

Edify

Burroway Solar Farm

Preliminary Hazard Analysis

Reference: BSF_PHA001

Issue | 17 August 2023

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2966000

Arup Australia Pty Ltd | ABN 76 625 912 665

Arup Australia Pty Ltd
Wurundjeri Woiwurrung Country
Sky Park One Melbourne Quarter
699 Collins Street
Docklands VIC 3008
Australia
arup.com

Document Verification

Project title Burroway Solar Farm
Document title Preliminary Hazard Analysis
Job number 2966000
Document ref BSF_PHA001
File reference Burroway Solar Farm PHA_Issue

Revision	Date	Filename	Burroway Solar Farm PHA_draft		
Draft	08 August 2023	Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Nick McEniry	Ben Smith	Ben Smith
		Signature			
Issue	17 August 2023	Filename	Burroway Solar Farm PHA_Issue		
		Description	Addressed comments		
			Prepared by	Checked by	Approved by
		Name	Nick McEniry	Ben Smith	Ben Smith
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document

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Abbreviations

Abbreviation	Definition
AC	Alternating Current
AS	Australian Standard
BESS	Battery Energy Storage System
BSF	Burroway Solar Farm
BYDA	Before You Dig Australia
DPE	Department of Planning and Environment
DPIE	Department of Planning, Industry, and Environment
EIS	Environmental Impact Statement
HAZID	Hazard Identification Study
HIPAP	Hazardous Industry Planning Advisory Paper
IBRA	Interim Biographical Regionalisation for Australia
LEL	Lower Explosion Limit
NFPA	National Fire Protection Association
NSW	New South Wales
PHA	Preliminary Hazard Analysis
REZ	Renewable Energy Zone
SEARs	Secretary's Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
UL	Underwriters Laboratories

Executive Summary

Edify Energy's (the Proponent) proposed Burroway Solar Farm (BSF), set to be located in Burroway, NSW, is subject to a risk screening and preliminary hazard analysis (PHA), as detailed in this report. The proposal includes a 100 MW AC solar photovoltaic generation capacity, coupled with an integrated 100 MW/400 MWh battery energy storage system (BESS). Project details are summarised in Table 1 below.

Table 1: Summary of project details

Project Detail	Description
Project Type	Solar farm with BESS
Electrical Connection	Connection to Essential Energy's existing 132 kV transmission line
Battery Technology	Hermetically sealed lithium-ion battery cell (chemistry composition TBC)
Battery Capacity	Estimated 100 MW/400 MWh
Battery Storage Duration	4 hours, at peak discharge rate (TBC during detailed design)
Battery Configuration	Centralised or decentralised (TBC during detailed design) outdoor modular battery units with ancillary balance of plant equipment
Project Location	Located in Burroway, approx. 17.5 km north of Narromine, NSW and 27 km west of Dubbo
SSD No.	5596873

The risk screening considers two options for battery configurations and finds that under the Resilience and Hazards State Environmental Planning Policy (SEPP) (formerly SEPP 33), the development does not meet the criteria for *potentially hazardous*. As such, a PHA is not required for the development per the Resilience and Hazards SEPP. However, as a requirement of the Planning Secretary's Environmental Assessment Requirements (SEARs) for the development, a PHA is required to be prepared to address the potential risks of the development. This report comprises the PHA.

A multi-level risk assessment approach is used to determine the assessment level required as defined by the NSW Department of Planning and Environment (DPE). A Level 1 qualitative risk assessment is appropriate due to there being no expected major off-site consequences and hence, negligible societal risk resulting from the BSF development.

The assumption of no major offsite consequences (the basis for a Level 1 assessment) is contingent on the adoption of the separation distances defined within the consequence modelling contained in this report. Additionally, this assessment provides guidance on the appropriate separation distances for on-site receptors to limit the potential for incidents to spread within the site boundary.

The methodology used to conduct the PHA for BSF is a hazard identification followed by consequence analysis and subsequent reporting.

Hazard identification is recorded using a HAZID risk register (see Appendix A). The hazardous scenarios assessed to be 'moderate' risk or higher in the HAZID and the hazardous scenarios where minor off-site consequences are anticipated are subject to qualitative assessment. These are:

- Security breach;
- Electrocutation;
- Vehicle impact;
- Battery fire;
- Release of firewater runoff; and
- Battery explosion.

The main recommendations include:

- Security fencing around the facility in accordance with AS 1725:2003 *Chain-link fabric security fences and gates*.
- Separate security fencing around critical and hazardous assets in accordance with AS 1725.
- A CCTV security system should be installed in accordance with AS/NZS 62676.1.1:2020 *Video surveillance systems for use in security applications. System requirements - Performance requirements for video transmission*, as a minimum around critical and hazardous assets.
- Regular O&M inspections to monitor for breaches should be undertaken, in line with the regular scheduled maintenance regime. The maintenance frequency will be developed in later stages of the Project.
- Electrical assets shall be installed in accordance with AS/NZS 3000:2018 *Electrical Installations*.
- Maintenance personnel should be appropriately qualified (electricians A/B class).
- Design and use of internal access roads with turning circles that suit the type of vehicle to be used on site. Swept path modelling may be used to map appropriate space allocation and design turning circles.
- The speed of vehicles shall be limited near BESS units. The safe speed is to be determined at the detailed design stage when road locations and distances from BESS units are known. Speeds should be determined such that vehicles are not likely to breach security fencing (or supplemental vehicle barriers shall be adopted).
- Provision of adequate stand-off distances for batteries from other BESS units and PV units (as shown in Section 6 or as outlined in a Underwriters Laboratories (UL) 9540A test report).
- Provision of adequate ventilation to relieve the off gassing of combustible gases from thermal runaway in line with National Fire Protection Authority (NFPA) 69.
- Inclusion of a battery monitoring system in BESS units and an off-gas detection system.
- The development of a site-specific Emergency Response Plan by the Proponent in consultation with emergency services, and in accordance with NSW WHS Regulations [1] and the latest guidelines set by FRNSW in the guidance note *Fire safety study considerations for large-scale external lithium-ion battery energy storage systems* [2].
- Design of fire water containment system in one of two ways:
 - Permanent containment system: the civil design of the site can be scoped such that it is possible to contain all runoff in a designated catchment area (e.g., a bund or some form of holding basin); or
 - Temporary containment: the site can be designed such that, in the event of a fire brigade response that may lead to contaminated runoff, drainage can be thoroughly sealed, and firewater contained on-site. In essence, this is a temporary bund.
- Usage of BESS units containing explosion prevention systems in accordance with NFPA 68 and/or NFPA 69.

The qualitative analysis determined that a battery fire has the potential to lead to non-major off-site consequences. As such, this scenario was carried forward for consequence analysis. BESS fire modelling was performed for two indicative types of modular BESS units. Acceptance criteria were defined to determine the minimum stand-off distances required. The modelling results inform recommendations for the intra-site placement of equipment.

The modelling results should be used as a guide for ongoing project development. As the models assume a conservative worst-case scenario, it is expected that the ultimate technology selection will provide further detail that can be used as the basis to reduce the recommended spacing requirements. Therefore, the total area required for the BESS units will be calculated in the detailed design phase of the project.

Notwithstanding the modelling results, a 20 m setback distance from the outermost battery units to the site boundary is recommended to mitigate the risk of external fire events impacting the BESS installation and the risk of a fire incident at the BESS propagating off site.

It is recommended that the batteries selected are manufactured and tested using UL 9540A *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems*.

If it is required, a future fire safety study (FSS) conducted for this site as part of the planning approvals process will consider the aforementioned technical information guidelines by FRNSW [2].

A Before You Dig Australia (BYDA) survey was conducted on the 3rd August 2023 and did not identify any gas pipeline assets running through or along the site boundary.

A review of the “Victorian Big Battery Fire” is also part of this assessment, capturing lessons learned from this incident. Key lessons learned related to:

- Commissioning procedures;
- Electrical fault protection devices;
- Thermal roof design; and
- Spacing of battery enclosures.

The implications of the review for BSF are that separation distances that are presented in UL 9540A fire test reports are considered sufficient for prevention of fire propagation between units. The implementation of shielding of overpressure vents is recommended to prevent flames, hot gases, and radiant heat from entering the internal battery bay. It is also recommended that the BESS design that is selected for use at BSF has undergone UL 9540A testing, including 45-degree flame tilt scenario testing.

1. Introduction

1.1 Project Background

Edify Energy Pty Ltd ('the Proponent') is developing Burroway Solar Farm (BSF, 'the Project') at Burroway, New South Wales. The Project site will have generation capacity of 100 MW alternating current (AC). It includes associated infrastructure such as grid connection and a 100 MW/ 400 MWhr Battery Energy Storage System (BESS). The project aims to connect to an existing Essential Energy 132 kV line that runs through the Site via a new 132 kV substation. This development has been subject to the NSW planning process as a State Significant Development (SSD) Application (SSD no.5596873). As part of the Secretary's Environmental Assessment Requirements (SEARs) for this SSD, a Preliminary Hazard Analysis (PHA) is required to assess the BESS-related risk at the site. The project has not yet confirmed a technology selection and is currently considering two design options for the BESS:

- Option 1: Centralised BESS located adjacent to the project substation; and
- Option 2: A decentralised BESS distributed throughout the solar farm.

Both design options are considered as part of this PHA.

1.2 Site Description

The Project site ('the Site') is located in the Central West and Orana region and is within the Central West and Orana Renewable Energy Zone (REZ). It is 17.5 km north of Narromine and 27 km west of Dubbo, within the Pilliga Interim Biographical Regionalisation for Australia (IBRA) subregion. The Site is accessible via Eumungerie Rd and Dubbo-Burroway Rd.

A Before You Dig Australia (BYDA) was conducted on the 3rd August 2023 and did not identify any gas pipeline assets running through or along the site boundary.

An area of 495 ha has been selected for assessment ('Study Area') as seen below in Figure 1. The Study Area is the lot, Lot 10 in Deposit Plan 1251856, known as 'Kookaburra'.

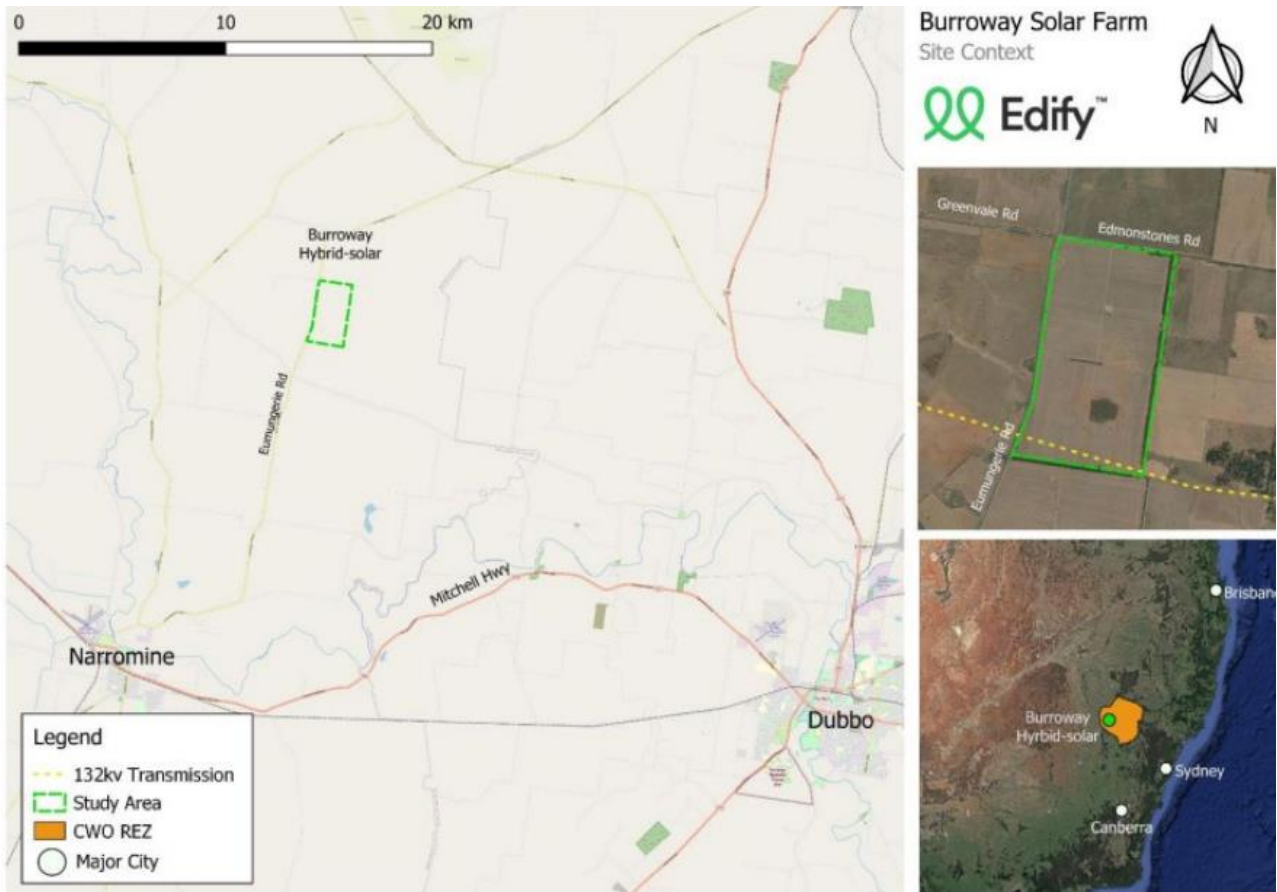


Figure 1: Site context map

The two options are present below in Figure 2 for the Option to Lease contract.

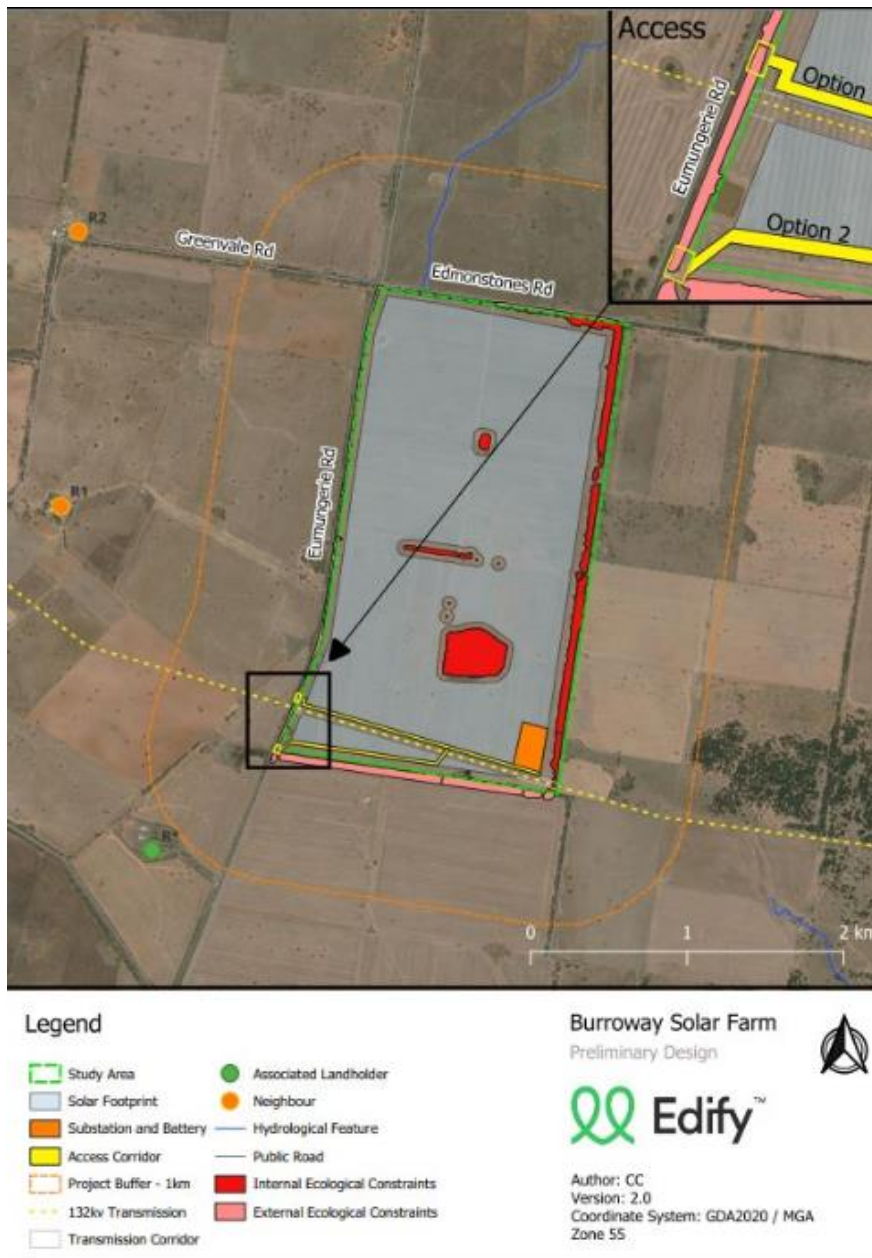


Figure 2: Indicate project development plan

1.3 Legislative Framework

The New South Wales *State Environmental Planning Policy (Resilience and Hazard) 2021* (Resilience and Hazard SEPP) commenced on 1 March 2022 [3]. The screening process is used to assess whether a development is “potentially hazardous” or “potentially offensive”.

The Resilience and Hazards SEPP incorporates the provisions of the now-withdrawn SEPP 33 in full. SEPP 33 was supplemented by supporting documentation providing guidance on its implementation, in particular the Hazardous and Offensive Development Application Guidelines *Applying SEPP 33* (2011) [4], which outlines the screening process used to assess whether the Resilience and Hazard SEPP applies (in the context of potentially hazardous or potentially offensive industry).

As the provisions of SEPP 33 are fully incorporated in the Resilience and Hazards SEPP, guidance material that refers to SEPP 33, including *Applying SEPP 33*, remains relevant and applicable. Any references to SEPP 33, particularly in extracts from *Applying SEPP 33*, should be taken as references to the Resilience and Hazards SEPP.

1.4 Purpose of Report

This report is prepared as a component of the Proponent's Environmental Impact Statement (EIS) to be submitted with the project Development Application (SSD 55968733). There are two SEARs to be addressed in this report, such that the EIS meets the requirements of the State Significant Development (SSD) framework. The relevant SEARs to be addressed in this report are discussed in more detail in Section 2.

The purpose of this report is to describe the hazards and risks associated with the proposal and the adequacy of safeguards. This includes determining if the proposed development is "potentially hazardous" and providing an assessment of hazards, risks, consequences and appropriate controls in line with relevant NSW policy and regulations. This information provides guidance to the Proponent, the regulator and other key stakeholders on how risks associated with the Project can be effectively managed and/or mitigated so it can be carried out with an adequate level of safety.

Under the Hazardous Industry Planning Advisory Paper No. 6 *Hazard Analysis* (HIPAP 6) [5] for the assessment of development proposals for NSW "the emphasis is on preventing or minimising major hazardous incidents on-site, such as fire and explosion or the release of significant quantities of toxic or biologically harmful chemicals, that could result in significant off-site effects".

The project is currently in the EIS preparation stage and key decisions regarding technology type and configuration have not yet been made. This report has been prepared based on the information currently available and, where required, conservative assumptions to allow for ongoing design flexibility. Hazards should continue to be assessed as design progresses and more detail is available

2. SEARs

The 12 SEARs that are required to be addressed to ensure that the EIS is of an appropriate standard to meet the requirements of the SSD framework are outlined in the Planning Secretary’s Environmental Assessment Requirements [6]. The relevant SEARs addressed in this report are listed in Table 2.

To determine if the development is “potentially hazardous” a preliminary risk screening must be completed in line with the Resilience and Hazard SEPP.

In addition to the Resilience and Hazards SEPP risk screening, a PHA must be prepared in accordance with the Hazardous Industry Planning Advisory Paper No. 6 *Hazard Analysis* [5] and *Multi-Level Risk Assessment* [7].

The SEARs requirements and the sections of this report in which these are addressed are presented in Table 2.

Table 2: SEARs requirements

Item	Source	SEARs Requirement	Relevant Section in Report
1	SSD-55968733 SEARs	Dangerous Goods - a preliminary risk screening completed in accordance with the State Environmental Planning Policy (Resilience and Hazards).	3
2	SSD-55968733 SEARs	Battery Energy Storage System - a Preliminary Hazard Analysis (PHA) prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis (DoP, 2011) and Multi-Level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No. 4, ‘Risk Criteria for Land Use Safety Planning (DoP, 2011)	4, 5, 6, 7

3. Resilience and Hazards SEPP

3.1 Resilience and Hazards SEPP Screening Process

Applying SEPP 33 describes the process to be followed when assessing whether a development application is to be considered *potentially hazardous*. Figure 1 of *Applying SEPP 33* (the SEPP 33 Process) is reproduced below in Figure 3. It should be noted that for SSDs, DPE is the responsible authority in the Resilience and Hazards SEPP process, not “council” as is referenced in Figure 1 from *Applying SEPP 33*, 2011 [4].

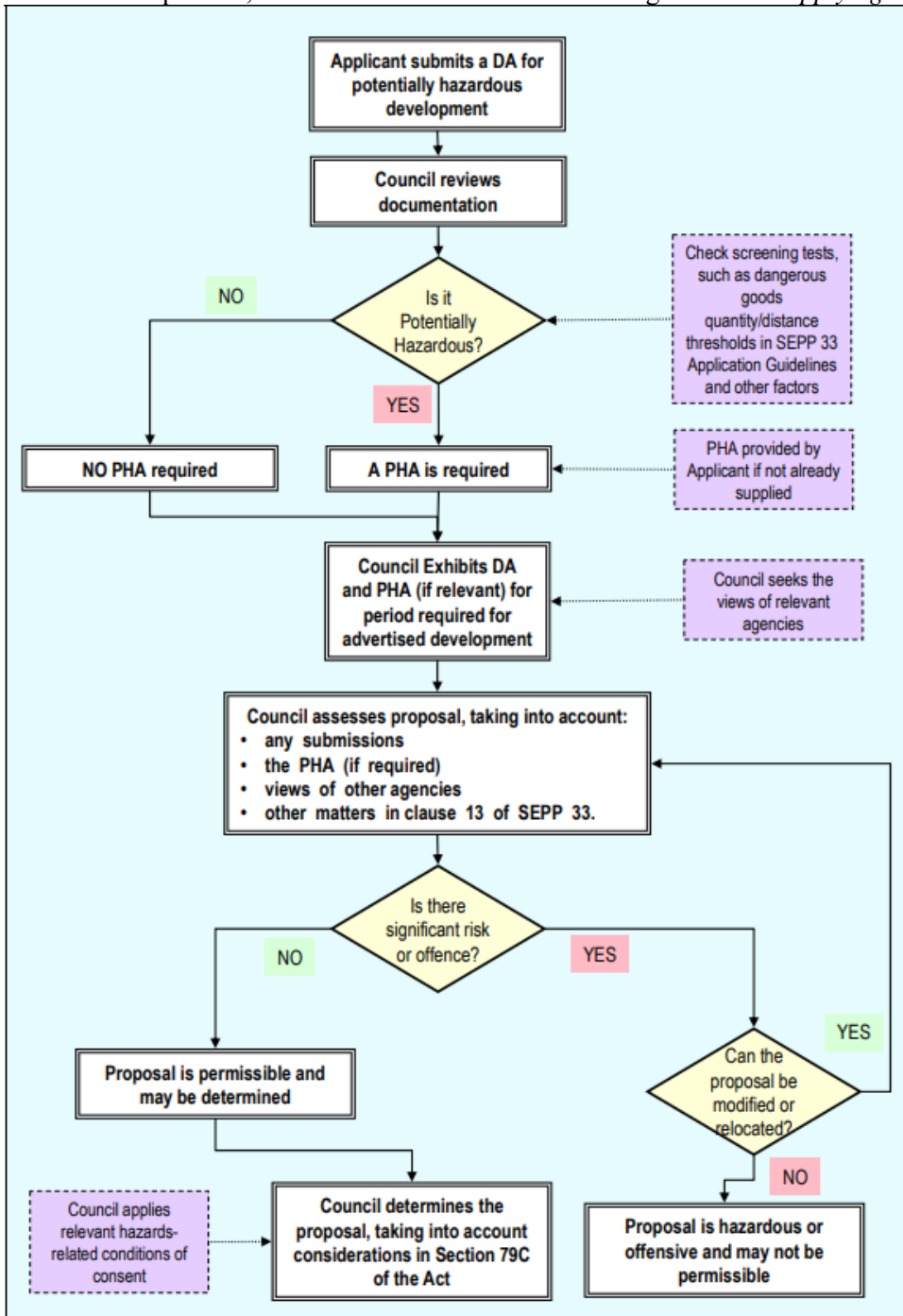


Figure 3: The Resilience and Hazards SEPP process (extract from *Applying SEPP 33* [4])

The screening method used to determine whether a development is potentially hazardous varies based on the class of dangerous good being assessed. Table 3 lists the table and figure references in *Applying SEPP 33* for the respective screening methods for each class of dangerous good.

Table 3: Screening method references in *Applying SEPP 33* [4]

Class	Description	Method to Assess Quantity (<i>Applying SEPP 33</i> references)	Method to Assess Transportation (<i>Applying SEPP 33</i> references)
1.1	Explosives – substances and articles which have a mass explosion hazard	Figure 5 (if > 100 kg)	Table 2
1.2	Explosives – substances and articles which have a projection hazard but not a mass explosion hazard	Table 3	Table 2
1.3	Explosives – substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both but not a mass explosion hazard	Table 3	Table 2
2.1	Flammable gases - pressurised (excluding LPG)	Figure 6 (if > 100 kg)	Table 2
2.1	Flammable gases - liquefied (pressure) (excluding LPG)	Figure 7 (if > 500 kg)	Table 2
2.1	Flammable gases - LPG (above and below ground)	Table 3	Table 2
2.3	Toxic gases	Table 3	Table 2
3PGI	Flammable liquids	Figure 8 (if > 2 tonne)	Table 2
3PGII	Flammable liquids	Figure 9 (if > 5 tonne)	Table 2
3PGIII	Flammable liquids	Figure 9 (if > 5 tonne)	Table 2
4	Flammable solids	Table 3	Table 2
5	Oxidisers, organic peroxides	Table 3	Table 2
6	Toxic substances	Table 3	Table 2
7	Radioactive material	Table 3	Table 2
8	Corrosive substances	Table 3	Table 2

Note: The risk screening methodology excludes classes 1.4, 1.5, 1.6, 2.2 and 9 from the risk screening as they are considered to not be potentially hazardous with respect to off-site risk [4]. Combustible liquids such as diesel are specifically excluded as dangerous goods in *Applying SEPP 33* and so are not considered for assessment.

3.2 Resilience and Hazards SEPP Screening Results

Based on Arup’s experience with similar developments, the dangerous goods that are expected to be stored on site are not anticipated to exceed the thresholds as defined in the Resilience and Hazards SEPP. As such a PHA is not required for the development as per Resilience and Hazards SEPP, however, as a requirement of the SEARs for the development, a PHA is required to be prepared to address the potential risks of the development.

4. Preliminary Hazard Analysis Guidance

PHAs are to be prepared in accordance with the relevant guidelines from NSW DPIE's *Multi-level Risk Assessment* [7] and Hazardous Industry Planning Advisory Papers No. 4 *Risk Criteria for Land Use Safety Planning* (HIPAP 4) [8] and No. 6 *Hazard Analysis* (HIPAP 6) [5].

During the analysis of the identified risks, reference is made to the relevant general principles as defined by HIPAP 4 [8] Section 2.4.1:

- The avoidance of all *avoidable* risks;
- The risk from a major hazard should be reduced wherever practicable, even where the likelihood of exposure is low; and
- The effects of significant risks should, wherever possible be contained within the site boundary.

Recommendations have been made against each of the identified risks to reduce and/or eliminate residual risks so far as is reasonably practicable (SFAIRP).

4.1 Multi-Level Risk Approach

The *Multi-Level Risk Assessment* approach is a basis for determining the level of risk assessment that is required considering the potentially hazardous nature of a project. It considers the project's location, the quantity and type of dangerous goods stored and used, and the technical and safety management control.

An overview of the approach is shown below in Figure 4.

Initially, a preliminary screening is performed, the methodology for which is set out in *Applying SEPP 33*. The screening is a broad estimation of all the possible off-site effects or consequences from hazardous materials. The requirement for further analysis can be determined if the quantities of stored hazardous materials surpass the screening thresholds.

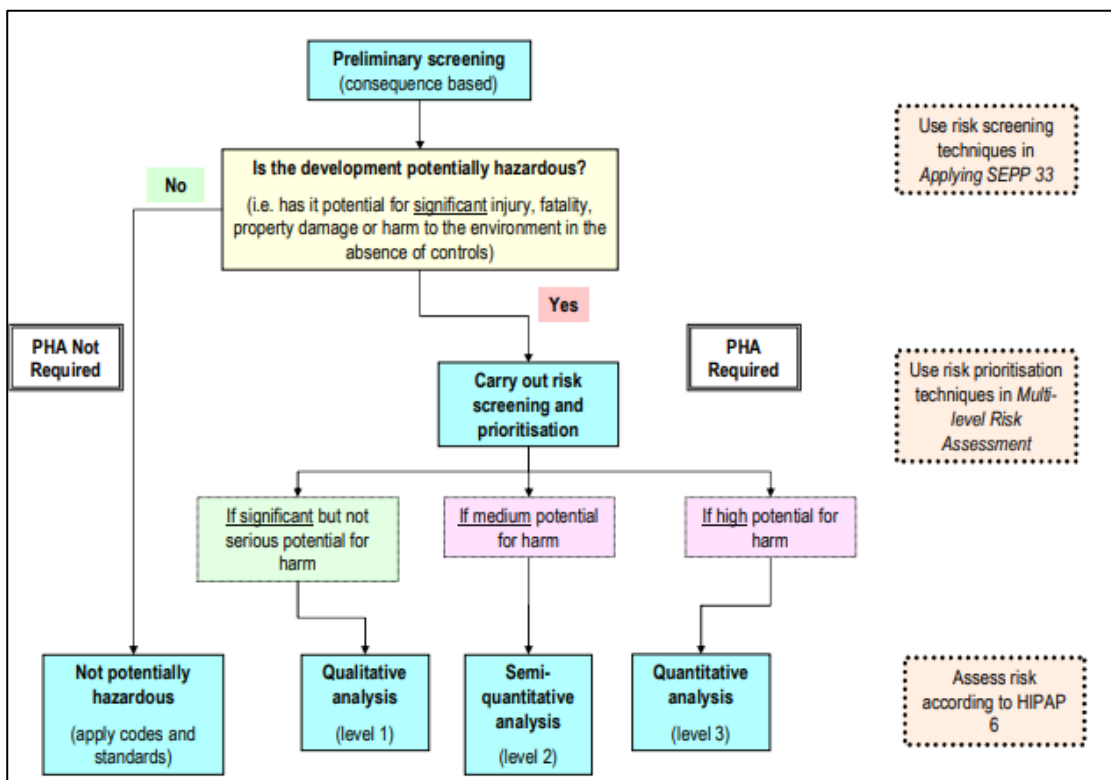


Figure 4: Multi-level risk assessment approach [7]

The potential risks are then screened and prioritised using the *Manual for the classification and prioritisation of risks due to major accidents in the process and related industries* [9]. This is a risk-based step that requires estimations of potential consequences and likelihood of accidents.

The three levels of risk assessment as defined by the NSW DPE (formerly known as NSW Department of Planning, Industry and Environment (DPIE)), are outlined in Table 4.

Table 4: Three levels of risk assessment as defined by the NSW DPE (formerly DPIE) [7]

Level	Type of Analysis Required	Summary of Assessment Criteria
Level 1	Essentially Qualitative	No major off-site consequences and societal risk is negligible
Level 2	Partially Quantitative	Off-site consequences but with low frequency of occurrence
Level 3	Fully Quantitative	Where Level 1 and Level 2 are exceeded

On the basis that the BESS units are spaced such that there is no fire propagation to the site boundary, other BESS units or the PV units, a **Level 1 qualitative risk assessment is determined** to be appropriate for Burroway Solar Farm as there are no major off-site consequences expected and hence the societal risk is negligible. The appropriate separation distances for BESS units have been calculated as part of a consequence analysis section of this PHA.

4.2 Preliminary Hazard Analysis Methodology

The following methodology is used to conduct the PHA for BSF:

- Hazard Identification** – A detailed HAZID is shown in Section 5 of this document for the site facilities, operations, and procedures related to start-up, shutdown, servicing, and commissioning.
- Consequence Analysis** – For hazards identified in the HAZID with potential to impact on and off-site sensitive receptors, consequence analysis is shown in Section 6 to provide the recommended separation distances. The modelling determines the distance impacted from the incident scenario and the results are then compared to HIPAP 4 acceptance criteria. From this comparison specified separation are determined.
- Reporting** – This PHA addresses SEARs requirements in Table 2

5. Hazard Identification

A qualitative hazard identification study (HAZID) was conducted for the Project. This HAZID was conducted by personnel with relevant experience of grid scale BESS units, to identify hazardous scenarios generated from the Project hazards that pose risks to the facility and its personnel.

The identified hazardous scenarios and their qualitative likelihood and consequence scores can be found in Appendix A. The hazardous scenarios assessed to be ‘moderate’ risk or higher in the HAZID, or where off-site consequences were identified have been carried forward for qualitative assessment.

The following hazardous scenarios have been brought forward for qualitative assessment:

- Security breach;
- Electrocutation;
- Vehicle impact with battery unit;
- Battery fire and ;
- Release of firewater runoff; and
- Battery explosion.

These hazardous scenarios are discussed in more detail in Section 5.1.

5.1 Hazardous Scenario Details

5.1.1 Security Breach

A security breach of the Site could credibly lead to theft or damage of equipment, or injury to staff, visitors or the instigators of the breach. This event is not considered likely to cause off-site impacts. Arup makes the following recommendations:

- Security fencing around the facility in accordance with AS 1725:2003 *Chain-link fabric security fences and gates*.
- Separate security fencing around critical and hazardous assets in accordance with AS 1725.
- A CCTV security system should be installed in accordance with AS/NZS 62676.1.1:2020 *Video surveillance systems for use in security applications System requirements - Performance requirements for video transmission*, as a minimum around critical and hazardous assets.
- Regular O&M inspections to monitor for breaches should be undertaken, in line with the regular scheduled maintenance regime. The maintenance frequency will be developed in later stages of the Project.

The recommendations provide a robust set of controls, with multiple layers of protection to minimise the likelihood of events escalating resulting in physical off-site impacts. Therefore, this scenario is not carried forward for further assessment.

5.1.2 Electrocutation

Electrocutation occurring in the BESS is a credible scenario that could lead to the injury or death of a person on site. Arup makes the following recommendations:

- Electrical assets shall be installed in accordance with AS/NZS 3000:2018 *Electrical Installations*; and
- Maintenance personnel should be appropriately qualified (electricians A/B class).

The recommendations provide a robust set of controls, with multiple layers of protection to minimise the likelihood of events escalating resulting in physical off-site impacts. Therefore, this scenario is not carried forward for further assessment.

5.1.3 Vehicle Impact

A vehicle impact with a BESS unit is a credible scenario that could lead to damage of BESS units or the serious injury of personnel. Arup makes the following recommendations:

- Security fencing around critical and hazardous assets in accordance with AS 1725.
- Design and use of internal access roads with turning circles that suit the type of vehicle to be used on site. Swept path modelling may be used to map appropriate space allocation and design turning circles.
- The speed of vehicles shall be limited near BESS units. The safe speed is to be determined at the detailed design stage when road locations and distances from BESS units are known. Speeds should be determined such that vehicles are not likely to breach security fencing (or supplemental vehicle barriers shall be adopted).
- Electrical assets shall be installed in accordance with AS/NZS 3000.

The recommendations provide a robust set of controls, with multiple layers of protection to minimise the likelihood of events escalating resulting in physical off-site impacts. Therefore, this scenario is not carried forward for further assessment.

5.1.4 Battery Fire

As the final battery technology has not yet been chosen for the site, this hazardous scenario has been considered for two different types of modular/cabinet battery units, which are described in Sections 6.2.2 and 6.2.3.

A fire could credibly form in a lithium-ion battery system as a result of a thermal runaway in one or more cells or from an external source such as a fire at the facility. Thermal runaway is a process whereby an equipment failure initiates a high temperature in the battery cells, which leads to exothermic reactions in the cells, releasing more heat and creating a further rise in temperature. A fire may result. A potential consequence is that a fire heats neighbouring cells and additional runaway exothermic reactions occur, causing the fire to spread from cell to cell. The fire can then propagate throughout the battery unit, and from unit to unit if the heat flux generated is large enough. There is a potential for a battery fire to have offsite impacts and as such, this scenario has been carried forward for consequence analysis in Section 6.

In addition to the information provided in Section 6, Arup makes the following recommendations:

- Provision of adequate standoff distances for batteries from other BESS units and PV units (as shown in Section 6 or as outlined in the UL 9540A test report).
- Provision of adequate ventilation to relieve the off gassing of combustible gases from thermal runaway in line with NFPA 69.
- Inclusion of a battery monitoring system in BESS units and an off gas detection system.
- The development of a site-specific Emergency Response Plan by the Proponent in consultation with emergency services and in accordance with NSW WHS Regulations [1].

5.1.5 Release of Firewater Runoff

In the event of a battery fire at the Site, the fire may be managed through the use of firewater for extinguishment or the application of cooling water to nearby assets, among other potential strategies. If firewater comes into contact with a burning battery unit or smoke from a battery fire, it may be contaminated. Therefore, it is possible that contaminated firewater may be present at the Site following a fire event. Contaminated firewater must be contained.

Broadly speaking, the contaminated firewater may be contained in one of two ways:

- Permanent containment system: the civil design of the site can be scoped such that it is possible to contain all runoff in a designated catchment area (e.g., a bund or some form of holding basin); or
- Temporary containment: the site can be designed such that, in the event of a fire brigade response that may lead to contaminated runoff, drainage can be thoroughly sealed, and firewater contained on-site. In essence, this is a temporary bund.

The most appropriate approach is determined as a function of the choice of battery technology, the “acceptable loss” strategy (i.e., whether the response to a fire is to suppress and extinguish, or to allow the unit to burn while protecting adjacent units), the design and budget implications on the broader site development, and fire brigade input to all of the above. This is therefore a decision that is to be made at the detailed design stage, once the configuration of the battery system is determined (i.e., centralised vs. decentralised). Runoff containment shall be designed such that contaminated water is prevented from reaching the hydrological feature located to the north-west (along Edmonstones Rd) of the Site boundary as seen in Figure 2.

5.1.6 Battery Explosion

Flammable vapours from thermal runaway reactions may accumulate in battery units. This could result in a confined vapour cloud explosion (VCE) occurring if there is a delay in the off gases finding an ignition source. The range of available battery technology on the market is evolving, with newer models tending to be smaller and externally accessible, compared to older models which were often housed in larger containers. The smaller unit size reduces the volume in which a flammable vapour cloud can form, in turn reducing the size of the potential explosion. Although it is not eliminated, overall, the risk of an explosion in a BESS facility has been reducing in recent years.

Most technologies incorporate a form of explosion protection into their units. Arup recommends the following explosion protection measures:

- Deflagration venting, designed in accordance with NFPA 68 *Standard for Explosion Protection by Deflagration Venting*; and/or,
- An exhaust system in accordance with NFPA 69 *Standard for Explosion Prevention Systems* to prevent reaching the lower explosive limit (LEL). The design of explosion protection is to be based on the cell level thermal runaway testing that forms part of the specific battery unit (determined in detailed design).

Underwriters Laboratories (UL) has released a research report [10] that provides an example of cell level thermal runaway properties, shown in Appendix B.

The battery system selected for the Site at the detailed design stage shall comply with NFPA 68 and/or NFPA 69. On this basis, the risk of potential off-site impacts from explosions is mitigated. This scenario is therefore not carried forward for consequence analysis.

6. Consequence Analysis

As per Section 5.1.4, a battery fire is identified as having the potential to cause off-site impacts. As such quantitative analysis is conducted to determine the appropriate separation distances to mitigate off-site impact SFAIRP. It should be noted that Arup recommends a minimum 20 m setback distance from the outermost battery unit to the site boundary irrespective of the modelling results. This is to mitigate the risk associated with external fire events impacting the BESS installation.

As the final battery technology has not yet been chosen for the site, this scenario is assessed for two types of modular/cabinet solutions, which are described in Section 6.2.2 and 6.2.3.

6.1 Acceptance Criteria

In order to determine the appropriate separation distances to mitigate potential off-site impacts and incident propagation on-site, HIPAP 4 and technical papers regarding the critical heat flux of PV panels are referenced.

HIPAP 4 provides criteria that define the maximum permissible heat radiation at the site boundary. Any heat radiation exposure above this level will cause injuries to humans. Similarly, HIPAP 4 defines the heat radiation that has potential to damage to structures and equipment within the site boundary. Additionally, technical papers are utilised to determine the maximum permissible level of heat radiation received by the PV panels.

According to HIPAP 4 [8], a radiation intensity of 4.7 kW/m^2 will cause pain and burn injuries to humans.

Moreover, HIPAP 4 [8] defines that at 12.6 kW/m^2 :

- The temperature of wood can rise to a point where it can be ignited by a naked flame after long exposure;
- Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure; and
- There is a significant chance of fatality with extended exposure and a high chance of injury.

As described in Yang et al. [11] and Ju et al. [12], typical PV panels and flexible PV panels have a maximum permissible heat flux of 26 and 20 kW/m^2 , respectively. As the PV panel technology has not been finalised 20 kW/m^2 will be utilised to calculate separation distances.

Therefore, sufficient separation distances must be provided such that:

- The heat radiation received at the site boundary is less than 4.7 kW/m^2 ;
- The heat radiation received at the adjacent modular/cabinet unit is less than 12.6 kW/m^2 ; and
- The heat radiation received by PV panels is less than 20 kW/m^2 .

6.2 BESS Fire Modelling

6.2.1 Key Assumptions and Fire Scenarios

A fire event in the two types of battery enclosures were modelled. In order to assess the worst credible case for off-site risk, it was assumed that all fire prevention measures had failed, and an enclosure had caught fire with all doors open on the unit. The modelling represents a worst-case scenario (upper bound), which can be refined as the project development progresses. Option 1 and 2 for the BESS layouts are considered.

The radiative heat flux emitted is calculated using the Stefan-Boltzmann Law:

$$j_{emitter}^* = \varepsilon\sigma T^4$$

where j^* is the radiant emittance, ε is the emissivity of the container, σ is the Stefan-Boltzmann constant and T is the surface temperature. The heat flux received is calculated using the view factor method. Further description of this methodology, the equations used and assumptions are presented in Appendix C.

The fire scenario is represented pictorially in Figure 5 (BESS Option 1) and Figure 6 (BESS Option 2).

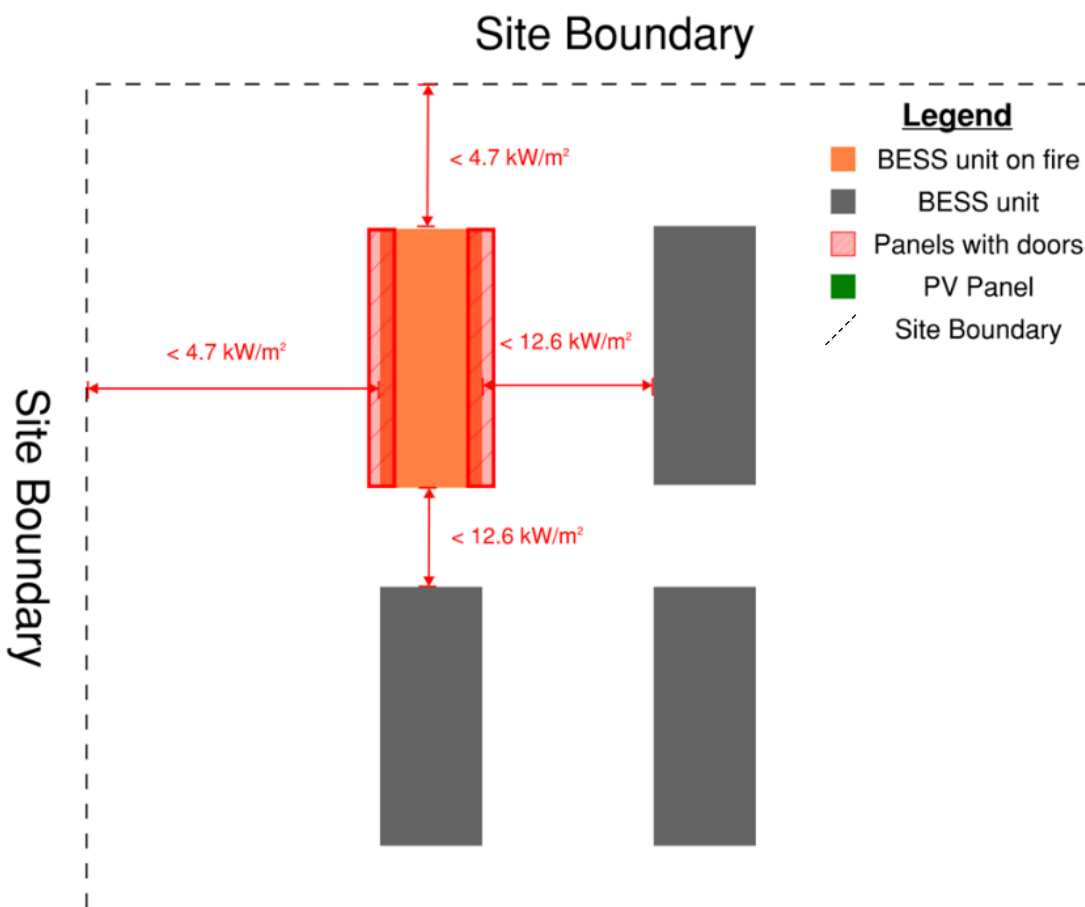


Figure 5: Pictorial representation of the centralised fire modelling scenario (not to scale)

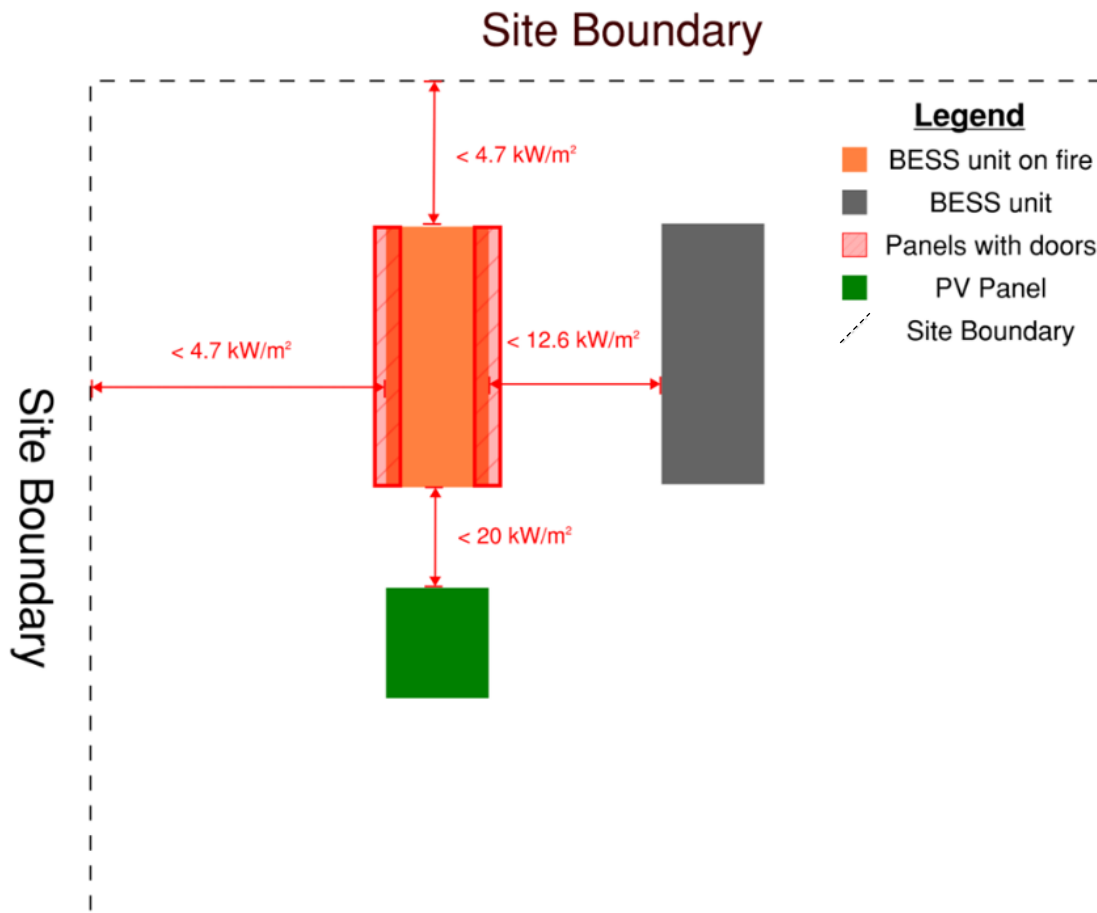


Figure 6: Pictorial representation of the decentralised fire modelling scenario (not to scale)

6.2.2 Modular/ Cabinet Type 1

A fire event in a battery unit is modelled to assess the impact on its surroundings. The modelling assumes that the battery management system and other safety features are unable to control thermal runaway, leading to a fire in the container.

The battery unit considered for this modelling is a large footprint rectangular prism unit with a 3 MWh storage capacity. The unit has dimensions of 7.14 m (L) x 1.60 m (W) x 2.36 m (H). It is assumed the unit has doors along the full length of the unit on a single side that are open when the fire breaks out, modelling a worst-case scenario event. A diagram of the fire scenario used for modelling can be seen in Appendix D.

Results

The results of the Type 1 BESS unit consequence modelling are shown in Table 5. Graphical and diagrammatical representations of the results can be seen in Appendix E.

Table 5: Results of type 1 unit consequence modelling

	Cabinet side	Site boundary * ($< 4.7 \text{ kW/m}^2$)	Adjacent modular/cabinet unit or structure ($< 12.6 \text{ kW/m}^2$)	Adjacent PV panels (for decentralised system) ($< 20 \text{ kW/m}^2$)
Type 1	Front/end of the modular/cabinet unit wall	2.5 m	1 m	1 m
	Door side of modular/cabinet unit wall	9 m	5 m	3.5 m
	Side of modular/cabinet unit wall	4.9 m	2.3 m	1.3 m

* As noted in Section 6 above Arup recommends a 20 m setback distance from the outermost battery unit to the site boundary irrespective of the modelling results.

Based on the assumed unit capacity of 3 MWh it is estimated that 200 Type 1 units would be required on the Site. The modelling results should be used as a guideline for ongoing project development. The area required by BESS units should be confirmed at the detailed design stage after technology has been selected.

6.2.3 Modular/ Cabinet Type 2

A fire event in a battery unit is modelled to assess the impact on its surroundings. The modelling assumes that the battery management system and other safety features are unable to control thermal runaway, leading to a fire in the container.

The battery unit considered for this modelling is a smaller footprint cube with a 1.12 MWh storage capacity. The unit has dimensions of 3.2 m (L) x 3.2 m (W) x 2.46 m (H). It is assumed the unit has a single door in the centre of one side one-third of the width of that side that is open when the fire breaks out, representing a worst-case scenario. A diagram of the fire scenario used for modelling can be seen in Appendix D.

Results

The results of the Type 1 BESS unit consequence modelling are shown in Table 6. Graphical and diagrammatical representations of the results can be seen in Appendix F.

Table 6: Results of type 2 unit consequence modelling

	Cabinet side	Site boundary * (<4.7 kW/m)	Adjacent modular/cabinet unit or structure (<12.6 kW/m ²)	Adjacent PV panels (for decentralised system) (<20 kW/m ²)
Type 2	Door side of modular/cabinet unit wall	4.1 m	2.2 m	1.8 m
	Side of modular/cabinet unit wall	3.1 m	1.6 m	1 m

* As noted in Section 6 above Arup recommends a 20 m setback distance from the outermost battery unit to the site boundary irrespective of the modelling results.

Based on the assumed unit capacity of 1.12 MWh it is estimated that 536 Type 2 units would be required on the Site. The modelling results should be used as a guideline for ongoing project development. The area required by BESS units should be confirmed at the detailed design stage after technology has been selected

6.3 Fire Tests

The analyses performed in Section 6.2 are independent of the details of specific technology options; this is a conservative approach which allows for greater flexibility in the final selection of technology options as the project progresses.

However, in the course of performing this more conservative analysis, design and safety features are not taken into consideration. It is appropriate to consider these features if a more specific analysis has been performed. Typically, this analysis takes the form of a fire test performed to appropriate standards, such as UL 9540A *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems* [13].

The UL 9540A method is referenced in UL 9540 *Standard for Energy Storage Systems and Equipment* and further in NFPA 855 *Standard for the Installation of Stationary Energy Storage Systems*, International Fire Code (IFC) [14] and other fire prevention codes.

Separation distances from UL 9540A fire tests would be an appropriate basis for the internal unit-to-unit spacing requirements for the BESS layout, regardless of what BESS unit technology is utilised.

Arup recommends that the 20 m setback distance between the edge of the outermost battery unit in the BESS and the site boundary be maintained irrespective of the results of the fire tests.

7. Victorian Big Battery Fire Review

7.1 Background

On 30 July 2021, a fire broke out at Neoen's 300 MW/450 MWh Victorian Big Battery (VBB) facility in Geelong, Australia. Thermal runaway occurred in one of the 212 Tesla Megapacks (MP) while the system was being installed and commissioned. The fire began in MP-1, resulting in the flame impinging onto a neighbouring Megapack, MP-2, the fire did not propagate any further and burned out after 6 hours. The Megapack had undergone UL 9540A fire testing to establish separation distances to minimize propagation of thermal runaway to adjacent units. The Megapacks failed safely and there were no explosions or deflagrations. As one of the largest battery installations in the world, the takeaways from this fire event are critical for future BESS installations.

7.2 Fire Causes

Fisher Engineering, Inc (FEI) found that a leak in the liquid cooling system caused arcing of the power electronics, which overheated the battery lithium-ion cells and led to thermal runaway. This was determined as the only likely cause from the evidence collected. MP-1, at the time, was being installed and commissioned and was disconnected via the keylock (effectively a lock-out tag-out safety feature that shuts off power for servicing or commissioning). This incident could have been prevented manually or automatically if the following factors did not occur.

The supervisory control and data acquisition (SCADA) system required 24 hours of activity before it began logging telemetry data and remote monitoring for the Megapack modules. When the fire struck, the module had only been operating for 13 hours meaning critical telemetry data such as the internal temperatures, fault alarms, etc, was not transmitted for remote monitoring. If the monitoring was active, the steep temperature increase in the unit when the fire started could have been detected.

Moreover, the commissioning procedures had the BESS unit switched off via a keylock, which caused many of the safety systems (telemetry, fault monitoring, electrical fault safety devices) to be disabled or have limited functionality. This led to the fire and thermal runaway being unnoticed, as telemetry data (e.g., temperatures, fault alarms) was not being transmitted to Tesla's off-site control facility due to the commissioning procedure.

Lastly, there was exposure of the liquid coolant onto the battery modules which likely disabled the power supply to actuate the pyro disconnect, which is a Tesla proprietary shunt- controlled pyrotechnic fuse. Actuation of the fuse would have likely prevented the fire from propagating from Megapack to Megapack.

7.3 Emergency Response

Tesla's Emergency Response Plan (ERP) and the facility's subject matter experts instructed the fire brigade to let the unit burn out and did not apply water onto either Megapack. Water was applied on equipment that was not designed to withstand the same thermal load as the Megapacks, i.e., electrical equipment and transformers. Cooling efforts lasted approximately 6 hours, followed by fire watch for almost 72 hours; highlighting the importance of a detailed ERP, availability of subject matter experts and pre-incident planning with the fire service.

7.4 Fire Propagation and Contributory Factors

The wind conditions on the day, 20-30 knots, caused the flames exiting the roof of the MP-1 to directly impinge on the neighbouring Megapack's thermal roof (deflagration vent); something the UL 9540A testing would not have shown due to the low wind conditions used (maximum 10.4 knots) in the test procedure. The direct flame impingement resulted in the ignition of the plastic overpressure vents that seal the battery bay from the thermal roof. These vents provided a direct path for flames and hot gases to enter the battery bay exposing the internal battery modules.

7.5 Key Lessons Learned

This incident uncovered key engineering operation and design flaws of Tesla's BESS. These can be considered as learning outcomes to better improve the VBB site and other BESS sites like the proposed Burroway Solar Farm. The learnings are summarised below:

7.5.1 Commissioning Procedures

Telemetry data was prevented from being transmitted when MP-1 first ignited due to the minimum 24-hour period required before data logging begins. This is not recommended as fire can occur at any period of operations, including start-up, shutdown and commissioning. Tesla has changed that period to 1 hour in response to the incident.

Additionally, the coolant system in the battery units need to be rigorously inspected during assembly of Megapack units and during end-of-line testing in the manufacturing process. This would assist in identifying and eliminating any leakages from occurring.

The Megapack's keylock function is to be limited to only be used when the unit is being serviced, not if the unit is being installed and/ or commissioned. This would ensure that the unit can transmit telemetry data, fault monitoring, and other electrical fault safety devices in case of an emergency.

7.5.2 Electrical Fault Protection Devices

In response to the electrical fault issues that contributed to the fire event occurring, the following safeguards were implemented. These recommendations ensure that the pyro disconnect's power supply was monitored and that all electrical fault protection devices were kept on regardless of the keylock's switch position.

- Alarms are to be installed to identify any coolant leakages in the unit;
- All electrical safety protection devices should be on regardless of keylock switch position; and
- Active monitoring and control of pyro disconnect's power supply, in the event that the power supply has failed.

7.5.3 Thermal Roof Design

Newly installed thermally insulated steel vent shields were designed to protect the plastic overpressure vents. The vents are shielded from direct flame impingement or hot gas intrusion; that is, the battery bay is isolated from the thermal roof. All new and existing Megapacks were fitted with this shield and unit tested to confirm that even with the entire roof on fire, the battery modules do not ignite and remain relatively unaffected. This mitigates the design weakness that allowed the potential for Megapack-to-Megapack fire propagation.

7.5.4 Spacing

With the vent shield mitigation detailed in Section 8.5.3, the spacing is sufficient to prevent fire propagation from Megapack to Megapack. The thermal insulation can provide thermal protection from a fire when the Megapack is installed 15 cm away in accordance with UL 9540A findings. The fire propagation was caused by the weakness in the thermal roof, not the heat transfer in the 15 cm spacing between the Megapacks.

7.6 Burroway Solar Farm Implications

The fire at VBB BESS highlighted that separation distances determined from UL 9540A fire testing is sufficient for prevention of fire propagation between units. Fire propagation occurred due to the unshielded venting in the overpressure vents which enabled the flames, hot gases, and radiant heat to enter the internal battery bay. Provided that appropriate shielding is implemented in the design, the separation distances from the UL 9540A fire testing are sufficient. The VBB highlighted the importance of ensuring that the BESS utilised at BSF undergoes UL 9540A testing including 45-degree flame tilt scenario testing.

8. Findings and Recommendations

This PHA, completed in accordance with the Resilience and Hazards SEPP finds that the proposal does not meet the criteria to be deemed potentially hazardous. However, the PHA was undertaken as a requirement of the SEARs.

The HAZIDs conducted identified six hazardous scenarios to be carried forward to qualitative assessment and one hazardous scenario relating to battery fire to be carried forward to consequence analysis.

The recommendations made in the management of hazardous scenarios in qualitative assessment and analysis are:

Security Breach

- Security fencing around the facility in accordance with AS 1725.
- Separate security fencing around critical and hazardous assets in accordance with AS 1725.
- A CCTV security system should be installed in accordance with AS/NZS 62676.1.1, as a minimum around critical and hazardous assets.
- Regular O&M inspections to monitor for breaches should be undertaken, in line with the regular scheduled maintenance regime. The maintenance frequency will be developed in later stages of the Project.

Electrocution

- Electrical assets shall be installed in accordance with AS 3000.
- Maintenance personnel should be appropriately qualified (electricians A/B class).

Vehicle Impact

- Security fencing around critical and hazardous assets in accordance with AS 1725.
- Design and use of internal access roads with turning circles that suit the type of vehicle to be used on site. Swept path modelling may be used to map appropriate space allocation and design turning circles.
- The speed of vehicles shall be limited near BESS units. The safe speed is to be determined at the detailed design stage when road locations and distances from BESS units are known. Speeds should be determined such that vehicles are not likely to breach security fencing (or supplemental vehicle barriers shall be adopted).
- Electrical assets shall be installed in accordance with AS 3000.

Battery Fire

Consequence analysis undertaken using BESS fire modelling found that, in order to meet acceptance criteria for reduced fire propagation risk, separation distances required for both types of modular and cabinet unit are as outlined in Table 7.

In addition to the separation distances required, the following is recommended:

- Provision of adequate standoff distances for batteries from other BESS units and PV units (as shown in Section 6 or as outlined in UL 9540A test report).
- Provision of adequate ventilation to relieve the off gassing of combustible gases from thermal runaway in line with NFPA 69.
- Inclusion of a battery monitoring system in BESS units and an off gas detection system.

- The development of a site-specific Emergency Response Plan by the Proponent in consultation with emergency services and in accordance with NSW WHS Regulations [1].

Table 7: Results of consequence modelling

	Cabinet side	Site boundary * ($<4.7 \text{ kW/m}$)	Adjacent modular/cabinet unit or structure ($<12.6 \text{ kW/m}^2$)	Adjacent PV panels (for decentralised system) ($<20 \text{ kW/m}^2$)
Type 1	Front/end of the modular/cabinet unit wall	2.5 m	1 m	1 m
	Door side of modular/cabinet unit wall	9 m	5 m	3.5 m
	Side of modular/cabinet unit wall	4.9 m	2.3 m	1.3 m
Type 2	Door side of modular/cabinet unit wall	4.1 m	2.2 m	1.8 m
	Side of modular/cabinet unit wall	3.1 m	1.6 m	1 m

* As noted in Section 6 above Arup recommends a 20 m setback distance from the outermost battery unit to the site boundary irrespective of the modelling results.

As these results are not based on specific technology selected it is deemed appropriate that future fire testing include consideration of design and safety feature of the technology. Fire tests should be undertaken in alignment with UL 9540A testing. Arup recommends a 20 m setback distance from the outermost battery unit to the site boundary irrespective the results of the fire tests.

The modelling results should be used as a guide for ongoing project development. As the models assume a conservative worst-case scenario, it is expected that the ultimate technology selection will provide further detail that can be used as the basis to reduce the recommended spacing requirements. Therefore, the total area required for the BESS units will be calculated in the detailed design phase of the project.

If it is required, a future fire safety study (FSS) conducted for this site as part of the planning approvals process will consider the aforementioned technical information guidelines by FRNSW [2].

Release of fire water runoff

Arup recommends that the fire water containment system is designed in one of two ways:

- Permanent containment system: the civil design of the site can be scoped such that it is possible to contain all runoff in a designated catchment area (e.g., a bund or some form of holding basin); or
- Temporary containment: the site can be designed such that, in the event of a fire brigade response that may lead to contaminated runoff, drainage can be thoroughly sealed, and firewater contained on-site. In essence, this is a temporary bund.

Battery explosion

The following explosion prevention measures are recommended:

- Deflagration vents in accordance with NFPA 68; and/or
- Exhaust system in accordance with NFPA 69.

Victoria Big Battery Fire Review

Key lessons learned from the Victorian Big Battery Fire review relate to:

- Commissioning procedures
- Electrical fault protection devices
- Thermal roof design
- Spacing of battery enclosure

The implications of the review for BSF are that separation distances that are presented in UL 9540A fire test reports are considered sufficient for prevention of fire propagation between units. The implementation of shielding of overpressure vents is recommended to prevent flames, hot gases, and radiant heat from entering the internal battery bay. It is also recommended that the BESS design that is selected for use at BSF has undergone UL 9540A testing, including 45-degree flame tilt scenario testing.

9. References

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Appendix A

BESS HAZID Risk Register

This HAZID assessment is specific to the identification of hazards and risks associated with dangerous goods and does not include hazards associated with general site construction, maintenance and operations where dangerous goods are not involved, such as slips, trips and falls. It is expected that general construction, operational and maintenance hazards will be managed as part of an appropriate wider site risk management process in line with AS ISO 31000:2018. The assessment is preliminary and based on the best available information available at the time. Any further dangerous goods identified as being required at the site in future stages of development will require additional assessment.

Table 8: BESS HAZID

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
Lithium-ion battery	A fault in the battery or damage to battery from impact leading to thermal run away of battery resulting in explosion of the battery unit or fire in the battery unit	Damage to surrounding assets. Serious injury	Major	Possible	High	<p>Preventative controls</p> <ul style="list-style-type: none"> • Adequate standoff distances of batteries from other BESS units, PV units. • Adequate ventilation to relieve the off gassing of combustible gases from thermal runaway and a gas detection system. • Inclusion of battery monitoring and gas detection systems. • Use of thermal CCTV security cameras to identify fires remotely. • The inclusion of lithium-ion batteries is to be incorporated into the overall fire safety strategy by the project fire engineer. 	This is expected to be a long developing scenario with a number of signals before an explosion or fire occurs in the battery unit. The controls listed will provide signals to operators as so that further preventative or mitigating actions might be taken. Controls to reduce the consequence by removing staff	Moderate	Unlikely	Moderate

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
						<p>Mitigating controls</p> <ul style="list-style-type: none"> • Coordination with local fire authorities. • Provision for complete flooding of individual battery cabinets in event of uncontrolled thermal runaway, may be a potential mitigating control if achievable within broader design constraints. 	<p>or personnel from the area.</p> <p>Standoff distances are a key control in reducing the consequence of this event. Further consequence modelling has been undertaken as part of the PHA to quantify conservative standoff distances for both Option 1 and Option 2.</p> <p>As such the controls implemented are considered to be SFAIRP. The risk is reduced from high to moderate.</p>			
Lithium-ion battery	Vehicle Impact with battery unit	Damage to assets. Serious injury.	Major	Unlikely	Moderate	<p>Preventative controls</p> <ul style="list-style-type: none"> • Use of perimeter fence around battery facility designed and 	<p>The controls reduce the likelihood of the</p>	Minor	Rare	Low

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
						<p>build in line with AS 1725.</p> <ul style="list-style-type: none"> • Use of internal access roads with turning circles that suit the type of vehicle to be used on site. Swept path modelling may be used to map appropriate space allocation and design turnaround circles. • Limit speed of vehicles within proximity of BESS units. Safe speed to be determined at later design stage where road locations and distances from BESS units are known. Speeds should be determined such that vehicles not likely to breach perimeter fence. • Normal electrical standards including AS 3000 and installation of appropriate earthing system. 	<p>event occurring by increasing physical barriers to BESS units, designing roads and speed limits such that loss of control of a vehicle is less likely to result in impact with a BESS unit.</p> <p>The consequence of the event is reduced by installation of an earthing system that prevents electrocution of vehicle operators and passengers in the event they do come into contact with the unit.</p> <p>As such the controls implemented reduce the risk from high to low. The risk is</p>			

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
							considered low and broadly acceptable manage with regular monitoring and review			
Lithium-ion battery	Fire spreading to battery unit from another source (including other battery on fire)	Damage to assets. Serious injury	Major	Possible	High	<p>Preventative controls</p> <ul style="list-style-type: none"> Adequate standoff distances of batteries from other BESS units, PV units. Adequate ventilation to relieve the off gassing of combustible gases from thermal runaway and a gas detection system. Inclusion of a battery monitoring and gas detection system. Use of thermal CCTV security cameras to identify fires remotely. The inclusion of lithium-ion batteries is to be incorporated into the overall fire safety strategy. <p>Mitigating controls</p> <ul style="list-style-type: none"> Coordination with local fire authorities. Provision for complete flooding of individual battery cabinets in 	This is expected to be a long developing scenario with a number of signals before an explosion or fire occurs in the battery unit. The controls listed will provide signals to operators as so that further preventative or mitigating actions might be taken. Controls to reduce the consequence by removing staff or personnel from the area.	Minor	Rare	Low

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
						event of uncontrolled thermal runaway, may be a potential mitigating control if achievable within broader design constraints.	Standoff distances are a key control in reducing the consequence of this event. Further consequence modelling has been undertaken as part of the PHA to quantify conservative standoff distances for both Option 1 and Option 2. As such the controls implemented reduce the risk from high to low. The risk is considered low and broadly acceptable manage with regular monitoring and review			
Lithium-ion battery	Damage to cells caused by external event resulting in leakage of	Clean up of materials required.	Minor	Unlikely	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Use of batteries that do not contain free liquid electrolytes. 	This risk is considered low and broadly acceptable manage with	Minimal	Unlikely	Low

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
	battery materials	Damage to adjacent equipment				<ul style="list-style-type: none"> Use of Individual cells to minimizes extent of release. 	regular monitoring and review			
Lithium-ion battery	Contaminated firewater run off due to battery fire, firefighting efforts	Environmental damage	Moderate	Possible	Moderate	<u>Mitigative controls:</u> <ul style="list-style-type: none"> Permanent or temporary provision for fire water containment 	Controls in place reduce the consequence to insignificant levels. The residual risk level is considered low.	Insignificant	Possible	Low
Over Head power lines	Collapse or fall of overhead lines.	Damage to assets. Serious injury.	Major	Rare	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Location of all equipment outside Essential Energy easements for overhead lines Adherence to AS 7000 for overhead lines 	This risk is considered low and broadly acceptable manage with regular monitoring and review	Insignificant	Rare	Low
Battery coolant	Minor leakage of coolant (typical of normal engine coolant) during minor maintenance activities at site, resulting in coolant entering eye	Eye irritation requiring first aid attention.	Insignificant	Possible	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Use of appropriately qualified maintenance personnel. Use of portable eye wash (squeeze bottle) for work on battery cooling system. Use of PPE when undertaking maintenance operations. 	This risk is considered low and broadly acceptable manage with regular monitoring and review	Insignificant	Rare	Low

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
Electrical Equipment	Person comes into contact with high voltage electricity as a result of a fault	Electrocution leading to serious injury.	Critical	Rare	Moderate	<p>Preventative controls</p> <ul style="list-style-type: none"> • Normal electrical standards including AS3000 and installation of appropriate earthing system. This may include the installation of a Residual Current Device (RCD) system that will shut off power if an earth leak occurs. This prevents electrocution if there was a case that someone comes in contact with the live system. • Use of appropriately qualified maintenance personnel. • SID should include capability to isolate BESS units for the purpose of maintenance and upgrades. This should be incorporated into a lockout system and permit to work, that ensures maintenance that requires potential contact with the batteries is undertaken only when batteries are isolated. 	Reduction in the consequence of the event is achieved through the ability to isolate the battery system before personnel are allowed to work in the area and the RCD safety system.	Minor	Rare	Low

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
Unauthorised personnel	Security breach of unauthorised personnel which leads to the theft of equipment and/or harm of staff	Damage to assets which will require replacement. Serious injury to staff.	Major	Rare	Moderate	<p>Preventative controls</p> <ul style="list-style-type: none"> • Installation of CCTV security system to monitor key areas. • O&M inspections to monitor for security breaches. • Installation of fencing around the site as well as the battery storage area/s in line with AS 1725. • The site will not be manned during normal operations, reducing exposure time. 	Controls in place assist in reducing the likelihood, by increasing difficulty of access. Likelihood is already rated as Rare. The removal of staff from areas of risk and isolation in secure areas is expected to reduce the consequences of such an event. This risk is considered tolerable with industry recognized risk controls identified. To ensure SFAIRP is met these controls must be implemented, monitored, and reported on with respect to their ability to reduce risk.	Major	Rare	Moderate

Hazard	Description of unwanted event or scenario	Consequences description	Consequence rating	Likelihood rating	Risk	Controls	SFAIRP comments	Residual risk		
								Consequence rating	Likelihood rating	Risk
Flooding	Water entering the property and coming into contact with electrical equipment	Restricted access to the site. Damage to electrical assets resulting in required replacement.	Moderate	Rare	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Undertake a site-specific flooding/hydrology study to determine site flood risk. Install all electrical equipment to be above the flood level with some freeboard. 	This risk is considered low and broadly acceptable manage with regular monitoring and review	Moderate	Rare	Low
Lightning strike	Lightning striking facility	Damage to assets. Injury to persons	Minor	Unlikely	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Completion of a lightning risk assessment in accordance with AS 1768. Include lightning protection measures if deemed necessary. 	This risk is considered low and broadly acceptable manage with regular monitoring and review	Minor	Unlikely	Low
High wind events and seismic events	High wind or seismic events causing structural damage to equipment or battery packs	Damage to equipment and injury to personnel	Minor	Rare	Low	<u>Preventative controls</u> <ul style="list-style-type: none"> Design in accordance with AS 1170 considering appropriate wind speed and seismic design requirements. 	This risk is considered low and broadly acceptable manage with regular monitoring and review	Minor	Rare	Low

Appendix B

Example Cell Level Thermal Runaway Properties

Table 9: Example Cell Level Thermal Runaway Properties

Property	Measurement
Cell vent temperature	130 °C
Thermal runaway temperature	204 °C
Gas volume	213 L
Gas composition	36.2 v% carbon monoxide; 22.1 v% carbon dioxide; 31.7 v% hydrogen; 10.0 v% hydrocarbons <u>Hydrocarbon breakdown</u> 7.4 v% methane; 0.92 v% ethylene; 0.61 v% ethane; 0.22 v% propylene; 0.04 v% propane 0.07 v% C4-hydrocarbons; 0.24 v% benzene; 0.03 v% toluene; 0.38 v% dimethyl carbonate
Gas LFL	8.9 v%
Gas UFL	40 v%
Gas P _{max}	93 psig
Gas burning velocity	35 cm/s

Appendix C

Heat Radiation Calculations

A fire event in a battery unit is modelled. In order to assess the worst credible case off-site risk, it is assumed that all fire prevention measures have failed, and a unit has caught fire.

The radiative heat flux emitted from the surface of the unit is calculated using the Stefan-Boltzmann Law:

$$j_{emitter}^* = \varepsilon \sigma T^4$$

where j^* is the radiant emittance, ε is the emissivity of the unit/smoke, σ is the Stefan-Boltzmann constant and T is the surface temperature. The heat flux received is calculated using the view factor method:

$$j_{receiver}^* = 4 \cdot \Phi \cdot j_{emitter}^*$$

The view factor, Φ , is given by the equation.

$$\Phi = \frac{1}{2\pi} \left[\frac{a}{(1+a^2)^{1/2}} \tan^{-1} \frac{b}{(1+a^2)^{1/2}} + \frac{b}{(1+b^2)^{1/2}} \tan^{-1} \frac{a}{(1+b^2)^{1/2}} \right]$$

The parameters a and b are given by the following equations, where h is half the height of the surface, w is half the width of the surface and s is the perpendicular distance from the surface to the point of interest:

$$a = \frac{h}{s} ; b = \frac{w}{s}$$

This is represented graphically as follows:

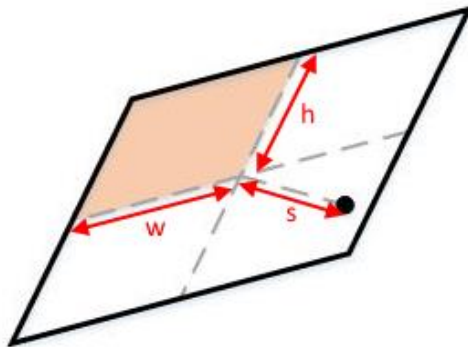


Figure 7: Calculation geometry

The following assumptions form the basis for the modelling:

- The temperature of open doors on the BESS units which represents the worst-case scenario fire event, are set to 840 °C (flame temperature). This is representative of an emitting heat flux of 84 kW/m² which is used for fire spread design between buildings such as offices (Approved Document B) [15] While the units do contain batteries, which would have combustible contents and some plastic materials, the overall structure of the enclosure is to be non-combustible and the majority of racking within the space is constructed of non-combustible metal. This results in a comparable fuel load. 840 °C is also within the flame temperature range recommended for use for fires based on the Fire Engineering Design Guide [16]. While adiabatic flame temperature is based on the chemistry of a flame, within a compartment the overall compartment dynamics and air ratio influence the temperature of a flame;
- The temperature of closed doors and container walls is set at 600 °C, which is generally the temperature at which flashover begins in a compartment as per the SFPE Handbook [17] and CIBSE Guide E [18]. This represents a severe fully developed fire throughout the container. While a flashover fire may reach higher temperatures than 600 °C, given that the enclosure has 60-minute rated fire walls, it is unlikely that the external surface temperatures would reach 600 °C or beyond;

- The emissivity of the door opening is taken to be 0.9. This represents a conservative emissivity for a severe fire and a good radiator;
- It is assumed that the radiating panel shall be based on the full height and length of the relevant modular/cabinet unit side at 600 °C;
- The heat flux from the emitting surface is assumed to be uniform; and
- No heat loss is assumed to intermediate media (i.e., to air or smoke).
- The basis of the fire modelling is to consider the worst-case conditions. It is a consequence-based assessment. In this context historical wind data does not affect the consequence assessment. Further, as detailed above the fire modelling ignores the integrity and insulation rating of the unit, providing further conservativeness.

Appendix D

Fire Scenarios

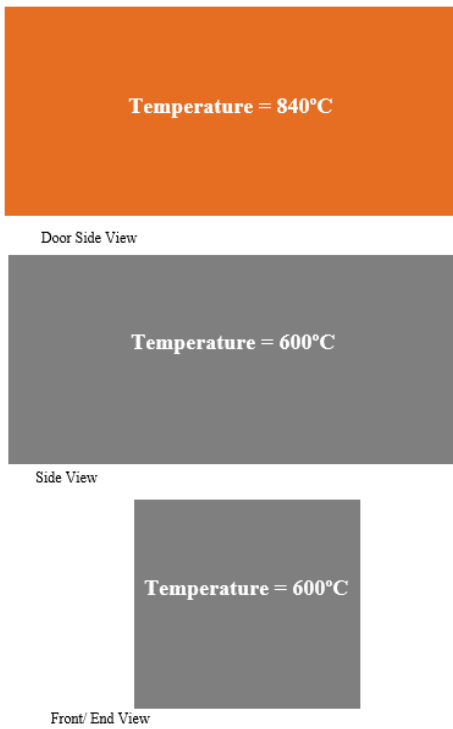


Figure 8: Type 1 BESS unit fire scenario

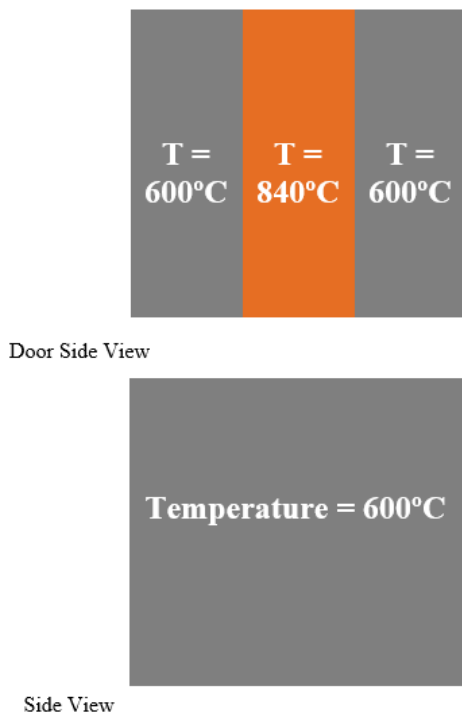


Figure 9: Type 2 BESS unit fire scenario

Appendix E

Type 1 Unit Consequence Modelling Graphical and Diagrammatical Representation

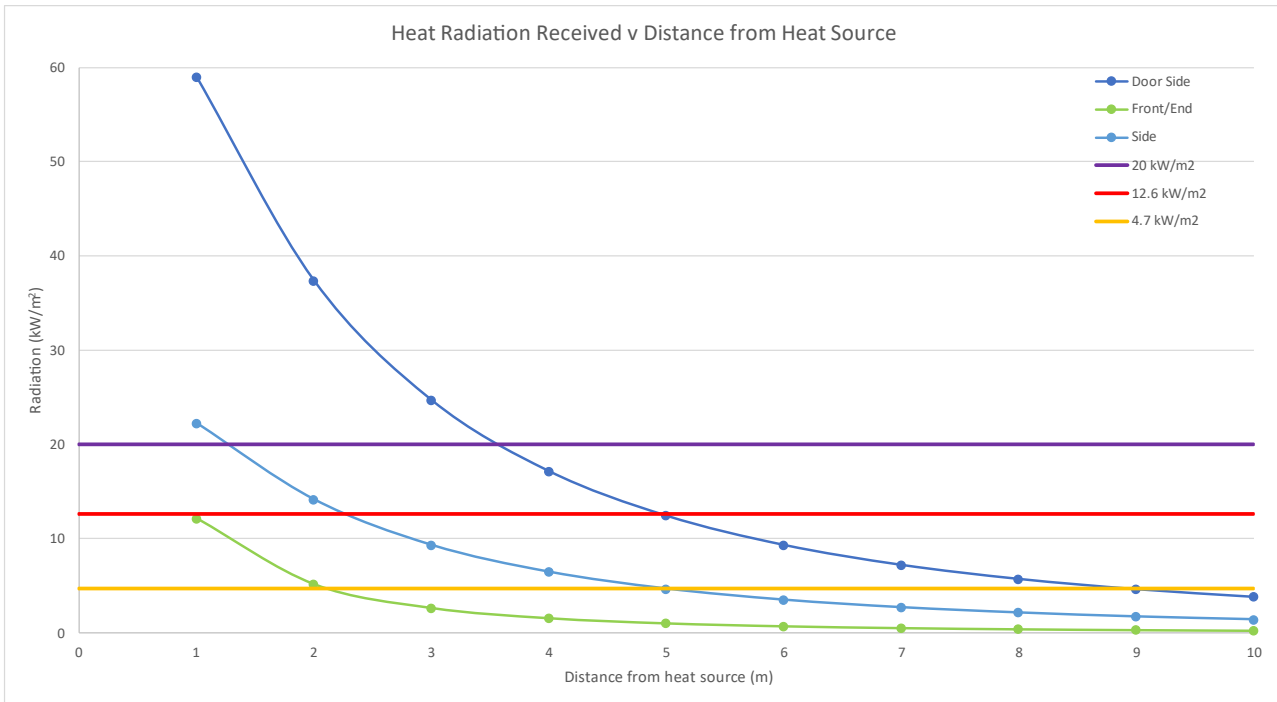


Figure 10: The results of the fire modelling for type 1 unit, showing heat flux radiation plotted against the separation distance

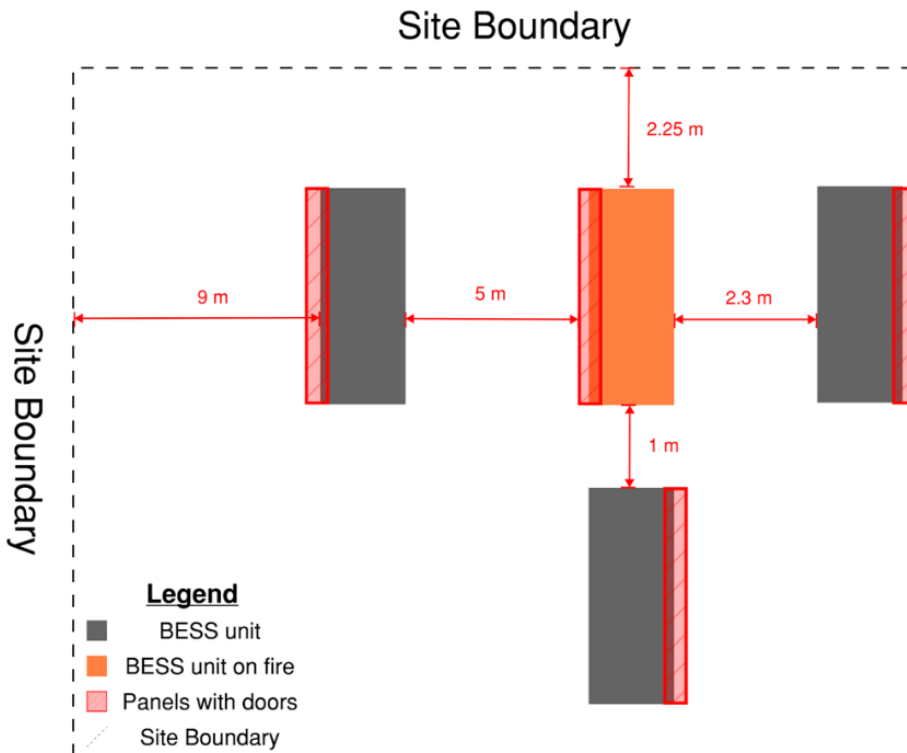


Figure 11: Type 1 centralised BESS layout option (not to scale)

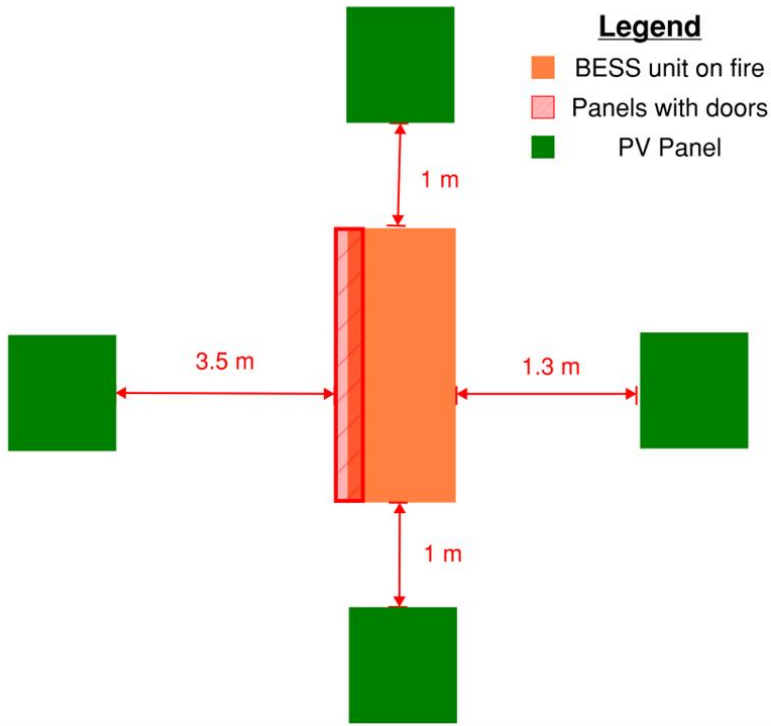


Figure 12: Type 1 decentralised BESS layout option (not to scale)

Appendix F

Type 2 Unit Consequence Modelling Graphical and Diagrammatical Representation

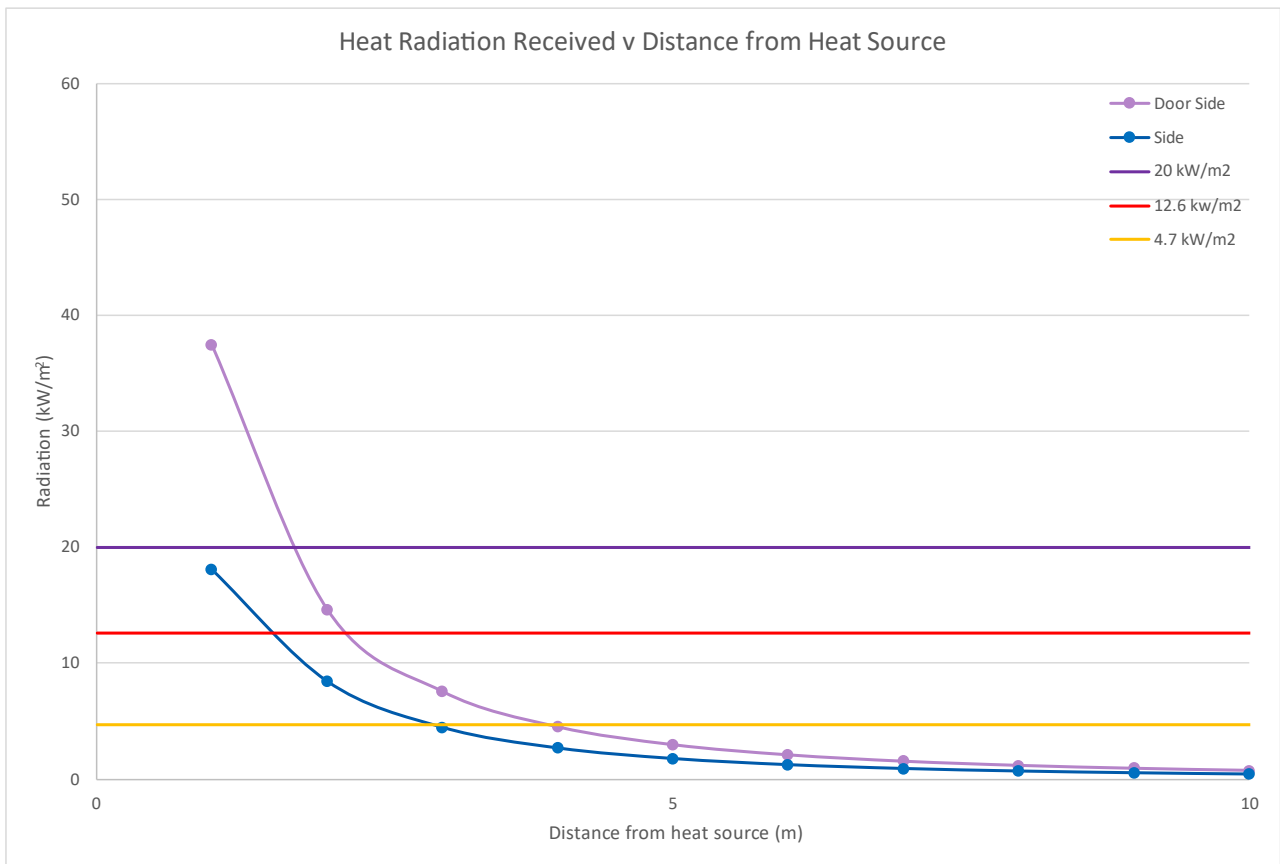


Figure 13: The results of the fire modelling for type 2 unit, showing heat flux radiation plotted against the separation distance

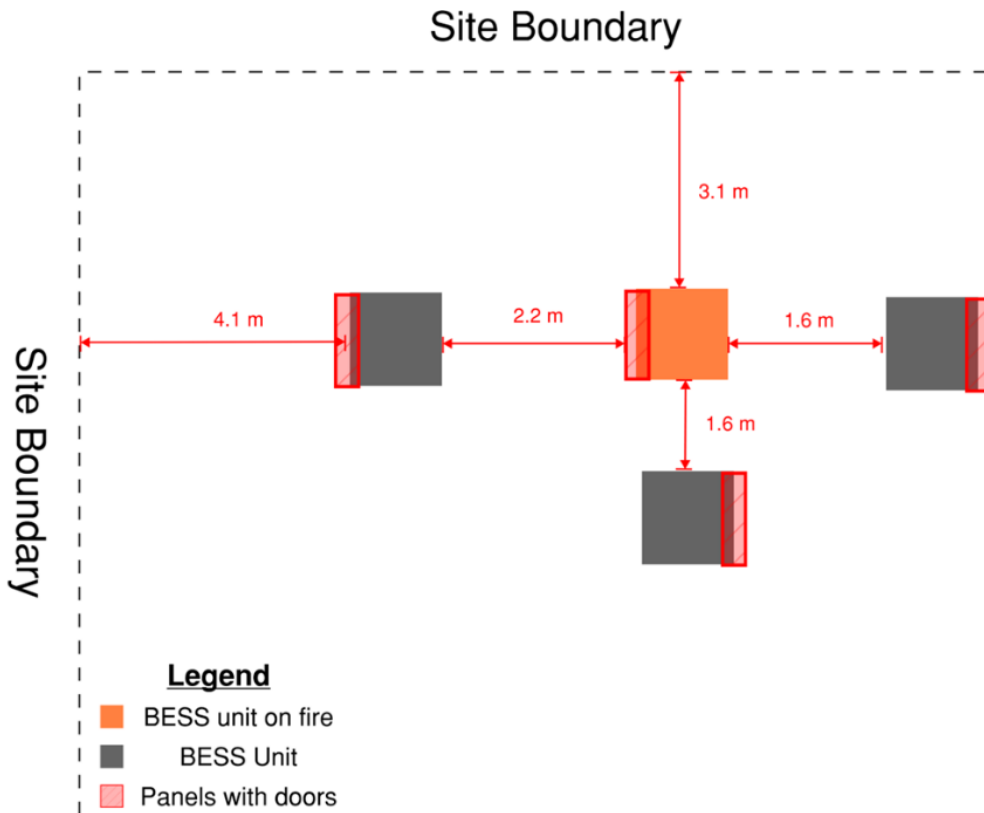


Figure 14: Type 2 centralised BESS layout option (not to scale)

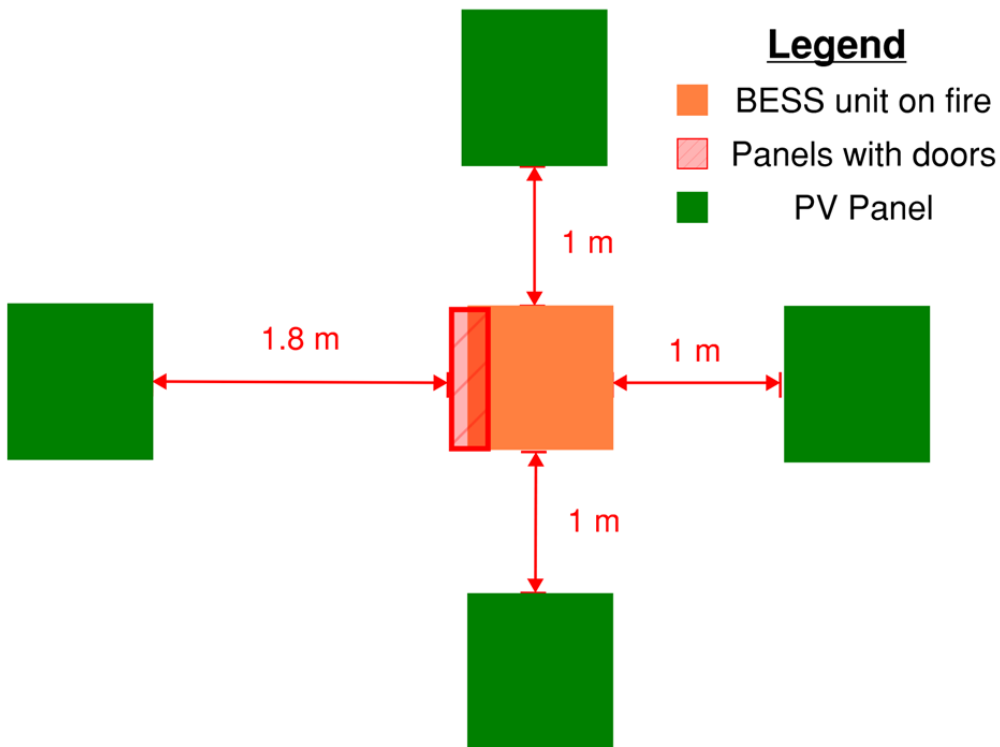


Figure 15: Type 2 decentralised BESS layout option (not to scale)