Industry Blueprint for the Deployment of Electric Buses by Private Operators

ELECTRIC VEHICLE COUNCIL

TROPICWINGS CAIRNS TOURS & CHARTERS

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www.electricvehiclecouncil.com.au
office@evc.org.au

www.tropicwings.com.au
media@capta.com.au

Report authored by:

Dr Jake Whitehead
Former Chief Scientist, Electric Vehicle Council

Mark Stephens
EV Data Scientist, Electric Vehicle Council

Colin Anderson
General Manager, Tropic Wings

Acknowledgement and Disclaimer:

This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Driving the Nation Program.

The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

This report is based on a compilation of data and feedback provided to the Electric Vehicle Council (EVC) to fulfil the knowledge-sharing component of this project, co-funded by ARENA. Participating parties do not necessarily endorse all recommendations included in this report.

The included recommendations are based on both the first-hand experience of the project parties directly through their involvement with this project, and also their reflections on what other proponents should consider for future electric bus deployments. The EVC has taken reasonable steps to confirm the information shared for this report and has synthesised this information into a series of practical recommendations, however, as an external party not directly involved in the project, the EVC does not warrant or accept any liability in relation to the quality, operability or accuracy of information contained in this report.

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Executive Summary

This ARENA knowledge-sharing report aims to provide a comprehensive industry blueprint for private operators in Australia that are considering the deployment of electric buses. The transition to electric bus fleets represents a significant opportunity for private operators to align with Australia's national target to achieve net zero emissions by 2050, while enhancing their operational efficiency and potentially achieve long-term cost advantages.

This industry blueprint has been developed by leveraging the lessons learnt from a deployment of 12 electric buses in North Queensland, by local tourism operator Tropic Wings, as part of an ARENA co-funded project.

The blueprint provides insight into:

- The importance of planning for the transition to electric buses
- What are the steps in planning to introduce electric buses
- Insights into the deployment and optimisation of electric buses, particularly for private operators
- Insights into the deployment and optimisation of charging infrastructure for electric buses
- Considerations based on driver and passenger experiences on electric buses
- Indicative analysis of the total cost of ownership for electric buses deployed in Australia for private operations, and
- Potential challenges and barriers to electric bus deployment that should be considered.

This blueprint concludes by providing key recommendations for private operators planning to electrify their fleets over the coming years.

NOTE ON REPORT LIMITATIONS:

The analysis captured in this report focuses on data collected between late 2023 and June 2025 as part of the case study for this project, led by Tropic Wings. Due circumstances beyond the project partners control, some elements of the original project scope were delayed, and are not expected to be completed until later in 2025. This includes:

- Deployment of battery energy station storage (BESS) at two bus charging sites
- Installation of load management systems associated with BESS
- Charging infrastructure at one site that was dependent on BESS installation.

Additionally, other data gaps emerged during the completion of this report, principally the inability to collect telematics data from two of the twelve electric buses deployed.

The Electric Vehicle Council, as the knowledge-sharing partner for this project, has completed this analysis with all data available up until June 2025. A supplementary report may be issued at a later date by ARENA and/or the project partners, which captures any data collected from June 2025 onwards, once the remaining components of the project are deployed.

Project Background

Tropic Wings, a tourism operator with a fleet of 34 vehicles located in Cairns, has undertaken an innovative and ambitious project introducing 12 new battery electric buses into its local fleet. This deployment has been carried as part of an ARENA co-funded project.

While the number of electric buses in public transport fleets is slowly expanding in Australia, deployment of this zero-emission technology in private fleets, including tourism-focussed fleets, has been very limited. In fact, Tropic Wings was the first private operator of an electric bus in Australia– back in 2019 – demonstrating the organisation's commitment to innovation. This project built on this leadership by demonstrating how a larger fleet of electric buses can be deployed by private operators in Australia.

This project was a collaborative effort supported by:

Tropic Wings — **Project Leader / Bus Operator**

EnergyAustralia — **Energy Lead**

VDI Australia — **Bus Lead**

To charge this new fleet of electric buses, Tropic Wings has installed 11 chargers, and in the future will install two battery energy storage systems to provide redundancy, minimise grid impact, and reduce operational costs.

This was a first of its kind project that can help to inform and guide the deployment of electric buses in more private fleets across Australia.

The primary objectives of this project were to:

1. Overcome barriers to accelerate the uptake of zero emission buses by fleets.
2. Optimise the integration of battery electric buses into the grid to ensure cost effective outcomes.
3. Demonstrate new use cases for battery electric buses and highlight opportunities for this technology to provide value.
4. Increase local skills, capacity and knowledge relevant to battery electric bus technology.

This project includes the deployment of both electric buses, and associated charging infrastructure, for use in private tourism operations in North Queensland.

The electric bus fleet is comprised of 12 buses in total, including:

2 x Eurise YBL5
11-seater mini-buses (106 kWh battery / ~300 km real-world driving range)

3 x Yutong C12E
53-seater buses (351 kWh battery / ~350 km real-world driving range)

2 x Yutong C12E
57-seater buses (351 kWh battery / ~350 km real-world driving range)

5 x Yutong D7E
28-seater buses (176 kWh battery / ~300 km real-world driving range)

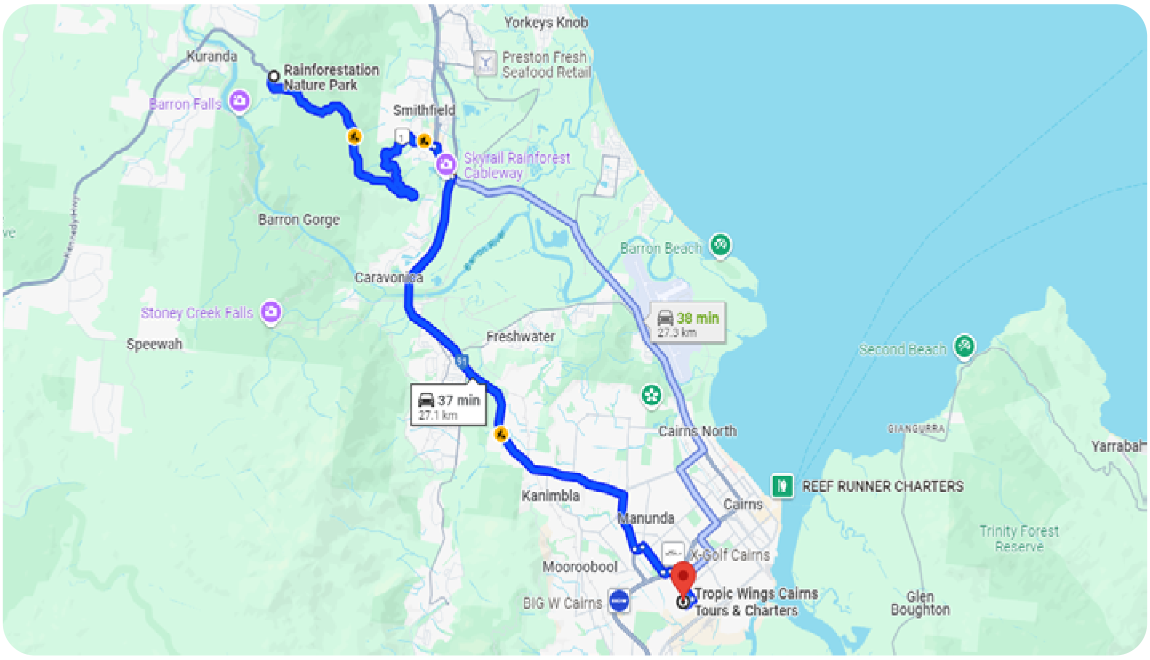
There are two principal charging locations for this fleet of buses:

Tropic Wings Depot in Cairns (otherwise referred to as Hartley Street Depot)

- 6 x 120 kW Yutong chargers (in addition to an existing 120 kW charger)
- 3 x 22 kW ABB chargers

Rainforestation in Kuranda

- 1 x 120 kW Yutong charger
- 2 x 22 kW ABB charger.



Tropics Wings Depot and Rainforestation are located approximately 27 km apart, separated by a significant climb up the Kennedy Highway to Kuranda.

Tropic Wings Depot is the primary charging location for the bus fleet, while Rainforestation provides mid-trip charging opportunities, as well as the ability to park and charge up to two buses while not in operation.

This project also involves the installation of two battery energy storage systems (BESS), one each at Tropic Wings Depot and Rainforestation, to provide additional redundancy and minimise any grid impact from charging multiple buses simultaneously. At the time the analysis was completed for this report the battery systems had not yet been installed, and the high power charger at Rainforestation was awaiting installation pending commissioning of the site's BESS.

The knowledge-sharing component of this ARENA project includes:

- Detailing the lessons learnt throughout the project, including stakeholder feedback.
- Analysis of bus operations to understand real-world capabilities
- Analysis of charging infrastructure deployment and operation, including optimisation of charging
- Indicative total cost of ownership analysis, accounting for both bus fleet costs and charging infrastructure costs.

These analyses have been combined to inform the development of this industry blueprint for other private bus operators to learn from and follow when electrifying other fleets around Australia.

The website for this project can be viewed here: https://arena.gov.au/projects/tropic-wings-battery-electric-supply-arena/.

Please also refer here to our previously published progress report which documented early lessons learnt as part of this project in 2024: https://arena.gov.au/knowledge-bank/tropic-wings-lessons-learnt-report-1/

1 Introduction: The Case for Electric Buses in Australia's Private Sector

The transportation sector is a substantial and growing source of greenhouse gas emissions both globally and within Australia. Transportation represents almost a quarter of Australia's national emissions, and as of December, 2024, is second only to the electricity sector. Transportation is also the fastest growing sector in terms of emissions, increasing by 1.9% between 2023 and 2024 – heading the opposite direction to our national emission reduction targets[1].

These figures underscore the critical need for supporting a transition to sustainable transport solutions to meet national targets. It also emphasises the urgency for private operators to explore and adopt zero emission alternatives like electric buses.

Transitioning to electric buses offers a multitude of potential environmental, economic, and social advantages for private operators. This includes improvements in air quality and urban amenity for communities, as well as smoother and quieter rides for passengers, and the potential for long-term cost savings for private operators. Economically, electric buses are also expected to have lower running and maintenance costs, leading to competitive total cost of ownership with diesel buses, for many applications. These costs are explored further in Section 6.0 of this report.

This industry blueprint is structured to provide a comprehensive guide for private operators in Australia considering the deployment of electric buses. The blueprint encompasses strategic planning, technology evaluation, infrastructure development, operational optimisation, financial considerations through a TCO analysis, analysis of electric bus driver and passenger experiences, as well as key recommendations for private operators.

This report has been developed by leveraging the lessons learned from this innovative ARENA co-funded project, led by Tropic Wings in North Queensland, and combines these findings with existing analysis of electric bus deployments in Australia and globally.

1 https://www.dcceew.gov.au/sites/default/files/documents/nggi-quarterly-update-december-2024.pdf

2 Planning for Electric Bus Deployment

The following section of this blueprint provides an overview of the planning process required when deploying electric buses, and the critical steps that should be followed by operators during this planning stage, prior to deployment of buses and associated charging infrastructure.

A successful transition to electric buses must include a thorough assessment of the operator's existing fleet. Private operators should analyse the **size**, **age**, and **operational requirements** of their current bus fleet, as well as the **specific demands** of their service routes.

Understanding the current fleet's operational patterns, including **daily distance travelled, route types**, and **energy/fuel consumption**, is fundamental to accurately determining the energy needs and charging infrastructure requirements for a future electric bus fleet. This critical initial step should include the analysis of existing operational data to assess the suitability of electric buses for specific use cases, and to optimise their subsequent deployment. If an operator does not yet have their vehicles fitted with telematics equipment, the first step is to collect at minimum a sample of data from the existing fleet, to analyse and understand existing operations.

The deployment of electric buses also requires a fundamental rethink of how these vehicles will be powered, who will be responsible for providing this energy, and ultimately where and when the energy will be dispensed i.e. charging of buses. While some bus depots already handle liquid fuels, the provision of charging infrastructure is generally a new frontier for bus operators, requiring new knowledge and skillsets, as well as cooperation with a range of new stakeholders. This includes, importantly, the local electricity distribution network. While operators may not invest in a full transition immediately, any deployment of charging infrastructure – even if phased – must account for future needs, both in terms of the siting of this infrastructure, and required upstream electrical infrastructure, including grid connection upgrades. Ultimately, the number and type of charging infrastructure will be dictated by the size and use case of the fleet.

This leads to the next critical step in undertaking a route suitability analysis to understand how electric buses could be expected to perform on existing routes, identify any low-hanging fruit options for initial deployment, and also flagging potential future route changes and/or fleet changes that may be required. Factors such as **route distance**, **topography**, **average speed**, **climate**, **idle times** and **passenger load** can all have a significant impact on the driving range and energy consumption of electric buses. **Depot locations** are another important consideration. By carefully analysing route characteristics, private operators can ensure the operational feasibility of deploying electric buses on their specific service networks.

Based on the fleet assessment, initial charging infrastructure investigation and route suitability analysis, operators can then determine the optimal number and type of electric buses required for a phased or full transition. This decision will of course also be influenced by other factors, such as the desired pace of electrification, available budget, government support, and the performance characteristics of different electric bus models.

2.1 | Selecting the Right Electric Bus Model/s

When selecting electric buses, evaluating different battery types, capacities, and ranges offered by manufacturers is crucial. Battery capacity is closely associated with the operational range of electric buses, a key consideration for route planning. Battery sizes can also vary significantly from less than 100 kWh (minibuses/vans) to over 500kWh (coaches), and individual models may be available with different battery sizes – depending on the use case. The choice of battery capacity and bus model should be carefully aligned with the specific energy demands and distances of the routes the buses will serve. Factors such as **passenger capacity**, **accessibility features**, and **manoeuvrability** might also influence the selection process.

A range of electric buses were deployed by Tropic Wings as part of this project. A summary of their battery size and expected driving range is included in the table below:

Bus	Seats	Battery Size	Real-world driving range
Yutong C12E (5 coach buses)	53 - 57	351 kWh	~350 km
Yutong D7E (5 coach buses)	28	176 kWh	~300 km
Eurise* (2 buses)	11	106 kWh	~300 km

*No telematics data was available for these buses at the time of analysis for this report.

These vehicles were ultimately selected to meet a range of use cases across the tours offered by Tropic Wings. These tours range both in terms of size of tour group, and duration of tour – thus distance travelled. For most cases, at least 300 km of real-world driving range was deemed to be sufficient based on existing operations. That said, not all tours offered by Tropic Wings can currently be fulfilled by these buses, primarily due to a lack of suitable on-route charging infrastructure specifically at locations that align with logical tour stops. If such infrastructure becomes available in the future, this could potentially expand the use cases of these electric buses to almost all routes offered by Tropic Wings.

Tropic Wings was ultimately able to determine suitable electric bus specification through analysis of existing fleet telematics data. This data provided insights into the duration and length of different tours, and some insights into energy/fuel consumption under different conditions e.g. different terrain, highway vs urban driving, variations across seasons, etc. Additional data collected on patronage numbers was also useful for understanding vehicle size requirements.

Detailed analysis of the Tropic Wings electric bus fleet is detailed in Section 3.4, which also provides indicative energy consumption values for electric buses that other operators could use for planning purposes when assessing route suitability, and selecting the right electric bus specification for procurement.

2.2 | Infrastructure Requirements: Charging and Depot Considerations

A critical element of electric bus deployment is the planning and development of adequate charging infrastructure, both at depots and potentially along routes. Private operators need to thoroughly analyse their existing depot space and layout to determine the optimal placement of charging stations and ensure efficient bus flow.

Determining the appropriate number and type of chargers is depends on the size of the electric bus fleet and the daily operational schedules. DC fast chargers are generally favoured for electric buses due to their ability to deliver higher power and significantly reduce charging times, allowing for quicker turnaround and maximising bus availability.

Private operators must also assess the existing electricity supply capacity at their depots and anticipate potential grid upgrades that may be necessary to support the increased demand from charging a fleet of electric buses. Upgrading grid connections can involve significant costs and lengthy timelines. Early engagement with electric distribution networks is critical. Further discussion of this process is outlined in Section 4.0.

Bus operators should also plan for the future expansion of charging infrastructure to accommodate fleet growth and technological advancements in charging solutions. This includes considering the scalability of the chosen charging systems.

2.3 | Operational Planning and Route Suitability Analysis

Developing efficient route schedules that specifically account for any required charging time and the real-world driving range of electric buses is a fundamental aspect of operational planning. Unlike diesel buses, electric buses require scheduled downtime for charging, which must be integrated into the daily operational flow – even if primarily carried out overnight at the depot. Flexible charging strategies may be necessary to improve fleet utilisation and reduce operational costs.

Implementing strategies for dynamic bus-to-route assignment can further optimise the usage and charging of electric buses. This involves adjusting the assignment of buses to routes based on factors like battery charge levels, route energy demands, and charging schedules, allowing for more flexible and efficient operations. The number of providers of this software continues to expand, and in time, this may become a cost-effective option not only for large fleets, but also smaller fleets.

2.4 | Summary

Below is a summary of the key steps when planning for the transition to electric buses:

Step 1 Equip at least part of the existing bus fleet with telematics equipment to collect data (if not already fitted), and analyse existing fleet operations.

Step 2 Undertake an initial assessment of existing depot sites and understand their ability to support charging infrastructure.

Step 3 Carry out a route suitability analysis to understand electric bus specifications required – accounting for availability of charging infrastructure.

Step 4 Select electric bus models that meet requirements.

3 Deployment and Optimisation of Electric Buses

In the following section of this blueprint, further information is provided regarding the deployment and optimisation of electric buses. This includes an analysis of the Tropic Wings case study to better understand a real-world deployment of electric buses in Australia, and the lessons learnt by this operator.

3.1 | Driver Training and Operational Best Practices for Electric Buses

Comprehensive driver training programs are essential for the successful operation of an electric bus fleet. Drivers need to be trained on the unique operational characteristics of electric buses, including maximising the use of regenerative braking to recover energy and adopting energy-efficient driving techniques to extend the bus's driving range. Driver-related factors, such as driving patterns and charging habits, can significantly affect energy consumption, and in turn, driving range.

Establishing clear operational protocols for monitoring battery status and managing charging needs during operation is also crucial. Drivers should be aware of the bus's current state of charge and the estimated remaining driving range to avoid operational disruptions.

Furthermore, developing specific procedures for handling operational challenges and emergencies related to electric buses, such as unexpected route changes or technical issues, can help to ensure both smooth and safe operations.

Tropic Wings implemented specific driver training related to electric buses as part of its deployment. This included training drivers in the safe operation and use of charging infrastructure, as well as monitoring the state of charge of the bus's battery.

The results of a survey of the drivers of the Tropic Wings' electric bus fleet is detailed in Section 5.2.

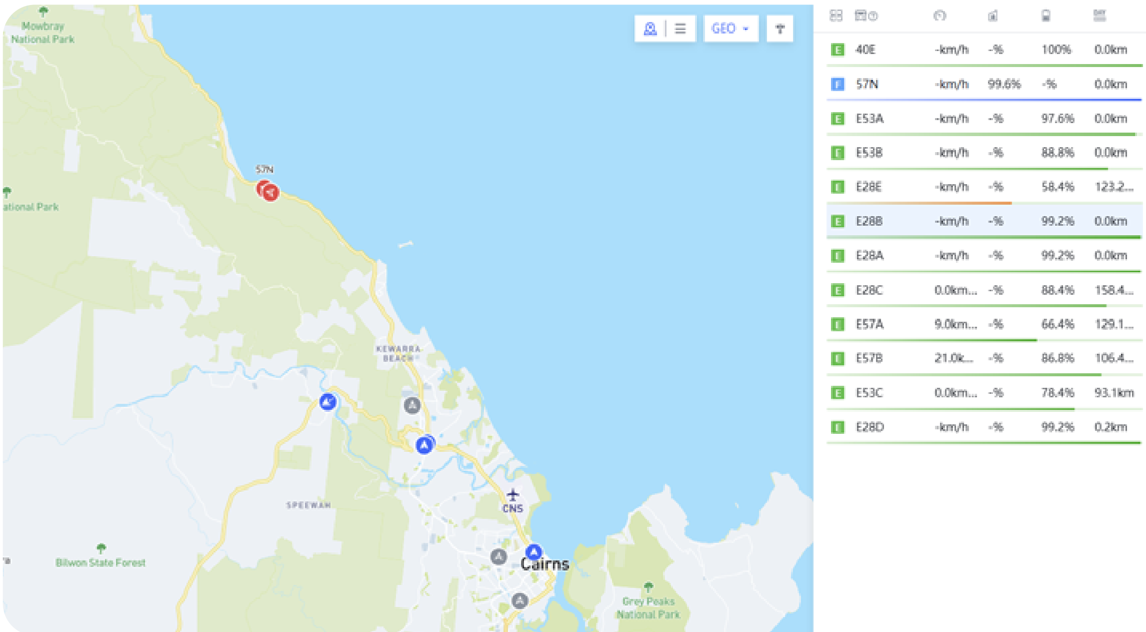
3.2 | Strategies for Managing Electric Bus Driving Range and Performance

Mitigating range anxiety among both drivers and passengers is important for fostering confidence in electric bus technology. Providing drivers with real-time information about the bus's state of charge, the estimated driving range for the current route, and the location of nearby charging infrastructure can help to alleviate these concerns.

Optimising the use of auxiliary power systems, such as air conditioning and heating, can also help conserve battery energy and extend the bus's driving range. Implementing strategies to minimise the energy consumption of these systems, where possible without compromising passenger comfort, can contribute to overall efficiency.

Utilising telematics and data analytics provides valuable insights into the performance of the electric bus fleet. By monitoring key metrics such as energy consumption, charging patterns, and vehicle utilisation, operators can identify areas for improvement, optimise operational strategies, and make data-driven decisions to enhance the efficiency and reliability of their electric bus fleet.

10 of the 12 electric buses procured by Tropic Wings, as part of this project, were equipped with telematics systems. The data collected from these systems is being used to inform further optimisation of bus operations, as detailed further in Section 3.3.



Screenshot of the telematics portal used to track, monitor and analyse the Tropic Wings' electric bus fleet

3.3 | Tropic Wings Case Study – Electric Bus Operations

Operations for 10 of the 12 electric buses deployed by Tropic Wings, as part of this project, have been analysed in the following section of this report. This analysis provides insight into the composition of the fleet, and how these buses have been used since their deployment in the first half of 2024.

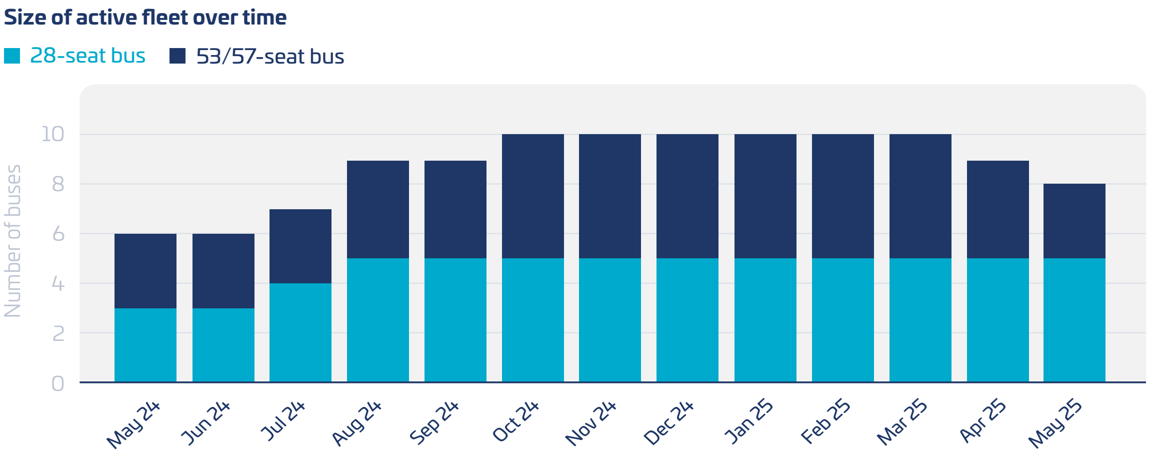
This analysis also aims to provide indicative insights into the typical energy consumption of different size electric buses to support other operators in planning for the deployment and operation of electric buses in their own fleets.

The window of analysis spans a 12-month period from April 2024 to May 2025. The two additional electric buses (Eurise) were not included as their telematics data was not available at the time of analysis.

3.3.1 | Fleet composition

The availability and utilisation of the Tropic Wings' bus fleet grew from six vehicles in May 2024 to 10 vehicles in October 2024 across two different vehicles models, namely the '53/57-seat bus' and the '28-seat bus'. The changes in size of the active fleet over time is shown in Figure 1.

FIGURE 1: Trends over time



It is important to note that the increase in size of the fleet over this period could contribute to explaining at least some of the observed variability in usage characteristics over time, more than just a seasonality affect, however, the analysis needed to be completed in June, 2025, and therefore was unable to capture a full 12-month period with all 12 buses.

It can also be observed that one 53/57-seat bus was offline during April 2025, and a second was also offline during May, 2025. Tropic Wings confirmed that in both instances this was a fault in the telematics systems for each of these buses, which resulted in operational data not being collected.

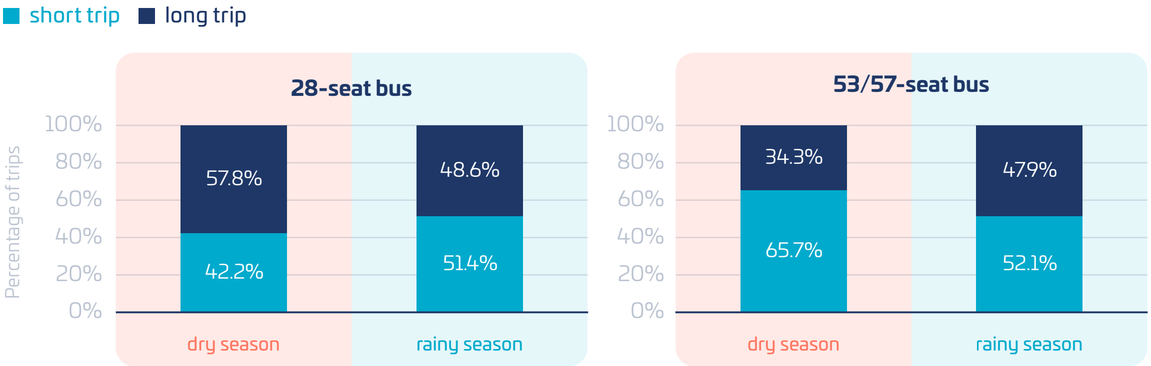
3.3.2 | Fleet usage – trips and distance travelled

The distances travelled by electric buses, and the different types of trips or routes that these buses are used on, is critical for informing their suitability to replace existing buses in a fleet. Here we provide insight into the range of use cases across Tropic Wings' electric bus fleet, including insights into the typical trip distances and total distances travelled per day per vehicle.

Tropic Wings' electric buses were observed to be used for two types of trips that were simply categorised as a short trip and a long trip. A **short trip** was defined as a journey that was **less than 60 kilometres**, with the remainder classed as **long trips**. Note that very short trips i.e. less than 2 kilometres, were filtered out of this analysis to avoid counting repositioning of buses at / around depots as regular trips.

An association between trip type and season was observed for both the 28-seat buses and 53/57-seat buses. For the 28-seat buses, the proportion of long trips completed in the dry season (May - October 2024) decreased from 57.8% to 48.6% in the rainy season (November 2024 - April 2025), while the opposite trend was observed for the 53/57-seat buses – see Figure 2. This was primarily due to the progressive increase in confidence of the buses' capabilities, and in turn, the types of tours the vehicles were used for, as opposed to any seasonal variations or effects.

FIGURE 2: Proportion of trip type across seasons for each bus category



As shown in Figure 3, the distribution of distance travelled per trip across seasons and different types of trips is relatively consistent for 28-seat buses. Conversely, the 53/57-seat buses were observed to have a slightly wider distribution of short trips in the rainy season versus the dry season.

In the rainy season, the 53/57-seat buses were also observed to generally not undertake as many trips greater than 150 km, with a maximum trip distance of approximately 250km in the rainy season. This is in contrast to the dry season where the maximum trip distance was greater than 300 km for this bus category. The median distance travelled per long trip was also observed to decrease in the rainy season compared to the dry season. The Tropic Wings team noted that these variations were again primarily due to confidence in the buses, and their use cases, evolving over time - as opposed to seasonal effects. Initially the bus fleet was charged less often to better understand real-world driving range. This changed as the fleet transitioned from an initial testing phase to a more optimised schedule based on the initial real-world experience and learnings.

Figure 4 illustrates the distribution of average speed per trip across the two bus types, differentiated by trip length and season. Overall, the distributions are relatively consistent across seasons and trip types for both bus models. However, a slight but noticeable increase in median average speed during the rainy season is observed. Despite seasonal shifts, the dispersion and range of speeds show minimal change, suggesting stable performance under potentially different weather conditions across the seasons.

FIGURE 3: The distribution of distance travelled per trip across seasons for the different trip types

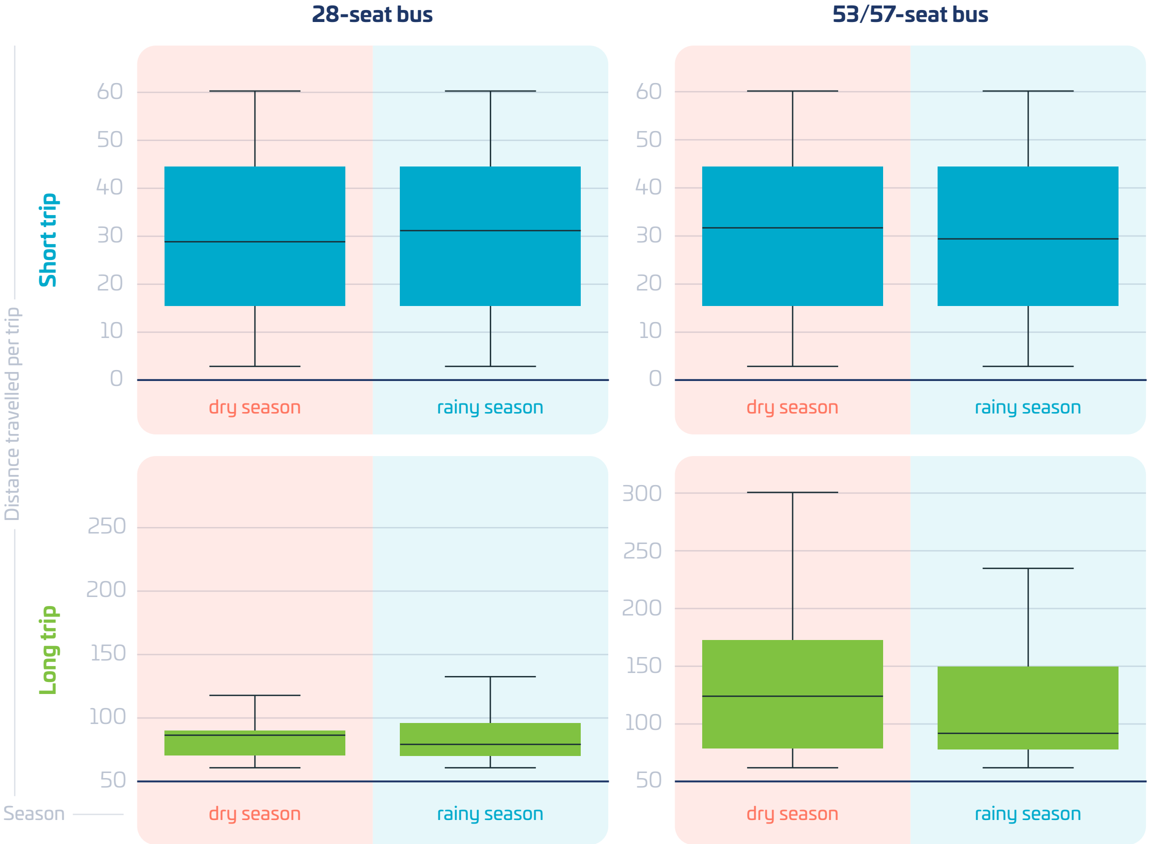
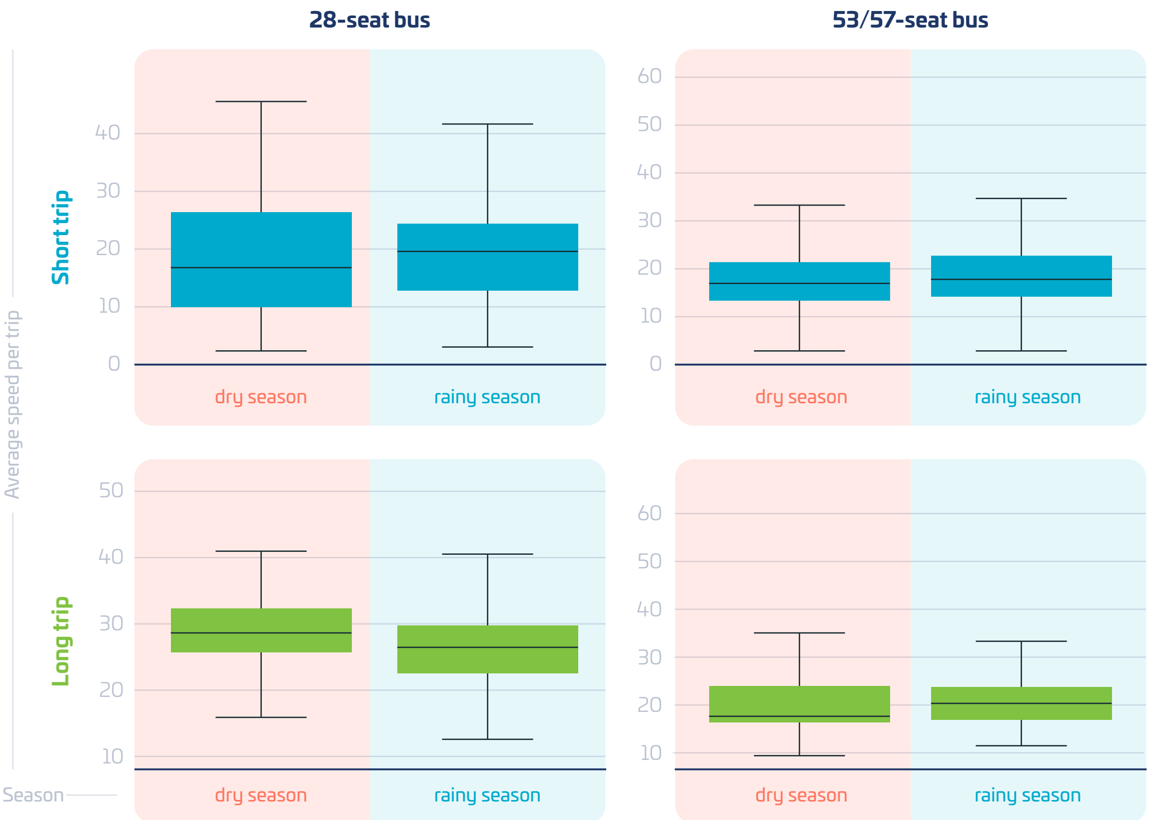


FIGURE 4: The distribution of average speed per trip across seasons for the different trip types

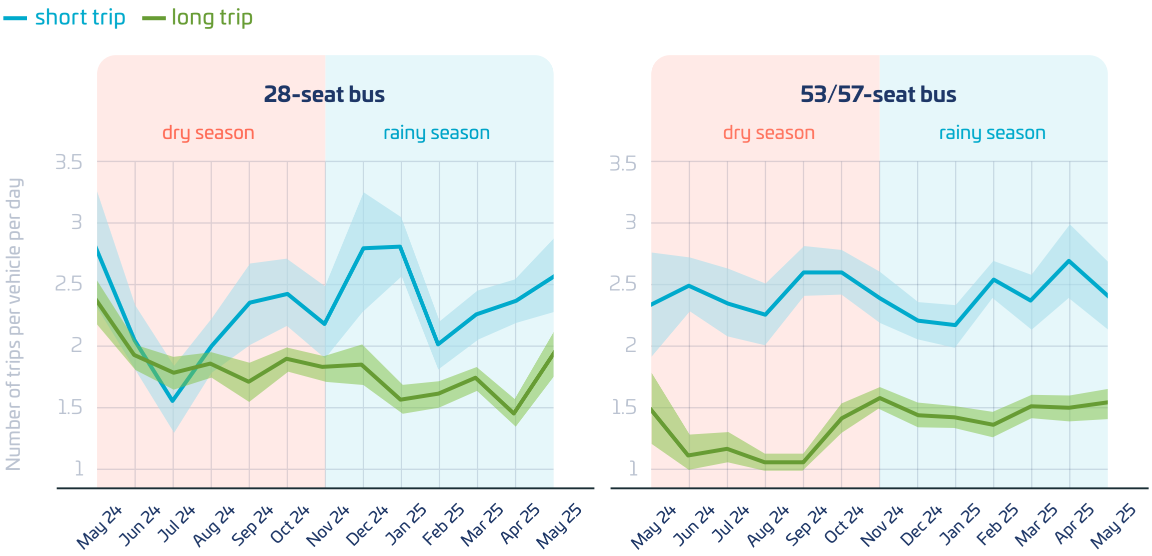


As shown in Figure 5, the 53/57-seat buses were observed to consistently travel more than two short trips per vehicle per day on average throughout most of the year, regardless of season. The 28-seat buses were also observed to generally increase in use during the rainy season to largely two or more short trips per vehicle per day on average.

The 53/57-seat buses also tended to travel more long trips during the rainy season, compared to the dry season, whereas the number of long-trips carried out by the 28-seat buses was relatively consistent across the year.

Overall, since October, 2024, when all 10 buses analysed were online in the fleet, both size buses have consistently undertaken a greater number of short trips (on average), compared to long trips, each day.

FIGURE 5: Trend in average number of trips per vehicle per day (by trip length)



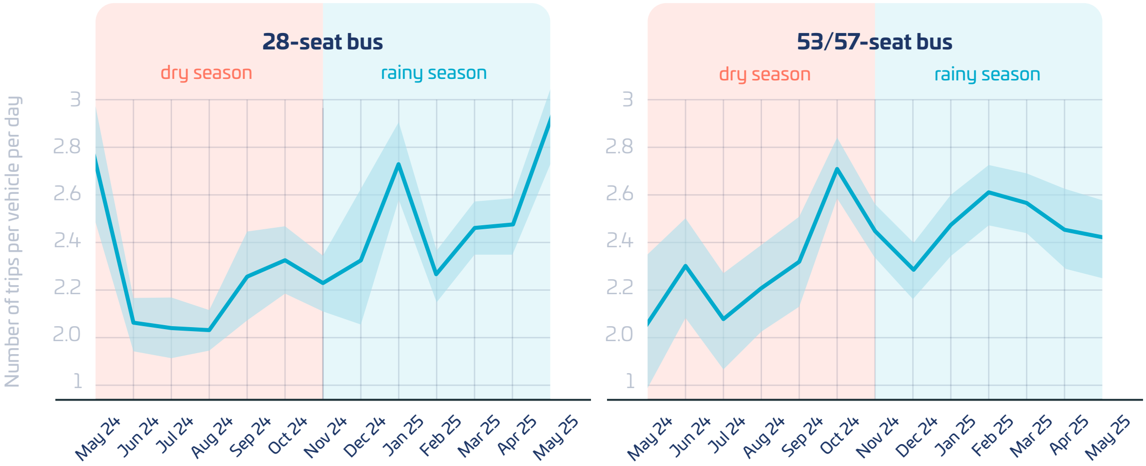
When combining all trips, the 28-seat buses on average carried out as high as 2.8 trips per day at the start of the dry season but this declined to an average of 2.2 trips per day as the season progressed.

The daily usage of the 28-seat buses steadily increased throughout the rainy season, with a notable spike during the January period, to peak to an average of almost 3 trips per day at the commencement of the new dry season.

The 53/57-seat buses carried out a low of 2 trips per day at the start of the dry season and peaked at approximately 2.7 trips per day on average before the season's end. The 53/57-seat buses also managed an average of 2.5 trips per day in the rainy season (see Figure 6).

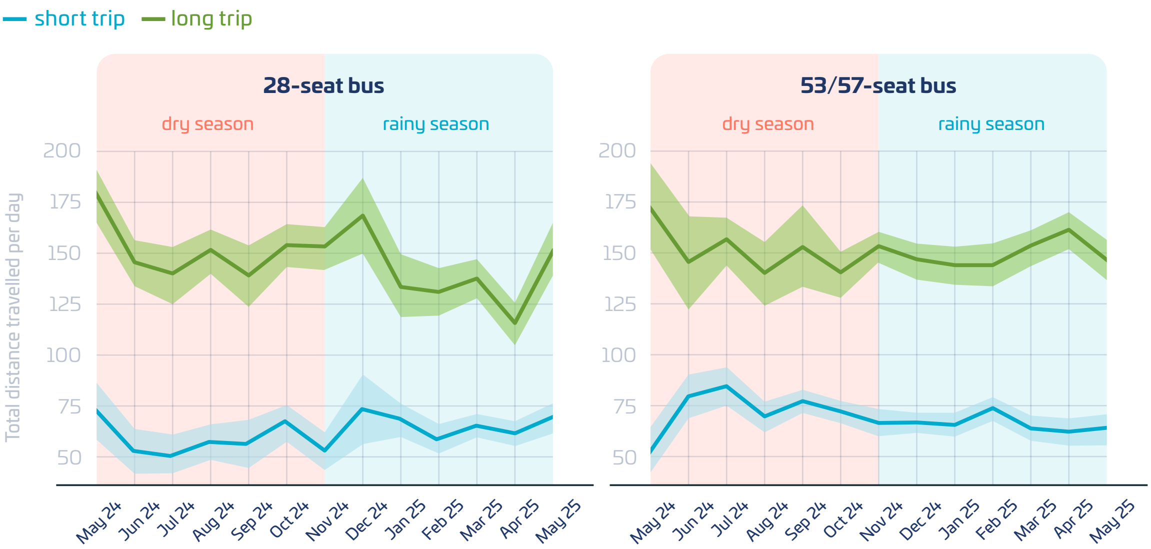
A complimentary trend between the bus types can also be observed with 28-seat bus trips per day generally reduced in months where 53/57-seat buses recorded a higher average daily trip count, and vice versa. This in part highlights that these buses are used interchangeably on demand for specific tours. It is also a product of the types of tours run during different parts of the year, and the number of passengers carried on these tours.

FIGURE 6: Trend in average number of trips per vehicle per day (overall)



Throughout the year, 28-seat buses generally travelled an average of 60 km for short trips, and decreased from an average of 170 km for long trips in the dry season to 140km in the rainy season. Similarly, the average distance travelled per vehicle per day for 53/57-seat buses was relatively consistent throughout the year at an average of 160 km for long trips and 70 km for short trips (see Figure 7).

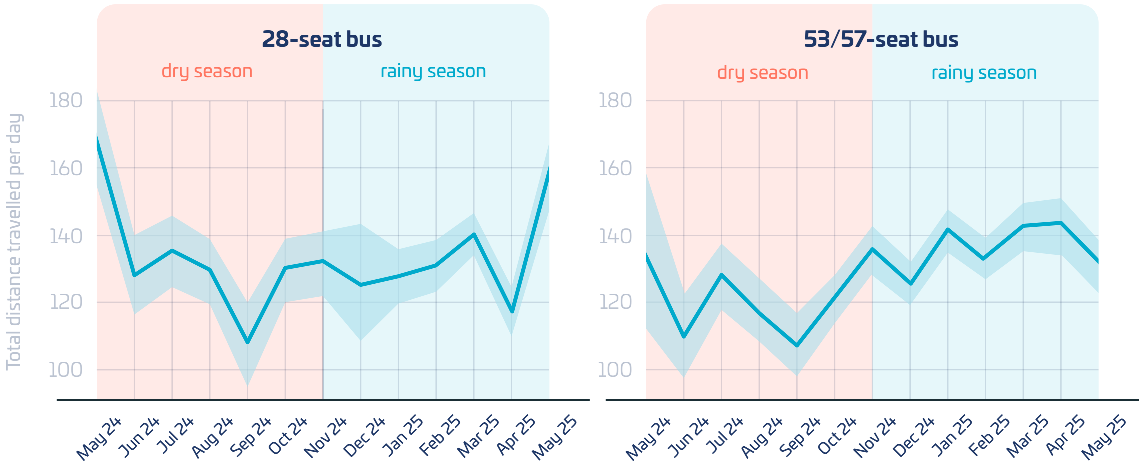
FIGURE 7: Trend in total distance travelled per vehicle per day (by trip length)



When combining all trips (see Figure 8), the 28-seat buses on average travelled 140 kilometres per day in the dry season and 130 kilometres per day in the wet season. This represents about 45% of the expected real-world driving range for this bus category.

The 53/57-seat buses travelled 120 kilometres per day in the dry season and 137 kilometres per day in the wet season. Similarly, this represents up to approximately 40% of the expected real-world driving range for this bus category.

FIGURE 8: Trend in total distance travelled per vehicle per day (overall)



3.3.3 | Energy Consumption

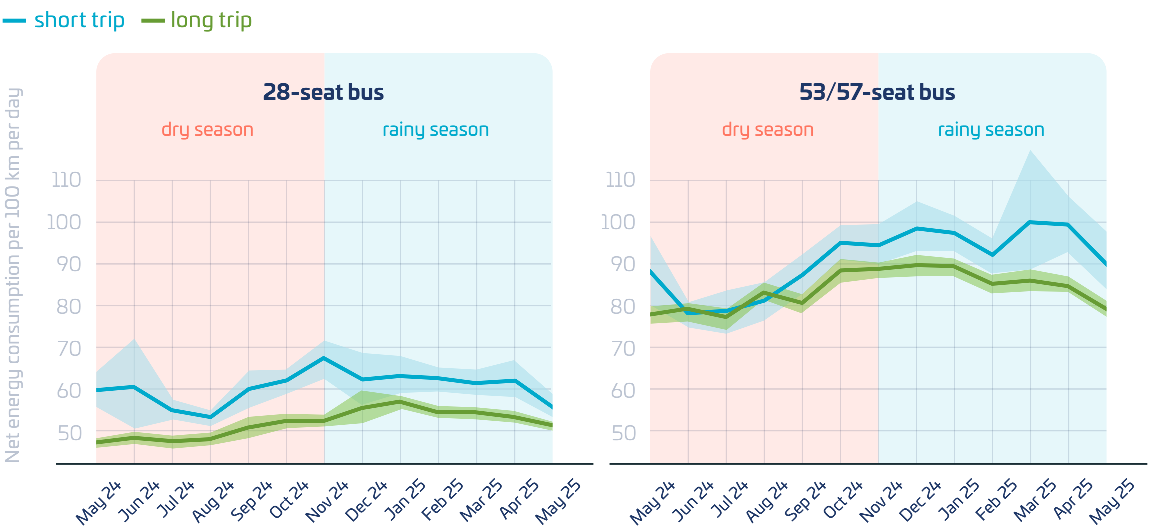
Understanding typical energy consumption of electric buses is critical for assessing their suitability for deployment on different routes, and under different conditions. The following section of this analysis provides insight into the energy consumption observed for the Tropic Wings' electric bus fleet and also investigates the components of this energy consumption.

This analysis also attempts to provide indicative energy consumption values that other operators could utilise when undertaking planning and suitability assessments for their own fleet transition to electric buses.

As shown in Figure 9 below, the variation in net energy consumption rates is predominantly dependent on bus model. The trip type can explain some variation, where long trips lead to less net energy consumption than short trips. It is suspected that this may be related to fixed energy consumption loads, such as the initial cooling of buses using the air-conditioner, which are relatively constant regardless of trip length, but inflate average energy consumption on short trips relative to long trips.

A marginal increase in net energy consumption rates is observed in the rainy season compared to the dry season, which could at least in part be related to higher air-conditioning loads during the rainy season – as shown in Figure 9.

FIGURE 9: Trend in Net Energy Consumption per 100km per day



To further capture vehicle usage beyond distance travelled, average speed per 60-minute interval was calculated and grouped into three categories:

- **low average speed** (5–30 km/h)
- **medium average speed** (30–55 km/h)
- **high average speed** (55–80 km/h)

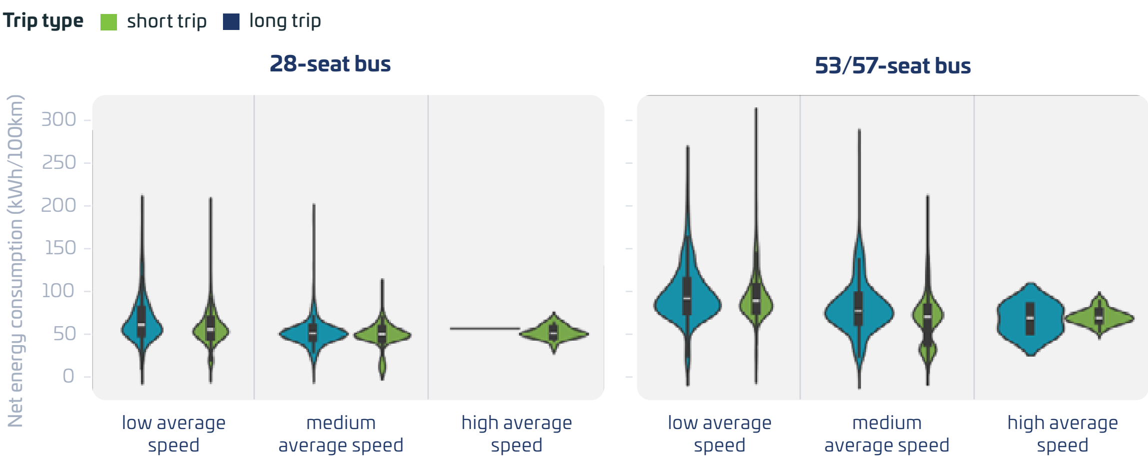
Figure 10 illustrates the distribution of net energy consumption across these speed categories and trip types.

Overall, both bus models—28-seat and 53/57-seat—exhibit greater energy efficiency at higher average speeds, with long trips generally consuming slightly less energy than short ones. The 28-seat bus demonstrates a more concentrated and lower energy consumption profile at medium and high speeds, particularly for long trips, indicating stronger efficiency.

By contrast, the 53/57-seat bus shows broader variability and generally higher consumption, though it also becomes more efficient as speed increases.

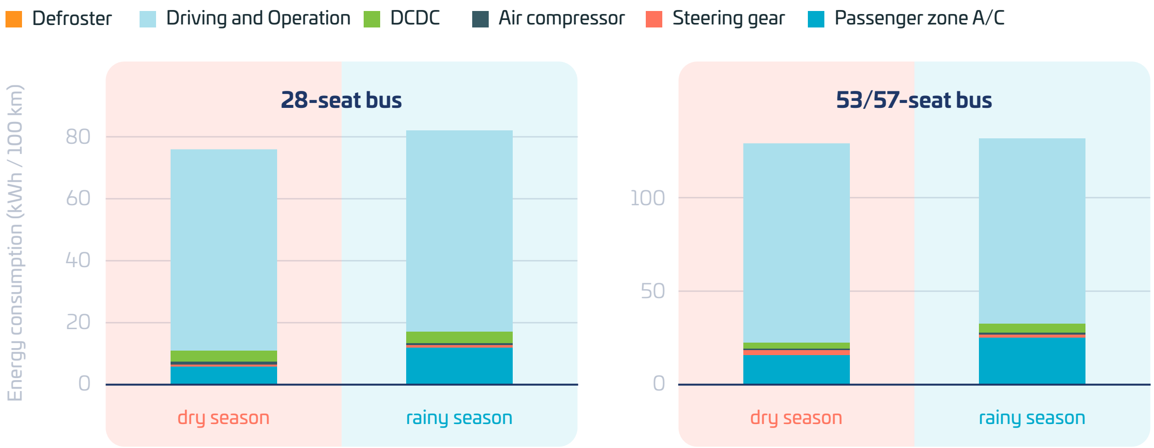
Notably, short trips at low speeds are the least energy-efficient across both models, while long trips at high speeds yield the lowest energy consumption, highlighting opportunities to reduce energy use by minimising short, low-speed operations.

FIGURE 10: Distribution in Net Energy Consumption per 100km across average speed and trip types



The average energy consumption per 100 kilometres due to passenger air-conditioning increased from 6 kWh/100km to 12 kWh/100km for the 28-seat buses, and from 16 kWh/100km to 25 kWh/100km for the 53/57-seat buses when comparing the hot and humid rainy season to the cooler dry season (see Figure 11). Collection of data over a longer period would be required to confirm this trend.

FIGURE 11: The distribution of types of energy consumption across models and times of year.



3.4 | Summary

As shown in the above analysis, the Tropic Wings electric bus fleet is being utilised for multiple trips each day, although overall, are only travelling a relatively modest proportion of total driving range on average e.g. 40-45%.

Although the two bus types analysed differ significantly in size, the analysis suggests they are used interchangeably, likely depending on demand for different tours or applications.

Overall, this analysis also highlights that under real-world conditions, in the Australian context, in a part of Australia known to require significant air-conditioning to provide comfort to passengers, that the consumption rates of the electric buses deployed are impressive, and more efficient than some might expect. In most cases, even the energy consumption of the larger 53/57-seat coaches is well below the generally assumed average electric bus energy consumption value of 100 kWh per 100 kilometres (or 1 kWh per kilometre).

To assist other private operators in planning for the deployment of electric buses in their fleets, a summary of average energy consumption values, based on the Tropic Wings fleet, have been developed and included in Table 1.

As shown, these values have been provided for a range of conditions to provide insight into the range of energy consumption rates that could be expected for many Australian operators.

It should be noted that these values may not be applicable to every electric bus model, and should be considered as indicative only. To be conservative, private operators may wish to undertake sensitivity testing to allow for electric bus models that may be efficient than the electric buses analysed as part of this case study.

TABLE 1: Average real-world net energy consumption rates for each bus type

Average Net Energy Consumption Summary kWh per 100km ± 95%CI		
Category	**28-seat bus (kWh/100 km)**	**53/57-seat bus (kWh/100 km)**
Dry season, short trip, low average speed	64 ± 2	92 ± 2
Dry season, short trip, medium average speed	52 ± 3	80 ± 7
Dry season, long trip, low average speed	55 ± 1	91 ± 1
Dry season, long trip, medium average speed	47 ± 1	61 ± 3
Dry season, long trip, high average speed	52 ± 3	69 ± 5
Rainy season, short trip, low average speed	70 ± 2	101 ± 2
Rainy season, short trip, medium average speed	53 ± 2	84 ± 5
Rainy season, long trip, low average speed	62 ± 1	98 ± 1
Rainy season, long trip, medium average speed	51 ± 1	71 ± 2
Rainy season, long trip, high average speed	53 ± 4	72 ± 3
Dry season, short trip	62 ± 2	91 ± 2
Dry season, long trip	51 ± 1	86 ± 1
Rainy season, short trip	66 ± 2	99 ± 2
Rainy season, long trip	58 ± 1	94 ± 1
Dry season	54 ± 1	88 ± 1
Rainy season	61 ± 1	95 ± 1
Overall	**58 ± 1**	**92 ± 1**

4 | Deployment and Optimisation of Bus Charging Infrastructure

In the following section of this blueprint, further information is provided regarding the deployment and optimisation of electric bus charging infrastructure. This includes an analysis of the Tropic Wings case study to better understand a real-world deployment of electric bus charging infrastructure in Australia, and the lessons learnt by this operator.

4.1 | Depot Charging Infrastructure: Design, Planning and Management

Efficient design of depot layouts is fundamental to optimising the use of charging infrastructure. Careful consideration should be given to the placement of charging stations to ensure smooth bus flow around the depot and minimise congestion, especially during peak charging periods. This design must also account for the sweep paths of the vehicles, with adequate clearances accounted for as part of the charger placement.

Implementing load management systems is critical for avoiding costly peak electricity demand charges and preventing overloads on the electricity grid. Smart charging management systems allow operators to schedule charging during off-peak hours when electricity prices are lower and to dynamically adjust charging rates based on grid conditions and energy availability. These systems can optimise the charging schedule for the entire fleet, ensuring that buses are charged when needed while minimising overall energy costs.

Accurate planning for the required power capacity at the depot and early coordination with the electricity distribution network is also essential to ensure that any necessary grid infrastructure upgrades are implemented in a timely manner. Engaging with experienced bus electrification delivery partners is also recommended to navigate the complexities of power supply requirements and grid connections.

Utilising software platforms for monitoring and managing the performance of charging infrastructure allows operators to track energy usage, identify potential issues, and ensure the reliability of their charging systems.

It is worth noting that the deployment of charging infrastructure, and in particular, the connection of this infrastructure to the electricity grid, was the greatest challenge faced by the Tropic Wings project. The project incurred significant delays through this process, and this had flow-on effects in terms of planning for the operation of the fleet and implementing smart charging strategies.

At the time the analysis for this report was completed, at least one high power charger was still awaiting connection, and both battery energy storage systems – and the associated load management systems – were not yet installed. As a result, this report was unable to capture data on these project elements, and are not considered as part of this report.

For further information on the challenges faced by Tropic Wings in deploying charging infrastructure, please refer to our previous lessons learnt report[2]. Analysis of the outstanding elements of this project will be documented separately at a later date by Tropic Wings and ARENA.

4.2 | Implementing Smart Charging Strategies for Cost and Energy Efficiency

Implementing smart charging strategies is crucial for achieving both cost and energy efficiency improvements in electric bus operations. Scheduling charging sessions to primarily occur during off-peak hours, when electricity prices are significantly lower, can lead to substantial reductions in operational expenses via time-of-use tariffs. See a further discussion on the potential cost impacts of charging in Section 6.0.

Smart charging software plays a vital role in dynamically adjusting charging rates based on real-time grid conditions, the availability of renewable energy, and the specific energy needs of each bus in the fleet. This intelligent management of charging processes ensures that buses are ready for service when required while minimising energy costs and reducing the strain on the electricity grid. While readily available for larger bus fleets, this software may be cost-prohibitive for smaller fleets – if not included as part of a telematics solution. There may be a need for government to consider how it can support smaller bus operators to gain access to these tools in order to reduce charging costs, and optimise bus charging to minimise impact on the electricity grid, and potentially provide support to the grid.

While smart charging software is planned for deployment as part of this project, unfortunately delays in receiving connection approval from the local electricity distribution network for the on-site battery storage has also resulted in a delay in activating this software. As a result, this report was unable to capture direct learnings on this technology.

4.3 | Integrating Renewable Energy Sources for Charging

Integrating charging infrastructure with on-site renewable energy generation, such as solar panels installed at the depot, can further enhance cost savings and reduce the environmental impact of electric bus fleets. That said, operators should be aware of potential complications that may arise as part of electricity distribution network requirements if upgrading a site with existing solar generation[2].

2 https://arena.gov.au/assets/2024/10/Tropic-Wings-Towards-Sustainable-Transport-In-Tourism-Lessons-Learnt-Report-1.pdf

Implementing battery storage solutions at depots can further maximise the benefits of renewable energy integration and/or cheap grid supply periods. Stored energy from solar or wind or cheap off-grid electricity can be used to charge buses during periods when renewable generation is low and grid demand is high, and it can also provide a backup power source or even support the grid during peak demand events, providing an additional potential revenue stream.

Vehicle-to-grid (V2G) technology should also be considered as part of future planning for any bus depot charging as it offers the potential for electric buses to not only consume energy from the grid but also to return energy back to the grid during peak demand periods. This technology could unlock an additional revenue stream for operators and contribute to grid stabilisation.

Bus2Grid project demonstrating electric buses at Northumberland Garage in North London connected to vehicle-to-grid chargers

Source: https://www.current-news.co.uk/worlds-largest-v2g-project-dubbed-bus2grid-launched-in-london/

4.4 | Exploring On-Route and Opportunity Charging Solutions

Private bus operators should evaluate the feasibility and potential benefits of deploying on-route or opportunity charging solutions at strategic transit stops or layover locations – where possible. Opportunity charging, where buses receive quick charges during short layovers, can extend their operational driving range and potentially allow for the use of smaller, lighter batteries, leading to reduced bus costs and increased passenger capacity.

While on-route charging can offer operational advantages, operators need to carefully assess the costs associated with deploying and maintaining the necessary infrastructure. There are also challenges in securing access to land.

For these reasons, it may be more efficient to engage with charge point operators (CPOs) to understand their plans for infrastructure deployment along key routes, and whether there are opportunities to purchase access to this infrastructure for electric buses. Local and state governments should also be engaged to undertake where opportunity charging may be deployed for public transport electric buses, and whether access could also be expanded to private operators.

4.5 | Tropic Wings Case Study – Electric Bus Charging

The charging of 10 of the 12 electric buses deployed by Tropic Wings has been analysed in the following section of this report. This analysis provides insight into how these buses have been charged since deployment in the first half of 2024.

This analysis also aims to provide indicative insights into the potential optimisation of electric bus charging by linking this charging analysis with the bus operations analysis previously detailed in Section 3.3. These insights will help to inform other operators in planning for the deployment and operation of electric buses in their own fleets.

The window of analysis spans a 12-month period from May 2024 to May 2025. Similar to the operational analysis, the two additional electric buses (Eurise) have not been included as their telematics data was not available at the time of analysis.

4.5.1 | Charging session overview

In analysing trends, it could be observed that charging sessions characteristics varied across electric bus model and month of the year, both in terms of the average number of charging sessions (Figure 12) and charging duration per session (Figure 13). Any charging sessions that occurred for less than 5 minutes in duration were regarded as false charge sessions and were filtered out from this analysis. These short duration sessions accounted for 3.3% of all charging sessions recorded over the 12-month period of analysis.

FIGURE 12: Average number of charging sessions per day

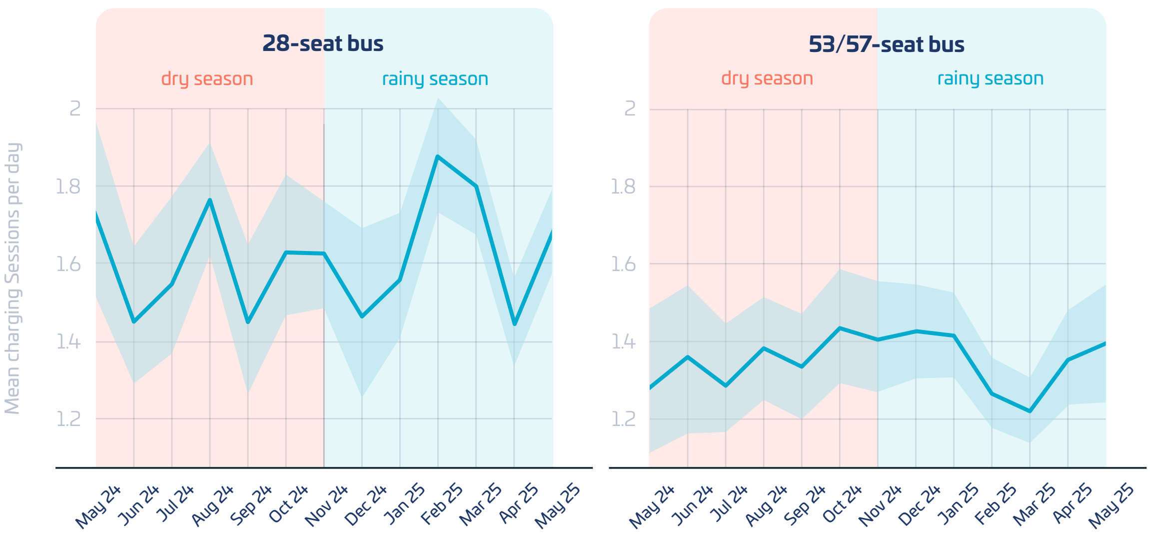
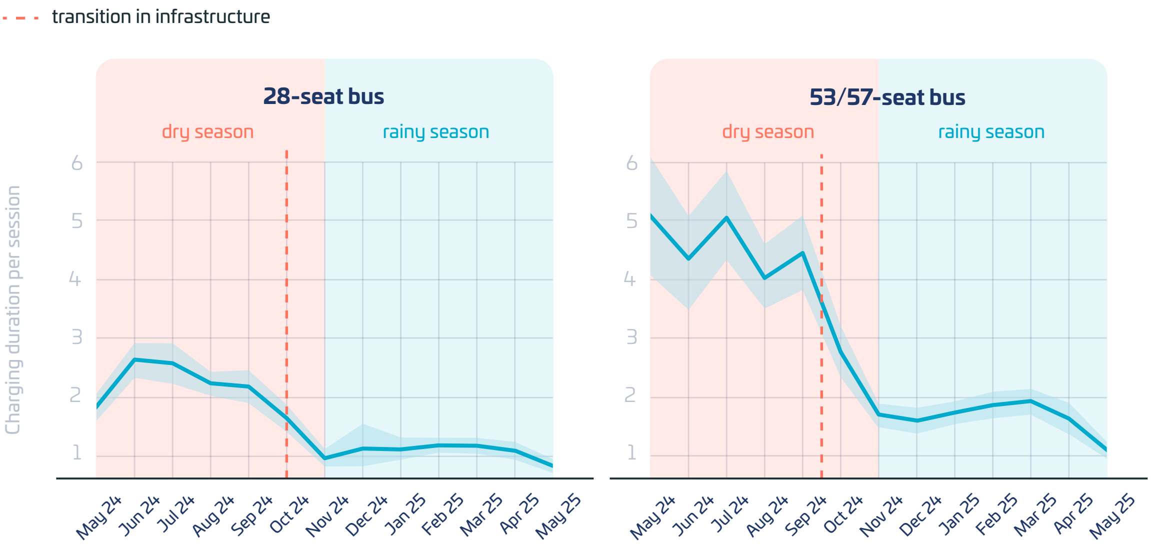


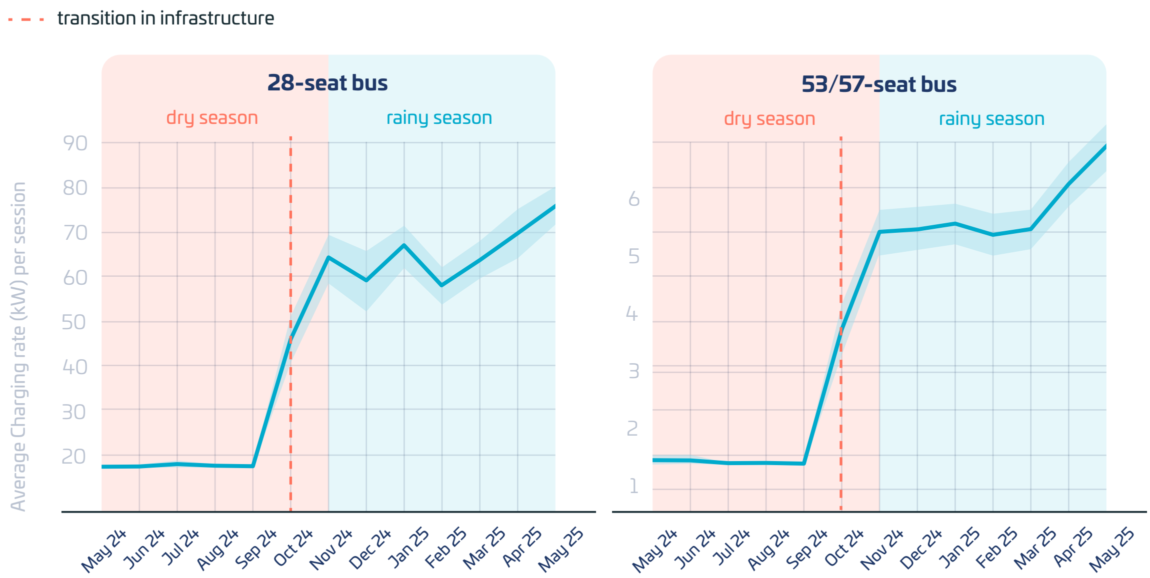
FIGURE 13: Average charging duration per session



The trend in charging duration per session across the two bus models was driven my multiple factors. Primarily there was a transition from a reliance on 22 kW chargers to 120 kW high power charging infrastructure from around October 2024 onwards – after the faster chargers were commissioned at Tropic Wings' main depot in Cairns. Additionally, shorter charging sessions (on average) tended to be associated with a higher number of charging sessions per day for the 53/57-seat buses.

Figure 14 also demonstrates an associated trend in the average charging rate per session due to the adoption of high-power charging infrastructure. The increasing average charging rate per session in Apil and May of 2025 also demonstrates an increasing prioritisation of high-power charging infrastructure, leading to the decrease in charging duration for the same period, as previously seen in Figure 13.

FIGURE 14: Average charging rate (kW) per session



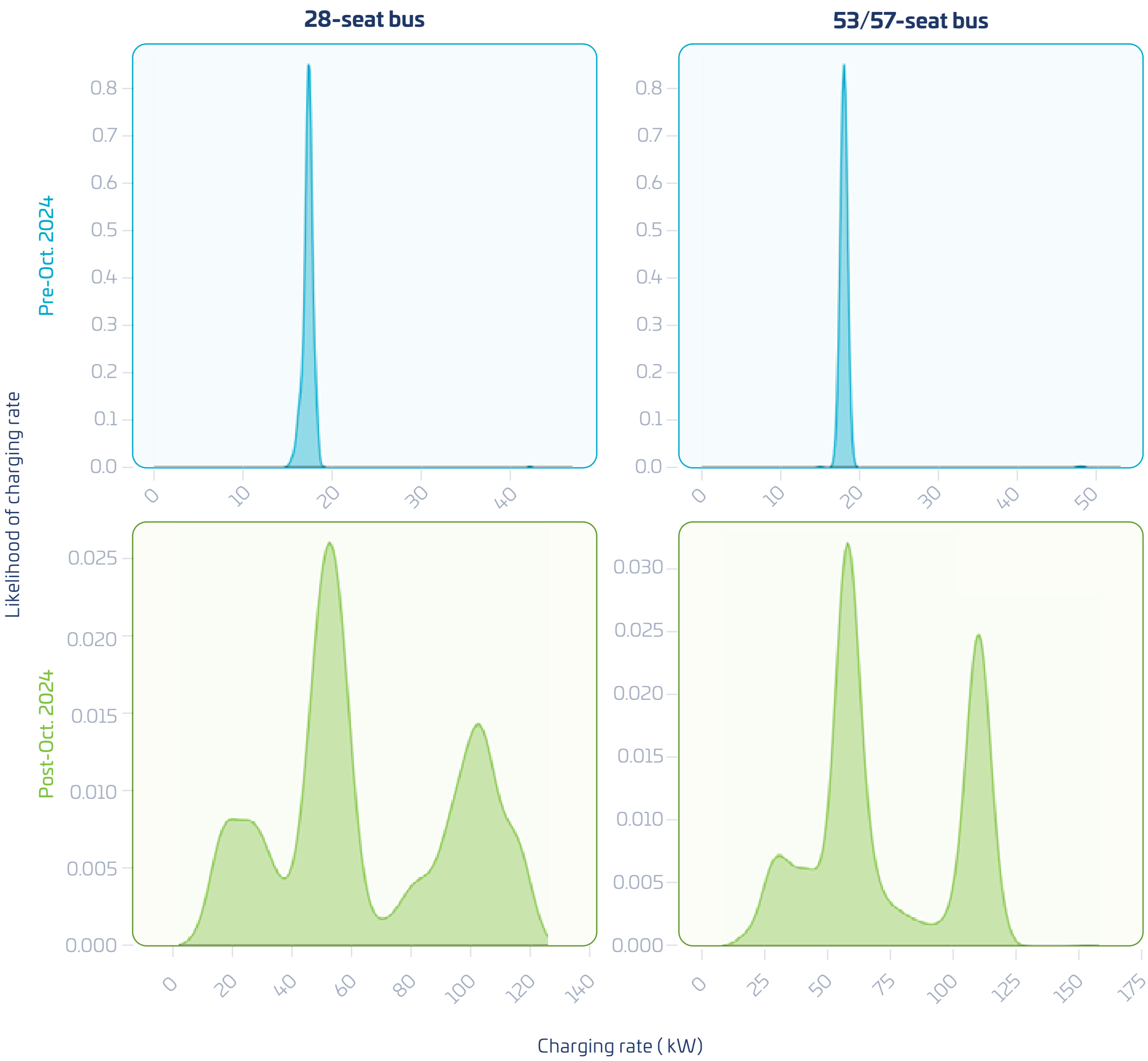
It is also not surprisingly that the 28-seat buses had shorter duration charging sessions compared to the 53/57-seat buses, given the battery capacity of the smaller buses is about half that of the larger buses.

Although the analysis also appears to suggest that, on average, the charging duration for both bus models was higher in the dry season compared to the rainy season, this is less likely to be related to any change in operations and/or conditions but primarily associated with the switchover to faster charging infrastructure.

The analysis detailed in Section 3.4 confirms this given there is no clear trend that would suggest buses where being operationalised in a way that would require shorter charging sessions in the rainy season versus the dry season, or vice versa.

Figure 15 highlights the relative frequencies of charging rates experienced by the 28-seat buses and the 53/57-seat buses. The density plots give a likelihood of the charging infrastructure used by the vehicles, by considering the expected average charging rates, aligning with the peaks of the curves. The two blue graphs, labelled 'Pre-Oct 2024', highlight the predominant use of 22 kW charging across both vehicle models prior to the transition to high-powered charging infrastructure employed at Tropic Wings' main depot.

FIGURE 15: Likelihood of average charging rate during a given charging session across buses and infrastructure



The fact that the narrow, sharp peaks are located at a charging rate that is less than the maximum power output of charging infrastructure is expected as the electric buses do not charge at a constant power rate throughout the session and instead follow a tapered charging curve.

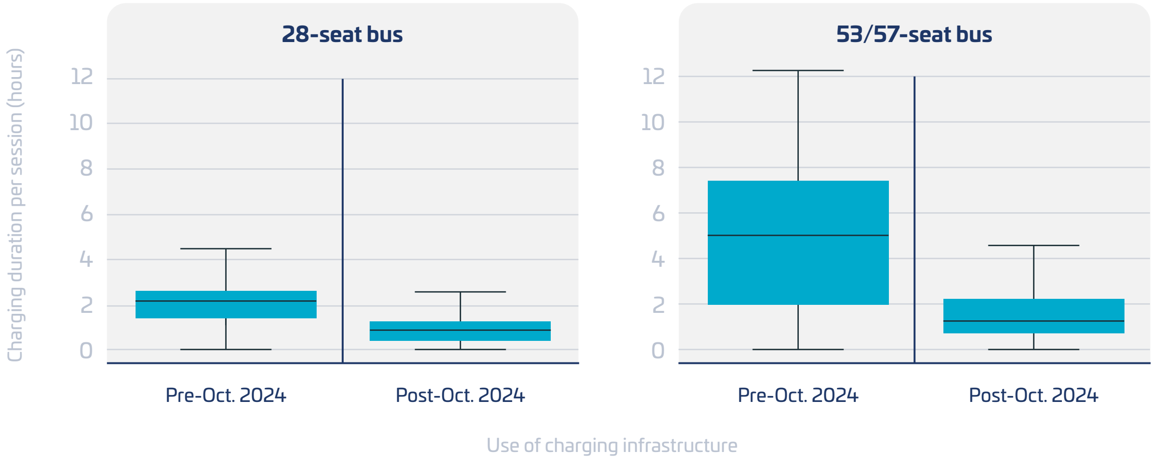
Drawing on this logic, the density plots of charging rate for the post-October 2024 period suggest utilisation of a mix of the 22 kW charging infrastructure with the high-powered 120 kW charging infrastructure.

Notably, in the post-October plots, clear peaks emerge around 60 kW for both bus types, indicating that the 120 kW chargers were often operating in dual-plug mode, where power is dynamically split between two buses, delivering up to 60 kW each. A smaller secondary peak near 100–110 kW suggests sessions where a single bus accessed the full capacity of a charger.

This distribution illustrates both shared and dedicated use of high-power charging infrastructure, highlighting the operational flexibility and load-sharing capability introduced after the depot was upgraded to include six 120 kW high power chargers.

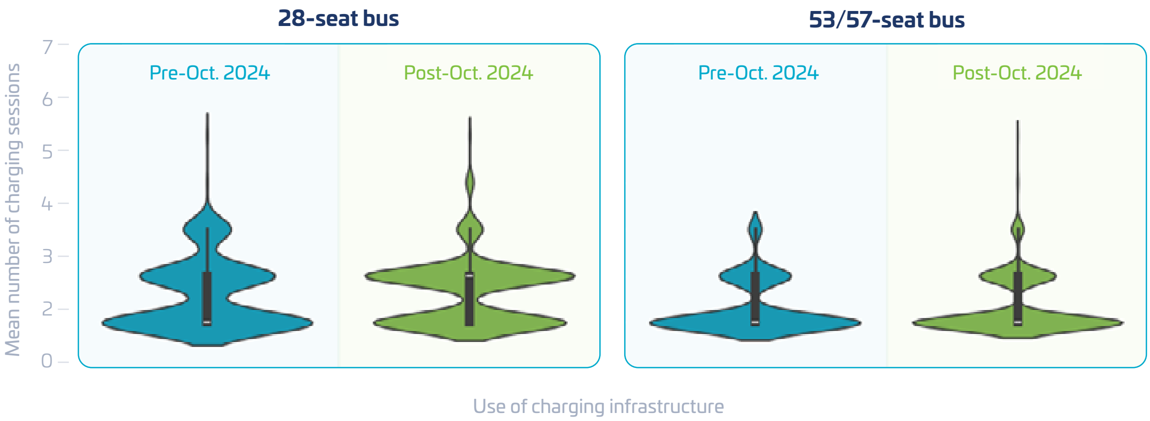
This trend towards shorter charging sessions, with greater utilisation of the higher power chargers can also be observed in Figure 16.

FIGURE 16: Distribution of charging duration per session across charging infrastructure



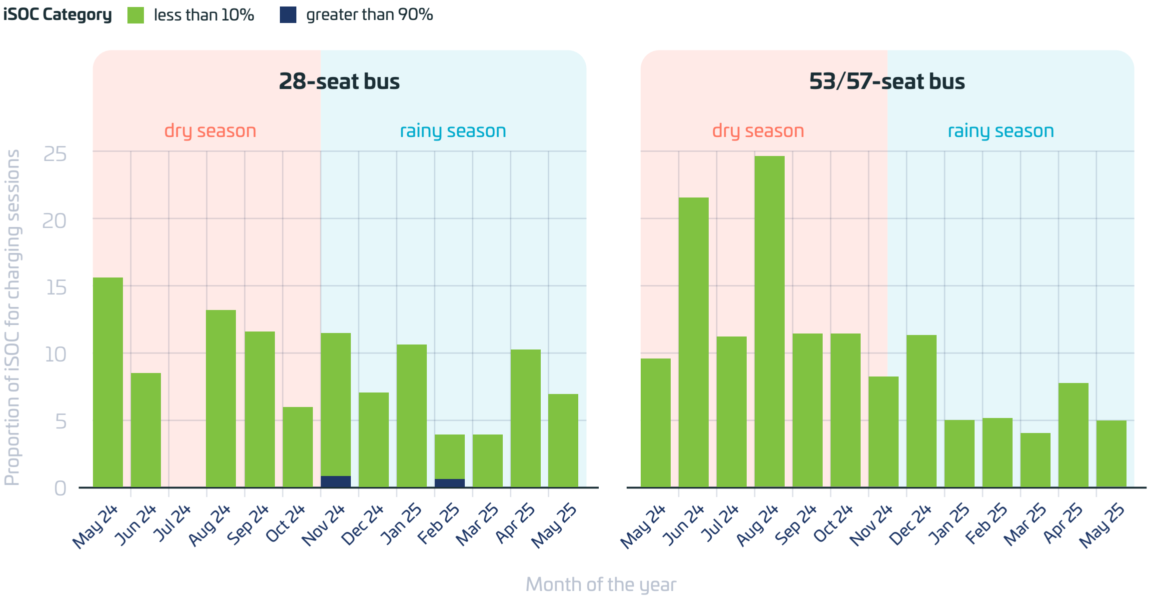
The change in charging patterns between Pre-Oct 2024 and Post-Oct 2024 can also be observed through a comparison of the distribution of the average number of charging sessions per day for both bus types (see Figure 17). In the case of the 28-seat bus, the availability of high-power chargers led to buses regularly being charged twice or more per day. This trend is less clear with the 53/57-seat buses, although there is a wider distribution meaning there were instances of these buses being charged 4 or more times per day Post-Oct 2024, that did not occur Pre-Oct 2024 – primarily due to the earlier reliance on slower 22 kW chargers.

FIGURE 17: Distribution of the average number of charging sessions per day



As shown in Figure 18, across the period of analysis, the initial state of charge (iSoC) was less than 90% and greater than 10% for the majority of the time for both bus models. In around 5-10% of charging sessions for both bus models, charging commenced at an iSoC greater than 90%. This demonstrates an overall strategy to keep buses topped up to full charge, plugging them in as often as possible. Of particular note, in August 2024, the 53/57-seat buses were placed on charge with an initial state of charge of 90% or greater approximately 25% of the time.

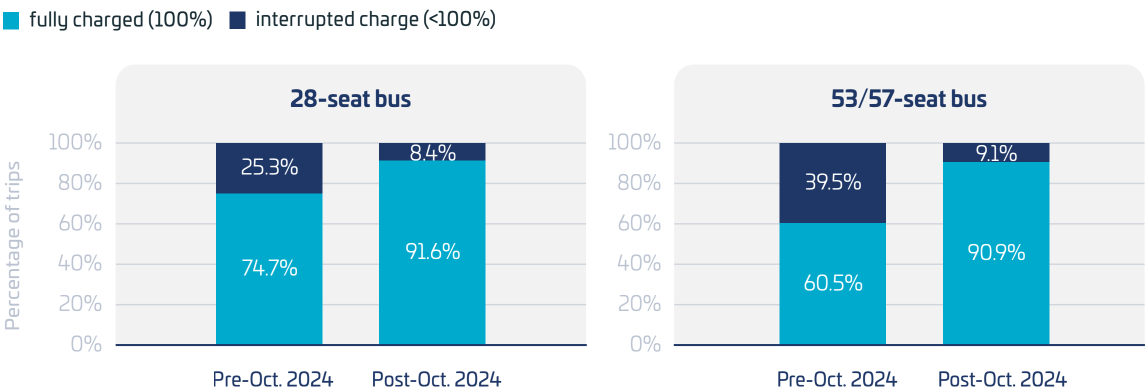
FIGURE 18: Trend in the distribution of Initial State of Charge



Over time, it can be observed the instances of charging starting at greater than 90% state of charge have reduced for both models. This is as a result of increased confidence in the real-world capabilities of the buses over time, as well as a shift towards faster chargers which reduced the need for the top-up charging strategy which would have been more important when using slower chargers e.g. 22 kW chargers.

Figure 19 shows that before the October 2024 charging-infrastructure upgrade, only 75% of charging sessions for the 28-seat buses and 61 % of charging sessions for the 53/57-seat buses continued until the buses were fully charged. After the upgrade, 100% charge rates jumped to about 92% and 91%, respectively, cutting interrupted sessions to below 10 % for both vehicle classes. The new high power charging hardware and scheduling clearly closed the gap between charging time and battery capacity.

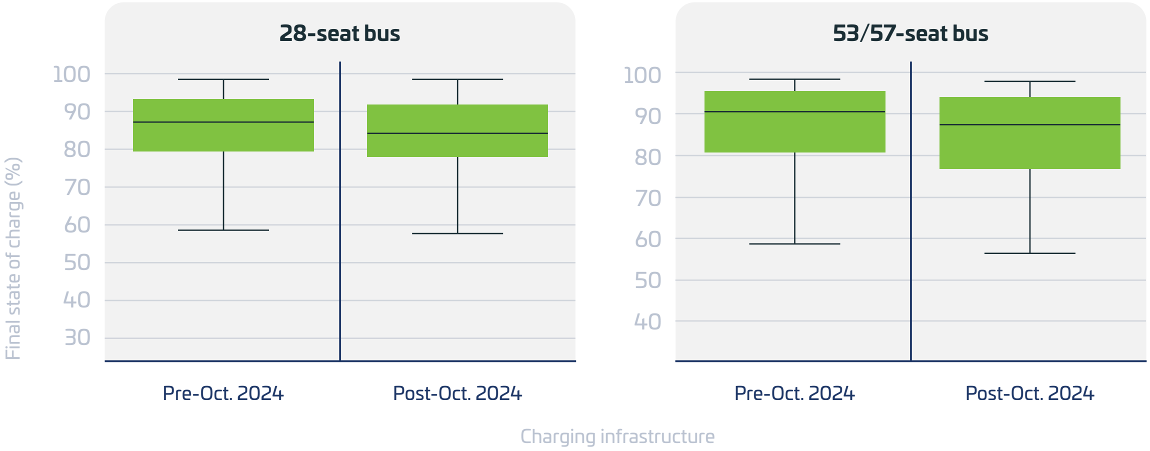
FIGURE 19: Proportion of final state of charge categories across infrastructure and vehicle



The box-plots in Figure 20 display the final state of charge (fSoC) for interrupted charging sessions, comparing periods before and after the October 2024 charging infrastructure upgrade. Before the upgrade, when buses primarily relied on 22 kW chargers, the median fSoC of these curtailed sessions sat in the high-80% range. After the higher-power chargers came online, many “almost-full” charging events now finish at 100%, and have dropped out of this subset, in turn reducing the median fSoC.

A handful of outliers, in the 25–40 % band, appear in both time periods and for both bus sizes. These extreme cases, although very infrequent, are operational red flags: if a vehicle re-enters service at one-third capacity, a schedule slip, face delays due road congestion, or experience an air-conditioning load spike, this could force an unscheduled detour to seek charging. That said, it is worth noting that this analysis is based on telematics data, and although efforts have been made to remove nonsensical data points, it is possible some of these are not true outliers.

FIGURE 20: Distribution of final state of charge of charging sessions of all vehicles across models and infrastructure.



4.5.2 | Optimising charging sessions

Beyond observing how the Tropic Wings fleet has been charged to date, it is also important to assess and highlight opportunities for further optimisation and improvement. To do so, it is first critical to understand the link between charging times, operation (driving) times and associated energy throughput.

Figure 21 highlights clear, repeated daily rhythms in operations. For both bus models, driving is highly concentrated in the morning, peaking sharply around 6 AM to 7 AM. The morning period between 4 AM to 10 AM, constitutes more than 50% of the driving activity for the 28-seat bus, and 70% for the 53/57-seat bus. This is followed by a modest secondary peak early-afternoon, around 1 PM.

The main charging activity, in contrast, clusters either side of each driving window, particularly for the 28-seat bus. There are three charging slots: a light top-up around 3AM, a mid-morning charging burst from 8 AM to 10 AM that coincides with the end of the first driving shift, and a late afternoon, 3 PM and 6PM session. The 53/57-seat buses rely far more on a single late-afternoon window, 3 PM to 7 PM, with only minor top-ups in the pre-dawn hours.

Interestingly, after the transition to high-powered charging infrastructure post-October 2024, a noticeable share of 28-seat bus charging migrates from the pre-dawn and mid-morning windows into the late afternoon peak, translating to an increase of 70%. While the 53/57-seat buses, already reliant on a single evening charging window (3PM to 7PM), also saw a 40% increase. Overall, the fleet's operational pattern leaves a sizeable overnight idle window and two predictable daytime charging windows—useful anchors for planning energy-management or load-shifting strategies to further optimise bus charging and reduce energy costs.

FIGURE 21: The likelihood of driving and charging of buses over a 24-hour period across Vehicle model and charging infrastructure

Figure 22 matches the battery energy available before each charging session (x-axis) with the energy that was drawn on the very next trip (y-axis). Because each dot represents one real charging event plus the single trip that followed it, the points are independent snapshots rather than a continuous timeline. The x-value already includes the energy added for that charging session, so every dot asks anew: "If this charge session had been skipped, would the bus still have finished its next trip with at least a 10% battery reserved?".

The red dashed line marks that 10% reserve threshold. Points below the line (green shading) indicate trips that could have been completed without the current charge session. Points above the line (pink shading) would have run out of energy without undertaking the charge session. Marker colours show the time-of-day charging window (overnight, morning, afternoon, evening).

For the 28-seat buses, most morning and overnight charging sessions cluster comfortably below the reserve boundary, suggesting that the current battery packs can typically carry these buses through their next assignment without an opportunistic top-up charge. The riskier points are concentrated in the afternoon and evening, when earlier trips during the day have already eroded the state of charge.

The larger buses (53/57-seat) display a heavier concentration of points above the reserve line, especially during the afternoon and evening charging windows. While many high-SoC morning departures remain in the safe zone, a more significant share of later trips in the afternoon and evening would have fallen short without undertaking the current charge session.

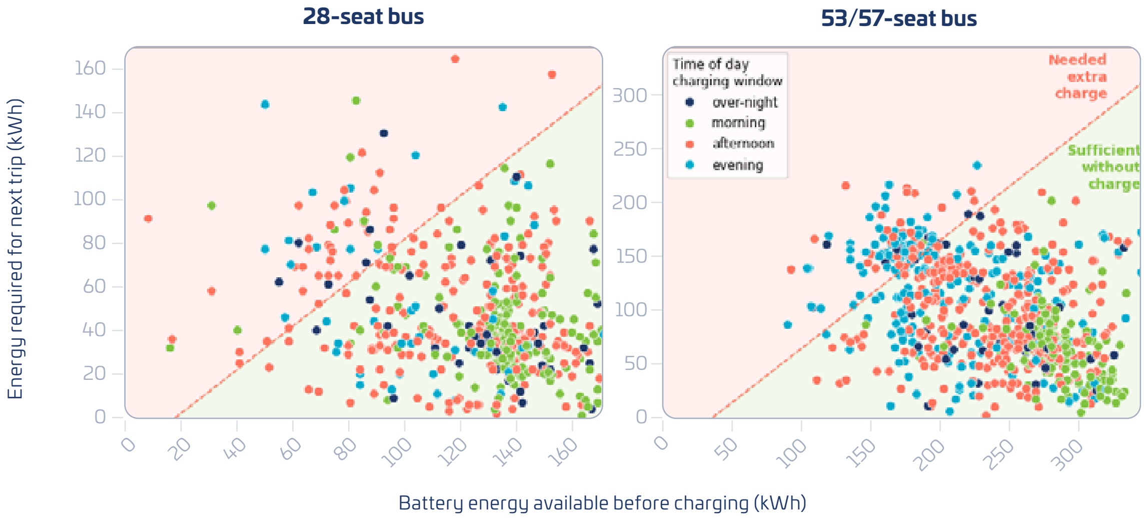
Overall, it can be concluded from Figure 23 that in the case of both types of buses, there are a significant number of opportunities to either delay or skip charging sessions. For the 28-seat buses this is primarily in the morning and sometimes in the evening, while for the 53/57-seat buses it is generally during the afternoon.

To be clear, there is nothing inherently incorrect about undertaking these charging sessions. In fact, it's expected that any operator with a new fleet of electric buses will likely be conservative and charge them as often as possible until enough data is collected to help optimise the charging scheduling. The primary downside of this strategy is that energy costs are likely to be much higher, with the buses regularly charged during peak energy demand periods. Conversely, through optimisation, these energy costs can be reduced by skipping unnecessary charging sessions and/or aggregating charging sessions to be scheduled around off-peak/low-cost energy periods. Indicative insights into the level of savings that could be achieved per bus through the optimisation of charging are provided in Section 6.0.

FIGURE 22: The incidence of subsequent energy usage to available battery energy before a charge session - identifying if a charge session is necessary

Can the battery's pre-charge energy cover the next trip? - 10% reserve included

Post-Oct 2024 charging infrastructure, Dashed line = energy available - 10% safety margin



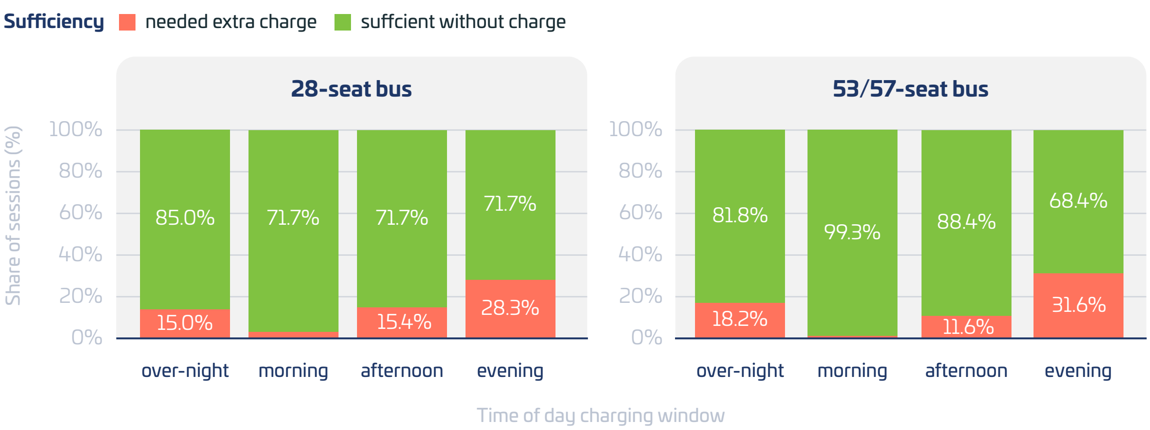
Building on the above, the stacked bars in Figure 23 show, for each time-of-day charging window, what share of charging sessions could have been skipped (green) versus those that were essential (red) for completing the next trip, after again accounting for a 10% battery reserve.

It is clear from this analysis that the overwhelming majority of morning charging sessions are almost never critical for completing the next trip, with the bus fleet analysed being able to meet these requirements 96% of the time without charging in the morning.

In contrast, the evening charging session was generally more important. For both bus types, around 3 in every 10 trips subsequent to these charge sessions, would not have been able to be completed without carrying out that charging session.

Combined, it appears that there is an opportunity for this bus fleet to avoid a number of charging sessions – particularly those that could be occurring during a morning peak – and prioritise charging during periods where lower-cost energy may be available, either via off-peak tariffs or on-site renewables. When considering the deployment of battery energy storage systems to support bus charging, this also highlights the important role these systems could play, particularly during the evening, and overnight – in addition to reducing grid loads during charging sessions that are necessary at peak energy times.

FIGURE 23: The share of charging sessions that could have been skipped across time-of-day windows



Finally, in Figure 24, the SoC buffer for the bus fleet has been analysed across different charging session time-of-day windows. This SoC buffer represents the surplus battery capacity remaining after accounting for the current charging session, and the energy required to complete the subsequent driving trip. In cases where a single charging session was followed by several trips throughout the day without any further charging, these multiple trips were aggregated to accurately reflect the true energy consumption (or demand) between charging sessions. These types of duty cycles can be observed particularly for the 28-seat bus, where morning charging sessions have a number of outlier observations where the SoC buffer is somewhat lower due to the vehicle being used across multiple trips during a day, between charging session.

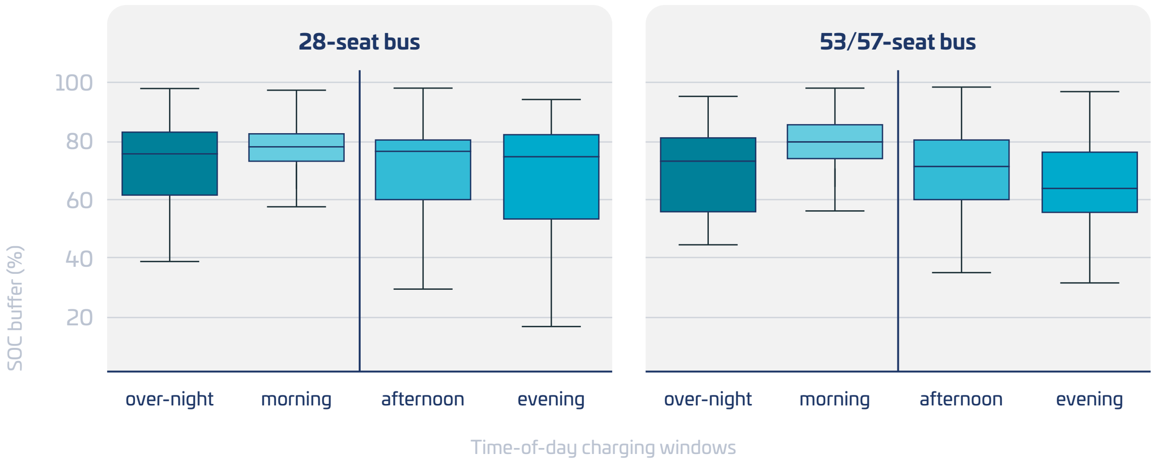
Consistent with earlier figures, it can be seen that the current charging strategy for this fleet is conservative and leads to relatively high levels of surplus battery capacity. In other words, the buses are charged regularly to be almost full (as shown earlier in Figure 20) and the trips subsequent to the charging session rarely consume a significant proportion of the battery capacity. This speaks to both the relatively high energy efficiency of the electric buses in this fleet, as well as the tendency to charge as often as possible.

For the 28-seat buses, the average SoC buffer is relatively consistent across time windows, although the spread is wider during the afternoon, evening and overnight. This aligns with earlier observations of these buses being charged more frequently throughout the day and also generally being used on more distinct trips throughout the day.

For the 53/57-seat buses, the average SoC buffer is highest in the morning – during charging sessions that probably largely unrequired, but gradually falls throughout the day, and are lowest in the evening. It's worth noting that as shown earlier in Figure 21, charging of these buses is most likely to be carried out during the evening, and so arguably, the evening SoC buffer is more reflective of the typical use of this bus. In other words, on average these buses have around a 60%

battery buffer, after accounting for the energy added as part of the current charging session, and the net energy consumption of the subsequent trip/s prior to the next charging session.

FIGURE 24: The distribution of state of charge (SoC) buffer across different charging windows



4.6 | Summary

As highlighted by this analysis, the Tropic Wings electric bus fleet analysed as part of this case study is regularly deployed and charged. It appears that a relatively conservative charging strategy has been adopted during the first year, which is expected. This also provides the opportunity to explore and test different strategies for optimising charging, and ultimately reducing charging costs.

Table 2 provides of summary of the different charging characteristics observed during this analysis. In particular, it is worth noting that every bus is charged at least once per day on average, and it appears that the level of charging infrastructure at the depot installed is more than sufficient to meet the requirements of this fleet.

As highlighted earlier, there was also a notable shift in charging patterns before and after the changeover to high power charging infrastructure in October, 2024. This switchover is also confirmed via the significant increase in average charging rate per session between the two time periods. For example, the average charging duration for each session at least halved on average after transitioning to high power charging infrastructure. Additionally, it appears that the time of day in which charging occurred – on average – shifted, with the morning period having the highest probability of a vehicle being charged pre-October, but this shift the afternoon period post-October, for both bus types.

Overall it appears that the buses have suitable capabilities for the use cases in which they are deployed, and in many cases could either be driven much further between charging sessions and/or required fewer charging sessions. Again, this is not to say that the conservative approach adopted is inappropriate; it is totally expected, however, it could be leading to higher energy costs versus a more optimised approach.

TABLE 2: Summary of charging characteristics

Charging Characteristics of Infrastructure for pre-Oct 2024 (± 95% CI)

Bus Type	Average Charging Duration (hr)	Average Charging Rate (kW)	Average Initial SoC %	Average Number of Charging Sessions (per vehicle per day)	Average SoC Buffer %	Average Trip Distance (km)	Share of Time of Day Charging Window
28-seat bus	2.2 ± 0.1	17.3 ± 0.1	73.3 ± 1.4	1.6 ± 0.1	75.5 ± 1.4	62.4 ± 2.9	over-night:13.8% morning: 50.7% afternoon: 30.1% evening: 5.4%
53/57-seat bus	4.5 ± 0.3	18.1 ± 0.3	67.8 ± 1.9	1.3 ± 0.1	70.9 ± 1.8	70.6 ± 5.8	over-night: 15.8% morning: 30.1% afternoon: 17.6% evening: 36.5%

Charging Characteristics of Infrastructure for post-Oct 2024 (± 95% CI)

Type	Average Charging Duration (hr)	Average Charging Rate (kW)	Average Initial SoC %	Average Number of Charging Sessions (per vehicle per day)	Average SoC Buffer %	Average Trip Distance (km)	Share of Time of Day Charging Window
28-seat bus	1.1 ± 0.1	65.6 ± 1.9	70.2 ± 1.3	1.7 ± 0.1	72.9 ± 1.2	59.3 ± 2.4	over-night: 5.9% morning: 39.9% afternoon: 46.6% evening: 7.6%
53/57-seat bus	1.7 ± 0.1	73.2 ± 1.9	67.2 ± 1.1	1.4 ± 0.0	70.8 ± 1.0	67.6 ± 2.7	over-night: 5.9% morning: 20.4% afternoon: 45.3% evening: 28.5%

5 Bus Passenger and Driver Experiences on Electric Buses Based on the Tropic Wings Fleet

The following section of this report documents the analysis of two questionnaires distributed as part of the Tropic Wings project. This included a survey of passengers on their experience travelling on an electric bus, as well as a second survey of Tropic Wings' employees who regularly drive an electric bus.

While the results of these surveys are not presented as definitive or even generally representative, they shed some light on both the opportunities to further promote and support the adoption and use of electric buses by public operators, public support for this technology, as well as opportunities to further improve and/or optimise operations.

5.1 | Passenger experiences on electric buses

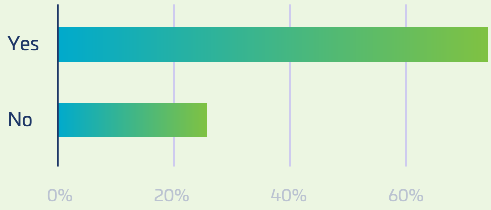
There are number of potential benefits for passengers travelling on electric buses. This survey was conducted to better understand the experience of Tropic Wings customers undertaking day tours in the Cairns region on an electric bus. No incentives were offered to complete the survey, and there was a limited period in which the data could be collected. In total, 32 responses were received during June 2025. The full questionnaire has been included in Appendix A.

QUESTION 1:

The purpose of this first question was to better understand how obvious it was to passengers that they were travelling on an electric bus. Anecdotally it had been reported that a significant number of passengers didn't realise they were on an electric bus – at least initially.

The results of this survey suggest that the majority of customers were probably aware, but more than a quarter did not realise they were travelling on an electric bus.

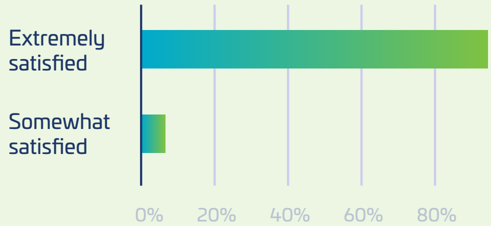
Were you aware you were travelling on an electric bus for your trip?



QUESTION 2:

Of the sample questioned for this survey, all passengers were satisfied with their electric bus journey, with the overwhelming majority extremely satisfied. This highlights the overall appropriateness of utilising electric buses for tourism activities.

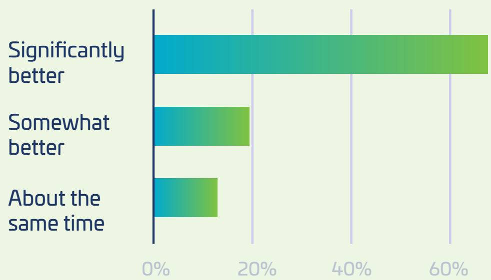
How would you rate your overall satisfaction with this electric bus journey?



QUESTION 3:

In line with the results of Question 2, most passengers reported their experience on an electric bus as being better than on a diesel bus – with the overwhelming majority again stating it was significantly better. Around 13% of passengers felt the experience was the same or similar to a diesel bus.

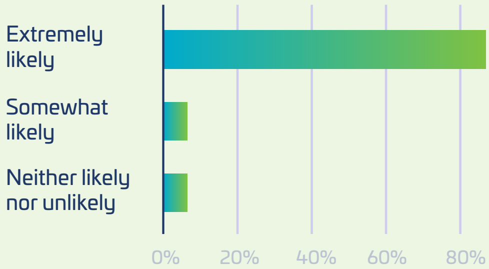
Compared to your experience on a regular, diesel bus, was this journey...



QUESTION 4:

Unsurprisingly, when asked about preferences for future journeys, consistent with earlier answers, the majority of respondents stated they would be likely, most extremely likely, to choose an electric bus for future trips.

How likely are you to choose an electric bus for future journeys (if available)?



QUESTION 5:

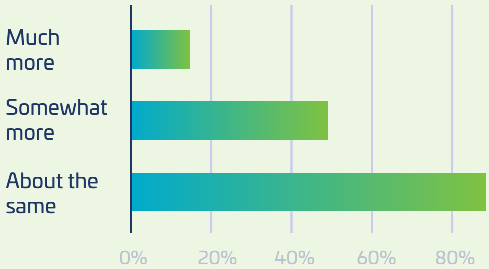
Although the responses to the initial questions were insightful, ultimately part of this exercise was intended to explore whether perceived benefits of travelling on an electric bus might translate into a willingness to pay a premium for this service.

Although different approaches to obtaining this information were explored during the construction of this survey, given the limited time period for data collection and the target audience, a decision was made to develop a qualitative assessment rather than quantitative.

As shown below, while the majority of passengers (58%) reported they would only be willing to pay about the same to use an electric bus – compared to a diesel bus – almost a third would be willing to pay somewhat more (32%) and a further 10% reported a willingness to pay much more.

The average day tour with Tropic Wings costs approximately $200 - $300. A few potential scenarios exploring electric bus price premiums, and the subsequent impact on the total cost of ownership, are detailed in Section 6.1

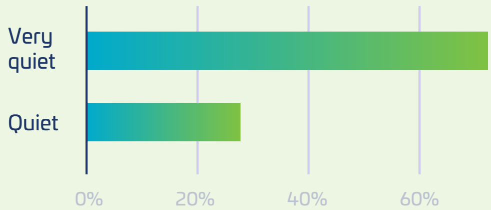
Compared to a diesel bus, for future trips on an electric bus would you be willing to pay...



QUESTION 6:

Further exploring potential benefits of travelling on electric bus, as expected, all passengers reported that noise levels inside the bus were either quiet or very quiet.

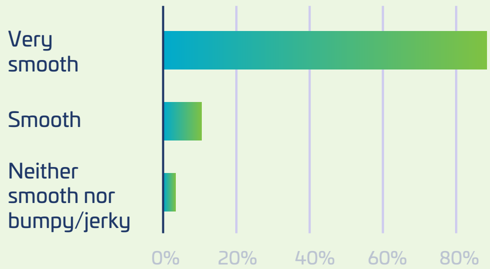
How would you rate the noise level inside the bus during this journey?



QUESTION 7:

The majority of passengers also reported the ride of the electric bus was either very smooth (86%) or smooth (10%).

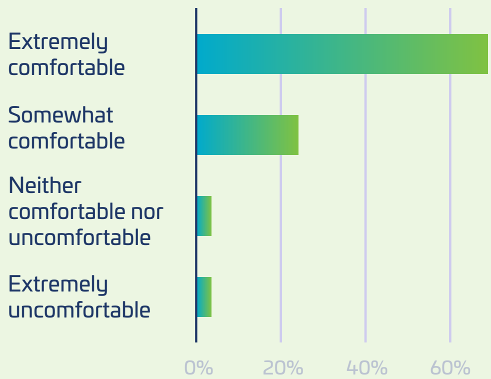
How would you rate the smoothness of the ride (acceleration, breaking) during this journey?



QUESTION 8:

Although not necessarily specific to an electric bus, the majority of passengers also reported that the seats were comfortable. Similar to Questions 9 and 10, these questions were included to understand if there may be other factors – not related to electric buses – that could impact the broader experience of passengers during their trips.

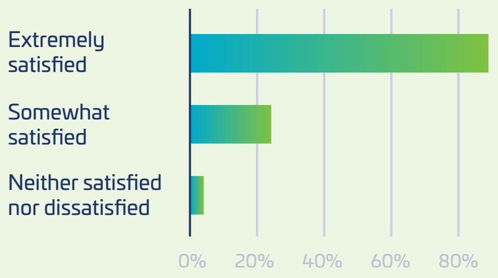
How comfortable were the seats on this bus?



QUESTION 9:

The majority of passengers also reported being satisfied with the temperature inside the bus. Again, while not necessarily specific to electric buses, it's important to note that electric buses provide the additional benefit to run the air-conditioning while stationary without any idling engine sounds, vibrations or exhaust fumes. It also highlights that Tropic Wings tours continue to provide satisfactory air-conditioning comfort to passengers while using electric buses.

How satisfied were you with the temperature inside the bus?

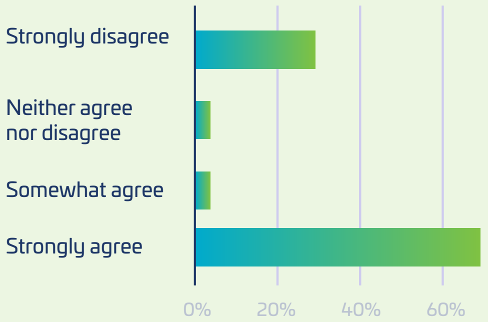


QUESTION 10:

Finally, passengers were asked whether they felt safe and secure during their journey. Interestingly around 28% strongly disagreed, however, it's not immediately clear whether this was due to a misunderstanding about the question or some other issue/s separate to the use of electric buses.

No additional comments were provided by passengers that would suggest any concerns about safety were related to the use of electric buses.

Did you feel safe and secure during this journey?



Additional Feedback:

In addition to the ten questions outlined above, passengers were also provided with the opportunity to include written comments about their experience. In line with the previously examined results, the overwhelming majority of feedback was positive. Comments included:

- The trip on this electric bus was awesome!
- It was great not to have to breathe in and smell diesel fumes.
- Very satisfied with the use of electric buses
- Excellent service by Tropic Wings
- Smooth and quiet ride.

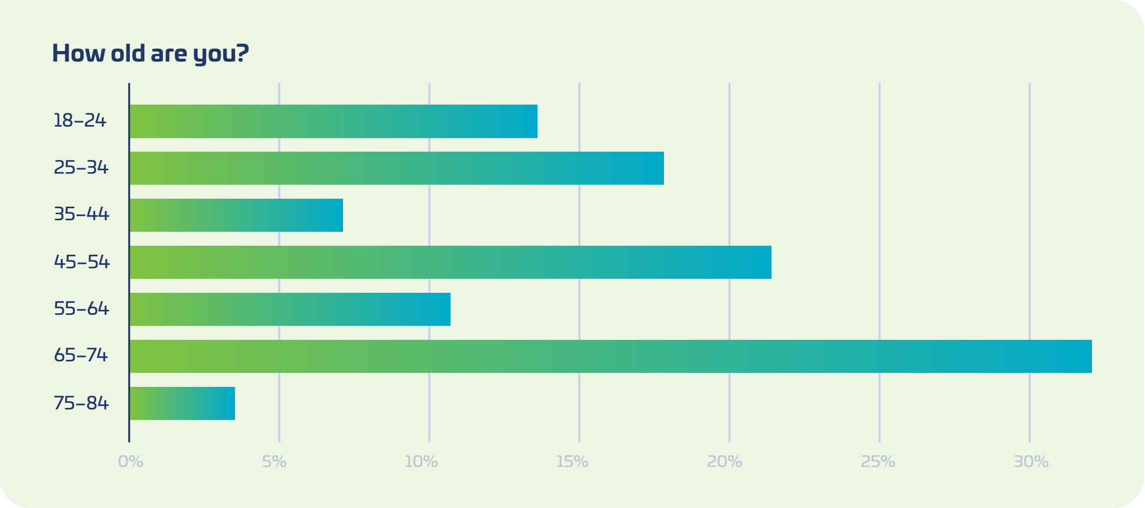
The primary negative commentary related to a perceived reduction in luggage storage space on the electric buses, with a particular reference to space under the 53/57-seat coaches.

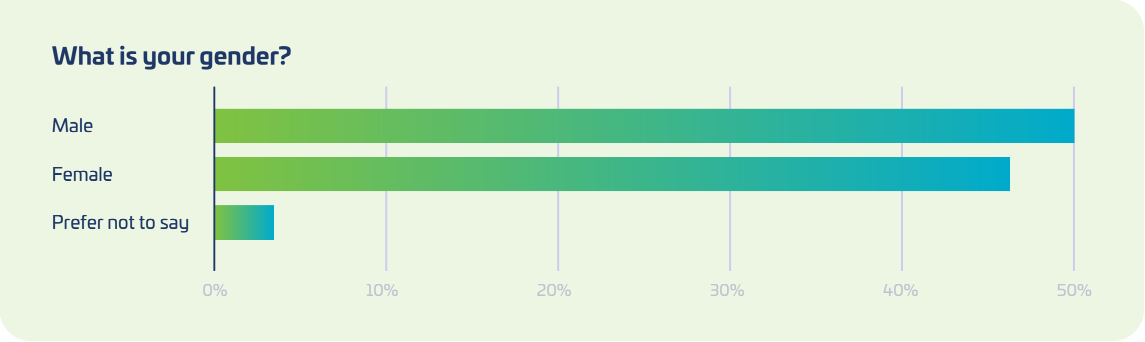
Demographics:

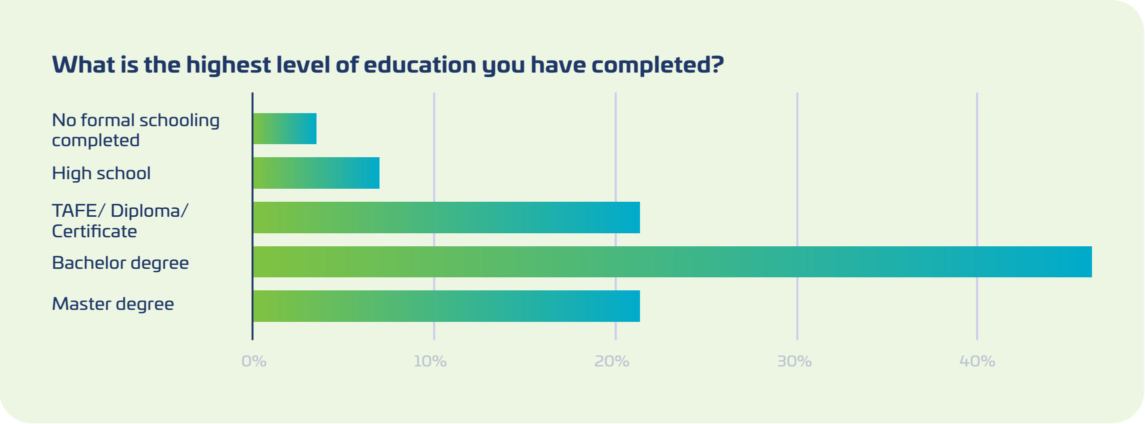
As highlighted earlier, these results were obtained from a relatively modest sample, and should not be interpreted as definitive or generally representative. That said, passengers were asked three demographic questions to understand the breadth of the sample.

As shown, the sample of passengers was reasonably spread over age cohorts, with around one-third of the sample aged 65-74. There was also a relatively even split between genders, and a spread across education levels.

Although not reported here for privacy reasons, respondents were also asked to state their home postcode, with passengers coming from around Australia, and a small number of international tourists also included in the sample.







Summary:

This sample of electric bus passengers was overwhelmingly positive about their experience, with a significant proportion willing to pay a premium to undertake a tour using these vehicles. It appears there remains some room for improvement, but overall, Tropic Wings leadership in adopting EVs is viewed positively by its customers, and provides the opportunity to explore how the total cost of ownership of electric buses could be further improved through potential tour price changes.

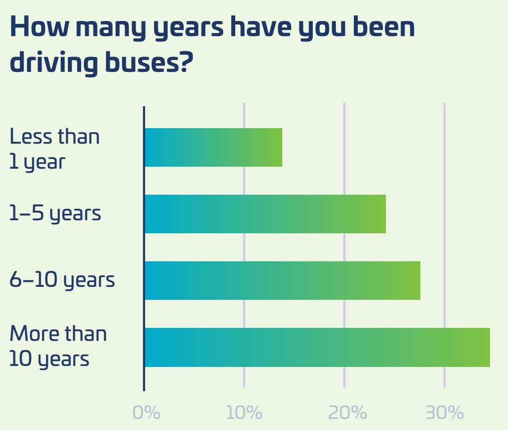
5.2 | Driver experiences on electric buses

In addition to the experience of passengers, it is also important to understand the experience of drivers to identify both benefits and potential barriers or challenges.

A total of 31 Tropic Wings bus drivers were surveyed during June 2025. The full questionnaire they were asked to complete has been included in Appendix B.

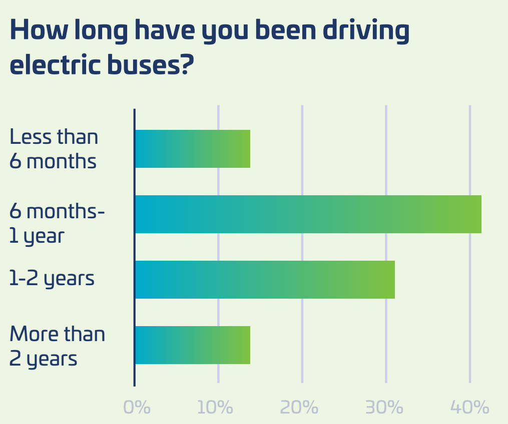
QUESTION 1:

This was question was designed to provide insight into the relative experience of drivers captured as part of this sample. As shown, just over one-third of drivers who responded (34%) had more than 10 years experience driving buses, followed by drivers with 6-10 years experience (28%), 1-5 years experience (24%), and 14% with less than 1 year experience.



QUESTION 2:

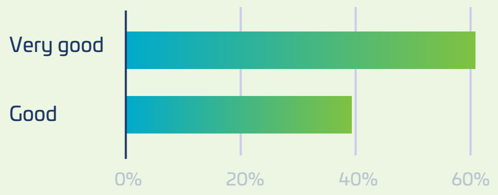
Regarding electric bus driving experience, 41% reported having 6 months to 1 year experience – consistent with the introduction of the larger electric bus fleet with Tropic Wings. 45% reported having 1 year or more of experience, which again is not unexpected given Tropic Wings has had an electric bus in operation since 2019.



QUESTION 3:

All drivers that responded to this survey rated the overall performance of the electric bus they typically drive as either good (39%) or very good (61%).

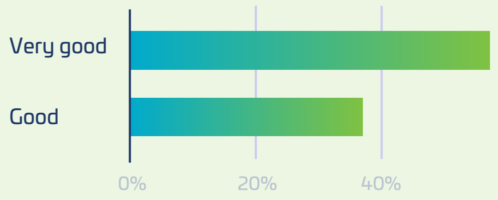
How would you rate the overall performance of the electric bus you typically drive?



QUESTION 4:

In line with responses to Question 3, all drivers all reported the handling and manoeuvrability of their electric bus as either good (43%) or very good (57%).

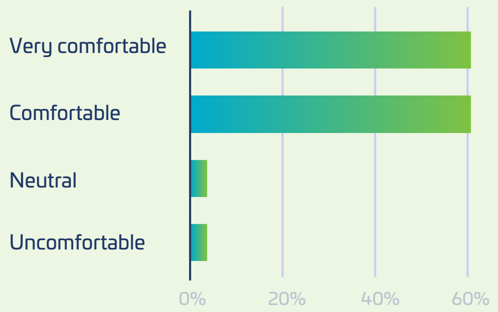
How would you rate the handling and manoeuvrability of the electric bus you typically drive?



QUESTION 5:

The vast majority of bus drivers also reported the driver's seat and cabin environment as being either comfortable (61%) or very comfortable (32%). A small minority responded neutral (4%) or uncomfortable (4%).

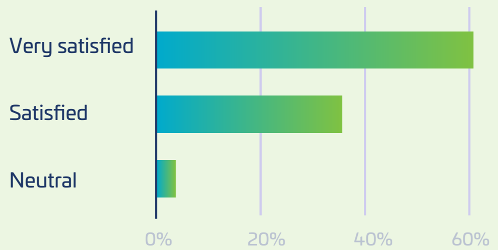
How comfortable is the driver's seat and cabin environment in the electric bus you typically drive?



QUESTION 6:

Again, the overwhelming majority of bus drivers were satisfied with the heating and colling system in the electric bus they typically. One respondent was neutral.

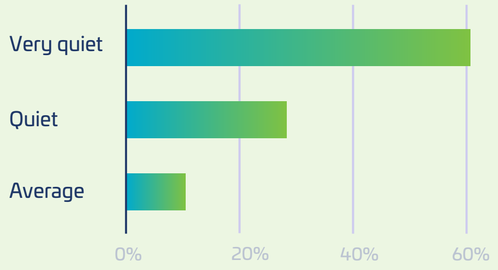
How satisfied are you with the heating and cooling system in the electric bus you typically drive?



QUESTION 7:

While around 11% of drivers reported noise levels inside the cabin of the electric bus being average, the majority reported noise levels as quiet (29%) or very quiet (61%).

How would you rate the noise level inside the cabin of the electric bus you typically drive?



QUESTION 8:

The next question provided the opportunity for open feedback regarding the specific features of electric buses that drivers found particularly useful or not useful for their job. A summary of this feedback has been provided below, divided into positive versus negative comments.

Positive feedback:

- Electric buses provide good overall performance
- They are easy to drive
- Great to be able to idle with air-conditioning running and no pollution/exhaust fumes
- Quiet and smooth for driver and customers

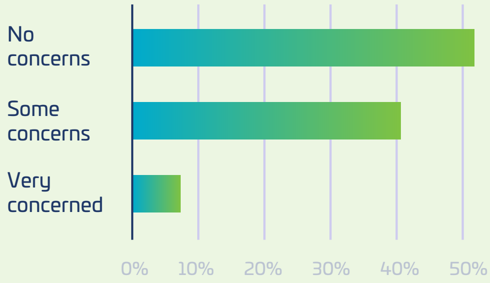
Negative feedback:

- Not enough on-board storage for driver, plus some limitations on luggage storage for passengers
- Annoyed by artificial sounds below 20 km/h, with one driver noting they are distracting
- Some complaints about throttle regulation being too conservative when starting buses from standstill resulting in delayed acceleration that can be a safety concern if not aware of the vehicle feature; some drivers referred to this as limp mode, others suggested this only seems to occur while on an incline.
- Finally, a few drivers observed that the location of the TV screens in the 28-seat buses can create hazard for passengers and should be repositioned if possible.

QUESTION 9:

Moving on to more specific questions regarding electric bus capabilities, a key question that is always asked is around range anxiety for drivers – whether it be of electric buses or other electric vehicles. In this survey, a slight majority of electric bus drivers reported having no concerns about the vehicle's driving range, however, 41% had some concerns, and 7% were very concerned.

Do you feel concerned about the battery (driving) range of the electric bus you typically drive?

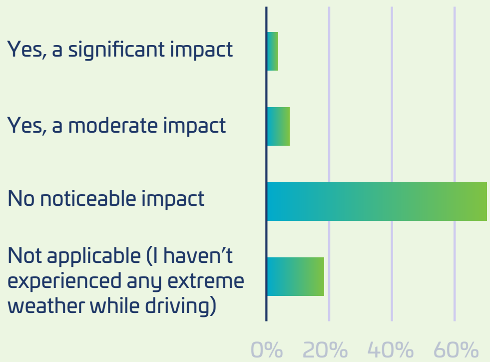


QUESTION 10:

Again, the majority of drivers did not believe weather conditions had a significant impact on driving range – which is also consistent with earlier analysis in this report on the energy consumption of Tropic Wings buses under different conditions.

It should be noted that 19% of drivers did not think they had experienced extreme weather (yet) to appropriately answer this question.

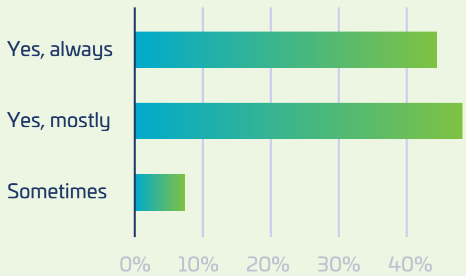
Have you noticed any significant impact of weather conditons (e.g. very hot or very cold) on the bus' battery (driving) range?



QUESTION 11:

Consistent with other responses to this survey, the majority of drivers report being confident in the performance of the electric buses on all parts of their tourism routes.

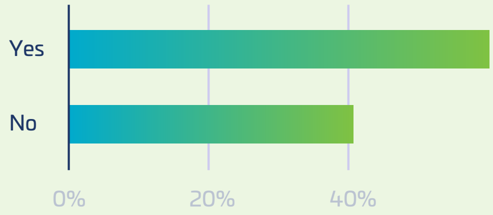
Do you find that the electric bus performs adequately on all parts of your routes (e.g. hills, busy roads, etc.) ?



QUESTION 12:

Interestingly, while the majority of drivers (59%) in this sample reported receiving training on how to drive electric buses efficiently, 41% reported they did not believe they had received such training.

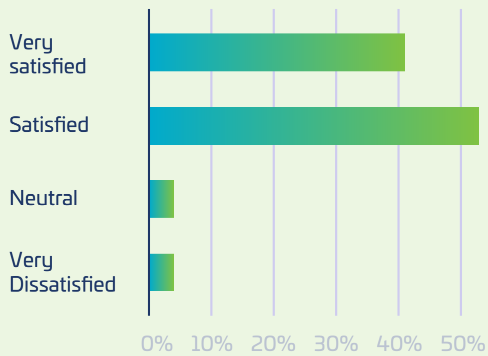
Have you received any specific training on how to drive the electric bus efficiently to maximise its driving range?



QUESTION 13:

Overall, drivers also largely reported being satisfied with the training they received on how to operate the electric buses.

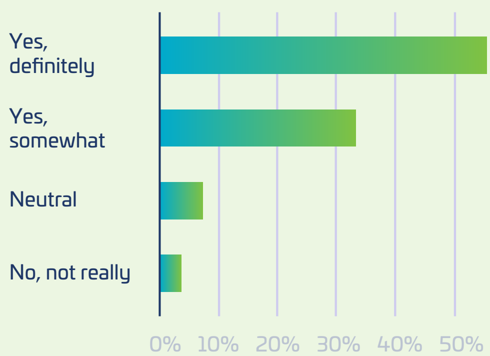
How satisfied were you with the initial training you received on how to operate electric buses?



QUESTION 14:

Consistent with Question 13, the majority of drivers also felt they had adequate support and resources.

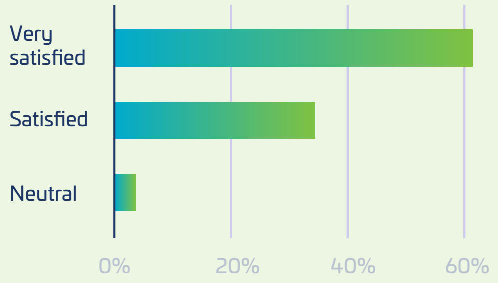
Do you feel you have adequate support and resources to address any issues or questions you have about the electric buses you drive?



QUESTION 15:

Again, consistent with previous questions, the overwhelming majority of drivers reported being satisfied with their electric bus driving experiences at Tropic Wings.

Overall, how satisfied are you with your experience driving electric buses?



QUESTIONS 16, 17, AND 18:

Three additional open-ended questions were asked to illicit any feedback from drivers that was not adequately captured by survey questions to this point.

First, drivers were asked what they liked most of the electric buses:

- Powerful
- Quiet, proving opportunity to talk to passengers
- Smooth, don't feel stiff after a long drive
- Feels like driving a car
- No idling issues, can run A/C
- Positive reaction from customers
- Don't have to breathe diesel

Second, drivers were asked about the biggest challenges. While many did not have specific issues, the primary concerns were:

- Driving range limits
- Lack of acceleration from standstill (limp mode) → this was a relatively consistent concern across the driver's sampled.

Finally, driver's were asked about any other suggestions they have to improve the electric buses:

- More storage for driver e.g. place to put your phone, documents, etc.
- Relocation of TV on 28-seat buses
- Increased driving range.
- Remove limp mode
- Remove artificial noises

Summary:

Overall, the results of this survey of electric bus drivers provides some useful insights into experiences in a private operator fleet used for tourism purposes. Of course, it's not unexpected that drivers had some concerns about electric buses, but the overwhelming response was positive, with a general encouragement to continue in this direction. This is notable given this sample of drivers is relatively experienced overall, meaning that the majority have been driving diesel buses for some time.

The results also suggest that initial concerns about drivers being potentially resistant to a shift to electric buses may be overestimated, however, it is clear that appropriate training and support – as that which has been provided by Tropic Wings (and confirmed by most drivers in this survey) – is important for addressing concerns, and supporting the transition.

6 Indicative Total Cost of Ownership Analysis for Electric Buses in Australia

A comprehensive total cost of ownership (TCO) analysis is essential for private operators to make informed decisions about transitioning to electric buses. A TCO analysis encompasses all costs associated with owning and operating a vehicle over its entire lifecycle.

Key components of the TCO for electric buses include:

- the initial purchase cost, which is often higher than that of a comparable diesel bus
- financing costs, considering the higher initial purchase cost
- the cost of purchasing and installing the charging infrastructure at the depot, including potentially upgrading grid connections
- energy costs for electric buses (electricity), which are typically lower than diesel buses (fuel)
- Maintenance and repair costs for electric buses, which are also generally lower
- The cost of battery refurbishment or replacement, which depends on the battery's lifespan
- Other operational costs, such as driver training and insurance, and
- The residual value of electric buses at the end of their lifecycle.

Table 3 provides a comparative estimate of the Total Cost of Ownership (TCO) for an example electric bus versus an example diesel bus in the Australian context over a 12-year lifecycle. The estimates presented here are based on a synthesis of information from various sources, including data collected as part of this ARENA co-funded project. It has been developed to reflect example costs and savings for the Australian market, however, are provided as a general guide only for informative purposes. Low, mid and high estimates have been provided to demonstrate the potential variation in costs.

TABLE 3: Summary of TCO analysis for example electric buses versus diesel buses

Cost component	Example Electric Bus (AUD)			Example Diesel Bus (AUD)		
	Low	Mid	High	Mid	Mid	High
Purchase cost	$750,000	$850,000	$950,000	$450,000	$550,000	$650,000
Financing Cost	$100,000	$115,000	$130,000	$60,000	$75,000	$90,000
Annual Fuel / Energy Cost	$4,000	$9,500	$15,000	$30,000	$40,000	$50,000
Annual Maintenance Cost	$5,000	$6,500	$8,000	$15,000	$17,500	$20,000
Infrastructure Cost (amortised over 12 years)	$15,000	$22,500	$30,000	-	-	-
Battery Replacement / Refurbishment Cost	$150,000	$175,000	$200,000	-	-	-
Other Annual Operation Costs (insurance, etc)	$5,000	$6,000	$7,000	$5,000	$6,000	$7,000
Residual Value (after 12 years)	$52,500	$73,750	$95,000	$22,500	$37,250	$52,000
Total cost over 12 years	$1,295,500	$1,600,250	$1,905,000	$1,087,500	$1,349,750	$1,612,000
Estimated cost per kilometre (over 12 years, assuming 50,000 km / year)	$2.159	$2.667	$3.175	$1.813	$2.250	$2.687

Note: These figures are estimates and can vary based on specific bus models, operating conditions, electricity and fuel prices, as well as evolving residual values.

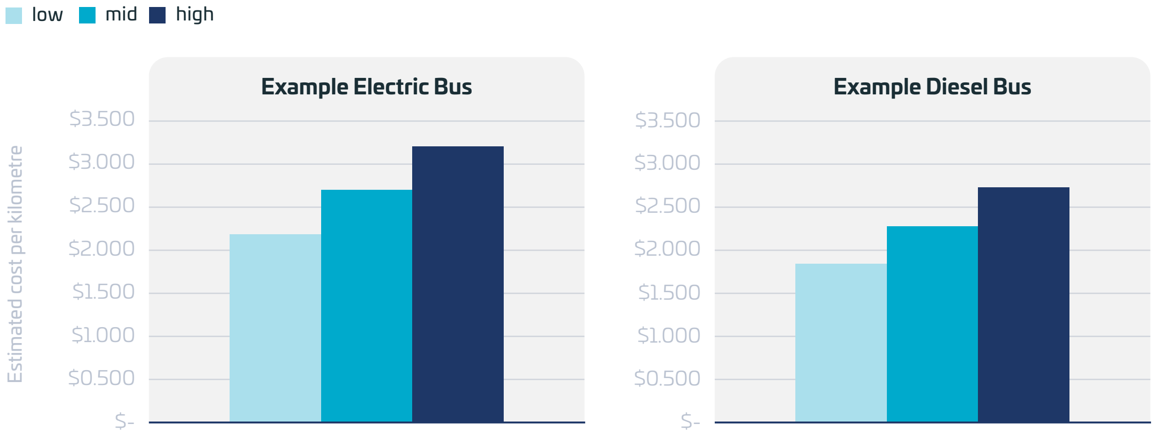
Further details regarding the TCO components included in this analysis are listed in Table 4.

TABLE 4: Notes on TCO cost components

Cost component	Notes
Purchase cost	Initial purchase price is higher for electric buses, although costs are expected to continue falling over the coming decade.
Financing Cost	Financing costs for electric buses are assumed to be higher due to the higher purchase cost, however, this analysis does not consider the potential availability of low-interest finance for green / sustainable assets.
Annual Fuel / Energy Cost	Electricity costs are significantly lower than diesel fuel costs, particularly when taking advantage of off-peak tariffs and/or renewable energy supply.
Annual Maintenance Cost	Fewer moving parts in electric buses leads to lower maintenance costs.
Infrastructure Cost (amortised over 12 years)	Includes high power charging station costs, and associate grid connection/ upgrade costs; assuming a fleet of bus:charger ratio of 2:1 on average
Battery Replacement / Refurbishment Cost	Estimated cost for battery replacement and/or refurbishment that may be required around year 7-10.
Other Annual Operation Costs (insurance, etc)	Similar for both types of bus.
Residual Value (after 12 years)	Estimates, noting electric bus residual values will continue to evolve over time, and are expected to increase while diesel residuals may decrease over the longer-term as they become less popular to own and operate.
Total cost over 12 years	Generally, a cost premium exists, however, for some applications electric buses can be cheaper.
Estimated cost per kilometre (over 12 years, assuming 50,000 km / year)	Electric bus cost per kilometre is increasingly competitive, however, there remains a need for policy support and/or innovative approaches.

The estimated costs per kilometres across low-, mid- and high-cost scenarios for both electric and diesel buses are shown in Figure 26. The variation across both electric and diesel buses can be relatively significant but similar at around +/- 20%. Although on average diesel buses are expected to still be cheaper than electric buses, under certain scenarios electric buses can be cheaper than diesel buses today.

FIGURE 25: Estimated total cost of ownership for electric versus diesel buses



Optimising the charging of electric buses, including the use of off-peak electricity tariffs, is one avenue to reducing the TCO and increasing the competitiveness of electric buses with diesel buses. Carefully managing infrastructure costs is another important consideration.

It is clear that as the upfront purchase costs of electric buses fall in time, and in turn any potential battery refurbishment / replacement costs, the TCO will fall to a point where diesel buses are no longer competitive for most applications. That said, it is difficult to predict with a high degree of certainty the timeline for these price reductions, particularly given the relatively small size of the Australian bus market.

Other opportunities to improve the cost-competitiveness of electric buses have been explored in the following section of the report.

6.1 | Example scenarios for further reducing the TCO of electric buses

There are several pathways to improving the cost-competitiveness of electric buses on a TCO basis. Two example scenarios are explored below.

First, assume a typical diesel bus has a total cost over 12 years of $1,349,750 – as per Table 3.

Scenario 1:

Under this scenario a typical electric bus is assumed to have a total cost over 12 years of $1,600,250 i.e. an 18.6% premium over the typical diesel bus, or $250,500 over 12 years.

Governments could support bus operators through the provision of zero interest loans for electric bus purchased. Over a 4-6 year period this could save around $115,000 in interest costs, on average.

Bus operators could also optimise charging over the 12-year ownership period, utilising cheap off-peak electricity tariffs, and charging from cheap renewable energy when available. This could save a further $66,000.

Finally, the bus operator could choose to charge a 1.1% premium to users opting for tours on an electric bus. Assuming an average day tour cost of $240, with the bus operating an average of 200 days per year at 65% capacity, this would translate to an additional $71,280 in revenue over 5 years. To put this into perspective, this translates to charging a $2.64 premium for electric bus tours (on average). As outlined in the earlier survey of Tropic Wings electric bus passengers, it appears that a significant proportion of customers would be willing to pay a modest premium to travel on an electric bus given the perceived benefits e.g. quiet, no fumes, smooth, etc. The price premium modelled in this scenario could be categorised as modest to very modest.

These measures are summarised below, and combined demonstrate a pathway for an electric bus to cost less than a diesel bus:

Total cost of electric bus (over 12 years)	**$1,600,250**
Access to zero interest loan	-$115,000
Optimised bus charging	-$66,000
1.1% bus tour price premium (over 5 years)	-$71,280
Net cost (over 12 years)	**$1,347,970 < diesel bus**

Scenario 2:

Under the second scenario it is assumed that the bus operator cannot access either a zero-interest loan or optimise bus charging to reduce energy costs. Instead, this pathway relies solely on recovering additional revenue from customers from the benefit of using an electric bus.

Building on the same assumptions from Scenario 1:

Total cost of electric bus (over 12 years)	**$1,600,250**
3.9% bus tour price premium (over 5 years)	-$252,720
Net cost (over 12 years)	**$1,347,530 < diesel bus**

As shown, under a marginally higher bus tour price premium it is feasible for the operator to reduce the total cost of the electric bus to be less than a diesel bus. A 3.9% price premium translates to $9.36 in the case of Tropic Wings' bus tours (on average).

Further consumer preference research would be required to definitively answer whether this premium would still be viewed as modest, however, at least anecdotally it appears that this rate would be viewed as reasonable.

Summary:

In conclusion, there are various opportunities to further reduce the total cost of ownership of electric buses. Evidence collected as part of this project suggests that there may be an opportunity to recover some costs from consumers, based on the perceived benefits of electric bus technology. Optimising charging of electric buses also presents an important cost-saving opportunity. Government's can also play an important role in supporting the transition initially, through the provision of incentives, such as low or zero-interest loans to help offset the higher upfront purchase cost of electric buses, and the related increase in financing costs.

7 Potential Challenges and Barriers to Electric Bus Deployment for Private Operators

For any bus operator exploring or undertaking a transition to electric buses, it's important to recognise the challenges and barriers, and potential strategies to address these. On the basis of the lessons learnt as part of the deployment of Tropic Wings' electric bus fleet, and other electric bus deployments in Australia, the key challenges and barriers have been listed below to not discourage, but inform planning by other Australian bus operators.

7.1 | Infrastructure Limitations and Grid Connection Challenges

Upgrading existing bus depots to accommodate electric bus charging infrastructure can present significant challenges for private operators. Many depots may have limited space for installing the required number of chargers, and the existing electricity supply capacity may be insufficient to meet the increased demand from charging a large fleet of electric buses. Grid upgrades can be costly and time-consuming, requiring careful planning and coordination with electricity distribution networks. There is also the potential for significant delays as part of this connection process and a need for governments to work with electricity distribution networks, and other relevant parties, to develop a streamlined connection approval process to address this major barrier that is slowing down the transition to electric vehicles in general, including electric buses.

7.2 | Higher Upfront Costs and Financing Options

The initial capital investment for purchasing electric buses and installing charging infrastructure is typically higher than that for traditional diesel buses. This can be a significant barrier for private operators, particularly smaller businesses. Exploring various financing models, such as leasing options or gaining access to government incentives in the early stages of market adoption, can help mitigate these upfront costs.

7.3 | Skills Gap and Training Requirements

The transition to electric buses requires a workforce with specialised skills in areas such as high-voltage electrical systems and electric vehicle maintenance. There may be a shortage of experienced technicians and engineers in Australia, potentially leading to challenges in servicing and maintaining electric bus fleets, as well as planning and deploying associated charging infrastructure. Bus drivers also require appropriate training and support during the transition to electric buses in order to maximise the efficiency of the fleet (and in turn reduce costs), while building confidence across the workforce in this new technology. Investing in comprehensive training programs for both drivers and maintenance personnel is crucial to address this skills gap.

7.4 | The Transition is a Major Learning Curve

It is clear that adopting battery electric buses remains a significant challenge compared to business as usual. Deployment projects, like the Tropic Wings fleet in North Queensland, help to provide insight into what the steps are, what challenges may be faced, and ultimately what changes will be required to support the widespread adoption of battery electric buses.

Without any form of government support or intervention, the major learning curve of the transition may deter many fleets from adopting electric vehicles and slow the decarbonisation of Australia's vehicle fleet. This will in turn jeopardise our ability to meet our national climate targets.

Further knowledge sharing from electric bus deployments is one avenue for helping to address these information gaps.

Fleets taking on this transition should be aware of the major commitment required, and seek support and input from other fleets – like Tropic Wings – that have already started this process.

8 Recommendations for Private Bus Operators considering the deployment of Electric Buses

Based on the findings presented in this report, and developed as a result of this project, the following list of recommendations have been developed for private bus operators considering the deployment of electric buses.

8.1 | Actionable Steps for Successful Electric Bus Deployment

- Conduct a detailed feasibility study and route analysis to understand the specific operational and energy requirements of your bus services.
- Develop a comprehensive transition plan with clear, phased timelines and measurable milestones for fleet electrification.
- Engage proactively with government agencies at both federal and state levels to stay informed about policies, incentives, and funding opportunities.
- Prioritise comprehensive training programs for drivers on energy-efficient operation and for technicians on the specific maintenance needs of electric buses.

8.2 | Strategies for Optimising Operations and Infrastructure

- Implement smart charging and load management solutions to minimise electricity costs and manage depot power demand effectively.
- Utilise advanced route optimisation software that considers the unique characteristics of electric buses, such as range and charging needs – where possible.
- Carefully evaluate the feasibility and benefits of on-route or opportunity charging for specific routes to extend operational range, and engage with government to seek support for shared electric bus charging at these locations.
- Explore the potential for integrating on-site renewable energy generation and battery storage at depots to further reduce energy costs and enhance sustainability[3].

8.3 | Financial Planning and Risk Mitigation

- Develop a detailed total cost of ownership (TCO) analysis that considers all relevant cost components over the lifecycle of the electric buses, comparing them to your existing diesel fleet.
- Actively explore various financing options, including traditional loans, leasing agreements, and green financing solutions, to manage the capital investment required.
- Implement robust strategies for battery management, including monitoring battery health and planning for eventual replacement or second-life applications.

3 Although part of the scope of this project, due to delays in the connection of this infrastructure this report is unable to assess the overall benefit of deploying and utilising renewable energy generation and battery energy storage systems as part of an overall electric bus charging solution.

- Explore opportunities to recover additional costs through modest price premiums that can be charged to customers where there is broad recognition of the benefits of travelling on an electric bus.

8.4 | Leveraging Government Support and Industry Partnerships

- Actively seek and apply for any available government grants at both federal and state levels to support the costs of electric bus procurement, charging infrastructure deployment, and/or optimisation of charging via telematics/software platforms.
- Collaborate with other bus operators, industry associations, and technology providers to share knowledge, best practices, and lessons learned from electric bus deployments.

9 Conclusion: The Future of Electric Buses in Australia's Private Transport Sector

The transition to electric buses presents a transformative opportunity for private operators in Australia. While challenges such as upfront purchase costs and charging infrastructure deployment still exist, the long-term environmental, economic, and social benefits that can be delivered by electric buses remain compelling. This is in addition to considering the benefits perceived by customers, and their potential willingness to pay more to travel on electric buses.

The lessons learnt as part of this ARENA co-funded project help to form a strong foundation for private operators looking to confidently embark on this electrification journey. By implementing strategic planning, optimising operations and charging infrastructure, and leveraging available government support, private bus operators can not only contribute to a more sustainable future but also enhance their operational efficiency and potentially achieve long-term cost advantages.

The future of Australia's private bus fleet is increasingly electric, and proactive operators who embrace this transition will be well-positioned for long-term success.

Appendix A: Electric Bus Passenger Questionnaire

Section 1: Overall Experience

- **Question 1:** "Were you were aware you were travelling on an electric bus for your trip?" (Scale: Yes / No)
- **Question 2:** "How would you rate your overall satisfaction with this electric bus journey?" (Scale: Very Dissatisfied, Dissatisfied, Neutral, Satisfied, Very Satisfied)
- **Question 3:** "Compared to your experience on a regular (non-electric) bus, was this journey..." (Options: Significantly Worse, Slightly Worse, About the Same, Slightly Better, Significantly Better, Not Applicable/First Time on an Electric Bus)
- **Question 4:** "How likely are you to choose an electric bus for future journeys, if available?" (Scale: Very Unlikely, Unlikely, Neutral, Likely, Very Likely)
- **Question 5:** "Compared to a diesel bus, for future trips on an electric bus would you be willing to pay..." (Options: Much Less, Somewhat Less, About the Same, Somewhat More, Much More)

Section 2: Specific Aspects of the Journey

- **Question 6:** "How would you rate the noise level inside the bus during this journey?" (Scale: Very Loud, Loud, Moderate, Quiet, Very Quiet)
- **Question 7:** "How would you rate the smoothness of the ride (acceleration, braking) during this journey?" (Scale: Very Bumpy/Jerky, Bumpy/Jerky, Neither Smooth nor Bumpy/Jerky, Smooth, Very Smooth)
- **Question 8:** "How comfortable were the seats on this bus?" (Scale: Very Uncomfortable, Uncomfortable, Neutral, Comfortable, Very Comfortable)
- **Question 9:** "How satisfied were you with the temperature inside the bus?" (Scale: Very Dissatisfied, Dissatisfied, Neutral, Satisfied, Very Satisfied)
- **Question 10:** "Did you feel safe and secure during this journey?" (Scale: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree)

Section 4: Open Feedback

- **Question 11:** "Do you have any other comments or suggestions regarding your experience on this electric bus?" (Open-ended text box)

Section 5: Demographics

- **Question 12:** "What is your home postcode?"
- **Question 13:** "In what year were you born?"
- **Question 14:** "What is your gender?"
- **Question 15:** "What is highest level of education you have completed?"

Appendix B: Electric Bus Driver Questionnaire

Section 1: Background Information

- **Question 1:** "How many years have you been driving buses?" (Less than 1 year, 1-5 years, 6-10 years, More than 10 years)
- **Question 2:** "How long have you been driving electric buses?" (Less than 6 months, 6 months - 1 year, 1-2 years, More than 2 years)

Section 2: Your Experience with the Electric Bus Vehicle

- **Question 3:** "How would you rate the overall performance of the electric bus you typically drive?" (Very Good, Good, Average, Poor, Very Poor)
- **Question 4:** "How would you rate the handling and manoeuvrability of the electric bus?" (Very Good, Good, Average, Poor, Very Poor)
- **Question 5:** "How comfortable is the driver's seat and cabin environment in the electric bus?" (Very Comfortable, Comfortable, Neutral, Uncomfortable, Very Uncomfortable)
- **Question 6:** "How satisfied are you with the heating and cooling system in the electric bus?" (Very Satisfied, Satisfied, Neutral, Dissatisfied, Very Dissatisfied)
- **Question 7:** How would you rate the noise level inside the electric bus cabin while driving? (Very Quiet, Quiet, Average, Noisy, Very Noisy)
- **Question 8:** Are there any specific features of the electric bus that you find particularly useful or not useful for your job? (Open-ended)

Section 3: Route and Operational Aspects

- **Question 9:** Do you ever feel concerned about the battery (driving) range of the electric bus during your route? (Very Concerned, Concerned, Neutral, Not Concerned, Not at all Concerned)
- **Question 10:** Have you noticed any significant impact of weather conditions (e.g., very hot or very cold) on the bus's battery range? (Yes, a significant impact; Yes, a moderate impact; No noticeable impact; Not applicable (haven't experienced extreme weather))
- **Question 11:** Do you find that the electric bus performs adequately on all parts of your route (e.g., hills, busy roads)? (Yes, always; Yes, mostly; Sometimes; Rarely; Never)
- **Question 12:** Have you received specific training on how to drive the electric bus efficiently to maximise its range? (Yes; No)

Section 4: Training and Support

- **Question 13:** How satisfied were you with the initial training you received on operating electric buses? (Very Satisfied, Satisfied, Neutral, Dissatisfied, Very Dissatisfied)
- **Question 14:** Do you feel you have adequate support and resources to address any issues or questions you have about the electric bus? (Yes, definitely; Yes, somewhat; Neutral; No, not really; No, not at all)

Section 5: Overall Satisfaction and Feedback

- **Question 15:** Overall, how satisfied are you with your experience driving electric buses? (Very Satisfied, Satisfied, Neutral, Dissatisfied, Very Dissatisfied)
- **Question 16:** What do you like most about driving an electric bus compared to a traditional bus? (Open-ended)
- **Question 17:** What are the biggest challenges or issues you have faced while driving an electric bus? (Open-ended)
- **Question 18:** Do you have any suggestions for improving the electric buses or the overall experience of driving them? (Open-ended)

www.electricvehiclecouncil.com.au
office@evc.org.au

www.tropicwings.com.au
media@capta.com.au