Risk Management Assessment Report (Fire Safety Study and Risk Assessment) for Rutherglen BESS Project

For Red Hill Renewable Energy Pty Ltd

28 April 2026

Doc. No.: J-000893-REP-01

Revision: 1

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DOCUMENT HISTORY AND AUTHORISATION

Rev	Date	By	Description	Check	Approved
A	10 Feb 2026	RR	First draft for client review.	JL	RR
B	26 Feb 2026	RR	Final draft with comments incorporated	-	RR
0	27 Feb 2026	RR	Final issue	-	RR
1	28 Apr 2026	RR	Updated to include reference to	-	RR

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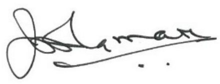
RPEQ: 15457



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Notation

Abbreviation	Description
AC	Alternating Current
Ah	Ampere hours
AS	Australian Standard
BESS	Battery Energy Storage System
BMS	Battery Management System
C_2H_4	Ethylene
CO_2	Caron Dioxide
ESD	Emergency Shutdown
FACP	Fire Alarm Control Panel
FIP	Fire Indicator Panel
FRL	Fire Resistance Level
FSS	Fire Safety Study
ft	Feet
GWh	Gigawatt hour
H_2	Hydrogen
ha	hectares
HIPAP	Hazardous Industry Planning Advisory Paper (NSW)
HV	High Voltage
kg/m^3	Kilogram per cubic metre
kg/s	Kilograms per second
kL	Kilolitres
km	kilometres
kPa	Kilopascals
kV	kilo-volt
kW/m^2	Kilowatts per square metre
L	Litres
L/min	Litres per minute
$L/min/m^2$	Litres per minute per square metre
LCS	Local Control Station
LEL	Lower Explosive Limit (also referred to as Lower Flammability Limit)
LIB	Lithium Ion Battery

Abbreviation	Description
LiFePO4	Lithium Iron Phosphate (LFP)
m	metres
m/s	Metres per second
m^2	Square metres
mm	millimetres
MMI	Modified Mercalli Index
MVA	Megavolt Amperes
MW	Mega Watt
MWh	Mega Watt hour
N/A	Not Applicable
NCC	National Construction Code
NFPA	National Fire Protection Association
O&M	Operations and Management
PCS	Power Converter System
PO	Performance Outcome
ppm	Parts per million by volume
QFD	Queensland Fire Department
RHRE	Red Hill Renewable Energy
SCADA	Supervisory Control and Data Acquisition
SDAP	State Development Assessment Provisions
UN	United Nations
V	Volt
VAD	Visual Alarm Devices

1 STATEMENT REGARDING ACHIEVEMENT OF PERFORMANCE OUTCOMES

Red Hill Renewable Energy Pty Ltd (RHRE) is proposing to construct a Battery Energy Storage System (BESS) at 837 Red Hill Road, Bororen, Queensland. It is referred as the Rutherglen BESS facility.

A hazard and risk assessment report for the facility under Queensland State Development Assessment Provisions (SDAP) Code 21: Hazardous chemical facilities [1] was prepared by Arriscar Pty Ltd [2].

The development needs to demonstrate compliance with the performance outcomes listed in State Code 27: Battery storage facility development [3]. Part of the requirements regarding natural hazards overlap between State Code 21 and State Code 27. The additional requirements in Code 27 are a Fire Safety study (FSS) and a risk assessment.

The present report undertaken by Arriscar Pty Ltd has addressed compliance with the Performance Outcomes in State Code 27 [3] for the proposed Rutherglen BESS facility. Only the performance outcomes relevant to safety and risk related matters are addressed in Table 1.

Table 1: Compliance with Performance Outcomes in State Code 27

Performance outcomes	Response
Risk mitigation	
PO2 Development is designed, sited and constructed to ensure that risks from physical hazards, chemical hazards and battery failure hazards are avoided and/or mitigated with respect to: • **human health and safety; and** • **the built and natural environment.**	☒ Compliant ☐ N/A ☐ Performance Solution As detailed in the hazard analysis report in Ref. [2]
PO3 Development mitigates the risks of fire, explosion and thermal runaway from battery storage infrastructure.	☒ Compliant ☐ N/A ☐ Performance Solution As detailed in in the hazard analysis report in Ref. [2] and in Section 11.
PO4 Development is designed to ensure fire and thermal events can be contained and isolated to prevent escalation and propagation to other developments and uses on and offsite	☒ Compliant ☐ N/A ☐ Performance Solution As detailed in Section . Compliance is expected to be achieved on the implementation of the recommendations of this report.
Incident response	
PO5 Development is designed to facilitate effective and efficient emergency service access and response in the event of a fire, bushfire (including cleared firefighting areas at the interface of hazardous vegetation), explosion, contamination leak or any other incident requiring an emergency service response.	☒ Compliant ☐ N/A ☐ Performance Solution Bushfire mitigation plan in Ref. [4]

Performance outcomes	Response
PO6 The development: • provides appropriate fire detection, monitoring and notification to the site operator; and • ensures the electrical safety of the facility, in the event of an incident requiring emergency response.	☒ Compliant ☐ N/A ☐ Performance Solution
PO7 Development demonstrates that there is capacity to provide a reliable, sustainable and fit-for-purpose water supply.	☐ Compliant ☐ N/A ☒ Performance Solution. See Section 7.5.
Natural hazards	
Covered in the hazard analysis report in Ref. [2] and the bushfire mitigation report in Ref. [4].	☒ Compliant ☐ N/A ☐ Performance Solution
Protecting water quality and stormwater management	
PO18 Development prevents the release of contaminants to surface water or groundwater in the event of an incident, including a fire or explosion.	☐ Compliant ☐ N/A ☒ Performance Solution. See Section 9.

2 INTRODUCTION

2.1 Background

Red Hill Renewable Energy Pty Ltd (RHRE) is proposing to develop a standalone Battery Energy Storage System (BESS) at 837 Red Hill Road, Bororen, Queensland. The site is located at approximately 52 km from Gladstone Central and falls within the Gladstone regional Council.

The facility will have a capacity of 400 megawatts (MW), up to 4 hours of energy storage from each charge (1600 MWh).

Approval requirements for battery storage development are covered in Queensland by the State Development Assessment Provisions (SDAP) Code 27 [3].

Arriscar Pty Ltd has been commissioned by RHRE to conduct the studies relating to safety and risk as listed in State Code 27 [3].

2.2 Scope of the Study

A hazard and risk assessment report for State Code 21 compliance [2] has covered some of the requirements of State Code 27 [3], as listed in the Planning Guideline in Ref. [5].

The present scope covers:

- Fire Safety Study
- Risk Assessment
- Assessment of compliance with relevant POs of State Code 27.

A hazard and risk assessment report for the facility under Queensland State Development Assessment Provisions (SDAP) Code 21: Hazardous chemical facilities [1] was prepared by Arriscar Pty Ltd [2]. It addresses the following items that overlap with State Code 27.

- Natural Hazard Risk Assessment
- Flood Assessment

A Bushfire Mitigation Report has been prepared by Eldon Bottcher Architect Pty Ltd [4] and is not covered here.

An Operational Emergency Management Plan has been deferred pending approval of the development and final facility design. This is expected to be a condition of development consent.

2.3 Study Basis

The present study is based on the following documents:

- Hazardous Industry Planning Advisory Paper No.2 – Fire Safety Study [6];
- AFAC Guideline for Large-scale BESS installations [7];
- State Code 21 compliance assessment report for Rutherglen facility by Arriscar [2];
- Bushfire mitigation report by Eldon Bottcher Architect Pty Ltd [4]; and
- Review report of available international fire protection standards.

3 SITE LOCATION AND DESCRIPTION

3.1 Site Location

The proposed site is approximately 7 km east of the township of Bororen, Qld. The site boundary encompasses an area of approximately 1,278 hectares (ha) (refer to Figure 1). The site address is 837, Red Hill Road, Bororen, Queensland 4678.

The site is located at approximately 52 km southeast of Gladstone Central, and the local government authority is Gladstone Regional Council.

Figure 1: Location of Rutherglen BESS Facility

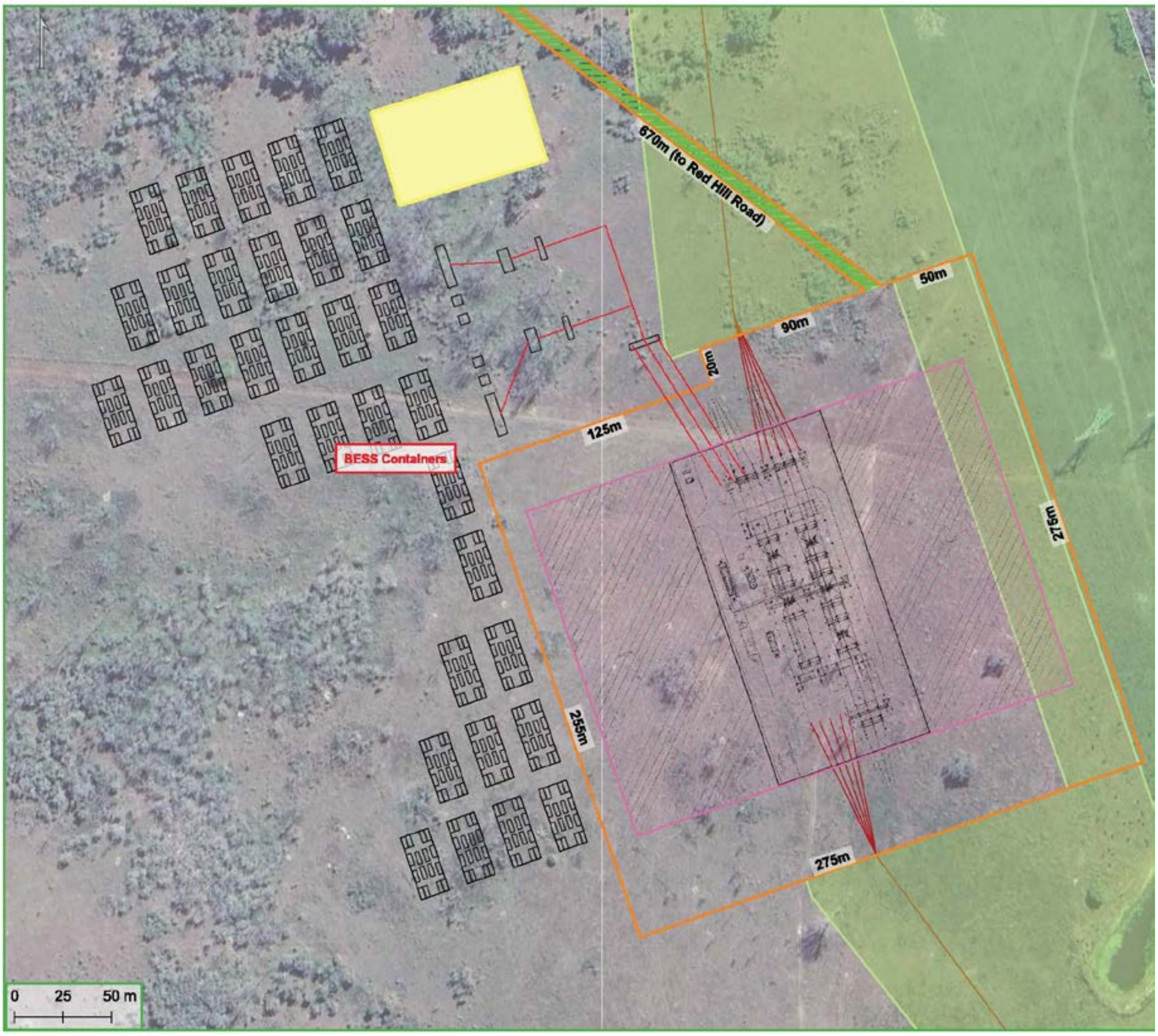
Source: Google Earth Pro

3.2 Site Description

The site is designated as Lot 132 in FD 700 and is located at 837 Red Hill Road, Bororen, Queensland. The development site is a total of ~25ha within the 1,277ha Lot 132. The specific disturbance area of the BESS is approx 6.6ha within the 25ha total.

A site plan is shown in Figure 2. Site access is from Red Hill Road. The land is described as plain and undulating. The area surrounding the site consists of gorges and mountains. The Erimbula National Park abuts the eastern boundary of the site.

Figure 2: Rutherglen Project BESS and Switchyard Site Plan



The Project area consists of 25ha (BESS + Switchyard). RHRE is applying to the Council for subdivision of Lot 132 in FD 700. Once granted, the Project area will become Lot 1 (BESS) and Lot 2 (Switchyard). The balance of the land (~1,252ha) will become Lot 3.

4 DESCRIPTION OF FACILITY

4.1 Overview

The Project involves the construction, operation and commissioning of a battery energy storage system with associated electrical equipment for grid interface. It operates by storing energy in batteries and converting it between AC and DC using power electronics, while interfacing with the Powerlink transmission network through a 275kV Substation.

High voltage (HV) AC power from power grid system is connected to power transformers that step down the voltage from 275 kV to 33 kV. Power converters convert the 33 kV power to 1500V direct current (DC) used to charge the battery units.

When power is to be drawn from the battery system, the power converters invert the DC power to 33 kV AC, which are again stepped up to 275 kV AC for feeding the grid.

The BESS an energy storage capacity of 400 megawatts (MW) and up to 4 hours of storage per charge (1600 MWh).

There is no power generation on the site.

The key components of the Project are:

- Up to 33 'modules' in each BESS DC block area, and contain 12x20 foot BESS containers of Lithium-iron phosphate batteries, and 4 x inverter/transformer stations;
- There will be up to 132 x FP4203MH inverter/transformer stations. The DC side voltage of FP4203MH station is at 33kV AC.
- 33kV Switch rooms.
- Two 250MVA three winding transformers which step the voltage up from 33kV to 275kV, located in a HV switchyard.
- Auxiliary transformers that step down the voltage from 33 kV to 440V to supply cooling load to all BESS containers.
- Operations and management (O&M) building where the control room is located;
- SCADA system for control and monitoring;
- internal access roads;

4.2 Battery Energy Storage System (BESS)

A Battery Energy Storage System (BESS) is an advanced technology developed for storing the electricity by using specially developed batteries.

The BESS includes Lithium Phosphate (LPF) battery cells, assembled into modules and packs, and stored in cabinets inside 20 ft. containers in the open. The DC electricity from the packs is fed through power converter system (PCS) also referred to as inverters to convert to AC, voltage boosted through power transformers and fed to the power grid.

4.2.1 Battery Storage

Multiple LPF cells are typically assembled into a module by connecting them in series and parallel arrangements. The modules are stacked and interconnected in a battery rack. The racks are stored in a cabinet for small installations and containerised storage for large installations.

The BESS will consist of up to 396 x 20ft storage containers. An example layout is shown in Figure 3 [8].

Figure 3: Example Layout of BESS Containers

A typical container is shown in Figure 4 [8].

Figure 4: Example of a Battery Container

The container has the following features:

- Cable penetrations.
- A cooling system maintaining the container temperature within safe operating limits (liquid cooling with chiller unit and fan).
- Smoke/heat/combustible gas detectors
- Fire protection system installation (aerosol units, sounders and Visual Alarm Devices (VADs), ventilation system, and water sprinkler heads).
- Explosion venting panels

The batteries are stacked and connected to the Battery Management System (BMS). The BMS is typically designed with a range of safeguards, such as:

- Prevention of overcharging and current surges.

- Maintaining voltage levels.
- System trip in the event of electrical shorts or overheating.
- Fire alarm control panel (FACP) and a local control station (LCS).

4.3 BESS Arrangements Considered for Study

The proposed development will have a capacity of 400 MW providing energy for 4 hours (1600 MWh).

Each individual BESS is containerised, and will use lithium-iron Phosphate ($LiFePO_4$) cell. The containers are grouped into 'modules', each module occupying an area of 15.2m x 33.4m, and separated by 10m access path on all sides.

The proposed configuration is summarised in Table 2.

Table 2: Features of BESS

Parameter	Description
No. of modules	Up to 33
No. of BESS 20 ft. containers per module	12
No. of inverters per module	4 (1 inverter for 3 BESS containers)
Battery storage capacity per container	5MWh
No. of racks (string of cells) per container	12
No. of LiFePO4 cells in each string	416
Ampere hour rating	0.75 Ah per cell (314 Ah per BESS container)

4.4 BESS Cooling and Ventilation System

Maintaining the temperature within limits is critical to the safety of the operations and this is typically achieved by dedicated cooling system for each container and controlled by the BMS.

The cooling system consists of the following [8]:

- Chiller unit for each container. The chiller cools the batteries via liquid cooling plates installed beneath each battery pack;
- Ventilation fan that would be started on detection of combustible gas at 10% lower explosive limit (LEL), based on hydrogen detection, and would not stop until the flammable gas concentration is reduced to less than 10% LEL.

4.5 Operations and Management Hub

The site operations are managed from an operations and management hub (constructed). Structures include an office control building with SCADA system, staff amenities, and equipment storage. These are the receival point for all equipment delivery during construction and all management activities during the project's operational period.

Car parking facilities are also provided for employee and service vehicles.

The facility operates 24/7 but is onsite staffed 8/7 (day shift only). The site is monitored and managed remotely after hours.

A layout of the BESS containers is shown in Figure 2.

4.6 Methodology

The main steps undertaken as part of this Fire Safety Study are summarised below.

1. Hazard Identification

Identification *of* all flammable and combustible materials present and establish their inventories. Hazard identification was conducted for the Code 21 hazard and risk assessment in Ref. [2].

2. Consequence Assessment

Assessment of the consequences of each fire scenario in terms of flame impingement and distances to specific heat radiation levels which could potentially cause escalation to adjacent containers . This includes maximum heat radiation levels for fire fighters to enable approach firefighting equipment as outlined in the Fire Brigade Intervention Model Guideline [9].

The impacts of credible fire scenarios were assessed using the consequence modelling software PHAST 9.0.

3. Fire Prevention, Detection and Protection Systems

The existing fire prevention, detection and protection systems for the scenarios under consideration are documented in this report. Their expected effectiveness is assessed. Fire system categories are:

- Prevention. These include ignition control, leak prevention, emergency shutdown (ESD) etc.;
- Detection (e.g. gas and fire detectors); and
- Passive/active protection systems (e.g. fireproofing, firewater deluge).

4. Fire water requirements for identified fire scenarios based on heat exposure
5. Accessibility of firefighting equipment on site by emergency personnel, based on the Fire Brigade Intervention Model [9].

4.7 Inventory of Flammable/ Combustible Materials

There are no chemicals stored on the site.

The materials that can be involved in a fire are:

- Lithium-ion batteries arranged in racks inside the container (396 containers)
- Cooling/ insulating oil within the power transformer in the sub-station
- Cooling/ insulating oil in auxiliary transformers in power converter system containers
- Electrical equipment on site

5 FIRE SAFETY SYSTEM

The fire safety system for BESS containers have been fully defined as described in Ref. [10], designed to comply with NFPA 855-2023 [11]. However, the firewater system has not been fully designed. This study is based on firewater requirements assessed from fire consequence calculations, and from the requirement of the following standards:

1. AS 2419.1-2021: Fire hydrant installations, Part 1: System design, installation and commissioning [12].
2. NFPA 13-2022: Standard for the installation of sprinkler systems [13]
3. NFPA 850-2026: Standard for Fire Protection for Electric Generating Plants and High-Voltage Direct Current (HVDC) Converter Stations [14]
4. NFPA 855-2023: Standard for the Installation of Stationary Energy Storage Systems [11].

5.1 Overview

Each BESS container will have the following fire protection [10]:

- Fire alarm control panel (FACP)
- Local control station (LCS)
- Smoke/heat detectors
- Combustible gas detectors
- Aerosol fire suppression units
- Alarm sounders and visual alarm devices (VADs)
- Ventilation system, and
- Water sprinkler heads.
- Finally, a dry pipe water sprinkler unit is installed that can be activated once the firewater pump is started either manually or remotely through the BMS.

The nearest fire brigade is located at Bororen rural fire station.

The fire protection and suppression system for the BESS are designed to meet the requirements of NFPA 855 [11] and other Australian Standards listed in Ref. [10].

5.2 Gas Detection

Each container has combustible gas detector installed.

Gas detector sensing 10% LEL of combustible gas will initiate a LEVEL 1 alarm and start the exhaust fan. The fan will not stop until the detector shows < 10% LEL.

When a gas detector detects gas above 10% LEL, the VAD is active on the panel in the control room, identifying the location of the detector. The alarm will be investigated by the operator while the exhaust fan is preventing gas build-up in the container.

5.3 Fire detection

In the event of ignition, A smoke detector is installed in each container to raise a fire alarm at the panel, identifying the container on fire.

A heat detector is installed in each container to raise a fire alarm at the panel.

The fire control logic for the BESS containers is as follows:

- In the event of ignition, a smoke detector or heat detector (1-oo-2) will initiate a LEVEL 1 fire alarm in the BMS, activate sounder and VAD for operator intervention.
- If both the smoke detector and heat detector are activated, a LEVEL 2 fire alarm is raised in the BMS. Sounder and VAD are activated and aerosol is released (automatically if in AUTO mode or manually from control room. The ventilation fan is stopped to prevent the aerosol being extracted out.

A Fire Indicator Panel (FIP) is located in the O&M hub, with a mimic panel identifying the origin of the fire alarm. The FIP will have a self-contained battery back-up system (UPS).

5.4 Container Fire Suppression

In the event of a container fire, there are two separate suppression systems installed in each container:

(a) Gaseous fire suppressant, released as aerosol, automatically triggered by both smoke and heat detection activation (2-oo-2). The aerosol system can also be manually activated.

(b) A dry pipe sprinkler system. When the firewater pumps start, water spray through the sprinklers occur, cooling the battery racks and suppressing the fire.

Details are provided in Ref. [15].

5.5 Firewater System

Firewater to the site is supplied from two firewater storage tanks of 180 kL capacity each. The site will be equipped with firefighting equipment consisting of the following:

- Two firewater pumps of each 1893 L/min capacity, one electric motor driven and the second (backup) diesel engine driven, or both diesel engine driven.
- Site ring main around the periphery of the site, with hydrant connections.
- Sprinkler system in each container
- Fire hydrants in accordance with AS 2419:1-2021 [12]
- Hose reels inside buildings in accordance with National Construction Code (NCC) [16].

6 Fire Scenarios and Consequence Analysis

The following fire scenarios were identified in the Rutherglen BESS facility.

1. BESS container fires
2. Transformer fires
3. Other electrical equipment fires
4. Building fires (O&M hub)

6.1 BESS Fires

A fire in a BESS container can occur from overheating of the battery and thermal runaway. The causes are:

(a) An external fire heating the container and the racks of cells within the container. This source is unlikely as the BESS layout is in an open cleared area with no flammable or combustible materials. A bushfire is a source of heat, and the bushfire management plan addresses this hazard [4].

(b) Electrical causes such as internal cell short circuit from damage, battery overcharging or discharging, over voltage/current, external short circuit, and manufacturing defect. The thermal runaway is associated with evolution of flammable and toxic gases and is self-sustaining, lasting a long time until the entire container contents are burnt out.

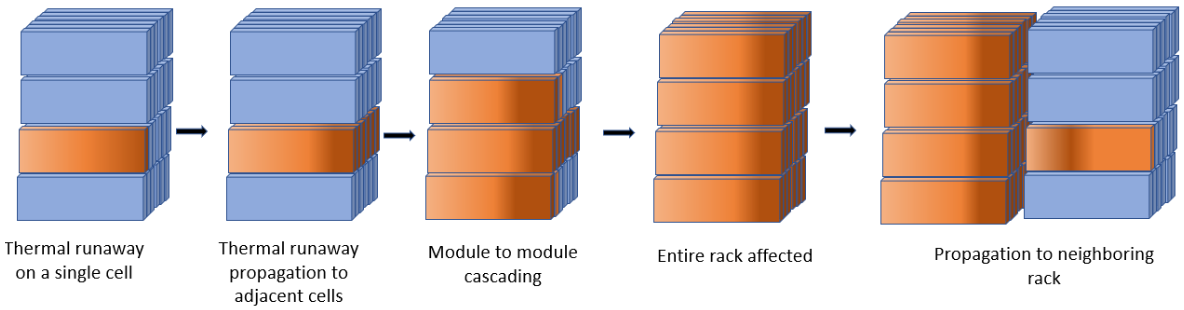
Thermal runaway is a self-accelerating reaction that can occur when the battery is overcharged, short-circuited, or physically damaged.

- In a thermal runaway, a battery cell generates heat faster than it can dissipate. This accelerates the chemical reaction and raises the temperature.
- The exothermic reaction of a failing battery cell overheats an adjacent battery cell or module.
- The adjacent battery fails in similar fashion and in turn overheats other batteries.
- The reaction continues until it is stopped by the fire protection system.

Not only the decomposing electrolyte, but the battery materials, cables and insulation materials containing plastics also get involved in the fire, as the fire spreads.

The fire spread is illustrated in Figure 5 [17].

Figure 5: Fire Spread from Thermal Runaway



Experiments on a Tesla Battery Pack conducted by Exponent Inc. [18] found the following:

- The propagation of fire within the container is slow when the source of fire was inside the container.
- The smoke is associated with thick white fumes vented through the container vent, with flames of up to 4m in height.
- At the centre of fire, temperatures up to 1100°C were experienced, but outside temperature of container was not significantly higher than the ambient.
- The walls of the container did not fail for a fire that lasted 90 minutes. Many panels were unaffected and could be reused.
- In the external fire exposure, flames were observed from the exhaust vent and front door.

In actual fire incidents, it was observed that the side walls of the container did not fail.

In a fire of a BESS facility in Victoria in 2021 [19], the fire was essentially confined to the originating container and the adjacent container downwind. See the Figure 6 [20]. Up to a maximum of 2 containers could be affected, depending on the wind speed and direction.

Figure 6: BESS Fire Incident in Victoria, 2021

The fire occurred during testing, prior to commissioning of the facility. The fire was allowed to burn out.

The above discussion indicates that the exposed container adjacent to the container on fire in the downwind direction should be kept cool by hydrant firewater application.

6.2 Container Fire Modelling

When a battery pack gets overheated, it produces off gases that are flammable and toxic. Typical composition of off gas for Lithium Iron Phosphate battery is listed in Table 3 [21].

Hydrogen (H_2) is missing from the reported data. In experiments conducted [21], it is reported that the H_2 sensor was saturated at a value of 1%, and that this saturation occurs almost immediately upon the onset of thermal runaway. This could explain why H_2 values in off gases have not been reported in many studies.

The DNV study states that literature data reports values of hydrogen between 5% and 30% by volume. In this study, a 5% hydrogen was assumed.

Table 3: Off Gas Composition from Overheating of Lithium Phosphate BESS

Chemical	Name	% in off gas (v/v)
CO_2	Carbon Dioxide	35.18
CO	Carbon Monoxide	11.34
CH_4	Methane	5.62
C_2H_6	Ethane	20.11
C_2H_4	Ethylene	5.82
C_3H_8	Propane	4.77
H_2	Hydrogen*	4.48
HCl	Hydrogen Chloride	1.05
HF	Hydrogen Fluoride	3.62
HCN	Hydrogen Cyanide	0.57
C_6H_6	Benzene	0.29
C_7H_8	Toluene	0.67
C_2H_5OH	Ethanol	4.00
CH_3OH	Methanol	2.48
	Total	100.0
Average Molecular weight		33.76
Density (kg/m^3)		1.102

The total flammable gas content is 59.6%.

The combustible gas detectors in the proposed BESS have sensors calibrated to act on detecting 10% LEL of hydrogen, i.e. 0.4% hydrogen present in the off gas.

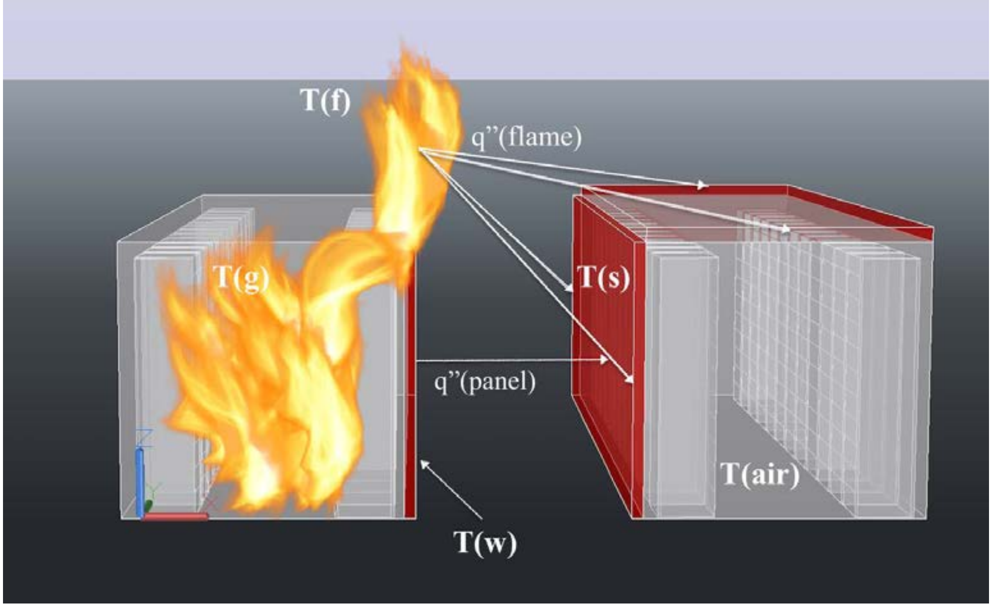
As the sprinkler system has to be manually activated, allowing for a 5-minute response time, the fire can spread to other strings in the rack. Cooling of the leaking container with the sprinkler system would reduce the temperature and rate of thermal runaway reaction, which may not be suppressed immediately.

The fire growth is schematically shown in Figure 7, reproduced from [22]. While Figure 7 shows the fully developed fire, it is necessary to take into account the fire protection aspects into account as an integral part of fire modelling, which makes the modelling more complex, but more representative of the fire.

From field data on actual fires and from experimental data described above, the fire radiation from a container on fire can affect an adjacent container downwind and needs cooling with firewater application.

The firewater requirements are calculated in Section 7.

Figure 7: BESS Container Fire Radiation Modelling Schematic



6.3 Transformer Fire

The BESS output in DC is converted into ultimate grid voltage of 275 kV AC through a series of power transformers.

The transformer oil total volume in the power transformer can be up to 10,000-12,000 L. The transformer is located in a bund. For the current analysis, a conservative value of 12,000L is assumed.

The transformers are either physically separated with m separation distance or separated by fire rated walls (FRL 120/120/120). For an oil volume <20kL, the separation distance required by AS 2067-2016 [23] is 5m. As per NFPA 850 [14], the distance required is 7.6m to prevent escalation of one transformer fire to an adjacent transformer.

It is necessary that that all bund penetrations, including conduits, are sealed with a suitable fire-resistant packing or sealant.

6.3.1 Impairment Criteria

The levels of heat radiation selected to examine the heat effects were 4.7, 12.6, 23, 30, and 37.5 kW/m^2, as given in HIPAP No.4 [24].

The general effects of these levels of heat radiation are summarised in Table 4. These heat flux radiation effects are widely accepted by industry and is appropriate for this analysis.

Table 4: Heat Radiation Effects

Heat Radiation (kW/m^2)	Effect
3	Limit for approach by firefighters in protective clothing for access to firefighting [9]
4.7	Maximum heat radiation level to which fire-fighting personnel may be exposed.
12.6	Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure. 30% chance of fatality for long exposure. High chance of injury.
23	Unprotected steel will reach thermal stress temperatures to cause failure. Pressure vessels need to be relieved, or failure will occur. 100% chance of fatality for long exposure and 10% chance of fatality for instantaneous exposure.
37.5	100% chance of fatality for instantaneous exposure.

6.3.2 Material Modelled

The transformer oil is a mineral oil, comprising of hydro-treated light naphthenic and paraffinic distillates. On this basis, hexadecane (C16) was selected as a representative single component material for the consequence modelling.

PHAST 9.11 models both the luminous and smoky part of the flame for calculating thermal radiation impact distances.

6.3.3 Pool Fire Results

The results in the following table represent the maximum ground level impact distance measured from the centre of the bund in a downwind orientation. The flame height represents the length of the flame from the pool surface to the tip of the flame.

The transformer is to be bunded to contain the contents of the tank, 12000L, and a quantity of fire water applied. An 8m equivalent diameter bund of 300mm height is assumed for the study.

The heat radiation hazard zones are determined using PHAST 9.11. The bund fire was modelled as a circular pool with an equivalent area to that of the area of the rectangular bund (equivalent 8m diameter).

Table 5: Transformer Bund Fire Characteristics

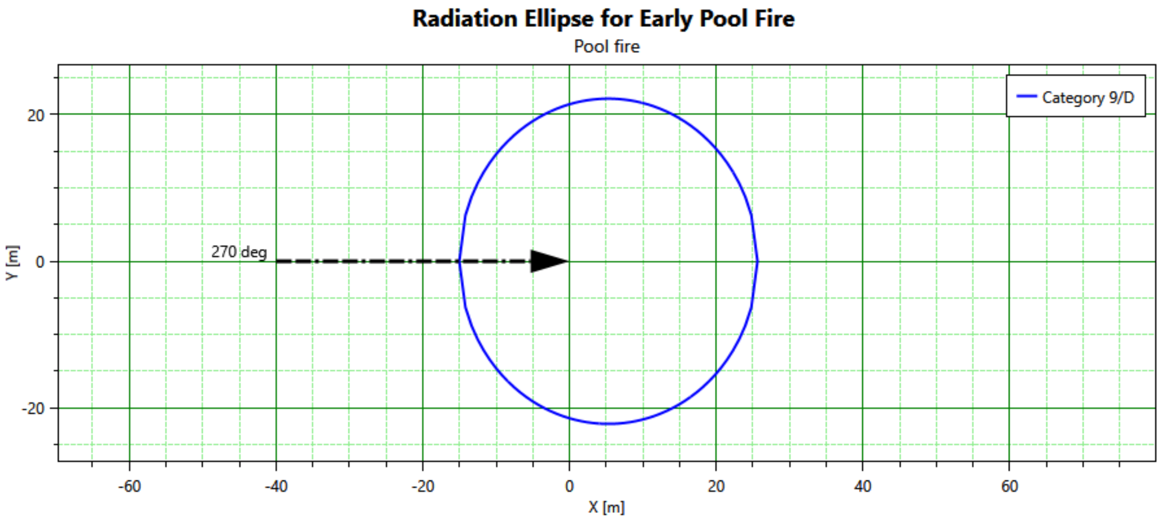
Parameter	Value
Material	Hexadecane
Pool diameter	8m
Flame height	10.9m
Burn rate	2 kg/s
Surface emissive power (luminous part of flame)	86.4 kW/m^2
Surface emissive power (smoky part of flame)	64.6 kW/m^2

Table 6: Transformer Bund Pool Fire Heat Radiation Impact Distances

Stability Class /Wind Speed	Flame Tilt by Wind (deg)	Distance to heat radiation kW/m² (m)			
		4.7	12.6	23	35
B3	44	22	16	12	8
D 1.5	30	21	14	10	7
D 5	53	22	16	13	9
D 9	61	22	17	14	10
E3	44	22	16	12	8
F1.5	33	21	14	10	8

The thermal radiation profile for a level of 3 kW/m^2 is shown in Figure 8.

Figure 8: Thermal Radiation profile to 3 kW/m^2 for Transformer Pool Fire (Weather D9)



The distance to 3 kW/m^2 is approximately 15m upwind and 25m in other directions. From fire hydrants available, the fire can be fought with fire water and foam from outside 15-25m radius from the transformer oil collection bund.

6.4 Other Electrical Fires

Electrical fires can occur in equipment and wiring due to the following causes:

- Loose Electrical Connections
- Overloaded Circuits
- Short Circuits
- Electrical Arcing
- Faulty wiring or damaged insulation
- Overheating electrical equipment/ cable

The fires are localised, but pose an electrocution danger. It is mainly detected by visible smoke. Fire extinguishers appropriate to use for electrical fires (dry chemical, CO_2) are provided.

Emergency de-energisation switches are provided for the equipment, which is activated prior to fire fighting.

6.5 Building Fires

The building onsite is the O&M hub for the facility. It consists of a control/ monitoring room, an office, workshop and amenities.

The building will be constructed to the requirements of the National Construction Code, and provided with smoke detectors/ alarms and fire hose reels.

7 FIREWATER REQUIREMENTS

7.1 Basic Design Requirements

The firewater system at the site has not been designed. The following basis is assumed.

- Sprinkler density of 10.1 L/min/m^2 of floor area of the container.
- At least four (4) fire hydrants capable of flowing simultaneously, each within 40 metres of fire.
- Hose reels installed in buildings in accordance with AS 2441-2005 [25].
- Water supply sufficient for not less than 4 hours supply (AS 2419.1-2021 [12]) for the worst case scenario.

7.2 Firewater requirement for BESS Container Fires

The container dimensions, external and internal are summarised in Table 7 [26].

Table 7: BESS Container Dimensions (20' Container)

Parameter	Internal Dimensions	External Dimensions
Length, m	5.89	6.1
Width, m	2.34	2.44
Height, m	2.39	2.59

The basis of the firewater demand is as follows:

- The container on fire is cooled on all sides and the roof
- The container adjacent to container on fire downwind is cooled on all sides and the roof
- The cooling water application density is 10.2 L/min/m2 as specified in NFPA 15- 2027 [27] for steel structures.

The surface area of walls and roof is: 59.1 m^2. For 2 containers, the area to be cooled is 118.2 m^2.

Therefore, water requirement for the BESS container walls and roof:

$$= 118.2 \text{ m}^2 \times 10.2 \text{ L/min/m}^2 = 1205.6 \text{ L/min}$$

This can be applied by two hydrants flowing simultaneously.

The sprinkler system installed is assumed to have a water spray density of 10.2 L/min/m^2. The floor area of the container is (5.89x 2.34) = 13.8 m^2.

The sprinkler water requirement is 13.8x10.2 = 140.6 L/min

Total water requirement for BESS fire protection is: 1205.6 + 140.6 = 1345.2 L/min

7.3 Firewater Requirement for Transformer Fires

In order to minimise water requirements in a remote location, the exposures to a transformer fire will be protected by passive fire protection. A fire barrier of FRL 120/120/120 as required by AS 2067- 2016 [23] will be installed.

The transformer will be bunded to contain any oil leak and a potential bund fire would be controlled by hydrant water and portable foam.

The water storage provided will adequately provide water for a transformer bund fire.

7.4 Firewater Storage Requirement

The maximum firewater application rate is 1345 L/min. According to AS 2419.1-2021, Section 2.2.5(D) [12], firewater must be available for a duration 4 hours.

In addition, Section 5.2.3.1 of AS 2419.1-2021 requires a height of 1m above net positive suction head (NPSH) for the pumps to be available in the tank. This is assumed to be a residual amount of 10%.

The firewater tank capacity = 1345 L/min x 240 minutes X 1.1 (include residual water height) = 355080L or 355 kL.

In addition, Section 5.1(b) of AS 2419.1-2021 [12] requires that during firewater tank maintenance, a minimum of 50% of the water demand must be available for the operating plant.

Therefore, two fire water tanks of each 180 kL capacity is recommended for the installation.

7.5 Firewater Availability

In the initial stages of the facility operation, water supplied in carts by contractors in the area will be used to fill the firewater tanks.

In the longer term, the stormwater detention and bio-retention ponds on site would be available to supply firewater as a top-up source. The supply from the retention ponds will have its own pump to boost the pressure to the ring main pressure, and in compliance with AS 2019-2021 [12].

7.6 Firewater System Summary

The firewater system will consist of the following:

1. Two firewater tanks of each 180 kL capacity.
2. Two firewater pumps (one electric and one diesel engine driven or both diesel engine driven), capable of delivering 1345 L/min each.
3. Firewater ring main with hydrants delivering at a pressure of 700 kPa minimum*.
4. A jockey pump to maintain ring main pressure
5. Piping connections to the sprinkler system to all BESS containers

A detailed design will be undertaken with hydraulic analysis as part of construction and installation.

* If fire brigade booster pump will be used to raise the pressure, AS 2419.1-2021 requires a pressure of 350 kPa. Otherwise 700 kPa is required to be supplied by the pump. Given the time taken for QFD response from Miriam Vale, the 700 kPa requirement is recommended.

8 ASSESSMENT OF ESCALATION POTENTIAL

In order to assess the potential for escalation, it is necessary to determine the time taken to initiate escalation prevention measures (e.g. emergency shutdown, cooling water application) and the time to bring the fire under control. This is a function of:

- Detection time
- De-energisation time
- Time taken to initiate firefighting/escalation suppression (manual and automatic)

For the sake of assessing the escalation potential at the site, this study aims to establish the fire prevention, detection and firefighting capabilities at the site.

8.1 Time for Gas and Fire Detection

Both gas and fire detectors are installed all the BESS containers. The detection times are summarised in Table 8. The fire detection time does not take into consideration the fact that gas detectors would detect the leak before ignition occurs, thus reducing the likelihood of a fire and the potential for escalation.

Table 8: Fire & Gas Detection Times

Event No.	Location/Scenario	Gas Detection Method	Fire Detection Method	Detection Time
1	BESS containers	Gas detector	Smoke and heat detectors	10 min (Note 1)
2	Transformer	Buckholz relay in transformer detects any gas generated and initiates ESD	Manual	1 min for gas detection 10 min. for fire detection by visual identification of smoke
3	O&M hub	-	Smoke detectors	1-3 minutes depending fire and sensor locations

Note 1: Typical maximum response time for gas detector is 30s. Ref. [2] calculated that it takes approximately 10 minutes to reach 10% LEL in the container that the sensor can detect.

8.2 Time to Apply Cooling Water

Where gas and fire detectors activate in the BESS container, an alarm is raised, the container is de-energised and the aerosol fire suppressant discharged automatically. It is assumed that sprinkler system is activated within in 3 minutes as the operator at the control panel can activate this remotely.

The site unattended afterhours, but monitored 24/7 remotely. The operator monitoring the facility can activate the sprinkler system remotely through the BMS if required, and arrange to visit the site.

Bushfirefighting will be carried out by the rural fire services from Bororen, and it could take 10-15 minutes to respond and set up the firewater system.

For BESS facility fires, Queensland Fire Department (QFD) brigade from Miriam Vale would attend in approximately 30 minutes, once notified.

9 DRAINAGE SYSTEM

The drainage system design is in progress. The site drainage and contaminated firewater containment is based on the requirements of the following standards:

- Queensland *Environmental Protection Act 1994* (EP Act): Section 319 (General Environmental Duty) requires all reasonable and practicable measures to be taken to prevent environmental harm.
- AS 1940:2017 [28] Storage and Handling of Flammable and Combustible Liquids: Adopted as the primary engineering standard for spill containment capacities and separation distances.
- AS 2067:2016 [23] Substations and High Voltage Installations: Specific to the containment of transformer oils and fire suppression.

An internal technical standard [29] describes specific requirements. The requirements are summarised below.

9.1 Containment of Contaminated Firewater

The following measures are required in the technical standard to prevent soil contamination and containment of firewater runoff.

- Design of BESS installation foundation to be impervious to electrolytes and coolants to prevent soil and groundwater contamination. This is achieved either by reinforced concrete slabs, sealed and chemically treated, or compacted structural fill utilizing heavy-duty chemical-resistant geo-membranes combined with a protective aggregate/crushed rock top layer.
- Bunding of each BESS module (consisting of 12 battery containers and 4 PCS/inverter containers) separately by concrete upturn bunds, blockwork walls, or lined earth berms/swales.
- Each BESS module bund to have the capacity to contain 100% of the firewater applied for the duration of the fire event.
- Each transformer to be separately bunded to contain 110% of the volume of the oil tank capacity, and 100% of the firewater applied.

The whole of the BESS bunded area is lined / concreted to retain firewater that may be contaminated.

A bund valve will regulate the discharge of the collected water. The valve will be normally open for stormwater runoff. A fire alarm activation will automatically close the bund valve for the module in which a fire occurs, through the BMS for the plant.

The firewater retention system design is in progress, and undertaken by WMS Engineering on behalf of RHRE. WMS Engineering will undertake the concept design for the capture, storage, and treatment of stormwater and retained firewater. The design will incorporate sizing of retention ponds, treatment methods, water quality for release of effluent, and linkage of bund valves to the BMS.

9.2 Site Drainage

Under normal operating conditions, the stormwater within bunded areas will runoff through the open bund valve to surface water.

Under a fire condition, the bund valve would be automatically closed by the BMS. At the end of fire emergency, the retained water would be discharged from the bunded area by opening the valve through the BMS by manual actuation. The water will be directed to detention and bio-retention ponds via piped systems. The detention and bio-retention pond systems are also controlled via the BMS to permit only effluent of acceptable quality to be discharged for surface flow to downstream areas.

Contaminated firewater would be disposed offsite through approved waste disposal tankers.

10 RISK ASSESSMENT

10.1 Introduction

State Code 27 requires a risk management and assessment report to comply with PO2 to PO4. The Planning Guideline for Code 27 [5] requires that

> *"A Risk Management Assessment Report (RMAR) be prepared and lodged with the application to demonstrate compliance with PO2-PO4. The risk assessment process supporting the RMAR should be aligned with AS ISO 31000:2018 Risk Management - Guidelines, or analogous processes in technical standards such as AS/NZS 5139."*

A risk assessment requires the following:

- Hazard identification
- Assessment of consequences of potential hazardous events
- Estimation of likelihood of the hazardous events
- Assessment and evaluation of risk

The RMAR has been carried out in two stages:

The hazard identification and consequence analysis has been carried out by Arriscar for the Rutherglen BESS facility, and detailed in Ref. [2]. The present report must be read in conjunction with the RMAR Consequence assessment in Ref. [2].

The likelihood assessment and risk evaluation part of the RMAR has been carried out in this section. Together with Ref. [2], the studies follow the requirements of AS ISO 31000-2018 [30].

10.2 Risk Matrix

Each hazard is risk ranked to determine its criticality taking into account the event severity and likelihood. The risk was assessed using a Risk Assessment Matrix shown in Figure 9 [31]. The matrix is typical of ones used in the industry.

The rule sets for assessing the impact rating and likelihood rating are listed in Table 9 and Table 10 respectively.

Figure 9: Risk Matrix Used in the Study

Likelihood	Consequence (Severity)				
	Low	Minor	Moderate	Major	Critical
Almost Certain	High	High	Extreme	Extreme	Extreme
Likely	Moderate	High	High	Extreme	Extreme
Possible	Low	Moderate	High	Extreme	Extreme
Unlikely	Low	Low	Moderate	High	Extreme
Rare	Low	Low	Moderate	High	High

Table 9: Rule Set for Consequence Assessment

Impact Rating	Description	Safety
1	Low	First aid injury. No impact on environment. Not a reportable incident.
2	Minor	Lost time injury. May need cleanup of local environment. No offsite effect.
3	Moderate	Serious injury requiring hospitalisation. Extensive cleanup required. Reportable incident.
4	Major	Disability or single fatality. Major environmental impact – contamination of waterways.
5	Critical	Multiple irreversible injuries or fatalities. Major permanent impact on environment.

Table 10: Rule Set for Likelihood Assessment

Rating Description	Assessment Description
Almost Certain	Expected to occur in most circumstances. Frequency between 1 and 10 times per year
Likely	Event will probably occur in most circumstances. Frequency between 1 in 10 years and 1 per year
Possible	Event should occur at some time during the facility lifetime. Frequency between 1 in 100 per year and 1 in 10 per year.
Unlikely	Event could occur at some time. Frequency between 1 in 1000 per year and 1 in 100 per year.
Rare	Event may occur, but only under exceptional circumstances. Frequency between 1 in 10000 per year and 1 in 1000 per year.

10.3 Risk Assessment

The severity rating of the fire events were based on the results in the Hazard Analysis report [2]. The likelihood assessments were qualitative, based on limited data in the literature. The results are summarised in Table 11.

Table 11: Risk Assessment Summary

No.	Incident description	Severity Rating	Frequency Rating	Risk	Comments
1	Toxic gas emission from thermal runaway without ignition and exposure to personnel	Low	Unlikely	Low	Note 1
2	Fire in BESS container	Minor	Unlikely	Low	Note 2
3	Power transformer fire	Moderate	Rare	Moderate	Note 3

Note 1: The total BESS capacity for the years 2018-2023 was 235 GWh [32]. During the same period, there have been 59 fire incidents reported in BESS worldwide Refs. [33], [34]. Therefore, the frequency of a BESS fire can be estimated as 59/[(235GWh)(6 years)] = 4.18E-02/ GWh-year. The capacity of Rutherglen BESS is 1.6 GWh. Therefore, the estimated frequency of a fire = 4.18E-02/GWh-year x 1.6 GWh = 6.7E-02 per year, or once in 15 years. It is not known what safety systems had been provided in the reported incidents. Given the multiple layers of safety systems provided, the risk at Rutherglen is expected to be at least an order of magnitude. This estimate is approximate, but place the likelihood in the range of “Unlikely”.

Note 2: The probability of ignition is an order of magnitude lower than the probability of gas release due to the gas detection and ESD and ventilation provisions that reduces the flammable gas concentration in the container to 10% of LEL. Hence the likelihood is rated unlikely.

Note 3: CIGRE TB 537 [35] lists the fire frequency for Australia/ New Zealand for the period 1997-2004 as 9.0E-04 per transformer year. However, from Ref. [36], the fire frequency has dropped to 2.38E-04 per year (1 in 4200 service years).

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Conclusions

The following conclusions were reached in the study:

1. No High or Extreme risk events resulted in the risk assessment.
2. The firewater systems are not yet designed and the requirements have been identified in this study and stated as recommendations.
3. Once the recommendations of the present study and the ones in the bushfire mitigation study are implemented, the POs of State Code 27 would be complied with.

11.2 Recommendations

1. Provide two firewater tanks of each 180 kL capacity.
2. Install two firewater pumps (one electric and one diesel engine driven or both diesel engine driven), capable of delivering 1350 L/min each.
3. Install a firewater ring main with hydrants delivering at a pressure of 700 kPa minimum.
4. Install a jockey pump to maintain ring main pressure
5. Provide isolatable piping connections to the sprinkler system to all BESS containers
6. Undertake a hydraulic analysis of the firewater system design and ensure that the hydrant at the hydraulically most disadvantaged location can provide required flow at a pressure of 700 kPa.
7. The installation design is to comply with AS 2419.1-2021 and certified.
8. Provide contaminated firewater containment on the site for a maximum volume of 330 kL.

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