Riskcon engineering

Preliminary Hazard Analysis

Gregadoo Solar Farm BESS

Premise Australia Pty Ltd
Document No. RCE-23056_Premise_PHA_Final_18Sep25_Rev(5)
Date 18/09/2025

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Quality Management

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A	12 May 2023	Draft issued for comment	Ezra Bagaskara	Jason Costa
0	17 July 2023	Final issued		
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3	15 October 2024	Updated per DPHI comments		
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Executive Summary

Background

Riskcon Engineering has been engaged by Premise Australia Pty Ltd to conduct a Preliminary Hazard Analysis (PHA) of the Gregadoo Battery Energy Storage System (the Project). 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, as a modification (Modification 4), seeks to optimise the approved Gregadoo Solar Farm. The optimised design has been conceived to utilise the approved development footprint more effectively by incorporating a Battery Energy Storage System ('BESS') while maintaining a power output of 65 MW(AC). The proposed BESS will have a generation capacity of 200MW_{AC} and 400MWh. This optimisation assists to ensure the orderly and economic use of land, while assisting to achieve State and Federal renewable energy targets and objectives for renewable energy and grid firming.

In addition, Modification 4 seeks to include an additional access point and internal access track from Boiling Down Road to the approved overhead transmission line between the Gregadoo Solar Farm and the Transgrid substation. The access point and access track are required to ensure that the approved overhead and underground transmission line can be constructed and maintained without impacting on the Boiling Down Creek or the adjoining riparian corridor.

This report supports a State Significant Development (SDD) Development Consent modification application pursuant to Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979*, as part of the Environmental Impact Statement (EIS) for the Project. It is noted that the BESS is an addition to the already approved Solar Farm project located on the same lot, and therefore has no specific SEARs.

Conclusions

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

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary 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 150 mm
- Spacing between BESS container accumulations (i.e. 4 containerised units) shall be a minimum of 2.5 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.
- Prior to commissioning, the UL test data for the selected battery units shall be made available to the DPE.
- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
ADG	Australian Dangerous Goods Code
AS	Australian Standard
BESS	Battery Energy Storage System
DC	Direct Current
DGs	Dangerous Goods
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	LiFePO4 (Lithium Iron Phosphate)
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

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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]).

1.3 Scope of Services

The scope of work is to complete a PHA study for the proposed Gregadoo BESS project to be located on the site of the approved Gregadoo Solar Farm and in proximity to the Transgrid Wagga Wagga Substation at Gregadoo, 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**.

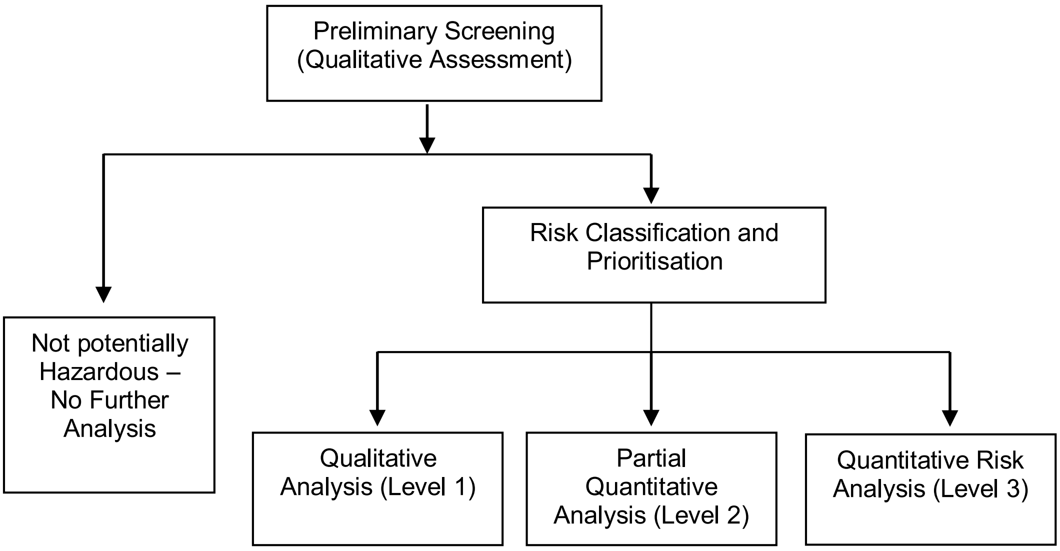

Figure 2-1: The Multi-Level Risk Assessment Approach

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 located within the Wagga Wagga Regional Local Government Area (LGA), approximately 13 km southeast of the Wagga Wagga CBD. Gregadoo Road borders the Project Area to the north and Boiling Down Road to the south.

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

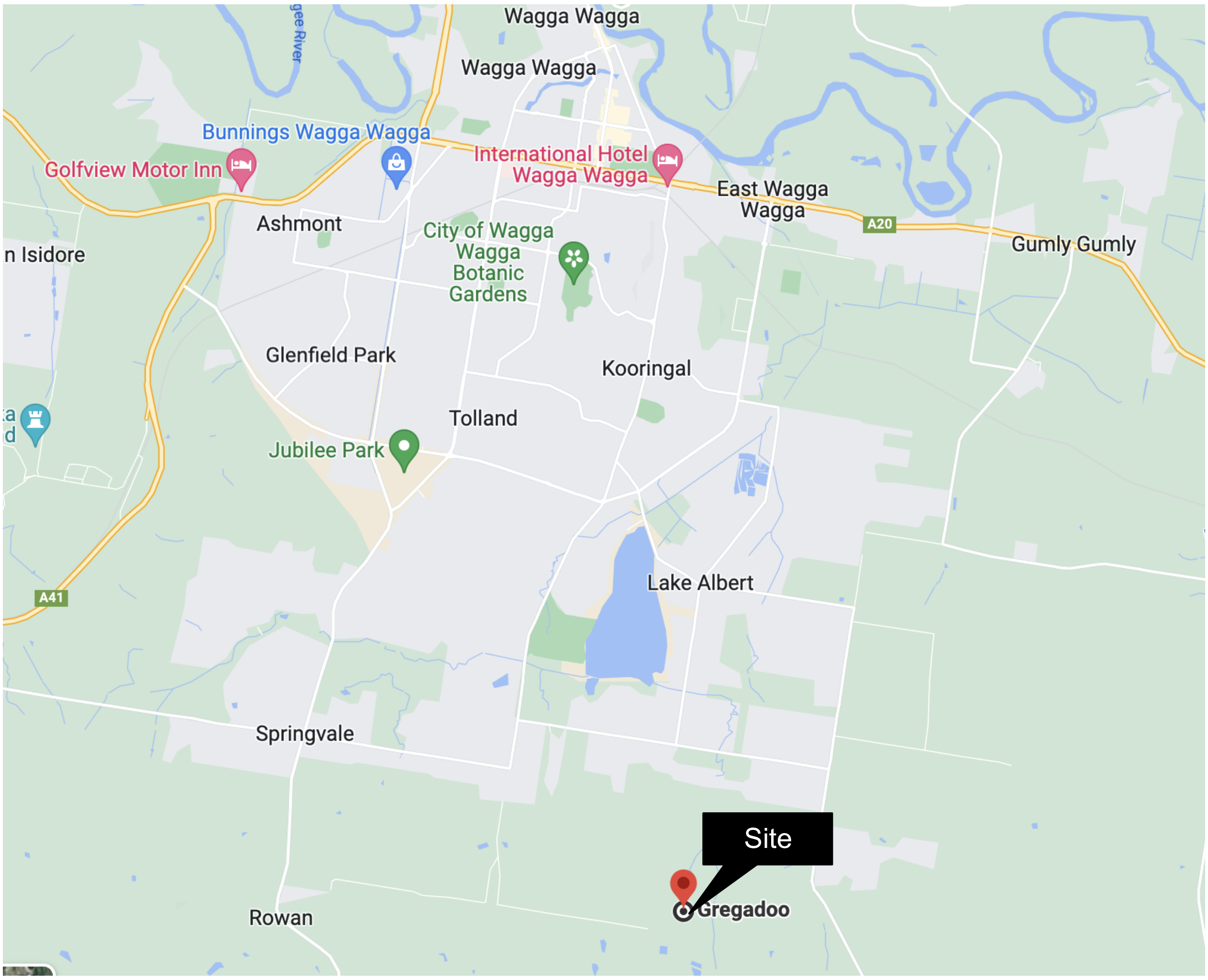

Figure 3-1: Site Location

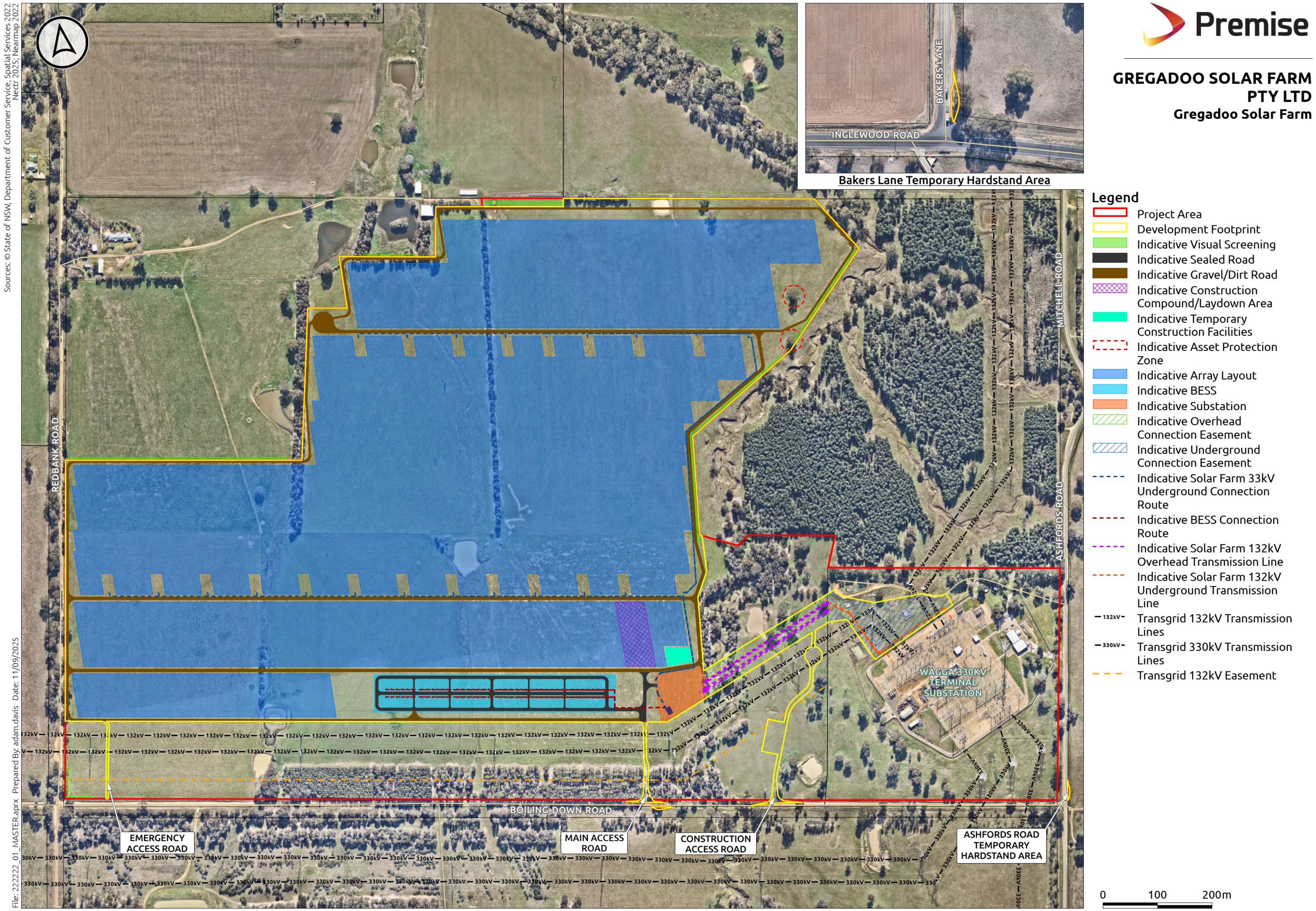

Figure 3-2: Conceptual Project Layout

3.2 General Description

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

- BESS with a capacity of up to 200 MW / 400 MWh;
- Solar Farm facility:
  - Approximately 130,000 solar panels;
  - Energy production of 155,000 MWh/yr;
- Electricity infrastructure:
  - Power Conversion Units (PCU);
  - Switching station;
  - Electrical reticulation infrastructure including underground and/or overhead 132 kV transmission lines; and
- On-site permanent supporting infrastructure:
  - Site access road and entry;
  - Operations and Maintenance (O&M) Facility including: control room, meeting facilities, storage facilities, benching and earthing, parking, ablutions buildings, septic, static water supply, waste management facilities, lighting and maintenance facility;
- Off-site supporting infrastructure:
  - Gregadoo Waste Management Centre;
  - Existing public road and communications network; and
- Construction from commencement to commissioning of the Project (including the solar farm) is expected to take 12 months with a peak period during the construction phase, with up to 150 Full Time Equivalent (FTE); and
- Operations will occur 24 hours a day, seven days per week, with around 3 FTE personnel.

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 200 MW / 400 MWh BESS which can be dispatched based on electricity demand fluctuations, providing the opportunity for greater supply dispatch flexibility when electricity demand is highest. This is enabled by the fast response times achievable through lithium-ion battery storage. The Project will have capacity to discharge up to 200 megawatts (MW) of power for 2 hours resulting in a storage of 400 MWh.

3.3.1 Medium Voltage Power Station (MVPS)

The MVPS house transformers and inverters which will be sited adjacent to the BESS units. There will be approximately 76 MVPSs installed throughout the project area which typically comprise:

1. 1 x 3,780 kVA transformer

2. 1 x inverter

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. MPVS 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 MVPS.

Figure 3-3: Typical MVPS

3.3.2 Battery Storage

The BESS will be located within a dedicated BESS storage area as depicted in **Figure 3-2**. The BESS converts electrical energy into chemical energy and stores the energy internally. It may also provide additional network support such as Frequency Control Ancillary Services (FCAS) assisting with transmission network grid stability. A typical BESS is shown in **Figure 3-4**.

Figure 3-4: Typical BESS Arrangement

3.4 Quantities of Dangerous Goods Stored and Handled

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

Table 3-1: Maximum Classes and Quantities of Dangerous Goods Stored

Area	Class	Description	Quantity
BESS	9	Lithium Batteries	7,380 T
MVPS	C2	Transformer oils	150,480 L
PCU Transformer	C2	Transformer oils	52,000 L
Control Room Generator	C1	Diesel	250 L

4.0 Hazard Identification

4.1 Introduction

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

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

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

  Those incidents exceeding 4.7 kW/m^2 at the site boundary are carried forward for further assessment (i.e. frequency and risk). This is a conservative approach, as HIPAP No. 4 (Ref. [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 more than 1.5 km from the closest BESS, hence, by selecting 4.7 kW/m^2 as the consequence impact criteria the assessment is considered conservative.

- *Explosion* - It is noted in HIPAP No. 4 (Ref. [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 more than 1.5 km from the closest BESS.

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

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

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

4.2 Properties of Dangerous Goods

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

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

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

* The Australian Code for the Transport of Dangerous Goods by Road and Rail (Ref. [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 cobalt, manganese, nickel, or any combination of these metals) oxidises (loses an electron) becoming a positively charged ion in solution which migrates through the battery separator to the cathode. At the same time, the lost electron travels through the circuit to the cathode. The lithium ions in solution then recombine with the electron at the cathode forming lithium metal within the cathodic metal composite. This process is shown in **Figure 4-1**.

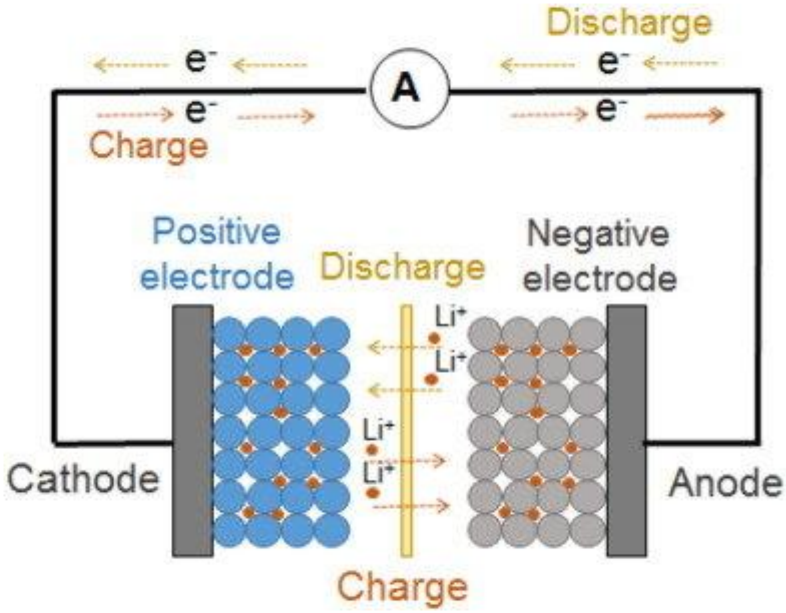

Figure 4-1: Cathode and Anode of a Battery (Source Research Gate)

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

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

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

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

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

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

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

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

A review of the batteries proposed to be used as part of this project indicates the battery chemistry is lithium-Ion phosphate ($LiFePO_4$, or simply LFP) which are considered to be one of the safest battery chemistries within the industry. When exposed to external heat the thermal rise of typical lithium-ion battery chemistries is 200-400 ^{o}C/min resulting in thermal runaway and fire which can then propagate to adjacent batteries escalating the incident to a full container fire. For LFP batteries, the thermal rise of the batteries at peak is 1.5^{o}C/min which results in a gradual temperature rise and does not result in fire and thus incident propagation to other batteries. The thermal rise of various battery chemistries is provided in **Figure 4-2** with a zoomed in temperature rise for LFP provided in the top right of **Figure 4-2**. The stability of the batteries is due to the cathode which does not release oxygen therefore preventing violent redox reactions that may result 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.

In addition to this, manufacturers and integrators can implement different means of preventing battery ignition or controlling if it occurs (such as physical construction arrangements, battery monitoring, heat detection, etc). These are implemented on a system-by-system basis and are specific to the system needs.

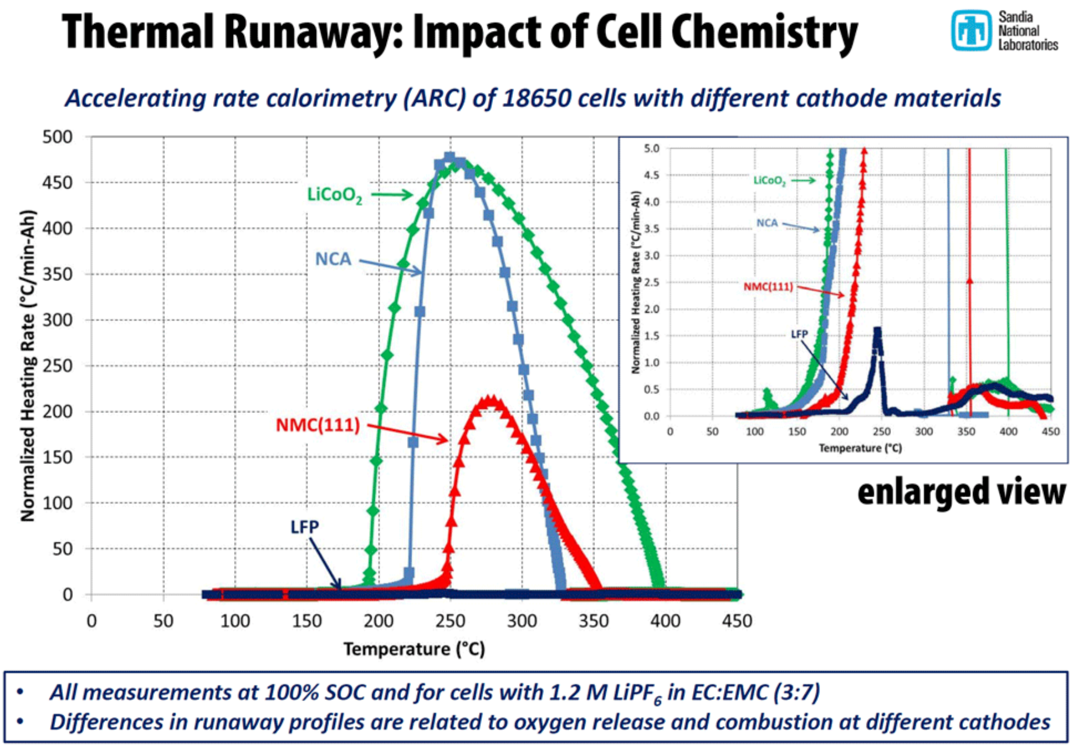

Figure 4-2: Temperature Rise of Lithium-Ion Battery Chemistries (Ref. [6]).

The preliminary battery product considered for the purposes of a preliminary hazard analysis for the project is the SolBank modular Energy Storage System (ESS). A UL9540A report is completed for this product (see Results in **Appendix B**). Notwithstanding, this is a newly released product (September 2022) and the extensive safety protections are outlined in the Safety Manual (**Appendix C**)

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

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

Furthermore, each SolBank container has 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 (**Appendix C**). Therefore, a container will automatically detect an internal fire in the first instance.

In addition to a UL9540A Report, the example SolBank 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. Table 1 of the Safety Manual (**Appendix C**) also indicates compliance with the Standards shown below in .

Table 4-2: Example SolBank 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 chosen LFP BESS product does not propagate from one module to another.

In conclusion, the LFP technology does not cause fire during thermal runaway. Should fire be developed within one BESS container it would not transfer to nearby containers due to the fire safety design features; hence, this incident has not been carried forward for further analysis.

Notwithstanding, based on conversations with and review by NSW Department of Planning and Environment (DPE), the following recommendations have been made:

- 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 150 mm.
- Spacing between BESS container accumulations (i.e. 4 containerised units) shall be a minimum of 2.5 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 DPE.

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 Gregadoo BESS.

The Gregadoo 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 Gregadoo BESS system will follow a similar arrangement and allows a compact back-to-back layout, with a minimum 150 mm rear spacing. Minimum 2.5 m spacing between two front sides allows sufficient access for operation and maintenance activities.

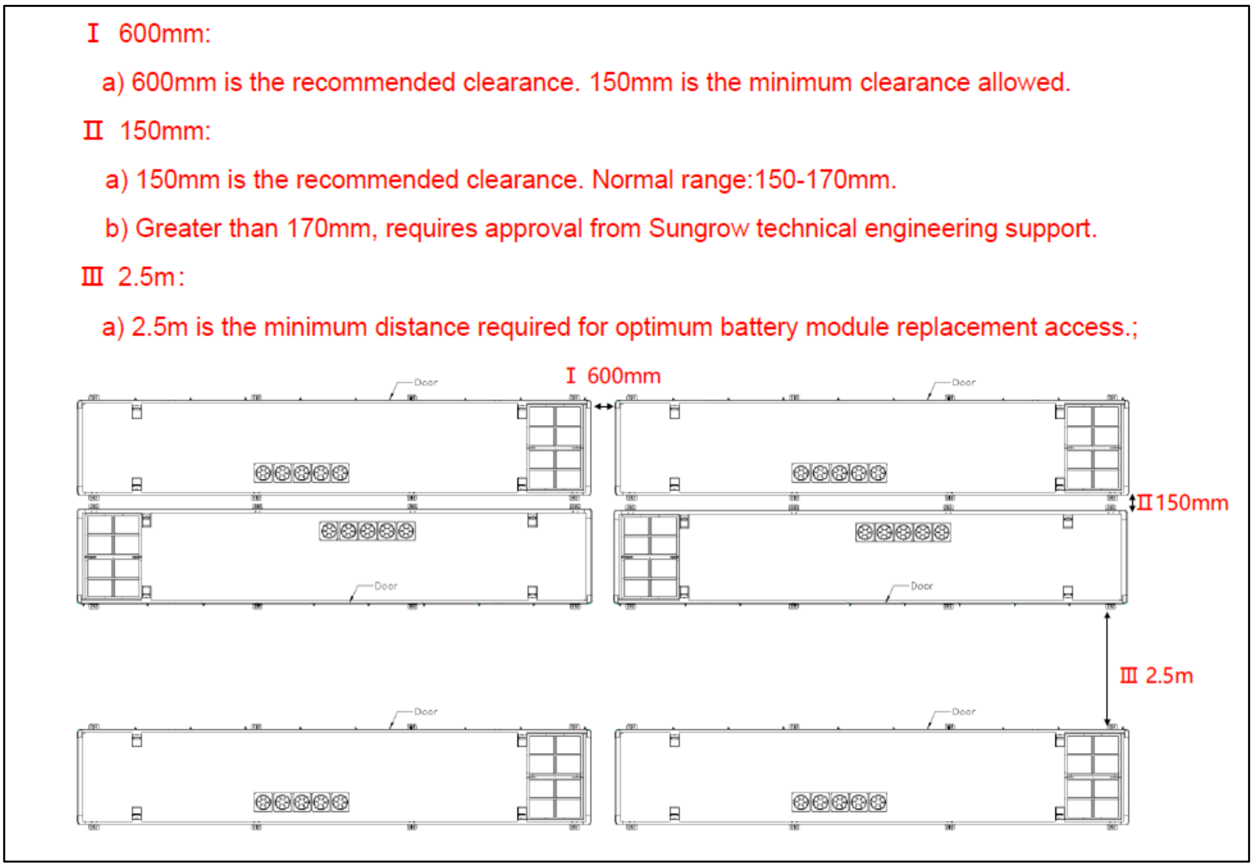

Figure 4-3: BESS Layout Guide

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

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

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

4.6 Li-ion Battery Fire and Toxic Gas Dispersion

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

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

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

4.6.1 Carbon Dioxide

Carbon dioxide is a colourless, odourless, dense gas which is naturally forming and is present in the atmosphere at concentrations around 415 ppm (0.0415%). At low concentrations carbon dioxide is physiologically impotent and at low concentrations does not appear to have any toxicological effects. However, as the concentration grows it increases the respiration rate with short term Exposure Limit (STEL) occurring at 30,000 ppm (3%), above 50,000 ppm (5%) a strong respiration effect is observed along with dizziness, confusion, headaches, and shortness of breath. Concentrations in excess of 100,000 ppm (10%) may result in coma or death.

Carbon dioxide is a by-product of combustion where hydrocarbon or carbon-based materials are involved. A typical combustion reaction producing carbon from a hydrocarbon has been provided in **Equation 4-1**. This reaction proceeds when there is an excess of oxygen to the fuel being consumed and is known as complete combustion as it is the most efficient reaction pathway.

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

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

4.6.2 Carbon Monoxide

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

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

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

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

4.6.3 Fluoride Gases

The electrolyte used in Li-ion batteries typically is lithium hexafluorophosphate ($LiPF_6$) or other li-salts containing fluorine. In the event of a thermal runaway, the electrolyte will expand and be vented from the battery. In the event of a fire, the vented gas and other components such as the polyvinylidene fluoride binders may form gases such as hydrogen fluoride (HF), phosphorous pentafluoride (PF_5) and phosphoryl fluoride (POF_3) (Ref. [7]).

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

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

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

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

Of the fluorine gases formed, PF_5 is a short-lived gas while POF_3 is a reactive intermediate. Thermal destruction of a several battery chemistry, configurations and State of Charge (SOC) indicated the vast majority of these did not produce observable POF_3 with the only observance occurring in a specific battery chemistry at 0% SOC (Ref. [7]). Therefore, the main fluorine gas of concern in a Li-ion battery fire is HF.

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

For a toxic gas dispersion, a battery container fire is necessary as the initiating event. As discussed in **Section 4.4** the potential for a fire to occur is considered negligible due to the highly stable and safe battery chemistries used. 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 create EMFs from operational electrical equipment, such as transmission lines, transformers and the electrical components found within BESS units, inverters, etc. This equipment has the potential to produced ELF EMF's in the range of 30 to 300 Hz.

4.10.2 Existing Standards

There are currently no existing standards in Australia for governing the exposure limits to ELF EMFs; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has provided some guidelines around exposure limits for prolonged exposure which limits the exposure to 2,000 milligauss (mG) for members of the public in a 24 hour period (Ref. [10]).

Table 4-3 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 4-3: EMF Sources and Magnetic Field Strength

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

Source	Typical Measurement (mG)	Measurement Range (mG)
Edge of easement	10	2 – 50

4.10.3 Exposure Discussion

A review of the site indicates there are no immediate non-associated receiver adjacent to the area where the solar farm or BESS will be developed providing substantial distance for attenuation of EMFs. Based upon the typical levels which may be generated by transmission equipment the cumulative effect would not exceed the 2,000 mG limit for prolonged exposure. In addition, the closest residence is over 1 km away from the EMF generating sources at the BESS; hence, the potential for the EMF to exceed the accepted levels is considered negligible.

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) advises that the strength of radiation decreases exponentially with distance from the source, and it will become indistinguishable from background radiation within 50 m of a high voltage power line and within 5 to 10 m of a substation. (Ref. [11]).

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

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

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

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

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

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

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

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

5.0 Conclusion and Recommendations

5.1 Conclusions

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

A review of the incidents carried forward for further analysis indicates that there were no observed offsite impacts; therefore, based on the analysis conducted, it is concluded that the risks at the site boundary 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.

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 150 mm
- Spacing between BESS container accumulations (i.e. 4 containerised units) shall be a minimum of 2.5 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.
- Prior to commissioning, the UL test data for the selected battery units shall be made available to the DPE.
- The vent covers of the BESS shall be constructed of non-combustible material.
- The vents shall not be located above battery packs within the BESS container.

6.0 Bibliography

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Appendix A

Hazard Identification Table

B1. Hazard Identification Table

Area/Operation	Hazard Cause	Hazard Consequence	Safeguards
Battery Storage	• Failure of Li-ion battery protection systems •	• Thermal runaway resulting in fire or explosion • Incident propagation through battery cells • Toxic smoke dispersion	• Batteries are tested by manufacturer prior to sale / installation • Overcharging and electrical circuit protection • Battery monitoring systems • Batteries composed of subcomponents (i.e. BBU, cells) reducing risk of substantial component failure • Batteries are not located in areas where damage could easily occur (i.e. within the fenced property) • Electrical systems designed per AS/NZS 3000:2007 (Ref. [13])
Switch rooms, communications, etc.	• Arcing, overheating, sparking, etc. of electrical systems	• Ignition of processors and other combustible material within servers and subsequent fire	• Fires tend to smoulder rather than burn • Isolated location • Switch room separation from other sources of fire
Substation	• Arcing within transformer, vaporisation of oil and rupture of oil reservoir	• Transformer oil spill into bund and bund fire	• Bunded • Isolated location
	• Power surge to transformers (e.g. from lightning)	• Major failure of surge protection in transformer, vapourisation of mineral oil, ignition and explosion	• Transformers have surge protection system to shut down upon detection of extreme energy input • Lightning protection to prevent lightning strikes impacting transformers • Control of ignition sources – no smoking / open flames around the transformers
EMF	• Electric and magnetic equipment	• Generation of ELF EMF and injury / nuisance to surrounding area	• Large separation distances allow for attenuation of EMFs • Cumulative impacts from equipment below acceptable thresholds. • Low occupancy density within vicinity of the development

Appendix B

UL9540A Test Result

B1. UL9540A Test Result (Cell Manufacturer - EVE)

Performance condition	Test observation/remark
If flaming outside the unit is observed, separation distances to exposures shall be determined by the greatest flame extension observed during the test.	No flaming was observed internally or externally of the Unit during the test.
Surface temperatures of modules within the target units adjacent to the initiating unit do not exceed the temperature at which thermally initiated cell venting occurs.	The maximum surface temperature of the target Unit B, adjacent to the initiating module was 42.0 °C, which is below the average cell venting temperature described in the cell-level test. The maximum surface temperature of the modules within the target Units C was 38.8 °C, which is below the average cell venting temperature described in the cell-level test.
For units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient temperature.	The maximum surface temperature on the adjacent wall A was 43.7 °C and the temperature on wall B was 39.8 °C, which are both below from the 97 °C performance criteria.
Explosion hazards are not observed, including deflagration, detonation, or accumulation of battery vent gases.	Explosion hazards were not observed during the test (internal and external).
Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2	Not reported

B2. UL9540A Test Result (Cell Manufacturer - Hithium)

Performance condition	Test observation/remark
If flaming outside the unit is observed, separation distances to exposures shall be determined by the greatest flame extension observed during the test.	No flaming was observed internally or externally of the Unit during the test.
Surface temperatures of modules within the target units adjacent to the initiating unit do not exceed the temperature at which thermally initiated cell venting occurs.	The maximum surface temperature of the target Unit B, adjacent to the initiating module was 75.6 °C, which is below the average cell venting temperature described in the cell-level test. The maximum surface temperature of the modules within the target Units C was 39.6 °C, which is below the average cell venting temperature described in the cell-level test.
For units intended for installation near exposures, surface temperature measurements on wall surfaces do not exceed 97°C of temperature rise above ambient temperature.	The maximum surface temperature on the adjacent wall A was 28.6 °C and the temperature on wall B was 23.6 °C, which are both below from the 97 °C performance criteria.
Explosion hazards are not observed, including deflagration, detonation, or accumulation of battery vent gases.	Explosion hazards were not observed during the test (internal and external).
Heat flux in the center of the accessible means of egress shall not exceed 1.3 kW/m^2	Not reported

Appendix C

SolBank Safety Manual

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SolBank
Safety Manual
(DC1324.8V)

V1.0

CSI Energy Storage Technologies Co., Ltd.

This manual is verified to be accurate at the date of publication identified within Section 1.4. CSI reserves the right to make product and documentation modifications at any time to achieve the goal of “Leading the energy revolution and creating a green future”.

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1 Preface

1.1 Document Purpose and Scope

The purpose of this document is to provide an overview of the electrical, chemical, and fire hazards that exist within the SolBank modular Energy Storage System (ESS). The scope of this document is limited only to equipment contained within the SolBank and does not include an analysis of all hazards existing at an ESS site. Topics covered include an overview of comprehensive site safety planning processes, SolBank safety systems and features, SolBank hazards, emergency response options, and other important system safety precautions.

This document should be made available to all field personnel participating in the design, installation, operation, and maintenance of the SolBank energy storage system in addition to project safety personnel and local emergency first responders.

This manual is to be considered supplemental to a project specific Environmental Health and Safety (EH&S) plan, Failure Mode Effects Analysis (FMEA), and Emergency Response Plan (ERP). Please read and understand all aspects of this document prior to initiating SolBank installation, commissioning, and operation.

Should any questions arise, please contact CSI support:

- By After Sales Management System at http://www.csisolar.com
- By email at supportAmerica@csisolar.com

1.2 Applicable Models

This manual covers the following models only:

- CSI-SolBank-S1K51K3A01
- CSI-SolBank-S1K5650A01

1.3 Reference Documents

The SolBank Installation Manual exists as part of library of product specific documents. Please consult the following documents to ensure a comprehensive understanding of SolBank attributes.

- *SolBank Installation Manual*
- *SolBank User Manual*
- ***SolBank Safety Manual***
- *SolBank Maintenance Manual*
- *SolBank Coolant Filling Manual*

1.4 Version Control

This is the initial release of the SolBank Safety Manual. As part of CSI's continuous improvement process, CSI reserves the right to make technology and document changes. Please contact CSI support to verify this manual reflects the most recent release or to report omissions or inaccuracies.

Version	Description	Date of Issuance
SolBank Safety Manual_v1.0	Initial publication date	03-17-2022

1.5 Document Safety Notices

Throughout this manual the below indicated Danger, Warning, and Caution labels are used to convey hazards associated with specific tasks, procedures, and equipment. These safety notices do not represent all hazards present. All personnel should adhere to industry safety best practices; the project specific EH&S plan, ERP, and FMEA; and local safety requirements and regulations. ***Only properly trained and qualified personnel should be permitted install, operate, and maintain the SolBank. All emergency first responders shall receive training regarding the hazards of the SolBank.***

“DANGER” indicates a hazardous situation which, if not avoided, will result in death or serious injury. The signal word "DANGER" is limited to the most extreme situations. DANGER indicators are not used for property damage hazards unless personal injury risk appropriate to these levels is also involved.

“WARNING” indicates a hazardous situation which, if not avoided, could result in death or serious injury. WARNING indicators are not used for property damage hazards unless personal injury risk appropriate to this level is also involved.

“CAUTION” indicates a hazardous situation which, if not avoided, could result in minor or moderate injury. CAUTION indicators without a safety alert symbol may be used to alert against unsafe practices that can result in property damage only.

1.6 SolBank Primary Hazards

This section summarizes the primary hazards associated with the SolBank. These hazards are discussed in detail within this guide, in addition to other notable hazards. For further guidance, please refer to the remainder of this manual, the documents identified in Section 1.3, and a project/site specific EH&S plan, Hazard Analysis, and Emergency Response Plan.

1.6.1 Electrocution Hazard

Personnel will be exposed to voltages in excess of 1300 VDC from the SolBank's battery packs, and 0.19222cal/cm^2 available incident energy. Battery packs cannot be de-energized. Low and medium voltage AC is also present – exposure levels will depend on site specific conditions. Risk of arc flash and electrocution is omnipresent at an ESS site. CSI encourages full compliance with the practices and procedures indicated in NFPA 70E including use of Personal Protective Equipment (PPE) sufficient to mitigate any hazards identified in a site-specific arc flash study. Emergency Response Personnel should rely on Standard Operating Procedures (SOP) for responding to incidents at electrical generating facilities.

1.6.2 Fire and Explosion Hazard

The SolBank contains combustible fuels, ignition sources, and sufficient oxygen to result in propagation of fire. Fire and other sources of extreme heat, if not properly mitigated, can lead to battery cascading thermal runaway and the release of combustible gases. **These combustible gases, if present in sufficient density, pose a risk of explosion.** If a fire, or other indications of thermal runaway are present within the SolBank or at the ESS site, first responders are advised to maintain a safe perimeter until it can be verified that entry into the ESS site is safe per the ERP and SOP.

1.6.3 Chemical Exposure Hazard

The SolBank contains the following hazardous chemicals: LFP battery electrolyte, lead acid battery electrolyte, R410a refrigerant, and Ethylene Glycol coolant. **These chemicals can be hazardous to both health and environment.** Please refer to the Safety Data Sheets (SDS) contained within Attachment A of this document for hazards and precautions specific to each chemical.

1.7 Product Certification and Compliance

The SolBank is compliant with the standards, regulations, and requirements identified in Table 1.

Table 1: SolBank Standards Compliance

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

2 Contents

3 Acronyms and Abbreviations

AC – Alternating Current

AHJ – Authority Having Jurisdiction

BMS – Battery Management System

BOL – Beginning of Life

DC – Direct Current

SolBank Controller – LOCAL Energy Management System (Battery system)

EOR – Engineer of Record

ESS – Energy Storage System

COG – Center of Gravity

HVAC – Heating Ventilation Air Conditioning

IFC - Issued for Construction

LFP – Lithium Iron Phosphate

LOTO – Lock-Out-Tag-Out

NFPA – National Fire Protection Association

PCS – Power Conversion System

PPE – Personnel Protective Equipment

SPD – Surge Protection Device

UPS – Uninterruptible Power Supply

EPC – Engineering, Procurement, and Construction contractor

CapEx - Capital Expenditures

4 Introduction

4.1 Comprehensive Site Safety and Emergency Response

Development of effective and comprehensive safety procedures and emergency response guidelines requires, among other things, i) analysis of project specific ESS architecture and all components within, ii) site specific risks and hazards, iii) engagement with project stakeholders, iv) and a clear understanding of both customer and fire department Standard Operating Procedures (SOP). CSI has provided this Safety Manual as an input to these processes and the development of the below recommended project specific documents.

- **Environmental, Health, and Safety (EH&S) Plan:** A living project safety plan which serves as an instructional tool for personnel working on a project, notifying them of hazards as well as procedures required to ensure personnel safety and environmental protections in consideration of such hazards.
- **Failure Modes and Effects Analysis (FMEA):** A bottom-up analysis which identifies the worst-case effect of component (software and hardware) failure on system performance and safety. An FMEA is similar to a Hazard Analysis. Reference International Electrotechnical Commission (IEC) 60812 for guidelines on how to perform an FMEA.
- **Emergency Response Plan (ERP):** An ERP leverages the FMEA, EH&S Plan, SOPs, and other inputs to develop a project specific plan which dictates the actions to be taken by key project stakeholders in response to an emergency at an ESS site. A copy of the ERP should be kept at the ESS site, at a location accessible to emergency first responders.

4.2 System Overview

The SolBank System integrates all power electronics, controls, and safety features required to support the DC side of a battery energy storage system. An overview of the SolBank layout and key features is shown in Figure 1 and further described in Table 2.

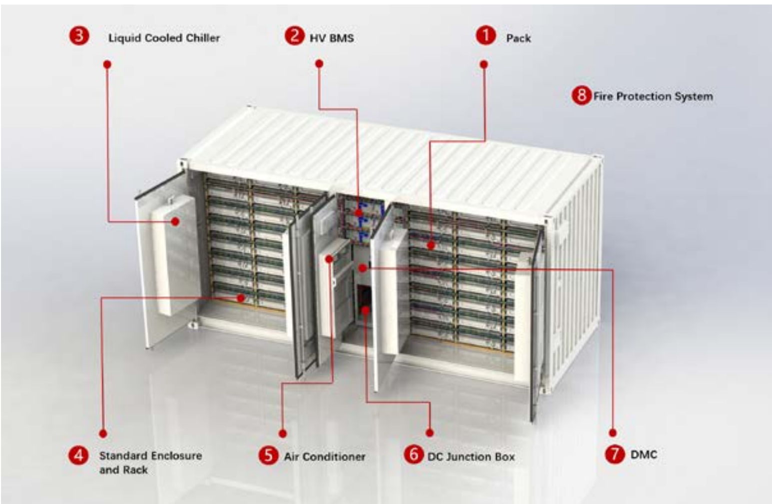

Figure 1: Layout and features of the SolBank

Table 2: Description of SolBank Safety Equipment and Features

No.	Name	Remarks
1	Standard Enclosure and Rack	All models of the SolBank utilize a standard IP-55 rated steel container. All components are accessed from the 3 exterior doors, eliminating the need for personnel to enter the container. Additionally, the SolBank is designed to limit hazard exposure to personnel when all access doors are closed and secured.
2	Battery Pack	The SolBank contains 48 LFP battery packs, each consisting of 69 series wired battery cells. Each battery pack has a maximum voltage of 220.8 VDC and is wired in series with five other battery packs to achieve a maximum string voltage of 1324.8VDC (1490.4 VDC during charging). Each battery pack contains roughly 3.8L (1gal) of electrolyte. Each SolBank contains roughly 182.4L (48gal) of electrolyte.
3	Liquid Cooling and Heating System	The battery pack is liquid cooled, allowing for greater heat dissipation and uniform cell temperature management. During charge and discharge, cell temperature is maintained between 20°C ~ 35 ° C. The SolBank's HVAC system contains 320L (84.8gal of Ethylene Glycol Coolant and 16kg (35.3lbs) of R134a refrigerant.
4	Battery Management System	The SolBank houses 8 rack-mounted, Battery Management Systems (BMS) (one for each string). The BMS ensure optimal battery functionality and safety by monitoring battery voltage, SOC, temperature and other key parameters.
5	DC Junction Box	The SolBank's DC Junction box contains all primary DC buswork, fusing, Surge Protection Devices (SPD), disconnects, and power monitoring required to safely exchange power between the SolBank and plant Power Conversion System (PCS), and isolate system electrical faults.
6	Distribution Management Cabinet	The Distribution Management Cabinet (DMC) houses all aux power distribution equipment including 2-hour lead acid battery-backup UPS; system communication, control, and monitoring hardware including network switch, and Energy Management Control Unit (EMCU); and all required customer communication, signal, and aux power interfaces.
7	*Fire Detection* and Alarming	*The SolBank incorporates heat and smoke detection, flammable* gas detection and venting, audible and visual alarming.

5 SolBank Safety Systems and Features

5.1 Battery Pack Chemistry and Design

The SolBank contains 48 Lithium Iron Phosphate (LFP) battery packs, each containing 69 LFP cells. LFP battery cells have high heat resistance relative to traditional cell chemistries such as Nickel Manganese Cobalt (NMC), and thus have a greater resistance to thermal runaway conditions. Furthermore, in a thermal runaway state, LFP cells generate a very small amount of energy as compared to other technologies, thereby slowing the progression of fault conditions, and reducing the chances of propagation to adjacent cells.

Each battery pack contains an integrated electrolyte sink, sized to capture all electrolyte contained within the battery pack in the event of substantial damage or pack rupture. Although, chances of a significant spill event are nominal due to the physical isolation of the 69 cells within, this feature provides added assurances of environmental protection during a significant fault event.

During transportation and maintenance, the power harness in series between the battery packs needs to be disconnected. When the power harness is disconnected, the DC voltage in the battery box is only 220.8V, which greatly reduces the risk of fatal electric shock. Note that during normal operation and fully installed, the battery pack voltage can exceed 1300Vdc.

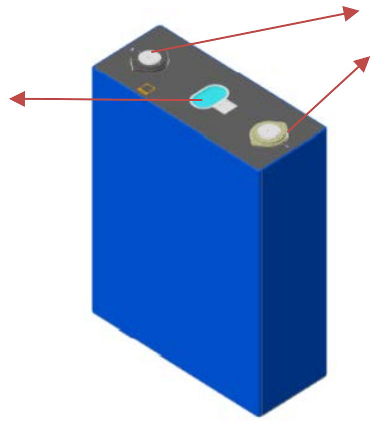

Figure 2: SolBank battery pack (top) and SolBank LFP battery cell (bottom). Each battery pack contains 69 battery cells.

5.2 Battery Management System

The SolBank's battery packs are wired as 8 strings of 6 packs, as shown in Figure 3 Each string is controlled and monitored by a dedicated Battery Management System (BMS). The BMS constantly monitors cell and pack level voltage, temperature, State of Charge (SOC), and other parameters to ensure early detection of pre fault conditions, and immediate detection of fault events. Should any parameter exceed a permissible value, the BMS will disconnect the effected string and surface an alarm to the site EMS.

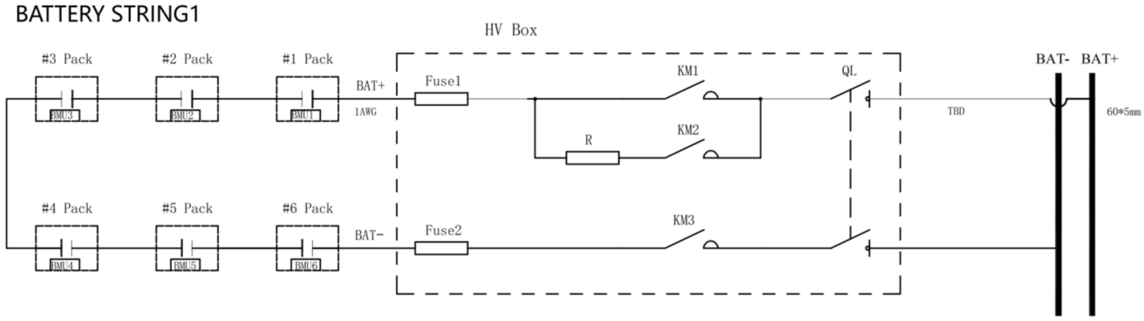

Figure 3: SolBank String Wiring. Each string consists of 6 battery packs and a single BMS.

5.3 Access Door Travel Switch

The external BMS access door on the SolBank has integrated position sensors. When the external BMS access door is opened during system operation, the SolBank will immediately shut down and all BMS will isolate their battery strings from the main system bus.

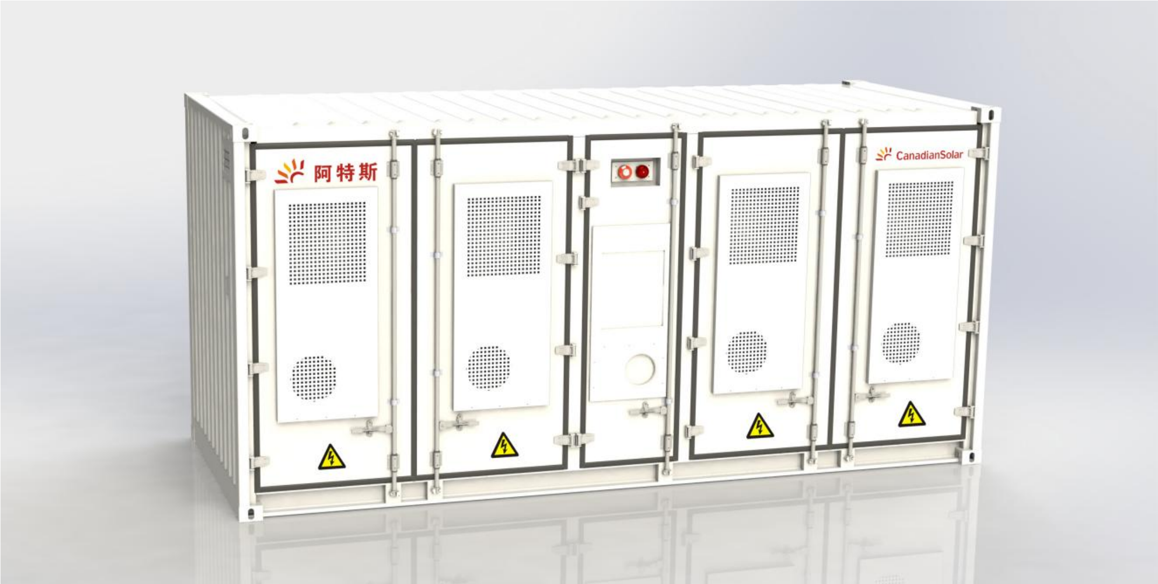

Figure 4: The position of external BMS access door

5.4 Estop

Each SolBank contains two Estop buttons on each end of the structure. When pushed, the SolBank will immediately commence shut down, and all BMS will isolate their battery strings from the main system bus. See Figure 8 and Section 7.1.1 for additional details.

5.5 Fire Detection and Alarming

The SolBank is equipped with smoke and heat detection sensors calibrated to detect early signs of fire within the SolBank. The spot-type smoke detector is calibrated to 2.5%. The temperature threshold of the heat sensor is 57.2℃. Both sensors are ceiling mounted as indicated in Figure 8. The SolBank contains both an audible fire alarm and visual fire strobe. If the smoke and heat sensors are triggered, both alarms will activate, and corresponding alarms will be sent to the ESS EMS.

The fire alarm logic is shown in the Figure 5.

The SolBank is equipped with flammable gas detection sensor and two off-gassing valves. The flammable gas detector is calibrated to 25% LEL. If the flammable gas sensor is triggered, both alarms will activate and the two off-gassing valves will be opened for exhaust. Corresponding alarms will be sent to the ESS EMS.

SolBank fire-fighting fault handling measures and recovery conditions					
Phenomenon	Temperature Sensor	Smoke sensor	Flammable gas sensor	Alarm behavior/level	Recovery conditions
A small amount of flammable gas, no smoke, no high temperature			x	Level 1 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, etc.) + exhaust system operation	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.
A lot of combustible gas, no smoke, no high temperature			x	Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off) + exhaust system running	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.
No flammable gas, smoke, no high temperature		x		Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off), exhaust system does not operate	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.
No flammable gas, no smoke, with high temperature	x			Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off), exhaust system does not operate	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.
No flammable gas, smoke, high temperature	x	x		Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off), exhaust system does not operate	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.

Small amount of flammable gas with smoke/high temperature	x	x	x	Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off) + exhaust system running	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.
A lot of combustible gas with smoke/high temperature	x	x	x	Level 2 fire alarm (sound and light + alarm bell, communication alarm, request PCS to stop, trip the contactor after 3 seconds, HVAC、auxiliary circuit power off) + exhaust system running	The fault signal disappears, and after manual maintenance, click the display and control to eliminate the fault.

Figure 5: Fire alarm and response logic

6 SolBank Hazards

The primary hazards associated with installation and operation of the SolBank are indicated in Table 3 and discussed in the following sections.

Table 3: SolBank primary hazards

Classify	HAZARD	DESCRIPTION	QUANTITY	RISK
Electrical hazards	DC voltage	Primary voltage of storage system	1500VDC	Electrocution
	AC voltage	Primary voltage of auxiliary power supply	480VAC	Electrocution
Chemical hazards	Ethylene Glycol	Coolant used in battery liquid cooling system	320L (84.8gal)	See Attachment A: MSDS Library
	R134a Refrigerant (Envicool HVAC)	Refrigerant used in HVAC system	16kg (35.3lbs) of R134a refrigerant	See Attachment A: MSDS Library
	Li-ion Electrolyte	Battery electrolyte used in LFP battery cells	182.4L (48gal)	See Attachment A: MSDS Library
	Lead Acid Electrolyte	Battery electrolyte used in UPS	0.16L(0.04gal)	See Attachment A: MSDS Library
Fire & Explosion Hazards	Electrical Fire	Fire caused by cable fault or component failure	--	Fire
	Thermal Runaway	Thermal runaway from battery fault or heat	--	Fire, off-gassing
	Battery off-gassing	Off-gassing resulting from thermal runaway	--	Explosion

6.1 Electrical Hazards

6.1.1 DC Voltage

Hazard: Exposure to 1500VDC

As shown in Figure 3, the SolBank's 48 battery packs are wired as 8 strings of 6 packs. Each SolBank pack has a maximum DC voltage of 248.4 VDC. When wired in a series string of 6 packs, the total voltage increases to 1324.8 VDC. Charging voltage can be as high as 1500VDC. Risk of electrocution exists.

Location: When system is shutdown, high DC voltage is present at the terminals of each battery and BMS. When the system is started or on-line, each BMS will close the string disconnect, and energize the main DC bus of the SolBank. If the system primary disconnect is closed, the conductors between the SolBank and DC terminals of the PCS will also be energized.

6.1.2 AC Voltage

Hazard: Exposure to 480VAC

The SolBank's auxiliary power system, which includes HVAC systems, control systems, and other system support equipment, operates of 480VAC. Risk of electrocution exists.

Location: 480VAC aux power feed is routed into the bottom of the SolBank Distribution Management Cabinet shown in Figure 1. 480 VAC supplies HVAC loads contained in the HVAC cabinet as well as a 480VAC/220VAC step-down transformer, which in turn supplies other loads through the SolBank.

6.2 Chemical Hazards

6.2.1 Ethylene Glycol Coolant

Hazard: Exposure to hazardous chemicals

The SolBank's liquid cooling and heating system circulates an Ethylene Glycol solution from the HVAC cabinet to each battery pack in the system. The solution consists of 50% water and 50% Ethylene Glycol. Ethylene Glycol is not flammable but does pose a health risk when exposed to personnel in sufficient quantity. See the safety data sheet (SDS) contained in Attachment A for further details.

Location: Ethylene Glycol circulates throughout the supply and return lines shown in Figure 6.

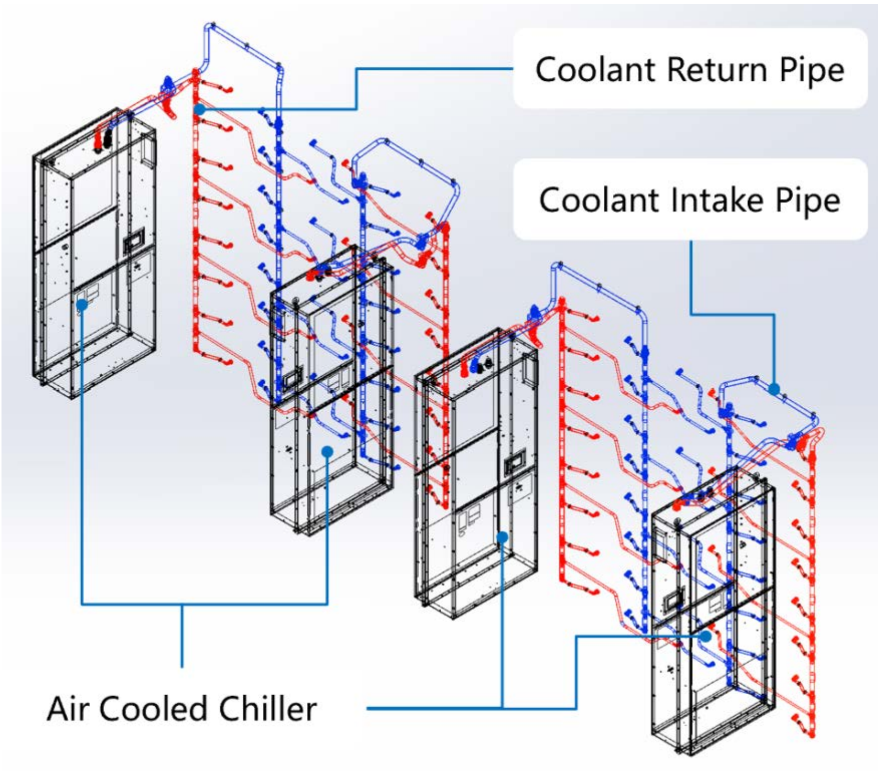

Figure 6: Coolant distribution schematic

6.2.2 R134a Refrigerant

Hazard: Exposure to hazardous chemicals

The SolBank's air conditioning system circulates R134a refrigerant to the entire HVAC system. R134a can be flammable under certain circumstances and does pose a health risk when exposed to personnel in sufficient quantity. See the safety data sheet (SDS) contained in Attachment A for further details.

Location: 16kg (35.3lbs) of R134a circulates throughout the HVAC system shown in Figure 7. Compressor and other supporting equipment can be found in the HVAC cabinet.

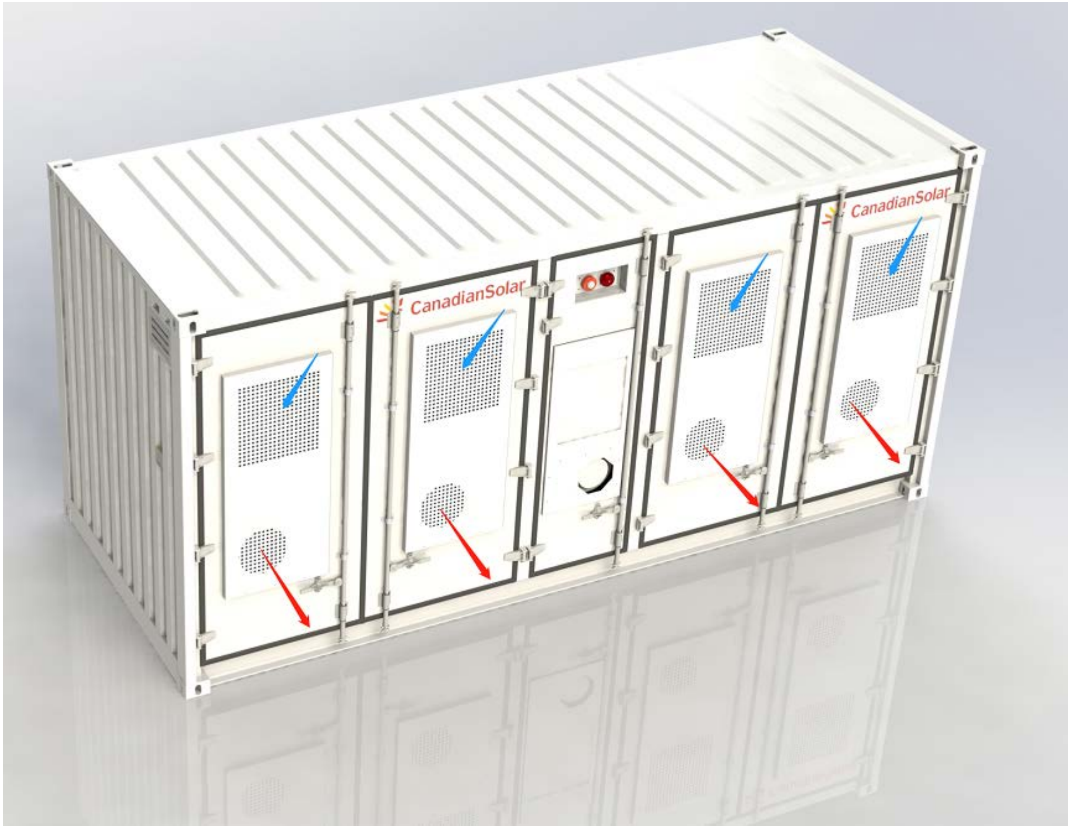

Figure 7: SolBank's HVAC system

6.2.3 Lithium Ion Electrolyte

Hazard: Exposure to hazardous chemicals

The electrolyte contained within the SolBank C15 battery packs consist of a volatile hydrocarbon-based liquid and a dissolved lithium salt such as lithium hexafluorophosphate. The electrolyte solution can be flammable under certain circumstances and does pose a health risk when exposed to personnel. See the safety data sheet (SDS) contained in Attachment A for further details. Additional materials used in the construction of the C15 LFP battery pack are indicated in Table 4.

Location: 336L (89gal) of electrolyte is contained within the SolBank's 24 battery packs (2,736 battery cells). The battery packs are located within the 6 steel racks shown in Figure 1.

Table 4: Non-electrolyte materials in SolBank battery packs

No.	Materials/Ingredients	Approx. % by wt.
1	Carbon	7-16%
2	Polypropylene	2.0-3.6%
3	Aluminum	16-26%
4	Copper	7-14%

6.2.4 Lead Acid Electrolyte

Hazard: Exposure to hazardous chemicals
The electrolyte contained within the SolBank's UPS consist of a sulfuric acid electrolyte. The electrolyte solution does not combust easily but does pose a health risk when exposed to personnel. See the safety data sheet (SDS) contained in Attachment A for further details.

Location: The Lead Acid Electrolyte is contained within the SolBank's UPS which is in the distribution box.

6.3 Fire & Explosion Hazards

6.3.1 Electrical Fire

As a result of short circuit, failed OCPD (over-current protection device), or other electrical component failure, electrical fires are possible within the SolBank.

6.3.2 Thermal Runaway and Battery Fire

Due to excessive heat build-up from external sources (i.e. electrical fire), or internal cell failure, it is possible that one, or many of the SolBank's LFP cells may be pushed into a state of thermal runaway. Should this occur, the design of the LFP cell and C15 battery pack is designed to reduce the changes of propagation of thermal runaway to adjacent cells, a process called "cascading thermal runaway."

6.3.3 Explosion of Battery Off Gas

When Li-ion batteries go into thermal runaway, toxic and flammable gases are released in a process called off-gassing. **During cascading thermal runaway events, when many cells are consumed, sufficient gas can build up within a confined space to create conditions sufficient for explosion.**

7 Emergency Response

7.1 Emergency System Shutdown

In the event of an emergency on site, the SolBank can be shut down locally, or remotely. A system shutdown will result in electrical isolation of the battery strings and cessation of battery charging or discharging. A system shutdown will not de-energize the battery bank, nor will it guarantee that a fault or thermal runaway event has been stopped. Do not open the SolBank until deemed safe to do so by an individual qualified to direct such decision.

Procedures for shutdown of the site and isolation from the grid should be dictated within the ERP.

7.1.1 Local Emergency Shutdown

If safe to approach the SolBank, as defined by the project Emergency Response Plan, SOPs, Emergency Incident Commander, or other qualified on-site personnel, the E-stop button located on either end of the SolBank can be pushed. See Figure 8 for the location of the E-Stop buttons.

When the E-stop is pushed, the SolBank BMSs will disconnect all battery strings from the main system bus, thereby stopping all charging and discharging. Simultaneously, the plant PCS will shut down if properly configured to do so. When multiple SolBanks exist on a single site, their Estop circuits can be interconnected, resulting in total system shutdown when one E-stop button is triggered.

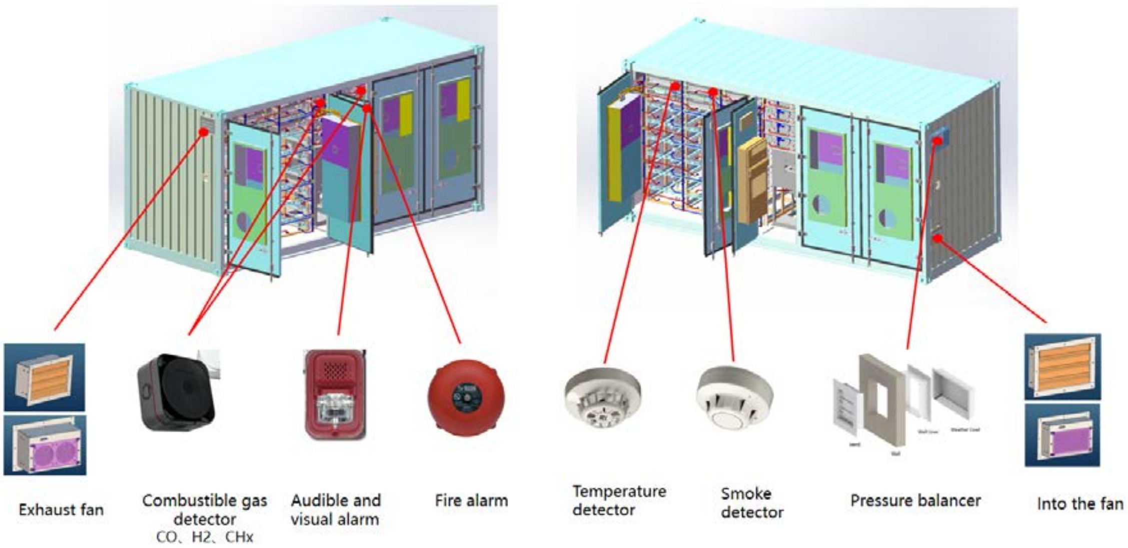

Figure 8: Location of Estop, fire sensing, and alarms.

Pressing the E-stop while charging and discharging places considerable stress on the system. Only use the Estop to stop the system during an emergency. Before restarting the system, the E-stop must be pulled out to its original position.

If indications of a fire within the SolBank exists, such as smoke emanating from the SolBank, or activation of the fire alarm strobe, it is recommended to immediately evacuate the area and maintain a safe perimeter. System shut down should be attempted remotely as described in Section 7.1.2. Do not open the SolBank access doors.

7.1.2 Remote System Shutdown

During normal operation, the SolBank will be under the control of a site Energy Management System (EMS) or Local Plant Controller (LPC). The EMS or LPC in turn will communicate with, and be controlled by, an offsite fleet controller, SCADA operations center, or other third-party dispatch and monitoring entity. SolBank alarms will be forwarded to such remote operations, and in turn, remote operations personnel can shut down the SolBank if determined to be necessary.

On-site personnel witnessing an emergency should not however assume automated alarms have reached the LPC or EMS or that they have been passed onto remote operations. Such personnel are advised to first call 911, and then contact remote operations directly in addition to other key stakeholders identified in the ERP.

7.2 Fire Alarm Response

7.2.1 Initial Indications of fire

If any of the below is observed, personnel should immediately evacuate the area, contact 911, and notify all stakeholders as defined within the ERP. **Do not open the SolBank access doors under any circumstance.**

- Acrid burning smell
- Excessively hot access door handles or outer surfaces
- Unusual sounds indicating electrical arcing or combusting materials
- Triggered audible or visual firealarm
- Smoke emanating from the SolBank

7.2.2 Establish Secure Perimeter and Monitor

In the event of a fire, or indication of a fire within the SolBank, CSI recommends that first responders establish a secure perimeter, monitor, and approach only when determined safe to do so by an incident commander or other qualified authority. **No direct suppression tactics are advised by CSI.**

7.2.2.1 Establish a Perimeter

The circumference of such perimeter should be calculated as part of a project specific ERP. Variables analyzed should include potential plume size (a product of system size), prevailing winds, proximity to other buildings and sensitive areas (schools, etc), and the potential blast radius should a cascading thermal runaway result in accumulation and ignition of explosive gases.

7.2.2.2 Monitor

In the absence of a justified reason to enter the site (i.e. entrapment of personnel), it is advised that emergency first responders not take direct action to suppress the fire. A communication link should be established with the remote system operator to obtain data regarding system status if available. Battery/cell status, temperature, and voltage trends should be observed to quantify scope of event and conditions within the SolBank. IR cameras can also be used to evaluate hot spots and decreasing/increasing temperatures. Note, a battery fire may continue for 24 hours or longer and can re-ignite due to the exothermic reaction of constituent materials from broken or damaged cells.

If deemed appropriate and safe to do so by the incident commander, water can be applied to the SolBank and adjacent structures to prevent fire spread. Such processes should be clearly indicated in the ERP and incorporated into fire department and customer SOPs.

7.2.2.3 Direct Suppression

It is outside the scope of this manual to advise on means and methods for direct suppression of Li-ion fires. Again, CSI does not advise direct firefighting tactics. CSI does however offer the following general information for consideration should it be necessary to take a direct suppression approach:

- Cascading thermal runaway events can only be safely stopped by cooling with large quantities of water.
- Foam and other chemical agents will not be effective. Foam suppressants may trap heat and increase rate of propagation.
- Ventilation of internal areas of the SolBank is essential to ensuring the absence of accumulated explosive gases. Firefighters are advised to not open access doors until flammable gas has been reduced to a safe value and the exhaust valve has been opened.
- Approaching the SolBank from the sides without access doors may minimize injury in the event of explosion.

8 Other System Precautions

8.1 Storage Precautions

Should the SolBank or Li-ion battery pack require storage for extended periods of time, the following is advised:

1. Storage temperature shall be between -20°C and 45°C. Elevated temperatures can result in increased capacity degradation and/or fire danger. Contact CSI if short duration storage is anticipated to exceed the above limits for reasons outside the installer/owner's control.
2. Batteries should be stored at a humidity <85% and protected from moisture, condensation, and flooding.
3. Batteries should be stored between 25%-60% SOC to prevent accelerated capacity degradation.
4. Battery system, and sub-assemblies should be stored in approved packaging.
5. Storage facility should be compliant with the appropriate local fire code requirements.
6. Acceptable storage density of battery packs and storage height of battery packs shall be defined by the local authority having jurisdiction (AHJ). Requirements and limits will be based upon a number of factors including the structural and fire protection characteristics of the storage area and recommendations for fire protection promulgated by the National Fire Protection Association (NFPA) and similar organizations.
7. At the time of this writing, no Commodity Classification has been defined for lithium-ion cells or battery packs. Until a Commodity Classification has been defined based on testing by NFPA or a similar organization, CSI recommends treating lithium-ion cells and batteries in packaging as equivalent to a Group a Plastic Commodity.

8.2 Installation, Operation, and Maintenance Precautions

Numerous safety hazards exist during the installation, operation, and maintenance of the SolBank. Please refer to the relevant manuals identified in Section 1.3 for further details.

8.3 Handling, Storage, and Transportation of Damaged Goods

If a battery pack has been damaged (battery enclosure has been dented or broken), it is possible that heating is occurring that may eventually lead to a fire. Damaged cells/batteries can result in the release of flammable vapors, and propagation of thermal runaway reactions to neighboring packs.

Before handling or transporting a damaged battery pack, wait at least one hour. Smoke in the vicinity of a battery pack may be an indication that a thermal reaction is in progress. If no smoke, flame, leakage of electrolyte, or signs of heat has been observed for one hour, the SolBank may be disconnected and moved into a safe location. To obtain specific instructions for evaluating and preparing damaged batteries for transport, please visit http://www.csisolar.com and contact the CSI Service team.

A damaged battery pack should be monitored during storage for evidence of smoke, flame, leakage of electrolyte or signs of heat. If full-time monitoring of the damaged product is not possible (for example during extended storage), the damaged product should be moved to a safe storage location.

A safe storage location for a damaged battery pack will be free of flammable materials, accessible only by trained professionals. Do not store a damaged battery pack adjacent to undamaged products.

8.4 Disposal Procedures

Batteries at the end of their service life should be disposed of or recycled in accordance with local, state, and federal regulations. Note that regulations regarding disposal of batteries vary by jurisdiction. In the United States, batteries are classified as “Universal Waste”, and in addition, many individual states have specific regulations regarding disposal of battery packs. For example, in California, all batteries must be taken to a Universal Waste handler or authorized recycling facility.

CSI Lithium-ion Batteries contain recyclable materials. CSI lithium-ion batteries do not contain heavy metals such as lead, cadmium, or mercury. CSI strongly encourages recycling. Please consult with local, state and/or federal authorities on the appropriate methods for disposal and recycling.

8.5 Transportation Information

Lithium-ion batteries are regulated as Class 9 Miscellaneous dangerous goods (also known as “hazardous materials”) pursuant to the International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air, International Air Transport Association (IATA) Dangerous Goods Regulations, the International Maritime Dangerous Goods (IMDG) Code, European Agreements concerning the International Carriage of Dangerous Goods by Rail (RID) and Road (ADR), and applicable national regulations such as the USA’s hazardous materials regulations. These regulations contain very specific packaging, labeling, marking, and documentation requirements. The regulations also require that individuals involved in the preparation of dangerous goods for transport be trained on how to properly package, label, mark and prepare shipping documents.

Table 5: Transportation of Lithium Ion Cells

UN Number	3536
Proper Shipping Name	Lithium-ion Batteries
Hazard Classification	Class 9 Miscellaneous
Packing Group	N/A

9 Attachment A

“Attachment A: SolBank Safety Data Sheet Library” includes the following documents. Attachment A is provided separately.

- Antifreeze Coolant MSDS
- R134a Refrigerant MSDS
- Li-ion Electrolyte MSDS
- LC UP EC Series (lead acid electrolyte) MSDS
- Other project specific MSDS as required