APPENDIX 16

Preliminary Hazards Analysis

umwelt
Environmental & Social Consultants

GUNDARY SOLAR FARM

Preliminary Hazard Analysis

FINAL

July 2024

GUNDARY SOLAR FARM

Preliminary Hazard Analysis

FINAL

Prepared by
Umwelt (Australia) Pty Limited
on behalf of
Lightsource bp

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Document Status

Rev No.	Reviewer		Approved for Issue	
	Name	Date	Name	Date
Final	Tim Procter	16/07/2024	Tim Procter	16/07/2024

Glossary

Abbreviation and Units	Description
PHA	Preliminary Hazard Analysis
Project	The Project as described in **Table 1.1**
PV	solar photovoltaic (solar panel)
BESS	Battery Energy Storage System
LIB	lithium-ion battery
$LiFePO_4$ or LFP	lithium iron phosphate
$LiCoO_2$ or LCO	lithium cobalt oxide cathode
$LiMn_2O_2$ or LMO	lithium manganese oxide cathode
NMC	cathode made of a combination of nickel, manganese and cobalt
CO, HCN, HF	Carbon monoxide, hydrogen cyanide, hydrogen fluoride
m, km	metre, kilometre
m^2, ha	square metre, hectare
L, m^3	litre, cubic metre
mg, kg, t	milligram, kilogram, tonne
ppm	part per million
MW	megawatt
MWh	megawatt-hour
kV	kilovolt
SEPP	State Environmental Planning Policy
HIPAP	Hazardous Industry Planning Advisory

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1.0 Introduction

Lightsource Development Services Australia Pty Ltd (Lightsource bp) is seeking to develop the Gundary Solar Farm in the Southern Tablelands region of New South Wales (NSW), approximately 10 kilometres (km) southeast of Goulburn within the Goulburn Mulwaree Local Government Area (LGA). The location of the Project is presented in **Figure 1.1**.

The Project involves the construction, operation, maintenance and decommissioning of an approximate 400 Megawatt peak (MWp) of solar photovoltaic (PV) generation with a Battery Energy Storage System (BESS) with a capacity to store up to 1,570 (MWh) of on-demand energy for supply to the grid. The Project further includes ancillary infrastructure, an onsite substation/switchyard and connection to deliver up to 555 MWp power to an existing 330 kilovolt (kV) transmission line.

1.1 Project Overview

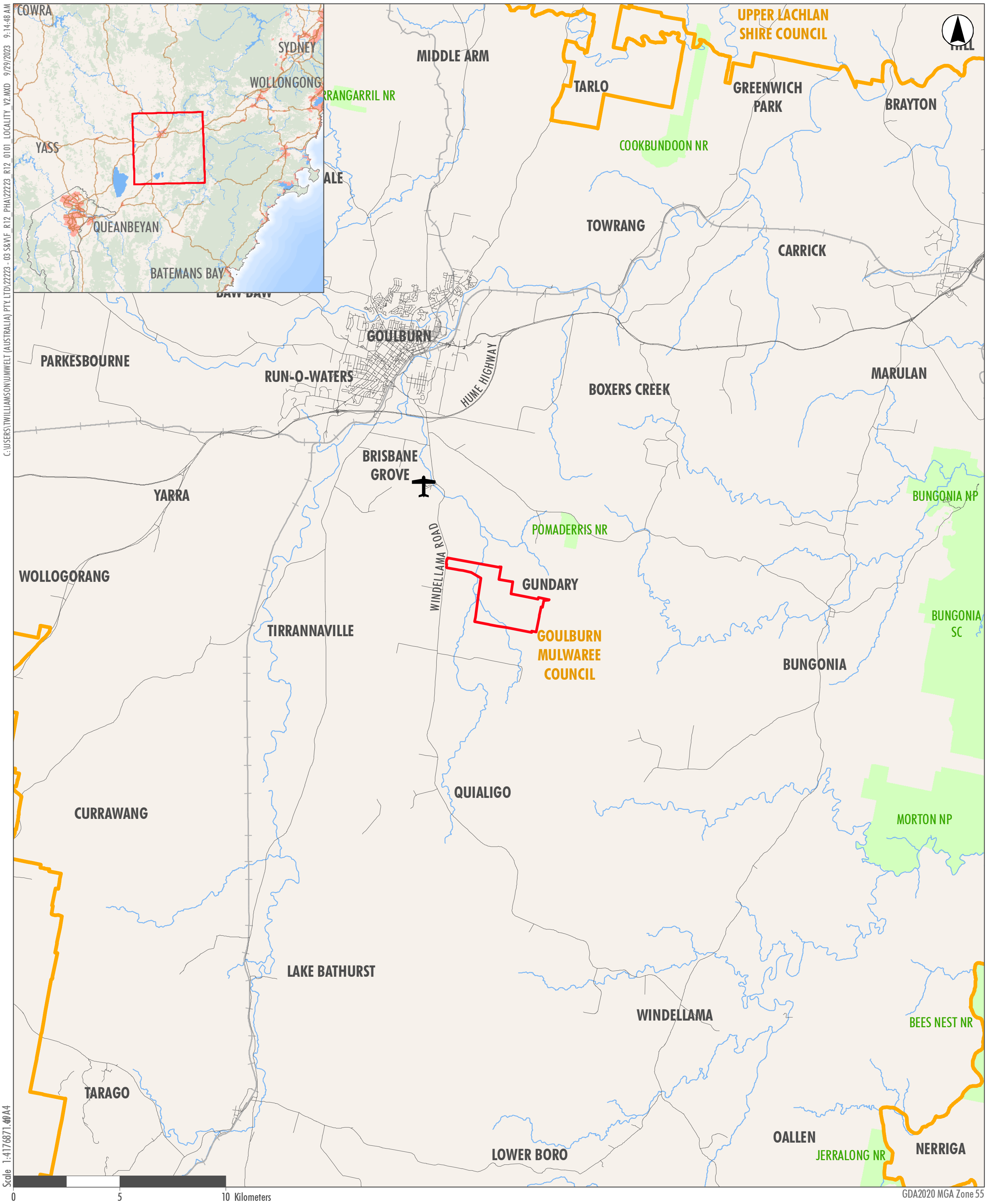
The Project Area of 702 ha shown in **Figure 1.2** is located in the rural locality of Gundary, near Goulburn in NSW. The Project Area comprises five freehold lots and a small portion of Windellama Road, including the road reserve. The layout of the solar panels, BESS and associated infrastructure would be entirely contained within the 512 ha area shown in **Figure 1.3**.

The Project will supply electricity to the National Electricity Market (NEM), via an onsite connection to the existing 330 kV overhead transmission line traversing the north-west corner of the Project Area. Project access will be via the existing driveway at 961 Windellama Road via the Hume Highway (refer to **Figure 1.1**). Intersection works on Windellama Road are proposed as part of the Project in order to upgrade the Project access to accommodate heavy vehicles.

The Project Area is zoned RU1 Primary Production under the Goulburn Mulwaree LEP. The freehold land within the Project Area has been subject to agricultural activities such as grazing (sheep and cattle). The Project Area is bounded by Windellama Road on the west, for approximately 500 m, with Kooringaroo Road bordering the northeast corner of the Project Area. Properties directly north, east, west and south of the Project Area are privately owned rural residential properties with agricultural land use.

The Project is expected to operate for 40 years. After its operational life, the Project would either be decommissioned (by removing all infrastructure and returning the site to its existing land capability) or repurposed with new PV equipment subject to technical feasibility and planning consents.

The Project is a State Significant Development (SSD) under State Environmental Planning Policy (Planning Systems) 2021 (Planning Systems SEPP), as the Project is development for the purposes of electricity generating works and the capital investment value of the Project is over $30 million. A development application (DA) for the Project is required to be submitted under Part 4 of the NSW *Environmental Planning and Assessment Act 1979*.



Legend

- Project Area
- Goulburn Airport
- Local Government Area
- NPWS Estate
- Roads
- Railway
- Watercourses

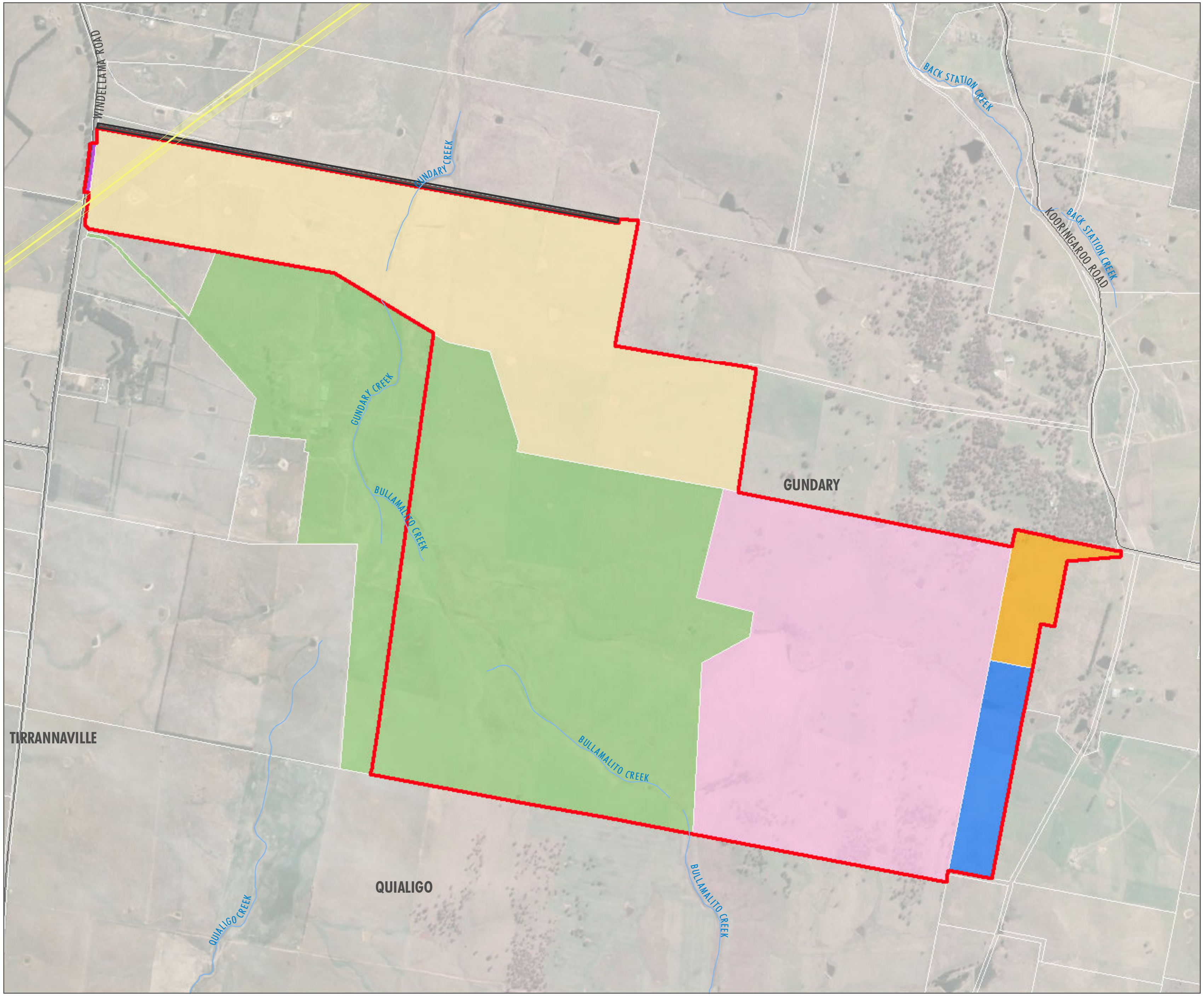
FIGURE 1.1

Locality and Regional Context

Data source: NSW DSFI (2022); Lightsource BP (2022)

FIGURE 1.2

Project Area

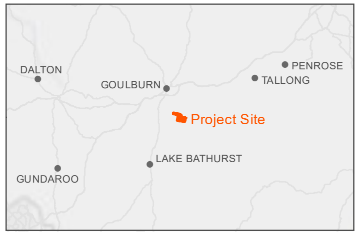


Legend

- Project Area
- Cadastre Boundaries
- Roads
- Watercourses
- Existing Transmission Line
- Indicative Overhead Line Easement
- Paper Road

Lots Identified within the Project Area

- 1/DP870101
- 12/DP1016332
- 2/DP1187724
- 80/DP750018
- Lot 3/DP1238347
- Project Area within Road Reserve



0 500 1,000

Meters

Scale: 1:0 at A4

GDA 1994 MGA Zone 55

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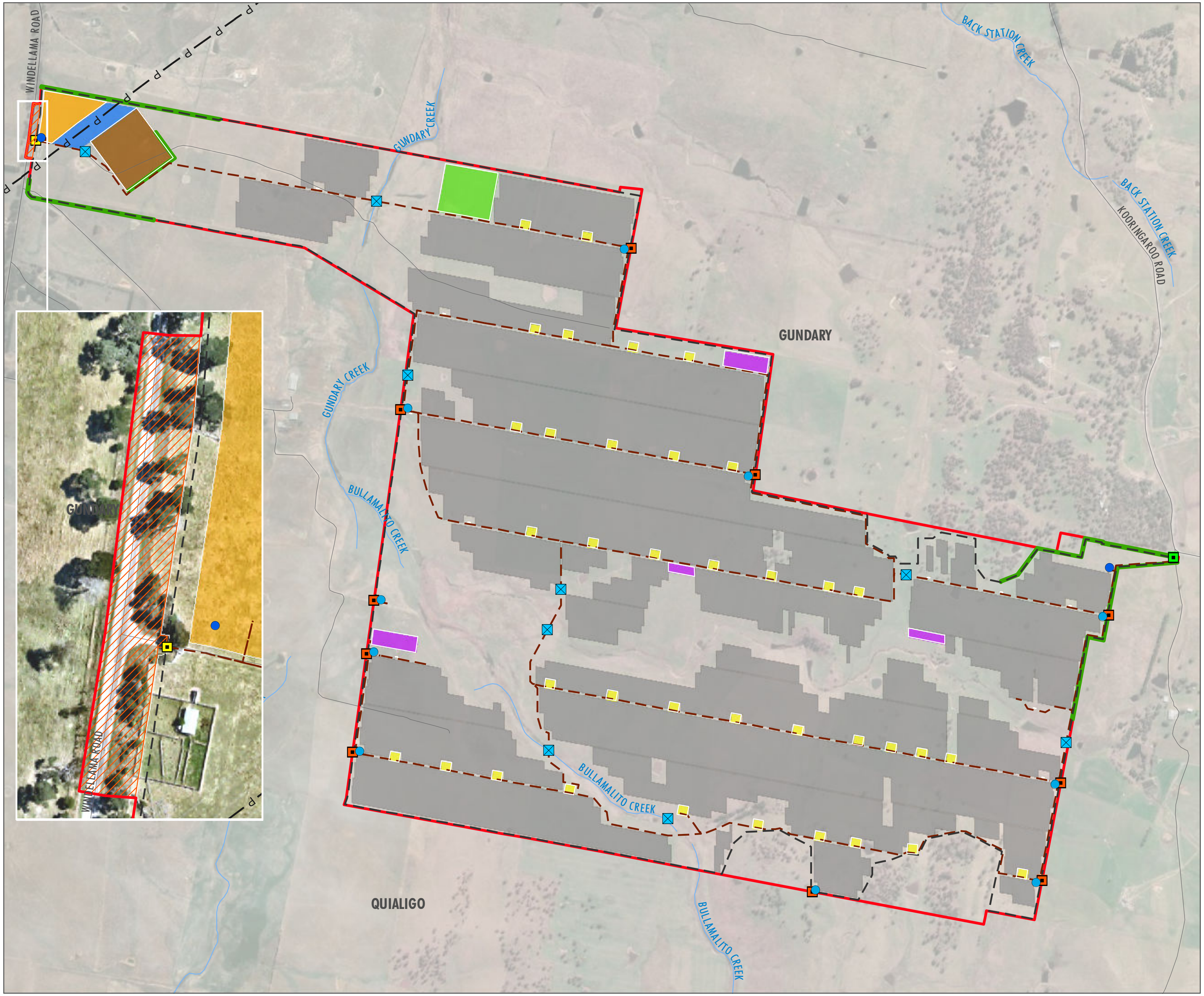
Image Source: ESRI Basemap (2023) | **Data Source:** NSW DFSI (2023)

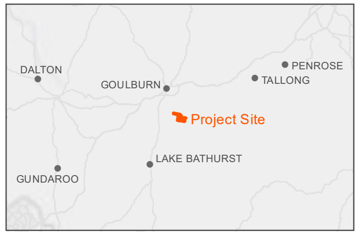
FIGURE 1.3

Project Conceptual Layout



Legend

- Access Roads
- Security Fence
- P Existing Transmission Line
- Roads
- Watercourses
- Watercourse / Bed Level Crossing
- Water Tank (40,000L)
- Water Tank (10,000L)
- Primary Access
- Emergency Access
- Emergency Gate
- Project Area
- Proposed Road Upgrade
- Solar Panels
- Landscaping Buffer (5m)
- Transgrid Line Works
- Centralised AC BESS
- Substation and O&M Facility Area
- Construction Compound Area
- Decentralised DC BESS
- Temporary Laydown Area



0 500 1,000

Metres

Scale: 1:0 at A4

GDA2020 MGA Zone 55

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Image Source: ESRI Basemap (2023) | **Data Source:** NSW DFSI (2023)

A summary of the relevant aspects of the proposed Project SSD-48225958, shown on **Figure 1.3**, for which approval is sought, is provided in **Table 1.1**.

Table 1.1 Project Summary

Project Element	Description
SSD Application Number	SSD-48225958
Solar generation capacity	Approximately 400 MWp (DC)
Project area footprint	Approximately 702 ha
Development Footprint	Approximately 512 ha
Exclusion zones and setback buffers	Setbacks include: • 10 m Asset Protection Zone (APZ) around the perimeter of the Project • 5 m landscaping buffer, strategically located outside the APZ and the security fencing • approximately 20 m to 40 m setbacks around 2nd order and higher streams, including some farm dams. Exclusion zones include: • Areas prone to flooding (1% AEP). • Areas with TECs and habitat for threatened fauna and flora species.
Solar arrays	• **Panels** – approximately 660,000 bifacial flat plate solar photovoltaic (PV) modules. • **Panel dimensions and area**– approximately 2.38 m x 1.3 m totaling approximately 3 m^2 per panel. • **Row spacing** – up to 5 m. • **Maximum height** – 3 m at full tilt with an occasional height of up to 4 m (depending on topography).[1]
Battery Storage	• **Capacity** – up to 555 MWp and 1,570 Megawatt hour (MWh) capacity. • **Configuration** – subject to detailed design, up to 89 battery stations will be housed in a series of outdoor containers, either distributed across the site (Option 1 – decentralised DC-coupled) and/or aggregated in one central location (Option 2 – centralised AC-coupled), as illustrated on **Figure 1.4** and **Figure 1.5**. • **Maximum height** – approximately 3 m.

Electrical infrastructure	• Substation/Switchyard:
	  o Onsite connection to the existing 330kV overhead powerline via a proposed 33/330 kV substation and switchyard including ancillary infrastructure to connect to the existing transmission line, which has a 60 m easement.
	  o Area – approximately 6.3 ha.
	  o Maximum height – approximately 3.5 m with taller ancillary components such as busbar at 14 m high, gantry and lightning arrestors up to 22 m high.
	• **Power conversion station** (PCS) – consisting of up to 128 inverters as well as medium voltage transformers and requisite infrastructure.

[1] The environmental assessment was based on a maximum 3 m high panel as the overall height of panels across the site will not exceed 3 m. The occasional panel height of 4 m will be typically limited to lower lying areas.

Project Element	Description
Project access	• Transport via road from Port Botany in Sydney or Port Kembla south of Wollongong, to the Project Area via the public road network with two access route options proposed. • Project's primary access via the existing driveway on Windellama Road, with intersection works proposed to upgrade the Project access to accommodate heavy vehicles. • Alternate access via Kooringaroo Road for emergencies only.
Internal access tracks	• Approximately 4 m wide tracks with turning bays for emergency vehicles, consisting of compacted gravel, with a main access track of 6 m wide to the substation to allow for the safe delivery, unloading and installation of key components, including some watercourse crossings (via culverts and bed level crossings).
Security fence, lighting and CCTV	• Perimeter security fencing consisting of chain wire including three strings of barbed wire on top, to a height of approximately 2.3 m plus motion detecting security lighting.
Operation and Maintenance (O&M) facilities	• **Location** – two small O&M facilities will be established, one within the construction compound area in the northwest corner of the Project Area and the other next to substation. • Facilities to include an office with staff amenities (kitchenette, toilets, showers), car park and workshop/shed.
Temporary ancillary facilities	• **Location** – proposed compacted gravel areas within the development footprint. • Main construction site compound to include office amenities, parking, storage, and associated facilities, with laydown areas suitable for storing plant and equipment, solar panels and cable drums, and areas to support waste management activities.
Workforce	• **Construction** – Approximately 400 full time equivalent (FTE) jobs with approximately 250 personnel on site during peak construction. • **Operation** – Up to four FTE jobs.
Construction hours	• Typical standard construction i.e.: ○ 7 am to 6 pm Monday to Friday ○ 8 am to 1 pm on Saturdays ○ No works on Sunday or public holidays. Lightsource bp proposes to carry out works outside of these hours which are inaudible at non-associated residences, emergency work, and deliveries and dispatches where requires by authorities for safety reasons.
Construction timing	Approximately 18 to 24 months (commencing in Q4 2025/Q1 2026)
Commencement of operations	Anticipated Q1 2028
Operation period lifespan	Approximately 40 years. Operating 24/7, 365 days a year.
Capital investment	Approximately $598 million

1.2 Description of the Battery Energy Storage System (BESS)

The Project would involve the installation of a lithium-ion BESS to store energy generated by the Project and off the energy grid. Depending on detailed design and the final layout, Lightsource bp is considering two BESS options with a duration of 2–4 hours i.e. Option 1 – a decentralised DC-coupled BESS, and Option 2 – a centralised AC-coupled BESS. Consent is being sought for either one, or both options to be implemented.

1.2.1 Decentralised BESS

A decentralised BESS with a proposed operational capacity of 230 MWp/920 MWh, with no additional inverters or transformers required. The decentralised BESS option has a combined area greater than the centralised option, due to the distribution of equipment and infrastructure across the Project Area and spacing between key items e.g., BESS containers/modules. The conceptual layout of a DC-coupled BESS battery station showing separation distances of the battery units per power conversion station (PCS) is presented in **Figure 1.4**.

The proposed decentralised DC-coupled BESS allows for:

- 37 battery stations with a maximum of 6 battery storage units per station.
- Battery storage units typically 6.0 m long, 2.4 m wide and 3 m high per station (i.e. a 20 ft shipping equivalent container).
- An energy storage capacity of each battery storage unit ranging approximately from 3.7 to 3.9 MWh. The energy storage capacity of the battery storage units, and hence the final number of batteries required has not been finalised due to ongoing contractual negotiations.
- A maximum total aggregate operational energy storage capacity of the estimated 222 batteries of 920 MWh.
- A peak 4hr charge/discharge capacity of up to 230 MWp.
- Cabinets installed with a space between facing battery storage units of up to 4.5 m. It is noted that in accordance with FM Global's Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems (2023) the recommended minimum separation distance between the sides of lithium iron phosphate batteries containing access panels, doors or deflagration vents would be separated by at least 1.5 m (5 ft).
- A hardstand area for each DC-coupled battery station of approximately 25 m by 30 m to allow for a separation distance between combustible vegetation and battery storage units of at least 3 m (10 ft) in accordance with NFPA 855 Clause 443.6.
- A buffer zone between each DC-coupled battery station and the solar panels approximately 5 m or greater.
- An approximate stored energy density of per battery station of 30 kWh/m^2.

1.2.2 Centralised BESS

A centralised BESS with a proposed operational capacity of 325 MWp/650 MWh. The centralised BESS would most likely comprise of a lithium phosphate iron battery system, to be housed in a series of outdoor containers, aggregated in one central location. The conceptual layout of the centralised AC-coupled BESS is presented in **Figure 1.5**.

The proposed centralised AC-coupled BESS allows for:

- 52 battery stations with a maximum of 4 battery storage units per station.
- Battery storage units typically 6.0 m long, 2.4 metres wide and 3 m high.
- An energy storage capacity of each battery storage unit ranging from 3.7 to 3.9 MWh. The energy storage capacity of the battery storage units, and hence the final number of batteries required has not been finalised due to ongoing contractual negotiations.
- A maximum total aggregate operational energy storage capacity of the estimated 208 batteries of 650 MWh.
- A peak 2hr charge/discharge capacity of up to 325 MWp.
- Cabinets installed with a space between facing battery storage units of up to 4.5 m. It is noted that in accordance with FM Global's Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems (2023) the recommended minimum separation distance between the sides of lithium iron phosphate batteries containing access panels, doors or deflagration vents would be separated by at least 1.5 m (5 ft).
- A hardstand area for the centralised AC-coupled BESS of approximately 250 m by 170 m to allow for a separation distance between combustible vegetation and battery storage units of at least 3 m (10 ft) in accordance with NFPA 855 Clause 443.61.
- An asset protection zone (APZ) around the BESS compound of 10 m or greater.
- Access roads running between the PCSs within the BESS compound.
- An approximate stored energy density of per battery station of 16 kWh/m^2.

1.2.3 Combined Centralised and Decentralised BESS

A combined centralised and decentralised BESS with a total capacity of 1,570 MWh. The combined centralised and decentralised BESS would have a peak charge/discharge capacity of up to 555 MWp representing the combined peak discharge from both systems. This option would encompass the greatest area for placement of BESS infrastructure. However, all infrastructure is proposed to reside entirely within the existing Project Area and Development Footprint, as assessed under the EIS.

The location of the combined centralised AC-coupled BESS and the distribution of the decentralised DC-coupled battery stations is shown on **Figure 1.3**. It is considered that there will be sufficient area within the centralised AC-coupled BESS and each of the DC coupled battery stations to enable adequate separation distances between adjacent battery cabinets and other sensitive equipment to achieve non-propagation of thermal incidents.

As noted above, the final capacity and layout options of the BESS options is subject to detailed design and the supply of the battery storage units. Consent is sought for the implementation of both options.

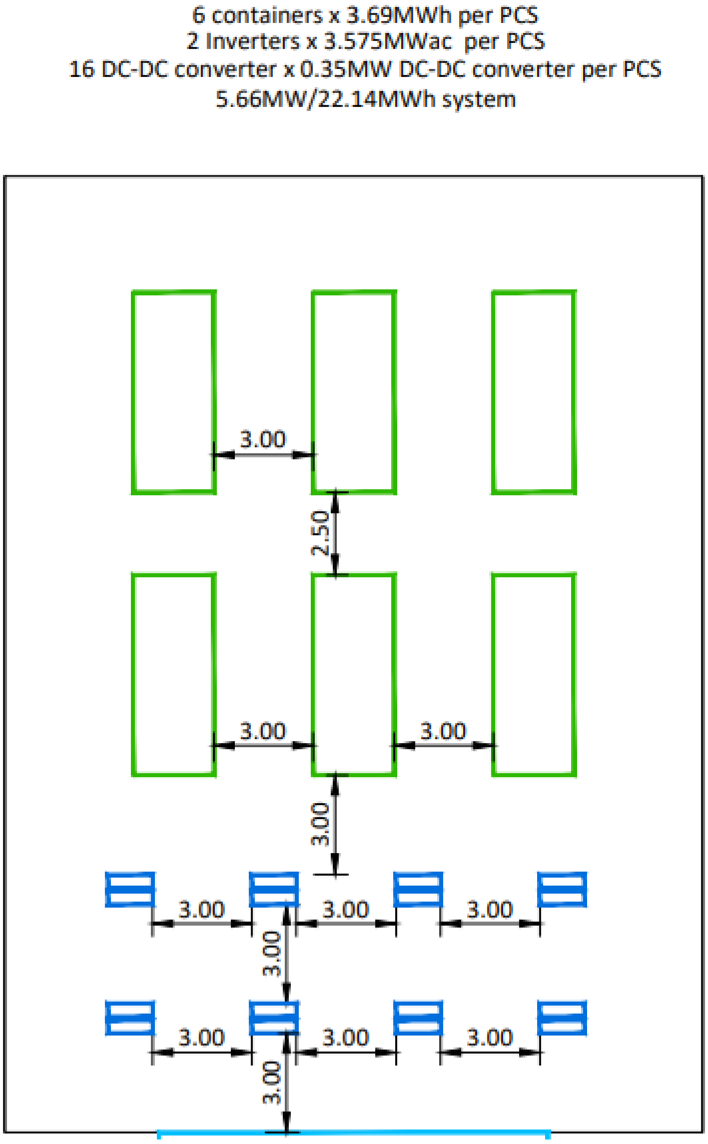

Figure 1.4 Conceptual Design of a Decentralised AC Coupled Battery Station

Figure 1.5 Conceptual Design of Centralised AC Coupled BESS

1.3 Purpose and Scope

This Preliminary Hazard Analysis (PHA) has been prepared by Umwelt (Australia) Pty Ltd (Umwelt), to satisfy the relevant Secretary's Environmental Assessment Requirements (SEARs) issued by the former Department of Planning and Environment (DPE) on 10 November 2022 and the requirements of *State Environmental Planning Policy (Resilience and Hazards)* 2021 (the Resilience and Hazards SEPP). The SEARs relating to this PHA are presented in **Table 1.2**.

It is noted that the SEARs to assess hazards and risks associated with electromagnetic fields and bushfire are not addressed in this PHA (other than bushfire as a potential initiating event). Hazards and risks associated with electromagnetic fields and bushfire have been separately assessed (refer to Project Environmental Impact Statement).

Table 1.2 Secretary's Environmental Assessment Requirements

Requirement	Where addressed in this report
Hazards – including:	
• a preliminary risk screening completed in accordance with the *State Environmental Planning Policy (Resilience and Hazards)*;	**Section 2.0**
• a Preliminary Hazard Analysis (PHA) prepared in accordance with *Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis* (DoP, 2011) and *Multi-Level Risk Assessment* (DoP, 2011). 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 *Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning* (DoP, 2011); and	This PHA **Section 4.3**, **Section 5.0** and **Section 7.0**
• 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*;	**Section 4.0** and **Section 5.0** Refer to Section 6.12 of the Project EIS
• identify potential hazards and risks associated with bushfires / use of bushfire prone land including the risks that a solar farm would cause bush fire and demonstrate compliance with *Planning for Bush Fire Protection 2019*;	Refer to Section 6.12 of the Project EIS.

In addition to the SEARs presented in **Table 1.2**, DPHI Industry Assessments has indicated that the PHA must also address the requirement presented in **Table 1.3**.

Table 1.3 DPHI Industry Assessments PHA Requirements

Requirement	Where addressed in this report
The PHA must:	
• Consider the most recent standards and codes such as and not limited to NFPA 855, AS 5139, IEC 62897, UL 9540, FM Global DS 5-33, and UL 9540A test reports when establishing separation distances;	**Section 4.3** and **Section 7.0**
• consider the scenarios and findings from the reports on the 2021 Victorian Big Battery fire, including fire propagation to the topside of the adjacent BESS subunits (containers, modules, etc.);	Refer to **Section 4.3** and **Appendix A**
• Demonstrate that the separation distances between BESS to on-site or off-site receptors and the separation distances between BESS sub-units (containers, modules, etc.) prevent fire propagation;	**Section 3.0** and **Section 4.3**
• Verify that the areas designated for BESS are sufficient taking into account separation distances between BESS sub-units; and	**Section 4.3**
• Demonstrate that the fire risks from BESS can comply with the Department's Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning.	**Section 5.0**

This PHA considers the hazards and risks posed to off-site receivers and dwellings associated with the transport, storage and use of hazardous materials for the Project and has been prepared in general accordance with and/or with reference to:

- *State Environmental Planning Policy* (Resilience and Hazards) (DPE, 2021)
- *Applying SEPP 33* (DoP, 2011a)
- *Multi-Level Risk Assessment* (DoP, 2011b)
- *Hazardous Industry Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning* (DoP, 2011c)
- *Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis* (DoP, 2011d).

In addition to the above guidelines and the requirement of the SEARs, this PHA has:

- Considered the standards and codes such as and not limited to NFPA 855, AS 5139, IEC 62897, UL 9540, FM Global DS 5-33, and UL 9540A test reports when establishing separation distances.
- Considered the scenarios and findings from the reports such as the 2021 Victorian Big Battery fire, including fire propagation to the topside of the adjacent BESS subunits (containers, modules, etc.).
- Demonstrated the area designated for BESS includes sufficient separation distances between BESS and on-site or off-site receptors to prevent fire propagation.

2.0 Preliminary Hazard Analysis

Under the Resilience and Hazards SEPP (DPE, 2021), a preliminary risk screening of a proposed development is required to determine the need for a PHA. The preliminary screening involves the identification and assessment of the storage of specific dangerous goods classes that have the potential for significant off-site effects. If, at the proposed location, and in the presence of controls, the risk level exceeds the acceptable criteria for impacts on the surrounding land use, the development is classified as 'hazardous' or 'offensive' industry and may not be permissible within most land use zones in NSW.

A 'hazardous industry' is one which, when all locational, technical, operational and organisational safeguards are employed, continues to pose a significant risk. An 'offensive industry' is one which, even when controls are used, has emissions which result in a significant level of offence e.g., odour or noise emissions. A proposal cannot be considered either hazardous or offensive until it is firstly identified as 'potentially hazardous' or 'potentially offensive' and subjected to the assessment requirements of the Resilience and Hazards SEPP. A PHA is required if a proposed development is assessed as 'potentially hazardous'. *Applying SEPP 33* (DoP, 2011a) contains a number of assessment criteria for the storage of hazardous materials that have the potential to create off-site impacts.

A proposed development may also be 'potentially hazardous' if the number of traffic movements for the transport of hazardous materials exceeds the annual or weekly criteria outlined in Table 2 of *Applying SEPP 33* (DoP, 2011a). If these thresholds are exceeded a route evaluation study is likely to be required.

Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis (HIPAP 6) (DoP, 2011d) and *Multi-level Risk Assessment* (MLRA) (DoP, 2011b) note that a PHA should identify and assess all hazards that have the potential for off-site impact. The expectation is that the hazards would be analysed to determine the consequences to people, property and the environment and the potential for hazards to occur.

The methodology used to identify and assess the potential Project hazards and respective failure scenarios that have the potential for off-site impact is outlined in **Figure 2.1** and is based on the methodology detailed in HIPAP 6 (DoP, 2011d) and MLRA (DoP, 2011b). The details of how this methodology is implemented are discussed in the respective sections of this report.

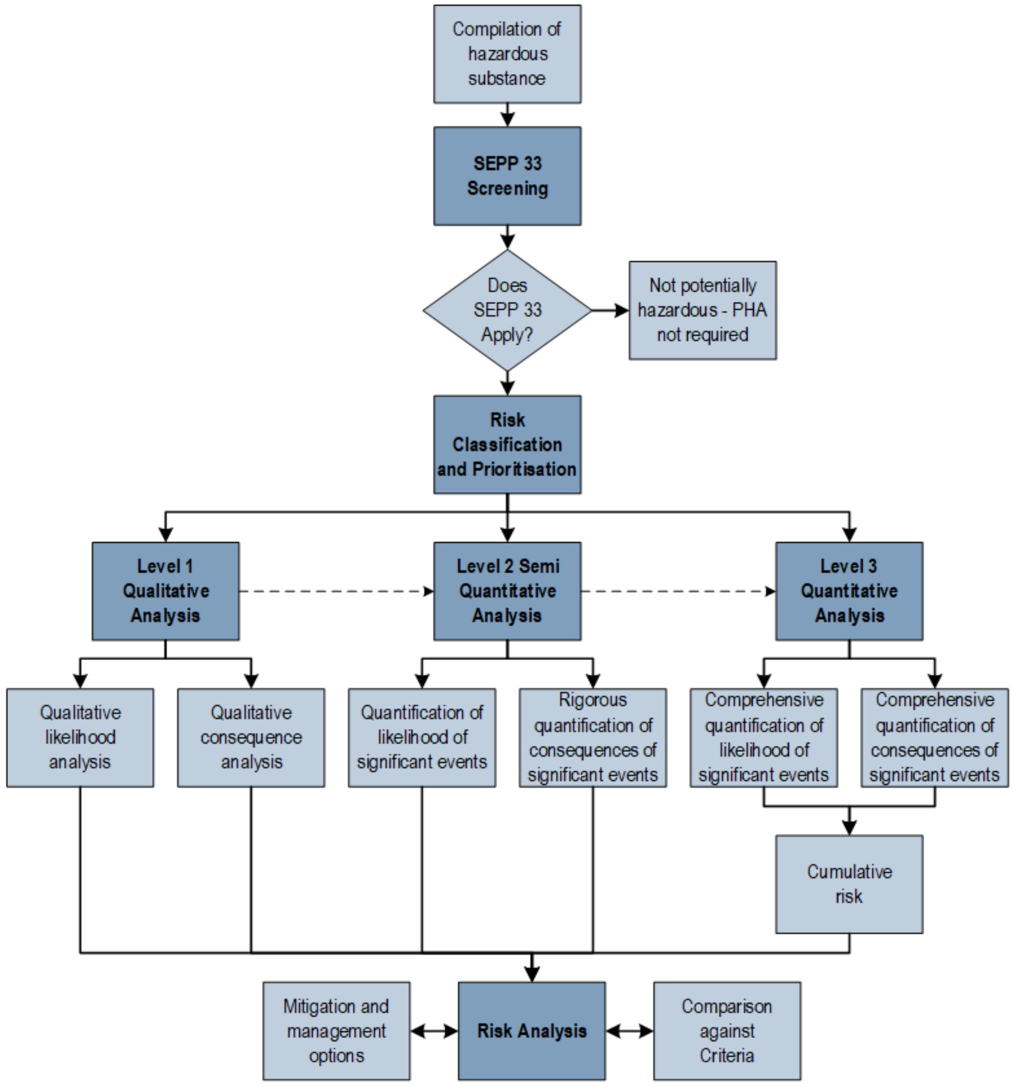

Figure 2.1 Overview of PHA Methodology

(adapted from Applying SEPP 33, MLRA, HIPAP 4 and HIPA6).

Preliminary SEPP 33 Screening
SEPP 33 Screening involves compiling information on the quantity of hazardous materials used, the mode of storage and location with respect to the site boundary and the number and size of annual and weekly road movements of the hazardous material.

A proposed development should be considered potentially hazardous and warrant further analysis if the storage or transport of hazardous substances exceeds the respective screening thresholds. If the storage or transport of hazardous substances does not exceed the thresholds then no further analysis is necessary and the safety management regime relies on observance of the requirements of relevant codes and standards.

Risk Classification and Prioritisation
Risk classification and prioritisation involves ranking of the facility using techniques to make broad estimates of the consequence and likelihood of accidents. The output may be expressed in terms of individual and societal risk and is compared against respective criteria to determine the appropriate level of analysis for further risk assessment.

Level 1 Analysis – Significant but not serious potential for harm
A Level 1 analysis is a qualitative assessment based on detailed hazard identification. The objective is to demonstrate that the activity does not pose a significant risk. Where the qualitative analysis cannot satisfactorily demonstrate there will be no significant risk, further analysis is required.

Level 2 Analysis – Medium potential for harm
A Level 2 analysis supplements the Level 1 analysis by quantifying the main risk contributors to show that their consequences are acceptable.

Level 3 Analysis – High potential for harm
A Level 3 quantitative analysis is required when the screening and hazard identification process and/or risk classification and prioritisation process has identified risk contributors with consequences beyond the site boundaries. The analysis requires a comprehensive quantification of significant consequences and their likelihood.

Risk Assessment
The Risk Assessment compares the results of the risk analysis with the respective risk criteria. Where the level of risk is not acceptable, risk minimisation, mitigation and management options need to be investigated.

2.1 Preliminary Risk Screening

Preliminary risk screening is undertaken to determine the requirement for a PHA. The Resilience and Hazards SEPP contains a number of assessment criteria for the storage and transport of hazardous materials that have the potential to create off-site impacts.

2.1.1 Storage Quantity Screening

The hazardous materials that will be stored and used for the Project are described in **Table 2.1**.

Table 2.1 Storage Quantities of Hazardous Materials

Hazardous Material	Quantity	Classification	Screening Threshold
Lithium-ion batteries (LIBs)	Approximately 6,280 t[2]	Class 9 miscellaneous dangerous good	NA
Electrical transformer insulating oil	Approximately 40,000 to 45,000 L (approximately 40 t based on an assumed specific gravity of 0.89)	Not classified as a dangerous good under the *Australian Code for the Transport of Dangerous Goods* (National Transport Commission, 2020)	NA

Neither the lithium-ion batteries (LIBs) nor the transformer insulating oil have relevant screening threshold in the Resilience and Hazards SEPP. However, the rapid proliferation of LIBs in portable devices, electric vehicles, energy storage systems and a range of other applications in recent years, presents unique fire and explosion hazards (Myers et.al 2020, Jeevarajan et.al 2022, Cozen et.al 2023, NFPA 2024)[3]. Jeevarajan et.al (2022) note that LIBs may present fire, explosion, and toxic gas release hazards as a result of manufacturing faults or a range of battery abuse scenarios (refer to **Section 4.3.1**), where the accumulation of combustible gases and the potential for thermal runaway can pose significant safety risks. Snyder and Thies[4] (2022) note that the failure of a battery is often accompanied by the release of toxic gas, fire, jet flames, and explosion hazards, which present unique exposures to workers and emergency response personnel.

In large grid-size BESS installations, the scale and complexity of the system increase the potential hazards associated with LIBs (Jeevarajan et.al, 2022). The larger number of cells and modules in large installations increases the potential for thermal runaway and the release of toxic and combustible gases. Additionally, the challenge of managing and suppressing a fire in a large system is more pronounced due to the complex geometry of the installations and the need for effective fire protection systems.

[2] Mass estimated based on 0.25 kWh/kg for a LIB cell from Bravo Diaz et al. (2020) and a total BESS capacity of 1,570 MWh combined operational capacity.

[3] Myers, T. I., Yen, M., Mendoza, S., & Ibarreta, A. F. (2020). *Mitigating the Hazards of Battery Systems*. Chemical & Engineering News, 98(19), 31–35.
Jeevarajan, J. A., Joshi, T., Parhizi, M., Rauhala, T., & Juarez-Robles, D. (2022). *Battery hazards for large energy storage systems*.
Conzen, J., Lakshmipathy, S., Kapahi, A., Kraft, S., & DiDomizio, M. (2023). *Lithium-ion battery energy storage systems (BESS) hazards*. Journal of Loss Prevention in the Process Industries, 81, 104932.
US National Fire Protection Association (NFPA) 2023: *Energy Storage Systems Safety Fact Sheet*.

[4] Snyder, M., & Theis, A. (2022). *Understanding and managing hazards of lithium-ion battery systems*. Process Safety Progress, 41(3), 440–448.

Applying SEPP 33 (DoP, 2011a) indicates that the risk screening process for determining if a proposal is 'potentially hazardous' under the Resilience and Hazards SEPP should not be used in isolation and 'other factors' should be taken into account. While *Applying SEPP 33* (DoP, 2011a) does not define 'other factors', the potential for hazardous events such as fire, explosion and toxic release involving LIBs and the large scale of the Project BESS (i.e., up to 1,600 MWh total storage capacity) are considered to be relevant. Further, given the limited global experience with large capacity, grid connected LIB BESSs, and to maintain a conservative approach with respect to the assessment of hazards and risk, further assessment is considered appropriate.

2.1.2 Transport Screening

As with the storage of LIBs and transformer insulating oil, there are no transport screening thresholds in *Applying SEPP 33* (DoP, 2011a) for either of these hazardous materials. The transportation of LIBs to the site in significant quantities and at a relatively high frequency will only occur during Project construction and decommissioning. Deliveries of LIBs to replace failed units will occur only in relatively small quantities and at less frequent intervals than during Project construction. LIBs will be transported to the site by a suitably accredited freight company using dangerous goods licensed vehicles and drivers.

The transportation of transformer insulating oil to the Project will only occur in significant quantities during Project construction and maintenance when the oil is replaced to ensure safe and efficient transformer operation. Delivery of transformer insulating oil to the Project site during operations will be very infrequent.

Based on the very low frequency of transport LIBs and transformer insulating oil to the Project site following the completion of construction, no further assessment of transport risks (e.g., a transport route analysis) is considered necessary for the LIBs and transformer insulating oil.

Other hazardous materials with SEPP 33 screening thresholds (e.g. flammable liquids within paints, compressed gases, herbicides) will be transported to the Project in quantities and at frequencies below screening thresholds.

3.0 Level of Assessment

MLRA (DoP, 2011b) suggests the use of a preliminary analysis of the risks related to a proposed development to enable the selection of the most appropriate level of risk analysis in the PHA.
This preliminary analysis includes risk classification and prioritisation using a technique adapted from the *Manual for classification of risks due to major accidents in process and related Industries* (International Atomic Energy Agency (IAEA), 1996). A complete description of the technique is presented in the MLRA (DoP, 2011b). The technique is based on a general assessment of the consequences and likelihoods of accidents and their risks to individuals and society, and the comparison of these risks to relevant criteria to determine the level of assessment required, be it qualitative or quantitative.

While not directly applicable to LIBs, Umwelt has applied the MLRA (DoP, 2011b) technique while preparing PHAs for other renewable energy projects involving a LIB BESS, conservatively treating the LIBs as a source of toxic gas. It has been found the application of the MLRA (DoP, 2011b) technique is overly conservative, typically resulting in a requirement for a Level 2 semi-quantitative assessment. Notwithstanding this, the MLRA (DoP, 2011b) risk classification and prioritisation methodology can be used to inform the appropriate level of analysis required for a development when coupled with an understanding of the unique site-specific characteristics of a development.

For this Project, the preliminary screening process used the risk classification and prioritisation process to initially inform the Level 1 qualitative analysis. This involved:

- classification of the type of activities and materials inventories
- estimation of probabilities of major accidents for fixed installations
- estimation of consequences
- evaluation of alternatives
- risk classification.

The credible hazard scenarios for the Project are:

- a LIB container rack fire
- a LIB container module vapour cloud explosion (VCE)
    - generation of gas from a sufficient number of battery cells to form a significant mass of flammable gas due to overheating/thermal runaway
    - ignition of gas.
- a toxic release of toxic gas (hydrogen fluoride (HF)) associated with a LIB container module fire/thermal runaway event.

MLRA (DoP, 2011b) notes that a Level 1 qualitative assessment is appropriate if:

- The frequency and number of individuals that could suffer a specified harm (i.e. the societal risk) is negligible. This relates to the proximity to dwellings and sensitive adjoining land use rather than the distance to the site boundary.
- There is no event consequence extending significantly beyond the site boundary at a frequency of greater than 1×10^{-7} accidents per year. Typically associated with adequate separation distances between BESS units to ensure non-propagation of events.
- The process/operation is well understood and covered by established and recognised standards and codes of practice. Demonstrated through the adoption of best practice in design and operation.

When the qualitative analysis can demonstrate there will be no significant risk to adjoining land uses by satisfying the above requirements a higher level of analysis will not be required.

However, a level 2 assessment should be completed with sufficient quantification of risk to demonstrate that the nominated risk criteria will be met. A full level 2 assessment is required when the preliminary assessment shows the potential for harmful off-site effects for events and scenarios that could be relatively frequent[5]. The aim of the full level 2 assessment is to demonstrate that all relevant numerical risk criteria will be met.

If there is the potential for off-site consequences from a hazardous event but the likelihood is relatively low, a Level 2 consequence analysis can be used to demonstrate that the potential for harmful off-site effects for the event does not extend to sensitive receiver locations.

5 'Relatively frequent' is triggered by a frequency of possible occurrence of greater than 10 e^{-7} in a Level 2 Semi-quantitative Analysis, based on the MLRA (DoP, 2011b).

4.0 Level 1 Qualitative Risk Analysis

MLRA sets out criteria for using the results of the risk screening, classification and prioritisation process to determine which of three levels of further analysis is appropriate. A Level 1 qualitative assessment is based on a comprehensive hazard identification process that is used to demonstrate that the activity does not pose a significant off-site risk. However, as indicated in **Section 3.0**, a higher level of analysis may be required if the qualitative analysis cannot demonstrate there will be no significant risk of off-site consequences.

4.1 Methodology

A Level 1 assessment requires (as a minimum):

- hazard identification using word diagrams, simplified fault/event trees and checklists
- identification of key scenarios and qualitative assessment of risks
- HIPAP 4 recommends the risk associated with a development should be evaluated against the following qualitative criteria:

  a. *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.*

  b. *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 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.*

  c. *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.*

  d. *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.*

- demonstration of adequacy of the proposed technical and management controls to ensure ongoing safety of the proposed development
- should include all facilities which reported exceedances of initial screening thresholds.

4.2 Level 1 Risk Analysis Scoring Criteria

The risk scoring criteria from Australian Standard *AS 4360:2004 – Risk Management*[6] were adopted for this Level 1 assessment. The criteria for consequence severity, frequency estimation and the associated risk matrix used in the Level 1 assessment are presented in **Appendix A**.

4.3 Hazard Identification

4.3.1 Lithium-Ion Batteries

The primary hazardous materials of concern to be located at the Project site are LIBs. LIBs comprise of:

- an anode (typically graphite) with a copper current collector
- a cathode (e.g., 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., $LiPF_6$) dissolved in a flammable hydrocarbon solvent (e.g., one part Ethylene Carbonate and two parts Diethyl Carbonate).

To inform the Level 1 assessment, a detailed description is provided in **Appendix A** on:

- The potential hazards associated with lithium-ion and the mechanisms that can lead to LIB thermal runaway, venting of vaporised electrolyte and decomposition products that could result in a fire, explosion and toxic gas hazards.
- Findings and learnings from recent BESS hazardous events such as the Victorian Big Battery Fire and the McMicken Battery Storage Facility System Explosion that have led to improvements in design standards.
- LIB fires and the range of effective suppressants options available when extinguishing a fire.

4.3.2 Project Batteries and Energy Density of BESS

The LIB cell type that will most likely be utilised at the Project will be a LFP, which is considered to have greater thermal stability compared to other typical LIB cell types (e.g. LCO, LMO or NMC[7]).

The locations of the proposed AC Coupled battery stations that make up the decentralised BESS and the location of the AC Coupled BESS is shown in **Figure 1.3**. The centralised BESS compound will have a footprint capable of housing up to 208 containerised battery storage units. For the decentralised BESS, up to 22 containerised battery storage units will be distributed through the Project site within 37 battery stations. Pending finalisation of the contract for the supply of the batteries, the Project BESS could consist of up to 484 if Option 3 is implemented with a total aggregate operational energy storage capacity of 1,810 MWh.

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6 The risk scoring criteria of AS 4360:2004 was adopted as the current AS 31000:2018 Risk management – Principles and guidelines does not include criteria.

7 LCO batteries use lithium cobalt oxide (LiCoO2) in the cathode, LMO batteries use a lithium manganese oxide (LiMn2O4) in the cathode while NMC batteries have a cathode made of a combination of nickel, manganese and cobalt.

The proposed space between facing battery storage units will be at least 3.0 m, shown in **Figure 1.4**. It is noted that in accordance with FM Global's Property Loss Prevention *Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (2023) the recommended minimum separation distance between the sides of LFP batteries containing access panels, doors or deflagration vents would be separated by at least 1.5 m (5 ft). The battery storage units will be/have been subject to testing under UL9540, UL 9540A and UL855 to determine the minimum separation distance between units to prevent propagation of thermal runaway events from unit to unit.

The proposed centralised BESS footprint will be a fenced compound with an area of approximately 40,600 m^2 which includes the access roads running between the banks of batteries that make up the BESS and a 10 m APZ. Based on an operational capacity of the centralised BESS of 650 MWh, the approximate stored energy density will be 16 kWh/m^2.

The proposed decentralised BESS footprint will be distributed across 46 battery stations each with six (6) containerised battery storage units on a hardstand area of 750 m^2. Each battery stations will have an operational capacity of 25 MWh, and an approximate stored energy density will be 34 kWh/m^2.
Each battery station will have a cleared area of at least 3 m around the containerised battery storage units and inverter transformers and least 5 m to the nearest PV arrays.

Given the relatively low energy density of the proposed Project, it is considered that there will be sufficient space to enable adequate separation between containerised battery storage units, as well as to other sensitive equipment to achieve non-propagation of thermal incidents.

The fire safety strategy for the BESS will be determined during the detailed design phase and preparation of a Fire Safety Study (FSS) for the Project.

4.3.3 Electrical Transformers

The Project substation will include a 33/330 kV substation and switchyard including ancillary infrastructure to connect to an existing 330kV transmission line. The substation will incorporate two (2) 330/33kV oil-filled electrical transformer. The substation transformer will contain mineral oil. The primary function of the mineral oil is to insulate and cool the transformer. Mineral oils are stable at high temperatures, have greater electrical insulating and thermally conductivity properties, but are combustible with a 'fire point' less than 300°C.

Leakage of substation transformer oil can result in environmental impacts due to toxicity and fire and/or explosion accidents should leaking oil directly contact high-voltage elements or other ignition sources. Under abnormal operating conditions when the internal temperature of a transformer reaches 150 to 300°C the mineral oils produce hydrogen and methane gases due to chemical decomposition (El-Harbawi & Fahad Al-Mubaddel, 2020). When temperatures exceed 300°C ethylene is formed, and large amounts of hydrogen and ethylene are produced when temperatures exceed 700°C (El-Harbawi & Fahad Al-Mubaddel, 2020). While contained in the transformer, these gases tend to dissolve in the mineral oil but will form flammable mixtures if released from the transformer oil compartment, potentially resulting in fire or explosion events (El-Harbawi & Fahad Al-Mubaddel, 2020).

The Project BESS units will be connected to 128 external inverter and transformer units. The transformer oil used in the BESS transformers will most likely be a synthetic oil. Synthetic oils have a 'fire point' greater than 300°C and a higher flashing point than mineral oils making them safer to use in potentially hazardous areas.

It is anticipated there will be 40,000 to 45,000 L of transformer oil on the site.

4.4 Hazard Study

Credible hazardous events and scenarios were identified for potential hazardous events that could have off-site impacts. The identified hazard and risk scores are attached in **Appendix A**.

The credible hazardous events scenarios associated with the BESS and substation with the potential for off-site consequences are:

- a LIB fire
- a LIB vapour cloud explosion that requires:
  - the generation of gas from a sufficient number of cells to form a significant mass of flammable gas due to thermal runaway within the BESS container
  - ignition of the vapour cloud.
- a toxic release of HF associated with a thermal runaway event in a LIB
- a transformer fire or explosion.

The consequences (thermal radiation, explosion overpressure and toxic gas concentrations) associated with a BESS hazardous event are expected to be relatively near field (i.e. less than 100 m). A total of 109 existing dwellings were identified within 4 km of the Project Area, including 22 potential future dwellings. **Table 4.1** provides distances to the nearest receiver locations from the BESS. **Figure 4.1** shows the relative locations of the dwellings listed in **Table 4.1**

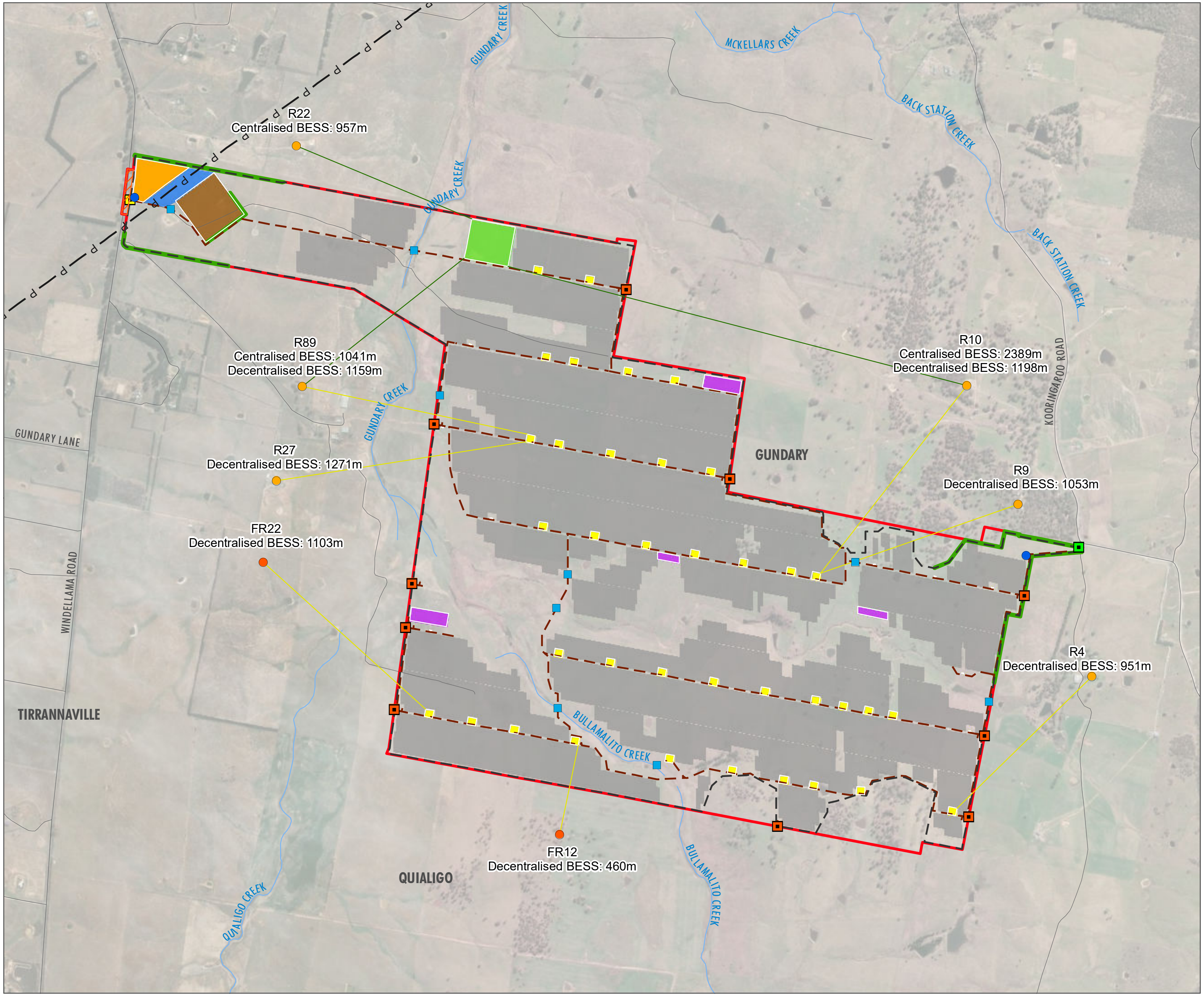
Table 4.1 Distances from Nearest Receiver

Receiver	Type	Centralised BESS		Decentralised BESS	
		Direction from BESS	Distance from BESS (m)	Direction from nearest Battery Station	Distance from nearest Battery Station (m)
R89	Commercial – Involved Dwelling	SW	1,050	W	1040
R22	Residential Dwelling	WNW	960	WNW	960
R27	Residential Dwelling	SSW	1,470	WSW	1,270
R9	Residential Dwelling	ESE	2,800	ENE	1,050
R4	Residential Dwelling	SE	3,600	NE	950
FR12 [1]	Vacant land	SSE	2,900	S	460

Note [1] *Location of potential future dwelling.*

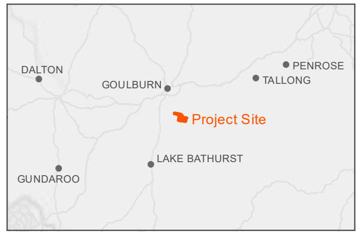
FIGURE 4.1

Dwellings and BESS Separation Distances



Legend

- Existing Dwelling (6)
- Potential Future Dwelling (2)
- Access Roads
- Security Fence
- Existing Transmission Line
- Solar Panels
- Roads
- Watercourses
- Watercourse / Bed Level Crossing
- Water Tank
- Primary Site
- Emergency Access and
- Emergency Gate
- Project Area
- Proposed Road Upgrade
- Landscaping Buffer (5m)
- Transgrid Line Works
- Centralised AC
- Substation and O&M Facility Area
- Construction Compound Area
- Decentralised DC BESS
- Temporary Laydown Area



0 500 1,000

Metres

Scale: 1:0 at A4

GDA2020 MGA Zone 55

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Image Source: ESRI Basemap (2023) | **Data Source:** NSW DFSI (2023)

The centralised BESS compound will be located 30 m from the northern perimeter fence, 610 from the eastern perimeter fence, 430 m from the southern perimeter fence, 1,720 m from the western perimeter fence and 960 m from the nearest off-site dwelling. There will also be a 10 m wide bush fire APZ on the northern and western boundary of the BESS compound. As such, it is considered that further analysis of off-site thermal radiation impacts associated with the BESS is not required.

The closest decentralised BESS battery stations to the perimeter fence of the Project will are 45 m from the northern perimeter fence, 70 m from the eastern perimeter fence, 160 m from the southern perimeter fence, 160 m from the western perimeter fence. The closest decentralised BESS battery stations to dwellings are 950 m from the nearest off-site dwelling and 460 m from the nearest off-site potential future dwelling. Each of the decentralised BESS battery stations will have a cleared area around the battery storge units of at least 3 metres. There will also be a 10 m wide bush fire APZ around the entire Project site. As such, it is considered that further analysis of off-site thermal radiation impacts associated with the BESS is not required.

While potential injurious or fatal impacts associated with a BESS explosion resulting from a LIB thermal runaway could extend beyond the site boundary, the impacts are not considered likely to extend to the nearest off-site dwelling. The dwelling nearest to the centralised BESS (R22) and decentralised BESS (R4) are located approximately 950 m away. A potential future dwelling on currently vacant land may also be located 480 m from the nearest decentralised BESS. It is also noted that the contemporary design of BESS units further mitigates the potential of a BESS explosions by including:

- IP66 rated water resistant enclosures that have a natural ventilation flow path that safely exhausts flammable gases, products of combustion, and flames through the roof during a thermal event
- passive overpressure vents not actuated or controlled by another device
- passive overpressure vents designed to relieve with a safety factor that reduces the risk of a deflagration or explosion from compromising the cabinet’s integrity, push open the front doors, or expel projectiles from the cabinet.

As a hazardous event involving a deflagration or explosion event does not pose a significant off-site risk no further analysis of the explosion scenarios is warranted.

Depending on the selection and design of the BESS module bays/containers, potential injurious impacts associated with the release of toxic gases during LIB thermal runaway could extend beyond the site boundary. While the impacts are not considered likely to extend to the nearest dwelling due to the contemporary design of BESS module bays, further analysis of the toxic release scenarios is warranted due to the accessibility of the northern and western BESS perimeter fence line.

While the hazard study also identified a transformer fire as a scenario with the potential for off-site impacts, it was considered that substation design, installation, commissioning, operation and maintenance of the transformers in accordance with relevant Australian Standards will be adequate to ensure off-site risks are acceptable. The substation layout and plant installed will also comply with any specific development, regulatory, environmental or TransGrid design requirements applicable to the construction of the substation. Further, the substation and associated transformers will be at least 100 m from the southern property boundary, at least 50 m from the northern property boundary and at least 380 m from the nearest dwellings, R25 to the south of the substation and R21B to the north of the substation.

4.5 Qualitative Analysis

Based on the results of the hazard identification study, the qualitative analysis cannot demonstrate that there will be no off-site consequences that could impact sensitive adjoining land uses. The results of the Level 1 Qualitative Analysis indicate a Level 2 Semi-Quantitative Risk Assessment of the potential impacts associated with the release of toxic gases during LIB thermal runaway and a Level 2 Semi-Quantitative Risk Assessment associated with LIB fire is warranted.

5.0 Semi Quantitative Risk Analysis

Based on the outcomes of the Level 1 Qualitative Risk Analysis the following hazardous event has been further assessed:

- a release of toxic gas associated with a thermal runaway event in LIB
- a LIB fire.

Based on the application of semi-quantitative consequence analysis described in **Section 3.0** a toxic gas release event of HF has been modelled using the BREEZE® software to determine the minimum required distance that LIB battery units should be setback from the nearest dwellings to ensure the risk criteria provided in HIPAP 4 are met.

5.1 Consequence Analysis – Toxic Gas

Acute Exposure Guideline Levels[8] (AEGLs) may be used by emergency planners and responders worldwide to guide land use planning for installations that have the potential to accidentally release hazardous chemicals into the air. AEGLs are expressed as specific concentrations of airborne chemicals, that when exposed to for a given period of time, are likely to cause health effects in the elderly, children and other individuals who may be more susceptible than the majority of the population.

AEGLs are calculated for five relatively short exposure periods – 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours with AEGL 'levels' dictated by the severity of the toxic effects caused by the exposure. Level 1 AEGLs are the least severe and Level 3 are the most severe (refer to **Table 5.1**).

Table 5.1 Acute Exposure Guideline Levels and Health Effects

AEGL	Health Effect
1	Notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
2	Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
3	Life-threatening health effects or death.

Source: Acute Exposure Guideline Levels, United States Environmental Protection Agency, 2021.

As mentioned, AEGL values represent threshold levels for the general public that includes susceptible subpopulations, such as infants, children, the elderly, persons with asthma and those with other illnesses. It should, however, be noted that individuals subject to unique or idiosyncratic responses could experience the effects described in **Table 5.1** at concentrations below the corresponding AEGL.

8 The Acute Exposure Guideline Levels (AEGL) are similar but not the same as the Emergency Response Planning Guideline (ERPG) Levels. AEGL are expressed as exposure levels for periods of 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours. ERPG levels are the maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hour.

As discussed in **Section 4.3.1** LIBs in a thermal runaway event are known to release a range of toxic gases, in particular fluoride gas species. Of the identified toxic gas species that may be released during a LIB thermal runaway/fire event with LFP type cells (i.e. the cells that are likely to be used in the Project), HF is the most toxic gas likely to be present in a significant release event (refer to **Section 4.3.1**). As such, the toxic gas release consequence assessment has been based on HF emissions. **Table 5.2** presents the HF concentrations corresponding to the respective AEGL health effects for a one-hour exposure.

Table 5.2 Acute Exposure Guideline Levels – One-hour Exposure to Hydrogen Fluoride (HF)

AEGL	Health Effect	HF Concentration (ppm)
1	Irritation	1
2	Injury	24
3	Life-threatening health effects	44

Source: Acute Exposure Guideline Levels, United States Environmental Protection Agency, 2021.

Given the highly toxic nature of HF, the consequence assessment for a toxic release scenario has been based on a release of HF. It is considered that if HIPAP 4 criteria are satisfied for a HF release then the criteria will be satisfied for other less toxic gases[9]. The research indicates the complexity of the cell design and materials of construction influence the gas emitted and the gas emission rate. The following information demonstrates the variability in the research information available:

- The maximum emission rate of HF derived from experimental data by Larsson et al. (2017)[10] from a battery pack with an energy capacity of 128 Wh and nominal capacity per LFP battery cell of 20 Ah in a thermal runaway/fire event was 198 mg/Wh.
- The experimental emission data reported by Larsson et al. (2017) does not indicate a relationship between HF emission rate and battery cell Ah capacity but with the burn rate of the battery cell (Wh/s). As such, the maximum HF emission rate was conservatively nominated at 200 mg/Wh burnt.
- The burn rate of a 100 kWh LIB module with LFP battery cells reported from experimental data by Fire Protection Research Foundation (2016)[11] was 7.4 Wh/s.
- Contemporary testing of BESS module bays indicates:
    - Fire propagation testing at a cell and modular level to UL 9540A identified the generation of carbon monoxide, carbon dioxide, hydrogen, methane, acetylene, ethylene, ethane, propene, propane, benzene, and toluene were detected at various percentages.
    - Fire propagation testing at a cell and modular level to UL 9540A does not always result in the generation of toxic gases such as HF and HCN.

A representative HF emission rate was determined based on data published by Larsson et al. (2017), the Fire Protection Research Foundation (2016) and commercial-in-confidence, manufacturer's data. The representative HF emission rate was used to simulate a toxic gas release associated with two conceptual thermal runaway events, using the AFTOX Gaussian plume dispersion model in the BREEZE® software.

9 It is noted that the potential cumulative effects of different toxic gases have not been fully evaluated (Peng et al., 2020).
10 *Toxic fluoride gas emissions from lithium-ion battery fires* (Larsson et al., 2017).
11 *Hazard Assessment of Lithium Ion Battery Energy Storage Systems* (Fire Protection Research Foundation, 2016).

The assumptions associated with the two conceptual thermal runaway events based on the Fire Protection Research Foundation (2016) research are described as follows:

- Event 1 – the failure of multiple cells within the tray of a battery module. The proposed thermal runway of the cells does not propagate to other cells within the module tray, or trays within the module.
- Event 2 –the worst-case catastrophic failure of multiple cells within the tray leading to the failure of the entire tray and propagation of fire to the battery module, the cabinet bay and then the section of the cabinet containing the bay.
- HF is released as a non-buoyant plume.
- Adverse meteorological conditions with a stability class of F (moderately stable) and a wind speed of 1.5 m/s (at a height of 10 m).

The expected consequences associated with exposure to AEGL concentrations for individuals within the concentration impact distance are detailed in **Appendix B** and outlined in **Table 5.3**.

Table 5.3 Modelled Distance to Hydrogen Fluoride 1-hour AEGL Concentrations

AEGL	Health Effect	Modelled Distance to AEGL for HF Emission, m	
		Event 1 – Cell Fire	Event 2 – Cabinet Fire
1	Irritation	26	575
2	Injury	-	57
3	Life-threatening health effects	-	33

For the worst-case scenario, the maximum distance at which an individual exposed to HF emissions from a battery storage facility toxic release event could experience an injury (i.e. exposure to the AEGL Level 2 concentration of 24 ppm for 60 minutes) is estimated to be 57 m.

5.1.1 Discussion

Based on the dispersion modelling of the HF, the potential injurious impacts for the worst-case scenario of a toxic gas release resulting from a LIB thermal runaway described in **Section 5.1** as Event 2 is not considered likely to extend to the nearest off-site dwelling. The dwelling nearest to a battery storage unit is R4 located approximately 950 m to the northeast of the battery station in the southeast corner of the Project Site. The estimated maximum 1-hour concentration of HF under stability F class conditions with a 1.5 m/s south-westerly wind at dwelling R4 for the worst-case scenario would be less than 1 ppm (which is unlikely to result in irritation or discomfort as per **Table 5.2**).

The ongoing development and testing of BESS battery systems (cells, trays, modules, bays and cabinets) is systematically reducing the likelihood of a thermal runaway of multiple cells within the tray leading to the propagation of fire to the battery module, the cabinet bay and then the section of the cabinet containing the bay. Based on the ongoing development of BESS battery systems, the more likely event leading to a toxic gas release resulting from a LIB thermal runaway, described in **Section 5.1** as Event 1, is unlikely to extend beyond the Project boundary.

5.2 Consequence Analysis – LIB Fire

This section details the methodology and results for the estimation of thermal radiation impact distances associated with a BESS fire scenario.

5.2.1 Impacts of Thermal Radiation Exposure

Table 5.4 presents the likely effects of various levels of thermal radiation on individuals and structures.

Table 5.4 Consequences of Thermal Radiation

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

Source: HIPAP No 4 – Risk Criteria for Land Use Safety Planning (DoP, 2011).

5.2.2 Fire Event Modelling

Fire scenario modelling was undertaken to estimate the incident heat flux experienced by a receiver at varying distances from:

- the end of a BESS container (2.4 m wide x 3.0 m high)
- the side of a BESS container (6 m long x 3.0 m high).

The emitted heat flux from the BESS container was estimated using the Stefan – Boltzmann equation based on the following conservative assumptions:

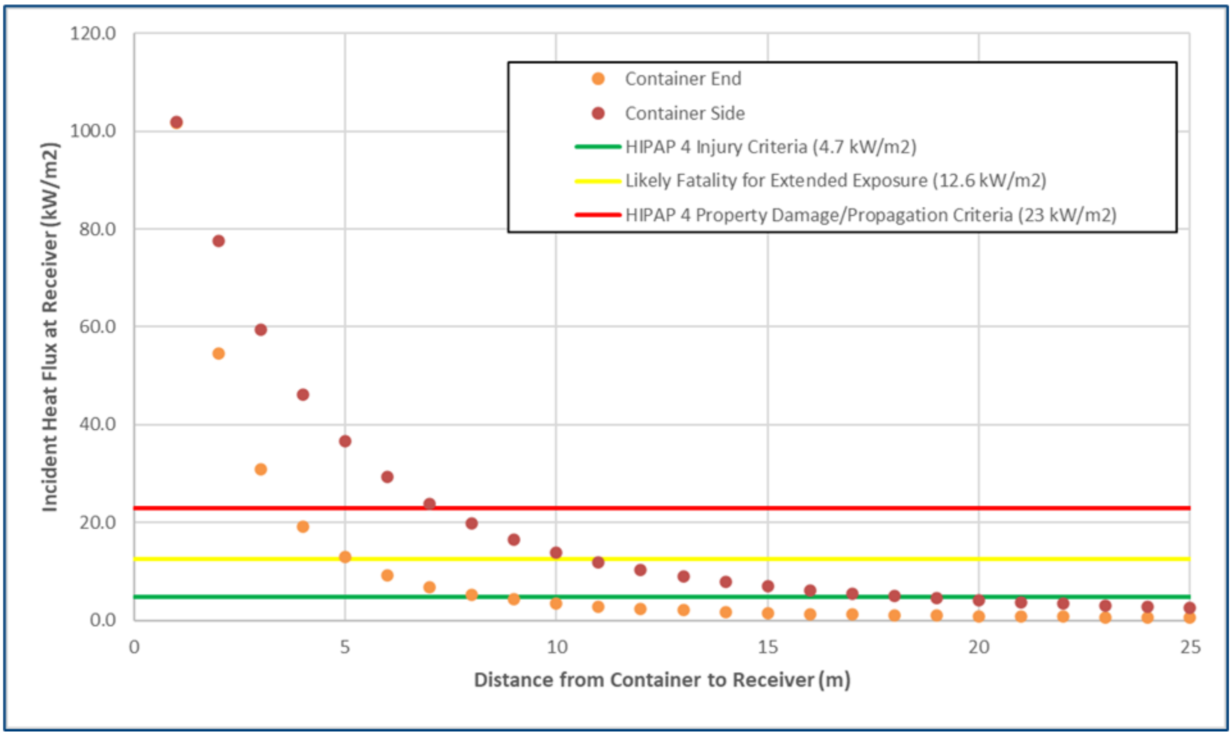
- an emitting surface temperature of 1,000°C (1,273.15 K)
- a surface emissivity of 1 (i.e. a black body).

Incident heat flux was estimated based on the estimated emitted heat flux from the BESS container and the configuration factors determined at varying distances from the centreline of the container end or side.

Incident heat flux results showing the heat flux at varying distance from the BESS container are presented in **Graph 5.1** and the radiation calculations are contained in **0**.

The results in **Graph 5.1** indicate:

- that the incident heat flux falls below the HIPAP 4 (DoP, 2011) property damage and propagation criteria of 23 kW/m^2 at a distance of approximately 8 m from the side of the container
- that the incident heat flux falls below the HIPAP 4 (DoP, 2011) property damage and propagation criteria of 23 kW/m^2 at a distance of approximately 4 m from the end of the container
- that the incident heat flux falls below the heat flux at which likely fatality will occur of 12.6 kW/m^2 at a distance of approximately 11 m from the side of the container
- that the incident heat flux falls below the heat flux at which likely fatality will occur of 12.6 kW/m^2 at a distance of approximately 6 m from the end of the container
- that the incident heat flux falls below the HIPAP 4 (DoP, 2011) injury criteria of 4.7 kW/m^2 at a distance of approximately 19 m from the side of the container
- that the incident heat flux falls below the HIPAP 4 (DoP, 2011) injury criteria of 4.7 kW/m^2 at a distance of approximately 9 m from the end of the container.



Graph 5.1 Incident Heat Flux at Varying Distance from BESS Container Fire

The expected consequences associated with exposure to each level of thermal radiation for individuals and structures within the impact distance are outlined in **Table 5.4**. The maximum distance at which an individual exposed to thermal radiation from a BESS fire could experience an injury based on HIPAP 4 injury criteria (4.7 kW/m2) is estimated to be 19 m, well within the Project boundary.

6.0 Risk Assessment

As indicated in **Section 4.1**, a Level 1 qualitative analysis requires evaluation against the HIPAP 4 qualitative criteria. **Table 6.1** presents an evaluation of the Project risks with respect to HIPAP 4 criteria.

Table 6.1 Qualitative Risk Evaluation

Qualitative Criteria	Project Risk Evaluation
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 Project does not involve the use of any hazardous materials or equipment that is not necessary to deliver the required Project outcomes (i.e. electrical energy storage and electricity supply). While there are hazards associated with the battery technology (LIBs) proposed (i.e. fire, explosion and toxic gas), this technology was selected as it has proven to be an effective and reliable option. It is also considered that with appropriate design, installation and maintenance, the associated hazards with LIBs can be safely managed. The hazardous components of the Project are located at distances greater than the expected impacts of a credible hazard event from the nearest dwelling (refer to **Section 4.4**). It is considered that all 'avoidable' risks have been avoided and the Project location is appropriate.
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 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.	The Project will implement a range of technical and non-technical measures to minimise the likelihood of a hazardous event involving the BESS and substation. These measures are outlined in **Section 7.0** and it is considered that they will, as far as practicable, ensure that the likelihood of hazardous events involving the BESS and substation are very low.

Qualitative Criteria	Project Risk Evaluation
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.	Based on the location of the centralised BESS, decentralised BESS battery stations and substation, it is possible that the impacts of a toxic release could extend off-site. The adjacent land is farmland with the nearest dwelling (R9) is approximately 130 m from the Project boundary. While it is considered the consequences of toxic gas release is low at the nearest dwelling, the scenario warranted further investigation. The modelling of a worst-case scenario determined maximum HF concentrations at dwelling R4 would be less than 1 ppm under stability F class conditions with a 1.5 m/s south westerly wind. 1ppm is the level 1 AEGL (Acute Exposure Guideline Level) where irritation can occur. In the contemporary designs of LFP battery cells the generation of toxic gases such as HF during a thermal runaway event has been significantly reduced from the emission rates report by Larsson et al. (2017).
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.	There are no other high risk hazardous installations within the vicinity of the Project that would contribute to an increase in cumulative off-site risk. Given the Project location, no future potentially hazardous industry development that would contribute to an increase in cumulative off-site risk is considered likely.

6.1 Environmental Impacts

As indicated in **Section 5.0**, a LIB BESS will generate toxic air emissions during a possible thermal runaway incident. This toxic plume has the potential to impact off-site receivers and first responders, with the quantity of LIB cells involved in the incident and meteorological conditions influencing the extent and location of the affected area. Therefore, the risk of potential toxic impacts to off-site receivers and first responders can be limited by limiting the quantity of LIB cells involved in a thermal incident (i.e. ensuring non-propagation between adjacent modules, racks and units/containers) and selecting an appropriate location for the LIB BESS with first responder access and egress to the LIB BESS from alternate directions (i.e. to allow access and egress via upwind direction).

If the fire safety strategy relies on the application of water for suppression of the thermal incident, the facility design must incorporate fire water containment with sufficient capacity to capture all contaminated fire water runoff for the expected duration of the incident. Consideration should also be given to the LIB BESS location with respect to drainage pathways to receiving waterways in the event the capacity of the fire water containment system is exceeded.

6.2 Emergency Response

HIPAP 1 emphasises the importance of the Emergency Plan (EP) encompassing the emergency response role of public authorities, such as the Police, Fire and Rescue, and statutory authorities such as the departments responsible for planning approvals and for environmental protection. The EP should also provide specific recommendations for first responders. HIPAP 1 recommends the preparation of information supporting the EP that is essential for emergency services be included as an attachment to the EP. This would be available as a separate information package to be given to the emergency responders when responding to an emergency at the site.

7.0 Risk Management

The control of risks is a continuous process where strategies are put into place to eliminate risks wherever possible, mitigate the residual risks identified using appropriate control measures, safeguards and procedures, and, lastly, accept the residual risk and manage the impacts should the hazardous event occur. The risk control strategies and their effectiveness are broadly described as:

- engineering control to either completely eliminate the risk (100% effectiveness) or to implement physical controls and safeguards (minimum 90% effectiveness)
- administrative control based around procedures (maximum 50% effectiveness)
- personnel control using training and the control of work methods (maximum 30% effectiveness).

The qualitative risk assessment identified a range of technical control measures and non-technical safeguards and procedures that will be put in place to eliminate or mitigate the level of risk associated with the operation of the Project. These technical control measures and non-technical safeguards and procedures are consistent with the findings and recommendation of investigation into LIB fires such as the Victorian Big Battery fire and McMicken BESS explosion.

Technical safeguards are those controls that are incorporated into the process or control system hardware, software or firmware. Non-technical controls are management and operational controls, such as security policies, operational procedures, maintenance procedures and training. Technical and non-technical safeguards can also be divided into preventive controls which inhibit or prevent hazardous events from occurring and detective controls such as control system alarms that warn of unacceptable process deviations, or security monitoring systems that initiate an alarm in the event of violations of security protocols.

There are four key components to mitigating LIB thermal runaway events (Bravo-Diaz et al., 2020):

- Prevention, which is addressed in the system design stage and may be achieved with control of heat generation by:
    - avoiding short circuits with cushioning or isolation materials for cell spacing to avoid mechanical abuse
    - applying cell internal safety design such as shutdown separators to reduce or cut off current when short circuit occurs
    - using more thermally stable cathode materials such as LFP instead of LCO.
- Compartmentation, which involves containing or delaying fire propagation within a battery pack once ignition occurs. This may be achieved by increasing cell spacing, dividing battery packs into several compartments with barriers that reduce heat transfer and mechanical impact between compartments.
- Detection of battery conditions (e.g., abnormal terminal voltages, cell temperatures, gas emissions) by the BMS which indicate the onset of thermal runaway and ignition to allow appropriate system shutdowns and preparation for emergency response.
- Suppression, which may involve chemical suppression, cooling (i.e., water mist) or fire isolation.

The following sections outline the technical and non-technical control measures that will be implemented as part of the Project to address the four key components for mitigation of LIB thermal runaway events as well as the control measures relating to electrical transformer hazards.

7.1 Technical Control Measures

The technical control measures that will be implemented as part of the Project will address the key components with regard to LIB hazards and will include:

- Purchasing a BESS that is designed and constructed to meet the requirements of *UL 9540 Standard for Safety of Energy Storage Systems and Equipment* (UL 9540) (Underwriters Laboratory, 2022).
- Purchasing a BESS that has been demonstrated to avoid fire propagation by being type tested in accordance with UL 9540A. The configuration of the LIB modules for the 'as constructed' Project will be consistent with a configuration determined by the UL 9540A testing to achieve no propagation.
- Ensuring the BESS system components purchased have been subject to rigorous factory acceptance testing prior to dispatch from the supplier.
- Ensuring the BESS and BMS incorporate adequate instrumentation, interlocks and alarms to minimise the risk of the LIB incubation period (the time at a particular temperature at which thermal runaway is likely to initiate) being approached by shutting down modules/racks and alarming unsafe temperatures or other unsafe conditions such as:
    - loss of cooling
    - charge/discharge voltage or current outside design parameters
    - internal electrical resistance outside design parameters during charging or discharge
    - rack fail-to-trip detected
    - inverter/charge fail-to-trip detected.
- Maintaining the separation distances between BESS containers to reduce the risk of accident propagation in accordance with manufacturer's instructions, appropriate standards/guidelines that may include *NFPA 855 Standard for the Installation of Stationary Energy Storage Systems* (NFPA 855) (National Fire Protection Association, 2022) and *Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (FM Global, 2023) and in line with testing conditions set during type testing for UL9540A.
- Ensuring the Project has an effective fire suppression plan that can be implemented over the full duration of the fire event should the fire safety strategy involve suppression (e.g. as per *Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (FM Global, 2023) requirements).
- Incorporating lightning protection at the Project site to reduce the risk of lightning initiating a LIB hazard event.
- Visual and audible alarms external to BESS that will be initiated should the BMS detect a thermal runaway event.

- Provisioning the Project site with adequate fire safety systems (e.g., provision of fire water tanks, hydrant booster sets and fire water containment) that will be determined following completion of Project design, and the bushfire assessment and the Fire Safety Study (FSS).
- Ensuring the Project site layout provides emergency services with clear access and egress to all areas of the site (including alternate access and egress routes) that may require an emergency response, in particular to BESS components.

It is noted that Australian and New Zealand Standard *AS/NZS 5139:2019 Electrical Installations – Safety of battery systems for use with power conversion equipment* (AS 5139) is only applicable to BESS with a maximum capacity of 200 kWh and may not be considered to be directly relevant to the Project. However, Section 7 of AS 5139 contains useful guidance on BESS safety signage (FRNSW, 2023). *IEC 62897 Stationary Energy Storage Systems with Lithium Batteries - Safety requirements* was a standard understood to be under development, however, it has not been released and it is unclear whether it will be released. As such, UL 9540, UL 9540A, NFPA 855 and FM Global's *Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (2023) are the most comprehensive and applicable standards and guidelines for the design and installation of the Project. In cases where these standards contradict applicable Australian Standards and guidelines, applicable Australian Standards and guidelines will take precedence.

The technical control measures that will be implemented as part of the Project to address the hazards associated with electrical transformers are:

- The substation and transformers will be designed, installed, operated and maintained in accordance with:
  - AS/NZS 60076.1:2014 Power transformers General
  - AS/NZS 60076.2:2013 Power transformers Temperature rise for liquid immersed transformers
  - AS/NZS 60076.5:2012 Insulated bushings for alternating voltages above 1000 V
  - AS/NZS 60076.6:2013 Power transformers Loading guide for oil-immersed power transformers
  - AS 60296:2017 Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear
  - AS 2067-2016 Substation and High Voltage Installations exceeding 1 kV AC.
  - AS 2374.8-2000 Power Transformers – Application Guide.

7.2 Non-technical Control Measures

The non-technical measures to be implemented for the Project include:

- A final hazard analysis (FHA) will be completed for the Project when the Project design has achieved an adequate level of detail (i.e. specific BESS technology has been selected and layout has been confirmed).
- LIBs will be transported to site by a suitably accredited freight company using dangerous goods licensed vehicles and drivers.

- A Fire Safety Study (FSS) will be prepared in accordance with the guidelines of HIPAP 2 and FRNSW's *Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations* and in consultation with FRNSW.
- A detailed Emergency Plan (EP) will be prepared consistent with HIPAP 1 in consultation with relevant emergency services organisations (i.e., FRNSW, NSW Rural Fire Service (RFS), NSW Ambulance and relevant local emergency management services). The EP will detail the management measures to minimise the risk of hazardous events as well as emergency response procedures including an evacuation plan for site personnel, the associated dwelling and surrounding premises. **Section 7.3** provides an outline of the anticipated EP that will be prepared should the Project proceed.
- First responders will be made aware of hazards (including those specific to LIBs and electrical hazards that pose a threat during emergency response) and appropriate responses to hazardous events in post construction inductions for first responders.
- Site security will include perimeter fencing and CCTV monitoring of the BESS facility entrance and electrical substation.
- All combustible materials (including vegetation) within an exclusion zone of 10 m will be maintained around all substation equipment to reduce the risk of fire propagation from or to the transformers.
- An Asset Protection Zone (APZ) 10 m wide will be maintained around Project site and 10 m wide on the northern and western boundaries of the BESS compound.
- On-site vehicle speed and traffic flow directions within the BESS will be managed based on the assessment of on-site hazards and the location of the battery storage facilities and electrical substations.
- Training will be provided for all personnel responsible for operations, maintenance and emergency response.
- Hot work/safe work procedures will be prepared for any maintenance works on battery storage facilities or electrical transformers.
- Routine preventative maintenance, interlock testing and condition monitoring (e.g. thermography, insulating oil analysis) of BESS LIB modules and electrical transformers will be undertaken.
- All waste batteries will be disposed of in a safe and responsible manner by suitably licensed waste contractors.
- Consultation with adjacent landholders and associated dwellings to ensure they are aware of the hazards associated with the BESS and understand the emergency systems and protocols (visual and audible alarms, communications from site, evacuation plans etc.) that will be implemented in the event of a thermal runaway event. The outcome of this consultation will be reflected in the Emergency Management Plan that will be completed provided approval for the Project is granted.

7.3 Emergency Plan Outline

A comprehensive EP and detailed emergency procedures consistent with NSW's HIPAP 1 and the NSW RFS *Planning for Bushfire Protection* will be developed and implemented should the Project be approved. Reference will also be made to *Australian Standard AS 3745-2010 Planning for emergencies in facilities* for the preparation of the EP. Prior to the preparation of a draft EP, an initial round of consultation will be undertaken with NSE RFS and FRNSW to determine any specific issues that need to be addressed in the EP and establish key contacts for ongoing consultation.

A hazard identification workshop involving key Project personnel and key stakeholders will be undertaken to identify emergency scenarios that could arise during Project construction and operation as well as hazard and risk mitigation measures (including the requirement to develop particular emergency response procedures).

The EP will have the following general structure:

- Introduction – general outline of the Project and location and the definition of an emergency.
- Aim and Objectives – a statement of the aims and objectives of the plan.
- Roles of Agencies, Industry, Community and Other Groups – define the roles and requirements of key stakeholder groups and when consultation is required (e.g., EP review and update).
- Hazards – detail the identified hazards that could have a significant impact on emergency events and the ability to respond to such events including dangerous goods/hazardous materials, electrical hazards and natural hazards (a figure(s) detailing the location of hazards will be included).
- Emergency Events – the types and level of emergency events that may occur on site or impact the site.
- Emergency Organisational Structure and Responsibilities – list of NSW RFS personnel and external agencies with emergency management functions, including contact details, their respective responsibilities in emergency planning and emergency events and how they can be identified in an emergency event.
- Site Security and Access – details and provisions for 24/7 access for emergency services.
- Emergency Procedures – clear, concise and practical procedures for the prevention and management of emergency events, likely to include:
    - Asset Protection Zone (APZ) management.
    - Bushfire response.
    - Hot work procedures including requirements for notifications to RFS and detailing work that cannot be undertaken in a total fire ban.
    - Dangerous goods storage and handling.
    - EP activation initial advice to emergency authorities and emergency termination.
    - Site evacuation (including evacuation plan drawings showing the evacuation routes).

- Emergency Resources – details of the resources (e.g., communication equipment, alarms, fire fighting equipment, material safety data sheets, PPE, water supplies) that are available for use in an emergency event (a figure(s) showing the location of emergency response equipment and other resources will be included).
- Reporting of Emergency Events – requirements for internal and external reporting of emergency events and post-emergency investigations.
- EP Testing and Training Requirements – requirements for training of personnel in emergency response, periodic drills to test the preparedness and effectiveness of the EP and relevant record keeping.
- EP Review, Update and Document Control – requirements/triggers (periodic or event based) for EP review and update and associated document control.
- Glossary – glossary of terms and abbreviations.
- Appendices:
    - Emergency Services Information Package.
    - Material Safety Data Sheets.
    - NSW RFS and FRNSW consultation records.

The draft EP will be submitted to the NSW RFS and FRNSW for comment prior to finalisation.

8.0 Conclusions

The PHA prepared for the Project identified a number of hazard events involving LIBs and electrical transformers with the potential for harmful off-site impacts. Other than LIBs and transformer oil, there will be no hazardous materials stored at, or transported to, the Project in significant quantities. However, given the adjacent land is typically unoccupied (farmland) and the large separation distances from the BESS units/containers and substation to the nearest dwelling, off-site individual injury, individual fatality or property damage impacts associated with LIB or electrical transformer hazardous events are not considered credible.

An evaluation of the identified Project risks with respect to HIPAP 4 qualitative risk criteria was undertaken and found the Project to be compliant with the criteria. Note that compliance with HIPAP 4 criteria is conditional on the technical and non-technical risk mitigation and management measures presented in **Section 7.1** and **Section 7.2** being implemented.

A FHA, FSS and EP will be prepared as the design of the Project progresses toward completion to ensure the final design adheres to the risk management measures outlined in **Section 7.0** and that the separation distances to the dwellings are appropriate for the specific battery cell type (i.e., chemistry and capacity) to be used at the Project.

9.0 References

Umwelt, 2022. *Preliminary Hazard Analysis Tallawang Solar Farm.*

Bravo Diaz L et al., 2020. *Review—Meta-Review of Fire Safety of Lithium-Ion Batteries: Industry Challenges and Research Contributions*, Journal of The Electrochemical Society: 167, 090559.

El-Harbawi M and Al-Mubaddel F, 2020. *Risk of Fire and Explosion in Electrical Substations Due to the Formation of Flammable Mixtures*, Scientific Reports: 10, 6295.

Fire Protection Research Foundation, 2016. *Hazard Assessment of Lithium Ion Battery Energy Storage Systems*. Report prepared by Blum AF and Thomas Long Jr. R.

Fisher Engineering Inc. and Energy Safety Response Group, 2022. *Victorian Big Battery Fire: July 30, 2021, Report Of Technical Findings*.

FM Global, 2023. *Property Loss Prevention Data Sheet 5-33, Lithium-Ion Battery Energy Storage Systems*.

Ghiji M, Novozhilov V, Moinuddin K, Joseph P, Burch I, Seundermann B and Gamble G, 2020. *A Review of Lithium-Ion Battery Fire Suppression*, Energies: 13, 5117.

Institute of Electrical and Electronics Engineers Spectrum, 2020. *Dispute Erupts Over What Sparked an Explosive Li-ion Energy Storage Accident.* Report by DC Wagman, https://spectrum.ieee.org/.

International Atomic Energy Agency, 1996. *Manual for the Classification and Prioritization of Risks due to Major Accidents in Process and Related Industries*.

Kong L, Li C, Jiang J and Pecht MG, 2018. *Li-Ion Battery Fire Hazards and Safety Strategies*, Energies: 11, 2191.

Larsson F, Andersson P, Blomqvist P and Mellander BE, 2017. *Toxic fluoride gas emissions from lithium-ion battery fires*, Scientific Reports: 7, 10018.

National Fire Protection Association, 2022. *NFPA 855 Standard for the Installation of Stationary Energy Storage Systems*.

NSW Department of Planning, 2011a. A*pplying SEPP 33: Hazardous and Offensive Development Application Guidelines*.

NSW Department of Planning, 2011b. *Multi-Level Risk Assessment*.

NSW Department of Planning, 2011c. *Hazardous Industry Planning and Advisory Paper No. 4 – Risk Criteria for Land Use Safety Planning.*

NSW Department of Planning, 2011d. *Hazardous Industry Planning and Advisory Paper No. 6 – Hazard Analysis.*

NSW Department of Planning, 2011e. *Hazardous Industry Planning and Advisory Paper No. 2 – Fire Safety Study Guidelines.*

NSW Department of Planning, 2011f. *Hazardous Industry Planning and Advisory Paper No. 1 – Emergency Planning*.

Standards Australia, 2017. *AS/NZS 1940:2017 The storage and handling of flammable and combustible liquids*.

Standards Australia, 2019. *AS/NZS 5139:2019 Electrical Installations – Safety of battery systems for use with power conversion equipment*.

Underwriters Laboratory, 2019. *UL 9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*.

Underwriters Laboratory, 2022. *UL 9540 Standard for Safety of Energy Storage Systems and Equipment*.

Barowy et al., 2021. *UL 9540A Installation Level Tests with Outdoor Lithium-ion Energy Storage System Mockups*.

Fire and Rescue NSW, 2023. *Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations.*

Ara Ake, 2023. *Stationary Battery Energy Storage Systems Analysis.*

APPENDIX A

Level 1 Qualitative Hazard Identification

Level 1 Hazard Identification

Job Title:	Gundary Solar Farm and BESS	**Job Number:**	22223

Job Description:	The proposed Gundary Solar Farm and BESS (the Project) includes the construction, operation, maintenance and decommissioning of a 400 MWp solar farm and a 650–1810 MWh BESS and associated infrastructure. Associated infrastructure would include internal access tracks, operational and maintenance facilities, civil works and onsite electrical infrastructure (substation) required to connect to the existing transmission line. At this stage, the BESS layout and technology have not been finalised. However, it is anticipated that the type of batteries within the BESS will be lithium ion which pose potential fire, explosion and toxic gas release hazards when subject to abuse conditions (electro-chemical, thermal, mechanical) or as a result of internal manufacturing defects. There will also be electrical transformers at the site which pose a potential explosion and fire hazard.

Purpose, Scope and Context:	The purpose of the hazard identification process is to identify hazardous events associated with the Project that may have off-site impacts on people, property and the environment. Where a Level 1 Qualitative risk analysis identifies possible off-site impacts associated with the Project, further investigations may be warranted. The Level 1 Hazard Identification process focuses on the risks posed to the health and safety of surrounding off-site land users and the risks posed to the surrounding biophysical environment. i.e. the risk rankings are relevant to off-site land users not on-site personnel.

To inform the Level 1 Hazard Identification process a detailed description of recent developments in the management of BESS installations is provided in **Section A1**.

The risk scoring criteria for consequence severity, frequency estimation and the associated risk matrix from Australian Standard *AS 4360:2004 – Risk Management* adopted for this Level 1 Hazard Identification is provided in **Section A2**.

The credible hazardous events and scenarios describing potential hazardous events that could have off-site impacts are provided in **Section A3**.

A1 Recent Developments in the Management of BESS Installations

Lithium-ion Battery Hazards

During normal use LIBs are sealed and, unlike lead acid batteries, do not vent to the atmosphere during normal operation. However, if subject to abnormal heating (external or internal) or other abuse (e.g., damage during transportation), flammable electrolyte and electrolyte decomposition products can vaporise, rupture the battery cell and be vented (Fire Protection Research Foundation, 2016). Vented electrolyte and electrolyte decomposition products may ignite if exposed to an ignition source including sparks, open flames and LIB cells undergoing thermal runaway.

Thermal runaway occurs when the internal temperature of a LIB cell increases beyond its operating 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. LIBs are susceptible to thermal runaway which can be initiated by a range of mechanisms including electro-chemical abuse (e.g., from overcharging, over-discharging and over voltage charging), mechanical abuse (e.g., physical damage to cell causing a short circuit), thermal abuse (overheating from an external source), manufacturing defects (e.g., internal short circuits) and design faults (e.g., inadequate clearance between cells or modules to allow heat dissipation). Statistics for electric vehicle fires attribute 80% of fires to spontaneous ignition events (Bravo-Diaz et al., 2020) suggesting manufacturing defects, internal defects that develop over time and design faults are the primary cause of LIB fires. However, FM Global's *Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (2023) indicates that electro-chemical abuse is acknowledged to be the most common failure mode.

Of the various mechanisms that can lead to LIB thermal runaway, only electro-chemical abuse can be interrupted by the battery management system (BMS) by early detection of elevated cell temperatures or trace gases associated with early-stage electrolyte decomposition (FM Global, 2023). In response to the detection of elevated cell temperature or trace gases associated with electrolyte decomposition, the BMS can isolate the relevant battery unit preventing further temperature rise in the impacted cells. Thermal abuse (e.g. cooling system inadequacy or failure) is likely to affect multiple cells simultaneously and progression to thermal runaway is considered unavoidable (FM Global, 2023). Isolation of cells that have internal short circuits as a result of physical damage or manufacturing defects will not prevent thermal runaway as the cells store their own energy (FM Global, 2023).

The vented gases from LIBs during thermal runaway can exceed 600°C and are likely to include flammable (alkyl-carbonates, methane, ethylene, ethane, hydrogen gas) and toxic species (carbon monoxide (CO), hydrogen cyanide (HCN), HF, phosphorus pentafluoride and phosphoryl fluoride), soot and particulates containing oxides of nickel, aluminium, lithium, copper and cobalt. Larsson et al. (2017) report on experimental work undertaken for a range of different LIB cell types including cells with a lithium cobalt oxide cathode ($LiCoO_2$ or LCO) and LFP cathode to determine toxic gas release rates and heat release rates. The experimental apparatus allowed for measurement of both phosphoryl fluoride and HF. However, phosphoryl fluoride was only detected during thermal runaway of the LCO type cell and indicates that phosphorus pentafluoride is rather short lived. It is understood that the most likely cell type to be used in the Project will be LFP. LFP cells are reported to have a greater thermal stability than LCO and lithium manganese oxide ($LiMn_2O_4$ or LMO) cells (Kong et al., 2018). The onset of thermal runaway in LFP cells has been reported as occurring at 246°C (Kong et al., 2018).

A study to quantify the toxic gas emissions associated with LIB fires found that HF may be generated in amounts of approximately 20 – 200 mg/Wh of nominal battery capacity for a range of battery types and chemistries (Larsson et al., 2017). If the enclosed battery modules to be installed at the Project have a capacity of approximately 0.16 MWh each, there is significant potential for the generation of toxic HF, which has a peak limited workplace exposure limit of 2.6 mg/m^3 (Safe Work Australia, 2013).

During installation level testing of a lithium-ion energy storage system mockup, Underwriters Laboratory recorded concentrations of CO exceeding 100,000 ppm within a container housing LIB units (Underwriters Laboratory, 2021). CO and HCN concentrations within approximately 900 mm of the outside of the container were recorded in excess of the gas meter detection limits of 2,000 ppm and 50 ppm respectively, while CO concentrations were recorded in excess of 400 ppm approximately 9 m from the outside of the container (Underwriters Laboratory, 2021). A visible vapour cloud containing gases that had not combusted was observed to form on the exterior of the container during the tests with the cloud primarily staying close to the ground with some buoyant gas behaviour observed (Underwriters Laboratory, 2021).

Flammable gases produced during thermal runaway pose both a fire risk, if immediately ignited, and an explosion risk if accumulated in significant quantities within a confined space (e.g., in an enclosed unit or container) prior to ignition. Three scenarios were tested by the Underwriters Laboratory as part of the installation level testing (no fire suppression, a gaseous fire suppression agent and water spray fire suppression) and deflagrations were recorded for all scenarios indicating an accumulation of flammable gas to within the explosive range and an available ignition source (Underwriters Laboratory, 2021). At the completion of the gaseous fire suppression scenario testing, a flashover occurred when the container door was opened and the accumulated flammable gases (at concentrations within the container above the upper flammability limit (UFL)) mixed with air and ignited (Underwriters Laboratory, 2021). Sustained high temperatures in excess of 500^{o}C were recorded within modules during the testing creating thermal exposure to adjacent combustible construction materials (Underwriters Laboratory, 2021).

Abnormal events resulting in the venting of vaporised electrolyte and decomposition products from LIBs have the potential for fire, explosion and toxic gas hazards. **Figure A1.1** presents an event tree that has been prepared to highlight the potential hazard events associated with LIBs.

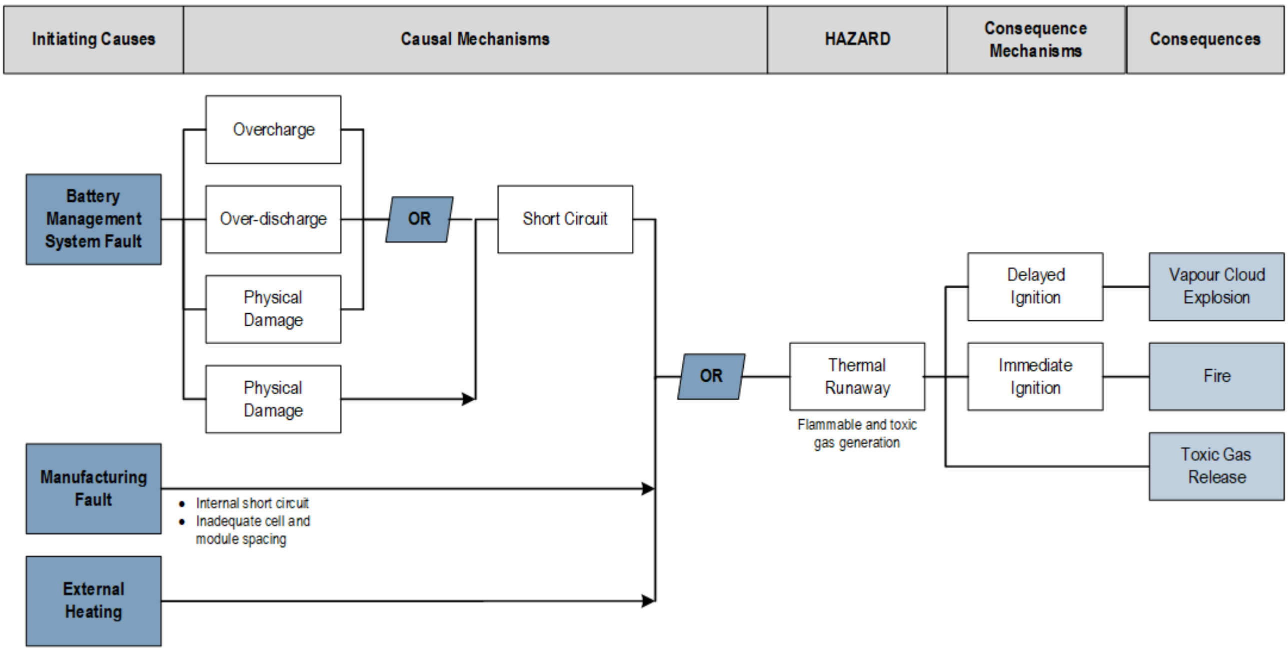


Figure A1.1 Lithium-Ion Battery Fault Tree - Event Tree Bowtie Analysis

Design Standards and Recent BESS Hazardous Events

The increasing use of LIBs in various applications has led to a growing need to consider their safety and appropriate control measures required, particularly in the event of thermal runaway. Thermal runaway can occur when the battery temperature increases to a critical point, causing a chain reaction that generates heat and gas, leading to potentially hazardous consequences. In response to these concerns, there have been improvements in design standards to manage the thermal runaway behaviour of LIB modules.

One of the key influences on the design standards has been past experience. Researchers and industry experts have analysed the causes and effects of thermal runaway incidents, such as those involving the Victorian Big Battery Fire and the McMicken Battery Storage Facility System Explosion discussed below. These incidents have highlighted the importance of proper battery management systems and thermal management strategies to prevent or mitigate thermal runaway. Design standards have evolved to include features such as thermal barriers, passive and active cooling systems, and early warning sensors to detect and prevent thermal runaway.

Other factors that have influenced design standards include regulatory requirements and industry standards. Regulatory agencies such as the United States National Highway Traffic Safety Administration (NHTSA) and the Federal Aviation Administration (FAA) have established safety guidelines for the use of LIBs in transportation, while industry standards developed in agreements between technical groups and manufactures and UL 9540A provide guidelines for the testing and certification of BESSs.

Overall, the improvement in design standards to manage the thermal runaway behaviour of LIB modules reflects a growing awareness of the safety risks associated with these batteries and a commitment to enhancing their safety and reliability. These design standards are shaped by past experience, regulatory requirements, and industry standards, and will continue to evolve as new technologies and applications emerge.

Victorian Big Battery Fire

The Victorian Big Battery (VBB) facility is a 450 MWh grid scale BESS located in Geelong, Victoria consisting of 212 Tesla Megapack units. A Tesla Megapack is a self-contained LIB BESS consisting of battery modules, power electronics, a thermal management system and control systems. Following is a summary of a fire incident that occurred at the VBB in July 2021, based on *Victorian Big Battery Fire: July 30, 2021, Report Of Technical Findings* (Fisher Engineering and Energy Safety Response Group, 2022).

On Friday 30 July 2021 at around 10:00 am while testing and commissioning was being undertaken at the facility, smoke was observed coming from one Megapack that had been manually shut down as it was not part of the testing and commissioning program for the day. At that time all Megapacks at the facility were electrically isolated and the Country Fire Authority (CFA) called to site. At approximately 10:30 am the CFA arrived at the facility and flames were observed coming from the Megapack. The CFA applied cooling water to nearby infrastructure but did not apply water directly to the burning Megapack in accordance with Tesla emergency response guidance. Flames were observed coming from an adjacent Megapack at approximately midday. Visible flames from the first Megapak to ignite subsided at approximately 12:30 pm and from the second Megapack at approximately 4:00 pm. A fire watch was maintained until approximately 3:00 pm on Monday 2 August 2021 at which time the CFA deemed the site under control. The key findings from an investigation into the VBB fire relating to causes and contributing factors are summarised as follows:

- The most likely root cause of the fire was a leak within the liquid cooling system causing arcing in the power electronics of the Megapack's battery modules.
- A Megapack supervisory control and data acquisition (SCADA) system required 24 hours to set up a connection for new equipment and provide full telemetry data functionality and remote monitoring by Tesla operators. The Megapack that ignited had only been in service for 13 hours prior to being shut down via the keylock switch on the morning of the fire and as such, had not been on-line for the required 24 hours. This prevented the unit from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility.
- The liquid coolant leak onto the battery modules is likely to have disabled the power supply to the circuit that actuates the pyro disconnect which is designed to interrupt a fault current passing through the battery module prior to it escalating into a fire event.
- Flames exiting the roof of the first Megapack to ignite were impacted by 37 to 56 km/h winds which pushed the flames towards the roof of the second Megapack to ignite. This direct flame impingement on the thermal roof of the second Megapack ignited the plastic overpressure vents that seal the battery bay from the thermal roof. The burning overpressure vents provided a direct path for flames and hot gases to enter into the battery bays, exposing the battery modules to temperatures above their thermal runaway threshold. While Tesla Megapacks have been tested to UL9540A, the wind conditions during testing are limited to 19.3 km/h which is approximately two to three times lower than the wind conditions experienced during the VBB fire incident.

The key findings relating to the VBB fire response are summarised as follows:

- There was effective pre-incident planning at the VBB facility with an Emergency Action Plan (EAP) and an Emergency Response Plan (ERP) available to emergency responders. The EAP and ERP were found to have been effectively used during the VBB fire with all site employees and contractors following proper evacuation protocols during the fire.

- Pre-incident plans were in place that clearly identified the subject matter experts, how to contact them, their role and other key tasks. It is understood that the facility subject matter experts provided valuable information and expertise to the CFA incident controller throughout the VBB fire.

- Available data and visual observations of the fire indicate that water application had limited effectiveness in terms of limiting fire propagation between Megapacks. Thermal insulation appears to be the primary factor in reducing heat transfer to adjacent Megapacks. However, water was effectively used to protect other equipment, which was not designed with the same level of thermal protection as a Megapack.

The investigation of the VBB fire identified several gaps in commissioning procedures, electrical fault protection devices and thermal roof design which has resulted in the implementation of a number of procedural, firmware, and hardware mitigations to address these gaps. Further, the investigation demonstrates the importance of understanding the limitations and parameters of testing undertaken to achieve certification (e.g., the wind speed parameters in UL9540A) with respect to the likely conditions that will be experienced on site.

<u>McMicken Battery Energy Storage System Explosion</u>

The 2 MWh McMicken BESS was located in Arizona, USA and housed in a container with over 10,000 LIB cells arranged in racks and modules (Institute of Electrical and Electronics Engineers Spectrum (IEEE Spectrum), 2020). On 19 April 2019, the Peoria Arizona Hazmat team responded to a call reporting smoke and odour in the area around the McMicken BESS. When the door of the BESS was opened by the Hazmat team captain, flammable gases that had accumulated in the container mixed with air to form an explosive mixture that ignited. The deflagration threw the captain approximately 22 m and another firefighter 10 m from the BESS container door, resulting in serious injuries.

Separate investigations into the explosion event were undertaken by a third party (DNV-GL) and the battery manufacturer (LG Chem). DNV-GL concluded that a single battery cell failure had initiated a cascading thermal runaway event that generated the flammable gases. LG Chem disputed this finding and concluded that external heating (e.g., electrical arcing) had initiated the thermal runaway event. While the event that triggered the initiation of thermal runaway cannot be confirmed, there are a number of other factors that contributed to the resulting explosion including:

- the absence of adequate thermal barrier protections between battery cells allowing rapid propagation through the battery rack

- the container not being ventilated to the outside, therefore allowing for the accumulation of flammable gases.

LIB Fire Response

There are a range of effective suppressants for extinguishing LIB fires (e.g., dry chemical powder, inert gas, foam, water). However, events involving thermal runaway often re-ignite unless cooling is sufficient to inhibit the exothermic decomposition reactions. In one fire suppression test conducted on a full-scale model vehicle in 2013 by the Fire Protection Research Foundation, the battery reignited 22 hours after the open flame was extinguished (Kong et al., 2018). Studies have shown that water is the most effective method for extinguishing thermal runaway LIB fires and preventing re-ignition (Ghiji et al., 2020). Installation level testing completed by Underwriters Laboratory demonstrated that ceiling water sprays positioned above battery units have the potential to prevent cascading thermal runaway to adjacent units (Underwriters Laboratory, 2021). The sprays did not prevent propagation between modules within each unit and after cessation of water supply to the sprays, thermal runaway continued in the unit and propagated to an immediately adjacent unit (Underwriters Laboratory, 2021). However, continuous operation of a water suppression system is considered likely to prevent propagation of thermal runaway to adjacent units.

Where the installation permits, response to a LIB fire can involve allowing the battery pack to slowly burn itself out while applying cooling to nearby infrastructure as required. Tesla's emergency response guidance advises this fire response approach for Tesla Megapacks (Fisher Engineering and Energy Safety Response Group, 2022) which are designed and installed such that fire propagation between battery packs does not occur when subject to the conditions in *Underwriters Laboratory (UL) 9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems* (Underwriters Laboratory, 2019) (UL 9540A).

Alternatively, FM Global's *Property Loss Prevention Data Sheet 5-33 Lithium-Ion Battery Energy Storage Systems* (2023) provides loss prevention recommendations when water is used as a fire suppressant and/or used to minimise the risk of propagation of a LIB BESS thermal incident in a BESS enclosure. While not a mandatory requirement, the data sheet provides guidance on the following:

- Sprinkler rate of 12 mm/min over the room area
- Additional allowance for 946 L/min for hose streams
- The expected duration of a fire should be determined based on the number of racks in a fire area
- A fire area is comprised of a row or rows of racks where minimum separation is not provided in accordance with the following:
  - 1.8 m separation between the accessible face of a LIB rack to non-combustible construction elements, non-combustible materials and adjacent racks
  - 2.7 m separation between the accessible face of a LIB rack to combustible construction elements and materials
  - Separation between non-accessible sides of adjacent racks to be determined by installation fire level testing (e.g. UL9540A testing)
- Where water is used as a suppressant, the fire water supply should be designed to be available for the entire fire duration, which can be estimated based on the number of adjacent LIB racks in a single fire area multiplied by 45 minutes.

Guidelines provided by organisations such as the American National Fire Protection Association (NFPA) and Fire and Rescue NSW (FRNSW) provide information on the assessment and determination of fire safety studies (FSS) and emergency plans (EP) for facilities containing large-scale LIB BESS. FRNSW’s D22/107002 *Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations* (2023) notes that LIB BESS pose unique challenges to firefighters when responding to LIB BESS incidents and recognises a LIB BESS as an electrical, hazardous chemical and fire risks that require special consideration at the design phase and throughout the project lifecycle. It is also noted that there is a range of LIB cell chemistries (FRNSW, Blum and Long 2016) and that the FSS and EP should be based on the particular battery cells to be used on the site.

NSW’s *HIPAP No 1 Emergency Planning* (HIPAP 1) (DoP, 2011e) and (*HIPAP No2 Fire Safety Study Guidelines* (HIPAP 2) (DoP, 2011f) provide information on the requirements of the EP and FSS. NFPA’s web page on *Energy Storage Systems (ESS) and Solar Safety* provides information on the hazards associated with the thermal runaway of energy storage systems and the potential impact of stranded energy.

Following is a collated summary of the advice provided by various organisations with respect to fire safety and emergency planning that requires consideration as part of the Level 1 qualitative assessment and during the planning phase of a LIB BESS project:

Assessment of Potential Consequences of Credible Incidents

FRNSW consider a credible incident to be one that propagates within a LIB BESS and involves the whole unit/container. Consequence analysis of a BESS incident should consider the potential for propagation and secondary incidents, including the potential for contaminated fire water runoff to impact receiving waters. Should the ultimate fire response strategy involve the application of water to suppress an incident, firewater containment is likely to be required and will need to be considered in the Project design phase.

To limit any requirement for fire water containment, LIB BESS design (including layout, e.g. centralised versus distributed) and procurement should consider passive measures to minimise the fraction of the overall LIB BESS that could be involved in a credible incident.

Defining the Fire Safety Strategy

An effective fire strategy will include measures to minimise the likelihood, severity and extent of an incident. Consideration of potential consequences of credible incidents is important in developing an effective fire strategy and will also inform Project design with respect to minimisation of the likelihood, severity and extent of an incident through the inclusion of appropriate measures that may include separation distances, abnormal LIB BESS condition detection systems, fire barriers, on-site fire water supply and fire water containment systems.

It is important to note that FRNSW does not support the adoption of fire safety strategies that are partially or wholly reliant on fire brigade intervention.

Electrical Hazards Posed to Firefighters

During a LIB BESS incident, significant electrical hazards may be present as:

- The state of charge of an affected LIB BESS unit may be unable to be determined
- High voltages can still be present at low states of charge
- Stranded energy may still be present in the LIB BESS unit
- It may not be possible to isolate the affected LIB BESS unit inputs and/or outputs
- Exposure to heat may degrade the ingress protection rating of the involved LIB BESS unit and surrounding units.

Given the potential for electrical hazards, the responding fire brigade may determine that no intervention activities can be undertaken in the event of an incident. As such, the Project design should consider ways to reduce uncertainty relating to the energy state of LIB BESS units as well as limiting radiant heat impacts on adjacent LIB BESS units to, as far as reasonably practicable, enable the responding fire brigade to undertake appropriate intervention activities.

Fire brigade intervention

Intervention activities at a facility containing a LIB BESS will be undertaken in a manner similar to that for large-scale electrical infrastructure, and fire brigade personnel may not enter the affected compound until an electrical facility representative has confirmed the isolation of power. As indicated above, the responding fire brigade may determine that no intervention activities can be undertaken in the event of an incident due to electrical hazards posed (and potentially other hazards such as toxic gas and explosion hazards) to firefighters and as such, the Project design should consider ways to minimise such a situation arising (i.e. the fire brigade standing down from intervention activities).

Implemented fire safety systems

Fire detection and protection measures may be required to ensure an adequate level of safety is achieved for a site containing a LIB BESS, and the fire detection and protection requirements will be informed by the assessment of credible incidents that may occur at the site and should be automatic in nature (i.e. not require manual operation by a first responder attending the incident). The selected fire detection and protection measures should be aligned with the objectives of the fire safety strategy.

FRNSW advise the installation of a fire hydrant system, even where the fire safety strategy does not rely on direct fire attack, to address other credible fire scenarios and protect LIB BESS units from becoming involved due to adjacent/nearby fire incidents. Street fire hydrants are not considered adequate to provide coverage for a LIB BESS facility.

BESS Unit Separation

The separation of LIB BESS units and containers by distance or using appropriately fire-rated barriers is considered by FRNSW to be a suitable fire safety strategy. Where separation distance is proposed to prevent propagation between surrounding racks, containers and/or associated infrastructure, an assessment demonstrating non-propagation will be required.

BESS Unit Ventilation and Flammable and Toxic Gases

Given a LIB BESS can produce large volumes of flammable, corrosive and toxic vapours and gases during a thermal event, a hazardous atmosphere may be generated within a BESS enclosure. LIB BESS design must demonstrate that consideration has been given to the detection and management of flammable, corrosive and toxic vapours during a thermal event including measures to mitigate the impacts of a deflagration or explosion should a flammable atmosphere within a BESS container or unit be ignited.

A2 Level 1 Assessment AS 4360 Risk Scoring System Scoring Criteria

Scoring Matrix

Level \ Likelihood		1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
A	Almost Certain	11	16	20	23	25
B	Likely	7	12	17	21	24
C	Possible	4	8	13	18	22
D	Unlikely	2	5	9	14	19
E	Rare	1	3	6	10	15

Legend

18 to 25	EXTREME RISK; immediate action required
10 to 17	HIGH RISK; senior management attention needed
6 to 9	MODERATE RISK; management responsibility must be specified
1 to 5	LOW RISK; managed by routine procedures

Qualitative Measures of Likelihood

Level		Description
A	Almost Certain	The event is expected to occur in most circumstances
B	Likely	The event will probably occur in most circumstances
C	Possible	The event might occur at some time
D	Unlikely	The event could occur at some time
E	Rare	The event may occur only in exceptional circumstances

Qualitative Measures of Consequence or Impact or Severity

Level		People Losses	Environmental Harm	Equipment Damage	Production Loss
1	Insignificant	No injuries	No-off site effects	Low financial loss	No production loss
2	Minor	First aid treatment	On-site release immediately contained	Medium financial loss	Up to 1 day production loss
3	Moderate	Medical treatment	On-site release contained with outside assistance	High financial loss	Between 1 to 5 days production loss
4	Major	Extensive injuries	Off-site release with no detrimental effects	Major financial loss	Between 5 to 20 days production loss
5	Catastrophic	Death	Toxic release off-site with detrimental effect	Huge financial loss	More than 20 days production loss

A3 Credible Hazardous Events and Scenarios

Date: 15/09/2023 **Job:** Gundary Solar Farm and BESS **Job #:** 22223

Section/Area: Centralised BESS

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	BESS	Fire/ Explosion	• Lithium ion battery (LIB) cell(s) thermal runaway event results in: • Fire (immediate ignition of flammable gases released from LIB electrolyte during thermal runaway) • Explosion (delayed ignition of flammable gases released from LIB electrolyte during	LIB thermal runaway event initiated by: • Manufacturing defect (e.g. cell internal short circuit) • Electrical abuse (e.g. overcharging, incorrect charging/discharging rate, surge due to lightning strike) • Mechanical abuse (e.g. vehicle collision with BESS unit/container, malicious acts) • Thermal abuse (e.g. failure of BESS cooling system, bushfire)	Possible injuries or fatality within impact zone of • Fire - thermal radiation • Explosion – overpressure • Toxic release - toxic gas cloud exceeding toxicity concentration thresholds	• BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. • BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. • BESS units/containers will incorporate either a ventilation system (to minimise the likelihood of an explosive atmosphere developing within the BESS enclosure) and/or deflagration panels (to mitigate the impacts of an explosion if it does occur). • Asset protection zones of 10 m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. • BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks. • Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to centralised BESS (R22) is 960 m to the NWW.	4	E	10	• Consider using BESS that has deflagration panels to ensure off-site overpressures that could be experienced are not injurious or fatal. • Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. • Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. • Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate. • Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsource bp to facilitate post construction inductions for first responders to ensure the hazards associated with a BESS thermal runaway

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
			thermal runaway within BESS unit/container) • Toxic gas release from LIBs during thermal runaway and fire events			• Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response. • Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. • On-site vehicle speed limits (20 km/h). • Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. • Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. • BESS to be installed above the 1% AEP + 200 mm.				events are understood and they are aware of the selected fire safety strategy and how to respond to hazard events.
2	BESS	Toxicity	Thermal runaway leading to toxic release	Manufacturing faults Electrical abuse Mechanical abuse Thermal abuse (bushfires, lightning strike, failure of cooling system)	Injuries and/or fatality to people within impact zone	• BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. • BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. • Asset protection zones of 10 m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. • BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks.	2	D	5	• Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. • Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. • Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate.

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
						• Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to centralised BESS (R22) is 960 m to the NWW. • Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response. • Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. • On-site vehicle speed limits (20 km/h). • Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. • Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. • BESS to be installed above the 1% AEP + 200 mm.				Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsoucre bp to facilitate post construction inductions for first responders to ensure the hazards associated with a BESS thermal runaway events are understood and they are aware of the selected fire safety strategy and how to respond to hazard events.
3	BESS	Fire	Thermal runaway leading to fire requiring suppression.	Fire occurs and is suppressed with water leading to contaminated fire water flowing off-site.	Water quality impacts on receiving waters.	If fire safety strategy requires water suppression (direct attack of BESS unit involved in fire), an assessment of the potential for generation of contaminated fire water will be undertaken and appropriate fire water containment incorporated into design as required.	3	E	6	Ensure appropriate fire water containment is incorporated into the Project design if fire safety strategy involves suppression with water.

Date:	15/09/2023	Job:	Gundary Solar Farm and BESS	Job #:	22223
Section/Area:	Decentralised BESS				

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	BESS	Fire/Explosion	Lithium ion battery (LIB) cell(s) thermal runaway event results in: Fire (immediate ignition of flammable gases released from LIB electrolyte during thermal runaway) Explosion (delayed ignition of flammable gases released from LIB electrolyte during thermal runaway within BESS unit/container) Toxic gas release from LIBs during thermal runaway and fire events	LIB thermal runaway event initiated by: Manufacturing defect (e.g. cell internal short circuit) Electrical abuse (e.g. overcharging, incorrect charging/discharging rate, surge due to lightning strike) Mechanical abuse (e.g. vehicle collision with BESS unit/container, malicious acts) Thermal abuse (e.g. failure of BESS cooling system, bushfire)	Possible injuries or fatality within impact zone of Fire - thermal radiation Explosion – overpressure Toxic release - toxic gas cloud exceeding toxicity concentration thresholds	BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. BESS units/containers will incorporate either a ventilation system (to minimise the likelihood of an explosive atmosphere developing within the BESS enclosure) and/or deflagration panels (to mitigate the impacts of an explosion if it does occur). Asset protection zones of 10 m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks. Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to a decentralised BESS Battery storage unit (R4) is 950 m to the NE of the unit Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response.	4	D	14	• Consider using BESS that has deflagration panels to ensure off-site overpressures that could be experienced are not injurious or fatal. Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate. Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsource bp to facilitate post construction inductions for first responders to ensure the hazards associated with a BESS thermal runaway events are understood and they are aware of the

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
						Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. On-site vehicle speed limits (20 km/h). Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. BESS to be installed above the 1% AEP + 200 mm.				selected fire safety strategy and how to respond to hazard events.
2	BESS	Toxicity	Thermal runaway leading to toxic release	Manufacturing faults Electrical abuse Mechanical abuse Thermal abuse (bushfires, lightning strike, failure of cooling system)	Injuries and/or fatality to people within impact zone	BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. Asset protection zones of 10 m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks. Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to a decentralised BESS battery storage unit (R4) is 950 m to the NE of the unit.	2	D	5	• Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate. Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsource bp to facilitate post construction inductions for first responders to ensure the

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
						Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response. Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. On-site vehicle speed limits (20 km/h). Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. BESS to be installed above the 1% AEP + 200 mm.				hazards associated with a BESS thermal runaway events are understood and they are aware of the selected fire safety strategy and how to respond to hazard events.
3	BESS	Fire	Thermal runaway leading to fire requiring suppression.	Fire occurs and is suppressed with water leading to contaminated fire water flowing off-site.	Water quality impacts on receiving waters.	If fire safety strategy requires water suppression (direct attach of BESS unit involved in fire), an assessment of the potential for generation of contaminated fire water will be undertaken and appropriate fire water containment incorporated into design as required.	3	E	6	Ensure appropriate fire water containment is incorporated into the Project design if fire safety strategy involves suppression with water.

Date: 07/05/2024 **Job:** Gundary Solar Farm and BESS **Job #:** 22223

Section/Area: Transformers

Ref	Asset	Guide words	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Transformer	Toxicity	Oil leakage	Pipe fitting failures, tank corrosion, physical damage and bunding failure.	Harm to environment - possible soil and waterway contamination.	Transformers transported to site empty, i.e. no oil. Routine maintenance and inspections will be undertaken to minimise likelihood of oil leakage. Transformers will be contained in bunds in accordance with relevant Australian Standards and any other federal, state or local requirements. Spill response kits will be maintained on-site and all relevant personnel will be trained in response to oil leaks.	3	E	6	-
2	Transformer	Fire /Explosion	Fire/ explosion involving transformer oil	Insulation breakdown.	Possible injury off-site.	Transformers will be designed and installed in accordance with relevant federal, state and local standards. Routine preventative maintenance, inspections and condition monitoring (i.e. oil analysis to detect insulation breakdown) will be undertaken. Substation will be fenced in addition to the perimeter fence and controls (including PPE) for entry will be in place. Significant distance to nearest dwellings (dwelling nearest to the substation) are R25 is 390 m to the south and R21B 390 m to the north	2	E	3	Include transformer management requirements in the site's fire safety strategy.

Hazard Identfication Workshop

Date of Workshop: 15-Sep-23

Location: Online Workshop

Job Title: Gundary Solar Farm **Job Number:** 22223

Job Description:

The proposed Gundary Solar Farm (the Project) includes the construction, operation, maintenance and decommissioning of a 400 MWp solar farm with a 200 – 400 MW BESS and associated infrastructure in the Southern Tableland region of NSW. Associated infrastructure would include internal access tracks, operational and maintenance (O&M) facilities, civil works and onsite electrical infrastructure (substation) required to connect to the existing 330 kV transmission line. At this stage, the BESS layout and technology have not been finalised and the BESS may consist of BESS containers/units distributed throughout the site (DC BESS) or centralised BESS (AC BESS) where containers/units are co-located.

However, it is anticipated that the type of batteries within the BESS will be lithium ion which pose potential fire, explosion and toxic gas release hazards when subject to abuse conditions (electro-chemical, thermal, mechanical) or as a result of internal manufacturing defects. There will also be electrical transformers at the site which pose a potential explosion and fire hazard.

Purpose, Scope and Context:

The purpose of this workshop is to identify risks associated with the Project hazards that may have off-site impacts on people,property and the environment. The NSW Department of Planning Secretary's Environmental Assessment Requirements (SEARs) for the Project have identified hazard and risk as an area to be addressed in the EIS. Risk screening and discussions with the DPE Industrial Assessments team indicates that a Level 1 Qualititative risk analysis should be adequate to assess the off-site risks associated with the Project.

The risk assessment will focus on health and safety risks posed to the surrounding off-site land users and the risks posed to the surrounding biophysical environment. i.e. the risk rankings are relevant to off-site land users not on-site personnel.

Workshop Attendees

Name	Company	Position/Role
Chris Bonomini	Umwelt	Principal Engineer - Risk
Marion O'Neil	Umwelt	Senior Environmental Scientist
Hajer Azher	Lightsource bp	
Alejandro Garcia	Lightsource bp	
Diana Mitchell	Lightsource bp	
Mieka White	Lightsource bp	

AS 4360 Risk Scoring System

Scoring Matrix

Likelihood		1	2	3	4	5
Level		**Insignificant**	**Minor**	**Moderate**	**Major**	**Catastrophic**
A	Almost Certain	11	16	20	23	25
B	Likely	7	12	17	21	24
C	Possible	4	8	13	18	22
D	Unlikely	2	5	9	14	19
E	Rare	1	3	6	10	15

Legend

18 to 25:	EXTREME RISK; immediate action required;
10 to 17:	HIGH RISK; senior management attention needed;
6 to 9:	MODERATE RISK; management responsibility must be specified; and
1 to 5:	LOW RISK; managed by routine procedures.

Qualitative Measures of Likelihood

	Level	Description
A	Almost Certain	The event is expected to occur in most circumstances
B	Likely	The event will probably occur in most circumstances
C	Possible	The event might occur at some time
D	Unlikely	The event could occur at some time
E	Rare	The event may occur only in exceptional circumstances

Qualitative Measures of Consequence or Impact or Severity

	Level	People Losses	Environmental Harm	Equipment Damage	Production Loss
1	Insignificant	No injuries	No-off site effects	Low financial loss	No production loss
2	Minor	First aid treatment	On-site release immediately contained	Medium financial loss	Up to 1 day production loss
3	Moderate	Medical treatment	On-site release contained with outside assistance	High financial loss	Between 1 to 5 days production loss
4	Major	Extensive injuries	Off-site release with no detrimental effects	Major financial loss	Between 5 to 20 days production loss
5	Catastrophic	Death	Toxic release off-site with detrimental effect	Huge financial loss	More than 20 days production loss

Centralised BESS

Date 15-Sep-23 **Job:** Gundary Solar Farm **Job #:** 22223

Section/Area: Centralised BESS

Ref	Asset	Guideword	Hazard Event Description	Threat (cause of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	BESS	Fire/Explosion	Lithium ion battery (LIB) cell(s) thermal runaway event results in: • Fire (immediate ignition of flammable gases released from LIB electrolyte during thermal runaway) • Explosion (delayed ignition of flammable gases released from LIB electrolyte during thermal runaway within BESS unit/container) • Toxic gas release from LIBs during thermal runaway and fire events	LIB thermal runaway event initiated by: • Manufacturing defect (e.g. cell internal short circuit) • Electrical abuse (e.g. overcharging, incorrect charging/discharging rate, surge due to lightning strike) • Mechanical abuse (e.g. vehicle collision with BESS unit/container, malicious acts) • Thermal abuse (e.g. failure of BESS cooling system, bushfire)	Possible injuries or fatality within impact zone of • Fire - thermal radiation • Explosion – overpressure • Toxic release - toxic gas cloud exceeding toxicity concentration thresholds	• BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. • BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. • BESS units/containers will incorporate either a ventilation system (to minimise the likelihood of an explosive atmosphere developing within the BESS enclosure) and/or deflagration panels (to mitigate the impacts of an explosion if it does occur). • Asset protection zones of 10m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. • BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks. • Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to centralised BESS (R22) is 957m to the NWW. • Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response. • Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. • On-site vehicle speed limits (20 km/h). • Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. • Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. • BESS to be installed above the 1% AEP + 200 mm.	4	E	10	• Consider using BESS that has deflagration panels to ensure off-site overpressures that could be experienced are not injurious or fatal. • Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. • Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. • Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate. • Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsource bp to facilitate post construction inductions for first responders to ensure the hazards associated with a BESS thermal runaway events are undrstood and they are aware of the selected fire safety strategy and how to respond to hazard events.
2	BESS	Toxicity	Thermal runaway leading to toxic release	Manufacturing faults Electrical abuse Mechanical abuse Thermal abuse (bushfires, lightning strike, failure of cooling system)	Injuries and/or fatlity to people within impact zone	• BESS design to prevent propagation between battery modules and racks - system to be installed will have met the large scale fire testing requirements of UL9540A Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems. • BESS unit/containers to be separated in accordance with relevant standards and manufacturers advice to prevent propagation between units/containers. • Asset protection zones of 10m will be maintained to mitigate the potential for bushfires to initiate a thermal runaway event (as well as reduce the risk of an incident involving Project infrastructure initiating a bushfire. • BESS monitoring and interlocks (Battery Management System (BMS)) for early detection of unsafe conditions (e.g. high cell temperatures, cooling system faults) that could lead to thermal runaway and trips to disconnect/shutdown impacted racks. • Separation distance from dwellings will be maintained to ensure fire, explosion and toxic gas release off-site impacts are within NSW land use planning risk criteria. Dwelling nearest to centralised BESS (R22) is 957m to the NWW. • Site layout has been designed to allow clear access/egress for emergency services in the event of an event requiring emergency response. • Pre-commissioning testing and hold point testing whereby full site capacity is gradually brought online. • On-site vehicle speed limits (20 km/h). • Controlled access to containers/units and all personnel (operations, maintenance, contractors) will be trained in regard to the hazards of Li ion batteries and safe work procedures. • Site security includes perimeter fencing for security, CCTV monitoring to reduce the risk of malicious damage initiating hazardous event. • BESS to be installed above the 1% AEP + 200 mm.	2	D	5	• Prepare Final Hazard Analysis when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) and ensure adequate separation distances to dwellings and adequate space is available to ensure non-propagation between BESS units/containers. • Prepare Fire Safety Study in accordance with HIPAP 2 and FRNSW's technical guideline "Large-scale external lithium-ion battery energy storage systems - Fire safety study considerations" when Project design has reached a suitable level of detail (e.g. battery cell technology selected, BESS arrangement confirmed) to inform appropriate fire safety strategy. • Prepare an emergency plan (EP) in accordance with HIPAP 1 in consultation with FRNSW, RFS, the LEMC and other stakeholders as appropriate. • Ensure first responders are aware of hazards and appropriate response to hazard events – Lightsource bp to facilitate post construction inductions for first responders to ensure the hazards associated with a BESS thermal runaway events are undrstood and they are aware of the selected fire safety strategy and how to respond to hazard events.

3	BESS	Fire	Thermal runaway leading to fire requiring suppression.	Fire occurs and is suppressed with water leading to contaminated fire water flowing off-site.	Water quality impacts on receiving waters.	If fire safety strategy requires water suppression (direct attack of BESS unit involved in fire), an assessment of the potential for generation of contaminated fire water will be undertaken and appropriate fire water containment incorporated into design as required.	3	E	6	Ensure appropriate fire water containment is incorporated into the Project design if fire safety strategy involves suppression with water.

Date 15-Sep-23 **Job:** Gundary Solar Farm **Job #:** 22223

Section/Area: Centralised BESS

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Transformers

Date 15-Sep-23 **Job:** Gundary Solar Farm **Job #:** 22223

Section/Area: Transformers

Ref	Asset	Guideword	Hazard Event Description	Threats (causes of hazard event)	Consequence	Current Barriers	C	L	R	Action
1	Transformer	Toxicity	Oil leakage	Pipe fitting failures, tank corrosion, physical damage and bunding failure.	Harm to environment - possible soil and waterway contamination.	Transformers transported to site empty, i.e. no oil. Routine maintenance and inspections will be undertaken to minimise likelihood of oil leakage. Transformers will be contained in bunds in accordance with relevant Australian Standards and any other federal, state or local requirements. Spill response kits will be maintained on-site and all relevant personnel will be trained in response to oil leaks.	3	E	6	
2	Transformer	Fire/Explosion	Fire/explosion involving transformer oil	Insulation breakdown.	Possible injury off-site.	Transformers will be designed and installed in accordance with relevant federal, state and local standards. Routine preventative maintenance, inspections and condition monitoring (ie.g. oil analysis to detect insulation breakdown) will be undertaken. Substation will be fenced in addition to the perimeter fence and controls (including PPE) for entry will be in place. Significant distance to nearest dwellings (dwelling nearest to the substation (R25) is 385m to the S)	2	E	3	

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APPENDIX B

Level 2 Consequence Analysis

Estimation of Hydrogen Fluoride (HF) Gas Release Rate from a LIB Module Fire

Basis

Battery Cathode – Lithium Iron Phosphate

The HF generation rate for a range of LIB battery packs is described in *Toxic fluoride gas emissions from lithium-ion battery fires* (Larsson et al., 2017). For a battery pack with an energy capacity ranging from 92 to 132 Wh and a nominal capacity per battery ranging from 3.2 to 20 Ah, the detected HF generation rate during the fire test ranged from 12 to 198 mg/Wh depending on the State of Charge (SoC) and the materials of, and type of construction.

The estimated burn rate of a LIB battery pack is based on the Tesla battery module pod fire test reported in *Hazard Assessment of Lithium Ion Battery Energy Storage Systems* (Fire Protection Research Foundation, 2016). The two conceptual thermal runaway events are described as follows:

- Event 1 is based on the failure of multiple cells with the tray of a battery module. The proposed thermal runway of the cells does not propagate to other cells within the module tray, or trays within the module.
- Event 2 is based on the catastrophic failure of multiple cells with the tray that leads the failure of the entire tray leading to propagation of fire to the battery module, the cabinet bay and then the section of the cabinet containing the bay.
- HF is released as a non-buoyant plume.
- Adver se meteorological conditions with a stability class of F (moderately stable) and a wind speed of 1.5 m/s (at a height of 10 m).

Specific HF Generation Rate

Battery Capacity (Ah)	Event 1 – Cell Fire	Event 2 – Cabinet Fire
Event description	Thermal runaway of multiple cells with the tray	Thermal runaway of multiple cells with the tray
Fire propagation	Thermal runaway does not propagate to other cells	Thermal runaway results in a fire that propagates to other cells in the tray, trays within the module and modules within the bay. This leads to the loss of 50% of the cabinet
Estimated loss, kWh	3.4	1950
Event duration, minutes	42	440
HF generation rate, mg/Wh[1]	20	20
HF release rate, g/s	0.027	1.48

Note 1: Contemporary fire testing of BESS module cells, trays and modules indicates the testing to UL 9540A does not always result in the generation of toxic gases such as HF.

Calculations

Battery Burn Rate, R is:

$$R = \frac{Wh\ burnt}{Time}$$

HF Release Rate, m_{HF} is:

$$m_{HF} = R \times HF_{av}$$

Results

BREEZE® input and output text data for the toxic gas release scenarios above predicting the AEGL distance for individuals exposed to HF emissions:

BREEZE Incident Analyst AFTOX Summary Output File	Event 1 – Cell Fire	Event 2 – Cabinet Fire
Meteorological data:		
Ambient temperature(C)	11	11
Ambient pressure(mmHg)	760	760
Relative humidity (%)	17	17
Wind direction (degrees)	225	225
Wind speed(m/s)	1.5	1.5
Anemometer height(m)	10	10
Surface roughness(m)	0.03	0.03
Stability option	Stability class	Stability class
Stability class(1=A - 6=F)	F (6)	F (6)
Computed Monin-Obukhov length(meters)	14.3	14.3
Inversion layer height(m)	None	None
Chemical data:		
Name	Hydrogen fluoride (anhydrous)	Hydrogen fluoride (anhydrous)
Molecular weight (g/g-mole)	20.006	20.006
Vapor heat capacity at constant pressure (J/kg-K)	1450	1450
Boiling point (C)	19.55	19.55
Heat of vaporization (J/kg)	373200	373200
Liquid heat capacity (J/kg-K)	2528	2528
Liquid density(kg/m^3)	973.5	973.5
Release data:		
Source type	Gas release	Gas release
Release type	Continuous	Continuous
Emission rate(g/s)	0.027	0.027
Release height(m)	2.4	2.4

BREEZE Incident Analyst **AFTOX Summary Output File**	**Event 1 – Cell Fire**	**Event 2 – Cabinet Fire**
Output data:		
Concentration level 1(ppm)	1	1
Concentration level 2(ppm)	24	24
Concentration level 3(ppm)	44	44
Concentration averaging time(seconds)	3600	3600
Height of interest(meters)	1.5	1.5
Results: Maximum Distance to Levels of Concern (LOC)		
Concentration (ppm)	Distance (m)	Distance (m)
1.0	25.8	575.0
24.0	-	56.6
44.0	-	33.7
Results: Maximum Concentration at Given Height and Time		
Downwind Distance (m)	20	20
Concentration (ppm)	1.3	68.9

Environmental & Social Consultants

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