# BATTERY POWERED PATHWAYS

## A guide to VET roles, courses and microcredentials

2025

POWERING AUSTRALIA

## Powering Australia

Powering Australia is a federally funded Industry Growth Centre that is helping to grow domestic clean-tech manufacturing by connecting business, accelerating commercialisation activity and building workforce capability. Our work spans solar, wind, industrial decarbonisation, carbon, transport and batteries and supports the expansion, upskilling and increased diversity of Australia's battery workforce through the development and delivery of targeted and accessible training.

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## Cover Image

*Lithium-ion batteries are now used extensively for e-mobility and for energy storage. Their manufacture, installation and management are opening doors of opportunity for a workforce wanting to participate in the energy transition [piai – stock.adobe.com]*

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# ACRONYMS

| | |
|---|---|
| ANZSIC | Australian and New Zealand Standard Industrial Classification |
| AUSMASA | Australian Mining and Automotive Skills Alliance (Jobs and Skills Council) |
| BESS | Battery Energy Storage System |
| BuildSkills | Build Skills Australia (Jobs and Skills Council) |
| CAM | Cathode Active Material |
| CEC | Clean Energy Council |
| CPC | Construction, Plumbing and Services (national training package) |
| CPP | Property Services (national training package) |
| EV | Electric Vehicle |
| FBICRC | Future Battery Industries Cooperative Research Centre |
| ICE | Internal Combustion Engine |
| IEA | International Energy Agency |
| kW | kilo Watts (a measure of power) |
| kWh | kilo Watt hours (a measure of energy) |
| LFP | Lithium iron phosphate (or ferrophosphate) cathode |
| Li-ion | Lithium-ion |
| MEM | Manufacturing and Engineering (national training package) |
| MSL | Laboratory Operations (national training package) |
| MSM | Manufacturing (national training package) |
| MWh | Mega Watt hours (a measure of energy) |
| NCA | Nickel Cobalt Aluminium oxide cathode |
| NiCad | Nickel-Cadmium cells (also NiCd) |
| NiMH | Nickel-Metal Hydride cells |
| NMC | Nickel Manganese Cobalt oxide cathode |
| OEM | Original Equipment Manufacturer |
| Pb-acid | Lead-acid batteries |
| P-CAM | Precursor-Cathode Active Material |
| PMA | Chemical, Hydrocarbons and Refining (national training package) |
| PV | Photo Voltaic |
| RII | Resources and Infrastructure Industry (national training package) |
| RTO | Registered Training Organisation |
| SSA | Solar Accreditation Australia |
| TAFE | Technical and Further Education |
| TLI | Transport and Logistics (national training package) |
| UEE | Electrotechnology (national training package) |
| V2G | Vehicle to Grid |
| V2H | Vehicle to Home |
| VET | Vocational Education and Training |
| VPP | Virtual Power Plant |
| VRFB | Vanadium Redox Flow Battery |
| WHS | Workplace, Health and Safety |

# 1. INTRODUCTION

## Background

Australia is experiencing amazing, long-term employment growth associated with the exponential worldwide demand for batteries. The wide range of employment opportunities include jobs that require vocational and training qualifications as well as jobs that require a university education.

It is estimated that a diversified Australian battery industry would support more than 61,000 workers by 2030 (Accenture, 2023b). Approximately 70% of the roles will be VET-trained operators, electricians, technicians, allied tradespeople, etc. Approximately 30% of these roles will be university-educated engineers, industrial metallurgists, electrochemists, etc.

To help support this new workforce, we have worked with stakeholders (via national consultation) to identify key skills that need to be addressed and to drive a nationally coordinated approach to ensure that courses and units are fit for the needs of the emerging battery sector.

Industry requires the availability of a skilled and competent workforce. This workforce, once ready, will benefit through the provision of new, high value jobs. These jobs will suit new entrants to the job market as well as those wishing to transition from existing fossil-fuel based industries.

## This guide

This guide is an outcome of the national consultation. It firstly describes what lithium-ion batteries are and why they are important to Australia's low emissions future. It builds upon the *Vocational Skills Gap Assessment and Workforce Development Plan* (FBICRC, 2021) project that was led by South Metropolitan TAFE.

The guide describes each of seven different segments of the battery value chain. For each segment it describes the type of industries that participate in it, the characteristics of the workforce needed for those industries and the possible vocational and training pathways to achieve fulfilling careers in those industries. More than 60 courses, microcredentials, skill sets and units of competency are listed, each with a link so that readers can access source materials quickly and make informed decisions.

Also identified for each segment are the VET national training packages relevant for those workforces and the Australian Jobs and Skills Councils that have oversight of the packages and which ensure that the packages reflect current industry needs.

### Who should read this guide

The guide is intended for multiple audiences. It is not meant to be a technical manual on batteries and it is not intended to include an exhaustive list of every possible course, unit of competency, micro-credential or skill set relevant to Australia's battery-related companies. Rather, it provides a broad-brush illustration of the opportunities that battery industries present for a trades entrant or for a transitioning worker seeking to diversify employment opportunities and transfer smoothly into a clean economy industry (CEDA, 2023).

The guide should also be useful for TAFEs and RTOs that are reviewing their clean economy workforce development plans and that are looking for industry intelligence on the opportunities in battery industries for current and future students.

Finally, the guide should also inform policy makers looking to identify critical workforce issues in their jurisdictions or industry sectors.

### Context around its timing

The release of this guide follows the 2024 launch of the *Australian Battery Strategy* (Australian Government, 2024a). The Strategy seeks to improve Australia's resilience and security and drive economic growth by expanding Australia's battery manufacturing capabilities and building skills.

Also released in 2024 was the *A Future Made in Australia National Interest Framework* (Australian Government, 2024b). The Framework recognises that Australia's abundant natural assets and resource endowments create significant opportunities to foster new globally competitive industries that can boost economic prosperity and resilience, while supporting decarbonisation.

The guide's release also coincides with a time of incredibly rapid change for the battery sector. It is less than 10 years since Tesla opened its first sales office in Australia. It is less than 8 years since the Hornsdale Big Battery became operational. The sector is still rapidly growing and new technologies are emerging almost monthly.

Every care has been taken to ensure the information is correct at the date of publication. However, given this rapid rate of change, readers should do further research on their areas of most interest before directly acting on this information.



# 2. BATTERIES AND THEIR VALUE CHAIN

## Modern battery development

### Early mobility batteries

The rechargeable battery supply chain has been dominated historically by lead-acid (Pb-acid) batteries. These have a comparably small amount of energy that can be stored per unit mass or volume of battery, i.e. their "energy density" is low.

Nickel metal hydride (NiMH) and nickel cadmium (NiCad) batteries became widespread in the latter part of the 1900s due to their energy density being higher than Pb-acid batteries. NiMH and NiCad batteries found acceptance in consumer electronics including mobile phones and laptops, portable gardening and power tools, and hybrid electric vehicles.

### Lithium-ion (Li-ion) batteries

The development of lithium-ion (Li-ion) batteries over the past 50 years has opened new opportunities for mobility and energy storage. Li-ion batteries have superior performance qualities to Pb-acid, NiMH and NiCad batteries. They normally have higher energy density and often have longer cycle life and lower self-discharge rates.

Their better performance has opened the door to their cost-effective use in electric vehicles (EVs) in recent years. The rapid scale-up of their manufacture for EVs resulted in cost reductions, thereby creating opportunity for them to also be used in Battery Energy Storage Systems (BESS). BESS units can store excess daytime output from solar and wind energy generation to power homes, communities and the wider electricity grid during the evenings when renewable generation is less reliable.

### Emerging technologies

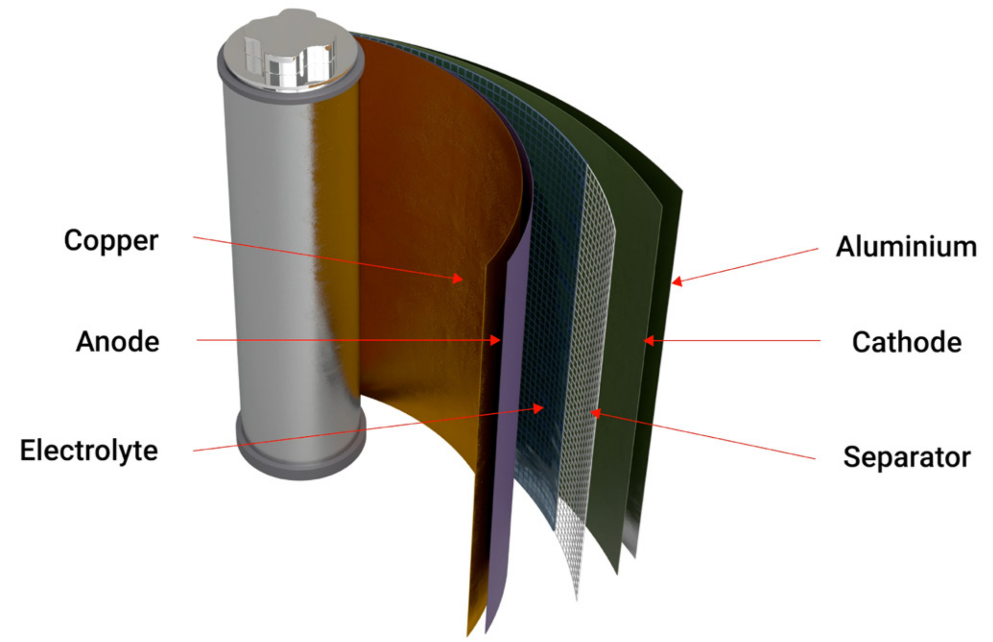
Ongoing research and development are leading to even further improvements in battery performance. New chemistries, forms and shapes, lower-flammability electrolytes and more effective cell components are being introduced. Smarter electronic Battery Management Systems (BMS) are being developed to prevent electrical imbalances in the modular assembly of battery cells.

Meanwhile, completely different battery systems are also being developed and commercialised. Sodium-ion batteries are being used in some smaller vehicles and BESS. Solid-state batteries are being used in niche applications to reduce flammability risks. Flow batteries, such as Zinc-Bromide or the Australian invented Vanadium Redox Flow Batteries (VRFB), are presenting viable options for longer duration energy storage. Cells with other chemistries – including nickel-cobalt-manganese-aluminium (NCMA), lithium titanate oxide (LTO), lithium-nickel-cobalt-oxide (LNCO), sodium-sulphur (Na-S), lithium-sulphur (Li-S), lithium metal-anode cells and graphene – are also being developed.

Each innovation will drive performance improvements in qualities such as cost, power output, energy density, safety, performance, life span, etc.

### A typical 2020s battery

This guide focusses on batteries used currently in typical EVs and BESS. These are normally Li-ion batteries comprising carefully manufactured Li-ion "cells".




*Key components of a typical Li-ion cylindrical cell. [JUNHO – stock.adobe.com]*

Each cell normally has an active cathode made of nickel, manganese, cobalt or aluminium oxides or phosphates of iron. Each cell also has an active anode made of finely powdered graphite, often infused with silicon. The anode and cathode are divided by a semi-permeable polymer separator.

An organic electrolyte containing mobile lithium ions fills the electrodes and separator. These (charged) lithium ions are free to move back and forward inside the cell through the separator between the anode and the cathode. This function is what allows a Li-ion cell to be charged and discharged several thousand times without undue deterioration.

In normal use, thousands (for a car) or even millions (for BESS) of these cells are combined – in parallel and in series – into battery packs to form modules that provide the required voltage and energy storage. Each cell is engineered in a highly controlled environment using high purity materials. Cells are tested to stringent acceptance qualities before being aggregated into packs and modules, connected to a BMS and integrated into their 'use-case'.

In a car that use-case could be to power one or more electric motors to create mobility. The BESS use-case could be to connect to and stabilise a microgrid for a remote community or it could be to feed into a national grid.

Modern cells can normally be charged and discharged several thousand times depending on their design, use-case and environment. They deteriorate over time and will eventually require removal. Removed cells may be applied to a new use-case with lower demand requirement or may be recycled to extract and re-use the valuable constituent materials.

**Battery demand and strategic importance**

Demand for batteries is expected to continue growing rapidly, driven predominantly by government policies and community expectations around decarbonisation. Interest in battery manufacturing and the securing of a domestic battery value chain are emerging priorities for many countries, due to the potential risk that material shortages could have on energy transition security.

Australia's interest in batteries is driven in part by its desire to decarbonise and establish energy security. However, Australia is also seeking to develop an economic opportunity provided by our vast wealth in battery-related minerals. The world needs large quantities of lithium, nickel, cobalt, manganese, copper, aluminium and graphite to produce cells and associated equipment and wiring. Australia has commercial reserves of each of these materials (Accenture, 2023b; Best & Vernon, 2020).

## The battery value chain

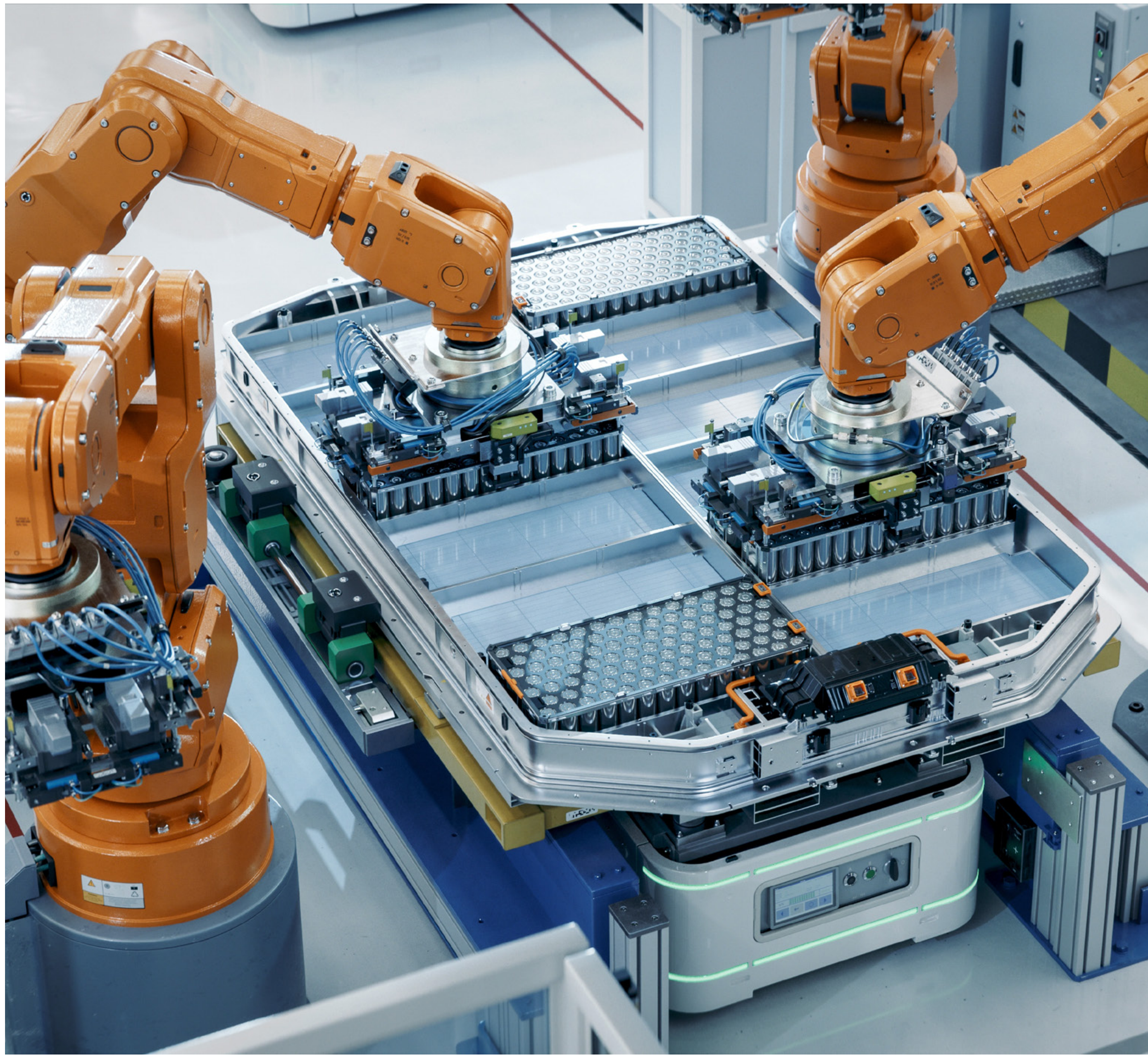
The production, use and recycling of Li-ion batteries is often described in terms of a "battery value chain" with seven segments such as these:

1. mining and mineral processing
2. refining/P-CAM/anodes/collectors
3. component and cell assembly
4. EV pack and BESS assembly and manufacturing
5. BESS installation and maintenance
6. EV service and support
7. dismantle and recycle.

The workforce and skills necessary to deliver product at each value chain segment vary significantly. Companies and businesses often operate in only one or two segments, selling their products to other companies along the value chain and retaining specialty areas of focus. For these reasons, this guide is structured into each of the value chain segments with some arbitrary license taken for convenience where segment boundaries blur.

The guide also presents the segments in the value chain in a linear fashion. However, the circular economy is of increasing importance. The final (recycling) segment will eventually blur into the first (mining) segment as what some call "urban mining" becomes normalised.

It should also be noted that the value chain described in this guide focuses mainly on Li-ion batteries of the types normally used for e-mobility and short-duration storage. Other types of batteries, such as longer duration storage flow batteries, have different value chains and may be mentioned but are not described in detail. Emerging battery types, yet to reach full commercial production, may also have different value chains.



# 3. MINING AND MINERAL PROCESSING

## The segment

Typical EVs and BESS contain hundreds or thousands of Li-ion cells. Each cell has an active cathode made of nickel, manganese, cobalt or aluminium oxides or phosphates of iron which are mixed with an organic electrolyte containing lithium-ions. Each cell also normally has an active anode made of finely powdered graphite often infused with silicon. Aluminium and copper metal current collectors surround the cathode and anode respectively.

Australia has significant reserves of lithium, nickel, cobalt, manganese, copper, aluminium, silicon and graphite. These reserves are spread across the nation but are most prevalent in Western Australia, Queensland, New South Wales and South Australia.

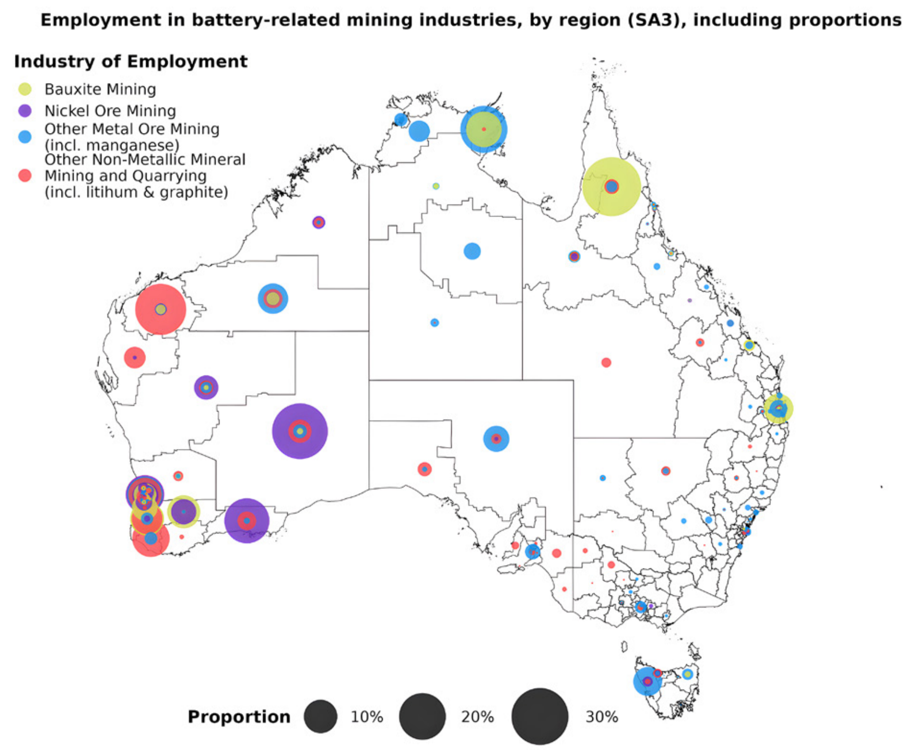
Australia's mining sector is well-established and mining operations are often conducted at very large scale. The operations include exploration and drilling, as well as the removal, crushing and concentrating of unrefined ores, and their transport to ports or refineries.

To contribute effectively to the battery value chain, the battery minerals must be extracted from raw reserves in a cost-effective manner while employing best practice environmental methods, engaging respectfully with First Nations stakeholders, and minimising greenhouse gas emissions from operations.

Battery minerals are mined above or below ground by blasting, and then crushing and screening the ore. A variety of mineral processing steps may then be employed depending on the ore type and concentration. The mineral processing steps may include further grinding and concentrating using separation techniques such as dense media separation, froth flotation, washing or chemical treatment. The purpose of each mineral processing step is to increase the proportion of the valuable mineral and remove non-valuable ore.

*Demonstrating awareness of workplace health and safety requirements is an important first step to jobs in Australian mining and mineral processing industries [Kings Access – stock.adobe.com]*






*Employment opportunities in battery-related mining industries are widespread across Australia [Used with permission, Jobs and Skills Australia (JSA), 2023, p. 182.]*

Some of the many and varied businesses that mine and process battery minerals in Australia include Alcoa (aluminium), AVL (vanadium), IGO (nickel), Glencore (copper), BHP (cobalt), Talison Lithium (lithium), Simcoa (silicon), South 32 (manganese), QEM (vanadium) and Renascor (graphite).

## Workforce description

The mining and production of mineral concentrates involves a range of vocational job roles across mine exploration and surveying, drilling and blasting, process operations, metallurgy and testing, materials handling, maintenance and support. These roles complement professionals from disciplines such as earth sciences, surveying, metallurgy, chemistry and engineering. The skills needed for planning or operating mines for battery minerals are like the skills required for mining other commodities.

New battery mineral mines incorporate high levels of automation and Industry 4.0 technologies to improve efficiency, enhance worker safety and improve workers' experiences. Hence, Information Technology skills are sought after for operating mines, and especially mines reliant on remote operations (FBICRC, 2021).

**Suitable national training packages**

National training packages for this segment of the battery value chain include packages for:

- Resources and Infrastructure Industry
- Laboratory Operations
- Manufacturing and Engineering
- Transport and Logistics
- Information and Communications Technology.

**Australian Mining and Automotive Skills Alliance** (AUSMASA), **Manufacturing Industry Skills Alliance**, **Industry Skills Australia** and **Future Skills Organisation** are key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

**Vocational training opportunities**

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships and traineeships available for those wishing to work in the battery mining and minerals processing sector. These include:

- **AUR – Automotive Retail, Service and Repair**
  - AUR30320 – Certificate III in Automotive Electrical Technology
  - AUR30620 – Certificate III in Light Vehicle Mechanical Technology
- **RII – Resources and Infrastructure Industry**
  - RII20120 – Certificate II in Resources and Infrastructure Work Preparation
  - RII30120 – Certificate III in Surface Extraction Operations
  - RII30320 – Certificate III in Underground Metalliferous Mining
  - RII30420 – Certificate III in Resource Processing
  - RII31820 – Certificate III in Drilling Operations
  - RII41421 – Certificate IV in Civil Infrastructure Asset Management

- MSL – Laboratory Operations
  - MSL30122 – Certificate III in Laboratory Skills.
  - MSL40122 – Certificate IV in Laboratory Techniques.
  - MSL50122 – Diploma of Laboratory Technology.
- MEM – Manufacturing and Engineering
  - MEM30219 – Certificate III in Engineering – Mechanical Trade.
  - MEM31419 – Certificate III in Engineering – Fixed and Mobile Plant Mechanic.
  - MEM50822 – Diploma Applied Technologies (Industry 4.0).
- TLI – Transport and Logistics
  - TLI27121 – Certificate II in Rail Infrastructure.
  - TLI40324 – Certificate IV in Supply Chain Operations.
- ICT – Information and Communications Technology
  - ICT20120 – Certificate II in Applied Digital Technologies.
  - ICT40120 – Certification IV in Information Technology.

**For the transitioning workforce**

As mentioned above, the skills needed for planning or operating mines for battery minerals are like the skills for mining other commodities. Therefore, it is relatively easy for workers from traditional commodities to move into battery minerals mining and process operations if they wish to be associated with mining that contributes to a lower-emission future.

**Workforce distinctives**

Many operations are situated in remote or regional locations and fly-in-fly-out operations are common. As ongoing shortages of skilled labour persist, remuneration for fly-in-fly-out operators often exceeds that provided to urban operators.

The mining and mineral processing industry is working to continuously improve its environmental performance; improve working conditions to achieve greater gender, cultural and neurodiversity; and to ensure that the rights of First Nations peoples are considered by integrating culturally sensitive practices into recruitment and retention. These matters are gaining careful industry attention (AUSMASA, 2024; IOM3, 2023).

The operations for mining and mineral processing can involve potentially hazardous operations, including working at heights, in confined spaces, underground or with heavy machinery. For this reason, safety is paramount and many courses and qualifications include units of competency related to safe working and following Workplace, Health and Safety (WHS) policies and procedures.





# 4. REFINING/P-CAM/ ANODES/COLLECTORS

*160 km south of Perth, the Kemerton refinery will produce battery grade lithium hydroxide monohydrate. [R. Thiele, FBICRC]*

## The segment

**Battery minerals refining**

The Australian Government's critical minerals strategy (Australian Government, 2023a) outlines opportunities to expand mining and mineral processing of battery minerals and to go "downstream" into the refining of these minerals.

Refining changes a mineral's chemical composition, rather than simply increasing its concentration. For example, a mining operator may crush and process lithium-bearing spodumene ore to produce a concentrate of around 5% lithium oxide content. A lithium hydroxide refinery can convert concentrated spodumene ore into battery-grade, 99.9% pure lithium hydroxide monohydrate.

In the early 2020s lithium hydroxide refineries were built in Australia by Tianqi Lithium Energy Australia and Albemarle. Covalent Lithium is constructing another lithium hydroxide refinery and several other mining and concentrating companies are considering refining battery cathode minerals in Australia.

Several other companies are building or planning to build refineries for battery anode minerals. These companies include Renascor, EcoGraf and International Graphite.

These investments in downstream processing are highly sought after, capital intensive and may be built with the assistance of Government subsidies. They can also be technically challenging to execute, reflecting the need for a technically skilled workforce for this segment of the battery value chain.

**P-CAM/Anodes/Collectors**

As mentioned above, Li-ion cells normally have an active cathode made of mixed nickel, manganese, cobalt or aluminium oxides or a phosphate of iron. The chemistry of the precursor-cathode active material (P-CAM) is a major factor in the cell performance. NMC cells (that contain mainly nickel, manganese and cobalt oxides in their cathodes) normally outperform LFP cells (that mainly have phosphates of iron in the cathode) on energy density but not necessarily on cost, cyclability or safety.

P-CAM is infused with an electrolyte containing lithium salts when the cell is assembled (see Segment 3). From then on it is known as CAM rather than P-CAM.

As mentioned above, Li-ion cells normally have an active anode made of finely powdered graphite, sometimes infused with silicon to improve its electrochemical performance. Various binders and electric conductive additives may be added to increase electric conductivity and strength.

In a cell, the cathode and anode active materials are in contact with current collectors of aluminium and copper respectively. These current connectors have tabs that allow the attachment of copper wires which conduct electricity to other cells, the BMS and ultimately the electric load. Electricity flows through these tabs in the reverse direction when the cell is being recharged.

## Workforce description

The refining of battery materials and production of cathodic and anodic materials and their current collectors are technically complex processes usually overseen by process operators and technicians, including production, panel and control room operators.

The process operators monitor, control and operate specific unit operations of the processing plant and they ensure that corrective actions are agreed and taken when required. Process technicians may also operate production equipment but are focussed on maintenance functions and solving complex problems which require theoretical knowledge, combined with an understanding of the production process and equipment across the plant.

Process operators and technicians are supported by laboratory technicians and maintenance teams. Laboratory staff collect and prepare samples, conduct specialist bench scale tests and produce certificates of assay. Maintenance teams may include electricians, electrical fitters, mechanical fitters and electrical instrumentation technicians. Training for maintenance team roles often include apprenticeship models of training.

### Suitable national training packages

National training packages for this segment of the battery value chain include packages for:

- Chemical, Hydrocarbons and Refining
- Laboratory Operations
- Manufacturing and Engineering
- Manufacturing
- Electrotechnology.

The **Manufacturing Industry Skills Alliance** and **Powering Skills Organisation** are two key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

### Vocational training opportunities

There are qualifications and courses – accessible as apprenticeships or institutional study modes – as well as bespoke skill sets and units of competency available for those wishing to work in the refining of battery materials and production of cathodic and anodic materials. These include:

- **PMA – Chemical, Hydrocarbons and Refining**
  - PMA20116 – Certificate II in Process Plant Operations.
  - PMA30120 – Certificate III in Process Plant Operations.
  - PMA40116 – Certificate IV in Process Plant Technology.
- **MSL – Laboratory Operations**
  - MSL20122 – Certificate II in Sampling and Measurement.
  - MSL40122 – Certificate IV in Laboratory Techniques.
  - MSL50122 – Diploma of Laboratory Technology.
  - MSL60122 – Advanced Diploma of Laboratory Management.
- **MEM – Manufacturing and Engineering**
  - MEM30119 – Certificate III in Engineering – Production Systems.
- **MSM – Manufacturing**
  - MSM30116 – Certificate III in Process Manufacturing.
- **UEE – Electrotechnology**
  - UEE30820 – Certificate III in Electrotechnology Electrician.
  - UEE40420 – Certificate IV in Electrical Instrumentation.

### The transitioning workforce

The skills needed for refining battery minerals are like the skills needed to refine other commodities, although battery materials may be refined to a higher purity than most mined products. Therefore, it is relatively easy for workers from traditional commodities to move into battery minerals refining if they wish to be associated with refining that contributes to a lower-emission future.

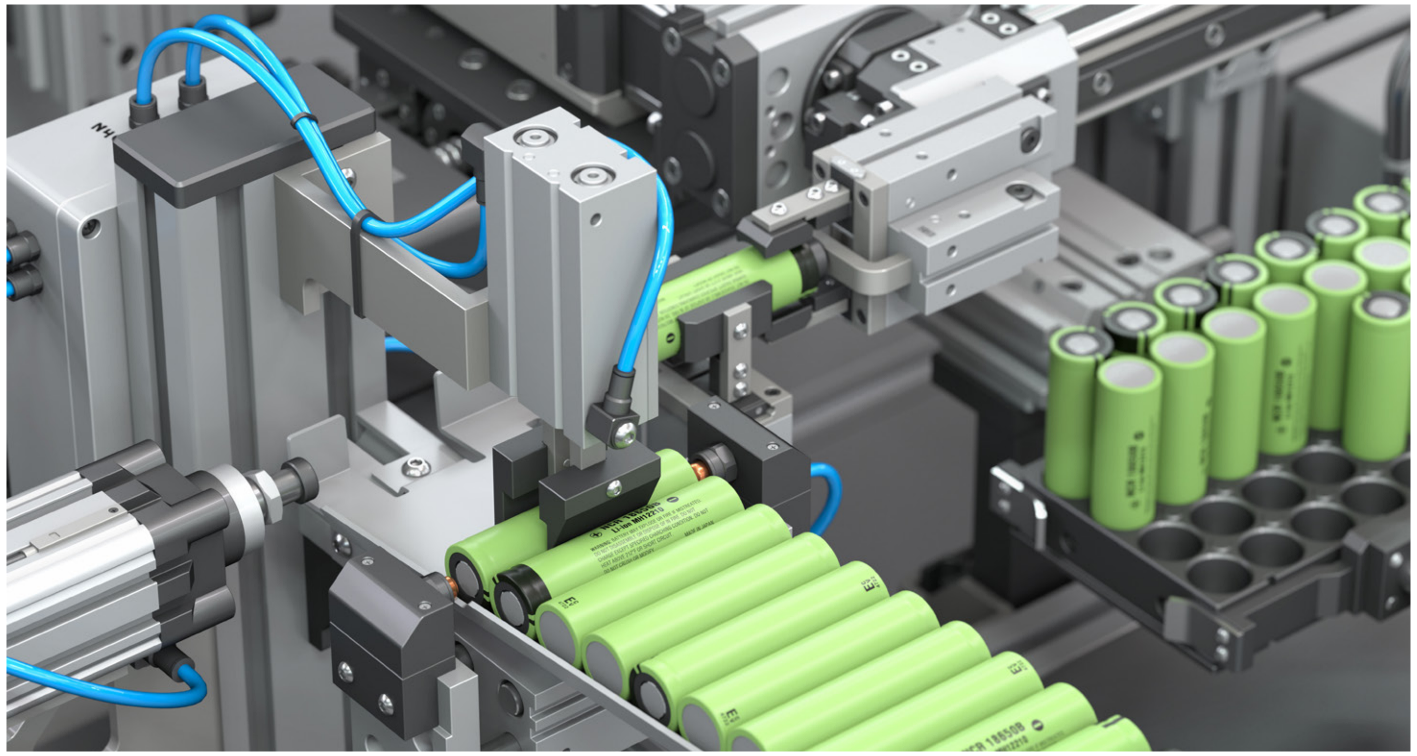
### Workforce distinctives

Each of the P-CAM, anode materials and current collectors must be manufactured under stringent purity constraints to prevent cell failure under operating conditions. The purity standards are often compared to those of the pharmaceutical or food industries rather than the minerals sector. In addition to the purity requirements, each chemical in the battery must be made to exacting particle size specifications to maximise cells' electrochemical performance.

For these reasons, the refining of mattery minerals and the production of P-CAM, anodes and current collectors are often done under environments carefully controlled for humidity and temperature. Australia's capability to refine material outputs to the purity required for battery minerals refining is still emerging, and much of the final, high-value-add processing currently takes place in other countries.

The operations for refining and making high-specification chemical and materials products may involve the use of potentially hazardous chemicals. For this reason, safety is paramount and many courses and qualifications include units of competency related to safe handling of chemicals and following WHS policies and procedures.

# 5. COMPONENT AND CELL ASSEMBLY



The manufacture of Li-ion cells is usually automated but requires high levels of technical planning and supervision [Filipp – stock.adobe.com]

## The segment

### Cell manufacturing steps

A typical manufacturing process for Li-ion cells consists of three main stages: electrode manufacturing, cell assembly and cell finishing. These three stages are critical to the performance and quality of the eventual battery pack.

During electrode manufacturing, CAM mixtures are produced in a slurry with binding chemicals and then coated in precise thicknesses onto aluminium foil current collectors. Anode slurries are applied similarly to copper foil current collectors and then the prepared electrodes are dried under stringent conditions to remove excess solvents. The solvents can be recycled in the system.

During cell assembly, the separator and current conductors holding the valuable cathode- and anode-active materials are precisely cut and the materials rolled or stacked depending on whether the cells are to be in cylindrical, pouch or prismatic cell form. Conducting tabs are welded to the current conductors and the cell interior put into gas-tight packaging. An organic electrolyte is injected into the cell under vacuum conditions.

During cell finishing, the cell films are further compressed through a roller to create better contact among all the cell components before going through their initial charge and discharge cycle. Degassing and aging take place before end-of-life testing which includes physical and electrochemical performance testing.

### The Australian context

Australia's capability to manufacture battery components and their cells is still emerging, and much of the manufacturing currently takes place in other countries. Therefore, many Australian companies involved in manufacturing batteries insert imported cells into locally manufactured modules and control them with locally manufactured BMS. Companies active in this segment include Gelion, Li-S Energy, Energy Renaissance and Master Instruments.

## Workforce description

The commercial-scale manufacture of battery components and cells is usually automated, using robotics and incorporating automated quality control. Production takes place under environments controlled for humidity and temperature. The production is not labour intensive, but it does require high levels of technical planning and supervision. Typical roles therefore include production operators, supervisors and controllers, and quality and equipment technicians.

Production operators and technicians oversee the use of multiple equipment types and computerised systems to mix raw materials, coat micro-layers, cut fine materials, assemble, dry, charge/discharge and package.

Quality and equipment technicians are critical to the process. They consider the precision and adherence to quality standards, use mechanical and electrical skills to troubleshoot, and make continuous improvements to the processes.

### Suitable national training packages

National training packages for this segment of the battery value chain include packages for:

- Manufacturing
- Manufacturing and Engineering
- Electrotechnology.

The **Manufacturing Industry Skills Alliance** and **Powering Skills Organisation** are two key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

### Vocational training opportunities

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships available for those wishing to work in the battery components and cell assembly segment. These include:

- **MSM – Manufacturing**
  - MSM20216 – Certificate II in Manufacturing Technology.
  - MSM30116 – Certificate III in Process Manufacturing.
- **MEM – Manufacturing and Engineering**
  - MEM20219 – Certificate II in Engineering – Production Technology.
  - MEM30422 – Certificate III in Engineering – Electronic Trade.
- **PMA – Chemical, Hydrocarbons and Refining**
  - PMA30120 – Certificate III in Process Plant Operations.
  - PMA40116 – Certificate IV in Process Plant Technology.
- **UEE – Electrotechnology**
  - UEE33020 – Certificate III in Electrical Fitting.
  - UEE40420 – Certificate IV in Electrical – Instrumentation.
  - UEE42220 – Certificate IV in Instrumentation and Control.

### Workforce distinctives

Modern battery cells must be manufactured with stringent process and quality controls to prevent cell failure under operating conditions. The purity standards are often compared to those of the pharmaceutical or food industries rather than the manufacturing sector. Cells, intended for a decade of field use, must exhibit exemplary physical and electrochemical performance.

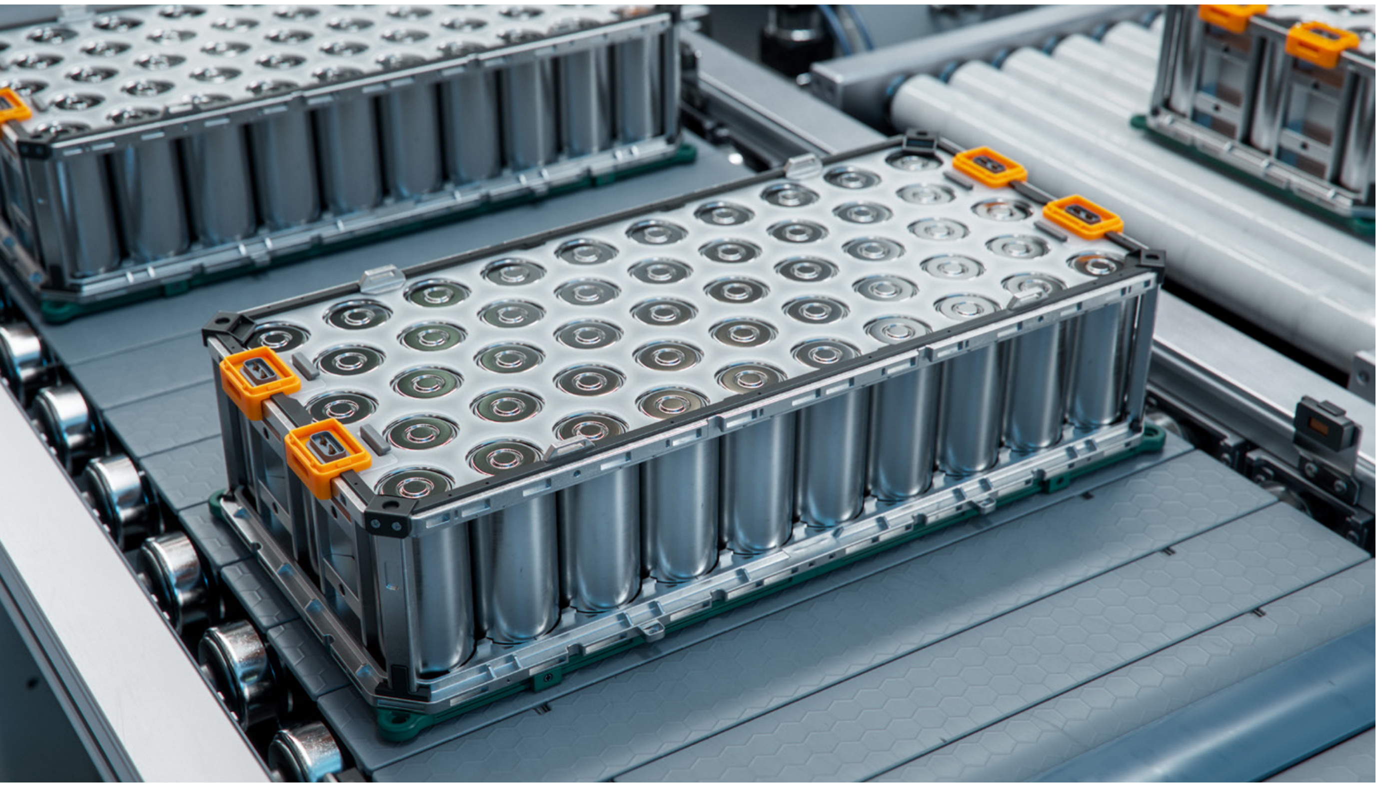
Manufacturers of automobiles and BESS installers demand that battery packs perform to specified standards. Under-performance can lead to significant social, environmental or economic losses. Therefore, it is vital that manufacturers keep records of every cell produced, and any changes to the operating conditions recorded. A traceability system so implemented creates a process by which under-performing cells can be traced back to the manufacturer and the reasons for under-performance identified.

For this reason, accuracy and precision are paramount and many courses and qualifications include units of competency related to the use of measuring instruments and standards in addition to WHS policy adherence.

In September 2024 it was announced that Queensland will host a TAFE Centre of Excellence – Clean Energy (Batteries). The centre will help increase participation, resulting in more workers with the skills to install, operate and maintain renewable energy systems and batteries (Giles et al., 2024).

SEGMENT 4

# 6. EV PACK AND BESS ASSEMBLY AND MANUFACTURING



Battery packs containing Li-ion cells are arranged in a combination of series and parallel circuits designed to produce the necessary energy, power and voltage [IM Imagery – stock.adobe.com]

## The segment

**Electric Vehicles (EVs)**

Domestic EVs normally contain thousands of Li-ion cells arranged in a combination of series and parallel circuits customised to produce the necessary power, voltage and range for the vehicle. Higher powered cars have tended to use NMC or NCA cathodes which have relatively higher energy density. LFP cells, which are cheaper but have lower energy density and therefore lesser range, are used more often for smaller vehicles and for newly designed vehicles that have a larger space available to house the battery.

Many countries have introduced targets and tax benefits to accelerate the phasing out of internal combustion engines (ICE) over the coming decade and therefore meet climate targets. These incentives drove investments in EV production internationally such that EVs accounted for around 18% of all cars sold in 2023, up from 14% in 2022 (International Energy Agency, 2024).

We are accustomed in Australia to EVs that have a large battery embedded permanently into their chassis. However, other models of e-mobility use “swappable” batteries. In a swappable model, a discharged battery is replaced quickly with a fully charged battery from a service vendor. Replacing the battery is faster than charging the battery. This may prove especially popular for two- and three-wheel e-mobility, and in heavy mining and industrial vehicles whose drivers can swap-and-go in minutes.

**Battery Energy Storage Systems (BESS)**

Because the production of Li-ion cells for EVs rapidly ramped up over the past decade, the cost per cell has declined markedly. This has made EVs more affordable but has also made BESS cost-effective. Currently more than two-thirds of Li-ion cells that are manufactured are used in EVs. However, the use of Li-ion cells in BESS is a rapidly growing segment of the market (Accenture, 2021).

Australia is fortunate to have wide scale energy generation from renewable sources such as solar and wind. Solar and wind produce well during the day but to a much lesser extent in the evening, the time when net energy demand on the grid can be highest. Without BESS, or some other energy storage such as pumped hydro, the grid requires gas- or coal-fired power stations to rapidly increase production for several hours each evening. Not only does this contribute to greenhouse gas emissions, coal-fired power stations are not designed to respond to rapid rises and falls in generation.

BESS presents a vital opportunity to store excess renewable energy in the day and dispatch it to the grid in the evenings. “Shifting” energy load greatly reduces emissions. In addition, BESS plays a role in stabilising the electricity grid to ensure that the variabilities of voltage and frequency introduced by renewable sources are moderated and the electricity supply is stable and reliable.

The first world-class “big battery” was commissioned in Hornsdale, South Australia, in 2017. Its initial installed energy capacity was 129 MWh. Interestingly, the primary use of this battery was to improve grid stability, rather than bulk energy storage.

Some Australian BESS installations currently under construction will store at least 2000 MWh of energy. They may make the original Hornsdale installation appear modest, but Hornsdale proved the concept and continues to operate effectively in 2024.

Most large Australian BESS units are being installed at sites close to retiring coal-fired power stations or next to large solar “farms” in renewable energy zones allowing them to take advantage of existing electricity transmission infrastructure.

Most battery cells used in large-scale BESS are imported in existing packs ready for installation on site and connection to each other and the grid. However, there is also an emerging BESS assembly industry in Australia, with local companies such as Energy Renaissance importing cells, inserting them into locally manufactured modules and controlling them with locally manufactured BMS. The BMS regulates and monitors factors such as charging, discharging, capacity, current and temperature.

**Pack assembly**

Battery pack assembly describes the arrangement of battery cells into battery packs. It involves wiring, soldering, and electrically connecting cells. Modules are configured to control the voltage and capacity of the battery pack.

BMS are included to prevent electrical imbalances in the modular assembly of battery cells, such as over- or under-voltage, over-current, and over- or under-temperature. The BMS’ main function is to shut down operations of the module (and sometimes the system) if any of the voltage, current, or temperature boundary conditions are violated. The BMS also controls interactions between individual cells, battery modules and battery packs with their electrical load.

Larger BESS units comprise multiple battery packs assembled using racking and contained within a metal storage unit with integrated cooling and energy management systems.

Battery packs and systems are tested under rigorous quality controls prior to installation.

## Workforce description

The main skills needed in this part of the battery value chain include electrical and electronic assembly, testing, and commissioning by electromechanical assemblers, electronics technicians and electricians.

Original Equipment Manufacturers (OEMs) would usually provide in-house training on EV pack assembly for those people who already hold automotive training credentials.

BESS manufacturing companies often employ university qualified electrical engineers and ICT professionals for the design of customised BESS including their BMS. However, electricians play a key role in the BESS manufacturing industry and skills shortages for electricians may impact the industry. Electrical trades are trained through established VET training pathways and are likely to require battery specific safety and handling knowledge. Mechanical assembly skills could be trained on site for people with good mechanical aptitude (FBICRC, 2021).

Battery assemblers may also become involved in BESS installation which involves grid connectivity and therefore electrical licenses. Electrical trades involved in the battery assembly process may also need to complete BESS design and installation training and accreditation designated by the Solar Accreditation Australia (SAA) as described in Segment 5.

**Suitable national training packages**

National training packages for this segment of the battery value chain include packages for:

- Manufacturing
- Manufacturing and Engineering
- Automotive Retail, Service and Repair.

Powering Skills Organisation, Manufacturing Industry Skills Alliance and AUSMASA are key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

**Vocational training opportunities**

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships available for those wishing to work in the EV pack and BESS assembly and manufacturing segment. These include:

- **UEE – Electrotechnology**
  - UEE30820 – Certificate III in Electrotechnology Electrician.
  - UEE30920 – Certificate III in Electronics and Communications.
  - UEE33020 – Certificate III in Electrical Fitting.
- **MEM – Manufacturing and Engineering**
  - MEM20219 – Certificate II in Engineering – Production Technology.
  - MEM30119 – Certificate III in Engineering – Production Systems.
  - MEM30219 – Certificate III in Engineering – Mechanical Trade.
  - MEM31922 – Certificate III in Engineering – Fabrication Trade.
  - MEM30422 – Certificate III in Engineering – Electronic Trade.
- **AUR – Automotive Retail, Service and Repair**
  - AUR31120 – Certificate III in Heavy Commercial Vehicle Mechanical Technology.
  - AUR32721 – Certificate III in Automotive Electric Vehicle Technology.

**Microcredentials for the transitioning workforce**

Current workers with existing qualifications may want to add to their skills so they can de-risk their current employment and transition to the clean economy workforce. Workers can supplement existing qualifications by selecting units of competency, skill sets and courses such as:

- **UEE - Electrotechnology**
  - UEERE0054 – Conduct site survey for grid- connected photovoltaic and battery storage systems.
  - UEERE0056 – Coordinate maintenance of renewable energy (RE) apparatus and systems.
  - UEERE0060 – Design grid-connected battery storage systems.
  - UEERE0077 – Install battery storage equipment power conversion equipment to grid.
  - UEERE0078 – Install battery storage to power conversion equipment.
- **AUR – Automotive Retail, Service and Repair**
  - AURSS00063 – Battery Electric Vehicle Diagnose and Repair Skill Set.
  - AURSS00064 – Battery Electric Vehicle Inspection and Servicing Skill Set.
- **Accredited courses**
  - VU22125 – Design a grid-connected battery storage system to meet client requirements.

**Workforce distinctives**

EV pack and BESS assembly and manufacturing is a rapidly growing segment which was virtually unknown in Australia only a decade ago. While EV pack assembly is yet to take place in Australia for the car market, the BESS market is flourishing. BESS is seen as an area in which Australia can excel if it leverages its solar and wind assets.

BESS designs come in a variety of forms. Bespoke applications are emerging for uses such as defence and mining. Meanwhile, community and domestic scale BESS are growing in popularity to reduce grid reliance and lower electricity costs.

The segment relies heavily on the electrical trades which are already in demand from other sectors of the emerging renewable industries as well as for traditional roles such a residential and commercial construction. Electrical trades should expect ongoing employment opportunities over the longer term (Powering Skills Organisation, 2023; Rutovitz et al., 2023).

SEGMENT 5

# 7. BESS INSTALLATION AND MAINTENANCE

## The segment

The approach to installing and maintaining BESS units differs depending on whether the system is for home, community or utility scale.

**Home batteries**

Home batteries are smaller BESS units, often installed to complement an installed rooftop solar photo-voltaic (PV) system. Home batteries typically store around 10 – 15 kWh of energy, equating to one or two days of PV output. By comparison, a medium size EV may have a battery that stores 50 – 90 kWh of energy.

Home batteries can dispatch stored electrical energy to the home when PV output is reduced, such as after sunset or on cloudy days. Home batteries can also provide short term power during blackouts and help where grid supply is unreliable. Residential batteries are a type of “behind the meter” battery and they are often installed in home garages.

**Community batteries**

Community batteries are a more cost-effective energy shifting solution than home batteries. They are normally installed and maintained by network providers because they are “in front of the meter”, often located in parks or open spaces. Community batteries may store around 200 – 500 kWh of energy. They have the benefit of relying less on long-distance transmission lines because they capture local PV output in the day and dispatch it to local households and businesses during the evening.

**Utility scale batteries**

Utility scale, grid scale or “big” batteries can be orders of magnitude larger. There are many utility scale batteries now feeding Australian grids, with more than 20 of these storing at least 100 MWh. Several of the big batteries under construction will store at least 2000 MWh (or 2,000,000 kWh) of energy.

On site, utility scale BESS units are arranged in arrays of containers, similar in size to sea containers. They are often installed next to large solar PV installations to store surplus daytime energy and avoid losses on transmission. Others are being installed at sites close to retiring coal-fired power stations, taking advantage of the existing electricity transmission infrastructure as residential distribution networks are inadequate to manage the power generated from large BESS units.

Due to their size and important role in grid stability, the planning, development, installation, and commissioning stages of BESS installation are complex and highly regulated. The approvals process for BESS installations often takes 2 – 4 years to be finalised.

**BESS maintenance**

Most large scale BESS units are installed by international companies, such as Neoen or Akaysha Energy, in close consultation with OEMs such as Tesla or CATL and local electrical utilities. Electrical trades continue to be involved as the new installations move past commissioning and into monitoring and troubleshooting.

*The Victorian Big Battery near Geelong comprises 106 of these Tesla BESS units [R. Thiele, FBICRC].*

## Workforce description

At residential scale, BESS installation must be performed by licensed electricians. To attract SAA accreditation, licensed electricians need to have completed designated VET units on BESS design and installation. Home installations generally take one to two days to complete. It is common for the same trades people who install rooftop PV to also install home BESS.

Community and grid scale batteries and their BMS are normally designed by teams of university qualified electrical and electronic engineers and ICT professionals. The installation of these larger systems normally involves a team of engineers and VET-qualified electrical and maintenance trades.

Li-ion batteries require temperature control and fire suppression systems to operate effectively and safely. Therefore, heating, ventilation, air conditioning (HVAC) trades are required to maintain BESS' cooling systems.

BESS presents employment opportunities also for lineworkers, construction and logistics workers, cable jointers, environmental planners, and emergency and safety workers. It is predicted that more than 12,000 additional electrical workers will be required by 2025 to build out the number of BESS units required to meet Australia's emission reduction targets (Accenture, 2023a).

Prior to the arrival of electrical workers, there will be many and varied jobs related to site planning and preparation, civil works, logistics and transport, and rigging and dogging.

**Suitable national training packages**

National training packages for this segment of the battery value chain include packages for:

- Electrotechnology
- Transmission, Distribution and Rail Sector.

Powering Skills Organisation, and BuildSkills are key Australian Jobs and Skills Council established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

**Vocational training opportunities**

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships available for those wishing to work in the BESS installation and maintenance segment. These include:

- **UEE – Electrotechnology**
  - UEE30820 – Certificate III in Electrotechnology Electrician.
  - UEE32220 – Certificate III in Air Conditioning and Refrigeration.
  - UEE43322 – Certificate IV in Electrical – Renewable Energy.

  - UEESS00191 – Grid-connected Battery Storage Systems Designer-Installer Skill Set.
  - UEESS00192 – Grid-connected Battery Storage Systems Installer Skill Set.
  - UEESS00193 – Grid-connected Photovoltaic and Battery Storage Systems Designer Skill Set.
  - UEESS00194 – Grid-connected Photovoltaic Systems Designer-Installer Skill Set.
  - UEESS00195 – Grid-connected Photovoltaic Systems Installer Skill Set.
  - UEESS00196 – Grid-connected Renewable Energy System Site Surveyor Skill Set.
  - UEESS00197 – Grid-connected Renewable Energy Systems Inspector Skill Set.
  - UEESS00198 – Hybrid Photovoltaic, Wind and Battery Storage Systems Installer Skill Set.
- **UET – Transmission, Distribution and Rail Sector**
  - UET30621 – Certificate III in ESI – Distribution Overhead.
  - UET30821 – Certificate III in ESI – Distribution Underground.
  - UET30921 – Certificate III in ESI – Very Remote Community Utilities.
- **CPC – Construction, Plumbing and Services**
  - CPC30720 – Certificate III in Rigging.

In addition to VET competencies, BESS manufacturers' training may be required for trades engaged in the installation and maintenance of BESS units, especially for community and grid scale units.

As BESS integrate with other distributed energy assets there will be a need for ICT skills to install, operate and maintain the highly networked energy power systems.

**Microcredentials for the transitioning workforce**

Current workers with existing qualifications may want to add to their skills so they can de-risk their current employment and transition to the clean economy workforce. Workers can augment existing qualifications by selecting units of competency and accredited and non-accredited (microskills) courses such as:

- **UEE – Electrotechnology**
  - UEERE0054 – Conduct site survey for grid-connected photovoltaic and battery storage systems.
  - UEERE0060 – Design grid-connected battery storage systems.
  - UEERE0077 – Install battery storage equipment power conversion equipment to grid.
  - UEERE0078 – Install battery storage to power conversion equipment.
  - UEERE0086 – Promote sustainable energy practices.
- **CPC – Construction, Plumbing and Services**
  - CPCCDO2011 – Handle and position dogging tools and equipment.
- **Accredited courses**
  - VU22125 – Design a grid-connected battery storage system to meet client requirements.
- **Non-accredited courses (TAFE microskills)**
  - Battery Maintenance Fundamentals (electrical trades upskill).
  - Grid Scale Battery (manage and maintain grid scale battery).

**Workforce distinctives**

As mentioned, most large Australian BESS units are being installed at sites close to retiring coal-fired power stations or larger solar PV farms taking advantage of the existing electricity transmission infrastructure and reducing loss on transmission. BESS units are often located in renewable energy zones presenting regional employment opportunities and jobs for those wishing to transition from fossil-fuel related employment.

Earlier in this decade, most workers in BESS manufacturing, supply, installation, operation and maintenance were working in smaller scale, distributed battery installations rather than community and grid scale installations (Clean Energy Council, 2020). This balance may change as the number of larger grid scale BESS installations grows.

The BESS maintenance workforce is normally much smaller than the BESS installation workforce. The monitoring of larger BESS units' operations can usually be done remotely. Hence, there are often only a handful of people onsite at large operating BESS sites, meaning that the employment opportunities will be greater for BESS installation than for its maintenance.

A different workforce will be required to disassemble and recycle end-of-life BESS units. This is addressed in Segment 7.

Overall, the segment relies heavily on the electrical trades which are already in demand from other sectors of the emerging renewable industries as well as for traditional industries. Electrical trades should expect ongoing employment opportunities over the longer term (Clean Energy Council, 2022).

Vehicle to home (V2H) and vehicle to grid (V2G) solutions will soon see smart, internet-informed connections between a home and an EV, turning the EV battery into a home BESS or helping to power the grid. Regulatory processes are still being established for this in Australian states and territories but preliminary trials have proven promising, including as a way to mitigate grid fluctuations (Australian National University, 2022, 2024).

An emerging opportunity is that of the Virtual Power Plant (VPP). A VPP aggregates thousands of individual PV and home batteries, allowing renewable energy to be quickly injected into the grid to address voltage and frequency imbalances, local disruptions or disturbances and keep the network stable. Participating households are rewarded, generally through direct payments or bill credits (ARENA, 2021).

For each of these emerging technologies there will be a need for electronics and communications trades as well as for market analysts and modellers.

A common pathway into the BESS workforce is by becoming a qualified and licensed electrical worker (e.g. Electrician or Electrical Distribution Trades Worker) who also gains a range of additional specialist skills, training and expertise fitted to the specific BESS requirements. VET enrolments in renewable energy units have grown from 20,000 in 2015 to around 38,000 by 2022 (Powering Skills Organisation, 2024).

In May 2024 it was announced that Western Australia will host a TAFE Clean Energy Skills National Centre of Excellence. The Centre will innovate training in clean energy technologies, including solar, wind, hydrogen, batteries and grid integration, and fast-track development and delivery of higher and degree-equivalent apprenticeship pathways (O'Connor, 2024b).



# 8. EV SERVICE AND SUPPORT

## The segment

Many countries have introduced incentives to phase out ICE vehicles to meet climate targets. These incentives accelerated investments in EV production internationally such that world-wide EV sales comprised 18% in 2023 (International Energy Agency, 2024). Australia lags international averages with full battery and plug-in hybrid EV purchases collectively comprising 8.5% of new car sales in 2023 but well up from the 3.8% sales result from 2022 (Electric Vehicle Council, 2024).

The transition from ICEs to EVs will occur over several decades. State governments, the Australian Government and private sector investment are contributing to the spread of public charging stations so that stations and associated infrastructure can keep pace with EV adoption. Widespread EV adoption is still needed across the larger commercial vehicles (Omnibus) vehicles segments, although electric-powered vehicles are increasingly being used on mine sites to reduce greenhouse gas emissions.

EV support includes the charging stations and charging docks used to re-charge EVs whether that be in residential, commercial or public areas.

*The transition of automotive service technicians to now work on EVs is well underway [Romaset – stock.adobe.com]*

## Workforce description

The transition of service technicians – who have mainly worked on ICEs to now work on EVs – is well underway. To date, this transition has been mainly managed by the OEMs in support of new car sales and marketing efforts. Over time, it can be expected that new apprentices entering the industry will already be qualified and practiced in EV servicing.

Some of the trades engaged in this segment include:

- EV service technicians - light vehicles
- EV service technicians - heavy vehicles
- Automotive electrician
- Electromechanical equipment asssembler
- Electronic assembler
- End of line testing technicians
- EV charging equipment installers.

**Suitable national training packages**

National training packages for this segment of the battery value chain include packages for:

- Automotive Retail, Service and Repair
- Manufacturing and Engineering
- Electrotechnology.

**AUSMASA**, the **Manufacturing Industry Skills Alliance** and **Powering Skills Organisation** are key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

**Vocational training opportunities**

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships available for those wishing to work in the EV service and support segment. These include:

- **AUR – Automotive Retail, Service and Repair**
  - AUR20720 – Certificate II in Automotive Vocational Preparation.
  - AUR30320 – Certificate III in Automotive Electrical Technology.
  - AUR30620 – Certificate III in Light Vehicle Mechanical Technology.
  - AUR32721 – Certificate III in Automotive Electric Vehicle Technology.
- **MEM – Manufacturing and Engineering**
  - MEM20219 – Certificate II in Engineering – Production Technology.
  - MEM30422 – Certificate III in Engineering – Electronic Trade.
- **UEE – Electrotechnology**
  - UEE30820 – Certificate III in Electrotechnology Electrician
  - UEE42622 – Certificate IV in Hazardous Areas – Electrical.

In addition to VET competencies, OEM training may be required for trades engaged in the EV servicing and EV charging installations.

**Microcredentials for the transitioning workforce**

The upskilling of current light and heavy vehicle mechanics is important. Not all of these will become EV service technicians, but all will require at least some EV knowledge and training to ensure safe operations.

Current workers with existing qualifications may want to add to their skills so they can de-risk their current employment and transition to the clean economy workforce. Workers can augment existing qualifications by selecting units of competency, skill sets or courses such as:

- **UEE – Electrotechnology**
  - UEERE0060 – Design grid-connected battery storage systems.
  - UEERE0077 – Install battery storage equipment power conversion equipment to grid.
  - UEERE0078 – Install battery storage to power conversion equipment.
- **AUR – Automotive Retail, Service and Repair**
  - AURETH011 – Depower and reinitialise hybrid electric vehicles.
  - AURETH012 – Service and maintain electrical components in hybrid electric vehicles.
  - AURETH015 – Diagnose, remove and replace heavy electric vehicle rechargeable energy storage systems.
  - AURETH101 – Depower and reinitialise battery electric vehicles.
  - AURETH102 – Inspect and maintain battery electric vehicles.
  - AURSS00037 – Hybrid Electric Vehicle Inspection and Servicing Skill Set.
  - AURSS00063 – Battery Electric Vehicle Diagnose and Repair Skill Set.
  - AURSS00064 – Battery Electric Vehicle Inspection and Servicing Skill Set.
- **Accredited courses**
  - 22609VIC – Course in electric vehicle charging infrastructure up to 22 kW.

Participants in the EV servicing industry should also be aware of the relevant Australian Standard (Standards Australia Limited, 2022) regarding EV maintenance and repair. This standard specifies requirements and guidance on the safe and appropriate handling procedures for those within the mechanical repair, body repair and refinishing industries when working on different types of EV.

**Workforce distinctives**

The automotive repair industry is highly skewed towards male participation with only 2.6% of automotive and engineering trades workers being females (AUSMASA, 2023). However, recent trends are showing increased participation by females in, for example, AUR20720 *Certificate II in Automotive Vocational Preparation*. Female participation in the automotive industry is not only an important opportunity for addressing labour shortages but also an opportunity to create a more diverse and welcoming culture for all (Capricorn, 2022).

An exciting transformation in the EV charging space is the deployment of "fast" chargers. Fast charging was traditionally considered detrimental to EV battery life. However, technology revolutions in battery cell design and chemistry allow some EVs to be charged much more rapidly. Some fast chargers claim to deliver around 200 kW, albeit often spread over several charging outlets. This is many times the power of chargers implied in *22609VIC Course in electric vehicle charging infrastructure up to 22 kW* (State of Victoria, 2022) illustrating the need for training packages to be constantly refreshed to keep pace with technological advances.

EV charging stations are being installed around Australia including in regional and remote locations. Australian company JET Charge is presently building out Australia's longest EV charging network, a 5,300 km series of chargers around Western Australia (JET Charge, 2022). Australian company eLumina is manufacturing EV charging stations that have built-in Li-ion BESS. These allow EVs to be fast charged in locations with low or unstable power supply. Such developments present regional and remote employment opportunities as well as jobs for those wishing to transition from fossil-fuel related employment.

Another EV technology transformation is the introduction by some OEMs of battery packs that deliver voltages (V) of around 800 V rather than the popular 300 to 400 V. This has led to concerns that the electrical training for automotive technicians may need to be expanded or that automotive technicians could be subject to a form of electrical licensing (AUSMASA, 2024). Either way, the safe handling of EV battery packs – and their de-energisation when required – will be an area of close attention for the automotive sector going forward.

With these revolutions, along with the potential for V2H and V2G adoption as mentioned earlier, there is a need for EV service technicians to participate in ongoing training to ensure their skills remain suitable in this rapidly evolving field and they can operate safely. Another model will be for specialist EV battery servicing companies to be established — such as Infinetev — that can support the broader EV and automotive OEM sector.

EVs can present a risk of fire in the event of damaged or malfunctioning batteries. Organisations such as EV Fire Safe provide safety training and current information for first responders dealing with EV incidents (EV Fire Safe, 2021). Companies involved with the transfer of battery materials need to comply with the *Australian Code for the Transport of Dangerous Goods by Road & Rail* (National Transport Commission, 2024).

In May 2024 it was announced that Canberra Institute of Technology will establish a TAFE Electric Vehicle Centre of Excellence. The Centre will help train EV technicians for the net zero transformation and be an important component of Australia's EV training landscape (O'Connor, 2024a).

# 9. DISMANTLE AND RECYLE

*Materials in modern cells are valuable and should be part of a circular economy [markobe – stock.adobe.com]*

## The segment

As the battery industries mature there will be an increasing supply of batteries available for reuse. Their reuse need not necessarily mean destruction of the cells and packs, as batteries' next lives may be through their repair or repurposing. However, some of these uses will still require dismantling of the battery packs.

The repair, repurposing or recycling of battery cells are important for several reasons. Firstly, they prevent materials going into the environment. These materials are potentially hazardous due to fire risk or the leaching of electrolytes or electrode active materials into the ground or waterways. Secondly, each cell contains valuable materials that have an associated carbon and environmental footprint. Therefore, efficient repair, repurposing or recycling are preferable compared to disposal and battery replacement with newly mined or manufactured materials.

### Battery repair

In some battery packs, a single cell or collection of cells may fail. If these cells can be removed and replaced with functioning cells, then the full capacity of the battery pack can be restored without great cost. However, in many commercial battery packs the cells are welded together and/or connected by cooling systems, structural supports, electrical management and power systems. These connections make the removal of individual cells more difficult. Some companies in Australia, such as Vaulta, are building specialisation into battery packs so that they can more easily be repaired.

### Battery repurposing

Over time and use, the maximum amount of energy that can be stored in a battery decreases, mainly due to undesirable changes in the chemistry and structure in the cells. For batteries used in high performance settings – such as in EVs – their effective life may end when their maximum energy storage is around 70 to 80% of their original capacity. However, batteries with this reduced energy density may still be suitable for other uses such as for off-grid BESS as a battery backup.

Interest in repurposing has started to gain momentum since the supply of EV batteries is rising significantly but while recycling processes for these batteries has yet to be well established. Thus, second-life use has been seen as economically and environmentally viable means to address this waste stream until a functioning battery recycling program is well established (Zhao, et al., 2021).

Repurposing cells from retired EVs has proven feasible for smaller scale commercial BESS up to 240 kWh such as the program with Sustainability Victoria and Infinitev. However, a greater feedstock is necessary to ensure ongoing commercial viability (Sustainability Victoria, 2023).

### Battery recycling

The use of Li-ion batteries has only become wide-spread in EVs and BESS over the latter part of the 2010s. The normal life of the cells is 8 to 12 years so the supply of end-of-life EV and BESS cells is now emerging as is the flow of cells from warranty and repair work.

Therefore, increasing attention is being given to end-of-life battery recycling. This is because the materials in modern cells are valuable and because there is a fire risk associated with their transportation and compaction during traditional waste treatment processes.

The recycling process starts with collection. Spent batteries are transported by truck or van in fireproof boxes to battery recyclers or specialist companies that can test, deenergise and dismantle. Once battery packs are disassembled, the cells can be recycled. Electronic wiring and components are separated from battery cells and sent to metal recyclers, and plastics are sent to plastic recyclers.

Battery cells are sorted by chemistry type and then processed through a shredder. Metal foils are then sent for domestic metal recycling and the CAM and anode battery material, known by recyclers as "black mass", is shipped offshore for further processing (Battery Stewardship Council, 2023a).

Envirostream, ReSource, Ecocyle, EcoBatt, SKtes, Battery Pollution Technologies and Renewable Metals are some of the Australian companies currently operating or developing Li-ion battery recycling facilities or looking to invest in black mass recovery.

Meanwhile, important consumer initiatives such as the Battery Steward Council's (2023b) B-cycle program seeks to facilitate the growth of accessible battery recycling services for consumers in metropolitan and regional areas across Australia.

### BESS dismantling

If an entire grid scale BESS was required to be decommissioned, the trades and technician, labourer and machine operator skills required during the decommissioning and demolition phase would be like those of the installation phase (see Segment 5) but with more focus on waste collection and remediation of the site.

## Workforce description

Job opportunities in the Li-ion battery dismantle and recycle segment are emerging because the industry is still emerging.

Electrical skills will be in high demand in the decommissioning and testing stages of end-of-life. These skills will be acquired through TAFE training pathways. However, additional training will be required in the safe handling and emergency procedures for lithium batteries at end-of-life.

Some of the trades engaged in this segment include:

- Warehouse operations
- Warehouse material scheduler
- Logistics managers and transporters
- First responders
- HazMat and dangerous goods analyst
- Material handler / sorter
- Laboratory technicians
- Recycling operator
- Electrical contractors.

**Suitable national training packages**

National training packages for this segment of the battery value chain include packages for:

- Transport and Logistics
- Automotive Retail, Service and Repair
- Laboratory Operations
- Chemical, Hydrocarbons and Refining
- Property Services
- Electrotechnology.

**Industry Skills Australia**, **AUSMASA**, **Manufacturing Industry Skills Alliance**, **BuildSkills Australia** and **Powering Skills Organisation** are key Australian Jobs and Skills Councils established to oversee industry input into these national training packages and ensure the packages are appropriate to support the future workforce.

**Vocational training opportunities**

There are qualifications and courses, as well as bespoke skill sets, units of competency and apprenticeships available for those wishing to work in the dismantle and recycle segment. These include:

- **TLI – Transport and Logistics**
  - TLI31222 – Certificate III in Driving Operations.
  - TLI40324 – Certificate IV in Supply Chain Operations.
- **AUR – Automotive Retail, Service and Repair**
  - AUR30320 – Certificate III in Automotive Electrical Technology.
  - AUR30620 – Certificate III in Light Vehicle Mechanical Technology.
  - AUR32721 – Certificate III in Automotive Electric Vehicle Technology.
- **MSL – Laboratory Operations**
  - MSL30122 – Certificate III in Laboratory Skills.
  - MSL60122 – Advanced Diploma of Laboratory Management.
- **PMA – Chemical, Hydrocarbons and Refining**
  - PMA20116 – Certificate II in Process Plant Operations.
  - PMA30120 – Certificate III Process Plant Operations.
  - PMA40116 – Certificate IV in Process Plant Technology.
- **CPP – Property Services**
  - CPP30719 – Certificate III in Waste Management.
  - CPP40919 – Certificate IV in Waste Management.
- **UEE – Electrotechnology**
  - UEE30820 – Certificate III in Electrotechnology Electrician.
  - UEE42622 – Certificate IV in Hazardous Areas – Electrical.

**Workforce distinctives**

Battery recyclers will usually partner with appropriately trained transport operators or collect batteries themselves for recycling, so will be well versed in the safe handling and transportation of Li-ion batteries at end-of-life.

A combination of electrical and mechanical skills will be required to dismantle batteries down to individual battery cells for shredding and processing. An understanding of the safety management for Li-ion batteries, particularly regarding thermal runaway, will be needed at end-of-life as this is the stage when battery components and cell function may be deteriorating, leading to higher risk of fire and explosion. Companies involved with the transfer of battery materials need to comply with state and territory legislation arising from the *Australian Dangerous Goods Code* (National Transport Commission, 2024).

The battery recycling industry in Australia and globally is in its infancy. Research and development on best practice battery handling at end-of-life is still emerging, and industry will need to stay abreast of the latest developments in recycling practices.

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