Riskcon engineering

Fire Incident Management Plan

Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336

Hive Battery Developments Pty Ltd
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Hive Battery Developments Pty Ltd

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Executive Summary

Background

Hive Battery Developments Pty Ltd (HBD) has proposed to develop a Battery Energy Storage System (BESS) located at Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336, including the storage of ten (10) battery units.

As part of the submission, a Fire Incident Management Plan (FIMP) is required for the site to assess the potential fire risks associated with the development. It is necessary to review the potential sources of fire at the site and the fire protection to determine whether the protection is commensurate with the risks. The assessment was undertaken in the form of a FIMP following the methodology provided in the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2 (Ref.) and the NSW Fire & Rescue Fire safety Guideline – Large-scale external lithium-ion battery energy storage systems - fire safety study considerations (Ref.).

Quintas Energy, on behalf of HBD, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the FIMP. This document represents the assessment of the facility located at Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336.

Conclusions

A Fire Incident Management Plan per the HIPAP No. 2 guidelines was prepared for the site. The analysis performed in the FIMP was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the proposed designs in conjunction with existing fire protection adequately manage the risks.

Recommendations

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

- All site personnel are to be trained in specific site procedures, emergency and first aid procedures and the use of fire extinguishers and hose reels.
- A team of site personnel are to be trained in the use of the water cart and first-attack firefighting methods.
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- A site Emergency Response Plan per the requirements of HIPAP No. 1 shall be prepared and shall include measures to advise neighbouring premises in the event of an emergency with potential offsite impacts.
- DG documentation shall be prepared as required by the Work Health and Safety Regulation 2017 to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- The DG storages shall be appropriately placarded per the requirements of the Work Health and Safety Regulation 2017.
- At least two powder-type fire extinguishers shall be located within 15 m of the bulk diesel tank, as per Clause 11.12.4(b) of AS 1940-2017.

- A BESS container shall not be located within 0.06 m when orientated side to side.
- A BESS container shall not be located within 0.1 m when orientated end to end.
- Any ventilation fans or ducts in the BESS container shall be constructed of non-combustible materials. The ventilation fans shall be located such that they do not reside directly above batteries within the container.

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Abbreviations

Abbreviation	Description
ADG	Australian Dangerous Goods Code
AS	Australian Standard
CBD	Central Business District
DA	Development Application
DGs	Dangerous Goods
DGS	Dangerous Goods Store
DPE	Department of Planning and Environment
ESFR	Early-Suppression, Fast-Response
FER	Fire Engineering Report
FRNSW	Fire and Rescue New South Wales
HIPAP	Hazardous Industry Planning Advisory Paper
PHA	Preliminary Hazard Analysis
SEARs	Secretary's Environmental Assessment Requirements
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SMSS	Storage Mode Sprinkler System
SSC	Spread Sheet Calculator
VF	View Factor

1.0 Introduction

1.1 Background

Hive Battery Developments Pty Ltd (HBD) has proposed to develop a Battery Energy Storage System (BESS) located at Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336, including the storage of ten (10) battery units.

As part of the submission, a Fire Incident Management Plan (FIMP) is required for the site to assess the potential fire risks associated with the development. It is necessary to review the potential sources of fire at the site and the fire protection to determine whether the protection is commensurate with the risks. The assessment was undertaken in the form of a FIMP following the methodology provided in the Hazardous Industry Planning Advisory Paper (HIPAP) No. 2 (Ref. [1]) and the NSW Fire & Rescue Fire safety Guideline – Large-scale external lithium-ion battery energy storage systems - fire safety study considerations (Ref. [2]).

Quintas Energy, on behalf of HBD, has commissioned Riskcon Engineering Pty Ltd (Riskcon) to prepare the FIMP. This document represents the assessment of the facility located at Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336.

1.2 Objectives

The objectives of the FIMP are to;

- Review the site operations and storages for the potential to initiate or become involved in a fire including flammables liquids and any combustible dusts which may be present at the site.
- Identify heat radiation impacts from potential fire sources at the site and determine the potential impacts on the surrounding areas and fire protection system, and
- Review the proposed fire safety features and determine the adequacy of the fire safety systems based on the postulated fires, and make recommendations for augmentation, as required.

1.3 Scope of Services

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

The FIMP focuses on the storage of commodities at the site as required by HIPAP No. 2. A review of the following components of the FIMP are within the scope of work:

- Determination of risk and consequences from fire or explosion scenarios throughout the facility;
- The preparation of a report on fire prevention, fire detection, fire alarm and fire suppression systems for the site;
- Firewater storage capacity for compliance with Australian Standards and Regulations and relevant NFPA standards;
- Hydrant hydraulic design screening calculations for the fire water system including the fire main sizing;
- External fire hydrant configuration and locations; and

- Recommendations based upon the study for implementation in the final design.

2.0 Methodology

2.1 Fire Safety Study Approach

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

- The fire hazards associated with the facility were identified to determine whether there were any fire or explosion hazards that may impact offsite or result in a potential to escalate. Where fire hazards with the potential to impact offsite or escalate were identified, these were carried forward for consequence assessment.
- The heat radiation impacts or overpressure impacts (consequences) from each of the postulated incidents from the proposed equipment were then estimated and potential impacts on surrounding areas assessed.
- Impacts of the fires from the proposed equipment were plotted on a layout plan of the proposed facility, to determine whether heat radiation impacts any critical areas (i.e. adjacent storage areas, fire services, safety systems, etc.) and whether such impact affected the ability of fire fighters to respond to the postulated fire. The heat radiation impact from incidents at adjacent sites on the buildings and structures at the facility were then assessed against the maximum permissible levels in HIPAP No. 4 (Ref. [3]).
- The firefighting strategies were then assessed to determine whether these strategies require update in light of the location of the proposed equipment and storage areas.
- The response times for fire services in the immediate vicinity were assessed. In addition, further outlying fire stations were included to provide a 'back-up plan' in the event that the closest fire brigades were unable to attend.
- A report was then developed for submission to the client and the regulatory authority.

2.2 Limitations and Assumptions

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

- The report is specifically limited to the project described in **Section 1.3**
- The report is based on the information provided.
- The report does not provide guidance in respect of incidents that relate to sabotage or vandalism of fire safety systems.
- The assessment is limited to the objectives of the FIMP as provided in the guidelines issued as HIPAP No. 2 (Ref. [1]) and does not consider property damage such as building and contents damage caused by fire, potential increased insurance liability and loss of business continuity.
- Malicious acts or arson with respect to fire ignition and safety systems are limited in nature and are outside the scope of this report. Such acts can potentially overwhelm fire safety systems and therefore further strategies such as security, housekeeping and management procedures may better mitigate such risks.

- This report is prepared in good faith and with due care for information purposes only and should not be relied upon as providing any warranty or guarantee that ignition or a fire will not occur.

3.0 Site Description

3.1 Site Location

The proposed facility is located at Site 6 (Tetra) - 981 New England Hwy, Aberdeen 2336 which is located approximately 135 km northwest of the Newcastle. **Figure 3-1** shows the regional location of the site in relation to Newcastle.

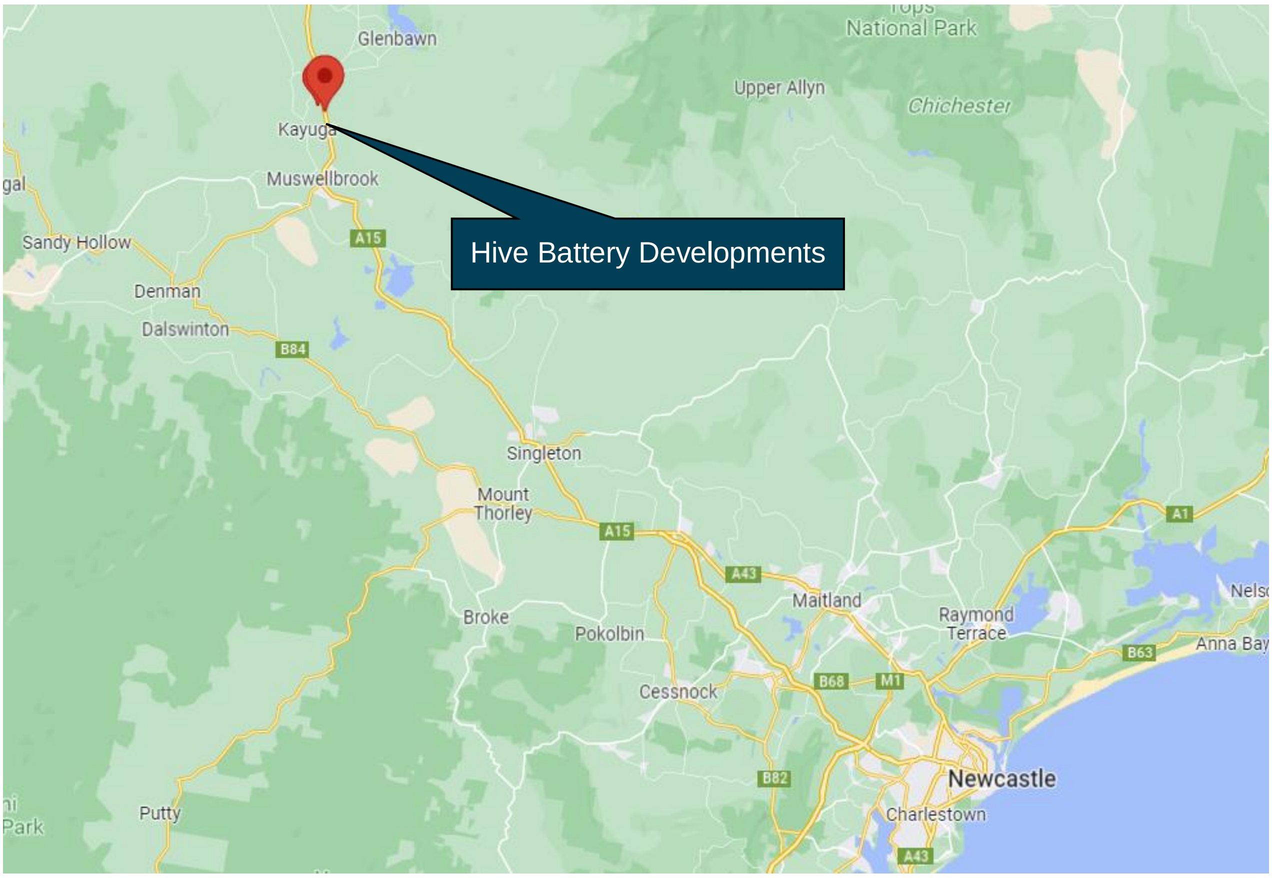

Figure 3-1: Site Location (source Google Maps)

3.2 General Description

The BESS storage will be composed of 10 x battery cubes each having a capacity of 2.7 MW each. The systems will be capable of charging and dispatching at 5 MW x 4 hours or 20 MWh. The systems will typically cycle through a charge / discharge cycle 1.7 times a day.

The BESS will utilise a Lithium Iron Phosphate (LFP) chemistry from Sungrow, specifically the Sungrow STUX2754 Power Titan Battery Cubes. This particular option includes a management system and liquid cooling to monitor temperature fluctuations of the batteries and cool the batteries to prevent thermal runaway. The site will also include a Power Conversion System running at 4.98 MW housing 4 inverters, Switch room, and auxiliary power room. An indicate image of the BESS cubes is shown in **Figure 3-2**.

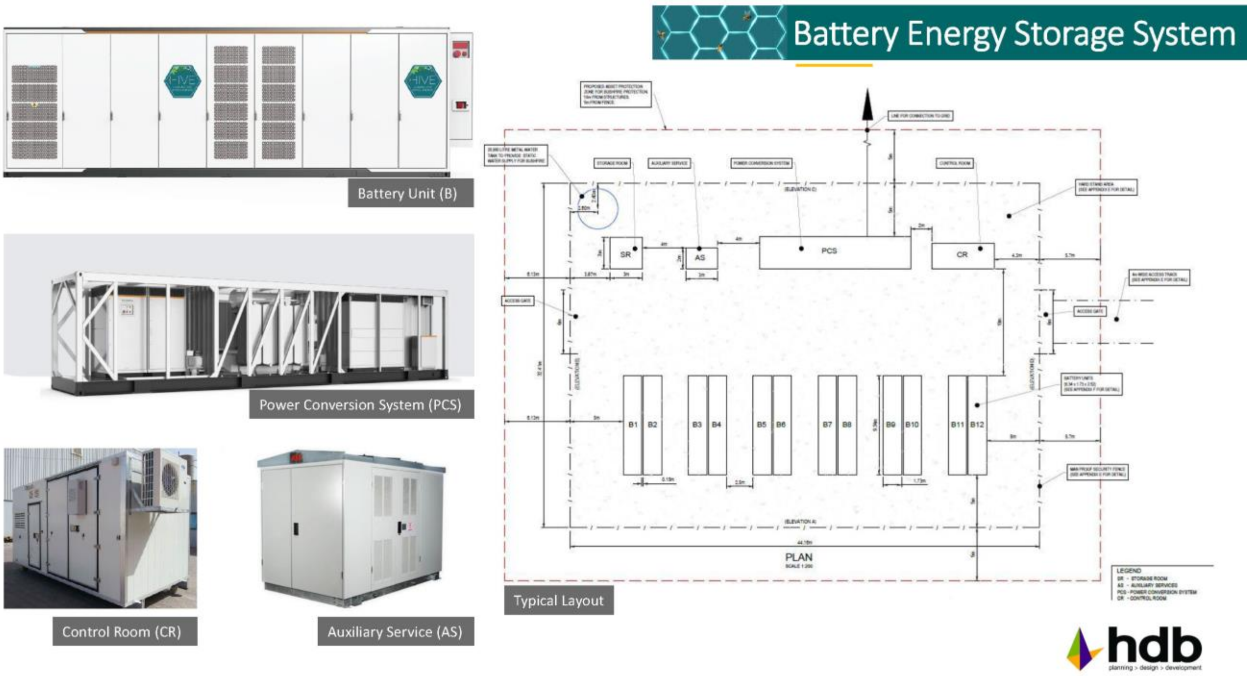

Figure 3-2: Battery Cubes and Ancillary Systems

The site layouts are shown in **Figure 3-3** and **Figure 3-4** which includes a compound with dimensions of 33 m x 44 m resulting in an area of 1,435 m^2. It is bounded by a 2.4 m high fence and has a 10 m wide Asset Protection Zone (APZ).

Figure 3-3: Indicative Side View 1

Figure 3-4: Indicative Side View 2

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. [4]). 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. [5]) 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. [5]) 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 more than 5 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. [5]) 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). 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 are more than 5 km from the closest BESS.

- *Toxicity* – Toxic bi-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. [5]) 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. [5]) 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 60.5ºC. 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. [6]

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.
- 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**.

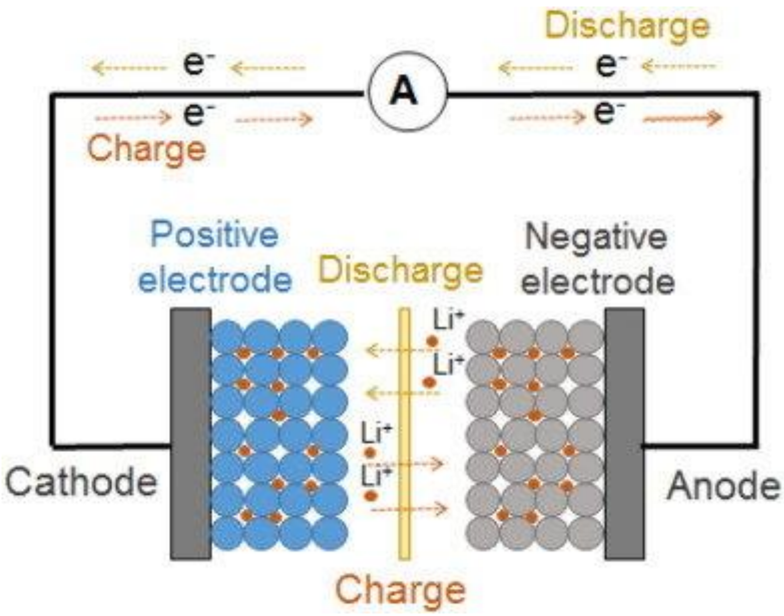

Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

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 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 bi-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.

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.

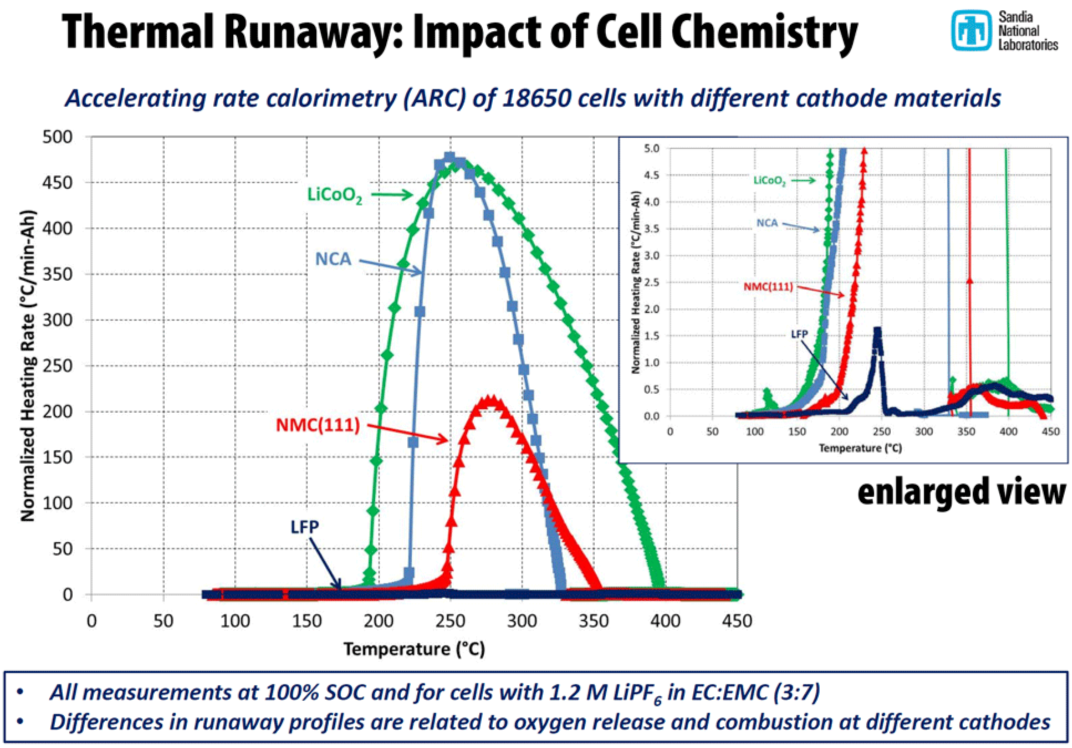

Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [7]).

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.

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, UL1741, UL1973, UN38.3; CE; EMC; NFPA 70; IEEE C37.32; IEC:62933, 62619, 60204, ASTM4169).

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 conversations with and review by NSW Department of Planning and Environment (DPE), 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 Project.

The 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) 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. 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 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.
- 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 bi-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; 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.

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

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. [8]).

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. [8]). 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. 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 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 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 the separation distance to the site boundary and other adjacent units would be unlikely to result in incident propagation and offsite impacts. Therefore, this incident has not 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, oil is used as an insulating material within the transformers to protect the mechanical components. However, if the transformer gets an extreme surge of energy, such as that which could occur due to a lightning strike, and the electrical surge protection measures fail, the mineral oil may start to decompose and vapourise, resulting in gas bubbles of hydrogen and methane (Ref. [9]) as temperatures above the autoignition of the gases.

The formation of gases will increase the pressure within the transformer which can result in the transformer structure rupturing which allows the ingress of oxygen. As the oxygen enters, the concentration of flammable gases falls within the explosive limits which are above their autoignition temperatures which ignite resulting in increased formation of hot gaseous products resulting in an explosion. The explosion may generate significant overpressure, sparks and fire and would result in a whole transformer fire, as discussed in **Section 4.8**.

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. [10]). Therefore, there is the potential for an explosion to occur which may result in offsite impacts; however, as previously noted, these units are ubiquitous and have a low potential for failure. Therefore, this incident has not 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 produced 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. [11]).

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 that the closest residential receiver is over 5 km away from the area where the solar farm or 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 5 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. [12]).

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. [13]).

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.

5.0 Details of Prevention, Detection, Protection and Mitigation Measures

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

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

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

5.1 Fire Prevention

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

5.1.1 Control of Ignition Sources

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

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

Table 5-1 presents the potential ignition sources and incidents for the facility which may lead to ignition and fire. The table also summarises the controls that will be used to reduce the likelihood of these potential sources of ignition and incidents resulting in a fire.

Table 5-1: Summary of Control of Ignition Sources

Ignition Source	Control
Smoking	No smoking policy for the site (i.e. within the warehouse) including processing and storage areas. Note: A designated smoking area is provided.
Housekeeping	The site will operate a housekeeping procedure to ensure accumulation of dust in delivery and processing areas does not occur. Limiting the accumulation of dust is an important method for minimizing the potential for fires or dust dispersions.
Electrical	Fixed electrical equipment to be designed and installed to AS/NZS 3000:2018 (Ref. [14]).
Arson	The site will have a security fence and will be staffed during business hours.
Hot Work	A permit to work system and risk assessment prior to starting work will be provided for each job involving the introduction of ignition sources.

5.1.2 Separation of Incidents

The separation of incidents is used to minimise the impacts of a hazardous incident on the surrounding operations or the generation of potential “domino” effects. The storage locations of products have been designed based upon whether a product can be adequately protected by the fire protection system. BESS units shall be separated as per the results of the UL9540A reports to minimise the potential for propagation.

5.1.3 Housekeeping

The risk of fire can be significantly reduced by maintaining high standards of housekeeping. The site shall maintain a high housekeeping standard, ensuring all debris is cleaned up and removed from the areas.

5.1.4 Work Practices

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

- DG identification
- Placarding & signage within the site
- Forms of chemical and DG information
- Availability of Safety Data Sheets
- Compatibility, segregation and safe storage of Dangerous Goods
- Compliance with the Work Health and Safety Regulation 2017 (Ref. [15]).
- HAZCHEM code adherence
- Safe work practices adhered to
- Personal Protective Equipment
- Emergency response plan and procedures
- Bushfire Management Plan
- Personal hygiene requirements
- Security
- Training of personnel

5.1.5 Emergency Plan

An emergency plan, prepared in accordance with HIPAP No. 1 – Industry Emergency Planning Guidelines (Ref. [16]), will be developed for the site as required by the Work Health and Safety Regulations 2017 (Ref. [15]). The emergency plan will clearly identify potential hazardous fire or explosion incidents and develop fire response procedures. The plan will also include evacuation procedures and emergency contact numbers as well as an onsite emergency response structure with allocated duties to various personnel on site. This will provide readiness response in the unlikely event of an incident at the site.

5.1.6 Site Security

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

5.2 Detection Procedures and Measures

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

5.2.1 Fire Detection and Alarming – BESS Units

The site will utilise SolBank BESS Units. The SolBank BESS Safety Manual (Ref. [17]) indicates that the BESS units are equipped with smoke detectors and thermal detectors to detect the early signs of a fire. In the event that elevated temperatures or smoke is detected, an audible fire alarm and visual fire strobes fitted on the BESS unit will be activated. In addition, corresponding alarms will be sent to the EMS systems to alert site personnel to begin emergency procedures.

5.2.2 Detection of Leaks – Diesel Tanks

Diesel will be stored in a self-bunded tank, which has shall be designed and built in accordance with AS 1940-2017 (Ref. [18]). Thus, the tank shall be fitted with high level alarms and overfill sensors. Diesel may also be released during use of the bowser to refuel vehicles. Operators will be present during vehicle refuelling and will readily identify and respond to a release.

5.3 Fire Protection

The required fire protection systems are summarised below. All drawings associated with the fire protection systems are provided in **Appendix D**. Note, the final location of fire protection equipment has not been confirmed.

5.3.1 Portable Fire Extinguishers

Portable fire extinguishers will be provided in all construction and operation vehicles. In addition, the following recommendation has been made:

- At least two powder-type fire extinguishers shall be located within 15 m of the bulk diesel tank, as per Clause 11.12.4(b) of AS 1940-2017.

5.3.2 Portable Hose Reels (Knapsacks)

Portable Hose Reels (knapsacks) with a capacity of 9 L will be available at all times. The location of the knapsacks has not yet been determined.

5.3.3 BESS Units – Aerosol Based Fire Suppression

The SolBank BESS units selected are fitted with a ceiling mounted aerosol fire suppression system. In the event of detection of a fire within the BESS unit, the aerosol suppression system is triggered, releasing water and providing cooling to the BESS.

5.4 Fire Mitigation

5.4.1 Fire Water Supply

Fire water is stored in two (2) 20,000 L storage tanks. The tanks will be located adjacent to the north entrance and the south entrance.

5.4.1 Water Cart

A 1,000 L water cart will be available on site at all times. The cart will undergo monthly testing during the Fire Danger Period. It is recommended that a team of site personnel are trained in the use of the water cart and first-attack firefighting methods.

6.0 Local Brigade Access and Egress

6.1 Overview

In order to assess the likely fire brigade response times an indicative assessment of fire brigade intervention has been undertaken based on the methods defined in the Fire Brigade Intervention Model (FBIM, Ref. [19]). The closest RFS stations to the site are described in **Table 6-1**. The expected routes from the stations to the site are illustrated in **Figure 6-1**.

Table 6-1: Station Locations

Station Name	Station Address	Distance (km)
FRNSW Aberdeen	20 Moray St, Aberdeen NSW 2336	2.3
FRNSW Muswellbrook	27-31 Market St, Muswellbrook NSW 2333	10.1

Figure 6-1: Location of Site with Respect to Closest RFS Station

6.2 Response Time – Fire Brigade Intervention Model (FBIM)

Due to the nature of the Fire Brigade Intervention Model (FBIM, Ref. [19]), it is necessary to justify the results through the inclusion of assumptions. The accuracy of results weighs heavily upon the measure of which assumptions are made and the sources from which they are derived. The model produced details the time it will take for brigade personnel within the aforementioned location to receive notification of a fire, time to respond and dispatch resources, time for resources to reach the fire scene, time for the initial determination of the fire location, time to assess the fire, time for fire fighter travel to location of fire, and time for water setup such that suppression of the fire can commence. The following are details of the assumptions utilised in this FBIM:

6.2.1 Location of Fire

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

6.2.2 Time between Ignition and Detection

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

6.2.3 Time for Initial Brigade Notification

- Fire brigade notification is expected to occur via a direct monitored alarm.
- Time for alarms/fire verification and any notification delays is 20 seconds based on Table B of the Fire Brigade Intervention Model (Ref. [19]).
- Therefore, the time from ignition at which the fire brigade will be notified is (1,800+20) = 1,820 seconds after flaming combustion has commenced.

6.2.4 Time to Dispatch Resources

- The fire station is considered to be manned at the time of the fire.
- Based on FRNSW response times statistics from the 2021/2022 annual report (Ref. [20]), the average time for the fire brigade to respond to an emergency call (including call processing, turnout time and travel time) is less than 8 minutes as shown in **Figure 6-2**. The 90th percentile of response time of approximately 12 minutes. However, as this is for inner city areas and the site is rurally located, it was assumed that RFS would respond 30 minutes later (1,800 s).

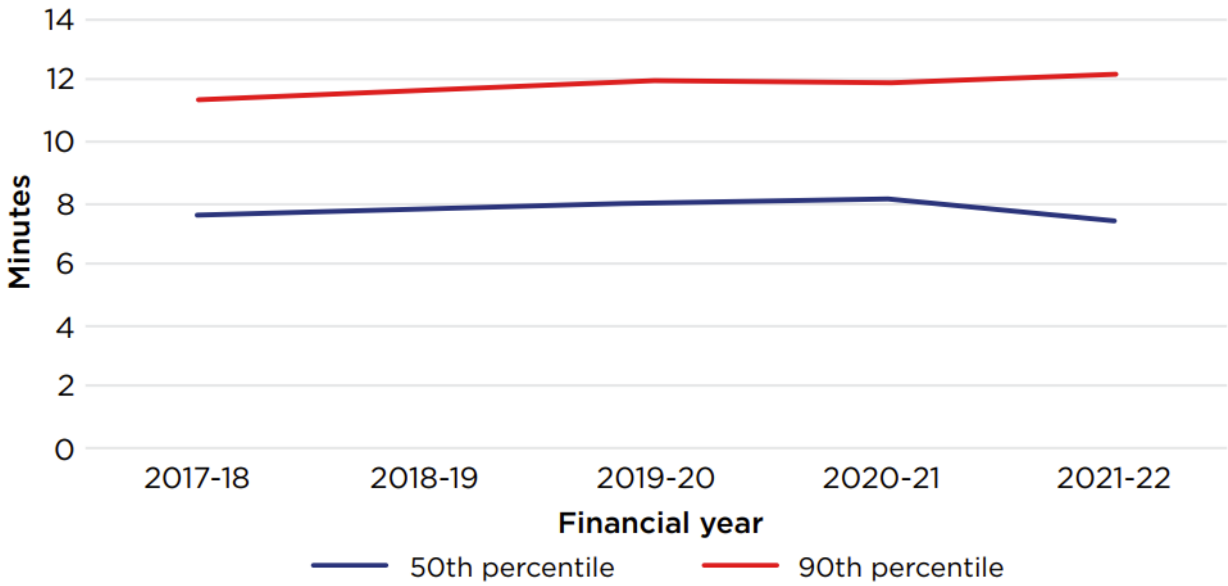

Figure 6-2: FRNSW Response Time from 2021/2022 Annual Report

- As the site is located in a rural area, additional travel time should be taken into account. The travel time has been assumed to be 55 minutes (3300 seconds).
- Therefore, with a brigade call out time of 1,820 seconds, response time of 1,800 seconds, and travel time of 3300 seconds (55 minutes), the fire brigade can be expected to arrive on site 6920 seconds after fire ignition (115 minutes).

6.2.5 Time for Initial Determination of Fire Location

- On arrival, the fire location may not be visible to the approaching brigade personnel, thus requiring information to be obtained from the Fire Indicator Panel (FIP) and evacuating occupants.
- Fire brigade personnel assemble at the FIP in the office area.
- Fire brigade tactical fire plans will be provided.
- It is assumed that a fire would occur during business hours and that staff are present on-site, providing assistance to fire brigade personnel in relation to identifying the fire location.

6.2.6 Time to Assess the Fire

- Horizontal egress speeds have been based on fire brigade personnel dressed in turnout uniform in BA. An average travel speed of 1.4 m/s with a standard deviation of 0.6 m/s as shown in **Figure 6-2**. As such, for the purposes of the calculations, a horizontal travel speed of 1.40 – (1.28x0.6) = 0.63 m/s is utilised.

Table 6-2: FBIM data for Horizontal Travel Speeds

Graph	Travel Conditions	Speed	
		Mean	SD*
Q1	Dressed in turnout uniform	2.3	1.4
Q2	Dressed in turnout uniform with equipment	1.9	1.3

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

*Standard Deviation

Horizontal travel distances will include the following:

- It was conservatively assumed that horizontal travel from the entrance to the farthest point of the site is 1,500 m, however RFS will be able to utilise vehicles to access these areas. As above, this results in a horizontal travel time of 90 s.
- It was assumed that RFS would only be required to travel approximately 100 m on foot. Coupled with an egress speed of 0.63 m/s results in a horizontal travel time of up to 63 seconds.
- Thus, the total horizontal travel time was taken to be 233 seconds.

6.2.7 Time for Water Setup

- The first appliance would be expected to commence the initial attack on the fire.
- Time taken to connect and charge RFS tanker units to the water tanks and collect the water is based on Table X of the Fire Brigade Intervention Model Guidelines, which indicates an average time of 201.6 seconds, and a standard deviation of 115.6 seconds. Using a 90th percentile approach as documented in the FBIM (Ref. [19]), the standard deviation is multiplied by a constant *k*, in this case being equal to 1.28. Therefore, the time utilised in this FBIM is 201.6 + (1.28x115.6) = 350 s.

6.2.8 Search and Rescue

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

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

6.2.9 Summary

As summarised in **Table 6-3** the FBIM (Ref. [19]) indicates that the arrival times of the brigade from the nearest fire stations is approximately 115 minutes after fire ignition, and it is estimated that it takes another 9.7 minutes for the fire brigade to carry out activities including the determination of fire location and preparation of firefighting equipment. As such, the initial attack on the fire is expected to commence approximately 125 minutes after fire ignition (note rounding affects the basic addition of the reported figures).

Given the significant travel time between RFS and the site, it is recommended that site personnel are trained in first-attack firefighting response.

Table 6-3: Summary of the Fire Brigade Intervention Model (FBIM)

Fire Station	Alarm Time	Travel Time	Time for Access & Assessment	Set-up Time	Time of Attack	Time for Search & Rescue

Fire Station	Alarm Time	Travel Time	Time for Access & Assessment	Set-up Time	Time of Attack	Time for Search & Rescue
Closest Fire Station	1,820 s	5,100 s	233 s	350 s	7503 s (125 minutes)	315 s

7.0 Fire Water Supply & Contaminated Fire Water Retention

7.1 Detailed Fire Water System Assessment

Hydrants are not available at this site due to its rural location. Instead, fire water will be supplied in two (2) 20,000 L water tanks, located at the north and south entrances to the site. This provides sufficient water for filling six response tanker units twice (each with a capacity of 4,000 L).

The design of the auxiliary equipment (pumps etc.) has not yet been finalised for the site, as such a detailed assessment of the fire water system cannot be carried out.

7.2 Contaminated Water/Fire Water Retention

Where materials are combusted in a fire, they may become toxic (i.e. formation of volatile organic compounds and aromatic hydrocarbons). Hence, when fire water is applied the materials may mix with the water resulting in a contaminated run off. To ensure environmental damage does not occur the facility is designed to contain a volume of liquid discharged from the site.

A risk assessment methodology is outlined by the Department of Planning document "*Best Practice Guidelines for Potentially Contaminated Water Retention and Treatment Systems"* (Ref. [21]), which requires an allowance of 90 minutes of potentially contaminated water, noting this includes all sources of application. Assuming the application of 3 hydrant hoses at 10 L/s (total 1.8 m^3/min), this results in a total release of 162 m^3. However, the maximum quantity of firefighting water site will store is 100,000 L.

It is unlikely that the site will be capable of containing this volume of water as earthworks will not be carried out. However, it is considered unlikely that contamination will occur in the event of a fire. The majority of the equipment on site does not contain dangerous goods. BESS and PCU units contain minimal quantities of flammable liquids which are contained in bunds. Furthermore, diesel is stored in a self-bunded tank, and therefore a release of diesel is not considered to be credible.

Thus, no recommendation has been made for the containment of contaminated water.

8.0 Conclusion and Recommendations

8.1 Conclusions

A Fire Incident Management Plan per the HIPAP No. 2 guidelines was prepared for the site. The analysis performed in the FIMP was based on credible fire scenarios to assess whether the protection measures at the site were adequate to combat the hazards associated with the quantities and types of commodities being stored. Based on the assessment, it was concluded that the proposed designs in conjunction with existing fire protection adequately manage the risks.

8.2 Recommendations

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

- All site personnel are to be trained in specific site procedures, emergency and first aid procedures and the use of fire extinguishers and hose reels.
- A team of site personnel are to be trained in the use of the water cart and first-attack firefighting methods.
- Site management to prepare and maintain operational procedures to minimise the number of hazardous incidents and accidents on site and to mitigate the consequences of incidents regarding the handling of dangerous goods and chemicals.
- A site Emergency Response Plan per the requirements of HIPAP No. 1 shall be prepared and shall include measures to advise neighbouring premises in the event of an emergency with potential offsite impacts.
- DG documentation shall be prepared as required by the Work Health and Safety Regulation 2017 to demonstrate the risks associated with the storage and handling of DGs has been assessed and minimised.
- The DG storages shall be appropriately placarded per the requirements of the Work Health and Safety Regulation 2017.
- At least two powder-type fire extinguishers shall be located within 15 m of the bulk diesel tank, as per Clause 11.12.4(b) of AS 1940-2017.
- A BESS container shall not be located within 0.06 m when orientated side to side.
- A BESS container shall not be located within 0.1 m when orientated end to end.
- Any ventilation fans or ducts in the BESS container shall be constructed of non-combustible materials. The ventilation fans shall be located such that they do not reside directly above batteries within the container.

9.0 References

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Appendix A

Hazard Identification Table

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. [22]) • UL9540A testing (**Appendix B**)
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.

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