Riskcon engineering

Preliminary Hazard Analysis

Tarrone BESS

Umwelt Australia Pty Ltd
Document No. RCE-23131_Umwelt_PHA_Final_16Dec24_Rev(2)
Date 16/12/2024

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Quality Management

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A	15 May 2024	Draft issued for comment	Ezra Bagaskara	Renton Parker
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Executive Summary

Background

Riskcon Engineering Pty Ltd was engaged by Umwelt Australia Pty Ltd (Umwelt) to conduct a Preliminary Hazard Assessment (PHA) of the Tarrone Battery Energy Storage System (BESS, The Project) for Global Power Generation Australia Pty Ltd (GPG, The Applicant).

The Project is a grid-scale battery energy storage facility proposed by GPG in Tarrone, Victoria. The BESS is anticipated to have a storage capacity of 200 MWac / 400 MWh, which will utilise the latest in grid forming inverter and Lithium Ion (Li-Ion) battery storage technologies. The purpose of the Project seeks to install battery storage capacity connecting to the existing Tarrone 500kV Terminal Station located to the west of the Project site. The Project aims to connect to and make use of the existing Tarrone Terminal Station. An underground Transmission line will stretch from the power transformer within the BESS to a recently built 132kV switchyard at the Tarrone Terminal Station. This switchyard is crucial for facilitating the connection of both GPG's Ryan Corner Wind Farm and Hawkesdale Wind Farm Projects.

This report is to accompany a planning permit application for the BESS to be submitted to the Minister of Planning at the Department of Transport and Planning in VIC. The Minister of Planning is the responsible authority for utility installations over 1 megawatt or greater pursuant to Clause 72.01-1 of the Moyne Planning Scheme.

Conclusions

A hazard identification table was developed for the Tarrone BESS Project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the Project Area are not considered to exceed the acceptable risk criteria; hence, the Project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site. It must be noted that the required bushfire assessment is provided under separate cover.

Recommendations

The following recommendations have been made as a result of the assessment:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.

- Before construction, detailed design to validate the system can be installed in the Project Area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.
- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
DC	Direct Current
DGs	Dangerous Goods
DPHI	Department of Planning, Housing and Infrastructure
DTP	Department of Transport and Planning
EIS	Environmental Impact Statement
ELF	Extra Low Frequency
EMF	Electric and Magnetic Field
ERPG	Emergency Response Planning Guideline
ESO	Environmental Significance Overlay
FCAS	Frequency Control Ancillary Services
FHA	Final Hazard Analysis
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IDLH	Immediately Dangerous to Life and Health
LFP	LiFePO4 (Lithium Iron Phosphate)
MVPS	Medium Voltage Power Station
NMC	Nickel-Manganese-Cobalt
NSW	New South Wales
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
PV	Photovoltaic
REZ	Renewable Energy Zone
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SOC	State of Charge
SSDA	State Significant Development Application
STEL	Short Term Exposure Limit

Abbreviation	Description
VBB	Victorian Big Battery
VIC	Victoria

1.0 Introduction

1.1 Background

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1.2 Objectives

Victoria does not have a strict criterion for the preparation of a PHA; hence, this document follows the methodology recommended by the NSW Department of Planning, Housing and Infrastructure (DPHI). The key objectives of this PHA are to:

- Complete the PHA according to the Hazardous Industry Planning Advisory Paper (HIPAP) No. 6 – Hazard Analysis (Ref. [1]);
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [2]); andl
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e. *Planning and Environment Act 1987, Dangerous Goods Act and Regulations 1985*).

1.3 Scope of Services

The scope of work is to complete a PHA study for the Tarrone BESS to be located 7.5 km east of the township of Orford, within the Moyne Shire Council local government area.

2.0 Methodology

2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [3]) published by the NSW DPHI, has been used as the basis for the study to determine the level of risk assessment required. The approach considered the development in context of its location, the quantity and type (i.e. hazardous nature) of Dangerous Goods (DGs) stored and used, and the Project's technical and safety management control. The Multi-Level Risk Assessment Guidelines are intended to assist industry, consultants and the consent authorities to carry out and evaluate risk assessments at an appropriate level for the Project being studied.

There are three levels of risk assessment set out in Multi-Level Risk Assessment which may be appropriate for a PHA, as detailed in **Table 2-1**.

Table 2-1: Level of Assessment PHA

Level	Type of Analysis	Appropriate If:
1	Qualitative	No major off-site consequences and societal risk is negligible
2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
3	Quantitative	Where 1 and 2 are exceeded

The Multi-Level Risk Assessment approach is schematically presented in **Figure 2-1**.

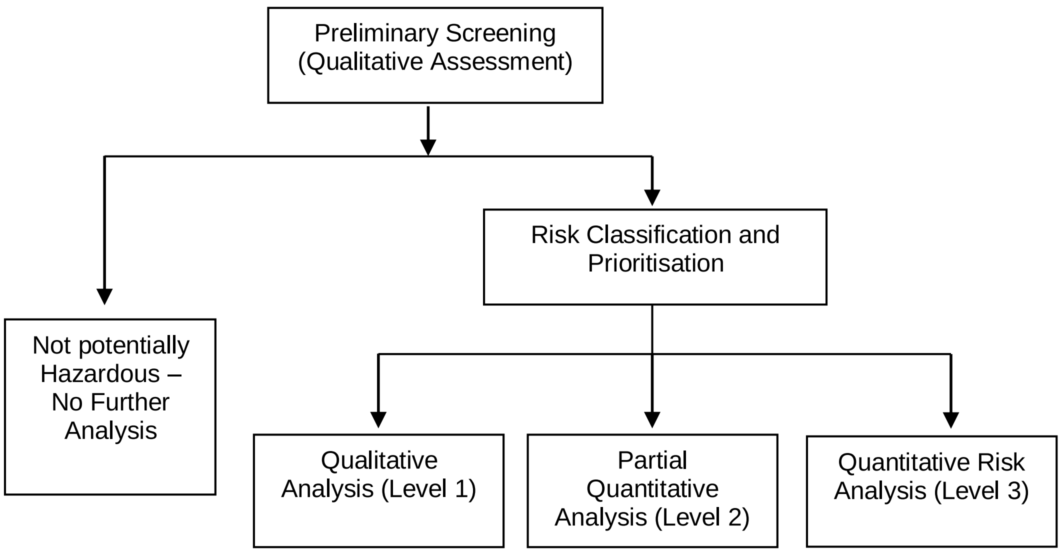

Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled at the Project, a **Level 2 Assessment** was selected. This approach provides a qualitative assessment of those DGs of lesser quantities and hazard, and a quantitative approach for the more hazardous materials to be used on-site. This approach is commensurate with the methodologies recommended in "Applying SEPP 33's" Multi Level Risk Assessment approach (Ref. [3]).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows:

Hazard Analysis – A detailed hazard identification was conducted for the site facilities and operations. Where an incident was identified to have a potential off-site impact, it was included in the recorded hazard identification word diagram (**Appendix A**). The hazard identification word diagram lists incident type, causes, consequences and safeguards. This was performed using the word diagram format recommended in HIPAP No. 6 (Ref. [1]).

Each postulated hazardous incident was assessed qualitatively in light of proposed safeguards (technical and management controls). Where a potential offsite impact was identified, the incident was carried into the main report for further analysis. Where the qualitative review in the main report determined that the safeguards were adequate to control the hazard, or that the consequence would obviously have no offsite impact, no further analysis was performed. **Section 3.1** of this report provides details of values used to assist in selecting incidents required to be carried forward for further analysis.

Consequence Analysis – For those incidents qualitatively identified in the hazard analysis to have a potential offsite impact, a detailed consequence analysis was conducted. The analysis modelled the various postulated hazardous incidents and determined impact distances from the incident source. The results were compared to the consequence criteria listed in HIPAP No. 4 (Ref. [2]). The criteria selected for screening incidents is discussed in **Section 3.1**.

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the Project Area), the solution was recommended, and no further analysis was performed.

Frequency Analysis – In the event a simple solution for managing consequence impacts was not evident, each incident identified to have potential offsite impact was subjected to a frequency analysis. The analysis considered the initiating event and probability of failure of the safeguards (both hardware and software). The results of the frequency analysis were then carried forward to the risk assessment and reduction stage for combination with the consequence analysis results.

Risk Assessment and Reduction – Where incidents were identified to impact offsite and where a consequence and frequency analysis was conducted, the consequence and frequency analysis for each incident were combined to determine the risk and then compared to the risk criteria published in HIPAP No. 4 (Ref. [2]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

Reporting – On completion of the study, a draft report was developed for review and comment. A final report was then developed, incorporating the comments received for submission to the regulatory authority.

3.0 Site Description

3.1 Site Location

The Project is located within Moyne Shire Council local government area, approximately 7.5 kilometres east of the township of Orford, 14.5 kilometres west of Hawkesdale, 23 kilometres north of Port Fairy and 250 kilometres west of Melbourne CBD.

Figure 3-1 shows the regional location of the site in relation to Orford. The conceptual Project Layout has been provided in **Figure 3-2**.

Figure 3-1: Site Location

ADVERTISED PLAN

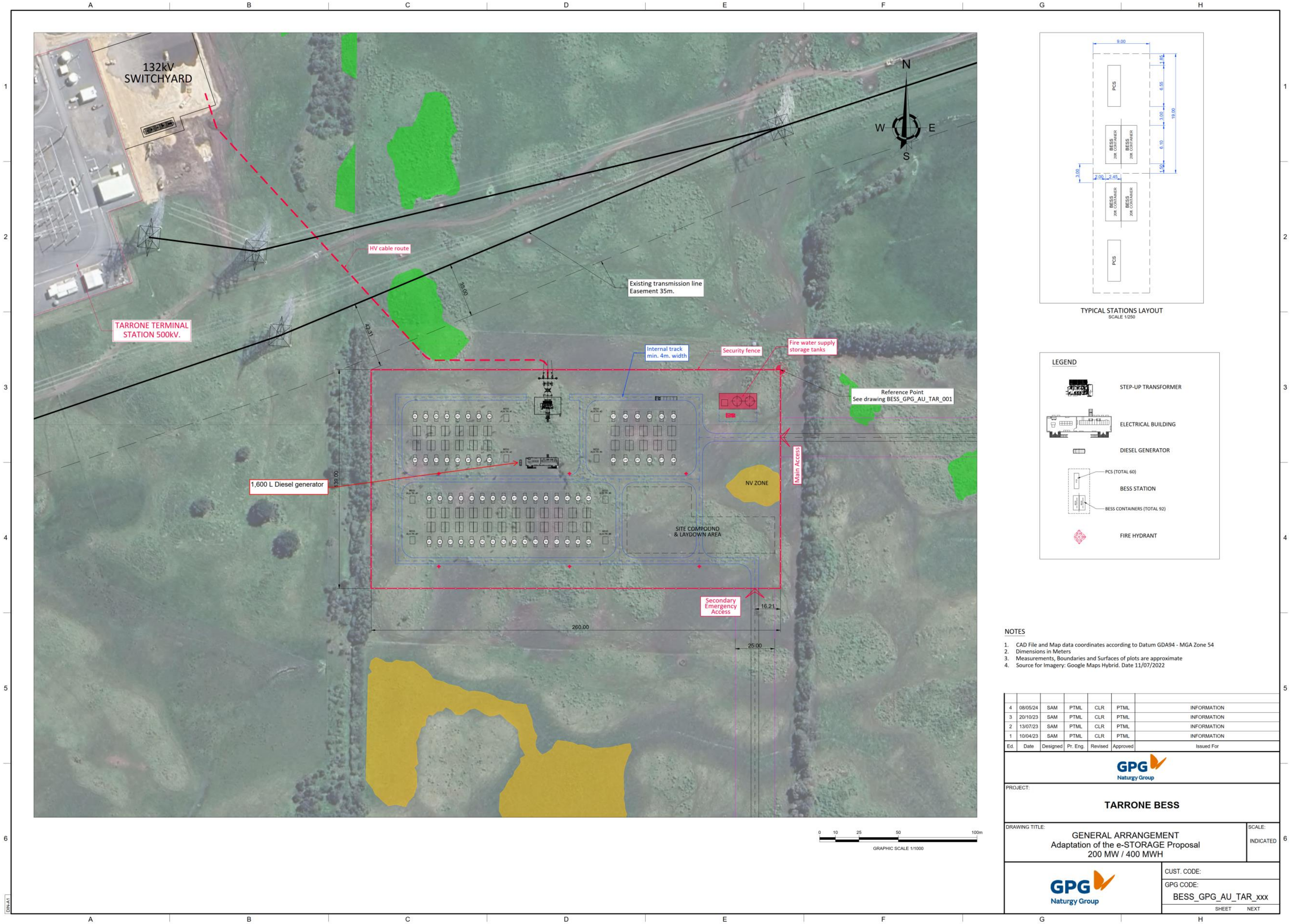

Figure 3-2: Conceptual Project Layout

3.2 Site Context

The Project is located within Moyne Shire Council local government area, approximately 7.5 kilometres east of the township of Orford, 14.5 kilometres west of Hawkesdale, 23 kilometres north of Port Fairy and 250 kilometres west of Melbourne CBD.

The Project site is located at 574 Tarrone North Road, Tarrone, VIC 3283 on land formally known as Lot 7~A PP2835, which is proposed to be subdivided as follows Lot 2 PS 918386 and Lot 2 LP218923. The Project site is owned by Ryan Corner Development Pty Ltd, a wholly owned subsidiary of GPG.

The Project site is approximately six hectares, inclusive of the transmission connection to the National Energy Market (NEM) at Tarrone Terminal Station. The Project site is generally bound by Riordans Road to the south, Tarrone Terminal Station to the south, a private road to the north (utilised to access the Tarrone Terminal Station) and Tarrone North Road to the east.

The primary land use within the Project site is agriculture (pasture and grassland). Under the Moyne Planning Scheme, the Project site is predominantly located in the Farming Zone (FZ) with a small portion of the Project site (transmission connection) located within the Special Use Zone – Schedule 6, which applies to the Tarrone Power Station. The majority of the Project site is also affected by the Environmental Significance Overlay (ESO) – Schedule 5, which relates to the Tarrone Power Station Environs. There are no crown land or public land sites present within the Project site. The Project site has historically been used for domestic stock grazing.

The Project site supports basalt soils with a topography consisting of a gently undulating landscape, characterized by wet depressions at the low points and stony rises, exposing basaltic rock at the high points. A coordinated ephemeral drainage line dissected the east of the study area in a north-south orientation.

There are no major or minor waterways that intersect with the Project site. The nearest waterways are Back creek, which runs parallel to the east of the site. There are also no wetlands within the Project site, however a recorded Wetland (#25686) is located approximately 17km of the south-west of the Project site boundary.

The Project site lies within the Victoria Volcanic Plain Bioregion and falls within the Glenelg Hopkins Catchment Management Area (CMA). Vegetation primarily consists of introduced pasture grasses and broad-leaf weeds. The broader property is surrounded by planted windrows of native trees and shrubs. Areas supporting native vegetation are primarily restricted to the wet depressions or stony rises, although drier flatter land along the adjoining reserves of Tarrone Nth Road and Riordans Road also support native vegetation. These wet depressions support wetland species typical of Plains Grassy Wetland, such as Spike Sedge, Rush, Australian Sweet-grass, Common Blown-grass and Common Tussock-grass. The stony rises supported Stony Knoll Shrubland and were characterised by the presence of Weeping Grass and Austral Bracken. Other native species included wallaby and spear grasses, Kidney Weed and Sheep's Burr. A large section to the Project site is located within an area of cultural heritage sensitivity. The relevant Registered Aboriginal Party (RAP) within the region pursuant to the *Aboriginal Heritage Act 2006* is the Eastern Maar Aboriginal Corporation.

The Project site is surrounded by numerous renewable energy projects including: Macarthur Wind farm which is approximately 11 km north of the Project site, Hawkesdale Wind farm approximately 11 km north-east, Woolsthorpe Wind farm approximately 15 km east and Ryan Corner Wind Farm approximately 10 km south-west.

3.3 Adjacent Land Uses

The land is located in a rural area surrounded by the following land uses, which are adjacent to the site:

- North – Rural farmland
- South – Rural farmland
- East – Rural farmland
- West – Rural farmland

3.4 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 site that can be considered sensitive. The locations of nearby residential receptors, both involved and non-involved with the Project, can be seen in **Figure 3-3**. The closest residential receptor to each BESS location has been summarised in **Table 3-1**. A review of the separation distances indicates that the nearest residential receptor to the BESS site is roughly 1 km.

Table 3-1: Distance between BESS and Closest Sensitive Receptor

Nearby residential receptor	Distance (km)
TBESS Receiver 01	1.0
TBESS Receiver 02	1.15
TBESS Receiver 03	1.0
TBESS Receiver 04	1.13

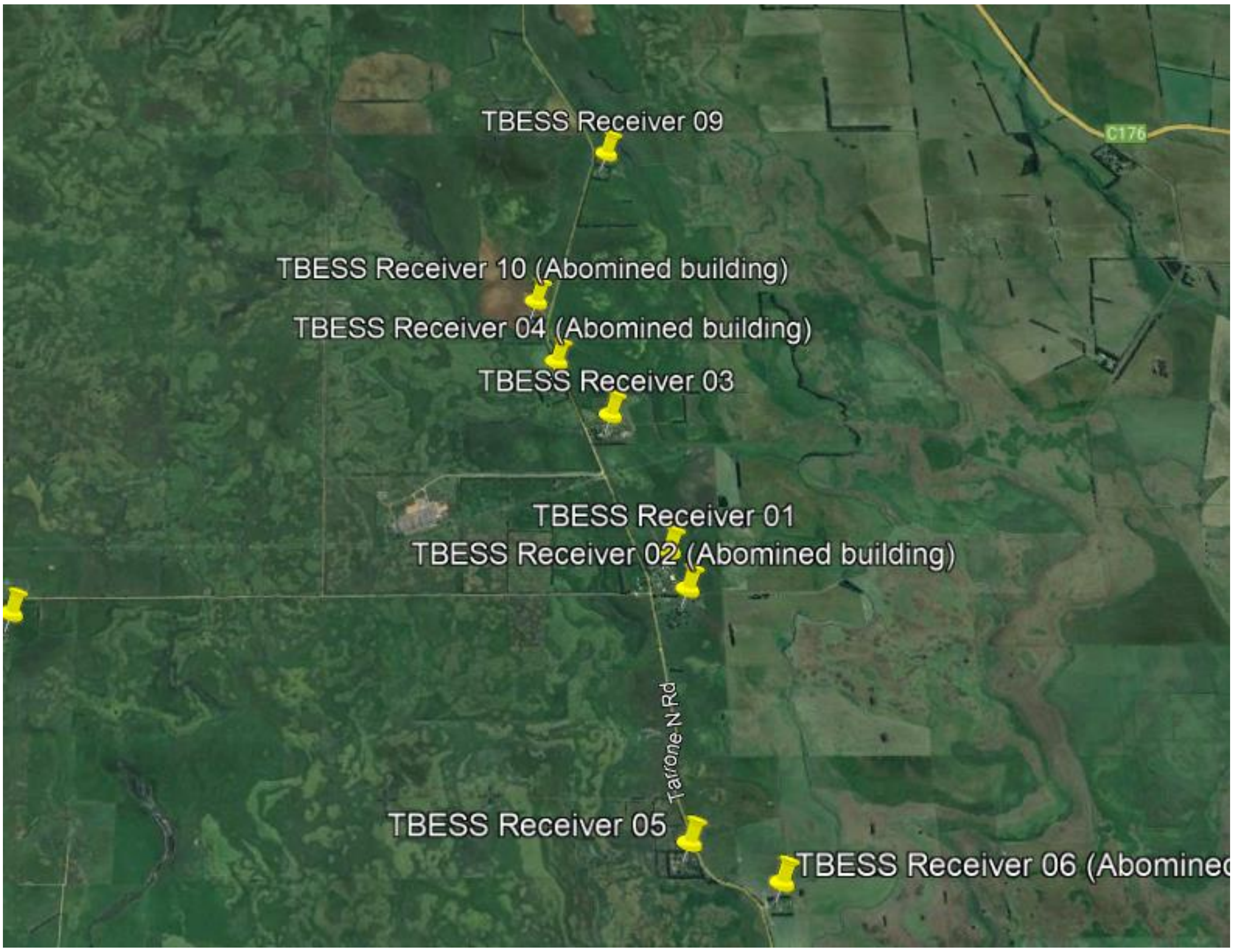

Figure 3-3: Location of Sensitive Receptors

3.5 Project Description

3.5.1 The Project

The Project consists of the key components and features outlined in **Table 3-2**.

Table 3-2: Key Project Components and Features

Component	Features
BESS	• Internal electrical facilities for the storage and export of power will comprise of up to 64 separate battery energy storage system (BESS) module arrays consisting of one electrical inverter and three or four BESS modules installed in groups with a total storage capacity of 200 MWac / 400 MWh. Each individual BESS module will have approximately 2.2 MWh of storage. • These individual BESS modules are fully enclosed in pre-fabricated shipping container sized containers, with individual fire detection and suppression, ventilation systems and cooling systems. The current site layout allows for up to 130 of the individual BESS modules. • The electrical inverters will be installed outside of the BESS module groups, mainly located towards the centre of the Project to reduce visual impact and noise of the inverters on nearby properties. • The combined inverter and BESS module stations are proposed to be arranged in three rows of approximately twenty stations per row and position in a north to south arrangement.

Component	Features
	• One 132/33/33 kV transformers (and supporting auxiliary systems). • Site facility containers. • Back-up diesel generator.
Transmission Line	• An underground 132 kV transmission line connecting the Project to the Tarrone Terminal Station with a length of approximately 200 m. • The transmission line will extend from the Project transformers within the BESS to a recently built 132 kV switchyard at the Tarrone Terminal Station to support the connection of the GPG's Ryan Corner Wind Farm and Hawkesdale Wind Farm Projects. • This connection will include the construction of a new 132 kV bay within the Tarrone Terminal Station 132 kv switchyard.
Ancillary Infrastructure	• Site office and control room. • Access to the Project site via access roads from Tarrone North Road and Riordan's Road, each with a proposed corridor of 25 metres. • Four-metre-wide internal access roads to support movement through the facility during the operations. • Security fencing of up to 2.1 m high around the Project infrastructure. • Fire water supply storage tanks. • A 10 m buffer zone to the east and west of the proposed facility location to provide an adequate buffer from site-based works to the existing vegetation located on the property. • A site laydown area of approximately 28 m by 135 m, for the housing of Project infrastructure, site construction facilities and parking (where required). This area is included in the Project impact area.

3.5.2 Project Timing

The time frame of the Project is subject to obtaining all necessary planning and environmental approvals, and associated permits and consents. The following timeframes are anticipated for the four key phases of the Project:

- **Construction**: Commence in 3Q2025
- **Operation:** Commissioning of the Project in 3Q2026
- **Decommissioning:** It is anticipated the Project would have an estimated lifecycle of 20 years. The BESS and associated infrastructure will either be decommissioned or upgraded to extend its operational period.

3.6 Detailed Description

The purpose of the Project is to provide dispatchable energy to the Victorian grid and contribute towards the goals of the VIC government's renewable energy target as outlined in the *Renewable Energy (Jobs and Investment) Act 2017* (63 GW by 2035).

The electricity will be capable of storage in a 200 MW / 400 MWh BESS which can 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. The Project will have capacity to discharge up to 200 megawatts (MW) of power for 2 hours resulting in a storage of 400 MWh.

3.6.1 Medium Voltage Power Station (MVPS)

The MVPS house transformers and inverters which will be sited adjacent to the BESS units. There will be approximately 70 MVPSs installed throughout the Project Area which typically comprise:

1. 1 x transformers
2. 1 x inverters

The inverters convert the Direct Current (DC) to Alternating Current (AC), while the transformers increase the voltage from Low Voltage to a Medium or High Voltage, as required for the electricity grid connection. MVPS are a compact, containerised product, with each unit measuring approximately 2.5 metres wide by 3 metres high, with a depth of 6 metres. **Figure 3-4** provides an example of a typical MVPS.

Figure 3-4: Typical MVPS

3.6.2 Battery Storage

The BESS will be located within the allocated BESS area noted in **Figure 3-2**.The BESS converts electrical energy into chemical energy and stores the energy internally. It may also provide additional network support such as Frequency Control Ancillary Services (FCAS) assisting with transmission network grid stability. A typical BESS is shown in **Figure 3-5**.

Figure 3-5: Typical BESS Arrangement

3.7 Quantities of Dangerous Goods (DGs)

The classes and quantities of DGs to be approved are provided in **Table 3-3**.

Table 3-3: Maximum Quantities of Dangerous Goods Stored

Area	Class	Description	Quantity
BESS	9	Lithium Batteries	3,965 T
Diesel Generator	C1/C2	Combustible Liquids - Diesel	1,600 L

4.0 Hazard Identification

4.1 Introduction

A hazard identification table has been developed and is presented at **Appendix A**. This table has been developed following the recommended approach in Hazardous Industry Planning Advisory Paper No. 6, Hazard Analysis Guidelines (Ref. [1]). The Hazard Identification Table provides a summary of the potential hazards, consequences and safeguards at the site. The table has been used to identify the hazards for further assessment in this section of the study. Each hazard is identified in detail and no hazards have been eliminated from assessment by qualitative risk assessment prior to detailed hazard assessment in this section of the study.

In order to determine acceptable impact criteria for incidents that would not be considered for further analysis, due to limited impact offsite, the following approach has been applied:

- *Fire Impacts* - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation at the Project Area (4.7 kW/m^2) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in a heat radiation less that at 4.7 kW/m^2, at the Project Area, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m^2 at the Project Area are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [2]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is approximately 1 km from the closest BESS, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible explosion over pressure at the Project Area (7 kPa) above which the risk of injury may occur and therefore the risk must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk, for this study, incidents that result in an explosion overpressure less than 7 kPa, at the Project Area, are screened from further assessment. Those incidents exceeding 7 kPa, at the Project Area, are carried forward for further assessment (i.e. frequency and risk). Similarly, to the heat radiation impact discussed above, this is conservative as the 7 kPa value listed in HIPAP No. 4 relates to residential areas, which is approximately 1 km away from the closest BESS.

- *Toxicity* – Toxic by-products of combustion may be generated by a BESS fire; hence, toxicity has been assessed.

- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the Project Area (23 kW/m^2/14 kPa) above which the risk of property damage and accident propagation to neighbouring sites must be assessed. Hence, to assist in screening those incidents that do not pose a significant risk to incident propagation, for this study, incidents that result in a heat radiation heat radiation less than 23 kW/m^2 and explosion over pressure less than 14 kPa, at the Project Area, are screened from further assessment. Those incidents exceeding 23 kW/m^2 at the Project Area are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

- *Societal Risk* – HIPAP No. 4 (Ref. [2]) discusses the application of societal risk to populations surrounding the Project. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a Project, the change in societal risk needs to be taken into account. In the case of the Project, there is currently no significant intensification of population around the proposed site; hence, societal risk has not been considered in this assessment.

4.2 Properties of Dangerous Goods

The type of DGs and quantities stored and used at the site has been described in **Section 3**. **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 60.5C. 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 source.

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [4])

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.
- Victorian Big Battery fire review.
- Li-ion battery fire and toxic gas dispersion.
- Electrical equipment failure and fire.
- Electromagnetic field Impacts.
- National Health and Medical Research Council review.
- Diesel generator leak, ignition and fire.

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 a Li-ion battery, the lithium metal composites (a composite of lithium with other metals such as cobalt, manganese, nickel, or any combination of these metals) oxidises (loses an electron) becoming a positively charged ion in solution which migrates through the battery separator to the cathode. At the same time, the lost electron travels through the circuit to the cathode. The lithium ions in solution then recombine with the electron at the cathode forming lithium metal within the cathodic metal composite. This process is shown in **Figure 4-1**.

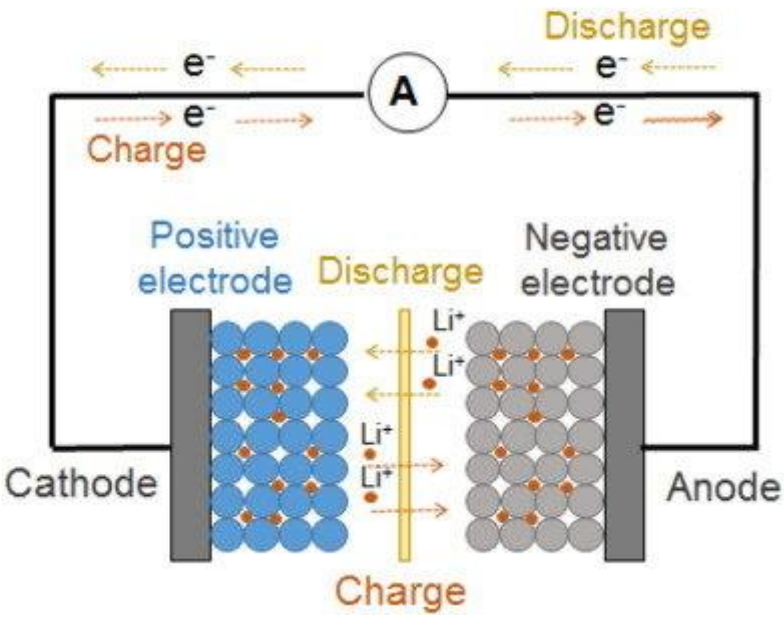

Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

Initial lithium batteries were designed around lithium metal (i.e. no composite structure) due to the high energy density yielded by the metal. However, when overcharging a battery, lithium ions can begin to plate on the anode in the form of lithium dendrites. Eventually, the dendrites pierce the separator within the battery resulting in a short of the battery which could result in heat, fire, or explosion of the battery. The technology evolved to move away from lithium metal to lithium ions (held within composite materials) which reduced the incidence of lithium dendrites forming resulting in an overall safer battery.

Despite the improvement in battery technology, there are several degradation mechanisms that are still present within the battery which can result in thermal runaway. These include:

- Chemical reduction of the electrolyte at the anode
- Thermal decomposition of the electrolyte
- Chemical reduction of the electrolyte at the cathode
- Thermal decomposition by the cathode and the anode
- Internal short circuit by charge effects

These effects arise primarily as a result of high discharge, overcharging, or water ingress into the battery which results in a host of by-products being formed within the battery during charge and discharge cycles.

As a result, Li-ion batteries are equipped with several safety features to prevent the batteries from charging or discharging at voltages which result in battery degradation, leading to shorting of the battery and thermal runaway. Safety features generally include:

- Shut-down separator (for overheating)

- Tear-away tab (for internal pressure relief)
- Vent (pressure relief in case of severe outgassing)
- Thermal interrupt (overcurrent/overcharging/environmental exposure)

These features are designed to prevent overcharging or excessive discharge, pressurisation arising from heat generated at the anode or from battery contamination. Protection techniques for Li-ion batteries are standard; hence, the potential for thermal runaway to occur in normal operation is very low with the only exceptions being due to manufacturing faults or battery damage (i.e. battery cell is ruptured as this can short circuit the battery resulting in thermal runaway).

In terms of physical damage, the batteries are contained within in modules which are located within a fenced area; therefore, there is a low potential for damage to occur to the batteries which may initiate an incident.

A review of the batteries proposed to be used as part of this Project indicates the battery chemistry is Lithium-Ion phosphate (LiFePO4, or simply LFP) which are considered to be one of the safest battery chemistries within the industry. When exposed to external heat the thermal rise of typical lithium-ion battery chemistries is 200-400 ^{o}C/min resulting thermal run away and fire which can then propagate to adjacent batteries escalating the incident to a full container fire. For LFP batteries, the thermal rise of the batteries at peak is 1.5^{o}C/min which results in a gradual temperature rise and does not result in fire and thus incident propagation to other batteries. The thermal rise of various battery chemistries is provided in **Figure 4-2** with a zoomed in temperature rise for LFP provided in the top right of **Figure 4-2**. The stability of the batteries is due to the cathode which does not release oxygen therefore preventing violent redox reactions resulting in rapid temperature rise as the oxygen oxides the electrolyte.

Additional testing for shock and damage to batteries (i.e. nail puncture test) has been shown that LFP batteries when punctured through membranes which typically results in a shorting of the battery and fire does not result in ignition of the battery demonstrating that the battery chemistry is protected against shock damage.

In the event that LFP chemistries do ignite by artificial means, the combustion by products release carbon dioxide which reduces the oxygen concentration within a confined space reducing the combustion rate. Finally, the containers are fitted with a fire suppression system which will activate to suppress and control a fire preventing escalation to other battery units.

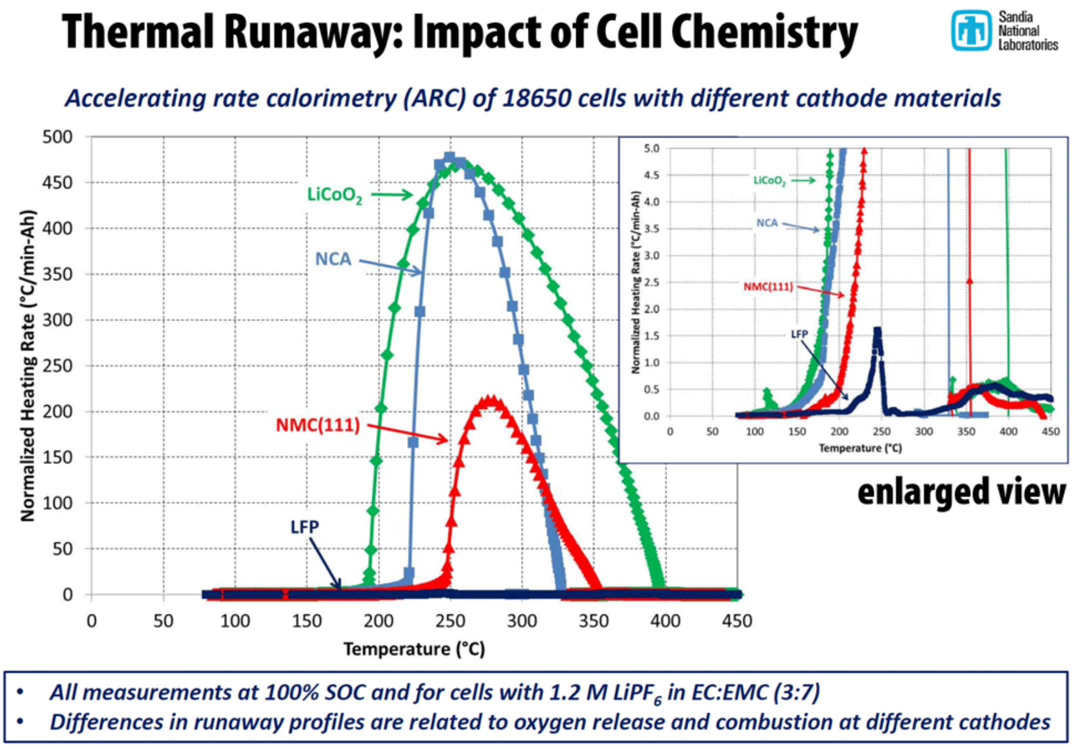

Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [5]).

It is important to consider whether the batteries have been certified to UL9540A, which is the UL safety standard for non-residential battery testing, which contains requirements for electrical safety, thermal safety, mechanical safety, fire safety, system performance, system reliability, and system documentation. The preliminary battery product considered for the purposes of a preliminary hazard analysis for the Project is a BESS with LFP technology. A UL9540A report has been completed for this product but is unable to be shared due to privacy reasons.

Similarly, based on data shown from UL9540A reports for similar systems, the results demonstrate that when thermal runaway is triggered in one cell in a BESS container, the heat generated would neither be transferred to all cells within one battery module, nor from the test module to adjacent ones. This is attributed to the nature of LFP technology as well as the sheer mass of the battery module (heavier objects have higher thermal capacity).

Although the LFP technology does not cause fire, there can be circumstances where battery modules catch fire due to leaking coolant or electric faults. In those cases, fire will be constrained by the stainless-steel enclosure. Similar systems show that generally the container wall remains intact after sustaining heating in a furnace to over 900°C.

Furthermore, each container should also have multiple built-in fire protection devices that work collaboratively, including smoke and thermal sensors, combustible gas detector, pressure relief system, and aerosol E-Stop buttons. Therefore, a container will automatically detect an internal fire in the first instance.

Different systems deploy different battery fire mitigation strategies depending on the solution, but in any case, the Project will implement the manufacturer’s recommended fire protection systems. The assessed and final selected system will hold relevant UL and IEC certifications (i.e. UL9540, UL9540A, UL1741, UL1973, UN38.3; CE; EMC; NFPA 70; IEEE C37.32; IEC:62933, 62619, 60204, ASTM4169).

In conclusion, the LFP technology is unlikely to cause fire during thermal runaway provided the protection systems are in place and operating. Should fire be developed within one BESS container it would not transfer to nearby containers due to the fire safety design features; hence, this incident has not been carried forward for further analysis.

Notwithstanding, based on conversations with and review by DPHI on past BESS projects, the following recommendations have been made:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.
- Before construction, detailed design to validate the system can be installed in the Project Area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.

4.5 Victorian Big Battery Fire Review

Notwithstanding the findings of **Section 4.4**, it is necessary to review recent large scale BESS fires to determine whether similar incidents could occur with the Tarrone BESS.

The Tarrone BESS has thoroughly considered the separation distance considering fire safety, and operation and maintenance. The fire safety assessment is essentially around heat transfer which has been discussed in detail in **Section 4.4**.

The Victorian Big Battery (VBB) incident occurred at a Geelong BESS facility in July 2021 and involves the fire (due to liquid coolant failure and the consequent thermal runaway) of a single Tesla Megapack which propagated to an adjacent module. According to the independent investigation report on its fire incidence, the back-to-back layout was not the cause. The main reason for fire propagation was strong wind blowing flames from one Megapack into the unprotected vent atop of an adjacent Megapack which resulted in the ignition of the plastic fan which was able to impact the battery modules directly beneath the fan.

Lessons learnt from the VBB incident results in fire safety precautions on the design of Tarrone BESS. The vent atop the containers shall be made of metal instead of plastic and covered by a metallic mesh shield. Furthermore, the placement of the fans shall be such that batteries or flammable materials shall not be located directly beneath ventilation openings. To ensure the above are captured the following recommendations have been made:

- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

Based upon the designs incorporated with the container based upon the VBB fire, the available area assessment and the separation distance assessment, it is considered that the propagation between two units is considered unlikely; hence, this incident has not been carried forward for further analysis.

4.6 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic by-products 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.
- Fluorine gases.

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

4.6.1 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 with Short Term Exposure Limit (STEL) occurring at 30,000 ppm (3%), above 50,000 ppm (5%) a strong respiration effect is observed along with dizziness, confusion, headaches, and shortness of breath. Concentrations in excess of 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.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3Co_2(g) + 4H_2O(g) \quad \textbf{Equation 4-1}$$

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 (i.e. Victoria BESS fire), 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. Therefore, this incident has not been carried forward for further analysis.

4.6.2 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**.

$$2C_3H_8(g) + 7O_2(g) \rightarrow 6CO(g) + 8H_2O(g)$$ **Equation 4-2**

As noted, in **Section 4.6.1** there is the potential for a fire to occur with the BESS units which could form carbon monoxide if there is insufficient oxygen to sustain complete combustion. 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. Therefore, it is considered that the formation of carbon monoxide at levels which would result in a substantial downwind impact are not considered credible and subsequent analysis of, this incident is not required.

4.6.3 Fluoride Gases

The electrolyte used in Li-ion batteries typically is lithium hexafluorophosphate ($LiPF_6$) or other li-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 (PF_5) and phosphoryl fluoride (POF_3) (Ref. [6]).

The decomposition of $LiPF_6$ can be promoted by the presence of water / humidity according to reactions **Equation 4-3** to **Equation 4-5**.

$$LiPF_6 \rightarrow LiF + PF_5$$ **Equation 4-3**

$$PF_5 + H_2O \rightarrow POF_3 + 2HF$$ **Equation 4-4**

$$LiPF_6 + H_2O \rightarrow LiF + POF_3 + 2HF$$ **Equation 4-5**

Of the fluorine gases formed, PF_5 is a short-lived gas while POF_3 is a reactive intermediate. Thermal destruction of a several battery chemistry, configurations and State of Charge (SOC) indicated the vast majority of these did not produce observable POF_3 with the only observance occurring in a specific battery chemistry at 0% SOC (Ref. [6]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

HF gas is hydroscopic readily dissolving into water vapour / humidity or moisture in airways forming hydrofluoric acid. Hydrofluoric acid is a weak acid although is highly corrosive and may result in chemical burns. In addition, it is calcium scavenging. 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 unlikely provided the protection systems are installed and operating. As the potential for the initiating event is considered unlikely, this incident has not been carried forward for further analysis.

4.7 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 offsite impact or incident propagation. Therefore, this incident has not been carried forward for further analysis.

4.8 Electromagnetic Field Impacts

4.8.1 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 EMF's in the range of 30 to 300 Hz.

4.8.2 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. [7]).

Table 4-2 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.

Table 4-2: 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

4.8.3 Exposure Discussion

A review of the site indicates that the closest residential receiver is over 1 km away from the area where the BESS will be developed 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. In addition, the closest residence is over 1 km away from the EMF generating sources at the BESS; hence, the potential for the EMF to exceed the accepted levels is considered negligible.

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. [8]).

A field study was undertaken to characterise the EMF between the frequencies of 0 – 3 GHz at two large scale facilities operated by the Southern California Edison Company in Porterville and San Bernardino, (Ref. [9]).

The field study findings were adopted to estimate the EMF measurements for the Project. The findings are as follows:

• The highest DC magnetic fields were measured adjacent to the inverter (277 µT) and transformer (258 µT). These fields were lower than the ICNIRP's occupational exposure limit.

• The highest AC magnetic fields were measured adjacent to the inverter (110 µT) and transformer (177 µT). These fields were lower than the ICNIRP's occupational exposure limit.

• The strength of the magnetic field attenuated rapidly with distance (i.e. within 2-3 metres away, the fields drop to background levels).

• Electric fields were negligible to non-detectable. This is mostly likely attributed to the enclosures provided for the electricity generating equipment.

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

As the potential for exposure to EMF exceeding the international guidelines is negligible, this incident has not been carried forward for further analysis.

4.9 Diesel Generator Leak, Ignition and Fire

A 1,600 L diesel generator will be used on-site as a power source for the electrical building. It will contain diesel which is a combustible liquid and may release from the generator due to potential collision and/or faulty manufacturing. However, it must be noted that diesel has a relatively high flash point (>60ºC) and is therefore difficult to ignite. In addition, there are design controls that are built-in into the generator that significantly reduces the potential of fuel release, such as containment, e-stop switch and a control system.

It is not expected that a diesel spill will ignite should a spill occur; therefore, this incident has not been carried forward for further analysis.

5.0 Conclusion and Recommendations

5.1 Conclusions

A hazard identification table was developed for the Tarrone BESS Project to identify potential hazards that may be present at the site as a result of operations or storage of materials. Based on the identified hazards, scenarios were postulated that may result in an incident with the potential for offsite impacts. Postulated scenarios were discussed qualitatively and any scenarios that would not impact offsite were eliminated from further assessment. Scenarios not eliminated were then carried forward for consequence analysis.

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the Project Area are not considered to exceed the acceptable risk criteria; hence, the Project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site. It must be noted that the required bushfire assessment is provided under separate cover.

5.2 Recommendations

The following recommendations have been made as a result of the assessment:

- BESS must be tested in accordance with UL9540A.
- Testing to demonstrate clearances required to prevent propagation of fires between separated units.
- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.
- BESS to be installed with fire protection systems specified by the manufacturer and UL9540A report.
- Before construction, detailed design to validate the system can be installed in the Project Area whilst meeting the recommended clearances.
- UL testing information shall be made available to the certifying authority. It is noted that a confidentiality agreement may be required.
- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

6.0 References

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Appendix A

Hazard Identification Table

Riskcon engineering

A1. Hazard Identification Table

Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
Battery Storage	• Failure of Li-ion battery protection systems	• Thermal runaway resulting in fire or explosion • Incident propagation through battery cells • Toxic smoke dispersion	• Batteries are tested by manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents (i.e. BBU, cells) reducing risk of substantial component failure • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property) • Electrical systems designed per AS/NZS 3000:2007 (Ref. [10]) • UL9540A testing
Switch rooms, communications, etc.	• Arcing, overheating, sparking, etc. of electrical systems	• Ignition of processors and other combustible material within servers and subsequent fire	• Fires tend to smoulder rather than burn • Isolated location • Switch room separation from other sources of fire
Substation	• Arcing within transformer, vaporisation of oil and rupture of oil reservoir	• Transformer oil spill into bund and bund fire	• Bunded • Isolated location
	• Power surge to transformers (e.g. from lightning)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• 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
EMF	• Electric and magnetic equipment	• Generation of ELF EMF and injury / nuisance to surrounding area	• Large separation distances allow for attenuation of EMFs • Cumulative impacts from equipment below acceptable thresholds.