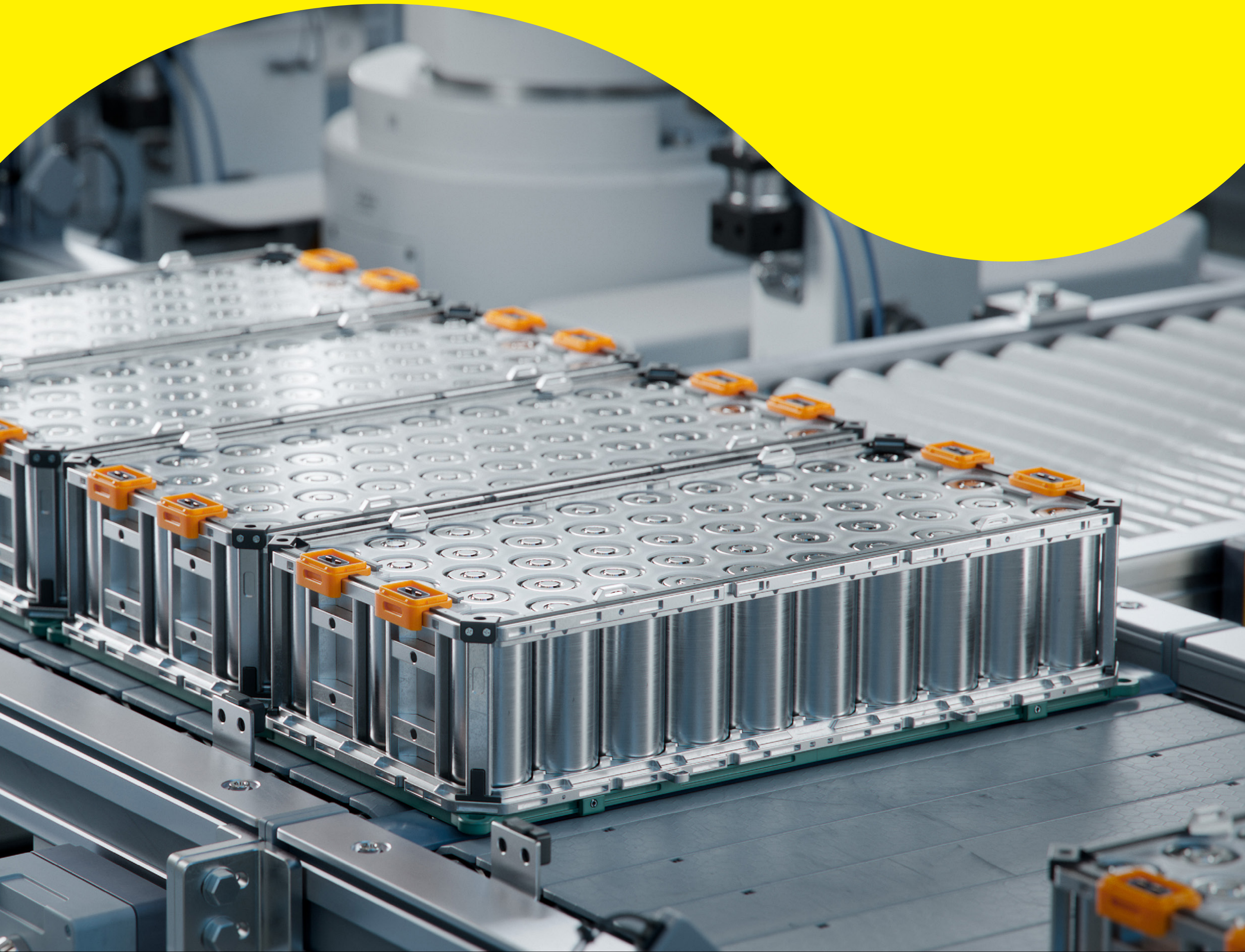
REPORT

Secondary Batteries – End User Safety

June 2025



Acknowledgements

Standards Australia extends its gratitude to the members of the End User Advisory Group for their invaluable insights and guidance throughout this project. Their expertise has been instrumental in shaping our approach and ensuring the relevance and applicability of the recommendations develop in this report.

We also wish to express our sincere appreciation to the Department of Finance for their generous funding support, which has been crucial in advancing this work. Furthermore, we acknowledge the ongoing assistance and collaboration provided by the Department of Industry, Science, and Resources. Their partnership has been vital in driving the project forward and achieving its goals. This collective effort exemplifies the power of collaboration.

ABOUT STANDARDS AUSTRALIA

Standards Australia is Australia's peak non-government, not-for-profit standards organisation. We work with Australian industry, government, academia, consumer groups, and the community to help address the challenges and opportunities facing the nation. Standards Australia represents Australia at the ISO and the International Electrotechnical Commission (IEC) and specialises in the development and adoption of internationally aligned standards.

Standards Australia's vision is to be a global leader in trusted solutions that improve life – today and tomorrow. This vision has taken on renewed importance as we grapple with emerging technologies that are transformative and developing at a rate that outpaces regulation and legislation. We work with a diverse group of stakeholders nationally and internationally to act on the opportunities and challenges posed by these technologies including quantum computing, smart cities, digital twin, the metaverse, and artificial intelligence (AI).

Key Terms, Abbreviations and Acronyms

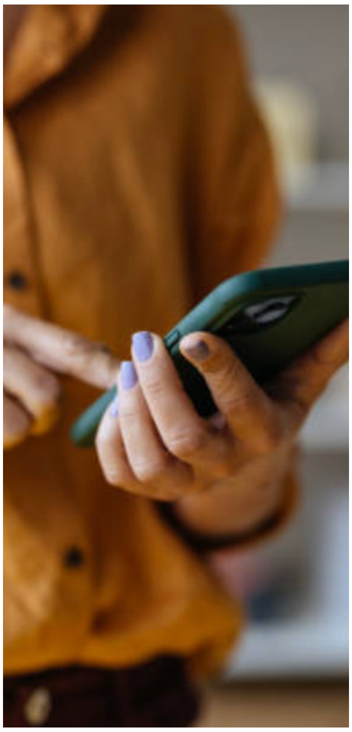
ANSI	American National Standards Institute - Standards development organisation
Battery Cells	The fundamental building blocks of a battery system, where electrochemical reactions occur to store and release electrical energy.
Battery Modules	Battery modules are individual units within a battery system that consist of multiple interconnected battery cells arranged to achieve a desired voltage and capacity.
Battery Packs	Battery packs are the complete assemblies that include one or more battery modules, combined with additional components to form a fully functional unit ready for deployment in various applications.
CEN	European Committee for Standardization - Standards development organisation
Deployment	Safe and efficient integration of batteries into systems or devices, ensuring they meet performance and safety standards during installation, operation, and maintenance.
E-mobility device	Devices including EVs, e-scooters, e-bikes, golf carts and personal mobility devices
Electric Vehicle	Includes electric cars, buses, trucks
End user	Person who uses a product
IEC	International Electrotechnical Commission - Standards development organisation
IEEE	Institute of Electrical and Electronics Engineers - Standards development organisation
ISO	International Organization for Standardization - Standards development organisation
JSA	Japanese Standards Association - Standards development organisation
NFPA	National Fire Protection Association
Performance	Overall efficiency, capacity, cycle life, voltage stability, and response time of batteries in various applications and conditions.
Reliability	Ability of batteries to consistently perform as expected over their lifespan, including maintaining stable capacity, voltage, and performance under various conditions.
SA	Standards Australia - Standards development organisation
SAC	Standardization Administration of China - Standards development organisation
Safety	Measures and standards implemented to prevent risks such as overheating, short circuits, and fires, ensuring the safe operation and handling of batteries.
Secondary Batteries	Rechargeable batteries
SDO	Standards Development Organisation
UL	Underwriters Laboratories - Standards development organisation

Executive Summary

The success of Australia's net zero transition depends heavily on the adoption of relevant technologies and energy storage solutions, including batteries. Secondary batteries are rechargeable and are pivotal for storing renewable energy, balancing grid supply and demand fluctuations, and powering electric devices. While Australia is a significant producer of raw materials commonly used in secondary batteries, such as lithium, the bulk of battery manufacturing currently takes place overseas. Under the National Battery Strategy (2024), the Australian Government aims to enhance domestic battery manufacturing capabilities to expedite the energy transition, boost productivity, and position Australia as a leading global producer of batteries and battery materials. Developing and adopting suitable standards is essential to support the growth of Australia's battery manufacturing sector. Standards Australia is actively participating in this strategy through a series of projects designed to identify gaps and opportunities in technical standards across the battery supply chain.

The current standards landscape for secondary batteries in Australia is robust. In recent years, Australia has consistently adopted international standards, incorporating necessary modifications to meet local requirements, and revising existing standards accordingly. Although Australia has a history of developing battery standards tailored to its unique needs, there is now strong emphasis on aligning with international standards to ensure consistency and interoperability. As Australia continues to play a leading role in global standardisation, it is crucial to focus on developing standards that address specific national needs while sharing these advancements internationally. This collaborative approach fosters a faster and more seamless global energy transition, rather than pursuing a purely competitive, commercial, or technological edge.

This report offers a thorough review of the standards landscape for end user applications, emphasising standards related to the safety, reliability, performance, and deployment of secondary batteries. It identifies current gaps in battery standards and provides recommendations for further standards development. The findings presented in this report are based on focused standard mapping research and valuable insights from the End User Advisory Group comprised of industry technical experts.



Recommendations Summary

Recommendation 1: Adoption of IEC 62933 series for grid-connected energy storage safety

Industry stakeholders and Standards Australia should collaborate to propose for the adoption of IEC 62933 series, *Electrical energy storage (EES) systems*, which primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used. This adoption aims to address safety requirements for grid-integrated electrical energy storage systems, thereby enhancing battery safety.

Recommendation 2: Establishment of minimum functional requirements for battery management systems

Standards Australia, in collaboration with key industry and government stakeholders, should initiate a project to identify and consider revising existing Australian standards for battery management systems to detail minimum functional requirements. These requirements should encompass protections against overvoltage, overcurrent and overtemperature, aligning with guidelines from the Battery Best Practice Guide and AS/NZ 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment*. Defining these baseline functionalities aims to ensure essential safety measures across all battery systems, mitigate failure, and enhance overall system reliability.

Recommendation 3: Adoption of key e-mobility safety standards

Industry stakeholders and Standards Australia should collaborate to propose for the adoption of key e-mobility standards, including standards developed by UL Solutions including: UL 2849, *Electrical Systems for eBikes;* UL 2271, ANSI/CAN/UL/ULC *Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications;* and UL 2272, *Electrical Systems for Personal E-Mobility Devices.*

Recommendation 4: Standards for secure external charging stations in multi-level residential buildings

Industry and government stakeholders and Standards Australia should collaborate to establish standards or guidelines for secure, external charging stations for small e-mobility devices in multi-level residential buildings and shared spaces. These guidelines aim to mitigate indoor charging risks effectively.

Recommendation 5: Guidelines for safe usage and maintenance of e-mobility devices

Industry and government stakeholders should collaborate with Standards Australia to disseminate informative documents and guidelines regarding the safe usage, maintenance, and modifications of e-mobility devices.

Recommendation 6: Standardisation of charging cables for e-mobility devices

Standards Australia and Industry stakeholders should collaborate to explore the implementation of standards for charging cables. These standards will aim to ensure fit-for-purpose solutions that prevent compatibility issues and promote safe charging practices across various e-mobility devices, addressing a critical gap in both Australian and international standards.

Recommendation 7: Development of comprehensive safety standards for flow batteries

Standards Australia, in collaboration with industry and government stakeholders and technical experts, should lead internationally in developing comprehensive safety standards for flow batteries by:

- Developing a new Battery Best Practice Guide specifically for flow batteries that integrates safety practices. The guide should:
  - Address issues such as on-site bunding and compliance with chemical storage regulations.
  - Include guidelines to facilitate disassembly and recycling, leveraging low batteries' recyclability advantages.
  - Establish specific testing protocols that account for flow batteries' distinct mechanical properties compared to lithium-ion counterparts.
  - Ensure standards for physical integrity that enhance flow batteries' resistance to mechanical damage, including puncture resilience.
- Revising AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* to encompass specific requirements for flow batteries, covering storage, handling, and installation needs comprehensively.

Recommendation 8: Alignment of battery management system cybersecurity standards with National CER Roadmap

Standards Australia, in collaboration with industry and government stakeholders, should explore aligning battery management system cybersecurity standards with emerging domestic guidelines following standards arising from the National CER Roadmap for remotely accessible devices. This includes safeguards against remote tampering and unauthorised alternations of critical functions, particularly for Distributed Energy Resources.

Recommendation 9: Development of enhanced testing standards for e-mobility device batteries

Standards Australia should explore the development of enhanced testing standards specifically for batteries used in e-mobility devices, while maintaining international alignment. These standards should incorporate rigorous tests such as higher drop tests, multiple vibration tests, and other stress simulations to replicate real-world usage scenarios.

Recommendation 10: Adoption of IEC 61508 for functional safety of battery management systems

Industry stakeholders and Standards Australia should collaborate to propose for the adoption of IEC 61508:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems,* which defines four Safety Integrity Levels to ensure robust safety system performance across various applications. This adoption aims to establish reliable Battery Management Systems standards, safeguarding against risks like overcharging and discharge related hazards, thereby enhancing battery safety.

Recommendation 11: Enhancing Australia's battery testing capabilities

Industry leaders should collaborate with key stakeholders to expand and enhance local testing facilities for batteries. This initiative includes developing advanced capabilities to reduce reliance on overseas testing, simulate extreme weather conditions, and position Australia as a premier battery testing hub.

Recommendation 12: Develop comprehensive standards for testing assembled battery systems to ensure safety and compatibility

Standards Australia should develop and implement comprehensive standards for end-product testing of assembled battery systems. This should include protocols for assessing the safety and compatibility of battery management systems and inverter integration.

Recommendation 13: Update AS/NZS 5139:2019 to require comprehensive testing of fully assembled battery systems for enhanced safety and performance

Industry stakeholders and Standards Australia should collaborate to propose for the update of AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* to include a requirement for the Power Conversion System to communicate effectively with the battery management system, ensuring the maintenance of safe operating parameters for fully assembled battery products and align with emerging international standards. These protocols should assess the entire system, including the compatibility and performance of all integrated components, rather than relying solely on pre-certified parts.

Recommendation 14: Develop and implement comprehensive education and training programs for battery assembly and testing

Manufacturers and assemblers in the battery industry should proactively develop and implement comprehensive education and training programs. These programs should focus on the latest standards and best practices for battery assembly and testing.

Recommendation 15: Promote and implement strategies to utilise Australian testing facilities for battery systems

Manufacturers and industry stakeholders should actively pursue and implement strategies to use Australian testing facilities. This approach aims to support local infrastructure and expertise while reducing the logistical challenges and costs associated with overseas testing.

See the fuller recommendations further is this report.

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Introduction

Purpose

The purpose of this report is to set out findings from the End User Advisory Group meetings and associated standards mapping research. This report aims to:

- Highlights gaps for end user battery standards relating to safety, reliability, performance, and deployment.
- Provide recommendations which may include the adoption and development of appropriate standards in Australia.

By identifying gaps and opportunities for end user battery standards, the project aims to minimise the impact of trade barriers for current and future Australian battery manufacturers, facilitate market demand and open access to both national and international markets. The development and adoption of international standards will be vital in enabling the Australian battery manufacturing industry to supply to both domestic and international markets. Standards for end users are necessary to support safety, interoperability and common approaches across supply chains and markets.

The benefit of this project's approach is that it brings together an Advisory Group to proactively identify and address gaps in the standards landscape. The collaborative aspect enables a more comprehensive analysis of existing standards, allowing the group to potentially anticipate and prioritise future needs based on industry trends and emerging technologies. By coordinating efforts across diverse stakeholders' expertise, the group can develop a defined strategy that leads to faster development cycles and a more streamlined approach for standards development. In addition, the Advisory Group facilitates consensus building, ensuring that the identification of gaps is robust and better aligned with industry needs.

Scope

This project aims to identify and provide a pathway to rectify gaps in end user standards related to secondary battery safety, reliability, performance, and deployment. This involves extensive mapping research of Australian and international standards, prioritising international standards developed by the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC), while also considering other relevant standards developed in other countries. The project encompasses standards for various battery chemistries, including lithium-ion and lead-acid, as well as alternative technologies and chemistries such as flow batteries.

The project focuses solely on secondary battery standards within the supply chain, excluding standards related to manufacturing, import/export, and battery reuse, repurpose, and recycling. Some of these out-of-scope topics are covered in the *Secondary Batteries - Reuse Repurpose Recycle report,* while others will be the focus of future research. Battery chemistries beyond the specified scope are also excluded from the report.

Standards Australia

Standards Australia is Australia's peak, independent, non-governmental, not-for-profit standards organisation. Standards Australia is Australia's representative of the ISO and IEC.

Standards Australia facilitates the development and adoption of internationally aligned standards in Australia. This is achieved through:

- Partnering in ISO and IEC standards development.
- Adoption of international standards, or regional standards where international standards do not exist.

- Creation and development of new standards where there are gaps in the international landscape or Australia has specific requirements.

Standards Australia is not responsible for enforcing regulations, mandating standards, or certifying conformance with standards.

Advisory Group

There are various stakeholders working to understand the secondary battery landscape. To ensure that the recommendations put forward in this report are well-considered and comprehensive, it was important to bring together a group of stakeholders that understand the impacts of secondary battery end user safety, reliability, performance, and deployment and can advise Standards Australia on the industry standardisation needs as a result.

The Advisory Group, representing the stakeholder engagement component of the project, was established to review and provide advice on secondary battery standards. The group used its expertise to shape the development of the standards mapping research, analyse of the gaps and opportunities, and identify a strategy to address them.

Advisory Group members involved in this project have relevant expertise in the project scope, standards development, industry, academia, and/or government policy and regulation. Their collective knowledge and insights were crucial in ensuring that the standards pathway is robust, relevant, and effective in addressing the needs of the secondary battery sector.

Role of Standards Australia in National and International Standards Development

Standards Australia develops standards that deliver a net benefit to the Australian community. Our processes are designed to ensure that standardisation in Australia remains robust, promotes economic efficiency, and supports consumer safety.

Standards Australia is committed to aligning with Australia's international obligations under the WTO Technical Barriers to Trade Agreement. This means using relevant international standards, guides, or recommendations as a basis for regulations, unless a relevant international standard does not exist, or the international standard is not appropriate to fulfill the policy objectives. For example, due to climatic or geographical differences. As Australia's representative at the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC), Standards Australia specialises in the development and adoption of internationally aligned standards in Australia. We facilitate technical committees of Australian experts who provide expertise to help shape international standards, ensuring Australia's interests are represented globally. Our contributions are made with the view that the International Standard will be used in Australia. In the absence of an International Standard, Standards Australia looks to relevant regional standards for adoption.

At a regional level, harmonisation of Australian and New Zealand standards is critically important. Australia and New Zealand are close trading partners with a common economic market and strong trade flows. The Trans-Tasman Mutual Recognition Act supports the harmonisation of standards in Australia and New Zealand by promoting bilateral integration and economic convergence. Standards Australia and Standards New Zealand work together to deliver joint standards appropriate for our economies across a range of sectors, including construction, consumer goods and electrical equipment. The identification of joint initiatives is a priority for Standards Australia, and we will continue to work with Standards New Zealand and relevant stakeholders to ensure harmonisation.

In some cases, relevant international standards do not exist, or are inappropriate for the Australian context. When this occurs, it may be necessary to develop an Australian Standard.

Standards Australia has established processes for the development of Australian Standards to ensure all relevant impacts are considered. Proposals for the development of new standards are assessed under strict criteria, with consideration for:

- Potential impacts on competition and innovation;
- Potential economic impacts across various domestic sectors; and
- Potential impacts on international alignment and global markets.

This assessment is used as part of the evaluation process to determine whether appropriate international standards are available for adoption, or whether an Australian Standard should be developed.

A proposal must be submitted to Standards Australia to adopt an international standard, to revise or amend an existing standard, or to develop a new standard. A proposal can be submitted by any member of the public and is reviewed on four key criteria: evidence that there is a need for the work, a robust scope, a well-defined net benefit case and comprehensive stakeholder support, considering many different stakeholders interest categories.

Proposals that meet all key quality criteria will be assessed and resourced monthly. Once a proposal is approved, generally, if a proposal is received to revise/amend an existing standard, the project will be assigned to the technical committee that initially developed the standard. Similarly, if a proposal is approved to adopt international standard, the adoption(s) will be facilitated by the Australian technical committee that mirrors the international technical committee. For a proposal to develop a new standard, Standards Australia will ultimately decide (in consultation with the proponent and relevant stakeholders) on which technical committee the project will be assigned to, or if a new technical committee is required.

In 2023, Standards Australia implemented alternate standards development pathways to accelerate standards development efforts in new and emerging areas of endeavour where traditional models of standards development may not be fit for purpose. A major pillar of the alternate standards development pathways is the establishment of ‘Project Committees’, which may be formed to develop an Australian Standard under the alternative path or where technical specifications or handbooks are desired, but no technical committee exists. Project Committees are not formally constituted but aim to engage a broad group of stakeholders.

In addition to standards, Standards Australia also publishes other types of documents such as handbooks and technical specifications. There are instances where a normative or informative technical document is required, and traditional standardisation processes may not deliver the optimal solution. These are referred to as ‘lower consensus solutions’ due to the lower degree of consensus and consultation required to publish such documents, as compared to Australian Standards. The initiation of a new document such as a handbook or technical specification is still subject to a proposal being submitted to and approved by Standards Australia.

Benefits of International Standards Adoption

Adopting international standards is vital for Australia to establish a competitive secondary battery manufacturing industry. These standards ensure consistent quality, reliability, and safety, enhancing consumer trust and minimising risks such as thermal runaway, short circuits, and electrolyte leaks. They align Australian products with international requirements, facilitating market entry, reducing trade barriers, and simplifying compliance. By incorporating the latest technological advancements and best practices, these standards support innovation and provide a clear roadmap for research and development, allowing Australian manufacturers to match global benchmarks. Operationally, standards streamline processes, reduce costs, and optimise supply chains through guidelines and efficient resource use.

Economically, compliance with international standards can attract foreign investment, support job creation, and integrate Australian manufacturers into global supply chains. Environmentally, international adoption of standards can promote sustainable manufacturing practices and provide guidelines for responsible sourcing, reuse, repurpose and recycling of batteries by supporting circular economy principles. Additionally, international standards ensure the interoperability of Australian batteries with various devices and systems, enhancing their appeal and usability in global markets. Overall, adopting international standards will strengthen Australia's reputation for producing high-quality, reliable batteries, aligned with national and international sustainability initiatives.

Standards Mapping Research

The Australian standards landscape for secondary batteries is robust and well-positioned. More recently, Australia has been actively adopting international standards, often integrating local modifications to better align with domestic conditions and industry needs. This approach reflects Australia's commitment to maintaining high-quality standards while adapting to the unique requirements of its own market. When international standards have not been available or appropriate for the Australian context, we have sought to develop battery standards that address specific domestic needs, such as environmental considerations, safety protocols, and performance metrics suited to our local context.

The strategy of harmonising with international benchmarks to ensure consistency and interoperability is crucial as it helps Australia's battery manufacturers and stakeholders to operate effectively within the international market, thereby facilitating trade, reducing compliance complexity, and ensuring that Australian products meet the expectations of global consumers and regulators.

As Australia continues to lead in the development and revision of battery standards, it is essential to balance national innovation with international collaboration. Developing standards that cater to Australia's specific requirements while remaining aligned with global norms ensures that Australian advancements are both relevant and applicable worldwide. This approach not only supports domestic industry growth but also enhances Australia's contribution to global standardisation efforts.

Sharing these advancements with the international community plays a vital role in fostering a cooperative and integrated approach to the global energy transition. By contributing Australian innovations to the international standards pool, Australia can help accelerate the adoption of best practices and cutting-edge technologies globally. This collaborative focus facilitates a faster, more efficient transition to sustainable energy solutions across the world, benefiting all stakeholders in the process. It underscores Australia's commitment to both local excellence and global progress in battery technology, ensuring a leadership role that supports widespread, effective, and harmonised advancements in energy storage and management.

Mapping Overview

To understand the existing standards landscape in Australia and internationally, research was conducted to review standards related to end user secondary batteries. Table 1 details the scope of the standards mapping research. The mapping exercise endeavoured to provide the Advisory Group with necessary data that members could then use to identify gaps relating to safety, reliability, performance, and deployment of secondary batteries. Advisory Group members used the mapping data to help shape recommendations for the adoption of international standards, modification of existing standards and/or the development of new standards in Australia.

No. of Standards	168 (15 of which are under development)
Regions Covered	Australia, New Zealand, International, Europe, United States, Japan, China, Germany.
Standards Development Organisations	Standards Australia (SA) International Standards Organisation (ISO) International Electrotechnical Commission (IEC) The European Committee for Standardization (CEN) Underwriters Laboratories (UL) Institute of Electrical and Electronics Engineers (IEEE) National Fire Protection Association (NFPA) National Electrical Manufacturers Association (NEMA) United Nations / International Air Transport Association (UN/IATA) Standardisation Administration of China (SAC) Japanese Industrial Standards Committee (JISC) European Telecommunications Standards Institute (ETSI) German Association of Automotive Industry (VDE) Society of Automotive Engineers International (SAE)
Areas Covered	Safety, Reliability, Performance, Deployment, Testing
Battery Chemistries Covered	Lithium-ion, Sodium-ion, Sodium Sulphur, Vanadium Redox Flow, Iron Flow, Nickel-metal hydride, Nickel-Cadmium

Table 1: Standards Mapping Scope

The mapping research includes standards specifically related to the end user secondary batteries criteria defined in the project scope. The Standards Development Organisations (SDOs) considered in this report were chosen based on Australia’s existing bilateral agreements, international trade partners, technological advancements, and recommendations from the Advisory Group. While the mapping is not exhaustive, it is tailored to meet the specific needs and objectives of the project.

One hundred and sixty-seven standards from 14 international and national SDOs were identified in the mapping research (see Figure 1). These standards were predominantly developed by international organisations (e.g., IEC and ISO), while others were developed by nationals SDOs based in the United States and China such (e.g., SAE and SAC) (see Figure 2). Twenty-two standards identified in the mapping were from Australia and New Zealand.

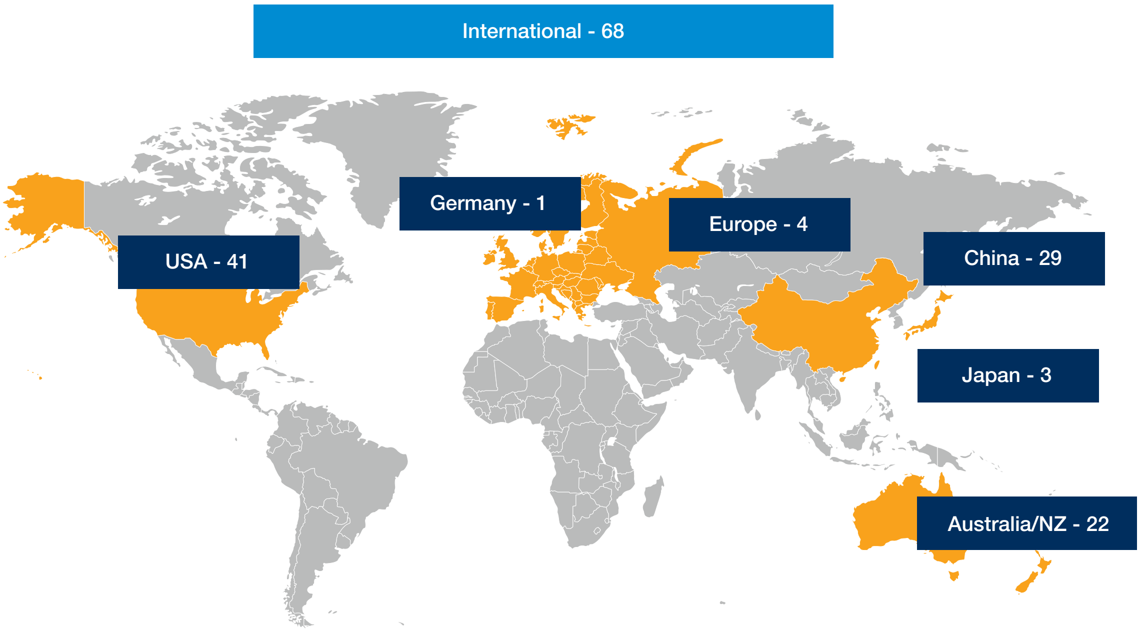


Figure 1: Number of standards mapped by region.

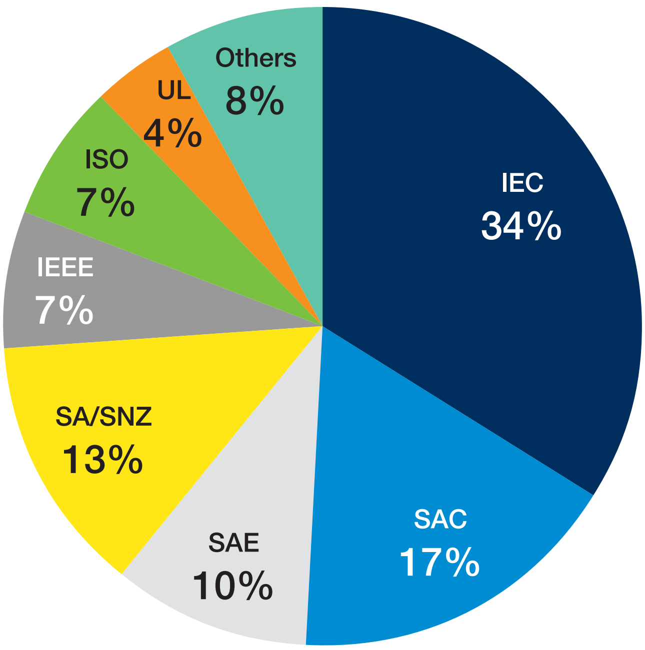


Figure 2: Percentage of standards mapped by SDO.

Mapping Insights

Beyond the project's scope of categorising standards into safety, reliability, performance, or deployment, additional focus was placed on testing standards to underscore their important role across secondary battery standards. Testing ensures end users can trust that secondary batteries in Australia are not only safe and reliable but also consistently perform well, are interoperable, and have undergone rigorous procedures to meet stringent quality requirements.

Fifty-nine percent of mapped standards include tests, followed closely by standards related to safety (54%), and performance (53%) (see Figure 3). It is important to note that these categories are not mutually exclusive, and overlaps occur across the areas of safety, performance, and testing, because standards often comprise multiple measures and assessments. For example, IEC 62133:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes-Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications,* outlines safety testing requirements for lithium batteries to ensure the battery meets various aspects including electrical, mechanical, and chemical safety.

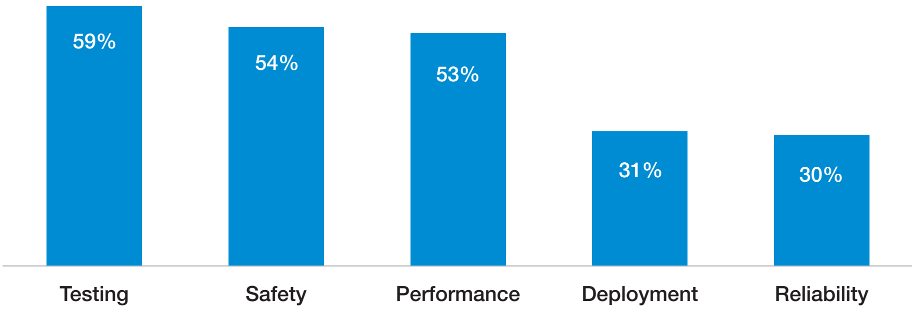


Figure 3: Percentage of standards mapped by category.[1]

Of the standards identified in the mapping research, 51% are chemistry-agnostic, meaning they do not pertain to any specific battery chemistry. Regarding chemistry, 32% of the standards specifically reference lithium-ion batteries. In contrast, only a small number of standards address other chemistries such as sodium-ion, nickel-metal hydride, and nickel-cadmium (see Figure 4).

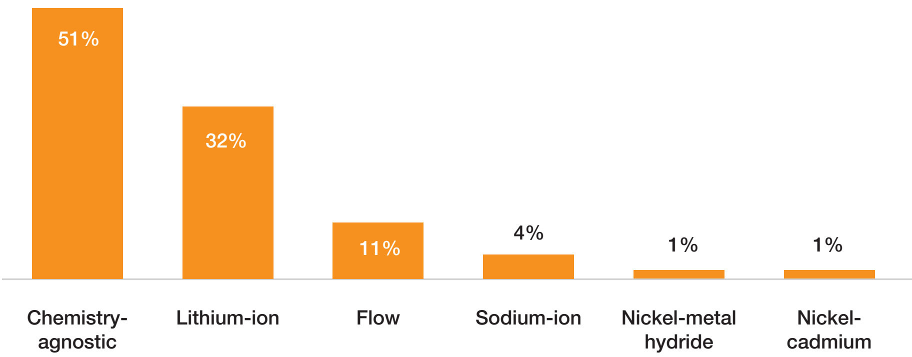


Figure 4: Percentage of standards mapped by chemistry type.

Key standards commonly referenced in documentation from battery suppliers or battery reviews are listed below. This list is not exhaustive but provides an overview of the important global standards landscape for secondary batteries.

Key standards for secondary batteries:

- **UN 38.3, *Testing for lithium batteries,*** lays out the compulsory testing framework for lithium-ion batteries for transportation. All lithium-ion batteries must pass the tests detailed in UN 38.3, *Testing for lithium batteries,* for transportation.
- **AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,*** sets out general installation and safety requirements

1 Figures in the chart do not add up to 100 because some standards cover multiple categories.

for battery energy storage systems for systems up to 200 kWh. This standard imposes specific location restrictions for Battery Energy Storage Systems and limits the proximity of other equipment near the battery energy storage system. Recognising the battery energy storage system as a potential ignition source, the requirements are designed to safeguard the unit from external influences such as physical damage and additional heat sources. This ensures that the battery energy storage system is adequately protected, minimising the risk of fire, and enhancing overall safety. Importantly the standard is restricted to batteries limited to 200 kWh so large industrial or grid-scale batteries are not in scope.
- **IEC 62619:2022, *Secondary lithium-ion cells for the propulsion of electric vehicles - Safety requirements,*** was first published in 2016, with the latest update in 2022. It outlines specific safety guidelines and testing procedures to ensure the safe design, production, and use of lithium-ion batteries in various industrial settings. It is a comprehensive guidance to help manufacturers, engineers, and users mitigate risks associated with the use of lithium-ion batteries, such as fire, explosion, and chemical leakage, by establishing requirements for construction, testing, and documentation.
- **IEC 62933, *Electrical energy storage (EES) systems*** series of standards covers the following aspects of Electrical Energy Storage Systems (EESS):
  - Vocabulary;
  - Unit parameters and testing methods;
  - Planning and Performance Assessment of EESS – General Specifications;
  - Guidance on environmental issues – General Specification;
  - Safety considerations for grid-integrated EES systems – General Specification; and
  - Safety requirements for grid-integrated EES systems –Electrochemical based systems.

Outside of the United States, IEC 62933, *Electrical energy storage (EES) systems* series are key standards for energy storage systems. Unlike UL standards such as UL 9540, *Energy Storage Systems and Equipment,* and NFPA standards which focus on safety, IEC 62933, *Electrical energy storage (EES) systems* series covers testing on aspects such as roundtrip efficiency, capacity and other methods for validating Energy Storage Systems performance.

Safety Standards

For the purposes of this project, safety is defined as the measures and standards implemented to prevent risks such as overheating, short circuits, and fires, ensuring the safe operation and handling of batteries.

Safety related standards are primarily designed to protect against the various hazards associated with secondary batteries for end users by covering areas such as safe battery installation, grid connection, overcharging and discharging, battery management systems, charging equipment and battery storage. These standards set out functional safety measures to:

- Assess thermal characteristics to address thermal runaway.
- Provide stringent requirements for systems connected to a power grid including inverter requirements.
- Evaluate design measures to prevent a battery from overcharging, protecting against internal short circuits.
- Outline safety requirements for both stationary and mobile applications.
- Specific requirements to provide safety features such as temperature protection systems.
- Mitigate hazards associated with energy storage systems.
- Set out functional requirements for safe battery and charger installations including electrical installations for households.
- Outline safety aspects associated with the installation, use, inspection, maintenance, and disposal of batteries.
- Evaluate a battery system’s ability to safely withstand simulated abuse conditions.
- Outline electrical safety requirements for battery storage equipment.

- Provide general guidance on general fire protection requirements for buildings, including battery management systems.
- Provide an expected performance level of a battery management systems.

Standards development organisations internationally, nationally, and regionally recognise the integral role of safety standards in the design, production, performance, storage, and usage of secondary batteries. This sentiment is reflected in the number of safety standards uncovered in the standards mapping process. Safety is the most common focus area for standards development organisations, with 54% of standards currently available or under development relating to safety (see Figure 5).

The standards mapping research identified 90 standards relating to safety, of which 84 are published and the remaining 6 standards are under development (in drafting). Safety standards currently under development relate to areas such as the repair and reuse of batteries, battery packs and cell modules and the necessary information required for an electrically propelled vehicle battery pack (i.e., manufacture, safe handling, and collection/recycling).

Over 50% of all safety related standards mapped provide an element of safety related testing. For example, UL 9540, *Energy Storage Systems and Equipment,* is a chemically agnostic standard that provides guidance for how a battery system is designed, built, tested, and marked. UL 9540, *Energy Storage Systems and Equipment,* protects the battery system by setting out requirements that mitigate against thermal runaway, fires, mechanical failures, and electric shock hazards.

Other safety standards include:

- Safety standards for e-mobility to prevent risks associated with high voltage batteries in e-mobility transportation. Standards such as UL 2271, *Batteries for Use In Light Electric Vehicle (LEV) Applications,* outlines the safety requirements for batteries used in light electric vehicles and includes temperature and environmental testing and vibration and impact testing.
- Standards for the installation of battery energy storage systems to prevent hazards such as fire and explosions and exposure to hazardous chemicals. Standards such as AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* safeguard against such hazardous events by providing safety requirements for the installation of battery energy storage systems for systems up to 200 kWh.
- Safety standards to protect batteries from thermal runaway, electrical fires, hazardous leakage, and prevention of overcharging or discharging. Standards such as UL 9540, *Energy Storage Systems and Equipment,* can be applied to the design, build, testing and marking of battery systems to ensure the battery operates safely and reliably.

Forty-six of the safety related standards are chemically agnostic and apply to all secondary battery types (see Figure 5). The second most common safety related standards are for lithium-ion batteries (31 standards), which is nearly triple the amount of safety related standards for flow batteries (13 standards). Standards for flow batteries primarily cover energy storage systems and safety performance requirements for the flow battery system.

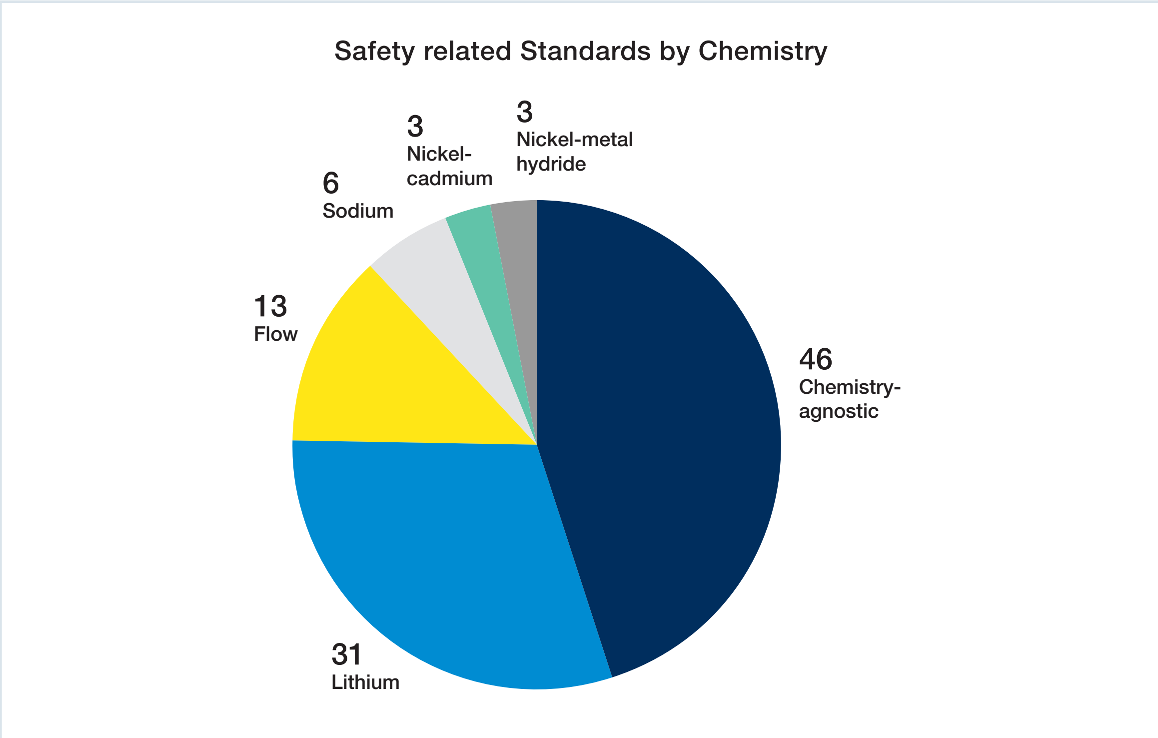


Figure 5: Number of Safety related standards, by chemistry type.

Reliability Standards

Reliability is defined within this report as a batteries' ability to consistently perform as expected over its lifespan, including maintaining stable capacity, voltage, and performance under various conditions. Ensuring consistent performance and predictable behaviour is important in minimising safety risks and reducing disruption. Reliability is particularly important for energy storage systems that store excess energy from renewable sources, such as solar and wind. Having reliable energy storage batteries is crucial in ensuring a stable power supply, thereby minimising the risk of disruption to society and the economy. Moreover, ensuring that batteries perform as expected over their lifespan means that end users can deploy them for longer, reducing the constant need for new batteries and critical resources.

Fifty standards which address reliability were mapped, making up 30% of the total standards mapped. Four international reliability standards are still under development, while almost a third of the existing standards have been published by SAC, the Chinese standards body.

Twenty-four of the reliability related standards are chemistry agnostic, 15 specify lithium-ion batteries, and 9 standards relate to flow batteries (see Figure 6).

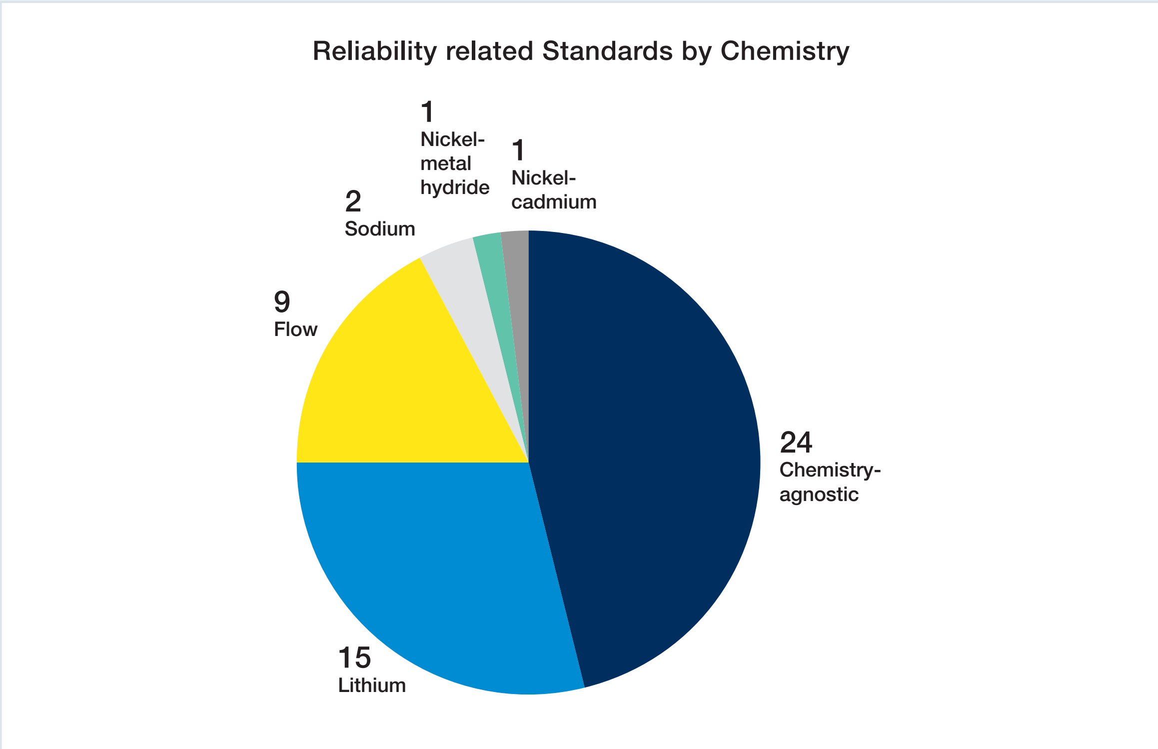


Figure 6: Number of reliability related standards, by chemistry type.

Reliability and performance are closely aligned, and consequently there is overlap in many of these standards. These overlaps exist in areas such as battery capacity, cycle life, safety, and voltage. Improving performance of secondary batteries in turn improves its reliability, and balancing the two areas is crucial for optimal battery manufacture.

Performance Standards

Performance in the context of secondary batteries refers to overall efficiency, capacity, cycle life, voltage stability, and response time of batteries in various applications and conditions.

Performance standards and tests are important in ensuring secondary batteries meet requirements such as maintaining power output, extending battery life, energy efficiency, and durability (through stress testing). Meeting performance standards and requirements creates better quality and more environmentally sustainable devices, ultimately building consumer trust and confidence.

Performance related standards make up 53% of the standards identified in the mapping research, of which 11 are still under development. These standards under development relate to areas such as the performance of rechargeable batteries for road vehicles in Europe, labelling of secondary batteries, capacitive energy storage device requirements, and performance rating of electric vehicle battery modules.

One third of the performance related standards are from international SDO's (e.g., ISO and IEC) and Chinese standards bodies (e.g., SAC). There are 6 standards in the Australia and New Zealand region covering areas including traction battery requirements, stationary batteries, grid connection requirements, secondary batteries for stand-alone power systems, and energy storage system performance.

Forty-three of the performance related standards are chemistry agnostic, while 26 specify requirements for lithium-ion batteries, accounting for the majority of the chemistry types (see Figure 7).

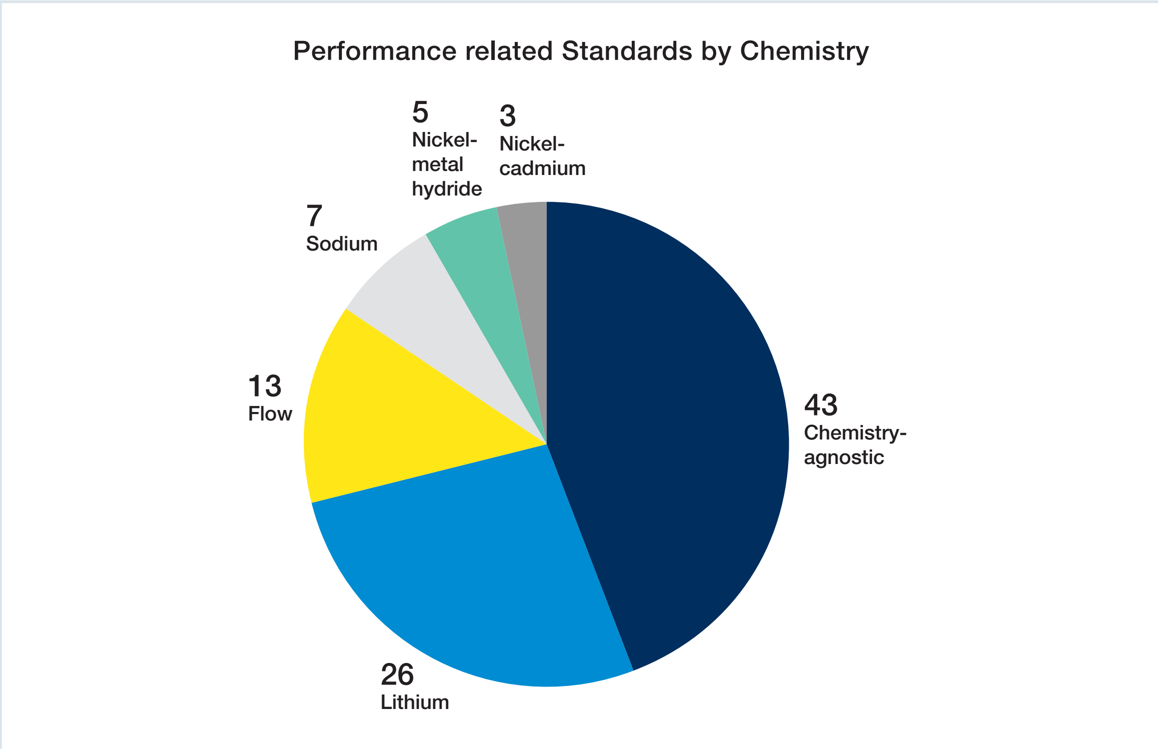


Figure 7: Number of performance related standards, by chemistry type.

Performance related standards cover several requirements and test procedures for secondary batteries for their use in applications such as e-mobility devices (i.e., IEC 61982, *Secondary batteries (except lithium) for the propulsion of electric road vehicles* series) and in EES systems (i.e., IEC 62933, *Electrical energy storage (EES) systems* series and AS 5374:2023, *Energy storage system performance*). Requirements and test procedures covered include:

- Verification of endurance, properties, and electrical performance.
- EES system performance defining – unit parameters and test methods.
- Recommended practices for measurement and reporting of performance.
- Verification methods to determine electric vehicle battery module performance.
- Durability assessment of electric vehicle batteries.
- Test procedures to obtain the essential characteristics of cells for vehicle propulsion applications regarding capacity, power density, storage life and cycle life.
- Performance and durability assessment of electric vehicle batteries.
- Inverter performance designed to facilitate connectivity between energy sources and the grid.
- Defining unit parameters and testing methods.

Deployment Standards

Deployment herein refers to the safe and efficient integration of batteries into systems or devices, ensuring they meet performance and safety standards during installation, operation, and maintenance. Standards related to deployment are important to ensure interoperability, safety, sustainability, and the effective utilisation of rechargeable batteries.

Standards related to deployment of secondary batteries and secondary battery systems make up approximately 33% (51) of the standards identified in the mapping process. Of these, 6 are currently under development. Some of the areas covered in standards under development include conditions and protocols for the safe repair/re-use of batteries designed for electric vehicle applications, recommended practice for energy storage applications, and labelling and end of life battery information for EVs.

There are five standards published from the Australia and New Zealand region related to the deployment of secondary batteries, covering areas such as installation and usage of traction batteries, connection to the grid, safety in electrical installations of battery systems, and demand response capabilities.

Thirty-two of the deployment related standards are chemistry agnostic, while 8 specify lithium-ion batteries, and 8 standards relate to flow batteries (see Figure 8).

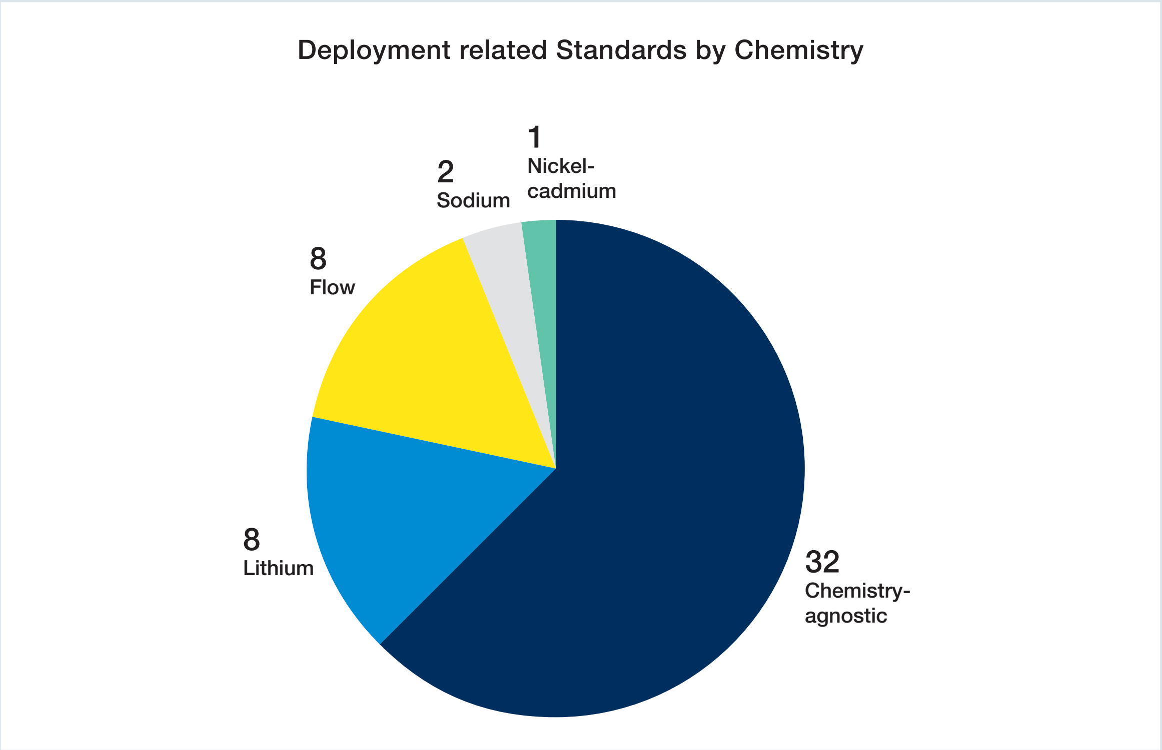


Figure 8: Number of deployment related standards, by chemistry type.

Standards identified include AS/NZ 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment*, which specifies the installation requirements for battery energy storage for systems up to 200 kWh, and covers areas of deployment including:

- Connectivity between energy sources and the grid.
- Traceability of battery packs, and information on the end of life of battery packs for EVs.
- Safety requirements for battery installations.
- Operation of lithium-ion batteries in electric off-road vehicles.
- Requirements for the installation and usage of secondary batteries of the vented type for installation in electric traction vehicles.
- Requirements for working and storage environmental conditions, power control, and operational adaptability.
- The start-up, shutdown, power control and off-grid switching of converters.
- Operation, maintenance, and overhaul.

Testing Standards

Testing standards are the most prominent standards category covered by researched SDOs in this project. Testing on secondary batteries supports several crucial aspects of the battery use. These standards are important because they provide recommended approaches and measures to ensure products meet technical, safety, and performance requirements. Tests are crucial from both end user and the manufacturing perspective. Testing standards provide safety assurance, quality control, performance evaluation, regulatory compliance, and support battery technology advancement.

There are 99 standards identified which feature test methods, and these account for 59% of the mapped standards. Standards often encompass multiple criteria, leading to extensive overlap. Overlap occurs with testing because the test protocols are designed to validate not only the functionality of a system but also its compliance with safety, performance, and reliability requirements.

Thirty-five of the testing standards specify lithium-ion batteries, while another 34 related standards are chemistry agnostic, and 11 standards relate to flow batteries (see Figure 9).

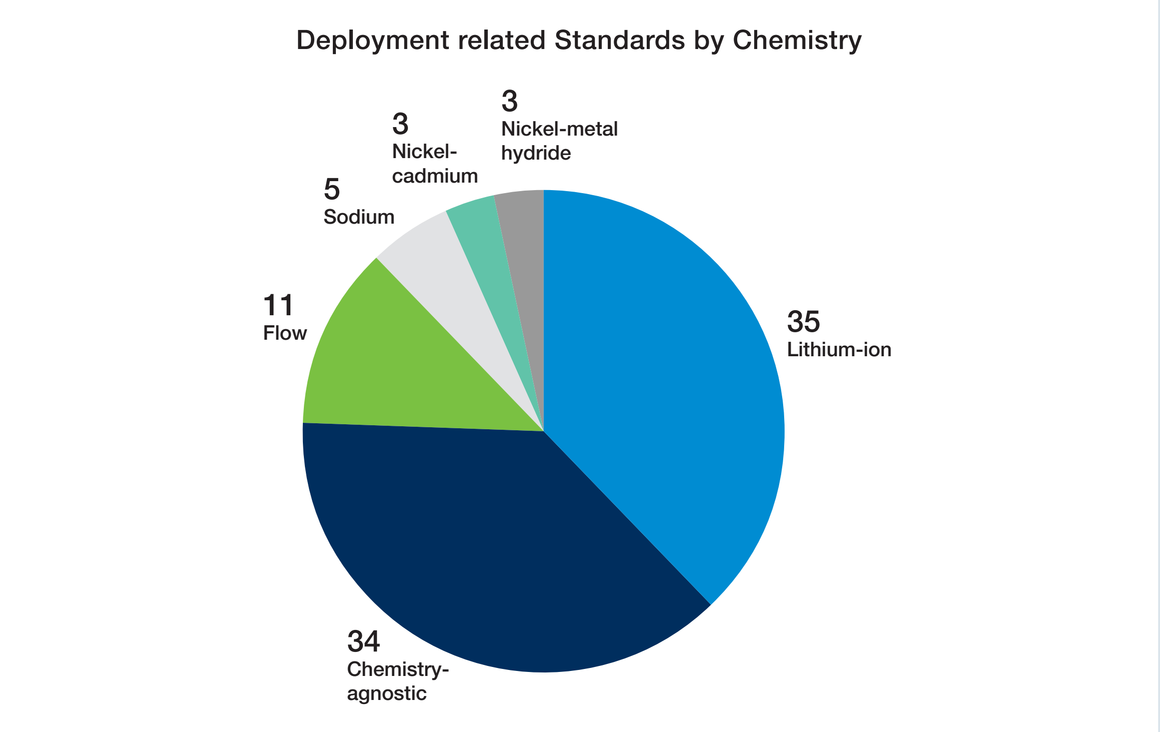


Figure 9: Number of testing related standards, by chemistry type.

Mapped standards relating to testing allow for tests conducted at cell, module, and systems levels. The parameters that are yielded by tests might include, but are not limited to the following:

- **Simulation of environmental conditions**: This test involves subjecting the batteries to controlled environmental factors such as: temperature, humidity, vibration, and shock, amongst other factors; to assess their performance, safety, and durability under different operating conditions. Testing aims to mimic real-world environmental conditions that batteries may encounter during storage, transportation, and use. IEC 62133-2:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems*.

- **Safety tests**: For example, but not limited to, IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications*, provides test requirements at both cell level and system level; as well as test requirements for the packaging and transport of lithium cells, modules, and battery packs.
- **Transportation tests**: Compulsory tests for transportation of batteries are provided in UN 38.3, *Testing for lithium batteries*, which is followed by International Civil Aviation Organization, the International Air Transport Association, the International Maritime Organization and other international organisations and/or government agencies. Transportation tests are also given in IEC 62281:2019, *Safety of primary and secondary lithium cells and batteries during transport*.
- **Electromagnetic Compatibility (EMC) testing**: EMC testing is a set of procedures and assessments performed on electronic and electrical devices to ensure that they can operate in their intended electromagnetic environment without causing interference to other devices or being susceptible to interference from external sources. It typically involves two main aspects:
  - *Emissions Testing*, which evaluates the electromagnetic emissions produced by the device under test when it is in operation.
  - *Immunity Testing*, which assesses the susceptibility of the device under test to electromagnetic interference from external sources.
- Other important and most used tests include life cycle and performance testing, over charge and over discharge, temperature, humidity, and condensation tests puncture/nail penetration, among others.

Relevant tests performed on batteries are often subject to the agreements among manufacturers, engineers, and wholesalers/importers/customers.

Some prominent testing standards include:

AS IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries*, for use in industrial applications is a fully adopted standard of IEC 62619:2022. The standard outlines specific safety guidelines and testing procedures to ensure the safe design, production, and use of lithium-ion batteries in various industrial settings. It helps manufacturers, engineers, and users mitigate risks associated with the use of lithium-ion batteries, such as fire, explosion, and chemical leakage, by establishing requirements for construction, testing, and documentation. The standard IEC 62619:2022 is also referenced in the standard IEC 62933-5-3:2023, *Electrical energy storage (EES) systems - Part 5-3: Safety requirements for grid-integrated EES systems - Performing unplanned modification of electrochemical based system.* These standards address first life cells and batteries. Reuse, repurpose, second life use or similar are not taken into consideration in this standard.

UL 9540A, *Test Method*, covers safety testing protocols and requirements for stationary energy storage systems, including battery systems and associated components. It focuses on fire safety aspects related to the installation and operation of energy storage systems, aiming to mitigate fire hazards and ensure the safe deployment of energy storage systems in various applications, such as residential, commercial, and industrial settings. UL 9540A, *Test Method,* is also referenced in IEC 62933-5-2:2020, *Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems*, large-scale fire testing on battery energy storage systems. UL 9540A, *Test Method,* provides critical testing methods on thermal runaway, external fire exposure, short circuit, crush, thermal cycle, and other environmental elements. On thermal runaway testing, UL 9540A, *Test Method,* provides testing methods at single cell level, including propagation assessment, fire containment assessment. The pass/fail criteria dictated in UL 9540A, *Test Method,* are based on the extent of thermal runaway propagation and the effectiveness of containment measures. Systems that meet the specified criteria are considered compliant with the standard, while those that fail may require design modifications or additional safety measures.

UL 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications*, is a safety standard that specifically addresses batteries used in light electric vehicles including electric bicycles, electric scooters, hoverboards, and other similar devices. It outlines the following aspects: safety requirements, chemical composition, cell configuration, insulation, and protection against physical damage, performance testing, temperature and environmental testing, vibration, and impact testing, marking, and labelling.

UL 2580, *Batteries for Use in Electric Vehicles,* caters to larger power electric vehicles. This is a safety standard that addresses lithium-ion batteries used in EVs. It outlines the following aspects: safety requirements, chemical composition, cell configuration, insulation, and protection against physical damage, performance testing, temperature and environmental testing, vibration, and impact testing, marking, and labelling.

Industry Needs

The following section is based on insights from the four Advisory Group meetings coordinated by Standards Australia and form the basis of the industry insights and recommendations.

Safety

Secondary batteries are ubiquitous across Australia, serving in grid-scaled energy storage systems, industrial equipment, consumer electronics like mobile phones, and personal mobility devices such as e-scooters. While generally safe, incorrect installation or poor maintenance can lead to serious hazards, including exposure to chemical hazards, arc flash burns, fire, and thermal runaway. In recent years, there has been a notable rise in incidents involving lithium-ion batteries, known for their high flammability. These incidents have caused over 1,000 fires annually in Australia, spanning from electric vehicle charging stations to seemingly innocuous scenarios like toolbox fires caused by an unattached battery. Emergency services are increasingly dealing with lithium-ion battery fires in golf carts, often stemming from inexpensive battery imports or do-it-yourself setups and retrofits. To address these concerns, Standards Australia solicited input from the Advisory Group through open discussion, thematic topic sessions and questionnaires.

Case Study – South Korea’s Tragedy

On June 24, 2024, a catastrophic fire broke out at a lithium battery manufacturing plant in South Korea, resulting in the deaths of 22 workers and injuries to eight others. The incident began with the explosion of a single battery cell, which quickly set off a chain reaction involving 35,000 units. The rapid spread of toxic fumes and intense fire within 15 seconds prevented the workers from escaping, leading to a devastating loss of life. The explosion obliterated the concrete and steel structure of the plant. While the exact cause of the initial explosion remains unclear, the incident underscores the critical need for stringent standards for the safe management of lithium-ion batteries to prevent such tragedies in the future.

Source: ABC News June 20, 2024

Battery Management Systems

Battery management systems are crucial for the safe and efficient operation of modern batteries. As the use of various battery technologies and applications grows, comprehensive standards are essential to ensure that battery management systems effectively protect batteries from common hazards, such as overcharging, overdischarging, and thermal runaway.

Standards should mandate compatibility checks between the battery management system and battery systems to prevent malfunctions that can lead to overheating or fires. Additionally, the battery management system must have appropriate isolation and cut-off mechanisms to protect the battery from overvoltage, overcurrent, and overtemperature scenarios. These safety features should be rigorously tested under various conditions to ensure efficacy.

Establishing minimum functional requirements for Battery Management Systems is critical to ensure safety and reliability across various applications. Standards should specify baseline functionalities, including overvoltage, overcurrent, and overtemperature cut-offs, as outlined in the Battery Best Practice Guide and AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment*. These requirements must also account for the unique needs of different battery chemistries and applications, such as vehicles versus stationary storage batteries, to provide appropriate protection and optimise performance and safety in diverse use cases.

The battery management system must isolate the battery from improper charging inputs to protect its longevity and performance. Standardised charging protocols are essential to avoid mismatched scenarios, like connecting a 24-volt pack to a 48-volt charger.

Testing and certification processes must be robust. If a manufacturer updates the battery management system or its microprocessor, the entire system must undergo testing and recertification to ensure that any modifications do not introduce new vulnerabilities or performance issues. This continuous validation of the battery management system technology maintains safety and functionality throughout the battery system’s lifecycle.

A comprehensive approach to battery management system architecture is essential. Battery packs, which are the complete assemblies ready for application, should have a battery management system or Energy Management System at the pack level. Battery modules, the intermediate units within packs that consist of interconnected battery cells, should also have their own battery management system. This ensures effective communication between the modules and the overall system controller. Implementing battery management systems at both the pack and module levels enhances system performance and minimises the risk of isolated failures.

Cybersecurity measures are increasingly important as battery management systems become more connected. Standards should address the cybersecurity of battery management systems, including protection against remote tampering and unauthorised overwriting of critical functionalities, preventing malicious interference that could compromise battery safety and performance.

Implementing these recommendations will provide a robust framework for battery management system standards, ensuring that batteries are safely and efficiently managed across various applications. Addressing compatibility, functional requirements, charging protocols, and cybersecurity will support the development of reliable, safe, and high-performance battery systems, contributing to Australia's leadership in the global battery industry.

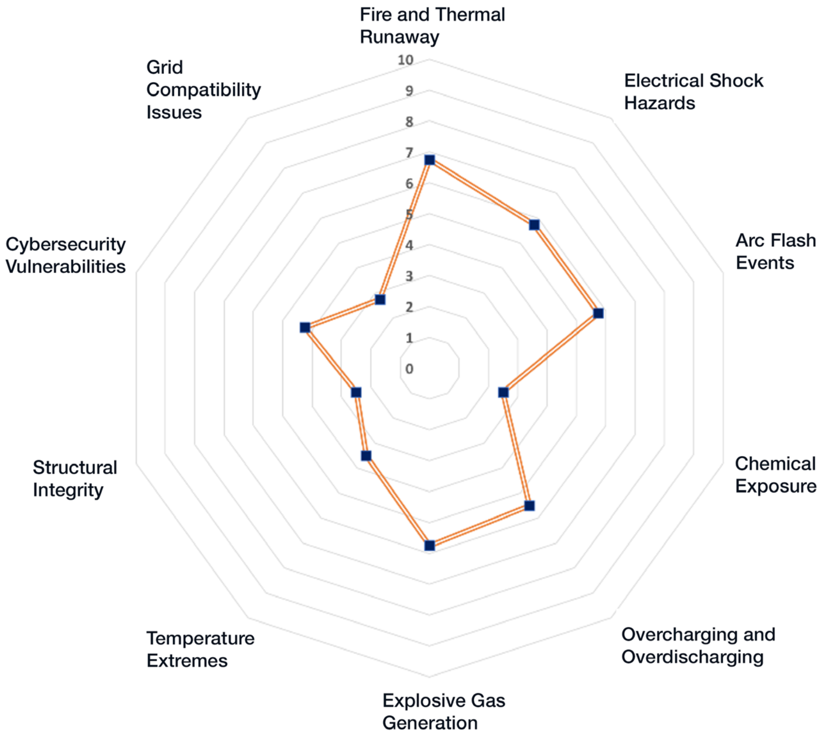
Advisory Group Survey, Question 1

What are the main safety concerns with large secondary battery installations connected to the grid?

Survey results indicate that the primary safety concerns for grid-scale secondary batteries include fire and thermal runaway, electrical shock hazards, arc flash events, overcharging, overdischarging, and explosive gas generation (see Figure 10).

These concerns underscore the urgent need for effective temperature control and hazard mitigation strategies to prevent fire and thermal runaway incidents. Robust insulation and stringent safety measures are essential for addressing electrical hazards such as shock events and arc flashes. Moreover, the risks of overcharging and overdischarging emphasise the critical role of efficient battery management systems in preventing degradation and controlling gas generation. Notably, large-scale utility battery energy storage systems are subject to a comprehensive, multi-layered due diligence process involving regulators, engineers, consultants, local governments, and first responders.

Survey comments emphasised the crucial role of integrated battery testing for cells and battery management system/energy management system combinations, highlighting that much of battery safety relies on the battery management system and software. Additionally, proper spacing, clearance, and accessibility between rows of battery energy storage system equipment, as well as effective bulk bunding for flow batteries, were critical for the safety of first responders and their vehicles. Moreover, the physical handling and transportation of large secondary batteries were identified as significant safety concerns that need addressing. These insights point to key areas where improved safety protocols and standards are necessary to enhance overall battery safety.



What are the main safety concerns with large secondary battery installations connected to the grid?

Figure 10: Advisory Group survey results considering safety concerns with large secondary battery installations connected to the grid

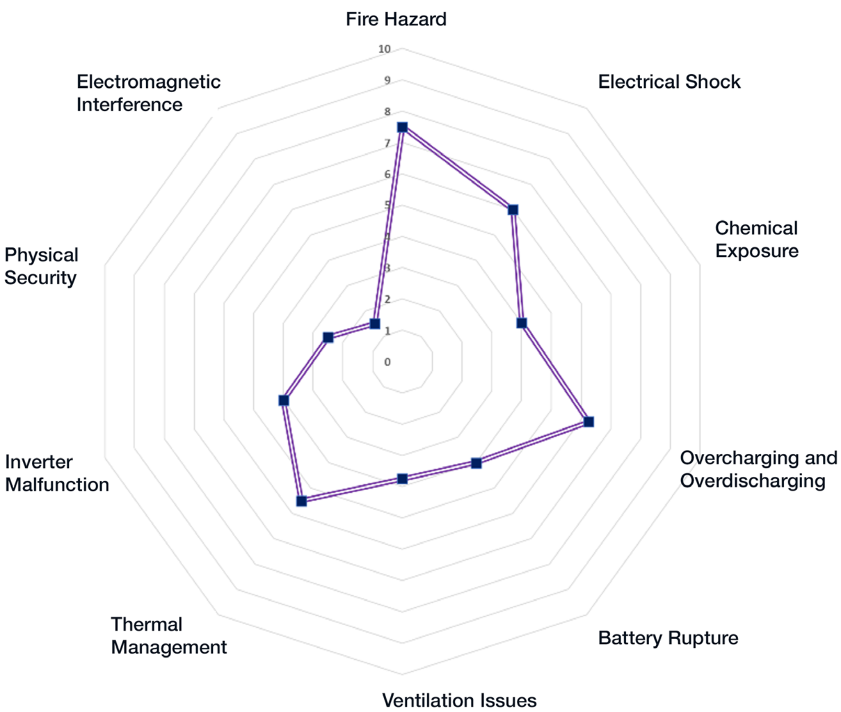
Advisory Group Survey, Question 2

What are the 10 main safety concerns with home secondary battery installations?

Survey results reveal that the top ten safety concerns for home batteries primarily involve fire hazards, electrical shocks, and issues related to overcharging and overdischarging (see Figure 11).

Fire prevention is the highest priority and necessitates effective temperature control and fire mitigation strategies. Additionally, reducing the risk of electrical shocks requires robust insulation and stringent electrical safety measures. While overcharging and overdischarging are perceived as less critical than fire hazards and electrical shocks, they pose significant risks, including thermal runaway and adverse chemical reactions, which can result in the release of hazardous gases and substances. These survey findings emphasise the importance of safety measures to address the various risks associated with home battery systems.

Additional safety concerns raised in the survey for home secondary battery installations included the physical configuration, cable terminations, and cybersecurity. Specifically, cybersecurity risks involve unauthorised remote access, tracking software change records, and monitoring firmware updates. It is considered essential to understand how these updates alter safety features to maintain system integrity and protection. Addressing these concerns is vital to ensure the safe installation and operation of home battery systems.



What are the 10 main safety concerns with home secondary battery installations?

Figure 11: Advisory Group survey results considering safety concerns with home secondary battery installations.

Advisory Group Survey, Question 3

What Secondary Battery area do you think have the greatest need for new standards?

Survey results indicate a high demand for new standards across various sectors, with personal mobility devices leading (78%), followed closely by home energy storage systems (75%) (see Figure 12). Significant need for standards are also identified in commercial-scale energy storage systems (60%) and transportation, particularly EV's (58%). Industrial equipment, such as power tools and robotics, show a notable demand (53%), while consumer electronics like smartphones and laptops register slightly lower (48%). Grid-scale energy storage systems and the "Other" category also demonstrate a need for new standards, albeit to a lesser extent (45% and 25%, respectively).

The survey findings highlight the critical need to develop and implement robust safety and operational standards across these sectors to ensure community safety and facilitate the integration of new technologies.

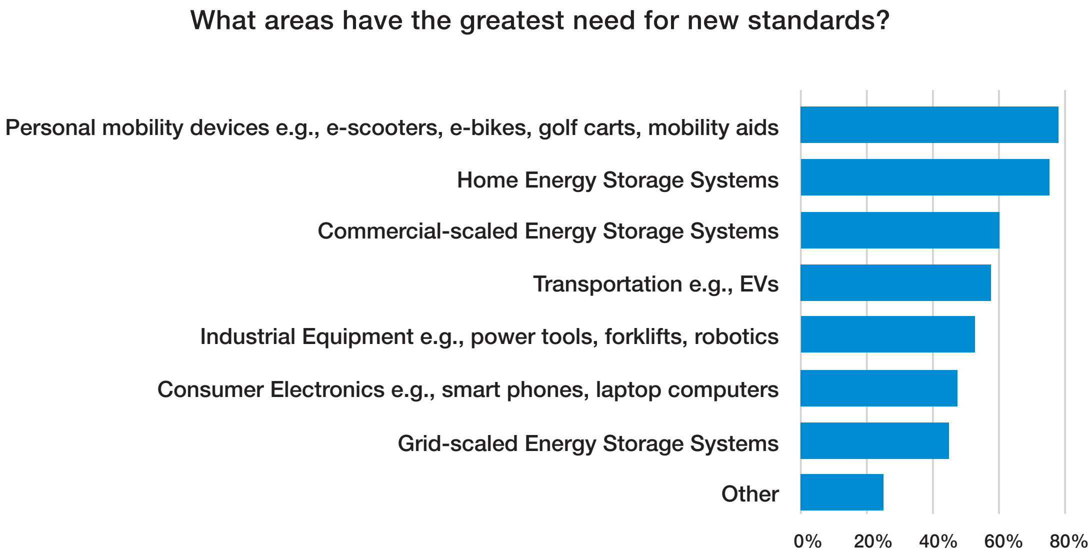


Figure 12: Advisory Group survey results considering what areas have the greatest need for new standards.

Advisory Group Survey, Question 4

Which Secondary Battery area poses the greatest risk of harm to the community?

Survey results highlight that personal mobility devices and home energy storage systems are perceived as the highest risk areas with the greatest harm to the community (scores of 84% and 81%, respectively) (see Figure 13). Following these are industrial equipment, including power tools and robotics (66%), and transportation, particularly EVs (64%). Commercial-scale energy storage systems and consumer electronics present moderate risks (56% and 55%, respectively). Grid-scale energy storage systems are somewhat lower (49%, while the "Other" category registers a risk of 30%). These findings underscore the urgent need for enhanced safety measures across these sectors to protect communities and manage the potential hazards associated with these technologies.

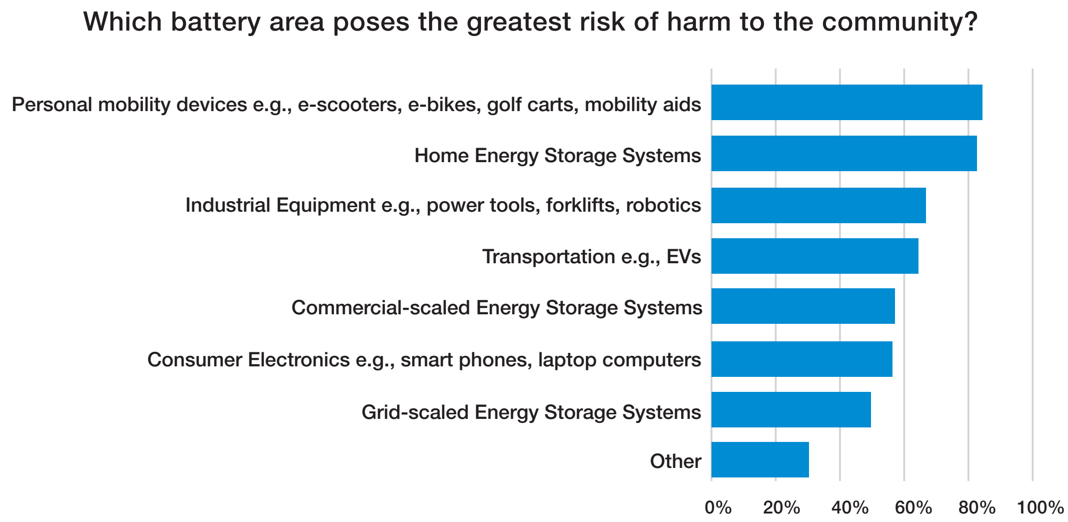


Figure 13: Advisory Group survey results considering which battery area poses the greatest risk of harm to the community.

E-Mobility

The rapid adoption of personal e-mobility devices, such as e-scooters and e-bikes, has brought significant attention to the quality and safety of their batteries. Notably, there is wide variance in the quality of smaller manufactured batteries, especially those imported from China. Batteries within e-mobility devices are subject to frequent drops and shocks, which current tests—like those defined in UN 38.3, *Testing for lithium batteries* — fail to adequately simulate common use scenarios. For example, the one-meter drop test specified in IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications,* and its limited shock testing do not reflect the real-world use and abuse that e-scooter batteries often endure.

Case Study – New York City

In March 2023, the New York City Mayor formalised a regulation mandating that any company involved in selling, leasing, or distributing micromobility devices—such as e-bikes or e-scooters—must obtain certification from an accredited testing laboratory within 180 days. The regulation was driven by several crucial findings about the e-mobility market including the importance of these devices for urban workers, widespread lack of awareness about the power sources and associated risks, behaviours that inadvertently increase fire hazards, and concerning safety issues arising from battery replacement practices. Under the regulation, companies are now required to certify against three key safety standards:

- **UL 2849, *Electrical Systems for eBikes***: This standard governs the electrical systems of powered bicycles sold, distributed, leased, or rented.
- **UL 2271, *Batteries for Use In Light Electric Vehicle (LEV) Applications***: This standard applies to the electrical systems of all powered personal mobility devices, including e-scooters.
- **UL 2272, *Electrical Systems for Personal E-Mobility Devices***: This standard pertains to the batteries used in light EV applications, ensuring safety for powered bicycles and mobility devices sold, distributed, leased, or rented.

Source:

1: UL Solutions March 20, 2023.
2: UL Standards & Engagement. Press Release May 7, 2024

One critical issue is the lack of robust battery management systems in many e-scooters, leading to problems such as overcharging and overvoltage. A robust battery management system is essential for providing the necessary isolation and cut-off mechanisms to prevent battery failures. This deficiency in battery management systems is particularly concerning given that do-it-yourself modifications to e-scooter batteries are a major cause of fires, accounting for about one-third of such incidents, as reported by Queensland Fire Emergency Services (see case study below).

There is also a lack of regulatory oversight for companies importing and selling e-scooters. In New York City, regulators conduct surprise inspections to ensure compliance with safety standards. Australia lacks such proactive measures. Retailers often bypass safety protocols, including speed limiters, and even encourage users to hack their devices. This lack of stringent regulation is compounded by the inadequate infrastructure for charging and storing e-scooters safely. Devices are often charged indoors, including in multi-story residential buildings, increasing fire risks, as exhibited in the case study below. Developing external, secure charging stations for multi-level buildings and other shared spaces could help mitigate these dangers.

Additionally, the lack of standardisation in charging cables can lead to significant safety concerns. For example, using a 48-volt cable with a 24-volt battery may cause serious fire hazards due to overheating, voltage drops, miswiring, and incompatible connectors and insulation. Introducing standards for charging cables can prevent compatibility issues and ensure safe charging practices. Public awareness campaigns and informative documents from Standards Australia would further enhance safety by educating users on the proper usage, maintenance, and modifications of e-mobility devices.

Addressing these gaps requires the development of comprehensive testing standards tailored to e-mobility batteries, incorporating higher drop tests, multiple vibration tests, and other stress tests to better simulate real-world usage. Additionally, stringent requirements for battery management systems in e-mobility devices should be established to ensure adequate protection against overvoltage and other issues. A regulatory framework for e-scooter imports and sales, including mandatory registration and compliance checks, is essential.

Case Study – Sydney

In March 2024, a fire broke out in an apartment building in Bankstown, Sydney after an e-bike with a modified lithium-ion battery went into thermal runaway. One man was injured and at least forty residents were required to evacuate the building. Sixty-three lithium battery fires have been recorded by New South Wales fire authorities in the first three months of 2024 alone, prompting officials to raise public awareness on the risks associated with lithium-ion batteries such as poor-quality battery cells and Do-It-Yourself modifications.

Source:
1. Fire and Rescue NSW post, 15 March 2024
2. Fire and Rescue NSW article, 14 March 202

Enhanced abuse testing protocols are also needed, particularly for e-mobility devices like e-scooters and e-bikes. Testing should simulate real-world abuse scenarios beyond those covered in UN 38.3, *Testing for lithium batteries,* and IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications*, helping to identify potential failure modes in extreme conditions and improve the safety and reliability of these devices.

Enhancing quality and performance standards for e-mobility batteries is essential and should focus on critical aspects such as rupture prevention and resistance to mechanical damage. Developing a certification system, like those used for 240-volt devices, would validate the safety and performance of e-mobility devices and their components, ultimately fostering a more secure and sustainable e-mobility market.

Alternative Battery Chemistries

There is a critical need for developing comprehensive safety standards tailored to flow batteries, which are becoming increasingly important in expanding energy storage options. Flow batteries, such as zinc-bromine and iron flow batteries, function differently from vanadium flow batteries. They deposit metallic layers on electrodes rather than storing energy in the electrolyte. These operational differences require specialised considerations in safety standards. For example, the aqueous electrolyte composition of zinc-bromine batteries can produce hydrogen, requiring robust airflow and thermal management. Standards are needed to address these unique challenges.

Currently, flow batteries can be classified as chemical stores when not operational, subjecting them to chemical storage regulations. This highlights a significant regulatory gap, as existing standards like AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* do not adequately cover the specific requirements of flow batteries. Developing a dedicated flow battery standard is essential to ensure safe storage, handling, and installation practices. The development of a parallel battery best practice guide for flow batteries, complementing the existing guides for lithium-ion batteries would be beneficial. This guide would consolidate common safety practices, address specific issues like on-site bunding, and navigate chemical storage regulations.

Beyond technical specifications flow batteries also offer substantial advantages in recyclability because they can be easily disassembled and disposed of. Standards would benefit from the incorporation of guidelines that facilitate safe and efficient recycling processes. Additionally, the safety protocols must account for the unique mechanical testing requirements of flow batteries, which differ significantly from those for lithium-ion batteries, particularly regarding puncture resistance and physical integrity.

Future considerations include the improvement of energy density by increasing electrolyte temperatures, which necessitates standards that accommodate best operational environments and insulation needs to manage temperature variations effectively. These specific flow battery standards need to integrate with broader regulatory frameworks domestically and abroad to enhance adoption and regulatory acceptance, positioning Australia as a leader in the safe and reliable deployment of flow battery technology.

Reliability

Overcharging/Overdischarging

Ensuring the safe and efficient operation of battery systems necessitates tight guidelines on overcharging and overdischarging practices. Without a battery management system, batteries, particularly lithium-based ones, are vulnerable to temperature extremes that can lead to hazardous conditions such as dendrite growth, short circuits, and fires. The absence of a battery management system means that batteries are at risk of overcharging and overdischarging, which can cause significant temperature fluctuations and safety concerns.

Charging is particularly dangerous if it occurs below the battery’s minimum allowable temperature. For lithium batteries, this practice can prompt dendrite formation, creating conditions ripe for short circuits and potential fires. Therefore, it is crucial to avoid charging these batteries below their specified temperature thresholds to mitigate such risks.

The issue of overdischarge is notably less severe for larger battery systems, such as those used in industrial settings because they have greater oversight during operation, compared to smaller, home-based batteries. Different battery chemistries also exhibit varying responses to discharge rates and temperature management, affecting their overall lifespan and performance. For example, lead-acid batteries handle overcharging differently than lithium batteries, underscoring the need for chemistry-specific guidelines.

Performance

Testing

The evolving landscape of battery technologies presents several challenges for testing standards, particularly regarding e-mobility devices, as highlighted in the E-mobility section. Existing standards often fail to account for the diverse chemistries of modern batteries, resulting in gaps that undermine the efficacy of current testing methods. For instance, certain standards exclude specific chemistries or contain test parameters irrelevant to others, such as the misalignment in testing zinc bromine hybrids flow batteries under standards designed for vanadium flow batteries.

Australia has traditionally hesitated to adopt North American standards due to differences in electrical grids, yet this reluctance is misplaced in the context of battery testing. Some IEC standards, like IEC 62933, *Electrical energy storage (EES) systems* series, reference North American standards such as UL 9540, *Energy Storage Systems and Equipment,* and UL 9540A, *Test Method,* demonstrating the need for harmonisation and alignment. Moreover, variations in how testing laboratories interpret standards lead to inconsistencies in test results. This inconsistency highlights the need for clarity in standards and unified implementation across testing facilities.

A significant issue is the absence of a universal testing framework that applies across all battery chemistries. While no single test currently fits all, developing chemistry-agnostic tests—like puncture tests instead of chemistry-specific ones—could provide a more comprehensive testing approach, where tests are based on hazards not chemistries.

There is also a pressing need for comprehensive testing standards across assembled battery systems, including battery management systems and inverters, to ensure overall safety and compatibility.

Developing new testing standards must be synchronised with establishing relevant infrastructure to ensure practical enforcement. The adoption of international standards should be prioritised where possible to ensure Australia is aligned with international compliance frameworks.

Testing in Australia

Strategically developing testing capacity in Australia should support various battery chemistries and applications, including large-scale chambers for shipping container-sized units with integrated HVAC and battery management systems. This development should be aligned with updating existing standards, such as IEC 62619:2022, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications,* and IEC 62133:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes- Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications*, to reflect modern technologies and installation practices.

Testing in Australia often involves sending batteries overseas, which incurs high costs and delays. Establishing local testing facilities could mitigate these expenses and support timely certification while safeguarding intellectual property. Existing Australian infrastructure, including CSIRO's thermal test chambers and QUT's cell development labs, requires expansion to support large-scale testing for grid storage, residential applications, and high-voltage systems.

Standardisation is specifically needed around the storage of batteries at testing facilities and disposal after testing. There is also a need for a testing best practice guide, which will inform facilities about testing for various battery chemistries in a safe and responsible manner. Start-ups and innovators face substantial costs in testing without achieving certification for new chemistries, underscoring the need for standards that accommodate emerging technologies to prevent innovation stifling.

Furthermore, Australia would benefit from developing niche expertise in testing under extreme weather conditions by leveraging facilities like James Cook University in northern Queensland. Environmental chambers capable of simulating high temperatures and humidity are crucial for testing batteries across diverse climates. An Australian testing and training facility could position the country as a regional hub for battery testing and certification, attracting interest from neighbouring APEC countries.

Addressing the challenges in battery testing standards requires enhancing local infrastructure, developing chemistry-agnostic tests, and updating existing standards to reflect contemporary battery technologies. Strategic development of testing capabilities, aligned with standardisation efforts, will support industry growth, and ensure the safety and reliability of battery products in the market.

Deployment

Integrated Batteries

In integrated battery systems, it is essential that inverters and charge controllers effectively communicate and control battery modules. This integration ensures that charge rates are managed efficiently, thereby protecting the battery from overcharge and overdischarge scenarios.

When integrating different battery types, such as lithium-ion and flow batteries, standards must ensure considerations for ventilation, compatibility, and system integration. Proper integration prevents issues like corrosion and inefficiency, ensuring safe and effective operation while leveraging the strengths of different battery chemistries.

Battery Assembly

In Australia, the secondary battery assembly industry faces significant challenges, particularly in terms of end assembly testing and overall product certification. Many manufacturers operate more as assemblers, acquiring certified equipment and components, then packaging them into modules, packs, or integrated battery energy storage systems. However, they often do not conduct comprehensive testing on the final assembled product. This results in a lack of certification for the final product's performance and safety, a critical gap in the industry.

Standards such as AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* along with the Battery Best Practice Guide, attempt to address these issues, but gaps remain for systems up to 200 kWh. For example, while flow batteries can be certified under AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment*, specific component considerations are often overlooked. Moreover, importing raw cells for assembly in Australia adds complexity, as the final product must undergo design testing, which typically requires shipping overseas, incurring additional time and cost.

To mitigate these challenges, some manufacturers opt to assemble modules overseas, where certification processes may be more streamlined. However, this approach still necessitates careful consideration of component certification and end-to-end system testing for compatibility and safety.

The distinction between manufacturing and assembly is crucial. Similarly, in Australia, if cells are sourced from elsewhere and assembled domestically, it should be explicitly stated that the product is assembled in Australia, rather than manufactured.

Component-level certification ensures the quality and safety of the components used in assembly. Substituting components may require additional testing, depending on their criticality.

Overall, addressing gaps in end assembly testing, certification processes, and component-level verification is essential for ensuring the safety and performance of secondary battery assemblies in Australia. This may involve refining existing standards, enhancing testing protocols, and promoting transparency in product labelling and certification practices.

Advisory Group Survey, Question 5

What is seen as the biggest impediment to Australia's ambition to become a secondary battery manufacturer?

The mass manufacture of batteries in Australia faces significant economic and logistical challenges. Key among these is the cost of production, which includes both materials and labour. Countries like China, with decades of experience and established supply chains, have a substantial head start, making it difficult for Australian manufacturers to compete. Additionally, the cost of importing advanced manufacturing equipment and skilled personnel is exorbitant, necessitating direct federal support and funding to make domestic production feasible.

Australia's lack of specialised battery testing laboratories further complicates the production process. This deficit hinders the ability to efficiently test and validate new battery technologies, increasing time to market and potentially compromising safety and quality. High labour costs in Australia drive the need for advanced, automated manufacturing processes. However, the vast numbers of skilled designers, developers, and technicians required to support these processes are not readily available through local tertiary institutions and vocational education and training programs, creating a skills gap that must be addressed.

Access to necessary standards presents another obstacle, particularly for small research and development (R&D) battery original equipment manufacturers. Costs associated with accessing these standards can limit the ability of smaller entities to innovate and comply with regulatory requirements. The high costs and extended timeframes associated with manufacturing and market entry make it difficult for new players to establish a foothold in the domestic market.

To overcome these barriers, forming joint ventures with established original equipment manufacturers could expedite market entry by leveraging existing capabilities and resources. Additionally, focusing on niche applications for battery energy storage systems in Australia that may not attract overseas original equipment manufacturers could offer a strategic advantage. These applications might include community batteries, autonomous vehicles, and remote area systems, which cater to specific local needs and capitalise on Australia's unique geographical and market conditions. Addressing these multifaceted challenges with targeted strategies will be crucial for advancing Australia's position in the global battery manufacturing landscape.

Recommendations

Based on extensive mapping research and valuable insights from the Advisory Group regarding industry needs, Standards Australia has formulated a set of recommendations to address existing gaps in secondary battery standards. These recommendations aim to seize opportunities within the evolving standards landscape, ensuring that Australia is well-prepared to establish a competitive edge in the international secondary battery manufacturing sector. Priority should be placed on adopting or modifying international standards or regional standards.

Safety

Recommendation 1: Adoption of IEC 62933 series for grid-connected energy storage safety

Recommendation: Industry stakeholders and Standards Australia should collaborate to propose for the adoption of IEC 62933 series, *Electrical energy storage (EES) systems*, which primarily describes safety aspects for people and, where appropriate, safety matters related to the surroundings and living beings for grid-connected energy storage systems where an electrochemical storage subsystem is used. This adoption aims to address safety requirements for grid-integrated electrical energy storage systems, thereby enhancing battery safety.

Rationale: Adopting the IEC 62933 series, *Electrical energy storage (EES) systems* would harmonise local safety standards with international guidelines, ensuring consistency and reliability in electrical energy storage systems. This alignment would enhance safety for individuals and the environment by addressing potential hazards associated with electrochemical-based EES systems. The series fills the standards gap for larger grid connected batteries not covered by AS/NZ 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment.* Additionally, it would simplify regulatory compliance for manufacturers, facilitating easier access to international markets and stimulating economic growth. The adoption of such advanced standards would attract investment, foster innovation in the energy sector, and support environmental goals by promoting the safe integration of renewable energy sources.

Expected benefits:

- **Improved Safety**: The primary benefit is the enhanced safety for individuals and the environment. This standard addresses potential hazards associated with electrochemical-based EES systems, reducing risks of accidents and ensuring safer operation.
- **Market Access:** Manufacturers in Australia would benefit from easier access to international markets as products designed to meet IEC standards are more readily accepted globally. This can enhance export opportunities and stimulate economic growth.
- **Innovation and Investment:** Adopting international standards can attract investment in the Australian energy sector, as companies are more likely to invest in markets where standards and regulations are predictable and aligned with global norms.
- **Environmental Protection**: Ensuring that energy storage systems operate safely contributes to broader environmental goals by supporting the integration of renewable energy sources and reducing reliance on fossil fuels.

Recommendation 2: Establishment of minimum functional requirements for battery management systems

Recommendation: Standards Australia, in collaboration with key industry and government stakeholders, should initiate a project to identify and consider revising existing Australian standards for battery management systems to detail minimum functional requirements.

These requirements should encompass protections against overvoltage, overcurrent and overtemperature, aligning with guidelines from the Battery Best Practice Guide and AS/NZ 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment.* Defining these baseline functionalities aims to ensure essential safety measures across all battery systems, mitigate failure, and enhance overall system reliability.

Rationale: Establishing minimum functional requirements for battery management systems guarantees a foundational level of safety and operational integrity. By aligning with established guidelines and international standards, this initiative addresses critical safety concerns and fosters confidence in battery systems performance.

Expected benefits:

- **Enhanced safety measures**: Establishing minimum requirements safeguards against critical electrical faults, enhancing overall systems safety.
- **Improved reliability:** Mitigates risks of system failures by ensuring battery management systems functionality aligns with industry standards and bets practice.
- **Industry consistency**: Promotes uniformity in battery management systems capabilities across diverse battery systems, facilitating interoperability and reliability.

Recommendation 3: Adoption of key e-mobility safety standards

Recommendation: Industry stakeholders and Standards Australia should collaborate to propose for the adoption of key e-mobility standards, including standards developed by UL Solutions including: UL 2849, *Electrical Systems for eBikes*; UL 2271, *ANSI/CAN/UL/ULC Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications;* and UL 2272, *Electrical Systems for Personal E-Mobility Devices.*

Rationale: Adopting the standards UL 2849, *Electrical Systems for eBikes;* UL 2271, *Batteries for Use In Light Electric Vehicle (LEV) Applications;* and UL 2272, *Electrical Systems for Personal E-Mobility Devices*. This collaboration aims to enhance consumer safety, reliability, and confidence in electric mobility solutions.

Expected benefits:

- **Enhanced safety**: Implementing internationally recognised standards improves the safety and reliability of e-mobility devices.
- **Consumer confidence:** Provides assurance to consumers regarding the safety and performance of electric mobility solutions.
- **Global compatibility:** Facilitates international market access by aligning with widely accepted safety standards.

Recommendation 4: Standards for secure external charging stations in multi-level residential buildings

Recommendation: Industry and government stakeholders and Standards Australia should collaborate to establish standards or guidelines for secure, external charging stations for small e-mobility devices in multi-level residential buildings and shared spaces. These guidelines aim to mitigate indoor charging risks effectively.

Rationale: Developing standards for secure external charging stations promotes safe practice in e-mobility infrastructure. This initiative addresses concerns related to fire hazards and electrical safety, ensuring safe charging environments in residential and shared spaces.

Expected benefits:

- **Enhanced safety measures:** Implementing standards for secure external charging stations reduces indoor charging risks associated with fire and electrical hazards.

- **Improved user confidence:** Promotes trust and confidence among users in the safety and reliability of e-mobility infrastructure.
- **Community well-being:** Supports sustainable and safe e-mobility adoption by ensuring safe charging solutions in residential and shared environments.

Recommendation 5: Guidelines for safe usage and maintenance of e-mobility devices

Recommendation: Industry and government stakeholders should collaborate with Standards Australia to disseminate informative documents and guidelines regarding the safe usage, maintenance, and modifications of e-mobility devices.

Rationale: Launching a public awareness campaign within the industry promotes safe practices and knowledge regarding the proper handling, maintenance, and customisation of e-mobility devices. This initiative aims to enhance user safety, device reliability, and overall industry credibility.

Expected benefits:

- **Enhanced user safety:** Empowers industry professionals with knowledge to safely operate, maintain, and customise e-mobility devices.
- **Industry credibility**: Demonstrates commitment to safety and professionalism, fostering trust among consumers and stakeholders.
- **Continuous improvement:** Promotes a culture of continuous learning and improvement within the e-mobility industry, ensuring ongoing safety and innovation.

Recommendation 6: Standardisation of charging cables for e-mobility devices

Recommendation: Standards Australia and Industry stakeholders should collaborate to explore the implementation of standards for charging cables. These standards will aim to ensure fit-for-purpose solutions that prevent compatibility issues and promote safe charging practices across various e-mobility devices, addressing a critical gap in both Australian and international standards.

Rationale: Introducing standardised charging equipment will ensure interoperability and safety across e-mobility infrastructure. This initiative addresses compatibility concerns, enhances user convenience, and improves safety during charging operations.

Expected benefits:

- **Compatibility Assurance:** Ensures charging cables are universally compatible with e-mobility devices, reducing inconvenience and improving user experience.
- **Enhanced Safety:** Promotes safe charging practices, minimising risks associated with incompatible equipment or faulty connections.
- **Industry Efficiency**: Streamlines e-mobility infrastructure development and deployment by standardising essential charging components.

Recommendation 7: Development of comprehensive safety standards for flow batteries

Recommendation: Standards Australia, in collaboration with industry and government stakeholders and technical experts, should lead internationally in developing comprehensive safety standards for flow batteries by:

- Developing a new Battery Best Practice Guide specifically for flow batteries that integrates safety practices. The guide should:
    - Address issues such as on-site bunding and compliance with chemical storage regulations.

- Include guidelines to facilitate disassembly and recycling, leveraging low batteries' recyclability advantages.
- Establish specific testing protocols that account for flow batteries' distinct mechanical properties compared to lithium-ion counterparts.
- Ensure standards for physical integrity that enhance flow batteries' resistance to mechanical damage, including puncture resilience.

- Revising AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* to encompass specific requirements for flow batteries, covering storage, handling, and installation needs comprehensively.

Rationale: Creating dedicated safety standards for flow batteries ensures their safe deployment and operation, positioning Australia as a leader in this field internationally. By addressing their unique characteristics and integrating comprehensive guidelines, we support industry growth while minimising risks associated with handling, installation, and recycling.

Expected benefits:

- **Enhance safety**: Establishing dedicated standards mitigates risks associated with flow battery deployment and operations.
- **Comprehensive coverage:** Updated standards and guidelines ensure all facets of flow battery management, from installation to disposal, adhere to rigorous safety protocols.
- **Facilitated industry growth**: Supporting flow battery technology with clear regulatory frameworks encourages innovation and marketing confidence.
- **Environmental sustainability:** Guidelines promoting recycling align with global sustainability goals, enhancing the industry's eco-friendly practices.

Recommendation 8: Alignment of battery management system cybersecurity standards with National CER Roadmap

Recommendation: Standards Australia, in collaboration with industry and government stakeholders, should explore aligning battery management system cybersecurity standards with emerging domestic guidelines following standards arising from the National CER Roadmap for remotely accessible devices. This includes safeguards against remote tampering and unauthorised alternations of critical functions, particularly for Distributed Energy Resources.

Rationale: Aligning battery management system cybersecurity standards with evolving protocols from the National CER Roadmap for remote devices ensures robust protection against cyber threats of battery systems. This initiative aims to safeguard the integrity and functionality of Distributed Energy Resources systems, promoting trust and reliability in energy infrastructure.

Expected benefits:

- **Enhanced cybersecurity:** Strengthening battery management system cybersecurity safeguards against remote tampering and unauthorised access, bolstering resilience against cyber threats.
- **Protection of critical functions:** Safeguarding Distributed Energy Resources systems from potential disruptions or compromises, ensuring continuous and reliable operation.
- **Industry confidence**: Building trust through robust cybersecurity measures, fostering confidence in the reliability and security of energy management systems.
- **Regulatory alignment:** Aligning with evolving regulatory requirements to meet cybersecurity challenges effectively, supporting compliance across the energy sector.

Recommendation 9: Development of enhanced testing standards for e-mobility device batteries

Recommendation: Standards Australia should explore the development of enhanced testing standards specifically for batteries used in e-mobility devices, while maintaining international alignment. These standards should incorporate rigorous tests such as higher drop tests, multiple vibration tests, and other stress simulations to replicate real-world usage scenarios.

Rationale: Creating specialised testing standards for e-mobility device batteries ensures reliability and durability under diverse operational conditions. This initiative aims to enhance product quality, safety, and performance in electric mobility solutions.

Expected benefits:

- **Enhanced product reliability**: Establishing rigorous testing standards ensures e-mobility device batteries meet stringent performance expectations.
- **Improved safety:** Mitigates risks associated with battery failures by validating resilience under varied operational environments.
- **Industry leadership:** Positions Australia as a leader in ensuring quality and safety standards for e-mobility technologies.

Reliability

Recommendation 10: Adoption of IEC 61508 for functional safety of battery management systems

Recommendation: Industry stakeholders and Standards Australia should collaborate to propose for the adoption of IEC 61508:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems*, which defines four Safety Integrity Levels to ensure robust safety system performance across various applications. This adoption aims to establish reliable Battery Management Systems standards, safeguarding against risks like overcharging and discharge related hazards, thereby enhancing battery safety.

Rationale: Adopting IEC 61508:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems,* as an Australian standard will provide a structured framework to measure battery management systems safety performance and have Australia align with international standards. This initiative seeks to mitigate potential battery risks, ensuring adherence to stringent safety protocols and preventing incidents such as battery explosions.

Expected benefits:

- **Enhanced safety measures:** Implementing IEC 61508:2010, Functional safety of electrical/electronic/programmable electronic safety-related systems, ensures robust safety protocols in battery management systems, minimising risks associated with battery operations.
- **Standardisation and reliability:** Establishing SILs provides a consistent approach to BMS safety, promoting reliability and performance predictability.
- **Risk mitigation:** Reduces the likelihood of battery-related hazards such as overcharging and explosives, safeguarding users, and environments.
- **Industry alignment:** Aligns Australian standards with global best practices, fostering international competitiveness and trust in local battery technologies.

Performance

Recommendation 11: Enhancing Australia's battery testing capabilities

Recommendation: Industry leaders should collaborate with key stakeholders to expand and enhance local testing facilities for batteries. This initiative includes developing advanced capabilities to reduce reliance on overseas testing, simulate extreme weather conditions, and position Australia as a premier battery testing hub.

Rationale: Developing comprehensive battery testing facilities within Australia reduces dependency on international resources, lowers associated costs, and enhances local capacity. It also promotes Australia as a leader in battery testing, attracting global clients and fostering international partnerships.

Expected benefits:

- **Enhanced local capacity**: Establishes robust local testing capabilities, reducing costs and dependency on international testing facilities especially benefiting start-ups and accelerating early-stage innovation.
- **Global competitiveness:** Establishes Australia as a premier battery testing hub, drawing international clients, and cultivating strategic global partnerships, particularly within the APEC region.
- **Safety and compliance**: Ensures adherence to safety standards and promotes best practices in battery storage and disposal.
- **Innovation and versatility:** Supports the development of versatile testing protocols that accommodate a wide range of battery chemistries (beyond lithium-ion) and configurations.

Deployment

Recommendation 12: Develop comprehensive standards for testing assembled battery systems to ensure safety and compatibility

Recommendation: Standards Australia should develop and implement comprehensive standards for end-product testing of assembled battery systems. This should include protocols for assessing the safety and compatibility of battery management systems and inverter integration.

Rationale: Adopting a rigorous Assess Full System Safety approach is crucial for ensuring the overall safety and reliability of battery systems. By establishing clear standards for testing fully assembled products, including the integration of battery management systems and inverters, the industry can achieve higher levels of product safety and compatibility.

Expected benefits:

- **Enhanced safety:** Improved overall product safety through comprehensive testing of assembled systems.
- **Compatibility assurance:** Better integration and compatibility of battery management systems and inverters, reducing the risk of system failures.
- **Industry alignment:** Standardised testing protocols facilitate consistent quality and performance across the industry.

Recommendation 13: Update AS/NZS 5139:2019 to require comprehensive testing of fully assembled battery systems for enhanced safety and performance

Recommendation: Industry stakeholders and Standards Australia should collaborate to propose to update AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment,* to include a requirement for the Power Conversion System to communicate effectively with the battery management system, ensuring the maintenance of safe operating parameters for fully assembled battery products and align with emerging international standards. These protocols should assess the entire system, including the compatibility and performance of all integrated components, rather than relying solely on pre-certified parts.

Rationale: Comprehensive end-assembly testing ensures that the safety and performance of battery products are maintained at the system level. By verifying the interaction and integration of all components in the assembled product, this approach addresses potential issues that pre-certification of individual parts may not reveal, leading to safer and more reliable battery systems.

Expected benefits:

- **Improved safety:** Ensures that fully assembled battery products meet stringent safety standards, reducing risks to consumers and the environment.
- **Enhanced performance:** Verifies the overall performance and compatibility of the entire system, leading to more reliable and efficient battery products.
- **Consumer confidence:** Increases consumer trust in the safety and performance of battery products by ensuring rigorous testing and quality control.

Recommendation 14: Develop and implement comprehensive education and training programs for battery assembly and testing

Recommendation: Manufacturers and assemblers in the battery industry should proactively develop and implement comprehensive education and training programs. These programs should focus on the latest standards and best practices for battery assembly and testing.

Rationale: Adopting up-to-date standards and best practices is crucial for maintaining consistent and high-quality assembly processes across the industry. By investing in targeted education and training, companies can improve product quality, safety, and competitiveness.

Expected benefits:

- **Quality improvement:** Enhanced product quality through adherence to best practices.
- **Consistency**: More uniform assembly practices across the industry.
- **Compliance**: Better compliance with industry standards, reducing the risk of product failures and recalls.

Recommendation 15: Promote and implement strategies to utilise Australian testing facilities for battery systems

Recommendation: Manufacturers and industry stakeholders should actively pursue and implement strategies to use Australian testing facilities. This approach aims to support local infrastructure and expertise while reducing the logistical challenges and costs associated with overseas testing.

Rationale: Leveraging local testing facilities enhances the utilisation of domestic resources, improves logistical efficiency, and can be more cost-effective compared to overseas alternatives. Utilising Australian facilities supports the development of local expertise, reduces turnaround times, and fosters economic growth within the country.

Expected benefits:

- **Identify incentives:** Develop financial or operational incentives such as tax benefits, grants, or subsidies to encourage the use of local testing facilities.
- **Promote awareness:** Conduct awareness campaigns highlighting the capabilities and advantages of Australian testing facilities to industry stakeholders.
- **Collaborate with industry:** Engage with industry associations and local testing facilities to align incentives with industry needs and foster partnerships.
- **Monitor and evaluate**: Continuously assess the effectiveness of the incentives and programs, adjusting as needed based on industry feedback and uptake.

Roadmap

The following provides a brief description of the recommendations outlined herein:

E-MOBILITY STANDARDS

Standards for e-mobility devices are urgently needed to ensure safety, performance, and interoperability, while also preventing battery fires and promoting safe home use.

Recommendations are focused on adopting international standards, addressing safety in muti-level dwellings, and creating public awareness.

BATTERY MANAGEMENT SYSTEM STANDARDS

Adopting or updating battery management systems' standards facilitates innovation, addresses emerging risks, and promotes interoperability, ensuring that products and systems meet current and future requirements effectively.

Recommendations are focused on adopting and modifying existing standards with a cybersecurity lens.

CHARGING CABLE STANDARDS

Charging cable standards are essential for ensuring safety, reliability, and compatibility across devices, preventing hazards, and enhancing performance.

Recommendations are focused on adopting standards.

FLOW BATTERY STANDARDS

As the global demand for sustainable energy storage solutions rises, flow batteries have emerged as a promising technology due to their scalability, long cycle life, and capacity for large-scale energy storage.

Recommendations are focused on modifying standards and developing a Battery Best Practice Guide specifically for Flow Batteries.

AUSTRALIAN TESTING STANDARDS

Australia urgently needs advanced testing facilities to support the development and validation of emerging technologies, ensuring safety, compliance, and competitiveness in global markets.

Recommendations are focused on uplifting Australian testing capabilities to meet battery industry demands to provide full system testing support through incentives to develop and support local test facilities.

ASSEMBLY AND MANUFACTURING STANDARDS

Standards for assembled batteries and handling training for manufacturers are vital to ensure safety, quality, and reliability, and to prevent accidents in battery production and use.

Recommendations are focused on encouraging full assembly testing locally and providing education and training for those working in the battery manufacturing industry.

Standards Pathway

Standards Adoption			
Designation	**Recommendation**	**Title**	**Proponent**
IEC 62933	1	Electrical energy storage (EES) systems	Industry
UL 2849	3	Electrical Systems for eBikes	Industry
UL 2271	3	ANSI/CAN/UL/ULC Standard for Batteries for Use In Light Electric Vehicle (LEV) Applications	Industry
UL 2272	3	Electrical Systems for Personal E-Mobility Devices	Industry
IEC 61508:2010	10	Functional safety of electrical/ electronic/programmable electronic safety-related systems	Industry

Standards Revision			
Designation	**Recommendation**	**Title**	**Proponent**
Battery Best Practice Guide	2	Battery Best Practice Guide	Industry
AS/NZ5139:2019	2 7 13	Electrical installations - Safety of battery systems for use with power conversion equipment	Industry

Standards Development			
Designation	**Recommendation**	**Rationale**	**Proponent**
External charging stations for small e-mobility devices in multi-level residential buildings	4	Addresses concerns related to fire hazards and electrical safety, ensuring safe charging environments in residential and shared spaces	Industry
E-mobility Charging Cables Guidelines	6	Addresses concerns regarding compatibility and enhanced user convenience and safety during charging operations.	Industry
Battery Best Preactice Guide - Flow Batteries	7	Supports industry growth while minimising risks associated with handling, installation, and recycling of flow batteries	Industry

Referenced Standards

AS/NZS 5139:2019, *Electrical installations - Safety of battery systems for use with power conversion equipment*.

AS 5374:2023, *Energy storage system performance.*

IEC 61508:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems.*

IEC 62133:2017, S*econdary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications.*

IEC 62133-2:2017, *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems.*

IEC 61982, *Series Secondary batteries (except lithium) for the propulsion of electric road vehicles*

IEC 62281:2019, *Safety of primary and secondary lithium cells and batteries during transport.*

IEC 62619:2022, *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 62933, *Series Electrical energy storage (EES) systems.*

IEC 62933-5-2:2020, *Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems.*

IEC 62933-5-3:2023, *Electrical energy storage (EES) systems - Part 5-3: Safety requirements for grid-integrated EES systems - Performing unplanned modification of electrochemical based system.*

UL 2271, *Batteries for Use in Light Electric Vehicle (LEV) Applications.*

UL 2272, *Electrical Systems for Personal E-Mobility Devices.*

UL 2580, *Batteries for Use in Electric Vehicles.*

UL 2849, *Electrical Systems for e-Bikes.*

UL 9540, *Energy Storage Systems and Equipment.*

UL 9540A, *Test Method.*

UN 38.3, *Testing for lithium batteries.*

Appendix 1. Advisory Group Members and Participants

Secondary Batteries – End User Advisory Group Members	
Akaysha Energy	Duwayno Robertson
Powercor	Hilary Lai
CSIRO	John K Ward
QUT	Josh Watts
Powin	Ryan Turner
Enphase Energy	David Minchin
Redflow	Conan Jones

Secondary Batteries – End User Participant Members	
Department of Industry Science and Resources	Dan Loudon
Department of Industry Science and Resources	Will Larn

Appendix 2. Participation in Secondary Battery Standards

National Committee EL-005 - Secondary Batteries Technical Committee
International Committee: IEC/TC 120 Electrical Energy Storage (EES) Systems
Current Active Members: 27 nominating organisations
Scope: Standardisation in the field of design, construction, performance, installation and maintenance of: • secondary batteries; • battery ancillary equipment, for example: battery management systems; • battery hydrometers; and • battery chargers and associated equipment of the automotive, motive power and stationary type

International Committee
IEC TC 120 Electrical Energy Storage (EES) systems

IEC Membership: 35 Full Country Members
Participating Countries: 26 countries (including Australia)
Observing Countries: 9 countries

Scope:

1. Standardization in the field of grid integrated EES systems in order to support grid requirements.
    - TC 120 focuses on system aspects on EES systems rather than energy storage devices.
    - TC 120 investigates system aspects and the need for new standards for EES systems.
    - TC 120 also focuses on the interaction between EES systems and Electric Power Systems (EPS).
2. For the purpose of TC120, “grid” includes and is not limited to applications in:
    a. transmission grids
    b. distribution grids
    c. islanded grids
    d. customer installation

    It is also confirmed that TC120 can include “smart grid” Storage in railway systems is considered if it contributes as an EES system to the grid as referenced in 2 (a) and (d).

    Note: Grid is a synonym for electricity supply network (ISO/IEC 15067-3). A smart grid is an electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:

    - To integrate the behaviour and actions of the network users and other stakeholders; and
    - To efficiently deliver sustainable, economic and secure electricity supplies (IEV 617-04-13).

5. EES systems include any type of grid-connected EES systems which can both store electrical energy from a grid or any other source and provide electrical energy to a grid. By that feature it maintains the balance between electrical energy demand and supply over a period of time.

    TC 120 considers all storage technologies as long as they are capable to store and to discharge electrical energy. (Energy storage itself is not in the scope of the work).

    Note: Thermal storage systems are included in the scope, only from the point of view of extracting and injection electricity. Uninterruptible power systems only having that function (UPS) and similar backup power sources are not included in the scope of TC 120.

6. The scope of TC 120 is to prepare normative documents dealing with the system aspects of EES systems.

    For example, TC 120 deals with defining unit parameters, testing methods, planning and installation, guide for environmental issues and system safety aspects.

Appendix 3. Australian Standards Adoption/Modifications 2017-2024

Standard Designation	Standard Title	Safety	Reliability	Performace	Deployment	Testing	Chemistry
AS 5374:2023	Energy storage system performance			✓		✓	Chemistry-agnostic
AS 5732:2022	Electric vehicle operations - Maintenance and repair	✓				✓	Chemistry-agnostic
AS 60095.1:2022	Lead-acid starter batteries, Part 1: General requirements and methods of test (IEC 60095-1:2018 (ED. 8.0), MOD)					✓	Lead Acid
AS 60095.6:2022	Lead-acid starter batteries, Part 6: Batteries for micro-cycle applications (IEC 60095-6:2019 (ED. 1.0), MOD)					✓	Lead Acid
AS 60896.11:2023	Stationary lead-acid batteries, Part 11: Vented types - General requirements and methods of tests (IEC 60896 11:2002 (ED 1.0) MOD)					✓	Lead Acid
AS 60896.21:2023	Stationary lead-acid batteries, Part 21: Valve regulated types - Methods of test (IEC 60896-21:2004 (ED 1.0) MOD)					✓	Lead Acid
AS 60896.22:2023	Stationary lead-acid batteries, Part 22: Valve regulated types - Requirements (IEC 60896-22:2004 (ED 1.0) MOD)			✓		✓	Lead Acid
AS IEC 62619:2023	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	✓				✓	Lithium
AS/NZS 4755.3.5:2016	Demand response capabilities and supporting technologies for electrical products, Part 3.5: Interaction of demand response enabling devices and electrical products - Operational instructions and connections for grid-connected electrical energy storage (EES) systems				✓	✓	Chemistry-agnostic
AS/NZS 4777.2:2020	Grid connection of energy systems via inverters, Part 2: Inverter requirements	✓		✓	✓	✓	Chemistry-agnostic
AS/NZS 5139:2019	Electrical installations - Safety of battery systems for use with power conversion equipment	✓			✓		Chemistry-agnostic
AS/NZS 60335.2.29:2017	Household and similar electrical appliances - Safety, Part 2.29: Particular requirements for battery chargers (IEC 60335-2-29 Ed 5.1, MOD)	✓					Chemistry-agnostic