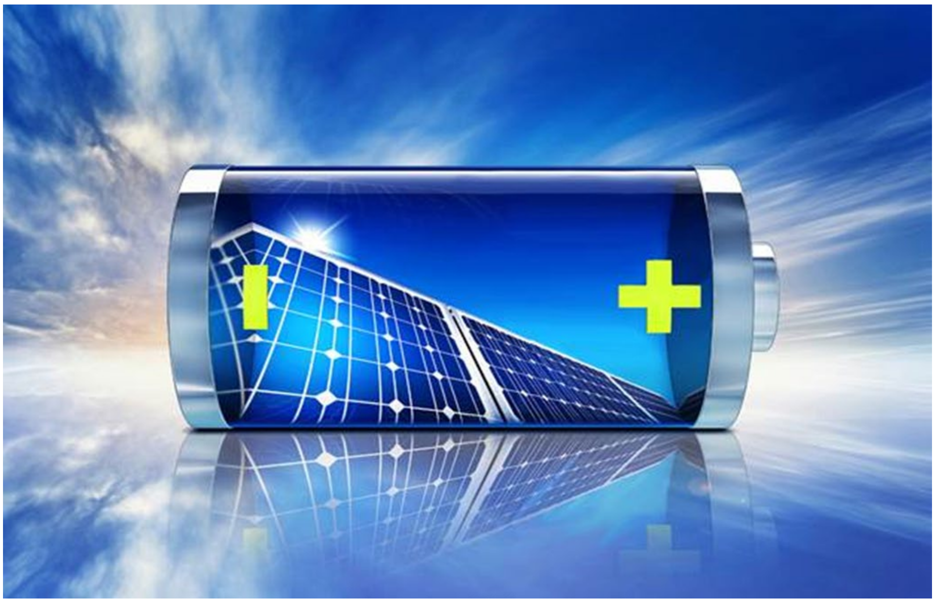
**Development of a Proposed Performance Standard for a Battery Storage System Connected to Domestic/Small Commercial PV System**

# Recommended Information for BESS and Battery Safety Information Sheets



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Australia's National
Science Agency

# Recommended Information for Battery Energy Storage Systems (BESS) and Battery Safety Information Sheets

Supporting document for ARENA project:

Development of a Proposed Performance Standard for a Battery Storage System Connected to Domestic/Small Commercial PV System

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# Executive summary

This document has been written to provide supporting information to industry and stakeholders in the battery energy equipment industries covering battery systems (DC batteries) and battery energy storage system (AC batteries with power conversion equipment). Battery safety is a critical requirement for any system sold in Australia. Although a range of documentation exists, as well as Standards, covering aspects of safety, there are a number of gaps and challenges where information is limited or non-existent. This document is written to provide information to assist industry and stakeholders where gaps in safety information currently exist.

The document focusses on providing safety information and recommendations for the transportation and storage, users and consumers, decommissioning, recycling, first responders and certification segments of the battery system and BESS supply chain.

# 1 Introduction

The Australian Renewable Energy Agency (ARENA) (through the Advancing Renewables Program) and the Victorian Government (through its New Energy Jobs Fund), have funded a draft battery performance standard development project for battery energy storage systems (BESS) connected to domestic/small-scale commercial photovoltaic (PV) systems. The project is titled: Development of a Proposed Performance Standard for a Battery Storage System connected to a Domestic/ Small Commercial Solar PV system.

The goal of the project is to develop a standardised process for measuring and reporting the performance parameters for a PV connected battery system for residential / small-scale commercial applications. This will enable consumers, industry, and stakeholders to be able to make informed choices about the range of products which exist on the market. By using a standardised measurement process and reporting framework across the industry, confusion regarding parameters (for example capacity, cycle life, energy, etc., all of which are strongly linked to the measurement method) can be removed and stronger consumer confidence in the growing market enabled. This project will define how the measurement of key performance metrics should occur, in a manner that is accessible to stakeholders from small to medium size enterprises all the way through to large multinationals.

The proposed Australian Battery Performance Standard is intended to cover battery systems with a maximum estimated size of 100 kW power capacity and 200 kWh energy capacity in total, which essentially covers the residential and small-scale commercial applications market. The project is led by DNV GL and is supported by CSIRO, Deakin University, and the Smart Energy Council.

As part of the project, the consortium is also developing a suite of documentation to assist industry and stakeholders in the application of PV connected batteries.

**This document is written to provide information and recommendations on the information to be included in safety guides and documentation for battery equipment**.

The recommendations made in this report are based on a literature survey of existing literature available for consumer batteries, identification of current best practices from existing documentation and consultation with stakeholders relevant to the industry.

In the time since the concept and scope of the project were developed and implemented, a range of documentation has been created by numerous agencies and advisory bodies (Section 3). The recommendations provided in this document will, as far as practicable, utilise the existing relevant recommendations in the other guides.

Note: Batteries are ubiquitous throughout society and found in most portable electronic devices, grid connected and off-grid systems and transportation devices. Under normal circumstances, when the battery is operated under manufacturer recommended conditions, the failure rates of batteries is in the order of one failure for every million cells.[1,2] Of these failures only some will lead to safety issues such as fire or electrical hazards. This guide is written for such failure scenarios.

[1. Loveridge et al. *Batteries,* 2018; 2. Jacoby, Chemical and Engineering News, 2013]

# 2 Safety Guidelines and Documentation Scope

The battery system (BS, a battery and ancillary electronics which requires connection to an inverter system not supplied by the manufacturer) and BESS (an all in one system which includes invertor as supplied by the manufacturer) market has a number of different areas where safety information is required. Figure 1 shows the supply chain for BESS and battery systems. Depending on the manufacturer, the technologies can be imported in their entirety or as components and assembled on-shore in Australia or can be fully manufactured onshore. These processes have specified safety and regulatory guidelines, such as transport and handling of dangerous goods needed for technologies such as lead acid batteries, or UN38.3 transportation required for of lithium batteries. The focus of this report will not be on these regulated areas, but rather focussed on the transportation (gaps not currently covered), installation, use and disposal areas where limited information exists.

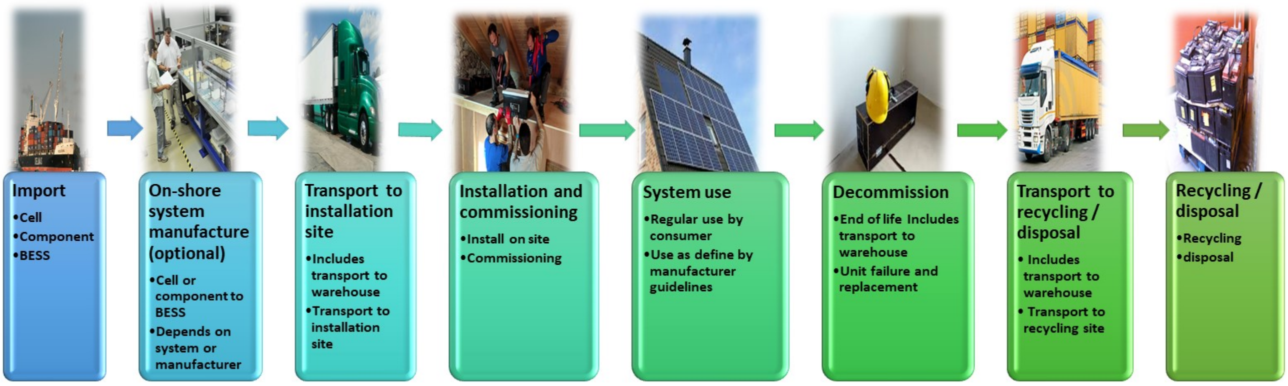


**Figure 1: Areas in the battery system and BESS supply chain where further safety information is desirable (source CSIRO 12/2019)**

### Importation and onshore manufacture

Importation of BS and BESS to Australia will typically involve shipping or air transport. For different battery types and sub-components, specific regulations exist. As such this report will not provide recommendations in this area aside from suggesting that importers adhere to the relevant international and national rules and regulations for the transportation of hazardous goods and batteries.

On-shore manufacture of full systems through sub-component assembly or from the manufacture of cells through to systems is covered by a range of regulations and laws applicable to Australian businesses. It is recommended that manufacturers consult with the Work Health and Safety (WHS) regulations and their local State or Territory safety agency to ensure compliance with all local laws and regulations (a list of bodies has been identified in Table 1 but it should be noted that this list is not comprehensive and readers should determine the appropriate authorities for their own specific conditions). This guide is not targeted for this area.

**Table 1: Selected list of State and Territory safety or regulatory agencies**

| | |
|---|---|
| **Australia** | |
| Australian Communications and Media Authority | www.acma.gov.au |
| Clean Energy Council | www.cleanenergycouncil.org.au |
| Clean Energy Regulator | www.cleanenergyregulator.gov.au |
| Civil Aviation Safety Authority | www.casa.gov.au |
| Comcare | www.comcare.gov.au |
| Electrical Equipment Safety System | www.eess.gov.au |
| National Industrial Chemicals Notification and Assessment Scheme | www.nicnas.gov.au |
| Safe Work Australia | www.safeworkaustralia.gov.au |
| **Australian Capital Territory** | |
| WorkSafe ACT | www.worksafe.act.gov.au |
| ACT Government - Environment, Planning and Sustainable Development Directorate | www.planning.act.gov.au/customer_information/industry |
| **New South Wales** | |
| SafeWork NSW | www.safework.nsw.gov.au |
| NSW Resources Regulator | www.resourcesregulator.nsw.gov.au |
| State Insurance Regulatory Authority | www.sira.nsw.gov.au |
| NSW Government – Planning and Environment – Energy, Water and Portfolio Strategy | www.energy.nsw.gov.au |
| **Northern Territory** | |
| NT WorkSafe | www.worksafe.nt.gov.au |
| **Queensland** | |
| Workplace Health and Safety Queensland - Office of Industrial Relations | www.worksafe.qld.gov.au |
| WorkCover Queensland | www.worksafe.qld.gov.au |
| Department of Natural Resources, Mines and Energy (DNRME) | www.dnrm.qld.gov.au |
| Electrical Safety Office - Office of Industrial Relations | www.electricalsafety.qld.gov.au |
| **South Australia** | |
| SafeWork SA | www.safework.sa.gov.au/ |
| Office of the Technical Regulator | www.energymining.sa.gov.au/energy_and_technical_regulation |
| Information and services for South Australians | www.sa.gov.au/topics/energy-and-environment/electrical-gas-and-plumbing-safety-and-technical-regulation |
| **Tasmania** | |
| WorkSafe Tasmania | www.worksafe.tas.gov.au |
| Consumer, Building and Occupational Services (CBOS) - Energy Standards and Safety | www.cbos.tas.gov.au/topics/technical-regulation |
| **Victoria** | |
| WorkSafe Victoria | http://www.worksafe.vic.gov.au |
| Energy Safe Victoria | http://www.esv.vic.gov.au |
| **Western Australia** | |
| WorkSafe WA - Department of Mines, Industry Regulation and Safety | www.dmirs.wa.gov.au/worksafe |
| WorkCover WA | www.workcover.wa.gov.au |
| EnergySafety - Department of Mines, Industry Regulation and Safety | www.dmirs.wa.gov.au/energysafety |

## Transport to installation

Transport of systems ready for installation can be conducted in a number of ways. This can involve transport of a large number of systems simultaneously (for example stocking of a warehouse or distribution point) all the way through to transport of a single unit for installation (for example, installer or delivery pick up and relocation to installation site). For the purposes of this report, requirements for storage associated with the transportation process is also considered. Section 4 provides recommendations for safety information sheets for transportation.

## Installation and commissioning

The installation and commissioning of BS and BESS has specific hazards and risks associated with it. This work should be performed by trained/competent persons with knowledge of the systems. The information recommended for these persons is provided in Section 5.

## System use

The safety information required by users will differ from that for the trained persons described above. Furthermore, the requirements may change depending on whether the user is a domestic consumer or a commercial user. The recommendations for safety information for both these types of users is discussed in Section 6.

## Decommissioning, transport and recycling/disposal

In addition to the recommendations for commissioning and installation, there will be additional recommendations for the decommissioning of BS and BESS. This process involves additional hazards and risks since the battery system is either aged, reached end-of-life or may even have to be removed due to failure or damage. The additional recommendations for this process is provided in Section 7.

# 3 Literature Review Summary and Gap Identification

A range of literature has been consulted to develop the recommendations listed in this report. The literature ranges from Standards, industry best practice guides and product safety documentation currently available at the time of writing. A list of the literature sources and versions consulted is provided in Tables 2 to 4. Table 1 lists the regulatory guidelines, Table 2 provides details on industry best practice guideline documents and Table 3 provides a list of applicable Standards which have safety components.

**Table 2: List of regulatory documentation applicable to battery systems and BESS**

| Document name | Date | Comments |
|---|---|---|
| **Model Work Health and Safety Regulations** | 15/01/2019 | Australian regulatory document providing a basis for national work health and safety laws (https://www.safeworkaustralia.gov.au/doc/model-work-health-and-safety-regulations) |
| **Safe Work Australia Preparation of Safety Data Sheets for Hazardous Chemicals** | 05/2018 | Code of practice for preparation of safety data sheets as approved code of practice under section 274 of the work health and safety act |
| **Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.6** | 2018 | Transport regulations for dangerous goods including alkaline or acid-based batteries |
| **UN38.3 Transport of Dangerous Goods** | 2015 | Transport regulations for lithium batteries |
| **Materials Safety Data Sheets (SDS) from different battery manufacturers** | Less than 6 months old | Multiple individual battery cells (or up to 12V module for lead-acid) manufacturers |
| **ACMA RCM supplier declaration of conformity and compliance folder** | 01/2018 | Australian regulatory document for suppliers to declare product compliance with relevant Australian electromagnetic compatibility standards |
| **Electrical Safety Certificate of Suitability** | 2019 | Certification of compliance with relevant Australian electrical safety standards issued by regulatory authorities or recognised external certification scheme providers |
| **ERAC Database Registration** | 2019 | Online database registering the responsible supplier, product brand, model name / number and certification number. |

**Table 3: Best practice guideline documentation applicable to battery systems and BESS**

| Guideline document | Date | Comments |
|---|---|---|
| **Battery Energy Storage Systems Guide for Electrical Contractors by Government of Western Australia** | 05/2018 | Guidelines developed by Department of Mines, Industry Regulation and Safety, WA Govt. |
| **Best Practice Guide: battery storage equipment electrical safety requirements** | 06/07/2018 | Guidelines developed by Smart Energy Council, Clean Energy Council, AI Group, CESA, and CSIRO. |
| **Energy Storage Safety** | 13/11/2015 | Guidelines developed by Clean Energy Council, CSIRO and ARENA |
| **Battery Install Guidelines** | 15/08/2017 | Installation guidelines developed by Clean Energy Council – now superseded by AS/NZS5139:2019 |
| **Batteries in transport – applicable US hazardous materials regulations and international dangerous goods regulations** | 03/2017 | General guidelines developed by the Portable Rechargeable battery Association (Consortium of battery manufacturers and related industries in the US). |
| **Guide to installing a household battery storage system** | 10/2019 | Guidelines developed by Clean Energy Council |

**Table 4: List of Australian and New Zealand Standards which reference safety applicable to battery systems and BESS**

| Standard | Date | Name |
|---|---|---|
| **AS/NZS 3000:2018** | 2018 | Wiring rules |
| **AS/NZS 3190:2016** | 2016 | Approval and test specification – residual current devices (current operated earth-leakage devices) |
| **AS/NZS 3760:2010** | 2010 | In-service inspection and testing of electrical equipment |
| **AS/NZS 3820:2009** | 2009 | Essential safety requirements for electrical equipment |
| **AS/NZS 4509.1:2009** | 2009 | Stand-alone power systems - Safety and installation |
| **AS/NZS 4777.1:2016** | 2016 | Grid connection of energy systems via inverters. Part 1: installation requirements |
| **AS/NZS 5139:2019** | 2019 | Electrical installations – safety of battery systems for use with power conversion equipment |
| **AS/NZS 5377:2013** | 2013 | Collection, storage, transport and treatment of end-of-life electrical and electronic equipment |
| **AS/NZS 60950-1:2015** | 2015 | Information technology equipment – Safety General Requirements (if communication circuits are included) |
| **AS 62040.1:2019 (IEC 62040.1)** | 2019 | Uninterruptable power systems (UPS) Safety requirements |
| **AS/NZS 61000.6.3** | 2012 | Electromagnetic compatibility (EMC) Generic Standards – Emission standard for residential, commercial and light-industrial environments |
| **AS/NZS 60529:2004 (R2018)** | 2004 | Degrees of protection provided by enclosures (IP Code) |
| **AS IEC 62619:2017** | 2017 | Secondary cells and batteries containing alkaline or other non-acid electrolytes - safety requirements for secondary lithium cells and batteries, for use in industrial applications |
| **IEC 62133-2:2017** | 2017 | Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems |
| **IEC 62485-6:2017** | 2017 | Safety requirements for secondary batteries and battery installations - Part 6: Safe operation of lithium-ion batteries in traction applications |

## 3.1 Stakeholder survey and gap identification

With a range of information already available in the literature, the project consortium also consulted with industry participants and stakeholders during a focussed workshop to identify the needs and gaps which exist. A survey of the stakeholders was conducted during the Battery Performance Standard Workshop #3 on 12th November 2019 at the Engineers Australia premises in Melbourne, Australia. Stakeholders attended from a range of different areas:

- Industry bodies
- Research Organisations and Universities
- Fire agencies
- Battery system integrators and suppliers
- Battery manufacturers
- System retailers
- Electricity retailers
- Electricity utilities
- State Governments
- Energy consultancies

Participants at the workshop were split into four working groups and asked to identify information gaps in the following areas:

- Suppliers
- Consumers
- End of life
- Emergency responders

The key themes identified from the stakeholder participants are shown in Table 5.

**Table 5: Stakeholder survey results to identify current gaps in safety information in the literature**

| Suppliers group comments | Gap identified |
| --- | --- |
| • The SDS requirements and safety regarding installation is well covered by AS/NZS 5139 and AS/NZS 3000<br>• BESS and battery storage requirements prior to installation are not always available<br>• Thermal conditioning of battery before handing onto consumers should be reported<br>• Aging-related safety issues should be reported<br>• [Where applicable] degassing conditions and environmental impacts of battery | • Storage specifications should be reported<br>• Storage temperatures and conditioning should be reported<br>• Age-related performance and safety should be reported<br>• Environmental impacts and where applicable degassing conditions should be reported |
| **Installers/Consumers group comments** | **Gap identified** |
| • The manufacturers installation guide for complete BESS is often sufficiently detailed.<br>• For some BESS systems, design parameters/basic information needed for compliance with AS/NZS 5139 is not always available from manufacturers (e.g. integrated circuit breakers, fuse sizing, fuse types etc.)<br>• Electrical hazards covered in AS/NZS 5139 | • Reporting requirements for manufacturers to assist with AS/NZS 5139 compliance |
| **Decommissioning/End of life group comments** | **Gap identified** |
| • Information and metrics about the recycling process is generally missing, such as who is commissioning (contracting) the work to decommission the BS/BESS system and who is responsible for battery during decommissioning procedure (the commissioner or the recycler if they are different)<br>• What is the decommissioning procedure from the manufacturer<br>• What transportation requirements and suitable packaging requirements are needed<br>• How to safely domestic transport decommissioned batteries<br>• During recycling who is responsible for the safety risks<br>• Disposing of cells requires chemistry and SDS if known and available | • Significant knowledge shortfall exists and key gaps identified<br>• Decommissioning procedures<br>• Transport of units to recycling facility including requirements for any special containers<br>• Storage at facility including leakage or venting of chemicals or gases<br>• Knowledge of chemicals inside batteries and availability of safety data sheets<br>• Component (e.g. hardware or electronics) removal for different system types<br>• How to deal with on-site fires or other hazards |
| **Emergency/first responders group comments** | **Gap identified** |
| • Basic information such as chemistry type, system setup and connections, system-specific response, fire extinguishing medium to use and not use, labelling and additional information using QR coding<br>• Clear guidelines for first responders (utilities, fire agencies, paramedics etc.)<br>• Visibility of batteries on the grid is not present still need to improve GIS and network data and sharing<br>• EV manufacturers are providing QR codes linked to safety data sheets and information | • Significant knowledge shortfall exists and key gaps identified<br>• Signage and knowledge of battery type and location<br>• Identification of chemistry type for appropriate firefighting response<br>• Likelihood and hazards of side reactions (e.g. venting of flammable gases, leakage of electrolytes etc.) occurring<br>• Re-ignition likelihood and mitigation methods<br>• Chemicals that first responders or the environment can be exposed to during fire or damage situations |
| **Additional comments group comments** | **Gap identified** |
| • Safety during compliance and certification testing of battery systems | • Safety needs which should be in place for testing of batteries particularly related to catastrophic failure of battery systems. |

# 4 Recommended Safety Information for Transportation and Storage

For Australian domestic transportation of battery systems in general, the requirements for the different chemistry classes are well covered by either the Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.6 or UN38.3 Transport of Dangerous Goods for lithium batteries. These documents specify requirements for handling and transportation containers etc.

Based on our analysis of the gaps, the following recommendations are made in addition to the requirements of the dangerous goods transportation and UN38.3:

1. For battery systems or BESS, the chemistry type should be clearly reported by the manufacturers in the documentation and physically on the packaging. The avoidance of generic terminology (for example lithium-ion) is also recommended. The accurate reporting of specific chemistry type aids multiple stakeholders in the supply chain to accurately prepare risk mitigation strategies for the specific hazards of each chemical used in the battery. It will also ultimately be required as part of the future, highly targeted, recycling strategies.
2. The storage requirements for different battery systems and chemistry types is to be provided by manufacturers for longer term storage prior to delivery for installation. These requirements should provide information on the:
    a. Container system requirements specific for chemistry and system type,
    b. Storage temperature requirements and variation levels accepted,
    c. Manual handling requirements for systems including information regarding stacking of multiple units and clearly stating any limitations,
    d. During the storage period, the hazards of storage should be specified (for example electrical, chemical, fire etc.) as well as any required methods for mitigation of these hazards. These will differ from one battery system to other. Therefore, it is recommended that manufacturers provide the information specific for the system under consideration.
3. During storage, the storage time should be recorded along with the ambient temperature of the storage location. It is recommended that this information is made available to others. The information can be utilised by a number of different points in the supply chain and so where possible it is recommended that this information is placed online, dated and cross referenced to the batch/serial number. If any performance degradation occurs during storage this should also be stated and information provided.
4. For transportation, any specific requirements for the transportation container temperature and ventilation for the specific battery system or chemistry type should be provided by the manufacturer. This information should be provided for new (pre-installation) battery systems, decommissioned systems and also for damaged/failed units.
5. For storage and transportation, some battery chemistry or system designs may have the possibility of venting/degassing or chemical exposure (e.g. electrolyte spillage). Where this could occur information should be provided as to the nature of the gas or liquids, hazards associated with the chemicals, mitigation strategies and also incident response requirements including details on the required personal protective equipment.

6. Where the possibility of venting/degassing occurs or where chemicals exposure (e.g. electrolyte spillage) exists, safety data sheets for the vented/exposed chemicals should be provided/sourced which adhere to the requirements of the Model Work Health and Safety Regulations and Safe Work Australia Preparation of Safety Data Sheets for Hazardous Chemicals.

# 5 Recommended Safety Information for Installation

During the installation process a number of different safety risks will be present. These risks are well covered by a range of Standards (see Table 4) and best practice guidelines (Table 5), for example, AS/NZS 5139:2019 Electrical installations – safety of battery systems for use with power conversion equipment. Table 3 provides a list of Standards that have safety implications for battery system/BESS installations.

Based on our review, it is apparent that some information regarding system design and parameters is not reported by manufacturers which makes compliance with some Standards such as AS/NZS 5139:2019 difficult.

For example, information regarding fault or short circuit currents, arcing energies (or data to permit calculation), installation hazards, overcurrent protection devices, types and locations, identification if integrated circuit breakers are part of the system or not etc.

It is noted that battery systems are generally compliant in terms of components, for example to Standards such as AS/NZS 62619:2017. As such, it is recommended that manufacturers provide the required information outlined in the relevant standards to enable others to show compliance of the battery systems/BESS with the Standard.

# 6 Recommended Safety Information for Consumers or Users

General safety information is typically provided for consumers or users of battery systems/BESS in the supplied manuals. Where this information is not available in the manuals, it is recommended that manuals be provided together with the required information. For general consumers or users this should include information on:

1. Electrical safety hazards including information on how to prevent risks of accidents and what to do in event of an injury or near-miss incident. These risks will change depending on how each individual system is constructed and what components/parts users are able to access.
2. Where the possibility of chemical release (e.g. electrolyte spillage or leakage) and contact with humans or environmental exposure exists, a Safety Data Sheet which details the hazards of the chemicals being released should be provided. The project consortium notes that at the time of writing most battery systems/BESS are typically designed not allowing this to occur (except in a failure scenario). As such, the manufacturer should provide information as to the likelihood of chemical release and contact with humans based on the system design under normal operating conditions.
3. Where the possibility of chemical release (e.g., electrolyte spillage, corrosion solids or gas venting) exists, users should be informed how to detect these issues and what steps are required to ensure user safety, including specific information for reporting requirements to manufacturers or suppliers for fault resolution (where applicable).
4. Users should also have access to the installation manuals which detail the safety risks as a reference source. We would suggest that where possible this information is placed online, dated and cross referenced to the batch/serial number.
5. A simple operation maintenance and fault identification process should be provided to users. This information should include (where required) details on fault codes, fault lights, alarms etc. The information should also specify what the user is expected to do in the event of a failure or fault including providing details for online resources and/or contact details. This information is typically found in most user manuals, but where this information is not present manufacturers should provide it. Where users are expected to provide maintenance to the battery system/BESS (for example a regular visual inspection) it is recommended that step-by-step instructions be provided with photographs or diagrams for clarity and safety risks and incident responses be provided by the manufacturer.
6. Information should be provided by the manufacturer on what to do, and what not to do including consideration for first aid firefighting when a battery/BESS fails and catches on fire, i.e. thermal runaway with a fire starting. Battery fires, in particular those connected to PV panels, present new risks unfamiliar to the general consumers.

# 7 Recommended Safety Information for Disposal/Recycling (including Disposal of Failed Systems)

## 7.1 Decommissioning and transport for end-of-life battery systems/BESS

Decommissioning of battery systems/BESS poses additional hazards due to the aged nature of the systems. As such it is recommended that specific information regarding the decommissioning process be provided by the manufacturers. This information should include aspects such as:

1. Electrical hazards and safety information including information and processes to discharge (de-energise) the BESS/battery systems before decommissioning. It is strongly recommended that the BESS/battery systems are completely de-energised before decommissioning to ensure worker safety. This information should also provide installers with adequate details as to fault finding and hazard identifications specific to the battery chemistry and design.
    a. Although not current industrial practice, if these BESS/battery systems are to be utilised for future second-life applications, where a used battery is repurposed/re-engineered for alternative use prior to disposal, specialised handling instructions and decommissioning processes will be required whereby the units are not de-energised.
2. Information on the removal of BESS/battery systems from the installation site should discuss handling of the BESS/battery systems, the removal process, recommended state of charge for removal, and methods to identify correct state of charge has been reached prior to decommissioning.
3. Identification of methods to ensure terminals or connection points are insulated in a manner which removes the possibility of electrocution.
4. Procedures for accidental release of chemicals during decommissioning process including specific chemical hazards to humans and environment, mitigation and treatment requirements. Where highly hazardous chemicals (e.g., concentrated acids or bases or hydrofluoric acid) require specific treatment strategies, these should be clearly stated and guides provided to workers for safety kit preparation prior to commencement of work.

It is also recommended that workers, prior to decommissioning, conduct a site and system specific risk assessment of the decommissioning process. This assessment should include reviewing information such as failure codes and fault alarms and hazard/risk identification processes.

At the end of the decommissioning process the units will be transported to disposal or recycling facilities. Due to the aged nature of these battery systems/BESS, it is recommended that manufacturers specify clearly whether the Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.6 or UN38.3 Transport of Dangerous Goods for lithium batteries will cover all the risks and hazards or if additional precautions such as specialist containers or handling is required.

The manufacturers should specify any restrictions on the stacking or loading of battery systems/BESS in vehicles. Additionally, where applicable, manufacturers should provide information regarding the effect of vibration on the decommissioned units. It is noted that this may not be of concern to most battery systems/BESS currently available in the market, however it is recommended that manufacturers and transporters confirm this for the specific systems prior to handling. Further, transportation container temperature control requirements and limitations with variations allowed should be stated. Special consideration should be given to road or train transport where high temperatures could be generated during summertime periods in containers exposed to the sun for extended periods of time.

Finally, manufacturers should provide information to transporters on how to detect potential safety issues during the transportation phase and risk mitigation strategies. It is also recommended that the specific chemicals in the battery system/BESS are identified and transporters are informed in the event of an incident that requires emergency response so that this information can be provided in a timely manner to first responders.

## 7.2 Decommissioning and transport for damaged or failed battery systems/BESS

In addition to the recommendations made in Section 7.1, there are additional concerns which arise for faulty or damaged battery systems/BESS.

It is recommended that a comprehensive fault finding and hazard identification process for the damaged units be provided to installers. This information should include information such as:

1. Fault and alarm codes that detail the specific failure mechanism.
2. Step-by-step instructions as to risk identification and subsequent system deinstallation.
3. Methods to mitigate electrical hazards, and protocols to identify the de-energised state of the BESS/battery systems. It is recognised that depending on the failure or fault mechanism, these will vary and are also strongly dependent on the actual system design.
4. Manufacturers should provide information for manual handling requirements for damaged or faulty units to installers. It is understood that for some system designs and/or failure mechanisms, this may be required for safety reasons.
5. Specific requirements for transportation containers and transportation methods for failed or damaged units. Depending on the failure or damage mechanism, there may be the possibility of additional requirements on top of the Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.6 or UN38.3 Transport of Dangerous Goods for lithium batteries. Manufacturers should provide this information to transporters and installers.
6. For some battery systems which have experienced a failure or damage which has led (or can lead) to fire have the possibility of reignition after the initial extinguishment has been achieved. Where this is a possibility it is recommended that manufacturers provide information regarding isolation time periods and how they should be stored for the isolation period including advice on any special containers to use or storage distance from other flammable materials.

## 7.3 Recycling and disposal

Recycling and disposal of battery systems is an important part of the lifecycle for these devices. As indicated above, while the risks are sometimes different from those associated with normal (installed) usage, they are by no means less significant. The provision for situations in which the battery or BESS becomes damaged at end-of-service, increases the complexity of measures that must be developed to cover all possibilities during decommissioning. Recycling and disposal of battery systems involve a number of different steps and processes:

1. Transport to recycling/disposal facility
2. Storage (short or long term) at facility
3. Hardware removal (battery management systems (BMS), ancillary electronics)

4. Battery recycling and materials recovery
    a. On-shore processing
    b. Off-shore export
5. Non-recyclable materials disposal

Each of these different steps has different safety aspects to consider as discussed below:

Although AS/NZS 5377:2013 (collection, storage, transport and treatment of end-of-life electrical and electronic equipment) is available to assist the industry, this Standard should be refined to include the additional risks, hazards and complexities of new technologies such as battery systems, BESS, larger systems such as electric vehicles or hybrid electric vehicle batteries, as well as any high-risk activities such as the recycling of large grid-connected or industrial battery systems.

### 7.3.1 Transport to recycling/disposal facility

The issues just described in connection with storage are also relevant to transportation of the battery/BESS at end-of-service. In reality, making a retired unit safe for transporting requires some additional care beyond simply sealing up the unit so as to prevent the escape of cell contents. The form of containment provided must be sufficiently durable to withstand any vibration or shock associated with the mode of transportation. In addition, provision must be made in the secure container for whatever form of manual handling is required, bearing in mind that large packs (with associated BESS hardware) are generally heavy and bulky items.

The requirements for transportation of used batteries are similar to those detailed in section 4. The requirements for transport are covered by the Australian Code for the Transport of Dangerous Goods by Road & Rail Edition 7.6 or UN38.3 Transport of Dangerous Goods for lithium batteries.

Specific recommendations for transport of used battery systems / BESS are that:

1. Specific chemistry of the battery or BESS is reported and the use of generic terminology is avoided.
2. For the battery or BESS the containment type needed for the transport is specified and communicated to transporters.
3. The method of terminal/connection point insulation to avoid electrocution hazards is communicated to transporters (where the transporter is different to the installer).
4. Information regarding manual handling requirements and stacking of units in transport vehicle, including information regarding stacking number limits, is provided.
5. During transportation, some battery chemistry or system designs may have the possibility of venting/degassing or chemicals exposure (e.g., electrolyte spillage). Where this could occur information should be provided as to the nature of the gas or liquids, hazards associated with the chemicals, mitigation strategies and also incident response requirements including details on the required personal protective equipment.

Based on the analysis of the information gaps undertaken, the following recommendations are made in addition to the requirements of the dangerous goods transportation and UN38.3:

1. For battery systems / BESS the chemistry type should be clearly reported by the manufacturers and the avoidance of generic terminology (for example lithium-ion) is recommended. The accurate reporting of specific chemistry type aids multiple stakeholders in the supply chain to accurately prepare risk mitigation strategies for the specific hazards of each chemical used in the battery.

2. The storage requirements for different battery systems and chemistry types be provided by manufacturers for longer-term storage prior to delivery for installation. These requirements should provide information about:
    a. Container system requirements specific for chemistry and system type
    b. Storage temperature requirements and acceptable tolerance levels
    c. Manual handling requirements for systems including information regarding stacking of multiple units and clearly stating any limitations
    d. During the storage period, the hazards of storage should be specified (for example electrical, chemical, fire etc.) as well as any required methods for mitigation of these hazards. These will differ from one system to another and therefore, it is recommended that manufacturers provide the information specific for the system under consideration.
3. During storage, the storage time should be recorded along with the ambient temperature of the storage location. It is recommended that this information is made available to others. The information can be utilised by a number of different points in the supply chain and so where possible it is recommended that this information is placed online, dated and cross referenced to the batch/serial number. If any performance degradation occurs during storage this should also be stated and information provided.
4. For storage and transportation, some battery chemistry or system designs may have the possibility of venting/degassing or chemicals exposure (e.g., electrolyte spillage). Where this could occur information should be provided as to the nature of the gas or liquids, hazards associated with the chemicals, mitigation strategies and also incident response requirements including details on the required personal protective equipment.
5. For transportation any specific requirements for the transportation container temperature and ventilation for the specific battery system or chemistry type should be provided by the manufacturer. This information should be provided for new (pre-installation) battery systems, decommissioned systems and also for damaged/failed units.

### 7.3.2 Storage at recycling/disposal facility

Considering the possibility that the battery (including individual cells) has developed a breach in a cell container, or that this might happen some time during the post-service period prior to removal, storage methods for retired batteries/BESS must offer appropriate levels of sealing for any spilled contents. Obvious examples include corrosive sulphuric acid solution escaping from lead-acid units and volatile/flammable/toxic organic electrolyte solutions escaping from lithium-ion cells. It is recommended that:

1. Storage information is provided by manufacturers for used batteries and includes information such as containment, storage temperature, ventilation requirements, hazards identification methods etc.
2. Where the possibility of venting/degassing occurs or where chemicals exposure (e.g. electrolyte spillage) exists, safety data sheets for the vented/exposed chemicals should be provided/sourced which adhere to the requirements of the Model Work Health and Safety Regulations (Australia) and Safe Work Australia Preparation of Safety Data Sheets for Hazardous Chemicals.

### 7.3.3 Hardware/ancillary electronics removal

1. Engineering manuals which enable full disassembly of the battery system to a component level as opposed to installation manuals, which cover connection of the unit and fault diagnostics or minor repairs, should be provided by manufacturers (this could be as an online resource) which aids in the safe removal of the associated hardware/ancillary electronics. In particular, information such as:
    a. How to de-energise the unit (where possible)
    b. If specialist tools such as ceramic/non-conductive tools etc. are required or if general purpose tools can be utilised
    c. Hazard identification and warning signs (e.g., swelling of cases, detection of electrolytes temperature increases etc.)
    d. Procedures for data security and how to secure on-board data or how to delete consumer data.

3. Where removal of hardware/ancillary electronics raises possibility of chemicals exposure (gasses, liquids or particulates) the safety data sheets for the vented/exposed chemicals should be provided/sourced which adhere to the requirements of the Model Work Health and Safety Regulations (Australia) and Safe Work Australia Preparation of Safety Data Sheets for Hazardous Chemicals.

### 7.3.4 Battery recycling and materials recovery

Materials recovery typically involves chemical separation through chemical or pyrometallurgical processes. Depending on the exact process utilised, contaminants from different battery types can be detrimental to the recovery process. This can be avoided through effective segregation of the different chemistry types. Under current business practices this can be a difficult process. An example of the common chemicals utilised for lithium battery construction is provided in Figure 2. Similarly, the transition metal composition, binders and carbons used as additives in particular in lead acid batteries also varies from manufacturer to manufacturer.

| Positive | Negative | Electrolyte |
|---|---|---|
| Nickel-Manganese-Cobalt oxide (NMC) | Graphite (includes graphene) | Liquid electrolyte (typically carbonate solvents) |
| Nickel-Cobalt-Aluminium oxide (NCA) | Lithium titanate (LTO) | Lithium ion conducting polymer (LiPo) |
| Cobalt oxide (LCO) | Hard carbon | Lithium ion conducting solid (solid state) |
| Lithium-iron-phosphate (LFP) | Tin-Cobalt alloy | |
| Lithium-Manganese oxide (LMO) | Silicon-Carbon | |
| Sulfur | Lithium Metal | |


**Figure 2: Example of the chemical composition of lithium batteries (source CSIRO December 2019)**

Information regarding the chemical composition of the specific chemicals in each battery unit/cell should be provided to assist with the contaminant identification process during materials recovery. This can be easily achieved through QR coding[1] and online resources linked to the codes and batch number of the unit. The use of QR coding can also assist in effective segregation of different battery chemistries and types.

**SDS and chemical identification**

While batteries and BESS/battery systems do not require a Safety Data Sheet (SDS), it is clear from the above discussion that for each of the contents of the constituent cells, an SDS must be provided. This requirement ensures that should there be any breach of one or more cells, the resultant hazard can be assessed with reference to a full description of the materials that might be released. From information included in the SDS, any warnings appropriate for the specific contents must be prominently displayed on the container in which the battery / BESS is housed prior and during removal from the installation site.

**Handling of batteries**

As noted in previous sections, additional precautions are required to handle batteries once they have reached end-of-service. This is because as the condition of a battery deteriorates, the chances of an individual cell reaching an extreme condition (e.g., very low voltage during discharge) increase significantly which in turn places greater stresses on that particular cell. Catastrophic failure may therefore be provoked in the very last stages of service, which may not be detected prior to decommissioning. Other factors that may increase risks associated with cells/batteries at end-of-service are simply that all components are aged, relative to new equivalents, and are therefore more prone to sudden failure, especially if subject to some form of shock, such as that likely to be imparted during decommissioning (e.g. removal from installation, loading on to transportation, etc.).

### 7.3.5 Non-recyclable materials disposal

Under current industrial recycling practices a range of non-recyclable materials is also collected. In this case, the SDS of these chemicals and materials and any hazards of these materials should be provided and made available. Further, disposal of these materials can occur via landfill sites and considerations should be made regarding potential detrimental reactions with mixed wastes. These can include long term issues such as release of materials into the environment.

### 7.3.6 Facility fire safety during on-site storage, processing and materials recovery

While acknowledging that the provisions for dealing with a battery fire are largely covered by AS/NZS 5139, it is worth noting the extra risk of fire that is associated with a battery or BESS that has reached end-of-service. Again, this is particularly the case in the event that the system has lost output rapidly (for example power output has rapidly reduced or voltage has dropped to below acceptable limits), which may signify catastrophic failure associated with a breach of the housing of one or more cells. Additionally, general information can also be found in Fire safety guideline - Fire safety in waste facilities by Fire and Rescue NSW (23 October 2019).

[1] QR code (abbreviated from Quick Response code) is the trademark for a type of matrix barcode (or two-dimensional barcode) first designed in 1994 for the automotive industry in Japan. A barcode is a machine-readable optical label that contains information about the item to which it is attached. In practice, QR codes often contain data for a locator, identifier, or tracker that points to a website or application. (Source: https://en.wikipedia.org/wiki/QR_code)

It is recommended that:

1. The specific SDS of the BESS/battery systems is provided with each installation which details the hazards of the fire
2. SDS sheets for the anticipated chemicals formed during fire scenarios are made available. The risks to humans upon exposure and health hazards should be identified for communication to medical personnel in the event of exposure. For example, where a time sensitive specific high-risk hazard exists such as exposure to hydrofluoric or sulphuric acids, these require immediate treatment to stabilise the injury until it can be assessed by medical professionals.
3. Firefighting measures are clearly stated for each BESS/battery systems. The firefighting medium should be specified and personal protective equipment for first responders specified. Some battery types (e.g. lithium) have the possibility of reigniting following extinguishment of the initial fire. Where this can occur, information and signage should be made available to firefighters.
4. The different chemistry types should be segregated and stored in the de-energised state. It is noted that the fire risks of batteries significantly decreases if the units are de-energised.
    a. Lead acid and NiMH: if the units are de-energised, fire risk can be mitigated by <u>preventing currents from flowing if the battery is dry</u>.
    b. Lithium ion: For de-energised batteries the fire risk arises from venting of flammable electrolyte gases if the battery unit is damaged (e.g. crushed, compromised, punctured etc.). The fire risk can be reduced by ensuring ignition sources and naked flames are not present and damage to the battery is prevented.
    c. All batteries: if the BESS/battery systems are not de-energised, fire risk increases from damage to the BESS/battery systems and/or uncontrolled high storage temperatures and/or short circuiting.
    d. All batteries: all batteries are capable of generating flammable gases under normal operation or under certain failure modes depending on the battery chemistry. Fire risk can be mitigated by ensuring adequate provision to safely vent gases for all battery systems to ensure gas concentrations in the atmosphere do not reach flammability limits.

# 8 Recommended Safety Information for Emergency Responders

Throughout the entire supply chain there is the possibility of exposure to chemicals from BESS/battery systems in the event of damage or failure. Depending on the battery chemistry, these can potentially include:

1. Exposure to liquid chemicals through electrolyte leakage
2. Exposure to solid or particulate materials of varied size
3. Exposure to vented gases
4. Exposure to hazardous chemicals formed during failure or damage
5. Explosion risks from volatile and flammable vented gases

First responders such as fire, paramedics/medical and police, amongst others, will have to deal with mixed hazards. As such it is important that the risks and hazards are clearly identified and communicated to the first responders.

### Medical/paramedics

Where the possibility of exposure of humans to chemicals can occur, the SDS and medical responses required should be provided for the battery chemicals and any potential chemicals formed during failure or damage. The following is recommended, and it is noted that significant work is still required to ensure these recommendations cover the entire risks:

1. The chemistry of the battery unit is clearly identified and appropriate SDS is made available (this can be as an online resource or QR coding).
2. Where a chemical specific hazard exists, first responders are made aware and any appropriate treatments are available. For example, in the event of the release of hydrofluoric acid, gluconate gels or hexafluorine is available or applied by first responders.
3. Where the possibility of vented gases exists, first responders should be made aware and appropriate personnel protective equipment (e.g. breathing apparatus with appropriate filters, chemical resistant gloves etc.) is provided or taken by first responders.
4. Where the possibility of chemical burns (e.g. acid or alkaline) exists, it is recommended that sufficient clean water is provided to ensure first responders and humans affected can rapidly wash the areas to minimise damage.
5. For risks due to electrical hazards or electric shock, these should be identified and communicated to first responders so appropriate precautions and responses to the injuries can be taken. Any person who receives an electric shock should be referred immediately to a hospital or health professional for an electrocardiogram (ECG) test.

### Police/other responders

In addition to the recommendations above, it is recommended that signage and information be provided which informs the first responder to the chemical, gas or electrical hazards. It is recommended that emergency services / other responders are made aware of the hazards so appropriate decisions can be made on-site and any exclusion zones can be effectively setup.

### Fire responders

Different battery types will have different fire responses and will require differing firefighting methods. For lithium, vanadium-flow and lead acid battery fires, further information can be found in “Considerations for ESS Fire Safety”, DNV GL, 9 February 2017. It is recommended that:

1. Signage located at the front of the complex and the electrical boards and specific chemistry type be provided and where possible it is communicated to fire responders that a fire could be related to a battery system or BESS.
2. Signage should also include information on how to shut off the system and what system components or building components will still be live following shutdown.
3. A schematic of the DC electrical flow through the building should also be provided since this cannot be detected by emergency service equipment.
4. Where a fire is occurring in surrounding areas (that is, the battery system or BESS is not the cause) it should be communicated that a battery system or BESS is present. Fire responders should be made aware that if fire spreads to the battery system or BESS, then there is a possibility of additional fire hazards from the battery.
5. Firefighting methods are stated and information as to chemical specific extinguishing media communicated in a timely manner to fire responders. Where battery fires utilise internal oxidant and fuel sources this should be communicated to fire responders so response can focus on keeping the surrounding areas from catching fire whilst allowing the immediate fire to exhaust the fuel source.
6. Risks of side reactions such as venting of flammable gases upon heating etc. be identified.
7. Risks of flammable gas formation (e.g., hydrogen) from the battery type or reactions with firefighting methods such as water etc. be identified and communicated.
8. As some battery systems pose additional risks, in that once the initial fire has been eliminated, there is the possibility for continuation of internal failure mechanisms, leading to further fire after more time has elapsed. In this scenario, recommendations on the appropriate monitoring and storage methods (for example immersion in water etc.) should be provided.
9. Firefighters carry a source of treatments such as:
    a. clean water for washing of acid/alkaline burns
    b. gluconate gel or hexafluorine for hydrogen fluoride contact (lithium-ion battery fires)

    Furthermore, these should be taken by responders to provide immediate treatment in the event of fire responders’ exposure to chemicals prior to seeking medical attention.
10. The specific chemicals that fire responders could be exposed to should be identified and communicated in the event of injury so that this can be communicated in a timely manner to health/medical providers.
11. Where chemical residues can be detrimental to the environment, this should be communicated to fire responders and any spillage collection methods identified (e.g., sand, washing with excess water etc.).
12. Under certain failure/fire conditions, some battery systems have the possibility of ejecting sparks during a fire. As such it is recommended, where a fire proof barrier or enclosure (as per AS/NZS

5138:2019 recommendations) is not available or used, that an exclusion zone of at least 6 meters be provided when installing BESS/battery systems in bushfire zones or outdoor or undercover areas where flammable materials may be present. This exclusion zone is determined from AS/3959-2009 “construction of buildings in bushfire-prone areas” for an adjacent structure, where here we assume the ‘adjacent structure’ is the flammable material. It is noted, this exclusion zone distance still requires clarification and the spark ejection distance be determined for different systems. Where this is known, manufacturers or other agencies should provide guidance. For internal installations, the recommendations of AS/NZS 5139:2019 should be followed. Fire responders should be aware of the possibility of spark ejection causing additional fire risks.

13. Information regarding manual handling requirements and any specialised storage/isolation containers requirements is provided to first responders as they are required to make the site safe which could include removal of the battery system.
14. In Australia, SAA/SNZ HB 76:2010 “dangerous goods – initial emergency response guide” considers all lithium battery types as a single entity as they are given the UN 3480 classification and hence categorised as water reactive substances and advises water or foam not be used. It is recommended that further investigations be conducted and only the batteries containing water sensitive materials be categorised as such and other battery chemistry types be re-categorised as appropriate under SAA/SNZ HB 76:2010 requirements.

It is noted that significant efforts are still required in this area to identify the key requirements for firefighting and first response. Some work is present in public literature, namely, “Considerations for ESS fire safety” report number OAPUS301WIKO(PP151894), 9th February 2017, published by DNV GL, New York.

# 9 Safety during compliance and certification systems testing

Compliance and certification testing poses additional risks in addition to those identified above. Failure is a key concern during the certification testing process. Although the list is not comprehensive, general recommendations are detailed following. It should be noted that these recommendations are additional to the requirements of the Model Work Health and Safety Regulations (Australia) and any State or Territory health and safety requirements.

### Testing facility recommendations

1. Where possible, testing should be performed in areas/facilities where damage or failure can be contained for a sufficient time to enable staff to vacate the area. Segregation of the battery system or BESS being tested from humans is recommended to minimise risks associated with electrical and fire hazards.
2. Battery testing areas are constructed to reduce or remove the likelihood of sparks or electrical arcing occurring during the setup and testing processes.
3. Where the possibility for chemicals exposure can occur (e.g. spillage), response procedures should be identified prior to starting testing. Where appropriate, chemical specific spill kits and personnel protective equipment should be made available.
4. Where gas venting or exposure can occur, the testing facility/area should have sufficient ventilation or extraction equipment to remove the risk of flammable gas build-up.
5. It is recommended that fire detection systems and appropriate fire extinguishing systems for the battery type are installed and working.
6. Monitoring systems to enable users to check on the battery under test from a remote/segregated area is utilised.
7. The battery testing area has sufficient space to enable safe manual handling and lifting/transportation tools to safely operate in.
8. Where appropriate/required, the battery testing area has appropriate explosion containment systems installed.

### System setup recommendations

1. During installation, it is recommended that insulated tools are utilised. If required, tools specified by the manufacturer should also be used.
2. It is recommended that tools are of an appropriate size, and oversized tools which can breach terminals and pose risk of short circuiting the battery system or battery cells are avoided.
3. It is strongly recommended that torque wrenches are utilised for bolted connections and the manufacturer specifications are followed.

## Testing recommendations

During electrical and thermal testing of systems for certification, certain precautions are recommended to enhance the safety of users and testers. It is strongly recommended that testing equipment be set up with functionality to automatically stop testing if certain limits are reached. For example:

### Lead-acid, NiMH and flow batteries

Voltage: automatic cut-off of electrical supply if the voltage reaches 3% above the set value.

Current: automatic cut-off of electrical supply if the current reaches 3% above the set value.

Capacity: automatic cut-off of electrical supply if the capacity reaches 10% above the manufacturer's specification.

Temperature: automatic cut-off of electrical supply if the temperature reaches 5% above the manufacturer's specification.

Time: automatic cut-off of electrical supply if the time reaches 5% over the set or expected time.

### Lithium batteries

Voltage: automatic cut-off of electrical supply if the voltage reaches 1% above the set value.

Current: automatic cut-off of electrical supply if the current reaches 1% above the set value.

Capacity: automatic cut-off of electrical supply if the capacity reaches 3% above the manufacturer's specification.

Temperature: automatic cut-off of electrical supply if the temperature reaches 45°C at the cell wall.

Time: automatic cut-off of electrical supply if the time reaches 5% over the set or expected time.

(It is noted that these values are determined from CSIROs 30+ years' experience in battery evaluation and encompass the majority of battery testing equipment response times)

# 10 Summary

A number of gaps and areas where safety information is required or advisable have been identified for different points in the battery system/BESS supply chain. Based on these, a range of recommendations have been made to assist the industry. Although these are not comprehensive and improvements can be made, the recommendations serve to provide a starting point for future safety improvements.

It is noted that although this document focusses on safety, the failure rates of batteries are typically one in a million cells and only a small percentage of these failures lead to safety issues. As can be seen from the sections above, a large number of the recommendations are applicable over multiple segments in the supply chain.

A summary of the main recommendations from this report and the different areas of applicability are shown in Table 6.

**Table 6: Summary of recommendations, and segments in the supply chain they can be utilised in**

| Recommendation | Transport | Storage | Installation | Users | Decommissioning | Disposal transport | Recycling facility | Recycling facility fire safety | 1st responders | Certification testers |
|---|---|---|---|---|---|---|---|---|---|---|
| List specific chemistry | ✔ | | | | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Storage requirements | | ✔ | | | | | ✔ | | | ✔ |
| Manual handling requirements | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | | ✔ | ✔ |
| Storage hazards | ✔ | ✔ | | | | | ✔ | ✔ | ✔ | ✔ |
| Ventilation requirements | ✔ | ✔ | ✔ | | | ✔ | ✔ | ✔ | ✔ | ✔ |
| Container requirements | ✔ | ✔ | | | | ✔ | | | ✔ | |
| SDS for exposed chemicals | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| SDS for chemicals formed during failure | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Chemical release procedures | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Chemical exposure detection methods | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Fault detection procedure | | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Installation manual | | | ✔ | ✔ | ✔ | | ✔ | | | ✔ |
| Engineering diagrams | | | ✔ | | ✔ | | ✔ | | | ✔ |
| De-energising procedure | | | | | ✔ | ✔ | ✔ | | | |
| Firefighting methods and extinguishing medium | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| Medical treatment procedure | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |

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