (provided by Prof. Thomas Bräunl)
2	Wikipedia. https://en.wikipedia.org/wiki/Category:Electric_bus_manufacturers
3	https://www.sustainable-bus.com
4	https://www.electrive.com
5	https://www.autobusweb.com
6	https://transphoto.org/models.php
7	https://busworldlatinamerica.org
8	https://cleantechnica.com
9	https://www.urban-transport-magazine.com
10	https://www.keybuses.com
11	https://electrek.co
12	https://transport.ec.europa.eu/
13	https://www.busnews.com.au
14	Australian Bus and Coach https://www.busnews.com.au/industry-news

Relying on the above sources of information to identify companies currently operating in the global electric bus manufacturing sector is unlikely to have identified all companies in the world currently manufacturing electric buses. This became evident as a small number of additional companies were identified incidentally while undertaking searches for other information. However, using these sources is likely to have identified a very high percentage of all companies that are currently building electric buses.

The second step in the process involved searches of the websites of each or the individual companies that were identified in the first step of the process. What this second step quickly revealed was that the information provided by the sources in Table 3-1 above were not limited to battery electric buses but included all types of electric buses, including fuel cell hydrogen buses, hybrid (diesel/electric) buses, electric trams, and electric trolly buses. A number of the companies identified were also found on further searching to have ceased production.

Therefore, it became necessary to sort the electric buses being built by the various companies around the world into types or categories. The categories used in this report are shown in Table 3-2 and below.

Table 3-2 Electric bus categories used in the global market analysis. .

Electric bus categories	Description
City Bus	Low floor passenger transit bus with seated and standing passengers.
Coach	Seated passengers only, with all seats forward facing.
Mini coach	Small coach with seated passengers only with all seats forward facing.
Mini shuttle bus	Low floor city bus with small seating capacity
Hydrogen bus	Hydrogen fuel cell electric bus
Articulated bus	Articulated city bus with large seating and standing capacity
Converted bus	Diesel bus converted into a battery electric bus.
Hybrid bus	Bus with both diesel/petrol engine and an electric motor.
Double decker	City bus with seats on two levels
4 x 4 coach	4WD electric coach with seated passengers only
4 x 4 mini coach	Small 4WD electric coach with seated passengers only
Trolly bus	Electric bus power using overhead electric cables.
Tram	Electric bus on rails
Ceased production	Identified as no longer building electric buses

Global Search Results

The results of the global electric bus market analysis are summarised in Table *3-3* and Figure 3-1 below. From these it is immediately apparent that electric low floor metro city buses currently dominate the global electric bus market. Over half (54%) of companies that build electric buses, produce electric city buses. Electric city buses, mini shuttle buses, hydrogen buses, articulated buses, double decker buses, articulated buses, trolley buses and trams together account for 71% of all models of electric buses currently being produced. In terms of absolute numbers of electric buses produced of each type, no information is readily available. However, given the large numbers of city bus fleets around the world, and the large numbers of buses per fleet, electric city buses are likely to account for a very high percentage of all electric buses currently being produced. This is not surprising as the typical high annual mileages and the relatively low average speeds of city buses make the return on investment on electric city buses high relative to the return on investment for other types of electric buses.

If electric city buses were suitable for use as school buses in regional, rural and remote areas of WA, there would potentially be a large number of suitable electric buses available on the world market. However, electric city buses have a number of design features that reduce their suitability for use as school buses in these areas. Some city bus models may not be suitable for use on unsealed roads and their low floor design mean that they would be at risk of ‘bottoming out’ on some road sections. Manufacturers would need to select a seating configuration for all seats facing forward. Overall, the wheel wells of low floor buses reduce the number of seats as compared to a high floor bus of the same length. Low floor city buses also lack the underfloor luggage space, which while not required for regular school bus services, but may be useful when students cycle, or when a school bus is used for other events, such as sporting carnivals.

For these reasons, low-floor city bus models were not considered as an option for use as regional area school buses in WA[1]. Also eliminated from the data set were electric trolley buses, trams, articulated buses and double-decker buses.

Table 3-3 Summary of global electric bus market analysis.

Bus Category	Total number of companies producing electric buses in the category	Total number of models produced in the category
City bus	118	167
Coach	33	61
Mini coach	15	23
Mini shuttle bus	11	13
Hydrogen bus	11	11
Articulated	7	7
Converted	8	-
Hybrid	3	3
Double decker	6	8
4 x 4 coach	2	2
4 x 4 mini coach	1	1
Trolly bus	5	5
Tram	4	4
Ceased production	11	-

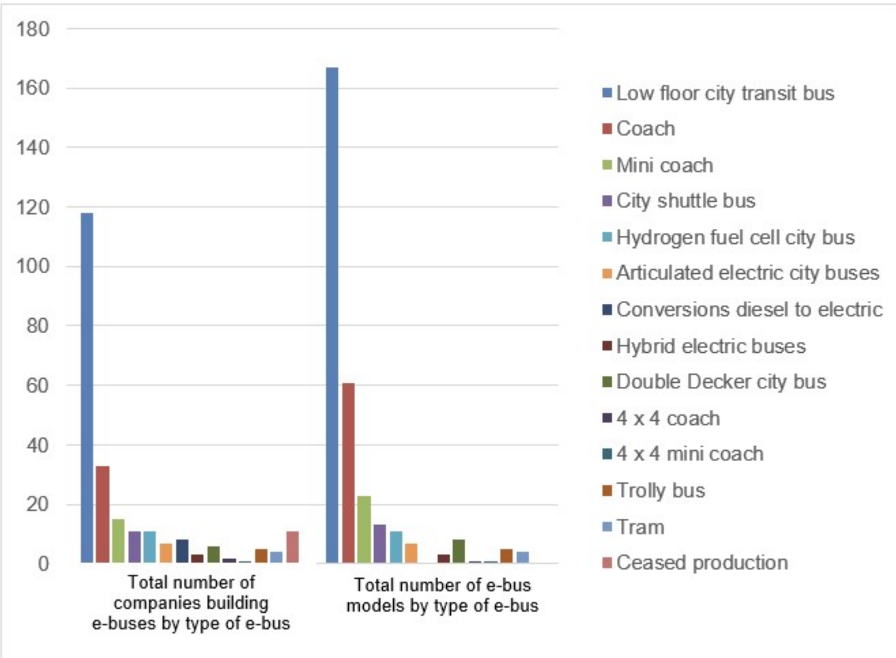

Figure 3-1 Summary of global electric bus market analysis.

[1] It is not quite accurate to say that no low floor buses are used as school buses in regional Western Australia. The BCI Proforma E W/C and the BCI Cruiser 10E W/C are low floor coaches that are used to provided school bus services on routes where wheelchair access is required. However, while these are low floor coaches, they are not low floor city metro buses.

Several makes and models of electric buses were eliminated from the data set on the basis of their country of manufacture, as the importation buses from those countries is unlikely (Table *3-4*).

Table 3-4 Electric bus models eliminated on the basis of their country of origin.

Russia	Alkor, Gorky Automobile Plant (GAZ), KamAZ, LiAZ, NefAZ (Neftekamsk Automotive Plant), SpetsAvtoEngineering, PK Transport Systems, Sinara , VMZ, Trolza, VolgaBus, SVARZ (Sokolniki Car Repair and Construction Plant).
Belarus	Belkommunmash (BKM Holdings, OJSC Holding Management Company), MAZ (Minsk Automobile Plant).
Kenya	Opibus EV
Columbia	Busscar
Tajikistan	Akia Avesto,

After eliminating the models and makes of electric buses discussed above, the only remaining electric buses considered as potentially suitable candidates for use as school buses in regional areas of WA were electric coaches, electric mini-coaches, 4 x 4 electric coaches and 4 x 4 electric mini-coach categories[2]. However, in the case of coaches, a significant proportion are ‘high-end’ coaches that used as luxury tourist or long-range luxury coaches and their high costs would be prohibitive for use as school buses. After eliminating those ‘high-end’ coaches, the list of electric buses being produced globally was narrowed down to those that would be potentially suitable for uses as school buses in regional, rural, and remote areas of WA, as provided in Table 3-5 below.

Table 3-5 Electric buses being produced globally that are potentially suitable for as school buses

Bus Class	Total number of companies producing electric buses in the class	Total number of models produced in the class
Class A (17 – 24 seats)	5	8
Class B (25 – 43 seats)	8	12
Class C (44 – 57 seats)	9	12
Class D (0 -16 seats)	15	23
Class F (4WD) (up to 17 seats)	6	6
Class G (4WD) (17 – 24 seats)	2	2
Class H (4WD) (25 – 34 seats)	1	1

Purpose Built School Buses

Purpose-built school buses (Figure 3-2) are manufactured in several countries (Table 3-6). Many of those purpose-built school buses are now electric models. Of interest was that of the eleven companies identified as building purpose-built school buses, eight currently produce electric school buses, six of which produce only electric models. This may be due in part to the subsidies provided by some governments to companies producing electric vehicles, and specifically for producing

[2] The only electric 4WD buses identified through the search were mini coaches (Classes F,G and H) and all were either conversions of older 4WD buses such as the Ford E 450 school bus in the USA, or were new custom made electric minibuses constructed by building on existing 4WD bodies.;

electric school buses. For example, the federal government in the USA offers a grant of US$400,000 per electric school bus produced[3].

Figure 3-2 Ciao purpose built electric school bus, Escolar, Brazil[4]

Table 3-6 Purpose-built school buses

Manufacturer	Country	Diesel / Petrol	Electric
Caio Induscar	Brazil	Yes	No
Caio EScholar	Brazil	No	Yes
Eurabus (Euracom Group)	Germany	Yes	No
Feniksbus	Slovenia	No	Yes
GreenPower Motor Company	USA	No	Yes
Karwa Motors	Qatar	Yes	Yes
Lightning Systems	USA	No	Yes
Lion	USA	No	Yes
REV Group	USA	No	Yes
ROŠERO-P Ltd	Slovakia	No	Yes
Shenlong	China	Yes	No
Sunwin	China	Yes	Yes
Tata Motors	India	Yes	No
Thomas Build Buses	USA	No	Yes
Yutong	China	Yes	Yes
Wuzhoulong Motor Company	China	Yes	No

3.2. Electric Bus Models Currently Available in Australia

A separate search was undertaken to identify electric bus models that are currently available on the Australian market. The sources of information included published reports, emails and phone calls with Australian bus distributors and internet web searches. The electric buses currently available in Australia are listed in Table 3-7 below.

The number of electric bus models currently available in Australia is relatively small. According to the Electric Vehicle Association (Thompson 2023)[5], the primary reason is that the Australian

[3] Canary Media, May 2024, https://www.canarymedia.com/articles/electric-vehicles/school-districts-receive-900m-from-epa-to-fund-electric-school-buses
[4] Personal communication. Document provided by Ciaio.
[5] Thompson, N. (2023). State of Electric Vehicles Report 2023. July 2023. Electric Vehicle Council, Sydney, NSW. Available online at https://electricvehiclecouncil.com.au/reports/soevs-report-2023/

Design Rule for buses which are high compared to the requirements in many other countries. However, there are likely to also be several other reasons. Overseas bus manufacturers need to have an Australian distributor able to undertake the necessary marketing and the required after sales servicing and warranty services. As the Australian market for buses is relatively small, finding such distributors is likely to be difficult for many overseas manufacturers. Buses imported into Australia also need to be right hand drive models, which eliminates several electric bus models manufactured overseas.

Table 3-7 Electric buses currently available in Australia.

Bus Manufacturer / Distributor	Model	Type	Passenger capacity
BCI	22E	Coach	17 to 22
BCI	Citirider E	City Bus	45 seated
BCI	Proma Low floor E	City Bus	25 to 39
BCI	Proma High Floor	Coach	25 to 39 seated
BCI	Cruiser 10E	Coach	25 to 47
BCI	Classmaster 57E	Coach	44 to 57
BCI	BCI 12-15E	Coach	12 to 15
BCI	Proforma Low Floor E W/C	Coach (W/c)	29
BCI	Cruiser 10E W/C	Coach (W/c)	33
Bus Stop / King Long	Evolution	Tourist Coach	44 to 51 seated
BusTech Group	Protera ZDI	City Bus	45 seated
BYD (Gemilang Chassis)	K9RA	Tourist Coach	35 seated
Custom Denning	Element	City Bus	70 seated
Daimler Truck and Bus	Mercedes Benz e-citaro	City Bus	29 seated+ 59
Ebusco	Ebusco 2.2	Midi coach	45 seated + 45
Foton Bus Australia	12.5 m Foton	City Bus	44 seated + 20
Foton Bus Australia	Joylong E6	City Bus	14 seated
Foton Bus Australia	E-School Bus	Coach	57
Nexport	ZE-B	City Bus	45 seated
Nexport	ZE-B 106	Coach	36 seated
Nexport	ZE-B 86	City Bus	28 seated
Nexport	ZE-B 75	City Bus	22 seated
Nexport	ZE-C125	Mini coach	60 seated
Nexport	MetroCity EV ZX5	City Bus	44 seated
LDV	LDV Deliver	Minibus	14
Optare	Optimus E-Bus	City Bus	29 seated
Protera	-	Coach	17 seated
Skywell	ED11-E	Minibus	10 seated+W/C
SEA-Electric	BZL	City Bus	90 total
Volgren / Volvo	D7E	Tourist coach	17 to 24
Yutong	E12 e-bus	Coach	40-44 seated.
Yutong	-	City bus	22 to 27
Yutong	E City	Mini coach	25 to 43
Yutong	-	Coach	44 to 57
Yutong	-	City bus	44 seated
Zemtec	Volt GT E	City bus	44 seated
Zero Bus Group	-	Tourist coach	57
Zero Bus Group		Tourist coach	24

Sources: Electric Vehicle Council (Thompson 2023), company websites, email. phone calls, emails and face-to-face meetings with representatives from local bus distributors.

Therefore, the actual number of electric bus models suitable for use as school buses in regional, rural and remote Australia as shown in Table *3-8* is quite limited at this time. However, the number of models available is likely to increase over the coming years. Three additional models became available during the study and two bus distributors advised that they planned to introduce further new electric bus models in the short-term.

Table 3-8 Numbers of electric buses potentially suitable for use as school buses in regional, rural and remote areas of Australia and WA

Bus Class	Total number of models currently available
Class A (17 – 24 seats)	4
Class B (25 – 43 seats)	3
Class B (W/C)	2
Class C (44 – 57 seats)	5
Class D (0 -16 seats)	5
Class F (4WD) (up to 17 seats)	0
Class G (4WD) (17 – 24 seats)	0
Class H (4WD) (25 – 34 seats)	0

Conversion of ICE Buses to Electric Buses

Several companies operating in other countries undertake conversions of diesel buses to electric buses. These include APS Systems (USA), Avass (Australia), Complete Coach Works (USA), Ebus (USA), Lightening USA), SHETAB (Iran) and SEA Electric. There are also likely to be many other companies that undertake such conversions that were not identified using an internet search for electric buses. These companies claim that converting a diesel bus to an electric bus is the quickest and cheapest means of electrifying a bus fleet.

However, according to SEA Electric, while electric bus conversion is a very large business in North America, that is due to the very significant government grants (US$400,000 per bus) for conversions in the USA. The company, which undertakes truck conversions in Australia, advised that converting diesel buses to electric buses in Australia would also be more costly than it is in the North America for two reasons. The first is that the cost of converting a diesel bus to an electric bus is lowest if the number of buses per model is large. Here in Australia where conversions would involve relatively small numbers of buses of different models, the cost per conversion would increase significantly. The second reason is that according to SEA Electric, the Australian Design Rules mean that the safety standard requirements for buses in Australia are higher than they are in North America, so converting diesel buses to electric buses in Australia would involve additional work to ensure that they remained compliant.

3.3. Electric Bus Prices

Electric bus prices versus diesel bus prices

Several reports and commentators provide estimates of electric bus prices. However, these tend to be either prices for urban transit electric buses or are very general statements that are not specific to any specific bus type or size. For example, one such commentator gave the price of a metro city bus in 2021 as being US$925,000 (AU$1,412,225)[6], while an earlier commentator in 2019 used a price of US$750,000 (AU$1,145,000), which it was stated was 50% higher than the cost of a similar electric model at the time[7] The same commentator stated that the cost of an electric school bus was US$230,000, which was 2.3 times the cost of a diesel equivalent bus. Yet another commentator stated that the price of a 40-foot electric school bus in 2021 was between US$230,000 and US$400,000, which was 2.3 to 4 times the cost of a US$110,000 diesel-powered school bus[8]. A more recent World Bank report on electrification of transport has estimated that the average price premium for an electric bus is currently around 60%, with a range in the premium of 30% to 90%[9].

In Australia, the cost range of an electric metro city bus is given in one report $700,000 to $1 million, 30% more than diesel buses. Another report by the Australia Institute used a price for diesel buses of around $480,000 and the price range of an electric bus to be between $550,000 and $900,000[10]. One Australian bus distributor has stated that an electric bus equivalent to a $480,000 diesel bus would cost around 40% more than the diesel bus[11]. A representative from one bus distributor in Perth also advised that the sale price of a new electric bus is typically around 30% to 40% higher than the price of a new equivalent diesel bus[12] and that while many of the estimated price differentials between diesel and electric buses refer to city buses, the price differential between diesel and electric coaches tends to be similar. Such statements and estimates are of limited value to this feasibility study as most of them refer to city buses. And that is because most electric buses currently being produced are city electric buses. Coaches make up a relatively small number of electric bus and coach models at this stage. For example, HIGER produces 8 electric city bus models, but only one electric coach model[13].

Therefore, it was necessary to attempt to obtain more accurate or definitive prices of electric buses that would be suitable for use as school buses in regional WA. However, for various reasons that proved to be quite difficult to achieve. While a large number of overseas electric bus manufacturers that produce electric buses and coaches that appeared to be potentially suitable for that purpose

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[6] Wright, M. (2021). Bus Electrification: A comparison of capital costs. Urban Transport Magazine. https://www.urban-transport-magazine.com/en/bus-electrification-a-comparison-of-capital-costs/#

[7] Horrox, J. Casale, M. (2019). Electric Buses in America: Lessons from Cities Pioneering Clean Transportation. Environment America Research and Policy Center, Frontier Group, and U.S. PIRG. https://pirg.org/wp-content/uploads/2022/07/US_Electric_bus_scrn-3.pdf

[8] Higgs, L (2021). Electric school buses are expensive but these 2 ideas could make getting them easier. https://www.nj.com/news/2021/03/electric-school-buses-are-expensive-but-these-2-ideas-could-make-getting them-easier.html

[9] Briceno-Garmendia, C., Qiao, W. and Foster, V. (2022). The Economics of Electric Vehicles for Passenger Transportation. International Bank for Reconstruction and Development / The World Bank, Washington, D.C., USA. https://openknowledge.worldbank.org/server/api/core/bitstreams/4c73ad87-2972-44e3-942e-cd2e3bb32350/content

[10] Boyd (2021) Start-up rides high on electric buses, https://www.afr.com/chanticleer/start-up-rides-high-on-electric-buses-20211008-p58ych

[11] Waterworth, D. (2022). Getting on the Electric Bus in Australia. Clean Technica. https://cleantechnica.com/2022/05/12/getting-on-the-electric-bus-in-australia/

[12] Personal communication, Armando Baylon, Sales Development Manager, BCI, 3 March 2024.

[13] https://en.higer.com/index.aspx

were contacted and information, including prices, the number that responded was very small. Even in the case of Australian bus distributors that supply electric buses, while most of those contacted were willing to provide technical information on the models that they offer, most were unwilling to provide prices.

In the case of overseas manufacturers, the most likely reason for non-responses is their lack of interest in the Australian market. Many manufacturers do not produce right hand drive (RHD) models, while may international RHD models are unlikely to meet the Australian Design Rules (ADR) requirements.

The process of obtaining reliable prices of suitable electric buses included searches of company websites, contacting overseas bus manufacturers, and contacting Australian electric bus distributors. Prices were obtained for 34 electric bus models considered potentially suitable for uses as regional school buses in WA. For each PTA school bus Class, the range in prices obtained through that process was large. While the prices offered by some bus manufacturers, and Chinese bus manufacturers in particular, are often significantly lower than the prices offered by other manufacturers, the large range also reflects lack of information about many of the buses, including whether they meet the ADR, and the freight charges to Australia, etc. Nor do the bus prices obtained reflect the differences in sizes (seating capacities) or battery capacity sizes (kWh). For that reason, the prices at the upper ends of the price ranges are likely to be more reflective of actual electric bus prices in Australia than are those at the lower end. However, that is not true for all classes. The lowest price for an electric bus in the D Class was an actual bus price in Australia.

The prices of high end luxury coaches were removed from the data set (one each for bus classes A, B and C) and the average prices of the remaining electric buses in the A, B, C and D Class[14] school buses obtained from bus distributors and bus manufacturers are provided in Table *3-9* along with the PTA's average prices for diesel buses in each class. No prices were obtained for electric F, G or H Class buses as no electric models of those classes are available in Australia at this time. Comparing the two average prices, the average price premium of the electric buses in the medium size A and B Classes was about 39%, while the average price premium of the small D Class buses was at 37% and of the large C Class buses only 36%.

*Table 3-9 Average p*rices of electric buses in four PTA school bus classes

PTA school bus Class	Average price (AUD)	PTA average diesel price (AUD)	Difference (%)
A	$180,852	$130,109	39%
B	$552,952	$397,807	39%
C	$589.243	$433,267	36%
D	$113,181	$82,614	37%

Projected Electric Bus Prices

The search for electric bus prices revealed that electric bus prices are declining and are projected to continue to do so. One report on electric bus prices forecast that electric buses will decline to the price level of diesel-fuelled buses by 2030[15], while the World Bank report cited above estimated that the cost differential by 2030 will still range from parity (0%) to a 40% premium, with a mid-range estimate of a 20% premium[16].

[14] No prices were obtained for electric buses in the F, G or H Classes.

[15] https://www.mordorintelligence.com/industry-reports/electric-bus-market

[16] Briceno-Garmendia, C., Qiao, W. and Foster, V. (2022). The Economics of Electric Vehicles for Passenger Transportation. International Bank for Reconstruction and Development / The World Bank, Washington, D.C., USA. https://openknowledge.worldbank.org/server/api/core/bitstreams/4c73ad87-2972-44e3-942e-cd2e3bb32350/contentt

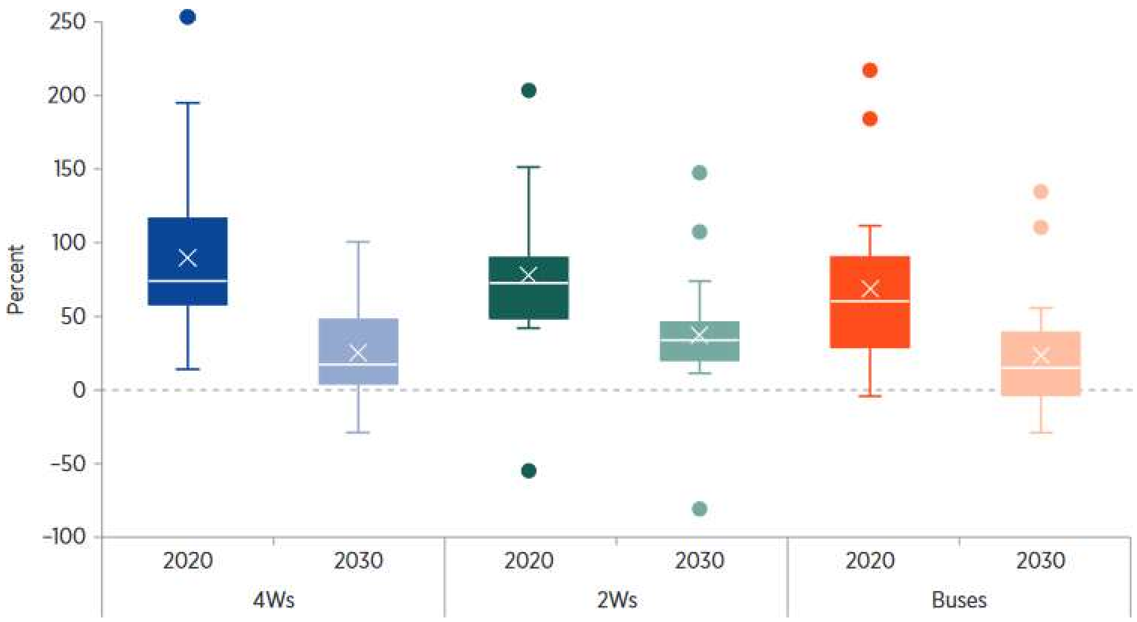


Figure 3-3 Cost of different types of electric vehicles relative to their ICE counterparts.

Electric bus battery costs.

Estimating the 'typical' price of an electric bus requires an understanding how the capacity (kWh) of the bus batteries influences its price. The sizes of batteries in the 214 electric buses offered by electric bus manufacturers that we found in the global electric bus market search described in Section 3.1 are shown in the scatterplot in Figure 3-4. What this scatterplot clearly demonstrates is that there are no 'standard' battery capacities and that manufacturers offer different battery capacities ranging from less than 50 kWh to over 700 kWh. The only discernible 'clumping' in the scatterplot is a battery capacity of around 350 kWh.

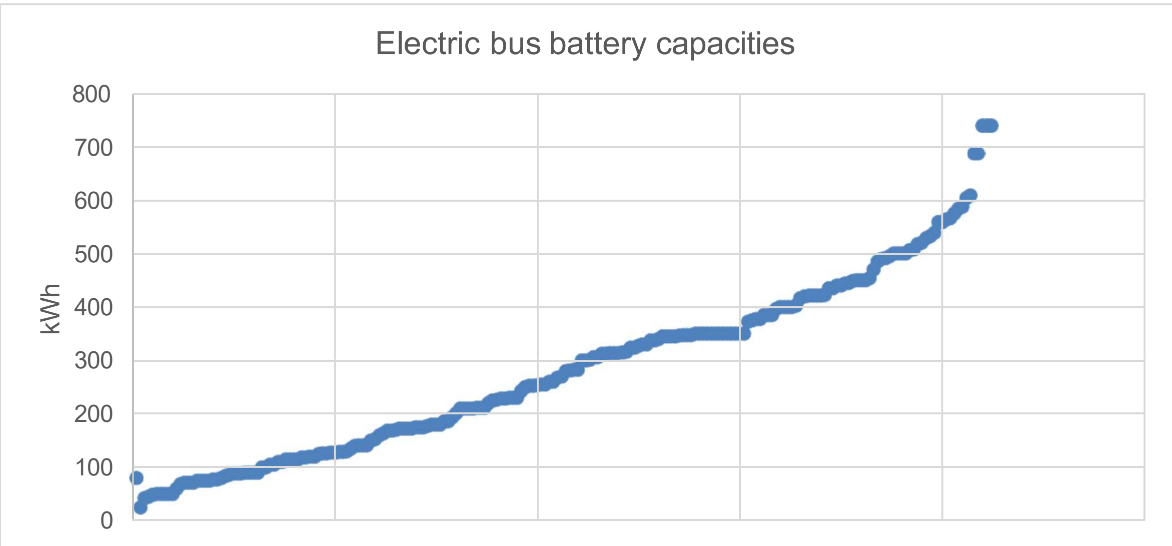


Figure 3-4. Scatterplot of battery capacities of 214 electric buses available on the global market.

The capacities (kWh) of batteries in electric buses that are currently available on the Australian market for each class of bus also indicates that for each class a range of battery capacities are offered by bus distributors (Figure 3-5), but with a greater degree of clustering of C class buses around 350 kWh and 420 kWh, B Class buses around 280 kWh, A class buses around 175 kWh and D class buses around 75 kWh and 100 kWh, which is due to the bus manufacturers offering different models with the same battery capacities.

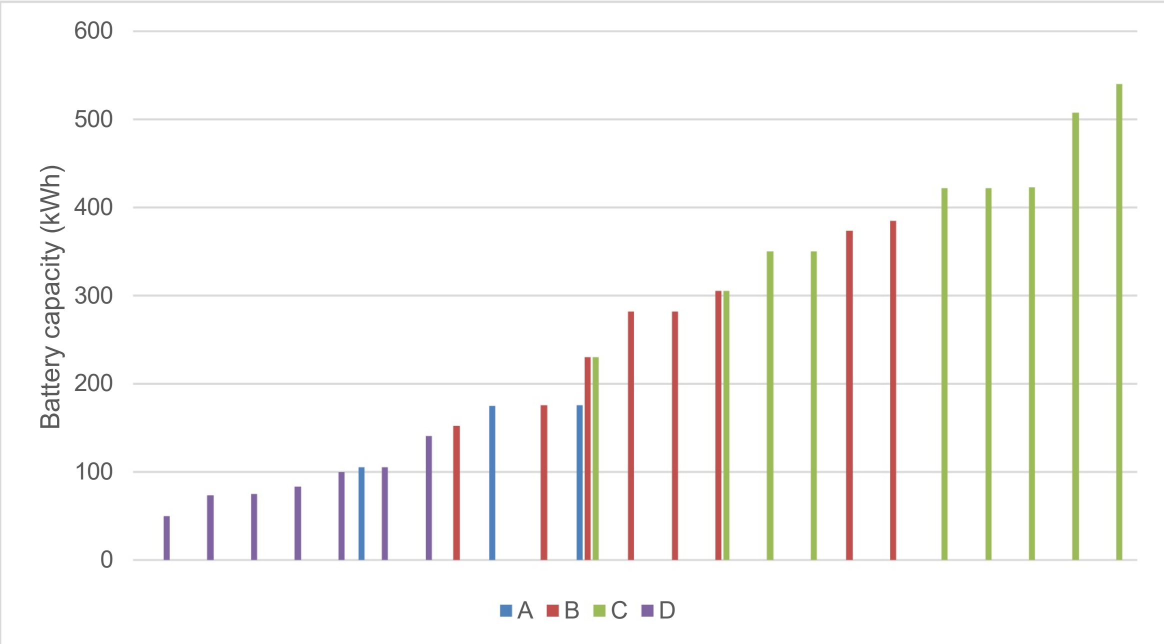
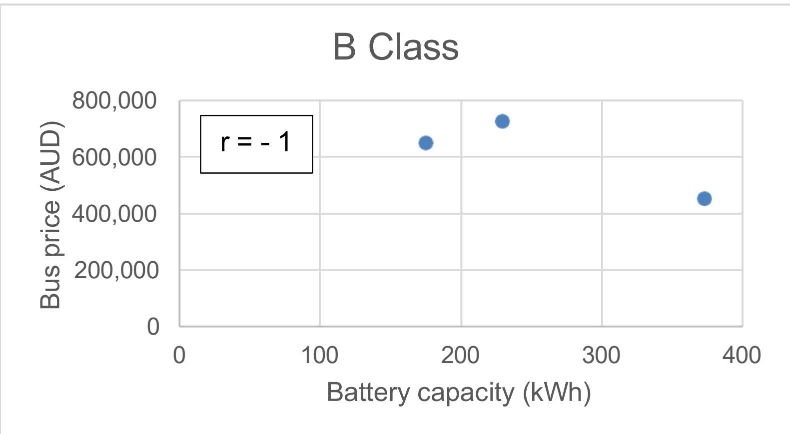


Figure 3-5. Battery capacities of electric bus models currently available in Australia.

In terms of battery capacity and bus price, in the case of electric buses currently available on the Australian market there is little to no relationship (Figure 3-6). Note that these correlation coefficients are based on only those buses for which distributors provided both the prices and the battery capacities. As that was the case for only one A Class bus, no correlation coefficient could be calculated for A Class buses.



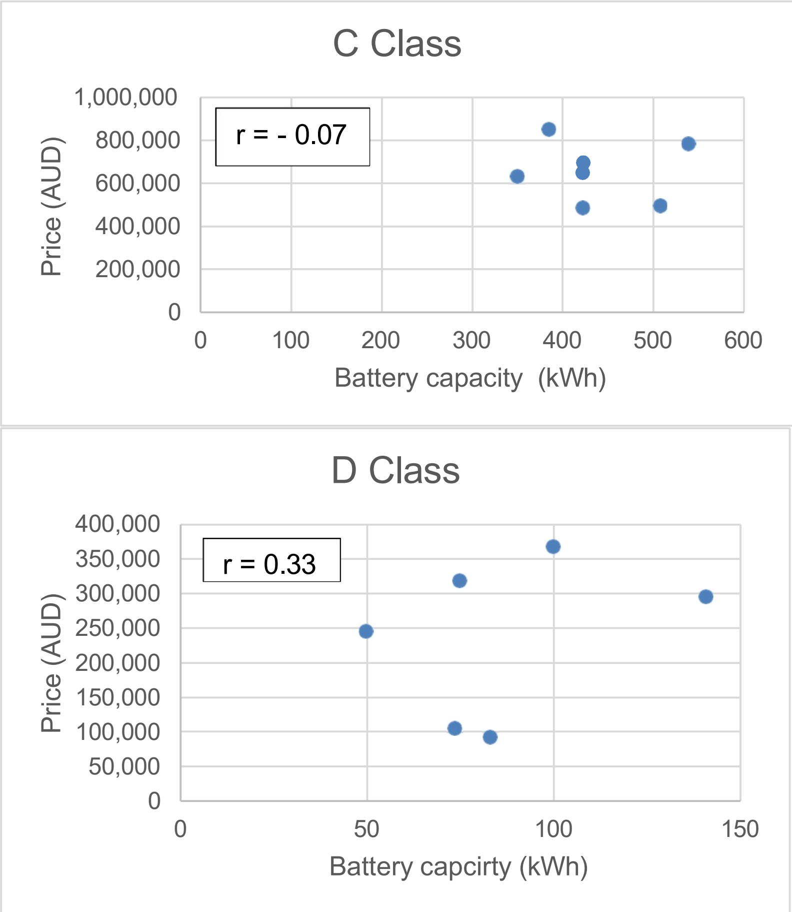


Figure 3-6. Correlation coefficients between bus battery capacities and bus prices for Classes B, C, and D electric buses currently distributed in Australia.

The lack of any 'standard' or common battery capacities for any bus class together with the lack of correlation between the bus battery capacity and the bus price meant that for the purposes of this study the prices of buses used in the case studies had to be calculated for each specific bus using a common price per kWh of battery capacity. The battery price used was determined by reference to an OECD report published in 2018 which recommended that a battery price of US$260 (AU$394) per kWh be used for e-buses[17]. As battery prices have declined since that report was published a lower figure needed to be used. One bus distributor provided different prices of a single bus model with different battery capacities for this study. Comparing the differences in the bus prices and differences in the battery capacities provided, it was calculated that the price of the battery was $306 per kWh. Therefore, this figure was rounded to $300 per kWh and was used as the battery price in calculating bus prices for the case studies.

[17] https://www.iea.org/reports/global-ev-outlook-2018

We note the difference between our estimated current cost of e-bus batteries of AUD 300/kWh and the current cost of EV car batteries as reported by Bloomberg NEF (BNEF)[18] at AUD 208/kWh (USD 139/kWh). This price difference has several reasons:

1. The $300/kWh for e-bus batteries was determined from the purchase costs of the same e-bus model with different battery capacities, so it is based on the end-product sales price, not the component purchasing price of the vehicle manufacturer.

2. The BNEF price refers to the raw battery and does not include costs like battery controllers, battery management systems, distribution, freight, warehousing, cabling, racking, and the labour costs of installing the battery.

3. A better comparison is looking at the battery replacement cost of an EV. The NRMA[19] estimated the replacement cost of the 40 kWh battery in a Nissan Leaf in 2024 at $11,800 = $295/kWh.

4. Our cost figure is in line with the pricing used by the International Energy Agency for e-bus battery analyses.

3.4. Electric Bus Summary

Due to their typical high annual mileages and the relatively low average speeds, which translates into a relatively high rate of return on investment, the global electric bus market is dominated by electric low-floor metro city buses. While the number of models of electric coach models being produced is increasing rapidly, many of these are high-end inter-city and long-range luxury tourist coaches which would be unsuitable for use as school buses in regional Western Australia due to their high purchase costs.

The total number of lower-end electric bus and mini-bus models currently being produced globally that could potentially be suitable for use as school buses in regional, rural, and remote areas of Western Australia is less than one hundred. Many of these models, however, are not suitable for various reasons, e.g. because they are unlikely to meet the requirements of the Australian Design Rules, or because they are not even available as right-hand drive models. Some models, particularly smaller buses and 4x4 models, are diesel buses that have been converted to electric buses. A further limiting factor is the small size of the Australian bus market. Overseas manufacturers of new electric bus models attempting to enter the Australian market would need to find or establish local distributors that could provide the necessary aftersales and warranty service.

Due to those various limiting factors, the number of electric bus models of all classes currently available in Australia that would be suitable for use as school buses in regional Western Australia at the time this report was produced was just nineteen (19), comprising two to five models in each of the A, B, C and D classes, but no models in the 4x4 classes. However, the number of available models did increase during the course of this study, and it is highly likely that the number will continue to increase over the coming years.

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[18] Bloomberg NEF, Dec. 2023, *Lithium-Ion Battery Pack Prices Hit Record Low at $139/kWh,* https://about.bnef.com/blog/lithium-ion-battery-pack-prices-hit-record-low-of-139-kwh/#:~:text=Given%20this%2C%20BNEF%20expects%20average,and%20%2480%2FkWh%20in%202030

[19] NRMA, Jan. 2024, How much does it cost to replace an EV battery? https://www.mynrma.com.au/electric-vehicles/owning/cost-to-replace-ev-battery

The upfront purchase price premium of suitable Class A, B, C and D electric buses was found to be on average between 36% to 39% higher than that of a comparable diesel bus. The average price premium is predicted in some analyses to be reduced to approximately 10% by 2030.

Electric buses are sold with a very wide range of battery capacities for each class of bus, and there is almost no 'typical' bus battery capacity for any class of electric bus. While no correlation was found to exist between electric bus purchase and the bus battery capacity, the battery capacity has a significant bearing on the purchase price of any electric bus of approximately $300/kWh.

4. Market Analysis EV Chargers and Stationary Batteries

In this chapter we analyse the current market for suitable EV charging stations and battery buffers to support E-buses. E-bus services have a rapidly growing number of charging options and products in a very dynamic market. In some circumstances it makes sense to combine chargers with stationary battery storage systems to allow a slow charging of a stationary battery from the grid and/or renewable sources, giving a capability for rapid discharge into an e-bus. Many charging station manufacturers already provide these combinations as standard solutions.

4.1. E-bus Charger Types

Smaller buses are likely to be suitably charged with common passenger electric vehicle chargers and cables (Level 1 and 2). Therefore, this analysis will typically look at rapid solutions that are more suitable to larger buses and bus fleets that require CCS2 capabilities (approximately 20-350 kW DC). Some of the less conventional technical solutions more suited to e-bus rollouts, including their associated costs, are highlighted below. For a list of all eligible EV charging hardware and software from CCS2 and lower power, please see the Western Australian Government's Energy Policy WA's compilation/tool outlining technologies eligible for specific Western Australian subsidies. https://www.wa.gov.au/organisation/energy-policy-wa/charge-workplace-ev-charging-grants. The two tables below demonstrate the high level of technological choice.

Table 4-1 The large choice of AC charging options approved in WA is demonstrated by only the first supplier (ABB) alphabetically listed in the interactive tool.

Model No	Description	kW	Mount	Max. ports	Cable
6AGC081279	Terra AC Wallbox - 3 Phase 22kW Socket, type 2 - Terra AC W22-T-0	22 kW AC	Wall	1	Socket
6AGC082157	Terra AC Wallbox - 3 Phase 22kW Socket, type 2, RFID -Terra AC W22-G5-R-C-0	22 kW AC	Wall	1	Tethered
6AGC085382	Terra AC Wallbox - 1 Phase 7.4kW Socket, type 2, RFID - TAC-W7-T-R-0	7 kW AC	Wall	1	Socket
6AGC081278	Terra AC Wallbox - 1 Phase 7.4kW Socket, type 2 - Terra AC W7-T-0	7 kW AC	Wall	1	Socket
6AGC082152	Terra AC Wallbox - 1 Phase 7.4kW Socket, type 2, RFID, 4G - TAC-W7-T-R-C-0	22 kW AC	Wall	1	Socket
6AGC085383	Terra AC Wallbox - 1 Phase 7.4kW Cable 5M, type 2, RFID, 4G - TAC-W7-G5-R-C-0	7 kW AC	Wall	1	Socket
6AGC085385	Terra AC Wallbox - 1 Phase 7.4kW Cable 5M, type 2, RFID, 4G - TAC-W7-G5-R-C-0	7 kW AC	Wall	1	Tethered
6AGC082153	Terra AC Wallbox - 3 Phase 22kW Socket, type 2, RFID, 4G - Terra AC W22-T-R-C-0	22 kW AC	Wall	1	Socket
6AGC082155	Terra AC Wallbox - 1 Phase 7.4kW Cable 5M, type 2, RFID - Terra AC W7-G5-R-0	7 kW AC	Wall	1	Tethered
6AGC082174	Terra AC W7-T-RD-MC-0 1 Phase with Display & MID Certified Meter 7.4kW Socket - Terra AC W7-T-RD-MC-0	7 kW AC	Wall	1	Socket
6AGC085386	Terra AC W7-G5-RD-MC-0 1 Phase with Display & MID Certified Meter 7.4kW Cable 5M - TAC-W7-G5-RD-MC-0	7 kW AC	Wall	1	Tethered

6AGC081281	Terra AC W22-T-RD-MC-0 3 Phase with Display & MID Certified Meter 22kW Socket - Terra AC W22-T-RD-MC-0	22 kW AC	Wall	1	Socket
6AGC081285	Terra AC W22-G5-RD-MC-0 3 Phase with Display & MID Certified Meter 22kW Cable 5M - Terra AC W22-G5-RD-MC-0	22 kW AC	Wall	1	Tethered

Source: https://www.wa.gov.au/organisation/energy-policy-wa/charge-workplace-ev-charging-grants, 2023

Table 4-2 Similarly, the large choice of DC charging options approved in WA by a supplier (ABB) listed in the interactive tool.

Model No	Description	kW range	Mount	Max. ports	Cable
6AGC075211	Terra54 C CE	25-149 kW DC	Pedestal	1	Tethered
6AGC063492	Terra54 CJ CE	25-149 kW DC	Pedestal	2	Tethered
6AGC070818	Terra54HV C CE	25-149 kW DC	Pedestal	1	Tethered
6AGC076568	Terra54HV CJ CE	25-149 kW DC	Pedestal	2	Tethered
6AGC102244	T94C	25-149 kW DC	Pedestal	1	Tethered
6AGC102218	T94CC	25-149 kW DC	Pedestal	2	Tethered
6AGC102224	T94CJ	25-149 kW DC	Pedestal	2	Tethered
6AGC102246	T124C	25-149 kW DC	Pedestal	1	Tethered
6AGC102220	T124CC	25-149 kW DC	Pedestal	2	Tethered
6AGC102226	T124CJ	25-149 kW DC	Pedestal	2	Tethered
6AGC085473	T124HC C	25-149 kW DC	Pedestal	1	Tethered
6AGC084253	T124HC CC	25-149 kW DC	Pedestal	2	Tethered
6AGC102783	T124HC CC - 6m	25-149 kW DC	Pedestal	2	Tethered
6AGC085474	T124HC CJ	25-149 kW DC	Pedestal	2	Tethered
6AGC102245	T184C	150 kW and above DC	Pedestal	1	Tethered
6AGC102219	T184CC	150 kW and above DC	Pedestal	2	Tethered
6AGC100993	T184CJ	150 kW and above DC	Pedestal	2	Tethered
6AGC085488	T184HC C	150 kW and above DC	Pedestal	1	Tethered
6AGC082856	T184HC CC	150 kW and above DC	Pedestal	2	Tethered
6AGC082857	T184HC CJ	150 kW and above DC	Pedestal	2	Tethered
6AGC102222	Terra 124 CC - 6m	25-149 kW DC	Pedestal	2	Tethered
6AGC085508	Terra 124 CC - 8m	25-149 kW DC	Pedestal	2	Tethered
6AGC085485	Terra 124HC CC - 8m	25-149 kW DC	Pedestal	2	Tethered
6AGC105090	Terra 184 CC - 6m	150 kW and above DC	Pedestal	2	Tethered
6AGC102221	Terra 184 CC - 8m	150 kW and above DC	Pedestal	2	Tethered
6AGC105091	Terra 184HC CC - 6m	150 kW and above DC	Pedestal	2	Tethered
6AGC085492	Terra 184HC CC - 8m	150 kW and above DC	Pedestal	2	Tethered
6AGC103236	Terra 184HC CJ - 6m	150 kW and above DC	Pedestal	2	Tethered

Source: https://www.wa.gov.au/organisation/energy-policy-wa/charge-workplace-ev-charging-grants, 2023

4.1.1. Small Portable Chargers

Portable chargers are designed to be a flexible/movable option for use in service workshops, bus depots, and emergency or backup services (Figure 4-1). They require an existing electricity supply (usually 3-phase) and rectify the AC supply to provide a DC charge rate with a CCS2 connector. Two examples are the Ocular portable DC charger models that need 3-phase to supply between 20 kW and 30 kW (DC) at an approximate cost of A$15,000-18,000 (ex-GST), respectively.

Figure 4-1 An example of portable EV charger, Ocular's 20-30kW DC Roam.
Source: https://ocularcharging.com.au/, 2023

4.1.2. Fixed Chargers and Charging Optimisation

Fixed chargers are the most common means to charge EVs of all types at a central location comparable to fuel station pumps. There are many companies offering products at differing prices that reflect quality, complexity, and rates of charging. This market analysis focusses on the higher quality and faster charging DC options most suitable for charging e-busses. The authors note that this is again a rapidly advancing market, and that new products and suppliers are the norm. Each technology has an interface and supporting software that assists to various levels of electrical load management and logistics analytics functions (such as kWh used, kW load, revenues, user behaviour, etc.). Figure 4-2 shows an example of a typical fixed fast charger.

Physical and electrical capabilities and options vary between charger makes and models, which enables e-bus owners to customise their charging needs to meet most charging station preferences, within the limitations of the electricity supply and e-bus charging needs. The following list is a small subsample describing selected technical elements and some retail costs from a selection of fixed charger technologies and suppliers in Australia. Some technology providers produce battery solutions that support their fixed chargers to increase charger operability under times of limited energy supply. The battery market will be discussed in more detail in the following. The authors note that these rapid solutions can meet the needs of multiple busses at a location. The majority of scenarios for school e-bus charging will need much smaller maximum charging rates, particularly in the case where there is only a single bus.

Figure 4-2 An example of a fixed rapid EV charger, Ocular's Atlas series.
Source: https://ocularcharging.com.au/, 2023

ChargeBox (ChargeBox Dispenser from ADS-Tec. https://go.ads-tec.de/en/hpc)

Selected specifications: up to 320 kW DC charge rate; 10 x CCS2 liquid cooled cables; 170 kg total weight, dimensions: 400 x 400 x 2.700 mm; can be located indoors or outdoors; can be installed up to 100 m from a ChargeBox Booster (the manufacturers battery solution). Price pending.

EVBox (Troniq High Power. https://evbox.com/en/ev-chargers/troniq-high-power#discover)

Selected specifications: up to 400 kW DC charge rate; 2 x CCS2 cables (up to 500 A / 920 V at 20°C); 1-phase (32 A) or 3-phase (16 A or 32 A), 230 V – 400 V Split phase (30 A); 680 kg total weight, dimensions: 600 x 1050.2 x 2479 mm; can be installed indoors or outdoors. Price pending.

Ocular (Titan. https://ocularcharging.com.au/ocular-dc-atlas/)

Selected specifications: 120 kW and 180 kW charging rates; 2 x 5 m CCS2 cables (150-1000V DC, 400A max., 500 A max.); 400-450 kg total weight, dimensions: 1007 x 1816 x 750 mm; located indoor or outdoor. Priced between A$75,000 and A$107,000 for the 120 kW and 180 kW charging options, respectively.

Tritium (PK350. https://www.tritium.com.au/product/pk-350/)

Selected specifications: up to 350 kW DC charging rates, 2 x 4.1 m CCS2 cables (up to 920 V DC and 500 A max.); 320 kg total weight, dimensions: 2,000 mm x 575 mm x 395 mm; can be located indoors or outdoors. Prices pending.

4.2. Stationary Batteries to Support Rapid E-Bus Charging

Locations with sufficient electricity supply infrastructure will not require battery support infrastructure to accommodate school bus electrification. However, e-bus chargers in many regional and remote areas may be limited by the electricity network connection capacity that will not support rapid 200+kW e-bus charging rates. While augmenting the electricity supply either through onsite renewable generation or through a grid upgrade would be one option at such sites, augmentation involves high costs and timeframes. Alternative strategies would be reducing the daily driven distance by eliminating empty drives, charging at alternative locations, or using stationary battery systems that can store electricity enabling a rapid charger to charge an e-bus while maintaining the electricity networks within safe limits. The large power available from available battery systems already in use on WA can be more than 10 times that of even of 3-phase power supplies. Many batteries developed for network support/storage, stand-alone applications, or greenfield development sites can be utilised in the EV industry to support rapid EV charging in remote or off-grid locations (Figure 4-3).

Figure 4-3 An example of commercial greenfield battery suitable for rapid chargers, from AMPD.
Source: https://www.ampd.energy/product#gallery, 2023.

4.2.1. Batteries vs Network Connection Basics

The strategy of installing large commercial-scale battery technologies is relatively new. Batteries to support rapid DC charging can be installed as part of the electricity network or can be connected as a simple conventional load to supply e-bus charging only. The battery can be charged by multiple inputs such as the electricity grid, or off-grid systems based on solar, wind, or hydro. This may lower energy costs and greenhouse gas emissions depending on the technology, location, and costs. Akin to conventional off-grid energy supply systems, component sizing can be matched to the known e-bus route energy demand to minimise costs, maximising bus availability, and minimising Scope 2 emissions. The battery component simply enables a balance between price, energy flows, and lower Scope 2 emissions by better matching demand to the availability of renewable energy systems at the location.

The rapid charger supporting battery market is relatively immature compared to the charger market or larger grid-connected battery market. However, many EV charger technology providers have begun to expand into battery products to enable greater utility of their chargers, with prices that reflect quality, complexity, and storage capacity. This market analysis focuses on stationary batteries suited to enabling rapid DC charging. The authors note that this is again a rapidly advancing market, and new products and suppliers are the norm. Below are examples of existing batteries that can be interfaced with a rapid EV charger. This is a recent technological development based on reductions in commercial battery technology and installation costs.

Figure 4-4 An example of fixed charger and a battery system from ChargeBox.
Source: https://www.ads-tec-energy.com/en/products/charging/system, 2023.

ChargeBox (Booster from ADS-Tec. https://go.ads-tec.de/en/hpc). These units include: 140 kWh storage; Power input: 110 kVA; dimensions: 1,300 x 1,300 x 1,400 mm; 2,800 kg total weight; can be located outdoors up to 200 m from the electricity network. Price A$369,000 ex. GST (quote from Elanga, Queensland).

AMPD (Enertainer L+. https://www.ampd.energy/). These units include: 449 kWh storage; power input: 380-415 VAC and 90 A (in addition to grid connection, it can accommodate approx. 30 kW of PV); power output 380 415 VAC at ± 2% and 665 A with 795 A peak (<1 min) at 50 Hz ± 0.5 Hz; dimensions: 3,050 x 2,440 x 2,600 mm; 9,700 kg total weight; can be located outdoors. Price around A$720,000 ex. GST, monthly rental charge is A$18,000 (quote from Blue Diamond, Perth.)

4.2.2. Concluding Observations

E-bus services have a rapidly growing number of charging options and products in a very dynamic market. Our market assessment revealed that the technical capabilities are extensive and improving/expanding, with an associated convergence of costs of charging solutions between suppliers due to competition. There are ongoing significant advances in flexible user software platforms, increasingly rapid charging speeds, and multiple fleet charging optimisation flexibility. E-bus owners will have access to numerous charging technical solutions to meet their needs (both public and private), much akin to the rapid evolution of the passenger EV charging market.

This chapter is not intended to provide an extensive list of the large and growing number of charger and associated battery technologies currently available. We simply aim to demonstrate the rapid advancement in the last few years of the numerous large battery/charger technologies developed that can cater for almost any size fleet and location in regional WA. This is in stark contrast to what was available when the authors were first contracted and asked to investigate technologies available to construct the WA EV Network in 2018[1]. The recent enormous commercial investment in a growing number of technical e-mobility technical solutions gives confidence that technical barriers to bus electrification have largely been overcome and are able to meet the requirements of any level of e-bus demand in regional and remote Australia – even in greenfield off-grid locations. The numerous (and growing) smaller modular technology providers entering the market will benefit the WA Government and bus owners in terms of ongoing improved useability, technical capability, and cost reductions in the years to come. What is unclear is how the market will mature and what technology providers will remain dominant in this sector over time.

Our analysis found that there are significant opportunities for offering e-bus charging services near schools or other large community buildings for daytime charging powered by solar photovoltaics (PV) mounted on building roofs. The daytime parking of e-buses between the morning and afternoon runs is around 9 am to 3 pm, which is also the period when the PV output matches bus parking times very well. Similarly, e-buses operators can avoid charging their e-buses during peak electricity demand periods (often in the evening or overnight) because that allows sufficient time for slow charging during the off-peak night-time period to provide the electricity required for the morning run. School e-bus charging solutions can be optimised to cater for local electrical network constraints and increasing clean energy system capacity factors on and off the major WA electrical networks. This infrastructure should be regarded as a logical extension of publicly available EV charging services to enable improved charging speeds at a greater number of locations around WA.

Charging infrastructure in relation to remote WA e-bus services need not be privately owned, or not accessible to the public, and can be shared community services. The key will be ensuring buses have access to charging infrastructure when needed at convenient locations. Current rapid public charging stations of 200 kW or above are priced at around 60 c/kWh, with some having highly variable flexible time-of-use prices depending on the day and location. At the same time, the actual cost of electricity for contestable customers (above 50 MWh per year) can be as low as 11 c/kWh.

[1] Bräunl, Harries, McHenry, Wager, Electric Vehicle Infrastructure Strategic Planning, Dec. 2018

5. Power Requirements for Electric Bus Services

The purpose of this chapter is to provide a detailed understanding of e-bus operational scenarios and to describe the strategies that can be used to address the challenges associated with their implementation, thereby contributing to a smoother transition to e-buses and a more sustainable transportation system. It aims to analyse e-bus operational energy requirements by considering the energy demand of a general school bus operation scenario and then exploring alternative energy supply solutions that could be used to meet that demand.

The first step involved gathering data on the existing bus network and operational practices. It included meetings with the Department of Transport (DoT) and the Public Transport Authority (PTA) and information-gathering appointments with all school bus operators in WA.

Analysing realistic e-bus operational scenarios involved utilising the collected data, considering factors such as bus energy seating capacity (energy consumptions), round-trip distance, route characteristics, and bus start/finish parking locations. We suggest alternative solutions for cases where the electricity supply capacity at charging locations is insufficient to support mains-connected charging.

Data collection

In transitioning school bus fleets to electric buses, the use of a multifaceted approach was essential to gather comprehensive data for effective decision-making. This initiative necessitated collaborative efforts with various stakeholders, including the Department of Transport (DoT), the Public Transport Authority (PTA), and the bus operators responsible for approximately 274 bus contracts scattered across 437 sites, encompassing a diverse fleet of around 935 individual buses.

To kickstart the data collection process, a pivotal step involved engaging in meetings between the DoT, PTA and the UWA PATREC research team. These meetings aimed to establish a deeper understanding of the general operations and network management related to these extensive bus contracts. Key objectives included mapping out the precise locations of all sites and capturing detailed information about the number and types of buses involved. These insights served as the foundational data to guide the transition towards electric school buses, helping to strategies infrastructure development, charging station placement, and budget allocation.

After analysing the data, it was discovered that some individual data sets contained missing information, potentially affecting the overall quality and reliability of the data. To address this issue and to ensure a more comprehensive dataset, the research team merged different data sets into a unified and consolidated form. This merging process aimed to fill in the gaps created by missing data points and create a more comprehensive and complete dataset for our analysis. By integrating these diverse sources of information, we aimed to enhance the accuracy and reliability of our data, providing a more solid foundation for our subsequent research and decision-making processes.

Electric Bus Energy Consumptions

The electric bus market analysis in Chapter 3 revealed that electric bus energy consumption data is not readily available. Most manufacturers do not provide energy consumption data, and the few that do provide a best-case scenario of energy consumption. Electric vehicle energy consumption estimates from manufacturers are often overestimated. Under worst case conditions, energy consumption can be 100% higher than stated by the manufacturer [Wager et al. 2016] [1].

For the electric school bus project, real road driving energy consumption would be more realistic. Several factors impact the energy consumption of electric buses, including vehicle design and efficiency, driving conditions, passenger loads, climate control, and charging infrastructure.

Vehicle Design and Efficiency

Electric bus design influences energy consumption significantly. Factors such as aerodynamics, weight, and rolling resistance impact the bus's overall efficiency. Advances in lightweight materials, streamlined designs, and improved drivetrain efficiency contribute to minimising energy losses during operation.

Driving Conditions

Driving patterns, routes, and topography significantly affect energy consumption. Stop-and-go traffic, uphill climbs, and regenerative braking can have an impact on the overall efficiency of an electric bus. Efficient route planning and driver training to optimise regenerative braking can contribute to energy savings.

Passenger Load

The number of passengers directly influences energy consumption. Higher passenger loads result in increased energy consumption due to greater weight and increased air conditioning demands. Load management strategies and effective thermal control systems can mitigate this effect.

Climate Control

Heating, ventilation, and air conditioning (HVAC) systems are energy-intensive components in electric buses. Extreme weather conditions require more energy for thermal comfort, affecting overall energy consumption. Improved HVAC designs, utilizing waste heat, and energy-efficient insulation can reduce this energy demand.

Charging Infrastructure

Charging efficiency and availability impact the required battery size of electric buses. Fast charging technologies and well-distributed charging infrastructure reduce downtime and ensure buses remain operational, minimising the need for higher energy reserves.

It is also critical to understand that fast charging has limitations. The charging rate of an EV battery depends on several factors, including the battery's chemistry, temperature, and the charger's power output. Charging an EV battery to 80% of its capacity is typically much faster than charging it to 100% because the battery's chemistry allows for faster charging at lower charge levels. Once the battery reaches 80%, the charging rate slows down significantly.

Due to the significant variation of energy consumption, a combination of data from scientific publications, modelling and actual real road driving energy consumption has been assumed for this project.

1 https://www.sciencedirect.com/science/article/pii/S1364032116301721

Based on electric bus real road driving and modelling research [Hendriks et al. 2022][2] [Ji et al. 2022][3], data from a Western Australian electric bus operator[4] and some electric bus manufacturers, the following energy consumptions (Table 5-1) were assumed and used in this analysis.

Table 5-1 Assumed energy consumption for electric busses.

PTA Bus Class	Energy Consumption
Class A, max 24 seats	0.7 kWh/km
Class B, max 43 seats	1.1 kWh/km
Class C, max 57 seats	1.3 kWh/km
Class D, max 16 seats	0.6 kWh/km
Class 4x4	1.5 kWh/km

5.1. Power Calculations per Site

To establish the operational requirements for electric school buses, we evaluated the round-trip energy demand based on the bus seating category's energy consumptions and the daily driving distance. We then determined the charging power requirement for each bus based on the available charging time. Interviews with Western Power, bus drivers and bus operators for the project revealed that buses could be charged without impacting the evening peak energy demand, for 14 hours per day, with 9 hours of charging at night and 5 hours during the day.

5.1.1. Overall Electric Bus Energy and Charge Power Demand

The daily round-trip energy and charge power requirements for all 935 buses (Figure 5-1) administered by the Perth Transport Authority (PTA) were calculated. The energy requirement calculations were performed by categorising the buses based on seat capacity, each category having an assigned energy consumption. The individual bus energy requirement was calculated based on the bus class and the daily distance (km) driven. Finally, the energy requirement of all 935 individual buses was integrated, resulting in a aggregate requirement of 174 MWh per day.

The charge rate (power demand) is critical for charging buses within a specific time. The higher the charge rate, the lower the charge time. However, a higher charge rate puts more stress on the electricity grid.

Charging Power

For the project, we assumed a 14-hour per day charging window. The required charge power was calculated using the following formula:

Charge Power (kW) = Total Daily Energy Requirement (kWh) / Charging Time (hours)

where:

2 The Australian National University, https://routezero.cecs.anu.edu.au/
3 https://www.sciencedirect.com/science/article/pii/S2772424722000191
4 Swan Transit WA, https://www.transitsystems.com.au/wa-perth-swan-transit-bus-services

- Total Daily Energy Requirement (kWh) is the sum of the daily energy requirements for an individual bus or charge location with multiple buses.
- Charging Time (hours) is the assumed 14-hour charging window.

The power required to charge an individual bus within the specified timeframe was determined by dividing the daily energy requirement by the charging time.

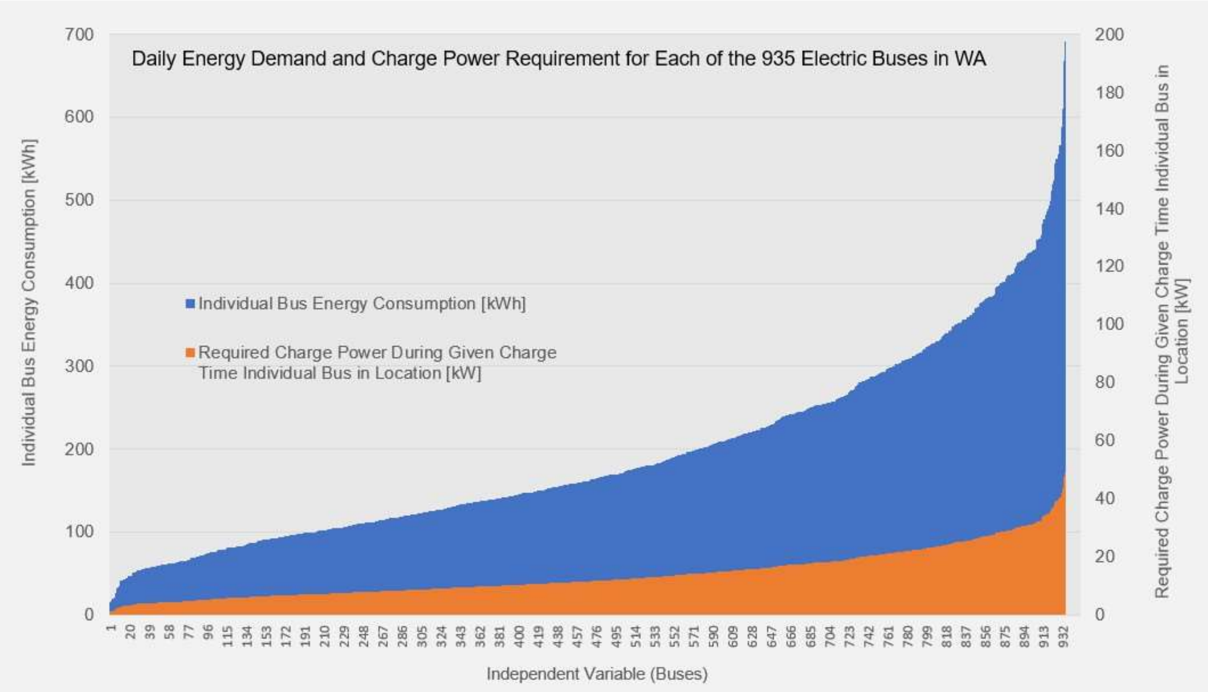

Figure 5-1 Individual Bus Energy and Charge Power Demand for 935 School E-Buses in Western Australia (2023)

5.1.2. Electricity Supply Requirement

The research team investigated the electricity supply requirements to assess the feasibility of transitioning to electric school buses. According to electricity suppliers Western Power and Horizon Power, all of their residential and business customers – anywhere in the state – can expect a minimum power connection of 15 kW (single-phase). This increases to 23 kW where three-phase connections are available. By utilising the methodology outlined in Section 5.1.1, the energy consumption and charge power requirements for all buses and unique charging locations with multiple buses were calculated and categorised.

Assumed categories:

- Less than 8 kW
- Between 8 kW and 15 kW
- Between 15 kW and 23 kW
- Over 23 kW

Figure 5-2 shows the number of individual electric buses categorised by charge power category in Western Australia in 2023. The largest segment of the pie chart is the 'Between 8 kW and 15 kW' category, accounting for 344 of all electric buses in Western Australia. The second-largest segment is the 'Less than 8 kW' category, comprising 257 electric buses. The remaining categories, 'Between 15 kW and 23 kW' and 'Over 23 kW,' represent 178 and 156 of all electric buses, respectively. Overall, the pie chart indicates that most electric buses in Western Australia require a charging power between >8 kW and <15 kW.

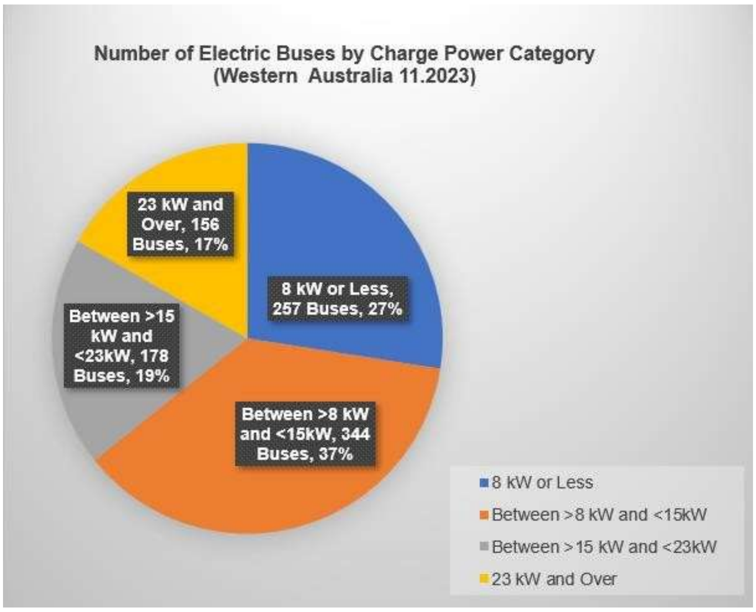

Figure 5-2: The number of buses by charge power categories

Since some locations have several buses on charge, it was of importance to calculate and categorise the number of charge-locations. Figure 5-3 depicts the quantity of charge-locations classified according to charge power categories in Western Australia for the year 2023.

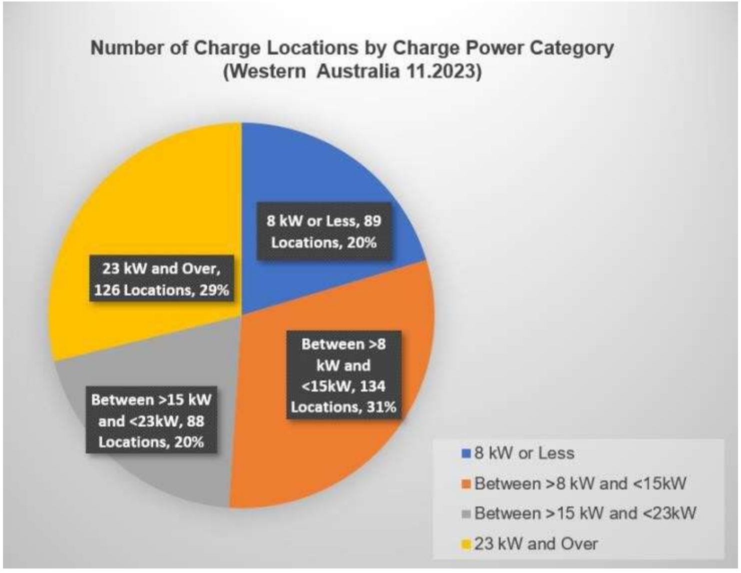

Figure 5-3: The number of charge-locations by charge power categories

The largest segment of the pie chart is the 'Between 8 kW and 15 kW' category, accounting for 134 of all charging locations in Western Australia. The second-largest segment is the 'Over 23 kW category, comprising 127 charge locations. The remaining categories, 'Between 15 kW and 23 kW' and 'Less than 8 kW,' represent 88 and 90 of all charge-locations, respectively. As above with the individual electric buses, the pie chart for charge-locations indicates that most locations in Western Australia require a charging power between 8 kW and 15 kW to fully charge the buses within 14 hours per day.

The preliminary study was crucial due to the limited data initially provided by the electricity supplier. Throughout the project, we liaised closely with the two electricity utilities and we were provided more detailed data. This data was then compared with the electricity demand for the individual buses and the depot. As a result of our collaborative efforts, the number of depot locations identified increased from 437 to 544.

The chart in Figure 5-4 illustrates the provisioning of electricity supply for 544 depots for Western Australia. Western Power dominates the market, supplying electricity for a significant 91% of all depots (496 buses). Horizon Power supplies electricity to 41 bus depots (7%), while Rio Tinto provides electricity to just 3 depots, or <1%. The remaining 4 depots (<1%) receive electricity from other electricity providers.

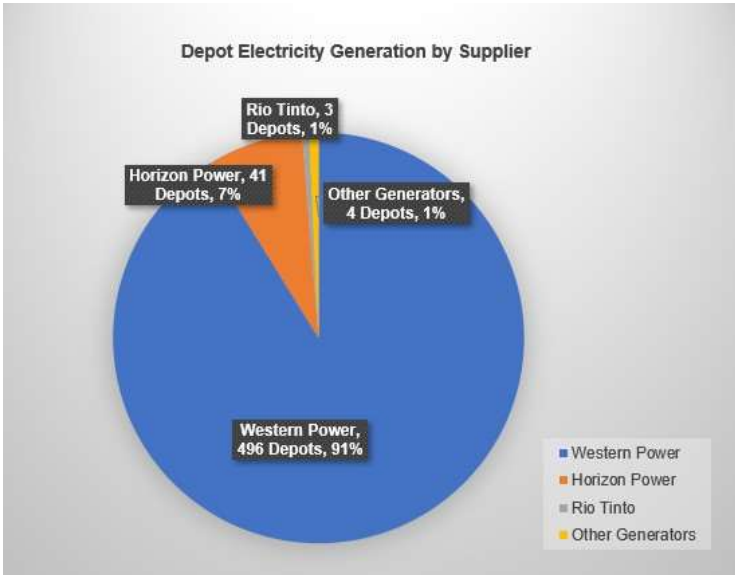

Figure 5-4: Electricity generation by supplier

Figure 5-5 depicts the distribution of depots according to whether they meet the electricity demand with their current grid capacity or require a grid upgrade or an alternative charging solution. The majority (77%, or 417 depots) meet the demand with their current grid. A smaller portion (10%, or 56 depots) do not meet the demand and require a grid upgrade. Electricity supply data for the remaining 13% (71 depots) is unavailable.

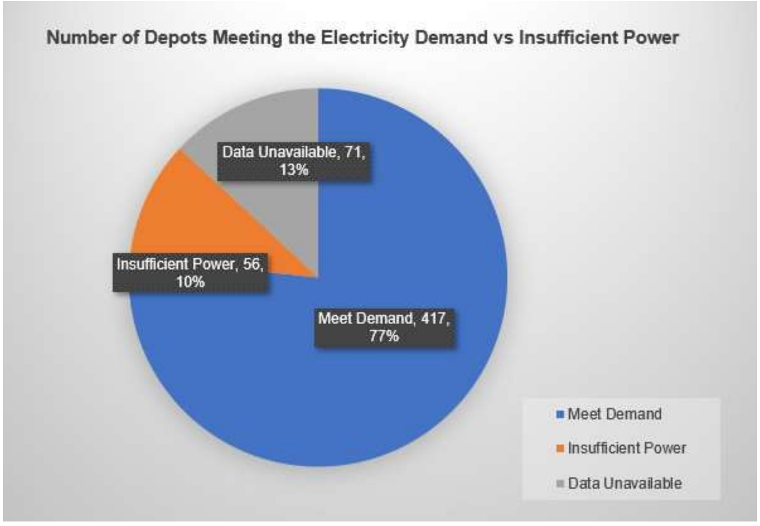

Figure 5-5: Depots meeting the electricity demand vs requiring grid upgrade

Figure 5-5 illustrated the distribution of depots capable of meeting e-bus electricity demands with their existing grid infrastructure. The subsequent pie chart (Figure 5-6) explores a scenario where buses undertake extended charter tours and reduced charging times. This scenario doubles the standard daily distance, also doubling the daily electric energy requirements and increases the power demand due to reduced charging times.

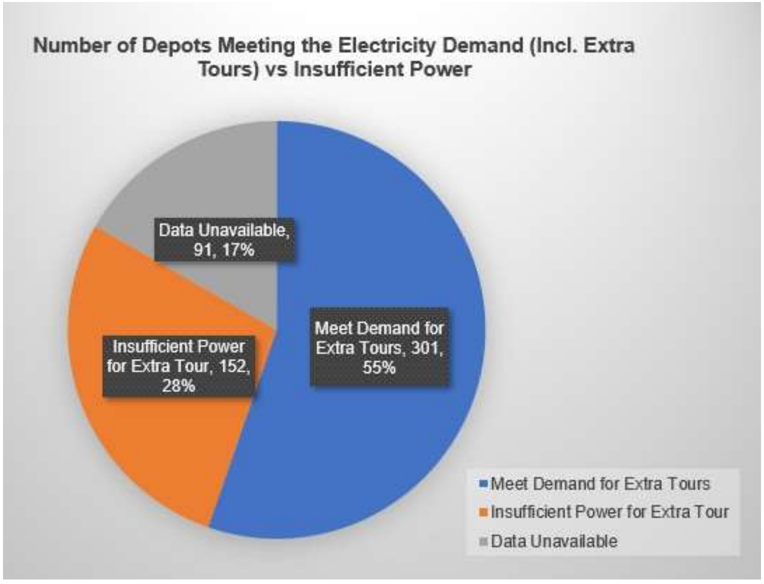

Figure 5-6: Depots meeting the electricity demand for extended charter tours

Figure 5-6 depicts the distribution of depots according to their ability to meet the electricity demand when buses operate extended routes (charter drives), compared to their ability to meet the standard route demand. Under this scenario of increased electricity and power demand, a smaller proportion of 301 depots (55%) meet the requirements, compared to 77% for the shorter standard route. Conversely, the percentage of depots requiring a grid upgrade or an alternative charging solution to meet the increased demand has grown significantly to 152 depots (28%), compared to 56 depots (10%) for the standard routes. Electricity supply data for the remaining 91 depots (17%) is unavailable, however, charging these e-buses at the serviced schools was possible for all investigated case studies.

The following charts relate to the buses rather than the depots. The pie chart in Figure 5-7 splits the bus fleet into three categories based on their electrical power demands. The largest segment (65%, representing 608 buses) includes those that meet current grid capacity. The second-largest segment (18%, representing 171 buses) highlights buses which currently cannot be charged at their depot. These buses either need to charge elsewhere (e.g. at schools) or the depot requires either local generation from renewables (solar PV) or a grid upgrade to accommodate their power needs. Finally, the smallest segment (17%, representing 157 buses) represents buses for which power data is unavailable. This lack of data for over 150 buses necessitates further investigation to ensure a complete understanding of the fleet's electrical demands.

In conclusion, two-thirds of the buses in the fleet appear to be capable operating within the existing electricity grid's capacity.

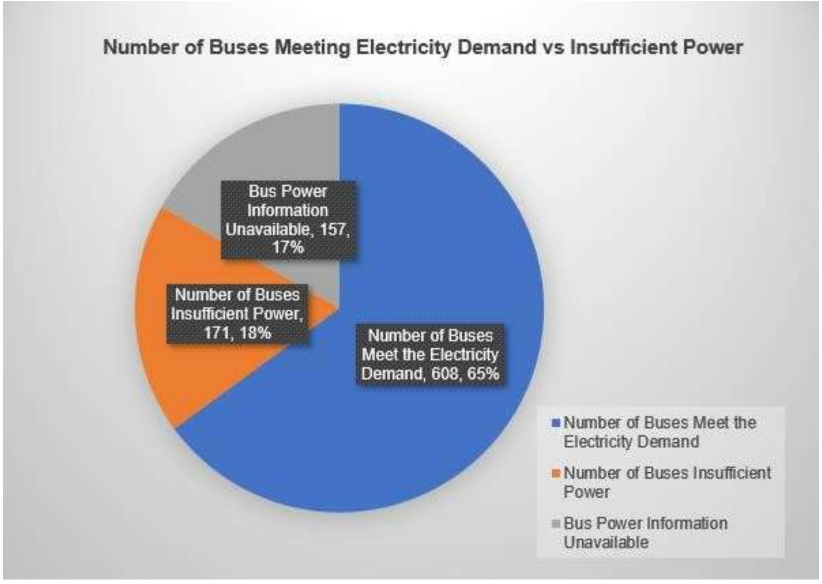

Figure 5-7: Buses meeting the electricity demand

The pie chart in Figure 5-8 depicts the school bus fleet split into three categories based on their electrical power demands including additional charter tours. The largest segment (43%, comprising 399 buses) consists of buses with sufficient grid capacity. The second-largest segment (37%, representing 344 buses) indicates buses that require more power than available at their depot site. Lastly, the smallest segment (20%, comprising 193 buses) represents buses for which depot power data is unavailable.

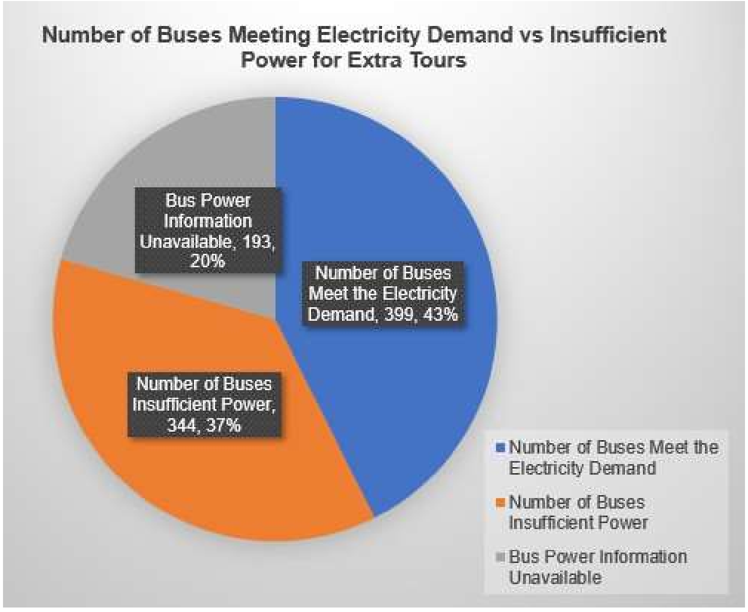

Figure 5-8: Grid demand for buses driving additional charter tours

In conclusion, adding additional charter tours to existing bus routes will more than double the number of buses for which the charging location has insufficient grid power, from 171 to 344. This will also increase the number of depots with insufficient grid connection from 56 to 152.

5.2. Electric School Bus Planning Tool

We developed an interactive web-based planning tool that assists in visualising and optimising the operating and charging scenarios of electric school buses. The tool uses realistic energy consumption values for various classes of buses and lets the user vary the daily distance driven, the grid capacity and the charging hours. It also allows the introduction of both solar PV systems and additional stationary batteries.

In combination with site-specific grid capacity data, this tool allows us to categorise each of the over 900 school bus services into the EV charging scenarios introduced earlier in this report. It will also be the first step in the upcoming case studies involving an in-depth look at selected school bus routes.

5.2.1. E-Bus Planning Tool Features and Usage

The web-based tool can be reached from the top menu of the REVproject.com home page and has the URL: https://REVproject.com/ebus/energy.php

By default, the tool shows the scenario shown in Figure *5-9*. It always assumes that school bus is driven between 7:00 and 9:00 and between 15:00 and 17:00 (shown as red shaded areas), each driving session using up half of the total daily distance. Actual charging times are shown as dark blue shaded areas, while available but unused charging times are shaded in light blue. Underneath the graph, the tool lists the daily energy required for charging, as well as the actual charging energy (matching the former unless there is insufficient energy) and the maximum available energy for charging.

Figure 5-9 Planning tool settings

The top-left radio-button allows changing from a daily view to a weekly view, while radio-buttons on the left allow the selection of the desired bus category (D, A, B, C) and slide rulers at the top left let the user change a variety of parameters:

- Daily driven distance [km]
- E-Bus efficiency [kWh/km]
- Grid connection power [kW]
- Solar PV availability (default 0) [kW]

- E-Bus battery size [kWh]
- Additional stationary battery (default 0) [kWh]
- Stationary battery discharge power [kW]
- Available midday charging hours (between 9:00 and 15:00) [hours]
- Available evening/night charging hours (between 17:00 and 7:00) [hours]

The electric school bus planning tool was implemented by UWA student Vicky Chow under the supervision of Prof. Bräunl.

5.2.2. E-Bus Charging Scenarios

In this section we look at typical e-bus charging scenarios and how the planning tool can assist in visualising each school bus situation as well as in finding the best charging solution. From the initial settings in Figure 5-9, we have now first increased the daily driven distance (Figure 5-10, left) and then, second, have reduced the available charging hours, in order to avoid charging during the evening peak demand period (Figure 5-10, right). Note that the bus can still be charged with the available grid power, and its battery reserve never drops below 100 kWh.

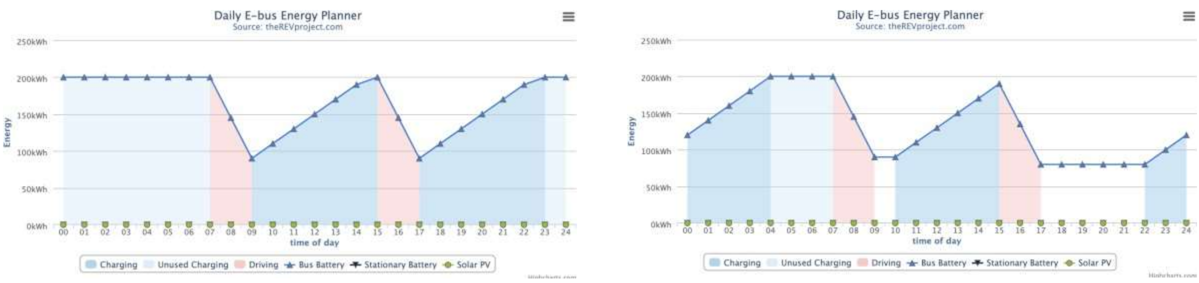

Figure 5-10 Increasing daily distance (left); decreasing charging hours (right)

In the next step in Figure *5-11*, left, we reduce the available grid connection to just 10 kW. This will now be insufficient for charging the bus; a warning message in red appears under the graph. To remedy this situation, we have added a solar PV of 18 kWp in Figure *5-11*, right. This now provides sufficient additional energy to charge the bus. However, please note that a backup generator will also be required in this scenario, as sufficient energy from the solar PV cannot be guaranteed for all days of a year.

Figure 5-11 Reducing grid power level (left); adding solar PV (right)

In Figure *5-12*, left, the same situation is resolved without using a solar PV system, but with an additional stationary battery, which can be charged independent from the bus and from which energy can be quickly transferred to the bus in about an hour before the morning school drive. Finally, *Figure 5-12*, right, shows the weekly scenario. As there are no school drives on the weekend, the additional charging time over Saturday and Sunday can help to fully charge the bus battery again if that did not occur during the weekdays.

Figure 5-12 Adding stationary battery (left); weekly overview (right)

5.2.3. Optimisation

The e-bus planning tool also contains a button labelled *"Generate optional solution"*. As the required driving distance, grid connection, bus efficiency and any limitations in charging hours cannot be changed, the optimiser only calculates:

- the required size of the bus battery and
- any required on-site renewable generation (solar PV).

The stationary battery is left at zero by the optimiser, as the same outcome can be achieved in most cases by using a larger bus battery.

5.3. Electricity Supply System Capacity

One of the critical components of any assessment of the feasibility of a bus electrification program is the capacity of the existing electricity supply system to supply the electricity required to charge the batteries of the electric buses. While this is an important issue for the electrification of city or urban transport buses, it is of even greater importance in the case of the electrification of a regional bus service as electricity grids in regional areas are generally significantly weaker than they are in metropolitan areas. In the case of the regional school bus service in Western Australia, it is a highly significant issue due to the long radial electricity feeders supplying many of the townships connected to and supplied by Western Power's South-West Interconnected Systems (SWIS). In the case of Horizon Power's supply systems, some of those are quite small supply systems in terms of both geographical coverage and in terms of the installed generation capacity.

When considering the capacity of the electricity supply systems in Western Australia to supply the charging requirements for an electric regional school bus fleet, three issues need to be considered separately: the generation capacity of the supply system, the capacity of the zonal electricity supply network, and the impacts that the charging load would have on the more local electricity distribution network. The following discussion addresses these issues separately for the South-West Interconnected System (SWIS), Horizon Power supply systems, and other networks.

This discission of the electricity supply system capacity needs to be undertaken with a basic understanding of the various elements of an electricity supply system and the diagram in Figure 5-13 will be referred to throughout this chapter.

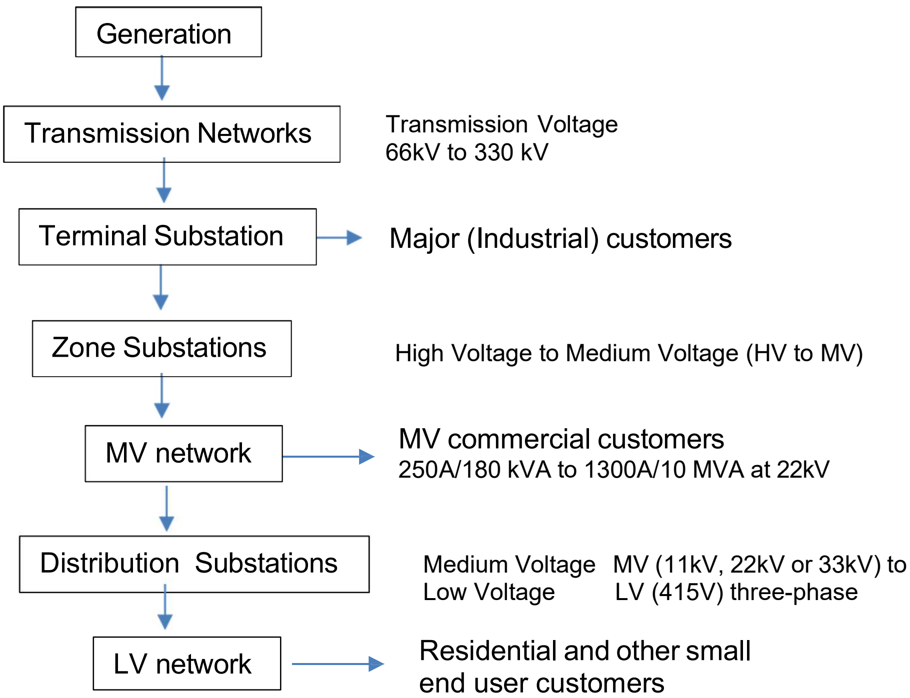

Figure 5-13 Diagrammatic representation of the major components of an electricity supply system.

5.3.1. South-West Interconnected System (SWIS)

SWIS Generation Capacity

Due to two factors, the additional electricity demand on the SWIS created by electrification of the regional school bus fleet is not expected to be a constraining factor in terms of available generation capacity. The first is that the electricity planning system used for the SWIS incorporates a reserve capacity mechanism, the purpose of which is to ensure that the installed generation capacity on the SWIS is adequate to meet the two-year ahead forecast peak demand load. The second is that electric vehicles are highly efficient compared to their internal combustion counterparts, which means that the increase in electricity demand would be relatively small and manageable.

Furthermore, the replacement of diesel buses with electric buses would occur over a period that would coincide with the timeframe over which a rapid transition of Western Australia's electricity supply system is expected to occur, or rather, is planned. The Australian Energy Market Operator (AEMO) is now forecasting the growth in electricity demand on the SWIS to be much higher than was previously forecast, with up to an average annual growth in demand of up to 4.7 % for the ten-year period 2023-2033. The AEMO expects the increase in demand to be driven by electrification (i.e. replacing gas appliances and equipment with electric appliances and equipment), an increasing take-up of electric vehicles, and new energy-intensive industries such as battery manufacturing and green hydrogen production. Simultaneous with that forecast increase in demand will be a major transition of the electricity supply system with large investments in lower-emission electricity generation projects and a phasing out of coal-fired generation[5]. The AEMO estimates that 1,118 MW of additional generation capacity will be required by 2026-27, increasing to 4,000 MW by 2032-33. Given the very large-scale of the planned electricity demand and supply transformation on the SWIS, the impacts on the demand side that would be created by electrifying the regional school bus fleet would be negligible.

Western Power Transmission Network Capacity

Based on the current and forecast capacities and loadings of Western Power's zone substation as published by Western Power in its Network Opportunities Map[6], the zone substation capacities should not be a constraining factor for the electrification of those regional school buses for which the electricity for battery charging would be supplied from the Western Power network. While some of Western Power's zone substations are currently and/or are expected to be overloaded by 2030, the projected remaining capacity of even those zone substations is adequate to meet the increase in demand created by school bus charging.

Another indication of the capacity of Western Power's zone substation and distribution MV feeder level capacity is provided by the Western Power Network Capacity Mapping Tool[7]. However, it does not provide any capacity indication at the LV feeder level. This online mapping tool provides the estimated remaining connection capacity for every year from 2023 to 2030. Using this tool would be useful in selecting initial sites for case studies as it would assist in selecting sites that are likely to have low network connection issues and costs.

Despite the expected large increase in demand project by the AEMO, the AEMO expects the outlook for long-term reliability to improve "due to strong capacity investment signals and planned transmission expansion"[8]. That is, investment in transmission capacity is expected to resolve or avoid any potential transmission system constraints. Given the relatively small sizes of the

[5] https://aemo.com.au/newsroom/media-release/aemo-reliability-outlook-flags-the-need-for-investment-in-wa-south-west-interconnected-system

[6] Western Power, (2022). Network Opportunities Map 2022.Western Power, Perth, WA. Available online at https://prd.westernpower.com.au/siteassets/documents/network-opportunity-map-2022.pdf

[7] https://www.westernpower.com.au/resources-education/calculators-tools/network-capacity-mapping-tool/?_sqt=network%20capacity

[8] AEMO (2023). 2023 Wholesale Electricity Market Electricity Statement of Opportunities. August 2023. AEMO. Available online at https://aemo.com.au/-/media/files/electricity/wem/planning_and_forecasting/esoo/2023/2023-wholesale-electricity-market-electricity-statement-of-opportunities-wem-esoo.pdf?la=en&hash=E05FBD7B0EEF023895B6360D590BAE26

additional loads on the SWIS that would be created by the electrification of the regional school bus fleet, it is highly unlikely that transmission capacity constraints will be a significant factor in the planning for the electrification of the school buses.

Western Power MV and LV Distribution Networks

Assessing the impacts of a electric school bus battery charging load downstream of a zone substation is a more difficult and complex task. The number of factors potentially involved in such an assessment is large, which means that there is no generic or simple answer to the question of whether the local distribution system has adequate capacity to supply the electricity required for charging electric buses at a particular site. It would depend on the charging load, on the specific distribution system, the location of the site load within that distribution network, whether the feeder supplies predominantly commercial loads, residential loads or missed loads, and whether the site is connected to the medium or the low voltage network (Figure 5-13).

Starting in April 2023, Western Power now offers customers a uniform or standard connection service capacity independent of where they are located on the SWIS[9]. The new standard offers for single-phase, three phase and split-phase customers are shown in Table 5-2.

Table 5-2 Western Power Standard Connection Offers

Phase	Current (Amps)
Single-phase	63 Amp (240 V)
Three-phase	32 Amp per phase
Rural split-phase	20 Amp to 30 Amp per phase

The potential impacts of connecting a load or embedded (distributed) generator to a network are determined by many factors, including what other loads and distributed generators are connected in the same area to that distribution system. For example, the impacts of connecting a charging station at connection points X, Y and Z shown in Figure 5-14 are likely to be very different.

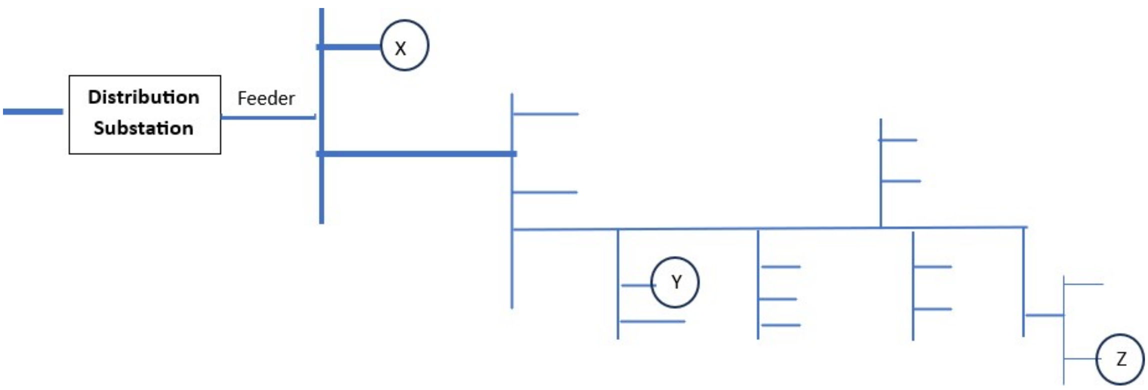

Figure 5-14 Connection points at different locations, X. Y and Z, on a radial distribution feeder.

[9] https://www.westernpower.com.au/news/new-standard-power-supply-allocation-for-the-swis/

Assessing the impacts of the connection of a new load or distributed generator at a site requires a detailed network study to be undertaken to be able to understand the impacts that the connection would have on various parameters such as the thermal capacity, voltage, power quality and the voltage drop. There is no alternative simple way of assessing those potential impacts. For that reason the number one rule for those planning to electrify their bus fleets is to work very closely with the network operator and to start those discussions as early in the planning process as possible.

The real question is not whether a distribution system has the capacity to supply the electricity that will be required to charge one or more electric buses at a site, but what upgrades to the distribution network would be required to do so, and what the cost of those network upgrades would be. Once the likely impacts of connecting a charging station at a site have been assessed, the next step in the process is to calculate the necessary network upgrades that would be required to avoid those negative impacts, and the associated cost of those network upgrades. There is no way of knowing those network upgrade details or costs prior to undertaking the network study. For that reason, this feasibility study has involved working closely with Western Power to undertake network studies for a sample of sites at which charging stations would be connected to provide an indicative range in the network upgrade costs that could be required.

As noted in the Section on distributed generation, network connection enquiry and connection application fees apply for each proposed connection, and the timeframe for connection approval increases in a stepped fashion as the size (kW) of the proposed load (or distributed generator) increases.

An important consideration in assessing the impacts of connecting a charging station to a distribution network is the impact on the peak load. The school bus charging loads will not have a material impact on the peak load in terms of the installed generator capacity but could have an impact on the peak loading of the distribution substation or transformers. Avoiding or minimising that impact by managing the timing of the electric bus charging will therefore play an important part of minimising any future network upgrade costs. The options for doing so include encouraging bus owners/operators to charge the batteries of the buses during off-peak periods using time-of-use tariffs, to control the timing of the charging using software control systems and using distributed generators to provide all or a significant portion of the electricity used for charging the batteries. It needs to be noted that the connection of distributed generator to a distribution network also requires approval and, therefore, the associated network studies and fees.

5.3.2. Horizon Power Supply Systems

The relatively small sizes of Horizon Power's thirty-eight (38) supply systems, in terms of both the geographical area of the networks and the generator capacities, makes it important to consider the generation capacity and the distribution network capacity (there are no HV transmission components) together. Unlike the situation on the SWIS, many of the generators supplying Horizon Power's supply areas are relatively small and most are diesel generators. A relatively large step-change in the load (either an increase or a decrease) can put stress on the diesel generators. In many cases this is exacerbated by the large number of distributed solar PV systems connected to the distribution network. The generator needs to be able to manage a worst-case scenario of both an additional new load coming online simultaneously with a sudden decrease in the combined output from the solar PV systems (or vice versa). For this reason, the connection application for a bus charging station in a Horizon Power supply area will need to consider not only the impacts on the distribution network, but also on the generator.

The connection of a charging station to the network will not have significant potential impacts on all of Horizon Power's networks. For those supply areas in which the installed generation capacity is relatively large, such as on the North-West Interconnected System, Esperance or Broome, the impacts of connecting an electric bus charging station on the generator would be negligible.

As with connection applications submitted to Western Power, it is not possible to know or estimate the nature or cost of any network upgrades that would be required to permit the connection of the charging station. This feasibility study did not involve working with Horizon Power to undertake network studies for a sample of sites to which charging stations would be connected. However, Horizon Power did provide data for this project on the remaining HV and distribution transformer supply capacities for the depots and schools for each of the case studies (Chapter 8) that are within a Horizon Power supply area.

Unlike the situation with the South-West Interconnected Systems, electric school bus charging loads in Horizon Power supply areas will have a material impact on the peak load in terms of both the installed generator capacity and on the peak loading of the distribution substation. This will make it even more important to avoid or minimise that impacts by managing the timing of the electric bus charging. It will also be necessary to work closely with Horizon Power to determine the optimal location of any charging station installation in terms of minimising network upgrade costs.

5.3.3. Rio Tinto Supply Systems

A very small number of regional school buses are garaged in locations that are not connected to either the SWIS or a Horizon Power regional supply network. Some of those sites are supplied by a Rio Tinto supply network. Due to the very large installed generation capacities at those sites, there would be no constraints to installing electric bus charging stations in terms of generation capacity. The networks tend to be similar in geographical scale to some of the Horizon Power distribution networks, but relatively strong. While it will be necessary to apply to the network operator to connect a charging station to one of those networks, the connection issues are likely to be less significant.

5.3.4. Community Supply Systems

Three regional school buses are garaged in locations in which the electricity is supplied by a small community-scale power supply system. While these buses are relatively small (Class F and Class G), the addition of a bus charging load would have a very significant impact on the generator. It may be necessary in these cases to install dedicated stand-alone power supply systems to supply the electricity for charging the electric school buses and/or stationary batteries. In all three cases, the solar radiation levels are high, which would make it possible for a large portion of the electricity to be supplied by solar PV systems.

5.3.5. Stand-Alone Off-Grid System

One regional school bus is garaged at an off-grid site. At this stage, no information is known about what on-site generation exists and is used on that site. The need to augment any existing stand-alone power supply system at the site would therefore need to be assessed.

6. E-bus vs Diesel Comparative Analysis

This case study of Denmark compares the 17-year contractual costs of the currently most common diesel bus (C Class) with an e-bus equivalent, including the cost of various EV chargers with and without 100% renewable energy, and also on-site PV and stationary battery storage systems. This has been undertaken to enable decision-makers to select the most appropriate systems to both minimise emissions and costs of the dominant bus class that currently service the town of Denmark and surrounding towns. This analysis serves as an example of how the most common school bus service type (Class C bus) can be electrified in a flexible ways cost-effectively and derive broader regional clean energy development scenarios that are lower cost than the status quo of diesel.

Comparison A: **Class C diesel bus vs e-bus with selected charge costs and GHGs.**
Comparison B: **Selected e-bus energy infrastructure investment costs and benefits.**

Comparison A assumes e-bus charging occurs over only 14 hours per day (the sum of a 5-hour daily charge interval approximately between the hours of 9:00 and 15:00 of 6 hours available, plus a 9-hour nightly charge interval approximately between 21:00 and 7:00 of 13 hours available. Using these charging intervals is designed to maximise daily charging times between maximum renewable energy (PV) output to lower costs, and minimise charging times during peak demand between 18:00 and 21:00 hours to ensure service availability and network stability.

Comparison B investigates the relative costs and benefits of maximising local economic returns for investing in clean energy and publicly available EV charging services alongside school e-bus services on a commercial basis. We discuss the options of the charging infrastructure for regional WA e-bus services being owned by either the bus operators, by the WA Government, or by independent private operators. We also analyse the economics of various means of reducing emissions of these charging technologies, in addition to generating additional revenues by designing e-bus charging outlets that are accessible to the public when not in use by buses, such as on weekends and during school holidays.

6.1. Denmark's Detailed E-bus Technical and Economic Analysis

This technical, emissions, and economic analysis was developed to explore in detail the differences in investing in an electric vs diesel Class C bus in Denmark WA, complete with representative averaged bus travel and meteorological data for Denmark using a common bus model for WA.

A simple economic model was developed to show the attributes of each technology and emission calculations. The model incorporated estimated 2024 market prices of electricity, rates, capital, and labour projected over the 17-year contractual lifetime, and included equipment installation, operating costs, maintenance/replacements, diesel fuel/fuel additives/electricity prices, etc. Each economic analysis incorporated an annual real discount rate of 6% (incorporating both inflation and time-based value of investments. Simplifications included an average capital cost of $422,000 for a Class C school bus in 2024 (based on averaged actual awarded bus contract data). A 36% additional capital cost value was assumed for an e-bus equivalent ($575,000) over the estimated 2024 Class C diesel bus cost, with the maintenance costs of the diesel estimated at 25% of the fuel cost, with the e-bus equivalent maintenance around half ($0.10/km). Insurance costs were estimated at 1% of the capital cost value charged annually and discounted at 6% per year. The e-bus modelling included an assumed battery replacement in year 10 of $30,000, and the model ignored any significant diesel engine overhaul. The assumed distance travelled per annum was assumed to be 40,000 km for both diesel and e-bus scenarios (The average daily trip of around 200 km is the approximate average for the sum of bus services around the location). The e-bus in this scenario is assumed to be charged with an inexpensive three-phase AC grid-connected charger (generally costing only around $2,000). Also included are scenarios in which higher cost electricity is purchased from publicly available rapid chargers.

For simplicity, the prices of electricity, diesel fuel, and fuel additive were assumed to be constant (after inflation) over the 17-year interval. The diesel fuel costs over the 17-year discounted economic model was at $1.86/L (ex GST). The fuel consumption of the Class C bus was assumed to be a constant 33.7L/100km as per PTA estimations. The fuel additive (AdBlue) was assumed mixed at 5% at a cost of $2.27/L (ex GST). (The authors note that the volatility and supply security of diesel fuel and additives have historically been a major uncertainty. This is expected to continue, but we have chosen conservatively to model a consistent price over time). The Class C e-bus electrical efficiency was assumed to be an average of 1.3 kWh/km. (The authors again note that electricity and fuel consumption per km is variable and heavily dependent on the weather and driver behaviour, as are other operational expenditures (OpEx).

The electricity tariff rates that were assumed constant for the 17-year discounted economic modelling were:

a) the Synergy business (L1) tariff of $0.279/kWh (ex GST);
b) a separate model of $0.1727/kWh (ex GST), representing a negotiated contestable customer rate from a typical school in Denmark, and;
c) a $0.6363/kWh (ex GST) rate representing the highest likely cost of e-bus charging using publicly accessible rapid EV chargers only.

The analysis has included an assumed additional cost of $0.06/kWh (ex GST) as a premium for purchasing zero emission electricity over the 17-year interval.

Scope 2 GHG emissions from electricity were calculated using the most recent (2022/23) SWIS emissions factor of 0.51 $kgCO_2$-e/ kWh, which was assumed to be constant over the 17-year interval (the authors note the SWIS emission factor is likely to decrease markedly, although our modelling enables a valid GHG emission comparison of diesel vs electric for the next few years). Included for comparison is a scenario of achieving net zero (Scope 2) emissions via purchasing renewable energy at the premium equivalent to the total lifetime electricity used in the bus for the entire 17-year interval). Diesel bus GHG emissions were calculated using an emissions factor of 0.0695 $kgCO_2$-e/MJ at an energy content of 38.6 MJ/L, and a fuel consumption of 13,480 L p.a. GHG emissions of the AdBlue were ignored for simplicity.

Included is a comparison of the economics of a 30 kW solar PV system, with both the displacement of electricity imports from on-site generation and exports to the SWIS network modelled as zero cost. This is a representative solar PV system suitable for installation at most bus depots, or even at schools, recreation centres, or other large-roofed structure with suitable vehicle access and electricity infrastructure. We have modelled the economic value and technical performance of the solar PV array based on actual historical inverter performance and capital cost data from a comparable PV system at a Denmark school (approximately $1.70/W installed, including maintenance costs). No capital subsidy was included to avoid 'double counting' of renewable energy certificates sold, avoiding falsely assuming zero GHG emissions as a result. The average monthly MWh production varies from a low of around 2 MWh in June, 5 MWh in January, with a total of around 45 MWh per year. This is around 80% of the average Class C e-bus charging requirement when travelling an assumed 40,000 km per year (around 55 MWh per year total demand). Additional electricity is sourced from the SWIS network.

Also modelled is the installation of a rapid (200 kW) DC charger coupled with a 190 kWh battery using technical efficiencies of a model presently available in WA, using the quoted costs ($250,000). This technology was included as an example of how this technology may avoid most major network upgrades via charging from the available network capacity at a site over time and delivering a rapid charge when needed from the battery, among other advantages. We have assumed the $0.172727/kWh SWIS electricity import costs based on a contestable customer negotiated tariff. As an example, this technology can be used to rapid charge the energy consumed by the assumed Class C e-bus in the morning trip (100 km) within about 40 minutes from either the grid or the battery or both. The bus in theory has more than 5 hours to complete this charge.

The model assumes a $5,000 p.a. operating cost for the system, and a major overhaul costing an additional $25,000 in year 8.

6.2. Comparison A – Economic Modelling Results

The following table shows the results of the scenarios compared over 17 years of a range of diesel vs e-bus scenarios.

Table 6-1 NPC and GHG emissions

Lifetime Class C Bus cost and emissions (with assumptions)	NPC	GHG (t CO2-e)
Diesel bus ($1.865/L plus $2.27/L, 5% AdBlue)	$814,619	615
E-bus ($0.6363/kWh rapid charge, +$0.06/kWh for 0 emissions)	$1,073,262	0
E-bus ($0.6363/kWh rapid charge with present SWIS Sc. 2 EF)	$1,015,427	<475
E-bus ($0.279/kWh standard charge +$0.06/kWh for 0 emissions)	$890,319	0
E-bus ($0.279/kWh standard charge with present SWIS Sc. 2 EF)	$855,909	<475
E-bus ($0.1727/kWh contest. charge, +$0.06/kWh for 0 emissions)	$829,357	0
E-bus ($0.1727/kWh contest. charge with present SWIS Sc. 2 EF)	$794,947	<475

The table above compares the total lifetime costs NPC (net present cost), all ex GST, based on the stated assumptions over the 17-year DCF (discounted cost factor) investment of an equivalent Class C diesel vs e-bus driven 40,000 km annually to deliver children to school. The lifetime NPC difference between the current diesel bus costs and an e-bus costs using the lowest cost SWIS electricity tariffs is negligible. The six e-bus charging scenarios in Denmark show that the cost of 'net zero' emission electricity is also negligible when compared to the choice of charging method (rapid charging is more expensive). Only the most extreme option of only ever using the most expensive rapid-charging services using 100% renewable energy increases costs over the 17 years by approximately 30% relative to the status quo of diesel. By using contestable, slower charging rates using 100% renewable energy there is no significant difference to the economics between fleet conversion and the status quo of diesel, despite a much higher capital e-bus cost vs diesel equivalent.

The economic DCF model excludes any carbon or exhaust emission costs. However, these GHG emission assumptions show that lowest cost e-bus charging using SWIS Scope 2 emission factors reduces GHG emissions by slightly more than 20% compared to a diesel Class C bus. The Table below shows the annual difference between these options, but we are aware the diesel bus purchase 'locks in' 17 years of diesel emissions over the bus contract - unless this diesel bus is converted to electric. In contrast e-buses allow flexibility of emission intensity. For example, any individual e-bus trip can be net zero by charging using 100% renewable energy. Even without purchasing 100% renewable energy the SWIS Scope 2 EF is expected to reduce steadily over time to be approximately half of what it is now over the 17-year contract. This means that any e-bus will be reducing GHG emissions by an estimated 40% relative to diesel in 17 years by using electricity supplied from the SWIS in Denmark.

Table 6-2 GHG emissions per year

Class C estimated GHG (t CO_2-e) emissions per year	
Diesel Class C (0.0695 kgCO_2-e/MJ, 38.6 MJ/L, 13,480 L p.a.)	36.163
E-bus Class C GHG emissions (100% renewable energy)	0
E-bus Class C GHG emissions (0.51 SWIS EF)	27.916

This analysis demonstrates that there are no significant technical and economic barriers to a school bus achieving zero emissions. It also demonstrates the flexibility of choice in e-bus charging solutions, ranging from low-cost private slow charging to rapid (more expensive) charging when it is needed.

These scenarios give insight into broad economic opportunities from electrification WA's school bus fleet. One major implication of bus fleet electrification is the large changes in cashflows due to the high capital cost of an equivalent e-bus to a diesel equivalent, and the choice of charging used. For example, approximately $393,000 is the discounted operational cost of the average diesel Class C driven 40,000 km annually over the 17-year contract. Approximately 75% of this cost is the cost of the purchased imported fossil fuel, with the remaining 25% being for local maintenance and servicing within WA. This can be compared to the approximately $220,000 to $500,000 costs of primarily electricity required over the 17 years for an e-bus equivalent operational lifetime. This will have implications for considerable revisions of the school bus contract model. The table below shows scenario differences in CapEx vs OpEx over the 17-year NPC comparison.

Table 6-3 CapEx and OpEx

Lifetime Class C Bus cashflows (with assumptions)	CapEx	NPC	OpEx
Diesel bus ($1.865/L plus $2.27/L, 5% AdBlue)	$422,000	$814,619	$392,619
E-bus ($0.6363/kWh rapid, + $0.06/kWh)	$575,000	$1,073,262	$498,262
E-bus ($0.6363/kWh rapid)	$575,000	$1,015,427	$440,427
E-bus ($0.279/kWh standard + $0.06/kWh)	$577,000	$890,319	$313,319
E-bus ($0.279/kWh standard)	$577,000	$855,909	$278,909
E-bus ($0.1727/kWh contestable + $0.06/kWh)	$577,000	$829,357	$252,357
E-bus ($0.1727/kWh contestable)	$577,000	$794,947	$217,947

The considerable changes in e-bus operational costs shows that the potential fleet electrification could generate significant new investment in WA electricity infrastructure and regional EV charging services. Akin to local assembly of buses, electrification enables new cost-effective investments in local energy infrastructure and services producing zero emission at the point of use. This contrasts with the status quo of the WA government expenditures flowing to primarily overseas oil producing nations' refining infrastructure, and locally exposing children to diesel exhaust. With millions of litres of diesel consumed each year from WA's school buses alone, opportunities such as these assist both Australia's aim of meeting net zero targets, and the legislated compliance requirement of a 90-day net liquid fuel import fuel security obligation.

6.3. Comparison B – Economic Modelling of Regional Rapid Charger Results

Table 6-4 shows the results of a simple economic model of how a rapid (200 kW) EV charger with a stationary battery (190 kWh) costing $250,000 (quoted values installed) recoups investment over a 17-year DCF analysis at current prices. It uses the same economic assumptions as the Class C diesel vs e-bus comparisons used in Comparison A travelling 40,000 km per year. No capital or running cost subsidies were included. The five MWh annual electricity sales values in the table below show the sensitivity to the volume of electricity sold and the relative purchase prices (from the SWIS network). Selected purchase prices from the SWIS for all four sales values in the table were a contestable rate of $0.1727/kWh (ex GST), and the sales rate was an approximation of current commercial prices paid at this time for rapid EV charging services in WA. The sales rate was an assumed $0.6363/kWh.

Table 6-4 NPC and payback periods

MWh sales DCF for a 200 kW charger with 190 kWh battery	NPC; Payback Period
50 MWh (~ 1 x Class C school bus annual demand.)	-$79,970; >17 years
75 MWh (~ 1.5 x Class C school bus annual demand.)	$39,080; 14 years
100 MWh (~ 2 x Class C school bus annual demand.)	$158,131; 9 years
125 MWh (~ 2.5 x Class C school bus annual demand.)	$277,181; 6 years
150 MWh (~ 3 x Class C school bus annual demand.)	$396,232; 5 years

The modelling results show that it is commercially viable to install rapid EV charging infrastructure and promote a maximum number of sales/customers to recoup the investment. For example, if the demand of 3 average Class C school buses in Denmark were charged in this scenario (150 MWh), the 17-year NPV of the rapid charging is almost $400,000, or more than $60,000 per year positive cashflow, paying off the investment within 5 years. In contrast, if the rapid EV charging system demand at this location was only 50 MWh per year, the investment would never be recouped. For comparison, 50 MWh is not a large sales volume; it would be the annual electricity required by only one Class C e-bus driven approximately 40,000 km each year. The small town of Denmark could theoretically support multiple rapid charging and battery investments of this kind using school e-buses alone. Denmark is also a tourist town with heavy weekend and thousands of holiday makers travelling to the town. often for only a few days. Such rapid charging technology can be made publicly available at minimal effort/parking bay redesign and would increase sales volumes outside of school hours/days. For example, 50 MWh per year can be theoretically achieved even if only 6 passenger vehicles use the rapid charging service for every day there is no school (weekends and holidays).

These rapid charging services need not be located at existing bus depots or schools. However, schools are the logical location for such bus charging infrastructure as they often have excellent grid connections and large roof spaces. The question of who invests in the charging infrastructure is an open one.

Our analyses shows that most regional schools (3 in Denmark alone) have the electricity network capacity (no network upgrade needed) to support at least 2 parallel 50 kW charge points. (These smaller 50 kW fast chargers cost around $50,000 each for two ports). The installation of this larger rapid EV charging and battery systems (200 kW and 150 kWh) would enable charging of a Class C school bus in less than 1 hour even without the grid. This capability could also buffer the electricity network and balance the energy demand from the school itself and multiple buses charging anytime.

The availability of this type of rapid EV charger and battery in WA's regional areas would have several implications. Using the town of Denmark as an example, it represents an EV charging capability (in kW) that is around ten-fold faster than the current 3 phase charge point available within a 50 km radius of the town (22 kW). (The nearest WA EV Network fast chargers are in Walpole and Albany, both over 50 km away). These analyses indicate that investing in rapid charging infrastructure would be an attractive private investment opportunity without government subsidies. School bus electrification is a flexible electricity load and may be the sole or foundational electricity demand to underpin commercially viable investments in rapid fast charging/storage infrastructure in rural WA towns. This is likely to avoid many costly network upgrades associated with mass passenger and public transport electrification. It would be a significant step towards light truck electrification in rural WA. Demonstration of these technologies is advisable to ensure technical and economic uncertainties are well understood prior to expansion.

In summary, there are no economic or technical barriers to rural/regional rapid EV charging infrastructure when using schools or similar public facilities with good electricity connections (aquatic centres, recreation centres, etc.). In terms of charging technology, commercially available options give passenger EV or e-bus owners the option of using either more expensive rapid charging services or much lower cost slow charging. Both charging options significantly lower direct and indirect GHG and exhaust emissions for school buses.

6.4. Summary of Implications for Regional WA

These detailed, yet simple analyses demonstrate that there are significant economic and GHG emission advantages to transitioning to e-buses from the diesel status quo, independent of the capital costs of the charging technology used. All EV charging technology investments would make it possible to meet net zero targets cost-effectively without subsidies. With rapid charging and battery systems available, it is now commercially viable to make maximum use of the lowest-cost daytime PV electricity production and low-cost night-time grid-import prices across WA. These storage technologies (stationary and EV batteries) enable the WA electricity network to cost-effectively meet the additional E-bus fleet energy demand. As diesel fuel represents around half of the total lifetime cost of a Class C diesel bus, electrification enables re-investment of WA's diesel fuel imports into WA's clean energy sector and regional electricity network (network upgrade costs are presently a major barrier in WA to the roll out of EV fast charging in regional areas). Crucially, electrical energy is a domestically produced, and has relatively stable energy supply, enabling a transport fleet that is not exposed to the geopolitical, market volatility, or supply chain sensitivities of the global oil market.

In the case of many towns like Denmark, stationary batteries can defer network investment to avoid peak electricity demand (typically from 6-10 pm daily, and also peak tourism times/holidays). These investments are commercially viable without subsidies because present rapid EV charging prices (up to 70 c/kWh) are significantly higher than the kWh tariff prices in homes/businesses (around 30 c/kWh or less. It is often the same or a significantly lower cost than diesel or petrol use. Contestable electricity contracts can be much lower than 20 c/kWh. As the WA electricity is increasingly decarbonised, there are significant commercial and GHG benefits to greater investment in regional rapid DC EV charging infrastructure. All modelled options demonstrate negligible regional transport lifetime costs to electrification with a greater certainty for those who wish to invest in transport vehicles and infrastructure. It also enables a gradual investment in small-to-medium scale distributed clean energy generation and associated services across WA without new transmission investment. The primary barrier is higher capital costs for electric vehicles. The secondary barrier is the lack of rapid EV charging services, despite their economic viability over their lifetime when installed in locations with suitable existing network capacity.

7. E-Bus Service and Alternative Zero-Emission Systems

7.1. E-Bus Servicing and Training

EV servicing, in general, is relatively simple due the major reduction of mechanical components and lower frequency of servicing requirements. EV servicing is evolving from a traditional ICE automotive approach towards custom high-voltage (HV) electrical systems. Dedicated servicing for EVs in WA is commonly undertaken through dealerships at established vehicle manufacturers with technicians trained on the specific drivetrains and HV systems. Independent mechanical businesses are upskilling their technicians and equipment to be able to undertake routine EV maintenance, with more complex repairs often requiring specialist referral. In rural and remote regions of WA there are fewer qualified EV technicians and dealerships, leading to longer wait times or requiring travelling long distances for servicing. Mobile independent servicing specialists can offer basic maintenance, with more complex repairs likely to require transporting to major centres. At this point in time, Transperth e-bus servicing is undertaken at dedicated centralised workshops with in-house technical expertise.

In WA there is no mandatory licensing requirement for servicing EVs, although future regulations are anticipated. Nationally accredited courses are delivered by Registered Training Organisations (RTOs), such as TAFE colleges and private training providers. EV servicing training course offered through TAFE is the ‘Battery Electric Vehicle Inspection and Servicing Skill Set (AURSS00064)’. It was developed to supplement existing qualifications in automotive electrical or mechanical technology, such as Certificate III in Automotive Electrical Technology. Non-accredited courses are offered by private training providers that focus on specific aspects of EV technology. One example is manufacturer-specific certifications with specialised training programs for specific EV models. Alternatively, industry associations, such as the Motor Trade Association of WA (MTA WA), also offer non-accredited training. Non-accredited training courses in WA include ‘Battery and Hybrid Electrical Vehicle’, offered by the MTA WA.

In general, the differences between conventional ICE automotive training and EV training can be described by the following technical areas:

1) High voltage, as EVs operate on HV systems requiring a safety focus.
2) Advanced diagnostics, as EVs require novel diagnostic tools and software use.
3) Technical precision, as EV components are often intricate and sensitive.
4) Mechanical simplicity, as EVs have significantly fewer moving parts relative to their ICE equivalents.

The demand for qualified EV-specialist technicians will grow significantly as the EV market expands in WA, as will the need for training. At this stage many components of an e-bus can be serviced by the existing skilled workforce. However, specialised components are often undertaken by flying in components and technicians when needed. One of the larger school bus fleet operators indicated during our stakeholder interviews that it would be happy to provide such a service[1] for smaller school bus operators.

The authors expect the lower servicing and associated lower ‘downtime’ of e-buses relative to ICE equivalents to be an advantage. A period where any bus is not able to be in service will be a familiar scenario to bus owners, and contingencies are commonly in place for such instances.

[1] Personal communication, Brian Thompson, Swan Transit. 19 April 2024.

7.2. E-Bus Maintenance

It is common to find statements in published documents and reports to the effect that the maintenance costs of electric buses are lower, or are likely to be lower, than those of diesel buses due to their fewer moving parts, the longer lives of their braking systems, and the fact that they do not require oil changes. Most of those statements, however, do not provide specific estimates of by how much lower the maintenance costs of electric buses are likely to be[2]. Furthermore, while a small number of reports do provide such estimates, there is little agreement between them. The various estimates of the maintenance costs of electric buses as a percentage of the maintenance costs of diesel buses found in the literature included estimates of 67%[3], 122.5%[4] and 32[5]. A report by the World Resources Institute published in 2023 estimated that the maintenance costs of electric school buses range from 58% to 68% of the maintenance costs of diesel school buses[6], while another study found that the maintenance costs varied significantly according to the size of the bus fleet[7].

An analysis of the service costs of the regional school bus service in NSW prepared by AECOM calculated the planned costs of diesel school buses to range from $0.14/km to $0.16/km, but for the costs to depend on the age of the bus and on the make and model of the bus. However, when compared with the estimated maintenance costs of diesel school buses obtained from one local school bus operator in Western Australia, those figures appeared to significantly underestimate the actual maintenance costs of diesel school buses.

From the above it was concluded that no accurate assessments of the maintenance costs of either diesel school buses or electric school buses are currently available. One reason for that was attributed to inconsistencies in terms of what is included and what is not included in the maintenance costs and whether they are based on estimates of the costs of planned maintenance only (oil changes, etc.) or whether they include other costs such as tyre and battery replacements, bus cleaning and repairs. Coupled with that uncertainty is the fact that electric buses are relatively new to the market and until bus operators have collected the maintenance cost data for their electric buses over their full operating lives, the maintenance costs of electric buses will be largely unknown[8]. Given these uncertainties, it was decided to only include the diesel engine-related maintenance cost in the comparison calculations.

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[8] Personal communication, Brian Thompson, Swan Transit. 19 April 2024.

7.3. E-Bus Driver Training

The replacement of diesel school buses with electric school buses will create a need for driver training. According to the *Electric School Bus Initiative* in the USA, the need for driver training arises from that fact that while electric school buses share many driving and performance characteristics with diesel and petrol buses, they require different driving techniques[9]. A document on e-bus training prepared for the *eBussed* program in the European Union by the Turku University of Applied Sciences in Finland argues that e-bus driver training is required to ensure that drivers are confident about operating the new vehicle type, recharging, economical driving, and safety issues, and that the training must be not about driving only, but also about getting to know the new electric buses[10]. In the view of one Australian bus operator, it's also about understanding the state of charge and what drivers needs to check before they drive the vehicle[11].

Training to achieve economical driving is considered necessary as it has been reported that without training electric buses tend to be driven more aggressively and faster on average than are diesel buses. The reason for that is thought to be due to electric powertrain's low-level noise feedback and superior power at low speeds[12]. Training drivers to use gentler 'feather touch' braking would result in maximum use of the regenerative braking systems and can increase the bus's energy economy by up to 30%[13].

The need for driver safety training arises from the fact that an EV bus has a lot more torque than a conventional diesel bus. According to a representative from one bus distributor in Perth, it will be important for e-bus drivers to understand the different need for acceleration of an e-bus compared to a d-bus when, for example, entering a roundabout[14]

How the driver training is provided will vary from one bus operator to another. A variety of formal training courses have been developed in the USA, including e-bus simulator training[15] and an electric school bus training module developed by the US Department of Energy[16]. In Europe, driver training courses are offered by e-bus manufacturers[17]. In Australia, the Certificate II Competency training module "TLIC0028 - Operate a battery electric bus or coach:" is a joint initiative of the federal and state governments[18].

[9] https://electricschoolbusinitiative.org/reskilling-workforce-training-needs-electric-school-bus-operators-and-maintenance-technicians

[10] Ikonen, M. (n.d.). The crucial role of driver training in the deployment of electric buses in the deployment of electric buses. Turku University of Applied Sciences, Turku, Finland. Available online at: https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1643628784.pdf

[11] https://www.busways.com.au/news-items/driver-training-industry-gains-insights-electric-future

[12] Vepsäläinen, J. (2017). Driving Style Comparison of City Buses: Electric vs. Diesel. *2017 IEEE Vehicle Power and Propulsion Conference (VPPC)*, Belfort, France, 2017, pp. 1-5, doi: 10.1109/VPPC.2017.8330942.

[13] https://www.sustainable-bus.com/news/electric-bus-range-electricity-consumption/

[14] Personal communication, Armando Baylon, BCI, Kewdale. 4 March 2024.

[15] https://www.faac.com/blog/2023/04/20/three-training-tips-to-ensure-ev-bus-success/

[16] https://afdc.energy.gov/vehicles/electric_school_buses.html#p7_m1

[17] https://www.ebusco.com/training-by-ebusco/

[18] https://training.gov.au/Training/Details/TLIC0028

In the case of Western Australia, the companies with larger school bus operations are likely to provide in-house training for drivers. The need and means of driver training for small or one bus operators will need to be assessed on a case-by-case basis.

7.4. Alternative Zero-Emission School Transport

7.4.1. Hydrogen Fuel-Cell Buses

Hydrogen is an alternative fuel for vehicles, offering zero emissions when produced from renewable sources. However, widespread adoption of hydrogen as a transport fuel faces many significant hurdles. Current production methods, like steam methane reforming, emit carbon dioxide, while cleaner alternatives, like electrolysis, require scalability and cost improvements. Establishing a hydrogen infrastructure for distribution also represents a significant challenge.

Energy intensity and efficiency issues arise in hydrogen production, primarily through electrolysis, which is an energy intensive process, impacting on sustainability. Storage and transportation present challenges due to hydrogen's low volumetric energy density, requiring high pressures which raise safety concerns.

Currently, hydrogen fuel costs more than fossil fuels and costs several times more than the equivalent of electricity for electric vehicles. The clean production of hydrogen requires between 2-4 times the energy[19,20] compared to electric drive systems, therefore electric drive systems will always have a better energy and emission balance as well as lower cost than hydrogen fuel-cell systems.

Carbon emissions from fossil fuel-derived hydrogen production undermine its low-carbon potential without carbon capture and storage (CCS) technologies. However, CCS itself faces challenges, including technological feasibility, cost-effectiveness, and environmental concerns. There are debates surrounding the efficacy of CCS in effectively reducing greenhouse gas emissions and its long-term storage safety. Additionally, the scalability of CCS to capture and store emissions from large industrial sources remains a significant challenge. Despite these challenges and debates, CCS technologies are being developed and implemented as part of broader strategies aimed at mitigating carbon emissions and combating climate change.

Hydrogen fuel-cell technology is still developing compared to internal combustion engines and electric vehicles, needing further research to improve efficiency, durability, and cost-effectiveness for competitiveness in the transportation market.

[19] Price Waterhouse Coopers, From CO2 neutral fuels to emission- free driving, online, https://www.pwc.de/de/automobilindustrie/alternative-fuels-powertrains-v2.pdf
[20] Lienkamp, Status-Elektromobilitaet-2018-HL, Technische Universität München, Report March 2018

While hydrogen technology progresses, electric buses powered by renewable energy sources offer a more mature and readily available alternative for immediate implementation in the transportation sector [21] [22] [23] [24]

7.4.2. E-Fuels (Synthetic Fuels)

E-fuels, or electro fuels, are renewable alternatives to traditional fossil fuels, produced using renewable energy sources such as wind, hydro or solar power. They can replace fossil fuels in existing vehicles, aircraft, and ships, thereby reducing carbon emissions.

Producing E-fuels involves capturing carbon dioxide during production to offset emissions. CO_2 is captured from the air or other sources, while renewable electricity is used to produce hydrogen from water via electrolysis. The hydrogen is then combined with the captured CO_2 through synthesis, producing e-fuels, often methanol, which can be used to power engines directly or be further refined. While this process produces close to net-zero GHG emissions, subsequent burning of these e-fuels in a combustion engine generates the same harmful NOx, HC and CO emissions like any other petroleum-based fuel, impacting air quality and population health.

The production process of e-fuels is very energy-intensive, making them even less efficient and more expensive than using hydrogen for fuel-cell vehicles.

Given ample renewable electricity supply, electric buses are the preferred solution for reducing emissions [25] [26] [27]

7.4.3. Biofuels

Biofuels, derived from organic materials such as crops, algae, or waste, can replace fossil fuels in traditional engines, reducing CO_2 emissions if sourced sustainably. However, these biofuels also have drawbacks; large-scale land use change leading to deforestation and habitat destruction, competition with food production, greenhouse gas emissions from production processes, water scarcity concerns, indirect land use changes, limited feedstock availability, energy-intensive production, socioeconomic impacts, soil degradation, and emissions during combustion. Also,

[21] U.S. Department of Energy. (2021). Hydrogen Production: Natural Gas Reforming. https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming
[22] United States Department of Energy. (2019). Hydrogen Storage. https://www.energy.gov/eere/fuelcells/hydrogen-storage
[23] Hydrogen Fuel Cell Vehicles: Opportunities and Challenges https://www.mdpi.com/2071-1050/15/15/11501
[24] Recent development of hydrogen and fuel cell technologies: A review https://www.sciencedirect.com/science/article/pii/S2352484721006053
[25] E-fuels explained: everything you need to know https://www.fleeteurope.com/en/new-energies/europe/features/e-fuels-explained-everything-you-need-know?a=jma06&t%5b0%5d=electrification&t%5b1%5d=hydrogen&t%5b2%5d=emissions&curl=1
[26] The production process of e-fuels https://efuel-today.com/en/production-process-of-e-fuels/
[27] Why cars running on e-fuel can’t replace EVs https://www.theverge.com/2023/3/8/23630413/efuel-car-ev-gas-price-engine-cars

same as for e-fuel, the combustion of biofuels emits harmful NOx, HC, CO and particulate matter emissions, impacting air quality and population health.

Given these drawbacks and assuming abundant renewable electricity, electric buses emerge as a more advantageous alternative [28] [29].

7.4.4. Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG)

While CNG and LPG buses offer some environmental advantages over gasoline and diesel options as they emit less CO_2 and fewer other harmful pollutants, their limitations such as limited infrastructure, high costs, and safety concerns, coupled with their reliance on finite resources with extraction-related environmental impacts, render them a less than ideal solution. Electric buses are emerging as a powerful alternative, boasting zero tailpipe emissions, reduced noise pollution, high efficiency, and potential for renewable energy use, while acknowledging higher upfront costs, battery degradation, and evolving charging infrastructure. CNG and LPG can play a transitional role in specific situations with existing infrastructure and cleaner gas sources, but electric buses are favoured for their long-term sustainability potential [30] [31]. In the past, CNG buses created a number of issues in Perth.

7.4.5. Hybrid Buses and Plug-in Hybrid Electric Vehicles (PHEVs)

Hybrid buses (sometimes called mild hybrids) are combining an internal combustion engine (ICE) with an electric motor and a small battery that cannot be charged from outside sources. Hybrid buses offer only a minor reduction in fuel consumption and CO_2 emissions and cannot take advantage of renewable energy sources.

Plug-in hybrid electric vehicles (PHEV) are combining an ICE with an electric motor and a somewhat larger, but still relatively small battery that can be charged from the outside. However:

- PHEV can drive only relatively short distances using the electricity supplied by their batteries. After that short distance they either have to be plugged in again or rely on their ICEs.
- While manufacturers claim significant fuel reductions, surveys have found that the diesel or petrol consumption savings are around one third of that claimed because divers tend to simply rely on their petrol or diesel engines. Therefore, the GHG savings are not large.
- Very few models of PHEV bus models are available in Australia. and there are likely to be few in the future as bus manufacturers regard PHEV as a transition technology and are now leapfrogging the technology and going straight to battery only buses.
- PHEV tend to have higher purchase costs than ICE, and higher operating costs and higher maintenance costs than EV.

[28] Bioenergy for Sustainable Development
https://www.ieabioenergy.com/wp-content/uploads/2017/01/bioenergy-and-sustainable-development-final-20170215.pdf
[29] Economics of Biofuels
https://www.epa.gov/environmental-economics/economics-biofuels
[30] Study Finds Electric Buses are Cleaner in All Parts of Country
https://www.ucsusa.org/about/news/study-finds-electric-buses-are-cleaner-all-parts-country
[31] Cng Vs. Lpg Vs. Lng Fuel: Understanding The Differences
https://www.uti.edu/blog/diesel/cng-lpg-lng-fuel

In contrast, electric buses present numerous advantages, including zero tailpipe emissions, lower operating costs, and quieter operation. They offer a cleaner, more sustainable alternative for public transportation, with ongoing battery technology advancements enhancing their appeal worldwide [32] .

7.4.6. Carbon Offset Programs

Carbon offsetting involves compensating for carbon emissions by supporting projects that reduce or capture CO_2 elsewhere, such as renewable energy, reforestation, or sustainable agriculture. This strategy benefits areas where transitioning to 100% renewable energy for electric buses is challenging. In regions with limited renewable energy charging infrastructure, carbon offsetting can offset emissions from conventional buses used for long-distance travel, particularly in remote areas like Western Australia.

While valuable, carbon offsetting should not replace direct emission reductions but should be used as a complementary measure during transitional periods or when specific challenges hinder complete emissions reductions. Effective carbon reduction requires a combination of electric bus adoption, renewable energy investment, and sustainable transportation solutions [33].

[32] Real-world performance of battery electric buses and their life-cycle benefits with respect to energy consumption and carbon dioxide emissions
https://www.sciencedirect.com/science/article/pii/S0360544215016837

[33] The pros and cons of carbon offsetting: is it just another form of greenwashing?
https://www.ucem.ac.uk/whats-happening/articles/carbon-offsetting-pros-and-cons/#:~:text=Carbon%20offsets%20may%20be%20cheaper,%2C%20long%2Dterm%20sustainability%20initiatives

8. Case Studies

This chapter looks at several locations and their school bus services in more detail. Current bus operations and routes are outlined and one or more scenarios for replacing diesel buses with electric buses are suggested, including their modes of operation, charging locations, required charging infrastructure and costing estimates.

Assumptions

Several assumptions had to be made for the case studies presented here:

- Bus depot locations and routes are continually changing, some even changed during the writing of this report. However, we assumed that the locations and routes remained as they were based on the 2023 data we were given.
- New e-buses, chargers, and battery buffers are becoming available on the market and their prices are declining rapidly. All cost estimates given are therefore indicative only.
- The standard daily maximum e-bus charging time is assumed to be 14 hours (out of possible 21 hours). This comprises five hours during the day between school runs (9:30 – 14:30) plus nine hours at night (22:00 – 7:00). Charging at these times avoids power usage during the evening peak energy demand period. Depending on the operation scenario, charging may occur at the depot, the school, another location, or even at a mix of locations.
- AC chargers are expected to operate at 100% of their nominal power, while DC chargers are assumed to deliver the continuous equivalent of only 75% of their peak charging rate, due the power reduction during the charging process.
- Bus battery sizes are specified with a 50 kWh reserve at all times (for classes C and 4x4; 40kWh for others), plus an additional 15% on top. This allows a safety range margin when driving, as well as to account for an estimated 10% battery capacity loss over time before a scheduled replacement after around 10 years of service.
- The cost of electricity for e-bus charging by large contestable customers (above 50 MWh per year) assumes a tariff of 19.00 c/kWh incl. GST (17.27 c/kWh ex GST).
- The cost of electricity for non-contestable customer assumes Synergy's flat L1 tariff of 30.7 c/kWh incl. GST (27.90 c/kWh ex GST).
- Non-contestable customers would benefit from significant savings, if Synergy decided to make its 'Midday Saver' tariff available to smaller business customers: 8.2 c/kWh (9:00 – 15:00) and 22.6 c/kWh (21:00 – 9:00), [avoiding 15:00 – 21:00 at 51.25 c/kWh], all incl. GST.
- Diesel prices were assumed to be constant over the 17 year bus contract period at $1.86 per litre ex GST. This is a conservative simplification, as the instability of diesel fuel prices is in stark contrast to the relatively stable cost of electricity.
- AdBlue consumption was assumed to be 5% of diesel consumption. AdBlue costs were conservatively assumed to be constant at $2.27 per litre ex GST. AdBlue supply risks and associated costs were conservatively excluded.
- We have not considered a possible road tax for EVs. We assumed that school buses will be exempt from this tax. We also expect that there will be a general delay in introducing this tax.
- We have not considered the negative human health costs of diesel exhaust emissions or GHG emissions from each bus type in this chapter.
- We have not considered the costs associated with GHG emissions from diesel or electric buses, or a GHG emission price or carbon tax.
- It was assumed that the risks associated with investing in an electric school bus will be factored into the contractual arrangements with the PTA, as will the higher purchase price of an e-bus relative to that of a diesel bus. When technology has matured, the lifetime costs of e-buses and diesel buses are very similar.

- Standard e-bus configurations include relatively large bus batteries, which add significantly to e-bus purchase cost but are not required for most bus routes in WA. Using smaller batteries reduces the cost of e-buses.
- Charging graphs for e-buses are estimates and are indicative of meeting basic school operational needs only. Additional e-bus trips (charter operation) will be possible at most sites if buses with larger batteries are purchased and/or higher-powered chargers are installed. To investigate those opportunities further, the additional trip distances and any available outside charging opportunities would need to be considered.

Scenarios

For each bus depot in each case study we consider one or more suitable operation scenarios. If the daily distances are relatively low, then charging once per day (at depot, school, or elsewhere) will be sufficient. However, for longer daily trips, charging the bus twice (during the day and again overnight) will be required to keep the e-bus's battery size within a reasonable range, and to be within site electricity capacity available without an upgrade. In the list below, issues for each scenario are marked as either positive or negative (+, –):

a. Return to depot during day; Overnight at depot; Charging at depot
+ "business as usual" – no change of current operations.

b. Stay at school during day; Overnight at depot; Charging at depot
+ reduced running cost – can be up to half the cost if the depot is far from the school
+ reduced e-bus purchase cost – as a smaller battery will be sufficient
– bus driver needs alternative mode of transport to return to depot.

c. Stay at school during day; Overnight at depot; Charging at school and depot
+ reduced running cost (as above)
+ reduced e-bus purchase cost (as above)
+ EV chargers can be used by general public after hours / weekends / school holidays
– bus driver needs alternative mode of transport to return to depot
– additional cost for charging stations at school (DC) as well as at depot (AC or DC).

d. Stay at school during day; Overnight at school; Charging at school
+ reduced running cost
+ no infrastructure to be installed at depot; easy change of depot / operator / contract
+ EV chargers can be used by general public after hours / weekends / school holidays
– requires sufficient secure parking space.

e. Return to depot *or* stay at school during day; Overnight at depot; Charging at school
+ almost "business as usual" (if return to depot), requires 1-2 hours charging at school,
+ reduced running and purchase cost (if bus stays between school runs)
+ no infrastructure to be installed at depot; easy change of depot / operator / contract
+ school EV chargers can be used by general public on weekends and school holidays
+ stationary batteries can provide support for school operation during power outages
– stationary batteries are required for charging at substantial cost (doubling battery cost).

Power

For each charging location (bus depot or school), we used the available power level where that data was provided by Western Power or Horizon Power. For sites where that information was not made available, we had to estimate the available power connection, knowing that each site in WA is at least guaranteed a 63 A single-phase connection, which equates to 15 kW. For charging sites with insufficient grid capacity, we proposed solutions[1] with combinations of stationary battery, local solar PV, and matching backup diesel generators which are usually cheaper than a network upgrade. All of the solutions presented here will reduce school bus emissions in WA.

[1] Although we had planned to propose solar PV generation for sites with weak grid connection, not a single site in the case studies required this.

Although we included the purchase and install cost of backup generators, we did not include their running cost, as the times and energy amounts required will greatly vary and are rather unpredictable.

Costing

All cost estimates for e-buses, charging and their comparison to diesel buses are indicative only and ex GST. With e-bus purchase prices predicted to fall, we expect that within about five years an electric bus service will be lower total cost than a diesel equivalent bus for most routes. Furthermore, we have conservatively assumed no major diesel engine overhaul within the diesel bus lifetime.

Similarly, we assume that all major e-bus components will last for the proposed lifespan of 17 years, except for the batteries, for which we allowed for one full replacement after 10 years of operation. It is expected that battery cost continues to fall, but the exact costs almost a decade into the future cannot be predicted accurately. We also make no predictions of the e-bus residual values at the end of their 17-year operation. Please note that these buses would have replacement batteries with at least 3 more years of acceptable capacity at that time, so they will be able to continue to operate.

1. E-buses versus diesel bus prices are shown below, also shown are standard battery sizes:

- Class A: $201,000 with 175 kWh battery versus diesel bus $145,000
- Class B: $540,000 with 306 kWh battery versus diesel bus $388,000
- Class C: $575,000 with 422 kWh battery versus diesel bus $422,000
- Class D: $115,000 with 105 kWh battery versus diesel bus $ 84,000
- Offroad: $490,000 with 200 kWh battery versus diesel bus $374,000

The standard battery sizes are much larger than what our analysis shows is needed, therefore we have discounted the bus prices to match the minimum required battery size at a rate of $300 per kWh. The calculation also includes a full battery replacement after 10 years of service estimated at the cheaper future battery price of $200 per kWh.

The minimum battery size for each bus was calculated based on its daily driving distance and available charging setup. We set a battery reserve of 50 kWh at all times for class C buses and 40 kWh for smaller buses. On top of this we added 15% to the battery size, which splits into 10% to allow for battery degradation over the years (as guaranteed by manufacturers) and 5% for extreme conditions (load, heat, cold, wind).

The given bus battery sizes are the minimum required to operate the given school routes and are based on twice daily charging. When deciding on the purchase of an actual e-bus model, PTA and bus operators need to consider additional factors when selecting its battery size, such as:

- Availability of different battery sizes for a given bus model,
- Ability to conduct additional charter trips in addition to daily school routes,
- Choose identical battery sizes when operating multiple buses, so they can swap routes,
- Choose larger bus batteries to cover both daily trips on a single charge, especially in regions with frequent power outages.

2. Charger and installation prices are estimated as follows.

- AC 22 kW or less: $ 1,000 install $ 1,000
- DC 25 kW: $15,000 install $ 2,000
- DC 50 kW: $40,000 install $ 10,000
- DC 75 kW $50,000 install $ 10,000
- DC 100 kW $70,000 install $ 10,000
- DC 150 kW $90,000 install $ 10,000
- Chargers are assumed to have two outlets per charger as a standard; the cost of additional DC outlets is estimated to be $10,000 each.

Larger systems and systems with more than two outlets or with battery buffer are priced as quoted by suppliers. Charger installation costs are highly site-specific. Prices listed above are therefore indicative only.

3. Local **renewable generation**[2] through solar PV installations are estimated at:
- $1,700 per kW-peak

4. Energy versus fuel cost are estimated as follows:
- Electricity unit cost for small consumers (< 50MWh per year): 27.90 c/kWh ex GST
- Electricity unit cost for large contestable consumers (>50MWh/yr): 17.27 c/kWh ex GST
- Diesel cost: $1.86 per litre ex GST
- AdBlue cost (at 5%) $2.27 per litre ex GST

5. Maintenance / Annual Service Cost:
Since there is no long-term data available on maintenance cost for e-buses, we only added the assumed additional engine-related maintenance cost (ex GST) for diesel buses as:
- $3,000 for class C
- $2,500 for class B
- $2,000 for class A
- $1,500 for class D
- $2,000 for class 4x4

6. Charging losses and battery capacities are assumed as follows:
- Energy losses during charging are estimated at 10%.
- Continuous power delivery of a DC station is assumed to be 75% of its rated peak power level.

Explanation of bus charging diagrams
For each of the buses in the following case studies, we have added a charging diagram, using our e-bus planning tool described in Section 5.2. For any given bus class and daily driving distance, this tool helps users understand the relationships between driving distance, bus battery size, and grid connection power. These graphs are indicative and allow variation of several parameters to achieve a desired reliable service, e.g.:
- Minimise grid connection to comply with any grid restrictions
(may result in longer charging times and larger e-bus battery)
- Minimise e-bus battery to reduce CapEx expenditure
(may result in a larger grid connection and larger e-bus battery)
- Minimise charging hours to maximize use of renewables and avoid peak demand times
(may result in larger grid connection and larger e-bus battery)

Figure 8-1 shows a typical e-bus diagram. We see the 24 hours of a day along the x-axis and the e-bus battery charging level in kWh along the y-axis. During the darker blue hours, the bus is charging (energy curve increasing). Lighter blue hours are additional available charging times that are not needed as the bus battery is sufficiently charged. White hours indicate restricted non-charging times, e.g. to avoid e-bus charging during peak electricity demand times (energy curve linear). Finally, the red hours are where the bus is driving its twice-daily route in the morning and afternoon (energy curve decreasing).

[2] Not a single site in the case studies required this.

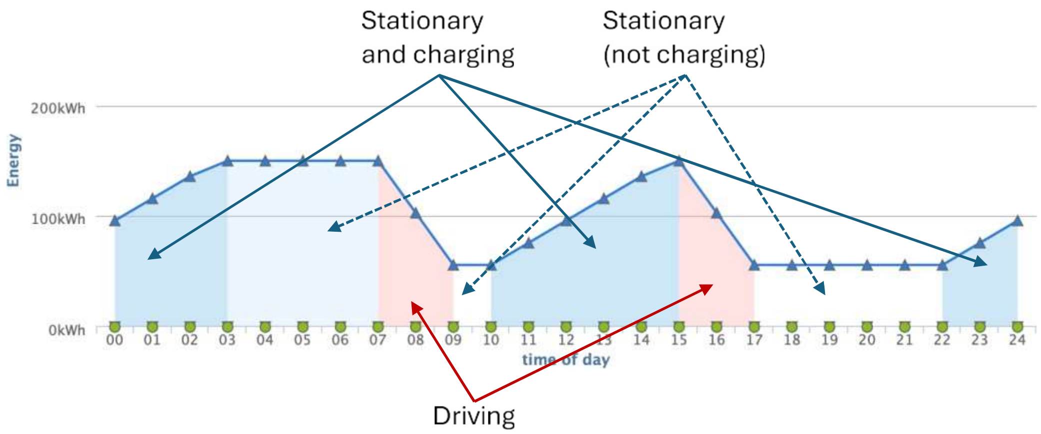


Figure 8-1 E-bus planning diagrams

As discussed earlier, there is not just a single optimal solution but several flexible solutions depending on what grid connection strength is available at which site, the size the e-bus battery, and the charging preferences. The figure below shows several viable solutions for the same e-bus route of 150 km daily for a C Class e-bus for grid connections between 10 kW and 75 kW.

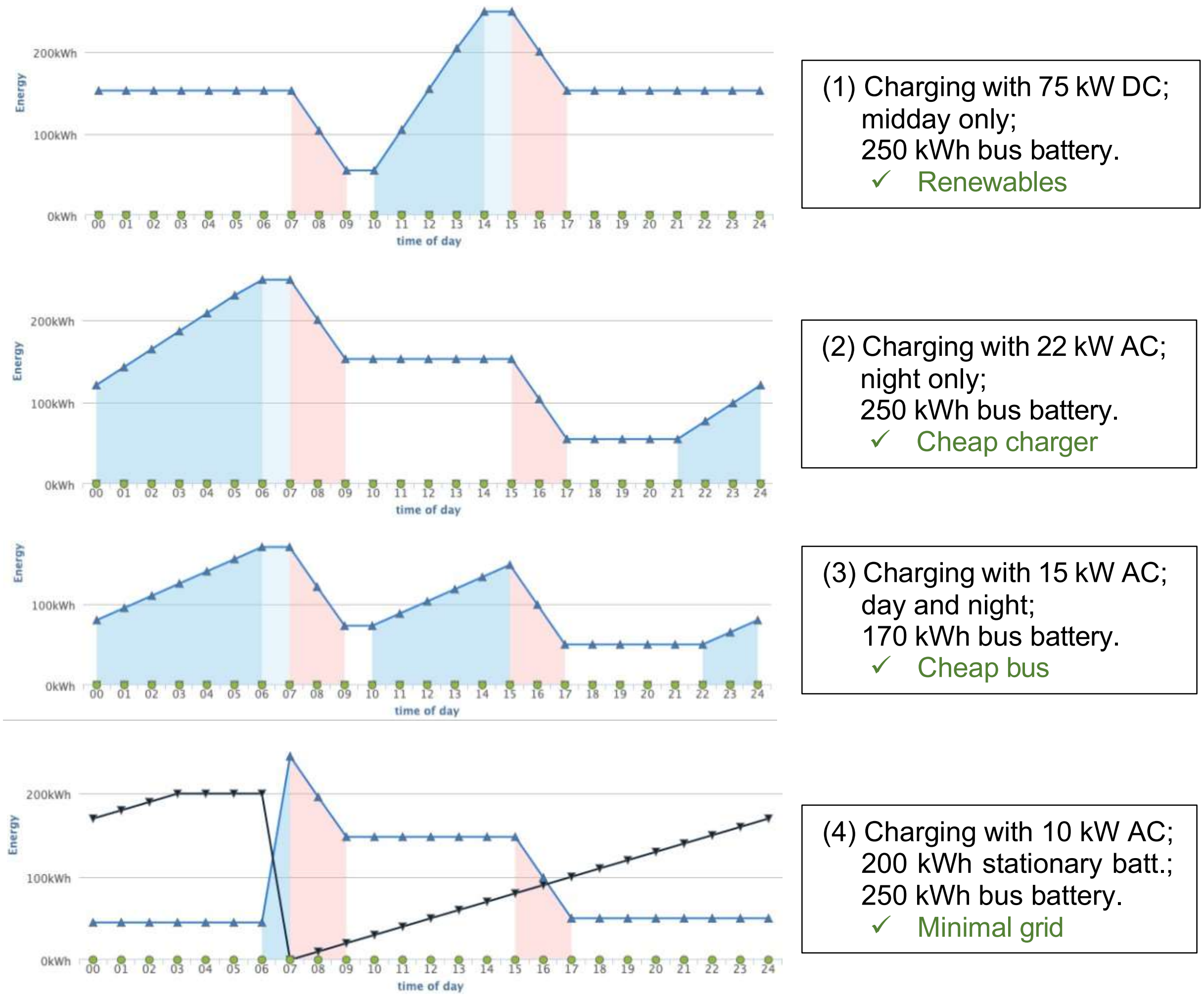


Figure 8-2 Different charging solutions for a C Class e-bus driving 150 km daily

8.1. Denmark

Denmark is a coastal town on the Wilson Inlet in the Great Southern of WA located 423 km south-southeast of Perth. The population of less than 5,000 often swells during tourism seasons to more than double that figure. The town is located on major roads with limited public transport. The town has long had a reputation of being progressive in terms of climate action and sustainability. The supportive Shire has a long history of fostering a culture of innovative solutions to reduce emissions, improve energy efficiency, and promote the adoption of clean technology. The town has a grid-connected community-owned wind farm and numerous sustainability initiatives have been implemented.

The four educational institutions within Denmark in the official bus timetables include Denmark Primary School, Kwoorabup Nature School, Golden Hill Steiner School, and Denmark Senior High School / Denmark campus of Great Southern TAFE. Other educational institutions in the region for which students living in Denmark are provided with school bus services include schools closer to and within Albany (Woodbury Boston Primary School, Lockyer Primary School, Bethel Christian School, St Joseph's College, Albany Senior High School, North Albany Senior High School, Great Southern Grammar, and Great Southern TAFE in Albany.) This analysis includes all 12 buses that are used to transport students from Denmark to schools in the region.

Figure 8-3 Denmark Primary School (left) and Denmark Senior High School (right)

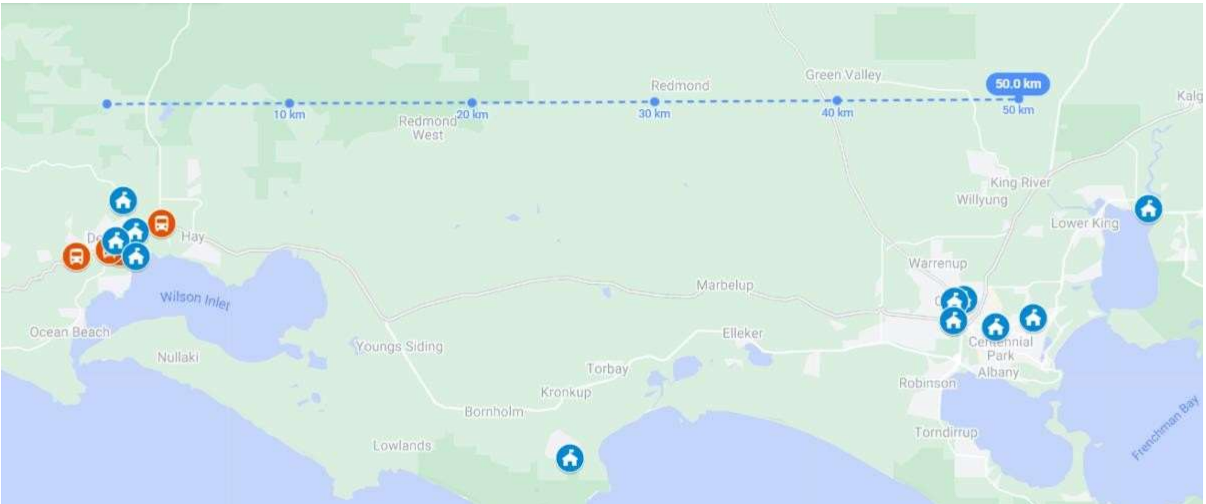
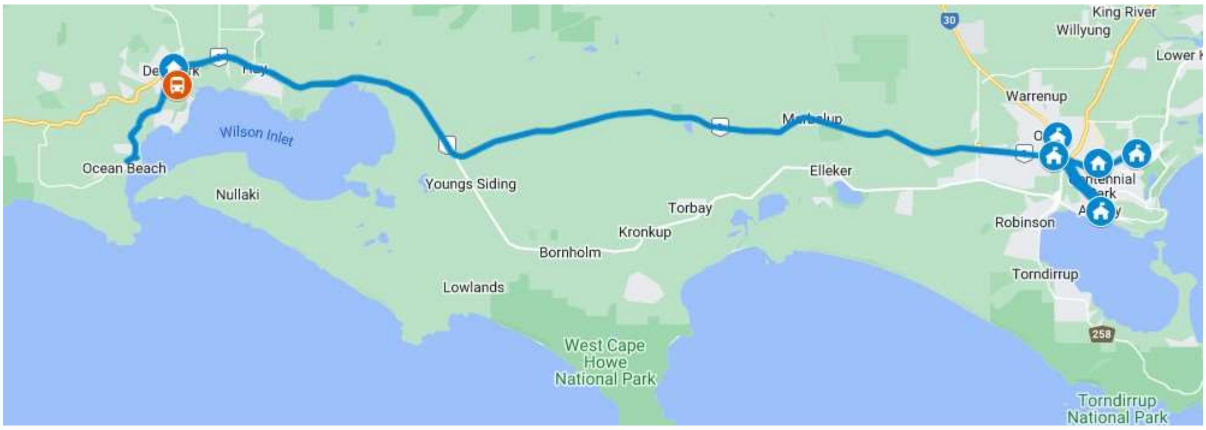


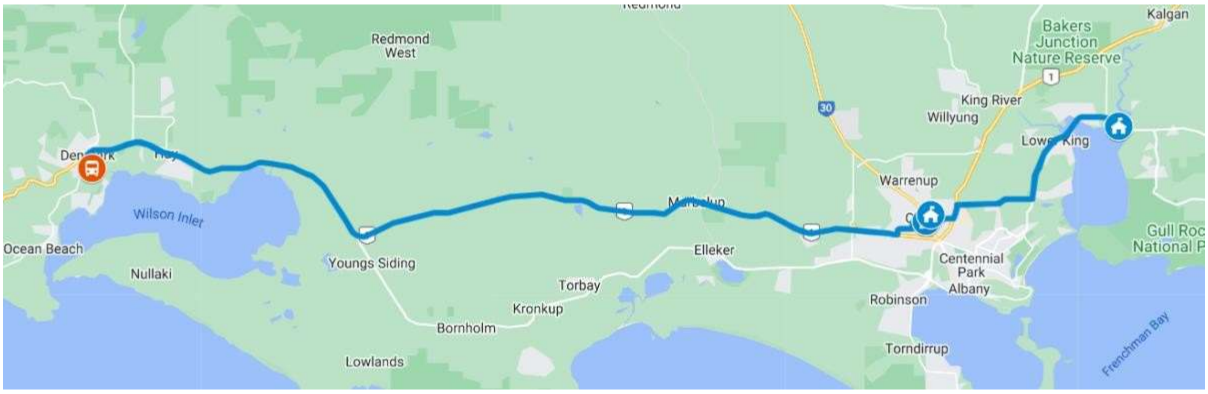
Figure 8-4 Overview of schools serviced for Denmark students (blue) and corresponding bus depots (red)

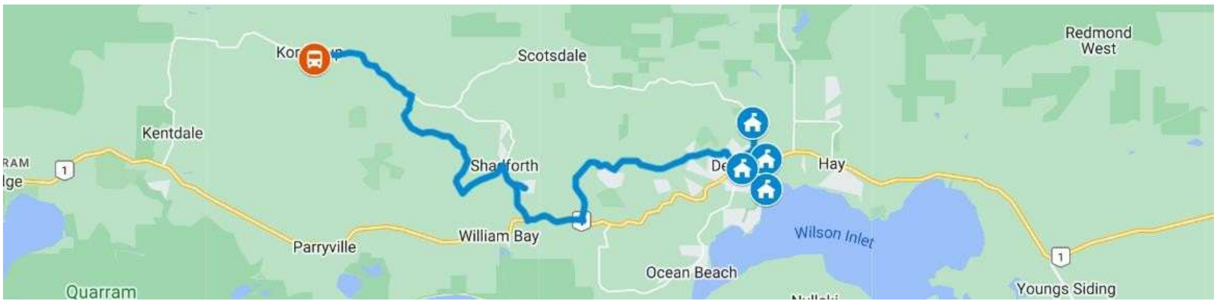
Denmark is currently served by twelve school buses that are housed in five different depots and serve ten different schools/TAFEs. Their individual routes are shown in the following sections, grouped by school-bus depots.

8.1.1. Denmark – Industrial Road

Five buses are housed in this depot. Their routes are shown in the following diagrams, while site details are shown in the table below.







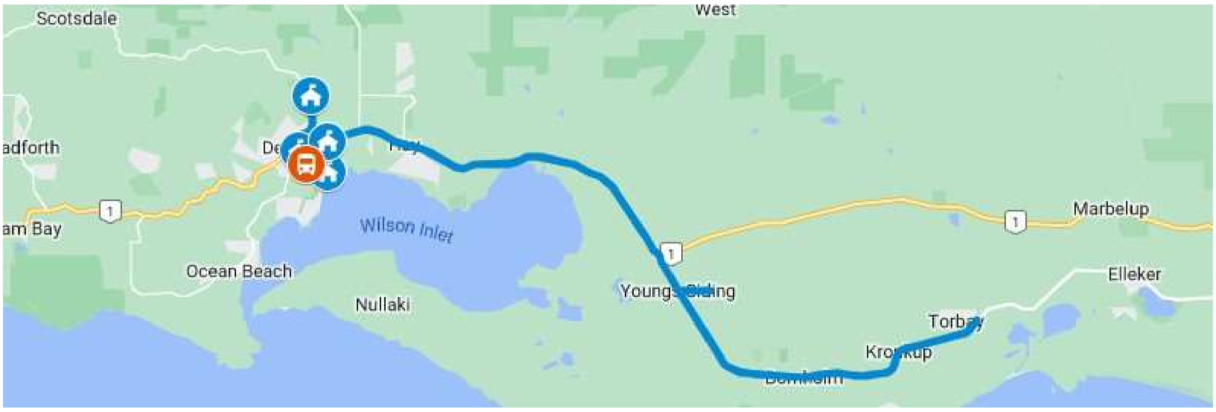


Figure 8-5 Denmark schools bus routes Albany Denmark #1, Albany High Denmark Express, Carmarthen Shadforth, Denmark Hazelvale, and Denmark Northeast

Table 8-1: Industrial Road Depot

SITE DETAILS	
School Bus Garaging Location	**9 Industrial Rd**
Location (Town)	Denmark WA 6333
School Bus Services	Albany Denmark #1, Albany High Denmark Express, Carmarthen Shadforth, Denmark Hazelvale, Denmark Northeast
Number of buses at site	5

SCHOOL BUS DETAILS	
Bus Classes	C, C, C, C, B
Current bus make/model	2015 Hino, RN8JSMA, 2015 Hino RN8JSMA, 2009 Hino, 2010 Hino RN8J, 2020 Hino
Bus Age [years]	9, 9, 15, 14, 4
School(s) serviced	Bethel Christ School Albany, Demark PS Denmark SHS, Great Southern Gram Sch, Mount Lockyer PS, North Albany SHS, St Joseph's College – Albany, Steiner - Golden Hill Sch, TAFE Gt Southern - Albany

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	265, 274, 145, 303, 213
Daily driving bus energy [kWh]	344, 356, 188, 394, 235
Daily charging energy [kWh]	382, 395, 209, 438, 261
Charging requirements (14h) [kW]	27, 28, 15, 31, 19

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	100
Total daily energy per depot [kWh]	1686
Charging requirements (MWh/year)	337
Power available at depot [kW]	100
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification Scenarios

Scenario 1: Business as Usual

Buses stay in their current depot overnight and return to their depot during school hours.

Advantage: *No change of bus operations*

Disadvantage: *Unnecessary high driving distances through empty drives; high energy cost*

Recommended E-Buses (incl. 15% battery margin):

4 x C Class e-buses with battery sizes of 280 kWh, 290 kWh, 180 kWh, 340 kWh
1 x B Class e-bus with a battery size of 210 kWh

Recommended Charging:

2 x 100 kW DC chargers with 2 outlets each,
1 x 22 kW AC charger with 1 outlet.
However, this charging scenario will not be possible without a grid upgrade or the addition of renewable energy.

Instead, it would be possible use:
2 x 50 kW DC chargers,
1 x 22 kW AC charger,
using extended charging hours and in combination with a charging management / load management system to ensure that all e-buses can be charged and the total power draw stays below the max. 100 kW for this depot.

Cost:		**Electric**	**Diesel**
	Buses:	$2,601,800	$2,076,000
	Chargers:	$ 182,000	–
	Battery repl.	$ 260,000	–
	Energy/Fuel	$ 52,400 annually	$ 154,600 annually
	Addl. mainten.	–	$ 14,500 annually
Lifetime:	NPC 17 years	-$3,442,000	-$3,636,000
	Difference	+$ 194,000 (E-bus is lower)	

Note: Instead of this scenario, we recommend implementing *Scenario 2*, as shown below.

Scenario 2: Avoiding empty drives & Charging at Schools – Recommended Scenario

Routes Carmarthen Shadforth and Denmark Northeast conduct their routes as usual, returning to their depot.
Routes Albany Denmark #1, Albany High Denmark Express, and Denmark Hazelvale (buses 1, 2 and 4) will not return after the school run, but stay at one of the schools in Albany during the day and only return to Denmark after school. This will reduce their daily distance by about 106 km.

The daily bus distances will therefore be reduced from:
from old [km]: 265, 274, 145, 303, 213;
to new [km]: 159, 168, 145, 197, 213.

Those 3 buses will use DC chargers at the schools, which can also be used by the community outside of bus charging times, plus a cheaper AC charger at the depot.

Advantage: *Reducing distances, bus battery size and charging cost*
Disadvantage: *Alternative method of transport required for bus drivers to return to Denmark and later in the afternoon back to Albany*

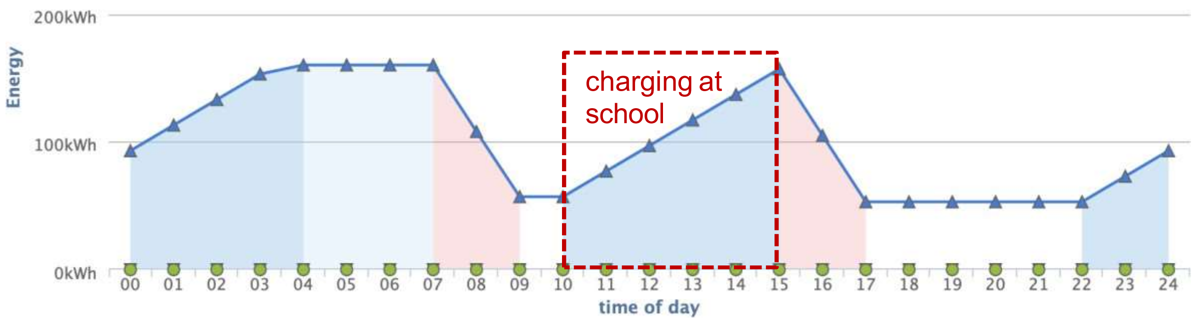
Recommended E-Buses (incl. 15% battery margin):
4 x C Class e-buses with min. battery sizes 190 kWh, 190 kWh, 180 kWh, 220 kWh,
1 x B Class e-bus with min. battery size 210 kWh.
Because of the reduced distances, bus batteries with relatively small capacities are sufficient.

Recommended Charging:
5 x 22 kW AC charger, one for each bus for depot charging
3 x 22 kW AC at North Albany SHS, St Joseph's College, TAFE Great Southern.
Or alternatively at these three schools:
1 x 22 kW AC plus
1 x dual output 50 kW DC.
The power levels at the depot and the schools are sufficient to charge all e-buses.

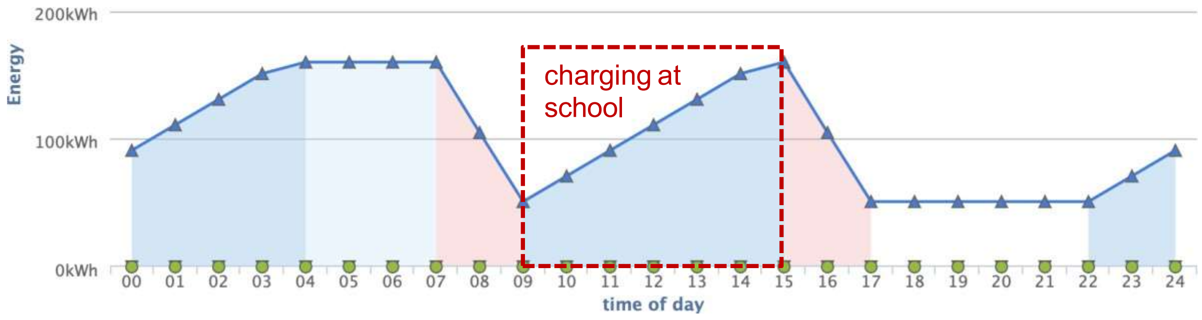
Cost: Annual OPEX are reduced by almost 40%; lower battery replacement cost; slightly higher cost for charging infrastructure; community benefit from school chargers. E-bus purchase prices would be significantly lower than listed, as much smaller battery sizes are required that standard.

		Electric	Diesel	
	Buses:	$2,538,800	$2,076,000	
	Chargers:	$ 16,000	–	
	Battery repl.	$ 198,000	–	
	Energy/Fuel	$ 31,900 annually	$ 112,200 annually	
	Addl. mainten.	–	$ 14,500 annually	
Lifetime:	NPC 17 years	-$2,960,000	-$3,244,000	*Both cheaper than Scen. 1.*
	Difference	+$ 284,000 (E-bus is lower)		

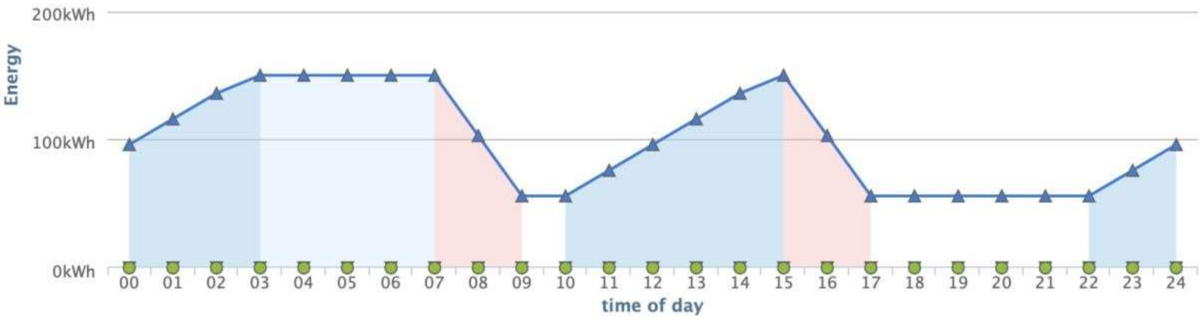
Bus 1 (C, 159 km, min. 160 kWh battery) stays at school over midday;
charged at **school** (dashed box) and depot with 20 kW AC.



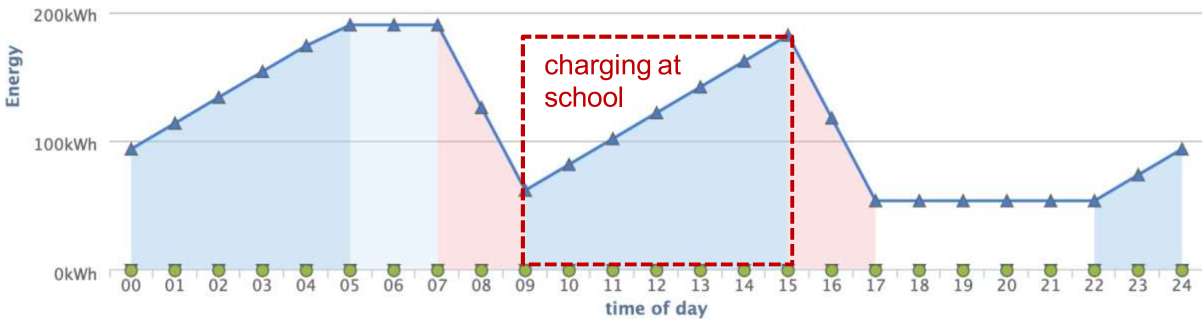
Bus 2 (C, 168 km; min. 160 kWh battery) stays at school over midday; charged at **school** (dashed box) and depot with 20 kW AC.



Bus 3 (C, 145 km; min. 150 kWh battery) drives back to depot after school run; charged only at depot with 20 kW AC (less time for midday charging).



Bus 4 (C, 197 km; min. 190 kWh battery) stays at school over midday; charged at **school** (dashed box) and depot with 20 kW AC.



Bus 5 (B, 213 km; min. 180 kWh battery) drives back to depot after school run; charges only at depot with 20 kW AC (less time for midday charging).

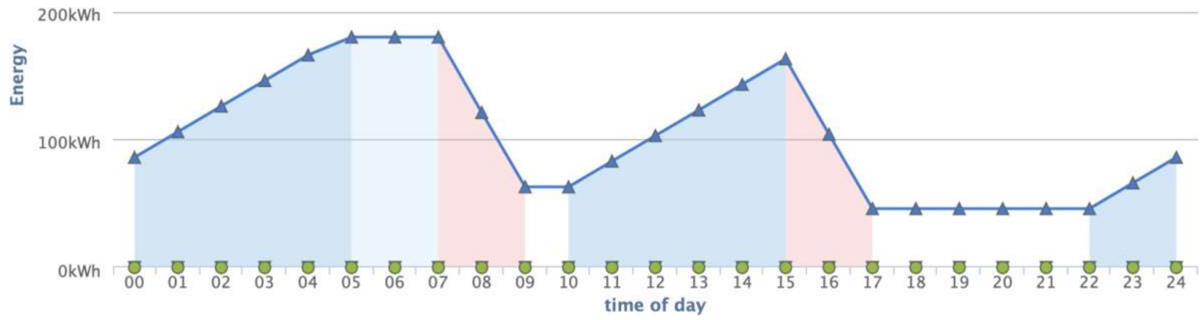


Figure 8-6 Denmark, Industrial Road bus charging schedules

8.1.2. Denmark – Scotsdale South Coast Highway

Four buses have short-term leases from a private transport company at this location. Bus routes are shown in the following diagrams, while site details are shown in the table underneath.

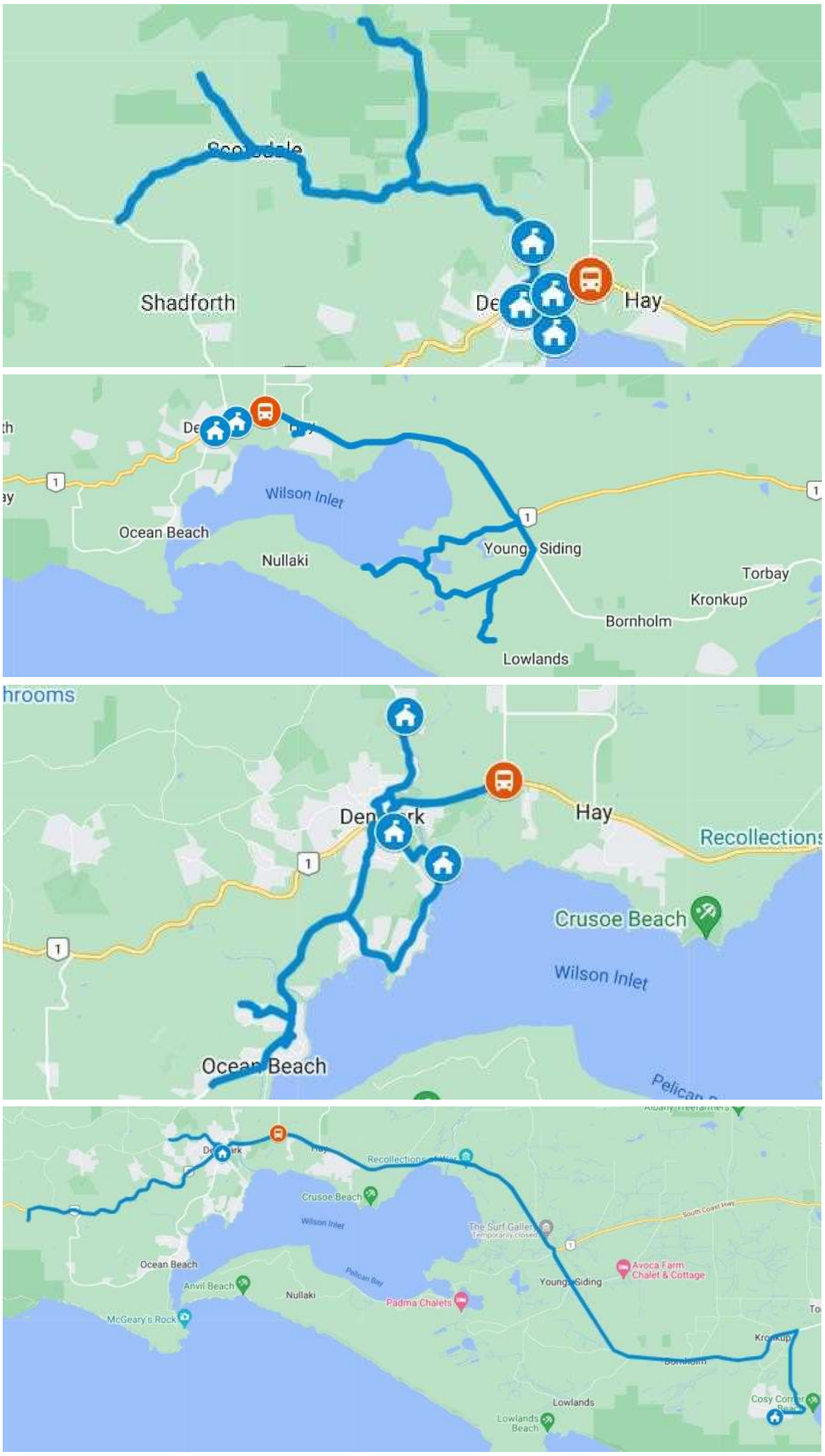


Figure 8-7 Schools bus routes Denmark Scotsdale, Denmark South East, Denmark William Bay, Woodbury Boston Denmark

Table 8-2: South Coast Hwy Depot

SITE DETAILS	
School Bus Garaging Location	**832 South Coast Hwy**
Location (Town)	SCOTSDALE WA
School Bus Services	Denmark Scotsdale, Denmark South East, Denmark William Bay, Woodbury Boston Denmark
Number of buses at site	4

SCHOOL BUS DETAILS	
Bus Classes	C, C, C, B
Current bus make/model	2010, Volvo B7R 2015, Daewoo BH117L 2015, Daewoo BH117L 2016, Isuzu
Bus Age [years]	14, 9, 9, 8
School(s) serviced	Kwoorabup Nature Sch, Denmark PS, Steiner - Golden Hill Sch, Spirit of Play Comm Sch, Denmark SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	135, 145, 78, 186
Daily driving bus energy [kWh]	175, 188, 101, 205
Daily charging energy [kWh]	195, 209, 112, 228
Charging requirements (14h) [kW]	14, 15, 8, 16

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	53
Total daily energy per depot [kWh]	744
Charging requirements (MWh/year)	149
Power available at depot [kW]	100
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: **Business as Usual**
Buses return to their depot after each school run.
Advantage: *No change of bus operations*
Disadvantage: –

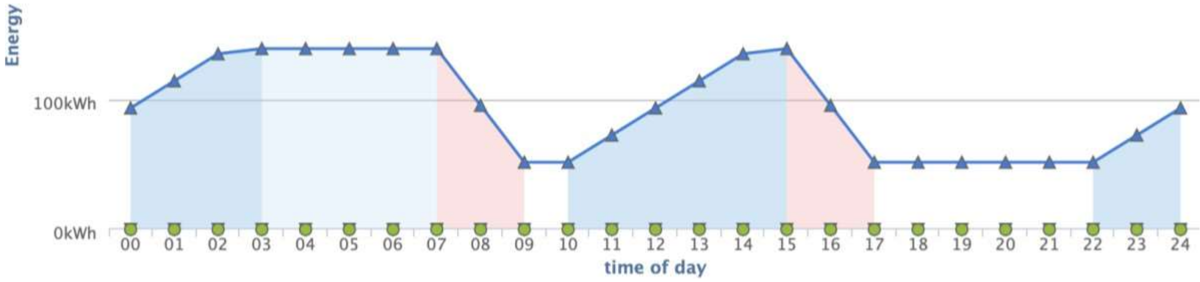
Recommended E-Buses (incl. 15% battery margin):
3 x C Class e-buses with minimum battery sizes of 160 kWh, 180 kWh, 120 kWh,,
1 x B Class e-bus with minimum battery sizes of 180 kWh.

Recommended Charging:

4 x 22 kW AC chargers.
The power level at the depot is sufficient to charge all e-buses directly.

Cost:		**Electric**	**Diesel**
	Buses:	$1,985,400	$1,654,000
	Chargers:	$ 8,000	–
	Battery repl.	$ 128,000	–
	Energy/Fuel:	$23,100 annually	$ 67,900 annually
	Addl. mainten.	–	$ 11,500 annually
Lifetime:	NPC 17 years	-$2,278,000	-$2,386,000
	Difference	+$ 108,000 (E-bus is lower)	

Bus 1 (C, 135 km; min. 140 kWh battery) charges at depot with 22 kW AC.



Bus 2 (C, 145 km; min. 150 kWh battery) charges at depot with 22 kW AC.

Bus 3 (C, 78 km; min. 100 kWh battery) charges at depot with 22 kW AC.

Bus 4 (B, 186 km; 150 kWh) charges at depot with 22 kW AC.

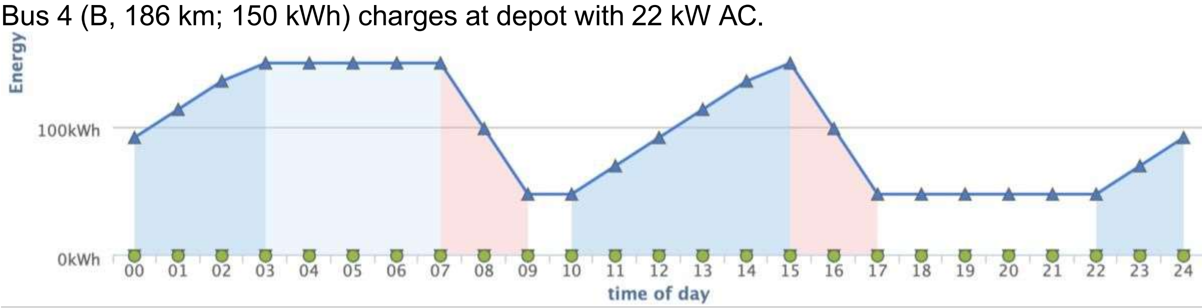


Figure 8-8 Denmark, Scotsdale bus charging schedules

8.1.3. Denmark – Shadforth Cussons Road

Two buses are housed in this depot. Their route is shown in the following diagrams, while site details are shown in the table underneath.

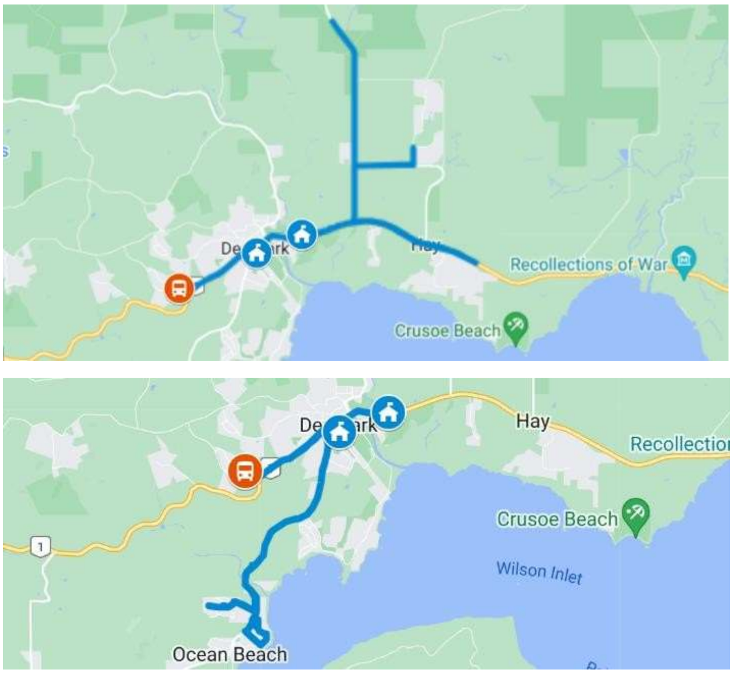


Figure 8-9 Denmark, Shadforth schools bus route Denmark Hay and Denmark Ocean Beach #2

Table 8-3: Cussons Road Depot

SITE DETAILS	
School Bus Garaging Location	**42 Cussons Rd**
Location (Town)	SHADFORTH WA
School Bus Services	Denmark Hay, Denmark Ocean Beach #2
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	C, C
Current bus make/model	Hino, BCI Classmaster
Bus Age [years]	2013, 2013
School(s) serviced	Denmark PS, Denmark SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	77, 45
Daily driving bus energy [kWh]	100, 59
Daily charging energy [kWh]	111, 65
Charging requirements (14h) [kW]	8, 5

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	13
Total daily energy per depot [kWh]	176
Charging requirements (MWh/year)	35
Power available at depot [kW]	100

Contestable Customer?	No
Current tariff (c/kWh)	28

Electrification recommendation

Scenario: **Business as Usual**

Buses return to their depot after each school run.

Advantage: *No change of bus operations*

Disadvantage: *None*

Recommended E-Buses (incl. 15% battery margin):

2 x C Class e-buses with minimum battery sizes of 120 kWh, 100 kWh

Recommended Charging:

2 x 22 kW AC chargers.

The power level at the depot is sufficient to charge all e-buses directly. As the daily distances are relatively short, a simple AC charger per e-bus will be sufficient.

Optionally:

In order to maximise green energy usage, a single dual-outlet 100 kW DC charger could be installed at either Denmark PS or Denmark SHS for the buses to charge after the morning run or before the afternoon run. Both schools have a sufficient power level. This DC charger could then also be used by the general community and generate additional income to the school or PTA.

Cost:		**Electric**	**Diesel**
	Buses:	$ 962,800	$ 844,000
	Chargers:	$ 4,000	–
	Battery repl.	$ 44,000	–
	Energy/Fuel:	$ 8,800 annually	$ 16,300 annually
	Addl. mainten.	–	$ 6,000 annually

Because of the higher energy tariff (non-contestable customer), the energy cost are significantly higher for this depot. When installing a DC charger that can also be used by the community, the cheaper tariff can be easily achieved.

Lifetime:	NPC 17 years	-$1,073,000	-$1,050,000
	Difference		-$ 23,000 (D-bus is lower)

Bus 1 (C, 77 km; min. 100 kWh battery) charges at depot with 22 kW AC.

Bus 2 (C, 45 km; min. 80 kWh battery) charges at depot with 22 kW AC.

Figure 8-10 Denmark, Shadforth bus charging schedules

8.1.4. Denmark – Ocean Beach Road

One bus is housed in this depot. Its route is shown in the following diagram, while site details are shown in the table underneath.

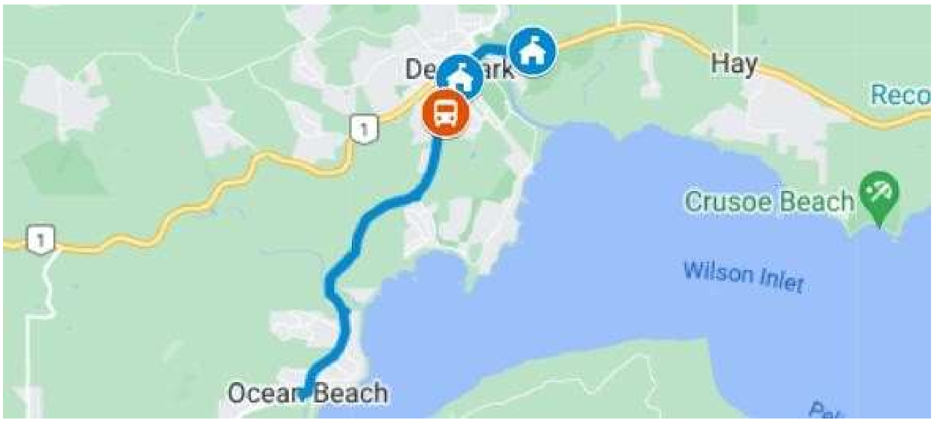


Figure 8-11 Denmark schools bus route Denmark Ocean Beach

Table 8-4: Ocean Beach Road

SITE DETAILS	
School Bus Garaging Location	**DENMARK, Lot 58 Ocean Beach Rd**
Location (Town)	Denmark WA
School Bus Services	Denmark Ocean Beach
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes (A,B, C, D, F, G)	C
Current bus make/model	2008 BCI PK6127
Bus Age [years]	16
School(s) serviced	Denmark PS, Denmark SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	67
Daily driving bus energy [kWh]	87
Daily charging energy [kWh]	96
Charging requirements (14h) [kW]	7

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	7
Total daily energy per depot [kWh]	96
Charging requirements (MWh/year)	19
Power available at depot [kW]	100
Contestable Customer?	No
Current tariff (c/kWh)	28

Electrification recommendation

Scenario: **Business as Usual**
Bus returns to its depot after each school run.
Advantage: *No change of bus operations*
Disadvantage: *None*

Recommended E-Buses (incl. 15% battery margin):
1x C Class e-bus with a minimum battery size of 120 kWh

Recommended Charging:
1 x 22 kW AC charger.
The power level at the depot is sufficient to charge this e-bus directly. As the daily distance is relatively short, a simple AC charger will be sufficient.

Optionally:
In order to maximise green energy usage, this bus could charge at a DC charger, if one was to be installed at either Denmark PS or Denmark SHS.

Cost:

	Electric	Diesel
Buses:	$ 484,400	$ 422,000
Chargers:	$ 2,000	–
Battery repl.	$ 24,000	–
Energy/Fuel:	$ 4,900 annually	$ 8,900 annually
Addl. mainten.	–	$ 3,000 annually

Because of the higher energy tariff (non-contestable customer), the energy cost are significantly higher for this depot. When installing a DC charger that can also be used by the community, the cheaper tariff can be easily achieved.

Lifetime:

	Electric	Diesel
NPC 17 years	-$545,000	-$532,000
Difference		-$ 13,000 (D-bus is lower)

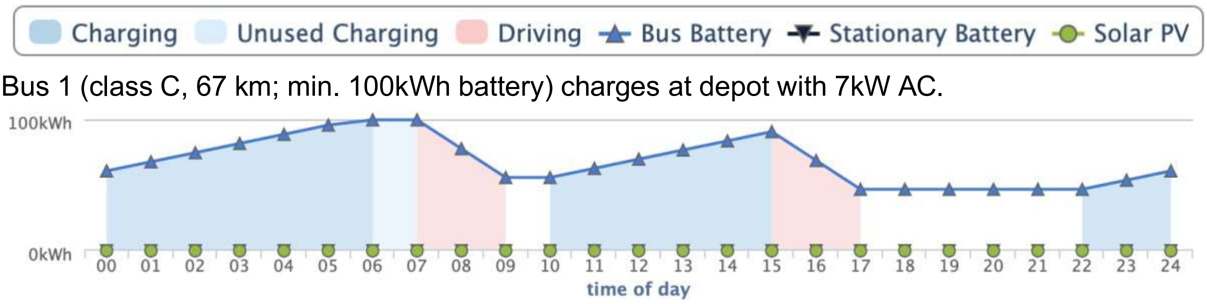


Figure 8-12 Denmark, Ocean Beach bus charging schedules

8.1.5. Denmark Summary and Policymaker Options

Electrification of all buses at all depot sites in Denmark is technically feasible. None of the depot locations and none of the schools will require a grid upgrade.

The PTA / DoT would be able to select an operational scenario from the ones presented, especially determining ***where*** an e-bus should be charged and ***where*** it should stay during the school day. Our recommendations include the opportunity for some school bus routes to include DC charging at school sites. Those DC chargers could be made available to the general public and thereby create additional revenue from energy sales outside of e-bus charging times. This will also reduce the energy tariff for the school buses, as the schools could become contestable customers.

Bus electrification brings opportunities for an “as is” scenario, where the bus returns to the depot after each school run, or alternative scenarios where the bus stays at the school between school runs or even overnight. Leaving the bus at the school during the day has significant advantages for several of the analysed school service routes between Denmark and Albany, as it will cut the daily distances almost in half, thereby significantly reducing running costs as well as the up-front e-bus purchase costs as a smaller batteries will be required. The decision on which operation scenario to adopt is administrative or political in nature – especially since the PTA indirectly covers all CapEx ad OpEx expenditures.

If EV chargers are being located at the school grounds with satellite charging outlets inside as well as outside school grounds, they can serve a dual purpose. School bused can be charged during school days, while the EV chargers will be available to the general public (locals and tourists) on weekends and during school holidays, Given the margin on EV charging electricity between 100% for small customers (30 c/kWh vs 60 c/kWh) up to 400% for large contestable customers (17c/kWh or less) – or even higher when using solar PV with battery buffering – this will add up to a substantial additional income for schools, as well as providing a significant push of e-mobility in rural and remote areas.

If it is logistically not possible to leave the buses at the school grounds between school runs and/or overnight, if would still be possible to adopt the beforementioned dual charging scenario for school buses and for members of the general public at school sites. However, this may require the installation of stationary batteries to match site demand within site limitations. Although this will create substantial additional CapEx, the NPC of the investment may be commercially attractive. It may also help in other circumstances, such as temporarily powering schools during a power outage or emergency.

In summary, leaving the longer distance schools buses operating between Denmark and Albany at the school grounds during class times, will have the following advantages:

- reduce daily route distances by around half in some instances;
- eliminate almost all driving with zero passengers, often empty back to the depot;
- reduce the kms travelled, which would decrease e-bus capital costs as batteries sizes can be reduced;
- schools often have excellent electrical connections already suitable for rapid EV charging;
- schools/large public buildings enable cost-effective installation of PV-battery systems;
- rapid EV chargers at schools can have charge points both off and off-school grounds;
- schools are close to major roads and have good public traffic/parking access;
- owning/operating rapid EV chargers is an attractive commercial investment;
- e-buses do not require charging in peak visitor periods (holidays/weekends), and;
- electricity market mechanisms enable zero emission vehicles instantly at low cost by sourcing clean electricity from accredited renewable energy generation.

8.2. Walpole

A single bus is housed in the Walpole depot. Its route is shown in the following diagram, while site details are shown in the table underneath.

Figure 8-13 Walpole schools bus route Walpole - Denmark

Table 8-5: Miguel Place Depot

SITE DETAILS	
School Bus Garaging Location	**4 Miguel Pl**
Location (Town)	WALPOLE WA
School Bus Services	Walpole North
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	B
Current bus make/model	2008 BCI PK6930
Bus Age [years]	16
School(s) serviced	Denmark PS, Denmark SHS, Steiner - Golden Hill Sch, Walpole PS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	112
Daily driving bus energy [kWh]	123
Daily charging energy [kWh]	137
Charging requirements (14h) [kW]	10

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	10
Total daily energy per depot [kWh]	137
Charging requirements (MWh/year)	27
Power available at depot [kW]	100
Contestable Customer?	No
Tariff	28

Electrification recommendation

Scenario: **Business as Usual**

Bus currently only does a single drive to Denmark, then returns after school finishes.

Advantage: *No change of bus operations*

Disadvantage: *None*

Recommended E-Buses (incl. 15% battery margin):

1x B Class e-bus with a minimum battery size of 130 kWh

Recommended Charging:

1 x 10 kW AC charger.

The power level at the depot is sufficient to charge this e-bus directly. As the daily distance is relatively short, a simple AC charger will be sufficient.

Optionally:

As the bus is already parked for the whole school hours in Denmark, it could maximise renewable energy usage by charging at one of the Denmark schools. This would require a 50 kW (or higher) DC charger to be installed at either Denmark PS or Denmark SHS.

Cost:		**Electric**	**Diesel**
	Buses:	$ 487,200	$ 388,000
	Chargers:	$ 2,000	–
	Battery repl.	$ 26,000	–
	Energy/Fuel:	$ 6,900 annually	$ 12,100 annually
	Addl. mainten.	–	$ 2,500 annually

Because of the higher energy tariff (non-contestable customer), the energy cost are significantly higher for this depot. When installing a DC charger that can also be used by the community, the cheaper tariff can be easily achieved.

Lifetime:	NPC 17 years	-$567,000	-$523,000
	Difference		-$ 44,000 (D-bus is lower)

Bus 1 (class B, 112 km; min. 110 kWh battery) charges at depot with 10 kW AC.

Figure 8-14 Walpole bus charging schedules

8.3. South Hedland

A single bus with its depot close to the schools is providing the service in South Hedland.

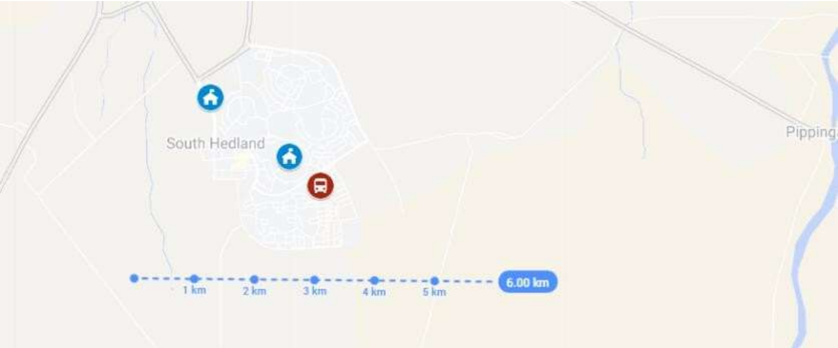


Figure 8-15 South Hedland schools and bus depot

Table 8-6: South Hedland, Egret Cres.

SITE DETAILS	
School Bus Garaging Location	**SOUTH HEDLAND, 11 Egret Cres**
Location (Town)	SOUTH HEDLAND WA
School Bus Services	South Hedland Turner River
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	D
Current bus make/model	2021 Toyota Commuter
Bus Age [years]	3
School(s) serviced	Cassia PS, Hedland SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	121
Daily driving bus energy [kWh]	73
Daily charging energy [kWh]	81
Charging requirements (14h) [kW]	6

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	6
Total daily energy per depot [kWh]	81
Charging requirements (MWh/year)	16
Power available at depot [kW]	15
Current tariff (c/kWh)	28 (Horizon Power)

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1 x D Class e-bus with a minimum battery size of 100 kWh

Recommended Charging:
1 x 8 kW AC charger.
The power level at the depot is sufficient to charge this e-bus directly. As the daily distance is relatively short, a simple AC charger will be sufficient.

Cost:		**Electric**	**Diesel**
	Buses:	$ 113,500	$ 84,000
	Chargers:	$ 2,000	–
	Battery repl.	$ 20,000	–
	Energy/Fuel:	$ 4,100 annually	$ 5,100 annually
	Addl. mainten.	–	$ 1,500 annually
Lifetime:	NPC 17 years	-$164,000	-$145,000
	Difference		-$ 19,000 (D-bus is lower)

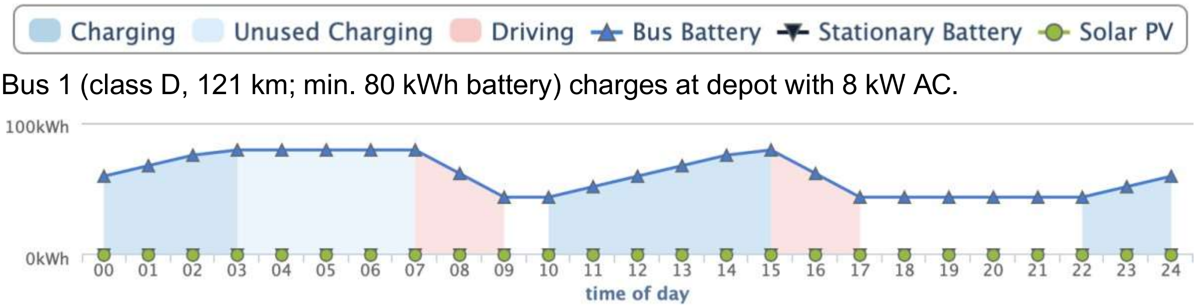


Figure 8-16 South Hedland bus charging schedules

8.4. East Carnarvon

Two buses service three schools close to the depot in the East Carnarvon area.

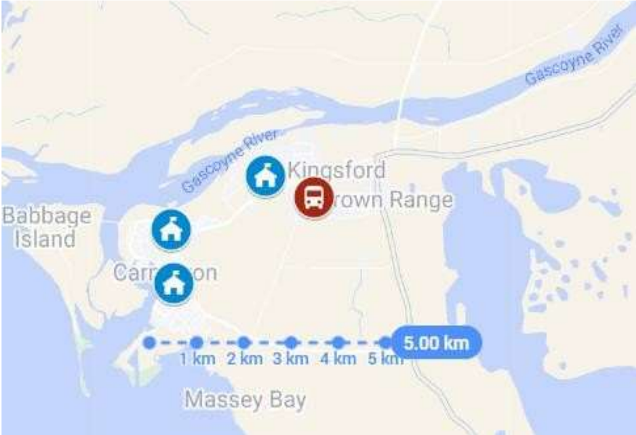


Figure 8-17 East Carnarvon schools and bus depot

Table 8-7: East Carnarvon, Holden St

SITE DETAILS	
School Bus Garaging Location	**EAST CARNARVON, 43 Holden St**
Location (Town)	EAST CARNARVON WA
School Bus Services	Carnarvon River Trip, Carnarvon Yankee Town
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	C, C
Current bus make/model	2016 Mercedes Benz 0500RF, 2009 Mercedes
Bus Age [years]	8, 15
School(s) serviced	Carnarvon Christ Sch, Carnarvon Comm Coll – Marmion, St Mary Star of The Sea Cath Sch

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	86, 80
Daily driving bus energy [kWh]	112, 104
Daily charging energy [kWh]	125, 115
Charging requirements (14h) [kW]	9, 8

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	14
Total daily energy per depot [kWh]	240
Charging requirements (MWh/year)	48
Power available at depot [kW]	15
Current tariff (c/kWh)	28 (Horizon Power)

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

2 x E-buses class C with minimum battery sizes of 150 kWh and 140 kWh

Recommended Charging:

2 x 7 kW AC chargers.

The power level at the depot is sufficient to charge both e-buses directly. However, the two buses have to share the available 15 kW power, which gives them a limited additional range over the midday charging period. This is being compensated by using larger bus batteries in combination with extended overnight charging times. As the daily distances are quite short, 2 x 7 kW AC chargers will be sufficient.

Cost:		**Electric**	**Diesel**
	Buses:	$983,800	$844,000
	Chargers:	$ 4,000	–
	Battery repl.	$ 58,000	–
	Energy/Fuel:	$ 12,000 annually	$ 22,100 annually
	Addl. mainten.	–	$ 6,000 annually
Lifetime:	NPC 17 years	-$1,131,000	-$1,103,000
	Difference		-$ 28,000 (D-bus is lower)

Bus 1 (class C, 86 km; min. 130 kWh battery) charges at depot with 7 kW AC charger.

Bus 2 (class C, 80 km; min. 120 kWh battery) charges at depot with 7 kW AC charger.

Figure 8-18 East Carnarvon bus charging schedules

8.5. Esperance

8.5.1. Esperance – Hill St

A single bus in the Esperance Hill St depot services two school in close proximity.

Figure 8-19 Esperance, Hill St depot and schools

Table 8-8: Esperance, Hill St

SITE DETAILS	
School Bus Garaging Location	**ESPERANCE, 10 Hill St**
Location (Town)	ESPERANCE WA
School Bus Services	Esperance Caitup
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	B
Current bus make/model	2010 Hino FD230
Bus Age [years]	14
School(s) serviced	Esperance PS, Esperance SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	189
Daily driving bus energy [kWh]	208
Daily charging energy [kWh]	231
Charging requirements (14h) [kW]	17

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	15

Total daily energy per depot [kWh]	231
Charging requirements (MWh/year)	46
Power available at depot [kW]	15
Current tariff (c/kWh)	28 (Horizon Power)

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1x B Class e-bus with a minimum battery size of 210 kWh

Recommended Charging:
1 x 15 kW AC charger.
The power level at the depot is sufficient to charge both e-buses directly.
As the daily distance is relatively short, a simple AC charger will be sufficient.

Cost:		**Electric**	**Diesel**
	Buses:	$511,200	$388,000
	Chargers:	$ 2,000	–
	Battery repl.	$ 42,000	–
	Energy/Fuel:	$ 11,600 annually	$ 20,500 annually
	Addl. mainten.	–	$ 2,500 annually
Lifetime:	NPC 17 years	-$644,000	-$600,000
	Difference		-$ 44,000 (D-bus is lower)

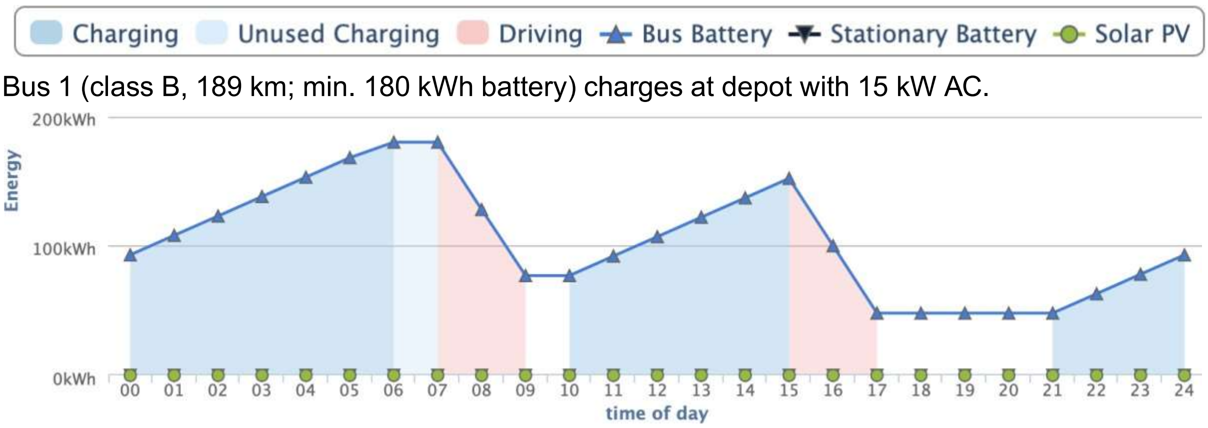


Figure 8-20 Esperance, Hill St bus charging schedule

8.5.2. Esperance – Norseman

Two school buses operate form the Norseman deport in Esperance to service six schools. The depot is in close proximity to all the schools, but both buses have to complete large daily distances.

Figure 8-21 Norseman depot and schools

Table 8-9: Esperance, Norseman Rd

SITE DETAILS	
School Bus Garaging Location	**ESPERANCE, 86 Norseman Rd**
Location (Town)	ESPERANCE WA
School Bus Services	Esperance Cape LeGrande, Esperance Gibson
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	C, C
Current bus make/model	Volvo B7R Daewoo
Bus Age [years]	14, 11
School(s) serviced	Castletown PS. Esperance Anglican Community School Esperance PS Esperance SHS Nulsen PS Our Lady Star of the Sea Cath. PS – Esp.

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	353, 253
Daily driving bus energy [kWh]	458, 329
Daily charging energy [kWh]	509, 366

Charging requirements (14h) [kW]	36, 26

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	72
Total daily energy [kWh]	876
Charging requirements (MWh/year)	175
Power available at depot and schools	15 kW after free upgrade (insufficient) schools unknown, but assuming 2 x 50 kW = 100 kW
Current tariff (c/kWh)	33 (Horizon Power)

Electrification recommendation

Scenario: Business as Usual

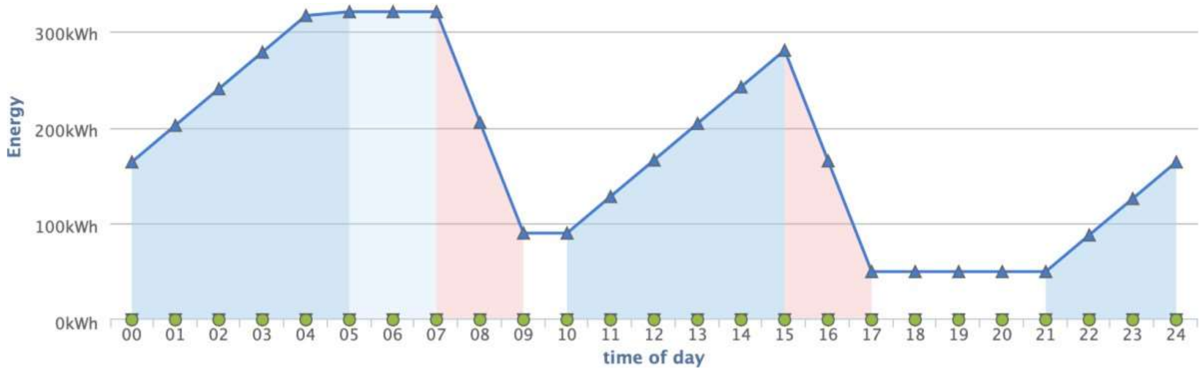
Recommended E-Buses (incl. 15% battery margin):
2 x C Class e-buses minimum battery sizes of 370 kWh and 310 kWh.

Recommended Charging:
1 x 50 kW DC charger,
1 x 22 kW AC charger.
Unfortunately, Horizon Power only provided grid capacity for the Esperance depots, not the schools. As Esperance is a larger town, we assume that there will be the opportunity to install 1 x 50 kW DC and 1 x 22 kW AC chargers at either two of the schools or at another location nearby.

There is a trade-off between a larger bus battery and a faster charger. We opted for larger bus batteries (below the standard size) and minimum required charging equipment. Both buses require extended overnight charging times unless the grid allows installation of faster chargers.

Cost:		**Electric**	**Diesel**
	Buses:	$1,100,800	$ 844,000
	Chargers:	$ 52,000	–
	Battery repl.	$ 136,000	–
	Energy/Fuel:	$ 27,200 annually	$ 80,800 annually
	Addl. mainten.	–	$ 6,000 annually
Lifetime:	NPC 17 years	-$1,480,000	-$1,645,000
	Difference	+$ 165,000 (E-bus is lower)	

Bus 1 (class C, 353 km; min. 320 kWh batt.) charges at 50 kW DC charger (equiv. 38 kW cont.)



Bus 2 (class C, 253 km; min. 270 kWh battery) charges at depot with 22 kW AC.

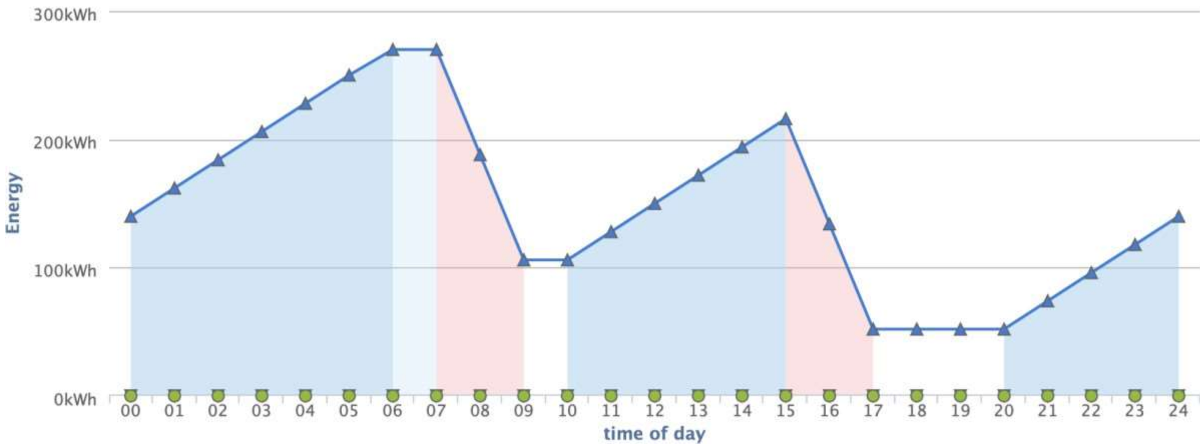


Figure 8-22 Esperance, Norseman bus charging schedules

8.6. Manjimup

8.6.1. Manjimup – Becker St

Manjimup is a regional hub town located approximately 300 km south of Perth with an urban population of around 4,400, and a regional population of around 5,500. Manjimup has two public primary schools, one public high school, and a private Catholic school. Manjimup is a progressive town with a long history of innovation in the agricultural and forestry sectors. The town is within the area supplied by the SWIS and is located on major roads. The two busses at the 39 Becker St depot are C Class busses that carry students to three schools in Manjimup.

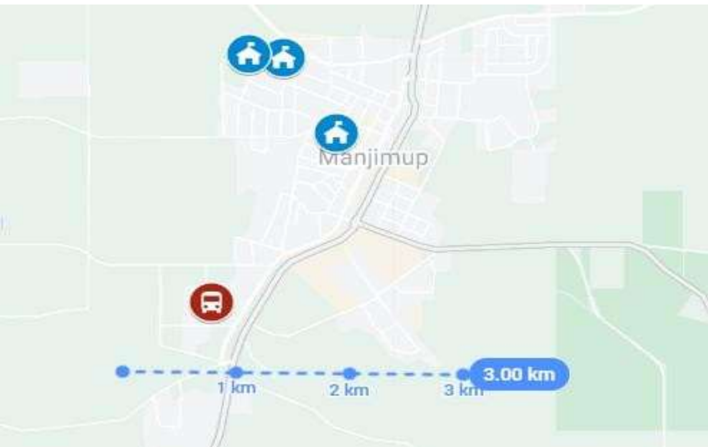


Figure 8-23 Manjimup depot at 39 Becker St, and three schools serviced.

Table 8-10: Manjimup, Becker St

SITE DETAILS	
School Bus Garaging Location	**MANJIMUP, 39 Becker St**
Location (Town)	MANJIMUP WA
School Bus Services	Manjimup Bridgetown #3, Manjimup Bridgetown No.1
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	C, C
Current bus make/model	2015 Hino RN8JSMA, 2015 Hino RN8J
Bus Age [years]	9, 9
School(s) serviced	Kearnan College, Manjimup PS, Manjimup SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	170, 187
Daily driving bus energy [kWh]	221, 243
Daily charging energy [kWh]	246, 270
Charging requirements (14h) [kW]	18,19

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	37
Total daily energy per depot [kWh]	517
Charging requirements (MWh/year)	103
Power available at depot [kW]	50
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

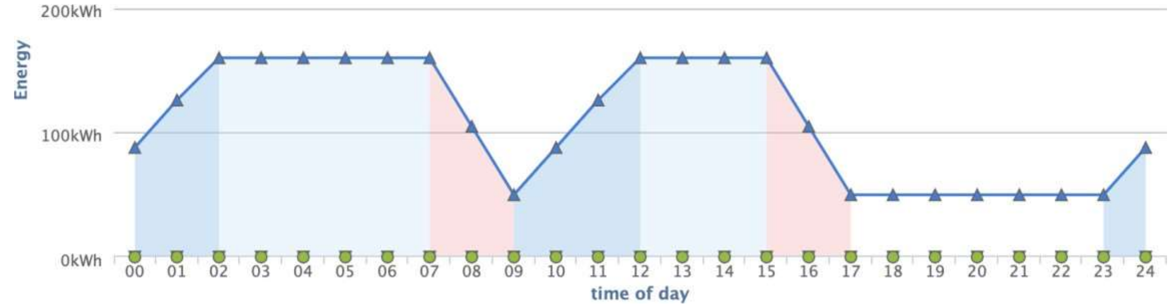
2 x C Class e-buses with minimum battery sizes of 190 kWh and 200 kWh.

Recommended Charging:

1 x 50 kW charger.
The network capacity at the depot is sufficient to install one DC charger with two ports to meet the requirements of the two busses.

Cost:		**Electric**	**Diesel**
	Buses:	$ 1,013,000	$ 844,000
	Chargers:	$ 50,000	–
	Battery repl.	$ 78,000	–
	Energy/Fuel:	$ 16,000 annually	$ 47,600 annually
	Addl. mainten.	–	$ 6,000 annually
Lifetime:	NPC 17 years	-$1,255,000	-$1,338,000
	Difference	+$ 83,000 (E-bus is lower)	

Bus 1 (class C, 170 km; min. 160 kWh battery) **immediate** charging at depot with 50 kW DC.



Bus 2 (class C, 187 km; min. 170 kWh battery) **delayed** charging at depot with 50 kW DC.

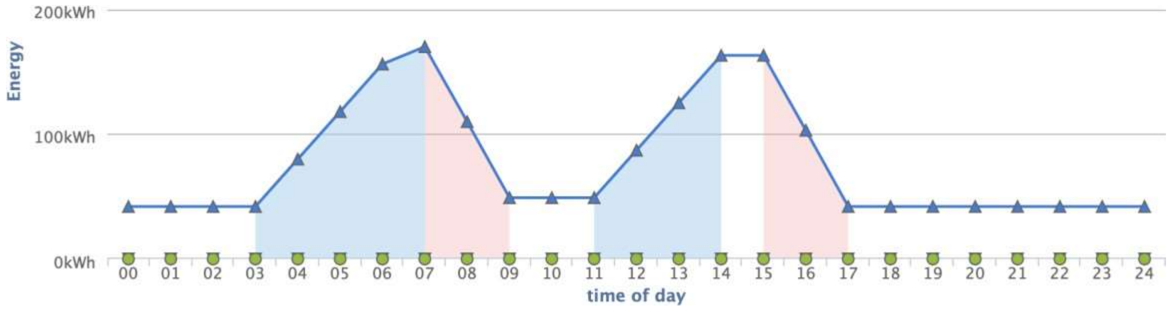


Figure 8-24 Becker St charging schedules

8.6.2. Manjimup – Crouch St

The second depot in Manjimup, located at 16 Crouch Street, has 12 buses (1 x A Class, 6 x B Class, and 5 x C Class) that are used to service four schools. All four schools are within 3 km of each other and the depot.

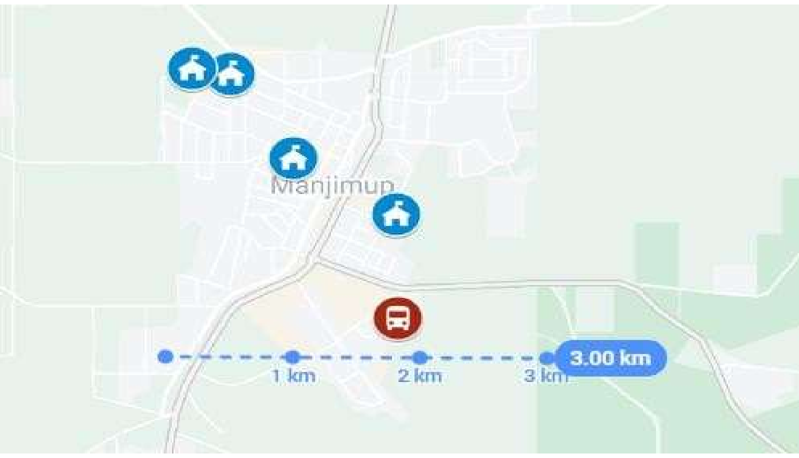


Figure 8-25 Manjimup depot at 16 Crouch St, and four schools serviced.

Table 8-11: Manjimup, Crouch St

SITE DETAILS	
School Bus Garaging Location	**MANJIMUP, 16 Crouch St**
Location (Town)	MANJIMUP WA
School Bus Services	Manjimup Boyup Brook, Manjimup Deanmill Middlesex, Manjimup Donnelly River, Manjimup Glenoran, Manjimup Nyamup Tone River, Manjimup Palgarup, Manjimup Pemberton, Manjimup Perup Road, Manjimup Quinninup Smithsbrook, Manjimup Seven Day Road, Manjimup Upper Warren, Manjimup Yanmah
Number of buses at site	12

SCHOOL BUS DETAILS	
Bus Classes	C, B, B, C, A, B, C, C, C, B, B, B
Current bus make/model	2016 Scania K310, 2010 Hino FD230, 2010 Hino FD230, 2019 Scania, 2012 Mitsubishi Rosa, 2016 Man TGL12250, 2013 Hino RN8J, 2009 Hino RN8J, 2009 Hino RN8J, 2021 Scania, 2020 Denning,

	2006 Hino
Bus Age [years]	8, 14, 14, 5, 12, 8, 11, 15, 15, 3, 4, 18
School(s) serviced	East Manjimup PS Kearnan College Manjimup PS Manjimup SHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	283, 48, 112, 243, 278, 96, 143, 181, 138, 195, 186, 140
Daily driving bus energy [kWh]	368, 52, 123, 315, 195, 106, 186, 235, 179, 215, 204, 154
Daily charging energy [kWh]	409, 58, 136, 351, 216, 118, 207, 261, 199, 239, 227, 171
Charging requirements (14h) [kW]	29, 4, 10, 25, 15, 8, 15, 19, 14, 17, 16, 12

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	185
Total daily energy per depot [kWh]	2592
Charging requirements (MWh/year)	518
Power available at depot [kW]	300
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

5 x C Class e-buses with min battery sizes of 280 kWh, 300 kWh, 170 kWh, 210 kWh, and 170 kWh.

6 x B Class e-buses with minimum battery sizes of 90 kWh, 130 kWh, 120 kWh, 180 kWh, 180 kWh, and 170 kWh.

1 x A Class e-bus with a minimum battery size of 170 kWh.

Recommended Charging:

1 x 50 kW DC charger,

11 x 22 kW AC chargers (or lower).

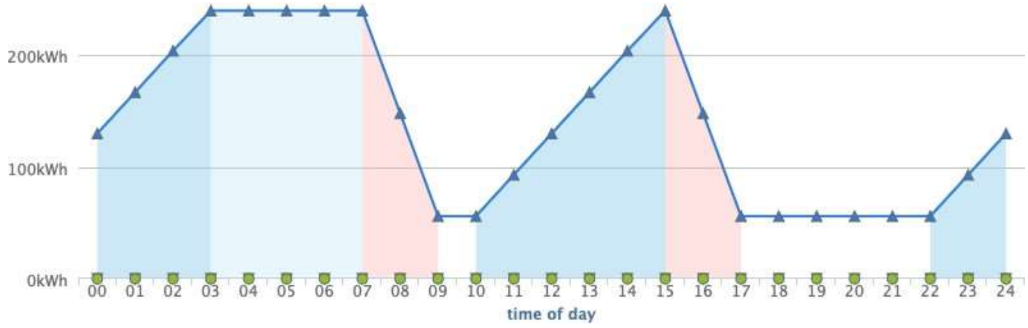
Only a single bus enquires a 50 kW DC charger, the 11 other buses can be charged with AC chargers at power levels between 5 kW – 22 kW.

Alternatively, the site could be equipped with 4 x 75 kW chargers with additional outlets, which gives shorter charging times and greater flexibility for the bus operator. An intelligent charging software will distribute the charging power between all buses.

Cost:		**Electric**	**Diesel**
	Buses:	$ 5,736,700	$ 4,583,000
	Chargers:	$ 72,000	–
	Battery repl.	$ 438,000	–
	Energy/Fuel:	$ 67,300 annually	$ 234,000 annually
	Addl. mainten.	–	$ 32,000 annually
Lifetime:	NPC 17 years	-$6,666,000	-$7,036,000
	Difference	+$ 370,000 (E-bus is lower)	

Note: *E-bus charging times need to be staggered by software (not shown in graphs).*

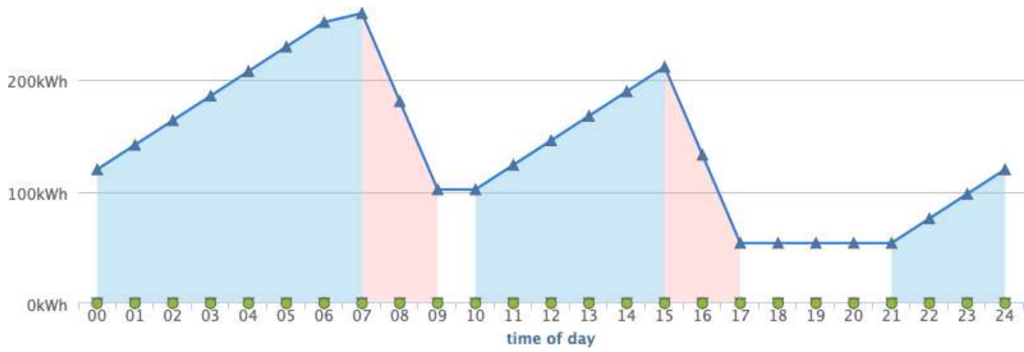
Bus 1 (class C, 283 km; min. 240 kWh battery) charges with 50 kW DC



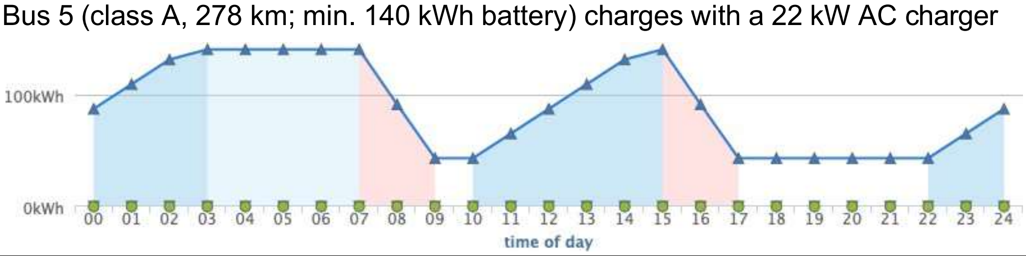
Bus 2 (class B, 48 km; min. 70 kWh battery) charges at depot with a 5 kW AC charger

Bus 3 (class B, 112 km; min. 110 kWh battery) charges with a 15 kW AC charger

Bus 4 (class C, 243 km; min. 260 kWh battery) charges with a 22 kW DC charger



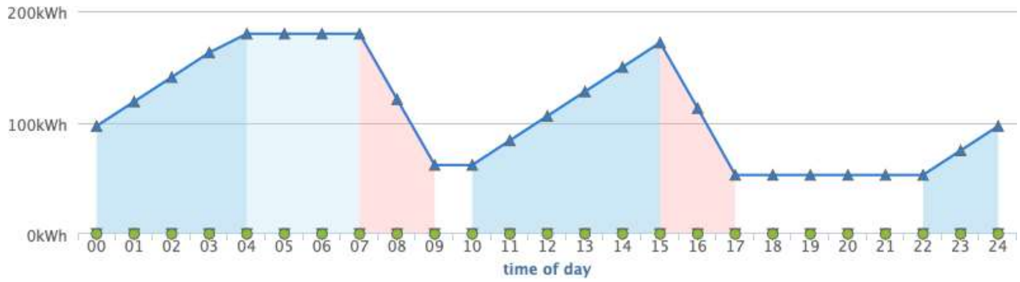
Bus 5 (class A, 278 km; min. 140 kWh battery) charges with a 22 kW AC charger



Bus 6 (class B, 96 km; min. 100 kWh battery) charges with a 10 kW AC charger

Bus 7 (class C, 143 km; min. 140 kWh battery) charges with a 22 kW AC charger

Bus 8 (class C, 181 km; min. 180 kWh battery) charges with a 22 kW AC charger



Bus 9 (class C, 138 km; min. 140 kWh battery) charges with a 22 kW AC charger

Bus 10 (class B, 195 km; min. 150 kWh battery) charges with a 22 kW AC charger

Bus 11 (class B, 186 km; min. 150 kWh battery) charges with a 22 kW AC charger

Bus 12 (class B, 171 km; min. 140 kWh battery) charges with a 22 kW AC charger

Figure 8-26 The Twelve buses at 16 Crouch St bus charging schedules

8.7. Green Head

The town of Green Head is located in the Mid-West in the Shire of Coorow on the Indian Ocean Drive approximately 300 km north of Perth. The normal population of around 300 residents can swell significantly during peak tourist seasons when tourists visit for fishing and nature-based activities. Green Head school students travel to the nearby Leeman Primary School, or Jurien Bay District High School. The small town is grid-connected to the SWIS. There is a single D Class bus at the depot at 56 Grigson Street in Green Head that travels to the Leeman Primary School.

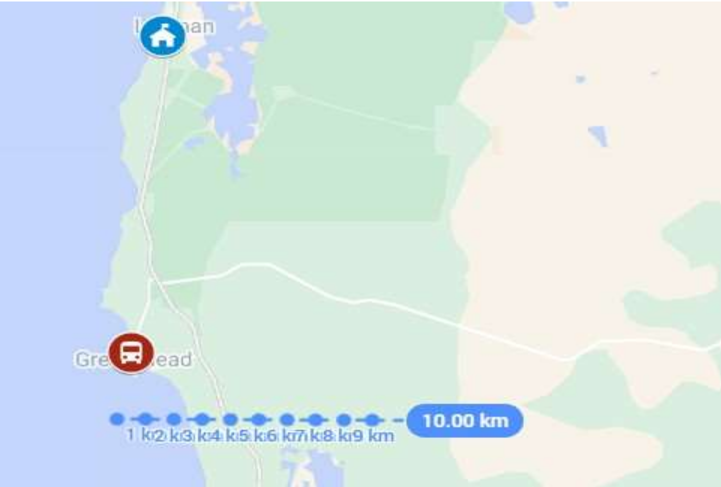


Figure 8-27 Green Head depot at 56 Grigson St travels to Leeman Primary School

Table 8-12: Green Head, Grigson St

SITE DETAILS	
School Bus Garaging Location	**GREEN HEAD, 56 Grigson St**
Location (Town)	GREEN HEAD
School Bus Services	Leeman Greenhead
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	D
Current bus make/model	2015 Toyota Commuter
Bus Age [years]	9
School(s) serviced	Leeman PS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	63
Electricity cons. per round trip [kWh]	42
Charging (14h) requirements [kW]	3

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	3
Total daily energy per depot [kWh]	3
Charging requirements (MWh/year)	8

Power available at depot [kW]	15
Contestable Customer?	No
Current tariff (c/kWh)	31

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1 x D Class e-bus with a minimum battery size of 70 kWh

Recommended Charging:
1 x 7 kW AC charger.
The network capacity at the depot is sufficient to install one AC charger to meet the requirements of the bus.

Cost:		**Electric**	**Diesel**
	Buses:	$ 104,000	$ 84,000
	Chargers:	$ 2,000	–
	Battery repl.	$ 14,000	–
	Energy/Fuel:	$ 2,100 annually	$ 2,600 annually
	Addl. mainten.	–	$ 1,500 annually
Lifetime:	NPC 17 years	-$134,000	-$122,000
	Difference		-$ 12,000 (D-bus is lower)

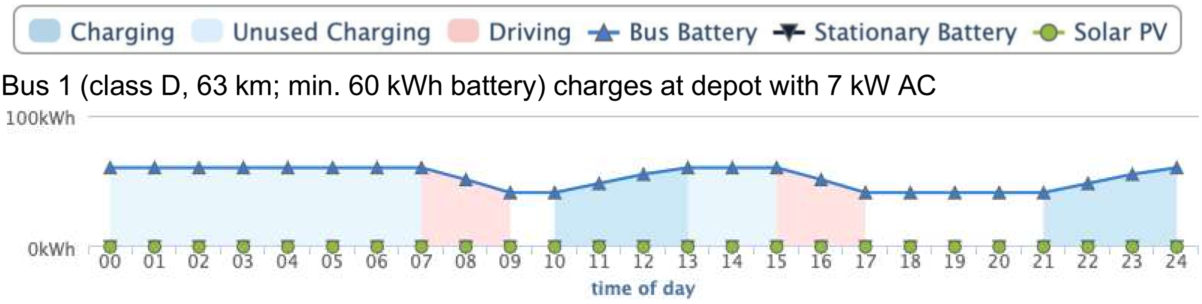


Figure 8-28 Green Head bus charging schedule

8.8. Morawa

Morowa is a small Mid-West town approximately 370 km north of Perth with a stable population of around 440. The town is grid-connected to the SWIS, has good road access and is traditionally farming-based with growing mining activity. There are two public schools, one of which is a primary and the other is a high school. There is also a College of Agriculture for high school students. There is one B Class bus located at the 10 Lodge Street depot which is only servicing the Morawa District High School.

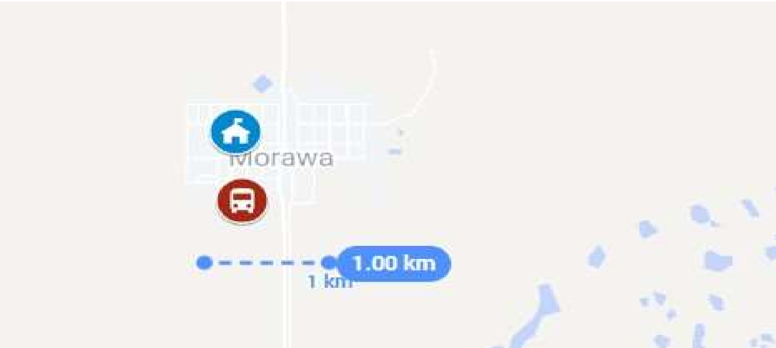


Figure 8-29 Morawa depot and school map

Table 8-13: Morawa, Lodge St

SITE DETAILS	
School Bus Garaging Location	**MORAWA, 10 Lodge St**
Location (Town)	MORAWA WA
School Bus Services	Morawa Mingenew
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	B
Current bus make/model	2014 Daewoo BH117L
Bus Age [years]	10
School(s) serviced	Morawa DHS

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	288
Electricity cons. per round trip [kWh]	350
Charging (14h) requirements [kW]	25

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	25
Total daily energy per depot [kWh]	352
Charging requirements (MWh/year)	70
Power available at depot [kW]	100
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1 x B Class e bus with a minimum battery size of 290 kWh

Recommended Charging:
1 x 22 kW AC charger.
The network capacity at the depot is sufficient to install one AC charger to meet the requirements of the bus.

		Electric	Diesel
Cost:		**Electric**	**Diesel**
	Buses:	$ 535,200	$ 388,000
	Chargers:	$ 2,000	–
	Battery repl.	$ 58,000	–
	Energy/Fuel:	$ 10,900 annually	$ 31,200 annually
	Addl. mainten.	–	$ 2,500 annually
Lifetime:	NPC 17 years	-$ 670,000	-$ 699,000
	Difference	+$ 29,000 (E-bus is lower)	

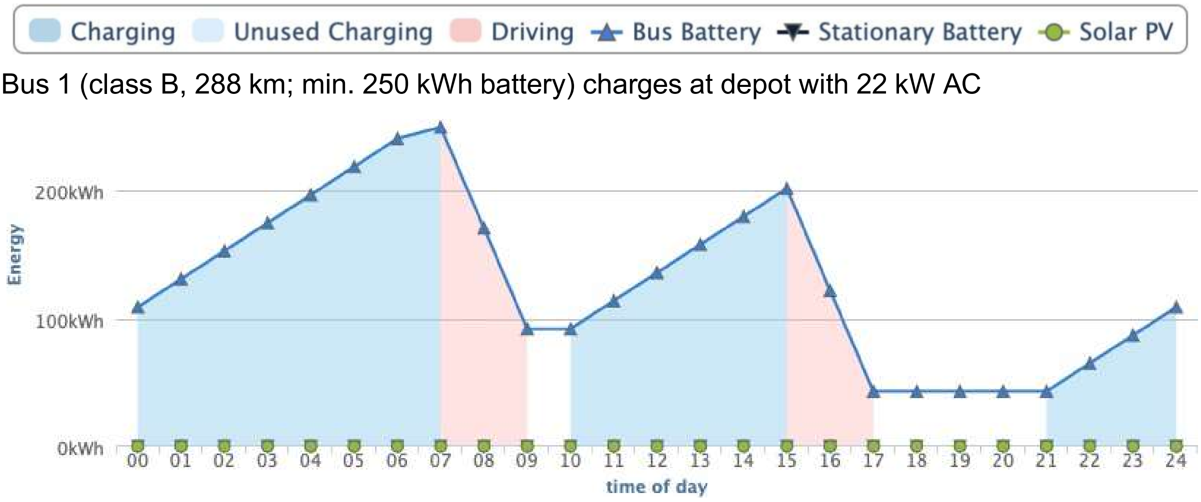


Figure 8-30 Morawa bus charging schedule

8.9. Fitzroy Crossing

Fitzroy Crossing is a small town in the Kimberley region with a population of around 1,181 (2021 Census) and is located 400 kilometres east of Broome, 300 kilometres west of Halls Creek, and approximately 2,524 kilometres north of Perth. Seven of the school buses used in Fitzroy Crossing are garaged at the one depot at Lot 185 Bell Road in Fitzroy Crossing. These buses service two schools, the Fitzroy Valley District High School, which is located 1.6 km north of the bus depot, and the Bayulu Community School, which is located 15.2 km south of the bus depot. Six of the seven buses travel from Fitzroy Crossing to other communities to transport students to the Bayulu Community School and to the Fitzroy Valley District High School. These are all 4x4 Class school buses. The other bus is used to provided school bus services within Fitzroy Crossing to the Fitzroy Valley District High School and is a D Class school bus.

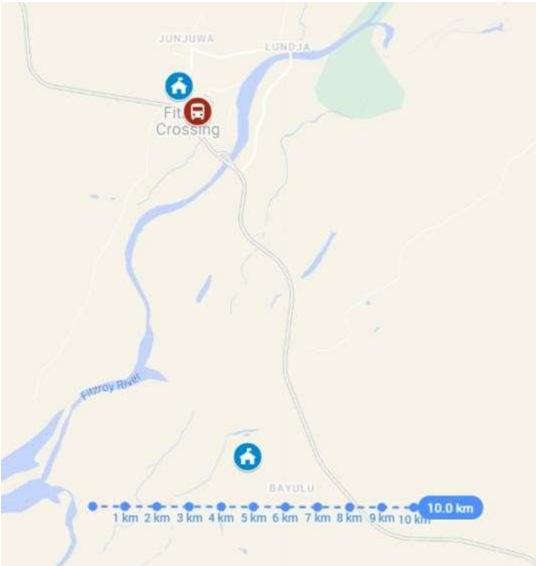


Figure 8-31 Fitzroy Crossing with locations of the bus depot, Fitzroy Valley District High School and Bayulu Community School

All of these seven school buses are currently garaged at the depot (Lot 185, Fitzroy Crossing) during the day. Six of the buses do two return runs from the depot at Fitzroy Crossing per school day. The other bus is garaged overnight at the Wangkatjungka remote Indigenous community, located approximately 130 km southeast of Fitzroy Crossing, travels to Fitzroy Crossing in the morning, and returns to Wangkatjungka after school.

Table 8-14: Fitzroy Crossing

SITE DETAILS	
School Bus Garaging Location	**FITZROY CROSSING, Lot 185 Bell Rd**
Location (Town)	FITZROY CROSSING WA
School Bus Services	Bayulu 8 Mile Bayulu Gillarong Fitzroy Crossing Eight Mile Fitzroy Crossing Ngalingkadji Fitzroy Valley ESU Fitzroy Valley Muludja Fitzroy Valley Wangkatjungka
Number of buses at site during day	7

SCHOOL BUS DETAILS	
Bus Classes	4x4, 4x4, 4x4, 4x4, D, 4x4, 4x4
Current bus make/model	2015 Isuzu FTS800A 2012 Isuzu 2014 Hino 2013 Isuzu 2012 Toyota HiAce (D) 2013 Isuzu 2009 Isuzu
Bus Age [years]	9, 12, 10, 11, 12, 11, 15
School(s) serviced (names, locations)	Baiul Remote Community School, Fitzroy Valley District High School

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	84, 84, 116, 305, 28, 143, 231
Electricity cons. per round trip [kWh]	139, 141, 194, 509, 19, 238, 385
Charging (14h) requirements [kW]	10, 10, 14, 36, 1, 17, 10 +18

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	122
Total daily energy per depot [kWh]	1228
Charging requirements (MWh/year)	292
Power available at depot [kW]	HV feeder remaining capacity 0.112 MVA = 112 kW Distribution Transformer Remaining Capacity (GPP) 0.124 MVA = 124 kW
Power available at Fitzroy Valley District High School	Unknown but it is assumed to be at least as high as the remaining capacity at the depot (112 kW) as the school is relatively new.
Power available at Bayulu Community School [kW]	Unknown but assumed HV Feeder remaining capacity 1.366 MVA = 1366 kW and Distribution Transformer Remaining Capacity (GPP) 056 MVA = 56 kW
Power requirement Wangkatjungka [kW]	17
Total daily energy Wangkatjungka [kWh]	173
Contestable Customer?	No
Current tariff (c/kWh)	L4 (> 50 MWh/y) = 30.6731 c/kWh

Electrification recommendation

Scenario: **Five buses are only charging at the depot;**
One bus is charging at Fitzroy Crossing DHS day and night;
One bus is charging at Fitzroy Crossing DHS at day and at the Wangkatjungka remote community overnight.

Advantage: Avoids need for network upgrades
Disadvantage: None, as the school location is close to the depot

Recommended E-Buses (incl. 15% battery margin):

6 x 4x4 Class e-buses with minimum battery sizes of 130 kWh, 130 kWh, 180 kWh, 380 kWh, 220 kWh, and 260 kWh.

1 x D Class e-bus with a minimum battery size of 60 kWh.

Recommended Charging:

6 x 22 kW AC chargers (5 at depot, 1 at Wangkatjungka),

2 x 50 kW DC chargers at the Fitzroy Valley District High School,

The power level at the depot is sufficient to charge five of the e-buses using 22 kW AC chargers.

The power level at the Fitzroy DHS is assumed to be sufficient to charge two e-buses using 2 x 50 kW DC chargers. Both buses are charged at the school during the day, one is charged at the school overnight, while the other is charged overnight at the Wangkatjungka remote community using a 22 kW AC charger.

In case the Wangkatjungka site cannot support a 22 kW connection, it needs the installation of a more expensive 50 kW DC charger with a 200 kWh battery buffer and a lower grid connection of 10–15 kW.

.

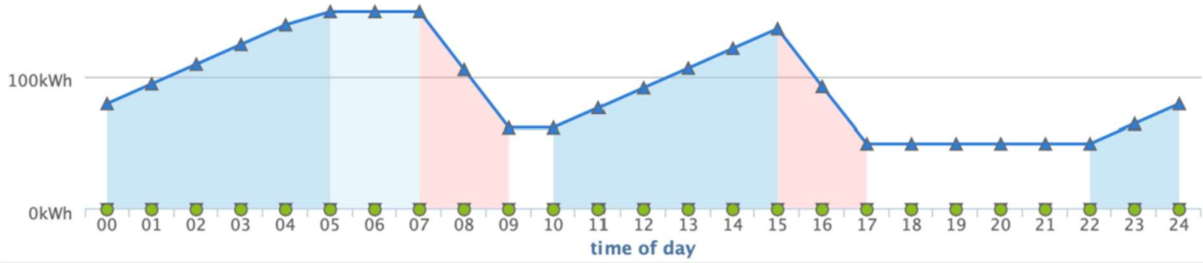
Cost:		**Electric**	**Diesel**
	Buses:	$3,071,500	$2,328,000
	Chargers:	$ 112,000	–
	Battery repl.	$ 272,000	–
	Energy/Fuel:	$ 89,600 annually	$ 140,200 annually
	Addl. mainten.	–	$ 13,500 annually
Lifetime:	NPC 17 years	-$4,162,000	-$3,745,000
	Difference		-$ 417,000 (D-bus is lower)

Note: E-bus charging times need to be staggered by software (not shown in graphs).

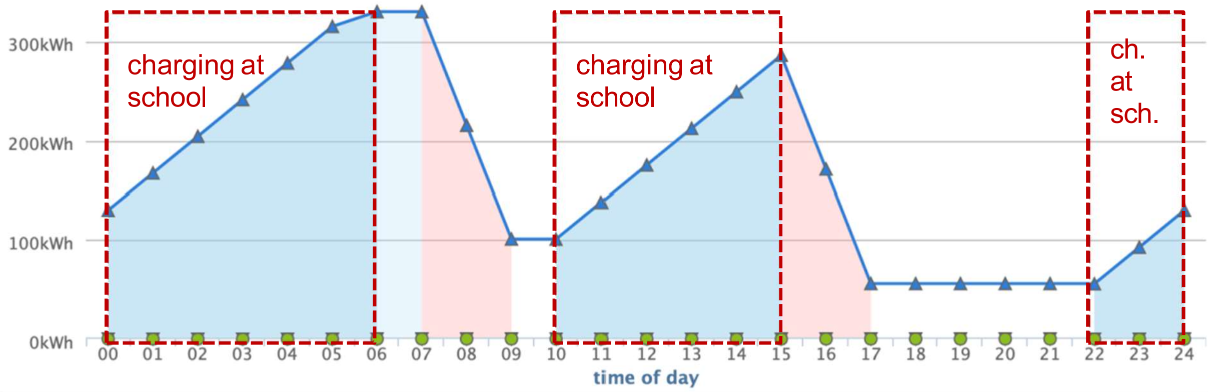
Bus 1. (Class 4x4, 84 km, min. 110 kWh battery). Charged using a 10 kW AC charger at depot.

Bus 2. (Class 4x4, 84 km, min. 110 kWh battery). Charged using a 10 kW AC charger at depot.

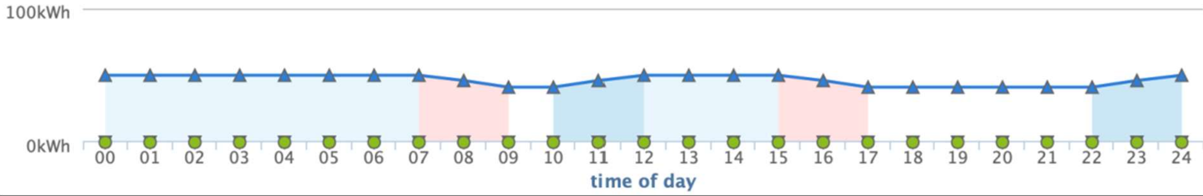
Bus 3. (Class 4x4, 116 km, min. 150 kWh battery) charged using a 15 kW AC charger at depot.



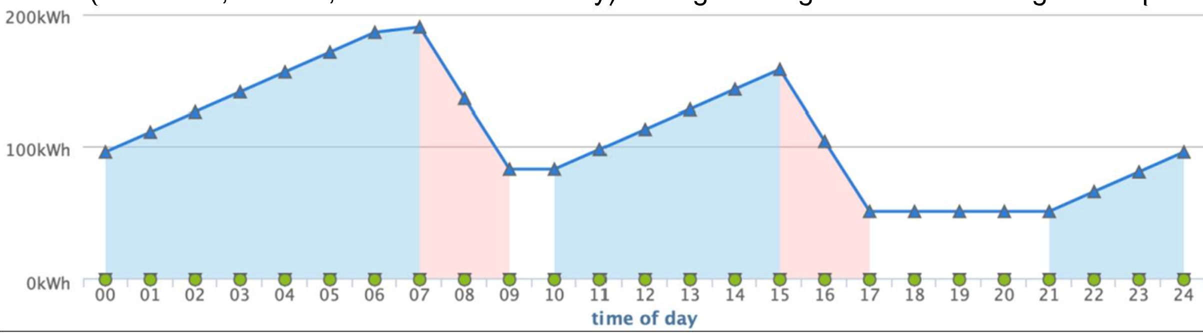
Bus 4. (Class 4x4, 305 km, min. 330 kWh battery) charged using a 50 kW DC charger at **school**.



Bus 5. (Class D, 28 km, min. 50 kWh battery). Charged using a 5 kW AC charger at depot.



Bus 6. (Class 4x4, 143 km, min. 190 kWh battery). Charged using a 15 kW AC charger at depot.



Bus 7. (Class 4x4, 231 km, min. 220 kWh battery). Charged using 22 kW AC overnight at remote community and using 50 kW DC at **school during the day**.

Figure 8-32 Fitzroy Crossing bus charging schedule

Fitzroy Crossing Summary

The electricity supply to the depot in Bell Street is sufficient to charge five of the buses using 5 x 22 kW AC chargers. One e-bus (Bus 4) would need to be charged at the Fitzroy Valley District High School both at night and during the day using a 50 kW charger. One bus (Bus 7) would need to be charged during the night at the Wangkatjungka remote community using a 22 kW charger and during the day at the Fitzroy Valley District High School. The power supply capacity at the Wangkatjungka remote community is unknown but the diesel power station in the community is thought to be 70 kW, which would be adequate.

8.10. Northam

Northam, a town in the Midwest of WA with a population of 11,358 (2021 Census) and is located approximately 97 km east-northeast of Perth. The seven schools in the region are serviced by a total of 13 buses, which are garaged at five locations.

8.10.1. Northam – Moore St

Nine of the school buses are garaged at 11 Moore Street, five of which are C Class buses and the other four are B Class buses. These nine buses service five schools in Northam (Avonvale ESC Primary School, Northam Primary School, Northam Senior High School. St Joseph's Junior Campus, and St Joseph's Senior Campus). The current electricity network capacity supplying the depot is highly constrained, with a capacity to connect only a single 7 kW charger. The network capacity at each of the five schools serviced by the buses is sufficient to connect 2 x 50 kW chargers.

Figure 8-33 Northam Moore St depot and schools

Table 8-15 Northam : Northam, Moore St

SITE DETAILS	
School Bus Garaging Location	**NORTHAM, 11 Moore St**
Location (Town)	NORTHAM WA
School Bus Services	Northam Beverley Northam Goomalling Northam Inkpen Estate Northam Jennapullin Northam Meckering Northam Mokine Northam Southern Brook Northam Wundowie Northam York
Number of buses at site	9

SCHOOL BUS DETAILS	
Bus Classes	C, B, C, C, C, B, B, B, C
Current bus make/model	2020 Volvo B8R 2021 Scania K310 2012 BCI Classmaster 2016 Mercedes Benz OH1830L 2008 Iveco Delta 2007 Iveco 2011 BCI Classmaster 2014 Iveco Delta 2016 Iveco Delta

Bus Age [years]	4, 3, 12, 8, 16, 17, 13, 10, 8
School(s) serviced (names, locations)	Avonvale ESC PS. Northam PS. Northam SHS. St Joseph's Sch. - Northam Jnr Campus, St Joseph's Sch. - Northam Snr Campus

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	290, 325, 200, 208, 208, 152, 294, 195, 333
Electricity consumptions per round trip [kWh]	420, 397, 289, 301, 300, 186, 360, 238, 481
Charging (14h) requirements [kW]	30, 28, 21, 21, 21, 13, 26, 17, 34

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	212
Total daily electricity use [kWh]	2,972
Charging requirements (MWh/year)	594
Power available at depot [kW]	15 (insufficient)
Power available at schools [kW]	3 * 100 + 2 * 50 = 400 (sufficient)
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Charging the e-buses at the schools

Recommended E-Buses (incl. 15% battery margin):

5 x C Class e-buses with minimum battery sizes of 330 kWh, 250 kWh, 250 kWh, 260 kWh and 360 kWh.
4 x B Class e-buses minimum battery sizes of 300 kWh, 160 kWh, 290 kWh and 190 kWh.

Recommended Charging:

3 x 100 kW DC chargers, one each installed at 3 of the schools,
1 x 50 kW DC charger, installed at one other school, and
2 x 22 kW AC chargers, installed at the remaining school.

As the network capacity at the depot is insufficient to charge any of the buses, all buses will need to be charged at schools during both the day and overnight. The electricity supply at each of the 5 schools sites is sufficient to install 2 x 50 kW DC chargers.

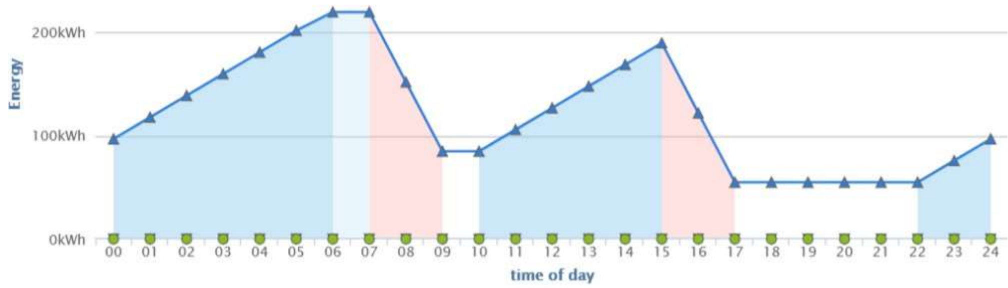
Cost:		**Electric**	**Diesel**
	Buses:	$ 4,751,800	$ 3,662,000
	Chargers:	$ 324,000	–
	Battery repl.	$ 478,400	–
	Energy/Fuel:	$ 92,400 annually	$ 269,800 annually
	Addl. mainten.		$ 25,000 annually
Lifetime:	NPC 17 years	-$6,195,000	-$6,381,000
	Difference	+$ 186,000 (E-bus is lower)	

Bus 1. (C, 290 km, min. 280 kWh battery). Charged at **school** using a 50 kW DC charger.

Bus 2. (B, 325 km, min. 260 kWh battery). Charged at a **school** using a 50 kW DC charger.

Bus 3. (C, 200 km, min. 210 kWh battery). Charged at **school** using a 50 kW DC charger.

Bus 4. (C, 208 km, min. min. 220 kWh battery). Charged at **school** using a 50 kW DC charger.

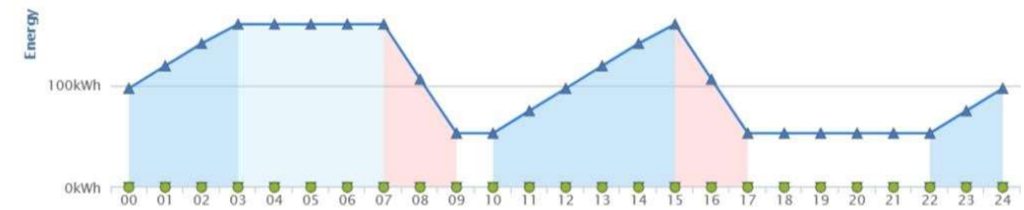


Bus 5. (C, 208 km, min. 220 kWh battery). Charged at **school** using a 50 kW DC charger.

Bus 6. (B, 152 km, min. 140 kWh battery). Charged at **school** using a 22 kW AC charger.

Bus 7. (B, 294 km, min. 250 kWh battery). Charged at **school** using a 50 kW DC charger.

Bus 8. (B, 195 km, min. 160 kWh battery). Charged at **school** using a 22 kW AC charger.



Bus 9 (C, 333 km, min. 310 kWh battery). Charged at **school** using a 50 kW DC charger.

Figure 8-34 Northam, Moore St. charging schedule

8.10.2. Northam – Dempster Rd

Northam's second depot is located in Dempster Road which has a single bus that is used to service the Edmund Rice College in Mooliabeenee, which is located approximately 10 km north of Bindoon.

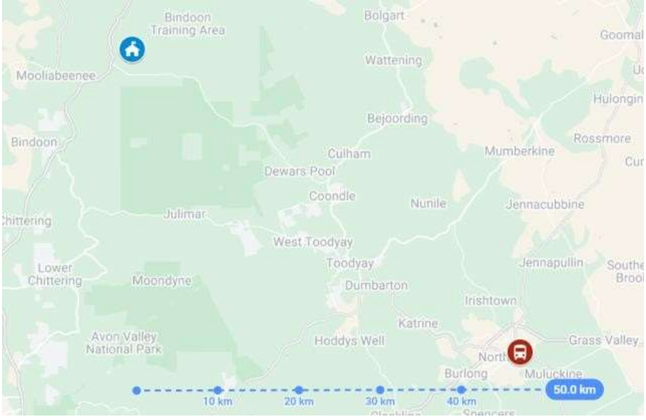


Figure 8-35 Northam Dempster Rd depot and school

Table 8-16: Northam Dempster Rd

SITE DETAILS	
School Bus Garaging Location	**NORTHAM, 18 Dempster Rd**
Location (Town)	NORTHAM WA
School Bus Services	Bindoon CAC Northam
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	A
Current bus make/model	2018 Toyota Coaster
Bus Age [years]	6
School(s) serviced (names, locations)	Edmund Rice Coll - Cath Agri Coll Bindoon

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	389
Daily driving bus energy [kWh]	272
Daily charging energy [kWh]	303
Charging requirements (14h) [kW]	22

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	22
Total daily energy per depot [kWh]	303
Charging requirements (MWh/year)	61
Power available at depot [kW]	50
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1 x A Class e-bus with minimum battery size of 260 kWh

Recommended Charging:
1 x 22 kW AC charger.
As the network capacity at the depot is sufficient to charge the e-buses, the bus is charged during the day and overnight at the dept using an AC charger.

		Electric	Diesel
Cost:	Buses:	$ 226,500	$ 145,000
	Charger:	$ 2,000	–
	Battery repl.	$ 52,000	–
	Energy/Fuel:	$ 9,400 annually	$ 25,400 annually
	Addl. mainten.	–	$ 2,500 annually
Lifetime:	NPC 17 years	-$ 359,000	-$ 398,000
	Difference	+$ 39,000 (E-bus is lower)	

Bus 1. (C, 290 km, min. 220 kWh battery). Charged at **school** using a 22 kW AC charger.

Figure 8-36 Northam, Dempster Rd charging schedule

8.10.3. Northam – Purkiss Drive

Northam's third depot is located in Purkiss Drive. A single bus at this depot services five schools.

Figure 8-37 Northam, Purkiss Dr depot and schools

Table 8-17: Northam Purkiss Dr

SITE DETAILS	
School Bus Garaging Location	**NORTHAM, 11 Purkiss Dr**
Location (Town)	NORTHAM WA
School Bus Services	Northam York Central
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	C
Current bus make/model	2021 Yutong Brumby
Bus Age [years]	3
School(s) serviced (names, locations)	Avonvale ESC PS. Avonvale ESC Secondary Campus Northam SHS St Joseph's Sch. - Northam Jnr Campus St Joseph's Sch. - Northam Snr Campus

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	176
Daily driving bus energy [kWh]	228
Daily charging energy [kWh]	254
Charging requirements (14h) [kW]	18

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	18
Total daily energy per depot [kWh]	254
Charging requirements (MWh/year)	51
Power available at depot [kW]	15kW after free upgrade; OK with extended charging time.
Contestable Customer?	N/A
Current tariff (c/kWh)	N/A

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

1 x C Class e-bus with a minimum battery size of 250 kWh

Recommended Charging:

1 x 15 kW AC charger.

Although the current power supply to the depot is insufficient, it can be increased to 15 kW through a free network upgrade. In combination with extended night charging hours, this will be sufficient to charge the e-bus during the day and overnight at the depot using a small AC charger.

Cost:

	Electric	**Diesel**
Buses:	$ 523,400	$ 422,000
Charger:	$ 2,000	–
Battery repl.	$ 50,000	–

	Energy/Fuel: Addl. mainten.	$ 12,800 annually –	$ 23,500 annually $ 3,000 annually
Lifetime:	NPC 17 years Difference	-$ 671,000	-$ 666,000 -$ 5,000 (D-bus is lower)

Bus 1. (C, 290 km, min. 210 kWh battery). Charged at the depot using a 15 kW AC charger.

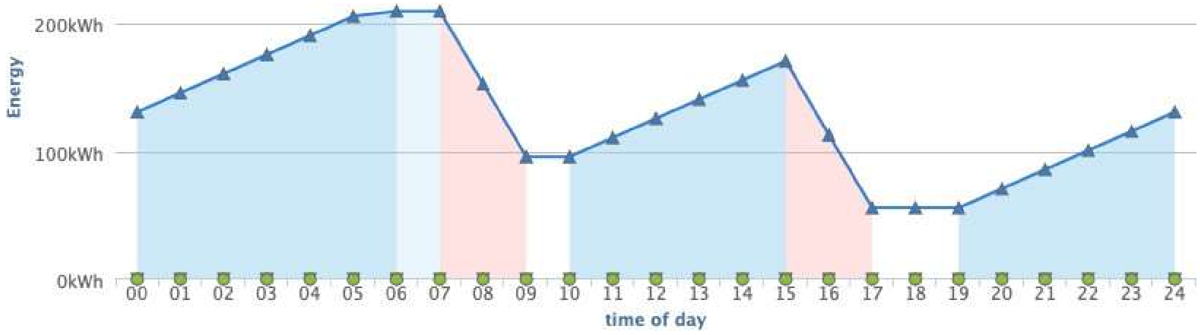


Figure 8-38 Northam, Purkiss Dr charging schedule

8.10.4. Northam – Strickland Ave

Northam's fourth depot is located in Strickland Ave. A single bus services three schools (four campuses).

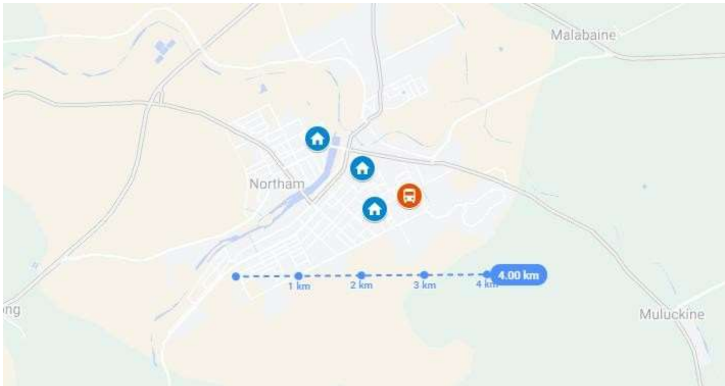


Figure 8-39 Northam, Strickland Ave depot and schools

Table 8-18: Northam Strickland Ave

SITE DETAILS	
School Bus Garaging Location	**NORTHAM, 17 Strickland Av**
Location (Town)	NORTHAM WA
School Bus Services	Northam York No 2
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	C
Current bus make/model	2021 Yutong Brumby
Bus Age [years]	3

School(s) serviced (names, locations)	Northam PS. Northam SHS. St Joseph's Sch.- Northam Jnr Campus St Joseph's Sch. - Northam Snr Campus

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	159
Daily driving bus energy [kWh]	207
Daily charging energy [kWh]	230
Charging requirements (14h) [kW]	16

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	16
Total daily energy per depot [kWh]	230
Charging requirements (MWh/year)	46
Power available at depot [kW]	44
Contestable Customer?	No
Current tariff (c/kWh)	31

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

1 x C Class e-bus with a minimum battery sizes of 190 kWh

Recommended Charging:

1 x 22 kW AC charger.
As the network capacity at the depot is sufficient to charge the e-bus, the bus is charged during the day and overnight at the depot using an AC charger.

Cost:		**Electric**	**Diesel**
	Buses:	$ 505,400	$ 422,000
	Charger:	$ 2,000	–
	Battery repl.	$ 38,000	–
	Energy/Fuel:	$ 11,500 annually	$ 21,200 annually
	Addl. mainten.	–	$ 3,000 annually
Lifetime:	NPC 17 years	-$636,000	-$645,000
	Difference	+$ 10,000 (E-bus is lower)	

Bus 1. (C, 290 km, min. 160 kWh battery). Charged at the depot using a 22 kW AC charger.

Figure 8-40 Northam, Strickland Ave charging schedule

8.10.5. Northam – Crorkan Rd

Northam's fifth depot is located in Crorkan Road. A single bus at this depot services three schools (four campuses).

Figure 8-41 Northam, Crorkan Rd depot and schools

Table 8-19: Northam Crorkan Rd

SITE DETAILS	
School Bus Garaging Location	**NORTHAM, Lot 206 Crorkan Rd**
Location (Town)	NORTHAM WA
School Bus Services	Northam Juradine
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	C
Current bus make/model	2010 Hino
Bus Age [years]	14
School(s) serviced (names, locations)	Northam PS Northam SHS St Joseph's Sch. - Northam Jnr Campus St Joseph's Sch. - Northam Snr Campus

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	185
Daily driving bus energy [kWh]	240
Daily charging energy [kWh]	267
Charging requirements (14h) [kW]	19

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	19
Total daily energy per depot [kWh]	267
Charging requirements (MWh/year)	53
Power available at depot [kW]	44
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):
1 x C Class e-bus with a minimum battery sizes of 210 kWh

Recommended Charging:
1 x 22 kW AC charger.
As the network capacity at the depot is sufficient to charge the e-bus, the bus is charged during the day and overnight at the depot using an AC charger.

Cost:		**Electric**	**Diesel**
	Buses:	$ 511,400	$ 422,000
	Charger:	$ 2,000	–
	Battery repl.	$ 42,000	–
	Energy/Fuel:	$ 13,400 annually	$ 24,700 annually
	Addl. mainten.	–	$ 3,000 annually
Lifetime:	NPC 17 years	-$ 660,000	-$ 677,000
	Difference	+$ 17,000 (E-bus is lower)	

Bus 1. (C, 290 km, min. 180 kWh battery). Charged at the depot using a 22 kW AC charger.

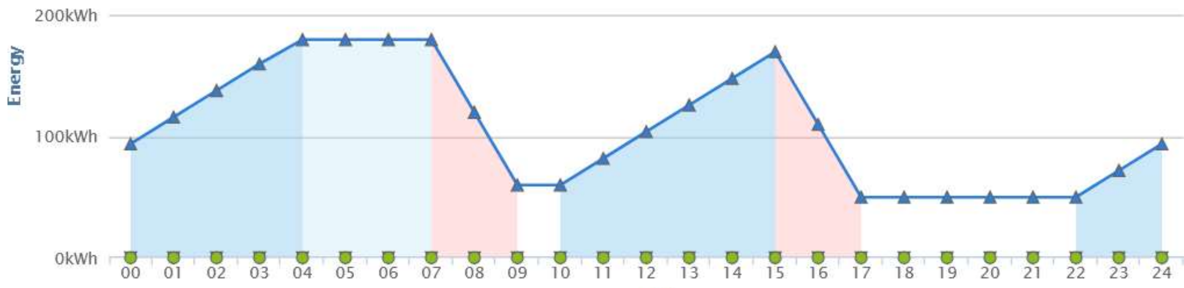


Figure 8-42 Northam, Crorkan Rd charging schedule

8.10.6. Northam Summary

While the electricity supply to the depot with the largest number of buses (9) at 11 Moore Street, is insufficient to charge any of the e-buses, the electricity supply capacities at each of the schools is more than sufficient to charge those e-buses. At each of the other four bus depots the electricity supply is sufficient to charge each of the single buses garaged at those depots. Therefore, an efficient transition to e-buses would require some buses to be charged during the day and at night at schools. While that would involve the drivers of the buses from the Moore Street depot to use alternative means of transport from the schools to the depot, the distances are all less than 2.5 km. The advantage is that those EV chargers could be made available to members of the public when not used to charge the school buses. Using the above strategy for charging the e-buses would mean that no network upgrades would be required.

8.11. Narrogin

Narrogin is a town with a population of 4,779 (2021 Census) in the Eastern Wheatbelt Region located on the Great Southern Highway 192 kilometres southeast of Perth between Pingelly and Wagin. There are six schools (pre-kindergarten, kindergarten, primary, secondary, TAFE and an agricultural college) that are served by eleven school buses garaged at five different depots.

8.11.1. Narrogin – Havelock Street

Two of the eleven school buses are garaged at a depot at 62 Havelock Street in Narrogin. These two C Class school buses are used on the Narrogin-Pingelly and the Narrogin-Wagin routes, and serve two schools in Narrogin, the Narrogin Senior High School and St Matthews School.

The electricity network capacity suppling the garaging site is highly constrained and only a single 7 kW charger could be installed at the site without a network upgrade. The network capacities supplying both of the schools are adequate for 2 x 50 kW chargers to be installed at both of the schools.

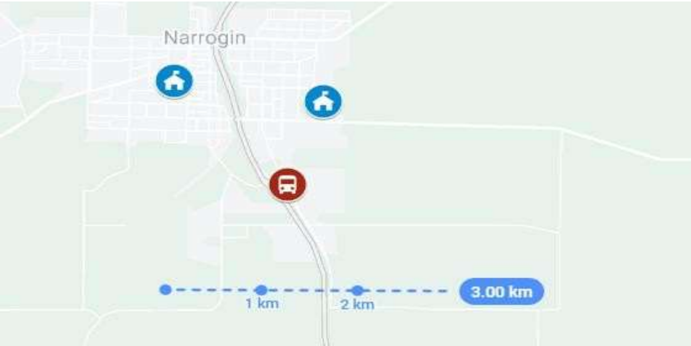


Figure 8-43 Narrogin, Havelock St depot and schools

Table 8-20: Narrogin Havelock St

SITE DETAILS	
School Bus Garaging Location	**NARROGIN, 62 Havelock St**
Location (Town)	NARROGIN WA
School Bus Services	Narrogin Pingelly, Narrogin Wagin
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	C, C
Current bus make/model	2013 Hino RN8J, 2013 Daewoo BH117L
Bus Age [years]	11, 11
School(s) serviced (names, locations)	Narrogin SHS St Matthews School

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	296, 206
Daily driving bus energy [kWh]	385, 268
Daily charging energy [kWh]	428, 298
Charging requirements (14h) [kW]	31, 21

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	52
Total daily energy per depot [kWh]	726
Charging requirements (MWh/year)	145
Power available at depot [kW]	15 after free upgrade (insufficient) 2 * 50 = 100 at schools (sufficient)
Contestable Customer?	Yes
Current tariff (c/kWh)	17

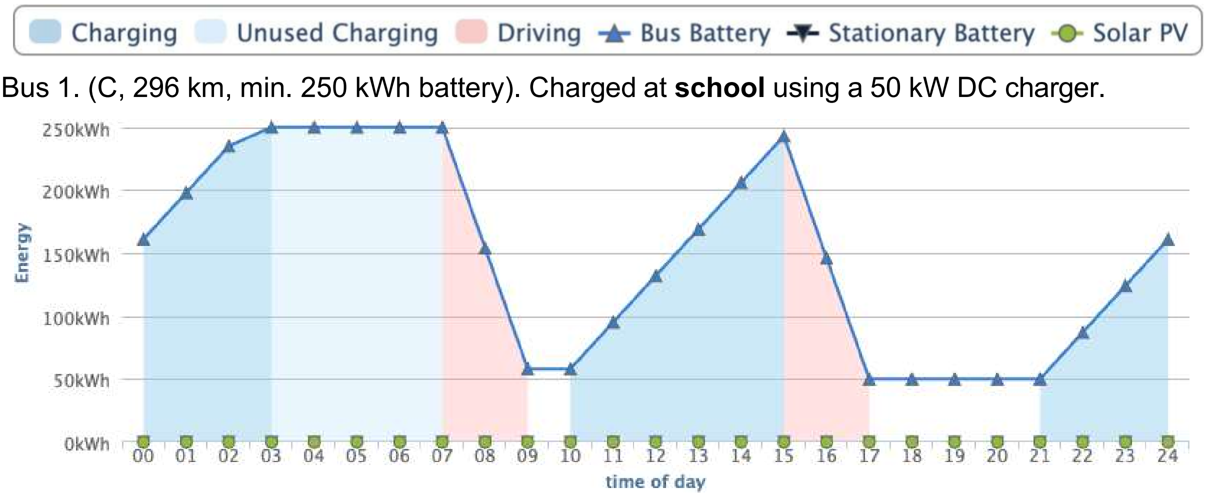
Electrification recommendation

Scenario: Charging at Schools

Recommended E-Buses (incl. 15% battery margin):
2 x C Class e-buses with minimum battery sizes of 290 kWh and 250 kWh.

Recommended Charging:
1 x 50 kW DC charger,
1 x 22 kW AC charger.
As the network capacity at the depot is insufficient to charge the e-bus, the buses are charged during the day and overnight at schools using one AC charger and one DC charger.

Cost:		**Electric**	**Diesel**
	Buses:	$ 1,058,800	$ 844,000
	Charger:	$ 52,000	–
	Battery repl.	$ 108,000	–
	Energy/Fuel:	$ 22,500 annually	$ 66,900 annually
	Addl. mainten.	–	$ 6,000 annually
Lifetime:	NPC 17 years	-$1,379,000	-$1,516,000
	Difference	+$ 137,000 (E-bus is lower)	



Bus 1. (C, 296 km, min. 250 kWh battery). Charged at **school** using a 50 kW DC charger.

Bus 2. (C, 206 km, min. 210 kWh battery). Charged at **school** using a 22 kW AC charger.

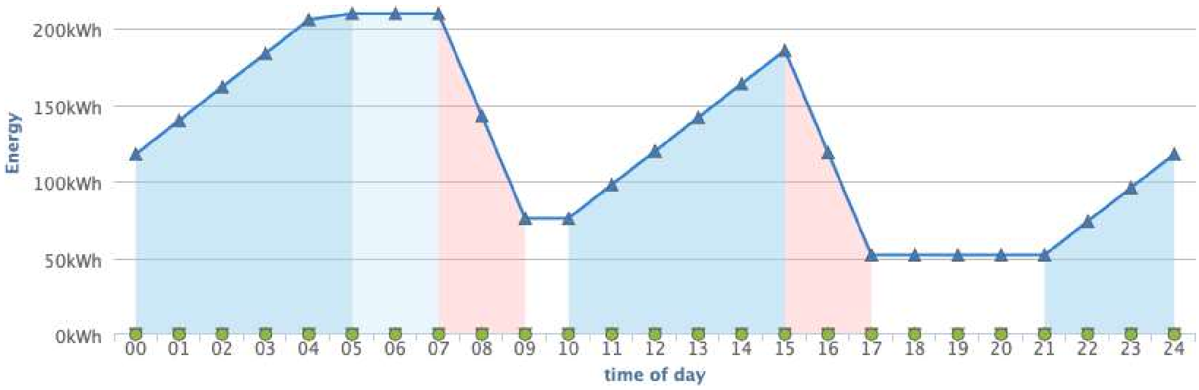


Figure 8-44 Narrogin, Havelock St charging schedule

8.11.2. Narrogin – Lydeker Way

Four of the eleven school buses are garaged at a depot at this depot: two A Class buses, one B Class bus and one C Class bus. These two C Class school buses are used on the Narrogin-Boundain, Narrogin-Pingelly, Narrogin-Wickpen, Narrogin-Williams-Geeralying routes. The electricity network capacity suppling the garaging site is sufficient to charge all four buses.

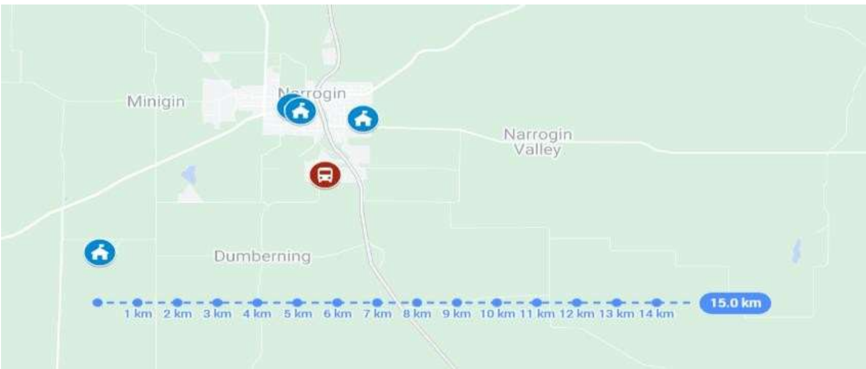


Figure 8-45 Narrogin, Lydeker Way depot and schools

Table 8-21: Narrogin Lydeker Way

SITE DETAILS	
School Bus Garaging Location	**NARROGIN, 15 Lydeker Way**
Location (Town)	NARROGIN WA
School Bus Services	Narrogin Boundain, Narrogin Pingelly #2, Narrogin Wickepin, Narrogin Williams Geeralying
Number of buses at site	4

SCHOOL BUS DETAILS	
Bus Classes	A, A, B, C
Current bus make/model	2018 Mitsubishi Rosa, 2016 Toyota Coaster, 2021 Man, 2009 Hino

Bus Age [years]	6, 8, 3, 15
School(s) serviced (names, locations)	Narrogin PS Narrogin PS Kindy Narrogin SHS St Matthews School WA College of Agriculture – Narrogin

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	174, 206, 200, 294
Daily driving bus energy [kWh]	122, 144, 220, 382
Daily charging energy [kWh]	135, 160, 244, 425
Charging requirements (14h) [kW]	10, 11, 17, 30

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	69
Total daily energy per depot [kWh]	964
Charging requirements (MWh/year)	193
Power available at depot [kW]	200
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

2 x A Class e-buses with minimum battery sizes of 130 kWh and 140 kWh.
1 x B Class e-bus with a minimum battery sizes of 190 kW.
1 x C Class e-bus with a minimum battery sizes of 340 kW.

Recommended Charging:

1 x 50 kW DC charger,
3 x 22 kW AC chargers.
As the network capacity at the depot is sufficient to charge the e-buses, they can be charged during the day and overnight at the depot using one DC charger and three AC chargers.

Cost:		**Electric**	**Diesel**
	Buses:	$ 1,433,600	$1,100,000
	Charger:	$ 56,000	–
	Battery repl.	$ 160,000	–
	Energy/Fuel:	$ 30,000 annually	$ 85,600 annually
	Addl. mainten.	–	$ 9,500 annually
Lifetime:	NPC 17 years	-$1,810,000	-$1,977,000
	Difference	+$ 167,000 (E-bus is lower)	

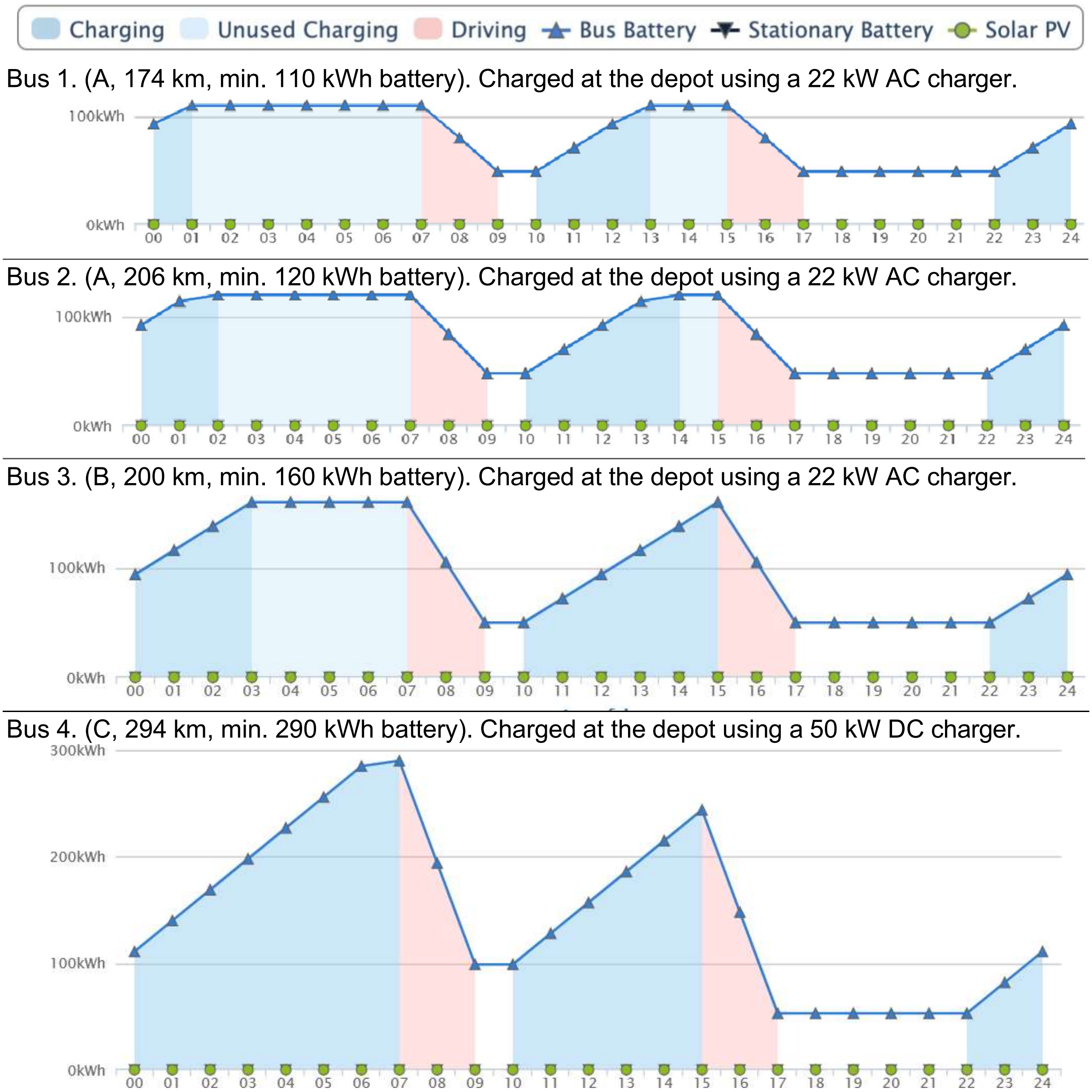


Figure 8-46 Narrogin, Lydeker Way charging schedule

8.11.3. Narrogin – Gibson St

Two of the eleven school buses are garaged at this depot: one A Class bus and one C Class bus. These two buses are used on the Narrogin-Yilliminning and Narrogin-Yornaning routes. The electricity network capacity suppling the garaging site is sufficient to charge both buses.

Figure 8-47 Narrogin, Gibson St depot and schools

Table 8-22: Narrogin Gibson St

SITE DETAILS	
School Bus Garaging Location	**NARROGIN, 47 Gibson St**
Location (Town)	NARROGIN WA
School Bus Services	Narrogin Yilliminning, Narrogin Yornaning
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	A, C
Current bus make/model	2021 Mitsubishi Rosa, 2015 Yutong
Bus Age [years]	3, 9
School(s) serviced (names, locations)	East Narrogin PS Narrogin PS Narrogin PS Kindy Narrogin SHS St Matthews Sch

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	165, 263
Daily driving bus energy [kWh]	116, 342
Daily charging energy [kWh]	129, 380
Charging requirements (14h) [kW]	9, 27

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	36
Total daily energy per depot [kWh]	508

Charging requirements (MWh/year)	102
Power available at depot [kW]	100
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

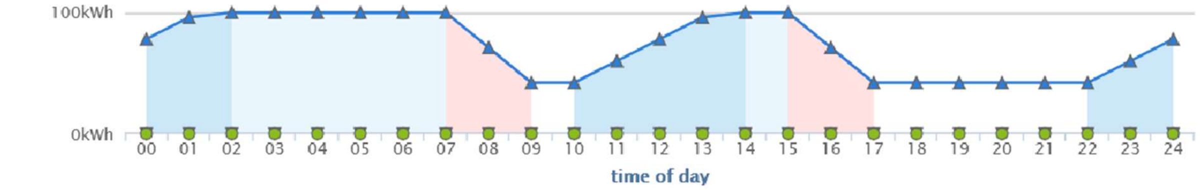
1 x A Class e-bus with a minimum battery size of 120 kWh.
1 x C Class e-bus with a minimum battery size of 300 kWh.

Recommended Charging:

1 x 50 kW DC charger,
1 x 22 kW AC charger.
The network capacity at the depot is sufficient to charge both e-buses. The A Class e-bus is charged with an AC charger, while the C Class e-bus is charged with a DC charger. Both buses are charged at the depot during the day and overnight.

Cost:		**Electric**	**Diesel**
	Buses:	$ 722,900	$ 567,000
	Charger:	$ 52,000	–
	Battery repl.	$ 84,000	–
	Energy/Fuel:	$ 15,800 annually	$ 45,800 annually
	Addl. mainten.	–	$ 5,000 annually
Lifetime:	NPC 17 years	-$ 968,000	-$1,035,000
	Difference	+$ 67,000 (E-bus is lower)	

Bus 1. (A, 165 km, min. 100 kWh battery). Charged at the depot using a 22 kW AC charger.



Bus 2. (C, 263 km, min. 260 kWh battery). Charged at the depot using a 50 kW DC charger.

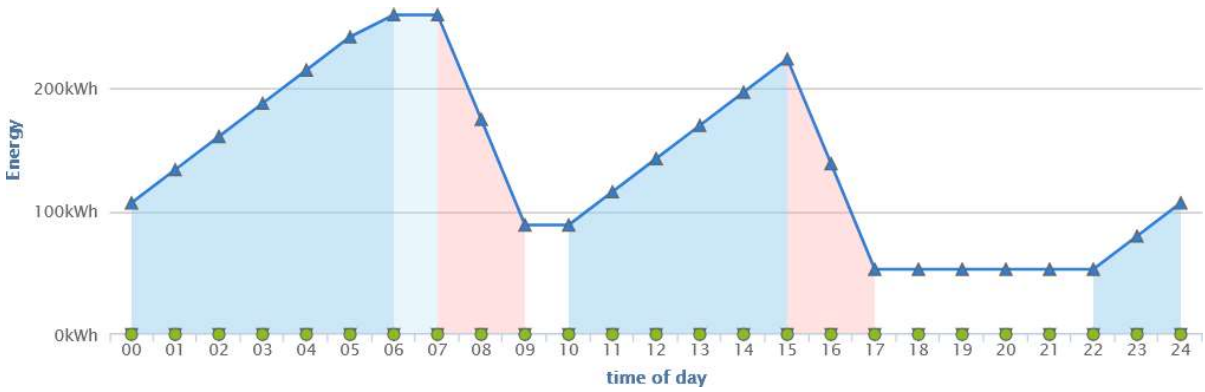


Figure 8-48 Narrogin, Gibson St charging schedule

8.11.4. Narrogin – Grant Street

Two of the eleven school buses are garaged at a depot at this depot, both of which are B Class buses. These two school buses are used on the Narrogin-Narrogin Valley and Narrogin-Popanyinning East routes. The electricity network capacity suppling the depot is sufficient to charge both buses.

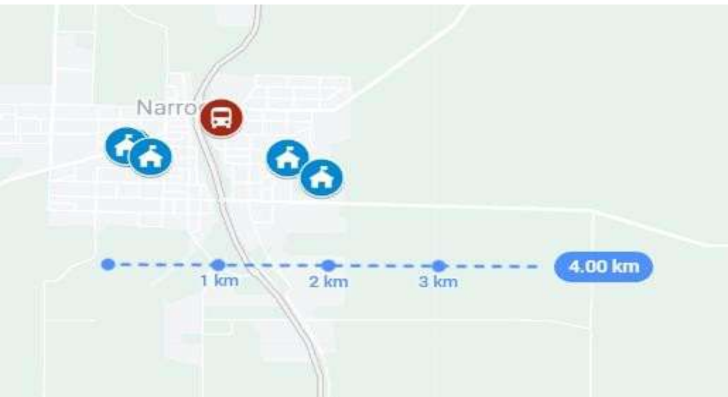


Figure 8-49 Narrogin, Grant St depot and schools

Table 8-23: Narrogin Grant St

SITE DETAILS	
School Bus Garaging Location	**NARROGIN, 7 Grant St**
Location (Town)	NARROGIN WA
School Bus Services	Narrogin - Narrogin Valley, Narrogin - Popanyinning East
Number of buses at site	2

SCHOOL BUS DETAILS	
Bus Classes	B, B
Current bus make/model	2009 Hino, 2012 BCI
Bus Age [years]	15, 12
School(s) serviced (names, locations)	East Narrogin PS Narrogin PS Narrogin PS Kindy Narrogin SHS St Matthews Sch

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	161, 204
Daily driving bus energy [kWh]	177, 224
Daily charging energy [kWh]	197, 249
Charging requirements (14h) [kW]	14, 18

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	32
Total daily energy per depot [kWh]	446

Charging requirements (MWh/year)	89
Power available at depot [kW]	50
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Buses (incl. 15% battery margin):

2 x B Class e-bus with a minimum battery size of 150 kWh and 190 kWh.

Recommended Charging:

2 x 22 kW AC chargers.
The network capacity at the depot is sufficient to charge both e-buses using two AC chargers. Both buses are charged at the depot during the day and overnight.

Cost:		**Electric**	**Diesel**
	Buses:	$ 998,400	$ 776,000
	Charger:	$ 4,000	–
	Battery repl.	$ 68,000	–
	Energy/Fuel:	$ 13,900 annually	$ 39,500 annually
	Addl. mainten.	–	$ 5,000 annually
Lifetime:	NPC 17 years	-$1,169,000	-$1,186,000
	Difference	+$ 17,000 (E-bus is lower)	

Bus 1. (B, 161 km, min. 130 kWh battery). Charged at the depot using a 22 kW AC charger.

Bus 2. (B, 204 km, min. 160 kWh battery). Charged at the depot using a 22 kW AC charger.

Figure 8-Narrogin, Grant St charging schedule

8.11.5. Narrogin – Narrakine Rd

A single B Class school bus is garaged at a depot which is used on the Narrogin-Boddington route and transports students to two schools in Narrogin. The electricity network capacity suppling the depot is sufficient to charge the bus.

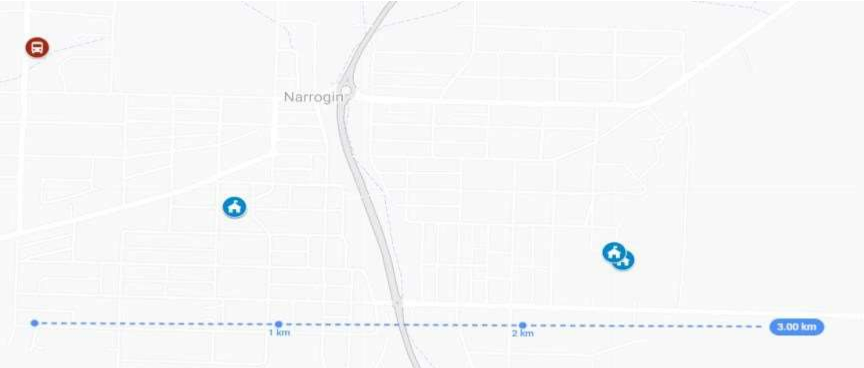


Figure 8-50 Narrogin, Narrakine Rd depot and schools

Table 8-24: Narrogin Narrakine Rd

SITE DETAILS	
School Bus Garaging Location	**NARROGIN, 85 Narrakine Rd**
Location (Town)	NARROGIN WA
School Bus Services	Narrogin Boddington
Number of buses at site	1

SCHOOL BUS DETAILS	
Bus Classes	B
Current bus make/model	2012 Man
Bus Age [years]	12
School(s) serviced (names, locations)	Narrogin SHS St Matthews School

BATTERY CHARGING REQUIREMENTS	
Bus route length [km]	347
Daily driving bus energy [kWh]	382
Daily charging energy [kWh]	424
Charging requirements (14h) [kW]	30

SITE ELECTRICITY SUPPLY	
Power requirement for depot [kW]	30
Total daily energy per depot [kWh]	424
Charging requirements (MWh/year)	85
Power available at depot [kW]	50
Contestable Customer?	Yes
Current tariff (c/kWh)	17

Electrification recommendation

Scenario: Business as Usual

Recommended E-Bus (incl. 15% battery margin):
1 x B Class e-bus with minimum battery size of 290 kWh.

Recommended Charging:
1 x 50 kW charger.
The network capacity at the depot is sufficient to charge the B Class e-bus with a DC charger at the depot during the day and overnight.

Cost:		**Electric**	**Diesel**
	Buses:	$ 535,200	$ 388,000
	Charger:	$ 50,000	–
	Battery repl.	$ 58,000	–
	Energy/Fuel:	$ 13,200 annually	$ 37,600 annually
	Addl. mainten.	–	$ 2,500 annually
Lifetime:	NPC 17 years	-$ 739,000	-$ 758,000
	Difference	+$ 19,000 (E-bus is lower)	

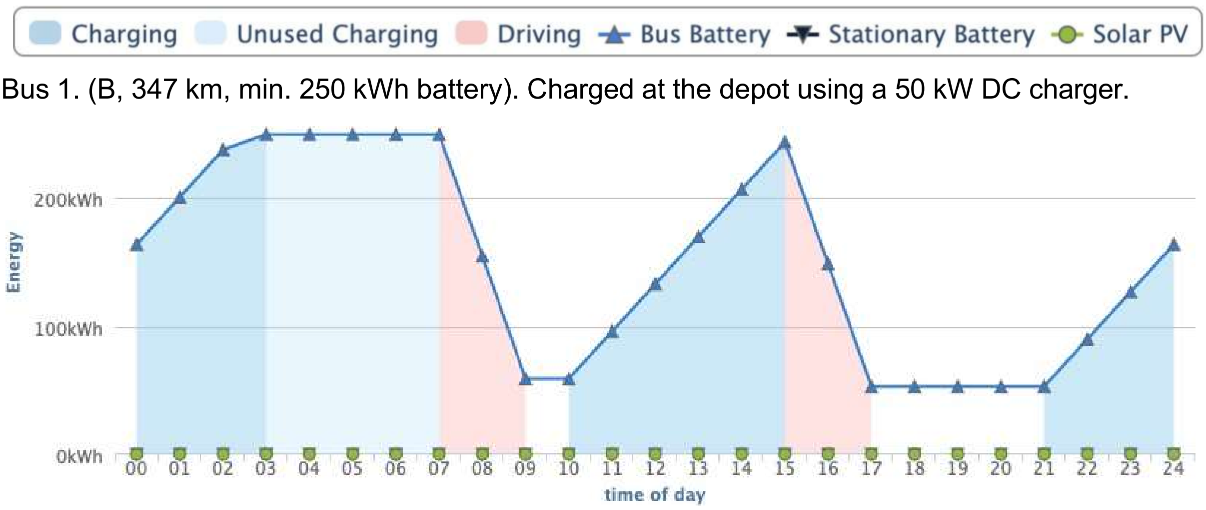


Figure 8-51 Narrogin, Narrakine Rd charging schedule

8.11.6. Narrogin Summary

The electricity supply at only one of the five depots would be insufficient to charge the two buses at that depot. However, the electricity supply at the schools is adequate to charge those two buses. At all four of the other depots, the electricity supply is sufficient to be able to charge the buses at those depots. Therefore, an efficient transition to e-buses would require the two buses currently garaged at the Havelock Street depot to be charged during the day and at night at schools. While that would involve the drivers of the buses from that depot to use alternative means of transport from the schools to the depot, the distances are all less than 2.5 km. The advantage is that those EV chargers could be made available to members of the public when not used to charge the school buses. Using the above strategy for charging the e-buses servicing schools in Narrogin would mean that no network upgrades would be required.

8.12. Case Study Summary

The case studies cover 11 towns with all of their 24 school bus depot sites. The studies have demonstrated that the transition of electric buses is feasible at all of these sites. For every case in this study there was sufficient power available either at the bus depot or at the serviced schools, so did not have to consider the inclusion of a stationary buffer battery or any grid augmentation with local generation through solar PV (although adding solar PV would be a good idea for any site). However, we should note:

- There were a few sites with unknown data, so we had to estimate these towns' grid connections from other sources.
- The selected 24 sites may not be representative of all connection scenarios. More detailed network connection studies for other sites might suggest that stationary batteries may be required there and could represent a more cost-effective solution versus augmenting the network.
- With the growing demand for electric energy and other EV charging stations for passenger vehicles, buses and trucks coming online, grid upgrades through the power utilities will most likely be necessary in the future.

The required bus battery sizes and charging systems cover the daily bus routes and are relatively small for almost all sites investigated. This means that cheaper electric buses with smaller than standard battery sizes can be selected. Bus operators wishing to undertake additional charter services or having greater flexibility in scheduling and charging of multiple buses can then opt to purchase larger batteries and higher-powered charging systems.

This investigation has highlighted that an electrified rural school bus service enables greater flexibility and new economic opportunities for regional and remote areas. Initial data from Western Power shows that there could be sufficient capacity available at many rural schools. More detailed studies would be required to confirm this via a formal connection application.

If confirmed, this would avoid expensive network upgrades at bus depots and would also avoid concentrating 'market power' into a small number of bus operators with the ability to afford major network upgrades and a secure tenure of the depot over long timeframes.

Although all cost values are estimates, our analysis has shown that the net present cost (NPC) for a 17-year electric bus service compared with a 17-year diesel bus service is of similar cost in most cases and even cheaper in several cases.

Our analysis shows that there is an attractive economic margin between converting electricity purchased/self-produced (5-30 c/kWh) to EV rapid charging services (50-60 c/kWh). The school e-bus operator maybe become the 'cornerstone investor' enabling such an EV charging investment over time, providing a much needed publicly available service in rural and remote areas on a commercial basis. The installation of additional EV charging and/or stationary batteries in regional areas can enable a better matching between electrical distribution network supply and demand, and enable other emergency services, such as power outages and/or evacuations during natural disasters.

If rapid EV chargers are located at the school grounds with satellite charging outlets both inside and outside school boundaries, these charging services have the potential to become a publicly accessible asset with a commercial return to a school or operator. Under this scenario, any contractor of a school e-bus can have priority for charging during school days, while the EV chargers will be available to the general public (locals and tourists) on weekends and during school holidays.

Appendix

A. Power Requirements vs Available Power

Location of Multible Buses	Number of buses	Power req. for all buses [kW]	Power req. Incl. extra tours [kW]	Electricity Provider	Meet Power req. for all buses	Meet Power req. Incl. extra tours
DAVENPORT, 13 Sylvan Wy	41	760	2129	Western Power	FALSE	FALSE
WANGARA, 89 Windsor Rd	16	279	782	Western Power	TRUE	FALSE
CENTENNIAL PARK, 17 Vine St	14	240	672	Western Power	FALSE	FALSE
NORTHAM, 11 Moore St	9	212	594	Western Power	FALSE	FALSE
MIDDLE SWAN, 416 Great Northern Hw	16	211	591	Western Power	FALSE	FALSE
MANJIMUP, 16 Crouch St	12	187	525	Western Power	TRUE	FALSE
GINGIN, 35 Weld St	6	153	429	Western Power	TRUE	TRUE
MOUNT BARKER, Lot 605 Mcdonald Av	9	145	407	Western Power	TRUE	FALSE
PINJARRA	9	140	391	Western Power	Unavailable	Unavailable
KOJONUP, 78 Pensioner Rd	11	134	376	Western Power	FALSE	FALSE
KARRATHA, 1941 Anderson Rd	5	124	349	Horizon Power	Unavailable	Unavailable
MARGARET RIVER, 21 Auger Wy	7	118	330	Western Power	TRUE	FALSE
FITZROY CROSSING, Lot 185 Bell Rd	7	116	325	Horizon Power	Unavailable	Unavailable
CHADWICK, 209 Harbour Rd	4	104	291	Horizon Power	Unavailable	Unavailable
BUSSELTON, 38 Cook St	7	101	282	Western Power	TRUE	TRUE
CHADWICK, 86 Norseman Rd	3	100	280	Horizon Power	Unavailable	Unavailable
MANDURAH	6	90	253	Western Power	Unavailable	Unavailable
TOODYAY, 25 Julimar Rd	6	90	252	Western Power	FALSE	FALSE
PARKERVILLE	5	88	247	Western Power	Unavailable	Unavailable
KAMBALDA WEST, 21 Solanum St	4	88	245	Western Power	TRUE	TRUE
MERREDIN, 4 Edwards St	5	87	245	Western Power	FALSE	FALSE
MOORA, Lot 18 Atbara St	6	83	232	Western Power	TRUE	TRUE
BOYUP BROOK, Lot 301 Railway Pde	7	79	220	Western Power	TRUE	FALSE
MARGARET RIVER, 13 Minchin Wy	6	75	210	Western Power	TRUE	FALSE
RAVENSTHORPE	4	75	209	Western Power	Unavailable	Unavailable
MERREDIN, Lot 2 South Av	3	74	206	Western Power	TRUE	FALSE
NARROGIN, 15 Lydeker Way	4	72	201	Western Power	TRUE	TRUE
DENMARK, Lot 981 Industrial Rd	3	70	197	Western Power	TRUE	FALSE
KATANNING, 28520 Great Southern Hw	4	64	180	Western Power	TRUE	TRUE
ESPERANCE, 86 Norseman Rd	2	63	175	Horizon Power	Unavailable	Unavailable
DERBY, 1 Sutherland St	4	60	169	Horizon Power	Unavailable	Unavailable
SEVILLE GROVE, 61 Champion Dr	5	59	165	Western Power	TRUE	TRUE
KUNUNURRA, 19 River Gum Av	5	58	163	Horizon Power	Unavailable	Unavailable
GLENFIELD, 628 Chapman Rd	4	57	160	Western Power	TRUE	TRUE
COCKBURN CENTRAL, 87 Hammond Rd	7	57	160	Western Power	TRUE	TRUE
COLLIE, 163 Hull Rd	4	56	157	Western Power	FALSE	FALSE
JERRAMUNGUP, 6 Bennett St	2	56	156	Western Power	TRUE	FALSE
LANCELIN, 35 Walker Ave	2	56	156	Western Power	TRUE	FALSE
Unkown	3	55	155	Western Power	FALSE	FALSE
WAROONA, 69 McLarty St	3	55	154	Western Power	TRUE	FALSE
JURIEN BAY, 3 Tern Wy	2	55	154	Western Power	TRUE	TRUE
QUAIRADING, 30 Dall St	5	55	153	Western Power	FALSE	FALSE
WEBBERTON, 155 Flores Rd	3	52	147	Western Power	TRUE	FALSE
CONDINGUP, Lot 2 Parish St	3	52	147	Horizon Power	Unavailable	Unavailable
ELLENBROOK	5	52	145	Western Power	Unavailable	Unavailable
NARROGIN, 62 Havelock St	2	52	145	Western Power	FALSE	FALSE
BUTLER	3	51	144	Western Power	Unavailable	Unavailable
NARROGIN, 6 Quigley St	4	51	144	Western Power	TRUE	FALSE
VASSE, 27 Northerly St	3	51	143	Western Power	TRUE	TRUE
PARKERVILLE, 125 McDowell Lp	3	50	141	Western Power	FALSE	FALSE

DENMARK, 9 Industrial Rd	2	50	140	Western Power	TRUE	TRUE
LAKE GRACE	4	50	139	Western Power	Unavailable	Unavailable
WELSHPOOL, 105-111 Ewing St	2	50	139	Western Power	TRUE	TRUE
HESTER, 11 Wandoo Wy	4	48	136	Western Power	TRUE	FALSE
DWELLINGUP	2	47	132	Western Power	Unavailable	Unavailable
BODDINGTON, Lot 8 Farmers Av	3	47	132	Western Power	TRUE	FALSE
BUSSELTON, 1 Kershaw St	2	46	128	Western Power	TRUE	TRUE
BELDON	6	44	123	Western Power	Unavailable	Unavailable
KATANNING, Lot 29 Warren Rd	2	43	120	Western Power	FALSE	FALSE
GERALDTON, 628 Chapman Rd	1	42	118	Western Power	TRUE	TRUE
TOM PRICE, 41 Bonderoo Rd	2	42	117	Rio Tinto	Unavailable	Unavailable
LAKE CLIFTON	2	40	113	Western Power	Unavailable	Unavailable
MUKINBUDIN, 8 Calder St	2	38	107	Western Power	TRUE	FALSE
NARROGIN, 47 Gibson St	2	38	105	Western Power	TRUE	TRUE
KING LEOPOLD RANGES, 21 Kupungarri	1	38	105	Unavailable	Unavailable	Unavailable
MANJIMUP, 39 Becker St	2	37	103	Western Power	TRUE	FALSE
MULUCKINE, 7756 Great Eastern Hwy	1	37	103	Western Power	FALSE	FALSE
PADBURRY	5	36	101	Western Power	Unavailable	Unavailable
CENTENNTIAL PARK, 17 Vine St	1	36	100	Western Power	TRUE	TRUE
SPRINGFIELD, Lot 37 River Gum Wy	2	35	99	Western Power	FALSE	FALSE
MARGARET RIVER, 19 Minchin Wy	4	35	98	Western Power	TRUE	TRUE
ARMADALE	5	35	97	Western Power	Unavailable	Unavailable
KENDENUP, 34 Harding Rd	2	35	97	Western Power	FALSE	FALSE
WOODRIDGE, 186 Nicklaus Av	1	34	96	Western Power	FALSE	FALSE
MORESBY, 28 Hill Creek Rd	1	34	94	Western Power	FALSE	FALSE
PINJARRA, 21 Fields St	2	34	94	Western Power	TRUE	TRUE
YORK, 10 Maxwell St	2	33	92	Western Power	TRUE	TRUE
COLLIE, Lot 2073 Collins St	2	33	92	Western Power	TRUE	TRUE
SOUTH BOULDER, 89-91 Chaffers St	2	32	91	Western Power	TRUE	TRUE
FITZOY CROSSING, Lot 185 Bell Rd	1	32	91	Horizon Power	Unavailable	Unavailable
STRATHALBYN, 9 Melaleuca Dr	1	32	90	Western Power	Unavailable	Unavailable
CHITTERING, 281 Hart Dr	1	32	90	Western Power	FALSE	FALSE
CORAL BAY, 19 Banksia Dr (Night)	1	32	89	Horizon Power	Unavailable	Unavailable
PERTH	3	32	89	Western Power	Unavailable	Unavailable
NARROGIN, 7 Grant St	2	32	89	Western Power	TRUE	FALSE
MORESBY, 9 Brockman Cl	1	32	88	Western Power	FALSE	FALSE
SERPENTINE	3	31	88	Western Power	Unavailable	Unavailable
WANNEROO, 23 San Rosa Rd	1	31	87	Western Power	TRUE	FALSE
DONNYBROOK, 9 Ramsay Tce	4	31	87	Western Power	TRUE	TRUE
LEDGE POINT	1	31	87	Western Power	Unavailable	Unavailable
NARROGIN, 85 Narrakine Rd	1	30	85	Western Power	TRUE	FALSE
CHADWICK, Lot 695 Effie Turner Dr	1	30	85	Horizon Power	Unavailable	Unavailable
NEERABUP, 10 Warman St	1	30	84	Western Power	TRUE	TRUE
PINGELLY, 2 Quartz St	3	30	84	Western Power	TRUE	FALSE
CLIFTON	2	30	83	Western Power	Unavailable	Unavailable
NORANDA	3	30	83	Western Power	Unavailable	Unavailable
WILLAGEE	4	29	83	Western Power	Unavailable	Unavailable
MERREDIN, 2 South Av	1	29	82	Western Power	TRUE	TRUE
BERESFORD, 15 Lorna St	1	29	80	Western Power	TRUE	TRUE
BRUCE ROCK, 72 Dampier St	2	29	80	Western Power	TRUE	TRUE
WYALKATCHEM, 75 Railway Tce	2	28	80	Western Power	TRUE	TRUE
CATTERICK, Lot 890 Wilga Rd	1	27	77	Western Power	FALSE	FALSE
LOWER CHITTERING, 231 Powderbark R	1	27	77	Western Power	FALSE	FALSE
MEELON	1	27	76	Western Power	Unavailable	Unavailable
KONDININ, 80 Cook St	1	27	76	Western Power	FALSE	FALSE
BUNBURY, 97 Forrest Av	3	27	76	Western Power	TRUE	TRUE
MULLEWA, 28 Gray St	3	27	75	Western Power	TRUE	TRUE
WILLYUNG, 20 Mallard Wy	1	27	74	Western Power	TRUE	TRUE

MANDURAH	2	26	74	Western Power	Unavailable	Unavailable
NORTHAMPTON, Lot 2124 Shea St	2	26	73	Western Power	TRUE	TRUE
AUSTRALIND, 3 Ditchingham Pl	2	26	73	Western Power	TRUE	TRUE
BLUFF POINT, 446 Chapman Rd	1	26	73	Western Power	TRUE	TRUE
PEMBERTON, 19 Blue Wren Ct	1	26	72	Western Power	FALSE	FALSE
BUSSELTON, 100 Strelly St	1	25	71	Western Power	TRUE	TRUE
BROOKTON, 86 Richardson St	3	25	71	Western Power	TRUE	TRUE
MORAWA, 10 Lodge St	1	25	70	Western Power	TRUE	TRUE
MIDDLE SWAN, 123 Albert Rd	1	25	70	Western Power	TRUE	FALSE
BEVERLEY, 106 Waterhatch Rd	1	25	70	Western Power	FALSE	FALSE
MIDVALE, 30 Rothschild Pl	1	25	70	Western Power	TRUE	TRUE
SPRINGFIELD, 52 Powderbark Lp	1	25	70	Western Power	TRUE	FALSE
LATHAM, 10 Britt St	1	25	70	Western Power	TRUE	TRUE
MCBEATH, Lot 23 Duncan Rd	1	25	70	Horizon Power	Unavailable	Unavailable
FRANKLAND RIVER, 176 Poison Hill Rd	2	25	70	Western Power	FALSE	FALSE
MORAWA, 11 Tilley St	1	25	70	Western Power	TRUE	TRUE
NORTHAM, 18 Dempster Rd	1	25	69	Western Power	TRUE	TRUE
KING LEOPOLD RANGES, Lot 34 Dodnun	1	25	69	Horizon Power	Unavailable	Unavailable
COODANUP	4	24	68	Western Power	Unavailable	Unavailable
BUSSELTON, 1 Artisan St	2	24	68	Western Power	TRUE	TRUE
BAKERS HILL, 201 Jose Rd	1	24	68	Western Power	FALSE	FALSE
WAGGRAKINE, 31 Mills Pl	1	24	68	Western Power	FALSE	FALSE
KELLERBERRIN	1	24	67	Western Power	Unavailable	Unavailable
RAVENSTHORPE, 17 Spence St	1	24	67	Western Power	TRUE	TRUE
DAVENPORT, 26 Major St	1	24	66	Western Power	TRUE	TRUE
DAMPIER PENINSULA, One Arm Point R	1	24	66	Horizon Power	Unavailable	Unavailable
SOUTH BUNBURY, 97 Forrest Av	2	24	66	Western Power	TRUE	TRUE
DALWALLINU, 27 Grant St (Night Depot	1	24	66	Western Power	TRUE	TRUE
DANDALUP	1	23	65	Western Power	Unavailable	Unavailable
KULIN, 119 Day St	2	23	65	Western Power	TRUE	TRUE
COOLUP	1	23	65	Western Power	TRUE	Unavailable
NAREMBEEN, 45 Currall St	1	23	65	Western Power	TRUE	TRUE
CUNDERDIN, 28 Cubbine St	2	23	65	Western Power	TRUE	TRUE
SCOTSDALE, 832 South Coast Hwy	2	23	64	Western Power	TRUE	TRUE
MUKINBUDIN, 65 Manuel Rd	2	23	63	Western Power	FALSE	FALSE
JARRAHDALE, 11 Johnson Rd	1	22	63	Western Power	TRUE	FALSE
WAROONA, 20 Sheridan Pl	1	22	63	Western Power	FALSE	FALSE
GERALDTON, 628 Chapman Road	1	22	63	Western Power	TRUE	TRUE
HOWATHARRA, 337 Hickety Rd	1	22	62	Western Power	TRUE	FALSE
KATANNING, 86 Mcleod St	2	22	62	Western Power	FALSE	FALSE
OLDFIELD, Loc 279 South Coast Hwy	1	22	62	Western Power	FALSE	FALSE
KULIN, 7 Bull St	1	22	62	Western Power	TRUE	TRUE
MIDDLE SWAN, 416 Great Northan Hw	1	22	62	Western Power	TRUE	TRUE
BALDIVIS, 831 Eighty Road	1	22	62	Western Power	TRUE	TRUE
YARLOOP	1	22	61	Western Power	TRUE	Unavailable
JERRAMUNGUP, 39 Derrick St	2	22	60	Western Power	TRUE	TRUE
MARGARET RIVER, 23 Auger Wy	2	21	60	Western Power	TRUE	TRUE
WILLIAMS, 10 Rosselloty St	2	21	60	Western Power	TRUE	TRUE
HARVEY, 283 Third St	1	21	59	Western Power	FALSE	FALSE
YORK, 9 George St	3	21	59	Western Power	TRUE	TRUE
MORAWA, Lot 230 Lodge St	1	21	59	Western Power	TRUE	TRUE
WARNBRO	3	21	59	Western Power	TRUE	Unavailable
LAKE CAMM, 1404 Broombush Flat Rd	1	21	59	Western Power	FALSE	FALSE
COLLIE, 16 Regent St	1	21	58	Western Power	TRUE	TRUE
BULLSBROOK, Lot 82 Ashton Rd	1	21	58	Western Power	TRUE	FALSE
LAKE GRACE, Lot 311 Mason St	1	21	58	Western Power	TRUE	TRUE
CANNING VALE	3	21	58	Western Power	TRUE	Unavailable
YERECOIN, Lot 7 Miling Rd	2	21	58	Western Power	TRUE	TRUE

NORTHAM, 18 Dempster St	1	21	58	Western Power	TRUE	TRUE
JARRADALE	1	21	58	Western Power	TRUE	Unavailable
THE VINES	1	21	58	Western Power	TRUE	Unavailable
BRABHAM	2	21	57	Western Power	TRUE	Unavailable
MUELLER RANGE, Lot 31 Yiyili Commun	1	20	57	Unavailable	Unavailable	Unavailable
CALINGIRI, 18 Harrington St	2	20	57	Western Power	TRUE	FALSE
CORRIGIN, 14 Campbell St	2	20	57	Western Power	TRUE	TRUE
CARNAMAH, 13 Forrester Av	2	20	57	Western Power	TRUE	TRUE
CLOVERDALE	4	20	57	Western Power	TRUE	Unavailable
YUNA, 6951 Chapman Valley Rd	2	20	57	Western Power	TRUE	TRUE
MINYIRR, 5/5 McDaniel Rd	1	20	57	Horizon Power	Unavailable	Unavailable
PARKWOOD	2	20	57	Western Power	TRUE	Unavailable
BINDOON, 6549 Great Northern Hwy	1	20	57	Western Power	FALSE	FALSE
DAWESVILLE	1	20	56	Western Power	TRUE	Unavailable
CUBALLING, 40 Colin St	1	20	56	Western Power	FALSE	FALSE
CORRIGIN, 56 Goyder St	2	20	56	Western Power	TRUE	TRUE
PERENJORI, 2892 Perenjori-Rothsay Rd	1	20	56	Western Power	FALSE	FALSE
MUNTADGIN, 33 Crossland St	1	20	55	Western Power	TRUE	FALSE
BEVERLEY, Lot 77 Waterhatch Rd	2	20	55	Western Power	TRUE	TRUE
BUNBURY, 13 Sylvan Wy	1	20	55	Western Power	TRUE	TRUE
MORANGUP, 228 Morangup Road	1	20	55	Western Power	FALSE	FALSE
SCADDAN, Lot 102 Griffiths Rd	1	19	54	Horizon Power	Unavailable	Unavailable
ALBANY, 13 Chevalier St	1	19	54	Western Power	TRUE	TRUE
MOSMAN PARK	2	19	54	Western Power	TRUE	Unavailable
LITTLE ITALY, 1723 Kulin-Holt Rock Rd	1	19	54	Western Power	FALSE	FALSE
WESTONIA, 54 Wolfram St	1	19	53	Western Power	TRUE	TRUE
NORTHAM, Lot 206 Crorkan Rd	1	19	53	Western Power	TRUE	TRUE
BEACON, 12 Kirby St	2	19	53	Western Power	TRUE	TRUE
WAGIN, 9 Nenke St	3	19	52	Western Power	TRUE	TRUE
CHADWICK, 86 Norseman Road	1	19	52	Horizon Power	Unavailable	Unavailable
MORAWA, 33 Solomon Tce	1	19	52	Western Power	TRUE	FALSE
JACUP, 27756 South Coast Hwy	1	19	52	Western Power	FALSE	FALSE
SOUTH BOULDER, 89 Chaffers St	4	18	52	Western Power	TRUE	TRUE
WEST RIVER, 3767 Koornong Rd	1	18	51	Western Power	FALSE	FALSE
PINJARRA, 2 Cox St	1	18	51	Western Power	TRUE	TRUE
GIBSON, 1523 Kentmont Rd	1	18	51	Horizon Power	Unavailable	Unavailable
BYFORD	2	18	51	Western Power	TRUE	Unavailable
BUSSELTON, 1 Kershaw Rd	1	18	51	Western Power	TRUE	TRUE
BEELIAR	2	18	51	Western Power	TRUE	Unavailable
NORTHAM, 11 Purkiss Dr	1	18	51	Western Power	FALSE	FALSE
BALDIVIS, 831 Eighty Rd	1	18	51	Western Power	TRUE	TRUE
BUSSELTON, 8 Kershaw St	1	18	51	Western Power	TRUE	TRUE
GRAMMAR	1	18	51	Unavailable	Unavailable	Unavailable
BENCUBBIN, 3233 Koorda-Bullfinch Rd	2	18	51	Western Power	FALSE	FALSE
BABAKIN, 15 Farrar St	2	18	50	Western Power	TRUE	FALSE
TOODYAY, 59 Fargo Wy	1	18	50	Western Power	TRUE	FALSE
KENWICK	2	18	50	Western Power	TRUE	Unavailable
PEMBERTON, 56 Blue Wren Ct	1	18	50	Western Power	FALSE	FALSE
BURLONG, 439 Northam Toodyay Rd	1	18	49	Western Power	FALSE	FALSE
MAIDA VALE, 10 Moonglow Ri	1	18	49	Western Power	TRUE	TRUE
KARLGARIN, 47 Federal St	1	17	49	Western Power	TRUE	FALSE
MOORA, Lot 200 Ferguson Rd	1	17	49	Western Power	TRUE	FALSE
WELLARD	2	17	49	Western Power	TRUE	Unavailable
GUILDFORD	1	17	48	Western Power	TRUE	Unavailable
DAVENPORT, Lot 26 Major St	1	17	48	Western Power	TRUE	TRUE
BEAGLE BAY	1	17	48	Horizon Power	Unavailable	Unavailable
BUSSELTON, 39 Albert St	1	17	48	Western Power	TRUE	TRUE
HAY, 36 Sea Change Cl	1	17	48	Western Power	TRUE	TRUE

PARABURDOO	1	17	48	Rio Tinto	Unavailable	Unavailable
EAST CARNARVON, 43 Holden St	2	17	48	Horizon Power	Unavailable	Unavailable
NANNUP, 104 Blackwood River Dr	1	17	48	Western Power	FALSE	FALSE
MALAGA, 150 Bellefin Dr	1	17	48	Western Power	TRUE	TRUE
LOWER CHITTERING, 254 Murray Grey	1	17	47	Western Power	FALSE	FALSE
MUKINBUDIN, 41 Shadbolt St	1	17	47	Western Power	TRUE	TRUE
BUSSELTON, Lot 61 Artisan St	1	17	47	Western Power	TRUE	TRUE
BADGINGARRA, 2 Butler St	1	17	47	Western Power	FALSE	FALSE
BOYUP BROOK, 19 Abel St	1	17	47	Western Power	TRUE	TRUE
MORAWA, 20 Dreghorn St	1	17	47	Western Power	TRUE	TRUE
BADGINGARRA, 1789 Bibby Rd	1	17	46	Western Power	FALSE	FALSE
ESPERANCE, 10 Hill St	1	17	46	Horizon Power	Unavailable	Unavailable
THREE SPRINGS, 35 Mayrhofer St	1	17	46	Western Power	TRUE	TRUE
NORTHAM, 17 Strickland Av	1	16	46	Western Power	TRUE	TRUE
WATTLE GROVE, Lot 49 Crystal Brook R	1	16	46	Western Power	FALSE	FALSE
HILL RIVER, Lot 9444 Cantabilling Rd	1	16	46	Western Power	TRUE	FALSE
SCOTSDALE, 9 Denmark-Mt Barker Rd	1	16	46	Western Power	TRUE	TRUE
PINJARRA, 199 Moores Rd	1	16	45	Western Power	FALSE	FALSE
NORTHAMPTON, 21 Hamersley St	2	16	45	Western Power	FALSE	FALSE
KATANNING, 102 Braeside Rd	1	16	45	Western Power	FALSE	FALSE
VARLEY, 2174 Pickernell Rd	1	16	45	Western Power	FALSE	FALSE
WAGIN, 8 Tasman St	2	16	45	Western Power	TRUE	TRUE
BUSSELTON, 62-66 Strelly St	1	16	45	Western Power	TRUE	TRUE
MUNSTER	1	16	44	Western Power	TRUE	Unavailable
RAVENSTHORPE, 24 Spence St	1	16	44	Western Power	TRUE	TRUE
NEDLANDS	1	16	44	Western Power	TRUE	Unavailable
BURRAN ROCK, 1115 Herbert Rd	1	16	44	Western Power	FALSE	FALSE
BEVERLEY, 77 Waterhatch Rd	1	16	44	Western Power	TRUE	FALSE
DARKAN, 8 Growden Pl	2	15	43	Western Power	TRUE	TRUE
GOSNELLS	3	15	43	Western Power	TRUE	Unavailable
CUNDERDIN, 28 Cubbine Rd	2	15	43	Western Power	TRUE	TRUE
BULLSBROOK, 67 Arborfield Wy	1	15	43	Western Power	TRUE	FALSE
MOOLIABEENEE, 60 Bridges Rd	1	15	43	Western Power	TRUE	FALSE
PICKERING BROOK, 65 Cunnold St	1	15	42	Western Power	TRUE	TRUE
BILINGURR, 12 Tanami Dr	2	15	42	Horizon Power	Unavailable	Unavailable
SOUTHERN CROSS, 68 Antares St	1	15	42	Western Power	TRUE	TRUE
GROVE	1	15	42	Western Power	TRUE	Unavailable
HYDEN, 6 Munday Lp	1	15	42	Western Power	TRUE	TRUE
PARKERVILLE, 695 Roland Rd	1	15	41	Western Power	TRUE	TRUE
CARNAMAH, 3 Macpherson St	1	15	41	Western Power	TRUE	TRUE
NANNUP, Lot 2 Boundary Rd	1	15	41	Western Power	TRUE	FALSE
KINGSLEY	2	15	41	Western Power	TRUE	TRUE
DOWERIN, 11 O'Loghlen St	1	15	41	Western Power	TRUE	FALSE
WAGGRAKINE, 54 Sutcliffe Rd	1	14	41	Western Power	TRUE	FALSE
COURTENAY, 431 Courtenay Rd	1	14	40	Western Power	TRUE	FALSE
NEERABUP, 11/21 Warman St	1	14	40	Western Power	TRUE	TRUE
DAVENPORT, 7 Major St	1	14	40	Western Power	TRUE	TRUE
ORANGE SPRINGS, 7127 Brand Highway	1	14	40	Western Power	TRUE	FALSE
NORTH DANDALUP, 356 Corio Road	1	14	40	Western Power	TRUE	FALSE
KATRINE, 6110 Northam-Toodyay Rd	1	14	40	Western Power	TRUE	FALSE
BERTRAM	1	14	40	Western Power	TRUE	TRUE
NANNUP, 337 Barrabup Rd	1	14	40	Western Power	TRUE	FALSE
CARNAMAH, 1 Macpherson St	1	14	39	Western Power	TRUE	TRUE
SCOTSDALE, 9 Denmark-Mount Barker	1	14	39	Western Power	TRUE	TRUE
NILGEN, 6 Banksia Way	1	14	39	Western Power	TRUE	FALSE
MINGENEW, Lot 2 Ernest St	1	14	39	Western Power	TRUE	TRUE
MCBEATH, 268 Duncan Rd	1	14	39	Horizon Power	Unavailable	Unavailable
MINGENEW, 4 Midlands Rd	1	14	38	Western Power	TRUE	TRUE

DOWERIN, 70 Stewart St	1	14	38	Western Power	TRUE	TRUE
CADOUX, 6142 Dowerin-Kalannie Rd	1	14	38	Western Power	TRUE	FALSE
HYDEN, 9 Naughton St	1	14	38	Western Power	TRUE	TRUE
CHITTERING, 356 Hart Dr	1	14	38	Western Power	TRUE	FALSE
NYABING, 8 Aspendale St	1	14	38	Western Power	TRUE	TRUE
LAKE GRACE, 8 Mason St	1	14	38	Western Power	TRUE	TRUE
CAPEL, 96 Capel Dr	1	14	38	Western Power	TRUE	TRUE
NAREMBEEN, 8 Northmore St	1	14	38	Western Power	TRUE	TRUE
KRONKUP, 41 Shelley Beach Rd	1	14	38	Western Power	TRUE	FALSE
CHIDLOW, 250 Cleaver St	1	13	38	Western Power	TRUE	FALSE
BRUCE ROCK, 2 Johnson St	1	13	37	Western Power	TRUE	TRUE
KENDENUP, Lot 4 First Av	1	13	37	Western Power	TRUE	TRUE
WICKEPIN, 22 Central Av	1	13	37	Western Power	TRUE	TRUE
BUNTINE, Lot 39 Nelson St	1	13	37	Western Power	TRUE	TRUE
DARLING DOWNS, 1304 Rowley Rd	1	13	37	Western Power	TRUE	TRUE
MUELLER RANGES, Kupartiya Communi	1	13	37	Unavailable	Unavailable	Unavailable
KEYSBROOK	1	13	37	Western Power	TRUE	TRUE
COOROW, Lot 86 Bristol St	1	13	36	Western Power	TRUE	TRUE
DOWERIN, 42 Cottrell St	1	13	36	Western Power	TRUE	TRUE
KALANNIE, 38 Locke St	1	13	36	Western Power	TRUE	TRUE
CASCADE, 5138 Griffiths Rd	1	13	36	Horizon Power	Unavailable	Unavailable
NEWDEGATE, 29 Collier St	1	13	36	Western Power	TRUE	TRUE
GOOMALLING, 8 Forward St	1	13	36	Western Power	TRUE	TRUE
PERENJORI, 135 Livingston St	1	13	36	Western Power	TRUE	TRUE
WELLSTEAD, 28 Windsor Rd	1	13	36	Western Power	TRUE	TRUE
KENSINGTON	1	13	36	Western Power	TRUE	TRUE
SHADFORTH, 42 Cussons Rd	2	13	35	Western Power	TRUE	TRUE
DUMBARTON, 6110 Northam-Toodyay	1	13	35	Western Power	TRUE	FALSE
GREENFIELDS, 5-9 Thornborough Rd	1	13	35	Western Power	TRUE	TRUE
TAMBELLUP, 135 Tambellup West Rd	2	12	35	Western Power	TRUE	FALSE
GNOWANGERUP, 6 Aylmore St	2	12	35	Western Power	TRUE	TRUE
BULLSBROOK, Lot 28 Kimberley St	1	12	35	Western Power	TRUE	TRUE
WAGIN, 51 Moore St	1	12	35	Western Power	TRUE	FALSE
WUNDOWIE, 23 Burma Rd	1	12	35	Western Power	TRUE	FALSE
BALLIDU, 63 Fairbanks St	1	12	34	Western Power	TRUE	TRUE
ROCKINGHAM	3	12	34	Western Power	TRUE	TRUE
BORDEN, 15 Moir St	1	12	34	Western Power	TRUE	TRUE
EXMOUTH, 38 Stokes-Hughes St	1	12	34	Horizon Power	Unavailable	Unavailable
HOPELAND	1	12	34	Western Power	TRUE	TRUE
GNOWANGERUP, 20 Whitehead Rd	1	12	34	Western Power	TRUE	TRUE
DONNYBROOK, 9 Ramsey Tce	1	12	34	Western Power	TRUE	TRUE
MANDURAH, 5-9 Thornborough Rd	1	12	34	Western Power	TRUE	TRUE
BREMER BAY, 12 Susan St	1	12	34	Western Power	TRUE	TRUE
LITTLE GROVE, 22 Paulas Wy	1	12	34	Western Power	TRUE	TRUE
RAVENSTHORPE, 11 Martin St	1	12	33	Western Power	TRUE	TRUE
ENEABBA, 380 King St	1	12	33	Western Power	TRUE	TRUE
MOUNT HELENA, 36 Chidlow St	1	12	33	Western Power	TRUE	TRUE
KUKERIN, 4 Scaddan St	1	12	33	Western Power	TRUE	TRUE
KATANNING, 18 Clive St	1	12	32	Western Power	TRUE	TRUE
SAWYERS VALLEY	1	11	32	Western Power	TRUE	TRUE
BUNGAREE	2	11	32	Western Power	TRUE	TRUE
BALLIDU, 81 Federation St	1	11	32	Western Power	TRUE	TRUE
FRANKLAND, Lot 122 Poison Hill Rd	1	11	32	Western Power	TRUE	FALSE
MINGENEW, 42 Linthorne St	1	11	31	Western Power	TRUE	TRUE
KALAMUNDA	1	11	31	Western Power	TRUE	TRUE
DUMBERNING, 119 Katta Rd	1	11	31	Western Power	TRUE	FALSE
WILLIAMS, 56 Millbrook Pl	1	11	31	Western Power	FALSE	FALSE
DALWALLINU, 982 Dalwallinu West Rd	1	11	31	Western Power	TRUE	FALSE

DARKAN, 34 Arthur St	1	11	31	Western Power	TRUE	TRUE
AVELEY	1	11	31	Western Power	TRUE	TRUE
NYABING, 72 Kuringup Rd	1	11	31	Western Power	TRUE	FALSE
MANNING	2	11	31	Western Power	TRUE	TRUE
TAKALARUP, 198 Cooper Rd	1	11	31	Western Power	TRUE	FALSE
DIANELLA	2	11	31	Western Power	TRUE	TRUE
MALYALLING	1	11	30	Western Power	TRUE	TRUE
GLEN IRIS, 1 Olive Ct	1	11	30	Western Power	TRUE	TRUE
NORNALUP, Lot 101 Macpherson Dr	1	11	30	Western Power	TRUE	FALSE
WILLIAMS, Lot 7 Growse St	1	11	30	Western Power	TRUE	TRUE
WONGAN HILLS, 34 Elphin St	1	11	30	Western Power	TRUE	TRUE
WICKEPIN, 48 Dumbleyung Rd	1	11	30	Western Power	TRUE	TRUE
MULLALOO	1	11	30	Western Power	TRUE	TRUE
PINJARRA, 30 Paceway Ct	1	11	30	Western Power	TRUE	TRUE
WELLSTEAD, Lot 4 Windsor Rd	1	11	30	Western Power	TRUE	TRUE
PEMBERTON, Lot 56 Blue Wren Ct	1	11	29	Western Power	TRUE	FALSE
DANDARAGAN, 3977 Dandaragan Rd	1	10	29	Western Power	TRUE	FALSE
COOROW, Lot 10498 Victoria St	1	10	29	Western Power	TRUE	TRUE
YORK, 8 Henry Rd	1	10	29	Western Power	TRUE	FALSE
MOORINE ROCK, Lot 65 Moorine South	1	10	29	Western Power	TRUE	FALSE
WUBIN, Lot 68 Woodhouse St	1	10	29	Western Power	TRUE	TRUE
ALEXANDER HEIGHTS	1	10	29	Western Power	TRUE	TRUE
BEVERLEY, Lot 77 Water Hatch Rd	1	10	29	Western Power	TRUE	TRUE
GOOMALLING, Lot 11 York Gum Dr	1	10	29	Western Power	TRUE	FALSE
MOORA, Lot 377 Melbourne St	1	10	29	Western Power	TRUE	TRUE
NORNALUP, 183 Conspicuous Beach Rd	1	10	29	Western Power	TRUE	FALSE
MERRIWA	1	10	29	Western Power	TRUE	TRUE
MARGARET RIVER, 13 Minchin Way	1	10	29	Western Power	TRUE	TRUE
KOORDA, 22 Lodge St	1	10	29	Western Power	TRUE	TRUE
NEWDEGATE, 11 Witham St	1	10	29	Western Power	TRUE	TRUE
SOUTHERN CROSS, 61 Taurus St	1	10	28	Western Power	TRUE	TRUE
BUNBURY, 97 Forrest Avenue	1	10	28	Western Power	TRUE	TRUE
LOWER KING, 213 Bushby Rd	1	10	28	Western Power	TRUE	FALSE
CASCADE, Lot 1 Beltana Rd	1	10	28	Horizon Power	Unavailable	Unavailable
MENZIES, 72 Gregory St	1	10	28	Horizon Power	Unavailable	Unavailable
COOMALBIDGUP, 1434 Ashdale Rd	1	10	28	Horizon Power	Unavailable	Unavailable
STAKEHILL	1	10	28	Western Power	TRUE	TRUE
MOUNT STIRLING, 2561 Kellerberrin-Yo	1	10	28	Western Power	TRUE	FALSE
BENNET SPRINGS	1	10	27	Western Power	TRUE	TRUE
MOUNT NASURA	1	10	27	Western Power	TRUE	TRUE
WALPOLE, 4 Miguel Pl	1	10	27	Western Power	TRUE	TRUE
ALLANOOKA, 4578 Erangy Spring Rd	1	10	27	Western Power	TRUE	FALSE
HAMILTON HILL	1	9	27	Western Power	TRUE	TRUE
HAZELMERE	1	9	27	Western Power	TRUE	TRUE
CARTMETICUP, 71 Hope Farm Rd	1	9	26	Western Power	TRUE	FALSE
BROOKTON, 122 Fancote Rd	1	9	26	Western Power	TRUE	FALSE
BECKENHAM	1	9	26	Western Power	TRUE	TRUE
WONGAN HILLS, 25 Wandoo Cr	1	9	26	Western Power	TRUE	FALSE
KULIN, 132 Day St	1	9	26	Western Power	TRUE	FALSE
NORTHCLIFFE, 384 Boorara Rd	1	9	26	Western Power	TRUE	FALSE
PINGRUP, 9 Sanderson St	1	9	26	Western Power	TRUE	TRUE
WOOGENELLUP, 3392 Woogenellup Rd	1	9	26	Western Power	TRUE	FALSE
PINGELLY, 22 Park St	1	9	26	Western Power	TRUE	TRUE
MOORA, 26 Bewsher St	1	9	26	Western Power	TRUE	TRUE
MOORINE ROCK, 500 Nulla Nulla Rd	1	9	26	Western Power	TRUE	FALSE
CAPE BURNEY	1	9	25	Western Power	TRUE	TRUE
KALGOORLIE, 67 Wortley St	1	9	25	Western Power	TRUE	TRUE
DENBARKER	1	9	25	Western Power	TRUE	TRUE

BULLSBROOK, Lot 28 Kimberly St	1	9	25	Western Power	TRUE	TRUE
HERNE HILL	1	9	25	Western Power	TRUE	TRUE
DUMBLEYUNG, 70 Absolon St	1	9	25	Western Power	TRUE	TRUE
BODDINGTON, 58 Bannister Rd	1	9	25	Western Power	TRUE	TRUE
LAKE GRACE, 1 School Pl	1	9	25	Western Power	TRUE	TRUE
WELLSTEAD, Lot 47 Sandalwood Rd	1	9	25	Western Power	TRUE	FALSE
YEALERING, 10 Dalton St	1	9	24	Western Power	TRUE	TRUE
MILING, Lot 5 Great Northern Hwy	1	9	24	Western Power	TRUE	FALSE
MADDINGTON	1	9	24	Western Power	TRUE	TRUE
SALMON GUMS, 133 Rogers Rd (Day)	1	9	24	Horizon Power	Unavailable	Unavailable
KALAMUNDA	1	9	24	Western Power	TRUE	TRUE
ONGERUP, 17 Lamont St	1	9	24	Western Power	TRUE	TRUE
WONGAN HILLS, 18 Ellis St	1	9	24	Western Power	TRUE	TRUE
HAWTHORN	1	9	24	Western Power	TRUE	TRUE
KWOBRUP	1	9	24	Western Power	TRUE	TRUE
DONNYBROOK, 43 Marmion St	1	8	24	Western Power	TRUE	TRUE
BEJOORDING, 39 Blackstone Rt	1	8	24	Western Power	TRUE	FALSE
BUNBURY, 17 Sturt St	1	8	24	Western Power	TRUE	TRUE
CENTENNIAL PARK, 15 Chevalier St	1	8	24	Western Power	TRUE	TRUE
BULLSBROOK, Lot 28 Kimberly Streeet	1	8	23	Western Power	TRUE	TRUE
BALDIVIS, 837 Eighty Rd	1	8	23	Western Power	TRUE	TRUE
GNOWANGERUP, 26 Mcdonald St	1	8	23	Western Power	TRUE	FALSE
MARTIN, 81 Station St	1	8	23	Western Power	TRUE	TRUE
WEST PINJARRA, 199 Moores Rd	1	8	23	Western Power	TRUE	FALSE
WAGIN, Lot 185 Vine Street	1	8	22	Western Power	TRUE	TRUE
KIARA, 82 Wheatstone Dr	1	8	22	Western Power	TRUE	TRUE
WAROONA, 113 South Western Hwy	1	8	22	Western Power	TRUE	TRUE
WEDGEFIELD, 9 Sandhill St	1	8	22	Horizon Power	Unavailable	Unavailable
GOOMALLING, 16 York Gum Dr	1	8	22	Western Power	TRUE	FALSE
KELLERBERRIN, 25 Moore St	1	8	22	Western Power	TRUE	TRUE
DAVENPORT, 6 Maxted St	1	8	22	Western Power	TRUE	TRUE
GOOMALLING, 28 York Gum Dr	1	8	22	Western Power	TRUE	FALSE
BULLSBROOK, 28 Kimberley St	1	8	22	Western Power	TRUE	TRUE
WUNDOWIE, 41 Gaden Rd	1	8	22	Western Power	TRUE	FALSE
WATTLE GROVE, 199 Crystal Brook Rd	1	8	22	Western Power	TRUE	TRUE
KULIN, 21 Price St	1	8	22	Western Power	TRUE	TRUE
JOONDALUP	1	8	22	Western Power	TRUE	TRUE
DUMBLEYUNG, 34 Taylor St	1	8	22	Western Power	TRUE	TRUE
LEDA	1	8	21	Western Power	TRUE	TRUE
KELMSCOTT, 5 Narrik Court	1	8	21	Western Power	TRUE	TRUE
ENEABBA, Lot 380 King St	1	8	21	Western Power	TRUE	TRUE
ARMADALE, 3 Brixey Ct	1	7	21	Western Power	TRUE	TRUE
BORDEN, 41 Moir St	1	7	21	Western Power	TRUE	TRUE
BINDOON, 85 Forrest Hills Pde	1	7	21	Western Power	TRUE	TRUE
KATANNING, 57 Arbour St	1	7	21	Western Power	TRUE	TRUE
CHADWICK, 15 Hill St	1	7	21	Horizon Power	Unavailable	Unavailable
NARRA TARRA, 74 Urch Rd	1	7	21	Western Power	TRUE	FALSE
BOYUP BROOK, 8 Bode St	1	7	21	Western Power	TRUE	TRUE
BEVERLEY, Lot 2947 Bally Bally Rd	1	7	21	Western Power	TRUE	FALSE
WESTMINSTER	1	7	20	Western Power	TRUE	TRUE
NEWDEGATE, 16 Mitchell St	1	7	20	Western Power	TRUE	FALSE
COOLBELLUP	1	7	20	Western Power	TRUE	TRUE
DARKAN, 158 Moodiarrup Rd	1	7	20	Western Power	TRUE	FALSE
TRAYNING, 158 Walker St	1	7	20	Western Power	TRUE	TRUE
MUNGLINUP, 61 Yorrel St	1	7	20	Horizon Power	Unavailable	Unavailable
WANDERING, 3 Michibin St	1	7	20	Western Power	TRUE	TRUE
GIRRAWHEEN	1	7	20	Western Power	TRUE	TRUE
PORT HEDLAND	1	7	20	Horizon Power	TRUE	TRUE

DONNYBROOK, Lot 1 Ramsay Tce	1	7	20	Western Power	TRUE	TRUE
CANNING VALE, 34 Mettler Ct	1	7	20	Western Power	TRUE	TRUE
CRANBROOK, 34 King St	1	7	19	Western Power	TRUE	TRUE
MILING, 12 Great Northern Hwy	1	7	19	Western Power	TRUE	FALSE
MANYPEAKS, Lot 465 South Coast Hwy	1	7	19	Western Power	TRUE	FALSE
DENMARK, Lot 58 Ocean Beach Rd	1	7	19	Western Power	TRUE	TRUE
NANARUP, 1207 Nanarup Rd	1	7	19	Western Power	TRUE	FALSE
THORNLIE	1	7	19	Western Power	TRUE	TRUE
WEBBERTON, 99 Flores Rd	1	7	19	Western Power	TRUE	TRUE
NORTHAMPTON, 52 Harvey Rd	1	7	19	Western Power	TRUE	TRUE
HAMMOND PARK	1	7	19	Western Power	TRUE	TRUE
PINGRUP, 40 Sanderson St	1	7	18	Western Power	TRUE	TRUE
WAROONA, 114 Invarell Rd	1	7	18	Western Power	TRUE	FALSE
BALLAJURA, 11 Larissa Ct	1	7	18	Western Power	TRUE	TRUE
ALLANSON	1	6	18	Western Power	TRUE	TRUE
MILPARA, 550 Albany Hwy	1	6	18	Western Power	TRUE	TRUE
AJANA, 180 Eastough Rd	1	6	18	Western Power	TRUE	FALSE
HOPETOUN, 15 Flinders St	1	6	18	Horizon Power	Unavailable	Unavailable
KARRATHA, Lot 1942 Anderson Rd	1	6	18	Horizon Power	Unavailable	Unavailable
LAVERTON, 15 Mikado St	1	6	18	Horizon Power	Unavailable	Unavailable
RIVERTON	1	6	17	Western Power	TRUE	TRUE
GERALDTON, 99 Flores Rd	1	6	17	Western Power	TRUE	TRUE
BRIDGETOWN, 7 Giblett Rd	1	6	17	Western Power	TRUE	TRUE
CUNDERDIN, 25 Main St	1	6	17	Western Power	TRUE	TRUE
BOORARA BROOK, 384 Boorara Rd	1	6	17	Western Power	TRUE	FALSE
MUNGLINUP, 12033 South Coast Hwy	1	6	17	Horizon Power	Unavailable	Unavailable
MOUNT CLAREMONT, Brockway Rd	1	6	17	Western Power	TRUE	TRUE
BOOKARA, 31565 Brand Hawy	1	6	17	Western Power	TRUE	TRUE
DAVENPORT, 33 Craigie St	1	6	17	Western Power	TRUE	TRUE
SUBIACO	1	6	17	Western Power	TRUE	TRUE
SOUTH LAKE	1	6	16	Western Power	TRUE	TRUE
BAYSWATER	1	6	16	Western Power	TRUE	TRUE
SOUTH FREMANTLE	1	6	16	Western Power	TRUE	TRUE
SCARBOROUGH	1	6	16	Western Power	TRUE	TRUE
SOUTH HEDLAND, 11 Egret Cres	1	6	16	Horizon Power	Unavailable	Unavailable
DANDARAGAN, Lot 3 Rose Valley Ct	1	6	16	Western Power	TRUE	TRUE
THORNLINE	1	6	16	Western Power	TRUE	TRUE
MOUNT HILL, 215 Fraser Rd	1	6	16	Western Power	TRUE	FALSE
LEEMING	1	6	16	Western Power	TRUE	TRUE
KEWDALE	1	6	16	Western Power	TRUE	TRUE
WANGARA, 74 Berriman Dr	1	6	16	Western Power	TRUE	FALSE
APPLECROSS	1	6	16	Western Power	TRUE	TRUE
TAMMIN, 9787 Shields St	1	6	16	Western Power	TRUE	TRUE
CAVERSHAM	1	5	15	Western Power	TRUE	TRUE
HALLS HEAD	1	5	15	Western Power	TRUE	TRUE
MEDINA	1	5	15	Western Power	TRUE	TRUE
TAMMIN, 18 Shields St	1	5	15	Western Power	TRUE	TRUE
BALGA	1	5	15	Western Power	TRUE	TRUE
KOJONUP, 78 Pensioner Road	1	5	14	Western Power	TRUE	TRUE
KULIN, 71 Day St	1	5	14	Western Power	TRUE	TRUE
DALWALLINU, 3 Wasley St	1	5	14	Western Power	TRUE	TRUE
KOONDOOLA, 38 Whitehouse Dr	1	5	14	Western Power	TRUE	TRUE
WICKHAM, 38 Oleander Pl	1	5	14	Rio Tinto	Unavailable	Unavailable
DAVENPORT, 25 Craigie St	1	5	14	Western Power	TRUE	TRUE
MIRRABOOKA, 5 Allspice Vs	1	5	14	Western Power	TRUE	TRUE
MECKERING, 86 Throssell St	1	5	14	Western Power	TRUE	TRUE
NANNUP, Lot 6 North St	1	5	14	Western Power	TRUE	TRUE
STIRLING ESTATE, 745 Ludlow Rd Nth	1	5	13	Western Power	TRUE	TRUE

CANNINGTON	1	5	13	Western Power	TRUE	TRUE
FORRESTFIELD	1	5	13	Western Power	TRUE	TRUE
NORTHCLIFFE, 46 Old Mill Rd	1	5	13	Western Power	TRUE	TRUE
AUGUSTA, 8 Oxley Pl	1	5	13	Western Power	TRUE	TRUE
WYNDHAM, 36 Koojarra St	1	5	13	Horizon Power	Unavailable	Unavailable
KARRATHA, Lot 1942 Anderson Road	1	5	13	Horizon Power	Unavailable	Unavailable
GAIRDNER, 1013 Devils Creek Rd	1	5	13	Western Power	TRUE	TRUE
EAST VICTORIA PARK	1	5	13	Western Power	TRUE	TRUE
BASSENDEAN	1	5	13	Western Power	TRUE	TRUE
KUKERIN, Lot 10 Scaddan St	1	4	12	Western Power	TRUE	TRUE
THREE SPRINGS, 40 Mayrhofer St	1	4	12	Western Power	TRUE	TRUE
SWAN VIEW	1	4	12	Western Power	TRUE	TRUE
PINJARRA, 6 Uldina Pl	1	4	12	Western Power	TRUE	TRUE
WOOROLOO, 63 Hovea Cre	1	4	12	Western Power	TRUE	TRUE
KUKERIN, 31 Scaddan St	1	4	12	Western Power	TRUE	TRUE
SOUTH PERTH	1	4	12	Western Power	TRUE	TRUE
BELMONT	1	4	11	Western Power	TRUE	TRUE
DONNYBROOK, 71 Collins St	1	4	11	Western Power	TRUE	TRUE
NOLLAMARA	1	4	11	Western Power	TRUE	TRUE
KENDENUP, 76 First Av	1	4	11	Western Power	TRUE	TRUE
LITTLE GROVE, 116 Bay View Dr	1	4	11	Western Power	TRUE	TRUE
BRIDGETOWN, 16 Bunbury St	1	4	11	Western Power	TRUE	TRUE
GNANGARA, 89 Windsor Rd	1	4	10	Western Power	TRUE	TRUE
CALINGIRI, 12 Cavell St	1	4	10	Western Power	TRUE	TRUE
BEECHBORO, 17 McAllister Way	1	3	10	Western Power	TRUE	TRUE
GREEN HEAD, 56 Grigson St	1	3	8	Western Power	TRUE	TRUE
MECKERING, 16 Knight St	1	3	8	Western Power	TRUE	TRUE
BEDFORD, 169 Rosebery St	1	3	7	Western Power	TRUE	TRUE
WILUNA, 132 Thompson St	1	3	7	Horizon Power	Unavailable	Unavailable
MULLALYUP, 20993 South Western Hwy	1	1	3	Western Power	TRUE	TRUE

DEPOT Location of Suggested Case Studies	Bus going to School Location:	Bus Energy Requirement [kWh] for all Combined Buses for a Particular Address	Annual (200 days) Depot Energy Demand [MW/h]	Required Power During Given Charge Time ALL Buses in Location [kW]	Average Power per Bus [kW]
Great Southern					
DENMARK, 9 Industrial Rd	Bethel Christ Sch	1686	337	120	24
	Denmark PS				
	Great Southern Gram Sch				
	Mount Lockyer PS				
	North Albany SHS				
	St Joseph's Coll - Albany				
	Tafe Gt Southern - Albany				
	Denmark PS				
	Denmark SHS				
WALPOLE, 4 Miguel Pl	Denmark PS	137	27	10	10
	Denmark SHS				
	Steiner - Golden Hill Sch				
	Walpole PS				
SCOTSDALE, 832 South Coast Hwy	Denmark PS	744	149	53	13
	Spirit Of Play Comm Sch				
	Steiner - Golden Hill Sch				
	Denmark PS				
	Woodbury Boston PS				
	Denmark PS				
	Denmark SHS				
SHADFORTH, 42 Cussons Rd	Denmark PS	176	35	13	6
	Denmark SHS				
DENMARK, Lot 58 Ocean Beach Rd	Denmark PS	96	19	7	7
	Denmark SHS				
Southwest:					
MANJIMUP, 16 Crouch St	East Manjimup PS	2592	518	185	15
	Kearnan Coll				
	Manjimup PS				
	Manjimup SHS				
MANJIMUP, 39 Becker St	Kearnan Coll	517	103	37	18
	Manjimup PS				
	Manjimup SHS				
MidWest:					
GREEN HEAD, 56 Grigson St	Leeman PS	42	8	3	3
MORAWA, 10 Lodge St	Morawa Dhs	352	70	25	25
FITZROY CROSSING, Lot 185 Bell Rd	Bayulu Rcs, Fitzroy Valley DHS	1624	325	116	17
Wheatbelt					
NARROGIN, 15 Lydeker Way	Narrogin PS	964	193	69	17
	Narrogin PS Kindy				
	Narrogin SHS				
	St Matthews Sch				
	Wa Coll Of Agri – Narrogin				
NARROGIN, 62 Havelock St	Narrogin SHS	726	145	52	26
	St Matthews Sch				
NARROGIN, 47 Gibson St	East Narrogin PS	508	102	36	18
	Narrogin PS				
	Narrogin PS Kindy				
	Narrogin SHS				
	St Matthews Sch				
NARROGIN, 7 Grant St	East Narrogin PS	446	89	32	16
	Narrogin PS				
	Narrogin PS Kindy				
	Narrogin SHS				
	St Matthews Sch				
NARROGIN, 85 Narrakine Rd	Narrogin SHS	424	85	30	30
	St Matthews Sch				
	Narrogin SHS				
	St Matthews Sch				
NORTHAM, 11 Moore St	Avonvale Esc PS	2972	594	212	24

	Northam PS				
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
NORTHAM, 18 Dempster Rd	Edmund Rice Coll - Cath Agri Coll Bindoon	303	61	22	22
NORTHAM, Lot 206 Crorkan Rd	Northam PS	267	53	19	19
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
	Northam PS				
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
NORTHAM, 11 Purkiss Dr	Avonvale Esc PS	254	51	18	18
	Avonvale Esc Sec Campus				
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
NORTHAM, 17 Strickland Av	Northam PS	230	46	16	16
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
	Northam PS				
	Northam SHS				
	St Joseph's Sch - Northam Jnr Campus				
	St Joseph's Sch - Northam Snr Campus				
Pilbara					
Port Hedland					
SOUTH HEDLAND, 11 Egret Cres	Cassia PS	81	16	6	6
	Hedland SHS				
Gascoyne					
CORAL BAY- 19 Banksia Dr (Night)	Exmouth Dhs				
EAST CARNARVON, 43 Holden St	Carnarvon Christ Sch	240	48	17	9
	Carnarvon Comm Coll – Marmion				
	St Mary Star Of The Sea Cath Sch				
Goldfields					
ESPERANCE, 86 Norseman Rd	Castletown PS	876	175	63	31
	Esperance Angl Comm Sch				
	Esperance PS				
	Esperance SHS				
	Nulsen PS				
	Our Lady Star Of The Sea Cath PS – Esp				
ESPERANCE, 10 Hill St	Esperance PS	231	46	17	17
	Esperance SHS				

B. Renewable Energy Generation

B.1. Solar Photovoltaics

Solar PV systems used at a specific electric school bus charging station site will need to be sized to provide the additional amount of electricity that needs to be supplied at the site. As solar radiation levels (kWh/m^2 per year) vary across WA, the actual size of the system (kW) required will depend on the site's geographical location.

The average annual specific outputs of solar PV systems across WA range from approximately 1,300 kWh/kWp per year in the south to 2,000 kWh/kWp in the Gascoyne and Pilbara regions (Figure B-1).

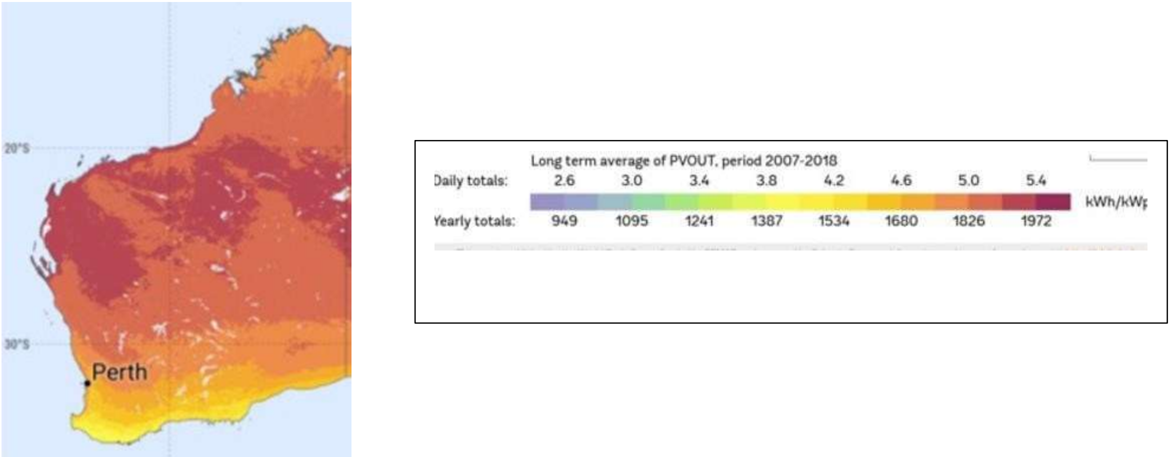


Figure B-1 Annual average specific solar PV output, Western Australia[1].

Based on annual average annual specific yields, a solar PV system in Albany would need to be larger (kWp) to produce the same amount of electricity per year than would a solar PV system installed in Port Hedland. However, when sizing solar PV systems, the usual practice is to base the calculations on the average monthly yield for the month with the lowest average monthly solar radiation rather than the annual average. For example, a 20 kWp solar PV system installed in Albany would produce 72% of the electricity per year that a 20 kWp system in Carnarvon would produce. But in June, the system in Albany would produce only 56% of the electricity that the system in Carnarvon would produce. To be able to provide the same amount of electricity in June as does the system in Carnarvon, the system in Albany would need to be almost twice as large.

It needs to be emphasised that actual PV system output depends on several factors other than the solar radiation levels at the site. Those factors include the efficiency of the make and model of the solar PV panels used, the efficiency of the make and model of the inverter(s) used, the tilt angle (from the horizontal), the orientation (degrees from true North) of the solar array, and the extent of any array shading or reflection. The optimisation calculation can be quite complex, and for this reason solar PV system design and output simulation optimisation software, such as HOMER Pro or PVSys, are used to determine the optimal sized solar PV system for a particular site.

[1] Source: https://solargis.com/maps-and-gis-data/download/australia

B.1.1. Installed Costs

Typical current installed costs of grid-connected solar PV systems, in urban and semi-urban areas, currently range from around \$1.30/W to around \$2.00/W for roof mounted systems and \$2.00/W to \$3.00/W for ground mounted systems. The installed costs of solar PV systems vary from one site to another and from one installer to another. The costs depend on the quality of the solar equipment used, the systems sizes, whether it is a roof mounted or a ground mounted system (ground mounted systems tend to be more expensive), the geographic location (installation costs are higher in non-urban areas due to travel and freight costs), the cable lengths from the solar array to the distribution board, whether the roof structure needs to be upgraded, whether the distribution board to which the system is connected needs to be upgraded or replaced, and the network connection costs.

The size of the solar PV system has a significant impact on not only the costs but also on the duration of the planning approval process. Both Western Power and Horizon Power require connection applications to be submitted before a system can be installed. The application fee and the length of time for the approval depend on the size of the proposed system, and the fees increase in a stepped fashion in line with the system size increments:

For systems > 30 kVA, an Early Enquiry fee of \$250 (+GST) and an Application Fee of \$5,000 apply. The application processing times are determined on a case-by-case basis but are typically 1 to 2 months for systems < 150 kVA.

The connection application fees for systems with solar inverter capacity > 150 kVA are an initial enquiry fee of \$3,500 plus GST, followed by an application fee of \$5,000 plus GST. The cost of any network study that is required is addition to the application fee and the fee amount depends on the location of the installation and the network complexities. The approval time can be over 6 months. The approval of larger systems may be contingent on incorporating additional equipment, such as network protection equipment, which can translate into significant additional costs.

B.1.2. Financial Incentives

In Australia solar PV systems with an installed capacity of 100 kW or less are eligible to claim small technology certificates (STCs). The number of STCs that the owner of a system is able to claim is based on the size of the system (kW), the year in which it is installed, and the zone in which the system has been installed. Although there can be significant differences in the actual specific annual yields (kWh/kWp per year) of systems installed in nearby locations, the Clean Energy Regulator uses four zones, based on postcodes (Figure B-2) to calculate the number of STCs that the owner of a system is able to claim. The value of the STCs is determined by the market. The current market price is approximately \$40.

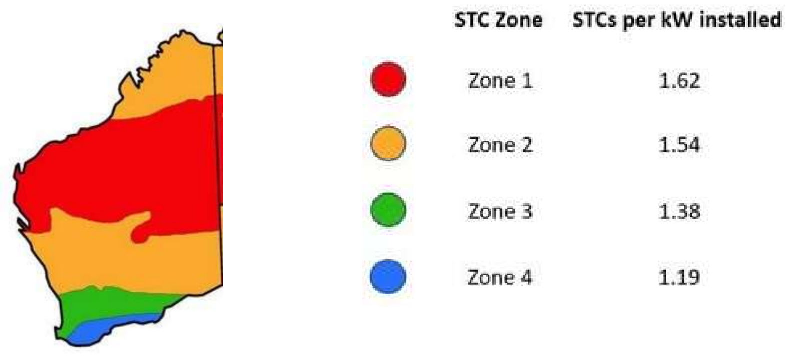


Figure B-2 Zones used to calculate Small Technology Certificates (STCs)[2].

[2] Source: https://www.solarchoice.net.au/learn/solar-rebates/solar-credits-and-rebates/

A 100 kWp system installed in Esperance (Zone 4) in June 2024 would be eligible for 820 STCs, which at today's STC price would be worth $32,800 (typically around 25% of the total installed cost). The same sized system installed in Karratha (Zone 1) at the same time would be eligible for 1,135 STC, which at today's prices would be valued at $45,400 (typically around 30% of the total installed cost).

The number of STCs that the owner of a system is eligible to claim is calculated on the deemed output of the system during the period from which it was commissioned to 2030 (the year in which the renewable energy target scheme is scheduled to end). For each year between 2023 and 2030 in which a system is installed, the number of STCs that the owner of the system is eligible to claim will decline. After 2030, the owners of small-scale renewable energy systems will no longer be able to claim STCs.

The owners of solar PV systems larger than 100 kW are not able to claim STCs but are eligible to claim Large Generation Certificates (LGCs). These are claimed in arrears and the number of LGCs that can be claimed is based on the metered output [3] of the solar PV system in the previous calendar year. The LGC spot price fluctuates over time. It reached a peak of $90/LGC in mid-2016 and a low of $27/LGC in mid-2020. At this stage, LGCs can be claimed annually up until 2030. The current (June 2024) spot price is $45/LGC.

Synergy's residential customers, as well as charitable or not-for-profit organisations, are also eligible to participate in its Energy Buy-Back Scheme. Customers earn 10 c/kWh for any excess electricity exported into the grid at rates during peak demand periods (3 pm to 9 pm) and 2.5 c/kWh during off-peak periods.

Synergy's larger (commercial and business) customers receive no payment for any excess electricity produced by their solar PV systems that is not used on site. The output of the solar PV system is either 'choked' so that no excess electricity is produced, or the excess electricity that is produced is exported into the grid but without compensation.

In the case of Horizon Power, the distributed energy buyback scheme (DEBS) buyback rate depends on the cost of generating electricity in the town and so is not one rate for all towns, but one of three rates. In towns such Beagle Bay, the current buyback rate is 55.99 c/kWh during peak periods and 16.80 c/kWh during off-peak periods. In towns such as Hopetoun, the current buyback rate is 37.76 c/kWh during peak periods and 11.66 c/kWh during off-peak periods. In larger towns or towns such as Esperance and Broome, and towns in which the hosting capacity has been reached, such as Carnarvon, there is no payment for any excess electricity fed into the grid[4].

Eligibility to participate in Horizon Power's energy buyback scheme is not limited to its residential customers. Under its Commercial Energy Buyback Scheme (COBS), customers with a system greater than 5 kW may be eligible for COBS provided that their systems meet any special conditions imposed by Horizon Power, and the buyback rate may need to be a negotiated rate.

B.1.3. Levelised Cost of Electricity

The levelised cost of electricity (LCOE) produced by small-scale solar PV systems depends on the installed cost per kW, the geographical location (and annual yield), the discount rate used to calculate the levelised cost, and the solar fraction (the percentage of the electricity produced by the solar PV system that is used on site). The average levelised cost of systems installed in Perth,

[3] Owners of renewable electricity generators can claim 1 LGC per MWh produced by the system in the previous calendar year.
[4] https://www.horizonpower.com.au/globalassets/media/documents/terms--conditions/hor160---commercial-buyback-scheme-cobs-terms-and-conditions_hr.pdf?v=4a04dc

taking into account the rebate, is between 8 c/kWh and 10 c/kWh, which is the lowest LCOE of all Australian capital cities. Investment in a solar PV system for customers on high tariffs is therefore an attractive option. The payback period for customers on Synergy's Home Plan (A1) tariff of 30.812 c/kWh, for example, would be around 2.5 years[5]. For larger contestable customers on tariffs around 10 c/kWh, investment in a solar PV system would be less attractive financially.

The maximum size of the inverter of a residential customer's solar PV system that can be connected to Western Power's network is 5 kVA. The Australian Standard for grid-connected solar PV systems[6] permits systems to be "over-panelled"[7] by up to 133%, meaning that the maximum size of the solar array connected to a 5 kVA inverter can be 6.65 kW. If the inverter has multiple maximum power point trackers (MPPTs), the solar array can be split into East and West facing arrays that would allow over 10 kW of solar PV panels to be connected to a 5 kVA inverter.

One of the important functions of solar PV system simulation software is to undertake a financial optimisation analysis to determine the system size and configuration that would provide the owner with the highest financial rate of return on the investment (payback period, ROI, etc.). The simulation analysis considers the site load, the site load profile, the electricity retail tariff and the amount (if any) that is paid by the customer's electricity retailer for any excess electricity that is exported into the grid.

B.1.4. Constraints on Solar PV Installation

The maximum size of the solar PV system that could be installed at a particular site may be constrained by factors such as limited available suitable roof area for a roof mounted system or limited available land area for a ground mounted system.

The network operator (Western Power or Horizon Power) may also impose size restrictions on the size (kVA) of a solar PV inverter that could be connected to its network due at the site due to either the local network capacity constraints and/or the existing number of solar PV systems connected to the network in that area.

In the case of Horizon Power networks, Horizon Power has set limits ('the hosting capacity') on how much solar PV the electricity system in the supply area is able to accommodate. In those supply areas in which the hosting capacity has already been reached, Horizon Power no longer approves further applications to connect solar PV systems. In some of its other supply areas, Horizon Power requires new solar installations to incorporate Feed-In Management (FIM) capabilities ('solar smoothers'), which essentially means a capacity to control the maximum rate at which the solar PV system ramps up or down.

B.1.5. Emission Reductions

The emission reductions achieved by replacing diesel buses with electric buses will depend on many factors, including the size of the bus (seating capacity), the route lengths, air conditioning loads, and the source of the electricity used for charging the batteries of the electric

[5] Australian Energy Council (2021). Solar Report: Quarter 2, 2021. https://www.energycouncil.com.au/media/cz3fz3je/australian-energy-council-solar-report_q2-2021.pdf
[6] AS/NZS 5033.2021
[7] Over-panelling means that the peak capacity of the solar PV array (kWp) is greater than the capacity of the inverter (kVA)

buses. However, charging electric buses using electricity supplied from any electricity supply network in WA network will result in a reduction in vehicle emissions, as the emission factors of all electricity supply systems in WA are not high.

By how much the GHG emissions will be reduced will depend on the emission factor of the electricity supplied from the grid that is used to charge the batteries of the electric buses. In the case of the SWIS, the emission factor for the year 2022/23 was 0.51 kg CO_2-e/kWh. The Scope 2 emissions of diesel fuel are 2.71 kg CO_2-e/L. Using those figures in an example, if a diesel bus has a fuel consumption rate of 25 L/100 km, it would produce Scope 2 emissions of 67.75 kg CO_2-e per 100 km. If an electric bus has an energy consumption rate of 80 kWh/100 km and the electricity used for charging the batteries is supplied from the SWIS, the current Scope 2 emissions produced by the electric bus would be 40.8 kg CO_2-e/100 km. In this example, replacing the diesel bus with the electric bus would result in a reduction in GHG emissions of approximately 40%[8].

Three things need to be borne in mind when calculating the reduction in GHG emissions. The first is that the emission intensity of the SWIS grid has declined steadily over the past two decades and is forecast to continue to decline steadily over the coming decades as new large windfarms and solar farms are installed, and as the number and sizes of smaller distributed solar PV systems continues to increase. The GHG emission reductions by replacing a diesel bus with an electric bus and charging the electric bus using electricity supplied from the SWIS will steadily improve over time.

The second point is that GHG emission factors vary from one network to another. The emission factors of electricity supplied from Horizon Power’s networks will be different to the emission factor of electricity supplied from the SWIS. They will also be different for each of Horizon Power’s supply networks. However, they will all decline over the coming years due to clean energy technologies becoming increasingly the lowest cost form of electricity generation.

The third point is that using electricity supplied from a solar PV system to charge an electric bus will result in zero emissions in the case of the electric bus. But there will be a net reduction in emissions relative to charging the electric bus from the grid only if the electricity used for charging the electric bus is not displacing other uses of the electricity that are subsequently met by electricity supplied from the grid. That is, for electricity produced from a solar PV system used to charge and electric bus to result in a reduction in emissions relative to charging the bus using electricity supplied from the grid, the solar PV system would need to be an additional rather than a pre-existing solar PV system. Finally, market mechanisms exist (such as buying LGCs) that enable 100% certified renewable energy to be purchased to meet any future GHG emissions target.

B.1.6. Off-Grid Solar Photovoltaic Systems

Historically, electricity in off-grid areas was often supplied by diesel generation, and they remain the dominant type of generation technology used for larger operations such as mine sites. However, solar PV systems are now commonly used alongside the diesel generators as a means of reducing diesel fuel use. As diesel costs increase and PV systems and battery costs decline, most systems currently being installed are solar PV systems with battery energy storage that use the diesel generators as back-up only (*Figure B-3*).

[8] This quick calculation does not consider the electrical loses in battery charging and therefore overestimates the reduction in GHG emissions.

A requirement included in the Australian Standard for the design of stand-alone power (SPS) systems, AS/NZS 4509, is for the system to have a minimum of three-days autonomy. That is, the capacity (kWh) of the energy storage system needs to be able to cover at least three days of low solar insolation (due to cloud cover, etc.). That can be achieved either by increasing the size of the energy storage system (which requires the size of the solar PV array to also be increased) or using a backup petrol or diesel generator. As with grid-connected solar PV systems, engineering simulation software is used to optimise the sizes of the energy storage, solar PV array and backup generator.

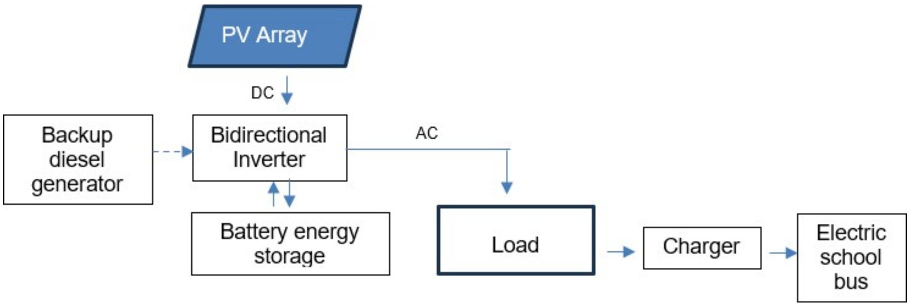


Figure B-3 Stand-Alone Power System (SAPS).

The levelised cost of electricity supplied from a stand-alone power supply system vary widely from one system to another. It also depends on the discount rate used in the calculation. As an example, the LCOE of an SPS system consisting of a 10 kW solar PV array, battery energy storage and inverter with no diesel backup generator would be approximately 18.3 c/kWh at a discount rate of 4%, and 24.7 c/kWh using a 10% discount rate. By comparison, a diesel generator supplying the same amount of electricity would have a LCOE of 53 c/kWh at a 4% discount rate, and 33.5 c/kWh using a discount rate of 10%[9].

SAPS supply electricity at a lower cost than the cost of electricity supplied from a grid taking into account the connection costs of connecting a site to the network. However, in WA if a site is already connected to the network, the tariff that the retailer charges for the electricity supplied from the grid will be lower than the cost of electricity produced using a solar-battery stand-alone power supply system as the former is cross-subsidised through the uniform tariff policy. Therefore, stand-alone power supply systems would be a viable option for charging electric school buses in only the very small number of cases in which the school bus garaging site is off grid. They may, however, also be an option for sites currently connected to a network but for which the network upgrade costs would be high enough to render investment in a SAPs a viable option.

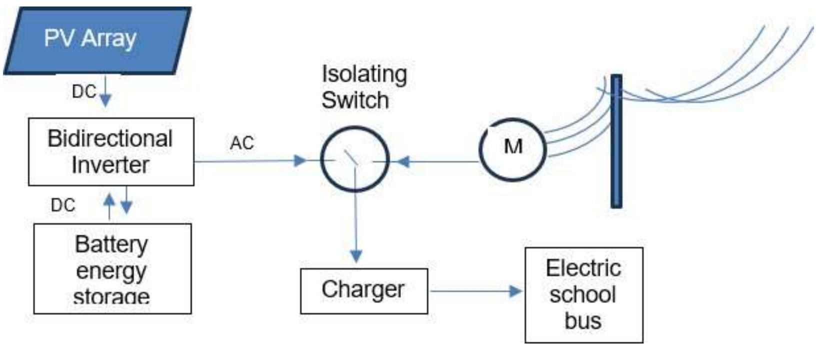


Figure B-4 Hybrid 'either / or' power supply configuration.

[9] https://www.gses.com.au/system-economics-stand-alone/

A hybrid solution that is increasingly being installed is to have a stand-alone power supply system in combination with but separate to grid connection (Figure B-4).

The most common hybrid solution would consist of a solar PV system coupled with battery energy storage on the one side and the grid on the other. No backup generator would be required. Provided that the solar + battery energy storage system is not connected to the grid, no network connection application is required, thereby avoiding costs and installation time delays.

The site load is connected to either stand-alone power supply system or to the grid, an EITHER/OR configuration that is controlled by switching between the two supply options. For example, an electric school bus could be supplied by the solar PV system / battery to charge the bus batteries during peak electricity demand periods and be suppled from the grid during off-peak electricity demand periods.

Switching between the grid and the stand-alone power system could be undertaken either manually or automatically. If undertaken manually, it requires all loads to be turned off, the switching to occur, and then turning the loads back on again, For the switching to be undertaken automatically, the bidirectional inverter needs to have the functionality of a grid-tie or grid-interactive inverter. Such an inverter has the ability to seamlessly synchronise with the grid by matching the grid voltage, and that the current and voltage are in phase with each other, and that the switching from one supply option to the other occurs within half a cycle of the AC power. Inverters with this capability are now becoming more available.

B.2. Small Wind Turbines

Small wind turbines (SWTs) represent another small-scale distributed renewable electricity generation technology option that has the potential to be used on suitable sites to produce electricity for charging electric school bus batteries. WA has some of the best wind resources in the world, primarily located in the south- western and southern coastal regions, but some inland in areas (*Figure B-5*).

However, relying on *Figure B-5* as a guide for the potential for using SWTs in WA would be misleading. While it suggests that there are many sites in WA that would be suitable for the installation of SWTs, for several reasons the actual number of sites at which the installation of a SWT large enough to supply the electricity required for electric bus battery charging would be viable is relatively constrained.

Constraints on Small Wind Turbine Installation

(i) Wind turbine hub height
The wind power density map shown in *Figure B-5* indicates wind power densities at a height of 100 m above ground level. Average wind speeds tend to increase rapidly with the height above the ground [10]. The wind flow is also more laminar as the height increases. A small wind turbine installed at a site is therefore highly likely to have a

[10] The wind resource map in Fig. X3 is the average wind speed at a height of 100 m above the ground.

significantly lower capacity factor[11] than would a large wind turbine with a large hub height installed at the same site.

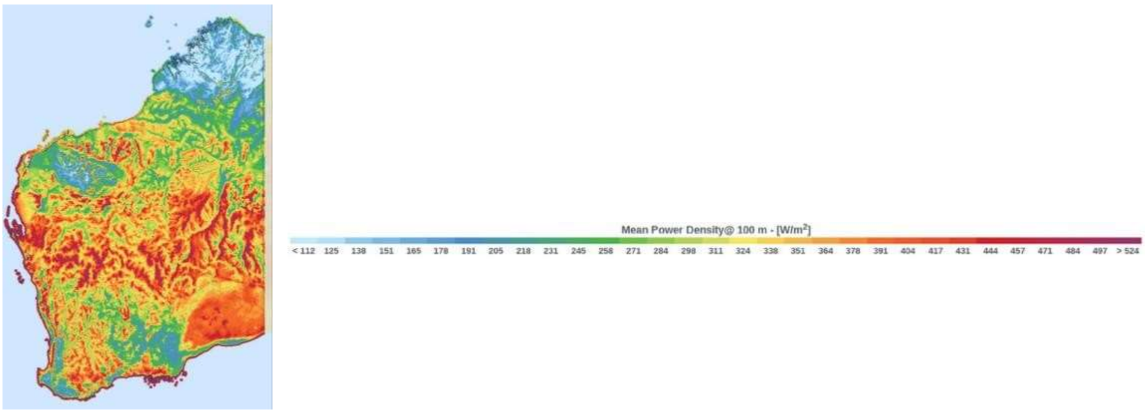


Figure B-5 Wind power density (W/m^2) at 100 m height above ground level[12].

(ii) Local topography
The local topography and local terrain features, such as nearby hills, trees, buildings, and surface roughness, all have a major influence on the wind speed and the wind variability in a particular area. The lower the hub height, the greater the impact those factors have. Unlike a distributed solar PV system, a detailed assessment of a specific site's wind resource would be required to assess the actual suitability of the site for the installation of a small wind turbine.

(iii) Planning approvals
Wind turbines can have negative visual, noise and other impacts, such as causing flicker effects on TV reception. For this reason, local councils tend not to approve proposals to install SWTs in built up (urban or semi-urban) areas.

(iv) Installed costs
The installed cost of SWTs depends on the type of wind turbine, the make and model of the wind turbine, the turbine's nameplate capacity (kW), and the installation location. The cost of a 15 kW SWT with a 15 m tower can range from $32,000 to $80,000. The installed cost can range from $40,000 to $120,000[13]. Assuming a capacity factor of 40% (i.e. a very high wind resource site), the turbine would produce around 6,000 kWh/year or 90,000 kWh over a 15-year working life, and the undiscounted levelised cost or electricity (ignoring maintenance costs) would range from $0.44/kWh to $1.33/kWh. For investment in a SWTs in WA to be a financially viable option, the site's wind resources would need to be exceptionally high.

(v) The wind speeds at a site tend to be highly variable, both in the short term (minutes) and over the course of a 24-hour period. In many locations, the wind speeds are greatest during the night. Depending on the site load profile, this may be either an advantage or a disadvantage. For nighttime charging of the batteries of the electric school buses, it would be an advantage.

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[11] Capacity factor is defined as the ratio of the total actual energy produced or supply over a definite period (usually a year), to the energy that would have been produced if the plant (generating unit) had operated continuously at the maximum or its nameplate rating.
[12] Global Wind Atlas online website, Technical University of Denmark. https://globalworldatlas.info
[13] https://www.skystreamenergy.com/how-much-does-a-15-kw-wind-turbine-cost/

A second factor that limits the potential role of SWTs in supplying the electricity required for charging electric school bus batteries is their installed cost. The installed cost of SWTs depends on the type of wind turbine, the make and model of the wind turbine, the turbine's nameplate capacity (kW), and the installation location. The cost of a 15 kW SWT with a 15 m tower can range from $32,000 to $80,000. The installed cost can range from $40,000 to $120,000[14]. Assuming a capacity factor of 40% (i.e. a very high wind resource site), the turbine would produce around 6,000 kWh/year or 90,000 kWh over a 15-year working life, and the undiscounted levelised cost or electricity (ignoring maintenance costs) would range from $0.44/kWh to $1.33/kWh. For investment in a SWTs in Western Australia to be a financially viable option, the site's wind resources would need to be exceptionally high.

The constraints listed above are the reason that so few SWTs have been and are being installed in WA. As an example, Western Power's stand-alone power systems (SPS) scheme involves removing selected distribution lines supplying rural customers and using stand-alone power supply systems to supply the customers' requirements. Western Power plans to install up to 4,000 SPS units over the next decade[15]. Of the 150 units that have been installed to date, all are solar-battery systems with diesel backup, and none have incorporated a SWT.

[14] https://www.skystreamenergy.com/how-much-does-a-15-kw-wind-turbine-cost/
[15] https://westernpower-website-pre-production.azurewebsites.net/our-energy-evolution/grid-technology/stand-alone-power-system/

C. Stakeholder Interviews

For this project, representatives from several key stakeholder organisations were interviewed and an information session for school bus operators was held.

Representatives from the following stakeholder organisations were interviewed:

Government
- Department of Transport
- Department of Education
- Public Transport Authority

Energy Utilities
- Western Power
- Horizon Power

Large Operators of School Buses and Tourist Buses
- Swan Transit
- Aus Transit
- Keolis Downer
- Go West Tours

Small Operators and Drivers of School Buses
- Several operators statewide
- Bus drivers in the Albany/Denmark area

Charging Station and Services Suppliers
- EV-NRG
- Wevolt
- AMPD
- Elanga
- Blue Diamond
- FreeWire
- Several others via personal communication.

C.1. Government and Energy Utilities

This study analysed all 935 PTA school buses under PTA contract. Since several schools operate their own buses in addition to the PTA contracted school bus services, the option of including their bus operations into this study was raised and discussed. Since school-owned buses do not have a regular schedule, it was decided to exclude them in this overall study of all 935 PTA school buses.

Western Power has been very engaged in this study and WP representatives met with our team on several occasions. We have received data on the available grid power levels for all school bus sites within the SWIS. Horizon Power was also able to provide power data for most of the case study sites in their distribution area.

C.2. Large School Bus Operators

Most school bus operators we talked to were very open to the introduction of electric buses. Many had simple pragmatic questions regarding general concerns about electrification and charging technology, and electric bus reliability/safety. Several of them asked if and how soon they could apply for an e-bus trial in their fleet.

Swan Transit is the only WA bus operator that already has experience with electric buses – although not in a school bus service – through its trial of four electric CAT buses in Joondalup as part of the Transperth system. Swan Transit has advised that their experience with these electric buses so far has been very positive, especially in the reduced operating cost due to the elimination of diesel and AdBlue cost versus cheaper electricity and the reduced maintenance cost.

C.3. Small School Bus Operators

Interviewing bus owners/drivers was revealing at the diversity of responses and levels of understanding of the benefits, costs, complexities and simplicities associated with school diesel bus fleet electrification. Several interesting observations and insights were provided. Firstly, interviewee responses demonstrated a very limited understanding of electric bus capabilities, and technical components of both the bus and the supporting charging infrastructure needed. Similarly, many respondents expressed concern about the probability of significantly higher purchase costs of e-buses, and the potential for limited availability and timeliness of servicing and spare parts in rural and remote areas. Some bus owners/drivers were excited about the opportunities that e-buses present, including lower maintenance costs and simplifying issues around fuel additives. Some interviewees were familiar with advantages of passenger vehicle electrification and were very interested to understand if e-busses presented comparable opportunities to lower the lifetime total operational costs. Of lesser concern to the respondents was the capacity of electrification of buses to reduce greenhouse gas emissions.

There was considerable interest amongst responders in providing safer and healthier transport services for children and drivers, including how fleet electrification could enhance or limit emergency responses to accidents, electricity service disruptions, and bushfires (as many busses are on-call for town evacuation). Importantly, bus owner/drivers have an unprecedented level of understanding of practical considerations of how conventional diesel busses are operated and maintained in a safe manner, and ideas and opportunities for improving both efficiency and safety. There was great interest in how an e-bus would compare in terms of practical advantages/ disadvantages and how these might be harnessed/managed in rural and regional areas.

The following section outlines technical and practical considerations arising from interviewing bus owners and drivers about the perceived advantages, disadvantages, and potential technical and contractual solutions to successfully transition towards a net zero school bus fleet.

C.4. Owner/Driver Technical and Practical Perspectives

The lack of familiarity of most bus owners about e-buses became apparent from the diversity of post-interview feedback and queries received. It was clear that bus owners and drivers had considerable experience and understanding of diesel engine and of bus servicing and fuelling requirements, they had very limited understanding of e-buses and electricity network services available in their location.

Interviewee responses clarified that there is a lot of misinformation surrounding vehicle electrification and their supporting technologies. Understandably, there were many technical uncertainties and questions from bus drivers and owners in relation to all aspects of school bus fleet electrification. Of importance was the question of how e-busses perform on gravel roads. Owners noted that modern sensors and electronics of newer diesel busses perform poorly on gravel routes and are an increasingly costly concern. This was not the case in older diesel busses with simpler electronics.

Most interviewees did not know the maximum electricity demand or the number of phases available at the location where they park their bus(es). Similarly, the area of available roof area for any PV system at the depot or place where buses were parked was largely unknown. The majority of queries received in relation to e-buses were straightforward to answer: maximum bus speeds; driving distances; how many students on an e-bus; how long will it take to charge; how much power is needed; what happens in the event of an electricity outage; how will an e-bus be serviced; etc. In most cases we could answer the technical questions directly within certain bounds of certainty based on manufacturer and existing e-bus trial data. This allayed most concerns and gave confidence to interviewees that technical solutions are available at present. We were able to discuss the different types of e-buses becoming available soon, nuances around e-bus charging and supporting technology, and the wide range in choice of the various technologies available.

One interviewee noted that if e-buses can enable technical data gathering that improves transparency of actual kms travelled, this can foster ‘transparency/trust’ and enable cost-reflective payments to operators via the PTA. The authors note that this might be as simple as automated energy consumption and GPS data transfer from the bus and charger data to reduce the administrative burden of both parties. Such examples could also be a simple means to enable/distinguish between PTA-related contractual obligations and numerous ‘other services’ that may arise over longer time horizons for e-busses (including additional charter tours or emergency services). It may even enable accounting for future services e-buses may enable, such as grid-connected PV export demand matching, frequency control ancillary services, demand supply management payments, electricity storage capacity market services, and vehicle to grid/load.

C.5. Learnings from Driver/Owner Interviews

Bus driver/owners were concerned about the relative immaturity of the e-bus market, charging infrastructure, and the changing nature of how electricity utilities are changing their business models. Also of note was the fluctuating priorities of successive governments in WA in relation to climate change and emission reduction policy. Outside of sovereign risks, bus owners pointed out there are likely to be rapid price declines of both e-buses and charging technologies in the next few years. The authors note that this issue requires policymakers to contemplate how ‘early adopters’ of e-buses may need to be compensated for lower residual value relative to diesel buses.

Bus driver owners/drivers highlighted the difficulty of estimating total lifecycle financial costs of each new technology and how capital and operating costs would change overtime. There were many questions associated with the many ways in which bus electrification could change their investments/contracts compared to the status quo. Of considerable concern was the expected higher capital cost of the busses that are currently funded by the contract holder. This can be contrasted with the expected time and financial savings of e-busses relative to the considerable time and administration associated with maintaining diesel vehicles and their associated fuel emission requirements (AdBlue, etc.). These considerable cashflow changes would likely impact on the bus contract value, and the corresponding influence on the livelihoods of owners/drivers, and supporting service industries that specialise in internal combustion engine repair and maintenance. The bus owners noted that the expected lower costs of charging an e-bus relative to diesel costs meant the PTA could see a significant saving in fleet electrification.

The authors would like to clarify that the eligible diesel fuel costs paid by the bus owners that are re-imbursed by the PTA gives the WA Government flexibility in re-allocating taxpayer funds from purchasing diesel towards EV charging solutions. This flexibility could enable significant creativity in how different WA departments could work together to lower the overall cost of transport electrification and electricity network emission factor reduction. For example, the lowest cost generation technology in many places on the WA electricity network is solar PV. Schools often install PV to lower electricity bills, and the schools are also the terminus of every school bus. Schools also have suitably large roofs on which to install considerable amounts of PV capacity.

Furthermore, WA schools have some of the best grid connection infrastructure throughout WA's rural regional areas. The combination of these characteristics alongside schools often being located near major roads make schools a highly prospective location to install additional EV/PV/battery/charging infrastructure that could become publicly available in each rural and regional town.

In relation to schools becoming a de-facto bus 'depot', it was clear from the interviews that bus depots are often informal or short-term leased arrangements. They often do not provide certainty for private investment in grid upgrades, on-site PV or battery investments, or fast charging services to either private bus operators or the public. Therefore, there was great interest in the development of a shared/public charging option/services where all school busses could be charged, regardless of the depot. This would remove one significant uncertainty in the bus contracts changing. Interestingly, bus owners themselves often noted schools could become a logical 'depot' for all buses regardless of electrification.

The authors analysis shows a significant opportunity to demonstrate effective reductions in clean energy costs and emissions while improving regional EV charging services. Interviewees noted that the increasing cost, volatility, and supply issues of diesel fuel and AdBlue in regional areas has had negative impacts on the costs of 'doing business' and on related local livelihoods. Therefore, there is considerable interest in trialing electric transport solutions that could in-turn enable improved regional electricity services, flexible charging at low tariff times, and improved local renewable energy system integration. The attractiveness of lower electricity costs displacing liquid fuel and internal combustion costs, and also the centralised fossil-based electricity generation with clean local energy alternatives was noted.

C.6. Trials to Clarify Costs/Benefits and Improve Health and Safety

Interviews and information sharing sessions clarified that many bus owner/drivers are interested in participating in electric bus trials. The authors suggest that this is a practical suggestion to refine technical and economic certainty and to gain confidence in any significant technical change in regional WA. Selected e-bus trials in the school fleet would enable drivers and owners to experience the advantages and disadvantages of electric bus capabilities when used within the primarily diesel-fuelled school bus fleet. Properly designed trials would also enable demonstration of charging infrastructure and operational logistics surrounding efficient use and greater adoption of electric busses within the school bus fleet. Trials would also enable the WA Government to determine real capital, operational, and maintenance costs of operating a range of electric buses and supporting infrastructure in regional and remote WA conditions over time. This data would enable the PTA to confidently propose new contractual obligations to bus owners to equitably share risk, costs, and benefits between the multiple local businesses who service, support, and operate WA school bus services and the WA Government. Trials enable certainty and awareness of the many implications that electrification will have for regional bus fleets. It will also indicate how a large-scale transition to electrification of trucking and farming sectors can proceed in regional WA.

Broader implications to the WA Government of school bus fleet electrification include:

- New private and public co-investment in zero emission school buses in WA;
- Reduction in fuel import supply and storage requirements and geopolitical/price leverage;
- Increased investment in WA clean energy and electricity supply services in regional WA;
- Improvement in air quality and reduction in fossil-fuel-related health impacts in WA;
- Schools and other public facilities becoming attractive EV charging locations due to existing excellent grid-connections highly suitable for additional PV/battery systems;
- Additional private and public co-investment in rapid electric vehicle charging in WA suitable for any EV - from small passenger vehicles, to buses, to large trucks.

One key insight from an interviewee included the optics of a trial being key in rural towns: *"If it goes well in one town, people will want it to happen in other areas". "Regional areas like ours are notoriously conservative and will refuse change. Even if it is in their own interests."* The authors note that several bus operators mentioned this resistance to change in rural areas. One interviewee suggested countering this reluctance by framing a trial around safety: *"We have an opportunity to demonstrate 'best practice'. For an example, the safety of the children and seat belts are key. If an e-bus has the ability to indicate if a child is properly restrained and safe there's little [argument]. Parents prefer safer busses."* The authors note the optics around safety includes the direct toxic bus emissions (not only GHGs) that children are exposed to each school day getting on and off the bus and during travel. Bus operators noted that these health and safety considerations of the various fumes/emissions are key, but said that parents of the children are largely unaware of their negative health impacts and mainly worry about on accidents. Therefore, there is also the need to effectively communicate the optics of safety of EVs. This includes proactively countering the predictable misinformation that will likely be disseminated about alleged fire risks of EVs, and actively promoting their demonstrated relative safety compared to diesel vehicles.

C.7. Concluding Observations

The interview data demonstrated a high level of practical consideration of how school bus services are operated and maintained in a safe manner under the numerous challenging conditions experienced in regional and remote areas of WA. There was considerable interest in providing simpler and safer transport services for schools. There was considerable questions in how an e-bus would compare in terms of practical advantages/disadvantages and how these might be harnessed/managed. The current level of bus operator uncertainty regarding financial, technical, and practical considerations about bus electrification pointed towards the merits of trialling selected routes/towns to determine real-world performance and costs. It would also enable communication and quantification of the advantages, disadvantages, and technical / contractual solutions to transition towards a net zero school bus fleet electrification.

D. School Bus Operator Survey

As part of this project an online survey among school bus operators was conducted, followed by an online meeting and feedback session. The meeting was a 'question-and-answer session' on the technical challenges that bus operators might face in the transitioning to electric buses.

D.1. Survey Summary and Results

The electrification of school bus fleets presents an opportunity to reduce GHG emissions as well as NOx and PM emissions, improve air quality, and lower operational costs. In this survey, we investigated the readiness of school bus operators and contractors to adopt electric bus technology by asking them a total of eight questions. We assessed their awareness, their interest in trials, and details about their current fleets, garage locations, and power infrastructure.

The PTA administers a total of 274 bus contractors (2023). From these we received 43 responses containing valuable insights into the readiness of school bus operators to adopt electric bus technology.

Question 1: How familiar are you with electric bus technology?

Figure D-1 shows the response from Question one. 41.9% of respondents are familiar with electric bus technology, while 58.1% are not.

The fact that over 40% of respondents are already familiar with electric bus technology is positive. It is important to note that this survey was conducted among a specific population group (school bus operators and contractors). It is likely that the level of awareness of electric bus technology is lower among members of the public. However, the result shows that there is still a relatively low level of awareness of electric bus technology in this group. This suggests education is needed about electrification technologies and their benefits.

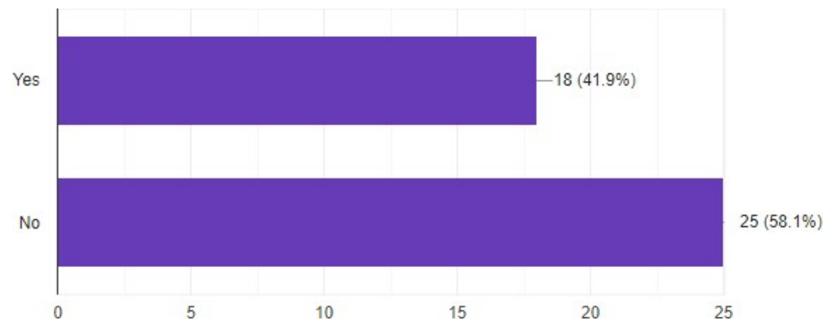

Figure D-1 Bus Contractor Survey Results - Question 1

2. Would you be interested in participating in a trial of electric buses within your school bus fleet?

The results of Question 2 (Figure D-2) of the survey show that a large proportion of school bus operators and contractors (48.8%) are interested in participating in a trial of electric buses within their fleet. This indicates growing interest in this technology among school bus operators. The reasons for participating in an electric bus trial may include:

- To learn more about the technology: Electric buses offer several potential benefits over traditional diesel buses, including lower operating costs, reduced emissions, and quieter operation. Participating in a trial would allow school bus operators to experience the difference first-hand.

- To gain experience with electric bus charging infrastructure: Electric buses require different infrastructure than traditional diesel buses. Participating in a trial would allow school bus operators to learn more about how best to integrate this infrastructure into their operations.
- To be early adopters of a new technology: Being an early adopter of a new technology can give school bus operators a competitive advantage. Electric buses are becoming increasingly popular, and school bus operators who are early adopters may be better positioned to attract new customers and contracts.

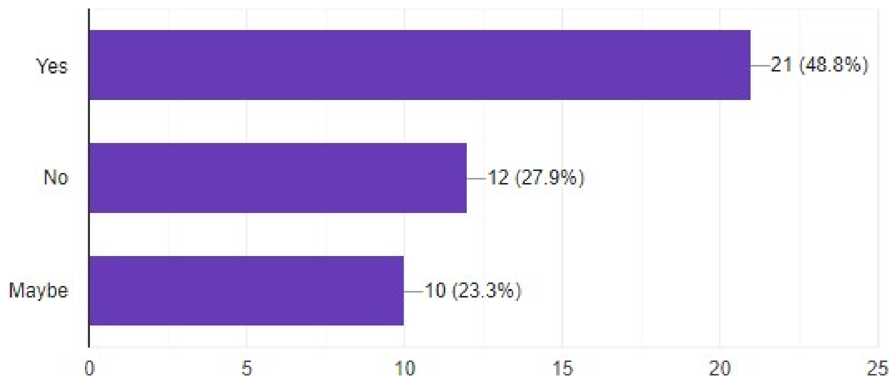

Figure D-2 Bus Contractor Survey Results - Question 2

Importantly, 27.9% of respondents are not interested, and 23.3% are not sure. Therefore, the results of Question 2 also suggest that there is a significant knowledge gap in the school bus service industry. By providing school bus operators with opportunities to learn more about electric buses and participate in selected trials, the transition to more sustainable technology can be well-managed.

3. How many school buses of each class (A.B,C, D) do you currently operate and what are their seating capacities?

For Question 3, we have received a very limited response rate from contractors, as only 43 attempted this survey. Accurate data about school bus classes A,B,C and D was received post survey from the PTA.

4. What is the Service Number for your buses or bus services?

As above, the limited survey attempt rate did not provide enough of the required information. The gap in the dataset was closed by the PTA.

5. Regarding battery recharge strategies, where are your buses garaged when not in use or overnight?

See summary of responses to Question 6

6. For battery recharge strategies, where are the buses garaged between the morning and afternoon school runs?

For Question 5 (Figure D-3) and Question 6 (Figure D-4), it is evident that the majority of the 43 respondents indicated that they park the bus either at the bus depot or at home. We also have received an indication that some bus operators need an alternative option for electrical connection for charging at the garaged location. In such scenarios, bus operators may have to change their routines by parking at the school or a nearby depot. Relocation of buses to areas with infrastructure also potentially increases options to add on-site generated renewable energy.

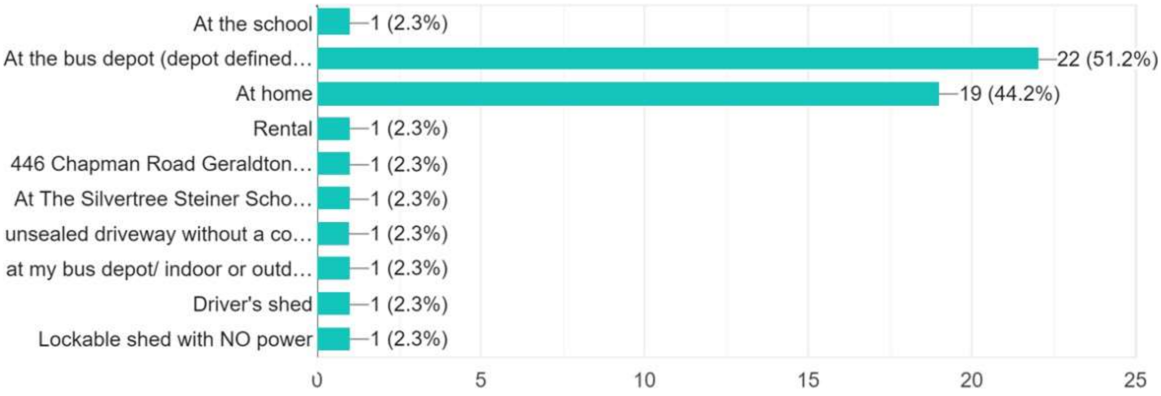

Figure D-3 Bus Contractor Survey Results - Question 5

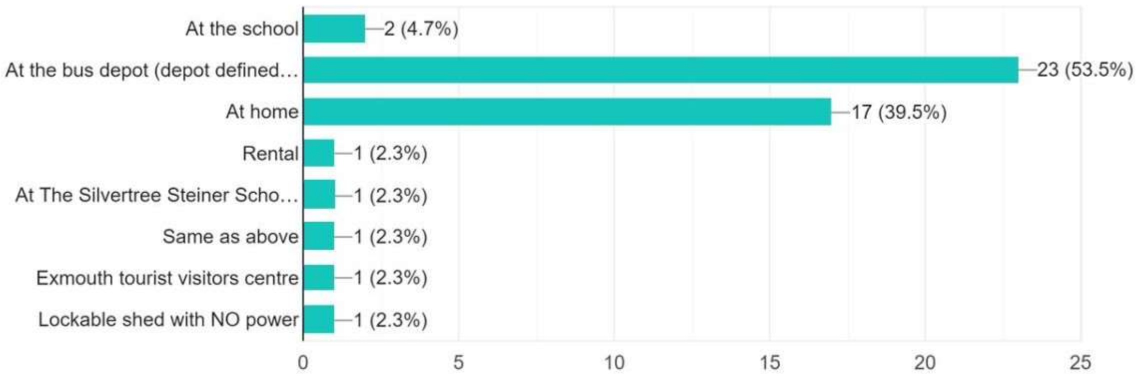

Figure D-4 Bus Contractor Survey Results - Question 6

7. Regarding potential battery charging, what is the level of power connection (in kW) available at your: School, depot, home or other location where buses are garaged

This question is important because the level of power connection available at the location where buses are garaged is a critical factor in determining the type of electric bus chargers that can be used and the charging speed that can be achieved.

The answers to the question suggest that there is a need for more education and outreach to school bus operators and contractors about the electrical requirements of electric buses. Many of the 40 respondents are unsure about the level of power connection available at their garages, which suggests that they may be unprepared for the transition to electric buses.

The answers also suggest that there is a range of power connection levels available at school bus garages. Some garages are supplied with single-phase power, while others are supplied with three-phase power. Some garages also have solar PV systems. This range of power connection levels means that there is a variety of electric bus charging solutions available to school bus operators and contractors.

D.2. Information and Feedback Session

The information and feedback session for bus operators was conducted online. It was a pivotal platform for sharing preliminary findings and engaging in insightful discussions based on Question 8 from the survey. The session provided a valuable opportunity for bus operators to express their main concerns and contribute to a constructive dialogue. As the presentation unfolded, participants delved into the nuances of the survey results, shedding light on various aspects of their experiences and challenges. The feedback session refined the critical issues raised in Question 8, allowing exploration of operator perspectives and the challenges faced by bus operators. This was a good foundation for more comprehensive and informed interviews to understand of the regional and remote school bus transportation landscape.

8. Are there any other questions or issues that you consider relevant and important to the electrification of the school bus fleet? What are the key things you would like to know about E-buses or other comments that you would like to add?

The following are the key questions and concerns raised by respondents to Question 8, regarding the electrification of the school bus fleet:

- Servicing in regional areas: Respondents expressed concerns about the availability of mechanics and specialists to service electric buses in regional areas.
- Distance able to travel: Respondents expressed concerns about the range of electric buses and whether they will be able to meet the needs of their school bus routes.
- Power supply and charging infrastructure: Respondents expressed concerns about the adequacy of the power supply and charging infrastructure for electric buses.
- Cost: Respondents expressed concerns about the upfront cost of electric buses, as well as the cost of bus replacement batteries.
- Reliability and durability: Respondents expressed concerns about the reliability and durability of electric buses under Australia's harsh climatic conditions.
- Other concerns: Respondents raised concerns about the impact of electrification on school bus contracts, the availability of electric bus technicians, and the suitability of electric buses for use in rural areas.

Overall, the responses to Question 8 suggest that there are several key questions and concerns that need to be addressed before electric buses can be widely adopted in WA. These include information on availability of servicing and charging infrastructure in regional areas, the range of electric buses, the upfront and ongoing costs, and the reliability and durability of electric buses.