



Report

Fire Safety Study

Waratah BESS Facility

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Executive Summary

Advitech Pty Limited (Advitech) was engaged by Akaysha Energy Pty Ltd (Akaysha) to complete a Fire Safety Study for the planned operational Waratah Super Battery infrastructure. The Waratah Super Battery is set to be the world's largest network battery with a storage capacity of up to 1680 MegaWatt hours.

The Waratah Super Battery will be located on part of the former Munmorah Power Station site at Colongra, within the Central Coast Local Government Area of New South Wales. The site is bounded by parts of the former the Munmorah Power Station and associated lands to the north-east and north-west and mature bushland to the south-west and south-east.

The Waratah Super Battery comprises of:

- A large-scale lithium-ion based battery energy storage system with 2600 Powin Stack750 Centipede battery segments and 3 associated PCS transformers
- A switchyard with 3 oil-cored transformers connecting the site to the NSW distribution grid.
- A separate operation and maintenance building for site control and administration with an adjacent storage and test area.

The Stack750 Centipede BESS units (Centipede) will be supplied by Powin Energy (Powin) of Tualatin, Oregon, USA, and are specifically designed to:

- Limit the risks of a thermal runaway initiating a battery fire.
- Prevent migration of a battery fire in a module to adjacent modules of a Centipede.
- Be robust against outside heat influence.
- Prevent an internal fire initiating a fire in adjacent infrastructure or nearby vegetation.

In 2023, Powin engaged Energy Safety Response Group (ESRG), Delaware, Ohio, USA, to conduct a large-scale fire test on a Centipede production model, with some minor modifications to some of the seals and weather stripping. The production model is identical to that expected to be installed at the Waratah site. Three segments were spaced 7.62 cm from each other. The initiator unit (i.e., the centre segment) was fully populated with modules and electrically connection, whilst the target units (i.e., the adjacent segments) were only half populated with modules located closest

The target unit (i.e., the centre segment) was fully populated with modules and electrically connected, the adjacent segments were half-populated. The modules in the three segments were left at the 'as-received' state of charge.

From the test, it was determined that fire spread through the target (initiating) segment, without any risk to the adjacent segments. The primary metric for the large-scale fire test was the temperature on the modules within the target and adjacent segments. The test concluded that the temperatures within the adjacent units were within safe operational bounds. The test was further successful in demonstrating that the walls of the segment are suitable for fire protection, the initiating segment posed no risk of segment-to-segment propagation.

It should be noted, water was used as a suppressant during the fire test. Water was applied to the Heating, Ventilation and Air Conditioning (HVAC) and Controls Compartment (i.e., the top compartments above the battery compartment) approximately 3 hours into the fire test. The fire resumed shortly after from the battery compartment.

Since the large-scale fire test noted above, Powin has made improvements to the Stack 750 Centipede unit's top cap design to further improve their resistance to fire propagation between units.

Main Findings and Recommendations

This Fire Safety Study has identified the following significant hazards and recommends the associated mitigation strategies summarised in the following Table 1.

Table 1 – Outline of fire related hazards and mitigation strategies

Hazard	Mitigation
Battery cell fire	Modules are designed specifically to prevent fire from propagating between adjacent modules, which has been demonstrated in independent fire tests.
Battery segment fire	- An entire battery segment fire is considered highly unlikely. - Segments are specifically designed with physical barriers, thermal insulation, and air gaps to prevent fire propagating between adjacent segments, which has been demonstrated in independent fire tests. - Powin implemented improvements to the Stack 750 Centipede unit top-cap design should further mitigate the risk of a multi-segment fire.
Bushfire triggering a battery fire	- Vegetation within the 10 m defendable space and 6 m clearway is maintained to ensure closest distance between a battery segment and surrounding hazard vegetation is 18 m (or greater).. - The physical barriers in battery segments limit the risk a bushfire poses to battery segments and to limit the heat flow from outside an enclosure to the battery cells. - Large-scale fire test results show a sustained heat flow (and direct flames) resulting in 300 °C external wall temperatures did not damage battery cells or equipment internal to a battery segment.
Non-battery infrastructure fire	- Switchyard components (including transformers) to be designed and operated to AS 2067:2016. - Appropriate clearways to be maintained around transmission lines. - Switchyard separation from BESS means the risk of a fire propagating from switchyard to BESS units to be considered low.
Explosion	- Hydrogen and thermal detectors are included in every battery segment to detect the presence of, or potential for, explosive gases. - Active and passive (fail-safe) ventilation systems are incorporated into the Centipede battery.
Toxic gas release	- Fire likely to affect only a single battery module, this significantly limits the total potential volume of toxic gas. - Even with an entire battery segment involved, the total potential volume of toxic gas is well below acceptable limits, both inside and outside the boundaries of the Waratah Super Battery site.
Environmental pollution hazards	- Fire management strategy for a BESS fire is to "let it burn", hence contaminated fire water risk is low. - If a fire consumes an entire battery segment, the segment remains mostly intact, limiting the exposure of rain to the burnt area minimising contaminated water. - Risk of a coolant leak from the oil-cooled switchyard transformers is managed by designing and operating the switchyard in accordance with AS 2067:2016.

Hazard	Mitigation
Electrocution hazards	▪ Designing and operating the system to relevant Australian standards relating to high voltage equipment. ▪ During a fire event automatically place the BESS into a safe state. ▪ The fire management strategy means fire responders do not need to approach the battery segments during a fire.
EMF hazards	▪ Equipment on site must comply with relevant Australian standards. ▪ The site is generally unmanned, significantly limiting personal exposure to EMF-producing equipment.

Summation

Broadly, based on the fire mitigation measures already in place in the Powin Centipede system, the recent updates to the top cap design, and the fire mitigation measures expected to be implemented in the Waratah Super Battery project, it is considered the key fire hazards identified for the project have all been suitably managed, and the risk of large or widespread fire, a fire causing significant human harm, or the initiation of a bushfire by a fire event on the WSB facility is relatively low.



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- B: Battery Management Plan
- C: Hazard Identification Workshop
- D: Bushfire Attack Level Assessment
- E: Thermal Runaway (UL9540A) and Large-Scale Fire Test Reports

Glossary

Table 2 provides a summary of the terms and abbreviations used in the FSS.

Table 2: Terms and Abbreviations

Abbreviations	Term / Definition
AC	Alternating Current
ACT	Australian Capital Territory
Ah	Amp hours
APZ	Asset Protection Zone
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BAL	Bushfire Attack Level
BC	Battery Cell
BCS	Battery Collection Segment
BESS	Battery Energy Storage System
BM	Battery Module Powin's system uses 10 battery cells per battery module
BMS	Battery Management System
BP	Battery Pack Powin's system refers to 3 battery modules per pack (30 cells)
BPAD	Bushfire Planning and Design
BPC	Battery Pack Controller
BS	Battery Stack/Segment Powin's system has 2 battery strings per battery stack/segment (840 cells)
BSt	Battery String Powin's system is 14 battery packs per battery string (420 cells)
Centipede	OR Stack750. The Centipede is made up of 9 battery segments and 1 collector segment. The battery segments are plugged in parallel to the collector segment.
CFD	Computational Fluid Dynamics
CSSI	Critical State Significant Infrastructure
cm	Centimetres
DC	Direct Current
E-Stop	Emergency Stop



Abbreviations	Term / Definition
EIS	Environmental Impact Statement
EMF	Electromagnetic Fields
EMS	Emergency Management System
EP&A	Environmental Planning and Assessment Act
EPRG	Emergency Response Planning Guidelines Exposure guidelines designed to anticipate health effects from exposure to certain airborne hazardous chemicals
ERC	Emergency Response Centre
ERP	Emergency Response Plan
ESRG	Energy Safety Response Group
FCP	Fire Control Panel
FRNSW	Fire and Rescue New South Wales
FSS	Fire Safety Study
GPM	General Property Management Pty Ltd
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
HMI	Human Machine Interface
HVAC	Heating, Ventilation, and Air Conditioning
ha	Hectares
ICNIRP	International Commission on Non-Ionising Radiation Protection
IP	Ingress Protection
Kg	Kilogram
km	Kilometres
kV	Kilovolt
kWh	KiloWatt hour
L	Litres
L/s	Litres/second
LEL	Lower Explosion Limit
LEPs	Local Environmental Plans
LFP	Lithium Iron (Ferrous) Phosphate Chemical formula – LiFePO_4
MW	MegaWatt



Abbreviations	Term / Definition
MWh	MegaWatt hours
m	Metres
m ²	Metres squared
m ³ /s	Metres cubed per second Airflow volume (m ³) of air passing a stationary point in one sec
mm	Millimetres
NCC	National Construction Code
NEMA	National Electrical Manufacturer Association Defines standards used in North American for various grades of electrical enclosures. NEMA has been applied as the manufacturer of the enclosure is from the US.
NSW	New South Wales
O&M	Operation and Maintenance building
PCS	Power conversion system The component of the BESS that includes the battery inverter.
PHA	Preliminary Hazard Analysis
PLC	Programmable logic controller
PPE	Personal Protective Equipment
ppm	Parts per million
R-value	Measurement of an insulation sheet's ability to resist heat flow
RFS	Rural Fire Services
ROC	Remote Operations Centre
SEARs	Secretary's Environmental Assessment Requirements
SEPPs	State Environmental Planning Policies
SCADA	Supervisory Control and Data Acquisition
SIPS	System Integrity Protection Scheme System designed to reserve and deploy battery power to support the electricity grid.
SSI	State Significant Infrastructure
UPS	Uninterruptible power supply
USA	United States of America
V	Volts
Vdc	Voltage direct current
Wh	Watt hour

1. Introduction

Advitech Pty Limited (Advitech) was engaged by Akaysha Energy Pty Ltd (Akaysha) to complete a fire safety study for the planned operational Waratah Super Battery project.

It should be noted that this report was prepared by Advitech Pty Limited for Akaysha Energy Pty Ltd ('the customer') in accordance with the scope of work and specific requirements agreed between Advitech and the customer. This report was prepared with background information, terms of reference and assumptions agreed with the customer. The report is not intended for use by any other individual or organisation and as such, Advitech will not accept liability for use of the information contained in this report, other than that which was intended at the time of writing

1.1 Scope of Report

The Waratah Super Battery project was granted Infrastructure Approval by the Minister for Planning on the 21st of February 2023. The granted approval is subject to a set of conditions which includes the provision of a fire safety study (FSS). The specific conditions related to the fire safety study are as follows [1]:

Schedule 2, Part B Environmental Conditions – General,

Fire Safety Study

- B21. *Prior to commencing construction of the battery storage, the Proponent must prepare a Fire Safety Study for the development, to the satisfaction of FRNSW and the Planning Secretary in writing. The study must:*
- (a) be consistent with the Department's Hazardous Industry Planning Advisory Paper No. 2 'Fire Safety Study' guideline;*
 - (b) include reasonable worst-case bush fire scenario to and from the battery storage and the associated bush fire management, including provision of asset protection zones developed in consultation with RFS;*
 - (c) describe the final design of the battery storage; and*
 - (d) identify measures to eliminate the expansion of any fire incident including:*
 - (i) adequate fire safety systems and appropriate water supply;*
 - (ii) separation and / or compartmentalisation of battery units; and*
 - (iii) strategies and incident control measures specific to the battery storage design.*
- Following approval by the Planning Secretary, the Proponent must implement the measures described in the Fire Safety Study.*

Note: 'to the satisfaction of FRNSW' above means confirmation in writing from FRNSW that the Study meets the requirements of FRNSW as required by the Department's Hazardous Industry Planning Advisory Paper No. 2 'Fire Safety Study' guideline.

And

Operating Conditions (section B23 (b) only)

- B23. *The Proponent must:*
- (a) minimise the fire risks of the development, including managing vegetation fuel loads on-site;*
 - (b) ensure that the development:*
 - meets the Aim and Objectives of Planning for Bushfire Protection 2019, including provision of appropriate asset protection zones developed in consultation with RFS; and*
 - includes a 10 metre defendable space around the perimeter that permits unobstructed vehicle access*
 - manages the defendable space areas as an Asset Protection Zone; and*

- *is suitably equipped to respond to any fires on site including provision of a 20,000 litre water supply tank for bush and grass firefighting fitted with a 65mm Storz fitting and a FRNSW compatible suction connection located adjacent to an internal access road;*

These Schedule 2 conditions require the FSS to be consistent with the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2 – Fire Safety Study Guidelines [2]. HIPAP No.2 outlines the objectives and principles of a FSS. The bushfire management aspects are consistent with the Aim and Objectives of the RFS's *Planning for Bushfire Protection 2019*. In combination, this ensures that the fire safety system is specifically designed to address the needs of the facility. The elements of a FSS include:

- Identification of fire hazards and the consequences of possible fire incidents.
- Fire prevention strategies and measures.
- Analysis of the requirements for fire detection and protection and identification of the specific measures to be implemented.
- Calculation of fire-fighting water supply and demand.
- Containment of contaminated fire-fighting water.
- First aid fire protection requirements.

This study considers the fire hazards associated with the Waratah Super Battery project during operation. It does not consider any unique fire hazards that may exist during construction or commissioning.

2. Description of the Waratah Super Battery facility

2.1 Waratah Super Battery – Munmorah

The Waratah Super Battery is set to be the world's largest network battery, and will allow Sydney, Newcastle, and Wollongong consumers access to more reliable energy from the existing electricity grid, particularly given the planned significant changes to the electricity system over coming years. In particular, the Waratah Super Battery project has been undertaken to ensure that New South Wales (NSW) continues to have reliable energy supply following the planned decommissioning and closure of the Eraring Power Station by 2025 [3].

The project includes, as defined in the 'Environmental Impact Statement' written by GHD [3]: The project includes, as defined in the 'Environmental Impact Statement' written by GHD [3]:

- A large-scale battery system, which has been designed to reserve and deploy battery power in support of the NSW electricity grid.
- Up to 850 MegaWatts (MW) active power capacity.
- An available storage capacity of up to 1680 MegaWatt hours (MWh).
- Transmission and related infrastructure to connect the battery system to the existing grid.
- Construction of other infrastructure and services as required for the project.

A summary of the key features of the project is provided in **Table 3**.

Table 3: Key Features of the Waratah Super Battery Project

Project Element	Summary
BESS capacity	850 MW active power 1680 MWh battery storage capacity
Battery unit	Battery units to be provided by Powin
Battery technology	Lithium Iron Phosphate (LFP)
Size of individual battery segments	Up to 3.3 m high, 1.6 m wide and 2.5 m deep
SIPS Operator / National Electricity Market (NEM) connection	Transgrid / Munmorah Substation
Service provider	Akaysha Energy
Availability	24 hours per day, 7 days per week, 365 days per year
Site area	- Project site: ~ 14 ha - Easements: transmission (2.7 ha), access road (0.2 ha)
Proposed infrastructure	- BESS (including batteries, inverters, transformers, earthing, switchgear etc) - Switchyard - Overhead transmission line, supporting structures and related infrastructure to connect to the existing Transgrid Munmorah Substation - Ancillary infrastructure (including access roads, site services, operation and maintenance building, site parking, signage and security etc.)
Proposed duration of construction	18 months

2.2 BESS Units – Powin Stack Technology

The Waratah Super Battery project includes a large-scale outdoor BESS and associated infrastructure, comprising of a large number of battery storage units. The project will utilise Powin's Stack750 Centipede BESS, referred to as the "Centipede".

The Stack750 Centipede BESS is scalable and modular, consisting of a line-up of factory assembled battery segments positioned directly adjacent to one another. At the end of the line-up is one Stack750 Collection Segment which forms the interface between the battery segments and a power conversion system (PCS).

The Centipede system comprises of the following components, as defined within the *Stack750 Centipede – A Modular Battery Energy Storage Platform Product Manual*: [4]:

- Cells
- Modules
- Packs

- Stacks
- Segments

Figure 1 presents the breakdown of a typical battery stack. Note the identical string on the rear of the stack is not presented (which would make up the complete battery segment).



Figure 1: Powin Battery Stack (Adapted from Powin Stack750 Product Manual) [4]

2.2.1 Cell

The fundamental unit of all batteries, both small and large, is the battery cell. The cell is where the potential electrical energy is stored as chemical energy. In the Centipede system, ten 280 Ah cells are wired in series to form a battery module.

The cells utilised in the Centipede system are based on the lithium iron phosphate (alternatively known as lithium ferrous phosphate, or LFP) chemistry, which has become widely utilised in the battery storage sector and is considered more fire-resilient than other common lithium cell chemistries. The Centipede system uses prismatic cells, and a typical cell is presented in Figure 2.



Figure 2: Typical Centipede system cell (Adapted from Powin Stack750 Product Manual) [4]



2.2.2 Module

Ten battery cells make up a module in the Centipede system, with three modules wired together in series to form a battery pack.

2.2.3 Packs

Three modules (comprising thirty cells in total) are connected in series to form a battery pack. The battery packs operate in a voltage range of 86 – 107 V. As they are connected in series, positive terminals being joined to negative terminals, the packs are configured in alternating orientations, installed and stacked directly underneath the battery pack controller [4].

The battery pack controller (BPC) collects voltage and temperature data from the battery pack cells, and reports this to the string controller. It contains:

- Power supply for control power.
- Separate power supply for balance charging.
- Power resistors and heat sink for balance discharging.
- Relays to connect power supply to the cell balancing circuit.
- Relays to connect the balancing circuit to each individual cell.

A key function of the BPC is the facilitation of cell voltage balancing. Balancing is either undertaken via 'Active' or 'Passive' means. 'Active' balancing occurs when the BPC utilises converted DC current to charge individual cells that have a lower voltage than other cells in the battery pack. 'Passive' balancing is where a resistor built into the BPC is used to discharge individual cells with a higher voltage than other cells in the battery pack [4].

2.2.4 Stacks

Fourteen individual battery packs are wired in series to form a string that is managed by a string controller. Two strings are then linked into a stack.

The string controller is responsible for safety, management, and performance along with warranty notifications for both strings of each battery stack. It is comprised of two different boxes:

- String controller AC section.
- String controller DC section.

The String controller monitors stack and DC bus voltages, reporting the data (along with relevant cell data) to the overall battery system software controller [4].

2.2.5 Segment

The Stack750 Centipede system comprises of two separate segments:

- Battery segment.
- Collection segment.

2.2.5.1 Battery Segment

The battery segment is the container housing the battery stack. The battery segment is an outdoor-rated National Electrical Manufacturer Association (NEMA) 4 enclosure. Included within the battery segment enclosure are:

- Heating, Venting and Air Conditioning (HVAC) compartment.
- Controls compartment.
- Battery compartment.
- Access panel for status display.
- Access door to the two battery strings contained within the enclosure.



Each battery segment contains two independent DC strings, with each string containing 420 battery cells in series. The battery segments have been designed in such a way to maximise the energy density within the BESS and allow for segments to be placed approximately 75 mm from each other.

2.2.5.2 Collection Segment

The collection segment connects the Centipede battery segments to the power conversion system (PCS). The collection segment is a separate pre-assembled outdoor rated NEMA 4 enclosure, with DC cable connections to the battery segments, and then to the PCS. Collection segments include:

- Air-cooled transformers and cabling.
- Circuit breakers for all AC power connections.
- Fire control panel (FCP).
- Environmental controller.
- DC switches and fuses.
- HVAC and heaters.
- UPS (for control power and communications).
- Networking equipment.

Collection segments can be equipped with up to three DC buses, with each DC bus able to connect to a maximum of ten battery segments. The environmental controllers within each battery segment report to and can be parameterised by a programmable logic-based master environmental controller located within the collection segment. The collection segment also comes equipped with a fire control panel, which communicates with the environmental controller and addressable fire safety system equipment within each battery segment [4].

2.3 Location and Site Description

2.3.1 Site Location

The Waratah Super Battery will be located on the former Munmorah Power Station site at Colongra, within the Central Coast Local Government Area in NSW. The proposed site is shown in Figure 3.

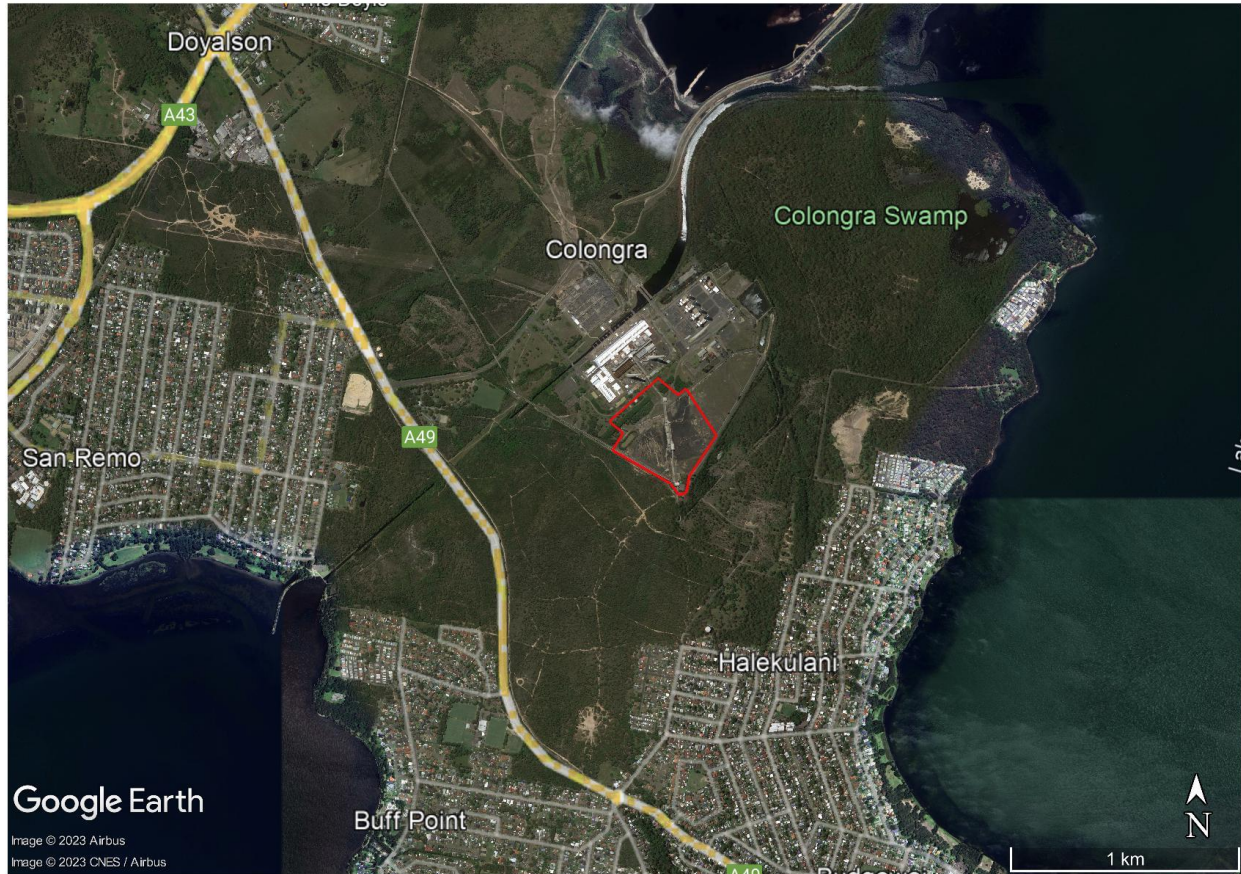


Figure 3: Site Location (Site Boundary in Red) (extracted from Google Earth)

The site of the former Munmorah Power Station comprises of multiple lots, with a total combined area of approximately 727 hectares. In 2016, the former power station and its surrounds were transferred to Generator Property Management Pty Ltd (GPM), a NSW government-owned company. GPM undertake decommissioning, demolition, and remediation of power station sites remaining in public ownership. They have previously managed the demolition and rehabilitation of the former power station, and are currently undertaking further rehabilitation, remediation and maintenance works in accordance with the existing approvals [3].

The proposed site comprises part of Lot 10 DP 120141, part of the subdivided lot for the former Munmorah Power Station. The proposed site has an approximate area of 14 hectares. The development is in an area classified as SP2 – Infrastructure (electricity generation works), per the Wyong Local Environmental Plan 2013 [5]. Figure 4 presents the land zoning of the former power station and surrounds.

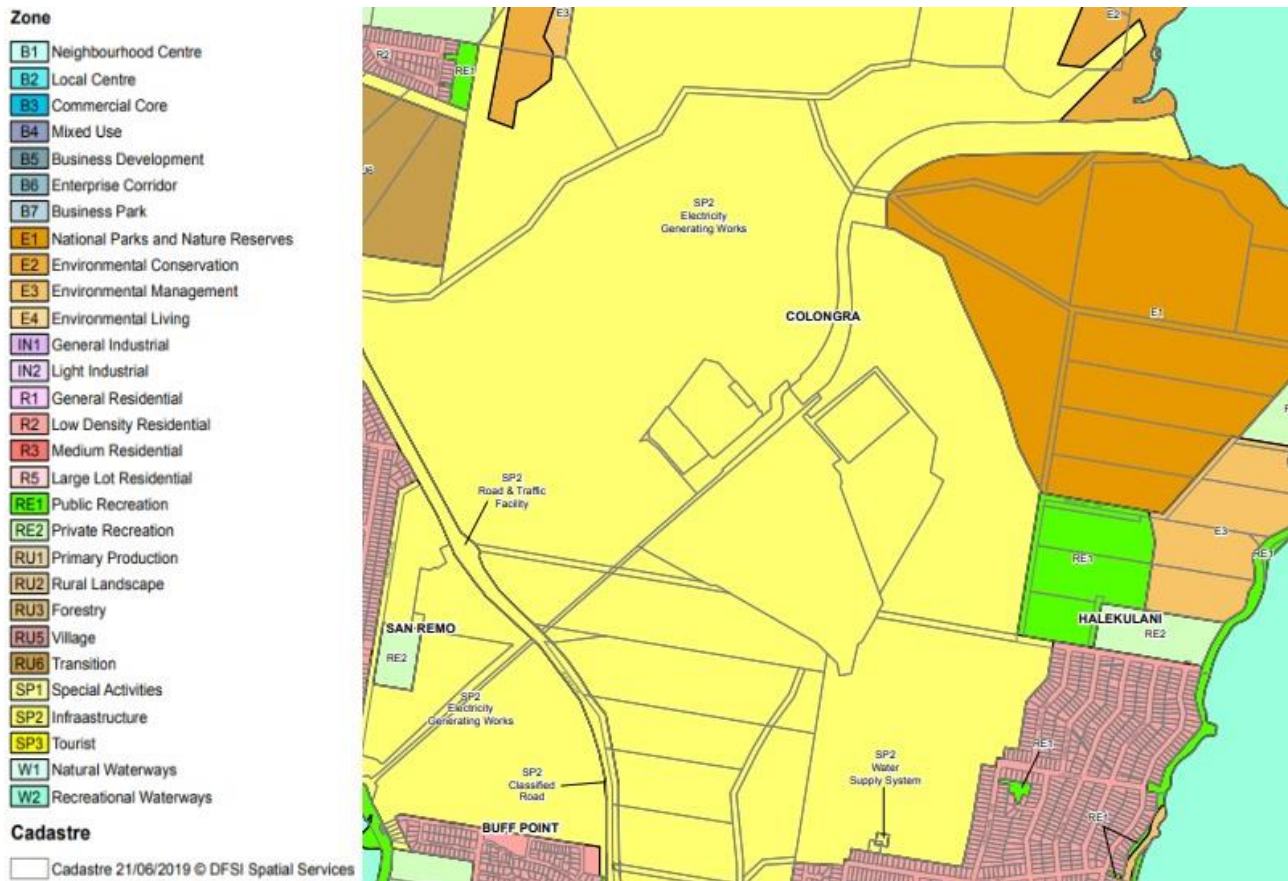


Figure 4: Land Zoning (adapted from *Wyong Environmental Plan 2013 – Land Zoning Map – Sheet LZN_018* [5])

The Munmorah site is considered particularly suitable for the development of the Waratah Super Battery for several reasons, including:

- The site is largely vacant, with the decommissioning of the Munmorah Power Station. The site is also of a considerable size, allowing for a number of potential locations to be investigated.
- The land is already owned by the NSW government.
- As the site was a former power station, it is reasonably remote from any sensitive receivers and largely clear of natural constraints (i.e., flooding, vegetation, heritage etc).
- The subject site is already located in proximity to an existing high-capacity substation with available bays for new transmission connections.

As shown in Figure 3, the remaining infrastructure from the decommissioned Munmorah Power Station includes a telecommunications tower (northwest), Colongra Power Station (northeast), transmission lines and electrical distribution infrastructure (north), and the former Munmorah Power Station and associated lands (northwest and north). The former Munmorah Power Station is surrounded by mature vegetation and set back from public roads on all sides.

The proposed site lies roughly central to the suburbs of Doyalson (approximately 2.1 km northwest), San Remo (approximately 1.3 km west), Buff Point (approximately 1.1 km southwest), Budgewoi (approximately



1.7 km southeast) and Halekulani (approximately 800 m southeast). To the west of the proposed site lies a Koala Park (685 m) and to the northeast lies Colongra Swamp (885 m).

2.3.2 Site Description

The Waratah Super Battery includes BESS units capable of discharging at up to 850 MW/hour, comprising of approximately 300 collection segments and 2600 battery segments arranged within the proposed 'BESS Yard. Each collection segment includes inverters, medium voltage transformers, switchgear, and control systems, all of which are contained within individual weatherproof enclosures. Each segment will be mounted on concrete footings on gravel [3].

Alongside the proposed BESS Yard, the proposed facility includes a switchyard, transmission lines and easement, operation, and maintenance (O&M) facility, storage yard, parking, and access roads.

The proposed switchyard provides connection between the BESS Yard and the Munmorah substation. It will be designed at a nominal distribution voltage of 330 kV and consist of three oil-cooled transformer units. All equipment in the switchyard except for the power transformers is expected to be air insulated [3].

Transmission from the switchyard to the Munmorah substation will be overhead via a double circuit 330 kV transmission line, approximately 650 m long with a 60 m wide easement. The proposed transmission line would run along the north-eastern boundary of the former power station and connect to two dedicated 330 kV feeder bays at the substation. To support the transmission line, steel poles at varying heights will be installed [3].

The operation and maintenance facility includes a building with space for a site control room and various employee facilities. It is proposed that the O&M building be utilised for repairs and preventative maintenance tasks for operational equipment. The O&M building will be designed to a Class 5 standard under National Construction Code (NCC) [6]. Connected to the O&M building and part of the broader O&M facility will be a storage warehouse used for the storage of materials and equipment. The warehouse will be designed and constructed in accordance Class 7 under the NCC [6].

The proposed facility site plan is presented in **Figure 5**, as well as Appendix A.

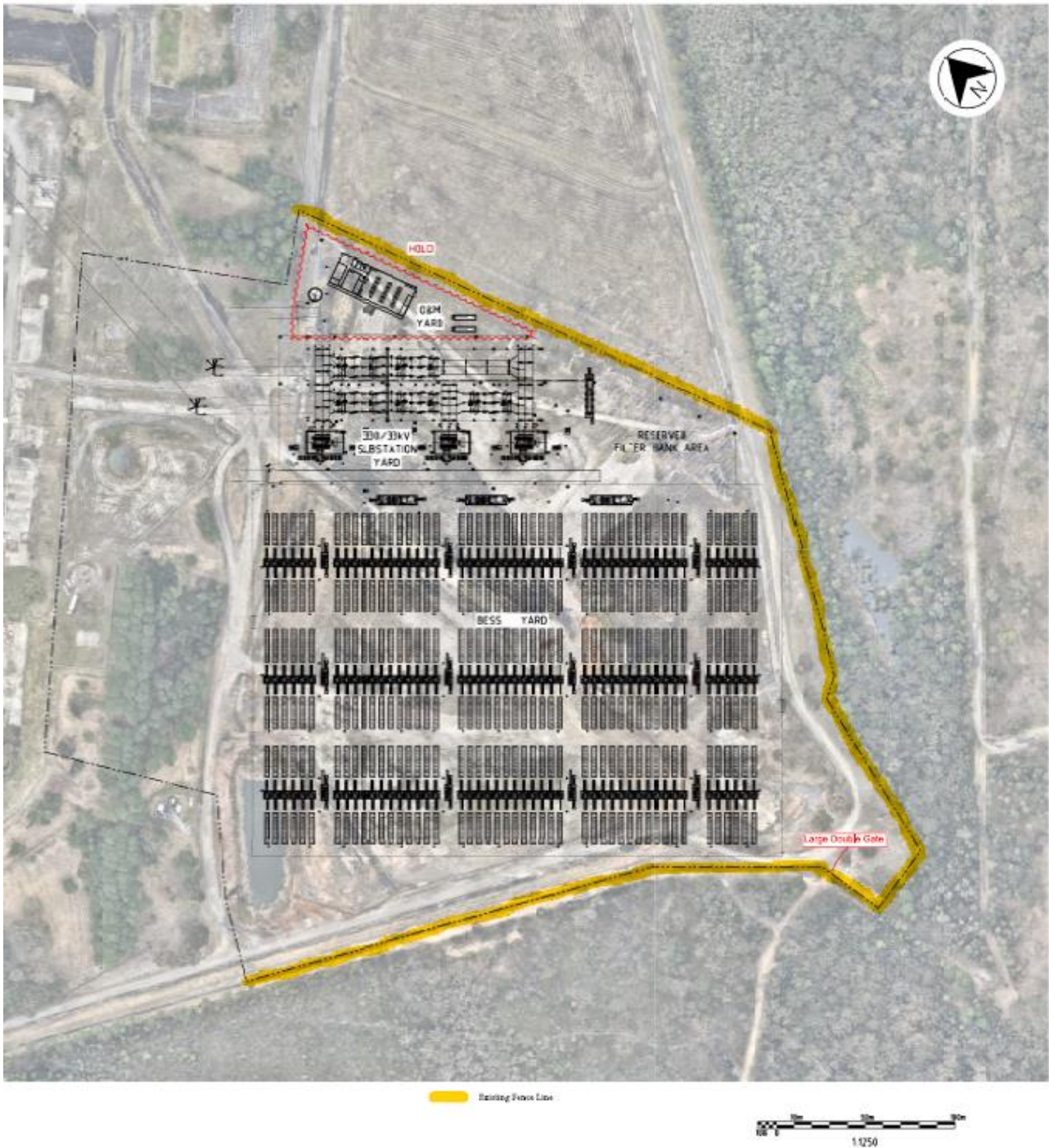


Figure 5: Proposed Site Plan
(as adapted from Drawing No. 12590-EL-DR-10000 Rev 0, Appendix A)

2.4 Scope of Development

2.4.1 Importance of the Waratah Super Battery

In recent times there has been a significant acceleration of plans for the retirement and decommissioning of traditional fossil fuel (largely coal) generators due to aging infrastructure, along with the drive towards renewable energy generation.

Four of the five remaining coal fired generators in NSW are set to reach the end of their technical lives before or just after 2030. They are:

- AGL's Liddell Power Station (capacity of 2000 MW) – retired in stages, with one unit closed in April 2022, and the remaining three units to be shut down in April 2023.
- Eraring Power Station (capacity of 2800 MW) – recently announced closing as of 2025, seven years earlier than originally scheduled.
- Vales Point Power Station (capacity of 1 320 MW) – expected to close in 2029.
- Bayswater Power Station (capacity of 2 640 MW) – slated for closure in 2032.

The last remaining coal fired power station in NSW, Mount Piper Power Station (capacity of 1400 MW), has a current predicted closure of 2040, in line with the drive towards net zero by 2050.

As coal-fired power stations close and are replaced with variable renewable energy generators such as solar and wind, it is clear that large-scale, highly efficient, and rapidly dispatchable energy storage systems will be critically important to the stability of the electricity system [7]. Large-scale batteries will meet a major portion of this need for energy storage.

The Waratah Super Battery project can be considered critical to avoid a forecast breach of the Australian Energy Market Operator's Energy Security Target, and directly supports the NSW Government's electricity strategy and infrastructure roadmap. The project has been designed and assessed with regard to Section 5.16 of the EP&A Act, including the objectives of the EP&A Act, and is considered to be consistent with the principles of ecologically sustainable development [8].

The development of the Waratah Super Battery is considered justified because it:

- Responds to a critical, recognised need and is consistent against several state and federal government plans, policies, and guidelines with regards to planning for a reliable, affordable, and sustainable electricity future in NSW.
- Is proposed on a site which already has appropriate zoning for energy infrastructure (the former Munmorah Power Station), is remote from sensitive receivers and would not result in any foreseeable land use conflicts with surrounding developments.
- Is consistent with the principles of ecologically sustainable development, the objectives of the EP&A Act [8] and is considered to be in the public interest.

2.4.2 Project Approval

The EP&A Act is the principal legislation regulating development in NSW. It establishes a regime for the assembly of development application, assessment of their environmental impacts, and the determination of those applications. It also allows for the making of environmental planning instruments such as *State Environmental Planning Policies* (SEPPs) and *Local Environmental Plans* (LEPs).

Part 5, Division 5.2 of the EP&A Act [8] provide for declaration, assessment, and approval of State Significant Infrastructure (SSI) and Critical State Significant Infrastructure (CSSI). The process for environmental assessment and approval of SSI and CSSI are set out as follows:

- Application for approval of the Minister for Planning (the Minister) to carry out the development.
- Development of Planning Secretary's Environmental Assessment Requirements (SEARs).
- Preparation of an Environmental Impact Statement (EIS).
- Public exhibition of the EIS.
- Response to submission(s) received during public exhibition of the EIS.
- Preparation of SEARs Report.
- Determination regarding the development by the Minister.

As the Waratah Super Battery project was declared a CSSI in accordance with Section 5.13 of the EP&A Act and Schedule 5, Section 30 of the Planning Systems SEPP, the project can be considered "essential for the state for economic, environmental or social reasoning" as per *Declaration of SSI and CSSI* [9].



3. Hazards Identified

Large-scale lithium-ion based BESS are a relatively new technology, and the understanding of the hazards associated with the operation of these facilities is continuing to mature as technology evolves and more systems are installed. Assessment of the likely hazard scenarios associated with a large-scale BESS, and the potential outcomes as a consequence of these hazard scenarios is rightly subject to the scrutiny of regulators, responder peak bodies, safety advocates and planners.

A hazard identification workshop was held at the offices of Advitech Pty Ltd on 29th March 2023 to consider the hazard scenarios specific to the Waratah Super Battery development. The hazard identification workshop aimed to build upon:

- The known hazards of lithium-ion BESS, as published within academia.
- The body of literature analysing incidents involving lithium-ion BESS from around the globe.
- The analyses already narrated within the preliminary hazard assessment (PHA) for the Waratah Super Battery development. A PHA was undertaken as part of the state significant infrastructure development application submission (Application Number SSI-48492458) for the proposed Waratah Super Battery project [10]. The PHA identified various scenarios included within the bullet list in Section 3.1.

During the hazard identification workshop each of the above was considered, or reconsidered, within the specific context of the nominated development site and layout, and what was known about the equipment to be installed on site.

3.1 Recognised Hazards Associated With Lithium-ion BESS Products and Electrical Installations

The hazard identification workshop identified several broad categories of hazards associated with lithium-ion BESS products, including:

- Fire (including thermal runaway events, propagation of thermal runaway events, potential for initiation of bushfires, etc).
- Heat radiation (including radiation from BESS fire events and susceptibility to overheating from external heat sources, etc).
- Explosion as a consequence of the accumulation of flammable gases resulting from contained cell venting.
- Toxic gas release as a consequence of the dispersion of combustion products and vented gas species.
- Potential for pollution from the release of environmentally hazardous species in combustion products, vented gases and water utilised for fire-fighting purposes.
- Electrocuting of personnel and responders operating within an environment with large stores of electrical energy.
- Human health and safety impacts associated with exposure to electromagnetic fields.

3.1.1 Battery Cell Fire Hazards

Many of the significant hazards associated with large-scale BESS relate to fire, whether triggered internally to the battery system, or by external sources. Key fire hazards include:

- Hazards related to the impact of external fire or heat sources on the battery segment. The battery cells in a BESS can be sent into thermal runaway (and/or fire) by an external heat source, and so the impact of external heat sources on a battery cell is a significant issue in large-scale BESS. Management of these risks, and prevention of a large fire triggered by outside heat sources, needs to be a key focus of BESS design and operating strategies.
- Hazards related to fires triggered within the battery segments- a battery cell going into thermal runaway due to internal fault, inappropriate cell management or other issue, and then igniting

into a fire. Evidence suggests that, over the lifetime of a system there is a significant risk of a single-cell fire in large-scale BESS, and thus appropriate risk management procedures are needed to manage this risk and stop a fire spreading more broadly.

Battery cell fire hazards mostly exist for operational battery cells installed in the BESS battery units, and the risk of thermal runaway or fire in these cells is greatest during cell charging or discharging. Battery cells that are stored passively in a warehouse facility (for example, being kept as spares for maintenance purposes) are considered a relatively low risk fire hazard risk given they are stored in much lower volumes than in the BESS, and not being charged or discharged. Gas and fire detectors will be installed within the warehouse storage area and the O&M building.

Damaged or depleted cells will be stored in a dedicated storage area. Degraded cells are more likely to enter thermal runaway and potentially spontaneously combust. From the battery management plan, a dedicated storage area should be located 15 m from any buildings. Further details are yet to be confirmed. Advitech recommends the dedicated storage area be on a covered concrete pad with bunding. The area should be designed to have the capacity to store the equivalent cells and/or modules of one battery segment unit, prior to removal and disposal off-site.

3.1.2 Non-Battery Infrastructure Fire Hazards

A large-scale BESS project will typically contain staff amenities and storage/maintenance buildings. These represent a low-level fire risk.

A more significant non-battery fire risk in a large-scale BESS project comes from the electrical infrastructure for electrical connection to the surrounding electricity grid. Transmission lines, oil-cooled transformers in particular can pose significant fire risk.

3.1.3 Explosion Hazard

Evidence from both laboratory testing and actual fire incidents has shown that BESS systems undergoing thermal runaway can produce a cloud of explosive gases. If this gas mixture is allowed to build up to sufficient volume and concentration, this "vapour cloud" can represent a significant explosion risk: there have been instances of large-scale BESS incidents resulting in an explosion that injured first responders and caused significant infrastructure damage. Best-practice management of BESS vapour cloud risks is based around ensuring that a sufficient volume of explosive gases cannot build up to represent an explosion hazard.

The risk of an explosion from vapour cloud build-up is closely associated with the volume and packing density of battery cells in a given enclosure. The risk is greatest where large number of battery cells are stored in a non-ventilated enclosure, as is common in the BESS modules. Individual battery cells stored as spares in a warehouse facility are considered unlikely to represent a significant explosion risk.

3.1.4 Toxic Gas Release Hazard

Fire or thermal runaway events in a BESS can result in the production of toxic gases. Of particular concern is the production of hydrogen fluoride (HF). Hydrogen fluoride is highly corrosive and a powerful contact poison. HF dissolves in water to form hydrofluoric acid, which has the ability to penetrate human tissue, causing very serious burns, damage to skin, eyes and airways.

3.1.5 Environmental Pollution Hazards

The main risk of water pollution from a large-scale BESS project is through contaminated water entering and polluting surrounding waterways. The most likely significant source of contaminated water in a BESS development is from water that becomes contaminated due to fighting a fire.

3.1.6 Electrocution Hazards

Electrocution is a significant risk in any electrical energy storage system operating above extra-low voltage levels. Typical BESS facilities operate at high voltage levels, however the risk of electrocution during routine operation is considered relatively low due to:

- Once the facility is constructed and in operation, minimum personnel attendance at site.

- Limited access to areas where electrocution risks exist, and such access is only granted to appropriately qualified persons.
- Training of personnel and responders.
- Incident training and information for neighbours and routine emergency drills being held to test protocols and communications.
- Risk management procedures specifically designed to manage electrocution risks that are expected to be contained in site incident management and operational procedures.

3.1.7 EMF Hazards

Electromagnetic Fields (EMF) form part of the natural environment, with electric fields present within the atmosphere and static magnetic fields created by the shifting of the Earth's core. EMF are also produced from electricity and electrical equipment whilst in use. At high powers, or for long periods of time EMF can represent a hazard.

Electrical equipment that may represent an EMF hazard at a typical large-scale BESS project include the BESS units and associated power electronics, electrical transmission infrastructure, transformers, and associated switchgear.

4. Fire Prevention and Harm Minimisation Strategies

4.1 Fire Safety Characteristics of Site Infrastructure

In the context of PHA Application Number SSI-48492458, the particular hazards identified in Section 3 of this report should be assessed in consideration of the various fire safety design features of the Powin Centipede and Stack750 technology. Although each of the recognised hazards listed in Section 3.1 of this study apply to the Waratah project, the Powin design does possess unique features specifically targeted at limiting many common lithium-ion BESS hazard scenarios and their potential impacts/consequences.

The Waratah Super Battery project takes a layered approach to hazard management, with the following broad layers:

- Local battery segment fire & thermal event sensing and management, that is designed to detect thermal events early and limit the potential for build-up of an explosive atmosphere.
- Battery segment physical design that minimises the potential for fire propagation.
- Site-wide fire and incident management strategy.
- General infrastructure management and incident response protocols and procedures.

4.1.1 Powin Centipede Architecture & Design Features

The selection of the Powin Centipede technology is key to minimising the fire potential at the Waratah Super Battery facility. The Powin Stack750 technology incorporates several unique design features designed to significantly reduce the risk of fire and fire or thermal-related hazards in the BESS, as summarised in the following sections.

4.1.1.1 Cell Selection

The fundamental unit of any BESS unit is that of the cell. The cells chosen for the Waratah project are based on lithium iron phosphate (lithium ferrous phosphate, or LFP) chemistry. LFP cells are generally considered less fire-prone than other lithium chemistries, typically requiring temperatures up to 50 °C higher than other common lithium cell chemistries to enter thermal runaway [11]. Similarly, the quantity of heat released by a venting LFP cell is lower than that of other chemistries.

The cells chosen for the Waratah Super Battery project include a safety vent to provide a controlled release of internal pressure during abnormal conditions and rigid aluminium exterior, making it difficult to mechanically damage the cell.

Additionally, these cells contain no liquid ‘freely flowing’ electrolyte. As such, it is unlikely that the electrolyte could leak out of the cell enclosure into the environment should the cell be damaged.

Individual battery cells in a Centipede module are grouped in a tiered subassembly of modules and packs, which are bonded within their own steel enclosures. This allows for greater earthing and protection against hazards associated with high voltage.

4.1.1.2 Module Design

Each module contains ten cells, with three modules connected in series to form a pack. Special considerations include:

- Each module is isolated from other modules by steel barriers. These steel barriers are both structural support for the BESS units and a thermal barrier, preventing effects of thermal runaway from propagating between modules.
- The modules themselves are stacked on steel racking and enclosed by an outdoor rated steel enclosure, largely protecting them from weather and external damages.
- Compared to other module designs seen in large-scale BESS, Powin’s modules contain fewer cells in a given volume, lowering the risk of cell failure in a module, and the likelihood of large releases of explosive gas.

4.1.1.3 Battery Segment Design

Each battery segment has been designed to ensure the continued integrity of all electrical components contained within. Battery segments are installed in a steel enclosure rated to IP 56 (NEMA 4), providing protection against environmental and physical exposures. Each segment is thermally insulated on the door panels to protect from environmental exposures. Each segment has been designed to withstand ambient temperatures up to 50 °C and up to 100 % humidity.

The battery segment has also been designed to allow access to each string contained within, whilst protecting the electrical equipment from potential hazards and environmental exposure. Each battery segment has two (2) sets of doors, allowing access to each string from both sides of the container. The doors are insulated with an insulation for an R-value of 4.2. Both sets of doors are also sealed with a rubber gasket and silicon bead. The other side walls of the segment (i.e., walls adjacent to other segments) and the top surface of the battery segment do not have additional insulation installed.

Battery segments have air-intake fans and a shroud assembly installed at the four bottom corners of the segment and four air vents at the top to allow for the ventilation of a segment if explosive gases are detected in a segment. These air vents are covered by a metal mesh, with the largest aperture in the mesh being 1.9 mm, meeting requirements of AS 3959:2018 [12]. Vents are louvered, and the expected operating strategy is these louvres remain closed during normal system operation.

In the event of a power failure or fire, the louvres will fail open.

Recent improvements by Powin to the design of the top of the battery segment, or top cap has further improved the resistance to fire propagation between battery segments [13] (See Figure 6).

System Architecture

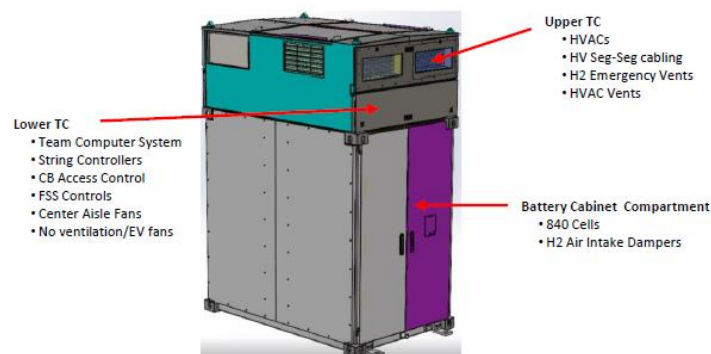


Figure 6: Stack 750 – Upper and Lower Top Cap positions



Temperature and humidity are managed within a stack through utilisation of two heating ventilation and air conditioning (HVAC) units mounted on top of the battery segment, supported by stack ventilation fans. Cool air is directed to the 'cold aisle', running down the centre of a stack. The HVAC units are controlled by a stack controller that aims to manage temperatures, humidity, prevent corrosion and premature failure of all electrical componentry contained within the stack. HVAC air supply is ducted directly to the battery modules via heatsinks. If any cell is outside normal operating ranges, the HVAC will turn on and remain on until the cell returns to operating temperature range. In the event of power failure, the UPS is designed to operate the exhaust fan for at least an hour. The stack design has undergone extensive CFD analysis and real-world testing of the HVAC cooling performance: the HVAC system has been deemed sufficient to maintain the operating temperature range allowed for each cell [11].

Under normal operating conditions and with battery segment doors closed, the battery segment does not pose an electrical hazard.

Battery segments are expected to be placed 76 mm from each other, with an approximate distance between individual 'Centipedes' (lines of battery segments with an adjoining collection segment) at 2.1 m.

4.1.1.4 Detection Mechanisms

Stack750 segments are all monitored in real time, down to the individual cell level. Real time data is fed back to Powin's Remote Operations Centre (ROC) for monitoring. Detection measures exist not only to identify whether a thermal runaway event has or will occur, but also when the conditions within the segment are evolving towards a potential thermal runaway event [11].

Detection measures within the segment operate at a cell level. These measures include:

- Voltage and temperatures of every cell within the segment are undertaken in real time. These measurements can be used to automatically shut down the system and disconnect all stacks from the DC bus, should any abnormal conditions arise.
- Automated 'cell health scans' are run daily from the ROC. These scans can be used to determine any behaviour indicating current and/or impending failure at a cell level.

The status of all safety related equipment (HVAC, gas detection, ground fault detection) is also all monitored in real time by the ROC:

- All segments are installed with heat and smoke detectors. These detectors automatically trigger Fire Safety Systems to undertake required actions.
- All segments have hydrogen gas detectors installed. The hydrogen gas detectors are calibrated to detect hydrogen at 1 % concentration (or 25 % lower explosion limit, LEL).
- Fire and gas sensor systems are backed up by a 6 kW UPS located in the collector segment, with an approximate run time of an hour. This ensures detection can still be undertaken in segments should there be a power loss event.

4.1.1.5 Emergency Ventilation

An emergency ventilation system operates in the battery segments. The emergency ventilation system operates in two modes, dependent on the presence of gases within the battery segment. The first mode is active, where the HVAC ceases to operate and booster fans activate to vent internal gases out of a battery segment. In the event of power loss to the segment, the UPS will provide power to the exhaust fans for approximately an hour. The second emergency ventilation mode is passive, where battery segment vents fail to the open position, should there be a power failure, to allow gases to be vented out using natural ventilation.

Should hydrogen be detected within a battery segment, the HVAC ceases to operate. Following shut down, the system enters an active ventilation mode which:

- Draws in fresh air at a rate of 0.15 m³/s using eight booster fans in the top cap to augment active ventilation.
- Starts the segment's bottom air-intake fans.
- Opens the air vents at the rear of the top cap to expel the explosive gases gas from the top of the unit.



Should there be a power failure (e.g., loss of power to the fans), the passive ventilation mode takes over, where the ventilation vents open by means of a fail-open actuator, enabling venting gases to escape through the effect of natural buoyancy.

When a fire alarm is activated, emergency ventilation modes and all HVAC functions will be overridden to stop airflow within the stack. Activation of emergency ventilation automatically triggers an emergency stop (E-Stop), immediately shutting down the system and disconnecting all stacks from the DC bus [4] [11].

4.1.1.6 Battery Management System (BMS)

The BMS forms part of the Stack Operating System and focuses on managing the DC battery. It is primarily concerned with battery performance, data acquisition and safety. It is used to monitor cell and battery packs for immediate safety conditions that may affect the battery's long-term performance and warranty. The BMS's essential role is ensuring the battery is operating within safe margins. At its core, it has been designed to manage the batteries state of charge, aggregating all information from cell level to stack level to be interpreted by the Emergency Management System (EMS).

Should the BMS register there are abnormal conditions present, a E-stop is triggered opening all DC contactors in the battery array, preventing further charge, discharge or balancing by disconnecting and isolating each individual energy segment from the DC bus [4].

4.1.1.7 Emergency Management System (EMS)

The EMS acts as the 'master controller' for the Centipede, that collects data from the battery management system (BMS) and other sensors for external monitoring and alarming.

Whilst the BMS monitors voltage and temperatures, the EMS acts as another level of monitor, examining the voltage and temperatures at the battery cell, stack and DC bus levels. The EMS includes a battery safety application, commanding system shutdowns in respond to a triggered E-stop and can place components into standby if warranted by an event and/or trigger.

4.1.1.8 Emergency Stop (E-Stop)

An E-Stop is an event where detectors within the battery unit send a signal to safely disconnect a PCS (or PCSs) and shut down an array (or arrays), as the parameters of the system are outside the desired normal operation of the system [4]. When an E-Stop event occurs, an alarm is sent to the ROC, Modbus API and all equipment associated with the triggered detector, putting the equipment into a safe state. Should an E-Stop sensor trip in an enclosure, it will also trip all arrays associated with the affected enclosure. The E-stop will trip in the following scenarios [14]:

- Fire suppression – including presence of smoke, heat and gas being detected by any of the detection measures described in sections above.
- E-Stop button – each PCS has a physical E-Stop button that can be pushed in the event should an event require a complete and sudden shutdown.
- Segment doors open – whilst in operation, all doors of the BESS units should be closed to ensure safe operation protocol. Should the door be open for any reason, the E-Stop will trigger. All doors have sensors indicating whether doors are open or closed.
- Loss of grid power – the systems utilise an inverter that uses configurable voltage and frequency ride-through tables to set trip points for grid abnormalities. If these are exceeded, the inverters will trigger an E-Stop.

Broadly, the choices made in the design of the Powin Centipede system dramatically reduce the risks from hazards identified in Section 3 of this study. In particular, the Centipede's modular approach to BESS design, including dedicated fire and heat shielding between battery segments brings significant fire risk advantages compared to the alternate large "shipping container" style BESS designs.

Further details on the hazard-reduction performance of these design features are provided in Section 5 of this study and summarised in Table 6.

4.1.2 Substation, O&M and other Ancillary Facilities

In addition to the BESS infrastructure, the Waratah Super Battery project includes a switchyard and associated electrical infrastructure, O&M building, storage facility, access ways and parking.



Risk of fire in the switchyard is managed by ensuring the switchyard (substation) design and operation comply with requirements under AS 2067:2016 [15] alongside relevant sections of the ABCB National Construction Code (NCC) Volume 1, 2022 [6].

Fire hazards in the O&M and storage buildings are managed by ensuring these facilities comply with the relevant requirements of the ABCB National Construction Code Volume 1, 2022. Specifically, further information on the prevention, protection, and mitigation of large-scale fire events in these facilities is provided in sections C, D and E of the NCC [6].

4.2 Testing of the Fire Safety Performance of the Powin Centipede Architecture & Design

Powin have undertaken numerous battery tests to the UL9540A test standards, and then further tests beyond the requirements of UL9540A, to demonstrate the fire-prevention properties of their battery components and system design [16]. The UL9540A test standard is derived from the requirements of UL9540 [17]. The tests were conducted by independent testing organisations, and the full reports are attached as appendices to this study.

In summary, the first testing undertaken by the independent test organisations showed significant resistance to fire propagation in the Powin Centipede system. The following excerpt is from the large-scale fire test (segment-to-segment) report completed by ESRG (February 2022) [18]:

"Testing provided both qualitative (visual) and quantitative metrics which demonstrate strong lateral unit-to-unit propagation resistance in the Powin Centipede Energy Storage product. Despite significant external stimuli (large propane torch) driving a significant thermal failure on multiple modules in a system charged to 100 % SOC, lateral target units did not achieve a hazardous condition internally based on module temperatures. Insulation in both the initiating and target units, along with the small air gap between units, was sufficient to keep module temperatures low, and though the inner walls did see higher temperatures, the thermal mass of the target modules, even in a unit only half populated, was more than sufficient to withstand these high temperatures, resulting in minimal temperature increase in the modules. Further, seals in the doors and overall system design prevented flames, even during windy periods of direct flame impingement on the doors, from entering the unit, resulting in the interiors of both target units appearing as new after the test. Throughout the event the fire never appeared visibly out of control..."

As many UL9540A tests are failing to produce working fires in systems during testing, large scale testing such as this provides much needed data on system resiliency and the ability of systems to withstand fire propagation in real world scenarios, especially in cases where environmental conditions, such as wind, may produce an even worse scenario than would be permissible in a lab environment. To that end, given the wind conditions and full failure in this test, confidence in the Powin system to withstand propagation should alleviate concerns about spacing and placement during safety and permitting reviews."

Following the February 2022 test, a further large-scale fire test was undertaken by ESRG. This test was conducted on a 'production' model of the Centipede system. The test was rather successful in demonstrating that the segment walls were suitable for fire protection, the doors remaining sealed and contained the fire. The following excerpts are from the test undertaken in April 2023 [19]:

"The primary quantitative metric for the test was temperatures on the modules and module shelves in the target units [i.e., external segments]. By that metric, test results were positive. The test was further successful in demonstrating that the system walls were suitable for fire protection, the doors remained sealed and contained fire, and the system posed no risk of unit-to-unit propagation when allowed to burn. While the rain may have had some impact on the intensity of the fire outside the unit, it is not believed the rain had an impact on fire or failure rate inside the unit. To that end, it is not believed any extreme or adverse event was prevented by the weather. Though the failure did not come as predicted, ultimately the battery system was able to burn fully and in a controlled manner as may occur during a similar real-world electronics fire..."

... The system performed exceptionally well during testing, as all flame exited through the top hat in a controlled manner. Concerns regarding flame exhaust from the north side ventilation port were unfounded, as an improved steel exhaust cover arrested flaming from that side and prevented direct flame impingement onto the north target. While a cable laid as a flame indicator between the three units was degrade heavily going into the north and south units, it did not appear to suggest that fire would

have travelled deep into the north or south cable tray. Wood caps placed on the far end of the target cable trays survived with no indication of fire impingement at all."

A summary of the various fire tests completed on the Powin Centipede components and overall system are presented in **Table 4**. The test undertaken in February 2022 was conducted on a prototype Centipede unit and the test in April 2023 was undertaken on a production model. The production model tested is quite similar to those to be installed at the Waratah Super Battery site, excluding the modifications made to the seals and weather stripping. Key differences and/or enhancements to the models to be installed at the Waratah site against the production model tested, include:

- Newer HVAC units are to be installed;
- A metal screen mesh has been added for the HVAC and Control compartments;
- Smoke detectors within the battery segment are to meet AS/NZS 3000:2018 compliance; and
- The various electrical componentry installed are to meet AS/NZS 3000:2018 compliance.

Table 4: Summary of Battery Test Reports

Test	Description	Summary/Commentary of Results
UL9540A Cell Test – EVE Power Co. Ltd. Cell [20]	UL9540A cell test of a Lithium-iron phosphate battery cell, Model LF280K. The cell has a capacity of 280 Ah and nominal voltage 3.2 Vdc.	▪ 4 individual cells tested ▪ Average vent temperature = 218.6 °C ▪ Average Onset of Thermal Runaway Temperature = 284.3 °C
UL9540A Cell Test – Ruipu Energy Co. Ltd. Cell [21]	UL9540A cell test of a Lithium-iron phosphate battery cell, Model CB71173204EB. The cell has a capacity of 280 Ah and nominal voltage 3.2 Vdc.	▪ 5 individual cells tested ▪ Average vent temperature = 166.1 °C ▪ Average onset of thermal runaway temperature = 299.8 °C
UL9540A Module Test – EVE Cells [22]	UL9540A battery test of a battery pack (3 modules) containing 30 LiFePO ₄ EVE cells total.	▪ Thermal runaway was initiated in cell 19 and propagated to cell 20, 18, 17, 16 and 15. ▪ No external flaming was observed. ▪ Time between initiating cell runaway event to last cell runaway event = 82 mins
UL9540A Module Test – Ruipu (REPT) Cells [23]	UL9540A battery test of a battery pack (3 modules) containing 30 LiFePO ₄ Ruipu (REPT) cells total.	▪ Thermal runaway was initiated in cell 19 and propagated to cell 20, 18, 17, 16, 15, 14, 13, 12 and 11. ▪ No external flaming was observed. ▪ Time between initiating cell runaway event to last cell runaway event = 109 mins



Test	Description	Summary/Commentary of Results
UL9540A Unit (Segment) Test – EVE Cells	UL9540A battery unit (segment) test of a 750 kWh Powin pre-production segment containing 28 Powin battery packs (30 LiFePO₄ EVE cells per pack, 840 cells in total). An adjacent unit (segment) was placed next to the initiating unit (segment) during the test.	- Thermal runaway was initiated in cell 19 of module 11 and propagated to cell 20, 18, 17, 16, 15, 14, 13, 12 and 11 within the same module. - No external flaming was observed. - Thermal runaway did not propagate from the initiating module to any other modules. - No damage was observed on the adjacent unit (segment). - Time between initiating cell runaway event to last cell runaway event = 114 mins
ESRG – Powin Centipede Prototype – Large-scale Fire Test – Feb 2022 [18]	Large-scale fire test of the 750 kWh Powin battery pre-production segment containing 28 Powin battery pack (30 LiFePO₄ EVE cells per pack, 840 cells in total). Battery fire was initiated using a propane torch until flames were self-sustaining. Two adjacent units (segments) containing 14 battery packs each were placed on either side of the initiating unit (segment) during the test.	- The initiating unit (segment) was produced a significant fire in which all aluminium bus bars were completely melted, all plastic components were completely burned, thin sheet steel was warped and beginning to fail mechanically, and shelves were sagging. - The maximum outer wall temperature of the adjacent segments = 500-550°C - The maximum inner wall temperature of the adjacent segments = 150 °C - The maximum module temperature in the adjacent segments = 70 °C - The adjacent unit suffered external heat damaged but maintained sufficient thermal protection to the modules.
ESRG – Powin Centipede production system – Large-scale Fire Test Apr 2023 [19]	Large-scale fire test of the 750 kWh Powin battery production segment containing 28 Powin battery pack (30 LiFePO₄ EVE cells per pack, 840 cells in total). Battery fire was initiated using a methane burner until flames were self-sustaining. Two adjacent units (segments) containing 14 battery packs each were placed on either side of the initiating unit (segment) during the test. The HVAC which was left offline for the purpose of the test.	- The initiating unit (segment) was produced a significant fire in which all internal components were completely destroyed - The maximum outer wall temperature of the adjacent segments = < 400°C - The maximum inner wall temperature of the adjacent segments = 150 °C - The maximum module temperature in the adjacent segments = < 60 °C - The system burned for nearly 18 hours, with suppression of the fire in the top hat in the third hour - The adjacent unit suffered external heat damaged but maintained sufficient thermal protection to the modules.

Test	Description	Summary/Commentary of Results
SAFE Laboratories and Engineering Corp – Stack 750 Fire Propagation Test [13]	Large scale FIRE test is to validate Stack750 Energy Segment design revisions intended to mitigate fire propagation for production and field installed units to <i>California Fire Code 1207.1.5 – Large-scale fire test</i>. These testing conditions are more severe than conditions required by Underwriters Laboratories UL 9540A:2019. Instead of using film heaters to heat a single cell in accordance with UL 9540A:2019, in this case an oxy-methane torch directed at a battery pack was used to initiate thermal runaway.	▪ Prior testing had indicated fire could propagate from one stack to another by entering through the cable tray wall penetrations. ▪ In this test, cell thermal runaway and venting was not observed in either target Stack. The battery compartment of both target Stacks was relatively undamaged compared to the upper top cap and initiating Stack. ▪ A relatively mild deflagration occurred in the battery compartment of the initiating Stack. The deflagration was absent flying debris or catastrophic failure. It opened the front doors of Stack 2, but they returned to a partially closed position. The doors stayed in this position for the duration of the test.

4.2.1 Fire/Thermal Runaway Propagation Between Cells in a Module

UL9540A testing reports presented by Powin demonstrate that a thermal runaway event will likely propagate to directly adjacent cells within a battery module. It is fair to assume that if a thermal runaway event was to occur in a particular cell, that it is likely an entire module would catch fire and/or suffer thermal damage (i.e., melted components, produce flammable and toxic gases) due to heat propagation.

During the UL9540A testing of the Powin cells and modules, the initiating cell would vent gases at elevated temperatures (approx. > 150 °C) before thermal runaway was observed. Once thermal runaway is initiated, test results indicate that thermal runaway will propagate to adjacent cells in the module in quick succession (i.e., approx. 1 to 10 minutes) [20] [22].

4.2.2 Potential for Fire/ Thermal Runaway Propagation Between Modules in a String or Stack

UL9540A testing report evidence presented by Powin demonstrates that a thermal runaway event in a single module should **not** propagate to adjacent modules (in the same or different battery string). In all the thermal runaway tests undertaken with complete battery packs, thermal runaway in a cell did not propagate beyond the initiating module. The test results indicate that there is a sufficient air gap between modules to prevent significant heat transfer to adjacent modules. In all the UL9540A tests, in cells undergoing thermal runaway, the cells and modules do not display external flames [20] [22].

4.2.3 Potential for Fire/Thermal Runaway Propagation Across Segments in a Centipede

Whilst the UL9540A testing showed that cell fires do not propagate across battery modules in the Centipede system, Powin had further independent testing performed to specifically examine the potential for fire to propagate across battery segments. These tests were based around positioning multiple battery segments as they would be installed at the Waratah Super Battery project, cutting a hole into the front of one unit (the “initiating” unit), using a butane torch to initiate a sustained and widespread fire in the initiating unit, and then monitoring the fire propagation within that unit, and temperature profiles in adjacent battery segments.

In the two large scale fire tests, the battery segments adjacent to the initiating unit had outside wall temperatures that reached between 300 °C and 400 °C for up to 1 hour (in the Feb 22 test) and up to 6



hours (in the Apr 23 test) without resulting in excessive internal heating of the internal battery modules: the heat flux imposed only resulted in maximum temperatures at the internal modules of the neighbouring battery segment up to 70 °C.

The induced fire in the initiating segment resulted in fire propagation within the entire battery segment and flames escaping from the front and rear of the initiating segment. Given the spacing of 76 mm between the initiating battery segment and the neighbouring battery segments, flames from the initiating battery segment clearly impinged directly upon the outer surface of neighbouring battery segment for a major part of both the two-hour and 18-hour test event. Despite this, in both test cases fire did not propagate from the initiating segment to the neighbour segment, and the cells in the neighbour segment stayed at a temperature well below that required to initiate thermal runaway.

Advitech understands identical segment separation to that used in these large-scale fire tests will be used for the Waratah Super Battery project. Ambient weather conditions during these tests were similar to those expected at the Waratah Super Battery site, and these results are considered extensible to the Waratah Super Battery operating conditions. Although these tests are helpful, they do not account for the effects that may occur in unfavourable weather conditions such as strong winds. Also, it is impractical to perform such tests during severe or disastrous fire situations.

4.2.4 Potential for Fire/Thermal Runaway Propagation Between Centipedes

Each of the battery Centipedes in the Akaysha project will be separated with a segregation distance greater than 2.1 m. The segment-to-segment battery fire tests described above found that a 76 mm separation distance between segments is sufficient to prevent fire propagation across segments. Therefore, the segregation distance of 2.1 m would effectively minimise the risk of fire propagation between Centipedes. The smoke, gas and heat detection systems in each segment are designed to provide early detection of a fire, enabling the BMS to disconnect the battery segment to further reduce the risk of a fire event spreading across the facility.

4.3 Bush Fire Protection

The following definitions are provided for clarity and consistency with the Bushfire Emergency Management Plan currently under development for Akaysha (refer to Table 5).

Table 5: Terms and Abbreviations

Term	Abbreviation	Definition
Asset Protection Zone	APZ	A buffer zone between a bushfire hazard and buildings that is managed to minimise fuel loads, reduce potential radiant heat levels, flame, localised smoke, and ember attack.
Defendable Space	–	An area within the Inner Protection Area of an Asset Protection Zone that provides a safe working environment in which efforts can be undertaken to defend the structure or development, before and after the passage of a bushfire.
Inner Protection Area	IPA	This is an area closest to buildings/infrastructure and creates a fuel-managed area which can minimise the impact of direct flame contact and radiant heat on the development by acting as a defendable space.

The entire WSB facility within the Site Boundary will be managed as an Inner Protection Area (IPA), in conjunction with a Defendable Space, 10 m wide, being maintained within the WSB facility. These areas are to be managed as an Asset Protection Zone (APZ) in accordance with the Appendix 4.1.1 of RFS's Planning for Bushfire Protection (PBP) [24].

The WSB facility has native vegetation on its south-western and south-eastern boundaries. The bush fire protection strategy is based on meeting Section 1.1, Aim and Objectives of the PBP [24].

The 6 m Clearway is on a fire access track, which has been maintained as such by the landholder for approximately 20 years. An approximately 90 m length of this 6 m Clearway will contribute to the minimum recommended separation of 18 m between any battery segment and hazard vegetation (see Section 5.3.1) at the south-western corner of the BESS Yard.

The short gap in the Defendable Space on the south-western boundary is due to the land in this area having a batter profile, rendering it unsuitable for a safe fire-fighting environment. The batter slope is essentially a rock face with no vegetation and is included within the IPA. Adjacent to this area, safe firefighting could be undertaken from the vehicle access track within the BESS Yard, see Figure 7.

The bushfire protection strategy relates to the boundaries and areas depicted in Figure 8.

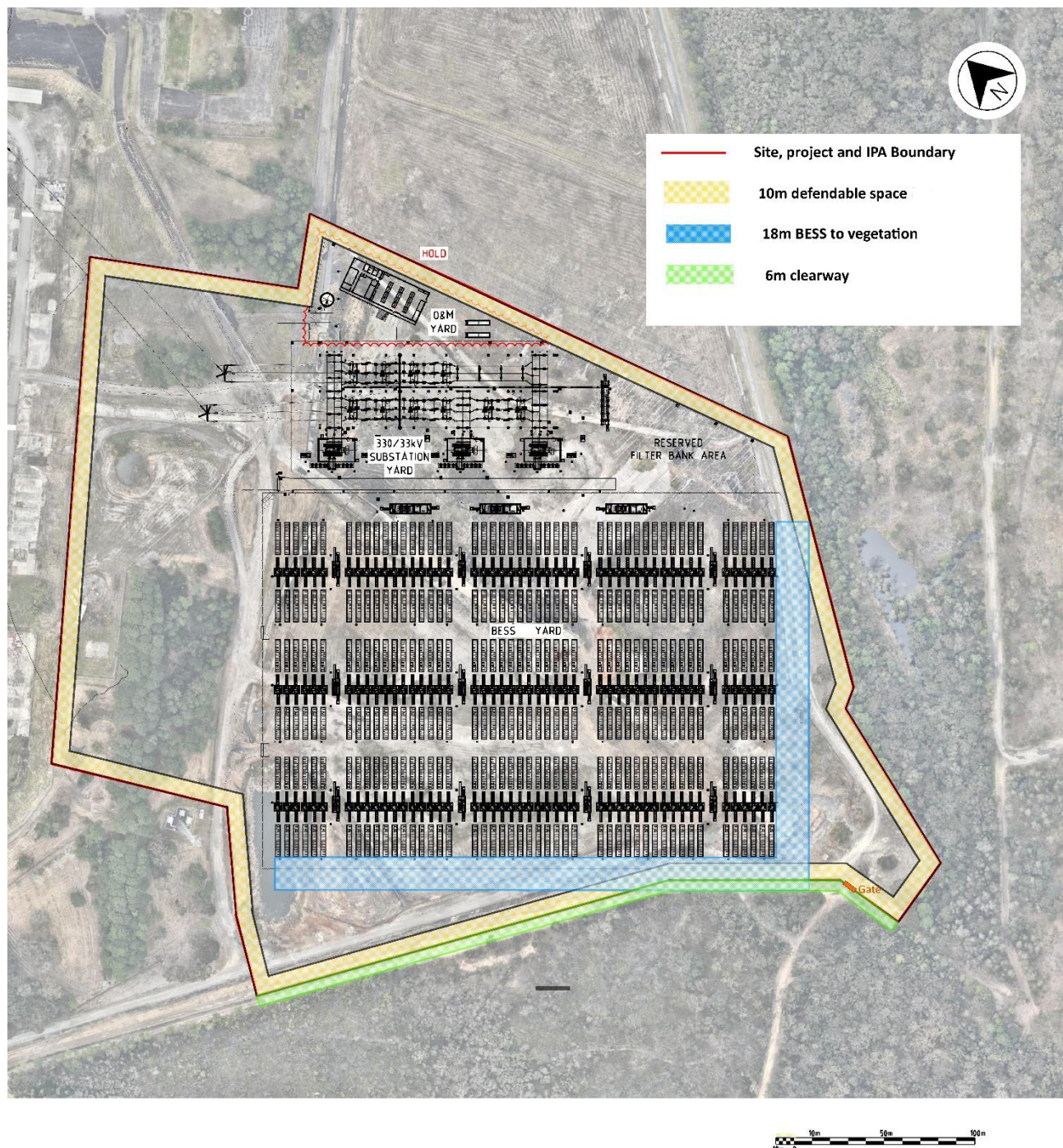


Figure 7: Bush Fire Protection Strategy Boundaries and Areas

The following extract is from the draft Bushfire Emergency Management Plan, currently under development. It shows the unobstructed vehicle access routes for the WSB facility including around the perimeter of the installation. In most locations this does not include use of the 10 m defendable space around the perimeter of the plant.

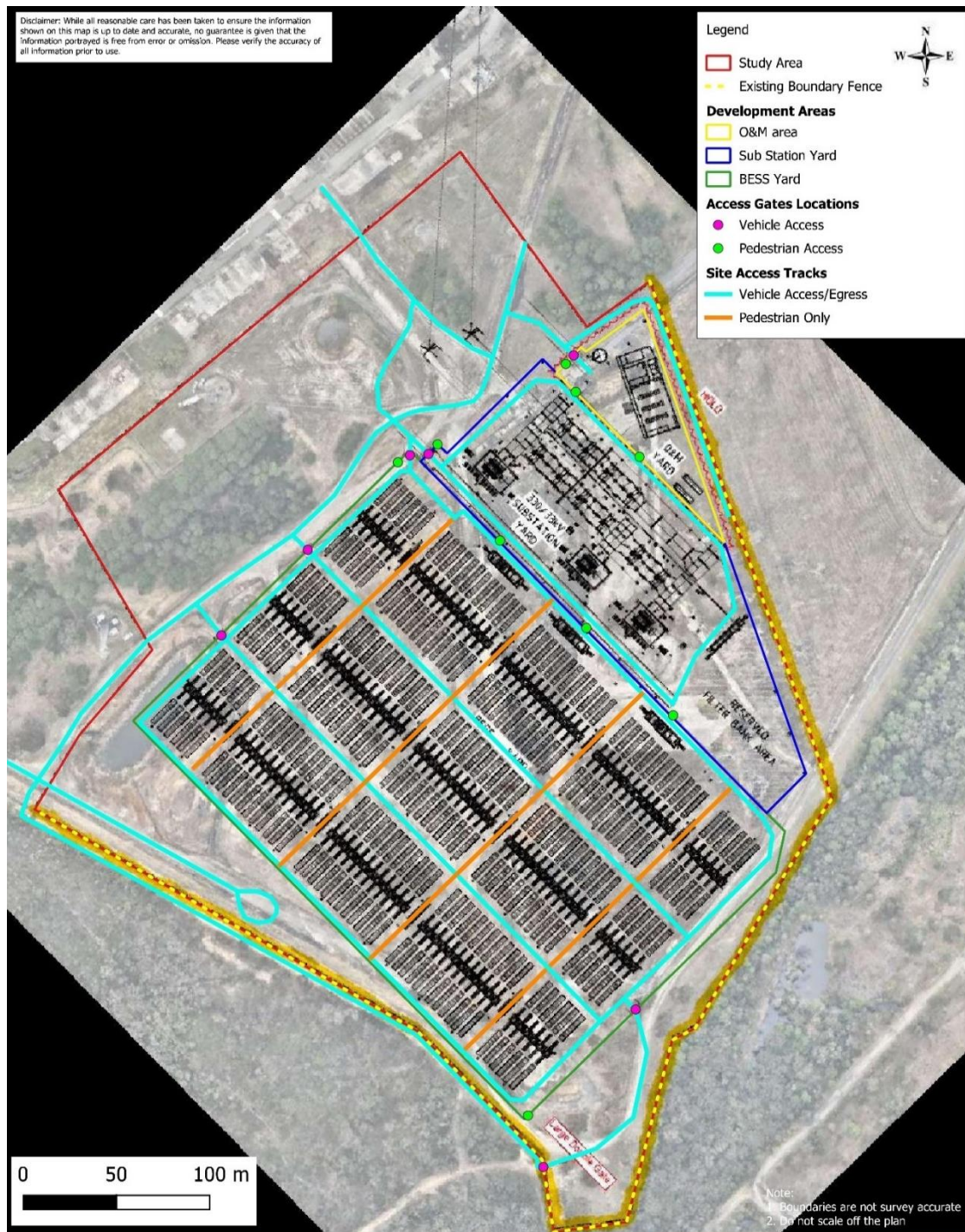


Figure 8: Unobstructed Vehicle Access Routes

(Source: Draft WSB Bushfire Emergency management Plan – Anderson EP)

5. Consequences of Hazard Incidents

Having determined the most significant fire-related hazards at the Waratah Super Battery project (Section 3), the unique design characteristics of the Powin system (Section 4.1) and the results of performance testing of these (Section 4.2), the following sections review the “real world” likely consequences of an incident involving the hazards identified. Table 6 summarises these findings.

5.1 Battery Cell Fire

Based on the results of the independent testing conducted by Powin, a fire within a Centipede battery cell is expected to propagate to all other cells in the module.

As described in Section 6 of this study, if a battery module fire occurs, the recommended fire response strategy is to let the entire module burn out. First responders should maintain a safe distance and simply monitor the fire, and so the risk to personnel from a battery cell fire is considered low.

Based on the results of the independent testing conducted by Powin, a fire in an individual module is not expected to propagate to surrounding modules in a battery segment. So, although a battery cell fire will result in destruction of the entire battery module, it is not expected to result in a fire across the entire battery segment.

5.2 Battery Segment Fire

As described in the previous section, a fire across an entire battery segment is considered unlikely. However, if such a fire were to occur, based on the results from the Powin segment-to-segment fire testing, the fire is not expected to propagate, or cause thermal runaway, in adjacent segments.

As described in Section 6 of this report, if a battery segment fire occurs, the recommended fire response strategy is to let the entire battery segment burn out. First responders should maintain a safe distance and simply monitor the fire, and so the risk to personnel from a battery segment fire is considered low.

Battery segments have louvred vents on them that are designed to fail to open during a fire event. The maximum aperture of these vents is expected to limit any ember flow out of the burning battery segment, meaning there is minimal risk of embers from the burning segment triggering fires elsewhere (including a bushfire).

Thus, a fire across an entire battery segment would result in destruction of that particular segment but is not expected to transfer to adjacent infrastructure or property. The prevention of bushfire initiation is critically dependent on the continuous management of vegetation within the inner protection areas of the APZ to NSW RFS Planning for Bushfire requirements [24].

5.3 Bushfire

5.3.1 Bushfire Triggering a Battery Fire

Parts of the Waratah site are adjacent to bushland and so at risk from a bushfire. Advitech’s BPAD Level-3 accredited assessor completed a bushfire heat flux analysis, which showed that in a 1-in-50 years bushfire event, battery segments closest to surrounding bushland may be exposed to BAL40 equivalent heat flux (Appendix D). This assumes a separation of 18 m or more between any battery segment and hazard vegetation. This is achieved on the:

- South-eastern boundary by all battery segments being 18 m or more from the boundary fence.
- South-western boundary with a maintained 6 m clearway outside the Waratah Super Battery site boundary fence, and the battery segments 12 m or more from the boundary fence.

Given the results of independent fire testing on the Powin Centipede system, the level of heat flux anticipated in a 1-in-50 years bushfire event is not expected to trigger a thermal runaway or fire within the battery segments. The segment-to-segment fire testing showed that with a 300 °C flame impinging on the external wall of a battery segment, internally the segment had no visible damage, and did not go into thermal runaway. Given a bushfire flame tip temperature is typically around 600 °C [25], a bushfire is not expected to result in enduring surface temperatures greater than 300 °C at the minimum separation



distance between battery segments and the adjoining bushland. The large-scale fire test demonstrates that the outer wall of the battery segment can withstand temperatures greater than 500 °C without triggering battery thermal runaway.

Powin has indicated all air vents on the battery segments are covered by a metal mesh, with the largest aperture in the mesh being 1.9 mm, meeting requirements of AS 3959:2018 [12]. Hence it is considered that bushfire embers would be prevented from entering a battery segment via any external vents or apertures.

5.3.2 Battery Fire Triggering a Bushfire

On review of the report of independent fire testing on the Powin Centipede system [18]:

- The observed external flame length from the top of a battery segment appears to be less than 3 m.
- No burning item or high temperature parts separated from the structure.

Furthermore, the recently conducted additional independent fire testing included in its Summary of Test Results, “...a relatively mild deflagration occurred in the battery compartment of the initiating stack. The deflagration was absent flying debris or catastrophic failure.” [13]

Given the above and that the any BESS infrastructure is to be located at least 18 m from any hazard vegetation, it is deemed unlikely that any fire in a battery segment would initiate a fire in any hazard vegetation either on the WSB facility or external to the WSB facility.

5.4 Non-Battery Infrastructure Fire

The Waratah Super Battery project contains several items of significant infrastructure outside of the BESS.

Fire hazards associated with the O&M building and storage facilities are considered relatively low and managed by compliance with the National Construction Code (NCC), which gives specific consideration to fire risk mitigation and management of fire incidents [6].

The transmission line for the project represents a fire hazard. If appropriate clearances to the transmission line are maintained, the risk of fire from the transmission line is considered relatively low.

The most significant non-BESS fire risk at the Waratah Super Battery project is represented by the power transformers located in the switchyard and BESS yard. These transformers are oil-cooled, and if a transformer fault develops, this can lead to a significant fire event. The risk of fire from transformers located in the BESS yard is managed by appropriate system design (including fire resistant ester transformer oil), equipment selection, and operation/maintenance. Whilst the transformers located in the switchyard (i.e., the 330 kV transformers) contain mineral oil, risk of fire will similarly be managed by equipment, and operation/maintenance. Australian Standard AS 2067:2016 is the current standard governing power transformer installations. It specifies minimum separation distances based upon oil volumes and electrical capacity. Fire-fighting infrastructure for the switchyard must also be compliant with this standard [15].

At the Waratah Super Battery project, the main power transformers and switchyard (including switchrooms) area are sufficiently remote from buildings and the BESS area to ensure that any incident involving a fire in the switchyard should not impact other infrastructure onsite. The minimum separation distance (as prescribed from FM Global 5-33 *Electrical Energy Storage Systems*) for BESS to non-combustible materials and non-combustible construction elements is 6 ft (1.8 m) [26]. Switchrooms have a 5 m clearance from the BESS yard, as such the risk of fire propagating may be considered low.

The PCS sections of the Powin Centipede system also contain power transformers and are much closer to the BESS units. However, these PCS transformers are air-cooled, and so the risk of a fire propagating from the PCS transformers to the battery segments is considered relatively low.

Overall, if the switchyard and associated power transformers are designed and managed to AS2067:2016, the risk of a large-scale fire in this area, and that fire propagating to other areas of the Waratah Super Battery site, is considered relatively low.

5.5 Explosion

The most significant explosion hazard in a BESS development is considered to be from the build-up of an explosive atmosphere during a cell thermal runaway event or battery fire. The Powin battery segments have been designed with active and passive ventilation mechanisms specifically to prevent the build-up of an explosive atmosphere in a battery segment. These ventilation mechanisms are integrated with dedicated hydrogen and temperature sensors and alarm mechanisms.

Based on the planned HVAC and ventilation system control strategies, the risk of explosion in the Waratah Super Battery project is considered low. Furthermore, given the recommended response to a battery segment fire is to let the fire burn whilst monitoring from a safe distance, if an explosion did somehow occur, first responders should be sufficiently distant from the battery segments to avoid any major consequence.

5.6 Toxic Gas Release

Research undertaken by Larsson, Andersson, Blomqvist and Mellander (2017) and published to 'Scientific Reports' [27] found that significant amounts of HF, between 20 mg and 200 mg per Wh of nominal battery capacity was released from a lithium ion battery fire. A Powin battery segment contains 840 cells and has a nominal 750 kWh of storage capacity. Therefore, potential emission from a single Centipede battery segment fire is estimated to be up to 150 kg of HF on the basis of the Larsson et al analysis [27].

A Powin battery segment contains 4578 kg of batteries with a composition of 3.2% LiPF_6 . Therefore, a segment contains $4578 \times 0.032 \times 0.75 = 109.9$ kg of fluorine (F), from the battery cell contents [28]. There may be other sources of fluorine within a segment, but the approximate amount of HF release, based on the Centipede cell composition, is consistent in scale with the maximum HF emission of 150 kg expected from the Larsson research [27].

According to research by Neoen regarding the Capital Battery in the ACT [29] the maximum emission rate of HF would be 0.025 kg/sec based on 60% HF release uniformly in the first hour of a segment fire event [29].

The Neoen analysis for the Capital Battery [29] suggested a worst-case fatality contour from HF emissions during a battery fire could be in excess of 1100 m. In the unlikely event of an entire Centipede battery segment (with 750 kWh of cells) catching on fire, the Emergency Response Planning Guideline (ERPG) levels of HF emissions would only occur much closer to the source than was the case in the Neoen analysis [29], which involved a much larger number of battery cells (4 MWh).

The closest distance from a Centipede battery segment to the boundary fence of Waratah Super Battery project is expected to be 15 m. The distance from the Waratah Super Battery project to sensitive receivers is:

- Halekulani residential area zoned R2 – approximately 600 m to the East and 800 m to the South
- San Remo residential area zoned R2 – approximately 1100 m to the Southwest.

It is expected that the notional 1-hour ERPG fatality contour associated with HF emissions during a fire at the Waratah BESS site is within the boundary of the battery storage area and is not expected to impact neighbours, first responders or passers-by.

The outputs of a preliminary AUSPLUME model using the Neoen maximum emission rate of HF is presented in **Figure 1**. A meteorological data set from previous work undertaken in Berkeley Vale, NSW was applied to the model as a representative data set.

The hourly average 30 ppm (Immediately dangerous to life or health (IDLH) concentration for HF) and 50 ppm (Emergency Response Planning Guidelines (ERPG-3) concentration for HF) contour have predicted a maximum impact distance of approximately 50 metres and 30 metres respectively. This aligns well with the recommended safety perimeter of 100 ft / 30.5 m. The risk to first responders can be further mitigated by use of gas masks and remaining upwind when attending a fire event.



Figure 9: Battery Segment Fire HF Ground Level Concentrations (30 and 50 ppm)

As detailed in Section 6 of this study, the recommended strategy to manage a burning battery segment is to let it burn itself out, and not use water to try and suppress the fire. This strategy means that there is little risk of water significantly exacerbating HF emissions during a fire event [27].

5.7 Environmental Pollution Hazards

The main risk of water pollution from a BESS project is through contaminated water entering and polluting surrounding waterways. As discussed in Section 6 of this study, the recommended strategy for managing a BESS fire at the Waratah Super Battery site is to let the fire burn out, and *not* apply water. This means there is little risk of large volumes of fire-suppression water being produced during a fire incident.

If a fire occurs in a battery module, based on the Centipede fire tests, it is not expected to propagate to surrounding modules, and the fire tests showed that even during an entire battery-segment fire, the steel segment casing and doors remained relatively intact. If it rained during or after a battery fire, the number of burnt battery cells (that create environmental pollutants) is expected to be limited to a module, and the burnt battery cells are expected to remain relatively isolated from rain, and thus the risk of a significant amount of contaminated rainwater runoff from a battery fire is considered low.

If the oil-cooled transformers in the switchyard were to leak, the leaking oil could produce a significant amount of environmental pollution. This risk is reduced to low by designing and operating the switchyard in accordance with AS 2067:2016 [15].

5.8 Electrocutation Hazards

In routine operation the risk of electrocution from the Centipede system is considered low, and managed by:

- Adherence to Australian standards for electrical design and installation

- Procedures managing who can access areas of the Waratah Super Battery facility where electrocution risks exist, and such access being only granted to appropriately qualified persons.

During a fire event, battery segments are isolated into individual units, limiting the potential voltage, and shut down into an idle state. Furthermore, given the recommended strategy to manage a burning battery module is to let it burn itself out, with first responders simply monitoring the fire from a safe distance, the electrocution risk to first responders during a fire event is considered low.

5.9 EMF Hazards

Key EMF hazards at the Waratah Super Battery project site include the proposed switchyard, two 330 kV transmissions lines to connect to the Munmorah Substation, and the BESS installation.

Australian standards and regulations exist to manage the risks of EMF from electrical equipment [30].

The Preliminary Hazard Analysis (PHA) as prepared by GHD for the Waratah Super Battery project found the impact of EMF to receptors outside the project site to be not significant [10].

The risks associated with EMF hazards to personnel within the boundaries of the Waratah Super Battery are also considered low, as the equipment on site will need to comply with Australian standards and regulations regarding EMF emissions, and people are not expected to spend significant time next to EMF-emitting equipment during routine operation. Moreover, as the Waratah Super Battery project is expected to be largely unmanned, the risks of potential exposure to EMF can be considered low.

The EMF risks to first responders during a fire event are even lower considering it is likely equipment would be deenergised should a fire occur.

Table 6: Key Hazards and their Existing Mitigation in Waratah Super Battery Project

Hazard	Mitigation
Battery cell fire	▪ Expected worst-case is a cell fire propagates to all cells in a module. ▪ Modules are designed specifically to prevent fire from propagating between adjacent modules. ▪ This performance has been demonstrated in independent fire tests.
Battery segment fire	▪ Given cell fires are expected to not propagate beyond a single module, an entire battery segment fire is considered highly unlikely. ▪ If such an event occurred, segments are specifically designed with physical barriers, thermal insulation, and air gaps to prevent fire propagating between adjacent segments. ▪ This performance has been demonstrated in independent fire tests.
Bushfire triggering a battery fire	▪ Vegetation within the site's 10 m defensible space and 6 m clearway along the south-western perimeter of the Waratah Super Battery site are maintained to ensure closest distance between a battery segment and surrounding hazard vegetation is greater than 18 m. ▪ The physical barriers designed to limit fire propagation between battery segments also limit the risk a bushfire poses to battery segments- steel enclosures, insulation and air gaps are specifically designed to limit the heat flow from outside an enclosure to the battery cells. ▪ Test results show a sustained heat flow (and direct flames) resulting in 300 °C external wall temperatures did not damage battery cells or equipment internal to the battery segment.



Hazard	Mitigation
Non-battery infrastructure fire	▪ Switchyard components (including transformers) to be designed and operated to AS 2067:2016. ▪ Appropriate clearways to be maintained around transmission lines. ▪ Switchyard is sufficiently distant from BESS components for the risk of a fire propagating from switchyard to BESS units is considered low.
Explosion	▪ Hydrogen and thermal detectors are included in every battery segment to detect the presence of, or potential for, explosive gases. ▪ Active and passive (fail-safe) ventilation systems are incorporated into the Centipede battery segments and operated to prevent the build-up of a volume of explosive gases.
Toxic gas release	▪ Because a fire is expected to be limited to a single battery module, this significantly limits the total potential volume of toxic gas expected during a fire incident. ▪ In the unlikely event a fire spreads to an entire battery segment, the relatively small size of individual battery segments again limits the total potential volume of toxic gas to well below acceptable limits, inside and outside the boundaries of the Waratah site.
Environmental pollution hazards	▪ Fire management strategy for a fire in the BESS Yard is to “let it burn”, meaning the risk of contaminated fire water being produced from a fire event is low. ▪ In the unlikely event a fire consumes an entire battery segment, fire testing shows the segment remains mostly intact, limiting the exposure of rain to the burnt area, and preventing the build-up of a significant amount of contaminated water. ▪ Risk of a coolant leak from the oil-cooled switchyard transformers is managed by designing and operating the switchyard in accordance with AS 2067:2016.
Electrocution hazards	▪ Designing and operating the system to relevant Australian standards, supported by procedures that limit personnel access and work activities around HV equipment. ▪ During a fire event, fire detection systems (that include backup power supply) automatically place the BESS into a safe state. ▪ The fire management strategy means fire responders do not need to approach the battery segments during a fire.
EMF hazards	▪ Equipment on site must comply with relevant Australian standards that limit EMF emissions. ▪ The site is generally unmanned, significantly limiting personal exposure to EMF-producing equipment.

6. Fire Response Strategy

The fire response strategy for the Waratah Super Battery project utilises Powin’s Battery Management Plan, Revision 1, April 2023 [31], for this project and recommends items to include in the site’s Emergency Response Plan, which is yet to be prepared.

In the unlikely event of a large fire or other thermal event, the following actions should be performed:

1. If the alarm system has not already signalled to the local fire department, immediately call the local fire department.
2. Call the Emergency Response Coordinator (ERC) listed in the Emergency Response Plan (ERP), and call Powin's Remote Operations Centre (ROC) at (Int'l)+1 855- 888-3659.
3. Establish a safety perimeter of 100 ft (30.5 m) around all sides of the involved Centipede unit(s) and do not allow personnel other than firefighters to enter the safety perimeter.
4. Provide copies of the Emergency Response Plan to first responders. Provide the HMI (Human Machine Interface) to first responders so that they can monitor the information/data regarding the condition of the involved and adjacent Centipede unit.

The ERC and/or the ROC can provide assistance to the first responders and guidance as to the systems on site.

6.1 Battery Fire Event

Powin's recommendation is to take a "passive" response strategy to a fire in the BESS Yard. They suggest that when responding to a fire event with a Powin BESS, do not approach the battery or Centipede segment directly in front of any doors. Do not attempt to open any enclosure doors. Coordinate all operations with the ERC and Powin's ROC utilising the system HMI to determine the condition of the Powin Centipede product, and the condition of surrounding Centipede units [31].

It is known that water application on a lithium-ion battery fire can suppress fire and slow thermal runaway, but real-world experience shows later thermal runaway events remain possible after the application of water, due to slow and ongoing heat build-up after the completion of the water application. Therefore, it is recommended that in the event of a battery fire, that the fire is allowed to fully consume all the combustible materials within the battery segment. Fire-fighting water for the purposes of fighting a Centipede fire will not be available at the Waratah Super Battery site.

The main advantage of the proposed passive fire response strategy is it reduces the fire/explosion risks to first responders at the scene of a fire. Managing the fire risk is not reliant on human intervention, rather is dependent on the inherent safety design features of the Powin system.

It is anticipated that a battery fire event would be closely monitored by local first responders, Powin's ROC and authorities. The Powin emergency response documents refer to a safety perimeter of 100 ft / 30.5 m during a fire event in accordance with NFPA 855 Clause G.11.8.3 (*Potential Impact Radius states: Explosion modelling has shown that the minimum distance [for first responders] should be 75 ft (23 m). It is recommended increasing that to a minimum clearance of 100 ft (30.5 m)*). Any personnel that are monitoring the fire event on-site should wear the recommended personal protective equipment (PPE) to limit any potential risks to their person.

Once the fire event has been determined to have ended by the relevant fire authority (i.e., FRNSW incident commander) with the use of thermal imaging, the battery segment doors may be opened following the procedures in Powin's Lithium-Ion Battery Emergency Response Guide For Powin Products Including Stacks, Smart Enclosures And Centipede and the segment monitored for 24 hours [32]. If there are no signs of further potential incident, the segment may be transported away from the fire scene and stored appropriately.

6.2 Transformer or Substation Fire Event

In the event of a transformer or substation fire, the response should be as per the site Emergency Response Plan, including:

1. If the alarm system has not already signalled to the local fire department, immediately call the local fire department.
2. Call the Emergency Response Coordinator (ERC) listed in the Emergency Response Plan (ERP), and call Powin's Remote Operations Centre (ROC) at +1 (855) 888-3659.

6.3 Bushfire Event

In the event of a nearby bushfire, the response should be as per the site Bushfire Emergency Management and Evacuation Plan, including:

1. If the alarm system has not already signalled to the local fire department, immediately call the local fire department.
2. Call the Emergency Response Coordinator (ERC) listed in the Bushfire Emergency Management and Evacuation Plan, and call Powin's Remote Operations Centre (ROC) at (Int'l) +1 (855) 888-3659.
3. If government or fire authorities declare an evacuation for the general Waratah site locality, shut the BESS facility down and leave it in a safe state.

The use of on-site water tanks should be made available to the local fire authorities to fight bushfires. It should be clearly stated that the water should not be used on any Centipede related fires.

7. Details of Fire Detection and Protection Mechanisms

7.1 Powin Fire Detection and Protection Measures

The Powin battery and energy segments incorporate protections and circuit controls that include [31]:

- Battery enclosures designed specifically to limit fire propagation and prevent build-up or a large-scale fire, through steel barriers, air gaps and a modular approach to BESS realisation.
- Monitoring and control systems that operate from individual battery cells up to whole-of-segment.
- Current and temperature sensor logic to monitor short-circuit events.
- Built-in protection against current surges, both through system control and solid-state over current protection devices.
- Each battery cell includes a safety vent to provide a controlled release of internal pressure during abnormal conditions and a rigid aluminium exterior provides an added degree of protection against external impacts.

The battery management system (BMS) is designed to properly manage individual battery cell's state of charge and prevent over or under charge states. The energy management system (EMS) collects data from the BMS (such as notifications and cell location, battery pack, and Stack-level temperatures and voltages) and communicates with the SCADA control system and Powin for remote operations and analytics.

The thermal management system includes thermal sensing of the cells to avoid overheating of cells. A fire detection system is closely integrated with the BMS and EMS, with a design base and function guided by NFPA 70 and NFPA 855 compliance [33] [34]. Each Centipede battery segment is designed to safely shut down the stack in a fire event. Addressable fire safety equipment is employed in the design of the fire safety system to be able to easily locate and isolate stacks. The fire detection system is comprised of:

- Heat detection.
- Gas detection.
- Smoke detection.

Each Centipede has a PLC-based environmental controller in each battery segment that orchestrates the HVAC system, the off-gas alarm system and any door/intrusion alarms. The controller monitors the system and reports all conditions to the environmental controller in the Collection Segment.

The segment ventilation system operates in two modes once the detection systems have detected the presence of flammable gases within the segment enclosure [4]:

- Active ventilation – should off-gases be detected in a battery segment, the HVAC ceases to operate and eight (8) booster fans are activated to vent out the gases and stay within gas safety limits inside the battery compartment. At least one booster fan is backed by UPS allowing for extended ventilation in the event of auxiliary power loss.
- Passive ventilation – should auxiliary power and the UPS fail during an active ventilation, the segment external vents are kept open by means of a fail-open actuator. Explosive gases are then vented outside the segment enclosure through natural buoyancy.

If an urgent problem (such as a fire) is detected, the emergency stop (E-Stop) response application opens all DC contactors in the battery array. The E-Stop response application prevents any further battery cell charge, discharge or balancing by disconnecting and isolating each individual energy segment from the DC bus.

7.2 Impact of Detection and Protection on “Credible” Fire Scenarios

The extensive detection and protection measures incorporated into the Powin Centipede system support the overall fire strategy of prevention and minimisation of impacts. The battery, energy and thermal management systems play a vital role in the Powin system’s ability to detect issues within the battery cells and segments before the issue escalates to a thermal runaway or fire event.

The safety features (including detection systems) incorporated into the Powin Centipede minimises the likelihood of a “credible” fire scenario (i.e., battery segment fire) from eventuating. The main hazard of lithium-ion batteries is thermal runaway leading to a battery fire. The layers of detection and protection have been designed to prevent the initial thermal runaway event from occurring undetected.

The first layer of protection is the BMS which monitors for irregularities within every cell. If the BMS does not detect an issue before it escalates, the fire safety system and E-Stop will respond to various dangers. E-Stop response application is designed to shut down to prevent or minimise thermal runaway impacts in the following case [4]:

- Hydrogen sensor detects hydrogen within the segment. The ventilation system also vents out off-gases to minimise the risk of reaching a flammable gas atmosphere.
- Loss of power or low voltage.
- Detection of smoke and/or heat in the battery segment. An alarm will also be raised.
- Opening of the segment doors. An alarm will also be raised.

In the very rare event fire prevention and detection controls prove ineffective, the Powin battery segments have demonstrated their inherent ability to minimise the propagation of thermal runaway between battery modules- see Section 4.2.2 of this study. Further large-scale fire tests demonstrated that in the event of a fire within a segment, the structural design of the segments resists the intense heat generated by the fire and maintains a safe operating temperature within the adjacent segment enclosure- see Section 4.2.3 of this study for further details.

7.3 Substation Fire Controls

The high voltage substation and associated power transformers will be designed and managed to AS 2067-2016. The standard outlines the requirements for protection against fire and explosion. The current design has implemented the following controls to minimise potential fire impacts:

- Physical separation.
- Fire barriers.
- Transformer oil containment.

A fire risk assessment should be undertaken in accordance with AS 2067-2016 to consider potential risk of fire on the substation and the adequacy of the control measures.



8. Detailed Description of the Fire-Fighting Systems

8.1 Overall Fire-fighting System Design Philosophy

8.1.1 Powin BESS System

The first line of defence against fire and thermal runaway is prevention. From cell to system, the Powin design incorporates high quality hardware and software that work together to minimize the likelihood that any one failure will turn into a propagating thermal event. Section 4 of this study details the system design features that are specifically targeted at reducing fire risk, and the results of extensive tests conducted to test this performance.

In the unlikely event of a fire or thermal runaway event in the BESS Yard, the Centipede system is designed to passively prevent further spread of fire within the facility, without the need for human intervention. A lithium-ion battery fire presents various hazards to first responders including heat radiation, toxic gases, and electrocution. Handling a battery fire event without human intervention significantly decreases the potential risks of these hazards on the first responders. Therefore, Akaysha and Powin have adopted a passive fire management strategy which minimises the need to actively fight a fire event.

8.1.2 Substation, O&M and Other Ancillary Facilities

In the event of a fire within the O&M facility and substation yard, fire-fighting systems have been provided in accordance with:

- Building Code of Australia – Volume One [6];
- AS 2067:2016 – Substations and high voltage installations exceeding 1 kV a.c. [15], and the associated standards;
- AS 2419.1:2021 – Fire hydrant installations, Part 1: System design, installation, and commissioning [35].

These systems are detailed in the following sections.

8.2 Purpose(s) For Fire-fighting Water Provision

Fire hydrants and on-site water supply will be provided for the explicit purpose of addressing the potential for building fires in the O&M facility. The on-site water is also available for bush and grass firefighting.

Hydrants and on-site water are not stipulated as a requirement for any other purpose. In particular, fire hydrants and on-site fire-fighting water supply are **not** mandated for the protection of BESS segments. The fire safety strategy for the battery segments specifically excludes fire intervention. This means any battery fires will be allowed to burn to completion without:

- The application of water or any other fire suppressant directly upon the burning BESS segment.
- The application of water or any other coolant onto adjacent BESS segments to prevent them overheating. As detailed in Section 5 of this report, independent testing (that went beyond UL9540A requirements) showed that cooling of the segments immediately adjacent to a segment on fire was not necessary for prevention of fire propagation [18].
- The necessity to finally extinguish the burning segment by flooding with water. Again, the results of fire testing demonstrate the utilisation of water is unnecessary in preventing propagation between adjacent segments.

The use of water (with or without foam additives) can be effective as a fire-fighting or fire suppression tool. However, there are some considerable disadvantages when using fire-fighting water in a lithium-ion battery or high voltage environment, including:

- Electrical conductivity – water is a good conductor of electricity, which means that it can create a risk of electrical shock if it comes into contact with energised equipment. This can be a



significant concern in transformer and substation fires, where high voltage electrical equipment is present.

- Toxic gas emissions – lithium-ion battery fire events have been shown to release toxic HF gases as a result of the battery electrolyte combustion. A recent study has demonstrated that the introduction of water to battery fire may lead to increased HF gas emissions [27].
- Water contamination – used fire-fighting water may contain high concentrations of lithium-ion battery combustion products and/or fire-fighting foam additives. Unless the fire-fighting water is captured and contained, there is potential risk for contamination of nearby water bodies and groundwater.

8.3 Anticipated Maximum Water Consumption for Credible Scenarios

Based on the size (945 m²) of the O&M facility (Class 5 and 7 building), it is anticipated that two (2) fire hydrant outlets are required to flow simultaneously in accordance with AS 2419.1:2021 [35]. Given the two-hydrant requirement and a minimum required flow rate of 10 L/s for a minimum duration of 4 hours, the minimum water capacity requirement is 288,000 L.

The Waratah Super Battery site will not have access to mains water supply. Therefore, the minimum water capacity requirements will be provided by a full capacity water storage tank. The water storage tank will comply with AS 2419.1:2017 requirements [35]. This water tank is likely to be filled from a tanker/s to site but may also be filled by other means (i.e., towns mains, rainwater, recycled water, bore water etc).

This water tank will be fitted with a 65 mm Storz fitting and a FRNSW-compatible suction connection located on the tank adjacent to the nearest internal access road.

8.4 Drawings of Fire Services Layouts

Figure 10 presents possible fire services layout for the O&M building, substation and other ancillary facilities. Note, the drawing is indicative and only provides a representative layout and the final location of the water tank is not set.

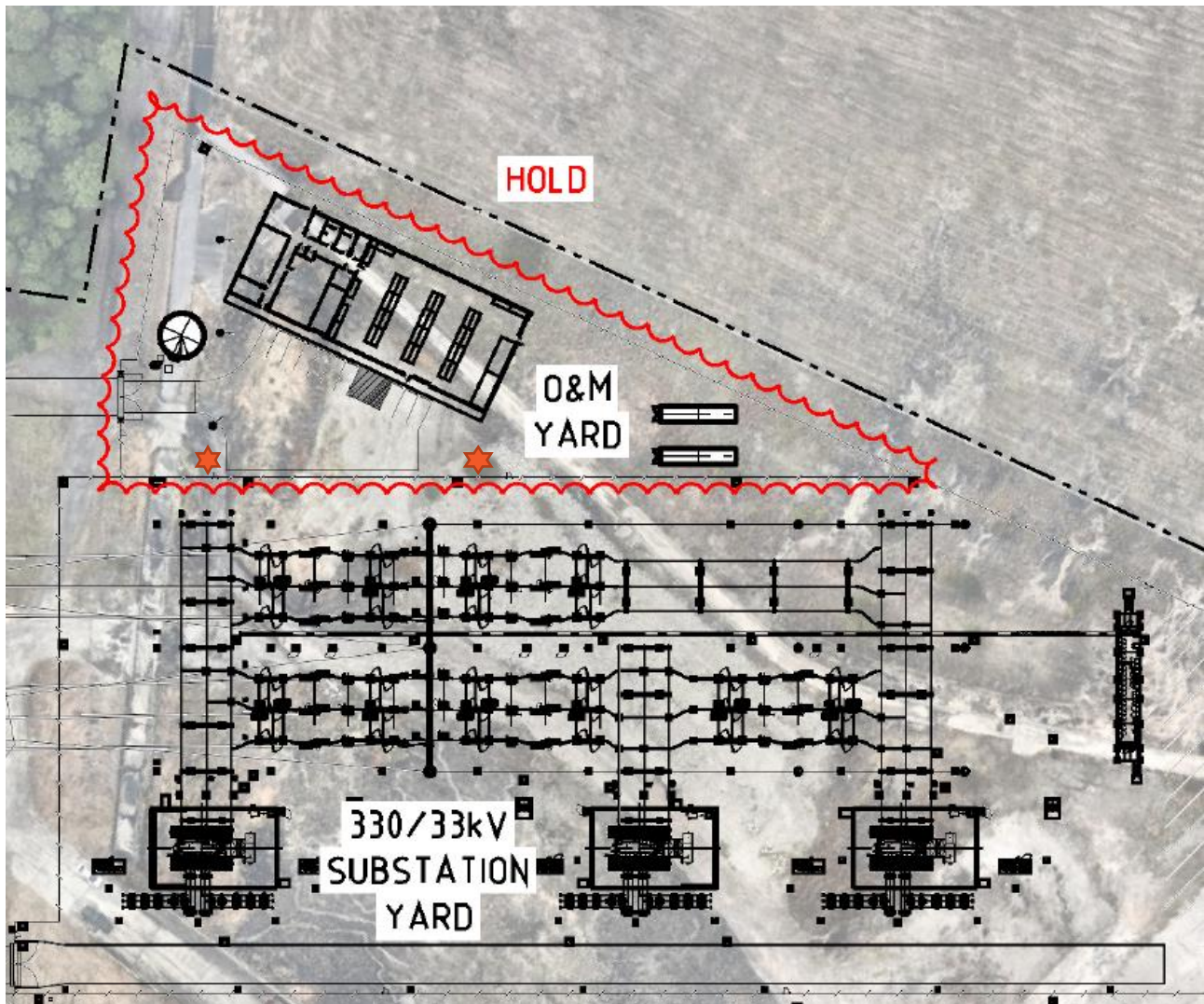


Figure 10: Fire Service Layout

8.5 Indicative hydrant locations

The locations of fire hydrants will be in accordance with AS 2419.1:2021 [35]. AS 2419.1:2021 specifies the requirements of external fire hydrants, which includes but is not limited to:

- Each external fire hydrant shall be located in a position that provides pedestrian access to the building.
- Each external fire hydrant shall be located in a position not less than 10 m from the building or fire compartment it is protecting.
- Each external fire hydrant shall be located in a position not less than 10 m from any high voltage main electrical distribution equipment such as transformers and distribution boards.
- Each external feed fire hydrant shall be located not more than 20 m from a hardstand area.

The fire hydrant system needs to be installed and commissioned in accordance with AS 2419.1:2021 [35] by an adequately qualified person.

8.6 Arrangements For Containing Contaminated Fire-Fighting Water

Fire-fighting water will be explicitly used for fighting a fire in the O&M facility. The O&M facility is a steel framed insulated building with a Colourbond roof. The office and warehouse space are separated by a fire-resistant internal wall. Combustible materials contained within the building will include office furniture, spare electrical components and spare BESS cells. The used fire-fighting water in a large O&M facility fire would be considered contaminated and would need to be treated as such.

A water management plan or environmental management plan and standard operating procedures should be prepared to include emergency responses during fires. This should consider potential collection of fire-water runoff, including testing and discharge requirements. The design of stormwater infrastructure should ensure that fire-fighting water can be contained within existing detention basins. To mitigate the potential contamination risk, containment strategies such as bunding of BESS cell storage room should be considered.

9. First Aid Fire Protection

In addition to the fixed fire protection systems, the following first aid fire protection equipment and operational arrangements are to be implemented at the Waratah Super Battery facility:

- Portable fire extinguishers will be placed in O&M facilities in accordance with AS/NZS 1850:2009 – Portable fire extinguishers [36]. The locations and types of fire extinguishers should be clearly displayed in the site emergency plan.
- Signage on gates and around site in accordance with AS 1319:1994 (reconfirmed 2018) – Safety Signs for the Occupational Environment [37]. Common types of signs that are typically installed in accordance with AS 1319:
 - Prohibition Signs: These signs feature a red circle with a diagonal line across a pictogram or text, indicating actions that are prohibited. Examples include "No Entry", "No Smoking", or "No Parking" signs.
 - Mandatory Signs: These signs feature a white pictogram or text on a blue background, indicating actions that are required. Examples include "Wear Safety Glasses", "Keep Door Closed", or "Hand Washing Station" signs.
 - Hazard Signs: These signs indicate specific hazards present. They feature a black symbol or text on a yellow background. Examples include "Fire Risk", "Electric Shock Risk," or "Non-ionizing Radiation Risk" signs.
 - Emergency Information Signs: These signs provide information related to emergency procedures and locations. Examples include "Emergency Exit", "Fire Extinguisher", or "First Aid Kit" signs.
 - Fire Signs: These signs provide information about fire safety and firefighting equipment. Examples include "Fire Alarm", "Fire Hose Reel", or "Fire Extinguisher" signs.
- Emergency Management Plan will be made available at the main gate at all times.
- A site block plan will be prepared in accordance with Australian standards before the construction of the O&M facility, substation and BESS facility. A site block plan will be available at ingress/egress points (including doors and gates) and central locations for the entrances to the site, O&M facility, switchrooms, substation and BESS facility.
- Training of staff on the management procedures of the various hazards at the facility. All staff should be aware of the hazards present on-site and comprehend the emergency management procedures.
- Induction of contractors/visitors. A record should be kept of all contractors and visitors entering the site. A relevant safety induction (depending on the access requirements) should be presented to all contractors/visitors.



Note, the above first aid measures are examples only. Reference should be made to internal emergency management plans where applicable.

10. Conclusion

The Waratah Super Battery is a state-significant project that is expected to be critical to the reliable operation of NSW's electricity system. Large-scale lithium battery installations can represent a significant fire risk if appropriate measures are not implemented to manage the fire and related hazards associated with the facility.

This study reviews the fire hazards, hazard mitigation measures and fire response protocols at the Waratah Super Battery site. The Waratah Super Battery will be built using BESS components that have many unique features specifically designed to limit the potential for fire propagation or build-up of a large-scale fire:

- Battery modules are relatively small, limiting the total volume of battery cells expected to catch on fire.
- Battery modules have steel enclosures and are separated by air gaps designed to prevent fire propagation, and
- Battery segments are insulated and designed specifically to prevent the build-up of explosive atmospheres or propagation of fire between battery segments.

These features have been independently tested in real-world fire tests of hardware expected to be identical to that installed at the Waratah Super Battery project. Such tests showed a fire was kept within the initiating battery segment or module and did not result in propagation or damage to adjacent modules. These results also indicate that a bushfire adjacent to the Waratah Super Battery site is expected to have a low risk of initiating a battery fire.

In event of a fire in the battery storage system, the recommended procedure is to let the fire burn itself out, and not fight the fire with water. This approach minimises the risks to first responders and prevents a build-up of contaminated fire water.

Further summary of significant fire hazards specifically associated with the Waratah Super Battery and their mitigation is provided in Table 6 of this study. Broadly, based on the fire mitigation measures already in place in the Powin Centipede system, and the fire mitigation measures expected to be implemented in the Waratah project, it is considered the key fire hazards identified for the project have all been suitably managed, and the risk of large or widespread fire, or a fire causing significant human harm, is relatively low.



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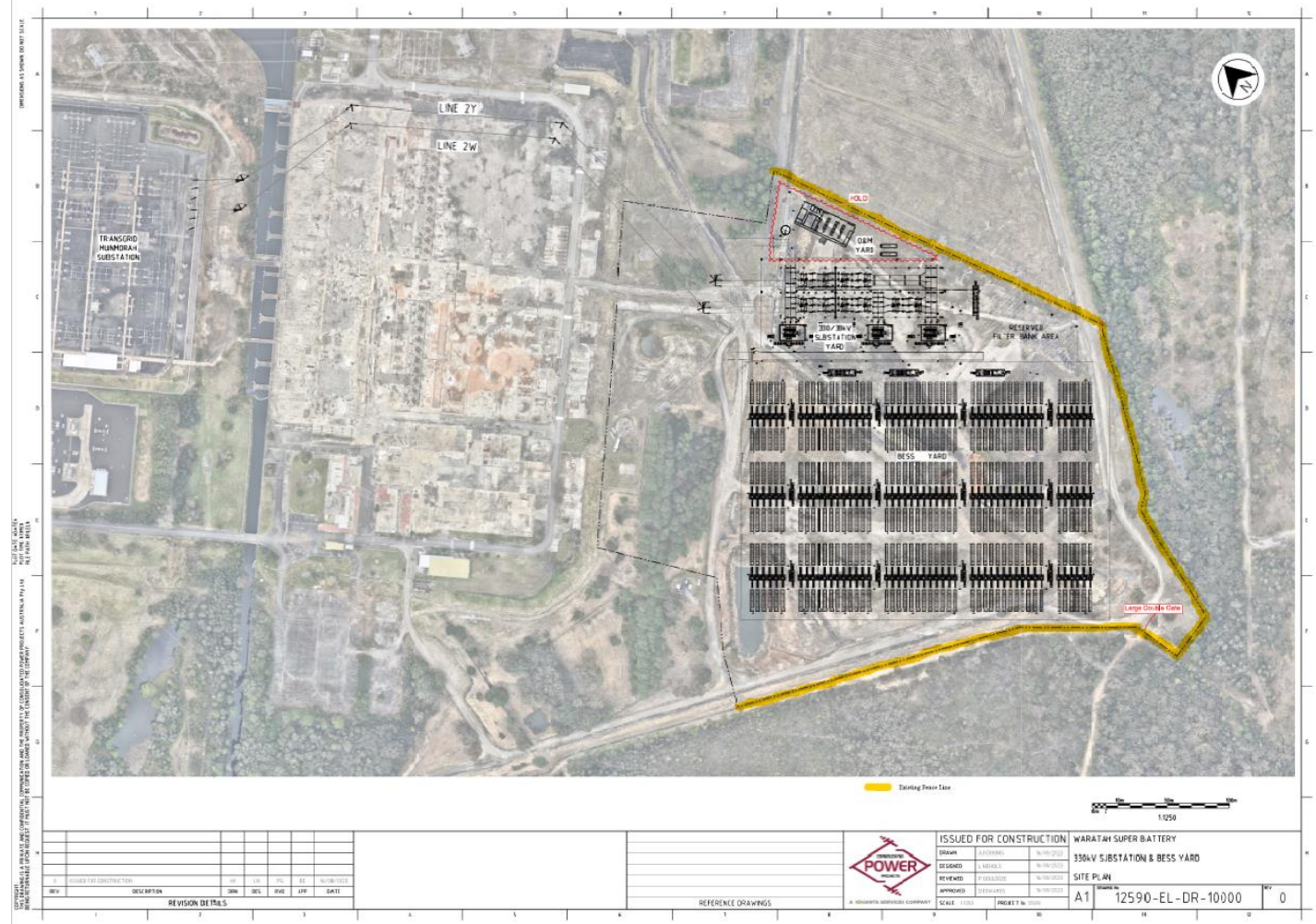
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Appendix A

Waratah Super Battery Facility – Site Layout





Appendix B

Battery Management Plan



POWIN

APRIL 2023

BATTERY MANAGEMENT PLAN

CONFIDENTIAL

Revision 1

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List of Abbreviations

Abbreviation	Definition
AC	Alternating Current
AHJ	Authority Having Jurisdiction
BESS	Battery Energy Storage System
BMS	Battery Management System
CH ₄	Methane
C ₂ H ₄	Ethene
C ₂ H ₆	Ethane
C ₃ H ₆	Propene
C ₃ H ₈	Propane
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
DC	Direct Current
EMS	Energy Management System
ERC	Emergency Response Coordinator
FPT	Functional Performance Testing
FSS	Fire Safety System
H ₂	Hydrogen
HCL	Hydrochloric acid
HCN	Hydrogen cyanide
HF	Hydrogen fluoride
HVAC	Heating, Ventilation, and Air Conditioning
ISO	International Organization for Standardization
kVAC	Kilovolt Alternating Current
LFP	Lithium Iron Phosphate
NFPA	National Fire Protection Association
OCPD	overcurrent protective devices
OSHA	Oregon Safety and Health Administration
PCS	Power Conversion System
PFC	Pre-Functional Checklist
PPE	Personal Protective Equipment
ROC	Remote Operations Center
UL	Underwriters Laboratories

1. Overview

As per the requirements of the Waratah Super Battery Environmental Impact Statement, the Battery Energy Storage System (BESS) should be stored, installed, operated, and maintained in accordance with the following Battery Management Plan. Furthermore, how to respond to an emergency and handle damaged batteries should be done in accordance with this Plan.

The BESS products contain sealed lithium-ion battery cells that are composed of Lithium Iron Phosphate (LFP). The LFP cells DO NOT contain lithium metal. LFP cells are generally considered the safest lithium-ion chemistry available today. The lithium-ion batteries used for the Waratah Super Battery project are tested and certified to ISO 9001.

2. Storage of the Batteries

Spare equipment must be stored in a climate-controlled environment to prevent damage to sensitive electrical components within the minimum and maximum temperature ranges specific in Table 1.

Table 1: Minimum and Maximum Storage Temperatures

Storage Period	Avg. Minimum Temperature for Period	Avg. Maximum Temperature for Period
≤ 1 Day	-20°C (-4°F)	45°C (113°F)
1 Day to 1 Week	-20°C (-4°F)	40°C (104°F)
1 Week to 1 Month	-20°C (-4°F)	30°C (86°F)
1 Month to 6 Months	0°C (-32°F)	25°C (77°F)

Relative humidity should be non-condensing and should not exceed 85%. All equipment, except for Stack750 Segments, should be stored away from direct sunlight.

The lithium-ion batteries storage area should be protected from flooding, based on the annual exceedance probability for the area and subsequent suitable selection of freeboard.

The health and safety of the batteries in storage can be maintained following a four-stage procedure:

1. Initial Storage
2. Stack Voltage Sampling
 - Taking voltage measurements of a sample from total
3. Stack Voltage Monitoring
 - Performing voltage sampling at regular intervals

4. Stack Recharging (if applicable)

3. Battery Installation & Commissioning

The Centipede Stack750 system is composed of two different segments:

- The Energy Segment
- The Collection Segment

The Centipede Stack750 Energy Segment (also referred to as a Stack) is where energy is stored in battery packs populated by LFP cells. Both the Energy Segments connected to a Collection Segment features temperature range controlled and ventilated outdoor rated enclosures. The energy is accessible through the Collection Segment that connects the lineup to the Power Conversion System (PCS). The PCS can also be referred to as an inverter.

One Collection Segment will be used for nine Energy Segments arranged in three Direct Current (DC) Buses with three Energy Segments behind each bus.

The BESS equipment and connections will be installed by qualified personnel. Training for installers will be provided and installation will have local resources available for support.

The battery system will be insulated and containerized. Each battery container will be verified for installation quality and operational values.

The BESS lineups should be arranged to optimize safe working and operation conditions, accommodating environmental considerations and comply with locally applicable codes and standards). AS5139 is not applicable for the project. Powin understands that Akaysha confirmed that BESS units are over 4.5 meters from site development boundary.

The BESS will follow a commissioning plan to confirm that the BMS is activated and operating during commissioning.

4. Battery Management System + Thermal Management System

The Battery Management System (BMS) is designed to properly manage the batteries state of charge, including battery balancing devices to avoid deterioration and individual cell over/under voltage during operation. The Energy Management System (EMS) includes a safety net of built-in applications which are always installed, always enabled, and always functioning at the highest priority.

If an urgent problem (such as a fire) is detected, the E-Stop Response application opens all DC contactors in the battery array. The E-Stop Response application

prevents any further charge, discharge or balancing by disconnecting and isolating each individual Energy Segment from the DC Bus.

If battery conditions approach certain limits, the Battery Safety application limits charging or discharging activity.

The EMS monitors safety parameters at many levels by:

- Responding to safety triggers at low levels.
 - For example, the Energy Segment opens contactors and prevents active balancing when it senses certain events. Similarly, a local controller in each Energy Segment responds automatically when it senses a mismatch of DC Bus voltages, voltages out of range, or temperatures out of range.
- Adjusting power commands to keep operations within prudent boundaries. These built-in adjustments are called “derating.”
- Displaying BESS Status Codes to inform appropriate personnel about system conditions at appropriate times.
- Monitoring voltages and temperatures at the battery cell, stack, and DC Bus levels.

Essential safety and monitoring controls exist onsite with the batteries so that a loss of internet at a given site does not prevent its continued operation.

The lithium-ion batteries and Energy Segments include protections and circuit controls including:

- Integrated enclosure insulation
- Monitoring and control at the Energy Segment, lineup, alternating current (AC) block and system level
- Current and temperature sensor logic to monitor short circuit events
- Built-in protection against current surges, both controls and solid state over current protection devices.
- Circuit interrupt device that protects against overcurrent
- Each LFP cell includes a safety vent to provide a controlled release of internal pressure during abnormal conditions and a rigid aluminum exterior provides an added degree of protection against external impacts.

The Thermal Management System includes thermal sensing of the cells to avoid over heating of cells.

A fire detection and suppression system is closely integrated with the BMS and EMS, with a design base and function guided by NFPA 70 and NFPA 855 compliance.

The electrolyte within LFP cells includes a volatile hydrocarbon-based liquid and a dissolved lithium salt (which is a source of the lithium ions). The electrolyte in LFP cells incorporated into BESS products is largely absorbed in the electrodes within the individual cells. In practical terms, there is no liquid electrolyte that is freely flowing within each LFP cell that can easily leak out into the environment once the cell is damaged.

In addition, each cell includes a rigid aluminum exterior providing an added degree of protection against external impacts. Because of this, it is very difficult to mechanically damage an LFP cell resulting in a leak of electrolyte material and the likelihood of an electrolyte spill from the BESS product is very small.

Modules of LFP cells are isolated from each other by steel barriers within BESS products, which act as structural members of the racking system and de facto thermal barriers between modules. These modules are stacked on the steel racking and are enclosed by an outdoor rated steel enclosure (Energy Segment). Each Energy Segment has the capacity to contain the liquid from a large number of LFP cells should there be a leak involving multiple cells.

The cell, steel barriers/racking, and steel external enclosure would have to be significantly damaged, crushed, or mechanically struck for the electrolyte liquid to come into contact with a user of a BESS product. Powin ESS products do not pose a significant liquid electrolyte release hazard based on the architecture and design of the LFP cell and the design and construction of the ESS products around those cells.

The FSS and its integration to the EMS will undergo Functional Performance Testing (FPT) prior to system operation. The purpose of FPT is to verify that all modes of operation function correctly and the mechanical equipment performs as expected.

The Waratah Super Battery project will include: one Pre-Functional Checklist (PFC) and one FPT per segment that covers the following components:

- Heating, Ventilation, and Air Conditioning (HVAC) system and controls
- Hydrogen sensor and emergency ventilation
- Controller response to Fire Suppression System alarming

5. Operations and Maintenance

Technicians should follow procedures and processes based on the standards below while commissioning, maintaining and servicing the BESS. Powin will follow local safety laws and regulations of battery energy storage systems.

- Oregon Safety and Health Administration (OSHA) 1910.147 (c) (4) (ii), the Control of Hazardous Energy (Lockout/Tagout)
- OSHA 1910.332 (b) (3) Training

- OSHA 1910.269 (a) (2) (ii) Electrical Power Generation, Transmission, and Distribution
- NFPA 101.1. National Fire Protection Association, Life Safety Code
- NFPA 70E Standard for Electrical Safety in the Workplace

Only qualified technicians, or qualified and authorized sub-contractors are permitted to work in or around the BESS.

On-site inspections and preventative maintenance are needed throughout the life of the product to ensure efficient function. Voltage, current, and temperature are remotely monitored both at the cell-level and Stack-level through the EMS. The data may indicate the need for maintenance outside the schedule in the following tables. An inspection and maintenance regime for the batteries, HVAC, and associated equipment will be implemented on regular established intervals as defined in these tables.

Recommended monthly inspections are shown in Table 2.

Table 2: Monthly Inspections

Component	Inspection
Exterior of Enclosures	Physical damage, corrosion, and cleanliness
Interior of Enclosures	Presence of moisture, dust, and corrosion
Cable Tray Area	Physical damage, corrosion, physical debris, animal infestation, and cleanliness
Spare Parts / Equipment (if applicable)	Inventory and Voltage Checks
Site Walk-through	General Cleanliness and Security

The following components in Table 3 are recommended for inspection based on the specified frequencies.

Table 3: Electrical Inspections and Maintenance

Component	Frequency
Visual Inspection of Cables	Annually
Functional Check of overcurrent protective devices (OCPD) and Disconnect Switches	Annually
Thermal scan of AC and DC Connection Points	Annually
Cooling/Heating Function	Bi-annually

Quarterly and annual inspections and maintenance are recommended for the HVAC as shown in Table 4.

Table 4: HVAC Inspections and Maintenance

Component	Frequency
Filters and Coils (clean or replace as needed)	Quarterly
Condensate Drain Line	Quarterly
Refrigerant Level	Annually

Table 5 shows the Fire Safety System (FSS) related components and the recommended cadences for inspection and maintenance.

Table 5: FSS Inspections and Maintenance

Component	Frequency
Inspect and test smoke and heat detectors	Bi-annually
Inspect manual pull station for physical damage (replace as needed)	Bi-annually
Ensure access to hazard areas, lines of egress, and manual pull stations are obstructed	Bi-annually
Inspect aerosol generators for physical damage or corrosion (replace as needed)	Bi-annually
Ensure aerosol generators are unobstructed	Bi-annually
Replace aerosol generators at end-of-service life	10 years
Replace Hydrogen gas detectors at end-of-service life (10 years from the date code on the sensor)	10 years

6. Battery Emergency Response Plan

Emergency planning and training should be provided by the BESS owner or their authorized representative so that facility operations and maintenance personnel and first responders can effectively address foreseeable hazards, associated with the BESS.

This information should aid the owner and the Authority Having Jurisdiction (AHJ) in establishing a site specific emergency operations plan.

Emergency operations training is required for all personnel responsible for the operation, maintenance, repair, servicing, and response of the BESS and must be retrained at least annually. All records of training must be documented and the record of training available onsite.

The BESS products contain sealed lithium-ion battery cells that are composed of lithium iron phosphate (LiFePO₄). In addition, R134A: 1,1,1,2-Tetrafluoroethane refrigerant is used in the HVAC units located in the top of the BESS Segments. The Uninterrupted Power Supply (UPS) use Lead Acid Batteries. Safety Data Sheets (SDS) for all items are available upon request.

If a BESS product has been visibly damaged or its outer enclosure has been compromised, practice appropriate high-voltage preventative measures until the danger has been assessed (and dissipated if necessary).

The BESS products are designed to withstand operating ambient temperatures up to 50°C and up to 100% relative humidity with no condensation.

The BESS products exposed to temperatures beyond what is listed above can degrade the battery, resulting in reduced battery service life or, possibly, failure or damage to the LFP cells themselves and should be avoided. This can lead to cells going into thermal runaway and possibly a fire or other thermal event. In addition, exposing the BESS products to heating equipment, localized heat sources, flames or sparks could result in cell thermal runaway reactions and should also be avoided.

To avoid and detect early any damage to the lithium-ion batteries, the battery system will be monitored 24 hours per day, 7 days per week, 365 days per year for alarms and symptoms related to system compromise, performance and or malfunction.

If gases or smoke are observed escaping from a BESS product, evacuate the area as the gases or smoke are likely flammable and could ignite unexpectedly. Immediately notify the supplier and/or the local Fire Department. The BESS product that is suspected of venting should only be approached by trained First Responders equipped with appropriate personal protective equipment (PPE).

Responding to a fire or other hazardous event involving a BESS product should only be performed by trained professionals.

In the unlikely event of a large fire or other thermal event in a BESS product, the following should be performed:

1. Immediately call the local Fire Department, if the alarm system has not already signaled them.
2. Call Remote Operations Center (ROC) at +1 (855) 888-3659. They will contact the Emergency Response Coordinator (ERC).
3. Establish a safety perimeter of 100 feet (30.5 meters) around all sides of the BESS product, and do not allow personnel other than firefighters to enter the safety perimeter.
4. Provide First Responders the site applicable Emergency Response documentation.

If a fire of a lithium-ion battery cannot be extinguished, cooling of adjacent units is available should the proponent wish to use it as an additional risk mitigant, but not required to prevent fire propagation between units. Consider using a wide fog pattern at lowest possible volume application.

The fire inside the Energy Segment is protected by several layers of steel and therefore, water does not have direct access to the batteries. As such, this will not stop the thermal runaway event and may only delay the eventual combustion of the entire BESS product.

A battery fire may continue for several hours, or days, and it may take even longer for the battery packs to cool after they have been fully consumed by a thermal runaway event. A lithium-ion battery fire that has been seemingly extinguished can flare up again if all cells have not been consumed. Therefore, it is advised to allow the ESS product to fully consume itself. The system separation distance has been modelled/tested under UL9540A and has been found to be safe and sufficient.

It is not recommended to initiate manual venting or reactivation of the emergency ventilation system after a fire event. The introduction of outside air can lead to re-ignition of a fire or lead to explosive conditions.

The LFP cell vent gas composition will depend upon several factors, including the cell state of charge and the cause of cell venting. However, testing has demonstrated that LFP cells release the following compounds when undergoing thermal runaway: Hydrogen (H_2), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Methane (CH_4), Ethene (C_2H_4), Ethane (C_2H_6), Propene (C_3H_6), Propane (C_3H_8). The compounds listed herein are a mixture of CO, CO_2 and H_2 and a combination of hydrocarbons. This mixture is flammable; however, no additional toxic compounds (such as HCN, HCL, HF, etc.) that are typically found in the products of combustion of modern fires are released by the cell during venting.

If the vented gas event leads to a fire that involves materials outside of the LFP cell (such as plastics within the module, wire insulation, etc.), combustion products that are typically found in a common plastics fire could be produced. Contact with any products of combustion from a fire or a vented gas without the appropriate Personal Protective Equipment (PPE) should be avoided.

7. Damaged Battery Handling

Damaged batteries should be handled accordingly:

- Contact the supplier immediately if they have not already been notified.
- If any sign of damage is present, remove the battery from service place it in an area away from flammable materials.
- Before handling or transporting a damaged BESS product, wait at least 24 hours or longer. Off-gassing or smoke may be an indication that a thermal reaction is in progress inside the battery enclosure. If evidence of heat, fire, explosion, or off-gas is not observed for 24 hours, the BESS product may be disconnected and moved to a designated location for safe storage.

- A safe storage location for a damaged lithium-ion battery is a location separated from combustibles, buildings, lots lines, etc. by at least 50 feet (15.2 meters). In addition, the storage area should be accessible only by trained professionals who are authorized to evaluate the damaged product. An example of a safe, designated storage space would be fenced in an open yard. Once safely moved to its designated storage location, a damaged BESS product should be monitored during storage for evidence of off-gassing, smoke, heat, flames, or any other signs of abnormal activity. If full-time monitoring of the product is not possible, the supplier can provide additional options to safeguard the BESS product during temporary storage prior to transport.
- Specific instructions for evaluating, disconnecting, and preparing a damaged BESS product for transport can be obtained from supplier. Please contact supplier before performing any activities associated with transporting a damaged BESS product.

If the product has been mechanically damaged in an obvious manner (i.e., the battery enclosure has been dented, cut, or compromised in some other manner), it is possible that cells inside the battery enclosure have been damaged. This could lead to thermal runaway of the damaged LFP cells and possibly spread thermal runaway to neighboring cells.

Before handling or transporting a damaged Powin BESS product, wait at least 24 hours or longer, as instructed by the EMC and Powin's ROC. Off-gassing or smoke may be an indication that a thermal reaction is in progress inside the battery enclosure. If evidence of heat, fire, explosion, or off-gas is not observed for 24 hours, the Powin BESS product may be disconnected and moved to a designated location for safe storage.

8. Revision History

Name	Date	Reason for Change	Rev
Sarah Davis	03/27/23	Initial Release	0
Sarah Davis	04/03/23	- AS5139 is not applicable for the project. - Powin understands that Akaysha confirmed that BESS units are over 4.5 meters from site development boundary. - The system separation distance has been modelled/tested under UL9540A and has been found to be safe and sufficient - Powin will follow local safety laws and regulations of battery energy storage systems. - Updated what to do if a fire of a lithium-ion battery cannot be extinguished	1



POWIN



Appendix C

Hazard Identification Workshop

RISK ASSESSMENT DETAILS AND CONTEXT

Client:	Akaysha
Project:	RA - Fire Safety Study 'Waratah Big Battery'
Job Number:	AV-J-231071
Folder Number:	F22946
Date:	Wednesday, 29 March 2023
Author:	Colin Barker, Patrick McGaw and Tait Worthington
Risk Context:	Risk Assessment for Waratah Fire Safety Study
Reference Documentation:	Waratah Super Battery - Munmorah (Environmental Impact Statement) - GHD Waratah Super Battery - Munmorah (Appendix F - Hazard and Risk Assessment) - GHD Waratah Super Battery - Munmorah (Response to Submissions Report) - GHD Relevant literature papers, Standards, Regulations and Guidelines
Objectives of Assessment:	The hazard identification workshop aimed to build upon: - the known hazards of lithium-ion BESS as published within academia - body of literature analysing incidents involving lithium-ion BESS from around the globe - the analyses already narrated within the PHA for the Waratah Super Battery development
Key Stakeholders:	Akaysha Powin NSW Department of Planning, Industry & Environment Wyong Shire Council Neighbours
Note:	It should be noted that Advitech Pty Limited prepared these risk assessment workshop results for the client in accordance with the scope of work and specific requirements agreed between Advitech and the customer. These notes were prepared with background information, terms of reference and assumptions agreed with the customer. The results of the workshop are not intended for use by any other individual or organisation and as such, Advitech will not accept liability for use of the information contained in these results, other than that which was intended at the time of writing.
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RISK ASSESSMENT METHODOLOGY

Risk Context:	Risk Assessment for Waratah Fire Safety Study
Methodology:	The risk assessment was conducted in the form of a structured workshop, facilitated by Advitech. The results of the workshop were input directly into this worksheet by an Advitech representative. Hazard scenarios were identified in a systematic process, utilising hazard guidewords described below.
Risk Classification:	Hazard scenarios were classified (scored) according to Advitech's Risk Classification System.
Hazards:	Hazards were defined as "sources of potential harm or situations with the potential to cause a loss". The hazard guidewords used to assist in risk identification were ... (refer to standard list, or list individual guidewords here)
Other Definitions:	Assets were defined as "tangible and intangible items of value or processes, procedures or tasks performing as intended". The system(s) studied were broken down into assets on the basis of ... ALARP (As Low As Reasonably Practicable) may signify one or more of the following: • All practical barriers and controls are in place to minimise the risk. • Likelihood is so remote that risk is tolerable without further action. • The level of risk is considered tolerable by the community. • Further risk reduction is either impracticable or the cost is grossly disproportionate to the improvement gained.
General Comments & Notes:	
Results:	The results of the risk assessment workshop are given in the following spreadsheet.



MEETING ATTENDANCE

[illegible]

Ref	N/A	Asset/Guidewords	Hazard	Scenario	Consequence	Current Barriers	C	L	R	Action	Comments
1			Thermal runaway of battery cell leading to battery fire	Battery cell failure leading to thermal runaway	Battery fire of one battery segment	Smoke, gas and heat detection. Module and segment design which minimises thermal runaway propagation between cells. Voltage and temperature monitoring of every cell.	2	E	10		
2			Thermal runaway of battery cell leading to battery fire	Bushfire leads to thermal runaway on battery segment	Battery fire of one or more battery segments	Insulated segment walls. 10m APZ	3	C	13	Management of the APZ to NSW RFS requirements. Examine the feasibility of a fire barrier	
			Battery Explosion	Explosion of battery off-gases due to thermal runaway	Explosion leading to catastrophic damage of segment, leading to further fires	Ventilation system to vent off gases	3	D	9		
3			Bushfire	Bushfire initiated by ember attack from battery fire	Bushfire leading to property damage	Smoke, gas and heat detection. Module and segment design which minimises thermal runaway propagation between cells. Voltage and temperature monitoring of every cell.	2	E	10	Management of the APZ to NSW RFS requirements.	
4			Toxic cloud	Fire leading to HF emissions	Battery fire of one battery segment	Separation distance to workers and homes Battery design which minimises fire risk	4	C	8		
5			EMF	EMF exposure to first responders at a fire incident	Potential long term health issues due to prolonged exposure	Fencing of high voltage electrical installations Minimal worker exposure	4	D	5		Potential risks to health are not well known
6			Substation Fire		Substation Fire	Substation Fire	4	D	5		
7			Switchroom Fire		Switchroom Fire	Switchroom Fire	4	D	5		
8			Transformer Fire		Transformer Fire	Transformer bunding, fire barrier	4	D	5		
9			Transformer Explosion		Transformer Explosion leading to further fires	Pressure relief system, fire barrier	3	D	9		
10									0		
11									0		

ADVITECH RISK CLASSIFICATION SYSTEM

QUALITATIVE MEASURES OF CONSEQUENCE

Category	Personnel	Financial	Environment	Community, Compliance, Reputation
1 Catastrophic	Fatality	Huge loss > \$_____. (e.g. > \$10m) (e.g. > \$1m)	Short and long term impacts; alteration to biological or biochemical systems; toxicological effects; shutdown during investigation. E.g. Ok Tedi (PNG), fish kills.	Inter/national public/media outrage; shutdown order; public enquiry; major prosecution and fines.
2 Major	Extensive injury or illness, permanent disability	Major loss \$_____ to _____. (e.g. \$1m - 10m) (e.g. \$100k - 1m)	Offsite release; long-term impact (>1 reporting period); fine, investigation or prosecution. E.g. Significant discharge of pollutant into air or water.	Widespread public/media concern; major breach; significant fines; investigation.
3 Moderate	Injury or illness requiring hospital admission, LTI, restricted work	High loss \$_____ to _____. (e.g. \$100k - 1m) (e.g. \$10 - 100k)	Offsite release; transient impact (<1 reporting period); reportable breach of license conditions; fine or prosecution. E.g. Persistent noise or odour complaints.	Public/media attention outside local area; regulation breach; reportable; fines likely.
4 Minor	Reversible injury or illness requiring offsite medical treatment	Medium loss \$_____ to _____. (e.g. \$10 - 100k) (e.g. \$1k - 10k)	Contained onsite; clean-up may require outside assistance; reportable to authorities (e.g. EPA). E.g. large chemical spill (i.e. IBC, pallet of drums) into bund.	Local public/media attention; minor regulation breach; reportable to authorities.
5 Insignificant	Negligible injuries requiring first aid treatment (onsite) or less	Low loss < \$_____. (e.g. < \$10k) (e.g. < \$1k)	Contained onsite; transient impact; not reportable. E.g. small chemical spill into bund.	Not noticeable to public/media, not reportable.

QUALITATIVE MEASURES OF LIKELIHOOD

Category	Description	Indicative Frequency
A Common	Expected to occur, happens often	1 a year or more frequent
B Likely	Has occurred, heard of it happening here or somewhere similar	1 in 10 yrs or so
C Possible	Could occur, unusual but possible, may happen within working lifetime	1 in 40 yrs or so
D Unlikely	Not expected to occur, remotely possible	1 in 100 yrs or so
E Rare	Conceivable only in exceptional circumstances, practically impossible	1 in 1000 yrs or less frequent

RISK ASSESSMENT MATRIX

		LIKELIHOOD				
		A	B	C	D	E
CONSEQUENCE	1	25	24	22	19	15
	2	23	21	18	14	10
	3	20	17	13	9	6
	4	16	12	8	5	3
	5	11	7	4	2	1

RISK RANKING PRIORITIES

Ranking	Range	Priority
Extreme	20 - 25	Requires urgent and immediate attention, senior management response needed.
High	12 - 19	Requires proactive management, senior management attention needed.
Moderate	6 - 11	Requires active monitoring, management responsibility must be assigned.
Low	1 - 5	Does not require active management, manage with routine procedures.

Risks reduced "so far as is reasonably practicable" may be signified by one or more of the following:

- All practical barriers and controls are in place to minimise the risk.
- Likelihood is so remote that risk is tolerable without further action.
- The level of risk is considered tolerable by the community.
- Further risk reduction is either impracticable or the cost is grossly disproportionate to the improvement gained.



Appendix D

Bushfire Attack Level Assessment

Legend

Site Compound

Site Boundaries (Lot 10 DP1201414)

Fire trail (6m wide subject to easement)

2m contours

Bushfire Attack Levels (PBP, Table A1.12.5)

BAL-FZ (<18m)

BAL-40 (18m-<24m)

BAL-29 (24m-<33m)

BAL-19 (33m-<45m)

BAL-12.5 (45m-<100m)

Notes:

1. Bushfire Attack Levels have been determined using site assessment information contained within Section 6.10 of the Environmental Impact Statement (GHD, November 2022).

2. The adopted site parameters (GHD, 2022) are:

- FDI 100 (Table 1.12.5)
- Forest vegetation formations existing at the site boundaries to the south and east
- effective slope is level

3. This plan has been prepared for discussion purposes only. Relationship between infrastructure and BAL lines is diagrammatic and actual separation distances are to be confirmed by survey.

Heat flux exposure	Description	AS 3959 construction level
N/A	Minimal attack from radiant heat and flame due to the distance of the building from the vegetation, although some attack by burning debris is possible. There is insufficient threat to warrant specific construction requirements.	BAL-LOW
≤12.5	Attack by burning debris is significant with radiant heat (not greater than 12.5kW/m²). Radiant heat is unlikely to threaten building elements (such as unscreened glass). Specific construction requirements for ember protection and accumulation of debris are warranted.	BAL-12.5
>12.5 ≤19	Attack by burning debris is significant with radiant heat flux (not greater than 19kW/m²) threatening some building elements (such as screened glass). Specific construction requirements for embers and radiant heat are warranted.	BAL-19
>19 ≤29	Attack by burning debris is significant and radiant heat flux (not greater than 29kW/m²) threatens building integrity. Specific construction requirements for ember and higher levels of radiant heat are warranted. Some flame contact is possible.	BAL-29
>29 ≤40	Radiant heat flux and potential flame contact could threaten building integrity.	BAL-40
>40	Significant radiant heat and significantly higher likelihood of flame contact from the fire front will threaten building integrity and result in significant risk to residents.	BAL-FZ

Note: Attack from burning debris increases with the Bush Fire Attack Level. Source AS 3959.

Australian Bushfire

ASSESSMENT CONSULTANTS

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www.accuplan.com.au

Project: Waratah Super Battery

Lot 10 DP1201414

Former Munmorah Power Station

Title: Bush Attack Levels

Scale: 1: 1500 (A3)

Date: 5/4/2023

0

50

100

150

200 m

Sources:

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© NSW Six Maps 2022

Planning for Bushfire Protection 2019

Consolidated Power Projects 2023

N



Appendix E

Thermal Runaway (UL9540A) and Large-Scale Fire Test Reports

Report Title	Test Description
UL9540A Cell Test – EVE Power Co. Ltd. Cell	UL9540A cell test of a Lithium-iron phosphate battery cell, Model LF280K. The cell has a capacity of 280 Ah and nominal voltage 3.2 Vdc.
UL9540A Cell Test – Ruipu Energy Co. Ltd. Cell	UL9540A cell test of a Lithium-iron phosphate battery cell, Model CB71173204EB. The cell has a capacity of 280 Ah and nominal voltage 3.2 Vdc.
UL9540A Module Test – EVE Cells	UL9540A battery test of a battery pack (3 modules) containing 30 LiFePO ₄ EVE cells total.
UL9540A Module Test – Ruipu (REPT) Cells	UL9540A battery test of a battery pack (3 modules) containing 30 LiFePO ₄ Ruipu (REPT) cells total.
UL9540A Unit (Segment) Test – EVE Cells	UL9540A battery unit (segment) test of a 750 kWh Powin pre-production segment containing 28 Powin battery packs (30 LiFePO ₄ EVE cells per pack, 840 cells in total).
ESRG – Powin Centipede Prototype – Large-scale Fire Test – Feb 2022	Large-scale fire test of the 750 kWh Powin battery pre-production segment containing 28 Powin battery pack (30 LiFePO ₄ EVE cells per pack, 840 cells in total).
ESRG – Powin Centipede Large-scale Fire Test – Apr 2023	Large-scale fire test of the 750 kWh Powin battery Stack 750 segment containing 28 Powin battery pack (30 LiFePO ₄ EVE cells per pack, 840 cells in total).
SAFE Laboratories and Engineering Corp – Stack 750 Fire Propagation Test – Dec 2023	Large scale FIRE test is to validate Stack750 Energy Segment design revisions intended to mitigate fire propagation for production and field installed units to <i>California Fire Code 1207.1. 5 – Large-scale fire test</i> . These testing conditions are more severe than conditions required by Underwriters Laboratories UL 9540A:2019.