



ERM

APPENDIX M UPDATED PRELIMINARY HAZARD ASSESSMENT



Preliminary Hazard Analysis

Bendemeer Solar Farm

Preliminary Hazard Analysis

Bendemeer Solar Farm

ERM Australia Pty Ltd

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Executive Summary

Background

Riskcon Engineering was engaged by ERM Australia Pty Ltd to conduct a Preliminary Hazard Analysis (PHA) of the Bendemeer Solar Farm (the Project) for Athena Energy Australia (Holdings) Pty Ltd (Applicant). Impacts assessed from the construction, operation and decommissioning phases of the Project are addressed in this report in accordance with relevant regulatory requirements and guidelines.

The Project will involve the construction, operation and decommissioning of a photovoltaic (PV) solar facility with a targeted electricity generating capacity of approximately 255 MW Direct Current (DC), battery energy storage system (BESS) with a capacity of approximately 150 MW / 300 MWh, and associated infrastructure. The Project will supply electricity to the national electricity grid via the existing electricity transmission network.

This report supports a State Significant Development (SSD) Development Consent approval under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979* (SSD-36651552).

The Bendemeer Solar Farm Environmental Impact Statement (EIS) was submitted to the (then) NSW Department of Planning and Environment (DPE; now Department of Planning, Housing and Infrastructure (DPHI)) and publicly exhibited between 27 July 2023 and 23 August 2023. Following the public exhibition of the EIS, a total of 244 submissions relating to the Project EIS were received from government agencies, local council, organisations and members of the public. A Submissions Report has been prepared to respond to matters raised in these submissions and agency advice, as well as an Amendment Report to assess impacts associated with the amended Project.

Amendments included an increase in the number of BESS units from 120 to 264, an increase in the number of BESS PCU/inverters from 40 to 44, and a decrease in the BESS disturbance footprint from 3.2 ha to 1.9 ha.

Conclusions

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

The qualitative review of the potential incidents indicates that offsite impacts would not be expected to occur; hence, no scenarios were carried forward for qualitative analysis. Based on the analysis conducted, it is concluded that the risks at the site boundary (i.e. project area) are not considered to exceed the acceptable risk criteria. Hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

Recommendations

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

- End-to-end spacing (short side) of BESS containerised units shall be a minimum of 600 mm.
- Back-to-back spacing (long side) of BESS containerised units shall be a minimum of 100 mm.
- Spacing between BESS container accumulations (i.e. 3 containerised units) shall be a minimum of 3 m.

- Prior to construction, the total area required for the BESS units shall be verified against the available space to demonstrate there is adequate area to achieve the required spacing.
- The BESS containerised units shall be provided with the fire protection system specified by the BESS manufacturer.
- The UL test data for the selected battery units shall be made available to the DPHI where requested.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
CBD	Central Business District
DC	Direct Current
DGs	Dangerous Goods
DPE	Department of Planning and Environment
DPHI	Department of Planning, Housing and Infrastructure
ELF	Extra Low Frequency
EMF	Electric and Magnetic Field
ERPG	Emergency Response Planning Guideline
FCAS	Frequency Control Ancillary Services
FHA	Final Hazard Analysis
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IDLH	Immediately Dangerous to Life and Health
LFP	LiFePO ₄ (Lithium Iron Phosphate)
MVPS	Medium Voltage Power Station
NMC	Nickel-Manganese-Cobalt
PHA	Preliminary Hazard Analysis
Pmpy	Per million per year
PV	Photovoltaic
SEARs	Secretary's Environmental Assessment Requirements
SEP	Surface Emissive Power
SEPP	State Environmental Planning Policy
SOC	State of Charge
SSDA	State Significant Development Application
STEL	Short Term Exposure Limit
VBB	Victorian Big Battery

1.0 Introduction

1.1 Background

Riskcon Engineering was engaged by ERM Australia Pty Ltd to conduct a Preliminary Hazard Analysis (PHA) of the Bendemeer Solar Farm (the Project) for Athena Energy Australia (Holdings) Pty Ltd (Applicant). Impacts assessed from the construction, operation and decommissioning phases of the Project are addressed in this report in accordance with relevant regulatory requirements and guidelines.

The Project will involve the construction, operation and decommissioning of a photovoltaic (PV) solar facility with a targeted electricity generating capacity of approximately 255 MW Direct Current (DC), battery energy storage system (BESS) with a capacity of approximately 150 MW / 300 MWh, and associated infrastructure. The Project will supply electricity to the national electricity grid via the existing electricity transmission network.

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Amendments included an increase in the number of BESS units from 120 to 264, an increase in the number of BESS PCU/inverters from 40 to 44, and a decrease in the BESS disturbance footprint from 3.2 ha to 1.9 ha.

1.2 Objectives

The key objectives of this PHA are to:

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

This PHA has been prepared in accordance with the Secretary's Environmental Assessment Requirements (SSD-36651552, dated 15 March 2022) as listed below. Bushfire risk is assessed in the separate Bushfire Assessment (Ember, 2023).

Hazards	The EIS must include an assessment of the following: • A preliminary risk screening completed in accordance with State Environmental Planning Policy No. 33 – Hazardous and Offensive Development and Applying SEPP 33 (DoP, 2011);
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- | |
|--|
| <ul style="list-style-type: none">• A Preliminary Hazard Analysis (PHA) must be prepared in accordance with 'Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis' (DoP, 2011) and Multi-Level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning (DoP, 2011); and |
| <ul style="list-style-type: none">• An assessment of potential hazards and risks including but not limited to bushfires, 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'; |

1.3 Scope of Services

The scope of work is to complete a PHA study for the Bendemeer Solar Farm project located at 4409-4461 Oxley Highway, Bendemeer 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, Industry and Environment, 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**.

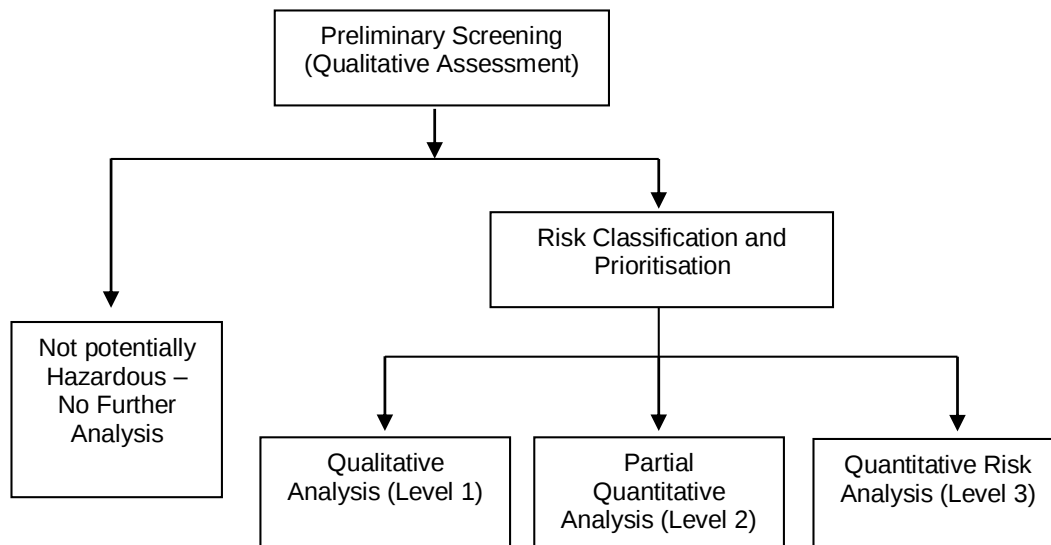


Figure 2-1: The Multi-Level Risk Assessment Approach

Based on the type of DGs to be used and handled at the proposed project, a **Level 2 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. This approach is commensurate with the methodologies recommended in “Applying SEPP 33’s” Multi Level Risk Assessment approach (DPIE, 2011).

2.2 Risk Assessment Study Approach

The methodology used for the PHA is as follows:

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

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

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

Where an incident was identified to result in an offsite impact, it was carried forward for frequency analysis. Where an incident was identified to not have an offsite impact, and a simple solution was evident (i.e. move the proposed equipment further away from the 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. [2]). Where the criteria were exceeded, a review of the major risk contributors was performed, and the risks reassessed incorporating the recommended risk reduction measures. Recommendations were then made regarding risk reduction measures.

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

3.0 Site Description

3.1 Site Location

The Project is situated about 1.8 kilometres (km) east of the Bendemeer village centre, represented by the Bendemeer Hotel, and is located 46 km (by road) north-east of the Tamworth Post Office to the Project access. The Oxley Highway borders the Project Area to the north and the Macdonald River to the south. The site address is 4409-4461 Oxley Highway, Bendemeer NSW.

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



Figure 3-1: Site Location

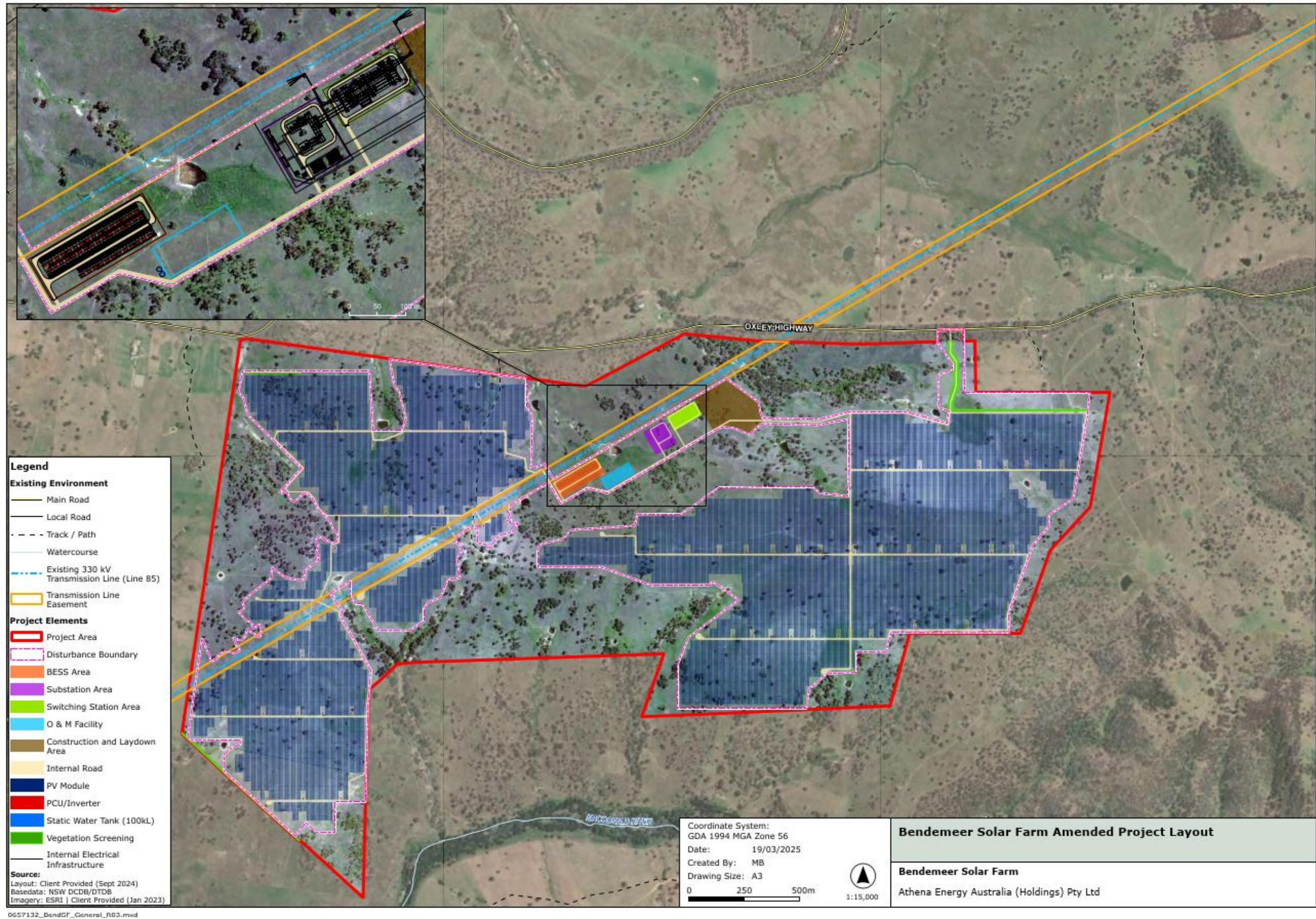


Figure 3-2: Project Layout

3.2 General Description

Riskcon Engineering was engaged by ERM Australia Pty Ltd to conduct a Preliminary Hazard Analysis (PHA) of the Bendemeer Solar Farm (the Project) for Athena Energy Holdings Pty Ltd (Applicant). Chemical hazard scenarios from the construction, operation and decommissioning phases of the Project are addressed in this report in accordance with relevant regulatory requirements and guidelines.

This report supports a State Significant Development (SSD) Development Consent approval under Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979* (SSD-36651552), as part of the Environmental Impact Statement (EIS) for the Project.

The Project is situated about 1.8 kilometres (km) east of the Bendemeer town centre, represented by the Bendemeer Hotel, and is located 46 km (by road) north-east of the Tamworth Post Office to the Project access. The Project is located within the New England Renewable Energy Zone (REZ), in the Tamworth Regional Council Local Government Area (LGA) in the New England Region of NSW. The Project Area extends across an area of approximately 606.9 hectares (ha), over three freehold land parcels, on land that is predominately used for agricultural activities.

The Project will involve the construction, operation and decommissioning of a photovoltaic (PV) solar farm, Battery Energy Storage System (BESS) and associated infrastructure. The Project includes:

- Solar Arrays with a Capacity of approximately 255 megawatts (MW) Direct Current (DC) and registered connection capacity of 200 MW Alternating Current (AC);
- BESS with a capacity of up to 150 MW / 300 MWh;
- Electricity infrastructure:
 - Power Conversion Units (PCU) housing up to 60 inverters;
 - One 33/330 kV collector substation and associated internal structures;
 - Switching station;
 - Electrical reticulation infrastructure including underground and overhead 33 kV cables;
 - Direct grid connection to existing 330 kV line 85 Armidale-Tamworth Transmission line;
- On-site permanent supporting infrastructure:
 - Site access road, entry and internal access tracks;
 - Operations and Maintenance (O&M) Facility including control room, meeting facilities, storage facilities, SCADA facilities, workshop, parking, ablutions buildings, septic, static water supply, waste management facilities, lighting and maintenance facility, fencing and asset protection zones;
- Off-site supporting infrastructure:
 - Tamworth waste and wastewater disposal facilities;
 - Existing public road network; and

- 24 hours a day, seven days per week operation with up to 15 Full Time Equivalent (FTE) personnel.

The Amended Project layout is shown on **Figure 3-2**.

3.3 Detailed Description

The purpose of the Project is to provide dispatchable energy to the NSW grid and contribute towards the goals of the NSW government's NSW Electricity Infrastructure Roadmap.

The electricity will be capable of storage in a 150 MW / 300 MWh BESS which can be dispatched based on electricity demand fluctuations, providing the opportunity for greater supply dispatch flexibility when electricity demand is highest. This is enabled by the fast response times achievable through lithium-ion battery storage. The lithium-ion batteries for this project are proposed to be Lithium Iron Phosphate (LFP) battery chemistries. The Project will have capacity to discharge up to 150 megawatts (MW) of power for 2 hours resulting in a storage of 300 MWh.

3.3.1 Power Conversion Units (PCU)

The PCU's housing switchgear, transformers, and inverters which will be sited adjacent to the BESS units and distributed throughout the solar array. There will be approximately 100 PCU's installed throughout the Project Area which typically comprise:

1. 60 PCU's for the solar farm
2. 44 inverters (housed within PCU's) for the BESS

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



Figure 3-3: Typical PCU

3.3.2 Battery Storage

The BESS will be located within the site compound, laydown and substation footprint area, adjacent to the substation (southwest). The BESS converts electrical energy into chemical energy and stores the energy internally. It may also provide additional network support such as Frequency Control Ancillary Services (FCAS) assisting with transmission network grid stability. A typical BESS is shown in **Figure 3-4**.



Figure 3-4: Typical BESS Arrangement

3.4 Dangerous Goods Stored and Handled

The classes of DGs to be approved in the Project are summarised **Table 3-1**.

Table 3-1: Classes of Dangerous Goods Stored

Area	Class	Description
BESS	9	Lithium-Ion Batteries
PCU Transformer	C2	Transformer oils
Substation Transformer	C2	Transformer oils
Control room generator	C1	Diesel

3.5 SEPP (Resilience and Hazards) Assessment

The SEARs require an assessment of the DG storage quantities against the General Screening Thresholds of “Applying SEPP 33” per SEPP - Resilience and Hazards (SEPP-RH), formerly known as SEPP 33. Threshold storage quantities are provided for each DG class, above which SEPP-RH applies. The classes of DGs to be stored at the facility are not limited by any threshold quantities in Applying SEPP 33, and therefore the SEPP-RH policy does not apply. This is summarised in **Table 3-2**.

Table 3-2: Assessment Against “Applying SEPP 33” Thresholds

Class	Description	SEPP 33 Threshold (kg)	Does SEP 33 Apply?
9	Miscellaneous substances	No SEPP 33 threshold	No
C1	Combustible liquids	No SEPP 33 threshold	No

Class	Description	SEPP 33 Threshold (kg)	Does SEP 33 Apply?
C2	Combustible liquids	No SEPP 33 threshold	No

4.0 Hazard Identification

4.1 Introduction

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

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

- **Fire Impacts** - It is noted in Hazardous Industry Planning Advisory Paper (HIPAP) No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation at the site boundary (i.e. project area in **Figure 3-2**) (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 than 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. [2]) indicates that values of heat radiation of 4.7 kW/m^2 should not exceed 50 chances per million per year at sensitive land uses (e.g. residential). It is noted that the closest residential area is over 1 km away from the closest BESS, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria the assessment is considered conservative.

- **Explosion** - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible explosion over pressure at the 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 over 1 km away from the closest BESS.
- **Toxicity** – Toxic by-products of combustion may be generated by a BESS fire; hence, toxicity has been assessed with criteria based upon the Emergency Response Planning Guidelines (ERPG).
- **Property Damage and Accident Propagation** - It is noted in HIPAP No. 4 (Ref. [2]) that a criterion is provided for the maximum permissible heat radiation/explosion overpressure at the site boundary ($23 \text{ kW/m}^2/14 \text{ kPa}$) 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 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/m² 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. [2]) discusses the application of societal risk to populations surrounding the Project. It is noted that HIPAP No. 4 indicates that where a development proposal involves a significant intensification of population, in the vicinity of such a project, the change in societal risk needs to be taken into account. In the case of the Project, there is currently no significant intensification of population around the proposed site; hence, societal risk has not been considered in this assessment.

4.2 Properties of Dangerous Goods

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

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

Class	Hazardous Properties
9 – Miscellaneous DGs	Class 9 substances and articles (miscellaneous dangerous substances and articles) are substances and articles which, during transport present a danger not covered by other classes. Releases to the environment may cause damage to sensitive receptors within the environment. It is noted that the Class 9s stored within this project are lithium-ion batteries (LFP) 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 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 iron, phosphate or cobalt, manganese, nickel, or any combination of these metals) oxidises (loses an electron) becoming a positively charged ion in solution which migrates through the battery separator to the cathode. At the same time, the lost electron travels through the circuit to the cathode. The lithium ions in solution then recombine with the electron at the cathode forming lithium metal within the cathodic metal composite. This process is shown in **Figure 4-1**.

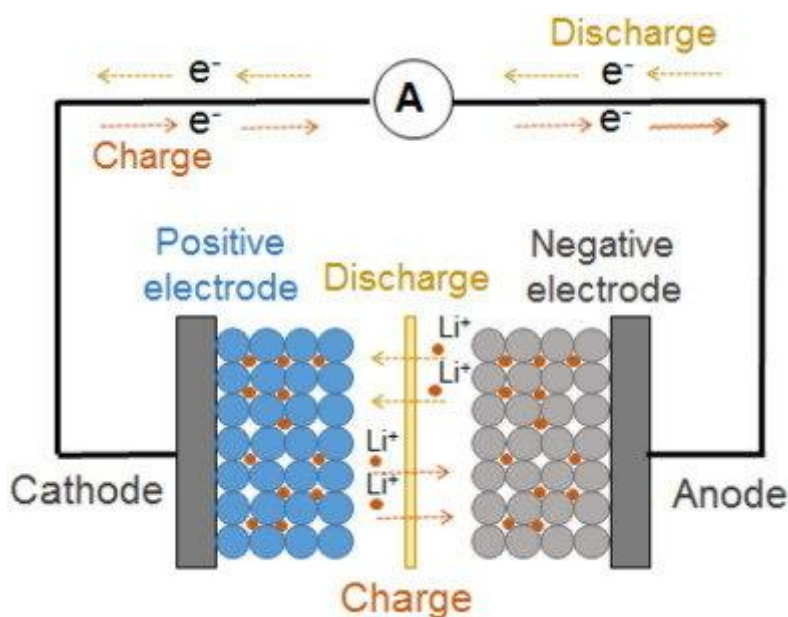


Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

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

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

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

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

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

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

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

In terms of physical damage, the batteries are contained within 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 will be Lithium-Iron-Phosphate (LFP). The battery chemistry has been assessed in detail in the following subsections.

4.4.1 LFP Battery Chemistry

LFP batteries 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 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 which is unlikely to 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.

Thermal Runaway: Impact of Cell Chemistry

Accelerating rate calorimetry (ARC) of 18650 cells with different cathode materials

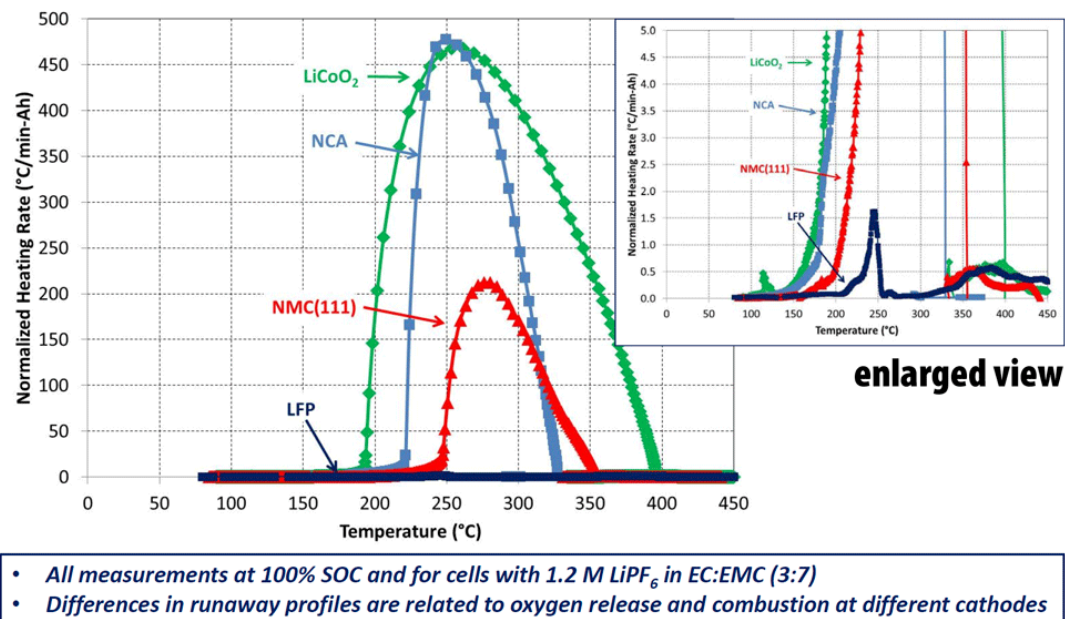


Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [6]).

4.4.2 Preliminary Li-ion Battery Product Assessment

One of the preliminary battery products considered for the purposes of this preliminary hazard analysis for the project is the Wartsila Gridsolv Quantum Energy Storage System (ESS). This is a relatively new product within the industry and is based on the latest safety information. The extensive safety protections are outlined in the Safety Manual, and these are representative of the configuration used for BESS containing both LFP and NMC battery chemistries. A UL9540A report has been completed for this product but is unable to be shared due to confidentiality reasons.

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 modern Li-ion technology as well as the sheer mass of the battery module (heavier objects have higher thermal capacity).

Although the Li-ion technology does not cause fire, there can be circumstances where battery modules catch fire due to leaking coolant, electric faults, or thermal exposure. 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 will 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.

In addition to a UL9540A Report, the system holds UL9540, UL1741 and UL1973 Certificates as well as Certificates in the following: UN38.3; CE; EMC; NFPA 70; IEEE C37.32; IEC: 62933, 62619, 60204 and ASTM4169. The Safety Manual also indicates compliance with the Standards shown in **Table 4-2**.

Table 4-2: Example BESS Compliance Standards

Standards	
System	NEC – National Electrical Code® IEC 60529 – Degrees of protection provided by enclosure UL 508 – Standard for Industrial Control Equipment UL 991 – Standard for Tests for Safety-Related Controls Employing Solid-State Devices. UL 1998 – Standard for Software in Programmable Components IEEE C84.1 – Standard Preferred Voltage Ratings for Alternating-Current Electrical Systems IEEE 693 – Recommended Practice for Seismic Design of Substations IEEE 1584-2018 – Guide for Performing Arc-Flash Hazard Calculations Modular Energy Storage Architecture – Energy Storage System (MESA-ESS) Standard
Fire Protection and Safety	NFPA 855 – Installation of Energy Storage Systems NFPA 70E® – Standard for Electrical Safety in the Workplace® NFPA 72 – National Fire Alarm and Signaling Code NFPA 69® – Standard on Explosion Prevention Systems NFPA 68® – Standard on Explosion Protection by Deflagration Venting UL9540A – Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

These certificates collectively demonstrate that thermal runaway on the representative BESS product does not propagate from one module to another.

In conclusion, the modern Li-ion battery technology proposed for this project should not cause fire during thermal runaway. Should fire be developed within one BESS container, it would be unlikely to 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 DPE (at the time), the following recommendations have been made to further reduce the potential for thermal interactions between BESS units:

- End-to-end spacing (short side) of BESS containerised units shall be a minimum of 600 mm.
- Back-to-back spacing (long side) of BESS containerised units shall be a minimum of 100 mm.
- Spacing between BESS container accumulations (i.e. 3 containerised units) shall be a minimum of 3 m.
- Prior to construction, the total area required for the BESS units shall be verified against the available space to demonstrate there is adequate area to achieve the required spacing.

- The BESS containerised units shall be provided with the fire protection system specified by the BESS manufacturer.
- The UL test data for the selected battery units shall be made available to the DPHI where requested.

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 Bendemeer BESS. One such incident was the Victorian Big Battery (VBB) fire. A detailed report of the findings from the VBB fire is included in Appendix C for further information.

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

Figure 4-3 shows a previously approved BESS installation layout, which has considered fire propagation, the thermal test result of the module thermal runaway and heat flux assessment from the UL9540A report. The Bendemeer BESS system will follow a similar arrangement and allows a compact back-to-back layout, with a minimum 100 mm rear spacing. Minimum 3 m spacing between two front sides allows sufficient access for operation and maintenance activities.

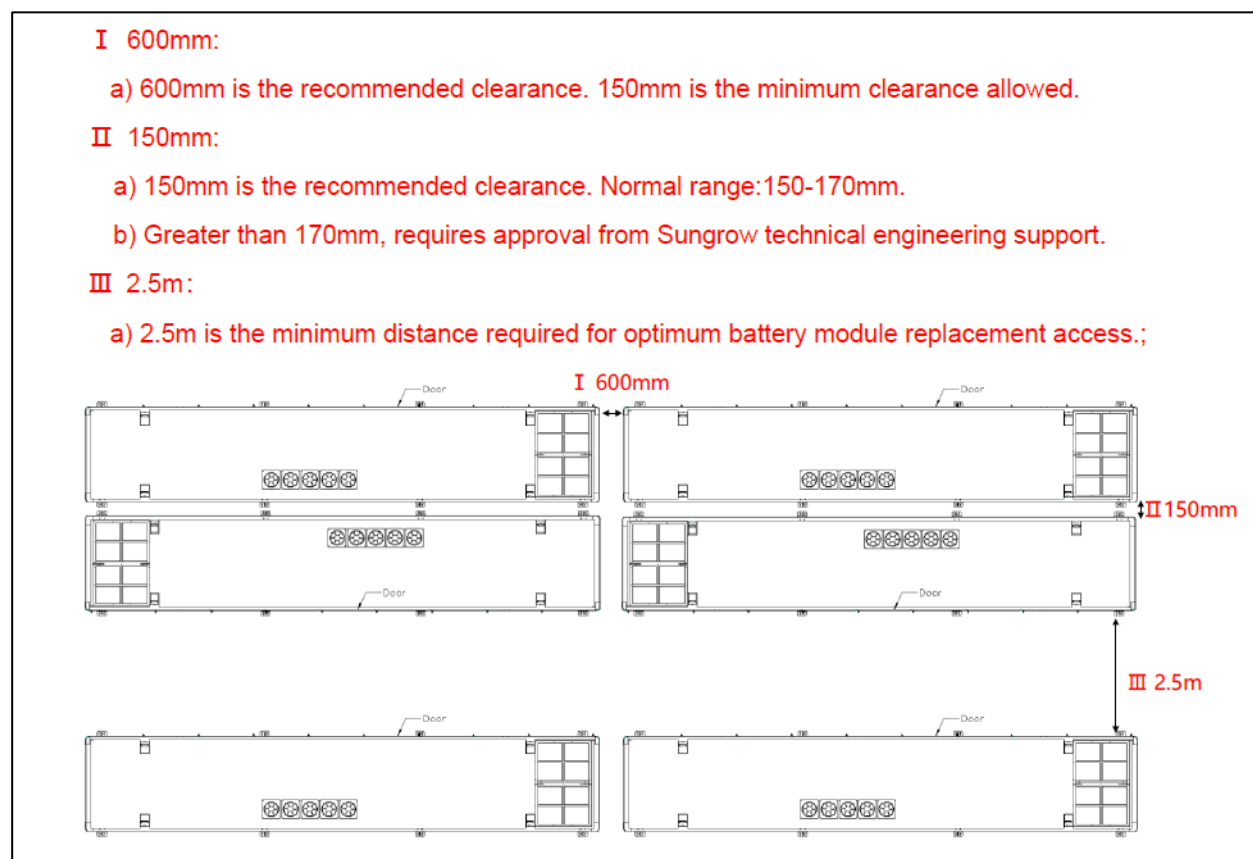


Figure 4-3: BESS Layout Guide

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 has resulted in fire safety precautions being incorporated into the design of BESS units industry wide. The vent atop the containers is now made of metal instead of plastic and covered by a metallic mesh shield. Furthermore, the placement of the fans is such that batteries or flammable materials are not located directly beneath ventilation openings. These improvements reduce the potential for a fire to result from the same cause as the VBB.

4.5.1 Available Space Review

An additional review has been conducted to demonstrate that there is sufficient space within the BESS area to maintain the required separation distances to prevent incident propagation between BESS subunits. Provided in **Table 4-3** is a summary of the dimensions, site areas, number of units, etc and total area required. As can be seen, 5,783 m² is required for all the BESS units with the required spacings to prevent incident propagation. The available space is 19,300 m²; hence, there is sufficient space to locate all the required units whilst maintaining the necessary separation distances.

Table 4-3: BESS Area Requirements

Item	Information	Comment
BESS	- BESS Dimensions: 3 units x 2.076 m (W) x 3.169 m (D). - Gross BESS footprint: 19.74 m² - Number of BESS units: 264	- Separation of Quantum strings by 3 m. - Water and glycol cooling BESS product
PCU	- PCU dimensions: 6.5 m (W) x 2.0 m (D). - Gross PCU footprint: 13 m² - Number of PCU units: 44	- Separation of Quantum strings by 3 m. - Noting that the PCUs are associated with the BESS.
Area	264 x 19.74 + 44 x 13 = 5,783 m ²	

4.5.2 Separation Review

Multiple Li-ion battery products are assessed among the limited options currently available in the Australian market which meet the requirements of utility application, containerized solution, and battery chemistry simultaneously. Their UL9540A unit-level test reports are assessed. A key takeaway message from the UL9540A test is the minimum required spacing between two battery units (racks) without propagating thermal runaway from one unit to another. This is then used to guide the separation distance requirement between BESS containers as summarised in **Table 4-4**.

Table 4-4: Minimum Separation Distance Required Between BESS Units

No.	Battery Manufacturer	Minimum Required Spacing between Battery Units	Product Simulated in UL9540A Test
1	Sungrow	160mm	Sungrow ST2752UX
2	CATL (Contemporary Amperex Technology Co., Limited)	10mm	
3	EVE POWER	160mm	
4	Ruipu Energy	160mm	
5	Wartsila	100mm	GridSolv Quantum

As can be seen from the table above, the minimum required spacing between two Li-ion battery units ranges between 10 mm and 160 mm.

Examination of the required separation distance between two example BESS containers is required to determine if it is appropriate. Based on the UL9540A report, the minimum separation distance allowed between containers is 100 mm. Through the testing process, this was identified to limit damage to only the initiating unit, from one initiating cell to two cells on either side.

Therefore, the minimum proposed battery container separation distance for the Bendemeer BESS of 100 mm is considered appropriate based on a generic Li-ion battery analysis and the testing data from the UL9540A report.

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

4.6 Li-ion Battery Fire and Toxic Gas Dispersion

If a BESS failure occurs resulting in a fire, toxic by-products of combustion may form. A literature review was conducted on lithium-ion battery fires to identify the toxic gases which may be generated in the event of a fire. These are applicable to both LFP and NMC battery chemistries which are proposed at the site. 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.



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**.

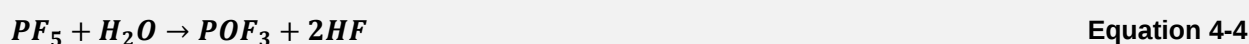


As noted, in **Section 4.6.1** there is the potential for a fire to occur with the BESS units which could form carbon monoxide if there is insufficient oxygen to sustain complete combustion. However, it is noted that the combustible load within the BESS which could result in the formation of carbon monoxide 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 (LiPF₆) 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 (PF₅) and phosphoryl fluoride (POF₃) (Ref. [7]).

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



Of the fluorine gases formed, PF₅ is a short-lived gas while POF₃ is a reactive intermediate. Thermal destruction of a several battery chemistry, configurations and State of Charge (SOC) indicated the vast majority of these did not produce observable POF₃ 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. 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. [8]) 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. [9]). 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, PCUs, substations, and other project components create EMFs from operational electrical equipment found within the BESS, substations, 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 4-5 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 4-5: EMF Sources and Magnetic Field Strength

Source	Typical Measurement (mG)	Measurement Range (mG)
Television	1	0.2 – 2

Source	Typical Measurement (mG)	Measurement Range (mG)
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 there are no immediate residences adjacent to the area where the project components will be developed providing substantial distance for attenuation of EMFs. Based upon the typical levels which may be generated by transmission equipment the cumulative effect would not exceed the 2,000 mG limit for prolonged exposure. In addition, the closest residence is over 1 km away from the EMF generating sources at the site; hence, the potential for the EMF to exceed the accepted levels is considered 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 Conclusion and Recommendations

5.1 Conclusions

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

The qualitative review of the potential incidents indicates that offsite impacts would not be expected to occur; hence, no scenarios were carried forward for qualitative analysis. Based on the analysis conducted, it is concluded that the risks at the site boundary (i.e. project area) are not considered to exceed the acceptable risk criteria. Hence, the project would only be classified as potentially hazardous and would be permitted within the current land zoning for the site.

The amendments outlined in the introduction were not identified to change the outcome of this assessment.

5.2 Recommendations

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

- End-to-end spacing (short side) of BESS containerised units shall be a minimum of 600 mm.
- Back-to-back spacing (long side) of BESS containerised units shall be a minimum of 100 mm.
- Spacing between BESS container accumulations (i.e. 3 containerised units) shall be a minimum of 3 m.
- Prior to construction, the total area required for the BESS units shall be verified against the available space to demonstrate there is adequate area to achieve the required spacing.
- The BESS containerised units shall be provided with the fire protection system specified by the BESS manufacturer.
- The UL test data for the selected battery units shall be made available to the DPHI where requested.

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 - 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
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 and - 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. - Low occupancy density within vicinity of the development

Appendix B

VBB Fire Independent Report of Technical Findings

Appendix B

January 25, 2022

Victorian Big Battery Fire: July 30, 2021

REPORT OF TECHNICAL FINDINGS

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Background

The Victorian Big Battery (VBB) is a 300-Megawatt (MW)/450-Megawatt hour (MWh) grid-scale battery storage project in Geelong, Australia. VBB is one of the largest battery installations in the world and can power over one million Victorian homes for 30 minutes during critical peak load situations.¹ It is designed to support the renewable energy industry by charging during times of excess renewable generation. The VBB is fitted with 212 Tesla Megapacks to provide the 300-MW/450-MWh of energy storage. The Megapack is a lithium-ion battery energy storage system (BESS) consisting of battery modules, power electronics, a thermal management system, and control systems all pre-manufactured within a single cabinet that is approximately 7.2 meters (m) in length, 1.6 m deep and 2.5 m in height (23.5 feet [ft] x 5.4 ft x 8.3 ft).

On Friday, July 30th, 2021, a single Megapack at VBB caught fire and spread to a neighboring Megapack during the initial installation and commissioning of the Megapacks. The fire did not spread beyond these two Megapacks and they burned themselves out over the course of approximately six hours. There were no injuries to the general public, to site personnel or to emergency first responders as the Megapacks failed safely (i.e., slowly burned themselves out with no explosions or deflagrations), as they are designed to do in the event of a fire. Per the guidance in Tesla's Lithium-Ion Battery Emergency Response Guide² (ERG), emergency responders permitted the Megapack to burn and consume itself while nearby exposures were being monitored at a safe distance. The total impact to the site was two out of the 212 Megapacks were fire damaged, or less than 1% of the BESS.

Following the emergency response, a detailed, multi-entity fire investigation commenced on August 3, 2021. The investigation process included local regulatory entities, Tesla, outside third-party engineers and subject matter experts. The investigation process involved analyzing both the fire origin and cause as well as the root cause of the fire propagation to the neighbor Megapack. In addition, given this is the first fire event in a Megapack installation to date, a review of the emergency response has been performed to identify any lessons learned from this fire event.

This report summarizes those investigations and analyses and has been prepared by Fisher Engineering, Inc. (FEI) and Energy Safety Response Group (ESRG), two independent engineering and energy storage fire safety consulting firms. In addition, this report provides a list of lessons learned from the fire and also highlights the procedural, software and hardware changes that have been implemented based on those lessons learned.

Incident Timeline

At the time of the fire, the VBB was fitted with approximately one-half of the 212 total Megapacks intended for the site. The Megapacks that were installed at VBB were undergoing routine testing and commissioning on the day of the fire. At 7:20 AM Australian Eastern Standard Time (AEST) on the morning of July 30, 2021, commissioning and testing of a number of Megapacks commenced. One such Megapack (denoted herein as MP-1), was not going to be tested that day and was therefore shut off manually by means of the keylock switch.³ At the time MP-1 was shut down via the keylock switch, the unit displayed no abnormal conditions to site personnel. Around 10:00 AM, smoke was observed emitting from MP-1 by site personnel. Site personnel

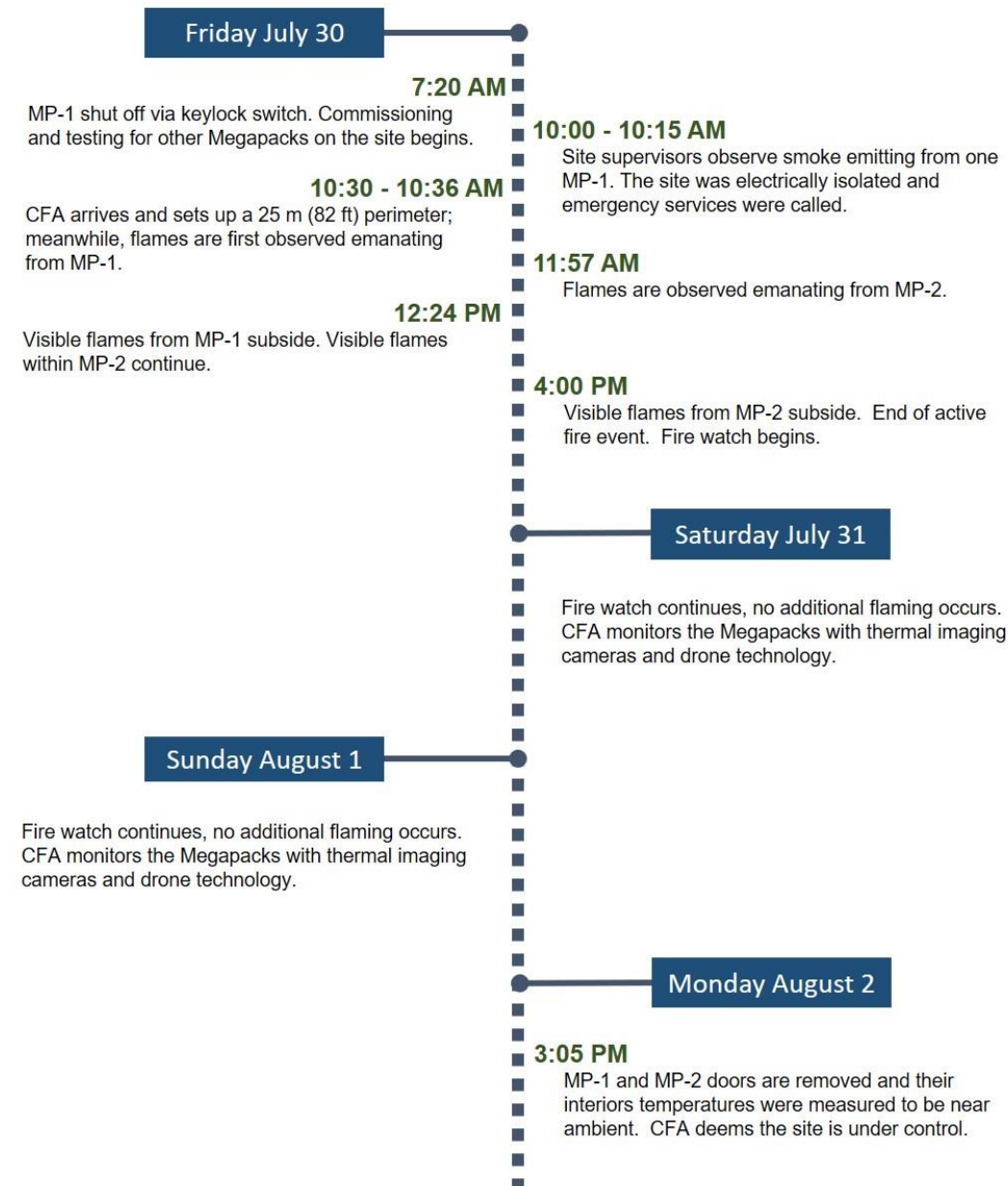
¹ <https://victorianbigbattery.com.au/>

² [https://www.tesla.com/sites/default/files/downloads/Lithium-Ion Battery Emergency Response Guide en.pdf](https://www.tesla.com/sites/default/files/downloads/Lithium-Ion_Battery_Emergency_Response_Guide_en.pdf)

³ The keylock switch is a type of "lock out tag out" switch on the front of the Megapack that safely powers down the unit for servicing.

electrically isolated all the Megapacks on-site and called emergency services: Country Fire Authority (CFA). The CFA arrived shortly thereafter and set up a 25 m (82 ft) perimeter around MP-1. They also began applying cooling water to nearby exposures as recommended in Tesla's ERG. The fire eventually spread into a neighbor Megapack (MP-2) installed 15 centimeters (cm), or 6 inches (in), behind MP-1. The CFA permitted MP-1 and MP-2 to burn themselves out and did not directly apply water into or onto either Megapack, as recommended in Tesla's ERG. By 4:00 PM (approximately six hours after the start of the event), visible fire had subdued and a fire watch was instituted. The CFA monitored the site for the next three days before deeming it under control on August 2, 2021, at which time, the CFA handed the site over for the fire investigation to begin.

Incident Timeline



Note: The time stamp is AEST (UTC+10) which is 19 hours ahead of USA PDT (UTC-7)

Investigation

A multi-entity fire investigation commenced on August 3, 2021. The VBB fire investigation process involved analyzing both the root cause of the initial fire in MP-1 as well as the root cause of the fire propagation into MP-2. The investigations included on-site inspections of MP-1 and MP-2 by the CFA, Energy Safe Victoria⁴ (ESV), Work Safety Victoria⁵ (WSV), local Tesla engineering/service teams and a local third-party independent engineering firm. In addition to the on-site work immediately after the incident, the root cause investigations also included data analysis, thermal modeling and physical testing (electrical and fire) performed by Tesla at their headquarters in California, USA and their fire test facility in Nevada, USA.

Fire Cause Investigation

On-site inspections commenced on August 3, 2021 and concluded on August 12, 2021. MP-1 and MP-2 were documented, inspected and preserved for future examinations, if necessary. Concurrently, all available telemetry data (such as internal temperatures and fault alarms) from MP-1 and MP-2 were analyzed and a series of electrical fault and fire tests were performed. The on-site investigation findings, the telemetry data analysis, electrical fault tests and fire tests, when combined, identified a very specific series of fault conditions present on July 30, 2021 that could lead to a fire event.

Fire Origin and Cause Determination

The origin of the fire was MP-1 and the most likely root cause of the fire was a leak within the liquid cooling system of MP-1 causing arcing in the power electronics of the Megapack's battery modules. This resulted in heating of the battery module's lithium-ion cells that led to a propagating thermal runaway event and the fire.

Other possible fire causes were considered during the fire cause investigation; however, the above sequence of events was the only fire cause scenario that fits all the evidence collected and analyzed to date.

Contributory Factors

A number of factors contributed to this incident. Had these contributory factors not been present, the initial fault condition would likely have been identified and interrupted (either manually or automatically) before it escalated into a fire event. These contributory factors include:

1. The supervisory control and data acquisition (SCADA) system for a Megapack required 24 hours to setup a connection for new equipment (i.e., a new Megapack) to provide full telemetry data functionality and remote monitoring by Tesla operators. Since VBB was still in the installation and commissioning phase of the project (i.e., not in operation), MP-1 had only been in service for 13 hours prior to being switched off via the keylock switch on the morning of the fire. As such, MP-1 had not been on-line for the required 24 hours, which prevented this unit from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility on the morning of the fire.
2. The keylock switch for MP-1 was operated correctly on the morning of the fire to turn MP-1 off as the unit was not required for commissioning and testing that morning; however, this action caused telemetry systems, fault monitoring, and electrical fault safety devices⁶ to be disabled or operate with

⁴ Victoria's energy safety regulator

⁵ Victoria's health and safety regulator

⁶ These elements include, among other devices, fuses at the cell and module level for localized fault current interruption and a battery module pyro disconnect that severs the electrical connection of the battery module when a fault current is passing through the battery module.

only limited functionality. This prevented some of the safety features of MP-1 from actively monitoring and interrupting the electrical fault conditions before escalating into a fire event.

3. The exposure of liquid coolant onto the battery modules likely disabled the power supply to the circuit that actuates the pyro disconnect.⁷ With a power supply failure, the pyro disconnect would not receive a signal to sever and would not be able to interrupt a fault current passing through the battery module prior to it escalating into a fire event.

Fire Propagation Investigation

The VBB fire investigation process involved analyzing not only the root cause of the initial fire in MP-1 but also the root cause of the fire propagation into MP-2. The Megapack has been designed to be installed in close proximity to each other without fire propagating to adjacent units. The design objective of the Megapack in terms of limiting fire propagation was mainly reliant on the thermal insulation of the Megapack's exterior vertical steel panels and the sheer mass of the battery modules acting as a heat sink (i.e., they are difficult to heat up). With this thermal insulation, the Megapack spacing can be as close as 15 cm (6 in) to the sides and back of each unit with 2.4 m (8 ft) aisles in front of each Megapack, as shown in Figure 1. This product spacing has been validated in UL9540A unit level tests.⁸ Similar to the fire origin and cause investigation, the on-site inspections were supported simultaneously with an analysis of telemetry data (such as internal temperatures) from MP-2 and fire testing. The on-site investigation findings, the telemetry data analysis and fire tests, when combined, identified a scenario where Megapack to Megapack fire propagation can occur.

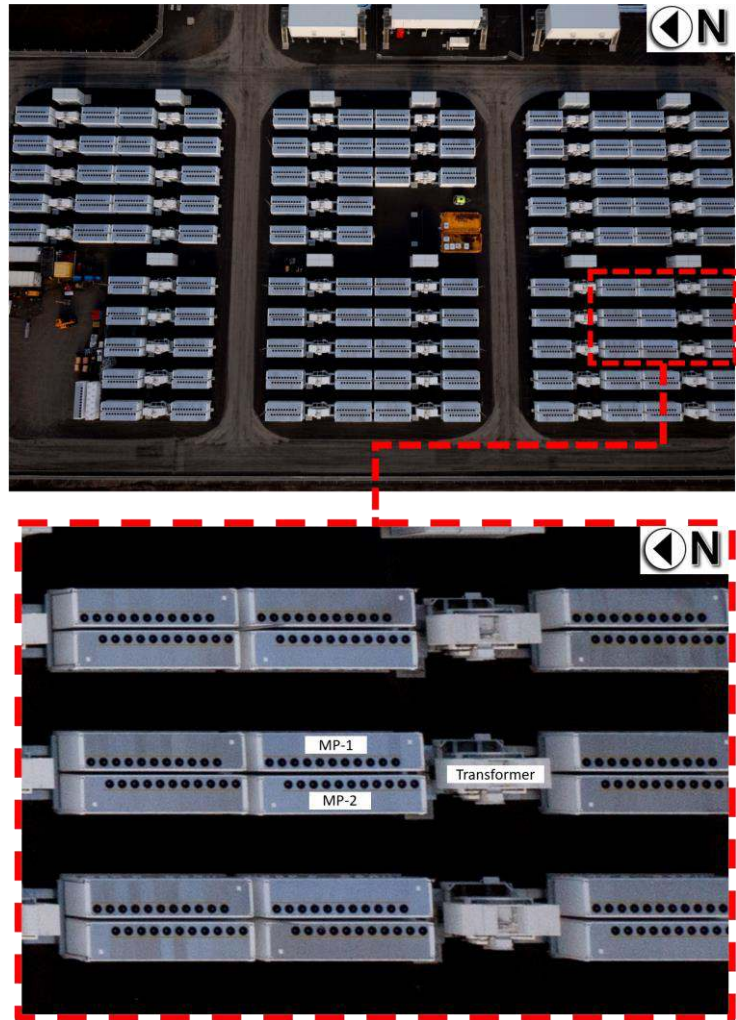


Figure 1 VBB Megapack layout (top) and area of fire origin (bottom)

⁷ The pyro disconnect is a Tesla proprietary shunt-controlled pyrotechnic fuse that allows for rapid one-time actuation. There is one pyro disconnect per battery module.

⁸ UL9540A, *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*. UL9540A is a test method developed by UL to address fire safety concerns with BESS. The test method provides a method to evaluate thermal runaway and fire propagation at the cell level, module level, and unit level. In addition to cell and module level tests, Tesla performed unit level tests to evaluate, among other fire safety characteristics, the potential for fire propagation from Megapack-to-Megapack. During unit level testing, fire propagation did not occur between Megapacks when they were installed with a spacing of 15 cm (6 in) to the sides and back of each unit.

Fire Propagation Determination

Flames exiting the roof of MP-1 were significantly impacted by the wind conditions at the time of the fire. Wind speeds were recorded between 20-30 knots⁹ which pushed the flames exiting the roof of MP-1 towards the roof of MP-2. This direct flame impingement on the top of the thermal roof of MP-2 ignited the internal components of MP-2, most notably, the plastic overpressure vents that seal the battery bay¹⁰ from the thermal roof. Once ignited, the overpressure vents provided a direct path for flames and hot gases to enter into the battery bays, thus exposing the battery modules of MP-2 to fire and/or elevated temperatures. Exposed to temperatures above their thermal runaway threshold of 139°C (282°F), the cells within the battery modules eventually failed and became involved in the fire.

Other possible fire propagation root causes were considered during the investigation; however, the above sequence of events was the only fire propagation scenario that fits all the evidence collected and analyzed to date. Of note, at the time when fire was observed within the thermal roof of MP-2, internal cell temperature readings of MP-2 had only increased by 1°C (1.8°F) from 40°C to 41°C (104°F to 105.8°F)¹¹. Around the same time that fire was observed within the thermal roof of MP-2, around 11:57 AM (approximately 2 hours into the fire event), communication was lost to the unit and no additional telemetry data was transmitted. However, given the internal cell temperatures of MP-2 had only recorded a 1°C (1.8°F) temperature rise 2 hours into the fire event and while the unit's roof was actively on fire, fire propagation across the 15 cm (6 in) gap via heat transfer is not the root cause of the fire propagation. Furthermore, this telemetry data from MP-2 demonstrates that the Megapack's thermal insulation can provide significant thermal protection in the event of a fire within an adjacent Megapack installed only 15 cm (6 in) away.

Contributory Factors

The wind was the dominant contributory factor in the propagation of fire from MP-1 to MP-2. At the time of the fire, a 20-30 knot (37-56 km/hr, 23-35 mph) wind was recorded out of the north. The wind conditions at the time of the fire pushed the flames exiting out of the top of MP-1 towards the top of MP-2 leading to direct flame impingement on the thermal roof of MP-2. This type of flame behavior was not observed during previous product testing or regulatory testing per UL9540A. In UL9540A unit level testing, the maximum wind speed permitted¹² during the test is 10.4 knots (19.3 km/hr, 12.0 mph); whereas, wind conditions during the VBB fire were two to three times greater in magnitude. As such, the wind conditions during the VBB fire appear to have identified a weakness in the Megapack's thermal roof design (unprotected, plastic overpressure vents in the ceiling of the battery bays) that allows Megapack-to-Megapack fire propagation. This weakness was not identified previously during product or regulatory testing and does not invalidate the Megapack's UL9540A certification, as the cause of fire propagation was primarily due to an environmental condition (wind) that is not captured in the UL9540A test method.

⁹ This equates to 37-56 kilometers per hour (km/hr) or 23-35 miles per hour (mph).

¹⁰ The battery bay is an IP66 enclosure that houses the battery modules. It is distinct from the thermal roof installed above it. Plastic overpressure vents are installed in the ceiling of the battery bay, sealing the two enclosures from one another.

¹¹ As a reference, the Megapack's normal operating cell temperature is between 20-50°C and cell thermal runaway does not occur until 139°C (98°C above cell temperatures of MP-2 before telemetry data was lost).

¹² This threshold is necessary for test reliability and reproducibility. If wind conditions are not bounded in some fashion in an outdoor fire test, large variances on product performance could be introduced due to varying wind conditions.

Mitigations

The investigation of the VBB fire identified several gaps in Tesla's commissioning procedures, electrical fault protection devices and thermal roof design. Since the fire, Tesla has implemented a number of procedural, firmware, and hardware mitigations to address these gaps. These mitigations have been applied to all existing and any future Megapack installations and include:

Procedural Mitigations:

- Improved inspection of the coolant system for leaks during Megapack assembly and during end-of-line testing to reduce the likelihood of future coolant leaks.
- Reduce the telemetry setup connection time for new Megapacks from 24 hours to 1 hour to ensure new equipment is transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility for remote monitoring.
- Avoid utilizing the Megapack's keylock switch during commissioning or operation unless the unit is actively being serviced. This procedural mitigation ensures telemetry, fault monitoring, and electrical fault safety devices (such as the pyro disconnect) are active while the Megapack is idle (such as during testing and commissioning).

Firmware Mitigations:

- Added additional alarms to the coolant system's telemetry data to identify and respond (either manually or automatically) to a possible coolant leak.
- Keep all electrical safety protection devices active, regardless of keylock switch position or system state. This firmware mitigation allows electrical safety protection devices (such as the pyro disconnect) to remain in an active mode, capable of actuating when electrical faults occur at the battery modules, no matter what the system status is.
- Active monitoring and control of the pyro disconnect's power supply circuit. In the event of a power supply failure (either through an external event such as a coolant exposure or some other means), the Megapack will automatically actuate the pyro disconnect prior to the loss of its power supply.

Hardware Mitigations

- Installation of newly designed, thermally insulated steel vent shields within the thermal roof of all Megapacks. These vent shields protect the plastic overpressure vents from direct flame impingement or hot gas intrusion, thus keeping the IP66 battery bay enclosures isolated from a fire above in the thermal roof. Their performance was validated through a series of fire tests, including unit level fire testing of entire Megapack units.¹³ The vent shields are placed over the top of the overpressure vents and will come standard on all new Megapack installations. For existing Megapacks, the vent shields can be installed in the field (retrofit) with minimal effort or disruption to the unit. At the time of this report, the vent shields are nearing production stage and will be retrofitted to applicable Megapack sites shortly.

¹³ The tests confirmed that, even with the entire thermal roof fully involved in fire, the overpressure vents will not ignite and the battery modules below remain relatively unaffected by the fire above. For instance, the cells within the battery modules saw a less than 1°C temperature rise while the entire thermal roof was fully involved in fire.

Emergency Response

Beyond the origin and cause and propagation investigations, another key aspect of the VBB fire was the emergency response. The CFA is the responsible fire service organization for VBB, and the facility is in their initial response jurisdiction. The location of the VBB facility is in a semi-rural location. The nearest fire station is the CFA Lovely Banks, approximately 4 km (2.5 miles) distance from VBB and thus relatively close, though other resources had more extended travel distances.

Upon arrival around 10:30 AM, CFA immediately established incident command (IC) in accordance with their protocols, and the IC worked closely with the facility representatives and subject matter experts (SMEs). This close coordination continued throughout the entire event. The facility was evacuated and all-site personnel accounted-for upon notification of the emergency event and the commencement of fire service operations. A 25 m (82 ft) perimeter was established around MP-1 while water application and cooling strategies were discussed with facility representatives and subject matter experts (SMEs). The decision was made to provide exposure protection to Megapacks and transformers adjacent to MP-1 and MP-2 using water hose lines, as recommended in Tesla's ERG. The fire eventually propagated into MP-2; however, flame spread did not advance any further than MP-1 and MP-2. The two Megapacks were permitted to burn themselves out, during which time the CFA did not directly apply water into or onto either Megapack. By 4:00 PM (approximately six hours after the start of the event), visible flames had subdued and a fire watch was instituted. The CFA continued to monitor the site for the next three days before deeming it under control on August 2, 2021, at which time, the fire investigation began.

Key Takeaways

A thorough review of the VBB fire emergency response yielded the following key takeaways:

- **Effective Pre-incident Planning:** VBB had both an Emergency Action Plan (EAP) and an Emergency Response Plan (ERP). Both plans were available to emergency responders and were effectively used during the VBB fire. For example, all site employees and contractors followed proper evacuation protocols during the fire and as a result, no injuries occurred to those personnel.
- **Coordination with SMEs:** VBB had thorough pre-incident plans that clearly identified the SMEs, how to contact them, their role and other key tasks. It was reported that the facility SMEs stayed in close contact with the CFA IC throughout the VBB fire, providing valuable information and expertise for the CFA to draw upon. For example, site representatives and SMEs worked closely with the CFA in determining water application and cooling strategies of adjacent exposures.
- **Water Application:** A key question regarding water application is the necessary amount and duration for effective fire containment. Tesla's design philosophy is based on inherent passive protection (i.e., thermal insulation), with minimal dependence on active firefighting measures like external hose lines. As such, water was not aimed at suppressing the fire but rather protecting the exposures as directed by Tesla's ERG and the SMEs on site. All available data and visual observations of the fire indicates water had limited effectiveness in terms of reducing or stopping fire propagation from Megapack-to-Megapack. The thermal insulation appears to be the dominant factor in reducing heat transfer between adjacent Megapacks. However, water was effectively used on other exposures

(transformers, electrical equipment, etc.) to protect that equipment, which are not designed with the same level of protection as a Megapack is (i.e., thermal insulation).¹⁴

- The fire protection design approach of the Megapack has inherent advantages over other BESS designs in terms of safety to emergency responders. The Megapack approach minimizes the likelihood of fire spread using passive compartmentation and separation, eliminates the danger to fire fighters of an overpressure event due to design features and a lack of confinement (e.g., outdoor versus indoor), does not rely on active firefighting measures like external hose lines and minimizes the dangers from stranded electrical energy to those involved with overhaul and de-commissioning with a fire response approach permitting the Megapack to burn itself out.

Environmental Concerns

The Environment Protection Authority Victoria (EPA) deployed two mobile air quality monitors within 2 km (1.2 miles) of the VBB site. Locations were chosen where there was potential to impact the local community. The EPA monitors confirmed “good air quality in the local community” after the incident; however, the measurements were not taken during the peak of the fire event. They were sampled around 6:00 PM, or approximately 2 hours after the fire was out. Therefore, the data cannot be used to understand the airborne hazards during the actual fire event. The data does demonstrate that two hours after the fire event, the air quality in the surrounding area was “good” and no long-lasting air quality concerns arose from the fire event.¹⁵

During the fire event, the CFA coordinated with site personnel to control the water run-off from fire hoses into a catchment. Water samples, collected by Tesla site personnel under the supervision of CFA, were extracted from the catchment. Laboratory results from those samples indicated that the likelihood of the fire having a material impact on the water was minimal. After the incident, as a precaution, the water was removed from the catchment, via suction trucks, and was transported to a licensed waste facility for treatment and disposal. It is estimated that approximately 900,000 liters of water was disposed of from the site after the event.

Community Concerns

Neoen, the project developer and owner, pro-actively engaged with the local community during and following the VBB fire. These engagements included door-to-door visits, phone calls and emails with the residential and agricultural properties within a 2-3 km (1.2-1.9 mile) radius of the VBB site. Neoen found their prior community outreach during the project planning stages to be invaluable as this outreach provided up-to-date contact information for Neoen when reaching out to the local community during and following the fire. In addition, Neoen formed an executive stakeholder steering committee comprising of key organizations within 24 hours of the incident. With multiple parties involved in the emergency response to the fire event

¹⁴ At the time of this report, final fire department reports were not available for review and inclusion. As that information becomes available, additional information regarding water usage and effectiveness may require inclusion in this report. Although the effectiveness of external water in a Megapack fire may be limited, water should still be made available for exposure protection and other unanticipated events in the future, as required by any applicable regulatory requirements.

¹⁵ It should be noted that prior regulatory testing (UL 9540A module level fire testing) has shown that the products of combustion of a Megapack battery module can include flammable and nonflammable gases. Based on those regulatory tests, the flammable gases were found to be below their lower flammable limit (LFL) and would not pose a deflagration or explosion risk to first responders or the general public. The nonflammable gases were found to be comparable to the smoke you would encounter in a typical Class A structure fire and do not contain any unique, or atypical, gases beyond what you would find in the combustion of modern combustible materials.

actively participating in the steering committee, this helped ensure that from the outset communication was timely, efficient, well-coordinated across different organizations and accurate.

In addition to the community outreach, Neoen and Tesla also briefed multiple industry, State and Federal Government Departments and Agencies immediately following the VBB fire and at the conclusion of the investigation process. These briefings helped ensure the wider energy sector with interests in BESS were able to be kept directly informed as information became available.

Overhaul and Remediation

On July 29, 2021 nearly half of the Megapacks had been installed and the site was in the testing and commissioning stage of the project. Following the fire event on July 30, 2021, fire department personnel, regulatory agencies and other emergency responders remained on-site for precautionary purposes until August 2, 2021. At that time the site was turned over for regulatory fire investigations to begin. On-site fire investigations started on August 3, 2021 and continued until August 12, 2021. During this time, starting on August 6, 2021, the site was permitted to continue the installation of Megapacks while the area around MP-1 remained cordoned off for the investigation. On September 23rd, 2021, less than two months after the fire, VBB was re-energized and testing and commissioning restarted. Remediation of the damaged equipment followed shortly after, and lasted a total of three days. All testing and commissioning efforts were completed without any further incidents and on December 8, 2021, VBB officially opened.

Lessons Learned

The VBB fire exposed a number of unlikely factors that, when combined, contributed to the fire initiation as well as its propagation to a neighboring unit. This collection of factors had never before been encountered during previous Megapack installations, operation and/or regulatory product testing. This section summarizes those factors as well as the emergency response to the fire, discusses the lessons learned from this fire event, and highlights the mitigations Tesla has implemented in response.

1. Commissioning Procedures

Lessons learned related to commissioning procedures include: (1) limited supervision/monitoring of telemetry data during the first 24 hours of commissioning and (2) the use of the keylock switch during commissioning and testing. These two factors prevented MP-1 from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's control facility and placed critical electrical fault safety devices (such as the pyro disconnect) in a state of limited functionality, reducing the Megapack's ability to actively monitor and interrupt electrical fault conditions prior to them escalating into a fire event.

Since the VBB fire, Tesla has modified their commissioning procedures to reduce the telemetry setup connection time for new Megapacks from 24 hours to 1 hour and to avoid utilizing the Megapack's keylock switch unless the unit is actively being serviced.

2. Electrical Fault Protection Devices

Lessons learned related to electrical fault protection devices include: (1) coolant leak alarms; (2) the pyro disconnect being unable to interrupt fault currents when the Megapack is off via the keylock switch and (3) the pyro disconnect likely being disabled due to a power supply loss to the circuit that actuates it. These three factors prevented the pyro disconnect of MP-1 from actively monitoring and interrupting the electrical fault conditions before escalating into a fire event.

Since the VBB fire, Tesla has implemented a number of firmware mitigations that keep all electrical safety protection devices active, regardless of keylock switch position or system state, and to actively monitor and control the pyro disconnect's power supply circuit. Furthermore, Tesla has added additional alarms to better identify and respond (either manually or automatically) to coolant leaks. Additionally, although this fire event was likely initiated by a coolant leak, unexpected failures of other internal components of the Megapack could create similar damage to the battery modules. These new firmware mitigations do not only address damage from a coolant leak. They also permit the Megapack to better identify, respond, contain and isolate issues within the battery modules due to failures of other internal components, should they occur in the future.

3. Fire Propagation

Lessons learned related to fire propagation include: (1) the significant role external, environmental conditions (such as wind) can have on a Megapack fire and (2) the identification of a weakness in the thermal roof design that permits Megapack-to-Megapack fire propagation. These two factors led to direct flame impingement on the plastic overpressure vents that seal the battery bay from the thermal roof. With a direct path for flames and hot gases to enter into the battery bays, the cells within the battery modules of MP-2 failed and became involved in the fire.

Since the VBB fire, Tesla has devised (and validated through extensive testing) a hardware mitigation that protects the overpressure vents from direct flame impingement or hot gas intrusion via the installation of new, thermally insulated, steel vent shields. The vent shields are placed on top of the overpressure vents and will come standard on all new Megapack installations. For existing Megapacks, the vent shields can be easily installed in the field. At the time of this report, the vent shields are nearing production stage and will be retrofitted to applicable Megapack sites shortly.

4. Megapack Spacing

Lessons learned related to Megapack spacing include: no changes are required to the installation practices of the Megapack with the vent shield mitigation (as described above) in place. Based on an analysis of telemetry data within MP-2 during the VBB fire, the Megapack's thermal insulation can provide significant thermal protection in the event of a fire within an adjacent Megapack installed 15 cm (6 in) away. The internal cell temperatures of MP-2 only increased by 1°C (1.8°F), from 40°C to 41°C (104°F to 105.8°F), before communication was lost to the unit, presumably due to fire, around 11:57 AM (approximately 2 hours into the fire event). Fire propagation was triggered by the weakness in the thermal roof, as described above in #3, and not due to heat transfer via the 15 cm (6 in) gap between Megapacks. With the vent shield mitigation in place, the weakness has been addressed and validated through unit level fire testing (i.e., tests involving the ignition of the Megapack's thermal roof). These tests confirmed that, even with the thermal roof fully involved in a fire, the overpressure vents will not ignite and the battery modules remain relatively unaffected with internal cell temperatures rising less than 1°C.

5. Emergency Response

Lessons learned from the emergency response to the VBB fire include: (1) effective pre-incident planning is invaluable and can reduce the likelihood of injuries; (2) coordination with SMEs, either on site or remotely, can provide critical expertise and system information for emergency responders to draw upon; (3) the effectiveness of applying water directly to adjacent Megapacks appears to provide limited benefits; however, water application to other electrical equipment, with inherently less fire protection built into their designs (such as transformers), can be a useful tactic to protect that equipment; (4) the fire protection design

approach of the Megapack has inherent advantages over other BESS designs in terms of safety to emergency responders; (5) the EPA indicated that there was “good” air quality 2 hours after the fire demonstrating that no long-lasting air quality concerns arose from the fire event; (6) water samples indicated that the likelihood of the fire having a material impact on firefighting water was minimal; (7) prior community engagement during the project planning stages is invaluable as it enabled Neoen to quickly update the local community and address immediate questions and concerns; (8) early, factual and where possible, face-to-face engagement with the local community is essential when a fire event is unfolding to keep the general public informed; (9) an executive stakeholder steering committee from the key organizations involved in the emergency response can help ensure that any public communications are timely, efficient, coordinated and accurate; and (10) effective coordination between stakeholders at the site allowed for rapid and thorough handover process after the incident, the swift and safe decommissioning of the damaged units and the site’s quick return to service.

In summary, the VBB fire event proceeded in accordance with its fire protection design and pre-incident planning. It presented no unusual, unexpected, or surprising characteristics (i.e., explosions) or resulted in any injuries to site personnel, the general public or emergency responders. It was isolated to the units directly involved, had minimal environmental impact, did not adversely impact the electrical grid, and had appreciably short mission interruption.