Battery Electric Bus Guidance – Zero Emission Bus Regional Trial

1 Introduction and trial overview

Victoria is transitioning its bus fleet to zero emission buses (ZEBs) in line with its target to achieve net-zero emissions in the region by 2045. From 1 July 2025, all new public transport bus purchases have zero tailpipe emissions. The Regional Victorian ZEB trial will involve battery electric buses (BEBs), the most widely available ZEB technology.

The purpose of this document is to provide key information about BEBs for operators invited to take part in the trial. The trial will work as follows:

- Operators will be provided a BEB to use in normal everyday operations
- A portable charging cart will be provided to recharge the BEB
- The BEB original equipment manufacturer (OEM) will provide all necessary training including operating an electric bus, charging the vehicle, and related software and systems
- Operators will collect operational data and provide feedback on driver and user experience.

1.1 Minimum trial requirements

1. At minimum, the portable charger requires a **32 amp 3-phase power** outlet connection available within approx. 10m of where the bus will charge (noting charging ports are typically at the rear of the bus). This is usually a relatively simple upgrade if not already in place, however it is recommended operators check their relevant power cap agreement with their electricity supplier before committing to the trial. Note that a **63 amp 3-phase power connection** would roughly halve the required charging time (see Charging section) so operators should consider the time available for recharging between daily operations. While the chargers are rated for external use, operators should store them inside when not in use or during inclement weather.
2. Operators must be willing to **collect operational data** and share it with DTP (via a provided template), including relating to:
   a) Operational data, such as range, charging behaviour, vehicle performance and costs.
   b) Feedback on user experience, operational challenges and barriers to adoption.

2 BEB basics

The trial will use a **battery electric bus (BEB).** BEBs are a type of zero emissions bus (ZEB) with zero tailpipe emissions, achieved by storing energy in an on-board battery that powers one or more electric motors (see Figure 1). Compared to diesel buses, BEBs help reduce greenhouse gas emissions from public transport, while also reducing bus noise and vibrations.

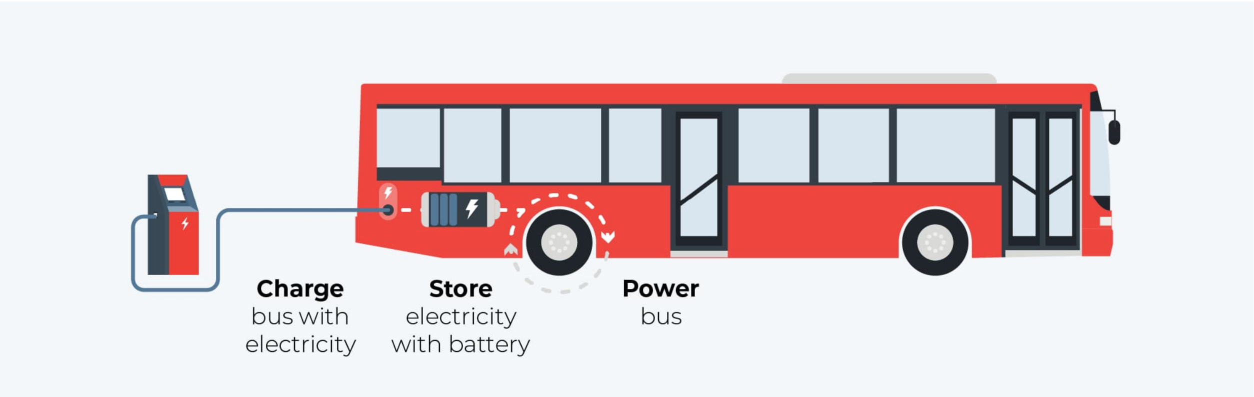

Figure 1: BEB basics

Basic power terminology

Kilowatts and kilowatt-hours: Power is mostly measured in kilowatts (kW), while power use and storage are mostly measured and paid for in kilowatt-hours (kWh) (see Figure 2):

- kW can be thought of as power's flow 'speed', directly related to the time taken to recharge an electric vehicle/BEB (see Figure 3).
- kWh is the volume of power transferred – also how battery size is measured, much like a fuel tank's size (see Figure 3).
- Like diesel buses, the daily energy requirements for a BEB will vary based on their operations, with distance travelled core to overall energy consumption. Typical electricity use in an Australian context ranges between 0.9 kWh/km and 1.4 kWh/km.

See Electrical terms glossary for further terms and information.

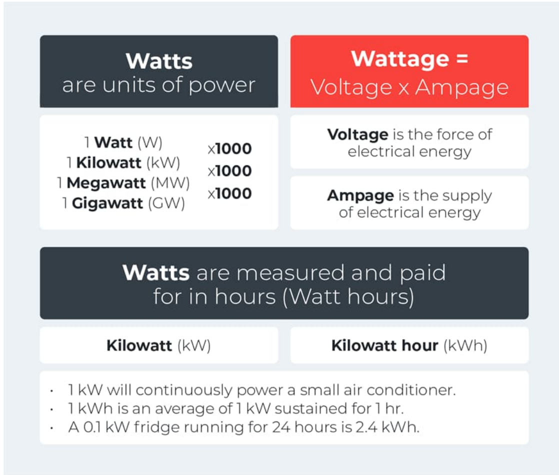

Figure 2: Basic power terminology

Figure 3: Charging compared to fuelling

2.1 Battery and range

Based on the BEBs currently operable in Victoria, on-board battery sizes range from 300 kWh to just under 400 kWh. As a guide, other operators have found a 350 kWh battery comfortably runs up to 350 km on a single charge, while still retaining at minimum 20% charge- the lowest desired state of charge. However, battery usage depends on many things, like bus weight, driver behaviour, route, and number of stops on the route. Also, extreme temperatures increase battery consumption.

An inbuilt battery management system (BMS) allows the operator to monitor the batteries' charge, performance, and any degradation.

Current battery lifespans are estimated at about 8-10 years, around half of a typical bus's 20-year lifespan. Generally, total rechargeability decreases over battery lifespans, which impacts ZEBs' achievable vehicle ranges, meaning the bus's travel-range degrades over time. Given that battery technology is continually improving, it is reasonable to expect that at the end of their lives, batteries will be replaced with higher performing technology.

2.2 Charging

Driving an electric bus is not too different from driving a diesel bus. Perhaps the biggest difference is the time required to “fuel” the vehicle. After a day of operations, the bus is plugged in to a charger via a Combined Charging System Type 2 (CCS2) socket, typically located on the side of the bus towards the rear (see Figure 4).

Figure 4: CCS2 socket

For the trial, operators will be provided a portable charger like the one shown in Figure 5. Typical charging times can range from 4 to 13 hours depending on the available plug socket and charge of the battery on return (see Table 1). Note that charging rate is not completely linear, the last 5–10% of charge will take slightly longer. Previous trial operators have found that typically, BEBs return to the depot with around 30–50% of charge remaining, meaning charging can comfortably occur overnight between operations.

Figure 5: Kempower Movable Charging Cart

Charging typically occurs overnight, often coinciding with off peak electricity rates, but the bus can also be recharged during the day if it returns to the depot.

Table 1: Typical recharging times for a portable charger

Power input available	**Charger maximum power output**	**Typical charging time**[1]	
		175kWh (sufficient to fully recharge from 50%)	**245kWh (sufficient to fully recharge from 30%)**
32A	20kW	9 hours	12.25 hours
63A	40kW	4.5 hours	6 hours

Figure 6 illustrates the typical daily cycle of a BEB battery.

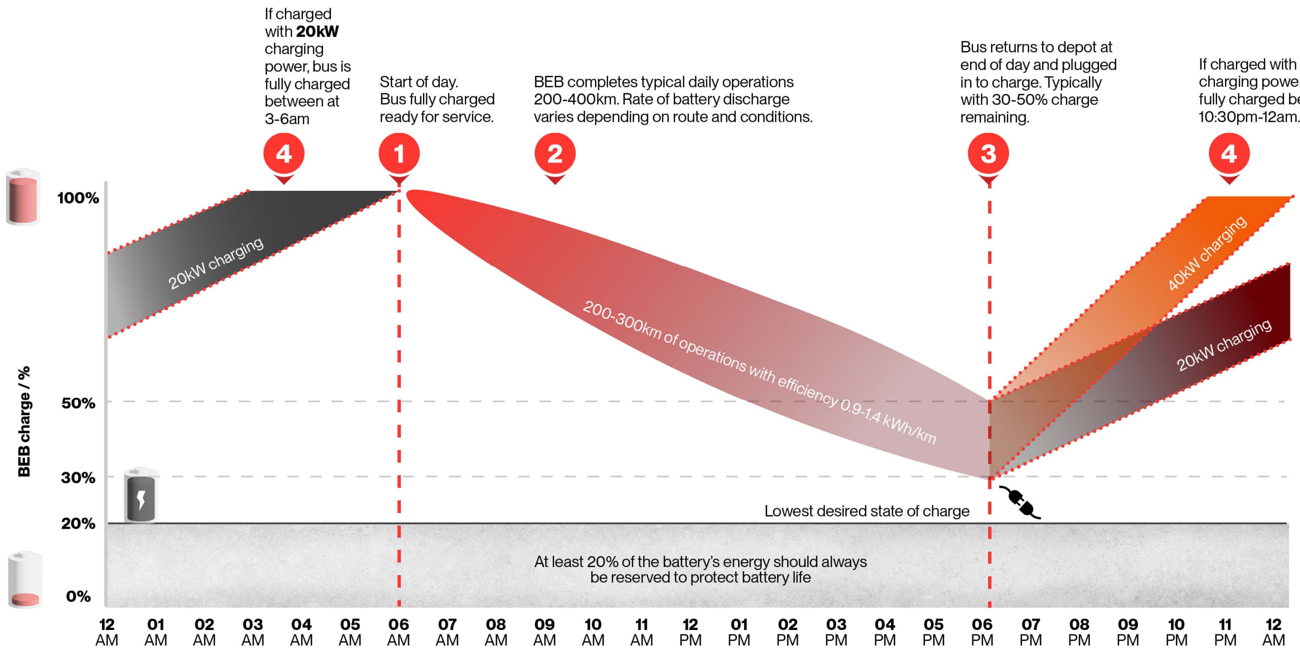

Figure 6: Overview of typical daily battery cycle

1 Based on a 350 kWh battery. Charging time presented is indicative, assuming 100% efficiency, which would not be expected to be achieved in reality.

3 FAQs

Is the technology tried and tested?

Similar technology as subject to this trial has operated successfully in Victoria and other Australian jurisdictions for over 3 years, including in Regional Victoria. Operators find it easy to adjust to BEBs and report them to be easy to charge, maintain and operate. While there can always be teething issues, particularly initially, this trial will benefit from lessons learned from previous trials and support from DTP and OEMs.

What is the range of a BEB, will it run out of power?

BEBs can be driven 200–400 km on a single charge, depending on the battery size, route and conditions. This is typically enough for a full day of normal operations, but limits their use for longer excursions (unless there is time for top up charging during the day). Live information on bus range and battery charge is typically available to the driver, reducing any potential for the battery to run out of charge without notice.

Are BEBs comfortable for drivers and passengers?

BEB are modern, comfortable and quiet. Drivers report them to be easy to operate, and passengers enjoy traveling with them. Local residents and passengers enjoy the reduced fumes, vibration and noise.

What additional costs are there to participate in the trial?

BEBs will be provided for the trial at no cost. Electricity costs are responsibility of the participating bus operators, but these are expected to be more than offset by diesel cost savings.

What happens if something goes wrong with the BEB or charger?

Any major issues or battery related fault, as well as scheduled maintenance, roadside support and tow & recovery for buses will be covered by the OEM. Depot maintenance staff will be trained by the OEM to undertake routine maintenance activities, with further support available as required. Operators report that overall, BEBs have less general maintenance requirements, with maintenance activities more focussed towards diagnostics and switching out a specific part with an issue when needed.

What happens if the bus hasn't charged due to power outage, broken equipment or incorrect use of the charger?

During previous trials, issues of this nature have very rarely disrupted operations. However, as a backup, operators will retain their existing diesel bus if something prevents using the electric bus during the trial.

Which software and systems will operators have to familiarise with for the trial?

Equipment provided will include necessary systems to monitor the battery and collect required data for reporting (battery management system – BMS). Later, when operators are transitioning the whole fleet permanently, charge management systems (CMS) and depot management systems (DMS) become relevant.

What are the fire and electrical safety risks?

Fire safety: Electric vehicle fires are extremely rare. Early research indicates that EV vehicles are 80 times less likely to catch fire than diesel/ gasoline vehicles[2]. Fire risks for diesel buses are primarily on-road, relating to fuels/lubricants/hot exhaust and friction brakes. As BEBs are electrically powered and use regenerative braking, these risks do not apply. Instead, BEB fire risk primarily relates to batteries and charging.

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2 Electric Vehicle Battery Fires – Data Update, EV FireSafe 2024

Monitoring battery health (via BMS) allows operators to detect any anomalies early and prevent usage of damaged batteries. As with a diesel bus fire, the priority in a fire event is to ensure the safety of passengers and staff, and to contact the emergency services – leaving the firefighting to trained professionals.

Electrical safety: Correct management of the portable charging cart and charging cables prevent damage and minimise the risk of electrical hazards (such as cable damage by being run over). Training will be provided for all depot staff for safe working with BEBs and chargers. Any battery related issues or faults will be fixed by the OEM off site.

What training will be provided?

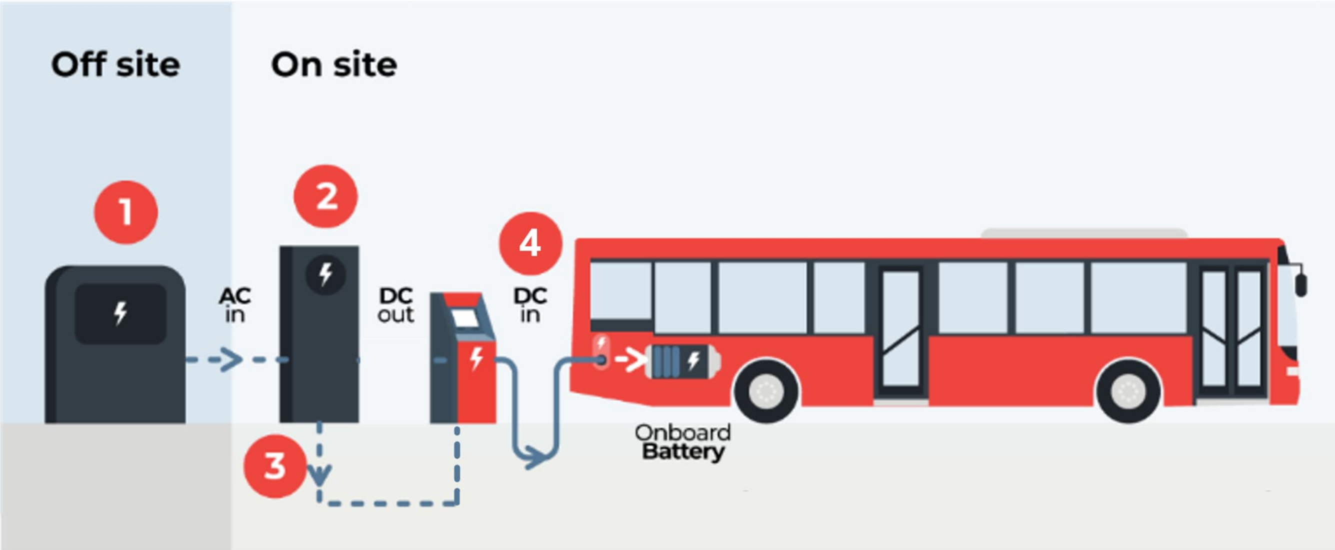
Comprehensive training will be provided for all staff and drivers by OEMs including relating to vehicle systems, regenerative breaking, torque management, charging systems, and maintenance familiarisation.

4 After the trial – Full transition to ZEB

4.1 Depot conversion

In line with Victoria's ZEB Transition Plan, eventually all buses and depots will be zero emission. This section provides an overview of the typical pathway and considerations relating to full depot transition.

Figure 7 shows the typical components of a full ZEB depot upgrade, focussed on delivery of charging infrastructure. These will vary based on the size and context of the site in question.



1	Off-site power infrastructure (grid upgrades)	Upgrades to assets owned by the electricity Distributed Network Service Provider (DNSP), such as at the zone substation, high voltage (HV) feeder lines (underground or overhead), and other infrastructure delivering power to depots. **Often not required for small depots (1-5 buses)**
2	On-site electrical infrastructure	On-site HV or low-voltage (LV) distribution transformers, cabling, circuit breakers, switchgears, and switchboards
3	Civil & earthworks	Excavation works are often required, such as for installing cable routes, pavements, and kerbing.
4	Charger and dispenser	Typically a fixed pedestal charger, although other low powered options are available for very small sites (see charging options in Table 2)

Figure 7: Typical key components of a fully electrified depot

4.2 Grid upgrades

While existing bus depots will have an existing power supply and other on-site electrical infrastructure, some power upgrade works may be required to provide the additional energy to charge BEBs. The extent of grid upgrade works needed depends on the size of the depot, and the available 'spare' capacity in the local distribution network. Many depots can charge 1 to 5 buses without needing grid-related upgrades.

Figure 8 provides an overview of the three typical depot upgrade electrical scenarios and associated equipment required. Regardless of the size of the depot, operators should contact their Distribution Network Service Provider (DNSP) to confirm whether there is sufficient capacity in the power grid, and any upgrades that may be required. For this, DNSPs require an estimate of the depot's power demand and its profile throughout the day, linked with the maximum number of concurrent charging buses. A list of DNSP contacts is shown in Table 3.

As it typically takes up to two years from the first enquiry's date for upgrade works to be completed, it is critical to start consulting with the DNSP as soon as practicable.

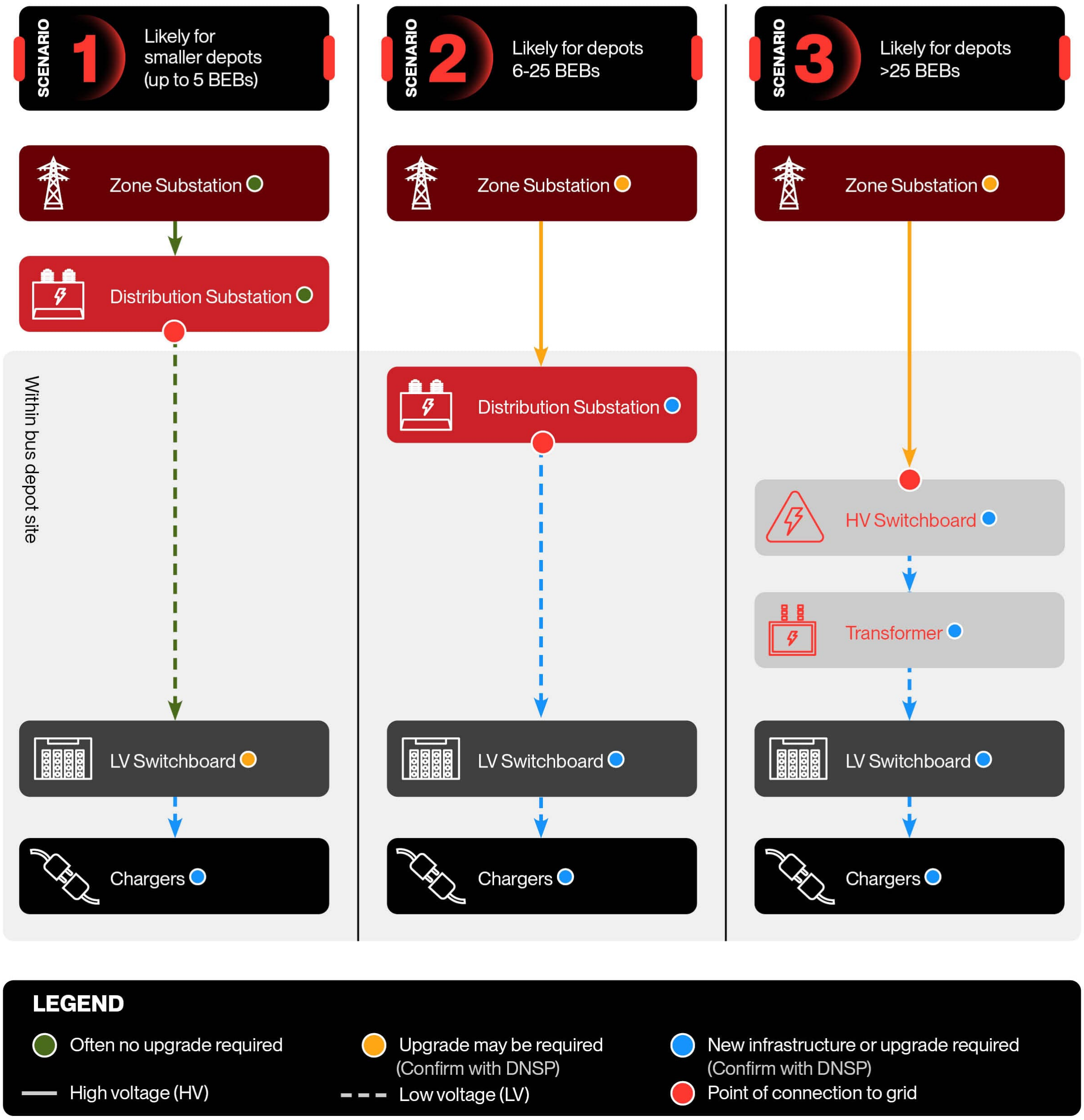


Figure 8 Overview of typical electrical scenarios and associated infrastructure

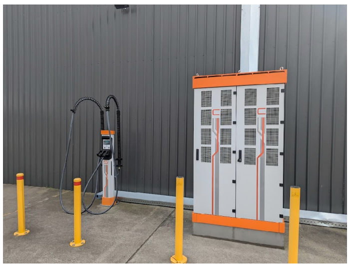
4.3 Charging infrastructure

When faster charging is required or more buses need to be charged simultaneously, the typical charging approach is ground mounted charging units (or pedestals), which may or may not be comprised of separate power cabinets and dispensers. Depending on the site context, this approach may require grid-related upgrades or upgrade of the existing LV switchboard.

Where there are a small number of BEBs (1-3), use of lower powered wall mounted or portable chargers may be sufficient. As per the trial, this typically does not require any grid-related electrical infrastructure upgrade, provided there is capacity and socket(s) for delivery of minimum 32-amp three phase power at each charging location.

The preferred charging approach may change over time, as more buses transition to battery electric, or as grid capacity becomes available.

Table 2: Typical charging times of different charging technology

Charger type	Example image	Input type	Power output	Charging time (300 kWh)
Portable DC charging cart		3-phase 32 amp socket	20 kW	15 h
		3-phase 63 amp socket	40 kW	7.5 h
Wall-mounted DC charger		3-phase 40 amp socket	24 kW	12.5 h
Fixed pedestal charger (power cabinet and dispenser)		Connected via LV switchboard	75 kW	4 h
			150 kW	2 h

4.4 Other considerations

1. **Space for charging infrastructure:** BEBs and diesel buses are similar in size, but BEBs require more space for charging infrastructure and personnel access. The capacity of a ZEB depot can be up to 30% less than the diesel capacity. Some depot space is also assigned for an isolation bay in the event of a fire.
2. **Maintenance facilities:** Most diesel bus maintenance facilities can be used for BEBs with minimal adjustment. However, as BEBs are typically ~30 cm higher than diesel buses, adjustments may be required to maintenance roof height, as well as consideration of any low hanging structures on the route.
3. **Solar panels**, combined with an on-site **battery energy storage system** can be used to reduce ongoing electricity costs and provide resiliency during power outages.
4. **Data, communication & systems:** Where multiple BEBs are in operation, charge management systems (CMS) are used to monitor bus charging and ensure adequate power for daily operations while optimising grid load and electricity costs. CMS can schedule recharging during off-peak times and prevent too many BEBs from charging at once.

5 Distribution Network Service Providers

As shown in Figure 9 and Table 3, there are 5 electricity distributors in Victoria, each handling a different geographic region. Contact details are provided for enquiries.

Table 3: Distribution Network Service Providers in Victoria

Company	Service area	Enquiries
Powercor	Western suburbs and western Victoria	General enquiry | CitiPower & Powercor info@powercor.com.au 13 22 06
Ausnet Services	Outer northern and eastern suburbs and eastern Victoria	Contact us – AusNet 1300 360 795
United Energy Distribution	Southern suburbs and Mornington Peninsula	General enquiry form – United Energy 1300 131 689
Citipower	City and inner suburbs	General enquiry | CitiPower & Powercor 1300 301 101
Jemena	Northern and north-western suburbs	Negotiated Connections | Jemena 1300 131 871

Figure 9: DNSP companies and geographic coverage

Electrical terms glossary

(k)W Power is mostly measured in watts (w) or kilowatts (kW, 1000 watts). It can be thought of as the amount of power flowing. For example, 10 watts will continuously power an LED light bulb, just like a burning oil lamp consumes oil constantly with a rate of 0.5 ounces per hour.

kWh Power use and storage are mostly measured and paid for in kilowatt-hours (kWh). kWh is the volume of power stored or used, just like fuel tank can store a certain volume of fuel in litres.

VxA=W Wattage is comprised of voltage and amperage, just like fuel flowrate depends on the pressure in the fuel hose and the size of the fuel hose.

V Voltage is the force of electrical energy. It can be compared to water pressure in the pipe network. Just like water is distributed to homes with a standard pressure, power is distributed to most homes and businesses with a standard voltage of 230 volts.

A Amperage is the supply of electrical energy. Just like a pipe with larger diameter can transfer more water at once, a cable with bigger amperage can transfer more watts. Since the voltage distributed is standard, cables and power sockets with bigger amperage are required to let through more power at once and therefore charge faster.

LV/HV and feeders Power is normally distributed to the end users through low voltage (LV) feeder lines at 230V from low voltage (LV) distribution substations. LV distribution substations get the power they distribute onwards from high voltage (HV) distribution feeder lines at 22 kV, that are used to transmit larger amounts of energy. Customers requiring large amounts of energy, like large factories and large BEB depots may connect directly to HV feeders.

Zone substation Zone substations receive power from sub-transmission network over long distances on very high voltage (> 66 kV), and distribute it to high-voltage (HV) distribution network at 22 kV.

Distribution substation Distribution substations receive power from high-voltage (HV) feeders at 22 kV, and distribute it onwards to end users at safer voltage (230V) through low-voltage (LV) feeders. Distribution substations are often provided by small transformers mounted in ground or roadside poles.

AC/ DC Power is supplied from the grid in alternating current (AC), where the direction of electric charge changes constantly. Batteries can only store direct current (DC), where the flow of electric charge is linear. Therefore, AC needs to be converted to DC with a rectifier. AC buses have a rectifier built in and can be charged directly from the grid, whereas DC buses need to be charged with direct current. Having the rectifier in the charger instead of in the bus allows faster charging and does not add extra weight on the bus itself. This is why DC buses are preferred in most situations.