PRELIMINARY HAZARD ANALYSIS

ROTHBURY

BATTERY ENERGY STORAGE SYSTEM

SSD-85939708

PREPARED FOR:	**Ausgrid**

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ABBREVIATIONS

AC	Alternating Current
ADGC	Australian Dangerous Goods Code
AEGL	Acute Exposure Guideline Level
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
AS	Australian Standard
APZ	Asset Protection Zone
BESS	Battery Energy Storage System
BMS	Battery Management System
CO	Carbon Monoxide
DC	Direct Current
DG	Dangerous Goods
DP	Deposited Plan
DPHI	Department of Planning, Housing and Infrastructure
DVC	Decisive Voltage Classification
EIS	Environmental Impact Study
ELF	Extremely Low Frequency
EMF	Electric and Magnetic Field
FM	Factory Mutual
FRNSW	Fire and Rescue New South Wales
G	Gauss
HAZID	Hazard Identification
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
HV	High Voltage
Hz	Hertz
ICNIRP	International Commission on Non-Ionizing Radiation Protection
kV	Kilovolt(s)
kW	Kilowatt(s)
kWh	Kilowatt hour(s)
LFP	Lithium Iron Phosphate
$LiPF_6$	Lithium Hexafluorophosphate
m	Metre(s)
MLRA	Multi-Level Risk Assessment
MV	Medium Voltage
MW	Megawatt(s)
MWh	Megawatt hour(s)
NEM	National Electricity Market
NFPA	National Fire Protection Association
NMC	Nickel Manganese Cobalt
NSW	New South Wales
NZS	New Zealand Standard

OEM	Original Equipment Manufacturer
OH&S	Occupational Health & Safety
PHA	Preliminary Hazard Analysis
PPE	Personal Protective Equipment
RFS	Rural Fire Service
RMU	Ring Main Unit
SDS	Safety Data Sheet
SEARs	(Planning) Secretary's Environmental Assessment Requirements
SEPP	State Environment Planning Policy
SPD	Surge Protective Devices
SSD	State Significant Development
T	Tesla
UL	Underwriters' Laboratories
UPS	Uninterruptible Power Supply
V	Volt(s)

TERMINOLOGY

Term	Definition
Applicant	Ausgrid
BESS facility	The central part of the site designated for the battery units, inverters/MV transformers the combined control/switch room, and other supporting infrastructure.
Off-site	Areas extending beyond the site.
Project Area	The area that is located within the site and constitutes the development footprint, i.e. the area that will be physically disturbed for the construction and operation of the Project. The Project Area is approximately 4.56 ha.
Sensitive receivers	Persons, facilities, or structures that are sensitive to potential noise, vibration, air and visual impacts, such as residents, schools, heritage structures, and medical facilities.
The Project	Construction, operation, and maintenance of a Battery Energy Storage System (BESS) facility. For the purposes of the PHA, this study covers the ‘operation phase’ of the BESS facility, connection to the existing Rothbury Zone Substation.
The site	The area of land owned by Ausgrid forming Lot 4, Deposited Plan (DP) 598847, covering an area of 11.8 ha. The address is 1309 Wine Country Drive, Rothbury, NSW 2304. Existing features of the site include the existing Rothbury 132 kV/11 kV Zone Substation and vacant grassland. The Project would be located in the central part of the site, to the west of the existing Rothbury Zone Substation.

1. EXECUTIVE SUMMARY

Ausgrid is seeking development consent for the construction, operation and maintenance of a Battery Energy Storage System (BESS) (the Project). The Project would be located to the west of the existing Ausgrid 132 kV/11 kV Rothbury Zone Substation at 1309 Wine Country Drive, Rothbury NSW 2320 (the site). The Project would have a power delivery capacity of up to 135 MW, over a four-hour duration (i.e. up to 540 MWh). The rated name plate capacity for the 135 MW BESS is 181 MW to account for losses at the point of connection inside the Rothbury Zone Substation under worst case network conditions.

Ausgrid has not finalised the BESS Original Equipment Manufacturer (OEM) and has nominated the use of a generic, containerised lithium iron phosphate (LFP) battery as the technology for the Project. Ausgrid will ensure the final layout meets the requirements of codes, standards and OEM recommendations to prevent fire propagation.

The Project has been designated a State Significant Development (SSD-85939708) requiring an Environmental Impact Statement (EIS). As such, the Planning Secretary's Environmental Assessment Requirements (SEARs) have been issued for the Project. This report specifically addresses the following SEARs:

- Dangerous Goods (DGs) – preliminary risk screening in accordance with *State Environmental Planning Policy* (SEPP) *(Resilience and Hazards) 2021* (SEPP (Resilience and Hazards)).
- BESS – hazards and risks in compliance with Hazardous Industry Planning Advisory Paper No. 6 (HIPAP 6) – *Hazard Analysis* and the Multi-Level Risk Assessment (MLRA) guideline using the criteria in HIPAP No 4 – *Risk Criteria*.
- Health – Electric and Magnetic Field (EMF) hazards.

The report makes the following conclusions:

- The Project is not potentially hazardous in the context of DGs assessed under the SEPP (Resilience and Hazards).
- Hazard Identification (HAZID) and consequence analysis found that there are no potential events with significant off-site consequences, and societal risk is negligible. Based on the MLRA guideline, Ref [1], the appropriate level of analysis is level 1 (qualitative).
- Based upon the proposed layout, a battery fire is unlikely to result in fatality or injury to offsite receptors. Irritation from toxic combustion products may extend 8 m from the northern boundary but does not affect any sensitive and/or residential land uses; hence HIPAP 4 risk criteria is met.

- The level 1 assessment concludes that the Project meets the HIPAP 4 risk criteria and should not be precluded on the basis of land use safety.
- EMF hazards would not exceed recognised criteria.

The report has two recommendations:

- Review the battery unit clearances and installation requirements, and transformer type and approval for separation distances once the OEM, make, and model are selected.
- Consider the location of the auxiliary transformer as the layout is finalised to ensure compliance with Australian Standard (AS) 2067 and consider a fire wall if required.

2. INTRODUCTION

2.1. Background

Ausgrid (the Applicant) is seeking development consent for the construction, operation and maintenance of a Battery Energy Storage System (BESS) (the Project). The Project would be located to the west of the existing Ausgrid 132 kV/11 kV Rothbury Zone Substation at 1309 Wine Country Drive, Rothbury NSW 2320 (the site).

The Project would have a power capacity of up to 135 MW, over a four-hour duration (i.e. up to 540 MWh). The rated name plate capacity for the 135 MW BESS is 181 MW to account for losses at the point of connection inside the Rothbury Zone Substation under worst case network conditions. The installed capacity will be subject to final design and Original Equipment Manufacturer (OEM) selection.

The Project is a State Significant Development (SSD-85939708) and is therefore supported by an Environmental Impact Statement (EIS). The Planning Secretary's Environmental Assessment Requirements (SEARs) for the Project, issued by the Department of Planning, Housing and Infrastructure (DPHI) include a requirement to address hazards associated with operation of the Project. The Applicant has engaged Sherpa Consulting Pty Ltd (Sherpa) to prepare this report in response to these SEARs.

2.2. Objectives

The objective of the study was to perform an assessment to address the 'Hazards' component of the SEARs. The SEARs, and reference to where they are addressed in this report, are shown in Table 2.1.

Table 2.1: Hazard analysis requirements

Assessment requirements	Section reference
A preliminary risk screening completed in accordance with the Hazards State Environment Planning Policy (SEPP) 2021.	Section 5
A Preliminary Hazard Analysis (PHA) prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 (HIPAP 6) – *Guideline for Hazard Analysis*, Ref [2] and Multi-Level Risk Assessment (MLRA), Ref [1]. The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with HIPAP 4 – *Risk Criteria for Land Use Safety Planning*, Ref [3]. The PHA must consider the effect of bushfires on batteries or other components of the BESS.	Sections 6-10
An assessment of potential hazards and risks including but not limited to fires, spontaneous ignition, electromagnetic fields or the proposed grid connection infrastructure against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) *Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields*.	Sections 6-10 **Note**: The requirement for a bushfire risk assessment is considered elsewhere in the EIS and not addressed in this document.

2.3. Scope

The EIS should be referred to for details of the overall Project. The key components that are relevant to the PHA study scope are summarised as follows:

- 135 MW, 4-hour duration BESS.
- Containerised lithium iron phosphate (LFP) battery units and associated infrastructure including inverters and medium voltage (MV) transformers.
- A 33 kV underground cable connection from the battery units to the Rothbury Zone Substation.
- Combined switch room and control room building.
- Ring main units (RMUs).
- Onsite workshop facility.
- One auxiliary transformer.
- Backup diesel generator.
- Onsite car parking.
- Ancillary infrastructure including:
  - Internal site access road
  - Laydown areas
  - Stormwater management
  - Boundary security fencing
  - Noise barriers
  - Lighting
  - CCTV.

To prepare its infrastructure for new and changing customer connections as part of the renewable energy transition, the Applicant plans to augment the Rothbury Zone Substation to include an additional transformer and connection. Substation augmentation works would be assessed and determined by the Applicant separately in accordance with Part 5 of the Environmental Planning and Assessment Act and is not included in the scope of this PHA study.

2.4. Exclusions and limitations

The study exclusions and limitations are summarised in Table 2.2.

Table 2.2: Exclusions and limitations

No.	Item	Exclusions and limitations
1	Design elements for the Project	Design elements for the Project may be subject to change prior to construction. Sherpa notes that the layout of the battery units would be finalised during detailed design. The assessment in this study uses a generic containerised LFP battery system, which was selected for the Project concept design.
2	Hazards associated with proposed operations	The PHA identified and assessed credible hazards associated with operation of the Project and excluded hazards relating to construction, commissioning, and decommissioning.
3	Bushfire hazard assessment	The assessment of bushfire risks has been excluded from this assessment and has been assessed separately in the EIS
4	Construction Safety Study	The PHA does not constitute a Construction Safety Study. Any requirement for a Construction Safety Study will be subject to the conditions of consent. For more information, refer to HIPAP 7 – *Construction Safety.*
5	Fire Safety Study	The PHA does not constitute a Fire Safety Study. Any requirement for a Fire Safety Study will be subject to the conditions of consent. For more information, refer to HIPAP 2 – *Fire Safety Study.*
6	OEM and layout changes	The PHA should be reviewed if there are any changes to the battery specification or to the site layout once the OEM is selected. The Applicant is responsible for ensuring the Project is designed and constructed according to the OEM's requirements and specifications.

3. FACILITY DESCRIPTION

The EIS contains the Project description and should be referred to for the full context and details. Only features that are relevant to this report are summarised here.

3.1. Location and Project Area

The site is located at 1309 Wine Country Drive, Rothbury, 2320. The site is within the Cessnock City Council local government area, approximately 4 km north of the North Rothbury township. Location of the Project is shown in Figure 3.1.

The Project (battery units, invertors, MV transformers etc.) would be located in the central portion of the site on approximately 1.47 ha.

Connection of the BESS to the Rothbury Zone Substation would be via a 33 kV underground cable. Figure 3.3 shows the preliminary site layout.

3.2. Surrounding land use

The surrounding land use is mostly rural (RU2) and primary production small plots (RU4), containing residential dwellings, areas of cultivation including vineyards and mixed bushland. The closest residential dwelling is located approximately 185 m south of the site boundary. North-west of the Project Area, there is one lot zoned as Environmental Management (C3) which is largely undeveloped and is comprised mainly of bushland. The approximate distances of these receptors, as well as other receptors of interest, is provided in Table 3.1 and illustrated in Figure 3.2.

Table 3.1: Off-site receptors

Receptor	Distance (m) from Project Area to receptor
Black Creek Farm	412
Quambatook House (Vacant)	185
Holiday Letting Residence	280
Rothbury Zone Substation	Adjacent to Project Area
Closest residential dwelling	200
Closest residential area (land zoned R5 'Large Residential Lot')	620

3.2.1. Hydrology

The site is located within the Black Creek catchment with Black Creek itself located approximately 205 m west of the project area. The Water Impact Assessment (Ref [4]) found that during rainfall events, surface waters around the Rothbury Zone Substation are collected to the north by a series of informal flow pathways, culverts and farm dams. During larger rain events, flow at the site continues to drain north but Black Creek spills onto the surrounding floodplain and there would be some localised flooding at the site. Flooding as an external event has been considered in the hazard identification (APPENDIX A).

Figure 3.1: Project location

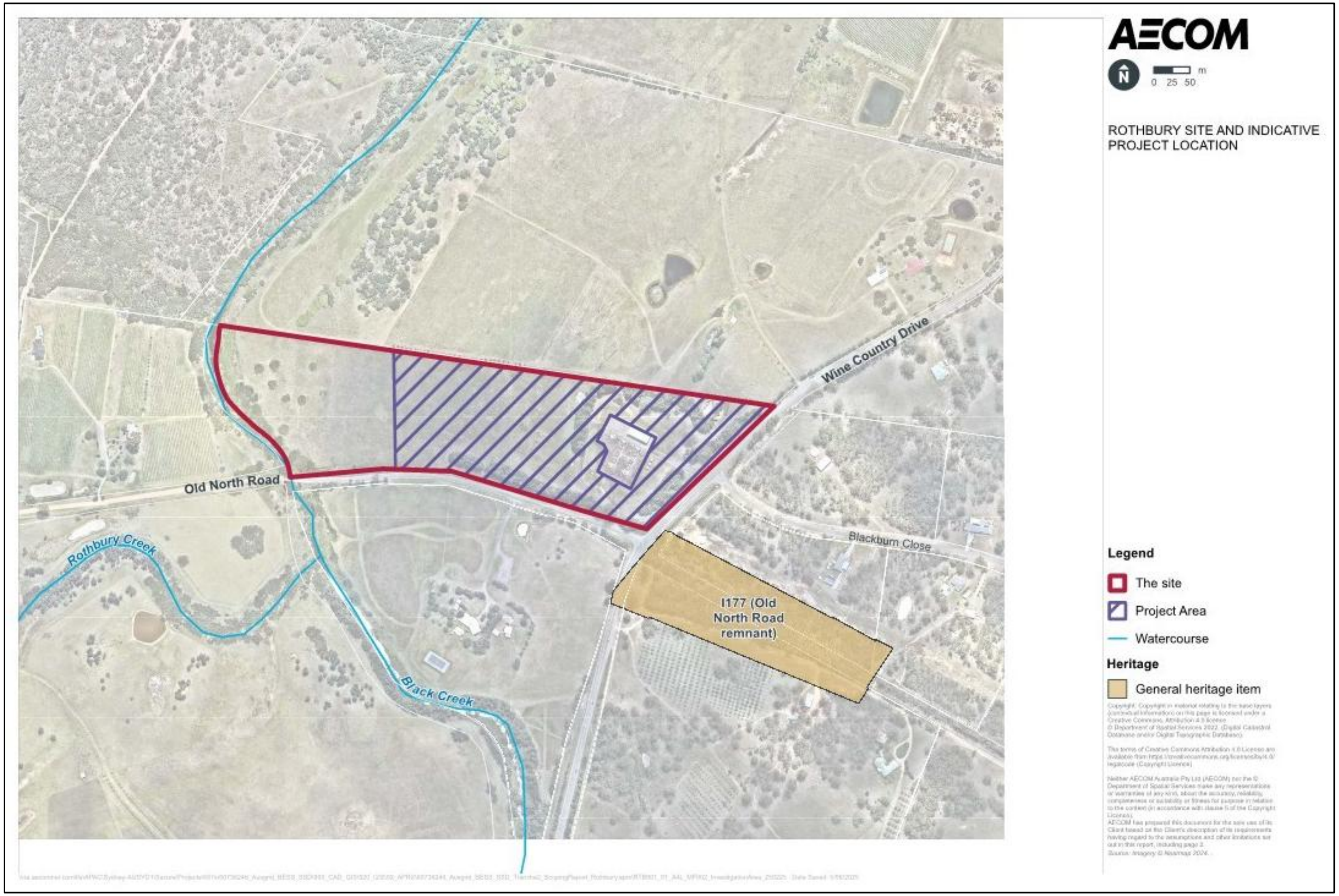

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Figure 3.2: Sensitive receptors on the land surrounding the BESS facility

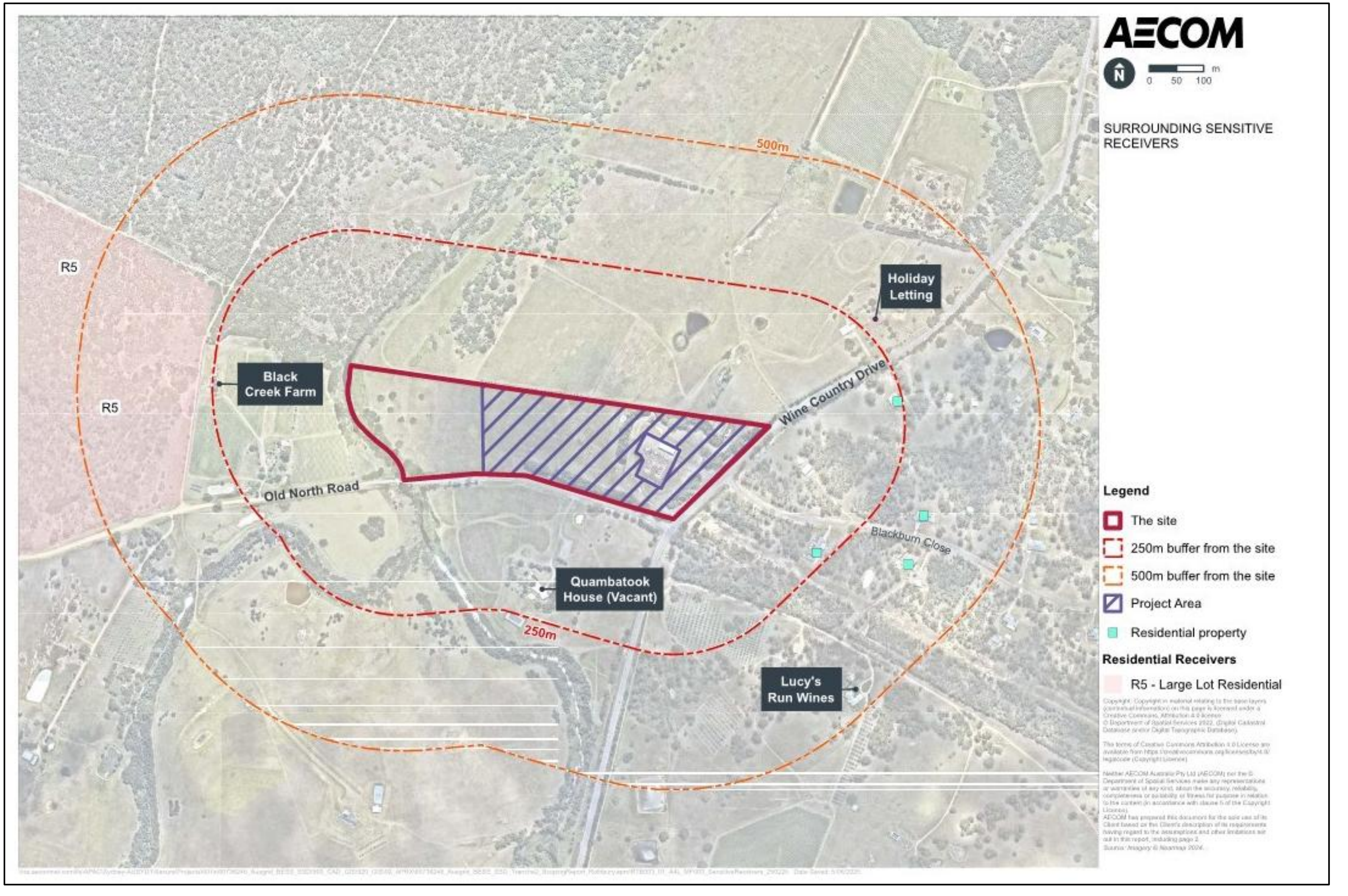
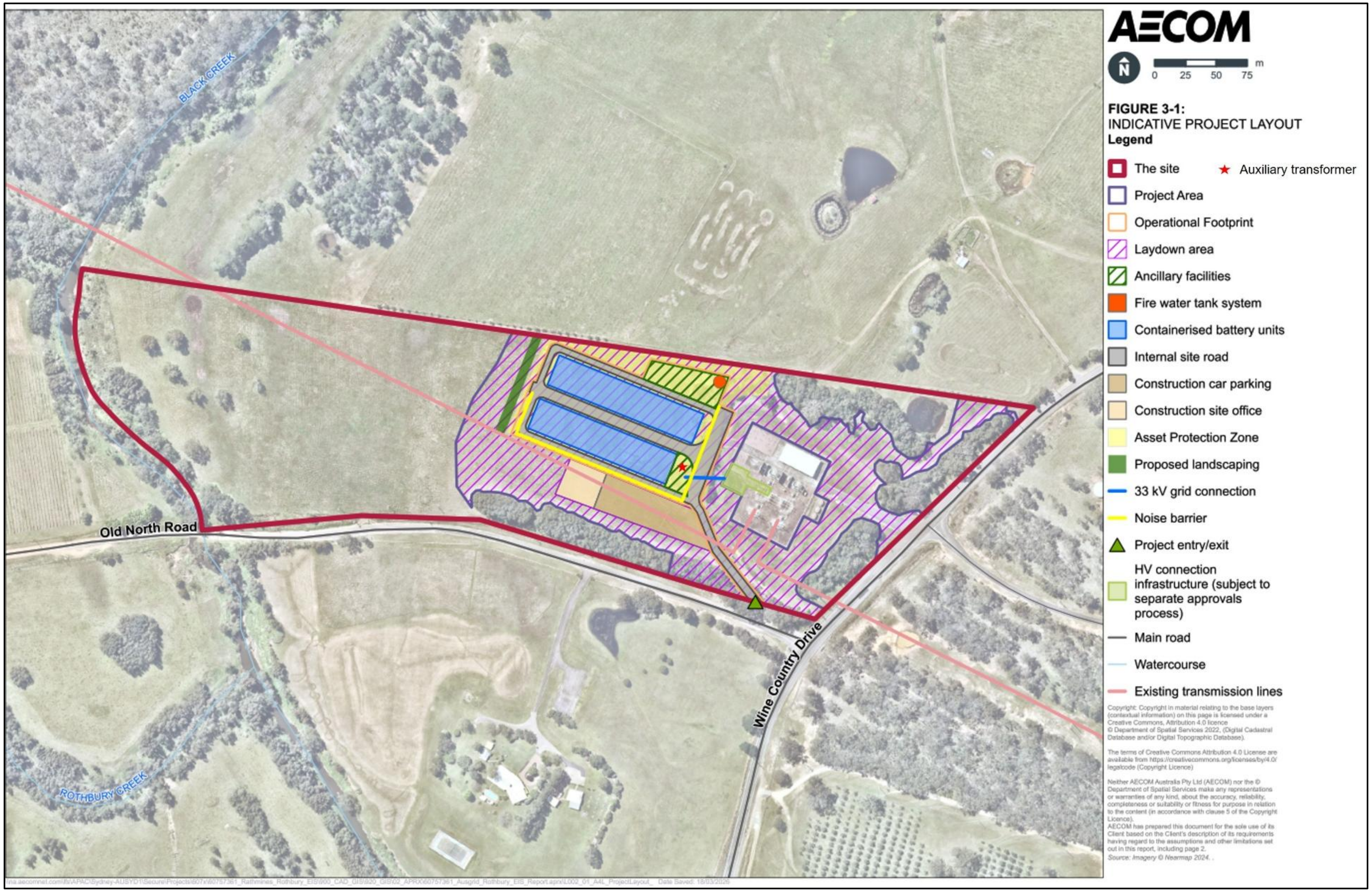


Figure 3.3: Preliminary site layout



3.3. Project key infrastructure

3.3.1. Battery Energy Storage System

A BESS is a type of energy storage system that utilises batteries to store and discharge energy in the form of electricity. The energy is released as a direct current (DC). A bi-directional inverter converts the electricity from/to alternating current (AC) for transmission to/from the grid.

The BESS would store excess energy during peak production periods to later transmit into the grid when required (e.g. peak demand periods) and would also provide stabilisation services to the National Electricity Market (NEM).

The BESS would have a power capacity of up to 135 MW over a 4-hour discharge period. The assessment made in this study is based on the use of generic, containerised LFP battery units. The battery units would be approximately 2.8 m tall and have a footprint of approximately 1.7 m by 9 m. To achieve the capacity at the point of connection the Project proposes 148 battery units. The rated name plate capacity for the BESS is 181 MW to account for losses at the point of connection inside the Rothbury Zone Substation under worst case network conditions.

Major components and expected features of the battery system are described in Table 3.2. Selection of the battery OEM and layout of the battery units and associated equipment within the BESS compound will be finalised during detailed design.

The following key points are noted as the basis for this study:

1. The battery units will be installed in accordance with the OEM's instructions provided for mitigation of fire propagation, including clearance requirements.
2. The specific BESS (make and model) will be tested to Underwriters' Laboratories (UL) 9540A *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems* to evaluate the thermal runaway and fire propagation characteristics, informing the required protection for its installation and operation. A UL 9540A test is considered successful if a fire does not propagate from one unit/cabinet to another during the test.
3. The designated area for BESS and associated infrastructure will be sufficient, considering onsite and off-site receptors.

Table 3.2: BESS components

Component	Description
Overview	The containerised battery system assumed in this assessment is a modular, fully integrated, AC-coupled industrial system which includes the battery modules, inverters, thermal management system, circuit breakers and other controls.

Component	Description
Enclosure	Each battery system enclosure is rated to IP66, typically mounted on a compacted gravel bed, screw piles or a concrete pad. The enclosure is a non-walk-in containerised design with dimensions measuring approximately (L) 8.8 m x (W) 1.7 m x (H) 2.8 m.
Battery modules	The battery system utilises a lithium iron phosphate chemistry technology. The rated energy for each unit will be approximately 3.9 MWh.
Battery Management System (BMS)	The battery system includes an electronic BMS system that monitors and manages the battery system electric and thermal states enabling it to operate within the safe operating region of the battery (e.g. protection against overcurrent, over-charge, over-discharge, overheating, over voltage). The BMS constantly monitors the battery cell, module, and unit level.
Thermal management system	The battery system is equipped with a sealed liquid cooling system. The coolant will likely be 50% ethylene glycol aqueous solution.
Fire and explosion protection system	Depending on the design, the battery system may be equipped with a fire control panel, built-in gas and fire detection, and fire suppression system, which includes: • Gas detectors (including hydrogen, carbon monoxide) • Smoke detector • Heat detector • Smoke exhaust ventilation system • Aerosol fire suppression system. The smoke exhaust ventilation system would meet the requirements of National Fire Protection Association (NFPA) 69 *Standard on Explosion Prevention Systems*. The system would receive signal from the gas detectors and opens the electric louver to exhaust the combustible gas in the battery compartment. The exhaust ventilation fan will not automatically turn off even if the concentration of the combustible gas falls within the set point threshold and can only be turned off by resetting the fire control panel. Upon confirmed fire detection from the either the smoke or heat detector, a fire alarm signal would occur, and the aerosol suppression system would be triggered automatically.
BESS Transformer	The battery system will be configured with a Factory Manual (FM) approved distribution transformer containing FR3 dielectric fluid.

3.3.2. Transformers

The Project has nominated FM Global approved transformers and transformer oil (FR3) as the MV transformer type for the assessment. The FR3 transformer oil has a high fire point (> 300°C) and when used in an FM approved transformer the requirements for separation distances to combustible surfaces is reduced to 0.9 m.

3.3.3. Supporting infrastructure

The Project will be supported by ancillary infrastructure including:

- Combined switch room and control room building.
- RMUs.

- Onsite workshop facility.
- One auxiliary transformer.
- Backup diesel generator.
- Onsite car parking.
- Internal access roads.
- Laydown areas.
- Stormwater management.
- Boundary security fencing.
- Noise barriers.
- Lighting.
- CCTV.

3.4. Operations

The Project will be nominally available 24 hours a day, seven days a week.

The Project will be primarily operated remotely with limited permanent staff on-site. Routine inspections and maintenance activities (preventative and corrective) will be undertaken by staff or contractors. Land management activities including vegetation, landscaping, road, and fence management will be undertaken on a regular basis.

3.5. Decommissioning

The Project is intended to have an operational life of up to 50 years. Any extension of this timeframe, through replacement or upgrade, would be subject to additional approvals at the time, if necessary. During decommissioning, BESS infrastructure would be removed and recycled where feasible, and the land rehabilitated per legislative requirements. The battery units would either be disposed of, repurposed, or recycled at a licensed disposal facility.

4. HAZARDS AND RISK ASSESSMENT METHDOLOGY

4.1. Overview

The hazards and risk assessment methodology and relationship between steps is shown in the study flowchart (Figure 4.1). This shows how the overall assessment addresses the five elements as required by the SEARS, being:

1. Undertake a preliminary risk screening.
2. Complete an assessment of Electric and Magnetic Field (EMF) hazards.
3. Consider separation distances between equipment to prevent fire propagation.
4. Consider hazards including fires, including spontaneous combustion in a hazard identification.
5. Undertake a PHA.

4.2. Preliminary risk screening

A preliminary risk screening was completed in accordance with SEPP (Resilience and Hazards), following the approach outlined in the Applying SEPP 33 guideline.

4.3. Preliminary Hazard Analysis

The PHA was completed following the methodology specified in HIPAP 6 *Hazard Analysis*, Ref [2].

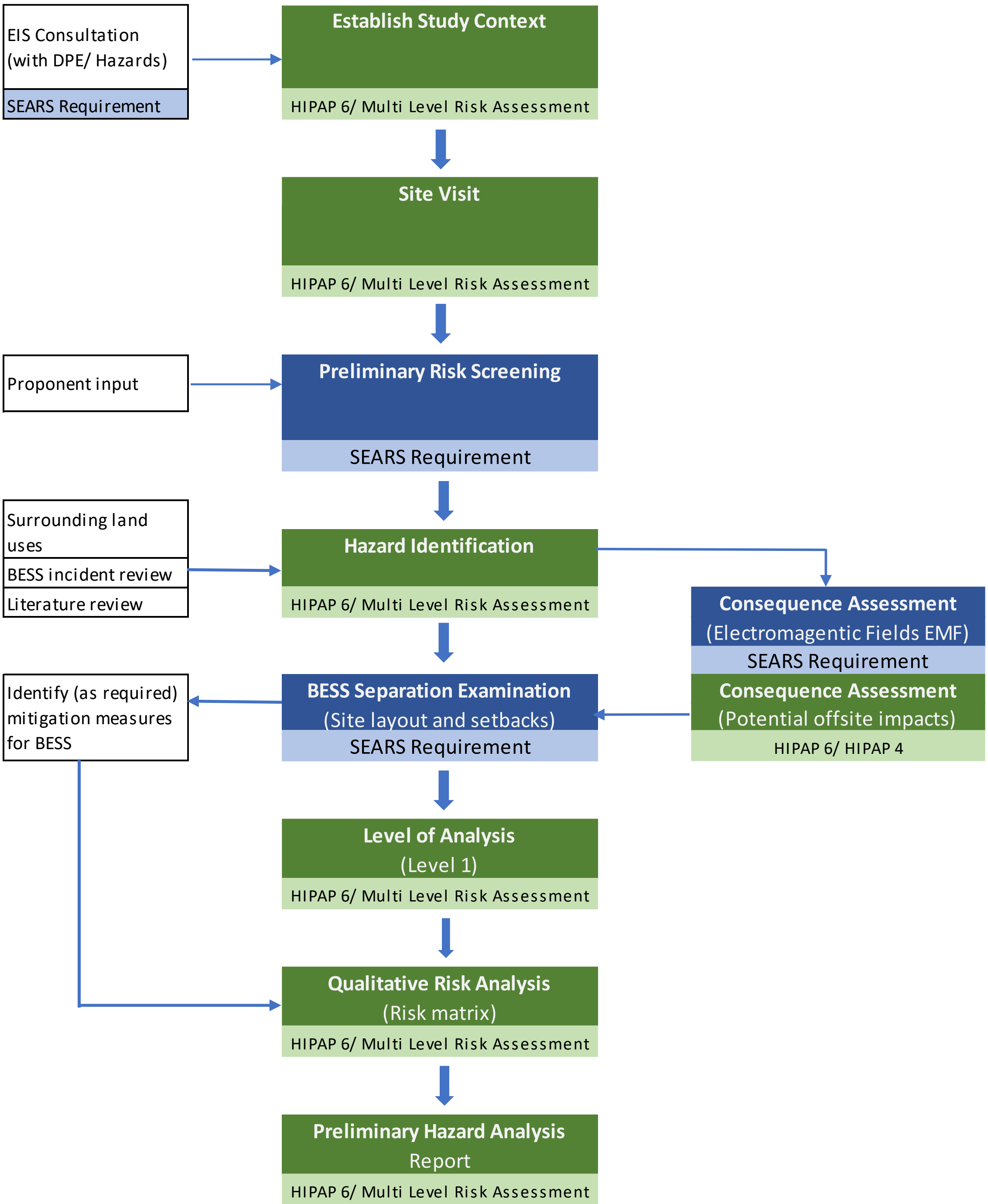
The HIPAP 6 methodology includes the following steps:

1. Establish the study context.
2. Identification of hazards resulting from the proposed Project and events with the potential for off-site impact *(Hazard Identification)*.
3. Analysis of the severity of the consequences for the identified events with potential off-site impact, e.g. fires and explosions *(Consequence Analysis)*.
4. Determination of the level of risk analysis required, and the risk assessment criteria.
5. Analysis of the risk of the identified events with off-site impact (*Risk Analysis*).
6. Assessment of the estimated risks from identified events against risk criteria to determine acceptability (*Risk Assessment).*

The PHA assessed the risks associated with proposed operation of the Project only.

The Hazard Identification (HAZID) included consideration of risks from all sources, including EMF and the potential for spontaneous combustion and fires with the potential for offsite impact.

Figure 4.1: PHA study flowchart – Rothbury BESS facility



4.4. Level of analysis

The MLRA guidelines, Ref [1], sets out three levels of risk analysis that may be appropriate for a land use safety planning assessment. These levels and a high-level summary of the justification required for each are shown in Table 4.1. The MLRA guidance document was consulted to determine the level of analysis required for this study.

Table 4.1: Level of analysis

Level	Analysis type	Appropriate/can be justified if
1	Qualitative	There are no potential events with significant off-site consequences and societal risk is negligible.
2	Partially quantitative	The frequency of occurrence of risk contributors having off-site consequences is low.
3	Quantitative	There are significant off-site risk contributors, and a Level 2 analysis is unable to demonstrate that the risk criteria will be met.

The outcomes of the *Hazard Identification* (Section 6) and *Consequence Analysis* (Section 8) were used to determine the level of analysis appropriate for the PHA.

4.5. Risk assessment criteria

The risk criteria used for assessment followed the guidance provided in HIPAP 4 *Risk Criteria for Land Use Safety Planning*, Ref [3], and are appropriate for determining the level of analysis and to complete the risk assessment.

4.6. ICNIRP considerations

The SEARs include a requirement to assess potential hazards and risks associated with exposure to EMF against the ICNIRP guidelines. This assessment considers the EMF exposures from the Project components (i.e. inverters, transformers, transmission lines, BESS) and compares it against the ICNIRP time varying electric and magnetic fields reference levels (general public and occupational). The results are used as an input to the BESS risk analysis.

5. PRELIMINARY RISK SCREENING

5.1. Overview

The objective of the preliminary risk screening was to determine whether the Project is considered as ‘potentially hazardous’ in the context of SEPP (Resilience and Hazards), Ref [5].

SEPP (Resilience and Hazards) defines potentially hazardous industry as follows:

“’Potentially hazardous industry’ means a development for the purposes of any industry which, if the development were to operate without employing any measures (including, for example, isolation from existing or likely future development on other land) to reduce or minimise its impact in the locality or on the existing or likely future development on other land, would pose a significant risk in relation to the locality:

(a) to human health, life or property, or

(b) to the biophysical environment,

and includes a hazardous industry and a hazardous storage establishment.”

Development proposals that are classified as ‘potentially hazardous industry’ must complete a PHA in accordance with HIPAP 6 *Guidelines for Hazard Analysis*, Ref [2], to determine the risk to people, property, and the environment. If the residual risk exceeds the acceptability criteria, the development is considered as a ‘hazardous industry’ and may not be permissible within NSW.

To determine whether a proposed development is potentially hazardous, the NSW DPHI *Applying SEPP 33* guideline[1], Ref [6], is used to guide a risk screening process. The risk screening process considers the type and quantity of hazardous materials to be stored on site, distance of the storage area to the nearest site boundary, specific types of industry and operations as well as the expected number of transport movements.

‘Hazardous materials’ are defined within *Applying SEPP 33* guideline as substances that fall within the classification of the Australian Dangerous Goods Code (ADGC), i.e. have a Dangerous Goods (DG) classification. Details of the DG classification are typically obtained from the materials’ Safety Data Sheet (SDS).

The *Applying SEPP 33* guideline is based on the 7th edition of ADGC, Ref [7], and refers to hazardous chemicals by their DG classification. Risk screening is undertaken by comparing the storage quantity and the number of road movements of the hazardous materials with the screening threshold specified in the guideline. The screening threshold presents the quantities below which it can be assumed that significant off-site risk is unlikely.

[1] SEPP No. 33 *Hazardous and Offensive Development* (SEPP 33) has been revoked and incorporated as Chapter 3 of SEPP (Resilience and Hazards) 2021. For the preliminary risk screening, the guidance document *Applying SEPP 33* still applies.

5.2. Risk screening

The Project was assessed based on a generic, containerised LFP battery. These batteries are typically classified as DG class 9 (miscellaneous). Battery coolant (ethylene glycol aqueous solution) is not classified as a DG, and if not stored with flammable or reactive materials, does not contribute to the screening threshold.

Transformer oil may be a combustible liquid and diesel for the backup generator is a combustible liquid. Combustible liquids do not have a screening threshold if they are segregated from flammable liquids.

Other materials considered as part of the SEPP risk screening include herbicide and pesticide. Herbicides and pesticides formulated for use are generally not classified as DG. They would also not be stored in significant quantities, as such they are excluded from the risk screening.

A summary of the expected hazardous materials to be stored and handled on site during the operational phase of the Project, transport movements, and the relevant SEPP screening threshold is presented in Table 5.1.

5.3. Other risk factors

Appendix 2 of the *Applying SEPP 33* guideline outlines other risk factors for consideration to identify hazards outside the scope of the risk screening method.

A review of these risk factors was completed, and it was noted that the Project would <u>not</u> involve:

- Storage or transport of incompatible materials (i.e. hazardous and non-hazardous). Hazardous materials will be stored in dedicated areas and storage protocols in accordance with standard and guidelines will be followed.
- Generation of hazardous waste.
- Possible generation of dusts within confined areas.
- Storage or processing operations involving high (or extremely low) temperature and/or pressures.
- Activities involving hazardous materials with potential to cause significant off-site impacts.
- Incompatible, reactive or unstable materials and process conditions that could lead to uncontrolled reaction or decomposition.

5.4. Industries that may fall within SEPP (Resilience and Hazards)

Appendix 3 of the *Applying SEPP 33* guideline provides a list of industries that may be potentially hazardous. It is noted that this list is illustrative rather than exhaustive. The current edition of the guideline does not include BESS facilities in the example industry listings that may fall within the SEPP (Resilience and Hazards) or be considered as potentially hazardous.

5.5. Risk screening assessment conclusion

The preliminary risk screening found that the Project is not ‘potentially hazardous’ and does not require a PHA under SEPP (Resilience and Hazards).

Regardless of the findings of the risk screening, the SEARs require a PHA covering hazards and risks associated with operation of the Project, which is presented below.

Table 5.1: Preliminary risk screening summary

Material	DG Class	Category	Storage threshold	Transport threshold		Project storage quantities and applicable SEPP screening	Exceed threshold?
				Movements	Quantities		
BESS battery (LFP)	9	Miscellaneous DGs	N/A	> 1000 (annual) > 60 (weekly)	No limit	No applicable SEPP screening threshold and excluded from risk screening. Transport movement threshold will not be exceeded. Movements are expected to occur during construction only and minimal post installation (e.g. battery replacement).	No
BESS coolant (50% ethylene glycol aqueous solution)	-	N/A	N/A	N/A	N/A	Not classified as DG. No applicable SEPP screening threshold and excluded from risk screening.	No
BESS MV and auxiliary transformer oil	C1	Combustible	N/A (unless stored with flammable liquids)	N/A	N/A	Transformers and associated oils will be segregated from flammable liquids.	No
Diesel	C1	Combustible				Diesel will be segregated form flammables.	No

6. HAZARD IDENTIFICATION

6.1. Overview

HAZID is a key step in the PHA process. The primary objective of the HAZID is to identify all reasonably foreseeable hazards and associated events that may arise due to the operation of the BESS through a systematic and structured approach.

The Applicant has not made a final decision on the BESS OEM. The HAZID is representative of a generic, containerised, LFP battery system and was completed using the following inputs:

1. Review of LFP battery system product specification sheets and product brochures, Ref [8, 9, 10, 11, 12].
2. Review of AS/NZS 5139:2019 *Electrical installations – Safety of battery systems for use with power conversion equipment,* Ref [13].
3. Literature research of past incidents involving similar BESS systems.
4. Previous risk assessments for similar BESS systems completed by Sherpa.
5. Review of satellite images to understand the potential interactions between the Project and surrounding land uses.
6. Consultation with the Applicant on separation distances for acceptance.
7. Site visit of the existing Rothbury Zone Substation and surrounds.

6.2. LFP battery hazards

Currently, LFP batteries are the dominant battery chemistry used in large scale BESS facilities. A typical LFP battery comprises:

- An anode (typically graphite) with a copper current collector.
- A cathode (lithium iron phosphate – $LiFePO_4$ or LFP) with an aluminium current collector.
- A porous separating layer between the anode and cathode (typically a polymer).
- An electrolyte comprised of a lithium salt (e.g. lithium hexafluorophosphate ($LiPF_6$)) dissolved in a solvent (e.g. ethylene carbonate and diethyl carbonate).

It is important to recognise that there is considerable research and ongoing development in LFP battery chemistry. This hazard identification is based upon available knowledge of the battery types in mid-2025.

Potential hazardous events associated with LFP batteries are:

- Thermal runaway potentially leading to thermal decomposition and potentially a battery unit fire.

- Toxic vapour generation (e.g. decomposition of $LiPF_6$) within the battery electrolyte due to the fire).
- Flammable gas accumulation due to electrolyte decomposition within a confined space (e.g. in an enclosed module) and a vented explosion.

6.2.1. Thermal runaway

Thermal runaway occurs when the internal temperature of a battery cell increases beyond its design range leading to exothermic decomposition reactions generating additional heat. If the additional heat is not dissipated, the cell temperature is further elevated, accelerating the process of decomposition and heat generation. This becomes a self-sustaining exothermic reaction and can lead to a fire.

The causes of thermal runaway involving LFP batteries may occur from a variety of failure modes including:

- Electrical abuse (e.g. overcharging/discharging).
- Thermal abuse (e.g. overtemperature).
- Mechanical abuse (e.g. external impact).
- Existing, latent defect (e.g. electrolyte leaks, faulty components).

Whilst the OEM will typically provide design measures to eliminate or reduce the potential of these failure mechanisms, the PHA has considered thermal runaway as a credible hazardous event due to reported BESS facility incidents (refer to Section 6.3).

6.2.2. Flammable and toxic vapour generation

$LiPF_6$ is widely used as a salt in the electrolytes for LFP chemistry. In the event of a LFP thermal runaway or battery fire involving the electrolyte, there is the potential to generate flammable (e.g. hydrogen, hydrocarbon gases) and toxic (e.g. hydrogen fluoride – HF, carbon monoxide – CO) gases. Experiments at a bench scale, Ref [14], have indicated that for certain LFP batteries, HF can be generated during thermal runaway (pre-ignition) and fire (post ignition).

The conditions under which flammable and toxic gas generation are considered in this PHA are shown in Table 6.1.

Table 6.1: Flammable and toxic gas generation conditions

Type of gas generated	Timing	Condition
Flammable	Pre-ignition	Decomposition of electrolyte at temperatures in the order of 200°C.
Toxic	Pre-ignition	Decomposition of electrolyte at temperatures in the order of 200°C.
	Post-ignition	Combustion of electrolyte with gases released in a high temperature (800-1000°C) plume.

6.3. Exposure to EMF

As a part of this PHA, the hazards and risks associated with exposure to EMF against the ICNIRP guidelines have been assessed. The details of this are presented in APPENDIX B.

Based on the detail in APPENDIX B, this study concludes that EMF created from the Project will not exceed the ICNIRP occupational exposure reference level.

As the strengths of EMF attenuate rapidly with distance, this study determined that the ICNIRP reference level for exposure to the general public will not be exceeded, and impact to the general public in surrounding land uses will be negligible.

For the risk assessment, consequence from exposure to EMF was assumed to result in no or minor injury ('Insignificant') in reference to the consequence impact rating shown in Table 10.2.

The identified contributors to the cumulative EMF in the vicinity of the Project are listed in Table 6.2. The cumulative exposure to EMF from the Project and other developments in the vicinity of the Project is considered negligible as the strength of EMF attenuates rapidly with distance. Thus, no off-site impact and no cumulative exceedance of EMF exposure limits is expected from the Project, and it is not carried forward for risk assessment or further assessment.

Table 6.2: EMF sources in Project area

No	Description
1	BESS (proposed)
2	Rothbury Zone Substation (existing)
3	Transmission lines (existing)

6.4. Review of incidents

There have been incidents involving large scale BESS facilities as reported in the public domain. Table 6.3 presents an incident summary (2019 to date) of selected events from the Australian Energy Council, Ref [15], and other recent incidents.

Table 6.3: Selected BESS fire events

Date	Location	Facility size	Description
April 2019	Arizona McMicken Facility, USA	2 MW/ 2 MWh	**Battery Fire** The investigation found that the following were contributing factors: • Internal defect within the LG Chemical batteries (Li-NMC) which initiated an "extensive cascading thermal runaway event" • Lack of thermal barriers between battery cells

Date	Location	Facility size	Description
			• Storage container design did not allow the vapour and gases produced during the incident to vent, leading to a build-up of flammable/explosive gases within the container • Inadequate emergency response plan which did not instruct personnel how to extinguish the fire or specify the entry procedure.
July 2021	Moorabool, Victoria Big BESS facility, Australia	300 MW/ 450 MWh	**Battery Fire** The Tesla Megapack batteries were of nickel manganese cobalt (NMC) type. Energy Safe Victoria investigation found that the probable root cause of the thermal escalation event was a leak in the internal coolant system of the Tesla Megapack 1.0 in combination with unmapped SCADA systems during the commissioning. The event started in one Megapack and escalated to another, and thermal radiation from this fire damaged two adjacent megapacks. Recommendations were made that Tesla has since adopted in operation of their batteries.
September 2021, February 2022, September 2022	Monterey County, California Moss Landing BESS facility, USA	400 MW/ 1,600 MWh	**Overheating (Sept 2021, Feb 2022)** Li-ion battery modules (Phase 1) were operating above their operational temperature limit. The investigation found overheating of the battery was not the cause of the incident. Rather, it was possibly due to a fan bearing causing smoke which triggered the water system. Due to faulty couplings, the water system improperly sprayed the battery racks which led to overheating of the batteries. A similar incident again occurred in February 2022. **Battery Fire (Sept 2022)** This incident resulted in highway closure due to possible hazardous gas releases during a fire incident. The root causes are not provided. Although there was an earlier incident in that period possibly caused by the overheating incident described above.
September 2023	Bouldercombe Battery Project, Queensland, Australia	50MW/ 100MWh	**Battery Fire** One of 40 Tesla Megapack 2 battery units (LFP type) caught fire without propagating to other units. The fire occurred at the final stages of commissioning phase. No injuries were reported.

Date	Location	Facility size	Description
April 2024	Neermoor, Germany	Unknown	**Battery Fire** A small container fire of a Li-ion battery module resulted in a flame jet and several explosions when firefighters opened the container door (unaware of the contents). Two firefighters were injured and a nearby highway was closed due to smoke. The container was cooled with water and moved with a crane to prevent propagation, with the fire declared extinguished after 10 hours. The cause of the initial fire has not been published as yet.
January 2025	Vistra Energy Moss Landing Power Plant, California, USA	300 MW	**Battery Fire** A fire spread across the 300 MW array of lithium-ion batteries at the Moss Landing power station, affecting most of the batteries. Over 1,000 residents were evacuated. No injuries were officially reported however residents have reported health issues including headaches, shortness of breath and other symptoms; and growing concerns for soil and air contamination. A lawsuit has since been filed against Vistra by a group of residents.
February 2025	Thurrock BESS, East Tilbury, Essex County, UK	300MW/ 600 MWh	**Battery Fire** Battery type not publicly available. A fault in one of the battery cells within a single containerised battery unit lead to a fire at the Thurrock BESS site, which was under construction. A water curtain was applied, and the fire was safely extinguished. The site’s safety measures, including reliable fire water supply, spacing between BESS units, and emergency response plan with the local fire service, were credited with the efficient resolution of the incident. An investigation is still underway to determine the cause of the fire.

6.5. Hazard Identification

Sherpa developed the HAZID in consultation with the Applicant and based upon site visit observations. The following factors were considered to identify the Project hazards:

- LFP battery chemistry.
- BESS component and type of equipment.
- Proposed operation and maintenance activities.
- BESS incident history.
- External factors (e.g. bushfire, unauthorised personal access, lightning storm).

Events with the potential to result in significant impacts to people (i.e. injury and/or fatality) were identified. The study excluded hazards related to Occupational Health & Safety (OH&S), e.g. slips, trips and falls as they do not have an offsite impact.

The types of hazards and associated events considered were informed from AS/NZS 5139, Ref [16]. The identified hazards and events present at/applicable to the Project are presented in Table 6.4 and in details in the HAZID table (APPENDIX A).

Table 6.4: Identified hazards and events by component

Hazard	Event	BESS Components			
		Battery System	BMS	Thermal management system (BESS coolant)	BESS MV transformer
Electrical	Exposure to voltage	✓	✓	-	✓
Release of energy	Arc flash	✓	✓	-	✓
Fire	Infrastructure fire, scrub fire[1]	✓	✓	✓	✓
Chemical	Release of hazardous materials	✓	-	✓	-
Explosive gas	Generation of explosive gas	✓	-	-	-
Reaction	Battery thermal runaway	✓	-	-	-
EMF	Exposure to EMF	✓	-	-	✓
External factors	Water ingress (rain and flood.[(a)]), unauthorised access/trespasser, lightning storm, high ambient temperature, bushfire.[(b)] Facility will be designed for the appropriate earthquake period.	✓	✓	✓	✓

Notes

(a) Design and operational considerations to minimize flood impact upon the BESS has been addressed in the Water Impact Assessment (Ref [4]) and summarized in the HAZID table (Appendix A).

(b) The requirement for a bushfire study is addressed separately in the EIS.

6.6. HAZID findings

The HAZID register is provided in APPENDIX A. A total of 17 hazardous events were identified, of which:

- Seven of the hazardous events were determined to involve a battery unit on fire with the potential for offsite effects.

- The remaining hazardous events were assessed as having no potential for offsite impact.

The following scenarios were carried forward to consequence assessment for further assessment to determine the potential impact to off-site receptors:

- A battery unit on fire.
- A transformer fire (MV, auxiliary, or High Voltage (HV)).

7. CONSEQUENCE ASSESSMENT

7.1. Overview

To inform the risk assessment, consequence analysis was undertaken for events identified in the HAZID as having the potential to result in offsite impact. The purpose of the consequence analysis was to determine if offsite injury or fatality was a credible outcome of the scenarios.

The scope of the consequence assessment is shown in Table 7.1.

- Fully developed battery unit fire.
- MV Transformer fire.

Table 7.1: Consequence assessment scenarios

BESS infrastructure	Scenario	Consequence	Analysis method
Battery unit	Single battery unit – thermal runaway (pre-ignition)	Toxic gas generated from decomposition of battery electrolyte	Qualitative (Section 7.2)
		Accumulation and ignition of flammable vapours inside a battery unit	
	Single battery unit – fully developed fire	Heat radiation	Quantitative (Section 7.4)
		Toxic products of combustion	
Transformer	Single transformer on fire	Heat radiation	Qualitative (Section 7.6)

The modelling input and assumptions are given in APPENDIX C with the key elements and findings summarised in this section.

In this study, a generic LFP chemistry was selected, and the assumed battery characteristics are summarised in APPENDIX C. When selecting the preferred OEM, the Applicant will ensure the battery characteristics meet the assumed characteristics otherwise an update to this PHA will be required.

7.2. Battery thermal runaway (pre-ignition)

In a thermal runaway event, decomposition of the battery electrolyte may result in generation of flammable and toxic gases. The conditions under which flammable and toxic gases may be generated are typically informed by testing in accordance with UL 9540A *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*, or an equivalent test standard (i.e. large-scale fire test).

At the time of this study, the UL 9540A test reports (cell, module and unit level) were not available and the composition[2] and properties of vented gas from battery thermal runaway are not known. Sherpa assumed that the battery system will meet the safety performance requirements of the UL 9540A unit-level test, which typically include the following observations:

- Module to module propagation was not observed.
- No flying debris or explosive discharge of gases observed during test.
- No sparks, electrical arcs, or other electrical events observed during test.
- No external flaming was observed during test.

The battery system is assumed to be designed with safety features to reduce the risk of thermal runaway propagation. These typical features are summarised in Table 7.2.

Table 7.2: Battery system typical safety features

System	Details
BMS	The BMS will monitor abnormal conditions (e.g. voltage, current, temperature) that will be a precursor to thermal runaway
Fire and explosion protection system	Fire alarm panel, heat and smoke detectors with aerosol suppression system, hydrogen and carbon monoxide gas detectors with exhaust ventilation system.
Uninterruptible Power Supply (UPS)	Each container is equipped with two UPS; one for the BMS and another for the fire and explosion protection system.
Emergency Stop/Automatic Shut-off	Local and remote

7.3. Criteria

7.3.1. Heat radiation

The HIPAP 4 criteria for heat radiation were used for the study, as outlined in Table 7.3.

Table 7.3: Heat radiation criteria

Criteria	Level (kW/m^2)	Commentary
Injury	4.7	Will cause injury after 30 seconds
Fatality	12.6	Significant chance of fatality for extended exposure. High chance of injury. Thin steel may reach thermal stress levels that cause it to fail.
Escalation	23	Steel will reach temperatures which can cause failure

[2] The UL 9540A unit level test report would include analysis of the composition of vented gas from battery thermal runaway.

7.3.2. Toxic gas dispersion

The Acute-Exposure Guideline Level (AEGL) concentration levels (60-minute exposure) for HF are presented in Table 7.4. These concentrations were used to inform harm levels following exposure (irritation, injury and fatality).

Table 7.4: AEGL levels for HF (60-minute)

AEGL level	Health effects	Concentration (ppm)
AEGL-1	Irritation threshold	1
AEGL-2	Injury threshold	24
AEGL-3	Life-threatening health effects threshold (fatality)	44

7.4. Battery unit on fire – Heat radiation model

7.4.1. Background

A battery unit on fire is modelled as a planar fire emitting heat with heat flux calculated for a receptor.

The key inputs are:

1. Area of the fire
2. Surface temperature of the fire
3. Distance to receptor
4. View factor (area of flame visible to the receptor).

7.4.2. Model validation

The general approach of representing a fire as a planar fire and calculating heat flux at a point based on surface temperature and a view factor is well established, and the Sherpa model has been validated against other industry models.

As the basis of the model is well established and the results are comparable to other OEM test results and model, the Sherpa model is considered appropriate for land use planning.

7.4.3. Model applicability

The Sherpa model is applicable for assessing heat radiation at the site boundary and heat radiation at equipment other than adjacent battery units.

Propagation of a fire between battery units is accounted for in OEM testing and takes into consideration both the sources of the fire and the effects of heat radiation leading to thermal runaway and fire propagation to an adjacent battery unit.

Heat radiation levels from the battery fire test are not reported by the OEMs.

7.4.4. Scenario

Sherpa modelled a fully developed battery unit fire. The method of initiation of the fire (forcing a set of modules into thermal runaway) may represent all possible battery unit fires (e.g. failure of safety system forcing all modules in thermal runaway).

A fire was modelled for areas representing:

- side (approximately 8.8 m wide x 2.8 m high)
- end (approximately 1.7 m wide x 2.8 m high).

7.4.5. Results

The modelling results for the Project heat radiation impacts are presented in Table 7.5.

The modelling found:

- fatality levels (12.6 kW/m^2) ranging from 4 m (end) to 9 m (side)
- injury levels (4.7 kW/m^2) ranging from 7 m (end) to 15 m (side).

The nearest site boundary is the northern boundary, which is approximately 15 m from the end of a battery unit. Based on the modelling results:

- fatal heat radiation effects are contained onsite for all battery units
- injury level heat radiation effects are contained onsite for all battery units
- fatality and injury impacts do not reach offsite receptors listed in Table 3.1.

The injury risk criteria for heat radiation are expressed as follows in HIPAP 4:

- Incident heat flux radiation at residential and sensitive use areas should not exceed 4.7 kW/m^2 at a frequency greater than 50 chances in a million per year.

Heat flux does not exceed 4.7 kW/m^2 at the site boundary, hence HIPAP 4 risk criteria are met.

Table 7.5: Battery unit on fire – heat radiation impact

Battery system aspect	Surface (L x H, m)	Distance (m) at receptor height (1.5 m) to heat radiation levels		
		4.7 kW/m^2 (injury)	12.6 kW/m^2 (fatality)	23 kW/m^2 (structural failure)
Side	8.81 x 2.79	15	9	6
End	1.65 x 2.79	7	4	3

7.4.6. Off-site and sensitive receptors impact

From the site visit, there are no populated or sensitive areas on the site boundary.

7.5. Battery unit on fire – Toxic products of combustion

7.5.1. Background

Toxic gas generation can form from decomposition of battery electrolyte due to fire. For LFP batteries, there is a potential for HF to be formed following electrolyte decomposition from a battery fire event. In this study, dispersion of HF was modelled to determine the impact to receptors. The following Pasquill weather stability and wind conditions were used for the dispersion modelling:

1. Typical day condition: Neutral (Class D) and wind speed of 5 m/s (D5).
2. Typical night condition: Very stable (Class F) and wind speed of 2 m/s (F2).

7.5.2. Results

The modelling results for toxic products of combustion (HF) dispersion impacts are presented in Table 7.6.

The modelling found:

- The distances to AEGL thresholds for injury (AEGL-2) and irritation (AEGL-1) at D5 condition are 10 m and 23 m, respectively.
- For the plume rise from fire model, further downwind distance was observed at the D5 condition compared to F2 condition. As a conservative approach, the distance to the irritation level (AEGL-1) at D5 condition was used to determine potential for off-site impact, i.e. 23 m.

The northern boundary is the nearest site boundary, which is approximately 15 m from the end of a battery unit. Based on the modelling results:

- Fatal and injury toxic exposure effects are contained onsite for all battery units.
- Fatality and injury impacts do not reach offsite receptors listed in Table 3.1.
- irritation toxic exposure effects are contained onsite for most battery units; the irritation distance (23 m) extends beyond the northern boundary by approximately 8 m.

The irritation risk criteria for toxic exposure are expressed as follows in HIPAP 4:

- Toxic concentrations in residential and sensitive use areas should not cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community over a maximum frequency of 50 in a million per year.

The land at the northern boundary is zoned as ‘Rural’ and irritation effects do not extend to any residential or sensitive receptors within this area, hence HIPAP 4 risk criteria are met.

Table 7.6: Battery unit on fire – toxic dispersion impact (HF)

Battery system	Capacity per unit (MWh)	HF generation rate (kg/s)	Wind weather stability	Distance (m) at receptor height (1.5 m) to AEGL levels		
				AEGL-1 (irritation)	AEGL-2 (injury)	AEGL-3 (fatality)
Concept design LFP battery system	3.9	0.22	D5	23	10	8
			F2	3	2	2

7.6. Transformer fire

Excessive voltage, overloading and degraded insulating material may result in internal arcing with sufficient energy to rupture the transformer oil tank and ignite the released oil resulting in a fire. The risk of harm from a transformer fire is managed by compliance with the relevant standards and codes. This includes requirements to provide, for example, bunding, fire wall and/or clearances to other transformers/equipment and buildings, as per AS 2067:2016 *Substations and high voltage installations exceeding 1 kV*, Ref [17].

In this study, a transformer fire was not quantitatively modelled. Instead, a review was completed to ensure the transformers' clearances meet the AS 2067 specified clearances. This is to ensure that the escalation risk of a transformer fault/fire is minimised.

A review of the clearances required was conducted for the following:

- <u>BESS transformers</u>: The BESS MV transformers will be FM approved, containing FR3 oil.
- <u>Auxiliary transformer</u>: Auxiliary transformer will be an oil insulated transformer, containing mineral oil.
- <u>Substation transformers</u>: HV transformers located at the Rothbury Zone Substation.

The findings are presented in Table 7.7.

The Applicant has not finalised the OEM but will ensure the final layout meets the requirements of codes, standards and OEM recommendations to prevent fire propagation. The transformers will meet the AS 2067 clearance specifications to ensure the effects of a transformer fire are localised (i.e. off-site impact is not expected).

Table 7.7: Clearances – outdoor transformers

Transformer	Transformer type	Liquid volume (L)	AS 2067 horizontal clearances to…		Remarks	AS 2067 clearances met?
			Other transformers, equipment or non-combustible surfaces	Buildings and combustible surfaces		
BESS MV transformers	FM type	6035	0.9	0.9	The Applicant confirmed that the final layout will meet the required OEM and AS 2067 distances.	To be verified once OEM selected
Auxiliary transformer	Oil insulated transformer[(a)]	≤ 1000	1	6	The distance of the auxiliary transformer to: • Nearest battery unit: approx. 3 m • Nearest site building: approx. 3 m • Nearest site boundary: > 80 m • Noise barrier: approx. 9 m	No
Substation HV transformers	Oil insulated transformer[(a)]	43,000	10	20	The separation distances from the substation area boundary to: • Nearest battery unit: ≥ 35 m • Nearest site boundary: > 40 m	Yes

Notes:
(a) Mineral oil or synthetic insulating liquid with fire point less than or equal to 300°C, referred to as combustible liquids according to AS 1940 (Table 6.1, Note 1), Ref [17].

8. SEPARATION DISTANCES

8.1. Overview

This section addresses the requirement for the PHA to consider all recent standards and codes and verify separation distances to onsite and offsite receptors to prevent fire propagation.

OEM separation distances are based upon standardised tests (e.g. UL 9540A unit level test) to prevent fire propagation between battery units, and FM approval for transformer type.

The Applicant has not finalised the battery and transformer OEMs but will ensure that the OEM separation distances are met for:

- Battery enclosure to battery enclosure.
- Battery enclosure to combustible and non-combustible surfaces.
- Transformer to other equipment or non-combustible surfaces, and to buildings and combustible surfaces.

8.2. Layout assessment – onsite receptors

The Applicant confirmed the final site layout will follow the OEM installation manual and the transformer FM approvals for separation distances:

- Between the battery units. Sherpa has assumed that the OEM specified clearances between units have considered the requirements of NFPA 855 and/or UL 9540A test result.
- From MV transformers the FM approved distances will be used to combustible and non-combustible surfaces.

Separation distances in AS 2067 are presented in the context of transformer fires being the source of the fire and escalation being to combustible and non-combustible surfaces.

The potential for an external fire to propagate to a battery unit is based on internal heat accumulation leading to thermal runaway. As this mechanism is not a function of the integrity of the battery enclosure the AS 2067 separation distances are not directly applicable for transformer to battery unit fire propagation.

A battery fire involves off gases and lithium oxides; these do not have the same fire characteristics as a transformer oil fire. Hence, is not appropriate to use AS 2067 to assess battery to transformer separation.

For this PHA it is conservatively assumed that a transformer fire could escalate to an adjacent battery unit and vice-vera. Consequence modelling has demonstrated the battery fire meets the HIPAP land use planning consequence criteria.

AS 2067 requirements for the auxiliary transformer may not be met for distances to combustible surfaces, as details of fire resistance of building surfaces are not yet finalised. The Applicant will need to consider where the auxiliary transformer will be when the layout is finalised or consider a fire-resistant barrier or fire resistance for the building as required.

8.3. Separation distance review findings

The review of BESS separation distances (for onsite and offsite) found that:

- Onsite:
  - The Applicant confirmed the final BESS layout (battery and transformer) will meet the recommended clearances specified by the OEM.
  - The onsite warehouse building, storing ignitable liquids, is approx. 12 m from the nearest battery unit.
  - The office and the combined switch room and control room building are approximately 9 m from the nearest battery unit. This is more than the estimated fatality distance calculated for the heat radiating from the side or end of a battery unit on fire but may result in injury. This distance also exceeds the calculated distance for fatality due to toxic exposure but may result in injury or irritation to onsite personnel.
  - The Rothbury Zone Substation boundary is approximately 35 m to the nearest battery unit. The escalation risk of a HV transformer fault/fire to the BESS is minimised.
- Offsite:
  - The distance between a battery unit and the nearest site boundary is approximately 15 m for the units at the north of the site. This is more than the estimated fatality distance from the battery unit fire (9 m), as well as the estimated injury distance (15 m). The offsite impact due to toxic combustion products dispersion is mostly contained on site, with the risk of irritation (23 m) extending approximately 8 m beyond the northern boundary. The land north of the boundary is zoned as ‘Rural’ and irritation effects do not extend to residential or sensitive uses within this area.
  - The distance between the Project Area boundary and the nearest residential receptor (Quambatook house) is approx. 185 m. This is more than the estimated fatality or injury distance for radiation effects from a battery unit fire and the estimated irritation distance from the toxic exposure. Fatal and injury impacts do not reach offsite receptors listed in Table 3.1.

9. LEVEL OF ANALYSIS DETERMINATION

9.1. Level of analysis

The HAZID and consequence analysis found there are no potential events with significant off-site consequences and societal risk is negligible.

Based on the above findings and the MLRA guideline, Ref [1], the appropriate level (Table 4.1) of analysis for this PHA is a qualitative approach (i.e. level 1 approach). The risk analysis is presented in Section 10.

9.2. Qualitative risk criteria

HIPAP 4, recommends a set of qualitative criteria/principles be adopted concerning the land use safety acceptability of a development.

The risk assessment against HIPAP 4 criteria is provided in Section 10.

10. RISK ANALYSIS AND ASSESSMENT

10.1. Risk analysis

10.1.1. Risk matrix and acceptance criteria

For this study, acceptance criteria used to assess the risk for off-site populations are:

- Extreme – Unacceptable; immediate action is required
- High – Unsatisfactory; an action plan is required which includes steps for timely risk prevention or mitigation
- Medium/Low – Tolerable; implement additional controls if reasonably practicable
- Very Low – Acceptable; no specific action is required.

The risk matrix (Table 10.1) used for this study is reproduced from AS/NZS 5139 *Electrical installations – Safety of battery systems for use with power conversion equipment*, Ref [18].

Table 10.1: Risk matrix

Consequence	**Likelihood**				
	Rare	**Unlikely**	**Possible**	**Likely**	**Almost Certain**
Catastrophic	Medium	High	High	Extreme	Extreme
Major	Medium	Medium	High	High	Extreme
Moderate	Low	Medium	Medium	High	High
Minor	Very low	Low	Medium	Medium	Medium
Insignificant	Very low	Very low	Low	Medium	Medium

10.1.2. Severity rating

For each event, the severity rating was assigned based on the consequence description identified in the HAZID register and the consequence analysis findings using the category scale and guidance shown in Table 10.2 (adapted from AS/NZS 5139).

Table 10.2: Consequence rating – off-site

Consequence rating	Rating definition
Catastrophic	Fatality (single or multiple).
Major	Non-recoverable occupational illness or permanent injury. Injury or illness requiring admission to hospital.
Moderate	Injury or illness requiring medical treatment by a doctor. Dangerous/reportable electrical incident.
Minor	Injury requiring first aid. Circumstances that lead to a near miss.
Insignificant	No or minor injury.

10.1.3. Likelihood rating

The likelihood of an event was estimated using the category scale shown in Table 10.3, which was adapted from AS 5139.

The likelihood ratings were assigned based on knowledge of historical incidents in the BESS industry (Section 6) and in consultation with the Applicant.

Table 10.3: Likelihood rating

Likelihood rating	Rating definition
Almost certain	Expected to occur whenever the system is accessed or operated.
Likely	Expected to occur when the system is accessed or operated under typical circumstances.
Possible	Expected to occur in unusual instances when the system is accessed or operated.
Unlikely	Expected to occur in unusual instances for non-standard access or non-standard operation.
Rare	Highly unlikely to occur in any instance related to coming into contact with the system or associated systems.

10.2. Risk analysis findings

Based on the consequence analysis two scenarios were carried forward to risk assessment. The qualitative risk assessment is shown in Table 10.4.

Table 10.4: Rothbury BESS risk assessment

Incident location	Risk analysis (off-site/public impact) – concept layout			Recommendations
	Severity	Likelihood	Risk	
BESS fire	Moderate (Medical treatment for burn)	Rare (area not occupied and escape possible)	Low	None
MV transformer fire	Moderate (Medical treatment for burn)	Rare (area not occupied and escape possible, FM approved transformer with low combustible oil)	Low	None

10.3. Risk assessment

10.3.1. Assessment against AS/NZS 5139 risk criteria

Using the risk matrix from AS/NZS 5139, the identified hazardous events were qualitatively risk profiled, and all found to be ‘Low’ risk.

10.4. Assessment against HIPAP 4 criteria

Assessment against the HIPAP 4 qualitative land use planning risk criteria is provided in Table 10.5.

Table 10.5: Assessment against HIPAP 4 qualitative risk criteria

HIPAP 4 qualitative criteria	Remarks	Complies?
All 'avoidable' risks should be avoided. This necessitates the investigation of alternative locations and alternative technologies, wherever applicable, to ensure that risks are not introduced in an area where feasible alternatives are possible and justified.	The PHA has identified hazardous events and assessed the risks associated with Project operations. The Project is situated in a rural area and the BESS facility itself will be in a secure fenced area. There are large separation distances to sensitive receptors (i.e. residential) to avoid off-site risks. It is not possible to eliminate batteries from a BESS development. The existing Rothbury Zone Substation is also necessary to connect the BESS to the electricity grid. Selection of the battery technology is a balance of cost and availability, with the most used versions being lithium-ion due to the energy storing capacity of this type of battery. The Applicant is proposing to use a LFP chemistry which is considered less flammable than other lithium-ion battery chemistries.	Yes; fatality effects are contained onsite and there are no residential or sensitive areas bordering the site boundary.
The risk from a major hazard should be reduced wherever practicable, irrespective of the numerical value of the cumulative risk level from the whole installation. In all cases, if the consequences (effects) of an identified hazardous incident are significant to people and the environment, then all feasible measures (including alternative locations) should be adopted so that the likelihood of such an incident occurring is made very low. This necessitates the identification of all contributors to the resultant risk and the consequences of each potentially hazardous incident. The assessment process should address the adequacy and relevancy of safeguards (both technical and locational) as they relate to each risk contributor.	Based on the separation distance to the site boundary and sensitive receptors, consequences from the identified hazardous events are not expected to have significant off-site impacts. Irritation toxic exposure effects may extend approximately 8 m beyond the northern boundary. The land at the northern boundary is zoned as 'Rural' and irritation effects do not extend to any residential or sensitive use areas within this area, hence HIPAP 4 risk criteria are met.	Yes.

HIPAP 4 qualitative criteria	Remarks	Complies?
The consequences (effects) of the more likely hazardous events (i.e. those of high probability of occurrence) should, wherever possible, be contained within the boundaries of the installation.	Events with high probability of occurrence are expected to be contained within the site boundary. All battery units will be located such a way that a fire will not escalate between units as per OEM specifications. All battery units are ≥ 15 m from the boundary, meaning that a potential battery fire is expected to have minimal impact off site.	Yes. The Applicant confirmed the final site layout will follow the OEM installation manual and the transformer FM approvals for separation distances.
Where there is an existing high risk from a hazardous installation, additional hazardous developments should not be allowed if they add significantly to that existing risk.	The Sunshine Estate BESS (SSD-92914712) is proposed to be installed north of the Project. The PHA for the Sunshine Estate BESS was not publicly available at the time of the study. The development was not assessed further within this study per the Applicant's request. It is assumed the development will be subject to planning controls that require consequences and risks to be managed to acceptable levels.	Yes.

11. CONCLUSION

11.1. Preliminary risk screening

To address the SEARs, a preliminary risk screening was completed in accordance with the applicable SEPP 33 guideline to determine whether the Project is considered as 'potentially hazardous' in the context of SEPP (Resilience and Hazards).

The preliminary risk screening found that:

- The storage and transport of hazardous materials for the Project will not exceed the relevant risk screening threshold.
- No other risk factors have been identified that could result in significant off-site impacts.

The Project is not considered 'potentially hazardous' in the context of the Resilience and Hazards SEPP and does not require a PHA.

11.2. Preliminary hazard analysis

Notwithstanding the outcome of the preliminary risk screening, the SEARs require (1) a PHA, and (2) an assessment of hazards and risks for the Project to be undertaken. To address these requirements, a PHA was completed to identify the hazards and assess the risks associated with the proposed operations of the Project to determine risk acceptability from a land use safety planning perspective.

The PHA was completed following the methodology specified in HIPAP 6 *Hazard Analysis* and the Multi-Level Risk Assessment guideline for assessment against the HIPAP 4 criteria. A level 1 PHA (qualitative) was completed.

11.3. Outcomes

In conclusion, the hazard related SEARs are addressed in this document with the following conclusions:

- The Project is not potentially hazardous in the context of SEPP (Resilience and Hazards).
- The HAZID and consequence analysis found there are no identified events with significant off-site consequences and societal risk is negligible. Based on the MLRA guideline, Ref [1], the appropriate level of analysis is level 1 (qualitative).
- The consequence analysis found a transformer or battery fire will not impact upon identified receptors including residential receptors.
- There is a residual risk of irritation due to dispersion of toxic products of combustion offsite, extending approximately 8 m beyond the northern boundary. The land at the northern boundary is zoned 'Rural', and irritation effects do not extend to any

residential or sensitive receptors within this area, hence HIPAP 4 risk criteria are met.

- A PHA, including a review of separation distances and health effects has been completed and the level 1 assessment concludes that the Project meets the HIPAP 4 risk criteria and should not be precluded on the basis of land use safety.
- The Applicant will ensure the final layout meets the requirements of codes, standards, and OEM recommendations to prevent fire propagation and that the proposed BESS capacity will fit within the designated Project Area.

11.4. Recommendations

There are two recommendations in the PHA:

- Review the BESS OEM clearances and installation requirements, and transformer type and approval for separation distances once the OEM, make, and model are selected.
- Consider the location of the auxiliary transformer as the layout is finalised to ensure compliance with AS 2067 and consider a fire wall if required.

APPENDIX A. HAZARD IDENTIFICATION

This appendix provides the HAZID table. It covers potential hazard scenarios arising from BESS operations.

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
1	Electrical	Battery modules BMS RMUs Transformers	Exposure to voltage	Short circuit/electrical connection failure • Faulty equipment • Incorrect installation • Incorrect maintenance • Human error during maintenance • Safety device/circuit compromised • Battery casing/enclosure damage Earth potential rise (exposure to step and touch potentials) • Electrical faults	• Electrocution • Injury and/or fatality to onsite employees • Injury and/or fatality to member of public due to touch and step potential (e.g. transferred through fences). Effects are expected to have only on-site impact.	• DC circuit breakers • Surge Protective Devices (SPD) • Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS/NZS 5139) and guidelines to minimise touch and step potential • Decisive Voltage Classification (DVC) followed, and equipment marked accordingly • Warning signs (electrical hazards, arc flash) • Engagement of certified electrical contractors • Installation, operations and maintenance will be undertaken by trained personnel in accordance with relevant procedures • Independent owner's engineers' endorsement • Site induction/substation training (i.e. high voltage areas) • Electrical switch-in & switch-out protocol • Battery BMS fault detection and safety shut off • Earthing study (mitigate touch and step potentials) • Earthing as per manufacturer and standards requirements • Perimeter security fence with signage (warning of electrical hazard) • Site Emergency Response Plan • Use of appropriate Personal Protective Equipment (PPE)	-	No
2	Energy	Battery modules BMS RMUs Transformers	Arc flash	• Incorrect procedure (i.e. installation/ maintenance) • Faulty equipment (e.g. corrosion on conductors) • Faulty design • Human error during maintenance • Insufficient isolation/insulation to applied voltage • Mechanical damage • Vibration	• Arc blasts and resulting heat, may result in fires and pressure waves • Burns • Exposure to intense light and noise • Injury and/or fatality to onsite employees Localised effects, the effects are expected to have only on-site impact.	• Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS/NZS 5139) and guidelines • Warning signs (arc flash boundary) • Engagement of certified electrical contractors • Installation, operations and maintenance will be undertaken by trained personnel in accordance with relevant procedures • Independent owner's engineers' endorsement • Site induction and training (i.e. high voltage areas) • Maintenance procedure (e.g. de-energize equipment) • Preventative maintenance (insulation) • Electrical switch-in & switch-out protocol • Site Emergency Response Plan • Use of appropriate PPE for flash hazard within the arc flash boundary. Conductive items not worn while working on or near energised or live conductive parts (e.g. rings, jewellery)	-	No

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
3	Fire	Battery modules PCS (inverters, transformers)	Battery unit fire	• Faulty equipment • Electrical fault • Mechanical damage or failure of battery case (e.g. overload, insulation breakdown, connection failures) • Battery thermal runaway (e.g. short circuit, overheating, overcharge) • External fire (e.g. Substation fire, fire at existing facility, neighbouring sites) • Bushfire • Flooding exceeding the Probable Maximum Flood (PMF) event (see ID 12).	• Fire radiation impact to personnel or possibly off-site • Release of toxic or/and explosive combustible products • Escalation to the entire BESS	• Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS/NZS 5139) and guidelines • Independent owner's engineers' endorsement • Installation, operations and maintenance by trained personnel in accordance with relevant procedures • To minimise fire escalation between the BESS sub-units and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the battery OEM and/or applicable standards • Preventative maintenance (e.g. insulation, replacement of faulty equipment) • BESS BMS temperature monitoring, fault detection and shut-off function • Battery fire and explosion protection system (battery system specific features) • Activation of emergency shutdown • Fire Management Plan (e.g. establishing defendable fire-fighting boundary) • Site Emergency Response Plan • External firefighting protocol (Fire & Rescue New South Wales [FRNSW] & Rural Fire Service [RFS])	-	Yes (radiation for battery unit)
4	Fire	Transformers (MV or auxiliary)	Transformer fire	• Faulty equipment • Transformer oil leak • Arc flash • Vandalism • External fire (e.g. battery unit on fire, switchyard fire) • Bushfire (e.g. encroachment of off-site bushfire, escalated event due to fire from other project infrastructure)	• Fire radiation impact to personnel or possibly off-site • Release of toxic or/and explosive combustible products • Escalation to the battery units	• Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS 2067) and guidelines • Equipment will be procured from reputable supplier • Independent owner's engineers' endorsement • All relevant requirements for connection will be met • Installation, operations and maintenance by trained personnel in accordance with relevant procedures • Clearance requirement for transformers as per AS 2067 • To minimise fire escalation between the battery units and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the OEM and/or applicable standards • Preventative maintenance (e.g. insulation, replacement of faulty equipment) • Electrical switch-in & switch-out protocol • Transformer fault detection and shut-off function • Battery fire and explosion protection system (battery system specific features, refer to Table 3.2. • Activation of emergency shutdown • Emergency Response Plan • Inclusion of Asset Protection Zone (APZ) buffer to minimise bushfire encroachment • External firefighting protocol (FRNSW & RFS)	The PHA will be used to provide recommendations for finalising separation distances in the BESS facility layout for the LFP battery and on-site infrastructure.	Yes (qualitative only)

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
5	Fire	Ausgrid Rothbury Zone substation	Substation fire	• Faulty equipment • HV transformer oil leak • Arc flash • Vandalism • External fire (e.g. fire escalation from adjacent BESS, fire at existing facility, neighbouring sites) • Bushfire (e.g. encroachment of off-site bushfire, escalated event due to fire from other project infrastructure)	• Fire radiation impact to personnel or possibly off-site • Release of toxic or/and explosive combustible products • Escalation to the battery units • As the BESS and MV transformers will be situated in a secured area, the effects are not expected to have an off-site impact.	• As for ID 4	-	Yes (as per ID 4 for HV transformer)
6	Fire	BESS Switchroom	Bushfire	• Encroachment of off-site bushfire • Escalated event due to fire from other Project infrastructure	• Escalation to adjacent infrastructure • Injury and/or fatality to onsite employees	• Bushfire risk assessment • Vegetation management/ clearance around BESS • Fire Management Plan • Defendable boundary for firefighting will be established • Site Emergency Response Plan • External firefighting protocol (FRNSW & RFS) • Inclusion of APZ buffer to minimise bushfire encroachment	-	No
7	Reaction	Battery modules	Thermal runaway in battery	<u>External impact</u> • Scrub fire • External fire on site (e.g. Main Substation) • Fire at neighbouring sites <u>Electrical failure</u> • Short circuit • Excessive current/voltage • Imbalance charge across cells <u>Mechanical failure</u> • Internal cell defect • Damage (crush/ penetration/puncture) • Coolant leak <u>Systems failure</u> • BMS failure • Thermal management system failure	• Fire and/or explosion in battery enclosure • Release of toxic or/and explosive combustible products • Escalation to the entire BESS • Impact to personnel on-site or possibly off-site	• Equipment and systems will be designed and tested to comply with the relevant international and Australian standards (e.g. AS/NZS 5139) and guidelines • Fire detection, protection, mitigation measures (e.g. deflagration panel) as per OEM design • Warning signs • Independent owner's engineers' endorsement • Installation, operations and maintenance will be undertaken by trained personnel in accordance with relevant procedures • BESS BMS temperature monitoring, fault detection and shut-off function • Cell chemistry selection • Activation of emergency shutdown • Site Emergency Response Plan • Fire protection for buildings within the BESS facility • To minimise fire escalation between the BESS sub-units and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the battery OEM and/or applicable standards • Ventilation requirements as per manufacturer's instruction Refer to ID 1 for proposed electrical failure controls. Refer to ID 3 for additional controls.	-	Yes (considered as part of a battery unit fire in ID 3)

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
8	Chemical	Battery modules Thermal management system	Release of electrolyte (liquid/vented gas) from the battery cell	Mechanical failure/damage • Dropped impact • (e.g. during installation/ maintenance) • Damage (e.g. crush/ penetration/puncture)	• Release of flammable liquid electrolyte • Vaporisation of liquid electrolyte • Potential injury to off-site if battery on fire • Potential environmental impact (local/ off-site). Environmental impacts are covered in the EIS Note: Depending on electrolyte, a fire may occur. This has been covered in ID 3.	• Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS/NZS 5139) and guidelines • Independent owner's engineers' endorsement • Installation, operations and maintenance by trained personnel in accordance with relevant procedures • Each battery pack contains an integrated electrolyte sink, sized to capture all electrolyte contained within the battery pack in the event of substantial damage or pack rupture • Selection of appropriate battery chemistry • Venting and containment requirements of the battery manufacturer and FRNSW to be followed • Battery modules are enclosed with external casing • Spill clean-up using dry absorbent material • BESS BMS fault detection and shut-off function • Activation of emergency shutdown • Site Emergency Response Plan (and spill cleanup kits) • Use of appropriate PPE Refer to ID 3 for proposed fire controls to minimise escalation.	-	Yes (considered as part of battery unit fire in ID 3)
9	Chemical	Battery modules Thermal management system	BESS coolant or refrigerant leak	• Mechanical failure/damage • Incorrect maintenance	• Irritation/injury to onsite employee on exposure to leak (e.g. inhalation and skin contact) • Ingress of coolant or refrigerant to battery or other electrical components (battery enclosure) leading to: – short circuit – thermal runaway and fire/explosion (1) – injury and/or fatality to onsite employees • Potential environmental impact (local/ off-site). Environmental impacts are covered in the EIS.	• Equipment and systems will be designed and tested to comply with relevant international and/or Australian standards (e.g. AS/NZS 5139) and guidelines • Independent owner's engineers' endorsement • Installation, operations and maintenance by trained personnel in accordance with relevant procedures • Each pack is designed to be water resistant (IP65 rated) and will protect a leak inside the enclosure from entering a pack or cascading between packs • BESS BMS fault detection and shut-off function • Activation of emergency shutdown • Site Emergency Response Plan • Containment of leaks and spills • Use of appropriate PPE Refer to ID 3 for proposed fire controls.	Nominated battery technology is Lithium Iron Phosphate (LFP material) $LiFePO_4$.	Yes[3] (considered as part of battery unit fire in ID 3 & ID 7)

[3] The Victorian Big Battery fire (30-Jul-21) was caused by a short circuit (a coolant leak from the cooling system leading to a fire in an electronic component) and subsequent overheating (thermal runaway). The fire involved 2 battery packs and was locally confined to the area. Energy Safe Victoria reported that the battery was offline and the monitoring and protection systems not being available, allowed the initial fault to go undetected. The OEM has since updated the BESS safety systems with consideration of auxiliary backup power/UPS system that can provide power. This will ensure that the safety systems are still operating in the event of an outage.

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
10	Gas generation	Battery system	Generation of flammable or toxic gas (e.g. hydrogen fluoride)	• Thermal runaway (pre-ignition) • External fire (e.g. fire from adjacent infrastructure, bushfire)	• Fire and/or explosion in battery enclosure • Release of toxic products of combustion • Injury and/or fatality to onsite employees	• Equipment and systems will be designed and tested to comply with the relevant international and Australian standards and guidelines • Equipment will be procured from reputable supplier • Independent owner's engineers' endorsement • Installation, operations and maintenance will be undertaken by trained personnel in accordance with relevant procedures • To minimise fire escalation between the battery units and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the OEM and/or applicable standards • Ventilation requirements as per manufacturer's instruction • BESS equipment fault detection and shut-off function • Battery fire and explosion protection system (battery system specific features, refer to Table 3.2 • Activation of emergency shutdown • Emergency Response Plan • Inclusion of APZ buffer to minimise bushfire encroachment • External firefighting protocol (FRNSW & RFS)	-	Yes (considered as part of battery unit fire in ID 3)
11	EMF	BESS Transmission line Switch room	Exposure to electric and magnetic fields	Operations of energy storage system and associated equipment	• High level exposure (i.e. exceeding the reference limits) may affect function of the nervous system (i.e. direct stimulation of nerve and muscle tissue and the induction of retinal phosphenes) • Injury to onsite employees EMF created from the BESS will not exceed the ICNIRP reference level for exposure to the general public. Additionally, the strengths of electric and magnetic fields attenuate rapidly away from the source. As the BESS will be situated in a rural area and there is a large separation distance to the nearest residential dwelling, the effects are not expected to have an off-site impact.	• Location siting and selection (i.e. separation distance to sensitive receptors) • Distribution and low intensity of modules • Reducing conductor spacing • Balancing phases and minimising residual current • Incidental shielding (i.e. BESS enclosure) • Equipment and systems will be designed and tested to comply with international standards and guidelines • Exposure to personnel is short duration in nature (transient) • Warning signs	-	No

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
12	External factors	BESS Switch room	Water ingress	• Rain • Flood (due to climate change, major rain event) • Earthquake	• Electrical fault/short circuit • Fire and/or explosion in battery enclosure • Injury and/or fatality to onsite employees	• Substation and switchroom will be housed in a dedicated building and constructed in accordance with relevant standards • Preventative maintenance (check for leaks) • BESS BMS fault detection and shut-off function • Activation of emergency shutdown • Site Emergency Response Plan Refer to ID 1 & ID 3 for proposed electrical failure and fire controls.	Based on the Probable Maximum Flood (PMF) event and flood modelling, impact at site will be minimised by providing a freeboard to BESS pad level and/or battery units, and site drainage systems to direct floodwaters around the BESS. Refer to Water Impact Assessment Ref [4] for flood impact assessment and control measures.	Yes (considered as part of battery unit fire in ID 3 & ID 7
13	External factors	BESS	Sabotage	• Cyber security attack targeting battery thermal runaway	• Fire and/or explosion in battery enclosure • Release of toxic products of combustion • Injury and/or fatality to onsite employees • Escalation to other project infrastructure	• System design and architecture will comply with the relevant international and Australian standards and guidelines for cyber security protection • Routine cyber security audits including penetration tests (network and system) • Implementation of software updates and backup system • Site cyber security protocol (e.g. multi-factor authentication) and training for employees • To minimise fire escalation between the battery enclosures and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the OEM and/or applicable standards • BESS equipment fault detection and shut-off function • Battery fire and explosion protection system (battery system specific features, refer to Table 3.2 • Emergency Response Plan • APZ buffer provides setback to minimise fire escalation to adjacent infrastructure • External firefighting protocol (FRNSW & RFS)	-	Yes (considered as part of battery unit fire in ID 3 & ID 7
14	External factors	BESS	Vandalism	• Unauthorised personnel access • Trespassing • Deliberate damage to BESS infrastructure • Asset damage	• Asset damage • BESS failure/fire • Potential hazard to unauthorised person (e.g. electrocution) • Injury and/or fatality to trespasser Effects to unauthorised person are expected to be localised and not expected to have an off-site impact. The impact is to a member of public but occurs onsite.	• Secure battery unit cabinets design • The BESS will be located within a secure area, which is fenced • Warning signs (i.e. trespassers and on-site hazards) • Site security plan for the site (e.g. mobile patrol, monitoring etc.) • BESS BMS has active monitoring. Interface will result in the BESS shutdown	-	No

ID	Hazard	BESS component/ infrastructure	Event	Cause	Consequence	Proposed controls	Site specific comments (Rothbury BESS Facility)	Potential off-site impact. Additional modelling required?
15	External factors	BESS	Lightning strike	Lightning storm	• Fire • Injury and/or fatality to onsite employees	• Lightning protection mast and surge protection devices • Earthing as per manufacturer and standards requirements • BESS BMS monitoring and activation of emergency shutdown for temperature deviations • Site Emergency Response Plan Refer to ID 3 for proposed fire controls.	-	No
16	External factors	Battery modules	Battery overheating	• Extreme temperature or humidity • Dust ingress to battery unit	• Potential for escalation to a thermal runaway event • Fire and/or explosion in battery enclosure • Injury and/or fatality to onsite employees • Asset damage	• Battery units designed for worse case ambient condition Refer to ID 3 & ID 6 for proposed thermal runaway and fire controls.	-	Yes (considered as part of battery unit fire in ID 3 & ID 7)
17	External Factors	Adjoined Ausgrid HV transformers	Fire/explosion of existing Ausgrid HV transformer on adjacent site	• Arc flash • Leak of transformer oil	• Transformer fire that escalates to BESS • Smoke from the transformer fire impacting on the BESS fan intakes (operational issue)	• By design, there is significant distance between the Rothbury substation transformers and the BESS. Therefore escalation potential is unlikely. • All relevant Ausgrid requirements will be met • Electrical switch-in & switch-out protocol • Circuit breakers provided for the substation • Fire protection for buildings within the BESS facility • Activation of emergency shutdown • Fire Management Plan (e.g. establishing defendable fire-fighting boundary) • Site Emergency Response Plan • External firefighting protocol (FRNSW & RFS) • To minimise fire escalation between the BESS sub-units and onto other adjacent infrastructure, the BESS configurations will follow the specified clearances required by the battery OEM and/or applicable standards	-	Yes (as per ID 4 for HV transformer)

APPENDIX B. ELECTRIC AND MAGNETIC FIELDS

B1. Overview

EMFs are naturally present in the environment. They are present in the earth's atmosphere as electric fields, while static magnetic fields are created by the earth's core. EMFs are also produced wherever electricity or electrical equipment is in use (e.g. household appliances, powerlines), Ref [19].

Electric fields are created where there is a difference in potential. Electric fields are related to and directly proportional to voltage (i.e. the higher the voltage the stronger the electric field). Electric fields are often described in terms of their strength and commonly expressed in volts per metre (V/m) or kilovolts per metre (kV/m).

Magnetic fields are created whenever electric current flows. Magnetic fields are directly proportional to the current (i.e. the higher the current stronger the magnetic field). Magnetic fields are often described in terms of their flux density and commonly measured in either Tesla (T) or Gauss (G).

Electric and magnetic fields are strongest closest to source, and their strength attenuates rapidly away from the source. The strength of electric fields is weakened due to shielding from common materials (i.e. buildings, walls), whereas magnetic fields are not.

Use of electricity means that people are exposed to EMF as part of daily life. The background electric and magnetic fields in a typical home are around 20 V/m and 0.1 μT, respectively. These may vary depending on the number and type of appliances, configuration and positioning, and distances to the other sources (e.g. powerlines). Typical EMF strengths for common household electrical appliances (at distance of 30 cm) are shown in Table B.1, Ref [20].

EMF associated with the generation, distribution and use of electricity power systems in Australia which have a frequency of 50 Hertz (Hz) are classified by Energy Networks Australia[4] as Extremely Low Frequency[5] (ELF) EMF, Ref [19].

[4] Energy Networks Association is the peak national body representing gas distribution and electricity transmission and distribution businesses throughout Australia.

[5] ELF EMF occupy the lower part of the electromagnetic spectrum in the frequency range 0-3000 Hz.

Table B.1: Typical EMF strengths for household appliances

Electric appliance	Electric field strength (V/m)	Magnetic field density (µT)
Refrigerator	120	0.01 – 0.25
Iron	120	0.12 – 0.3
Hair dryer	80	0.01 – 7
Television	60	0.04 – 2
Vacuum cleaner	50	2 – 20
Electric oven	8	0.15 – 0.5

B2. Effects of exposure to EMF

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is a federal government agency assigned with the responsibility for protecting the health and safety of people and the environment from EMF.

ARPANSA advises that:

- *"The scientific evidence does not establish that exposure to the electric and magnetic fields found around the home, the office or near powerlines causes health effects."*, Ref [21]
- *"There is no established evidence that ELF EMF is associated with long term health effects. There is some epidemiological research indicating an association between prolonged exposure to higher than normal ELF magnetic fields (which can be associated with residential proximity to transmission lines or other electrical supply infrastructure, or by unusual domestic electrical wiring), and increased rates of childhood leukaemia. However, the epidemiological evidence is weakened by various methodological problems such as potential selection bias and confounding. Furthermore, this association is not supported by laboratory or animal studies and no credible theoretical mechanism has been proposed."*, Ref [22].

B3. Study approach

Although the adverse health impacts have not been established, the possibility of impact due to exposure to EMF has not been ruled out. As part of a precautionary approach, the study assessed the typical exposure levels to EMF for the Project infrastructure.

A task group assembled by the World Health Organisation to assess any potential health risks from exposure to ELF EMF in the frequency range of 0 to 100,000 Hz found that there are no substantive health issues related to ELF electric fields at levels generally encountered by the public, Ref [23]. Therefore, the information presented in the following sections address predominantly the effects of exposure to ELF magnetic fields.

B4. Guidelines for limiting EMF exposure

The ICNIRP has produced a publication to establish guidelines for limiting EMF exposure to assist in providing protection against adverse health effects. Separate guidance is given for general public and occupational exposure within the guideline.

The guideline has defined general public and occupational exposures as follows:

- General public – individuals of all ages and of varying health status which might increase the variability of the individual susceptibilities.
- Occupational exposure – adults exposed to time-varying EMF from 1 Hz to 10 MHz at their workplaces, generally under known conditions, and as a result of performing their regular or assigned job.

The ICNIRP reference levels for exposure to EMF at 50 Hz is presented in Table B.2, Ref [24]. The guideline adopted more stringent exposure restrictions compared to occupational exposures recognising that in many cases the general public are unaware of their exposure to EMF.

Table B.2: Reference levels for EMF levels at 50 Hz

Exposure	ICNIRP Reference Levels	
	Electric field (V/m)	**Magnetic field (μT)**
General public	5,000	200
Occupational	10,000	1,000

B5. BESS EMF

B5.1. BESS

The magnetic field associated with a BESS will vary depending on a number of factors including configuration, capacity and type of housing. Due to the limited information on typical measurement of magnetic fields around BESSs, this study has assumed the typical magnetic field will not be too dissimilar with that of a substation. This study also assumed that the BESS will be designed in accordance with electrical safety standards and codes which will result in exclusion of general public exposures from these sources.

B5.2. Transmission line

The magnetic field from transmission lines will vary with configuration, phasing and load. The typical magnetic fields near overhead transmission lines measured at 1 m above ground level range between 1-20 μT (directly underneath) and 0.2-5 μT (at the edge of easement), Ref [25].

For underground transmission lines, the cables are typically installed 1 m below ground, whereas the conductors of an overhead line are typically more than 10 m above ground. Therefore, the magnetic field directly above an underground cable is usually higher than that directly below the equivalent overhead line. However, as the individual cables are installed much closer together than the conductors of an overhead line, the magnetic field attenuates more quickly with distance than the magnetic field from overhead lines. Overall, a larger magnetic field is observed directly above and for a small distance to the sides, but at larger distances to the sides the cable produces a lower field than the overhead line. The typical magnetic fields for a 400 kV underground cable buried 1 m depth are approximately 24 μT (directly above) and 3 μT (5 m from centreline), Ref [26]. A 33 kV underground cable connection is proposed to connect the battery units to the existing Rothbury Zone Substation.

B6. Controls to limit exposure to EMF

The following controls were identified to limit exposure to EMF:

- The design, selection and procurement of electrical equipment for the Project will comply with relevant international and Australian standards.
- Location selection for the Project infrastructure (i.e. it accounts for separation distance to surrounding land uses) and fencing within the Project's development footprint will assist to limit the exposure to EMF for the general public.
- Exposure to EMF (specifically magnetic fields) from electrical equipment will be localised and the strength of the field attenuates rapidly with distance.
- Duration of exposure to EMF for personnel onsite will be short.

B7. Conclusion

Based on the review completed in the preceding sections, this study concludes that:

- EMF created from the Project will not exceed the ICNIRP occupational exposure reference level.
- As the strengths of EMF attenuate rapidly with distance, this study determined that the ICNIRP reference level for exposure to the general public will not be exceeded and impact to the general public in surrounding land uses will be negligible.

For the risk assessment, consequence from exposure to EMF was assumed to result in no or minor injury ('Insignificant') in reference to the consequence impact rating shown in Table 10.2.

The cumulative exposure to EMF from other proposed developments in the vicinity of the Project has not been assessed in this study. However, as the strength of EMF attenuates rapidly with distance, cumulative impacts at the closest sensitive receptors are considered unlikely.

APPENDIX C. CONSEQUENCE MODELLING

C1. Overview

Consequence analysis of a battery unit on fire was completed to determine the potential for off-site impacts. The following scenarios were analysed:

- Fire involving a battery unit (e.g. propagated thermal runaway resulting in a fully developed fire).
- Toxic gas generation from decomposition of battery electrolyte due to fire.
- Impact distances associated with heat radiation due to fire and dispersion of toxic gas were estimated to determine potential for off-site impacts to sensitive receptors.

This appendix summarises the consequence modelling approach, input, assumptions, and results.

C2. Battery unit fire

C2.1. Modelling approach

Consequence modelling was undertaken based on the Stefan–Boltzmann correlation to analyse the heat transfer effect between two parallel planes, simulating a battery unit on fire and the heat radiation exposure to a receptor, as shown in Figure C.1. Distances to heat radiation levels in accordance with HIPAP 4 *Risk Criteria for Land Use Safety Planning*, Ref [3], were calculated.

To estimate the heat radiation generated from a battery unit on fire, the emitted heat flux was calculated using the Stefan-Boltzmann Law:

$$E_{emitted} = e\sigma T^4$$

Where E is the radiant emittance, e is the emissivity, σ is the Stefan-Boltzmann constant and T is the surface temperature.

The heat flux received was estimated using the view factor method, where *d* is the receiver distance to the battery unit on fire:

$$\emptyset = \frac{1}{2\pi}\left[\frac{a}{(1+a^2)^{1/2}}tan^{-1}\frac{b}{(1+a^2)^{1/2}} + \frac{b}{(1+b^2)^{1/2}}tan^{-1}\frac{a}{(1+b^2)^{1/2}}\right]$$

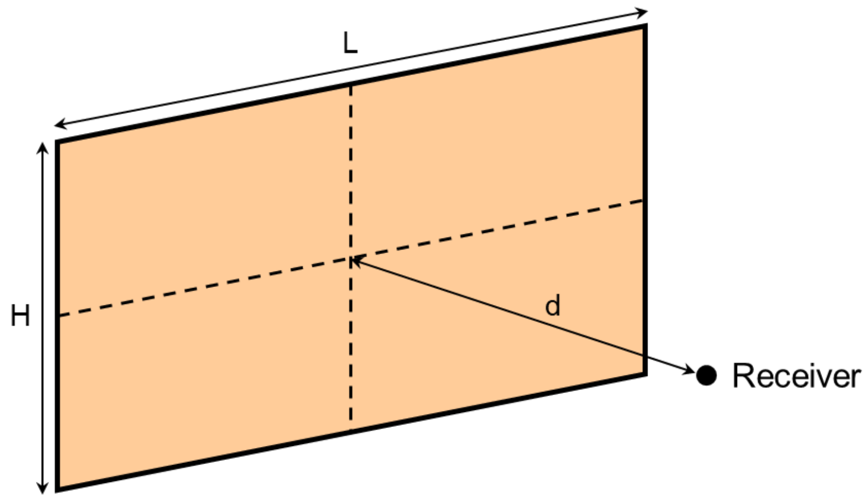
$$a = \frac{0.5\,H}{d}\,, a = \frac{0.5\,L}{d}$$

To calculate the heat radiation experienced by the receptor at height 1.5 m (approximately half of the battery unit height), the surface area of the battery unit (front aspect) is divided into 4 equal sections.

Figure C.1 illustrates the graphical depiction of the parameters used in the calculation.

$$E_{received} = 4\,\emptyset\,E_{emitted}$$

Figure C.1: The graphical depiction of the parameters (L, H, D)



C2.2. Comparison with fire tests

The OEM has developed a model to predict heat radiation and consequences from a battery unit on fire.

The model calculates:

- Heat radiation from a flame exiting the front face of a cabinet.
- Effects of heat radiation on adjacent battery units.

The model is primarily intended to set required spacing to prevent fire propagation between battery units but can also be used to assess heat radiation at a distance from the battery unit.

The model estimates the heat radiation from a flame based on an assumption of the flame temperature based on typical flame temperatures (i.e. the values are not based on measured OEM battery temperatures) and the area of the flame. This approach is consistent with the Sherpa model.

The OEM validated the model by comparing the results with measurements taken during a destructive test of their battery unit and reported a correlation of 'within 20%' and concluded this level of accuracy is 'more than acceptable' given the test was a single event in an outdoor location measured as an average heat flux.

The OEM battery unit fire was reported as:

- Flame dimensions 3.5 m high x 1 m wide.
- Heat radiation 15 kW/m^2 measured 8 feet (2.5 m) from the cabinet.

The Sherpa model was run with a flame dimension of 3.5 m x 1 m and the heat radiation level at 2.5 m from the cabinet reported. The test, and Sherpa model are presented in Table C.1.

Table C.1: Heat radiation impact model validation

Source	Heat radiation at 2.5 m	Commentary
OEM destructive test	15kW/m^2	Measured in outdoor as an average temperature
Sherpa model	18kW/m^2	+20% of the measured value

The validation shows the Sherpa model is consistent with the fire test.

The results show the Sherpa model is valid for assessing heat radiation from a battery unit on fire.

C2.3. Input and assumptions

The modelling input and assumptions used were as follows:

- The flame temperature of the emitting surface was set at 1000°C, which is the upper bound value measured for lithium metallic fires, Ref [27]. The data shows a range of 800-1000°C with the upper bound selected to ensure a conservative but credible assessment.
- The emissivity value was set at 0.9 (a black body has an emissivity value of 1).
- Receptor height was set at 1.5 m.
- The heat radiation calculation was performed for the front and side aspects of the battery unit and assumed a full planar fire. The aspect which is parallel to a given receptor is used to determine the possible heat radiation impact.

Using the full-face fire is conservative but credible. OEM results presented by OEM state that fire propagation was limited to modules 7 to 10 by heating a bank of modules into thermal runaway. However, there are other causes of thermal runaway that could result in additional modules experiencing thermal runaway (e.g. control and safeguarding system failure).

This is deemed appropriate to determine off site consequences from a fully developed fire in a battery unit.

C2.4. Heat radiation criteria

Consequences of various heat radiation levels in accordance with HIPAP 4 *Risk Criteria for Land Use Safety Planning*, Ref [3], are shown in Table C.2. For this PHA, distances to 4.7 kW/m^2 (injury), 12.6 kW/m^2 (fatality), and 23 kW/m^2 (structural failure) were calculated.

Table C.2: Consequences of heat radiation

Heat radiation (kW/m^2)	Effect
1.2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute

Heat radiation (kW/m^2)	Effect
4.7	Will cause pain in 15-20 seconds and injury after 30 seconds' exposure (at least second-degree burns will occur)
12.6	• Significant chance of fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved, or failure would occur
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of fatality for people exposed instantaneously

C2.5. Results

The distances to the specified heat radiation levels are presented in Table C.3. Distance to the injury level (4.7 kW/m^2) was used to determine potential for off-site impact, which is approximately 15 m from the side of the battery unit, or 7 m from the end of the battery unit.

Table C.3: Heat radiation impact –battery unit on fire

Battery system aspect	Surface (L x H, m)	Surface temperature (°C)	Distance (m) at receptor height (1.5 m) to radiation levels		
			4.7 kW/m^2 (injury)	12.6 kW/m^2 (fatality)	23 kW/m^2 (structural failure)
Side	8.81 x 2.79	1000	15	9	6
End	1.65 x 2.79	1000	7	4	3

C3. Dispersion of toxic gas

C3.1. Modelling approach

In the event of a battery unit fire, there is a potential for toxic gas to be generated from (1) decomposition of the battery electrolyte, and/or (2) combustion products. For LFP batteries, there is a potential for HF to be formed following electrolyte decomposition from a battery unit fire event. In this study, dispersion of HF was modelled to better understand its impact to receptors.

Consequence modelling was performed using the Gexcon EFFECTS v12.5.1 software (Plume Rise from Fire model) to simulate HF dispersion during a battery unit fire. The HF generation rate was based upon published experimental literature for LFP batteries. The downwind distances to the AEGL concentrations for HF were determined.

C3.2. Input and assumptions

The modelling input and assumptions used were as follows:

- Hydrogen fluoride is considered the most toxic decomposition products from the batteries fire, Ref [28].
- A lithium-ion battery cell experiment, Ref [28], indicates that the HF quantity released from a 1 Wh battery varies between 20 mg and 200 mg, depending on the battery type and state of charge. As a conservative approach, a generation rate of 200 kg per 1 MWh was adopted for the analysis. The HF generation rate was calculated based on the capacity a single battery unit and fire duration of 1 hour. The resulting HF generation rate used for analysis is conservative as typically the fire duration is longer than 1 hour.
- Release is continuous, with concentration averaging time of 60 minutes used for reporting.
- Surface roughness factor of 0.1 m was used (representing low crops and occasional large obstacles).
- The heat release rate from the battery (with 100% state of charge) is estimated to be 882 kW/m^2, Ref [29].
- The plume was assumed to be released from the top of the battery unit. This is viewed as a reasonable approach, based on observation from previous BESS fire incidents (e.g. Victorian Big Battery fire).
- Receptor height was set at 1.5 m.
- Wind and weather stability conditions of D 5 m/s (D5) and F 2 m/s (F2) were used to represent typical day and night conditions, respectively.

C3.3. Toxic exposure criteria

The AEGL concentration levels (60-minute exposure) for HF are presented in Table C.4. These concentrations were used to inform harm levels following exposure (irritation, injury and fatality).

Table C.4: AEGL levels for HF (60-minute)

AEGL level	Health effects	Concentration (ppm)
AEGL-1	Irritation threshold	1
AEGL-2	Injury threshold	24
AEGL-3	Life-threatening health effects threshold (fatality)	44

C3.4. Results

The distances to AEGL concentrations at receptor height of 1.5 m are presented in Table C.5. As a conservative approach, the distance to the irritation level (AEGL-1) was used to determine potential for off-site impact. This was found to be 23 m at D5 conditions.

Table C.5: Battery unit on fire – Toxic dispersion impact (HF)

Battery system	Capacity per unit (MWh)	HF generation rate (kg/s)	Wind weather stability	Distance (m) at receptor height (1.5 m) to AEGL levels		
				AEGL-1 (irritation)	AEGL-2 (injury)	AEGL-3 (fatality)
Concept design battery system	3.9	0.22	D5	23	10	8
			F2	3	2	2

APPENDIX D. REFERENCES

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