Riskcon engineering

# Preliminary Hazard Analysis

## Romani BESS

Environmental Resource Management Australia Pty Ltd
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Prepared by

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## Quality Management

| Rev | Date | Remarks | Prepared By | Reviewed By |
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| 5 | 27 August 2025 | Updated layout | | |

# Executive Summary

## Background

Environmental Resource Management Pty Ltd (ERM) have been engaged by Samsung C&T Renewable Energy Australia Pty Ltd to prepare an Environmental Impact Statement (EIS) for the Romani BESS to be located along Booroorban-Tchelery Rd, Booroorban NSW. The Project includes a standalone BESS with storage capacity of 200 MW / 800 MWH. The Secretary's Environmental Assessment Requirements (SEARs) requires the preparation of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Papers (HIPAP) No. 4 and No. 6 (Ref. [1][1] and [2][2]) as part of the EIS.

Riskcon Engineering Pty Ltd (Riskcon) has been engaged to prepare the PHA for the EIS.

## Conclusions

A hazard identification table was developed for the proposed Romani BESS 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. A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts.

Hence, based on the analysis presented in this report, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

## Recommendations

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

- 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.
- Where practicable, the vents shall not be located above battery packs within the BESS container.
- Confirm that all transformers are bunded to contain oil releases. Transformers may be self-bunded on a skid, otherwise they will require a dedicated concrete bund.

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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 |
| ELF | Extra Low Frequency |
| EMF | Electric and Magnetic Field |
| ERPG | Emergency Response Planning Guideline |
| HF | Hydrogen Fluoride |
| HIPAP | Hazardous Industry Planning Advisory Paper |
| HVAC | Heating Ventilation and Air Conditioning |
| ICNIRP | International Commission on Non-Ionizing Radiation Protection |
| IDLH | Immediately Dangerous to Life and Health |
| LFP | LiFePO4 (Lithium Iron Phosphate) |
| MV | Medium Voltage |
| NMC | Nickel-Manganese-Cobalt |
| PHA | Preliminary Hazard Analysis |
| PO | Performance Outcome |
| PV | Photovoltaic |
| SEP | Surface Emissive Power |
| SOC | State of Charge |
| STEL | Short Term Exposure Limit |
| VBB | Victorian Big Battery |

# 1.0 Introduction

## 1.1 Background

Environmental Resource Management Pty Ltd (ERM) have been engaged by Samsung C&T Renewable Energy Australia Pty Ltd to prepare an Environmental Impact Statement (EIS) for the Romani BESS to be located along Booroorban-Tchelery Rd, Booroorban NSW. The Project includes a standalone BESS with storage capacity of 200 MW / 800 MWH. The Secretary's Environmental Assessment Requirements (SEARs) requires the preparation of a Preliminary Hazard Analysis (PHA) in accordance with the Hazardous Industry Planning Advisory Papers (HIPAP) No. 4 and No. 6 (Ref. [1] and [2]) as part of the EIS.

Riskcon Engineering Pty Ltd (Riskcon) has been engaged to prepare the PHA for the EIS.

## 1.2 Objectives

The key objectives of this PHA are to:

- Complete the PHA according to the HIPAP No. 6 – Hazard Analysis (Ref. [2]).
- Assess the PHA results using the criteria in HIPAP No. 4 – Risk Criteria for Land Use Planning (Ref. [1])
- Demonstrate compliance of the site with the relevant codes, standards and regulations (i.e. WHS Regulation, 2017 Ref. [3]).

The report aims to address the additional assessment requirements identified in the SEARs and advice letter from the Department of Planning, Housing and Infrastructure Hazards team (**Table 1-1**).

**Table 1-1: SEARs - Hazards & Risks**

| Item | Requirement | Report Section |
|---|---|---|
| Hazards – Health | • an assessment of potential hazards and risks including but not limited to fires, spontaneous ignition, electromagnetic fields or the proposed grid connection infrastructure against the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields | **Section 4.0** |
| Hazards – Dangerous Goods | • A preliminary risk screening completed in accordance with the State Environmental Planning Policy (Resilience and Hazards) 2021 | **Section 3.3** |
| Hazards – Battery Energy Storage System | • a Preliminary Hazard Analysis (PHA) prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis (DoP, 2011) and Multi-Level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No. 4, Risk Criteria for Land Use Safety Planning (DoP, 2011). The PHA must consider the effect of bushfires on batteries or other components of the BESS. | **This report, notably Sections 4.4, 4.4.1 and 4.11.** |

## 1.3 Scope of Services

The scope of work is to complete a PHA study for the Romani BESS located along Booroorban-Tchelery Rd, Booroorban NSW.

# 2.0 Methodology

## 2.1 Multi-Level Risk Assessment

The Multi-Level Risk Assessment approach (Ref. [4]) published by the NSW Department of Planning, Housing and Infrastructure, 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**.

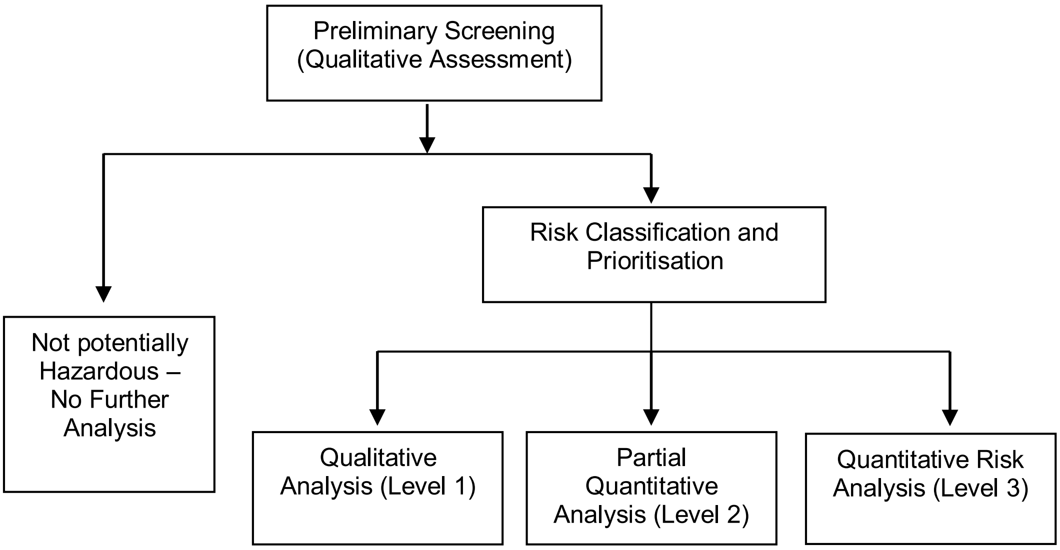


**Figure 2-1: The Multi-Level Risk Assessment Approach**

Based on the type of DGs to be used and handled at the proposed project, a **Level 1 Assessment** was selected for the Site. 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.

## 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. [2]).

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. [1]). 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 boundary), 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. [1]). 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 site is located along Booroorban-Tchelery Rd, Booroorban NSW approximately 44 km south of Hay NSW 2710. The surrounding properties are agricultural and the closest sensitive receptor separated by over 1 km from the BESS units.

**Figure 3-1** shows the regional location of the site. **Figure 3-2** shows the preliminary site layout of the full development.


**Figure 3-1: Site Location**

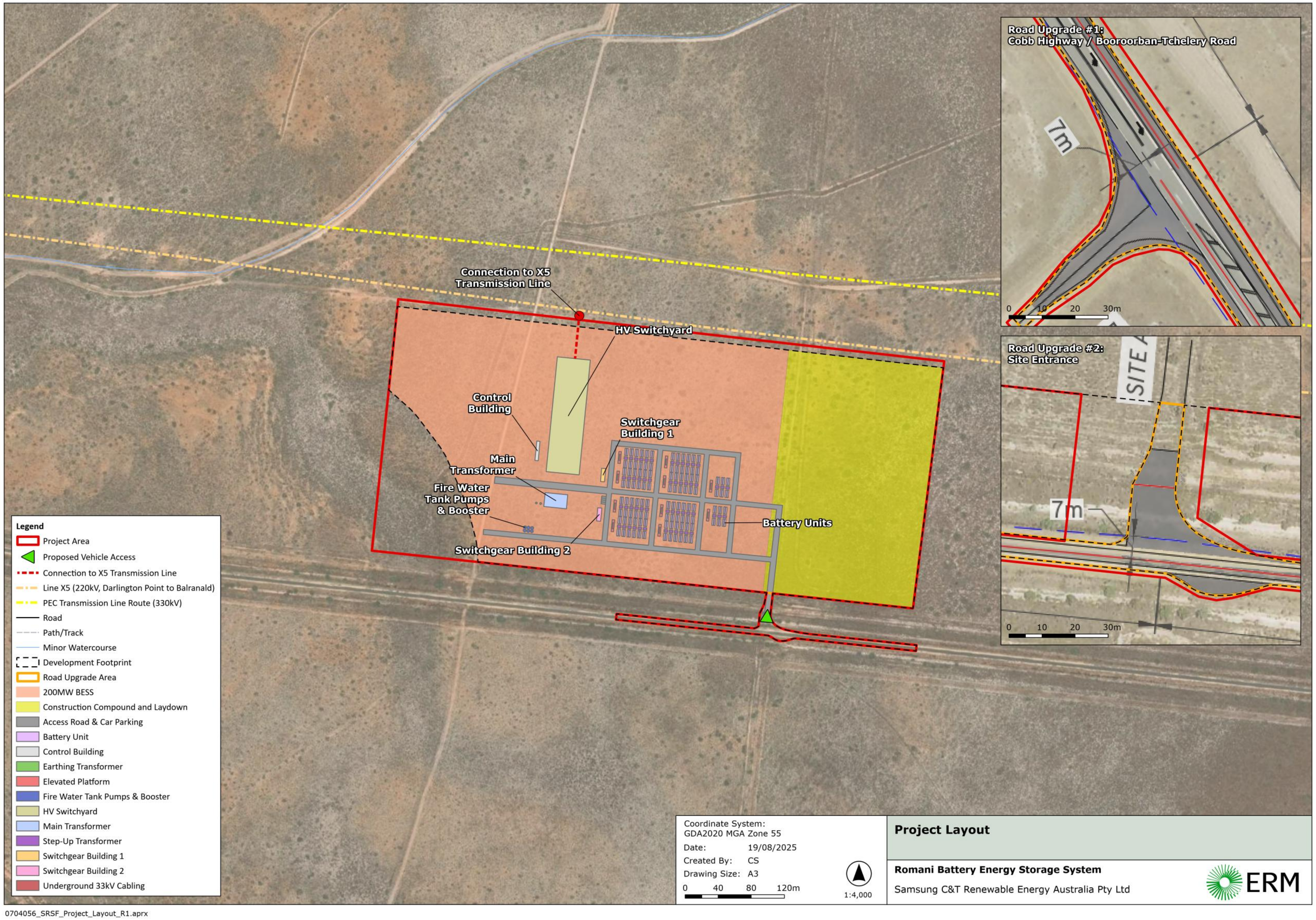


**Figure 3-2: Site Layout**

## 3.2 General Description

The project comprises a standalone BESS with 200 MW / 800 MWh capacity. The exact battery units have not been finalised yet, however the Tesla Megapack 2XL has been assumed for the purposes of this assessment. The maximum energy capacity of each unit is 3.92 MWh and there are 216 units proposed. Each unit employs lithium iron phosphate (LFP) battery modules and is equipped with a thermal management system using coolant and refrigerant and a Battery Management System for operational control. Each container measures 8800 × 1650 × 2785 mm, with a total weight of approximately 38.1 tonnes and an IP66 rating.

The containers conform to UL 1973, UL 9540, UL9540A, UL 1741 SB, IEC 62619 and IEEE 1547. Clearances/separations as per the manufacturer's installation manual are as a minimum 150 mm side to side/end to end, 460 mm back-to-back and 2,440 mm front clearance. The site layout complying with these clearances indicates there is sufficient space available.

Additional project features include:

- 1 x 220/33kV 240 MVA HV transformer 6 m
- 54 x 4.6 MVA inverter MV transformers
- Electrical reticulation network with grid connection via the existing X5 transmission line
- Permanent Operations and Maintenance (O&M) compound, control building / control room, switch room with a height of approximately 5m;
- Landscaping works, asset protection zones, access tracks, drainage;
- Vehicle access to/from Booroorban-Tchelery Road
- Construction period: 18 months
- Construction workforce (peak): 80-100 FTE
- Construction workforce (average): 30-50 FTE
- Operational workforce: 3-5 FTE

## 3.3 Quantities of Dangerous Goods and SEPP-RH Screening

The classes and quantities of DGs are provided in **Table 3-1**. The type of transformer oil is not yet confirmed; hence it is conservatively assumed as a C1 combustible liquid for the purposes of this PHA. Transformer oil quantities are estimated based on 1,000 L per 4.6 MVA transformer and 50,000 L for the larger 220 MVA transformer.

The SEARs requires a preliminary screening assessment against the SEPP-RH thresholds to determine if the site is considered ‘potentially hazardous. Above these thresholds, a Preliminary Hazard Analysis (the present report) is required to assess the potential for offsite impact. This screening assessment is included in **Table 3-1**.

**Table 3-1: Maximum Quantities of Dangerous Goods Stored**

| Area | Class | Description | Quantity | SEPP-RH Threshold? |
|---|---|---|---|---|
| BESS | 9 | Lithium Batteries | 8,230 t | n/a |
| Transformer oil | C1 | Combustible liquid | 104 kL | n/a |

It is noted that combustible liquids stored in an area where there are no flammable materials stored are not considered potentially hazardous, hence they do not exceed SEPP-RH thresholds. Class 9 DGs are ‘miscellaneous dangerous goods’ which pose little threat to people or property as per the planning guideline “Applying SEPP 33”. There is no published threshold for Class 9s, therefore they do not exceed SEPP-RH thresholds. However, the DPHI advice is that for BESS that exceed 30 MW, a PHA is required. Hence, in accordance with SEARs, this PHA has been prepared (present document).

# 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. [2]). 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 HIPAP No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (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 site boundary, are screened from further assessment.

  Those incidents exceeding 4.7 kW/m$^2$ at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [1]) 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).

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible explosion over pressure at the site boundary (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 site boundary, are screened from further assessment. Those incidents exceeding 7 kPa, at the site boundary, are carried forward for further assessment (i.e. frequency and risk).

- *Toxicity* – Toxic by-products of combustion may be generated by a BESS fire; hence, toxicity has been assessed with criteria based upon the Emergency Response Planning Guidelines (ERPG).

- *Property Damage and Accident Propagation* - It is noted in HIPAP No. 4 (Ref. [1]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary (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 site boundary, are screened from further assessment. Those incidents exceeding 23 kW/m$^2$ at the site boundary are carried forward for further assessment with respect to incident propagation (i.e. frequency and risk).

- *Societal Risk* – HIPAP No. 4 (Ref. [1]) discusses the application of societal risk to populations surrounding the Project. It is noted that HIPAP No. 4 (Ref. [1]) 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 60.5°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. |

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [5]

## 4.3 Hazard Identification

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

- 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.
- Transformer internal arcing, oil spill, ignition and bund fire.
- Transformer electrical surge protection failure and explosion
- Electromagnetic field impacts.

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**.

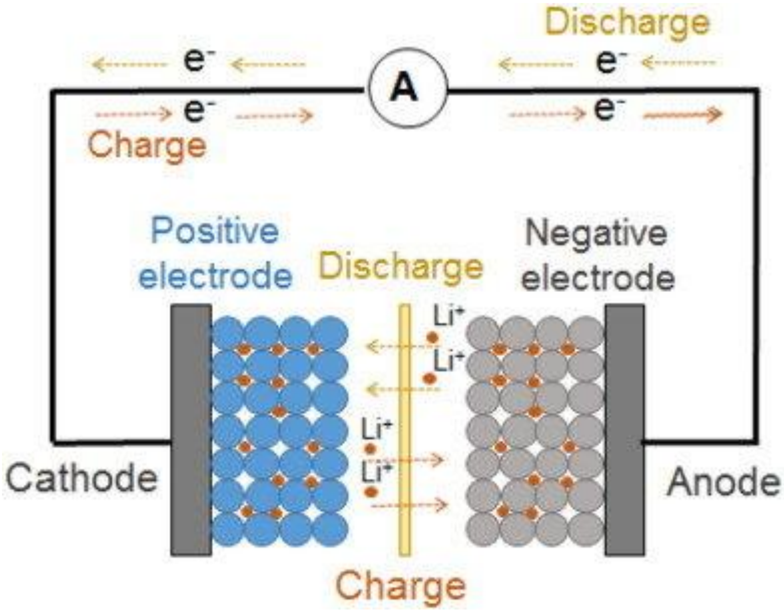


**Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)**

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 of 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 biproducts 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 anticipated to be lithium iron phosphate ($LiFePO_4$, 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 °C/min resulting in 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°C/min which results in a gradual temperature rise and does not result in fire and thus avoiding 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 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.

NMC batteries (nickel-manganese-cobalt) are also considered viable due to their high energy density relative to LFP batteries, however operation of NMC does result in oxygen release, potentially increasing fire risks. For this reason, LFP batteries are advised as the industry standard for safety in lithium-ion battery technology.

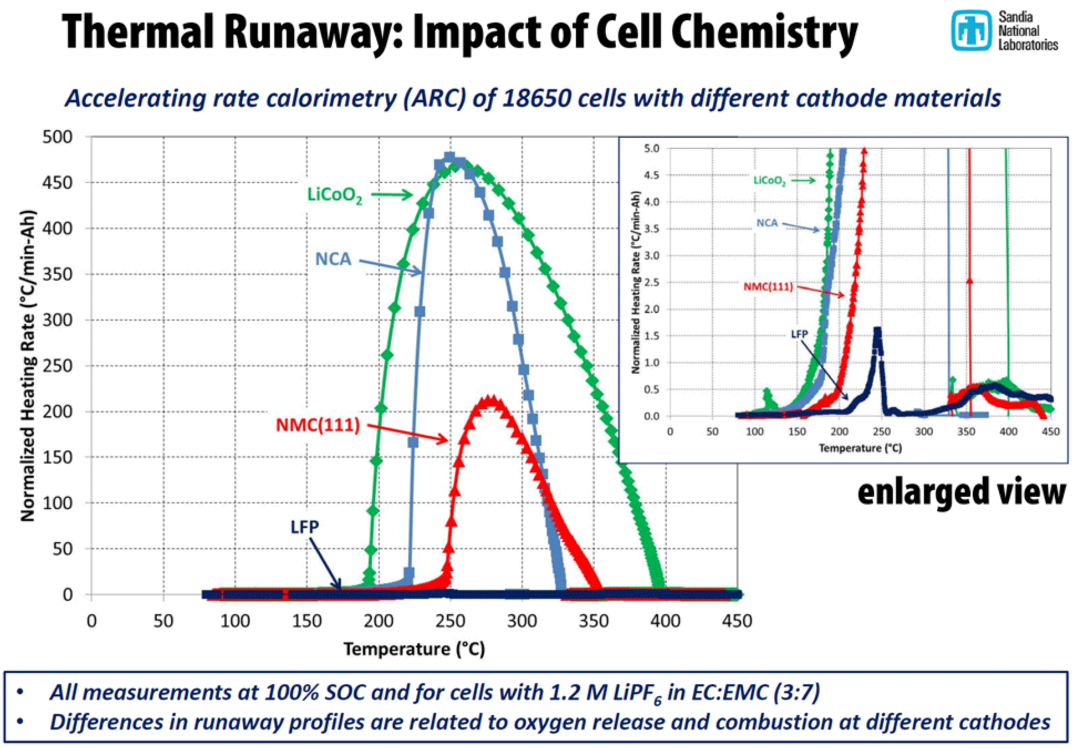


**Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [6]).**

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 (test standard report with a systematic evaluation of thermal runaway and propagation in energy storage system at cell, module, unit, and installation levels) may have been completed for this product and is unable to be shared due to privacy reasons. At install, the units will have been tested and have UL9540A test data for fire development and propagation.

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, E-stop buttons and a suppression system. Therefore, a container is expected to automatically detect an internal fire in the first instance.

In conclusion, the LFP technology does not cause fire during thermal runaway. 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 discussions with and review by NSW Department of Planning, Housing, and Infrastructure (DPHI) on other 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.

### 4.4.1 Separation Review

Notwithstanding the findings of **Section 4.4**, a further review of the separation distances to sensitive receptors is provided to address SEARs. The site is located in an unpopulated rural area where the nearest sensitive receptor (e.g. residence) is over 1 km from the site; therefore, it is considered that there is low potential for impact to sensitive receptors. BESS containers are separated in accordance with manufacturer's instructions with a minimum 150 mm side to side/end to end, 460 mm back-to-back and 2,440 mm front clearance. FM DS 5-33 provides a prescriptive separation requirement of 6 m, exceeding that of NFPA 855, AS 5139 and IEC 62897. While the separations provided by the manufacturer fall short of this requirement, it is expected that installation in accordance with the manufacturer's instruction will prevent propagation based on the results of Large Scale Fire Testing of similar LFP BESS technologies. Notwithstanding this, given the sites location in an unpopulated area separated from combustible material and infrastructure, propagation would not be expected to increase impacts for sensitive receivers located over 1 km away. Notwithstanding this, the following recommendation is made:

- BESS to be installed in accordance with manufacturer and UL9540A report recommended clearances based on testing.

## 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 present project.

The present project 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) experienced a fire in July 2021 which also has a back-to-back layout. According to the independent investigation report on its fire incidence, the back-to-back layout was not the cause for propagation. 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 the present project. 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.
- Where practicable, 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 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.

### 4.6.1 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.

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

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 a 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. [7]).

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. [7]). 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 negligible due to the highly stable and safe battery chemistries used. Therefore, a toxic gas dispersion impacting sensitive receptors is not deemed a credible scenario and 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 Transformer Internal Arcing, Oil Spill, 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.

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 anticipated to be 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.

Notwithstanding this, transformers are ubiquitous units with a low potential for failure and every transformer is to be self-bunded on a skid or have a concrete bund, limiting the spread of an oil pool fire. Additionally, the separation distance to the site boundary and other adjacent units would be unlikely to result in incident propagation and offsite impacts. Nevertheless, it has been decided to quantitatively determine the risk of such a fire, hence this incident has been carried forward for further analysis.

## 4.9 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, as described in **Section 4.8**, 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 oil may start to decompose and vaporise, resulting in flammable gas bubbles including hydrogen and methane (Ref. [8]) at 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 4.8**.

In order to protect against overheating and explosions, transformers generally have surge protection devices which shunt electrical surges safely to ground. However, this surge detection and protection devices are not universally installed nor do they protect against all events such as in the case of a major lightning strike or significant oil deterioration, leakage of water into the transformer, and physical damage such as a fallen tree (Ref. [9]). Therefore, while transformers are ubiquitous units with a low potential for failure, there is the potential for an explosion to occur which may result in offsite impacts. Hence, this incident has been carried forward for further analysis.

## 4.10 Electromagnetic Field Impacts

### 4.10.1 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 produce ELF EMF's in the range of 30 to 300 Hz.

### 4.10.2 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. [10]).

**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 |

### 4.10.3 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 1 km providing substantial distance for attenuation of EMFs.

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. [11]).

A field study was undertaken to characterise the EMF between the frequencies of 0 – 3 GHz at two large scale solar facilities operated by the Southern California Edison Company in Porterville and San Bernardino, (Ref. [12]).

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 the 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.

## 4.11 External Fire Impact

There is the potential for an external fire event to impact the BESS facility such as bushfire. The development area is not in proximity to high potential bushfire intensity prone land (**Figure 3-2**).

Notwithstanding this, with prevailing winds, embers can travel several kilometres which may result in ignition of vegetation at the BESS facility. The site is to operate a vegetation management plan to prevent the accumulation of combustible loads; hence, in such an event any escalation would be expected to be a 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 (assuming final location outside of the potential impact buffer) 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.

Based on the discussion above, the potential for incident escalation as a result of an external fire impact to occur would be considered negligible; hence, 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 proposed Romani BESS 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. A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts.

Hence, based on the analysis presented in this report, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

## 5.2 Recommendations

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

- 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.
- Where practicable, the vents shall not be located above battery packs within the BESS container.
- Confirm that all transformers are bunded to contain oil releases. Transformers may be self-bunded on a skid, otherwise they will require a dedicated concrete bund.

# 6.0 References


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# Appendix A

## Hazard Identification Table

Appendix A

## 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<br>• Incident propagation through battery cells<br>• Toxic smoke dispersion | • Batteries are tested by manufacturer prior to sale / installation<br>• Overcharging and electrical circuit protection<br>• Battery monitoring systems<br>• Batteries composed of subcomponents (i.e. modules, cells) reducing risk of substantial component failure<br>• Batteries are not located in areas where damage could easily occur (i.e. within the fenced property)<br>• Electrical systems designed per AS/NZS 3000:2018 (Ref. [13])<br>• HVAC system<br>• Blast panels and pressure relief vents<br>• Gaseous fire suppression<br>• 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<br>• Isolated location<br>• Switch room separation from other sources of fire |
| Transformers | • Arcing within transformer, vaporisation of oil and rupture of oil reservoir | • Transformer oil spill into bund and bund fire | • Self-bunded transformer skids<br>• Separated from combustible materials and sensitive receptors |
| | • Power surge to transformers (e.g. from lightning) | • Major failure of surge protection in transformer, vaporisation of oil, ignition and explosion | • Transformers have surge protection system to shut down upon detection of extreme energy input<br>• Lightning protection to prevent lightning strikes impacting transformers<br>• 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 | • Separation distances allow for attenuation of EMFs<br>• Cumulative impacts from equipment below acceptable thresholds. |

| Area/Operation | Hazard Cause | Hazard Consequence | Safeguards |
| --- | --- | --- | --- |
| | | | • Low occupancy density within vicinity of the development |