



Appendix I

Fire Safety Study



Fire Safety Study

Tully BESS QLD

Attexo Group Pty Ltd
Document No. RCE-25642_TullyBESS _FSS_Final_01Jun26_Rev(0)
Date 1/06/2026

Fire Safety Study

Tully BESS QLD

Attexo Group Pty Ltd

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Quality Management

Rev	Date	Remarks	Prepared By	Reviewed By
A	25 th February 2026	Draft issued for comment	Ezra Bagaskara	Renton Parker
B	5 th May 2026	Updated per comments		
0	1 st June 2026	Final issued		

Executive Summary

Background

Attexo Group Pty Ltd (Attexo) is assisting RWE Tully Battery Pty Ltd (RWE) with the development application for the Tully Battery Energy Storage System (BESS) located within the Cassowary Coast Regional Council. As part of the planning services, subspecialist reports will be required to meet the performance outcomes outlined in the published State Code 27: Battery storage facility development of the State Development Assessment Provisions. This document represents the Fire Safety Study (FSS) required.

The FSS uses the methodology proposed by the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2 (Ref. [1]). While it is acknowledged that this paper is from the New South Wales (NSW) Department of Planning, Housing and Infrastructure (DPHI), it is nevertheless consulted in the absence of QLD guidelines. Due to BESS being an emerging power systems facility, there is little regulation that directly aligns with the development of these facilities within Queensland. FRNSW have developed a comprehensive Fire Safety Guideline *Technical Information – Large-scale external lithium-ion battery energy storage systems – Fire safety study considerations* (Ref. [2]). This document will be consulted to further the safety provisions of the Tully BESS. In addition, the Electrical Safety Office Code of Practice (Ref. [3]) and The Best Practice Guide: Battery Storage Equipment 2018 (Ref. [4]) will also be considered in the assessment.

Attexo on behalf of RWE has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the required documentation for the Project. This document represents the FSS for the Tully BESS.

Conclusions

A FSS was prepared for the proposed Tully BESS site. The analysis performed in the FSS was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the designs and existing fire protection adequately managed the credible fire risks at the site.

Recommendations

Based on the analysis, the following recommendations have been made:

- A Large Scale Fire Test (LSFT) in compliance with the UL9540A 6th Edition shall be conducted for the Tesla Megapack 3 and provided to the Consenting Authority once available.
- A windsock shall be installed at the facility in a location visible from all operational areas
- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.
- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref. [5]).
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.

- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 QLD to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 QLD and any applicable storage and handling standards.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AFAC	Australasian Fire and Emergency Service Authorities Council Limited
APZ	Asset Protection Zones
AS	Australian Standard
BESS	Battery Energy Storage System
BMS	Battery Management System
CBD	Central Business District
CFD	Computational Fluid Dynamics
DA	Development Application
DGs	Dangerous Goods
DPHI	Department of Planning, Housing and Infrastructure
EMS	Environmental Management Strategy
FRNSW	Fire and Rescue New South Wales
HIPAP	Hazardous Industry Planning Advisory Paper
ISO	International Organization for Standardization
LEL	Lower Explosive Limit
NSW	New South Wales
MVPS	Medium Voltage Power Station
PCU	Power Conversion Unit
QLD	Queensland
QFD	Queensland Fire Department
RFS	Rural Fire Service
RMAR	Risk Management Assessment Report
SARA	State Assessment and Referral Agency
SEP	Surface Emissive Power

1.0 Introduction

1.1 Background

Attexo Group Pty Ltd (Attexo) is assisting RWE Tully Battery Pty Ltd (RWE) with the development application for the Tully Battery Energy Storage System (Tully BESS) located within the Cassowary Coast Regional Council. As part of the planning services, subspecialist reports will be required to meet the performance outcomes outlined in the published State Code 27: Battery storage facility development of the State Development Assessment Provisions. This document represents the Fire Safety Study (FSS) required.

The FSS uses the methodology proposed by the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2 (Ref. [1]). While it is acknowledged that this paper is from the New South Wales (NSW) Department of Planning, Housing and Infrastructure (DPHI), it is nevertheless consulted in the absence of QLD guidelines. Due to BESS being an emerging power systems facility, there is little regulation that directly aligns with the development of these facilities within Queensland. FRNSW have developed a comprehensive Fire Safety Guideline *Technical Information – Large-scale external lithium-ion battery energy storage systems – Fire safety study considerations* (Ref. [2]). This document will be consulted to further the safety provisions of the Tully BESS. In addition, the Electrical Safety Office Code of Practice (Ref. [3]) and The Best Practice Guide: Battery Storage Equipment 2018 (Ref. [4]) will also be considered in the assessment.

Attexo on behalf of RWE has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the required documentation for the Project. This document represents the FSS for the Tully BESS.

1.2 Objectives

The objectives of the FSS are to:

- Review the site operations and Dangerous Goods (DG) storage for the potential to initiate or become involved in a fire, including flammable materials which may be present at the site.
- Identify heat radiation impacts from potential fire sources at the site and determine the potential impacts on the surrounding areas and the fire protection system, and
- Review the proposed fire safety features and determine the adequacy of the fire safety systems based on the postulated fires.

1.3 Scope of Services

The scope of work is for the preparation of an FSS for the Project to assess the potential hazards at the site to ensure the fire protection systems are commensurate with the identified hazards. This document follows the methodology recommended in HIPAP No.2 (Ref. [1]).

The FSS focuses on the storage of commodities associated with the new development at the site, in addition to the existing operations at the site, as required by HIPAP No. 2. A review of the following components of the FSS is within the scope of work:

- Determination of risk and consequences from fire or explosion scenarios throughout the Project.
- The preparation of a report on fire prevention, fire detection, fire alarm and fire suppression systems for the site.
- Firewater storage capacity for compliance with Australian Standards and Regulations.

- External fire hydrant configuration and locations.
- Recommendations based upon the study for implementation in the final design.

2.0 Methodology

2.1 Fire Safety Study Approach

The following methodology was used in the preparation of the FSS for the Project. The methodology is to follow items required by HIPAP No. 2 (Ref. [1]).

- The fire hazards associated with the Project were identified to determine whether any fire or explosion hazards may impact offsite or have the potential to escalate. Where fire hazards with the potential to impact offsite or escalate were identified, these were carried forward for consequence assessment.
- The heat radiation impacts or overpressure impacts (consequences) from each of the postulated incidents from the proposed equipment were then estimated, and potential impacts on surrounding areas assessed.
- Impacts of the fires from the proposed equipment were plotted on a layout plan of the proposed Project, to determine whether heat radiation impacts any critical areas (i.e. adjacent storage areas, fire services, safety systems, etc.) and whether such impact affected the ability of firefighters to respond to the postulated fire. The heat radiation impact from incidents at adjacent sites on the buildings and structures at the Project was then assessed against the maximum permissible levels in HIPAP No. 4 (Ref. [6]).
- The firefighting strategies were then assessed to determine whether these strategies require updating in light of the location of the proposed equipment and storage areas.
- The response times for Queensland Fire Department (QFD) in the immediate vicinity were assessed. In addition, further outlying QFD stations were included to provide a 'back-up plan' in the event that the closest fire brigades were unable to attend.
- A report was then developed for submission to the client and the regulatory authority.

In addition, the FRNSW Fire Safety Guideline *Technical Information – Large scale external lithium-ion battery energy storage systems – Fire safety study considerations*, (Ref. [2]) herein referred to as the 'FRNSW BESS Guideline', was reviewed as part of the preparation of the FSS coupled with the Electrical Safety Office Code of Practice Managing electrical risks in the workplace 2021 (Ref. [3]).

2.2 Limitations and Assumptions

In this instance, the FSS is developed based on applicable limitations and assumptions for the development which are listed as follows:

- The report is specifically limited to the project described in **Section 3.0** and the methodology and approach outlined in **Section 2.1**.
- The report is based on the information provided by relevant stakeholders (e.g., Attexo, RWE, etc).
- The report does not provide guidance in respect of incidents that relate to sabotage or vandalism of fire safety systems.

- The assessment is limited to the objectives of the FSS as provided in the guidelines issued as HIPAP No. 2 (Ref. [1]) and does not consider property damage such as building and contents damage caused by fire, potential increased insurance liability and loss of business continuity.
- Malicious acts or arson with respect to fire ignition and safety systems are limited in nature and are outside the scope of this report. Such acts can potentially overwhelm fire safety systems and therefore further strategies such as security, housekeeping and management procedures may better mitigate such risks.
- This report is prepared in good faith and with due care for information purposes only and should not be relied upon as providing any warranty or guarantee that ignition or a fire will not occur.

3.0 Site Description

3.1 Site Location

The proposed site for the Tully BESS is approximately 4 km (via Tully Gorge Road) to the south-west of the centre of Tully and approximately 145 km south of Cairns via the Bruce Highway. **Figure 3-1** shows the location of the proposed site in relative to Tully. **Figure 3-2** shows the conceptual BESS Layout with the existing substation. It is acknowledged that the designs are preliminary at this stage; however, any changes to the design are unlikely to be significant to the hazards present.

3.2 Adjacent Land Uses

The land for the proposed site is located in a regional / rural area surrounded by the following land used which are adjacent to the sites:

- North – Power link substation
- South – Cane farm
- East – Wetland
- West – Rural land used for cattle grazing and evaporation ponds

3.3 Sensitive Receptors

Sensitive receptors refer to locations or areas that are vulnerable or responsive to changes in the surrounding environment which can include ecological, cultural, residential and agriculture bodies. A survey revealed that some residences are located within proximity of the Project area that can be considered sensitive. The locations of nearby residential receptor can be seen in **Figure 3-3**.

3.4 General Description

The Project includes a proposed BESS with a capacity up to 200 MW for a duration of 4 hours and associated infrastructure (e.g. transformer, OHTL, air insulated switchgear, access roads, laydown areas, foundations, hard stand, parking, switch rooms and storage). The BESS and associated infrastructure will comprise a total development footprint of approximately 9 ha within the 28.7 ha Project Site.

The Project has been designed to minimise impacts, in keeping with the sustainable nature of the development for supporting renewable energy projects and reducing greenhouse gas emissions. Accordingly, the existing environment; existing land use at the Site and the surrounding locality; proximity to existing electricity infrastructure; stormwater management; and noise impact have all been considered in the design development.

The primary components of the Project will consist of the following:

- Battery Units: Up to 188 battery units will cover a total area of up to 2.5 ha. The foundations for the proposed battery units will likely be screw piles, piers or concrete pad formations. The BESS will be connected to the adjacent switch rooms via underground cables.
- Switching Station: A switching station will be located to the north of the battery units and will include a 132/33 kV high-voltage transformer, associated switchgear, an auxiliary transformer, two 33 kV switch rooms, and, if required, harmonic filters.

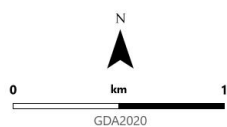
- **Stormwater Management:** Stormwater infrastructure will be designed and constructed to ensure the safe collection, containment, and management of runoff across the site during both construction and operational phases. This will include any emergency containment storage for containment for fire water in an emergency event.
- **Site Access and Internal Circulation:** Access to the site will be via the existing road network, including the Bruce Highway and Tully Gorge Road, with upgrades proposed to the two access point from Sandy Creek Road. The BESS facility will be secured by perimeter fencing. Internal access tracks will be provided around the battery units to facilitate operations, maintenance, and emergency response.
- **Grid Connection Infrastructure:** The Project will connect to the adjacent Powerlink 132 kV Tully Substation via an overhead transmission line extending north from the BESS area. The line will be supported approximately five (5) single-circuit 132 kV poles, each approximately 27.5 m in height.
- **Asset Protection Zone (APZ):** An Asset Protection Zone will be established and maintained around the battery infrastructure to mitigate bushfire risk and provide access for firefighting activities.
- **Fire Safety Measures:** Fire protection infrastructure will include, subject to detailed design, approximately 472,000 litres (L) of on-site static water storage, together with a fire hydrant system designed in accordance with Australian Standard (AS) AS 2419.1.
- **Acoustic Treatment:** A 6 m high noise wall is currently incorporated along the northern boundary of the BESS area to mitigate potential noise impacts. The requirement for this wall will be confirmed during detailed design and may be refined or omitted subject to equipment specifications and acoustic performance.
- **Earthworks:** Earthworks will include site levelling, formation of batters, and clearing necessary to facilitate construction and access.
- **Lighting:** Lighting will be installed to support maintenance activities, when maintenance works are to be undertaken at night; these will be on 10 m high poles. Security lighting will be sensor-controlled. All lighting will be designed and operated in accordance with AS 4282:2023 Control of the obtrusive effects of outdoor lighting.
- **Lightning Protection:** Lightning arrestors, up to 20 metres in height, will be installed within the development footprint to protect critical infrastructure.
- **Laydown and Operations Areas:** Temporary construction laydown areas and a permanent operations and maintenance (O&M) building will be established adjacent to Sandy Creek Road. This will include an O&M building, yard, parking areas, office facilities, and storage sheds.
- **Landscaping and Screening:** Landscape buffer planting will be established along the frontage and partially along the side boundaries of Lot 1 on RP852238 to provide visual screening and enhance integration with the surrounding landscape.



Project Location

Figure 1.1

DWG No: RWE-002-013 [B]
DATE: 11/09/2025
DRAWN: KB
REVIEWED SW
SCALE (A4): 1:15,000

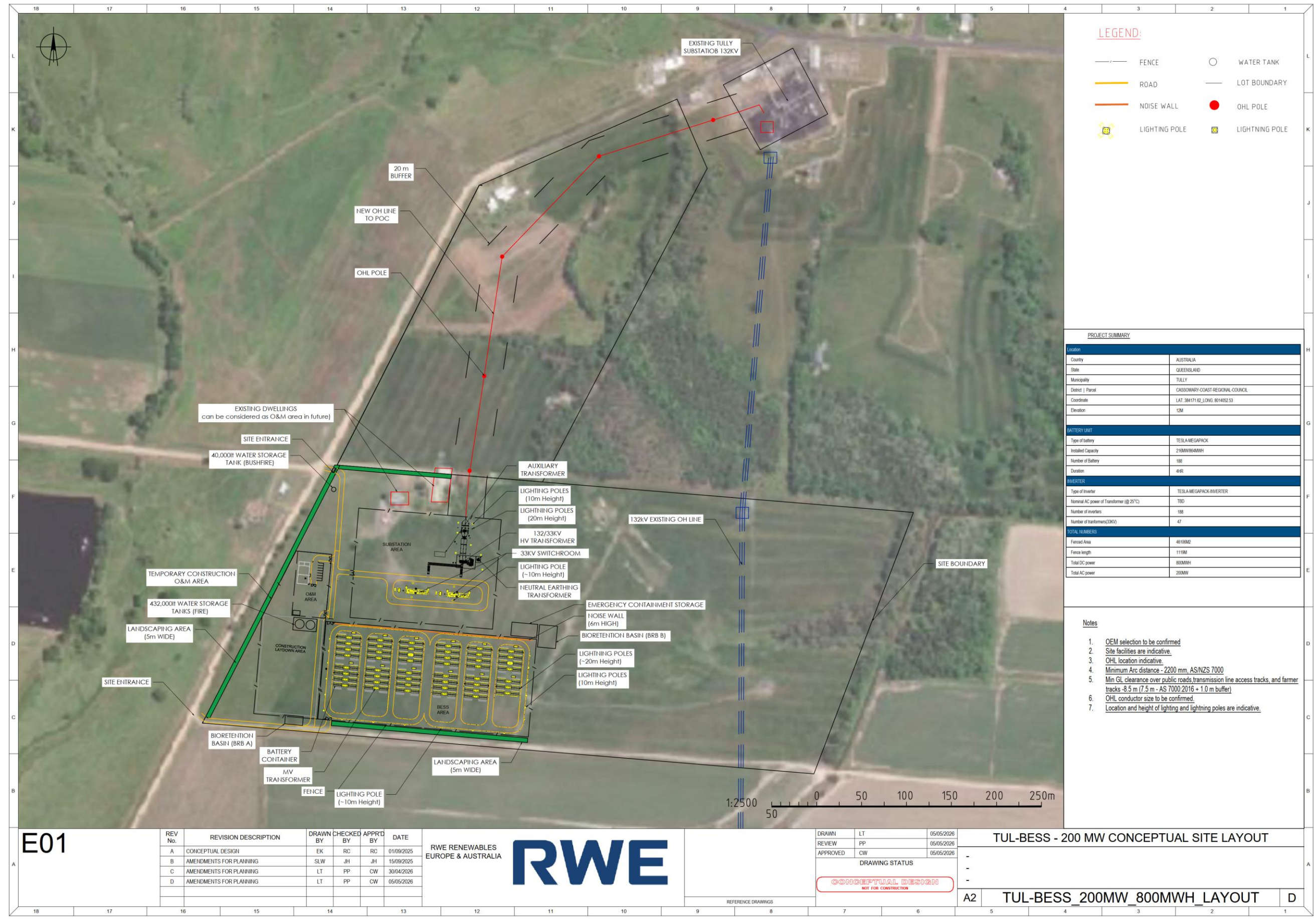


- Project Area
- Development Footprint
- Proposed Transmission Line Corridor
- Proposed transmission line
- 20m exclusion zone
- Main Road
- Local Road
- Cadastral Parcels

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Figure 3-1: Site Location



LEGEND:

—	FENCE	○	WATER TANK
—	ROAD	—	LOT BOUNDARY
—	NOISE WALL	●	OHL POLE
☀	LIGHTING POLE	☀	LIGHTNING POLE

PROJECT SUMMARY

Location	
Country	AUSTRALIA
State	QUEENSLAND
Municipality	TULLY
District / Parcel	CASSIDARY COAST REGIONAL COUNCIL
Coordinate	LAT: 30417162 LONG: 9014652 53
Elevation	12M
BATTERY UNIT	
Type of battery	TESLA MEGAPACK
Installed Capacity	210MWH/80MWH
Number of Battery	188
Duration	4HR
INVERTER	
Type of inverter	TESLA MEGAPACK INVERTER
Maximal AC power of Transformer (@ 25°C)	750
Number of inverters	188
Number of transformers(33kV)	47
TOTAL NUMBERS	
Fenced Area	46100M2
Fence length	1119M
Total DC power	800MWH
Total AC power	200MWH

- Notes**
- OEM selection to be confirmed
 - Site facilities are indicative
 - OHL location indicative
 - Minimum Arc distance - 2200 mm, AS/NZS 7000
 - Min GL clearance over public roads transmission line access tracks, and farmer tracks - 8.5 m (7.5 m - AS 7000 2016 + 1.0 m buffer)
 - OHL conductor size to be confirmed
 - Location and height of lighting and lightning poles are indicative

E01

REV No.	REVISION DESCRIPTION	DRAWN BY	CHECKED BY	APPRD BY	DATE
A	CONCEPTUAL DESIGN	EK	RC	RC	01/09/2025
B	AMENDMENTS FOR PLANNING	SLW	JH	JH	15/09/2025
C	AMENDMENTS FOR PLANNING	LT	PP	CW	30/04/2026
D	AMENDMENTS FOR PLANNING	LT	PP	CW	05/05/2026

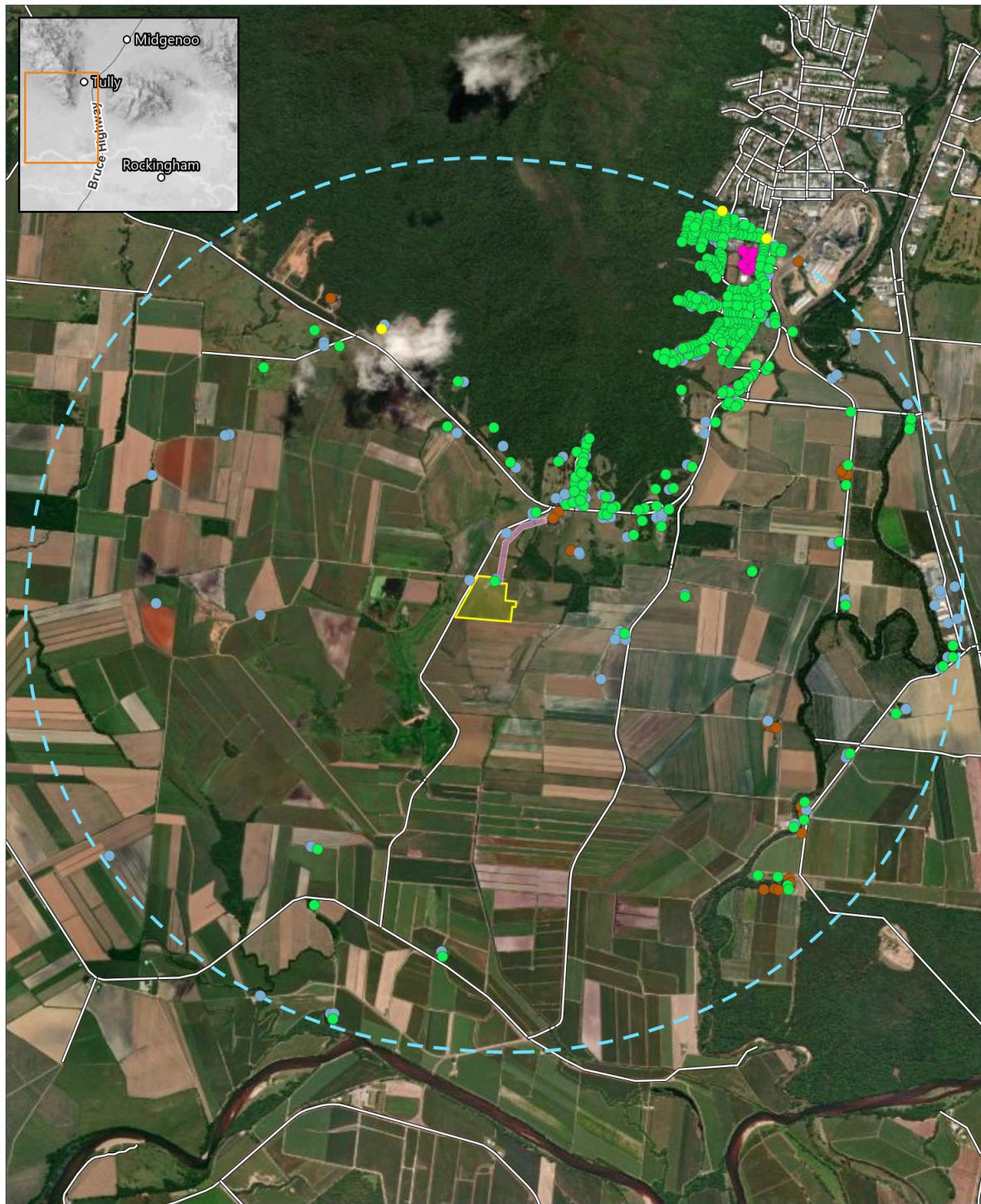
RWE RENEWABLES EUROPE & AUSTRALIA

DRAWN	LT	05/05/2026
REVIEW	PP	05/05/2026
APPROVED	CW	05/05/2026
DRAWING STATUS		
CONCEPTUAL DESIGN NOT FOR CONSTRUCTION		

TUL-BESS - 200 MW CONCEPTUAL SITE LAYOUT

A2 TUL-BESS_200MW_800MWH_LAYOUT D

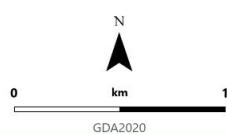
Figure 3-2: Conceptual BESS Layout



Sensitive Receivers

Figure 4.3

DWG No: RWE-002-037[A]
DATE: 19/05/2026
DRAWN: KB
REVIEWED: EJ
SCALE (A4): 1:35,000



- | | | |
|----------------------------|----------------------------|----------------------------------|
| Development footprint | Sensitive receivers | Educational Building |
| Transmission Line corridor | Residential Building | Community Or Commercial Building |
| 3km buffer from site | Other Building | Roads |
| | Infrastructure Building | |

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Figure 3-3: Sensitive Receptor Locations

3.5 Detailed Description

The purpose of the Project is to store excess dispatchable energy generated by the national grid, as part of Queensland's commitment to decarbonisation.

The Project will be able to store electricity with a capacity of approximately 200 MW / 800 MWh. The BESS units will store the electricity to be dispatched based on electricity demand fluctuations, providing the opportunity for greater supply dispatch flexibility when electricity demand is highest. This is enabled by the fast response times achievable through lithium-ion battery storage.

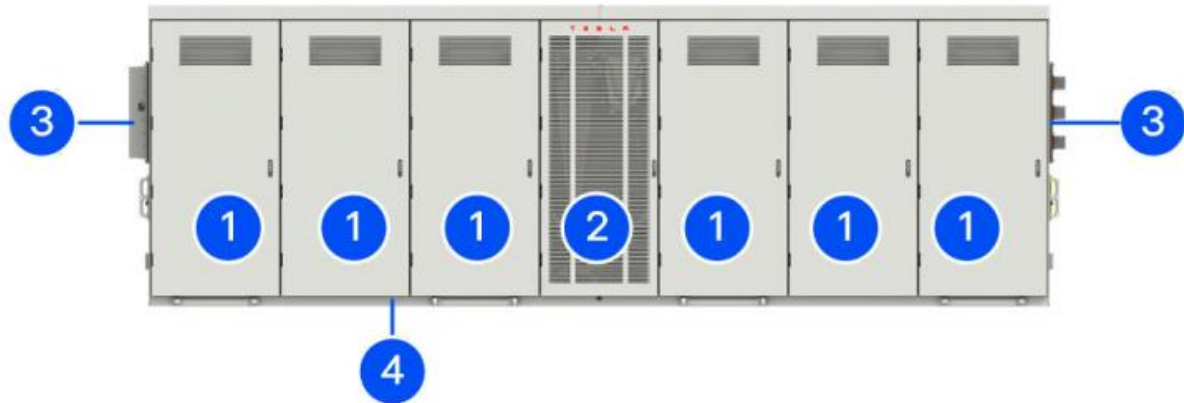
3.5.1 Battery Storage

The BESS units will be located within the designated BESS area. The BESS converts electrical energy into chemical energy and stores the energy internally. The BESS model is expected to be the Megapack 3 which is shown in **Figure 3-4**.



Figure 3-4: Tesla Megapack 3 Model

The Tesla Megapack 3 is a fully integrated battery energy storage unit capable of charging and discharging real power and injecting and absorbing reactive power. The overall dimension of each unit is 8,550 (W) mm x 2100 (D) mm x 2,785 (H) mm, which houses six Li-Ion (Lithium Iron Phosphate – LFP) battery module bays, a therm and bus assemblies that connect to the Megablock's MV transformer. Each model is monitored by a Battery Management System (BMS). The BMS tracks cell voltages and temperatures, and ensures the stability of the batteries, preventing thermal runaway by isolating any cell that falls outside operating parameters. Temperature and humidity within the container are regulated by an internal cooling system that uses liquid to cool. An overview has been provided in **Figure 3-5**.



1. Battery module bays ([Battery Modules on page 13](#))
2. Thermal bay ([Thermal System on page 13](#))
3. Megapack bus connector to the MV transformer ([MV Assembly on page 14](#))
4. IP66 enclosure (Megapack); IP2X enclosure (thermal bay)

Figure 3-5: Tesla Megapack 3 Overview

Battery modules are factory-installed into the Tesla Megapack 3 battery module bays and contain prismatic lithium-ion battery cells. A battery module in turn is the smallest field-replaceable battery unit. Each of the Tesla Megapack 3's six battery bays contain up to two battery modules. Each battery module includes an integrated inverter module for power conversion. Battery modules are connected in parallel to Megapack's internal AC bus, each with an AC power and communications output connection. An image of the battery module has been provided in **Figure 3-6**.

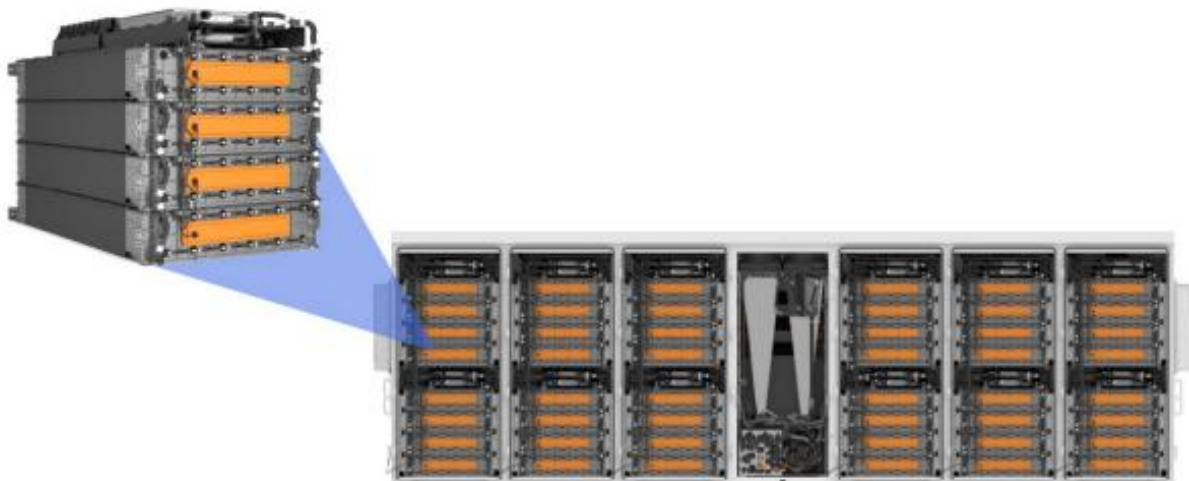


Figure 3-6: Battery Module in a Tesla Megapack 3

While the Tesla Megapack 3 has not undergone third party certification to attain UL9540A, the adjacent battery model (Tesla Megapack 2XL) has been certified in accordance with UL9540. As the battery chemistry is identical between the models, it is not expected that the UL9540A results would be materially different in all levels, from cell to unit level. Hence, it is concluded that the inherent fire mitigation in the design of the BESS is sufficient to operate without additional suppression methods in the event of a fire.

Note that the Tesla Megapack 3 is currently planned to be installed in the “Megablock” arrangement. This arrangement is essentially two or more Tesla Megapack 3s connected together by a single MV transformer in a single line. **Figure 3-7** has been provided to visualise this.

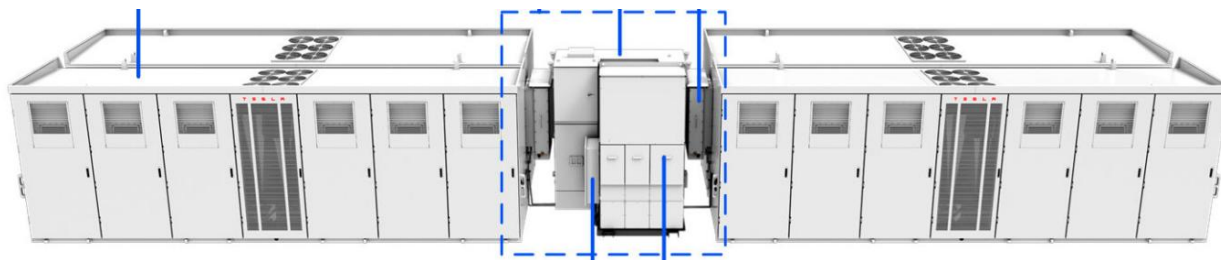


Figure 3-7: Megablock Arrangement

3.5.2 Protection Measures

While the Tesla Megapack 3 has not undergone third party certification to attain UL9540A, the adjacent battery model (Tesla Megapack 2XL) has been certified in accordance with UL9540. As the battery chemistry is identical between the models, it is not expected that the UL9540A results would be materially different in all levels, from cell to unit level. Furthermore, the fire-safety features of the Tesla Megapack 3 offer the same or higher level of protection in comparison to the Tesla Megapack 2XL. **Table 3-1** has been provided to showcase the key fire-safety features of the Tesla Megapack 3 in comparison the Tesla Megapack 2XL.

Table 3-1: Key Fire-Safety Features of the Tesla Megapack 3

Fire-Safety Feature	Description
BMS	Similar to the Tesla Megapack 2XL, the Tesla Megapack 3 features a complex BMS that continuously monitors cell temperatures, voltages, currents, insulation levels, and general system health. The BMS automatically responds to off-normal conditions and plays a central role in limiting or preventing escalation during early-stage anomalies. In addition to baseline monitoring functions, the Tesla Megapack 3, incorporates BMS-driven protective modes, such as: (1) Automatic Safe Discharge which lowers the battery’s state of energy if potential thermal runaway indicators are detected, and (2) Thermal Limp Mode, which reduces module or unit-level power output when temperatures approach unsafe thresholds.
Thermal Management System (TMS)	Mirroring the philosophy used in the Tesla Megapack 2XL, the Tesla Megapack 3 uses a fully integrated active thermal management system that provides active cooling and heating to maintain safe operating temperatures across all internal components. An external HVAC or thermal system is therefore not required for the Tesla Megapack 3 to operate. The system consists of: (1) Thermal Bay and (2) Coolant manifolds.
Explosion Control System Sparkers	Like the Tesla Megapack 2XL, the Tesla Megapack 3 includes a Sparker System that proactively ignites low-concentration flammable gases before they reach hazardous levels. By combusting gases early, sparkers significantly reduce deflagration potential and work in tandem with the overpressure vents for a fully engineered explosion-mitigation strategy.
Explosion Control System Pressure-Sensitive Vents	As with the Tesla Megapack 2XL, the Tesla Megapack 3 incorporates overpressure vents in each battery bay that open automatically during a rapid internal-pressure rise. Once

Fire-Safety Feature	Description
	activated, these vents route gases and combustion products from the battery bay into the thermal bay and then out through the doors, preventing pressure buildup and preserving enclosure integrity.
Explosion Control System Automated Door Opening	Not found in the Tesla Megapack 2XL, the Tesla Megapack 3 further enhances deflagration mitigation by incorporating automated door opening when harmful interior conditions are detected. This provides additional pressure relief and supports more rapid ventilation, thereby shortening the duration and severity of a thermal event. Prior to door opening, an external warning the form of audible and visible notification will be given, alerting site personnel to the potential hazard.
Safety Controller	Not found in the Tesla Megapack 2XL, the Tesla Megapack 3 includes a dedicated Safety Controller located in the thermal bay, responsible for aggregative safety-related sensor data, executing alert logic, and initiating protective actions when required. The safety controller provides an external warning and communication system which consist of an audible alarm and flashing lights as well as Alarm communication to the Tesla System Controller. The safety controller hardware/firmware is evaluated under UL 1998 and UL 991, confirming robustness of safety-related controls and proper fail-safe behaviour.

NFPA 855 allows for the BESS units to be installed without fire suppression systems where fire, explosion and fault condition testing documents indicate the inherent BESS design is sufficient to limit thermal runaway events.

While the BESS layout in **Figure 3-2** is preliminary, its design contains safety features that are assumed to be incorporated into the final layout design. These include:

- Storage of infrastructure (BESS and MVPSSs) no less than 9 m from site boundary
- A 3 m clearance of infrastructure (BESS and MVPSSs) from site access roads and other infrastructure
- BESS access roads 6 m in width.
- Implementation of recommendations from the Bushfire Hazard Management Plan.

3.6 Quantities of Dangerous Goods

Prior to operations, lithium-ion batteries held on-site are considered to be Class 9: Miscellaneous Dangerous Goods under the Australian Dangerous Goods Code (ADGC). However, once the BESS units are operational, it is not considered a DG under Division 1 Part 7.1 of the Work Health and Safety Regulation 2011 (Ref. [7]). Other DGs that are expected to be stored onsite include oil in the transformers (often ester or mineral oils). The precise quantities of DGs are to be confirmed, however **Table 3-2** contains the expected quantities of DGs onsite for a project of this scale.

The threshold column in **Table 3-2** indicates placard threshold, at which there are certain legal requirements to comply with Work Health and Safety Regulation 2011 (Ref. [7]).

Table 3-2: Maximum Quantities of Dangerous Goods Stored & Preliminary Risk Screening

Area	Class	Description	Quantity	WHS 2011 Placard Threshold
BESS Units	9	Li-Batteries	2,847 T	n/a

Area	Class	Description	Quantity	WHS 2011 Placard Threshold
Transformer oil	C1	Combustible Liquid	400 kL*	10,000 L

*TBC. Estimated quantity based on similar projects

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. Those hazards identified to have a potential fire or explosion impact are assessed in the following sections of this document.

Where the hazards or hazardous events are qualitatively deemed to be of low enough consequence or likelihood, a qualitative risk analysis is conducted at the end of each subsection, and a risk level is assigned. Where the hazards required further analysis, they are carried forward for quantitative risk analysis.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Table 3-2**. **Table 4-1** provides a description of the DGs to be stored and handled at the site, including the Class and the hazardous material properties of the DG Class.

Table 4-1: Properties* of the Dangerous Goods and Materials Stored at the Site

Class	Hazardous Properties
9 – Miscellaneous DGs	Class 9 substances and articles (miscellaneous dangerous substances and articles) are substances and articles which, during transport present a danger not covered by other classes. Releases to the environment may cause damage to sensitive receptors within the environment. It is noted that the Class 9s stored within this project are lithium-ion batteries which may undergo thermal runaway (i.e. escalating reaction resulting in heat which ultimately leads to failure of the battery and a fire).
Combustible Liquids	Combustible liquids are typically long chain hydrocarbons with flash points exceeding 60.5°C. Combustible liquids are difficult to ignite as the temperature of the liquid must be heated to above the flash point such that vapours are generated which can then ignite. This process requires either sustained heating or a high-energy ignition source.

* According to the Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [8])

4.3 Hazard Identification

Based on the hazard identification table presented in **Appendix A**, the following hazardous scenarios have been developed:

- Li-ion battery fault, thermal runaway and fire.
- Li-ion battery fire, toxic gas dispersion.
- Electrical equipment failure and fire.
- Transformer, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Bushfires.

Each identified scenario is discussed in further detail in the following sections.

4.4 Li-Ion Battery Fault, Thermal Runaway and Fire

Lithium ion (Li-ion) batteries are composed of a metallic anode and cathode which allows for electrons released from the anode to travel to the cathode where positively charged ions in the solute migrate to the cathode and are reduced. The flow of electrons provides the source of energy which is discharged from a battery and used for work. In lithium iron phosphate (LFP) batteries, the cathode is composed of LFP or LiFePO_4 and the anode is composed of graphite. During charging, lithium ions are released from the cathode, through the electrolyte and across the separator and are stored in the graphite. When discharge occurs, the electrons are released in the circuit and the lithium ions exit the anode and return to the cathode. This process is shown in **Figure 4-1**.

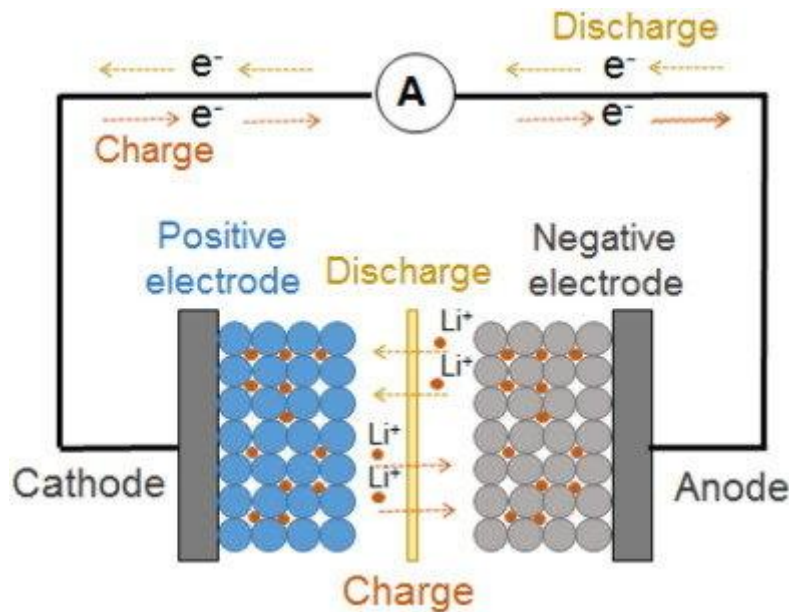


Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

The key hazard associated with Lithium-ion-BESS (Li-BESS) systems is thermal runaway which can be initiated in a cell by several events including (Ref. [9]) :

- Manufacturing defects
- Overcharging
- Overheating
- Mechanical abuse

During thermal runaway, cells can release a large quantity of both toxic and flammable gases creating a risk for explosion and toxicity to bystanders. Thermal runaway in a single cell within a BESS unit has potential to induce thermal runaway propagation which may eventually lead to larger-scale fire and/or explosion incidents (Ref. [10]).

The likelihood and consequence of thermal runaway in a BESS is dependent on several factors including the design, battery chemistry and installed systems. The battery product that has been proposed for this project is the Tesla Megapack 3 of which the battery chemistry is LiFePO_4 , or simply LFP. LFP cells are the current standard for large-scale BESS systems accounting for approximately 80% of the total battery storage market as of 2023. This is largely due to lower cost, higher cycle lives and safety considerations when compared to other chemistries such as nickel manganese cobalt (NMC)(Ref. [11]). Although NMC has a higher energy density, LFP batteries

have begun to dominate the grid-scale energy market due to the following advantages when compared to NMC (Ref. [12]):

- Longer cycle life and less capacity reduction over time
- Higher thermal stability and less prone to overheating
- Better mechanical stability
- More stable electrochemically with fewer side reactions which accelerate degradation
- More resilient to state of charge (SOC) and depth of discharge (DOD) with less degradation from deep cycling

While the Tesla Megapack 3 has not yet attained its certification, the Tesla Megapack 2XL has. The two models share the same battery chemistry and arrangement on a system level; hence, the results of the tests are expected to be comparable as discussed in **Table 3-1**. The testing would have demonstrated in the event of thermal runaway initiated in a single cell; it is highly unlikely that propagation beyond the initiating module would occur even in absence of active control measures. Tesla has provided a letter of commitment to provide the test results once it is available, which has been provided in **Appendix C**.

During a thermal runaway triggered at the cell level, flaming outside of the unit does not typically occur as can be observed in the Tesla Megapack 2XL’s UL9540A test results. However, should a larger issue such as electrical faults or arcing in a number of cells occur, thermal runaway in multiple cells may occur with may cause the entire unit to catch fire and the spacing between units would be relied upon to prevent fire spread.

Therefore, it is important that adequate clearance between units (specifically in the Megablock arrangement as described in **Section 3.0**) have been provided. Tesla has provided recommended clearances in its datasheet. This can then be compared with other established minimum clearances provided by different standards/sheets, which has been assessed in **Table 4-2**.

Table 4-2: Separation Distance Requirement Review

Organisation	Standard / Sheet	Clause	Requirement	Current Design Compliance
Tesla	Megablock System Specification	8.5.1	2.5 m front-to-front (i.e., long side)	Y
Factory Mutual Insurance Company	FMDS 5-33	2.3.2.2	1.5 m on sides that contain access panels, doors or deflagration vents	Y

As observed in the BESS layout provided in **Figure 3-2**, the front-to-front clearance of one Megablock to another is a minimum of 3 m; hence, the requirements of FMDS 5-33 and the Megablock System Specification are complied with. The arrangement of a Megablock can be seen in **Figure 3-7**

As would be seen in the UL9540A report, the LFP technology does not provide a source of ignition during thermal runaway. Should fire develop within one BESS container it would not transfer to nearby containers due to the fire safety design features and recommended separation.

Notwithstanding, this incident has been carried forward for further analysis to identify whether fire protection equipment is impacted.

4.4.1 Risk Analysis

The consequences and likelihood of a flaming Li-ion battery fire are summarised in **Table 4-4**.

Table 4-3: Qualitative Risk Analysis of Li-Ion Battery Fire

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Li-ion Battery Fire	Puncturing or internal damage Internal arcing	Injury/single fatality Damage to property <\$1M	<ul style="list-style-type: none"> Low likelihood of initiating event (stable battery chemistry) Unmanned site during regular operations – low likelihood of people being present No sensitive receivers within 650 m of site Inherent design limits incident propagation (when UL 9540A compliant) Sufficient spacing between units to limit propagation 	4	D	M

4.5 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic biproducts of combustion may form. A literature review was conducted on lithium-ion battery fires to identify the toxic gases which may be generated in the event of a fire. The review identified the following gases or classes of gases can form:

- Carbon dioxide;
- Carbon monoxide; and
- Fluorine gases.

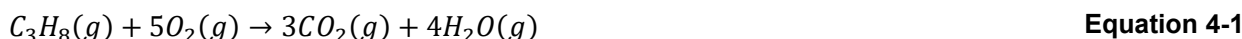
Each of these have been discussed in further detail in the following subsections.

4.5.1 Carbon Dioxide

Carbon dioxide is a colourless, odourless, dense gas which is naturally forming and is present in the atmosphere at concentrations around 415 ppm (0.0415%). At low concentrations carbon dioxide is physiologically impotent and at low concentrations does not appear to have any toxicological effects. However, as the concentration grows it increases the respiration rate of exposed persons. The Short Term Exposure Limit (STEL) is 30,000 ppm (3%) as established by SafeWork Australia; thus, levels above 50,000 ppm (5%) will induce a strong respiration effect, along with dizziness, confusion, headaches, and shortness of breath. Concentrations more than 100,000 ppm (10%) may result in coma or death.

Carbon dioxide is a by-product of combustion where hydrocarbon or carbon-based materials are involved. A typical combustion reaction producing carbon from a hydrocarbon has been provided

in **Equation 4-1**. This reaction proceeds when there is an excess of oxygen to the fuel being consumed and is known as complete combustion as it is the most efficient reaction pathway.



The lithium-ion batteries are predominantly composed of metal structures. However, during a fire event ancillary equipment and materials within the batteries will be involved in the fire including wiring, plastics, anodes, etc. which will liberate carbon dioxide. However, a review of the toxicological impacts indicates high concentrations would be required to result in injury or fatality. Based upon a review of the sensitive areas, and the similar BESS fires, it is not considered that the formation of carbon dioxide in a fire would be sufficient to result in downwind impacts sufficient to cause injury or fatality. In other words, there would be insufficient production of carbon dioxide to generate a plume of sufficient concentration to displace the required oxygen for a significant downwind consequence to occur. This incident has not been carried forward for further analysis.

4.5.2 Carbon Monoxide

Carbon monoxide is an odourless, colourless gas which is slightly denser than air and occurs naturally in the atmosphere at concentrations around 80 ppb. Carbon monoxide is a toxic gas as it irreversibly binds with haemoglobin which prevents these molecules from carrying out the function of oxygen / carbon dioxide exchange. The loss of 50% of the haemoglobin may result in seizures, coma or death which can occur at concentration exposures of approximately 600 ppm (0.06%).

Carbon monoxide is by-product of combustion if there is insufficient oxygen to enable complete combustion. The reaction pathway for the formation of carbon monoxide is provided in **Equation 4-2**.



Carbon monoxide may be generated if there is insufficient oxygen to sustain complete combustion during a BESS fire. However, it is noted that the combustible load within the BESS which could result in the formation of carbon monoxide is relatively low compared to the available oxygen in the surrounding atmosphere. This incident has not been carried forward for further analysis.

4.5.3 Fluoride Gases

The electrolyte used in Li-ion batteries typically is lithium hexafluorophosphate (LiPF₆) or other lithium salts containing fluorine. In the event of a thermal runaway, the electrolyte will expand and be vented from the battery. In the event of a fire, the vented gas and other components such as the polyvinylidene fluoride binders may form gases such as hydrogen fluoride (HF), phosphorous pentafluoride (PF₅) and phosphoryl fluoride (POF₃) (Ref. [13]).

The decomposition of LiPF₆ can be promoted by the presence of water / humidity according to reactions **Equation 4-3** to **Equation 4-5**.



Of the fluorine gases formed, PF₅ is a short-lived gas while POF₃ is a reactive intermediate. Several tests on different variables, such as battery chemistry, configuration and State of Charge (SOC),

indicated most of the batteries did not produce observable POF_3 with the condition that a specific battery chemistry was at 0% SOC (Ref. [13]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

HF gas is hygroscopic that readily dissolves into water vapour / humidity or moisture in airways, forming hydrofluoric acid. Although hydrofluoric acid is a weak acid, it is highly corrosive and may result in chemical burns. In addition, it has calcium scavenging properties. Hence, it will readily bind with calcium in cells and tissues disrupting the nerve signalling. The immediately dangerous to life or Health (IDLH) for HF is 30 ppm and the 10-minute lethal concentration is 170 ppm.

For a toxic gas dispersion, a battery container fire is necessary as the initiating event. As discussed in **Section 4.4** the potential for a fire to occur is considered negligible due to the highly stable and safe battery chemistries used. By ensuring the BESS units implemented are compliant with the UL9540A test criteria, the presence of toxic gases released in the unlikely event of thermal runaway will be negligible.

Furthermore, Franqueville *et al.* (Ref. [14]) completed a Computational Fluid Dynamics (CFD) study to determine the dispersion of toxic gases from Li-Ion batteries in various scenarios. In a worst case scenario, in which the wind reaches 32 km/h and the failed BESS is actively burning, the study showed that a safe distance from the burning Li-Ion battery would be maximum of 54 m. Therefore, a toxic gas dispersion impacting any sensitive receptors within a 600 m radius from the BESS facility is not deemed a credible scenario. Notwithstanding, this incident has been carried forward for further analysis.

4.5.4 Risk Analysis

The consequences and likelihood of toxic gas formation and dispersion from a Li-Ion battery are summarised in **Table 4-4**.

Table 4-4: Qualitative Risk Analysis of Li-Ion Battery Toxic Gas

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Li-ion Battery and Toxic Gas Release	Li-Ion fire	Risk to worker health Air pollution	<ul style="list-style-type: none"> Low likelihood of initiating event (stable battery chemistry) Rapid dispersion of potentially toxic gases to below the threshold IDLH Unmanned site during regular operations – low likelihood of people being present No sensitive receivers within 100 m of site 	3	E	L

4.6 Electrical Equipment Failure and Fire

Electrical equipment is located within the switch room which may fail resulting in overheating, arcing, etc. which could initiate a fire. In the event of a fire, it may begin to propagate to adjacent combustible materials (i.e. wiring). It is noted that electrical equipment fires typically start by smouldering before flame ignition occurs resulting in a slow fire development.

The type of equipment used within the project is ubiquitous throughout the world and across industry segments and is therefore not a unique fire scenario. Based upon fire development within

switch rooms the fire would be considered to be relatively slow in growth and would be unlikely to result in substantial impacts in terms of impacts to firefighting equipment and incident propagation. Therefore, qualitative risk analysis is considered suitable for this hazardous event.

4.6.1 Risk Analysis

The consequences and likelihood of an electrical fire from electrical equipment failure are summarised in **Table 4-4**.

Table 4-5: Qualitative Risk Analysis of Electrical Fire

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Electrical fire	Electrical equipment failure	Fire Damage to equipment <\$1M Injury to worker (some lost time)	<ul style="list-style-type: none"> • Slow fire development • Arcing safeguards in equipment • Lightning protection • Switch-off procedure 	3	E	L

4.7 Transformers, Oil Release, Ignition and Bund Fire

Transformers contain oil which is used to insulate the transformers during operation. If arcing occurs within the transformer (e.g. due to a low oil level), the high energy passing through the coolant vaporises the oil into light hydrocarbons (methane, ethane, acetylene, etc.) resulting in rapid pressurisation within the reservoir. To minimise the likelihood of such occurrence, transformers are fitted with a low oil pressure switch, oil temperature monitoring and switches, gas formation detectors and a pressure surge protection. These devices identify potential oil and pressure events within the transformer, isolating power and alarming operators.

Notwithstanding the protection systems, if the pressure rise exceeds the structural integrity of the reservoir, and the installed pressure relief devices, the reservoir can rupture allowing the release of oil into the bund. The rupture also allows oxygen to enter the reservoir. The temperature of the gases is above the auto ignition point, but this does not occur until oxygen is present. When oxygen enters the reservoir, the gases auto ignite which generates sufficient heat to ignite the oil in the bund.

The transformer to be used on site will be insulated using natural ester based insulating oil. Natural esters have a flash point exceeds 300°C (Ref. [15]) and are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [8]). Therefore, ignition of the fluid is extremely difficult, and a fire occurring from a natural ester insulated transformer is not considered a credible scenario. Furthermore, transformers are ubiquitous units with a low potential for failure.

Notwithstanding this, due to the number of transformers on site, and the potential for natural ester oil to be substituted with more flammable transformer oil, this incident has been carried forward for quantitative risk analysis for conservatism.

4.8 Transformer Electrical Surge Protection Failure and Explosion

Transformers generate large amounts of heat as a result of the high electrical currents that pass through them; hence, oil is used as an insulating material within the transformers to protect the mechanical components. However, if the transformer gets an extreme surge of energy, such as

that which could occur due to a lightning strike, and the electrical surge protection measures fail, the mineral oil may start to decompose and vapourise, resulting in gas bubbles of hydrogen and methane (Ref. [16]) as temperatures above the autoignition of the gases.

The formation of gases will increase the pressure within the transformer which can result in the transformer structure rupturing which allows the ingress of oxygen. As the oxygen enters, the concentration of flammable gases falls within the explosive limits which are above their autoignition temperatures which ignite resulting in increased formation of hot gaseous products resulting in an explosion. The explosion may generate significant overpressure, sparks and fire and would result in a whole transformer fire, as discussed in **Section 4.7**.

In order to protect against overheating and explosions, transformers have surge protection, which programs them to shut down upon detection of an energy spike. However, the surge protection can have a slight delay. In the event of a major lightning strike, significant oil deterioration or physical damage such as a fallen tree, the surge protection may be too slow to stop an electrical overload (Ref. [17]).

However, the transformers will be protected against lightning as per the requirements of AS 2067:2016 (Ref. [18]). Furthermore, the transformers will use natural esters as the insulating liquid instead of mineral oil. As previously discussed, natural esters have a flash point exceeding 300°C (Ref. [15]), and so are classified as non-dangerous goods under the Australian Dangerous Goods Code (Ref. [19]).

Therefore, there is the potential for an explosion to occur which may result in impacts to fire protection equipment; however, as noted, these units are ubiquitous and have a low potential for failure. Qualitative risk analysis is deemed sufficient for this event.

4.8.1 Risk Analysis

The consequences and likelihood of a transformer explosion from surge protection failure are summarised in **Table 4-4**.

Table 4-6: Qualitative Risk Analysis of Transformer Explosion

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
Transformer	Surge protection failure	Explosion Damage to property < \$1M Fatality/fatalities Incident propagation	<ul style="list-style-type: none"> Low likelihood of lightning strike Lightning protection Use of natural esters for insulating oil (non-flammable) Global use indicates relative safety 	4	E	M

4.9 Electromagnetic Field Impacts

4.9.1 Introduction

Electric and Magnetic Fields (EMFs) are associated with a wide range of sources and occur both naturally as well as man-made. Naturally occurring EMFs, occurring during lightning storms, are generated from Earth’s magnetic field. Man-made EMFs are present wherever there is electricity; hence, EMFs are present in almost all built environments where electricity is used.

Extremely low frequency (ELF) electric and magnetic fields (EMF) occupy the lower part of the electromagnetic spectrum in the frequency range 0-3,000 Hz which is the current will change direction 0-3,000 times a second. ELF EMF result from electrically charged particles. Artificial sources are the dominant sources of ELF EMF and are usually associated with the generation, distribution and use of electricity at the frequency of 50 Hz in Australia. The electric field is produced by the voltage whereas the magnetic field is produced by the current.

BESS create EMFs from operational electrical equipment, such as transmission lines, transformers and the electrical components found within BESS units, inverters, etc. This equipment has the potential to produced ELF EMFs in the range of 30 to 300 Hz.

4.9.2 Existing Standards

There are currently no existing standards in Australia for governing the exposure limits to ELF EMFs; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has provided some guidelines around exposure limits for prolonged exposure which limits the exposure to 2,000 milligauss (mG) for members of the public in a 24 hour period (Ref. [20]).

Table 4-7 provides typical magnetic field measurements and ranges associated with EMF sources. It is noted that electric fields around devices are generally close to 0 due to the shielding provided around the equipment. In addition, EMF levels drop away quickly with distance; hence, while a value may be measurable at the source, within a short distance the EMF is undetectable. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) advises that the strength of radiation decreases exponentially with distance from the source, and it will become indistinguishable from background radiation within 50 m of a high voltage power line and within 5 to 10 m of a substation. (Ref. [21]).

Table 4-7: EMF Sources and Magnetic Field Strength

Source	Typical Measurement (mG)	Measurement Range (mG)
Television	1	0.2 – 2
Refrigerator	2	2 – 5
Kettle	3	2 – 10
Personal computer	5	2 – 20
Electric blanket	20	5 – 30
Hair dryer	25	10 – 70
Distribution powerline (under the line)	10	2 – 20
Transmission power line (under the line)	20	10 – 200
Edge of easement	10	2 – 50

4.9.3 Exposure Discussion

A review of the site indicates the nearby residences adjacent to the area where the BESS will be developed are separated by over 650 m providing substantial distance for attenuation of EMFs. Based upon the typical levels which may be generated by transmission equipment the cumulative effect would not exceed the 2,000 mG limit for prolonged exposure.

As the potential for exposure to EMF exceeding the international guidelines is negligible, this incident can be qualitatively analysed.

4.9.4 Risk Analysis

The consequences and likelihood of damage from electromagnetic field impacts are summarised in **Table 4-8**.

Table 4-8: Qualitative Risk Analysis of EMF Impacts

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R
EMF impacts	Electrical equipment and BESS	Minor health impacts from extended exposure	<ul style="list-style-type: none"> Inherently lower levels than background radiation Drop off within short distances No sensitive receivers within 1,000 m of the site 	1	C	L

4.10 Bushfires

There is the potential for an external fire event to impact the BESS Project such as a bushfire incident. The proposed BESS site is located outside of bushfire prone land with a Very High, High and Medium Potential Bushfire Intensity, as indicated in **Figure 4-2**. As such, the site shall maintain good groundskeeping procedures to prevent the accumulation of combustible loads; hence, in such an event any escalation would be expected to be a minor grass fire. Grass fires can move quickly; however, they tend to be short lived as the combustible load is exhausted. Subsequently, sustained radiant heat impacts at the site would not be expected and would be unlikely to result in sufficient heat to impact the BESS or other infrastructure such that incident propagation occurs.

A bushfire hazard assessment and associated bushfire management plan has been developed by Meridian Urban. It is expected that the design of the site will incorporate the recommendations and findings of the assessment to mitigate the risks of bushfire impact on the BESS. In addition, during operations, the O&M buildings also have portable fire extinguishers that can help in the case of minor fires. In the case of larger bushfires, emphasis will be placed on evacuating the site if required. A fire water supply will be provided in a 40 kL tank for the brigade to use as well.

The equipment on the site is also protected by the features described in the previous sections and are thus unlikely to be significantly damaged to minor bushfires. The pieces of equipment are also arranged to be sufficiently separated from one another, meaning there is empty space with no fuel between equipment pieces. This would decelerate the bushfire and reduce the impacts.

The potential for incident escalation as a result of an external fire impact to occur is considered low; hence, this incident is reasonably analysed qualitatively.

4.10.1 Risk Analysis

The consequences and likelihood of site damage from bushfire disasters are summarised in **Table 4-4**.

Table 4-9: Qualitative Risk Analysis of Bushfire Impacting BESS

Hazard	Cause	Consequence	Safeguard	Assessed Risk		
				S	L	R

Bushfire	<p>Lightning strike</p> <p>Spontaneous combustion of organic matter due to exothermic reaction (decay)</p> <p>Arson</p> <p>Power line failures</p> <p>Discarded cigarettes</p> <p>Accidental ignition from activities such as parties, campfires, etc</p>	<p>Damage to property < \$1M</p> <p>Fatality/fatalities</p> <p>Incident propagation</p>	<ul style="list-style-type: none"> • Separated arrangement of equipment to limit propagation (remove fuel) • Housekeeping procedures to keep grass low • Inherent fire protection in BESS and high heat resistance of other equipment 	4	D	M
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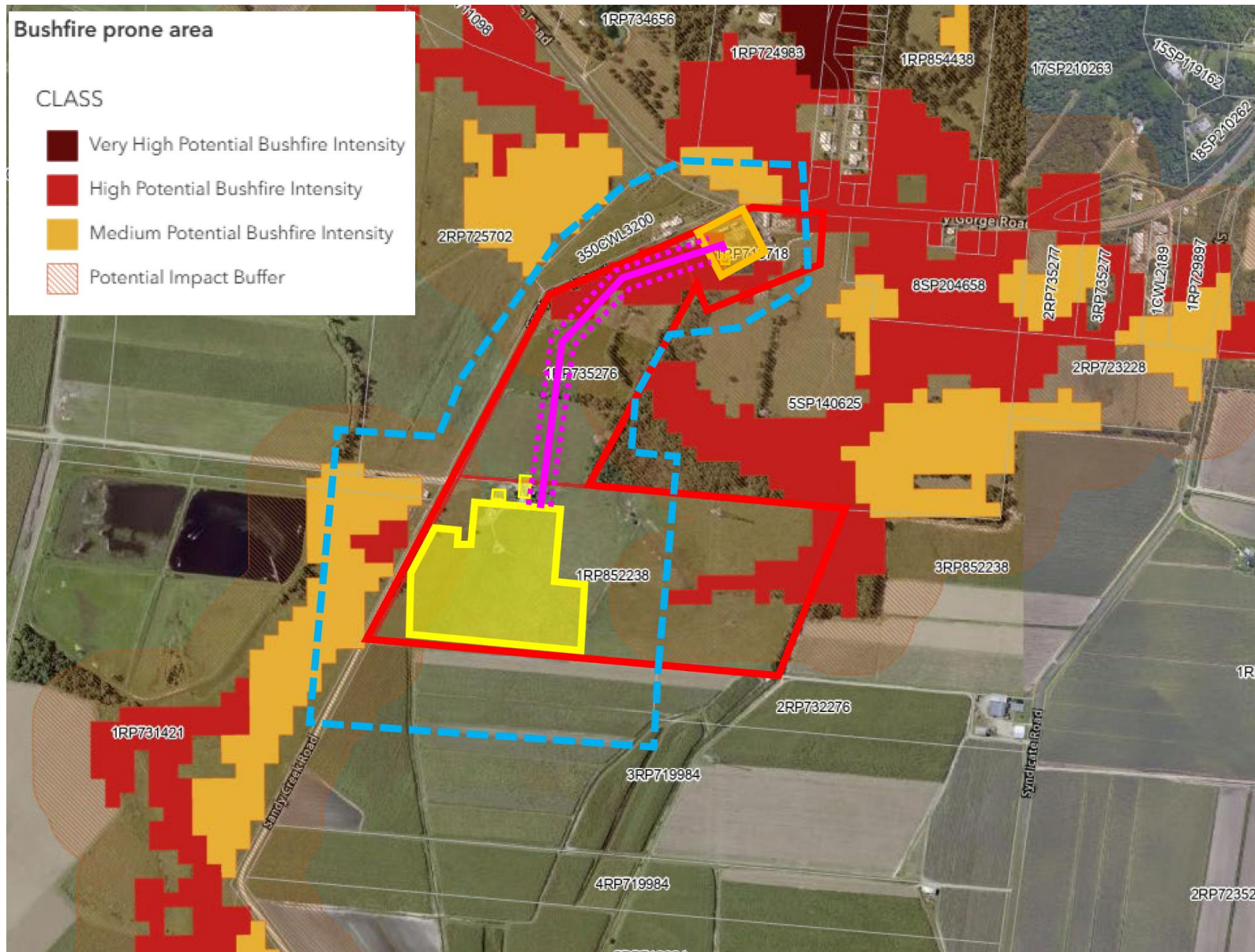


Figure 4-2: Bushfire Prone Land

5.0 Consequence Analysis

5.1 Incidents Carried Forward for Consequence Analysis

The following incidents were identified to have the potential to impact fire protection systems or to complicate firefighting interventions:

- Li-ion battery fault, thermal runaway and fire.
- HV transformer, oil spill, ignition and bund fire.
- MV transformers, oil release, ignition and fire.
- Li-ion battery fire and toxic gas dispersion.

Each incident has been assessed in the following sections, with acknowledgement of the two potential sites where applicable. A detailed analysis of each scenario is outlined in **Appendix B**, along with the criteria used to assess each incident.

5.2 Li-Ion Battery Fault, Thermal Runaway and Fire

5.2.1 Radiant Heat Modelling

Currently, there are little established data to ascertain the radiant heat emitted from a BESS lithium fire. However, a Large Fire Scale Test (LFST) has been conducted on a BESS for a past project with similar capacity noting that the exact details of the test are under a non-disclosure agreement. The results from the test indicated that fire propagation is minimal and only the unit that was initiated to undergo thermal runaway had caught on fire. It was observed that the adjacent unit suffered only cosmetic damage; however, it remained operational throughout the duration of fire from the initiating unit. The flame characteristics from the unit observed are as follows:

- A maximum flame temperature of 675.3°C was recorded.
- Peak flame extended 1.8 m vertically and 1.2 m horizontally.
- Maximum heat flux is 48.72 kW/m² at a distance of 1.2 m.
- No adjacent units have initiated thermal runaway due to the fire event in the initiating unit; hence, a full BESS container fire is not considered to be credible.

Based on the data provided, the radiant heat contour impacts can be determined by using the known maximum heat flux at the measured distance and the view factor methodology provided in **Appendix B**. The maximum view factor can be derived using the provided which yielded a F_{max} of 0.5. **Equation A-1** can then output a SEP value of 95.6 kW/m² which will be used as the basis to calculate the distances of radiant heat impacts. This has been summarised in **Table 5-1** below.

Table 5-1: Radiant Heat Impact from a BESS Unit Fire

Heat Radiation (kW/m ²)	Distance (m)
48.72	1.2
35	1.3
23	2.0
12.6	2.8
4.7	4.2

3.0	5.9
-----	-----

The 23 kW/m² contour has been used to assess the potential for propagation of the incident. The results indicate the 23 kW/m² contour may impact its own MV transformer. The consequence analysis of the MV transformer has been provided in **Figure 5-2**. The separation distance between neighbouring Megablocks is 3.0 m; hence, incident propagation is not expected to occur. Furthermore, the fire safety features inherent to the BESS units and MV Transformers are not considered in the modelling of the pool fires and make the risk of incident propagation negligible. If the layout in **Figure 3-2** is emulated in the final design, there will be no fixed fire protection systems in proximity to any Megablock arrangement; hence, these are unimpacted by the 23 kW/m² contour.

5.2.2 FM Global Datasheet 5-33 Compliance

There is potential that a Li-Ion battery may fault resulting in thermal decomposition and fire which may spread throughout the whole fire unit if not isolated / protected. As of this report's writing, a Large Scale Fire Test (LSFT) has not been finalised for the Tesla Megapack 3. While past UL9540A test results will conclude on whether fire propagation, based on different levels, would occur during thermal runaway, it does not induce a sustained fire condition (i.e., flammable gas emitted by thermal runaway reactions and ignited). A recommendation has been made to address this:

- A LSFT in compliance with the U9540A 6th Edition shall be conducted for the Tesla Megapack 3 and provided to the Consenting Authority once available.

Tesla has provided a letter of commitment to provide the test results once it is available, which has been provided in **Appendix C**.

Notwithstanding the above, it is important to identify whether the design, excluding the inherent fire safety systems and BMS of the Tesla Megapack 3, has adequately provided measures against the risks of fire. FM Global Datasheet 5-33 (Ref. [22]) has been consulted to review the design against its relevant requirements. The datasheet contains loss prevention measures that are applicable to BESS that exceed 20 kWh. FM Global describes its recommendations based on live fire testing data that it conducts in its facility; however, the information is proprietary and thus cannot be shared. Nevertheless, a clause-by-clause assessment of the design has been conducted and can be found in **Table 5-2** against the datasheet's relevant provisions. It is expected that adequate compliance with FM Global Datasheet 5-33 will result in the mitigation of fire and explosion risks so far as is reasonably practicable. However, if the design is not prescriptively complied with, the level of protection is assessed whether it meets the intent.

As observed in the table, the design complies with level of protection required by FM Global Datasheet 5-33.

Table 5-2: Clause-by-Clause Assessment of FM Global Datasheet 5-33

No.	Loss Prevention Requirement	Compliance Assessment
2.3.1.1	Locate BESS in an enclosure outside an away from critical buildings or equipment in accordance with 2.3.2	Yes - BESS units are located wholly outdoors and in special designated enclosures away from critical buildings or equipment.
2.3.2.1	Select or construct LIB-ESS enclosures/containers using only non-combustible materials.	Yes – BESS enclosures/containers are made of non-combustible materials.

No.	Loss Prevention Requirement	Compliance Assessment
2.3.2.2	For containerized LIB-ESS comprised of LFP cells, provide aisle separation of at least 1.5 m on sides that contain access panels, doors or deflagration vents.	Yes – Each Tesla Megablock is separated by at least 3.0 m front-to-front. Additionally, a Tesla Megapack 3 in a Megablock is separated by at least 1.5 m on sides that contain access panels, doors or deflagration vents.
2.3.2.4	Provide separation between solid walls having no openings based on installation-level testing that demonstrates thermal runaway cannot propagate between containers. Where a fire test report is not available or the test did not result in a fire in the unit of origin, provide separation as indicated in Section 2.3.2.2.	Yes – The separation distances are compliant per Section 2.3.2.2.
2.3.2.4.1	If any penetrations are present, the separation should be extended, or the penetrations should be protected or equipped with FM Approved fire-safe wall penetrations.	Yes – The separation is in excess of the recommendation in Section 2.3.2.2. Additionally, any penetrations would be protected by the inherent systems in each BESS unit.
2.3.2.4.2	Where explosion vents or other penetrations are provided, ensure they are arranged and directed away from surrounding equipment and buildings.	Yes – The explosion vents or other penetrations are arranged and directed away from buildings and/or other BESS/electrical equipment.
2.3.2.5	Provide a minimum space separation between LIB-ESS enclosures and adjacent buildings or critical site utilities or equipment in accordance with Data Sheet 1-20 using hazard category 3 for the exposing building occupancy.	Yes – The separation distance between the nearest BESS enclosure to the adjacent building or critical site utilities is 50 m, which is more than adequate in terms of separation distance.

5.2.3 Past Battery Incidents

It is important to validate the discussion and findings in both **Sections 5.2.1** and **0**. Tesla has provided several case studies on past incidents involving BESS thermal runaway. This subsection contains a review of these incidents, involving the cause, key takeaways and observations, which are provided in **Table 5-3**.

Table 5-3: Review of Past Battery Incidents

Location	Date (DD/MM/YYYY)	Model	Cause	Emergency Response	MP3 Safety Implementations
Geelong, Victoria Australia	30/07/2021	MP1	<ul style="list-style-type: none"> • Coolant leak within the liquid cooling system of MP-1. • Leak of conductive liquid on electrical system led to arcing in the power electronics of the Megapack's battery modules. • This resulted in heating of lithium-ion cells that led to thermal runaway. • Contributory causes include the lack of a SCADA system, lack of telemetry, fault monitoring and electrical active safety devices. 	<ul style="list-style-type: none"> • The MP1 was shut off manually prior to the fire incident. Once smoke was observed by site personnel, they electrically isolated all MP1s and called the brigade. • The brigade set up a perimeter and started applying cooling water to the nearby exposures. • Fire propagated from one container to another via plastic vents on the roof (combustible). • The MP1s was allowed to burn out, and water was not applied to it. 	<ul style="list-style-type: none"> • Improved inspection of the thermal system. • Reduced telemetry setup from twenty-four hours to one hour, along with avoiding using the keylock switch during commissioning or operation unless the unit is being actively serviced. • Updated firmware, to include alerts for the thermal system, keeping all active safety systems active, and monitoring of the pyrotechnic disconnect. • Replaced the plastic roof vents with thermally insulated steel vent shields. • Refinement of the ERP to avoid using water on an MP fire, but only on nearby exposures, to allow the MP to burn out.
Elkhorn, California USA	20/09/2022	MP1	<ul style="list-style-type: none"> • Rainwater intrusion into the units due to result of displaced umbrella valves on the roof which were displaced during the installation of new vent shields. 	<ul style="list-style-type: none"> • The initiating MP1 fire detection alarms, and the site operator called 911 shortly thereafter. • Firefighters set up two hose streams on exposures. 	<ul style="list-style-type: none"> • Introduction of an Automatic Safe Discharge (ASD) feature. • Updated alarms and approval processes, including battery isolation failure alerts, server-side alarms now being elevated to Tesla operators.

Location	Date (DD/MM/YYYY)	Model	Cause	Emergency Response	MP3 Safety Implementations
			<ul style="list-style-type: none"> Water ingress ultimately led to electrical shorts which initiated thermal runaway of the battery cells. Sustained flame condition was observed. 	<ul style="list-style-type: none"> No fire propagation between containers was observed. The MP1 was allowed to burn out, and water was not applied to it. 	<ul style="list-style-type: none"> Playbook guidance for isolation-failure alerts. Prioritisation of thermal-alarm transmission to eliminate the delay of alerting the fire brigade. Refinement of the ERP regarding roles, responsibilities and training. Update on the water-application guidance: cooling water is not to be applied to nearby MPs.
Bouldercombe, Queensland Australia	26/09/2023	MP2	<ul style="list-style-type: none"> A fault occurred on the AC side of the specific MP2 which led to arcing. This resulted in heating of lithium-ion cells that led to thermal runaway. 	<ul style="list-style-type: none"> The initiating MP2 caused a trip in the RMU, isolating it from the rest of the site. The brigade set up two hose streams on exposures. No fire propagation between containers was observed. The MP2 was allowed to burn out, and water was not applied to it. 	<ul style="list-style-type: none"> Review of inverter module and AC bus quality assurance and inspection, and replacement of parts. Updates to firmware to better detect a thermal event. Improved commissioning and service self-testing.

5.2.4 The Victorian Big Battery Fire

As outlined in **Table 5-3**, an incident involving propagation between two BESS containers occurred in Geelong VIC on 30 July 2021 which has been named as the Victorian Big Battery (VBB) fire. The VBB is a 300 MW / 450 MWh BESS facility which is fitted with 212 Tesla Megapacks. The Megapacks was designed to safely operate in close proximity to adjacent units, in which they are arranged as close as 15 cm apart in one 'block'. This design was validated through UL9540A testing.

However, a fire occurred due to a coolant leak resulted in several LPF cells undergoing thermal runaway. The specific chain of events occurred are as follows:

1. Flames exiting MP-1's roof were pushed sideways by strong winds directly onto the MP-2 roof.
2. This flame impingement ignited the combustible plastic overpressure vents on the MP-2 roof.
3. The burning vents created an open pathway for flames and hot gases to enter the MP-2 battery bays.
4. Battery cells exposed to temperatures above 139°C entered thermal runaway and caught fire.

Telemetry data from MP-2 was critical in ruling out alternative causes. At the time when fire was observed within the roof of the MP-2, internal cell temperatures had only risen by 1°C over two hours which strongly suggests that either radiant and/or conductive heat transfer across the 15 cm gap between the containers was not the cause. The fire propagated through direct flame impingement/exposure on the roof, not through the gap between containers. UL9540A testing permits a maximum wind speed of only 19.3 km/h which is lower than the wind conditions present during the VBB fire. The higher winds created flame behaviour that could not be observed during the UL9540A testing.

Ultimately, it was identified that the vulnerability lied in the plastic overpressure vents which are combustible. These have been replaced with steel vents in the MP3.

5.3 HV Transformer, Oil Release, Ignition and Bund Fire

There is potential that arcing may occur within the 33/132 kV transformer in the substation which may lead to generation of gases and pressure above the structural integrity of the oil reservoir. This may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund.

A detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-4**. The radiant heat contours associated with a fire occurring within a transformer bund are shown in **Figure 5-1**.

Table 5-4: Radiant Heat from a Transformer Fire

Heat Radiation (kW/m ²)	Distance (m)
35	18
23	19
12.6	23
4.7	30
3.0	35

The 23 kW/m² contour has been used to assess the potential for propagation of the incident. **Figure 5-1** shows that the 23 kW/m² heat radiation contour from a transformer fire will not impact the site boundary, nor additional infrastructure. Furthermore, the modelling has been completed without consideration for additional fire protection features that may be implemented, such as fire walls. Thus, the impact of a transformer bund fire will be negligible.

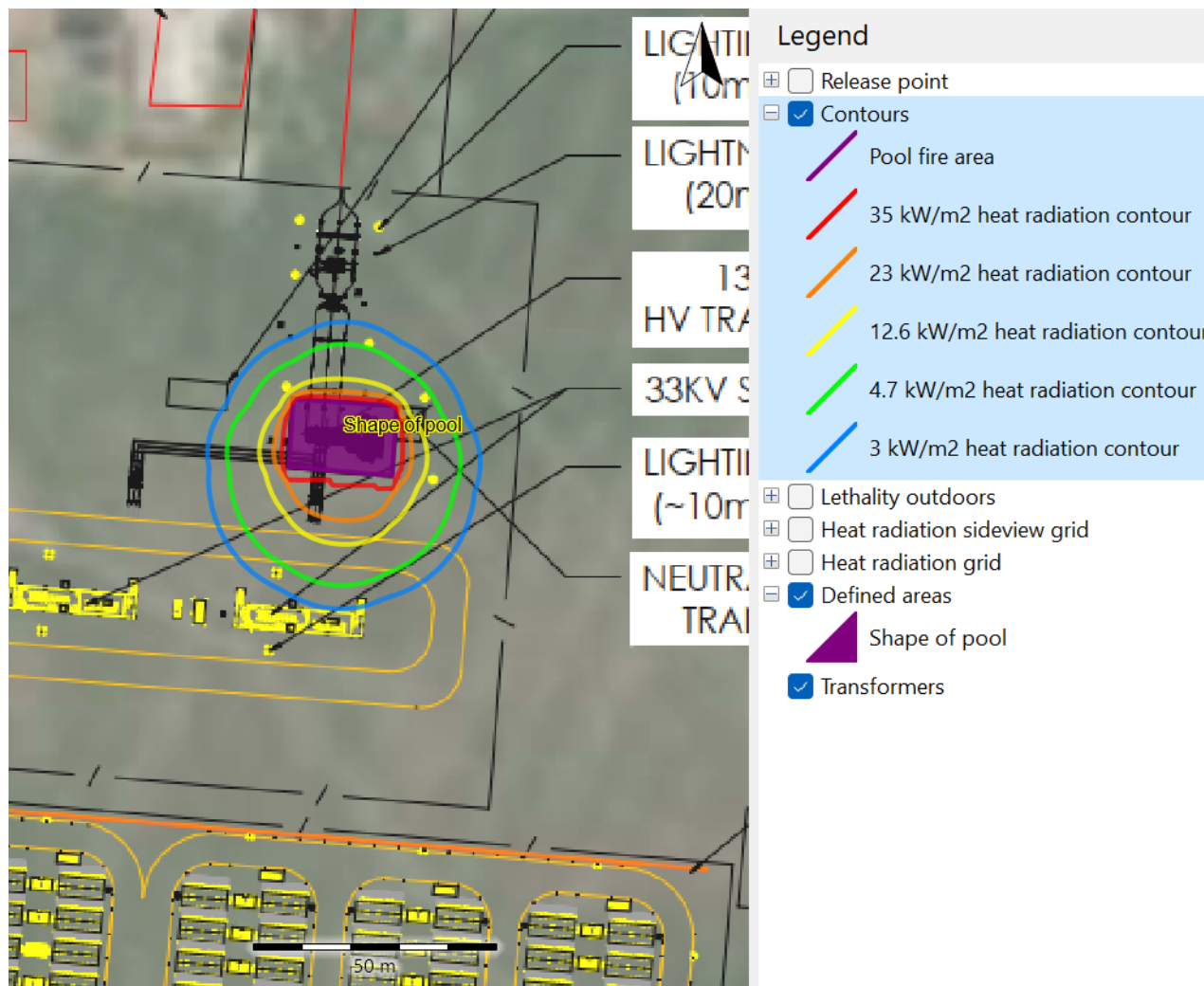


Figure 5-1: Transformer Fire Radiant Heat Contours

5.4 MV Transformers, Oil Release, Ignition and Fire

There is potential that arcing may occur within the MV transformers which may lead to generation of gases and pressure above the structural integrity of the oil reservoir which may rupture leaking oil into the bund. As a result of the arcing and rupture, the oil may ignite leading to a bund fire within the dimensions of the bund.

A conservative detailed analysis has been conducted in **Appendix B** and the radiant heat impact distances estimated for this scenario are shown in **Table 5-5**. The radiant heat contours associated with a fire occurring within the MV Transformers are shown in **Figure 5-2**.

Table 5-5: Radiant Heat from a MV Transformer Fire

Heat Radiation (kW/m ²)	Distance (m)
35	4.5

23	4.8
12.6	5.8
4.7	8.5
3.0	9

The 23 kW/m² contour has been used to assess the potential for propagation of the incident. The results in **Table 5-5** indicates the 23 kW/m² contour may impact adjacent infrastructure (other MV Transformer or adjacent BESS units) as they are within 5 m of the incident MV Transformers. However, the fire safety features inherent to the BESS units and MV Transformers are not considered in the modelling of the pool fires and make the risk of incident propagation negligible. Furthermore, **Figure 5-2** shows that the contours are shown not to impact the site boundary. If the layout in **Figure 3-2** is emulated in the final design, there will be no fixed fire protection systems in proximity to the MV Transformers; hence, these are unimpacted by the 23 kW/m² contour.

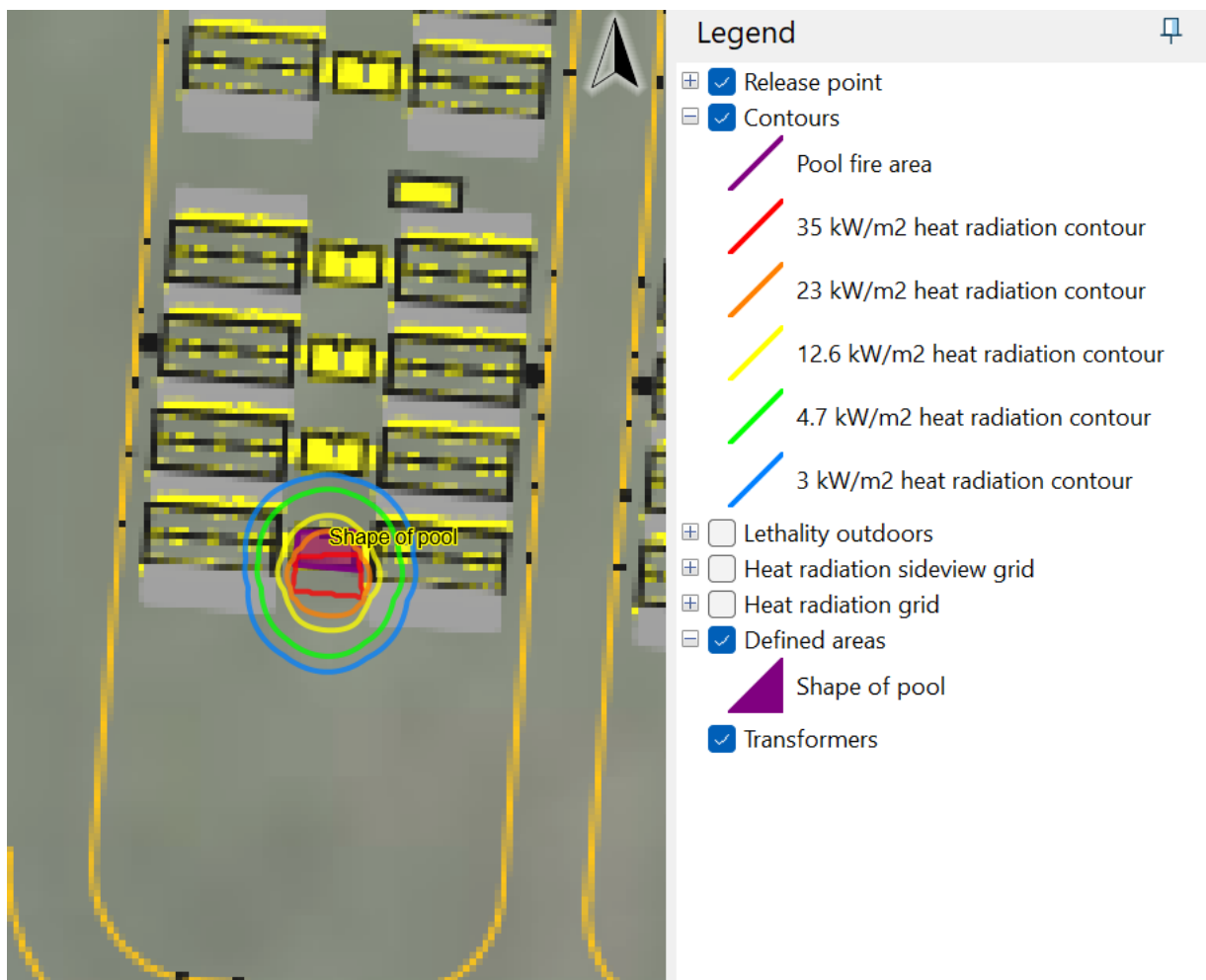


Figure 5-2: MV Transformer Fire Radiant Heat Contours

5.5 Li-ion Battery Fire and Toxic Gas Dispersion

As discussed in **Section 4.4**, there is potential for a battery fire that will lead to the emission of several toxic gases. A detailed analysis has been conducted in **Appendix B** using GEXCON EFFECTS modelling software. The anticipated distances to the defined AEGL toxicity thresholds, assessed at a representative breathing height, are presented in **Table 5-6**

Table 5-6: HF AEGL 5 Minute Exposure Contours to 1.5 m Receiver (Breathing Height)

AEGL Level	Impact Distances (m)
AEGL 2 (Injury)	14
AEGL 3 (Life threatening health effects)	11

Figure 5-3 illustrates the HF plume geometry resulting from the worst-case BESS fire scenario, while **Figure 5-4** presents the spatial extent of AEGL-2 and AEGL-3 exposure zones at a received height of 1.5 m. These figures demonstrate the potential exposure of personnel during evacuation or movement to shelter, as well as the proximity of the toxic plume to external receptors.

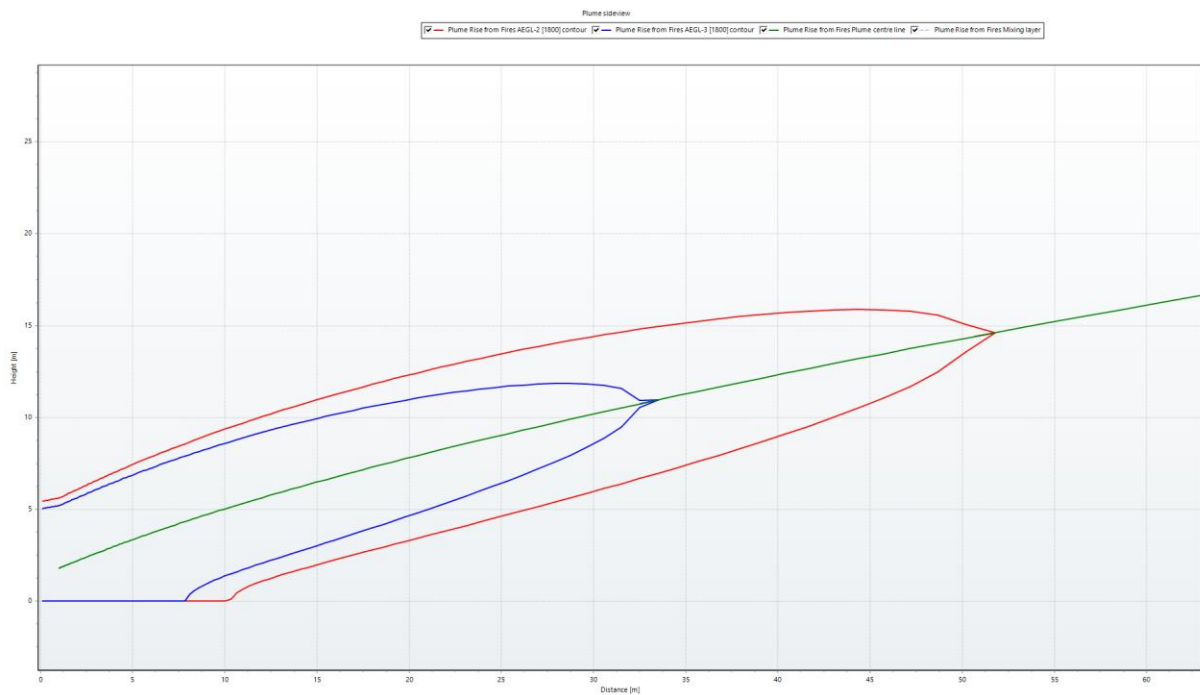


Figure 5-3: HF AEGL 5 Minute Exposure Plume Sideview

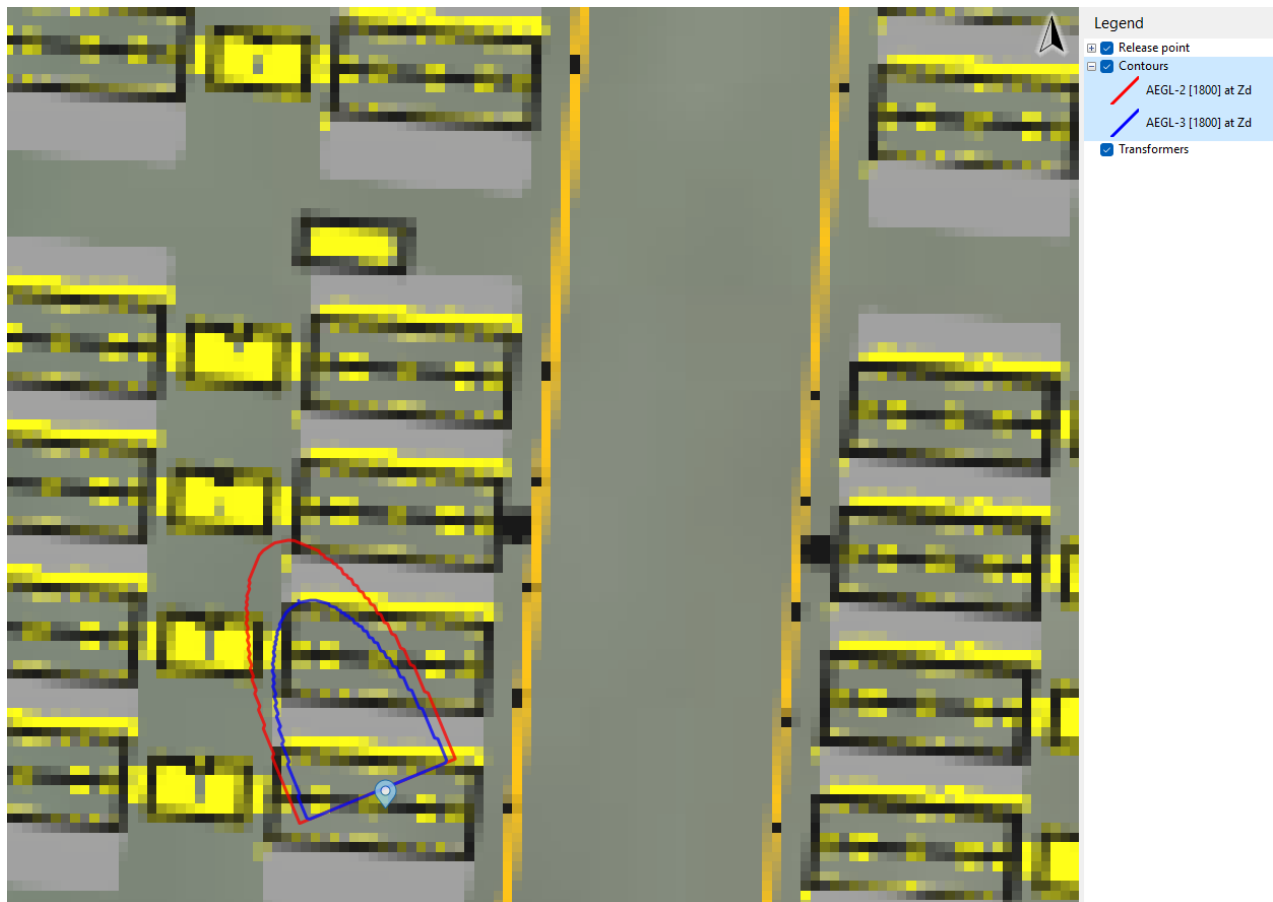


Figure 5-4: HF AEGL 5 Minute Exposure Contours Proximity to Offsite Receptors.

The modelled AEGL contours for a 5-minute exposure duration indicate that toxic impacts associated with the worst-case BESS fire scenario are highly localised and limited in extent, with AEGL-2 and AEGL-3 thresholds confined to within 14 m and 11 m of the source, respectively. These distances demonstrate that personnel are able to evacuate the immediate vicinity or reach a place of safety without significant exposure likely to result in long-term health effects, particularly given the short duration of exposure associated with movement to shelter or evacuation.

It is noted that BESS fires are characterised by high heat release rates, resulting in strong plume buoyancy and vertical entrainment. For the purposes of this assessment, the convective heat release has been conservatively modelled using parameters representative of cellulosic materials, which are significantly cooler than a BESS fire. This approach reduces plume buoyancy and results in increased predicted ground-level concentrations, thereby providing a conservative estimate of toxic exposure. This assumption also implicitly addresses both early-stage fire conditions (where heat release may be lower) and later-stage scenarios, ensuring that potential impacts are not underestimated.

The plume modelling indicates that, as the release travels downwind, it rises in elevation due to buoyancy and entrainment, resulting in reduced concentrations at typical human breathing height (approximately 1.5 m). Consequently, AEGL threshold exceedances are not predicted to extend to off-site receptors at ground level. As the plume continues to travel, it cools and disperses, with concentrations decreasing below AEGL thresholds prior to reaching sensitive receptors.

Based on prevailing meteorological conditions, winds at the site are predominantly from the either south or north/northeast based on the day, and emergency response arrangements have been developed accordingly. The following recommendation has been made:

- A windsock shall be installed at the facility in a location visible from all operational areas.

The windsock will enable personnel and emergency responders (including QFD) to readily determine wind direction and select an appropriate assembly point or command location.

Given the nature of BESS fire events and the potential for localised toxic releases, it is recommended that personnel evacuate in an upwind direction away from the release point, unless otherwise directed. This approach provides the most reliable means of minimising exposure during an incident.

6.0 Details of Prevention, Detection, Protection and Mitigation Measures

The fire safety systems at the site can be split into four main categories:

1. **Fire Prevention** – systems, installed to prevent the conditions that may result in initiating fire.
2. **Fire Detection** – systems installed to detect fire and raise alarm so that emergency response can be affected (both evacuation and firefighting)
3. **Fire Protection** – systems installed to protect against the impacts of fire or explosion
4. **Fire Mitigation** – systems installed to minimise the impacts of fire and to reduce the potential damage (e.g. fire water application)

Each category has been reviewed in the following sections, with respect to the existing systems incorporated into the design and those to be provided as part of the recommendations herein.

6.1 Fire Prevention

This section describes the fire prevention strategies and measures that will be undertaken at the site.

6.1.1 Control of Ignition Sources

The control of ignition sources reduces the likelihood of igniting a release of material. The site has a number of controls for ignition sources. These include controls for fixed potential ignition sources and controls for introduced ignition sources.

1. A permit to work or clearance system will be used - hot work will be controlled as part of the permit to work system.
2. Designated smoking areas within the site (i.e. external from building areas).

Table 6-1 presents the potential ignition sources and incidents for the Project which may lead to ignition and fire. The table also summarises the controls that will be used to reduce the likelihood of these potential sources of ignition and incidents resulting in a fire.

Table 6-1: Summary of Control of Ignition Sources

Ignition Source	Control
Smoking	No smoking policy for the site with smoking only permitted in designated areas.
Electrical	Fixed electrical equipment to be designed and installed to AS/NZS 3000:2018 (Ref. [23]).
Arson	The site will have a security fence and monitored security cameras.
Hot Work	A permit to work system and risk assessment prior to starting work will be provided for each job involving the introduction of ignition sources.

6.1.2 Separation of Incidents

The separation of incidents is used to minimise the impacts of a hazardous incident on the surrounding operations or the generation of potential “domino” effects. The storage locations of products have been designed based upon whether a product can be adequately protected by the fire protection system. The BESS UL 9540 A test will indicate that propagation between modules will not occur from thermally running away battery cells. Furthermore, the BESS shall be arranged such that appropriate separation between units is required. The risk of propagation has been

assessed in **Section 5.2**. Therefore, propagation within the BESS is unlikely and therefore propagation between adjacent BESS units is not considered to be credible.

6.1.3 Housekeeping

The risk of fire can be significantly reduced by maintaining high standards of housekeeping. The site shall maintain a high housekeeping standard, ensuring all debris is cleaned up and removed from the areas. In addition, the site has little vegetation present, which will eliminate the accumulation of combustible vegetation in proximity to the site equipment. This will minimise the potential for bushfire escalation.

6.1.4 Work Practices

The following work practices will be undertaken to reduce the likelihood of an incident. They include:

1. DG identification
2. Placarding & signage within the site
3. Forms of chemical and DG information
4. Availability of Safety Data Sheets
5. Compliance with the Work Health and Safety Regulation 2011 (Ref. [7]).
6. Safe work practices adhered to
7. Personal Protective Equipment
8. Emergency response plan and procedures
9. Bushfire Management Plan
10. Training of personnel”

6.1.5 Safety and Emergency Management Plan

A Safety and Emergency Management Plan in accordance with State Code 27 and HIPAP No. 1 has been established for the site. The document contains the appropriate response plans for different incident scenarios, ranging from fires/explosions to bomb threats. Personnel will be made aware of the response plan and trained appropriately before commencing work on-site.

6.1.6 Site Security

Maintaining a secure site reduces the likelihood either of a fire being started maliciously by intruders or by accident. Access to the site will be restricted at all times and only authorised personnel will be permitted within the site.

6.2 Fire and Gas Detection

This section discusses the detection and protection from fires for the hazardous incidents previously identified. These include detection of fire pre-conditions, detection of a fire suppression activated condition and prevention of propagation. This assessment includes identification of the detection and protection systems required.

6.2.1 Fire Detection and Alarming

The site will utilise BESS units that are UL 9540A compliant. Such BESS units are equipped with smoke detectors and thermal detectors to detect the early signs of a fire. If elevated temperatures or smoke are detected, an audible fire alarm and visual fire strobes fitted on the BESS unit will be activated. In addition, corresponding alarms will be sent to the EMS systems to alert site personnel to begin emergency procedures.

6.2.2 Gas Detection and Alarming

BESS units compliant with UL 9540 are fitted with flammable gas detection, which will alarm and activate the ventilation system. Flammable gases are a by-product of thermal runaway in the battery chemistries; hence, detection of the flammable gases provides another point to isolate BESS failure.

6.3 Fire Protection

To be FM-Global Datasheet 5-33 and NFPA 855 compliant, BESS containers must be constructed of non-combustible materials. BESS units may be fitted with water or gas fire suppression systems. In the event of detection of a fire within the BESS unit, the fire suppression system is triggered, releasing water or inert gas for fire suppression. However, NFPA 855 allows for the BESS units to be installed without fire suppression systems where fire, explosion and fault condition testing documents indicate the inherent BESS design is sufficient to limit thermal runaway events. Note that FM Global Datasheet 5-33 does not require any fire suppression systems for outdoor BESS units. With evidence of UL 9540A data, the exclusion of a fire suppression system is justified.

6.4 Fire Mitigation

6.4.1 Fire Water Supply

The Australasian Fire and Emergency Service Authorities Council Limited (AFAC) published guidelines for Large-scale battery energy storage systems installations in February 2025 (Ref. [24]). The guidelines recommend the provision of a minimum of a hydrant system complying with the requirements of AS 2419.1:2021 or an assessment of a similar static supply of water. The guidelines also state that, if the nominated BESS site does not have adequate water supply or the designer proposes not to install firefighting infrastructure, evidence must be provided that a fire will be contained within the site boundaries. The analysis provided in **Section 5.0** shows this is the case for the Tully BESS; hence, no firewater supply as a result of the BESS units is required.

Notwithstanding the above, the bushfire assessment report conducted by Meridian Urban has recommended that a static water supply tank with a minimum capacity of 40 kL be installed on-site. It will be fitted with a 50 mm male camlock fitting for emergency fire service use and is provided with clear access within 6 metres of the tank for a medium rigid vehicle (15 tonne fire appliance). The location of the tank has been provided in Error! Reference source not found..

Additionally, a consultation with QFD has noted a requirement to provide firewater supply to account for scenarios other than a BESS fire. It has been established that water cannot extinguish a fire that is the result of thermal runaway reactions due to its self-sustaining loop. Nevertheless, a consensus has been reached to provide additional firewater supply. AS2419.1:2021 Table 2.2.5(D), provided in **Figure 6-1**, contains protection requirements for open yard sites.

Table 2.2.5(D) — Number of fire hydrant outlets required to flow simultaneously — Open yards

Yard area, m ²	Number of fire hydrant outlets
≤ 3 000	1
> 3 000 ≤ 9 000	2
> 9 000 ≤ 27 000	3
> 27 000	4

Figure 6-1: Number of Fire Hydrant Outlets Required to Flow Simultaneously - Open Yards

The BESS enclosure itself (not including the HV transformer and O&M building area) has an area of approximately 25,500 m², which means that operation of three (3) 10 L/s hydrants for a minimum of 4 hours is required. This equates to 432 m³ of fire water. The location of the 432 m³ tank has been provided in **Figure 7-1**. Error! Reference source not found.

6.4.2 Ventilation

In the event of thermal runaway, flammable gases are generated which if ignited could result in an explosion. The units are fitted with an extraction system that activates when a flammable gas is detected. The purpose of this system is to extract the gases to prevent accumulation to the explosive limits to minimise the potential for an explosion to occur.

7.0 Local Brigade Access and Egress

7.1 Overview

In order to assess the likely fire brigade response times an indicative assessment of fire brigade intervention has been undertaken based on the methods defined in the Fire Brigade Intervention Model (FBIM, Ref. [25]). Error! Reference source not found. is a modified version of **Figure 3-2** and illustrates the site layout with entry points to the site. The closest fire station to the site is described in **Table 7-1**. The expected route from the station to the site is illustrated in **Figure 7-2**.

Table 7-1: Station Locations

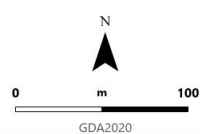
Station Name	Station Address	Distance (km)	Time (min)
Tully Fire & Rescue Station	600 Murray St, Tully QLD 4854	5.0	10



Fire Service Entry Point and Site Infrastructure

Figure 7.1

DWG No: RWE-002-039[A]
DATE: 21/05/2026
DRAWN: KB
REVIEWED EJ
SCALE (A4): 1:3,500



- Development footprint
- Proposed Access Track Footprint
- Transmission Line corridor
- Site layout
- ◆ Site entrance
- H Fire water access points (hydrants)
- 40 kL water tank
- 432 kL water tank
- Fire Brigade access

Vantor, © State of Queensland (Department of Resources) 2024, © State of Queensland (Department of Resources) 2023.

C:\Users\kardouli\OneDrive\Documents\RWE-002 - Tully BESS Approvals - 4.05142 Works\plans\33814_emergencyplan_figures\33814_emergencyplan_figures.aprx

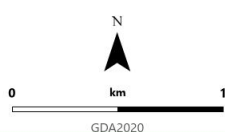
Figure 7-1: Fire Services Entry Point and Firefighting Infrastructure



Location of BESS Site Relative to Tully Fire and Rescue Station

Figure 7.2

DWG No: RWE-002-036[A]
 DATE: 18/05/2026
 DRAWN: KB
 REVIEWED EJ
 SCALE (A4): 1:15,000



- Development footprint
- Transmission Line corridor
- Roads
- Tully Fire and Rescue Station route to site
- Tully Fire and Rescue Station

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Figure 7-2: Location of BESS Site Relative to Tully Fire & Rescue Station

7.2 Response Time – Fire Brigade Intervention Model (FBIM)

Due to the nature of the Fire Brigade Intervention Model (FBIM, Ref. [25]), it is necessary to justify the results through the inclusion of assumptions. The accuracy of results weighs heavily upon the measure of which assumptions are made and the sources from which they are derived. The model produced details the time it will take for brigade personnel within the aforementioned location to receive notification of a fire, time to respond and dispatch resources, time for resources to reach the fire scene, time for the initial determination of the fire location, time to assess the fire, time for fire fighter travel to location of fire, and time for water setup such that suppression of the fire can commence. The following are details of the assumptions utilised in this FBIM:

7.2.1 Location of Fire

This FBIM will only be an indicative model of one fire scenario within the Project. For conservative purposes, the FBIM will consider a fire in the furthest incident from the point of entry.

7.2.2 Time between Ignition and Detection

1. It is assumed that the initial brigade notification is via a direct contact by the site personnel.
2. It was conservatively assumed that the time from ignition, detection and notification to fire brigade is 30 minutes, or 1,800 seconds, due to the remote nature of the site.

7.2.3 Time to Dispatch Resources

1. The fire station is considered to be manned at the time of the fire.
2. As the site is located in a rural area, additional travel time should be considered. The travel time has been assumed to be 10 minutes (600 seconds).
3. Therefore, with a call out time of 1,800 seconds, and travel time of 600 seconds, the fire brigade can be expected to arrive on site up to 2,400 seconds after fire ignition (40 minutes).

7.2.4 Time for Initial Determination of Fire Location

1. On arrival, the fire location may not be visible to the approaching brigade personnel, thus requiring information to be obtained from the site emergency box.
2. Fire brigade personnel assemble at the office area.
3. Fire brigade tactical fire plans will be provided.

7.2.5 Time to Assess the Fire

1. Horizontal egress speeds have been based on fire brigade personnel dressed in turnout uniform in BA. An average travel speed of 1.4 m/s with a standard deviation of 0.6 m/s as shown in **Table 7-2**. As such, for the purposes of the calculations, a horizontal travel speed of $1.40 - (1.28 \times 0.6) = 0.63$ m/s is utilised.

Table 7-2: FBIM data for Horizontal Travel Speeds

Graph	Travel Conditions	Speed (m/s)	
		Mean	SD*
Q1	Dressed in turnout uniform	2.3	1.4
Q2	Dressed in turnout uniform with equipment	1.9	1.3

Graph	Travel Conditions	Speed (m/s)	
		Mean	SD*
Q3	Dressed in turnout uniform in BA with or without equipment	1.4	0.6
Q4	Dressed in full hazardous incident suit in BA	0.8	0.5

*Standard Deviation

Horizontal travel distances will include the following:

1. Travel from one of the site entrances to the furthest MV Transformer is no more than 350 m. Assuming vehicles are travelling at 60 km/h, this results in a travel time of 22 s.
2. It was assumed that QFD would only be required to travel approximately 50 m on foot. Coupled with an egress speed of 0.63 m/s results in a horizontal travel time of up to 32 seconds.
3. Thus, the total horizontal travel time to respond to an incident in the farthest location would be expected to be in the realm of 54 s.

7.2.6 Time for Water Setup

1. The first appliance would be expected to commence the initial attack on the fire.
2. Time taken to connect and charge QFES tanker units to any water tanks onsite and collect the water is based on V3 Table V of the Fire Brigade Intervention Model Guidelines, which indicates an average time of 201.6 seconds, and a standard deviation of 115.6 seconds. Using a 90th percentile approach as documented in the FBIM (Ref. [25]), the standard deviation is multiplied by a constant k , in this case being equal to 1.28. Therefore, the time utilised in this FBIM is $201.6 + (1.28 \times 115.6) = 350$ s.

7.2.7 Search and Rescue

Search and Rescue of the site will consist of a perimeter search of the control building located adjacent to the BESS area. It was assumed this will provide firefighting personnel with an additional 500 m of travel.

At a speed of 0.63 m/s, this will take firefighting personnel approximately 315 seconds.

7.2.8 Summary

As summarised in **Table 7-3** the FBIM (Ref. [25]) indicates that the arrival times of the brigade from the nearest fire stations is approximately 40 minutes after fire ignition, and it is estimated that it takes another 7 minutes for the fire brigade to carry out activities including the determination of fire location and preparation of firefighting equipment. As such, the initial attack on the fire is expected to commence approximately 47 minutes after fire ignition (note rounding affects the basic addition of the reported figures).

Table 7-3: Summary of the Fire Brigade Intervention Model (FBIM)

Alarm Time	Travel Time	Time for Access & Assessment	Set-up Time	Time of Attack	Time for Search & Rescue
1,800 s	600 s	54 s	350 s	4,800 s (80 minutes)	315 s

8.0 Fire Water Supply & Contaminated Fire Water Retention

8.1 Detailed Fire Water System Assessment

As explained in **Section 6.4.1**, AFAC require BESS facilities to be provided with a hydrant system in accordance with AS 2419.1:2021 or an equivalently adequate system. The AFAC guidelines allow for no additional fire water to be provided, other than that carried by the fire truck, if evidence that a fire event would be contained to the site boundaries is provided. **Section 5.4** provides this evidence. Notwithstanding this exclusion, firewater may be provided for conservatism.

The site will be equipped with portable fire extinguishers to supply fire protection in place of a fire water supply. The fire hazards have been assessed in **Sections 4.0 and 5.0** which identified that there is a low potential for a fire to occur within the BESS units and that in the event of thermal runaway the radiant heat generated would be unable to result in incident propagation. Furthermore, in the unlikely event of a BESS fire, it is explicitly discouraged to apply water to a BESS fire, negating the need for excess firewater. However, a 432 m³ static water supply tank will be provided for use. Furthermore, a 40 m³ static water supply tank will also be provided for bushfire mitigation purposes.

8.2 Contaminated Water/Fire Water Retention

Where most materials are combusted in a fire, they may become toxic (i.e. formation of volatile organic compounds and aromatic hydrocarbons). Hence, when fire water is applied the materials may mix with the water resulting in a contaminated run off. To ensure environmental damage does not occur, the ability of a site to retain contaminated fire-fighting water must be assessed.

A risk assessment methodology is outlined by the NSW Department of Planning document “*Best Practice Guidelines for Contaminated Water Retention and Treatment Systems*” (Ref. [26]). This guide is consulted to provide a conservative assessment of the site in the absence of an alternate guide provided by QLD regulation.

In the case of BESS fires, water should not be applied to a BESS fire; the application of fire water to a BESS fire does not result in extinguishment as the fire will continue until the energy has been discharged from the battery. In addition, application of water can result in additional side reactions as the fire progresses which can form potentially toxic by-products. Therefore, water shall not be applied directly to the BESS itself, but rather to any spot fires in surrounding vegetation to avoid propagation to other equipment/units.

The UL 9540A test data indicates that a flaming fire is not expected to occur; hence, the incident will likely be heated batteries which rupture resulting in the release of flammable gases which are handled by the ventilation system to prevent ignition. Therefore, it is expected an overheating event will mostly be contained within the BESS enclosure itself. The BESS enclosure would thus provide protection in the event that the incident occurs in the rain, avoiding water contamination.

Notwithstanding the above, a review can be undertaken to further understand the risk of contamination should fire water be applied to a flaming BESS unit. Since LFP BESS use a lithium/iron cathode, it would not eject the toxic heavy metal oxides such as nickel, manganese and cobalt, unlike a typical NMC battery, in a thermal runaway event. Nonetheless, LFP BESS may emit compounds such as per- and polyfluoroalkyl substances (PFAS), fluorinated compounds, phosphorus and copper. This becomes a particular concern during firewater application as it can provide a pathway for these contaminants to leach into the soil and nearby water sources. However,

a paper by The American Clean Power Association (Ref. [27]) has concluded that available data from real-world incidents and testing does not support this. In a literature review, it found that the chemical byproducts produced during a BESS fire possesses low solubility which limits the potential for groundwater contamination if hydrant water is applied to the flaming BESS unit. This is supported by the environmental soil and water sampling results of several BESS incidents, such as the Melba Battery Fire, the Chaumont BESS Fire, the Escondido Battery Fire, which showed that metal concentrations were within normal or acceptable concentrations. EPRI's white paper (Ref. [28]) noted that while sampling does identify some toxic compounds that are emitted by flaming BESS units, these may be converted or reacted to form other non-toxic compounds before being released to the environment.

Furthermore, vegetated areas around BESS are typically used for grazing of livestock; hence, the area will not be paved, preventing any reasonable method for providing containment in the event that contamination of fire-fighting water does occur. However, given the protection systems incorporated into the BESS design, the likely outcome of thermal runaway not resulting in a flaming fire, the potential for contaminated water to be generated from this incident is considered low. Accommodating the unlikely formation of contaminated water would be disproportionately expensive to the risk of contamination.

Notwithstanding this, a bio-retention basin with a containment capacity of 432 m³ will be provided on-site to contain the full firewater capacity.

Based on the above discussion, no recommendations have been made with respect to contaminated water retention.

9.0 Conclusion and Recommendations

9.1 Conclusions

A FSS was prepared for the proposed Tully BESS site. The analysis performed in the FSS was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the designs and existing fire protection adequately managed the credible fire risks at the site.

9.2 Recommendations

Based on the analysis, the following recommendations have been made:

- A Large Scale Fire Test (LSFT) in compliance with the UL9540A 6th Edition shall be conducted for the Tesla Megapack 3 and provided to the Consenting Authority once available.
- A windsock shall be installed at the facility in a location visible from all operational areas
- All site personnel shall be inducted in site procedures and emergency response protocols relevant to their roles.
- All site personnel who require training must undergo formal training in the required procedures and emergency response protocols relevant to their role.
- Necessary personnel to provide first aid are to be trained in accordance with the QLD Code of Practice for first aid in workplaces 2021– high-risk workplaces (Ref. [5]).
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- Dangerous Goods (DG) documentation shall be prepared as required by the Work Health and Safety Regulation 2011 QLD to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- Any DGs stored at the site shall be stored and handled in accordance with the Work Health and Safety Regulation 2011 QLD and any applicable storage and handling standards.

10.0 References

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Appendix A

Hazard Identification Table

Appendix A

A1. Hazard Identification Table

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
1	Battery Storage	<ul style="list-style-type: none"> Battery fault / failure Failure of Li-ion battery protection systems 	<ul style="list-style-type: none"> Thermal runaway resulting in fire or explosion Incident propagation through battery cells Damage to property <\$1M 	<ul style="list-style-type: none"> Batteries are tested by manufacturer prior to sale / installation Overcharging and electrical circuit protection Battery monitoring systems Batteries composed of subcomponents reducing risk of substantial component failure (such as liquid cooling system) 	4	D	M
2			<ul style="list-style-type: none"> Toxic smoke dispersion Injury to worker Short-term environmental damage 				
3	Switch rooms, communications, etc.	<ul style="list-style-type: none"> Arcing, overheating, sparking, etc. of electrical systems 	<ul style="list-style-type: none"> Ignition of processors and other combustible material within servers and subsequent fire 	<ul style="list-style-type: none"> Fires tend to smoulder rather than burn Isolated location Switch room is separated from other sources of fire 	3	E	L

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
4	HV Transformer and MV Transformers	<ul style="list-style-type: none"> Arcing within transformer, vaporisation of fluid and rupture of fluid reservoir 	<ul style="list-style-type: none"> Transformer fluid release spill, ignition and fire 	<ul style="list-style-type: none"> Natural ester used as dielectric fluid – Natural esters have a high flash point (>300°C) such that ignition is very unlikely to occur. Transformers are banded Electrical protection for transformer faults Control of ignition sources – no smoking / open flames around the transformers 	Carried forward for quantitative analysis		
5	HV Transformer	<ul style="list-style-type: none"> Power surge to transformers (e.g. from lightning, fault, etc.) 	<ul style="list-style-type: none"> Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion 	<ul style="list-style-type: none"> Transformers have surge protection system to shut down upon detection of extreme energy input Lightning protection to prevent lightning strikes impacting transformers Control of ignition sources – no smoking / open flames around the transformers 	4	E	M
6	MV transformers	<ul style="list-style-type: none"> Power surge to transformers (e.g. fault) 	<ul style="list-style-type: none"> Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion 	<ul style="list-style-type: none"> Transformers are in containers which protect from lightning and cables are underground. Control of ignition sources – no smoking / open flames around the transformers 	4	E	M
7	Electrical equipment	<ul style="list-style-type: none"> Constant release of electromagnetic field 	<ul style="list-style-type: none"> Minor health impacts from extended exposure 	<ul style="list-style-type: none"> Inherently lower levels than background radiation Drop off within short distances 	1	C	L

ID	Area/Operation	Cause	Consequence	Existing Safeguards	Risk		
					S	L	R
				<ul style="list-style-type: none"> No sensitive receivers within 1 km of the site 			
8	Bushfire	Lightning strike Maliciously lit fire	Damage to property < \$1M Fatality/fatalities Incident propagation	<ul style="list-style-type: none"> Separated arrangement of equipment to limit propagation (remove fuel) Asset Protection Zones Housekeeping procedures to keep grass low Inherent fire protection in BESS and high heat resistance of other equipment Bushfire hazard assessment and management plan 	4	D	M

Appendix B

Consequence Analysis

Appendix B

B1. Incidents Assessed in Detailed Consequence Analysis

- Li-ion battery fault, thermal runaway and fire.
- HV transformer, oil spill, ignition and bund fire.
- MV transformers, oil release, ignition and fire.
- Li-ion battery fire and toxic gas dispersion.

Each incident has been assessed in the sections below.

B2. Radiant Heat Physical Impacts

Appendix Table B-1 provides noteworthy heat radiation values and the corresponding physical effects of an observer exposed to these values (Ref. [6]).

Appendix Table B-1: Heat Radiation and Associated Physical Impacts

Heat Radiation (kW/m ²)	Impact
35	<ul style="list-style-type: none"> • Cellulosic material will pilot ignite within one minute's exposure • Significant chance of a fatality for people exposed instantaneously
23	<ul style="list-style-type: none"> • Likely fatality for extended exposure and chance of a 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
12.6	<ul style="list-style-type: none"> • Significant chance of a 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
4.7	<ul style="list-style-type: none"> • Will cause pain in 15-20 seconds and injury after 30 seconds exposure (at least second degree burns will occur)
3.0	<ul style="list-style-type: none"> • FRNSW criterion for accessibility of hydrants and other fire protection systems. Assumed as the criterion for QFD

B3. Gexcon - Effects

The modelling was prepared using Effects where appropriate, which is proprietary software owned by Gexcon which has been developed based upon the TNO Coloured books and updated based upon CFD modelling tests and physical verification experiments. The software can model a range of incidents including pool fires, flash fires, explosions, jet fires, toxic dispersions, warehouse smoke plumes, etc.

B4. View Factor Radiant Heat Model

The modelling for the BESS units was carried out using a manual view factor calculation method outlined below.

B4.1 Radiant Heat Flux

The heat flux (Q) for the view factor model is given by **Equation 10-1**.

$$Q = \tau EF$$

Equation 10-1

Where;

- Q = heat flux (kW/m²) at the target
- F = geometric view factor
- τ = transmissivity
- E = SEP (kW/m²)

Each of the required inputs is determined in the sections following.

B4.2 View Factor

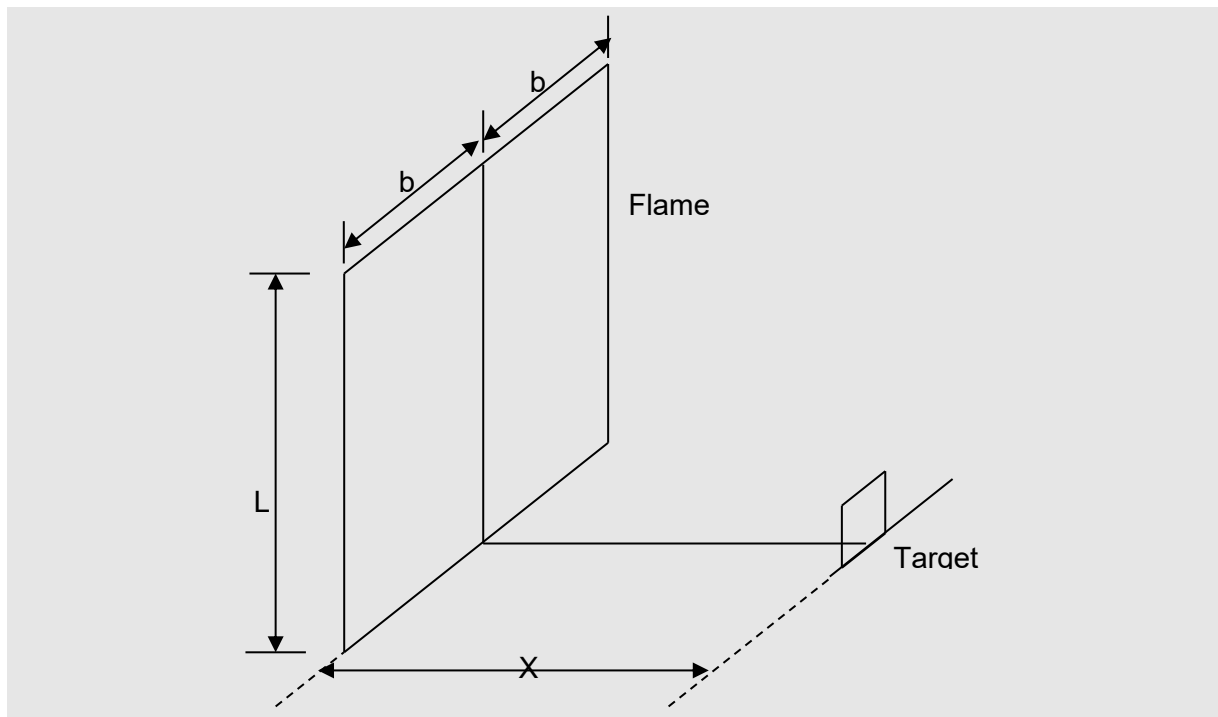
The view factor for a flat surface fire is estimated using the scenario shown in **Appendix Figure B-1** where the flame is the vertical surface of height L and length 2b with receiver located centrally and at a distance of X. Two dimensionless parameters are calculated, and the view factor read from **Appendix Figure B-2**. The dimensionless parameters are shown in **Equation 10-2** and **Equation 10-3**.

$$L_r = \frac{L}{b}$$

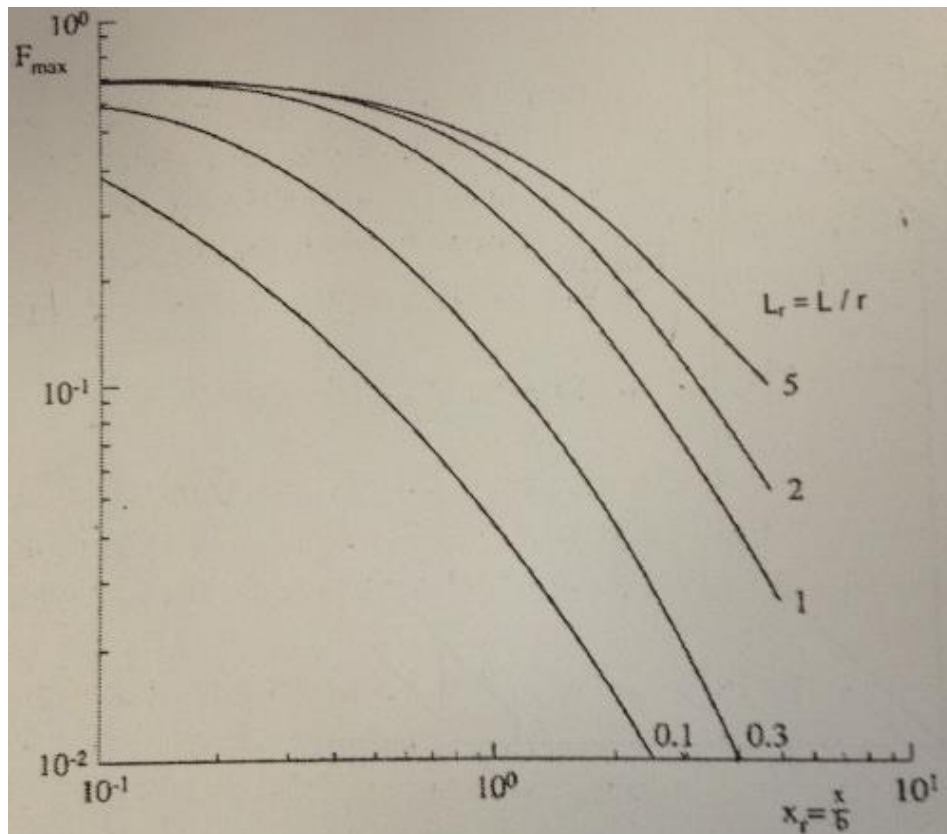
Equation 10-2

$$X_r = \frac{x}{b}$$

Equation 10-3



Appendix Figure B-1: Vertical Flame Geometry View Factor Geometry



Appendix Figure B-2: Vertical Flame Maximum View Factor (Ref. [29])

B4.3 Transmissivity

The transmissivity is estimated using **Equation 10-4**.

$$\tau = 1.006 - 0.01171(\log_{10} X(H_2O) - 0.02368(\log_{10} X(H_2O))^2 - 0.03188(\log_{10} X(CO_2) + 0.001164(\log_{10} X(CO_2))^2)$$

Equation 10-4

Where:

- $X(H_2O) = (R_H \times L \times S_{mm} \times 2.88651 \times 10^2)/T$
- $X(CO_2) = L \times 273/T$

And;

- R_H = percentage relative humidity
- L = distance to target (m)
- S_{mm} = saturated water vapour pressure in mm mercury at temperature (at 200°C $S_{mm} = 11549$)
- T = temperature (473 K assumed air is heated to 200°C)

B5. Li-Ion Battery Fault, Thermal Runaway and Fire

The flame characteristics from the unit observed are as follows:

- A maximum temperature of 675.3°C was recorded.
- Peak flame extended 1.8 m vertically and 1.2 m horizontally.
- Maximum heat flux is 48.72 kW/m² at a distance of 1.2 m.

- No adjacent units have initiated thermal runaway due to the fire event in the initiating unit; hence, a full BESS unit is not considered to be credible.

Based on the data provided, the radiant heat contour impacts can be determined by using the known maximum heat flux at the measured distance and the view factor methodology. The maximum view factor can be derived using the graph in **Appendix Figure B-2** and the variables discerned from the LSFT results, which yielded a F_{max} of 0.5. **Equation A-1** can then output a SEP value of 95.6 kW/m^2 which will be used as the basis to calculate the distances of radiant heat impacts. This has been summarised in the table below. Note that the assessment does not consider the effect of safeguards that are available in the BESS, such as the aerosol fire extinguishing device and primary firefighting equipment.

Appendix Table B-2: BESS Fire Radiant Heat Distances

Heat Radiation (kW/m^2)	Distance (m)
48.72	1.2
35	1.3
23	2.0
12.6	2.8
4.7	4.2
3.0	5.9

B6. HV Transformer, Oil Release, Ignition and Bund Fire

Transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

The transformer is assumed to be banded and so in the event of a spill and ignition, the pool fire will have dimensions of the bund. The inputs for the model are provided in **Appendix Table B-3**.

Appendix Table B-3: HV Transformer Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200°C . Natural ester oils typically have flash points exceeding 330°C , thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target. The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.

Input	Value	Justification
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	n/a	Spill is limited to bund dimensions and not by spill mass
Temperature of pool	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	n/a	Spill is limited to bund dimensions and not by spill mass
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a
Wind speed	6 m/s	High wind speed modelled for worst-case scenario.
Wind direction	North	Worst-case direction, pushing flames towards BESS units.
Ambient temperature	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	40%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-4**.

Appendix Table B-4: Heat Radiation Impacts from a Transformer Bund Fire

Heat Radiation (kW/m ²)	Distance (m)
35	18
23	19
12.6	23
4.7	30
3.0	35

B7. MV Transformers, Oil Release, Ignition and Fire

The MV transformers contain oil to provide cooling and insulation. If arcing occurs within the transformer, the oil will rapidly heat generating gases above their auto ignition point. The pressure of the gases may rupture the reservoir allowing oxygen to enter resulting in the gases auto igniting. The oil is released from the reservoir and is ignited by the burning gases.

It has been assumed that the transformer has bund dimensions of the MV transformers; hence, if a spill from the transformer was to occur it would fill the base of the bund resulting in a pool fire with the dimensions of the bund. The inputs for the model are provided in **Appendix Table B-5**.

Appendix Table B-5: MV Transformer Fire Modelling Inputs

Input	Value	Justification
Chemical name	Linoleic acid	Transformer oil to be used is a natural ester, which is typically a combustible liquid of some formulation which have high flash points. For the purposes of providing a conservative analysis, linoleic acid has been selected. This material has a flash point of approximately 200°C. Natural ester oils typically have flash points exceeding 330°C, thus this material selection is considered to be conservative.
Type of pool fire calculation	Rew & Hulbert	The model has been developed for modelling fires based on the radiant heat emitted from the radiant surface. The model uses the clear and sooty portions of the flame to estimate the radiant heat at the target. The terminology (i.e. pool fire) is because these models were originally developed from liquid pool fires. However, the model actually works by looking at the flame surface to estimate the radiant heat that is emitted from that surface. The flame surface is present irrespective of the material burning (i.e. a solid or liquid pool will have a flame that will have a clear and sooty portion). Based on the above discussion, it is considered that the Rew & Hulbert model is appropriate for modelling the fire.
Type of pool fire source	Instantaneous	Conservative as it assumes full fire immediately
Soot definition	Calculated	Calculated
Total mass released	2,500 kg	Estimate mass of oil in the MV transformer
Temperature of pool	25°C	Conditions expected to be observed regularly. Also, negligible impact on results.
Type of pool	Polygon	Modelled based on transformer bund area.
Max pool surface area	n/a	Dimension of MV enclosure
Height of confined pool above ground level	0 m	Modelled at ground level
Include shielding to bottom side of flame	No	No shielding provided in modelling.
Height of shielding	n/a	n/a
Wind speed	6 m/s	High wind speed modelled for worst-case scenario.
Wind direction	North	Worst-case direction, pushing flames towards boundary.
Ambient temperature	30°C	Conditions expected to be observed regularly. Also, negligible impact on results.

Input	Value	Justification
Ambient pressure	1.0151 bar	Atmospheric pressure
Ambient relative humidity	40%	Typical humidity in the area
CO2 concentration	0.0004	CO2 concentration in atmosphere

The results of the analysis are shown in **Appendix Table B-6**.

Appendix Table B-6: Heat Radiation Impacts from a MV Transformer Fire

Heat Radiation (kW/m ²)	Distance (m)
35	4.5
23	4.8
12.6	5.8
4.7	8.5
3.0	9

B8. Li-ion Battery Fire and Toxic Gas Dispersion

The toxic gas source term associated with a BESS thermal runaway event has been developed using a modelling approach consistent with the Gexcon EFFECTS “Li-ion Battery Storage Thermal Runaway” model. This model simulates the decomposition of battery materials during thermal runaway and estimates the generation rates and total mass of key toxic species over the duration of the event. The model accounts for both partial thermal runaway (limited to a single module) and full BESS involvement, where thermal propagation occurs across multiple modules or the entire unit. Inputs to the model include battery capacity, assumed chemistry, and release duration, which together define the rate of gas generation and temporal release profile. A conservative approach has been undertaken assessing a full BESS involvement. Hydrogen fluoride is typically adopted as the controlling toxic species due to its high toxicity and conservative representation of potential impacts. The resulting time-dependent mass release forms the basis for subsequent dispersion modelling.

B9. Plume Rise from Fire Model

It is necessary to assess the associated impacts of the smoke plume downwind of the facility, as it may have far reaching impacts on the wider community. When assessing the downwind impacts of the fire plume, the main contributors to the dispersion are:

- The fire size (diameter) and energy released as convective heat
- The atmospheric conditions such as wind speed, relative humidity, atmospheric stability and ambient temperature.

These parameters interact to determine the buoyancy of the smoke plume (vertical rise) which is controlled by the convective energy within the smoke plume in addition to the atmospheric conditions. The atmospheric conditions will vary from stable conditions (generally night time) to unstable conditions (high insolation from solar radiation), which results in substantial vertical mixing which aids in the dispersion. Contributing to this is the impact of wind speed which will limit the vertical rise of a plume but may exacerbate the downwind impact distance.

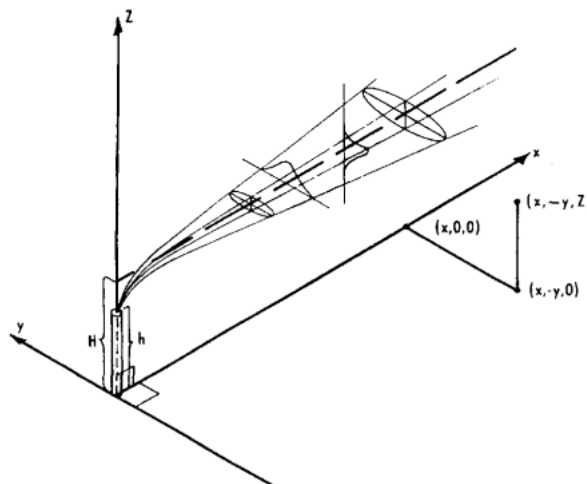
The atmospheric conditions are classified as Pasquill Guifford’s Stability categories which are summarised in **Appendix Table B-6** (Ref. [30]).

Appendix Table B-7: Pasquill Guifford’s Stability Categories

Surface wind speed at 10 m height (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Thinly overcast or $\geq 50\%$ cloud	$< 50\%$ cloud.
<2	A	A-B	B	-	-
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

Generally, the most onerous conditions are F conditions which result in stable air masses and typically have inversion characteristics. Inversion characteristics occur when a warm air mass sits above a cold air mass. Typically, hot air will rise due to lower density than the bulk air; however, in an inversion, a warm air mass sits above the cooler denser air; hence, as the warm air rises through the cold mass it hits a ‘wall’ of warmer air preventing vertical mixing above this point. In a fire scenario, the hot smoke plume will cool as it rises; however, if it encounters an inversion, it will begin to run along this boundary layer preventing vertical mixing and allowing the smoke plume to spread laterally for substantial distances.

A smoke plume is buoyant, and will disperse laterally and vertically as it rises essentially following a Gaussian dispersion as shown in **Appendix Figure B-3** Ref. [30]).



Appendix Figure B-3: Co-ordinate System for Gas Dispersion

Effects has been used to model a smoke plume arising from a BESS fire. The model has been developed based on a Gaussian dispersion model accounting for modifications to the plume drag coefficients required to model a plume dispersion from a warehouse fire. D5 conditions have been used to model the plume dispersion.

B10. Toxic Effect Threshold

The toxic effect thresholds for HF are defined by the US EPA's Acute Emergency Guideline Levels (AEGLs) drawing on human exposure data from the AEGL documentation. The three harm levels were mapped to the AEGL tiers as follows:

- Fatality / life-threatening effects were linked to the AEGL-3 concentration

- Serious injury was linked to the AEGL-2 concentration

Appendix Table B-8: AEGL Health Levels, Effects and Concentration for Hydrogen Fluoride

AEGL Level	Health effects	HF concentration (ppm)
AEGL-2	Injury threshold	24
AEGL-3	Life-threatening health effects threshold	44

B11. Wind Climate

Wind data recorded at Cairns Aerodrome (Bureau of Meteorology Site 031011, May 1941 to July 2019) shows a difference in wind directions between morning and afternoon. In the morning, winds are almost exclusively southerly, moderate in strength (typically 10–30 km/h), and calm conditions are relatively common at around 9% of observations. By the afternoon, the wind shifts markedly to the north and northeast as a sea breeze develops, becoming stronger with speeds more frequently exceeding 30 km/h, while calm conditions drop to just 2% of observations.

Given that 3 pm represents the period of maximum solar heating in subtropical Tully, the prevailing stability class conditions are physically incompatible with the stable, near-calm nocturnal state. Accordingly, a D5 atmospheric stability class has been adopted to represent a most probable daytime dispersion scenario, characterised by neutral stability and moderate wind speeds.

The use of D5 conditions therefore provides a robust and representative assessment, capturing realistic prevailing conditions for the site while also considering a conservative worst-case credible scenario for dense gas dispersion to inform emergency response planning.

B12. BESS Fire Source Model

The BESS configuration proposed for the Tully site incorporates sufficient separation distances between adjacent units to prevent thermal runaway propagation. On this basis, the consequence assessment has conservatively considered a single BESS unit in a fully involved fire scenario. The scenarios were modelled using the following key inputs:

Appendix Table B-9: BESS Fire Source Model Parameters

Parameter	Value	Justification
Battery Chemistry	LFP	Battery chemistry used.
Energy Capacity Based On	Battery System	Conservatively assessing a BESS unit fire.
Energy Capacity	5 MWh	The energy capacity of each BESS unit.
Duration of release	43,200 Seconds	Full BESS reaches thermal runaway over 12 hours. Such estimation is in line with the duration of full BESS fires, which can last for days. A 12-hour assessment provides conservative results, yielding a greater HF release per unit time.

The generated HF was determined to be 0.02585 kg/s from a fully involved BESS fire burning over a 12-hour period.

B13. BESS Plume Rise

Toxic exposure duration has been determined based on a defined approach that considers the application of appropriate exposure limits relative to the scenario. The duration of exposure may be influenced by several factors, including the time required for personnel to seek shelter or evacuate, the time taken for the toxic plume to reach a given location, and the duration of the release itself.

In the event of a BESS fire at the facility, it is assumed that personnel exposed to a potential toxic release would initiate emergency response actions, including seeking shelter or evacuating to a designated safe area upwind from the incident. Based on the site layout and access to shelter locations, it is conservatively estimated that personnel would require approximately 5 minutes to reach a suitable refuge or move to a non-affected area.

Accordingly, the assessment adopts a 5-minute exposure duration to represent the period during which personnel may be exposed to the toxic plume while relocating. The following inputs and calculations have been developed to quantify the potential exposure to personnel during this period and to determine the corresponding AEGL-based impact thresholds for emergency response planning.

To further the sensitivity of the analysis the heat release rate has been reduced to cellulosic levels, accounting for variance in the heat due to the size of the fire, which in turn increases AEGL impact distances at receiver height; this conservative assumption has been adopted as the basis for the consequence assessment.

Appendix Table B-10: Plume Rise from BESS Fire Source Model

Parameter	Value	Justification
Chemical Name	Hydrogen Fluoride	Most Toxic gas released from BESS fire.
Mass flow rate of the source	0.02585 kg/s	Mass flow rate of BESS fire over 12 hours.
Height of release (Z-coordinate)	1.25 m	Release from the centre of the BESS.
Pasquill stability class	D	D5 is the probable stability class and F2 is the sensitive stability class determined from the wind rose provided by the Cairns weather station.
Wind speed at 10 m height	5 m/s	
Predefined wind direction	S/SSE	Prevailing wind seen in Cairns weather station windrose (9 am and 3 pm)
Ambient temperature	20 deg C	Ambient temperature.
Roughness length description	High Crops scattered large objects	The BESS facility is surrounded by rural farmland and a substation.
Reporting/ receiver height (Zd)	1.5 m	Breathing height.

Appendix C

Tesla – Letter of Commitment

Appendix C



Attachment A Megapack Compliance and Testing Overview

Megapack 3 Fire Safety Documentation

Compliance Deliverables:
Megapack 3 UL 9540A Cell Testing
Megapack 3 UL 9540A Module Testing
Megapack 3 UL 9540A Unit Testing
Megapack 3 Large-Scale Fire Testing
Megapack 3 Fire Protection Engineering Report
Megapack 3 UL Compliance Package

Megapack 3 UL 9540A Cell Testing

- It is expected (like MP2XL) that the MP3 UL9540A cell-level test applicable to this project will fail UL9540A cell testing and UL 9540A module testing being required as cell thermal runaway (TR) will occur with flammable vent gases in the cell test.

Megapack 3 UL 9540A Module Testing

- It is expected (like MP2XL) that the MP3 UL9540A module level test applicable to this project will fail due to the flammable gases measured in the UL 9540A cell level test and Unit level testing will be required.

Megapack 3 UL 9540A Unit Testing

- It is expected (like MP2XL) that MP3 UL9540A Unit-level test applicable to this project will pass.

Megapack 3 Large-Scale Fire Testing

- While Tesla considers UL9540A unit level testing a robust demonstration of safety features, Tesla will conduct an additional Large Scale Fire Test demonstrating safety during a fully developed fire condition. The methodology Tesla will use is in line with the UL9540A 6th edition methodology which was published on the 13th of March 2026.
- The 6th edition is the first edition of UL9540A to provide a LSFT methodology and using the UL9540A 6th edition methodology is aligned with direction of industry. Tesla's LSFT for MP3 will have neighboring units present during the test with the evaluation criteria being no thermal runaway or cell venting in the neighboring units.



- This is an enhancement on the testing conducted for MP2XL which had a bespoke destructive fire test with a FLIR camera captured the temperature contour of the external surface of the initiating MP2XL, but no target units were installed nearby due to the absence of an appropriate LSFT methodology for MP2XL at the time of testing.



Attachment B Megapack 3 and Megapack 2XL Key Fire-Safety Features

Summary

- Tesla has a long-standing commitment to robust fire-safety practices across its energy storage portfolio. Building on this established foundation, it is anticipated that Megapack 3 will uphold the same rigorous expectations for safety performance and is actively progressing toward obtaining UL 9540 certification.
- The following provides a high-level overview of the fire-safety measures incorporated into the previous Megapack model (MP2XL), as well as a summary of the anticipated fire-safety features for Megapack 3

Summary of Key Fire-Safety Features in Megapack 2 XL (MP2XL)

- Battery Management System (BMS)
The MP2XL features an integrated Battery Management System that continuously monitors cell, module, and cabinet conditions including temperature, voltage, current, and state of charge. The BMS autonomously responds to off-normal conditions by activating cooling, isolating an affected module, or disconnecting it entirely. These automatic protections can prevent a localized failure from escalating and help limit thermal propagation within the cabinet.
- Thermal Management System (TMS)
The MP2XL employs a dual thermal management strategy combining a closed-loop liquid cooling system with an integrated air-cooling thermal roof to maintain safe battery operating temperatures. The system circulates a water glycol coolant through the battery modules and power electronics, using pumps, heaters, and a compressor to autonomously regulate internal temperatures across varying environmental conditions. Above the battery bays, the MP2XL includes an IP20 rated thermal roof containing radiators and fans. Cool ambient air enters through front grates, passes over the radiators to absorb heat, and is then exhausted upward. This air cooling layer removes heat from the coolant loop. This helps prevent cell over-temperature and reduces the likelihood of thermal runaway events.
- Explosion Control System
The MP2XL includes an explosion control system to mitigate the risk of uncontrolled deflagration. The system includes pressure-sensitive vents (overpressure vents) and sparkers installed throughout the battery module bay.

- Sparkers: MP2XL incorporates sparkers strategically placed throughout the battery module bays. These devices intentionally ignite flammable gases early before the gases can accumulate to a concentration that may cause deflagration. This engineered early ignition strategy has been validated in largescale testing across Megapack generations and effectively minimizes explosion risk inside the enclosure.
- Pressure Sensitive Vents: The system also includes passive overpressure vents installed on the roof of the sealed IP66 battery bay. These vents open automatically only when internal pressure increases, safely releasing gases upward into the thermal roof. This design prevents cabinet doors from opening during a thermal event, avoids projectile hazards, and maintains enclosure integrity while directing gases away from personnel and adjacent equipment.

Summary of Key Fire-Safety Features in Megapack 3 (MP3)

- Battery Management System (BMS)

Similar to MP2XL, MP3 features a complex Battery Management System that continuously monitors cell temperatures, voltages, currents, insulation levels, and general system health. The BMS automatically responds to off-normal conditions and plays a central role in limiting or preventing escalation during early-stage anomalies. In addition to baseline monitoring functions, MP3 incorporates BMS-driven protective modes such as:

- Automatic Safe Discharge, which lowers the battery's state of energy if potential thermal-runaway indicators are detected.
- Thermal Limp Mode, which reduces module or unit-level power output when temperatures approach unsafe thresholds.

These controls act as preventative safety barriers that limit fault escalation before it develops into a thermal event.

- Thermal Management System (TMS)

Mirroring the philosophy used in MP2XL, Megapack 3 uses a fully integrated active thermal management system that provides active cooling and heating to maintain safe operating temperatures across all internal components. An external HVAC or thermal system is therefore not required for Megapack 3 to operate. The system consists of:

- Thermal bay (accessible by Service Providers only), located in the middle part of Megapack 3, containing fans, radiators, pumps, compressors, thermal power electronics. The thermal



bay also provides an upward ventilation path for air, helping to direct heat away from critical components.

- Coolant manifolds
- Explosion Control System
 - Sparkers: Like MP2XL, the MP3 includes a Sparker System that proactively ignites low-concentration flammable gases before they reach hazardous levels. By combusting gases early, sparkers significantly reduce deflagration potential and work in tandem with the overpressure vents for a fully engineered explosion-mitigation strategy.
 - Pressure-Sensitive Vents: As with MP2XL, MP3 incorporates overpressure vents in each battery bay that open automatically during a rapid internal-pressure rise. Once activated, these vents route gases and combustion products from the battery bay into the thermal bay and then out through the doors, preventing pressure buildup and preserving enclosure integrity.
 - Automated Door Opening: MP3 further enhances deflagration mitigation by incorporating automated door opening when harmful interior conditions are detected. This provides additional pressure relief and supports more rapid ventilation, thereby shortening the duration and severity of a thermal event. Prior to door opening, an external warning in the form of audible and visible notification will be given, alerting site personnel to the potential hazard.
- Safety Controller

MP3 includes a dedicated Safety Controller located in the thermal bay, responsible for aggregating safety-related sensor data, executing alert logic, and initiating protective actions when required. The safety controller provides an external warning and communication system which consists of an audible alarm and flashing lights as well as Alarm communication to the Tesla System Controller. The safety controller hardware/firmware is evaluated under UL 1998 and UL 991 (1998 - Software in Programmable Components: for the firmware on the board. 991 - Tests for Safety-Related Controls Employing Solid-State Devices), confirming robustness of safety-related controls and proper fail-safe behavior.



Attachment C Firefighting Response

[MP Emergency Response Guide] outlines the information relevant to emergency responders and Authority Having Jurisdiction (AHJs) regarding safety surrounding MPs. During storage or operation, signs of an emergency include but are not limited to:

- Suspicious odor observed near the MP
- Smoke or fire emanating from the MP
- Severe physical impact on the MP

In case of an emergency, isolate, deny entry and perform the following steps:

1. If possible, and if trained and properly equipped, shut off the unit/system
2. Evacuate the area.
3. If not already present, notify appropriately trained first responders, the local fire department, and any appointed subject matter expert (SME) if available.
4. Contact Tesla for guidance

The following further advice is provided regarding firefighting measures:

- Firefighters should wear SCBAs and structural firefighting gear.
- Do not approach the unit and attempt to open any doors which are not already opened
- If a fire develops, allow the affected unit to consume itself as it is designed to do. Applying water to the burning unit will have minimal effect and will only slow down its eventual combustion.
- At the discretion of first responders, use a fog pattern to cool nearby exposures.
- It may take 24-48 hours for the unit to cool down so continue to remain at a safe distance.

Attachment D Megapack (MP) Case Studies

There are no recorded MP2XL or MP3 fires at the time of writing this memo. This section will focus on known fires of other MP products and their learning outcomes.

VBB

The VBB fire occurred on 30 July 2021 during the commissioning phase of the Neoen site, near Geelong, Victoria, Australia. The fire involved two MP1s with the following key components, extracted from the [Blum Report]:

- The initiating MP1 was shut off manually prior to the fire incident. Once smoke was observed by site personal, they electrically isolated all MP1s and called the Country Fire Authority (CFA).
- The CFA set up a perimeter and started applying cooling water to the nearby exposures. Despite this, the fire spread to the nearest MP1 via the plastic vents on the roofs.
- The CFA allowed both MP1s to burn out and did not apply water directly on them.
- Six hours after the start of the fire event, visible fire had subdued, and the CFA monitored the site for three days before deeming it under control.
- The most likely root cause of the fire was a cooling-system leak within the initiating MP1 that caused arcing in the power electronics of a battery module. This resulted in heating of the battery module's Li-ion cells and resulted in TR.
- Contributory to the root cause was the lack of Supervisory Control and Data Acquisition (SCADA), lack of telemetry, fault monitoring and electrical active safety devices. The power supply to the pyrotechnic disconnect was also most likely disabled by the leaking coolant, which would have otherwise interrupted the fault current passing through the battery module prior to it escalating to a fire event.

The following mitigation measures were incorporated into the MP2 and MP2XL and will be incorporated for MP3 based on learnings from the VBB fire, as well as updated Emergency Response Plan (ERP) and commissioning processes:

- Improved inspection of the thermal system.
- Reduced telemetry setup from twenty-four hours to one hour, along with avoiding using the keylock switch during commissioning or operation unless the unit is being actively serviced.



- Updated firmware, to include alerts for the thermal system, keeping all active safety systems active, and monitoring of the pyrotechnic disconnect.
- Replaced the plastic roof vents with thermally insulated steel vent shields.
- Refinement of the ERP to avoid using water on an MP fire, but only on nearby exposures, to allow the MP to burn out

Elkhorn

the Elkhorn fire occurred on 20 September 2022 in Monterey County, California, United States of America. The fire involved a single MP1 with the following key components, extracted from the [Grant Report]:

- The initiating MP1 initiated fire detection alarms, and the site operator called 911 (similar to 000 in Australia) shortly thereafter.
- The North County Fire Protection District (NCFPD) set up two hose streams on exposures.
- The NCFPD allowed the MP1 to burn out and did not apply water directly on it.
- Initial water application for 3.7 hours, with a follow-up water application for 2.2 hours, mostly using two hose streams for the duration.
- Six hours after the start of the fire event, visible fire had subdued, and the NCFPD lifted the road closures and shelter in-place advisory approximately 18 hours after the initial fire detection.
- The root cause of the fire was water ingress. That allowed electrical shorts to initiate TR. A displaced umbrella valve was the cause. It was incorrectly installed with the new steel vent shields from the VBB learning outcomes.

The following mitigation measures were incorporated into the MP2, and MP2XL and will be incorporated for MP3 based on learnings from the Elkhorn fire, as well as updated ERPs and commissioning processes:

- Introduction of an Automatic Safe Discharge (ASD) feature.
- Updated alarms and approval processes, including battery isolation failure alerts, server-side alarms now being elevated to Tesla operators.
- Playbook guidance for isolation-failure alerts.
- Prioritization of thermal-alarm transmission to eliminate the delay of alerting the fire brigade.
- Refinement of the ERP, known as the Emergency Response Guideline, regarding roles, responsibilities and training.



- Update on the water-application guidance: cooling water is not to be applied to nearby MPs

Bouldercombe

The Bouldercombe fire occurred on 26 September 2023 near Rockhampton, Queensland, Australia.

The fire involved a single MP2 with the following key components, extracted from the

[Bouldercombe Findings]:

- The site had completed compliance testing, demonstrated stable operation, and was awaiting final approval.
- The initiating MP2 caused a trip in the RMU, isolating it from the rest of the site.
- QFB set up two hose streams on exposures. Around this same time, CCTV images show signs of fire and arcing from the initiating MP2. Tesla received a call from the customer representative approximately an hour after this, alerting Tesla to the fire.
- QFB allowed the MP2 to burn out and did not apply water for the duration of the incident, including no water used to cool nearby exposures. • Approximately forty-eight hours after the start of the fire event, visible fire had subdued, and QFB returned to the site the following day.
- The most likely root cause of the fire was an arcing event in the CIB, which is the AC area of the MP2, and therefore not caused by a Li-ion cell or a battery module.

Based on learnings from the Bouldercombe fire the following mitigation measures were incorporated into the MP2 and MP2XL and will be incorporated for MP3, as well as updated ERPs and commissioning processes:

- Review of inverter module and AC bus QA and inspection, and replacement of parts.
- Updates to firmware to better detect a thermal event.
- Improved commissioning and service self-testing.

In conclusion, the Elkhorn and Bouldercombe case studies, which involved smaller firebreaks, are not directly applicable to MP2XL or MP3 units, however, they still illustrate that the radiant heat flux and the target-unit cell temperatures are not expected to result in fire spread between units.