Battery Risk & Safety Study

White Paper

June 2020

A partnership project of GPT, ERM Power & City of Sydney

Executive Summary

The introduction of battery storage in Australia is expected to lead to a transformational change in energy supply and security at the network and asset level. Yet despite the financial, environmental and societal benefits this technology has to offer, the number of commercial battery installations in Australia to date is quite small. It is likely the range of OHS&E risks posed by the battery chemistries, along with the investment risks in adopting a relatively untried technology, are key contributors to the current lack of uptake.

To help overcome these risks, GPT has partnered with ERM and CTP to conduct a risk and safety study into the installation / operation of stationary batteries, along with electric vehicles / electric vehicle charging infrastructure, in commercial buildings. Additional funding for this study has been provided by City of Sydney that enables the findings and recommendations of this study to be made publicly available, with the expectation this will assist other companies in their endeavors to implement battery storage solutions across their assets. The advancement of this knowledge, with the intention to drive a significant uptake of battery storage applications in Australia, is therefore the overarching objective of this project.

The following risk categories have been considered for this study:

- Health and Safety
- Environment
- Community and Reputation
- Legal & Compliance
- Operational
- Strategy
- Financial

An extensive literature review was undertaken, with relevant resources collected in each risk category that focus on instances of deployment, incidents posing hazards, new standards and regulations, strategic and financial models and issues surrounding installation / operation of batteries in commercial buildings. Complementing this research, related knowledge has been pooled from within the project partner organisations and a broad array of stakeholders within industry and academia.

From this collective knowledge, a Battery Hazard Review Tool has been created and used to underpin this initial risk assessment process. The tool looks at the degree of applicability the various risks pose through the different stages of the project, as well as how the respective technologies compare, as too, the types of assets considered. Suggested control measures to mitigate the various risks were drawn from prevailing Standards and industry practices and supported by best-practice policies, procedures and practices (e.g. procurement, contractor management, OHS&E and risk management).

The considerations, examples, references and case studies within each risk category aim to provide a solid foundation to enable a more detailed, site-specific evaluation of battery applications. To aid in this process, a preliminary investigation of an office tower and a regional shopping centre was undertaken to illustrate the types of costs that would need to be considered within a full feasibility analysis for proposed novel energy storage deployments of lithium-ion and vanadium flow batteries.

Some of the key findings drawn from this study are outlined below.

- Currently, lithium-ion batteries are considered to be the dominant technology in stationary applications, in terms of cost-effectiveness, cycle life and efficiency, although they do pose a very serious risk of explosion / fire under certain extreme circumstances. In contrast, flow batteries are far more inert, but due to relatively poor energy density /efficiency, they result in significant space and weight penalties. The idiosyncratic nature of these two main battery chemistries will thereby necessitate differing works and costs to mitigate the potential risks they individually pose.
- Despite the novel nature of battery storage applications, there is likely to be comparable plant (e.g. diesel fuel tanks, lead-acid batteries), a multitude of existing health, safety & environmental hazards and compliance challenges that building owners have learned to safely and effectively manage. This, coupled with prior exposure to (and learnings from) previous investments in energy infrastructure projects (e.g. solar panels, co-gen units) should provide some comfort and guidance to companies considering commercial battery applications.
- The most material financial risks are likely to stem from project delays and/or poor system performance, which are caused by:

- failures in the design or supply chain processes;
- unsuccessful engagement with key stakeholders (e.g. local residents, tenants, insurers);
- a lack of suitably-skilled technicians or availability of key parts; and
- uncertainty or misinterpretation of prevailing standards or grid connection processes.

At the completion of this study, it is clear, with the breadth of potential hazards posed by the various battery chemistries and the differing nature of assets to be targeted for commercial applications, that detailed planning and investigations are warranted to best inform investment decision-making. It is hoped this study, and subsequent updates from others via the Battery Hazard Review Tool, will provide greater depth of understanding to assist in this process and thereby unlock the considerable benefits offered by commercial battery systems.

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1 Background & Approach

In 2019 GPT devised an Energy Master Plan (EMP) which included a battery stream. Within this battery stream, ERM identified and developed, through desktop analysis, six battery pilot project opportunities for GPT. During this phase of the project it was determined that there was not stakeholder confidence to proceed with these battery projects without:

- developed and agreed risk and safety managed parameters for batteries; and
- a full feasibility assessment of delivering batteries – capturing and substantiating all project costs required to deliver projects turnkey and without variations.

GPT Wholesale Office Fund (GWOF) has committed funds to undertake a Risk and Safety study on batteries. Additionally, the City of Sydney has provided support funding to expand the scope of the study to ensure the knowledge developed is captured and shared to achieve broader societal buy-in on the development and implementation of battery projects that enable decarbonisation. For phase 2 of the battery project, the scope has expanded to include establishing risk managed parameters for electric vehicles (EVs) and electric vehicle charging infrastructure (EVCI). Throughout this process, the collective EV / EVCI risks are considered only in the context of risks specific to EVs in buildings that are unique to the battery storage and no other vehicular risks.

As part of the City of Sydney funding, GPT is committed to producing a public report for the City to increase broad sector knowledge on how to unlock batteries and EVs / EVCI in office and retail assets. The project will also be opened to contributors from a broader range of industries as well as broader range of companies from with the property industry.

Learnings from this project will assist decision-making with regard to future deployment opportunities by applying them to real building situations. Therefore, the project includes identifying how battery storage and EVCI may impact the risk profile of two GPT sites, 580 George Street and Rouse Hill Town Centre, by:

- reviewing characteristics of different battery chemistry types;[1]
- considering equipment compliance with IEC62619 (international best practice) and AS/NZS 5139 (Australian battery installation standard), as well as prevailing and proposed regulatory standards for batteries/EVs;
- developing parameters and controls for installation and battery chemistries that meet current and future standards;
- preparing functional descriptions of installation works, O&M, and impacts to site operations; and
- carrying out an assessment of how battery parameters compare with existing technologies present in GPT's assets, such as UPS systems, diesel generators, and EV charging points.

The project will also involve engaging third parties to assist in determining how the intended approach impacts the risk profile of the 580 George Street and Rouse Hill sites.

A grid connection early inquiry will need to be submitted and the business cases for battery pilot projects on each of the sites will need to be developed, covering off on proposed connection arrangements and revenue streams. These business cases will determine funding requirements and provide a basis for risk assessments to be conducted by third parties (e.g. insurers, structural assessors, operational assessors).

Whilst the publicly available nature of the report enables it to be used as a reference point for others who are considering the implementation or impact of batteries in buildings, it is important to note it should not be used in place of a suitably detailed evaluation that takes into account the specifics of a building. In this regard, building owners should undertake their own due diligence, risk assessment and review processes to ensure that their particular buildings and risk management frameworks are considered in appropriate detail and context.

[1] Note that GPT buildings already contain UPS batteries, which tend to use Lead-Acid and Nickel Cadmium chemistries

2 Sources of Knowledge

This report aims to bring together knowledge and learnings as a practical reference source for companies considering the implementation of battery projects, or impacts of batteries from EVs and EVCI, in their buildings.

The knowledge has been sourced from:

- literature reviews;
- The GPT Group;
- ERM and its parent entity (Shell);
- technical consultants to the project (Clean Technology Partners); and
- industry contributors to a reference consultation group (see Appendix 1).

2.1 Literature Review

Guided by the identified battery technologies and risk categories set out in subsequent sections of this report, and drawing on the insight of experts around the world working for ERM's parent entity, a detailed literature review has been conducted based on:

- incidents of battery deployment in commercial buildings across the world;
- heath, safety, and environmental incidents that have been reported in academic and industrial journals relating to battery installation and operation in commercial buildings;
- incidents in commercial buildings that present hazards analogous to those posed by batteries (hazardous material, other electrical infrastructure etc.);
- articles covering community and reputational issues associated with battery installation and operation in commercial buildings;
- reporting and commentary around new standards and regulations to govern the installation and operation of batteries in commercial buildings; and
- publications commenting on financial frameworks for batteries in commercial buildings and battery economics across various markets.

2.2 The GPT Group

The GPT Group is an owner, developer, manager and fund manager for commercial office, retail and logistics properties. GPT Wholesale Office Fund (GWOF) is an international leader in decarbonising its premium office portfolio which will achieve Carbon Neutral Certification for all of its 18 operating office towers by end 2020.

GWOF's commitment to carbon neutrality has led to it exploring implications of operating in a low or no carbon energy future. In being an early adopter of switching to renewable energy, it realises that it also needs to be an early manager of a less dispatchable electricity supply and, in this regard, batteries and other demand side energy flexibility projects are being reviewed and implemented. These learnings have been utilised in development of risk management processes and shared in this paper.

2.3 ERM and Shell

ERM has been engaged as the principle consultant to deliver this review and report. ERM is one of Australia's leading commercial and industrial electricity retailers, providing large businesses with end to end energy management, from electricity retailing to integrated solutions that improve energy productivity.

Its parent company Shell Energy is 100% Shell-owned and provides new competition and choice in the Australian energy market, reflecting the Shell Group's aim to meet the energy needs of society in ways that are economically, socially and environmentally viable, now and in the future

Through these operations, locally and internationally, ERM is able to contribute to the knowledge development of risk management practices for novel energy storage technologies deployed in commercial buildings by accessing insights from storage deployment pilots across the globe in a variety of project environments.

2.4 Clean Technology Partners

The report has drawn on the expertise of ERM's project partner, CTP, and cross-referenced literature findings with its knowledge bank around battery installation and operation in commercial buildings.

CTP is a renewable energy consulting and project management company. It has experience in over 1 GW of clean energy projects and has successfully completed over 1,000 major projects across all of Australia. CTP's work spans solar PV, wind generation and energy storage across the entire project lifecycle from upfront feasibility studies through to system commissioning and operational troubleshooting. Principal consultants from CTP were involved in the development of the newly released Australian Standards for AS 5139 covering safety of battery systems for use with power conversion equipment

2.5 Industry Contributions

As part of this report, a broad range of stakeholders has been consulted in the development of the knowledge base and, in particular, consideration of potential risks that battery technology may bring to buildings. Whilst there has been a focus on the property industry, contributors have come from the follow relevant stakeholder groups:

- Commercial and retail operations management
- Property risk professional
- Insurance brokers
- HVAC engineers
- Fire safety specialists
- EV specialists
- Energy storage technology specialists

A full list of the stakeholders that were consulted in the process is included in Appendix 1

3 Stationary Storage Technologies

This report has focussed on battery technologies that are under consideration for in-building battery storage technologies, however, it has also drawn from the knowledge developed over years of utilising energy storage for other building purposes, particularly back-up electricity.

Relevant stationary energy storage includes:

- Diesel fuel;
- Lead acid batteries;
- Lithium-ion batteries;
- Flow batteries; and
- Other emerging battery technologies.

3.1 Diesel Fuel

Diesel fuel coupled with a diesel-fired electricity generator is a common form of on-site energy storage. Unlike gas generation, which typically requires a site to be connected to a gas reticulation network, diesel enables a site to have on-site backup generation for a nominated period, depending on the size of the diesel storage tank. Diesel is a stable, though highly flammable liquid, and must be stored and protected appropriately to minimise risk of fire and contamination. The prevalence of diesel generation in commercial buildings makes it an important reference point when considering the risks posed by new stationary energy storage technologies.

3.2 Lead-Acid Batteries

Lead acid batteries are the earliest type of rechargeable battery. They have a relatively high power-to-weight ratio, making them suitable for starting motors in internal combustion engine vehicles and for uninterruptable power supply (UPS) systems. While their very low energy-to-weight ratio and energy-to-volume ratio makes them less well suited to high-volume stationary storage within commercial buildings, the prevalence of lead acid batteries in low-volume UPS systems, as well as vehicles that are already integrated into commercial buildings, makes them an important reference point when considering the risks posed by new stationary energy storage technologies.

3.3 Lithium-Ion Batteries

Lithium-ion includes the following technologies:

- Lithium Cobalt Oxide (LCO) – Commonly used in portable electronics as it offers the highest energy density of commercial lithium battery technologies. Its short cycle life, however, makes it unsuitable for most stationary storage applications.
- Lithium Titanate (LTO) – Offers extreme thermal stability, power delivery, and cycle life, but has high cost per unit of energy capacity. The ability of LTO to deliver its energy capacity repeatedly and over an extremely short period makes it competitive in high-power, high-cycling applications, but low energy density generally makes them unsuited for most stationary storage applications.
- Lithium Iron Phosphate (LFP) – Offers high thermal stability, power delivery, and cycle life and therefore competitive in stationary storage applications, competing with NMC/NCA for majority market share. This technology has a lower energy density than NCA/NMC equivalents.
- Lithium Nickel Manganese Cobalt Oxide (Li-NMC) & Lithium Nickel Cobalt Aluminium Oxide (Li-NCA): similar performance to LFP, but lower thermal stability. Some researchers claim superior high temperature tolerance. Higher material costs but lower manufacturing costs than LFP.

Lithium-ion batteries are currently the dominant technology in high-cycling stationary applications owing to the following properties:

- Low cost per unit of nameplate power capacity
- Moderate cost per unit of nameplate energy capacity
- Moderate-high cycle life
- High round-trip efficiency

Lithium-ion battery technology has been widely deployed and is readily scalable due to its modular nature. There are reputable lithium-ion battery suppliers in Australia who can provide local technical support. The widespread deployment of this technology has meant that fault issues and performance characteristics are widely understood. Standard warranties typically cover 10 years or 2,750+ cycles.

Among conventional battery technology, lithium-ion has the highest energy density and its round-trip efficiency is typically 80-85%. However, cycling more than once per day will reduce battery efficiency and lifespan, as will exposure to high or low temperatures.

The major drawback of the technology is that each lithium-ion battery cell must be kept within strict voltage and temperature limits to avoid failure and fire/explosion risks. The result is that sophisticated monitoring and protection devices must be integrated into each battery string, with the capacity of each string limited by its weakest cell.

While lithium-ion batteries do not produce gases during normal operation, thermal runaway can be initiated at temperatures of 70-90 degrees Celsius. At temperatures of greater than 200 degrees Celsius, lithium-ion cathodes begin to breakdown, releasing oxygen and increasing the potential for fire and explosion. This sort of temperature can result from a short-circuit within a cell as a result of physical damage or improper use (e.g. recharging an over-discharged cell, recharging a cell below 0 degrees Celsius, or charging / discharging too rapidly), thereby heightening the importance of a suitable battery management system.

Recycling of lithium-ion batteries remains in its infancy worldwide. It is generally unprofitable to recycle lithium-ion batteries, meaning that most are disposed of via traditional landfill. If batteries are fully discharged before reaching landfill then this is not a significant issue, however, if batteries retain charge and are subsequently crushed, there is increased chance of short-circuit resulting in explosion and fire. Some manufacturers offer disposal and recycling options and are researching ways to reduce recycling costs as this is anticipated to become a significant issue in the medium term.

3.4 Flow Technology & Other Emerging Technologies

Unlike conventional batteries, which store energy as the electrode material, flow batteries store energy as electrolytes in flow cells. This means that flow batteries can recharge close to instantly by replacing electrolyte liquid and can cycle more often and to greater depths (100%) than conventional batteries with no impact on battery lifespan. The use of flow batteries is considered only as a source of energy storage and utilisation within a building and not for use with EVs.

3.4.1 Vanadium

Redox flow batteries use two fully-soluble redox couple solutions in each half-cell, making it more like a rechargeable fuel cell than a battery. Most of the redox flow battery development of recent decades has focused on vanadium redox battery (VRB) technology.

While first developed in the 1980’s, vanadium battery technology is yet to achieve widespread commercial deployment, mainly due to limitations in the proton exchange membrane technology. Recent technology developments have brought costs down, to the point where proponents argue that VRB technology is now competitive with lithium-ion technology. Key advantages of a VRB system include:

- the electrolyte does not degrade with cycling; it is fully recyclable or can be sold at end of battery life (representing ~30% of CAPEX);
- it is a non-flammable electrolyte; and

- it is able to operate in harsh or extreme temperature environments.

VRB energy density and round-trip efficiency (~70%), however, are among the poorest of all commercial battery technologies, resulting in a significant space and weight penalty when compared to other battery storage technologies.

Off-the-shelf VRB products are still limited in their availability and current applications in Australia have been designed for specific facility or system requirements, with little scope to reduce or increase capacity as requirements change. While annual servicing is required (with a major overhaul of all components after 15 years), there are few qualified technicians in Australia, which would therefore necessitate flying in a technician from overseas (battery manufactures are typically based in the US, Japan, or Germany).

VRB is considered low-power high-energy, generally designed with a 1:4 power to energy ratio. This means that VRB technology tends to be poorly suited to sites with limited available space, however, VRB will perform well in applications that require high cycling (more than once per day) and can cope with a range of extreme temperatures.

While VRB electrolyte is non-flammable, small amounts of hydrogen are generated during charging and this gas must be discharged from electrolyte tanks into the atmosphere to minimise the risk of explosion and fire. The electrolyte, which consists of vanadium dissolved in sulphuric acid, is highly corrosive, although (to date) tank rupture is rare and recycling opportunities are widely available due to the electrolyte's high residual value.

3.4.2 Zinc-bromine (Gelion) batteries

A hybrid flow battery technology employing zinc-bromine is being developed by Gelion Technologies, which was spun out of the University of Sydney. The rationale for developing this battery chemistry was to utilise broadly accessible components and to achieve low operating costs at scale. Gelion's technology is currently in pre-commercial stages with the aim for an initial pilot deployed in India in 2020.

Gelion's Endure is a stationary energy storage battery comprising multiple sealed cells with an aqueous electrolyte and a simple manufacturing process. It provides 100% depth of discharge and in its uncharged state the electrolyte is a relatively benign aqueous salt that poses minimal risk to people or the environment. When charged, it will contain a stabilised form of bromine that has been complexed with a proprietary chemical that acts as a fire retardant, making the battery virtually incombustible. The battery is also fully recyclable at end of life, with its primary materials being plastic, carbon, and saltwater.

The ability to fully discharge to 0V improves electrical safety as transport, installation, and maintenance can all be performed with the battery carrying no electrical potential.

3.4.3 Aqueous hybrid batteries

Otherwise known as 'saltwater' technology, aqueous hybrid-ion batteries are composed of saltwater electrolyte, manganese oxide cathode, carbon composite anode, and synthetic cotton separator. This technology is advantageous from a safety and environmental perspective as it does not contain heavy or toxic chemicals and is non-flammable and non-explosive.

3.4.4 Lithium-sulphur batteries

Some consider lithium-sulphur batteries as a natural successor to lithium ion batteries, given their higher energy density and lower input costs. Monash University is a leader in this technology, having developed what it claims to be the world's most efficient lithium-sulphur battery. These batteries use the same materials that are found in lithium-ion batteries but with reconfigured sulphur cathodes to accommodate higher stress loads without a drop in overall capacity or performance. The technology offers higher performance, lower manufacturing costs, easily sourced input materials, and a smaller environmental footprint.

4 Mobile Energy Storage Technologies

This report also considers the impact of EV's and EV charging stations on buildings. Whilst this is currently a cottage industry, it is likely to grow exponentially in the coming decade, so building owners need to be aware that EVs and EV charging stations will be a part of their car park risk profile in the future.

Many of the risks relating to EVs are not completely new. Petrol, LPG and diesel vehicles already come with a set of risks. Knowledge developed over years of dealing with vehicle risks and energy storage in the form of fuels provides a baseline risk management capability for many buildings that will need to be refined and added to for EVs and EV charging.

Relevant mobile energy storage includes:

- Internal combustion engine vehicles (ICEs) using petrol fuel;
- Electric vehicles (EVs) using lithium-ion batteries; and
- Hydrogen fuel cell electric vehicles (FCEV) using hydrogen fuel.

4.1 Internal Combustion Engines

Petrol-fuelled ICEs are the dominant form of light-vehicle transport and therefore are already well integrated into commercial buildings, including GPT's sites. ICEs therefore provide an important reference point when considering the risks posed by new mobile energy storage technologies.

4.2 Electric Vehicles

Lithium-ion is the dominant battery technology for EVs and so the risk posed by EVs are similar to those of stationary lithium-ion batteries. Unlike ICEs, however, that are not typically re-fuelled within commercial buildings, the housing of EVs tends to warrant the availability of charging facilities. Fast-charging infrastructure is likely to pose various challenges from an installation (including grid connection) perspective, as well as from an operational perspective.

4.3 Fuel-Cell Electric Vehicles

Hydrogen-fuelled electric vehicles are becoming more prevalent in European markets, where growing infrastructure for re-fuelling, along with incentives to nudge consumers away from ICEs, are supporting their uptake. While there is some progress towards using hydrogen to power heavy vehicle fleets in Australia, as a mobile energy storage technology it remains in its infancy, however, the uptake of FCEVs, like EVs, is expected to accelerate in the medium to longer term. FCEVs, therefore, provide an important reference point when considering the risks posed by new mobile energy storage technologies.

5 Risk Assessment Process

During the first phase of engagement in this part of GPT's Energy Master Plan, most participants noted health and safety as the primary concern relating to large-scale battery applications. The consultation process for this study returned a similar finding, in that health and safety risks garnered the biggest area of focus, although additional risks were also considered to enable a more wholistic assessment.

The risks assessed within this study have been broadly categorised, with a high-level summary tabulated below:

Risk Category	Some Examples of Risk Sources
Health & Safety	- Electrical - Thermal - Chemical - Internal Environment - Structural
Environmental	- Chemical (toxic substances)
Community & Reputation	- Reputational
Legal & Compliance	- Compliance
Operational (People, Processes & Systems)	- Operational - Cyber security
Strategy	- Project delays
Financial	- Project delays - Poor system performance - Lack of project precedence

To facilitate the risk assessment process a Battery Hazard Review Tool was developed (refer to Appendix 2). This tool has been designed to assist would-be battery project proponents in the initial decision-making process by raising awareness of the potential challenges that need to be taken into account. Such challenges are presented across the various stages of a battery project: from the human rights considerations associated with the mining / manufacture of batteries; to practical issues presented in the transportation and installation processes; the potential performance problems encountered in the operation / maintenance period; and finally, the environmental challenges in disposal of batteries at end-of-life.

Suggested control measures to mitigate the various risks are drawn from prevailing Standards and industry practices and supported by 'best-practice' policies, procedures and practices relating to procurement, contractor management, OHS&E and broader risk management.

The Battery Hazard Review Tool also enables evaluation of the degree of applicability to which the various risks are likely to present across the respective battery technologies. It also provides a mechanism for comparing the potential for risk across and within different asset classes.

By way of example, this could mean assessing:

- the extent to which the costs to safely accommodate the size and weight of a large-scale vanadium flow system in a retail car park, and the resultant loss in revenue, outweigh the system's benefits;

- which location within a portfolio of high-rise office assets best provides the required level of protection to house a large-scale lithium-ion stationary battery system; or

- which location across the country poses the lowest risk of problems with grid connection approvals or stakeholder opposition.

Beyond the project decision-making process, the tool could be used to create a planning checklist and be modified to enable a risk assessment of a completed installation.

This section of the report expands on the considerations for each of the risk categories. It introduces a few examples of specific risks, as well as provide references and case studies for deeper consideration.

The considerations, examples, references and case studies for each risk category aim to provide a solid foundation to then move into risk assessment processes for battery projects and EV's in commercial office and retail buildings.

It's important to note the hazards and control measures listed in the tool and this report are not considered definitive. Additionally, each company will have its own unique risk management frameworks and appetites that should separately consider likelihood and consequence of impact from the hazards. Different companies have different risk appetites, which is why the risk review focusses on hazards and controls and leaves the end user to overlay their own risk management framework for classifying inherent and residual risk status.

The reference group that was consulted in developing the risk tool has been invited to contribute to updates to it in the future. Further, it is hoped that the body of knowledge continues to grow with the public release of this report. The purpose of this report is to share the knowledge gained from GPT's Battery Risk and Safety Study and provide a platform to also grow the knowledge from other future reviews and projects.

Finally, GPT has used 580 George St and Rouse Hill Town Centre to provide context for the development of this matrix in order to understand how the risk profile of the buildings may be impacted by the installation of stationary batteries or the installation of EV charging stations and growth in EV vehicles in its buildings' car parks.

5.1 Health and Safety

GPT sees health and safety as the number one consideration when undertaking any new process in its buildings and it shares that principle with many of its counterparts in the property industry.

Batteries, both stationary and in EVs, have the potential to introduce new hazards into buildings. Batteries can also provide an additional item in a building for which a known hazard and control already exists.

As noted in the table below, the types of hazards categorised as health and safety generally relate to electrical, thermal, chemical, internal environment and structural. These potential risks are most likely to be presented in the installation and operations stages of the project, given the spread and nature of the works involved. The specific battery chemistries will influence the degree of applicability for thermal, chemical and structural hazards, although electrical and internal environment hazards could be presented across all types of batteries and assets.

Many health and safety risks will be identified in prevailing battery standards and regulatory requirements. Given the relatively early stage of on-site battery implementation, however, it cannot be assumed that these standards and regulations will identify all relevant risks from a commercial and retail property owner's perspective. It is therefore important to, in the first instance, identify relevant health and safety risks for technology types and building categories.

To the extent that these risks are covered by prevailing standards, they may also be classified under the 'Legal and Compliance' sub-section below, although, where these risks remain unaddressed by prevailing standards, it will be important to be satisfied that the risk is adequately managed.

The most material health and safety hazards posed by commercial battery installations can lead to very serious consequences (e.g. electrocution, intoxication, asphyxiation and burns) and these are outlined in the table below.

Hazards	Commentary
Electrical	Electrical hazards are common in buildings and, as such, there are well-established controls that can readily be applied to batteries in most cases. New electrical hazards posed by batteries include: - overcharging or abnormal charging of batteries; - incorrectly plugging in or charging EVs that are not suitable; and - failure to isolate batteries during outage events or shutdowns for works (similar to on-site generation risks).
Thermal	Batteries, particularly lithium chemistry batteries, may add an additional ignition point or fuel source to buildings and change the buildings fire risk profile. This can be the case for both stationary and EV batteries. Planning for buildings with batteries should consider new fire and/or explosion hazards and the capability of suppressions for events such as thermal runaway caused by: - battery faults; - control system overcharging; - excessive temperatures from exposure to nearby heat loads (e.g. co-located electrical equipment or vehicles); and - a lack of effective ventilation to remove high-pressure or explosive gases within the enclosure.
Chemical	Batteries generally introduce new chemistries into buildings which have the potential to result in exposure to toxic substances caused by: - a lack of adequate ventilation within the enclosure; - damage to the battery system from abnormal / incorrect operation, impact, fire, mechanical fatigue or oxidation; and - supply chain safety hazards from the mining and manufacture of batteries
Internal Environment and Structural	With the exception of some new build projects, most batteries (or EV chargers) will be installed into existing buildings that originally weren't designed for that purpose. In this regard, detailed consideration is needed to ensure that their introduction controls hazards that pose risks of physical injury from: - impacts, trips and falls caused by restricted / congested space conditions; - exposure to sharp or protruding objects; - a lack of suitable engineering design / installation practices (leading to unsafe structural integrity of equipment housing or installation); and - accidental impacts from either vehicles or other equipment causing damage to batteries or charging stations, which in turn can cause any of the above-mentioned hazards.

5.1.1 Case studies & references

1. Report: considerations for ESS Fire Safety, NY, Jan 2017

Summary: This report summarises the main findings and recommendations from extensive fire and extinguisher testing program that evaluated a broad range of battery chemistries. The batteries exhibited complex fire behaviours that led to abundant water use; however, it was found that the extinguishing requirements for batteries need not be excessive if an intelligent, system-level approach is taken that includes external fire ratings, permits direct water contact, and implements internal cascading protections.

Technology: The batteries tested in this program were as follows: 1. Li-ion NCM (4 vendors); 2. Li-ion LiFePO4 (2 vendors); 3. Li-ion LTO; 4. Lead Acid; 5. Vanadium Redox; 6. An additional Li-ion chemistry described as BM-LMP.

Health/Safety risk implications: The main conclusion from the program was that installation of battery systems into buildings introduces risks, though these are manageable within existing building codes and fire-fighting methods when appropriate conditions are met. While cases of incidents will be covered further into this report, this comprehensive study concludes risks are manageable provided due consideration is given to appropriate control measures.

Program implications: The program having found that risks are manageable given appropriate conditions are important as, subject to those conditions, it means technology decisions can be made on other factors such as financial and availability considerations.

Link: The full article can be sourced at:

https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Energy-Storage/20170118-ConEd-NYSERDA-Battery-Testing-Report.pdf

2. Report: Safety, operation and performance of grid-connected energy storage systems, Sep 2017

Summary: This Recommended Practice (RP) aims to accelerate safe and sound implementation of grid-connected energy storage by presenting a guideline for safety, operation and performance of electrical energy storage systems.

Technology: Covers a broad range of energy storage technologies

Health/Safety risk implications: The objective of this RP is to provide a comprehensive set of recommendations for grid-connected energy storage systems. It aims to be valid in all major markets and geographic regions, for all applications, on all levels from component to system, covering entire life cycle.

Program implications: Program decision makers, system designers, installers end users, operators and other stakeholders will be able to take this RP as their single all-encompassing document providing them with direct guidance or referencing through other guidelines and standards.

Link: The full article can be sourced at:

https://www.maxwell.com/images/documents/DNVGL-RP-0043.pdf

3. Risk Matrix: For battery energy storage equipment

Summary: Comprehensive risk matrix across each type of battery storage equipment, categorised into: prevention of access to live hazardous parts; normal operation; abnormal operation/fault protection; resistance to heat, fire, explosion; constructional requirements; marking/instructions; miscellaneous. Includes reference to relevant standards.

Technology: Covers battery module, pre-assembled BS, pre-assembled BESS equipment

Health/Safety risk implications: Thorough coverage of risks and associated standards across all facets of project implementation and operation.

Program implications: Good reference across each of the categories of applicability that can be utilised throughout planning, installation and operation.

Link: The full article can be sourced at:

https://batterysafetyguide.com.au/

4. Report: Energy Storage Safety report for Clean Energy Council, Nov 2015

Summary: This report focuses on a range of energy storage safety considerations for energy storage systems from 1kWh - 200kWh.Safety is considered in terms of the installer and designer, consumer, and the effects of energy storage on the environment.

Technology: Lead-acid (advanced, flooded-cell and sealed); lithium (ion and polymer); nickel-based(metal hydrides and cadmium);flow (zinc bromine and vanadium redox);sodium-ion analogue.

Health/Safety risk implications: The report is broad and older (Nov-2015) and several of the questions it raises will be addressed by subsequent, more thorough studies. It is, however, still a useful paper to understand broad safety considerations across design and installation.

Program implications: It provides a reference to the sorts of questions that should be asked of installers and designers at a higher level.

Link: The full article can be sourced at:

https://www.energymatters.com.au/wp-content/uploads/2015/11/battery-safety-study.pdf

5. Web resource: Clean Energy Council accredited solar and battery installers, 2020

Summary: This web page can be used to source local, Clean Energy Council accredited installers.

Technology: All solar/battery.

Health/Safety risk implications: Clean Energy Council accredited installers are certified and trained to ensure systems meet industry best practice standards and all relevant Australian Standards.

Program implications: this list can be used to select/check credentials of installers

Link: The list of accredited installers can be sourced at:

https://www.cleanenergycouncil.org.au/consumers/buying-battery-storage

6. Best practice guide: Battery storage equipment electrical safety requirements, Jul 2018

Summary: This guide provides safety criteria for battery storage equipment. It is intended to be used by manufacturers, importers, regulatory authorities, testing laboratories, certifiers, importers, retailers and installers. It was created by peak Australian industry bodies such Clean Energy Council, Smart Energy Council, as AI Group, CESA and CSIRO.

Technology: Battery containing lithium as part of the energy storage medium, with rated capacity between 1-200kWh energy storage capacity.

Health/Safety risk implications: This guide has been developed to apply consistent and transparent minimum safety criteria with reference to principles of AS/NZS 3820:2009 Essential safety requirements for electrical equipment.

Program implications: While this guide doesn't specifically cover equipment being used in commercial, industrial or other non-domestic/residential settings, the general requirements and principals can be applied to offer guidance in such situations.

Link: The full guide can be sourced at:

https://batterysafetyguide.com.au/

7. Presentation: ESS Fire Hazard Elimination and Suppression, Jun 2019

Summary: Presentation on fire hazard elimination and suppression.

Technology: Lithium-ion

Health/Safety risk implications: Key takeaways are that thermal runway is an unstable (but foreseeable) hazard, and safety constraints involved in preventing fire propagation are easier to enforce with reduced state-of-charge and early active cooling. Includes safety risk links to EMS, Inverter, Battery String and BMS data.

Program implications: Should Lithium-Ion be the chosen technology, the findings should be applied to design and operational/emergency procedures. It is also worth noting the causal factors around EMS/BMS operations and fire risk in risk registers (P37).

Link: The full presentation can be sourced at:

http://groundsmart-mail.com/documents/ess-fire-hazard-elimination-and-suppression-20190614-constraints-and-the.html

8. Report: Planning for safer, better, bigger battery energy storage, Jul 2019

Summary: DNV-GL and Brand Studio collaboration

Technology: General coverage of grid-scale

Health/Safety risk implications: It is noted that fire suppression for a large BEESS can be complex, and that the trend toward flexibility of use cases makes it more complex to balance safety and performance. It also notes space limitations constrain how much capacity can be installed, which in turn can limit revenue. Space considerations are complex for outdoor systems in close proximity to neighbours, and even more challenging for indoor systems within occupied spaces.

Program implications: Safety measures suggested include: monitoring and sensors, fire-suppression equipment, required setbacks, ventilation and egress requirements, and access to fire hydrants. Smoke detectors and other sensors should be housed inside the battery cabinet, as well as outside. Other safety measures include: constantly comparing sensor data to operational data; eliminating contamination during manufacturing; enhanced packaging for shipping the BESS; safeguards during integrations; cross check procedures for electrical, thermal and mechanical damage threats; and configuring operational software with thermal management in mind.

Link: The full report can be sourced at:

https://www.dnvgl.com/publications/safer-better-bigger-battery-energy-storage-161304

9. Study: Industrial Lithium Ion Battery Safety – What Are the Tradeoffs?, Aug 2007

Summary: VRB Energy paper that discusses the trade-offs between a battery being safe in both normal and abusive conditions, having a long life, high energy density, good electrical performance and high availability.

Technology: Lithium-ion

Health/Safety risk implications: This paper discusses the abuse tolerance of industrial lithium ion batteries and some of the international standards to which these batteries are being qualified.

Program implications: Key takeaway is that the lithium ion system is quite complex, and prudent battery design choices cannot be made by focusing on a single issue to the exclusion of everything else. Battery manufacturers must design their products to meet the highest possible level of safety while also meeting the needs of the application. At the same time, users must recognize that they are unlikely to achieve the highest possible levels of energy density without some sort of trade-off in terms of operating life and safety.

Link: The full report can be sourced at:

https://ieeexplore.ieee.org/document/4448871

10. Study: Safety focused modelling of lithium-ion batteries: a review, Jul 2019

Summary: This paper offers a review of significant modelling works performed in the area with a focus on the characterization of the thermal runaway hazard and their relating triggering events.

Technology: Lithium-ion

Health/Safety risk implications: Safety issues pertaining to Li-ion batteries justify intensive testing all along their value chain. However, progress in scientific knowledge regarding lithium-based battery failure modes, as well as remarkable technologic breakthroughs in computing science, now allow for development and use of prediction tools to assist designers in developing safer batteries.

Program implications: According to market trends, the report notes is anticipated that safety may still act as a restraint in the search for acceptable compromise with overall performance and cost of lithium-ion based and post lithium-ion rechargeable batteries of the future.

Link: The full report can be sourced at:

https://www.sciencedirect.com/science/article/abs/pii/S037877531530598X

11. Study: Lithium Battery Safety, Apr 2018

Summary: This paper provides information to help prevent fire, injury and loss of intellectual and other property from rechargeable storage devices.

Technology: Lithium-ion battery

Health/Safety risk implications: The key message of the paper is that lithium-ion battery fires and accidents are on the rise and present risks that can be mitigated if the technology is well understood.

Program implications: Particularly applicable may be the 'Best storage and use practices' from pages 3-5, which cover a range of practical considerations across procurement, storage, charging practice, handling and use, and disposal. 'Lithium battery system design' on page 5 has advice around incorporating specific risks to this technology to the design and O&M procedures. The 'Emergencies' section on page 5 could be incorporated into emergency management plans.

Link: The full report can be sourced at:

https://www.ehs.washington.edu/system/files/resources/lithium-battery-safety.pdf

12. Report: Hazard Assessment of Lithium Ion Battery Energy Storage Systems, Apr 2018

Summary: At the request of the Fire Protection Research Foundation (FPRF), Exponent performed a fire hazard assessment of lithium ion (Li-ion) batteries used in energy storage systems (ESSs).

Technology: Lithium-ion battery

Health/Safety risk implications: This report summarizes a literature review and gap analysis related to Li-ion battery ESSs, as well as full-scale fire testing of 100 kilowatt hour (kWh) Li-ion battery ESSs.

Program implications: Key from the recommendations was ensuring design, monitoring and first responder tactics were tailored to the specific risks that Lithium Ion batteries present around fire hazards.

Link: The full report can be sourced at:

https://www.nfpa.org/News-and-Research/Data-research-and-tools/Hazardous-Materials/Hazard-Assessment-of-Lithium-Ion-Battery-Energy-Storage-Systems

13. Energy Storage Safety Strategic Plan, Dec 2014

Summary: This comprehensive report develops a high-level roadmap to enable the safe deployment of energy storage by identifying the current state and desired future state of energy storage safety.

Technology: Vanadium redox flow, zinc bromine flow, lead-acid, lithium ion, sodium nickel chloride and sodium sulphur technologies.

Health/Safety risk implications: The document covers three interconnected areas: science-based safety validation techniques; incident preparedness; and safety documentation.

Program implications: The document specifically warns against passive safety plans, reactionary safety approaches, and ineffective first response procedures. Alongside other supporting documentation in this section, this report provides advice to address these risk areas. Particularly section 6 (from page 41) on incident preparedness is a good source of practical advice.

Link: The full report can be sourced at:

https://www.nfpa.org/News-and-Research/Data-research-and-tools/Hazardous-Materials/Hazard-Assessment-of-Lithium-Ion-Battery-Energy-Storage-Systems

5.2 Environmental

As with health and safety, the management of environmental risks is of critical importance to businesses, particularly commercial property owners / investors, who understand the need to have robust policies, procedures and systems in place to protect the environment from their business activities and thereby meet their legal, fiduciary and moral obligations.

The environmental risks posed by battery applications all relate to the release of, and exposure to, toxic substances. These risks occur across the full life cycle of batteries and are common to both lithium-ion and vanadium flow technologies. Although dictated by site-specific factors (e.g. storage location, proximity of stormwater drains, etc), it is likely the environmental risks from on-site batteries would be more prevalent in ground-level outdoor storage locations favoured by retail assets.

The potential release of hazardous materials / toxic substances from commercial buildings is not novel to battery storage systems, with existing hazards inclusive of diesel, chemicals (e.g. cleaning agents, weed-killers, biocides, inhibitors), refrigerants, asbestos, as well as batteries that form part of uninterruptible power systems.

Like health and safety risks, environmental risks may be covered by prevailing standards and regulation, whether battery-specific or otherwise. Similarly, it must be assumed that these prevailing standards will not necessarily cover all risks that need to be managed.

Hazards	Commentary
Chemical (toxic substances)	Release of, and exposure to, toxic substances from on-site battery applications can be caused by: • poor quality of engineering design or manufacturing workmanship in either the batteries or their mountings; and • equipment damage / deterioration from impacts, mechanical fatigue or oxidation Hazards faced across the lifecycle of batteries may include: • migration of toxic chemicals from mining activities into local waterways or soil, which could result in the death of fish and animals resulting in community loss of food sources, through to illness and death; and • operational / durability issues with the batteries, requiring them to be retired much early than expected, with a possibility they are disposed of to landfill due to appropriate recycling facilities not yet being available. In terms of controls, it is important to firstly take into account the risk of leakage and associated environmental impacts specific to each of the chemistries when selecting batteries for commercial applications. Independent of battery chemistry, the system's installation and mounting can exacerbate leakage hazard and associated environmental impacts, meaning that detailed engineering design and robust installation practices are in place minimise these hazards. From a life cycle perspective, it is imperative strong supply chain management practices are in place to mitigate the risk in the production of batteries. Similarly, owners of battery storage systems will need to work with government and industry stakeholders to drive the creation of environmentally responsible recycling and disposal facilities.

5.2.1 Case studies & references

1. Report: The Environmental Impacts of Utility-Scale Battery Storage in California, Jun 2018

Summary: In this study a life-cycle assessment was carried out to determine the environmental impacts of utility-scale battery storage vs natural gas to determine which option had a lower environmental impact.

Technology: Lithium-Ion batteries

Environmental risk implications: The report concluded that battery storage had a lower impact than natural gas-electricity in four out of six environmental impact categories assessed. Hence it was concluded that implementing large-scale battery storage can reduce the climate change impact of California's energy sector by 8 percent.

Program implications: A useful reference if community groups or other stakeholders request further information around the environmental impacts of battery storage systems or question the sustainability credentials of the projects.

Link: The full article can be sourced at:

at https://ieeexplore.ieee.org/document/8980665

2. Environmental Impact of sourcing materials for battery technologies, Aug 2018

Summary: An August 2018 'Wired on Energy' article investigated the global impact of lithium, cobalt and nickel mining on local ecologies. Examples included: masses of dead fish in Tibet were linked to contaminated water from mining runoff; 65% of water in Chile's Salar de Atacama, impacting local farmers; toxic chemical leakage from evaporation pools into water supplies in Tibet.

Technology: Lithium-Ion batteries

Environmental risk implications: Materials being used in the program being linked to such projects would be detrimental to the sustainability credentials GPT is looking to build through the program.

Program implications: When selecting brands and products, information should be sought and considered around the source of materials used.

Link: The full article can be sourced at:

https://www.wired.co.uk/article/lithium-batteries-environment-impact

3. Report: Sustainability Evaluation of Energy Storage Technologies, Mar 2017

Summary: This University of Technology, Sydney report of key energy storage technologies identified and evaluated a range of social and environmental impacts along the supply chain.

Technology: - Five key stationary energy storage technologies are reviewed: Battery technologies – i.e., the dominant lithium-ion chemistries, lead-acid, sodium-based chemistries and flow batteries; pumped hydro energy storage (PHES); compressed air energy storage (CAES); hydrogen energy storage; and, concentrated solar power with thermal energy storage (CSP TES).

Environmental risk implications: Lithium ion batteries were singled out for issues across the supply chain, ranging from pollution and human rights issues during mining through to a future waste management challenge.

Program implications: The mitigation strategies should be incorporated where possible, relative to the technology type selected. These include: ethical sourcing, supporting development of mining standards, and looking into recycling options early in the operational lifecycle. Such considerations will assist should community groups or other stakeholders request further information around the environmental impacts.

Link: The full article can be sourced at:

https://acola.org/wp-content/uploads/2018/08/wp3-sustainability-evaluation-energy-storage-full-report.pdf

4. Paper: Battery Storage Systems: What are their chemical hazards? Sep 2016

Summary: This article looks into the chemical hazards associated with battery technology and ways of managing these hazards.

Technology: The paper studies selected lead-acid battery technologies and lithium-ion battery technologies. For the purpose of this report we are interested in the lithium-ion battery findings.

Environmental risk implications: Regarding lithium-ion, the key finding of the paper was that, due to the inherent risks of the material, battery manufacturers put a lot of attention in the casing design to make it as rigid as possible. But it was noted that does not mean that the risks are eliminated completely.

Program implications: For this reason, installers must strictly follow manufacturers' instructions to ensure its safe operation. It is important to install the battery systems correctly and ensure that they are housed in compliant fire-resistant enclosures. The article also notes that first response teams are advised to wear self-containing breathing apparatus and full protective gear when approaching lithium battery fires, and to avoid contact with any battery material. This information must be communicated to the operations team and form part of emergency response processes.

Link: The full paper can be sourced at:

https://www.gses.com.au/wp-content/uploads/2016/09/GSES_Battery-Storage-Systems_what-are-their-chemical-hazards.pdf

5. Lithium battery recycling in Australia, Apr 2018

Summary: This CSIRO report studied the current status and opportunities for developing a new lithium ion recycling industry in Australia. At the time of publication, some states had already commenced or were considering a landfill ban for the disposal of batteries which will result in greater numbers of LIB being diverted from landfill. CSIRO were further investigating recovery of secondary resources such as cobalt, lithium and graphite. Development of novel battery materials was also under study.

Technology: Lithium-Ion batteries

Environmental risk implications: Lithium battery recycling is an emerging industry in Australia, and at the time of the report publication less than 2% of the waste was collected and exported overseas for resource recovery, and waste is growing at a rate of over 20% per annum. This represents an emerging and growing waste problem.

Program implications: It is recommended that project participants keep across progress made in development of lithium ion recycling industries, preferably in Australia. The CSIRO website is a good source of information. Potentially, should lithium-ion technology be selected, relationships or contributions could be considered to such programs, as they would be a strong response to any community or stakeholder concerns. This information should also be considered in the deliberation between battery technology types with better environmental credentials.

Link: The full article can be sourced at:

https://www.csiro.au/~/media/EF/Files/Lithium-battery-recycling-in-Australia.PDF?la=en&hash=924B789725A3B3319BB40FDA20F416EB2FA4F320

6. Lithium Australia turns battery waste into supply stream for production of new LIBs, Sep 2019

Summary: This Proactive Investors article reports on Lithium Australia's success in turning battery waste into a supply stream for production of new LIBs.

Technology: Lithium-Ion batteries

Environmental risk implications: Developing a local industry to recover battery metals would pave the way for more sustainable use and disposal of LIBs.

Program implications: As per the CSIRO article, progress in this area should be monitored to provide a strong response to any community or stakeholder concerns around waste materials program impacts.

Link: The full article can be sourced at:

https://www.proactiveinvestors.com.au/companies/news/902997/lithium-australia-turns-battery-waste-into-supply-stream-for-production-of-new-libs-902997.html

5.3 Community and Reputation

Commercial buildings can, by their very nature, lead to the creation of internal communities, as well as sit within the neighbouring community and, as such, these buildings necessitate a broad range of stakeholders. These community stakeholders may include:

- building tenants, contractors and suppliers;
- local residents;
- community-based organisations
- local government organisations

The importance of the societal role commercial buildings play is quite pronounced and is most clearly seen with retail assets, where regional and suburban shopping centres are often the focal point for local communities. These assets can be instrumental as a driver of local economies, a hub for social gatherings, a supporter of local sporting / community groups and a place of shelter during extreme weather events or natural disasters.

Because of these and other links, a commercial building will impact, and be impacted by, its communities, which will significantly shape the reputation of both the asset and its owners, In the age of social media, a company's brand and related fortunes can quite quickly and adversely be affected by on-site health, safety and environmental incidents, including workplace fatalities, outbreaks of Legionnaires' disease, detections of asbestos and Coronavirus cases. The list of stakeholders impacted by these reputational risks will extend to investors, financiers, insurers, along with the general public.

With respect to batteries, community and reputational risks will be influenced by other risk factors described in this section, notably health and safety, environmental, legal and financial risks. Aside from a specific incident taking place during operation, the greatest potential for these risks to occur is in the initial engagement process with stakeholders and is more tied to the proposed installation of stationary batteries than EV systems.

Hazards	**Commentary**
Reputational	Adverse media attention and/or reputational damage may arise from: • building occupants, local residents, local government and/or community-based organisations who may develop opposition to novel energy storage technologies due to perceived health, safety and environmental concerns, leading to protests and lobbying of decision makers; or • major tenants pressuring a building owner to prioritise their buildings for the deployment of EV charging systems. Additionally, community and reputational risks that manifest in significant regulatory penalties applied, loss of rental income, decline in retail and/or leasing activity or a decline in share price may occur where a battery failure results in: • an explosion or fire that necessitates the evacuation of building occupants and subsequent closure of the building; or • a release of toxic substances into nearby waterways that causes substantial ecological damage. The obvious strategy to reduce the likelihood and consequences of community and reputational risks is endeavouring to prevent the primary incidents from occurring in the first place. In this regard, the need to have robust control measures in place to mitigate the health and safety, environmental, legal and financial risks is abundantly clear. These measures must be complemented by an over-arching communications strategy to ensure information surrounding any incident with a battery storage application is suitably controlled to minimise misinformation that can unduly harm the business.

5.3.1 Case studies & references

1. Article: Fire-fighters fret over battery risks to homes, Australia, Nov 2018

Summary: The Australian reported on an investigation by the Australasian Fire Authorities Council into concerns raised by fire agencies across the country around an increased risk of fires caused by lithium-ion battery technology.

Technology: Lithium-ion battery

Community/reputational risk implications: Articles such as this can concern community members, residents and site users. These concerns may then be raised with project sponsors, site managers and parties engaged to install/run the technologies. These issues would be best addressed quickly, proactively and comprehensively to avoid concerns escalating.

Program implications: Concerns such as these must be considered in selection of the battery technology, location, installation and warranty periods. O&M and emergency procedures must take such cases into consideration and involve liaison with industry experts. Materials communicating the steps taken to address safety risks should be prepared for GPT to distribute to any concerned community members.

Link: The full article can be sourced at:

https://www.theaustralian.com.au/subscribe/news/1/?sourceCode=TAWEB_WRE170_a_GGL&dest=https%3A%2F%2Fwww.theaustralian.com.au%2Fnation%2Fclimate%2Ffirefighters-fret-over-battery-risks-to-homes%2Fnews-story%2F0d4193728bcb64fa6af984f522fb05ac&memtype=anonymous&mode=premium

2. Suspected solar battery home fire in Brisbane, Dec 2018

Summary: In a December 2018 article published in the Brisbane Times, fire crews who battled a house fire in inner Brisbane attributed the fire to a system connecting batteries to solar panels. Sixteen firefighters spent an hour bringing the fire under control, and another hour extinguishing flames. The firefighter stated, "they burn with a ferocity that moves through the house quickly".

Technology: Three Lithium-ion battery banks

Community/reputational risk implications: Incidents involving fire carry particular community interest, especially given the 2020 bushfire crisis in Australia. Statements from firefighters carry particular weight in the community, given their experience with fire situations and the associated risks. As above: cases such as this can concern community members, residents and site users and would be best addressed proactively and comprehensively to avoid concerns escalating.

Program implications: As above: incidents such as this must be considered in selection of the battery technology, location, installation and warranty periods. O&M and emergency procedures must take such cases into consideration and involve liaison with industry experts. Materials communicating the steps taken to address safety risks should be prepared for GPT to distribute to any concerned community members.

Link: The full article can be sourced at:

https://www.brisbanetimes.com.au/national/queensland/solar-home-battery-warning-after-brisbane-house-fire-20181227-p50od1.html

3. Battery explosion in Surprise, Arizona, Apr 2019

Summary: In April 2019, a battery managed by Arizona Public Service exploded in Surprise, Arizona. Four HAZMAT technicians required hospitalisation with chemical burns.

Technology: Lithium-Ion batteries

Community/reputational risk implications: As per Australian examples, cases such as this can concern community members, residents and site users. These would be best addressed quickly and comprehensively to avoid concerns escalating.

Program implications: As above: incidents such as this must be considered in selection of the battery technology, location, installation and warranty periods. O&M and emergency procedures must take such cases into consideration and involve liaison with industry experts. Materials communicating the steps taken to address safety risks should be prepared for GPT to distribute to any concerned community members.

Link: The full article can be sourced at:

https://www.azcentral.com/story/news/local/surprise/2019/08/09/report-surprise-aps-battery-explosion-hosptialized-hazmat-offers-few-answers/1951399001/

4. Presentation: Energy Storage Safety Monitor, Oct 2019

Summary: VRB Energy

Technology: Reference presentation which lists and analyses recent lithium-ion battery storage fire incidents, and links to related articles

Community/reputational risk implications: A good starting point for analysing the global lithium-ion battery storage fire incidents which dogged the burgeoning industry throughout 2019. While covering the South Korea and Arizona incidents, it also addresses fire hazards not linked to stationary storage in addressing incidents in Eastern China (electric bus explosion) and a battery fire on a diesel-electric passenger ferry in Norway.

Program implications: The table of global incidents from 2012-2019 on page 4 is a particularly useful reference to the scope and application of incidents. The program spokespeople should be aware of incidents that community/stakeholders may refer to, should any oppose the projects on safety grounds.

Link: The full report can be sourced at:

https://vrbenergy.com/wp-content/uploads/2019/11/Energy-Storage-Safety-Monitor-October-2019.pdf

5. Series of battery explosions in South Korea, Jun 2019

Summary: 23 energy storage system fires occurred in South Korea since August 2017. Fires resulted in system losses valued at over $32M USD. This article reviews the findings of an investigation committee of academics, research institutions, laboratories and ESS industry experts into the causes of the fires. These were summarised as: insufficient battery protection against electric shock; inadequate management of operating environment; faulty installations; and insufficient ESS system integrations.

Technology: Lithium-Ion batteries

Community/reputational risk implications: As above: cases such as this can concern community members, residents and site users.

Program implications: As above: incidents such as this must be considered in selection of the battery technology, location, installation and warranty periods. O&M and emergency procedures must take such cases into consideration and involve liaison with industry experts. Materials communicating the steps taken to address safety risks should be prepared for GPT to distribute to any concerned community members.

Link: The full article can be sourced at:

https://nexceris.com/2019/06/14/south-korea-identifies-top-4-causes-that-led-to-ess-fires/

5.4 Legal and Compliance

A fundamental requirement for businesses is to operate in accordance with all relevant legal provisions, including compliance with subordinate legislation, such as regulations and prevailing standards, guidelines and industry codes of practices.

Despite the relatively novel nature of commercial battery applications, there is a large and varied list of prevailing standards and supporting documents (refer to Appendix 3). Other than those pertaining directly to batteries, these documents also cover electrical installations, grid connections and the design of building structures.

Legal and compliance risks arise from obligations imposed by regulatory and standard-setting bodies. With respect to batteries, these bodies include:

- Standards Australia (SA)
- Smart Energy Council (smartenergy.org.au)
- Underwriters Laboratories (UL)
- International Organisation for Standardisation (ISO) Network Operators
- Australian Energy Regulator

The legal risks posed by batteries are closely tied to health, safety and environmental risks, which are themselves covered by comprehensive legislation in all Australian States and Territories. Pertaining specifically to commercial battery applications, the potential compliance risks are most likely to be posed by uncertainty / misinterpretation of prevailing standards, which may be borne out during each of the project stages. In terms of the degree to which these risks are reflected in the various battery technologies, it is unlikely that EV systems will be as exposed as lithium-ion stationary batteries or, to a lesser extent, the vanadium flow equivalents.

Hazards	Commentary
Compliance	The rapidly evolving nature of standards and regulations covering battery installations in Australia may lead to confusion or misinterpretations regarding compliance, resulting in: • the electrical contractor failing to submit a Preliminary Notice to the relevant network operator, resulting in the system not being able to be activated until the process is carried out retrospectively, incurring delays and missing market revenue opportunities; • adverse findings derived from an investigation by insurance or lending institutions; or • a prosecution stemming from an independent investigation by a regulatory authority. Depending on the severity of the non-compliance and nature of the findings, the consequences of these outcomes could include: • significant fines or losses; • adverse media coverage and related reputational damage; • negative impacts on insurance coverage; • decrease in revenue generation; and • a decline in the company's share price. To mitigate the legal and compliance risks associated with batteries, companies should conduct their own detailed analysis of prevailing legislation and standards at the outset of the project and avail themselves to up-to-date information from key government departments and industry bodies. This initial approach should be supported by robust processes to stay abreast of changes to these applicable standards / regulations. More broadly, companies should be encouraged to seek compliance with prevailing Australian standards, whether strictly binding or not, as a minimum threshold for best practice

5.4.1 Case studies & references

1. **Reference document: Clean Energy Council Approved Lithium-based Energy Storage devices, Dec 2019**

Summary: The Clean Energy Council's Battery Assurance Program includes a list of lithium-based batteries (energy storage devices) that meet industry best practice requirements. The list provides consumers with independent information on the safety of battery products that are independently tested to confirm they meet certain electrical safety and quality standards.

Technology: Lithium-based

Legal/compliance risk implications: Products listed in the document have been assessed against the compliance methods outlined in the Best Practice Guide: Battery Storage Equipment. The list includes lithium-based battery system (BS) and battery energy storage system (BESS) products that meet the Australian or international version of the lithium battery safety standard 62619:2017.

Program implications: This list ensure compliant hardware selection. While the list tends more towards home battery devices, it provides a good guide to reputable manufacturers/models.

Link: The full document can be sourced at:

https://assets.cleanenergycouncil.org.au/documents/products/ESD-List-200710.pdf

2. **Reference document: NSW Government Emerging electricity infrastructure paper, Nov 2019**

Summary: NSW Department of Planning, Industry and Environment published this Emerging Electricity Infrastructure paper to advise planned changes to 'State Environmental Planning Policy (Infrastructure) 2007' to facilitate the efficient delivery of emerging electricity infrastructure in NSW.

Technology: Storage and related renewable generation technologies

Legal/compliance risk implications: Proposed changes to the 'State Environmental Planning Policy (Infrastructure) 2007' will have potential implications for sizing decisions, installation standards and requirements, and development approval pathways. Note that the general tone of the paper indicates the intention is to facilitate delivery of such infrastructure by providing regulatory certainty and efficiency. If this is achieved, it should reduce rather than adding risk.

Program implications: The proposed changes to the 'State Environmental Planning Policy (Infrastructure) 2007' should be monitored due to the legal/compliance risk implications listed above.

Link: The full document can be sourced at:

https://shared-drupal-s3fs.s3-ap-southeast-2.amazonaws.com/master-test/fapub_pdf/Exhibition+attachments+/Explanation%2Bof%2BIntended%2BEffects%2B-%2BEmerging%2Belectricity%2Binfrastructure.pdf

3. **Reference document: NSW Government Smart Batteries for Government Minimum performance Specifications, Nov 2019**

Summary: NSW Department of Planning, Industry and Environment paper outlining the technical standards to be followed by the NSW Government's smart battery for Government Buildings' program. Great source of NSW relevant information on relevant standard. This is also a useful reference for installations, compliance, labelling, materials, workmanship, technical and safety considerations.

Technology: Storage and related renewable generation technologies

Legal/compliance risk implications: Useful reference document to ensure compliance with relevant standards and best practice.

Program implications: This document should be referred across all stages of technology selection, project planning, installation, O&M planning and execution and controls.

Link: The full document can be sourced at:

https://energy.nsw.gov.au/renewables/clean-energy-initiatives/smart-batteries-key-government-buildings

4. **Reference article: Top 10 Lithium Ion Battery Regulations, May 2017**

Summary: Article to share the most relevant regulations which address prevailing Lithium-ion battery safety concerns. The authoring company, Li-ion Tamer ®, develop products to improve battery safety and ensure adherence to safety regulations.

Technology: Lithium ion

Legal/compliance risk implications: If lithium ion technology is used, this will be a useful source of information across the supply chain process as well as to address any safety concerns from project stakeholders or community.

Program implications: This document should be referred if Lithium ion technology is selected, to form a criteria list for manufacturers, suppliers, installers and operators.

Link: The full document can be sourced at:

https://liiontamer.com/the-top-10-lithium-ion-battery-regulations-and-why-the-are-important-to-everyone/

5. **Chart: Inverter Categories - Required Standards (date unknown)**

Summary: This Clean Energy Council reference chart lists the Australian and International standards to which different inverter categories must adhere.

Technology: All

Legal/compliance risk implications: The reference includes a flow chart to verify whether the device is within the scope of the CEC product listing and determine its category, then a table showing the standards related to that category, including a breakdown of sub-categories where relevant.

Program implications: Useful reference to check the relevant standards are being adhered to.

Link: The full document can be sourced at:

https://assets.cleanenergycouncil.org.au/documents/products/inverter-categories.pdf

6. Paper: Policy & regulatory reforms to unlock potential of energy storage in Australia, May 2017

Summary: This Clean Energy Council briefing paper lists recommended reforms designed to: level the playing field in the energy market; remove regulatory barriers to storage behind the meter; recognise and reward the full value of storage behind the meter and establish standards and protect consumers.

Technology: All storage (paper is at a regulatory/policy high level)

Legal/compliance risk implications: It should be noted that since this paper's 2017 release, some of the recommendations have already been implemented, for example the Nov 2017 announcement of five-minute settlement in the NEM. Generally, though it provides a good coverage of the direction of industry's thinking which may predict future regulatory and policy changes.

Program implications: This and future Clean Energy Council publications may provide guidance towards the direction of future regulatory/policy shifts that may impact the program's legal/compliance requirements.

Link: The full document can be sourced at:

https://assets.cleanenergycouncil.org.au/documents/resources/reports/unlocking-energy-storage-in-australia.pdf

5.5 Operational

Operational risks relate to people, processes, and systems and reflect the degree to which an unexpected event may impact on an asset or business unit, as well as any subsequent critical system / services outages or infrastructure damage. With respect to batteries, neither these risks or their related controls, are seen as being overly dissimilar in nature to what on-site teams would be expected to plan for.

Due to their nature, the timing of these risks is most likely to occur during the installation / commissioning and/or operation stages of the project. The application of EV charging systems is becoming more commonplace and the technology is less complex than the various stationary battery technologies, which should mean the former presents a lower potential for exposure to the operational risks discussed below.

Hazards	Commentary
Operational	There is no shortage of examples where, what's touted to be, a simple, straightforward and trouble-free installation / operation of novel equipment in a commercial building turns out to be a long-running saga of operational problems that adversely impact the site team. With batteries, this type of outcome could come from: • a lack of suitably-skilled technicians or availability of key parts that results in persistent problems with the battery system. These problems could require an excessive amount of time from the on-site operational team, which potentially may result in essential works being delayed or missed entirely with possibly dire consequences.

Hazards	Commentary
Operational (Continued)	To mitigate this risk, the awarding of a battery project and the subsequent maintenance contracts should be strongly influenced by the availability of skilled technicians and equipment parts. As part of this approach, tenderers / suppliers should not only be screened on their respective resourcing capacities, but consideration given to incentivising contractors to meet operational KPIs.
Cyber-security	When evaluating the types of threats that could result in significant damage to critical systems, services or the asset itself, consideration should be given to the potential for unauthorised access to, and malicious use of, control systems. With respect to batteries, a possible scenario could be: • a hacker overrides safety protection systems that leads to a thermal runaway of a lithium-ion battery storage, resulting in an explosion, fire and/or release of toxic substances. Extensive cyber security mechanisms, in particular, strong network and software protection, are required that cover novel energy storage technologies and critical systems.

5.5.1 Case studies & references

1. Report: Gap Analysis of Existing Battery Energy Storage System Standards

Summary: DNV GL, CSIRO, Smart Energy Council and Deakin University collaborated to develop this proposed performance standard for a battery storage system connected to a domestic/small commercial Solar PV system

Technology: Lead acid, nickel cadmium, flow, hybrid ion and lithium

Operational risk implications: Particularly useful for a list of all standards relevant to BESS system. Also has useful reference to standards with relation to metrics of performance such as life span, efficiency and environmental operating conditions. Note: the related project to produce an Australian Battery Energy Storage System (BESS) Performance Standard (ABPS) is still underway as at Feb-2020. Updates can be found on the ARENA website.

Program implications: This report should be referenced to determine relevant standards, and when determining metrics around performance standards in the operational stage. Once the BESS APBS project is completed, findings referring to it should also be referred.

Link: The full article can be sourced at:

https://www.dnvgl.com/publications/considerations-for-energy-storage-systems-fire-safety-89415

2. WorkCover QLD WorkCover QLD guide to safe installation of BESS, Sep 2019

Summary: Article aimed at installers covering the considerations applicable to installers of BESS to ensure they have the appropriate safe systems of work, technical expertise, training and competence for installation of storage technology.

Technology: Lead-acid (advanced, flooded-cell and sealed), lithium (ion and polymer), nickel-based (metal hydrides and cadmium), flow (zinc bromine and vanadium redox), and hybrid ion.

Operational risk implications: High level coverage of battery selection; system design; electrical and chemical hazards; suitability of installation locations; installation; electrical safety requirements; testing and commissioning; and Australian Standards references.

Program implications: Could be referred by installers during project implementation as it provides a good high level summary

Link: The full article can be sourced at:

https://www.worksafe.qld.gov.au/injury-prevention-safety/electricity/installing-battery-energy-storage-systems-bess

3. Operational Risk Management in the U.S. Energy Storage Industry: Lithium-Ion Fire and Thermal Event Safety, Sep 2019

Summary: This paper describes how fire and thermal event risk prevention and management is currently being addressed in the storage industry, the types of operational risks in energy storage, current codes and standards governing battery storage systems, and additional best practices.

Technology: Lithium ion is the focus due to the current market dominance in new deployments.

Operational risk implications: Good and very recent reference material for best practice in an operational context.

Program implications: The useful summary of the key US/global standards in this space can be used during operational design to ensure standards are cross checked. The communications and training best practices section (page 13-14) will also be a good reference for coverage of operational procedures around safety.

Link: The full article can be sourced at:

https://energystorage.org/thought-leadership/operational-risk-management-in-the-u-s-energy-storage-industry-lithium-ion-fire-and-thermal-event-safety/

5.6 Strategy

As noted in Section 3, the Energy Master Plan is a key strategic objective of GPT and one that has necessitated considerable investment in both time and finances to deliver the existing elements. Aside from maximising the generation of solar PV systems, the role of battery storage is considered to be critical in further augmenting the benefits of the EMP's demand response / management programs by:

- providing cleaner, more responsive and less risky alternatives to the use of diesel generators;
- helping to reduce the financial exposure of our partnered energy retailer to upside fluctuations in energy market prices; and
- improved financial outcomes as a collective result of the above.

In this regard, strategy risks are closely aligned to financial risks (as detailed in the following sub-section), but also to those risks pertaining to reputation, given GPT's credentials as a global leader in sustainability.

Strategy risks are agnostic as to the types of stationary batteries and the types of assets targeted, although they are squarely limited, in terms of timing, to the project delivery stage, as outlined below.

Despite the extremely high importance placed on climate response at GPT, it is clear that batteries would not impact the broader company strategy for creating value in the long term. As such, strategy risks associated with batteries are restricted to the energy plans and the battery projects themselves for GPT and other like-minded companies.

Hazards	Commentary
Project delays	Lengthy and costly project delays may include: • grid connection being held up by either the market operator, the local network service provider or both, leading to delays in the delivery of the project. Such delays may result in a company missing the opportunity of being an early mover in battery technology and the failure to deliver on the expectations of its key stakeholders, notably investors, employees and tenants; or

Hazards	Commentary
Project delays (Continued)	• the project is delayed indefinitely due to firmly-held views of major stakeholders (e.g. insurers, key parts of the business) regarding safety concerns, leading to a proponent being reliant on non-renewable energy sources for much longer than anticipated. In each case, a robust risk assessment process is duly required to identify and manage the potential causes of delay or cancellation of the project, with particular focus on stakeholder engagement, system design, procurement, installation (including network connection) and commissioning.

5.6.1 Case studies & references

1. Report: ARENA Large-Scale Battery Storage Knowledge Sharing Report, Sep 2019

Summary: Report intended to provide information on the key lessons and innovation opportunities for Large-Scale Battery Systems (LSBS) projects in Australia based on specific project insights gathered through the Australian Renewable Energy Agency (ARENA), Aurecon's industry experience, and publicly available information.

Technology: All were Li ion batteries.

Strategy risk implications: This report summarises the key lessons and innovation opportunities for LSBS projects in Australia, based on all LSBS operational programs operational in Australia at the time of publication. Worth noting that the key revenue streams of these projects have been wholesale energy market participation, regulation FCAS and contingency FCAS. In addition, LSBS in Australia have proven their ability to provide other services for voltage control, system integrity and portfolio causer pays reduction which, in some instances, can be monetised but are not major revenue streams for any LSBS projects to date.

Program implications: Should any future projects be of a larger scale (>1MW) it will be a useful reference in terms of the more common dispatch scenarios at this scale, and the recommendations ARENA will be providing to Government around regulatory changes which may impact strategic directions.

Link: The full article can be sourced at:

https://arena.gov.au/knowledge-bank/large-scale-battery-storage-knowledge-sharing-report/

2. Australian Energy Storage Market Analysis, Sep 2018

Summary: This report is a comprehensive analysis of the Australian energy storage market, covering residential, commercial, large-scale, on-grid, off-grid and micro-grid energy storage.

Technology: All battery storage systems

Strategy risk implications: The report assesses the current state of energy storage and makes projections for uptake from 2017 to 2020. It also includes state by state coverage of relevant government policies, R&D, investment and recommendations for future growth, and price projections for BESS components and systems.

Program implications: This information can broadly be applied to program strategic decisions. Section 6 (barriers and opportunities for growth by state government policy) may be particularly useful in understanding strategic ramifications of Government policies.

Link: The full article can be sourced at:

https://www.smartenergy.org.au/sites/default/files/uploaded-content/field_f_content_file/australian_energy_storage_market_analysis_report_sep18_final.pdf

3. The Economics of Battery Energy Storage, Oct 2015

Summary: This report analyses how multi-use, customer sized batteries deliver the most services and value to customers and the grid. Note it is a U.S. publication so will be within the context of US market conditions.

Technology: All battery storage systems

Strategy risk implications: The report analyses considerations such as value service stacking, challenges in defining the economic benefits under prevailing const structures, and barriers to energy storage systems providing services to the electricity grid – particularly regulatory.

Program implications: While the application is the U.S. market, the broad considerations apply in the Australian market and it provides insight into strategic considerations specific to this technology.

Link: The full report can be sourced at:

https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

4. Battery storage on trial … the good, the flat and the gone-out-of-business, Jul 2019

Summary: An article by ecogeneration

Technology: Technology agnostic

Strategy risk implications: Battery storage is a rapidly evolving industry, with a large number of manufacturers entering (and some exiting) the market. Of the 18 batteries installed under the trial, one manufacturer and one distributor have become insolvent since the trial started (leaving batteries which are not properly cycling). The reliability of the products, as well as the level of support available, varies widely, both for battery storage products and associated components (such as inverters). It is also noted that the market, standards and regulations are very much developing and evolving.

Program implications: In BESS investments more than most, given the low maturity of the technologies and industry, there are higher than usual benefits in selecting very reputable and established retailers and manufacturers.

Link: The full article can be sourced at:

https://www.ecogeneration.com.au/battery-storage-on-trial-the-good-the-flat-and-the-gone-out-of-business/

5.7 Financial

There are financial implications with each of the risk factors previously discussed in Section 7, but the financial risks described here essentially relate to increased costs or decreased revenue occurring in the installation and operations phases of the project, due mostly to project delays, poor system performance and/or the lack of precedent in these types of projects, the latter being more applicable to stationary batteries. Notwithstanding, the risks with (and related mitigation approaches to) these projects are unlikely to be too removed from those presented by existing energy technologies such as solar PV or co-gen / tri-gen systems.

Hazards	Commentary
Project delays	Costly delays in the project can arise due to: • stakeholder opposition; • protracted grid connections; • supply chain and procurement issues; • and unfavourable market or business conditions.

Hazards	Commentary
Poor system performance	There are multiple factors that could result in less than expected performance of the battery system, including: • the system selected is unsuited to the environment in which it's located, is undersized or is incompatible with the building's control systems; • faulty manufacture or workmanship; • the failure of ancillary systems (e.g. solar PV) reduces the capacity and utilisation of the stored energy; or • the technology selected for the stationary system suffers from prolonged periods of shutdown due to shortages in skilled technicians or parts.
Lack of project precedence	The relatively novel nature of commercial battery applications could create a variety of risks that result in diminished financial outcomes, including: • the insurer considers the battery system poses severe risks to the asset, leading to significant increases in expected insurance premiums that jeopardise the business case for the project; • the market operator, the local network service provider or both increase connection costs well beyond initial expectations; • the installation or subsequent operation / maintenance costs become more expensive than anticipated; and • the relative immaturity of the technology / markets and the potential for major regulatory changes leads to an inability to effectively forecast or generate the targeted value from solar, DR or peak lopping programs.
	The delays described in the above rows can be avoided or at least minimised, by: • having frank, informative and meaningful consultation with stakeholders early and regularly during the project; • engaging with the relevant authorities and ensuring connection applications are submitted well before (e.g. months) the expected date of project delivery; and • implementing effective design, tendering, project management and contractor management processes; and • conducting a rigorous investigation that informs investment decision-making.

5.7.1 Case studies & references

1. Australian Financial Review (AFR) article: Battery project line-up defies lingering market risks, Sep 2019

Summary: AFR report on the anticipated proliferation of global battery projects, the financial benefits, and further investigation and regulatory change required to drive confidence in business models.

Technology: All storage

Financial risk implications: The article addresses and debunks industry financial risk concerns, arguing that the global scale of emerging projects and range of potential revenue streams give credibility to the business case. It describes the potential value of battery storage undertakings on both a national and global scale. It does note that changes in regulation and market rules will be required to ascribe value to the services being delivered.

Program implications: This article outlines potential revenue streams including arbitrage, contingency ancillary services and avoidance of costly interconnector upgrades, which will be worth considering in the context of the business case.

Link: The full article can be sourced at:

https://www.afr.com/companies/energy/battery-project-line-up-defies-lingering-market-risks-20190912-p52qk9

2. **Price Waterhouse Cooper (PWC) paper: Energy storage: financing speed bumps and opportunities, Feb 2019**

Summary: PWC paper assessing financial frameworks surrounding utility-scale energy storage developments and identifying key obstacles to investment from the private sector. In particular the paper analyses: uncertainty in forecasting revenues; uncompensated benefits of improved loss factors and reduced congestions to surrounding projects; additional benefits that energy storage assets can provide; and a potential framework and solution for asset ownership.

Technology: All storage

Financial risk implications: The paper notes that while challenges are clear, including transition to 5-minute trading intervals, the benefits remain clear. They include the ability to trade in wholesale markets, provide ancillary services and stability to local networks. The paper notes that market / regulatory reformation would help promote private sector financing.

Program implications: The findings will be worth considering in the context of the business case.

Link: The full article can be sourced at:

https://www.pwc.com/jp/ja/issues/globalization/news/assets/pdf/au-energy-storage.pdf

3. **Development of a Proposed Performance Standard for a Battery Storage System connected to a Domestic/ Small Commercial Solar PV system, Dec 2019**

Summary: The purpose of this analysis is to compare performance metrics across different battery chemistries and investigate the correlation between the measurable parameters and the state of charge of a battery.

Technology: Lithium-ion, Advanced Lead Acid and Lead Acid batteries

Financial risk implications: The analysis investigates the current, voltage and power characteristics for different batteries during charging and discharging conditions, both as functions of time and state of charge. The impact of weather conditions, degradation of available battery capacity and terminal voltage is also evaluated with the number of cycles for different batteries. This information defines threshold criteria for benchmarking and comparing battery performance.

Program implications: useful for development of a more detailed and accurate battery model for a more realistic evaluation of battery performance for business case planning.

Link: The full report can be sourced at:

https://issuu.com/dnvgl/docs/63148b96498948ae9ec8585b7652d6fe

4. **Public Report 6 - Lithium Ion Battery Testing, Jun 2019**

Summary: Lithium Ion Battery Test Centre involves performance testing of conventional and emerging battery technologies. The aim of the testing is to independently verify battery performance (capacity fade and round-trip efficiency) against manufacturers' claims. This report describes testing results and general observations or issues encountered.

Technology: Lithium-ion, Advanced Lead Acid and Lead Acid batteries

Financial risk implications: It was noted that Sony, Samsung, Tesla (Phase 1), BYD and Pylontech (Phase 2) battery packs generally demonstrated high reliability, with minimal issues encountered, while the Samsung and BYD battery packs in particular demonstrated consistently high round-trip efficiency. It was also noted that many battery packs installed in the Test Centre have had to be removed or replaced prematurely owing to faults. These issues are symptomatic of new technology and a new market and are expected to improve over time.

Program implications: This guide should be referred at the procurement planning stage when deciding on technologies, particularly given its recent publication. Generally, it points to investing in more mature technologies and established brands to mitigate reliability and performance risks in operation.

Link: The full report can be sourced at:

https://batterytestcentre.com.au/wp-content/uploads/2017/07/Battery-Testing-Report-6-June-2019.pdf

6 Considerations for Proposed Deployments

The purpose of this section is to illustrate the considerations that will be necessary within a full feasibility analysis for proposed novel energy storage deployments. GPT is yet to conduct such a full feasibility study for its sites, however, it has conducted preliminary investigation in relation to two of its sites, namely:

- 580 George St – an office tower; and
- Rouse Hill – a shopping centre.

This preliminary investigation has included consideration around the elements of battery storage systems and the possible application of two nominated novel stationary energy storage technologies:

- Lithium-ion battery technology; and
- Vanadium flow battery technology.

These investigations provide insight regarding the considerations that would feed into a risk assessment taking account of the hazards outlined in this report.

It is important to note this paper is principally a risk and safety study of commercial battery installations and the inclusion of costs in the following sections is only intended to provide an insight into the types of costs that may need to be considered. As indicated throughout the paper and the supporting tool, the idiosyncratic nature of the two battery chemistries assessed will necessitate differing works to mitigate the potential risks they individually pose. As an example, the increased protective measures required for a lithium-ion installation on the rooftop of CBD office tower is likely to incur higher transportation, traffic management and lifting costs than a vanadium flow installation in a suburban shopping centre, where there is likely to be a correspondingly greater focus on spill containment costs and car park revenue loss.

In this regard, there has been no analysis provided around the high-level costs outlined in Sections 6.2 and 6.3. More detailed site-specific investigations would be required accordingly to enable the preparation of a suitably comprehensive business case from which an investment decision could effectively be made.

6.1 Battery Energy Storage System

An energy storage system comprises various electrical components which, when combined to form a complete system, is commonly referred to as a battery energy storage system (BESS). The major sub-assemblies and components of a ‘pre-assembled battery system’ and a ‘pre-assembled battery energy storage system’ are:

- Battery system
- Power converter equipment (PCE)
- Auxiliary equipment

According to Australian Standard AS 5139:2019 (Electrical installations – Safety of battery systems for use with power conversion equipment) an energy storage system can be classified as follows:

- Pre-assembled battery system (BS) – System comprising one or more cells, modules, or battery systems, and/or auxiliary supporting equipment. Depending on the type of technology, the battery system may include a battery management system. Pre-assembled battery systems may come in a dedicated battery system enclosure. However, this system does not include (PCE), which is required to interface with AC loads or sources (generation).
- Pre-assembled integrated battery energy storage system (BESS) – Battery energy storage system equipment that is manufactured as a complete, pre-assembled integrated package. The equipment is supplied in an enclosure with the PCE, battery system, battery management system, protection device and any other required components as determined by the equipment manufacturer.
- Everything else – A battery energy storage system that does not fit either of the categories above (and will not be considered as part of this feasibility assessment).

6.1.1 Battery system

The components of a battery system are as follows.

Component	Description
Cell	A basic functional unit which is the source of electrical energy
Module	Multiple cells connected in series
Tray	One or more modules connected in series and parallel
Rack	Multiple modules/tray connected in series
Rack frame	Mechanical framework to mount multiple trays and BMS
Switchgear	DC fuse, voltage and current sensing device, DC contractor
Battery management module (BMM)	Control device that monitors and manages either as an individual cell, tray, or rack
System battery management system (BMS)	Control device that monitors and manages the overall battery upstream of the BMM
Enclosure	An indoor or outdoor rated cabinet for the battery system and optionally the PCE, depending on the configuration. This may include heating and/or cooling depending on the installation environment and warranty requirements.

Each of these components of the energy storage system will have implications for the hazards and control measures identified in this report and the accompanying Battery Hazardous Review Tool. For example, the scope to control hazards, particularly electrical hazards, will depend on the system configuration and each of its components. In practice, nominated suppliers with appropriate certification may be an appropriate way to control for such hazards across the system.

6.1.2 Power conversion equipment

Power conversion equipment (PCE) is an electrical component converting and/or modifying one kind of electrical power from a voltage or current source into another kind of electrical power with respect to voltage, current, and/or frequency. Typically, PCE will convert DC to AC and AC to DC, however, it may comprise several electrical components to perform this work.

PCE will be particularly relevant to health and safety hazards discussed in this report and listed in the Battery Hazardous Review Tool.

As with battery system components, each of the components of the power conversion equipment contribute to the risk profile of a novel energy storage component and must be considered in relation to identified hazards and proposed control measures. These considerations will be particularly relevant to electrical hazards and, given the involvement of communications equipment, will also be relevant to broader operational, strategic, and financial hazards that can be impacted.

6.1.3 Auxiliary equipment

Auxiliary equipment components are often collectively referred to as the balance of system equipment, which are required to complete the system and include communication devices, protection devices and consumables such as cabling.

Component	Description
Protection devices	Relay, AC and DC protection and disconnection devices such as circuit breakers and switched fuses
Cabling	Power and communication cables. Commonly include AC power cables between the battery systems and switchboard, PCE and battery system
Metering	Optional item and determined by functions of project requirements
Communications	Devices enabling communication within and external to BESS, such a 4G modem and switch
Industrial PC	A rugged PC to assist during commissioning and remote monitoring

6.2 Hypothetical Deployment at an Office Tower

GPT's site at 580 George Street is an office tower in the centre of Sydney's CBD. This complex has a net lettable area of 41,400 square metres and includes 33 floors of commercial office space with three levels of retail, all linked by a pedestrian underpass to Town Hall railway station.

With a higher height-to-footprint ratio, deployment of novel energy storage technologies will typically be limited to spaces within, or on the roof of, the building. Particularly in an CBD location, where land space is at a premium, there are unlikely to be ground mounted outdoor areas that can be utilised for novel energy storage. However, basements and carparks can potentially offer deployment locations, although the risk of these, as with rooftops and mid-level locations, will need to be balanced around considerations of access, containment, as well as the forfeited opportunity to us the space for other purposes (CBD car spaces, for example, can be relatively valuable when used to park cars).

The nominated batteries were sized using meter data and optimised for the best payback resulting in a focus on reducing demand charges. Preliminary cost estimates have been prepared using the following assumptions:

1. Battery system costs have been sourced from vendor pricing for this site's closest modelled size. These estimates have been provided by vendors in the absence of a concept design and are therefore generic estimates. A 15% contractor margin has been added to the battery system cost estimates to reflect pricing to GPT. Where applicable figures have been converted to AUD, the following rates have been adopted: 1 AUD = 0.71 USD; 1 AUD = 0.63 EUR; 1 AUD = 0.54 GBP.
2. Project management and engineering design costs have been estimated at 10% of the sum of the battery system equipment and installation costs. Installation costs have been estimated on a typical per rack or module basis. No installation quotes have been sought from contractors in preparing this estimate. Switchboard modification costs are excluded from the battery pricing where the system will be installed on the same master switch board as a new solar system. A 15% contractor margin has been added to installation works cost estimates to reflect pricing to GPT.
3. Where battery installation will be co-located with a new solar system, the grid connection costs will be excluded from the battery costing and incorporated into the solar pricing. A 15% contractor margin has been added to the grid connection cost estimate where applicable to reflect pricing to GPT.
4. To accommodate site specific complexities, the following variable costs have been considered: additional logistical costs due to location (applicable to CBD locations) at an approximate cost of $0.025/MWh; additional battery control equipment includes meters, relays, switches and controls not integral to the battery system package or solar distribution board; an approximate 15% contractor margin has been added to the variable cost estimate to reflect pricing to GPT.

During the site visit to 580 George Street, one location was identified for deployment of a battery storage system. This location was a largely empty space of 59m2 on Level 34/35 which provides restricted access via a service lift to Level 32, from which a roof crane would be required to transport goods to Level 35. Some core drilling to penetrate the walls for short cable runs may be required, and there would likely be sufficient space for a future expansion if required.

The location is partially protected from the elements, though an outdoor rated enclosure would likely be required for a lithium-ion battery deployment to ensure that operating temperatures would remain within the warranty range. The size of the space means there would be multiple layout configurations possible for each of lithium-ion and vanadium flow battery technologies.

6.2.1 Hypothetical lithium-ion battery deployment

Based on the energy usage profile of this site, along with considerations around product availability, a lithium-ion battery rated 150kW / 222kWh at the beginning of its life has been considered.

For such a storage system, high level budget estimates, based on the assumptions outlined above, are as follows:

CAPEX	Budget Rate	Budget $ (ex GST)
BESS System Cost	$854 / kWh	$189,400
Battery modules		$122,400
Battery inverter		$16,000
Battery enclosure and wiring		$22,600
Contractor margin		$28,400
Installation Works	$271 / kWh	$60,000
Project management and engineering design		$17,000
Installation and commissioning		$34,000
Switchboard modifications		•
Contractor margin		$9,000
Grid connection cost	N/A	N/A
Variable	$62 / kWh	$16,200
Logistics		$5,500
Additional battery control equipment		$8,300
Contractor margin		$2,400
TOTAL	**$1,198 / kWh**	**$265,700**

OPEX	Standard	Capacity Guarantee
Year 1 cost (increase by 3% pa)	$1,250	$3,000
Total 10-year cost	$14,350	$34,400

These estimates are based on a LG Chem lithium-ion battery system with an SMA inverter, ComAp protection relay and an EnerSys Slimline Shelter outdoor rated enclosure with AC.

The majority of maintenance processes for a lithium-ion battery system (mechanical inspection, electrical and communication wiring inspection, cabinet cleaning, fan/AC inspection and cleaning, air filter replacement) would be conducted annually. The cooling fan replacement would be conducted every 5-7 years.

Three alternative layout options were considered that represent different ways of utilising the space. Two of these options, namely the exterior end wall of the enclosure or the adjacent wall of the enclosure represent partially enclosed locations and each of these options would accommodate 2 racks or 34 modules, which would permit a battery system of 220 or 332kWh (which would be between 3,070 and 3,973kg). The third option, which would be inside the enclosure, would accommodate a smaller battery system of 1 rack or 17 modules, which would permit a battery system 110or 166kWh (which would be between 2,212 and 2,625kg).

6.2.2 Hypothetical vanadium flow battery deployment

Based on the energy usage profile of this site, along with considerations around product availability, a vanadium flow battery rated 100kW / 198kWh at the beginning of its life has been considered.

For such a storage system, high level budget estimates, based on the assumptions outlined above, are as follows:

CAPEX	Budget Rate	Budget $ (ex GST)
BESS System Cost	$1,610 / kWh	$318,700
Battery modules		$216,000
Battery inverter		$54,900
Battery enclosure and wiring		•
Contractor margin		$47,800
Installation Works	$511 / kWh	$101,200
Project management and engineering design		$28,600
Installation and commissioning		$57,400
Switchboard modifications		•
Contractor margin		$15,200
Grid connection cost	N/A	N/A
Variable	$79 / kWh	$15,600
Logistics		$5,000
Additional battery control equipment		$8,300
Contractor margin		$2,300
TOTAL	**$2,199 / kWh**	**$435,500**

OPEX	Budget $ (ex GST)
Year 1 cost	$865
Total 10-year cost	$65,500

These estimates are based on a UET vanadium flow battery system with Victron Qualtro or Princeton inverter , ComAp protection relay and a 40ft shipping container.

By way of maintenance schedule, external inspection, U-Tube solution replacement, and mechanical inspection would be completed annually. The air filter replacement would be completed every six months, electrical inspections would be every 2 years, and cooling fan replacement and electrolyte pump replacement would be completed every 5-7 years.

Four alternative layout options were considered that represent different row and module configurations. The first option consists of 10 modules across two rows with a walkway, thereby accommodating a 222kWh (22,144kg) system. The second option would consist of 7 modules across one row, accommodating a 154kWh (15,477kg) system. The third option would consist of 7 modules within a 40ft shipping container, accommodating a 154kWh (19,427kg) system. The fourth option would consist of 5 modules across one row, accommodating a 110kWh (11,0777kg) system. All layout options would include the inverter being located on the adjacent wall.

6.3 Hypothetical Deployment at a Shopping Centre

GPT's Rouse Hill site is a shopping centre on the corner of Windsor Road and White Hart Drive in Rouse Hill, around 50km north west of Sydney. The site resembles a town centre with streets, outdoor dining, and a mix of indoor and outdoor spaces, and the centre is divided into four quadrants that meet at a 'town square' space.

In contrast to an office tower, a shopping centre will tend to have a lower height-to-footprint ratio and offer possible outdoor locations for novel energy storage deployment. Car parks and roof spaces can equally be considered within shopping centres, however, as with office towers, the operational, strategic, and financial viability of these locations will be subject to considerations of access, containment, as well as the forfeited opportunity to us the space for other purposes.

The nominated batteries were sized using meter data and optimised for the best payback resulting in a focus on reducing demand charges. Preliminary cost estimates have been prepared using the following assumptions:

1. Battery system costs have been sourced from vendor pricing for this site's closest modelled size. These estimates have been provided by vendors in the absence of a concept design and are therefore generic estimates. A 15% contractor margin has been added to the battery system cost estimates to reflect pricing to GPT. Where applicable figures have been converted to AUD, the following rates have been adopted: 1 AUD = 0.71 USD; 1 AUD = 0.63 EUR; 1 AUD = 0.54 GBP.
2. Project management and engineering design costs have been estimated at 10% of the sum of the battery system equipment and installation costs. Installation costs have been estimated on a typical per rack or module basis. No installation quotes have been sought from contractors in preparing this estimate. Switchboard modification costs are excluded from the battery pricing where the system will be installed on the same master switch board as a new solar system. A 15% contractor margin has been added to installation works cost estimates to reflect pricing to GPT.
3. Where battery installation will be co-located with a new solar system, the grid connection costs will be excluded from the battery costing and incorporated into the solar pricing. A 15% contractor margin has been added to the grid connection cost estimate where applicable to reflect pricing to GPT.
4. To accommodate site specific complexities, the following variable costs have been considered: additional logistical costs due to location (applicable to CBD locations) at an approximate cost of $0.025/MWh; additional battery control equipment includes meters, relays, switches and controls not integral to the battery system package or solar distribution board; an approximate 15% contractor margin has been added to the variable cost estimate to reflect pricing to GPT.

During the site visit, there were three location options identified for battery storage deployment. The first option is an existing motorcycle parking space, which is publicly accessible and approximately 42m^2 in size with a sloping ceiling height of 1.9m at the lowest point. This ceiling height may present an issue for the vanadium flow battery system but would likely accommodate the lithium-ion battery system. Cable runs from this location to the major switchboard would likely be short, though there may be some core drilling required. This location option could potentially accommodate a 166kWh (2,625kg) lithium-ion battery system or a 154kWh (15,477kg) vanadium flow battery system.

The second location option is a car parking space within the vicinity of the first option motorcycle parking space, also undercover but at a further distance from the major switchboard. As with the first option location, this location is publicly accessible and would provide good access for battery installation. With the greater distance from the major switchboard, the cable runs would be longer than those for the first location option and some core drilling may be required. As with the first location option, this location option could potentially accommodate a 166kWh (2,625kg) lithium-ion battery system or a 154kWh (15,477kg) vanadium flow battery system.

The third location option is space in an area that will be redeveloped. The space will provide for approximately 60m^2 that could be reserved for battery storage deployment with appropriate planning. A deployment in this location could connect to a different major switchboard to the one nominated for location options one and two above. As this the first and second option, this location option could potentially accommodate a 166kWh (2,625kg) lithium-ion battery system or a 154kWh (15,477kg) vanadium flow battery system.

6.3.1 Hypothetical lithium-ion battery deployment

Based on the energy usage profile of this site, along with considerations around product availability, a lithium-ion battery rated 75kW / 166kWh at the beginning of its life has been considered.

For such a storage system, high level budget estimates, based on the assumptions outlined above, are as follows:

CAPEX	Budget Rate	Budget $ (ex GST)
BESS System Cost	$856 / kWh	$142,500
Battery modules		$91,800
Battery inverter		$8,000
Battery enclosure and wiring		$21,300
Contractor margin		$21,400
Installation Works	$205 / kWh	$34,100
Project management and engineering design		$12,000
Installation and commissioning		$17,000
Switchboard modifications		•
Contractor margin		$5,100
Grid connection cost	$53 / kWh	$8,800
DNSP fee		•
Grid engineering		$1,800
Grid protection unit		$4,500
Testing		$1,200
Contractor margin		$1,300
Variable	$50 / kWh	$9,800
Logistics		•
Additional battery control equipment		$8,300
Contractor margin		$1,500
TOTAL	**$1,173 / kWh**	**$195,200**

OPEX	Standard	Capacity Guarantee
Year 1 cost (increase by 3% pa)	$1,250	$3,000
Total 10-year cost	$14,350	$34,000

These estimates are based on a LG Chem lithium-ion battery system with an SMA inverter, ComAp protection relay and an EnerSys Slimline Shelter outdoor rated enclosure with AC.

The majority of maintenance processes for a lithium-ion battery system (mechanical inspection, electrical and communication wiring inspection, cabinet cleaning, fan/AC inspection and cleaning, air filter replacement) would be conducted annually. The cooling fan replacement would be conducted every 5-7 years.

Three alternative layout options were considered that represent different ways of utilising the space. Two of these options, namely the exterior end wall of the enclosure or the adjacent wall of the enclosure represent partially enclosed locations and each of these options would accommodate 2 racks or 34 modules, which would permit a battery system of 220 or 332kWh (which would be between 3,070 and 3,973kg). The third option, which would be inside the enclosure, would accommodate a smaller battery system of 1 rack or 17 modules, which would permit a battery system 110or 166kWh (which would be between 2,212 and 2,625kg).

6.3.2 Hypothetical vanadium flow battery deployment

Based on the energy usage profile of this site, along with considerations around product availability, a vanadium flow battery rated 90kW / 154kWh at the beginning of its life has been considered.

For such a storage system, high level budget estimates, based on the assumptions outlined above, are as follows:

CAPEX	Budget Rate	Budget $ (ex GST)
BESS System Cost	$1,600 / kWh	$246,400
Battery modules		$168,000
Battery inverter		$41,400
Battery enclosure and wiring		•
Contractor margin		$37,000
Installation Works	$503 / kWh	$78,700
Project management and engineering design		$22,200
Installation and commissioning		$44,600
Switchboard modifications		•
Contractor margin		$11,800
Grid connection cost	$57 / kWh	$8,800
DNSP fee		•
Grid engineering		$1,800
Grid protection unit		$4,500
Testing		$1,200
Contractor margin		$1,300
Variable	$64 / kWh	$9,800
Logistics		•
Additional battery control equipment		$8,300
Contractor margin		$1,500
TOTAL	**$2,231 / kWh**	**$343,600**

OPEX	Budget $ (ex GST)
Year 1 cost (increase by 3% pa)	$600
Total 10-year cost	$46,500

These estimates are based on a UET vanadium flow battery system with Victron Qualtro or Princeton inverter , ComAp protection relay and a 40ft shipping container.

By way of maintenance schedule, external inspection, U-Tube solution replacement, and mechanical inspection would be completed annually. The air filter replacement would be completed every six months, electrical inspections would be every 2 years, and cooling fan replacement and electrolyte pump replacement would be completed every 5-7 years.

Four alternative layout options were considered that represent different row and module configurations. The first option consists of 10 modules across two rows with a walkway, thereby accommodating a 222kWh (22,144kg) system. The second option would consist of 7 modules across one row, accommodating a

154kWh (15,477kg) system. The third option would consist of 7 modules within a 40ft shipping container, accommodating a 154kWh (19,427kg) system. The fourth option would consist of 5 modules across one row, accommodating a 110kWh (11,0777kg) system. All layout options would include the inverter being located on the adjacent wall.

Appendix 1: Reference Stakeholder Group

Throughout this process, stakeholders were consulted across the project partner organisations, as well as external private, governmental and academic organisations with insight regarding novel energy storage technologies. A list of individual participating stakeholders is set out below.

Organisation	Name	Title
GPT	Steve Ford	Head of Sustainability
GPT	Marsha Costanzo	National Manager, Energy Solutions
GPT	Dale O'Toole	National Manager, Building Performance
GPT	Jeff Bracken	National Director, Office & Logistics Property Operations
GPT	Scott Crellin	National Director, Retail Operations
GPT	Darin Eskriett	Regional Operations Manager, Office
GPT	Shane Nolan	Portfolio Operations Manager, Retail
GPT	Ben Hunt	Operations Supervisor, 580 George St
GPT	Pawan Subedi	Operations Manager, Rouse Hill Town Centre
GPT	David Moreton	Regional General Manager, Retail
GPT	Chris Moses-Zahar	General Manager, 580 George St
GPT	Melissa Jack	National Manager, Capital Works, Retail
GPT	Martin Keyes	Development Manager, Sustainability & Operations, Retail
GPT	Chris Errington	Head of Procurement & Property Services
GPT	Geoff Dyer	National Manager, Technical Services, Sustainability & Property Services
GPT	Jacqui O'Dea	Chief Risk Officer

Organisation	Name	Title
GPT	Alison Bradley	Director, Risk and Audit
GPT	Dakhshina Quar	Risk & Audit Analyst
GPT	Lauren Allen	Group Manager, Health & Safety
ERM	Nick Jones	Head of Strategic Clients
ERM	David Hershan	Head of New Markets
ERM	Sarah Paparo	Principal Consultant
CTP	Lachlan Bateman	Managing Director
CTP	William Salis	Senior Renewable Engineer
City of Sydney	Chris Collins	Senior Manager
JLL	Dave Bullock	Sustainability Consultant
JLL	Ian McDonald	Manager – NSW & QLD, Energy & Sustainability Services
JLL	Phil Pereira	Head of Operations & Engineering, Darling Park Management
AMP Capital	Darren Teoh	General Manager Sustainability
Lend Lease	Andrew Cole	General Manager, Sustainability
Lend Lease	Hamed Faraoui	Senior Development Manager
UTS	Benjamin Duncan	Head of Sustainability (acting)
UTS	Jonathan Prendergast	Technical Director
UNSW	Hou Sheng Zhou	PhD Candidate

Organisation	Name	Title
Race for 2030	Chris Dunstan	Chief Research Officer
EV Council	Tim Washington	Chair
Gelion Technologies	Stuart Rayner	General Manager
Marsh	Indri Yasin	Senior Account Executive
Chubb	Bilal Chohan	Risk Engineering Services Engineer
TESG	Brad Johannsen	Director
TESG	Greg Payne	National Operations Manager

Appendix 2: Battery Hazardous Review Tool

Appendix 3: List of Reference Standards & Guides

Standard	Description
AS/NZS 1768	Lightning Protection
AS 1939	Degree of Protection
AS/NZS 1170.2	Structural design actions – General principles
AS 1170.4	Structural design actions – Earthquake actions in Australia
AS 2676	Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings
AS/NZS 3000	Electrical Installations (Wiring Rules)
AS/NZS 3008	Electrical Installations – Selection of cables
AS/NZS 3011	Electrical installations – Secondary batteries installed in buildings
AS/NZS 3100	Approval and Test Specification – General Requirements for Electrical Equipment
AS 4086	Secondary batteries for use with stand-alone power systems
AS/NZS 47755.3.5	Demand Response Capabilities and supporting technologies for electrical products
AS/NZS 4777.1	Grid connection of energy systems via inverters – Installation requirements
AS/NZS 4777.2	Grid connection of energy systems via inverters – Inverter requirements
AS/NZS 5033	Installation and safety requirements for photovoltaic (PV) arrays (where installed with a solar PV system)
AS/NZS 5139	Electrical installations – Safety of battery systems for use with power conversion equipment
AS/NZS IEC 60947	Low-voltage switchgear and control gear
IEC 60947-3:2015(ed.3.2)	Low-voltage switchgear and control gear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
AS/NZS 61439.2	Low-Voltage switchgear and control gear assemblies – Power switchgear and control gear assemblies
AS IEC 62619	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 62619	Lithium-Ion battery packs and modules shall be certified to meet the requirements of IEC62619
IEC 62133-2	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems

Standard	Description
IEC 62443	Industrial communication networks
IEC 99	International vocabulary of metrology
IEEE 2030	Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads (U.S. Standard)
IEEE 1547-2018 draft	Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces (U.S. Standard) (note that U.S. Standards are guidance only due to differences in electrical frequencies, voltages et cetera)
DNSP	Distribution Network Service Provider Service and Installation rules.
CEC	Best Practice Guide for Battery Storage Equipment – Electrical Safety Requirements (Version 1.0)
CEC	Clean Energy Council (CEC) 'Grid Connected Solar PV Systems: Install and Supervise Guidelines for Accredited Installers' (where installed with a solar PV system)
CEC	Clean Energy Council (CEC) Grid Connected Energy Systems with Battery Storage Install Guidelines
WHS	Work Health and Safety Act of 2017