NJM DESIGN

Fire Safety Study (FSS)

Project Name:	Murchs Corner BESS – Stony Point, 2977 Hamilton Highway, Darlington VIC 3271
Job Number:	9708
Date:	11 December 2025
Client:	Ebare Pty Ltd. ATF Stony Point Trust
Revision	02

Revision	Issue Date	Document Control	
01	31 October 2025	Prepared by: William Tadman	Approved by: Javier Piedrahita – PE0003748
02	11 December 2025	Prepared by: William Tadman	Approved by: Javier Piedrahita – PE0003748

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1 Glossary and Abbreviations

AC	Alternating Current
AS	Australia Standard
BAL	Bushfire Assessment Level
BESS	Battery Energy storage System
BMS	Battery Management system
BPA	Bushfire Prone Area
CRTS	Cressy Terminal Station.
DC	Direct Current
DPHI	Department of Planning, Housing and Infrastructure
EMF	Electromagnetic fields
ESV	Energy Safe Victoria
ESS	Energy Storage System
FBIM	Fire Brigade Intervention Model
FDS	Fire Dynamics Simulator
FZ	Farming Zone
HCL	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrogen Fluoride
HIPAP	Hazardous Industry Planning Advisory Paper
HRR	Heat release rate
HV	High Voltage
IFEG	International Fire Engineering Guidelines
LFP	Lithium Phosphate
MOPS	Mortlake Terminal Station
MV	Medium Voltage
NCC/BCA	National Construction Code/Building Code of Australia
NEM	National Energy Market
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
O&M	Operations and Maintenance

PCU	Power Conversion Unit
PPE	Personal Protection Equipment
SCBA	Self-contained breathing apparatus
SUT	Set up Transformer
UL	Underwriters Laboratories
VBB	Victorian Big Battery

2 EXECUTIVE SUMMARY

NJM Design has been engaged by Ebare Pty Ltd. ATF Stony Point Trust to undertake a Fire Safety Study (FSS) for the Murchs Corner BESS located at Stony Point, 2977 Hamilton Highway, Darlington VIC 3271, approximately 4km southwest of Darlington.

The subject BESS has not defined the BESS provider at this stage, however, in order to perform a preliminary assessment, this document will perform the assessment based on statistical data. The final BESS supplier will be selected during the detailed design stage.

Murch's Corner BESS is a 500 MW/2,000 MWh BESS connected through underground cables to the Haunted Gully to Tarrone line cut in terminal station (See Figure 1 below).

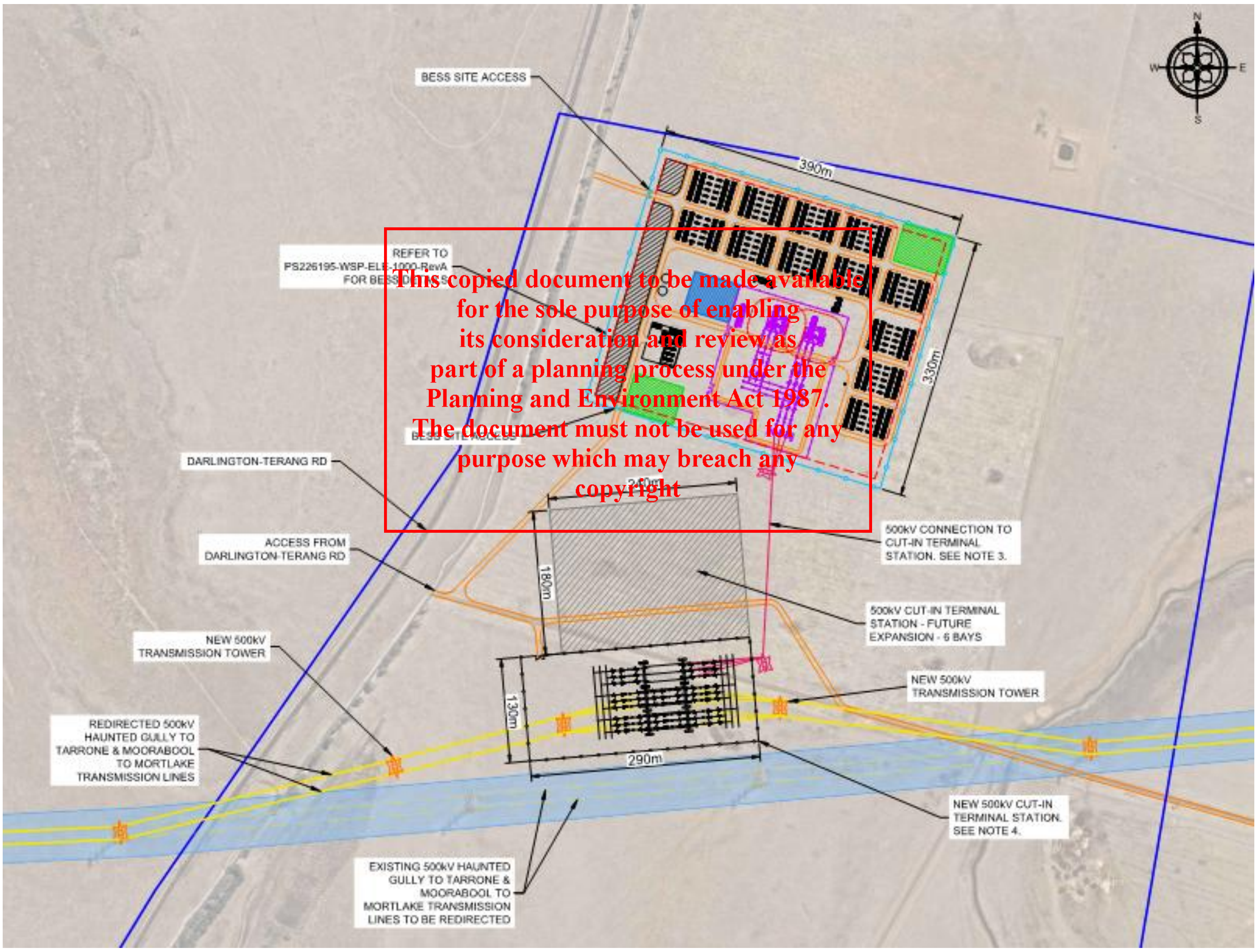


Figure 1- Murchs Corner BESS- - General Location/ Site Plan

The BESS will connect to the National Energy Market (NEM) via an onsite terminal station, which will cut into the overhead 500 kV transmission line. The overhead powerlines carry two 500 kV lines that connect Mortlake Terminal Station (MOPS) to Cressy Terminal Station (CRTS). Two connection options will be considered: connection to a single circuit or connection to both circuits [1]. Murchs Corner BESS facility is as presented in the plans in Appendix A.

The project includes:

- BESS units.
- Power conversion units.
- 500/33kV Substation.
- Underground transmission lines from the substation to the Cut-in terminal.
- 4*33kV Switchrooms.
- O&M Building.
- 2 x 300kl water tanks.

This Study formulates part of an integrated assessment process for safety assurance of development proposals, which are potentially hazardous. The assessment is based on the methodology outlined in the AFAC Guidelines, the Hazardous Industry Advisory Papers (HIPAPS) and the Fire Safety Studies for BESS [2].

The process is shown diagrammatically in Figure 2.

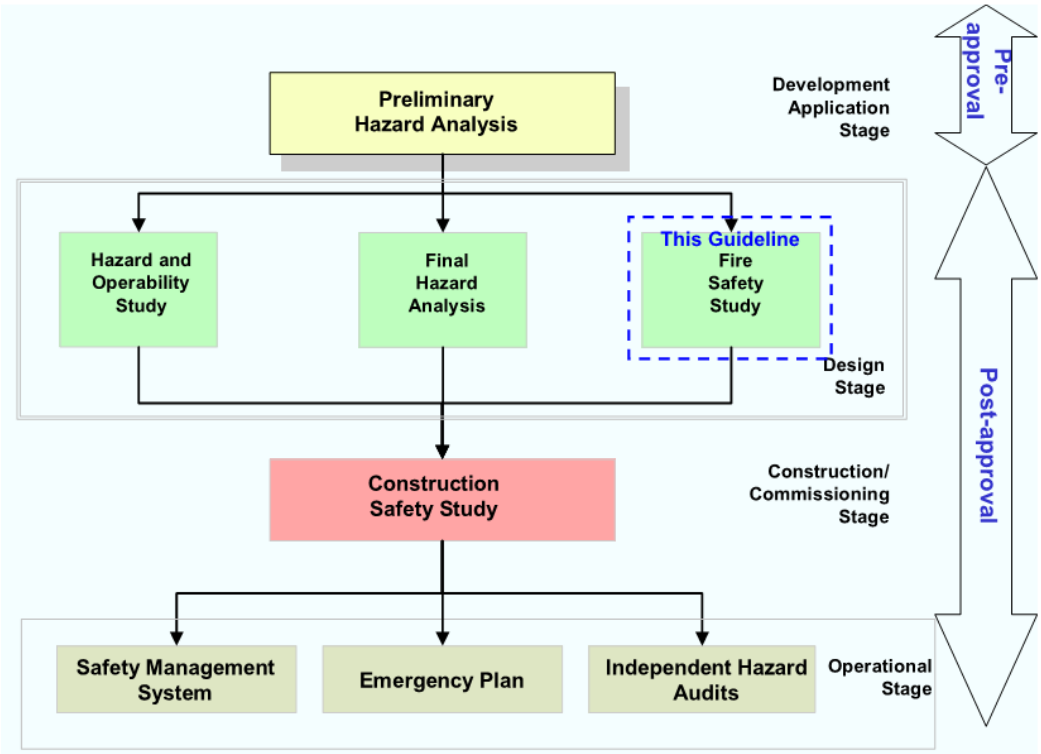


Figure 2: The Hazards-Related Assessment Process

As per the AFAC Guidelines, a BESS development should be assessed considering the FRV Fire safety guideline GL54, New South Wales Department of Planning Hazardous Industry Planning Advisory Paper No 2 Fire Safety Study (2011), and the Country Fire Authority Design Guidelines and Model Requirements for Renewable Energy Facilities (2023).

Several Hazardous Industry Advisory Papers (HIPAPS) have been published to assist stakeholders in implementing the process, i.e.:

- No.–1 - Industry Emergency Planning Guidelines.
- No.–2 - Fire Safety Study Guidelines.
- No.–3 - Environmental Risk Impact Assessment Guidelines.
- No.–4 - Risk Criteria for Land Use Planning.
- No.–5 - Hazard Audit Guidelines.
- No.–6 - Guidelines for Hazard Analysis.
- No.–7 - Construction Safety Studies.
- No.–8 - HAZOP Guidelines.
- No.–9 - Safety Management System Guidelines.
- No. –0 - Land Use Safety Planning (Consultation Draft).

The studies detailed in the HIPAP papers involve case-specific hazard analyses and design of fire safety arrangements to meet those hazards. The approach is particularly important where significant quantities of hazardous materials as is the case with BESS units involved.

The review of the risks are consistent with fire risk assessment techniques for Hazardous Industry Planning Advisory Paper 2 (HIPAP 2) (i.e., the development of this study), the Fire Safety Studies for BESS [2] (i.e., the development of this study), and the CFA Guidelines for Renewable Energies Revision 4 [3] (requirements described in Appendix B).

3 MAIN FINDINGS AND RECOMMENDATIONS

The findings and recommendations listed in this section have been gathered based on the assessment developed in this document and the advice of the stakeholders involved.

The findings and recommendations at this stage are the following:

1. The design of the BESS units will be acceptable and cover all fire initiation and fire spread risks to the degree necessary if provided with:
   - Test UL9540A to Unit Level test, and/or test in accordance with CSA TS-800:24.
   - Fire safety protection measures.
   - Explosion control system.
   - Remote shutdown provisions.
   - Electrical fault protection devices.
   - Battery Management system (BMS).
   - Thermal management system (TMS).
   - Site Controller and Monitoring.

2. The proposed installation procedures and Units have designed and provisions that address the issues raised by the Victorian Big Battery (VBB) fire (refer to Appendix D).
3. The risk of fire development and spread is no worse than that posed by existing utility infrastructure in the community or the adjacent buildings in the community due to the clearances between equipment and allotments, and the provided fire safety measures.
4. Fire spread to adjacent allotments would not be predicted to occur, based on the distances from the subject site equipment/structures surpass the clearances specified by the NCC and the Australian standards. This will be confirmed by the following:
   - Fire spread analysis performed in Section 7.
   - The destructive test to the BESS Units.
   - Building clearances compliant with the NCC DtS provisions.
   - Compliance with AS2067 separation distances for transformers (see sections 0 and 0).
   - Fire breaks are not less than 10m as required by the CFA guidelines.
5. All equipment must be Scada Alarmed and will allow automatic notification to the operators, who will proceed according to the Emergency plan and the protocols.
6. Where transformers are oil-insulated, transformers shall use an FR3 (or similar) Ester oil where practical in lieu of the normal mineral oil.
7. The MV/SUT (Medium Voltage/Step-up) transformers should be self-bunded transformers that include splash guards for AS1940 compliance.

8. The 500/33kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow.
9. HV and MV transformers must comply with AS2067 separation distances (refer to sections 0 and 0). The minimum clearances required are as follows:

Table 1: Transformers' clearances

Equipment to assess	Adjoining equipment	Required Distance (m) as per AS2067	Proposed Distance (m)
500KV HV Substation transformers	500KV HV transformer	≥ 23.0 without firewall < 23.0 with firewall	TBC
	O&M compound	≥ 23.0	≥ 23.0
	MV transformers, BESS units, switch rooms	≥ 23.0	≥50.0
MV/SUT transformers without enhanced protection	500kV HV Transformer	≥ 4.5	~60.0
	BESS Container	≥ 4.5	~4
	O&M Compound	≥ 4.5	~200.0
	Switch room building	≥ 4.5	~16.0
	Closest Boundary	≥ 4.5	~17.0
	MV/SUT transformers	≥ 4.5	~4.1
MV/SUT transformers with enhanced protection	500kV HV Transformer	≥ 0.9	~60.0
	BESS Container	≥ 0.9	~4
	O&M Compound	≥ 0.9	~200.0
	Switch room building	≥ 0.9	~16.0
	Closest Boundary	≥ 0.9	~17.0
	MV/SUT transformers	≥ 0.9	~4.1

10. Given a catastrophic failure of either the transformers or BESS units, only the equipment on fire (e.g., transformers or BESS units) is expected to be lost and all surrounding equipment/buildings are expected to be able to work and not be physically affected by fire.

    It is encouraged that attending fire fighters allow total burn out of any equipment. Local firefighting authorities are encouraged to attend site to monitor and protect adjacent infrastructure and bushland when summoned by the staff (see 5.2.4). Adjacent infrastructure and bushland may be cooled down if required with the use of the fire hydrant system.

Electrical consequences can occur where equipment/buildings associated with an equipment on fire can stop working. All equipment is expected to be protected by their own breakers to be isolated given the presence of fire, but further consequences and electrical backup measures are out of the scope of this report. Those electrical consequences must be addressed by another consultant separately.

11. Water storage with not less than 288kL must be provided at an entrance of the facility, and 600kL are provided in the preliminary design, surpassing the requirements of the CFA guidelines. The water storage must have a compliant hard stand and booster assembly in accordance with the latest CFA Guidelines Revision 4 [3] as follows:

    - Water access points must be clearly identifiable and unobstructed to ensure efficient access.
    - Static water storage tank installations must comply with AS 2419.1-2021: Fire hydrant installations – System design, installation and commissioning.
    - The static water storage tank(s) must be an above-ground water tank constructed of concrete or steel.
    - The static water storage tank(s) must be capable of being completely refilled automatically or manually within 24 hours.
    - The static water storage tanks must be located at vehicle access points to the facility and must be positioned at least ten (10) metres from any structure.
    - The static water tanks may be located at the proposed location in Appendix A, subject to compliant wayfinding signage to direct the fire brigade.
    - The hard-suction point must be provided, with a 150mm full bore isolation valve equipped with a Storz connection, sized to comply with the required suction hydraulic performance.
    - Adapters that may be required to match the connection are: 125mm, 100mm, 90mm, 75mm, 65mm Storz tree adapters with a matching blank end cap to be provided.
    - The hard-suction point must be positioned within four (4) metres to a hardstand area and provide a clear access for emergency services personnel.
    - An all-weather road access and hardstand must be provided to the hard-suction point. The hardstand must be maintained to a minimum of 15 tonne GVM, eight (8) metres long and six (6) metres wide or to the satisfaction of the CFA.
    - The road access and hardstand must be kept clear at all times.
    - The hard-suction point must be protected from mechanical damage (e.g., bollards) where necessary.
    - Where the access road has one entrance, a ten (10) metre radius turning circle must be provided at the tank.
    - An external water level indicator must be provided to the tank and be visible from the hardstand area.
    - Signage indicating ‘FIRE WATER’ and the tank capacity must be fixed to each tank.
    - Signage must be provided at the front entrance to the facility, indicating the direction to the static water tank.

12. Portable fire extinguishers must be provided as per AS 2444, and a minimum of two (2) suitable fire extinguishers must be provided within 3m-20m of each PCU (Power Conversion Unit).

13. A fire hydrant system must be provided in accordance with AS 2419.1-2021: Fire hydrant installations, Section 3.9: Open Yard Protection. The location of hydrants must be designed as follows:

    - The hydrants will be located such that all infrastructure can be covered by at least 2 hydrants.

      Note: If a Fire Hydrant system is not provided throughout the BESS, the BESS units supplier must provide the results of a large-scale test in accordance with CSA TS-800:24 and the laboratory/centre certifications.

14. A containment and management plan of contaminated fire water runoff from the BESS is to be developed by the facility.

15. Given the clearances from adjoining residential areas, toxic gasses from a fire within the BESS facility are not expected to harm adjoining communities or fire brigade staff (refer to section 6.6 of this FSS) and use of the fire protective gear of the fire brigade staff (i.e., self-contained breathing apparatuses). Nonetheless, further assessment is to be performed at a later stage of this report.

16. The access to the site is not expected to be prevented given that that there are at least 2 alternative entrances.

    If a given fire/emergency prevents the access to the site via the main entry, access through the alternative entry will be provided via intercom or by opening 003-key padlocks.

    The fire Brigade will also access accompanied by staff who is on site or will arrive to the site given an emergency, given that the fire brigade will only attend the site upon a call from the BESS staff.

17. Fire brigade and Staff intervention during an emergency is expected to be managed to the degree necessary given the following safety measures:

    - Provision of warning signs. Some signage includes the following examples (not limited to):
        - Exit signs.
        - First aid firefighting equipment (fire hydrants, water storage tanks, fire extinguishers, etc.).
        - Electrical hazards (e.g., high voltage).
        - Equipment use instruction signs.
        - Entrances to the facility and buildings (e.g., RMUs, SUT, SWG, Control building, etc.).
        - Presence of chemical hazards.
        - Toilets and facility related signs.
        - Rescue and resuscitation signs.
        - Fire exit doors.
        - Restricted personal access to specific areas/buildings.
        - Name to equipment/enclosures (e.g., RMUs, SUT, SWG, Control building, etc.).
    - Firefighters should wear self-contained breathing apparatuses (SCBAs) and structural firefighting gear.
    - Firefighters will not enter the facility unless instructed and accompanied by a qualified employee.

18. The adjoining allotments and areas within the subject site have managed grassland. AS3959-2018 considers this

grassland as a low threat and hence the development does not require specific construction specifications.

19. An electrical hazards and risk assessment is to be performed by the facility (another consultant to address).
20. Develop a Fire Management Plan. The HIPAP No.1 Emergency Planning [4] (not limited to) may be used as an example to develop the plan. Other items to include are the following:
    - Post-incident clean-up disposal.
    - As part of the PPE for Emergency procedures, firefighters should wear self-contained breathing apparatuses (SCBAs) and structural firefighting gear.
    - Safety measures for potential and identified hazards (e.g., electrical, EMF, fire, environmental, ecological, noise, bushfire, leakage, social, etc) must be documented a spart of the Emergency Management Plan.
    - Evacuation Plans.
    - A bushfire management plan.
    - Access restriction to the substation when it is on.
    - Emergency contact details.
    - Roles and responsibilities.
    - Emergency muster points.
    - Induction, training, drills.
    - Public and mass media management.

4 SCOPE OF REPORT

4.1 GENERAL

The objective of this report is to identify primary fire risks associated with the implementation and function, location, proposed fire systems and fire brigade intervention of the BESS units, Substation and ancillary infrastructure. This includes the fire risks from the unit itself, those posed to the attending fire brigade, the buildings in close proximity to the units, and the community in which these units are situated.

It is out of the scope of this report to include consequences related to financial impact, legal and regulatory, electrical, community and property protection.

In particular the scope of work is to:

- Provide a Fire Safety Study (FSS) consistent with fire risk assessment techniques for Hazardous Industry Planning Advisory Paper 2 (HIPAP 2) and the Fire Safety Studies for BESS [2].
- Quantify severity of fires including heat radiation level at various distances from BESS and transformer fires and durations of the fire.
- Put the risks into context via comparison with other accepted risks such as those from existing power infrastructure and surrounding buildings in the community.
- A review of the design to applicable standards has also been undertaken as well as a comparative risk assessment to existing power utility infrastructure and industrial facilities in the same setting.
- Recommend mitigation measures if required considering the above.

NJM Design makes all reasonable efforts to incorporate substantial and relevant fire protection concepts into its advice. The extent to which this advice is carried out affects the probability of fire safety. It should be recognised, however, that fire protection is not an exact science. No amount of advice can, therefore, guarantee freedom from either ignition or fire damage.

The implementation of the findings of this report is the responsibility of others, including but not limited to:

- Development of drawings and specifications.
- The installation of hardware and construction system.
- The operation and maintenance of those systems.

4.2 SOURCES OF INFORMATION

The development of the study was based on the review of the below drawings, standards, reports and manuals:

- Murchs Corner BESS Plan Pack, provided by Cogency, revision 2, dated 19/09/2025.
- Murchs Corner BESS Concept Layout Plan, provided by Cogency, Rev A, dated 05/09/2025, (refer to 0).
- Murchs Corner BESS – Table of assumptions provided by Cogency, v.2, dated 19/09/2025 [1].

- Best Practice Guide for Battery Storage Equipment - Electrical Safety Requirements, Version 1.0 – Published 06 July 2018.
- AS 2067-2016 [5] has also been reviewed to is used for guidance on required clearance for transformers.
- AS 3000: Electrical installations.
- Building Code of Australia (BCA) 2022.
- Energy Safe Victoria (ESV) "Statement of Technical Findings - Fire at the Victorian Big Battery.
- AS 2419.1-2021: Fire hydrant installations [6].
- Hazardous Industry Planning Advisory Paper No.1 (HIPAP No. 1). NSW Government, January 2011.
- Hazardous Industry Planning Advisory Paper No.2 (HIPAP No. 2). NSW Government, January 2011.
- Incident Report – Bouldercombe BESS. Tesla Energy products. Revision 04 dated 29/02/2024.
- Elkhorn BESS Fire of September 20, 2022. Public Report of Technical findings. Dated 01/05/2023.
- Country Fire Authority (CFA) Specialist Risk and Fire Safety Unit, Fire Safety Studies for Battery Energy Storage Systems, Version 1, State of Victoria (Country Fire Authority), June 2025.
- Country Fire Authority (CFA) Specialist Risk and Fire Safety Unit, Design Guidelines and Model Requirements - Renewable Energy Facilities. v4.4, Victoria: State of Victoria (Country Fire Authority), June 2025.
- Large-scale battery energy storage system installations. AFAC Guideline 2025 [7].
- Murchs Corner BESS – Lanscape and Visual Impact and Visual Assessment Report. Peter Haack Consulting. Draft review issued on 09/10/2025.

4.3 Project Stakeholders

The relevant stakeholders in accordance with NCC A2G2(4) for the Murchs Corner BESS project are detailed in Table 2 below:

Table 2 – Design and Regulatory Stakeholders.

Role	Organization	Representative
Client	Ebare Pty Ltd ATF Stony Point Trust	Will Reed
Project Manager	Robert Luxmoore	Will Reed
Fire Safety Engineer	NJM Design (Vic) Pty Ltd.	Javier Piedrahita
Fire Brigade	FRV (CFA)	TBC

4.4 Legislative requirements

The primary objectives of the NCC, as summarised in the first edition of the International Fire Engineering Guidelines (IFEG) [8], are to protect:

- Life safety of occupants – the occupants must be able to leave the building (or remain in a safe refuge) without being subjected to hazardous or untenable conditions.
- Adjacent buildings – structures must not collapse onto adjacent property, and fire spread by radiation should not occur.
- Life safety of fire fighters – fire fighters must be given a reasonable time to rescue any remaining occupants before hazardous conditions or building collapse occurs.

4.5 Client objectives

It is understood that the client's objectives are to comply with the requirements of the NCC (National Construction Code), FRV/CFA (Fire Rescue Victoria/Country Fire Authority) and DPHI (Department of Planning, Housing and Infrastructure).

The fire safety objectives are met if the relevant legislation and regulations are complied with as stated in Clause A2G1 of the NCC, 'Compliance with the NCC is achieved by satisfying the Performance Requirements.'

The NCC Performance Requirements are intended to meet the objectives and functional statements of the NCC, being:

- Life safety of occupants – the occupants must be able to egress the building, or remain in a safe location, without being exposed to untenable conditions.
- Allow for Fire Brigade Intervention – provisions should be made to allow the Fire Brigade to undertake firefighting operations before the onset of untenable and hazardous conditions, as defined in the Fire Brigade Intervention Model (FBIM) [9].
- Protection of neighbouring buildings – structures should not collapse onto adjacent property or spread fire due to flame extensions or radiation.

5 FACILITY CHARACTERISTICS

5.1 FACILITY LAYOUT AND EQUIPMENT DESCRIPTION

5.1.1 General

The proposed Murchs Corner Battery Energy Storage System (BESS) is located in Stony Point, 2977 Hamilton Highway, Darlington 3271, Victoria, approximately 4km south-west of Darlington.

The subject BESS has not defined the BESS provider at this stage. The final BESS supplier will be selected during the detailed design stage.

The BESS facility has a capacity of 500 MW / 2,000 MWh. The BESS development has the below layout distribution, and the facility will be enclosed within a security fence (see Figure 3 below or Appendix A).

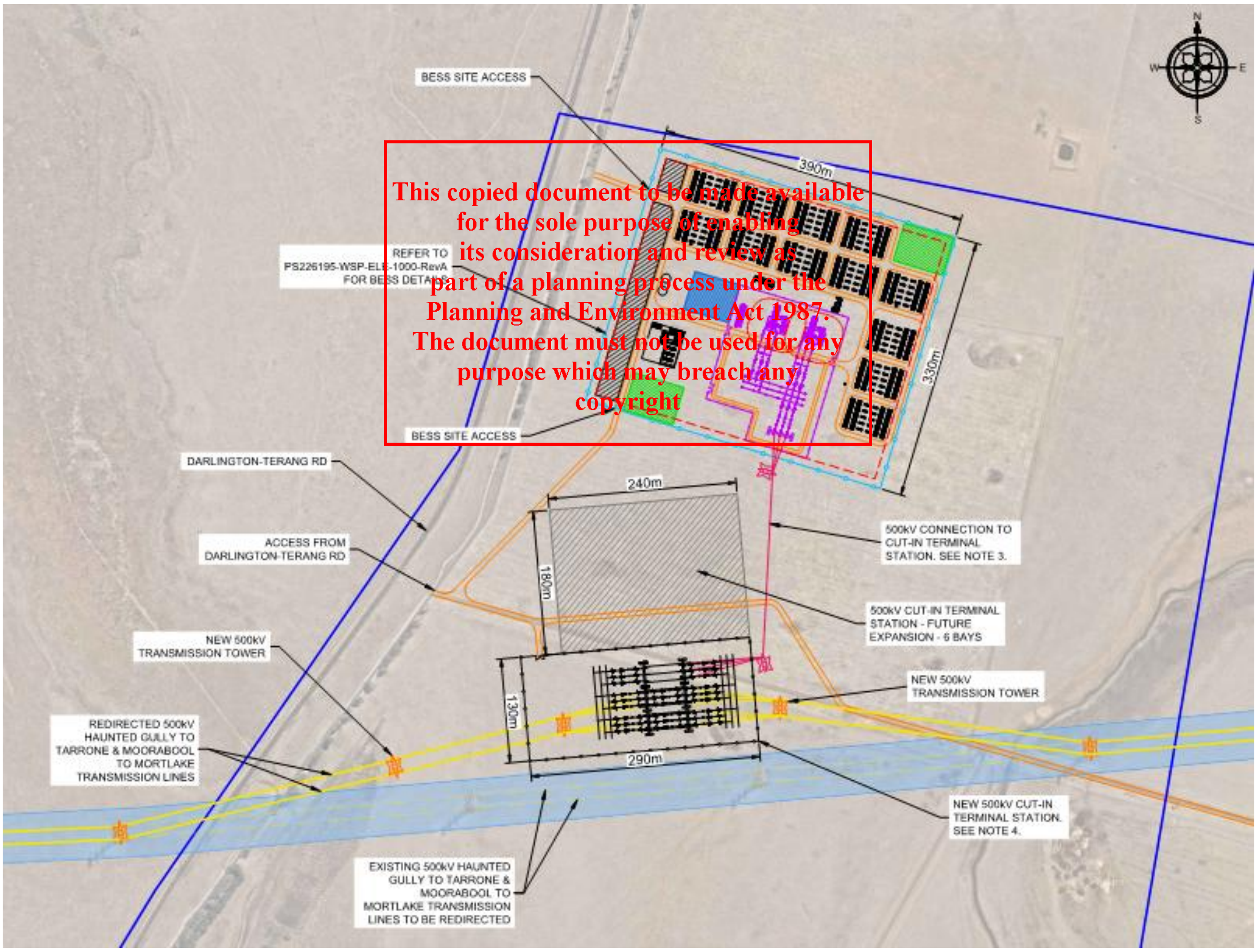


Figure 3: BESS layout.

The proposed Murchs Corner BESS has the following equipment/facilities:

- BESS units
  - 256 Container Style units
  - Test UL9540A to Unit Level test, and/or test in accordance with CSA TS-800:24.
  - Fire safety protection measures.
  - Explosion control system.
  - Remote shutdown provisions.
  - Electrical fault protection devices.
  - Battery Management system (BMS).
  - Thermal management system (TMS).
  - Site Controller and Monitoring.

- 500/33kV substation.
  - Composed by HV transformers 500/33kV compliant with AS2067. They are assumed to have mineral oil.
- Power conversion units (total of 120 units).
- 500kV Underground cable connection from substation to Cut-in Terminal station.
- 4*33kV Switch rooms.
  - It is a Class 8 building as per the NCC with type C construction.
  - Colorbond cladding (i.e., non-combustible metal sheet).
  - Each switch room has an approximate area of 220m^2.
- O&M Building.
  - It is a Class 8 building as per the NCC with type C construction.
  - Colorbond cladding (i.e., non-combustible metal sheet).
- 2*300kL Water Tanks.
- Portable fire extinguishers as per AS 2444.

Further to the above facilities, the site has the following provisions:

- The facility has firebreaks of at least 10m wide (as shown in Appendix A).
- There are 2 available entrances to the site located to the west of the facility.

The BESS will connect to the National Energy Market (NEM) via the onsite terminal station, which will cut into the overhead 500 kV transmission line. The overhead powerlines carry two 500 kV lines that connect Mortlake Terminal Station (MOPS) to Cressy Terminal Station (CRTS). Two connection options will be considered: connection to a single circuit or connection to both circuits [1].

5.1.2 Dominant Occupant Characteristics

Based on the use of the subject site, the occupant characteristics and attributes have been identified as part of the performance process and are summarised in Table 3 below.

Table 3 - Dominant Occupant Attributes.

Attributes	Description
Staff	
State of awareness	Generally alert, awake and aware of their surroundings. It is considered that being a place of work the staff members will not be under the influence of drugs or alcohol.
Familiarity with the building	Due to being members of staff, it is expected that they will generally be aware of the building configuration and exit routes.
Mental and physical aspects	Staff are generally not expected to have a mental or physical impairment.
Emergency training	It is not expected that the members of staff are trained in the operations of the firefighting systems. However, it is expected that the staff members will be aware of the actions required during an event requiring an evacuation, use of portable fire extinguisher and summoning the fire Brigade.

5.1.3 Location

The proposed Murchs Corner Battery Energy Storage System (BESS) is located in Stony Point, 2977 Hamilton Highway, Darlington 3271, Victoria, approximately 4km south-west of Darlington.

Figure 4 – Murchs Corner BESS Location

The project area is located within the Stony Point farming property and is surrounded by rural land generally used for agriculture, with some rural residences. There are two sensitive receptors within 2km of the investigation area, including the associated dwelling. The project area boundaries are as follows [1]:

- North: Hamilton Highway, 2 dwellings along Hamilton Highway, and a creek that running along the eastern boundary of the investigation area.
- South: A centre pivot and farming dam.
- East: The associated Stony Point manor and Mount Emu Creek.
- West: The proposed Darlington Wind Farm, a wetland and dwelling along Hamilton Highway.

Two dwellings are located close to the BESS area at the following locations [1]:

- 2977 Hamilton Highway (associated dwelling), ~1.3km from the BESS area.
- 3282 Hamilton Highway, ~1.2km from the BESS area.

The new BESS development is located within a Farming Zone (FZ) and all the adjoining allotments have the same farming purpose (Figure 1). The area is also classified as a bushfire Prone Area (Figure 6), but it is not within a Bushfire Management Overlay (BMO).

The subject allotment is classified as a BPA (Bush Fire Prone Area) in accordance with the VIC Planning portal (Figure 6). However, it is also a Farming Zone, and therefore owners must maintain the land to minimize the risk of fire spread. The vegetation of the project area has been assessed within the Peter Hack Consulting LVIA (Landscape Visual impact and Visual assessment) report. Within the LVIA report the subject site is classified as a cleared area comprising flat landscape of open pasture or cropping land with sections of trees and shrubs. Under those conditions, no BAL (bushfire assessment level) assessment is required to be addressed in this document in accordance with the AS3959-2018.

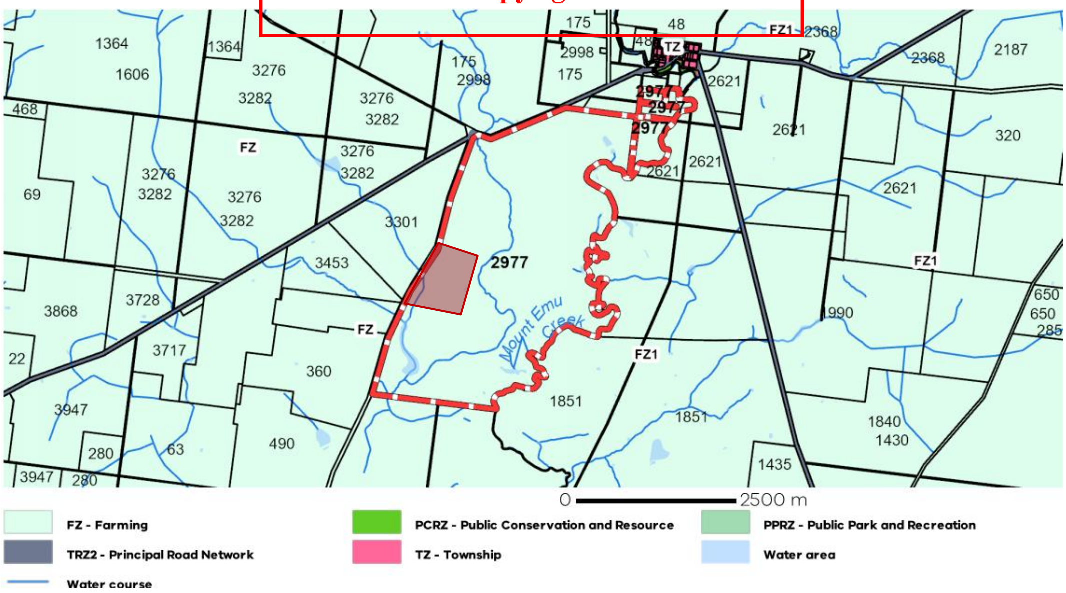


Figure 5 – Development within a Farming Zone.

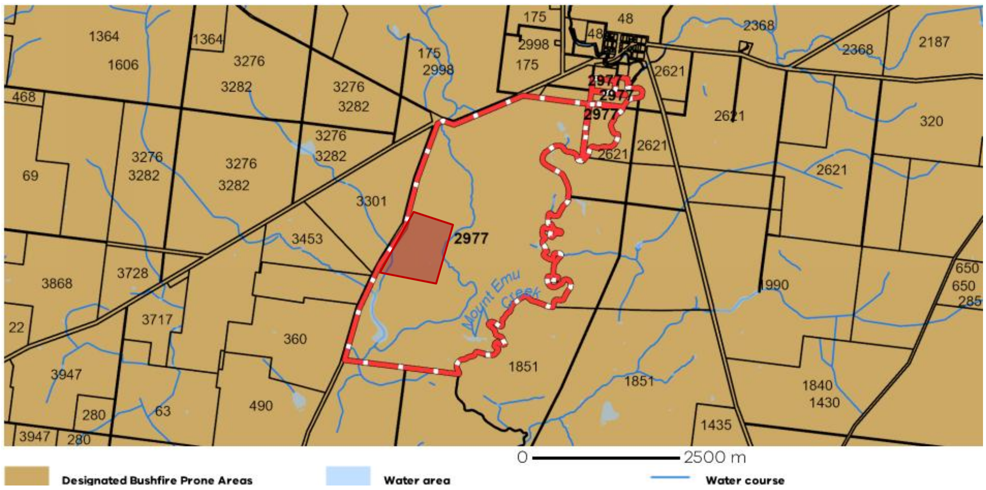


Figure 6 – Bushfire Prone Areas.

Further the adjoining allotments, the Darlington Common Flora Reserve is located approximately 4km to the north-east, the Darlington 'stony point' Airfield 1 and Airfield 2 (both dormant) are located approximately 3.5km towards north-east and 1.5km Southwest respectively, and the closest residential area is Darlington 1.2km away. (Figure 7).

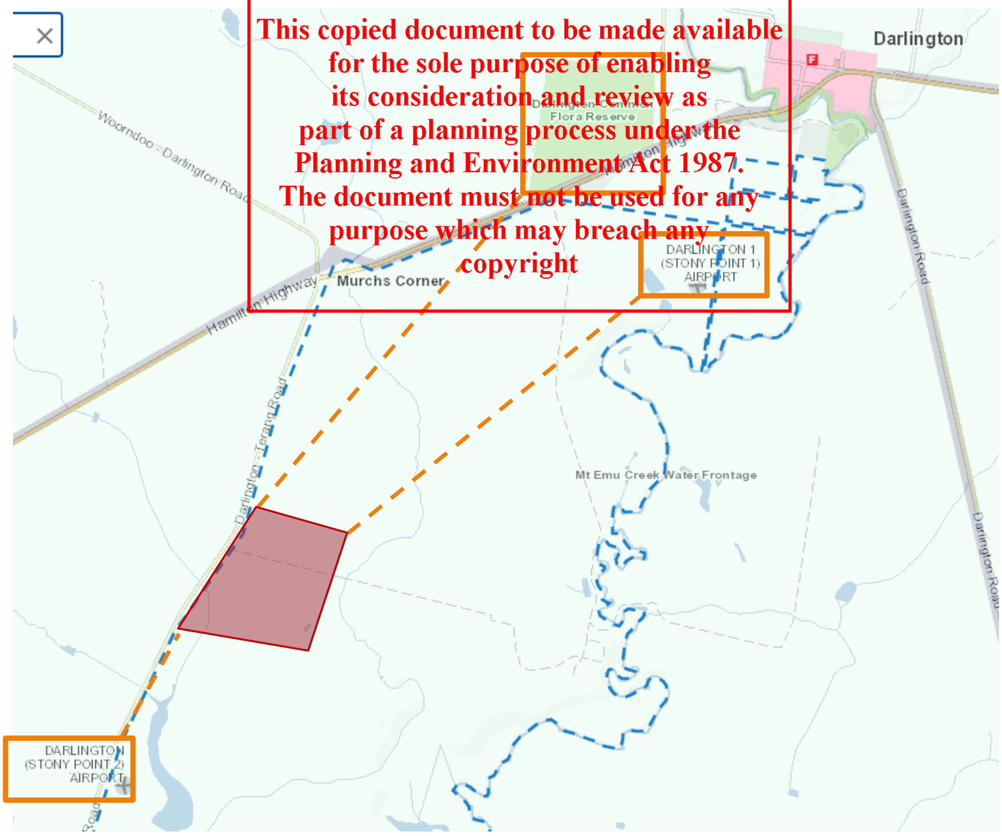


Figure 7 - Closest public and natural areas.

5.1.4 Murch's Corner weather conditions

The closest weather station to Murch's Corner BESS development is at the Mortlake Racecourse. In accordance with the available data at the Bureau of Meteorology, the average weather conditions are the following (Figure 8 Figure 9) [10]:

- The average temperature is 19.4°C and the highest temperature can reach up to 26.3°C in January.
- The mean relative humidity is 83% in the morning, and 45% in the afternoon.
- Wind statistics (Figure 9):
  - Wind is calm 1% of the time.
  - The strongest wind comes from the south-east with a speed of more than 40 km/hr (11.1m/s), approximately 0.5% of the time.
  - Maximum average speed of the wind is 22.0km/hr (6.1m/s).

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years		Plot	Map
Temperature																	
Mean maximum temperature (°C)	26.3	26.3	24.1	20.1	16.2	13.6	13.1	14.0	15.9	18.3	20.9	23.7	19.4	35	1990 2025		
Mean minimum temperature (°C)	11.2	11.6	10.0	8.1	6.5	4.9	4.6	4.9	5.7	6.5	8.1	9.4	7.6	35	1990 2025		
Rainfall																	
Mean rainfall (mm)	36.2	30.4	31.0	43.6	55.2	56.5	62.3	63.5	57.5	55.4	48.8	40.6	582.1	31	1994 2025		
Decile 5 (median) rainfall (mm)	23.6	27.0	31.6	38.8	47.8	54.8	59.5	56.0	55.0	47.0	42.6	35.8		32	n/a n/a		
Mean number of days of rain ≥ 1 mm	4.2	3.5	5.5	7.1	9.5	10.1	12.4	12.3	11.4	9.5	6.7	6.2	98.4	30	1994 2025		
Other daily elements																	
Mean daily sunshine (hours)																	
Mean number of clear days																	
Mean number of cloudy days																	
9 am conditions																	
Mean 9am temperature (°C)	16.9	16.7	14.7	13.1	10.3	8.0	7.5	8.6	10.7	12.5	13.9	15.7	12.4	19	1991 2010		
Mean 9am relative humidity (%)	75	79	83	83	90	92	91	88	84	79	79	74	83	19	1991 2010		
Mean 9am wind speed (km/h)	17.2	15.9	13.6	15.2	14.5	14.9	16.4	18.7	20.2	20.1	18.3	18.5	17.0	18	1991 2010		
9am wind speed vs direction plot																	
3 pm conditions																	
Mean 3pm temperature (°C)	23.7	24.4	22.0	18.5	15.1	12.4	11.9	12.7	14.2	16.3	19.1	21.3	17.6	19	1991 2010		
Mean 3pm relative humidity (%)	47	46	49	55	68	75	74	71	68	63	59	52	61	19	1991 2010		
Mean 3pm wind speed (km/h)	22.7	21.7	21.3	20.1	19.6	20.9	21.8	23.8	24.1	22.9	21.9	22.6	22.0	19	1991 2010		
3pm wind speed vs direction plot																	

Figure 8 – Murch's Corner AWS weather statistics.

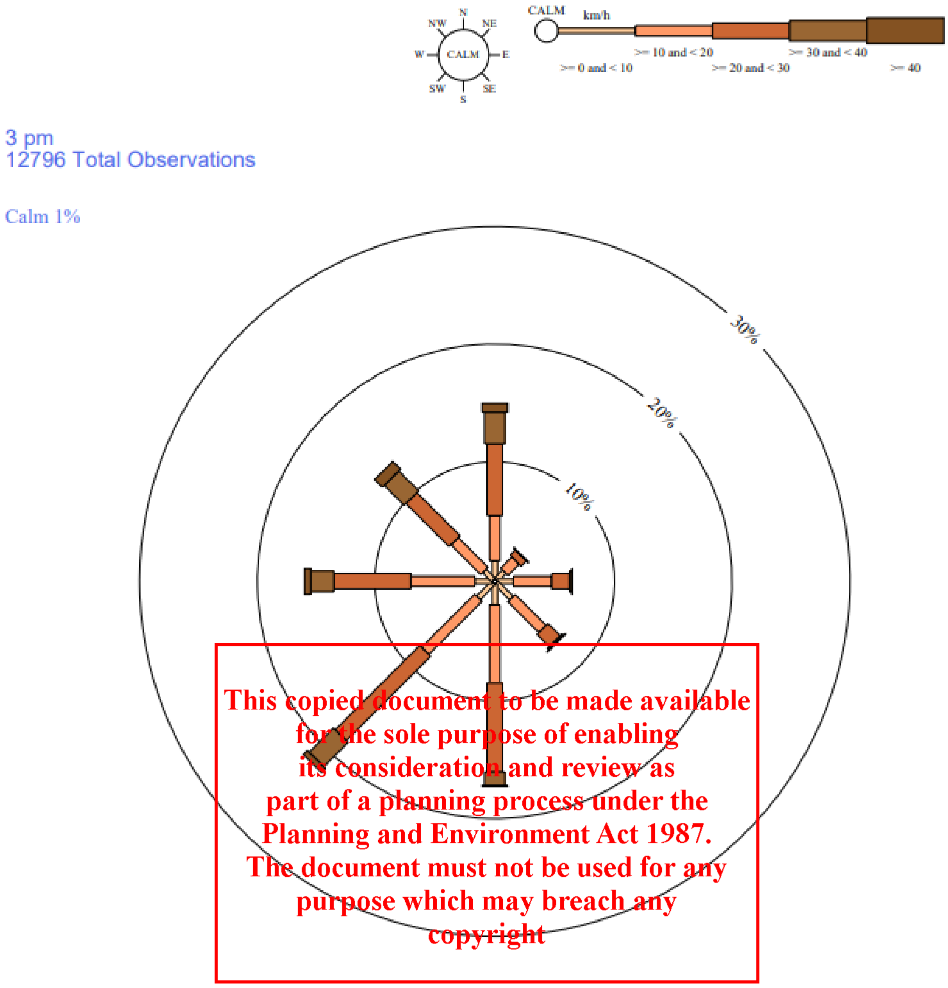


Figure 9 – Wind Rose from Mortlake Racecourse Station.

5.2 FIRE BRIGADE

5.2.1 Fire Brigade Objectives

The overall philosophy of the Fire Brigade objectives throughout Australia is to protect life, property and the environment from fire as noted in the FBIM [9].

Firefighters must be given reasonable time to enter buildings to conduct occupant search and rescue activities and to carry out internal firefighting before exceeding conditions that are likely to threaten fire fighter safety and prior to building collapse.

Under reasonable circumstances, structures must not collapse onto adjoining property, and fire spread must be prevented. Also, fire spread within a building must be limited.

The Fire Brigade also has functions with regard to property protection and considerations regarding occupational health and safety for its employees. These issues are outside the building regulatory framework and NCC.

5.2.2 Fire Brigade Stations

The closest fire brigade stations are the Darlington Fire Station 4km away to the northeast, and the Wooriwyrite Fire Station at 12.8km to the south from the subject site.

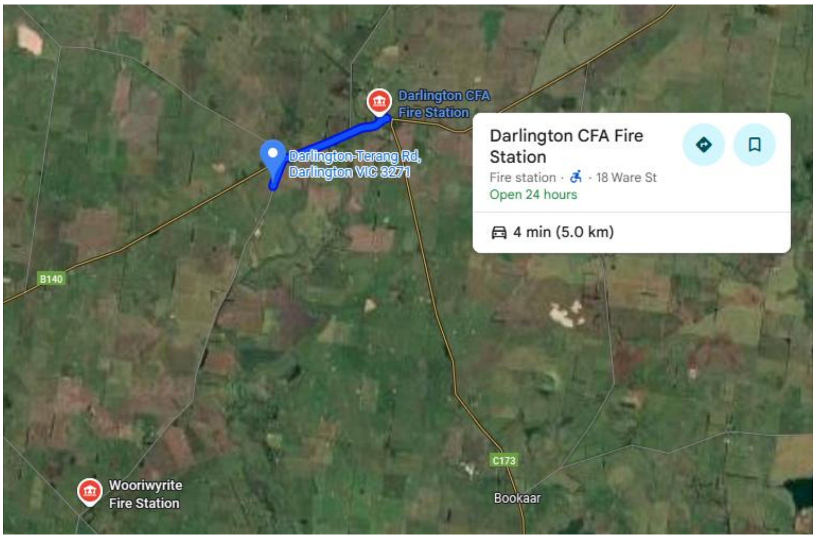


Figure 10 –Darlington Fire Station to subject site.

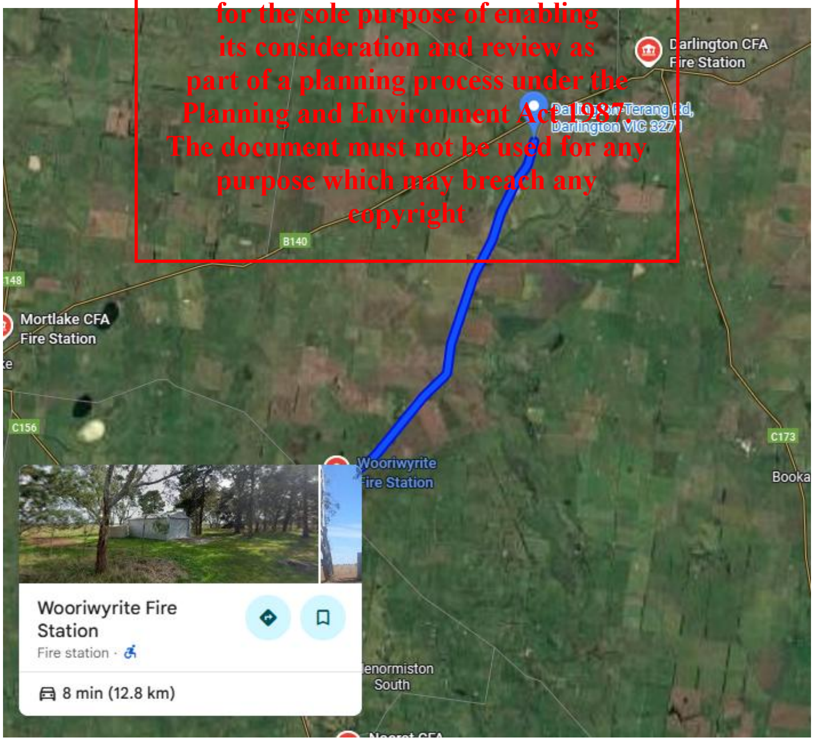


Figure 11 – Wooriwyrite Fire Station to subject site.

5.2.3 Fire Brigade Access

The access roads (2 alternative entrances) to the new Murch's Corner BESS development are located on the west side of the development and to the south. The southern access connects onto internal Stony Point access track, that connects to Darlington-Terang Rd. (Figure 12).

The access roads and roads around the BESS array areas are not less than 4.5m wide, surpassing the requirements of the Fire Brigade guidelines.

The roads are for the fire brigade truck and maintenance purposes, and the roads extend around and within the facility. The fire truck will run within the fence that encloses the facility to reach all equipment.

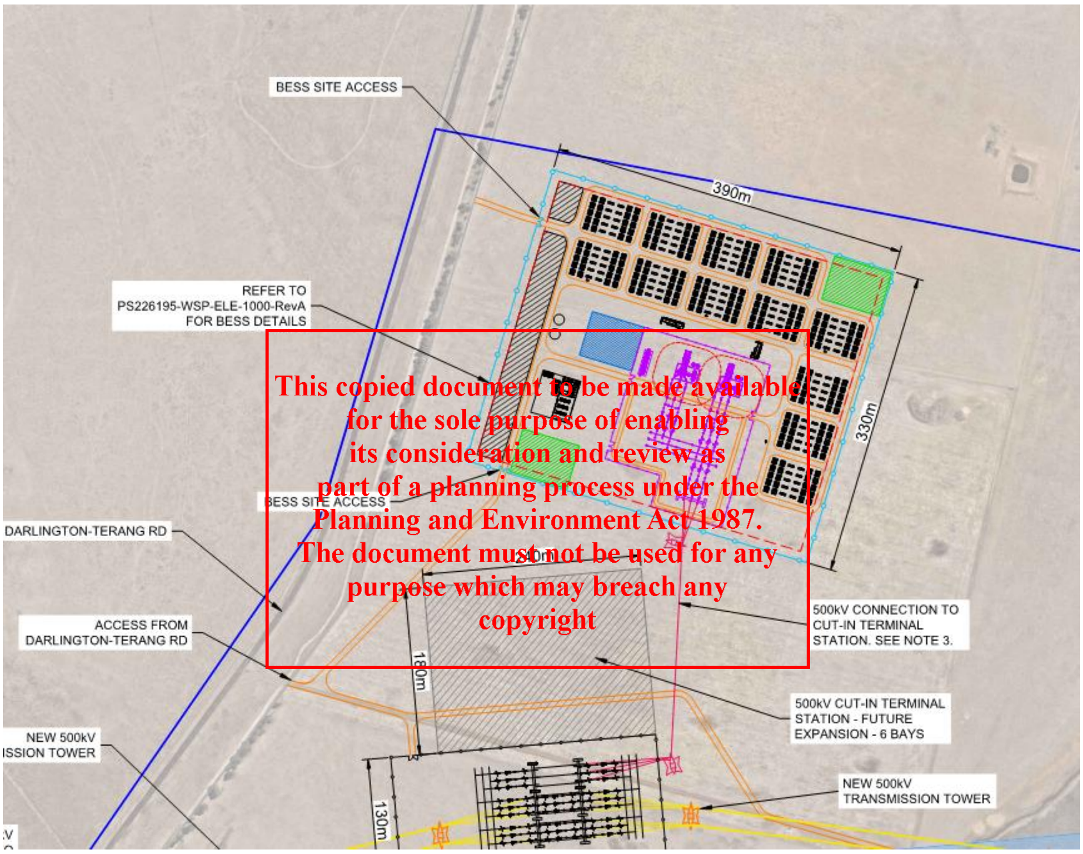


Figure 12 – Access roads to BESS to the western side.

5.2.4 General Fire Safety Strategy

All equipment should be alarmed and automatically notify an operator who will proceed according to the Emergency plan and the protocols provided by the equipment suppliers. Any fire associated with the battery should be confirmed via telemetry and a 24/7 operations centre that will call out the brigade.

In the worst case scenarios assessed in the study where any equipment or infrastructure is on fire, the total burn out can be allowed without the need for fire brigade intervention given that fire spread is not expected to occur between equipment/infrastructure (Section 7). If a building is on fire, the Fire Brigade can proceed with the standard fire brigade intervention procedures as they judge convenient given the fire protection systems provided and the input from the staff.

As part of the fire protection systems, portable fire extinguishers and a fire hydrant system should be provided throughout. Where any infrastructure or equipment is on fire, the fire brigade can use the fire hydrant system to cool adjoining areas/vegetation/infrastructure if required while the main fire extinguish itself (i.e., not to attempt to extinguish the main fire).

Although fire spread is not expected, the fire brigade will have available a water storage of 600kL (2*300kL) for bushfire events or manage site fires as per above.

It is expected that the responding Fire Brigade will respond to site after notification of an event by an emergency call from the staff on site, staff monitoring the site remotely or a member of the public when any of them visualise a fire. When the fire brigade intervenes, they are expected to help control a safe perimeter around the fire and allow equipment on fire to self-extinguish.

Firefighters should wear self-contained breathing apparatuses (SCBAs) and structural firefighting gear.

All gates should be provided with either 003-key padlocks or handled via intercom to facilitate the access of the Fire Brigade via any entrance available to the site. Staff will always assist the fire brigade when they arrive to the site.

The attending personnel and vehicles will be equipped to commence the firefighting activities including investigations, set up and firefighting.

Before the worst-case scenario above occurs to a BESS container or transformer, the risk of a potential fire may be detected by the fire safety measures (refer to Section 8). When any of those sensors is triggered, the signal of the abnormal condition is detected by the safety systems and sent to the 24/7 remote monitoring centre for appropriate action [10].

Detailed contacts and further emergency responses will be listed in the Emergency Management Plan of the site, and it will also consider the input from the equipment suppliers where provided.

6 Fire Hazards Identified

The subject BESS will comprise a number of equipment components with associated hazards. The main hazards associated to the subject facility are the following:

- Thermal runaway events to battery containers, and hence fire spread to adjoining equipment/facilities.
- Fire from substations and hence fire spread to adjoining equipment/facilities.
- Fire from transformers and hence fire spread to adjoining equipment/facilities.
- Bushfire hazard from adjoining allotments.
- Release of contaminant gasses (i.e., pollution) and toxic gasses (i.e., HF, HCL, and HCN) (Hydrogen Fluoride, Hydrogen Chloride, Hydrogen Cyanide) from a fire to BESS Container or transformer.
- Leakage of the transformers' oil and contaminated water runoff.
- Electrocution and EMF Hazards.
- Flammable liquids or gasses.

The following section will explain past events, causes and findings regarding the above risks, and the fire safety measures are described in Sections 8 and 9.

6.1 Thermal Runaway Events and Hence Fire Spread To Adjoining Equipment/ Facilities

One of the main hazards associated with the use of lithium batteries for energy storage is overheating and thermal runaway resulting in a fire. Cell thermal runaway refers to rapid self-heating of a cell derived from the exothermic chemical reaction of the highly oxidizing positive electrode and the highly reducing negative electrode; it can occur with batteries of almost any chemistry.

Lithium-ion batteries contain highly energetic materials and combustible materials (i.e., electrode, separator, electrolyte and organic solvents). If they are subject to overcharging, short circuit, extrusion, collision and exposed in fire, this can trigger thermal runaway and lead to a fire and explosion.

The combustion process of batteries could be summarized into the following stages: heating to ignition, violent ejecting or explosion, stable burning, and weakening and extinguishment. Both the state of charge and incident heat flux have significant impact on the combustion behaviour of the battery. The battery with high charge presents a fierce combustion process and higher surface temperature than the others, especially when imposed with a high external heat flux.

In order to obtain an understanding of the hazards associated with BESS facilities a summary of past fires is presented in Appendix C including the Moorabool Fire (i.e., Victorian Big Battery (VBB) fire).

In the Article "Burning concern: Energy storage industry battles battery fires", in the S&P Global market Intelligence website, 24 May 2019 it was reported by Ken Boyce, a principal engineer at product safety certification, testing and advisory firm UL LLC that: "In general, it's a very safe technology. Lithium-ion battery cells fail at a rate of only around one in every 12 million". This is the rate of 8x 10-8 per year.

Since 2011, Electric Power Research Institute (EPRI) has recorded 81-88 incidents of BESS failures worldwide, where:

- 5.78 average failures per year per 530MWh.
- 0.63 failures per year due to battery cells/modules per each 530MWh.
- 0.01589% of MWh will have a failure incident per year (i.e., 1.59 x 10-4 failures per year per MWh).

6.2 FIRE FROM SUBSTATIONS

The Murch's Corner BESS will have a new 500kV Substation (High Voltage), composed by two 500/33kV transformers.

The combustible materials in distribution substations and equipment involved in substation fires may include the electrical wire or cable insulation, transformers (e.g., transformer fluids, especially oil), valves, outdoor or indoor oil-insulated equipment, oil-insulated cable, hydrogen-cooled synchronous condensers, PCB-insulated equipment and other items.

The Ministry of Economic Development (MED) provides annual statistics reports in New Zealand. In accordance with MED, from the substation's fires in New Zealand between 1946 and 1995, 65% of these fires had the electrical wire or cable insulation as the object first ignited (Figure 13Figure 13 – Substation fires distribution.). Compared to the cable insulation, the probability of having transformer or transformer fluid as the object first ignited is much lower (20%).

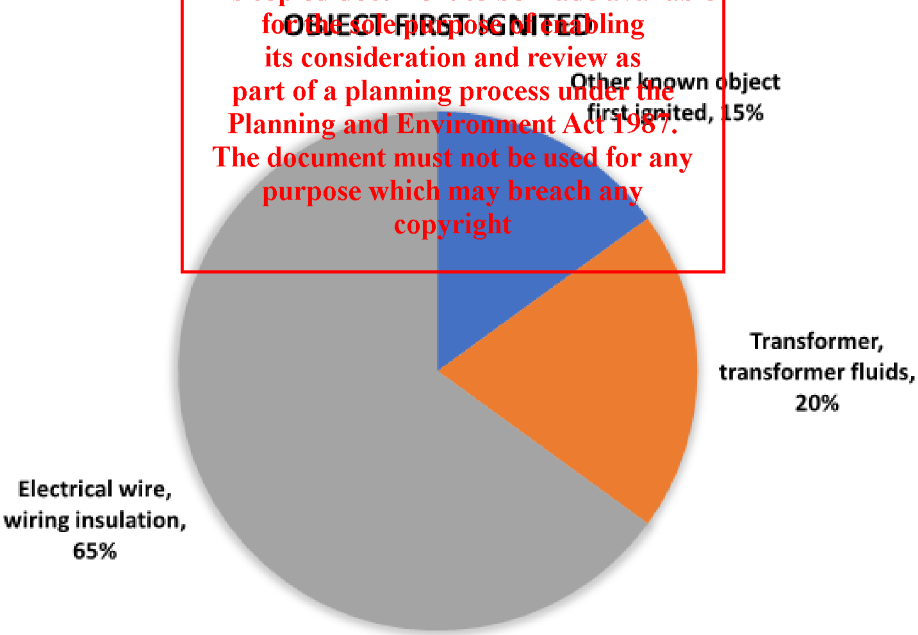


Figure 13 – Substation fires distribution.

The EEP (Electrical Engineering Portal) [13] indicates that fires in substation are not common, however consequences are catastrophic for the company and consumers. The EEP lists the types and origins of fires in substations between 1971 and 1994 in Figure 15.

Types and Origins of Fires	Percentages
Oil-insulated circuit breakers	14.0
Current transformers	14.0
Power transformers	9.3
Hot work procedures (welding, cutting, and grinding)	9.3
Potential transformers	7.8
Engine-driven generators	7.0
Arson	6.3
Smoking	6.0
Lightning	4.7
Flammable liquid storage or handling	3.1
Terrorism	1.6
Miscellaneous fires	15.8

Figure 14 – Types and origins of Substation fires.

Also, CIGRE [14] has completed a survey of reliability and failures of in-service high voltage equipment, such as SF6 circuit breakers, disconnectors, earthing switches, instrument transformers and GIS. The survey gathered data from 90 utilities from 30 countries. The main findings were the following:

- The overall failure frequency for circuit breakers is 0.30 major failures per 100 circuit breaker years of service.
- For disconnectors and earthing switches the overall major failure frequency is determined to be 0.21 major failures per 100 circuit breaker years of service.
- Instrument transformers have an overall failure frequency of 0.053 major failures per 100 single phase instruments transformers years of service.
- In general, individual equipment installed in GIS appears to have lower failure frequencies than equipment in air insulated substations. The overall major failure frequency for GIS bays is about 0.37 major failures per 100 GIS circuit breaker bay years of service (a GIS circuit breaker bay includes one circuit breaker and all associated disconnectors, instrument transformers, interconnecting busducts and/or parts of busbars and associated terminals).

6.3 Fire from Transformer

The Murch's Corner BESS will have the below transformers:

- MV transformer (also SUT – Step-up transformer).
- 500 kV HV Substation. Composed by 500/33kV transformers

The following section details the likelihood of transformer fires from various sources:

- The last Australian CIGRE reliability report in 1995 came up with a failure rate for a failure causing a fire as 0.01%, i.e., $1x10^{-4}$/yr. This was for transformers above 60 kV.

- A more recent survey (not a formal survey) covering 1800 transformer tanks from 6 utilities over 7 years calculated a risk of causing a fire as 0.09%, i.e., 9 x 10^{-4}/year (re CIGRE transformer Technology Conference 2008, presentation on Risk of Transformer fires by Arne Petersen).
- With regard to the Victorian transmission system for transformers 220 kV and above, there has only been one fire in 32 years giving a rate of 0.021%, 2.1x10^{-4}/yr.
- The New Zealand Ministry of Commerce, now known as the Ministry of Economic Development (MED), is a government department responsible for the government ownership of public properties. The number of distribution substations and the population in New Zealand are provided in their annual statistics reports. The statistical data on the number of distribution substations in New Zealand was obtained from the MED between 1946 and 1995. Since the statistical data after 1995 was not available, the number of distribution substations between 1995 and 2006 is estimated based on the growth rate measured in the previous 50 years. The NZFS FIRS database during the 6 years period from January 2000 to January 2006 indicated 24 fire incidents, 20 fire incidents were related to distribution substations, and 4 fire incidents are related to power or terminal substation. The 4 fires related to power or terminal substations were indicated to originate in switchgear areas or transformer vaults as shown in Figure 16.

Therefore, the average rate of fire starts in a transformer is - 4 x 10^{-4}/year.

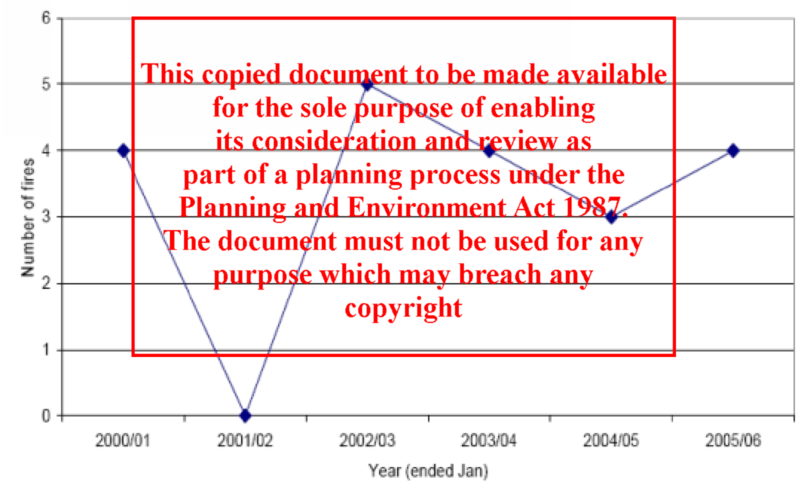


Figure 15 – Number of distribution substation fires from 2000 -2006 (Source NZFS FIRS)

6.4 Fire from Ancillary Areas

Minor areas in the facility are the O&M Compound and the Switch room buildings.

Those facilities do not comprise special hazards and will be constructed as per the NCC DtS provisions, hence the risk of fire spread can be assessed as per the mythologies accepted by the NCC. Given the clearances shown in Appendix A, fire spread is not considered to occur, however further assessment is performed in Section 0 of this document.

6.5 BUSHFIRE HAZARD FROM ADJOINING ALLOTMENTS

Given the location of the development, where the BESS area is within a farming zone without vegetation, the risk of a bushfire is not required to be addressed (refer to section 5) in accordance with the AS3959-2018.

Also, the AS3959 requires to assess any vegetation within 100 from the facility boundary fence.

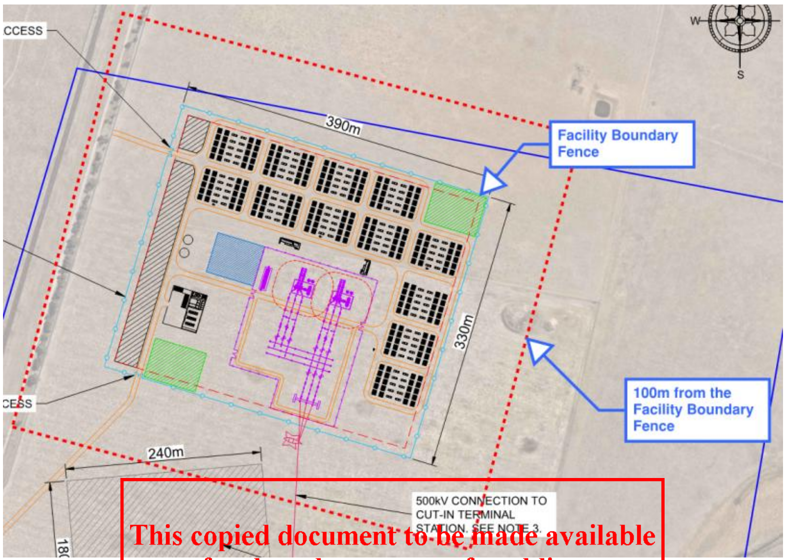


Figure 16 – Area of 100m from the facility boundary.

Although the subject site is located with a bushfire prone area, the figure below show that the predominant vegetation is grassland and isolated trees, therefore a further assessment is not required in accordance with the AS3959-2018.

Figure 17 – Dominant vegetation at the Murch's Corner BESS site (Google Maps).

6.6 RELEASE OF CONTAMINANT GASSES (I.E. POLLUTION)

Given a fire to a BESS Container or a transformer, the most common toxic gases released are HF (Hydrogen Fluoride), HCL (Hydrogen Chloride), HCN (Hydrogen Cyanide), CO (Carbon monoxide), CO_2 (Carbon dioxide), H (Hydrogen) and other flammable hydrocarbons like acetylene and methane from the oil's decomposition.

Those gasses are a hazard to the human life safety (people to the surrounding community and the fire brigade) if the exposure thresholds are surpassed.

It is recognized that the location of large residential communities is more than 4km away, and there are dwellings at the surrounding farmlands to manage the farming activities at 1.2km away.

Humans start feeling some discomfort due to CO concentration higher than 30pp (30×10^{-6} mol/mol), and CO_2 concentration of 1,000ppm ($1{,}000 \times 10^{-6}$ mol/mol) [11].

Assuming a fire of an average transformer that uses mineral oil with a capacity of 60,000 litres (60.0 m^3), with a bund of 19m x 13m, the figures below demonstrate that concentration of pollutants to more than 1.0km away from the subject site are not expected to surpass the human thresholds.

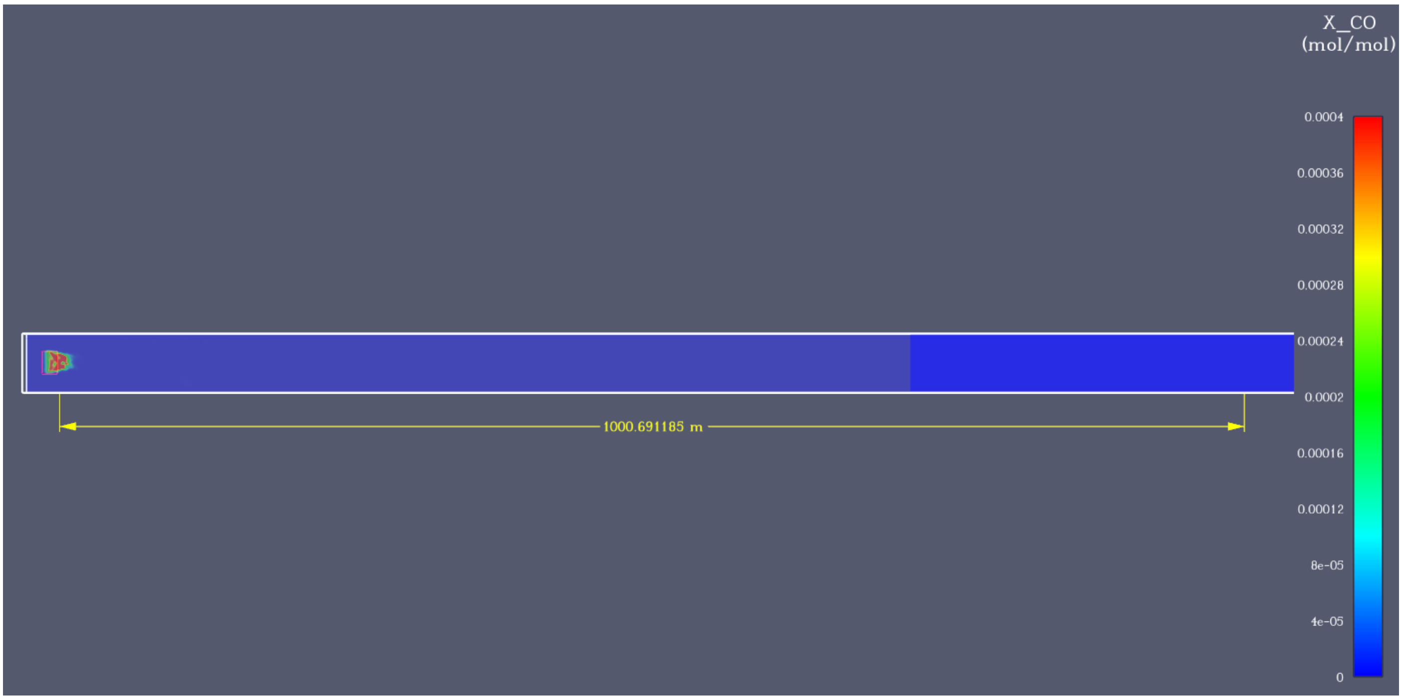


Figure 18 – CO Concentrations at residential communities.

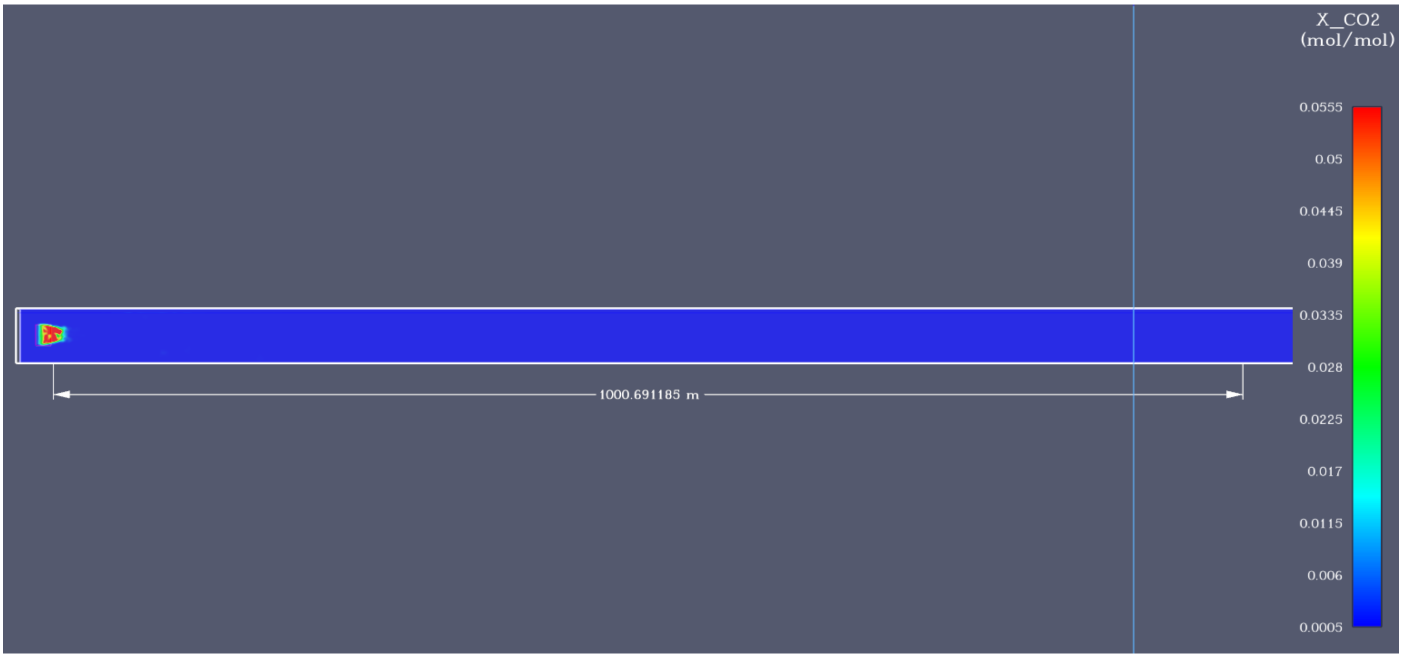


Figure 19 – CO_2 Concentrations at residential communities.

6.7 Leakage of the Transformers' Oil and Contaminated Water Runoff

Oil transformers and the water storage of 600kL have the risk of contaminated runoff water. The following measures should be provided by the facility:

- Transformers:
  - The MV/SUT (Medium Voltage/Step-up) transformers should be self-bunded transformers that include splash guards for AS1940 compliance, hence the oil will remain enclosed, preventing potential environmental damage and fire spread.
  - The 500/33kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow. This will also prevent potential environmental damage and fire spread.
- Water runoff:
  - A containment and management plan for fire water runoff from the BESS is to be developed by the facility.

6.8 Electrocution and EMF Hazards

Further assessment to electrocution and EMF hazards is out of the scope of this study. The assessment is to be provided by the facility.

This documentation is listed as a requirement in Section 8 of this document, and safety measures are to be added in the Emergency Management Plan.

It is recognized however that the site should be provided masts for lighting protection, and that most BESS Containers are provided with a lighting protection design.

6.9 FLAMMABLE LIQUID AND GASSES

Storage of flammable liquids or liquified flammable gasses in tanks will not occur within this site, therefore this risk and associated events are not applicable to this study.

7 Consequence of Incidents to Equipment/ Facilities

This section assesses the consequences of fire given a fire of the BESS units, Substation and ancillary infrastructure. It is out of the scope of this report to include consequences related to financial impact, environment, legal and regulatory, community, and Property protection.

7.1 Fire Spread Acceptance Criteria

- IEEE Std 979-2012 [16]:

Table B.3 of IEEE Std 979-2012 [16] gives some typical examples of the amount of radiant heat necessary to ignite common materials used in substations.

Table 4 – Typical radiant heat flux intensities (Table B.3IEEE Std 979-2012) [16].

Impact of radiant heat flux	Heat flux (kW/m^2)
Sufficient to cause damage to process equipment	37.5
Equipment failure	35
Damage to unprotected metal	30
Spontaneous ignition of wood	25
Cable insulation degrades	20
Pilot ignition of wood	12.5
Plastic melts	12.5
Pain threshold reached after 8s. Second degree burns after 20s.	9.5
Possible failure of ceramic bushings	5
Skin burns	5

- AS 1530.4-2014 [18]:

Where other façade/lining materials are present in adjoining building or equipment, Table A3 of AS 1530.4-2014 [18] contains a listing of heat flux required for radiant ignition for piloted and unpiloted ignition. The heat flux (q_{cr}) level for piloted ignition is taken as 13 kW/m^2, and for non-piloted ignition is taken as 25 kW/m^2. Refer to the table below.

Table 5 – Typical radiant heat flux intensities based on AS 1530.4-2014 [18].

Phenomena (Maximum for indefinite exposure for humans)	kW/m^2
Pain after 10s to 20s	4
Pain after 3 s	10
Piloted ignition of cotton fabric after a long time	13
Piloted ignition of timber after a long time	13
Non-piloted ignition of cotton fabric after a long time	25
Non-piloted ignition of timber after a long time	25
Non-piloted ignition of gaberdine fabric after a long time	27
Non-piloted ignition of back drill fabric after a long time	38
Non-piloted ignition of cotton fabric after 5s	42
Non-piloted ignition of timber in 20s	45
Non-piloted ignition of timber in 10s	55

The assessment methodology requires that a fire will not cause a received heat flux (q_r) in excess of the critical heat flux (q_{cr}) on the allotment boundary or equipment.

Acceptance will be demonstrated if $q_r < q_{cr}$.

- Fire Brigade:

Acceptable levels of radiation for firefighter operations shall be a maximum of 3.0 kW/m^2 from the ground level, level at which the fire brigade will perform fire brigade operations [19].

- Equipment criteria:

Based on the critical heat flux criteria outlined above, the following standards will be applied to the equipment or structures in the proposed development:

Table 6 – Critical heat flux criteria.

Equipment / Building / Vegetation	kW/m^2
500kV HV Transformer	5.0
MV/SUT transformers	5.0
BESS units / Battery container	37.5
Switch rooms	30.0
O&M compound	30.0
Vegetation (closest fence/boundary)	13.0
Fire Brigade	3.0

7.2 500KV HV SUBSTATION

In order to assess the impact of a transformer fire on other objects, the transformer will be treated as a pool fire and will be assessed in accordance with AS2067.

<u>Transformer pool fire:</u>

The transformer fire is treated as a pool fire is based on liquid hydrocarbon fire. The method used to calculate the heat flux received at a target was one that is generally accepted in the risk engineering discipline detailed in the Yellow Book (Committee for the Prevention of Disasters).

Enclosure Fire Dynamics gives a correlation equation (Equation 3.6) to estimate the free burn mass loss rate as below:

$$\dot{m}'' = \dot{m}''_{\infty}(1 - e^{-k\beta D})$$ (Equation 3.6, *Enclosure Fire Dynamics)* [12]

Where:

- $\dot{m}_{\infty}$: 0.039 kg/m^{2}s [12]
- $k\beta$: 0.7 (m^{-1}) [12]
- D: diameter of the pool fire as a circle.

Petroleum products				
Benzine	740	0.048	44.7	3.6
Gasoline	740	0.055	43.7	2.1
Kerosine	820	0.039	43.2	3.5
JP-4	760	0.051	43.5	3.6
JP-5	810	0.054	43.0	1.6
Transformer oil, hydrocarbon	760	0.039[b]	46.4	0.7[b]
Fuel oil, heavy	940–1000	0.035	39.7	1.7
Crude oil	830–880	0.022–0.045	42.5–42.7	2.8

Figure 20: Extract Burning rate estimates [12].

As can be seen from the above equation the fire size in terms of mass loss rate and hence heat release rate is independent of the transformer size and volume of oil.

A liquid fuel pool fire in the transformer will be modelled using the NIST Fire Dynamics Simulator model.

The National Institute of Standards and Technology (NIST) has been developing Fire Dynamics Simulator (FDS), to predict fire spread in a structure. Over the past few years, it has also been used to predict smoke and hot gas plume behaviour produced by outdoor fires. FDS is well documented and is widely used by fire protection engineers around the world. The model is being extended to include fire spread from structure to structure and generalizing FDS to include a means to predict fire spread in both continuous and discrete natural fuels.

The fire growth and spread were modelled using the National Institute of Standards and Technology (NIST) Fire Dynamics Simulator (FDS) software package and Smoke-view which is used to view the results.

Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires.

In accordance with the methodology described above and considering the average characteristics of the transformer of the substation, a bund of approximately 336m^2 with a fire of 452.6 MW (Figure 21) is estimated.

Volume oil	60000.00	L	
	60.00	m^3	
Bund			
Area TK & Radiator	40.00		
L	25.00	m	
W	16.00	m	
H	0.15	m	
Ideal mass loss	0.039	kg/s.m^2	
A	360.00	m^2	
V Bund	54.00	m^3	
D	21.41	m	
m"	0.039	kg/m^2.s	$\dot{m}'' = \dot{m}''_{\infty}(1 - e^{-k\beta D})$ (Equation 3.6, *Enclosure Fire Dynamics)*
Hc	4.605E+07	J/kg	
q	1257.16	kW/m^2	
Ballast Factor	1.00	-	Without ballast = 1, with ballast = 0.2.
Q	452.58	MW	$\dot{Q} = A_f \dot{m}'' \chi \Delta h_c$ (Equation 3.5, *Enclosure Fire Dynamics)*

Figure 21 – HRR Calculation substation.

The FDS model result are presented in figures below, and the fire scenario characteristics are as follows:

- Fire Origin: Transformer at substation 500/33kV.
- Fire growth: Instant.
- Weather conditions (refer to Section 5.1.4): Wind speed – 6.1m/s; Temperature – 26.3°C; Relative humidity –

45%.

- Heat release rate: 452.6 MW (Figure 21 above).
- Hydrocarbon (transformer fires, properties obtained from Table 3-4.19 of SFPE handbook):
  - REAC ID="REAC"
    - C=4.00 N=0.00
    - H=10.00 HEAT_OF_COMBUSTION=4.605 x10^7
    - O=0.00 SOOT_YIELD=0.0600 gr/gr

Given the location of the subject facility equipment shown in Appendix A, the table below summarizes the heat flux received at the different locations (approximate distances) within Murchs Corner BESS.

Table 7 – Heat flux results.

Exposed equipment	Distance (m)	Incident Radiation (kW/m^2)		
		Wind (Figure 22)	No wind (Figure 23)	Critical Criteria
HV transformer	24.0	< 4.0	0.0	5.0
MV/SUT transformers	62.0	< 4.0	0.0	5.0
BESS units	62.0	< 4.0	0.0	37.5
Switch rooms	100.0	< 4.0	0.0	30.0
O&M compound	100.0	< 4.0	0.0	30.0
Vegetation (fence/boundary)	120.0	< 4.0	0.0	13.0

The results indicate that, regardless of wind presence, the maximum heat flux levels at the various critical locations from a fire in the substation are well below the critical heat flux for both piloted and unpiloted ignition. Hence, fire spread is not expected to occur.

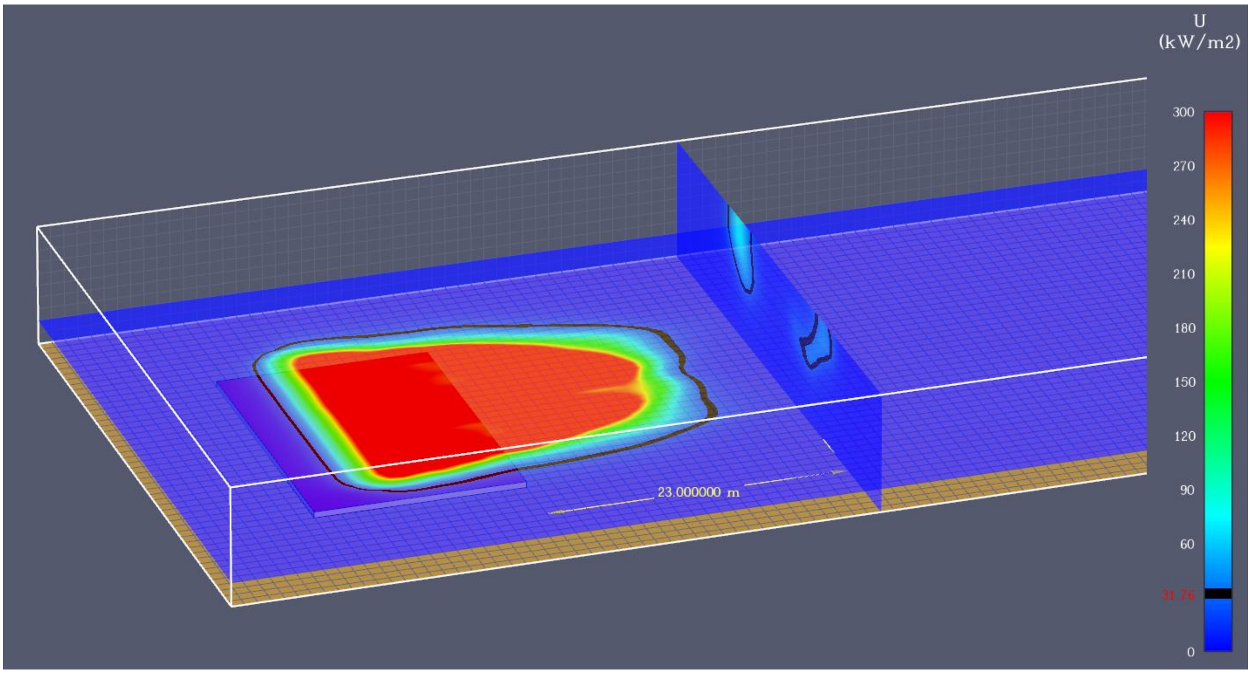


Figure 22 – Radiant heat flux intensities with wind (HV-Transformer).

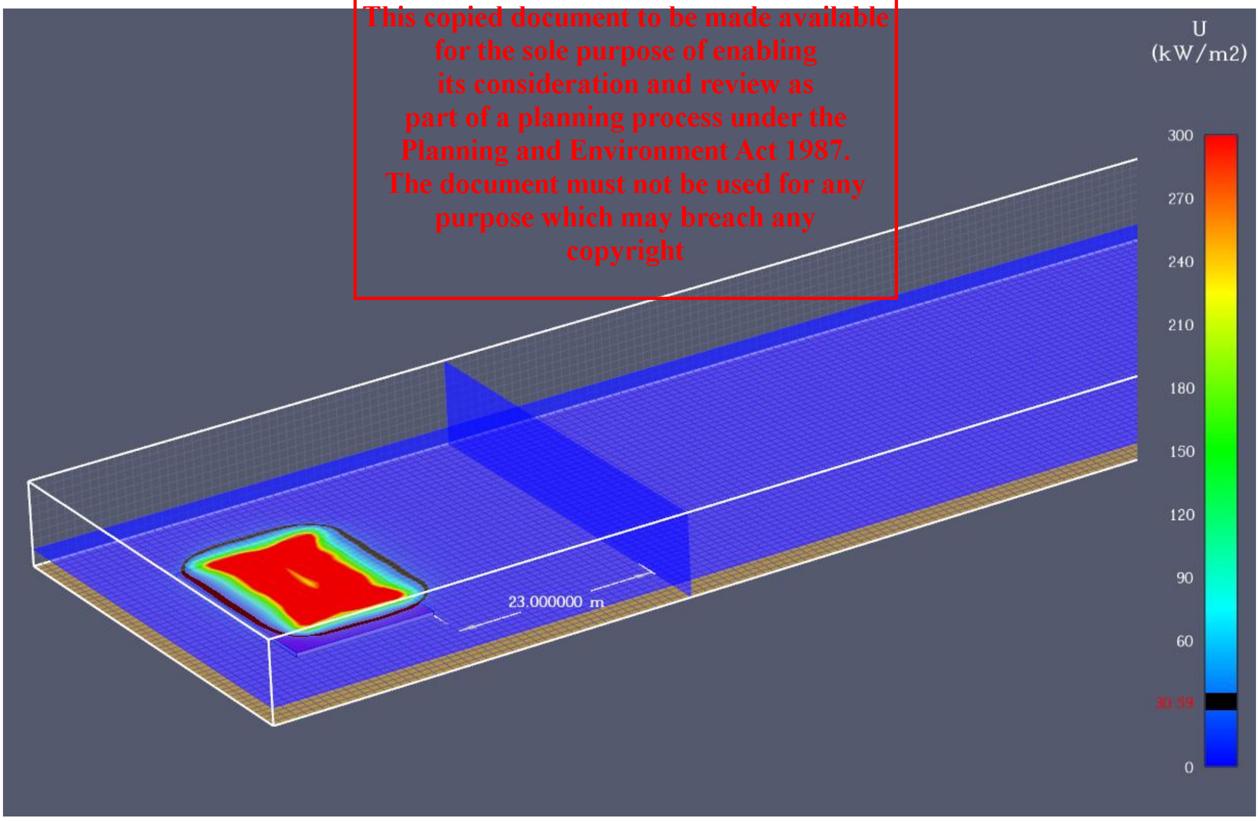


Figure 23 – Radiant heat flux intensities without wind (HV-Transformer).

Transformer location review as per AS2067:

Australian Standard AS2067-2016 is the most relevant standard with respect to the location of existing power utility infrastructure. The standard is based on oil transformer equipment and not batteries. However, the fire risk from a transformer is considered to be similar to that of a BESS.

The minimum separation distances are specified in AS2067 Table 6.1 below, considering that the transformers will use mineral oil and their oil capacity is expected to be an average of over 60,000 litres (60.0 m^3).

Table 8: AS 2067 Table 6.1

CLEARANCES FOR OUTDOOR TRANSFORMERS

Transformer type	Liquid volume	Clearances to other transformers or equipment	Clearances to buildings		
		Horizontal separation G_1 to other transformers or non-combustible surfaces	Horizontal clearance G_2 to combustible surfaces	Horizontal clearance G_3 to 2 hour fire resistant surfaces of buildings	Vertical extent G_4 for 2 hour fire resistant surfaces of buildings
	L	m	m	m	m
Oil-insulated transformers (O)	100 ≤1000	1	6	1	4.5
	>1000 ≤2000	1.5	7.5	1.5	7.5
	>2000 ≤20 000	5	10	4.5	15
	>20 000 ≤45 000	10	20	7.5	30
	>45 000 ≤60 000	15	30	7.5	30
	>60 000	23	30	7.5	30
Less combustible liquid-insulated transformers (K) without enhanced protection	100 ≤1000	1	6	1	4.5
	>1000 ≤38 000	1.5	7.5	1.5	7.5
	>38 000	4.5	15	4.5	15
Less combustible liquid-insulated transformers (K) with enhanced protection (refer to Note 1)	Clearance G_1 to other transformers or building surfaces				Vertical extent G_4 for 2 hour fire resistant surfaces of buildings
	Horizontal m				Vertical m
	0.9				1.5
Dry-type transformers (A) Fire behaviour class F_0	1.5				3.0

below summarizes the distances of the HV transformers from the adjoining equipment where there is the main risk of fire spread, compared with the requirements of the Australian Standard AS2067.

Table 9: Distance assessment to HV Transformers

Equipment to assess	Adjoining equipment	Required Distance (m) as per AS2067	Proposed Distance (m)	Compliant (Yes/No)
500KV HV Substation transformers	500KV HV transformer	≥ 23.0 without firewall < 23.0 with firewall	~24.0	Yes
	O&M compound	≥ 23.0	~100.0	Yes
	MV transformers, BESS units, switch rooms	≥ 23.0	~29	Yes

7.3 MV/SUT TRANSFORMERS

The assumed Step-up transformers are expected to have Natural Ester filled FR3 oil, an oil volume of not more than 38,000 L. Enhanced protection is to be confirmed.

The MV/SUT transformer is a self-bunded transformer that includes splash guards for AS1940 compliance. The self-bund construction will prevent potential environmental damage and fire spread.

Australian Standard AS2067-2016 is the most relevant standard with respect to the location of existing power utility infrastructure. The minimum separation distances are specified in AS2067 Table 6.1 unless a fire rated wall is used to provide protection. specifies that the proposed transformer must be located to not less than 0.9m from any equipment/facility when enhanced protection is provided, otherwise, distances not less than 4.5m must be provided.

Tables below summarize the distances of the transformers from the adjoining equipment where there is the main risk of fire spread, compared with the requirements of the Australian Standard AS2067.

Table 10: Distance to MV/SUT transformers without enhanced protection (red is not acceptable)

Equipment to assess	Adjoining equipment	Required Distance (m) as per AS2067	Proposed Distance (m)	Compliant (Yes/No)
MV/SUT transformers without enhanced protection	500kV HV Transformer	≥ 4.5	~61.0	Yes
	Battery Container	≥ 4.5	~4.0	No
	O&M Compound	≥ 4.5	~110.0	Yes
	Switch room building	≥ 4.5	~14.0	Yes
	Closest Boundary	≥ 4.5	~16.0	Yes
	MV/SUT transformers	≥ 4.5	~5.0	Yes

Table 11: Distance to MV/SUT transformers with enhanced protection (red is not acceptable)

Equipment to assess	Adjoining equipment	Required Distance (m) as per AS2067	Proposed Distance (m)	Compliant (Yes/No)
MV/SUT transformers with enhanced protection	500kV HV Transformer	≥ 0.9	~61.0	Yes
	Battery Container	≥ 0.9	~4.0	Yes
	O&M Compound	≥ 0.9	~110.0	Yes
	Switch room building	≥ 0.9	~14.0	Yes
	Closest Boundary	≥ 0.9	~16.0	Yes
	MV/SUT transformers	≥ 0.9	~5.0	Yes

The above demonstrates that all the equipment have compliant distances in accordance with the Australian Standard AS2067, in order to mitigate the risk of fire spread.

Table 12: AS 2067 Table 6.1

CLEARANCES FOR OUTDOOR TRANSFORMERS

Transformer type	Liquid volume	Clearances to other transformers or equipment	Clearances to buildings		
		Horizontal separation G_1 to other transformers or non-combustible surfaces	Horizontal clearance G_2 to combustible surfaces	Horizontal clearance G_3 to 2 hour fire resistant surfaces of buildings	Vertical extent G_4 for 2 hour fire resistant surfaces of buildings
	L	m	m	m	m
Oil-insulated transformers (O)	100 ≤1000	1	6	1	4.5
	>1000 ≤2000	3	7.5	1.5	7.5
	>2000 ≤20 000	5	10	4.5	15
	>20 000 ≤45 000	10	20	7.5	30
	>45 000 ≤60 000	15	30	7.5	30
	>60 000	23	30	7.5	30
Less combustible liquid-insulated transformers (K) without enhanced protection	100 ≤1000	1	6	1	4.5
	>1000 ≤38 000	1.5	7.5	1.5	7.5
	>38 000	4.5	15	4.5	15
Less combustible liquid-insulated transformers (K) with enhanced protection (refer to Note 1)	Clearance G_1 to other transformers or building surfaces				Vertical extent G_4 for 2 hour fire resistant surfaces of buildings
	Horizontal m				Vertical m
	0.9				1.5
Dry-type transformers (A) Fire behaviour class F_0	1.5				3.0

Further to the above, unless the BESS supplier provides the results of a large-scale test in accordance with CSA TS-800:24 and the laboratory/centre certifications, a Fire hydrant system should also be provided throughout the facility for fire brigade intervention procedures. Where a SUT transformer is on fire, the fire brigade can use the fire hydrant system to cool adjoining areas/vegetation/infrastructure if required while the main fire extinguish itself (i.e., not to attempt to extinguish the fire).

7.4 Battery Fire - Large scale fire destructive test

Further assessment will be developed at a later stage of this study upon information provided by the supplier.

However, it is noted that latest BESS models are tested as per UL9540A, which intends to demonstrate no fire spread occurs between adjoining BESS containers.

7.5 Fire in other Area of the facility (i.e., O&M Compound and Switch room buildings)

Further to the BESS units and the transformers, the facility contains an O&M Compound and Switch room buildings. The fire associated with these buildings are considered to be no greater than a small office type building. The closest building (i.e., O&M building) is located to not less than 10 from the site boundary.

Based on the International Fire Engineering Guidelines the likelihood of an office fire is $6.2x10^{-3}$ per year and a fire size of approximately $250kW/m^2$. Accordingly, the peak fire size is predicted to be 23MW assuming adequate ventilation.

Given the separation distances to the battery units and other areas of over 6m it is considered that the risk of fire spread is extremely low and significantly less than that for a building with NCC compliant separation distances (3m to the boundary and 6m between buildings) that are considered to represent the community acceptance level for fire spread.

7.6 Fire in Adjacent Allotments

The adjoining allotments are agricultural production lands, and the subject site has firebreaks of not less than 10m away from the closest allotment.

The NCC allows non-load bearing openings within buildings to be 3m from the boundary or 6m from another building on the same allotment. Given the separation distances of the battery units from the boundary (i.e., 14m) it is considered that the likelihood of a fire and the consequence are no worse than in the general community.

Nonetheless, if a grassfire occurs, a Fire hydrant system should be provided throughout the facility for fire brigade intervention procedures and control the fire spread of a grassfire.

8 Fire Prevention Strategies/ Measures

As part of the risk assessment, the following recommendations are to be implemented to satisfy the objectives of the relevant authorities and the client.

Refer to Appendix A for overall floor plans indicating the main Fire Engineering Requirements.

8.1 Fire & Explosion Prevention Strategies

This section describes the Fire & Explosion Prevention Strategies for the BESS units and transformers:

8.1.1 Battery Container

- Test UL9540A to Unit Level test, and/or test in accordance with CSA TS-800:24.
- Fire safety protection measures.
- Explosion control system.
- Remote shutdown provisions.
- Electrical fault protection devices.
- Battery Management system (BMS).
- Thermal management system (TMS).
- Site Controller and Monitoring.

8.1.2 Transformers

- The HV and SUT/MV transformers should comply and surpass the clearances established by the AS2067. The compliant clearances mitigate to the degree necessary the risk of fire spread and damages due to explosions.
- Where necessary it is also possible for the HV transformers to have a fire rated wall in between to prevent hazards between each other.
- The 500/33kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow.
- Where transformers are oil-insulated, transformers shall use an FR3 (or similar) Ester oil where practical in lieu of the normal mineral oil.
- The MV/SUT (Medium Voltage/Step-up) transformers should be self-bunded transformers that include splash guards for AS1940 compliance.

8.2 BESS Fire Detection Requirements

This section describes the fire detection systems required throughout the facility and equipment. All fault detection should be Scada alarmed and hence notify the operators to proceed according to the relevant procedures.

8.2.1 Battery Container

- Fire safety protection measures.
- Explosion control system.
- Remote shutdown provisions.
- Electrical fault protection devices.
- Battery Management system (BMS).
- Thermal management system (TMS).
- Site Controller and Monitoring.

8.2.2 Transformers.

- The HV and MV/SUT transformers (500/33kV transformers) should have electrical protection.

8.2.3 O&M Compound and Switch room buildings.

These buildings will be provided with a smoke detection and alarm system as per AS1070.1 with an FIP (location TBC).

The smoke detection will trigger the General Fire Alarm (GFA) throughout the buildings to alert all occupants and will be connected to an FIP which will provide a local alarm through a Scada system (i.e., NOT connected to a fire station or fire dispatch centre in accordance with AS 1670.3).

8.3 General protection systems and facility safety measures

Preliminary assessments in Section 7show that there is no risk of fire spread between equipment/buildings due to the equipment clearances, mitigating to the degree necessary the risk of fire spread.

However, in order to consider any fire contingency, the facility should be provided with a reticulated fire hydrant system throughout the facility in accordance with AS2419.1 fed from static water tanks (see Figure 24 below). The requirements of the fire hydrant system can be limited if the BESS units are tested in accordance with CSA TS-800:24.

In addition to the water storage, the whole development should be provided with Portable fire extinguishers as per AS 2444, and during the operation stage, all vehicles must carry at least a nine (9)-litre water stored-pressure fire extinguisher with a minimum rating of 3A. Also, two (2) suitable fire extinguishers will be provided within 3m-20m of each PCU.

In addition to the fire assessment developed in this FSS, an electrocution and EMF hazards assessment must be performed for the facility.

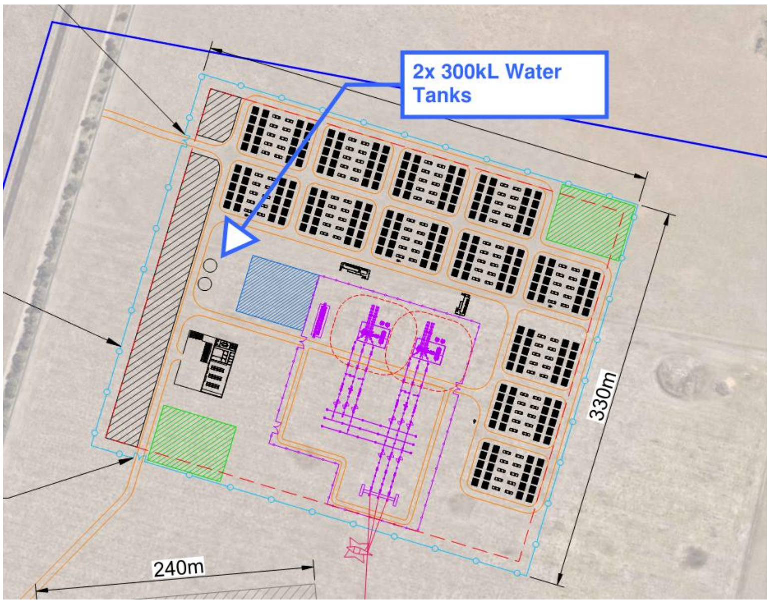


Figure 24: 600kl water storage location.

Further to the above, the following will be provided:

1. Warning signs must be provided as applicable (based upon site assessment). Some signage includes the following examples (not limited to):

- Exit signs.
- First aid firefighting equipment (fire hydrants, water storage tanks, fire extinguishers, etc.).
- Electrical hazards (e.g., high voltage).
- Equipment use instruction signs.
- Entrances to the facility and buildings (e.g., RMUs, SUT, SWG, Control building, etc.).
- Presence of chemical hazards.
- Toilets and facility related signs.
- Rescue and resuscitation signs.
- Fire exit doors.
- Restricted personal access to specific areas/buildings.
- Name to equipment/enclosures (e.g., RMUs, SUT, SWG, Control building, etc.).
- All gates to main alternative entrances must be openable with either a 003-key padlocks or intercom provisions to facilitate the access of the Fire Brigade.
- A Fire Management Plan. Refer to section 10.

8.4 Fire Water Supply and Demand

A reticulated fire hydrant system compliant with the AS2419.1 for fire brigade intervention procedures should be provided, where any infrastructure within the facility will be covered by at least 2 hydrants (in case one of the hydrants is not accessible due to fire hazard conditions).

Water storage of at least 288kl at an entrance of the development (see Figure 25 below) for fire brigade intervention procedures must be provided as per the CFA guidelines.

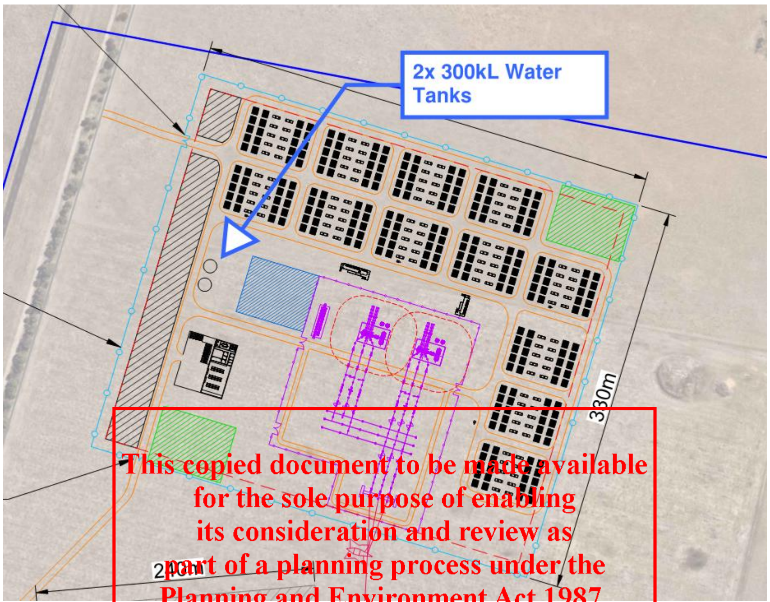


Figure 25: 600kl water storage location.

As per the latest CFA Guidelines Revision 4, for facilities with battery energy storage systems, the fire protection system must include at a minimum, where reticulated water is available, a fire hydrant system that meets the requirements of AS2419.1-2021: Fire hydrant installations, Section 3.9: Open Yard Protection, and Table 2.2.5.(D): Number of Fire Hydrants Required to Flow Simultaneously for Protected Open Yards. Except, that fire hydrants must be provided and located so that every part of the battery energy storage system is within reach of a 10m hose stream issuing from a nozzle at the end of a 60m length of hose connected to a fire hydrant outlet.

AS2419.1-2021 - Table 2.2.5.(D) is reproduced below:

NUMBER OF FIRE HYDRANT OUTLETS REQUIRED TO DISCHARGE SIMULTANEOUSLY FOR PROTECTED OPEN YARDS

Area of yard m^2	Number of fire hydrant outlets required to flow simultaneously (see Note)
≤3 000	1
>3 000 to ≤9 000	2
>9 000 to ≤27 000	3
>27 000	4

The area of the facility which has the equipment and buildings is almost 125,000m^2 within the security fence and the distribution of the equipment is as shown in Appendix A.

In accordance with the CFA guidelines, the yard area "may be considered that of the battery installation, including the minimum 10m fire break around the battery infrastructure, rather than the entire area of the yard or site". Hence, given the large-scales tests to BESS units which demonstrates that fire spread is not likely to occur between BESS, the "yard area" will be defined as one of the battery arrays that are separated 10m from each other (see figures below).

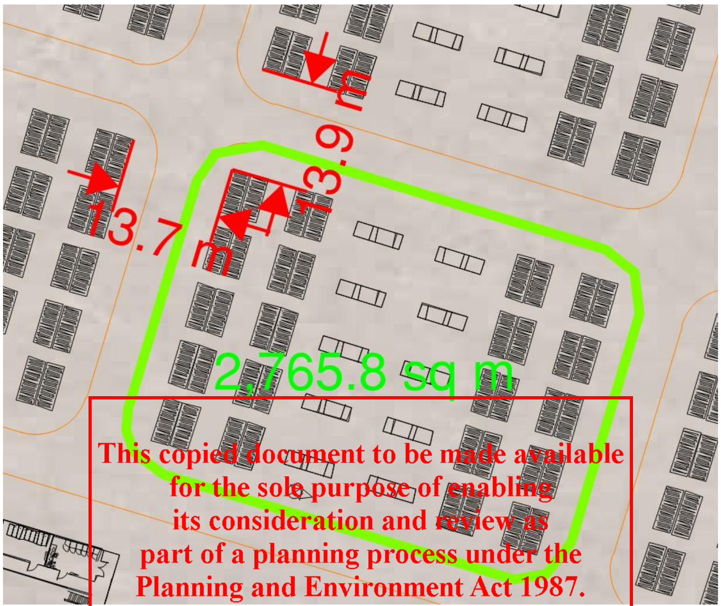


Figure 26: "Yard area" definition from BESS yard.

Each one of the battery arrays has an area of approximately 2,750m^2. Accordingly, 1 hydrant running for 4 hours at 10L/s is required by the AS 2419.1-2021 for a BESS development.

The water storage tank is therefore required to allow for 1 hydrant at 10L/s each for 4 hours, i.e., 144kL. Nonetheless, the CFA Guidelines Revision 4 also states that the minimum quantity of water to store for BESS developments must be at least 288kL, whichever is the larger. Therefore, 288kL storage of water is designed for the subject site.

The water storage must be provided at an entrance to the facility with a compliant hard stand and booster assembly in accordance with the latest CFA Guidelines Revision 4 [13] as follows:

- Water access points must be clearly identifiable and unobstructed to ensure efficient access.
- Static water storage tank installations must comply with AS 2419.1-2021: Fire hydrant installations – System design, installation and commissioning.
- The static water storage tank(s) must be an above-ground water tank constructed of concrete or steel.
- The static water storage tank(s) must be capable of being completely refilled automatically or manually within 24 hours.

- The static water storage tanks must be located at vehicle access points to the facility and must be positioned at least ten (10) metres from any structure.
- The static water tanks may be located at the proposed location in Appendix A, subject to compliant wayfinding signage to direct the fire brigade.
- The hard-suction point must be provided, with a 150mm full bore isolation valve equipped with a Storz connection, sized to comply with the required suction hydraulic performance.
- Adapters that may be required to match the connection are: 125mm, 100mm, 90mm, 75mm, 65mm Storz tree adapters with a matching blank end cap to be provided.
- The hard-suction point must be positioned within four (4) metres to a hardstand area and provide a clear access for emergency services personnel.
- An all-weather road access and hardstand must be provided to the hard-suction point. The hardstand must be maintained to a minimum of 15 tonne GVM, eight (8) metres long and six (6) metres wide or to the satisfaction of the CFA.
- The road access and hardstand must be kept clear at all times.
- The hard-suction point must be protected from mechanical damage (e.g., bollards) where necessary.
- Where the access road has one entrance, a ten (10) metre radius turning circle must be provided at the tank.
- An external water level indicator must be provided to the tank and be visible from the hardstand area.
- Signage indicating 'FIRE WATER' and the tank capacity must be fixed to each tank.
- Signage must be provided at the entrance to the facility, indicating the direction to the static water tank.

It should be noted that this level of design can be undertaken and complied with as a condition of the planning permit, during the detailed design stage.

8.5 Management of Fire Water Runoff

Oil transformers and the water storage of 600kl have the risk of contaminated runoff water.

The following measures should be provided by the facility:

- Transformers:
  - The MV/SUT (Medium Voltage/Step-up) transformers should be self-bunded transformer that includes splash guards for AS1940 compliance, hence the oil will remain enclosed, preventing potential environmental damage and fire spread.
  - The 220/33kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow. This will also prevent potential environmental damage and fire spread.
- Water runoff:
  - A containment and management plan for fire water runoff from the BESS is to be developed by the facility.

9 FIRST AID FIRE PROTECTION

The following first aid fire protection equipment and operational arrangements should be part of the safety measures of the BESS Facility:

- Portable fire extinguishers as per AS 2444, and a minimum of two (2) suitable fire extinguishers must be provided within 3m-20m of each PCU.
- Warning signs (e.g., exit signs, placarding and first aid fire-fighting equipment use instruction signs).
- Training of operators/staff who will proceed in accordance with the Fire management plan and the equipment manuals.
- A firebreak of at least 10m wide is maintained as shown in Appendix A.
- During the operation stage, all vehicles must carry at least a nine (9)-litre water stored-pressure fire extinguisher with a minimum rating of 3A.
- A reticulated fire hydrant system compliant with the AS2419.1 for fire brigade intervention procedures, where any infrastructure will be reached by at least 2 hydrants fed from static water tanks.

10 Emergency Management and Planning

The HIPAP No.1 Emergency Planning [4] (not limited to) may be used as an example to develop the plan. Some of the items to include are the following:

- Post-incident clean-up disposal.
- As part of the PPE for Emergency procedures, firefighters should wear self-contained breathing apparatuses (SCBAs) and structural firefighting gear.
- Safety measures for potential and identified hazards (e.g., electrical, EMF, fire, environmental, ecological, noise, bushfire, leakage, social, etc) must be documented a spart of the Emergency Management Plan.
- Evacuation Plans.
- A bushfire management plan.
- Access restriction to the substation when it is on.
- Emergency contact details.
- Roles and responsibilities.
- Emergency muster points.
- Induction, training, drills.
- Public and mass media management.
- Electrocution and EMF hazards

It should be noted that this level of design can be undertaken and complied with as a condition of the planning permit, during the detailed design stage.

11 CODES AND REFERENCES

[1] Cogency, Table of Assumptions for Murchs Corner BESS, v.2, Cogency, 19/09/2025.

[2] Country Fire Authority (CFA) Specialist Risk and Fire Safety Unit, Fire Safety Studies for Battery Energy Storage Systems, Version 1, State of Victoria (Country Fire Authority), June 2025.

[3] Country Fire Authority (CFA) Specialist Risk and Fire Safety Unit, Design Guidelines and Model Requirements - Renewable Energy Facilities. v4.4, Victoria: State of Victoria (Country Fire Authority), June 2025.

[4] NSW Government, Hazardous Industry Planning Advisory Paper No. 1 - Emergency Planning, Sydney, 2011.

[5] Australian Standard, AS2067-2016: Substations and high voltage installations exeeding 1kV a.c., Standards Australia, 2016.

[6] Standards Australia, *AS 2419.1:2021. Fire hydrant installations, Part 1: System design, installation and commissioning,* Standards Australia Limited, 2021.

[7] AFAC (Australasian Fire and Emergency Service Authorities Council Limited), *Large-scale battery energy storage systems installations,* Melbourne, 2025.

[8] A. B. C. Board, International Code Council, Department of Building and Housing and National Research Council of Canada, International Fire Engineering Guidelines, Australian Building Codes Board, 2005.

[9] Metropolitan Fire & Emergency Services Board Community Safety Directorate, Fire Brigade Intervention Model, 2010.

[10] Bureau of Meteorology, "Climate statistics for Australian locations," Australian Goverment, [Online]. Available: http://www.bom.gov.au/climate/data/index.shtml.

[11] Department of Health, "Air quality," Department of Health, [Online]. Available: https://www.health.state.mn.us/.

[12] B. Karlsson and J. G. Quintiere, Enclosure Fire, Florida: CRC Press LLC, 2000.

[13] M. Hurley, SFPE Handbook of Fire Protection Engineering, Springer, 2016.

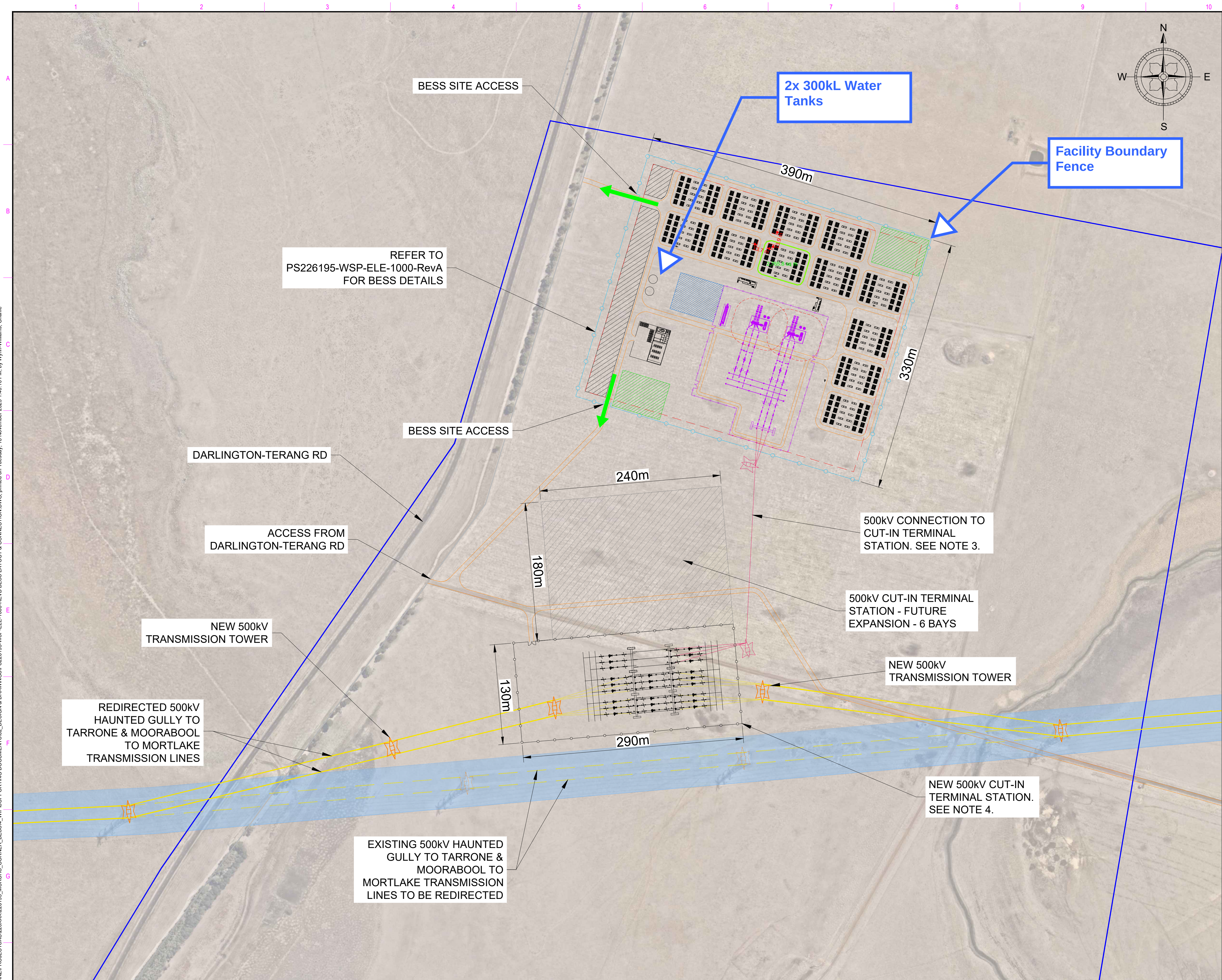
[14] Australian Standard, AS 2419.1: 2021 Fire hydrant installations Part1: system design, installation and commissioning, Standards Australia, 2021.

[15] Fisher Engineering, "Fire Protection Engineering analysis," 2023.

[16] Fire & Risk Alliance, "Destructive Fire Test and Fire Modelling Report," Rockville, 2024.

Appendix A. PROPOSED FACILITY LAYOUT

PS226195-WSP-ELE-1000-RevB BESS



NOTES :

1. PRELIMINARY ONLY - DRAWING IS PRE-CONCEPTUAL AND PROVIDED FOR INFORMATION PURPOSES ONLY. THIS DRAWING IS SUBJECT TO DESIGN CHANGE.
2. ALL DIMENSIONS ARE IN METERS UNLESS OTHERWISE SPECIFIED.
3. TYPE OF CONNECTION, OVERHEAD LINE OR UNDERGROUND CABLE, TO BE DETERMINED IN LATER DESIGN STAGES.
4. FINAL LAYOUT OF NEW 500kV CUT-IN TERMINAL STATION TO BE DETERMINED BY TRANSMISSION NETWORK SERVICE PROVIDER. INDICATIVE LAYOUT OF HV EQUIPMENT IS SHOWN. BUILDINGS AND INTERNAL ROAD HAVE NOT BEEN SHOWN.

SYSTEM OVERVIEW

POWER CAPACITY AT POC (MW)	500
ENERGY CAPACITY (MWh)	2,000
BATTERY UNIT OEM	TBC
BATTERY UNIT MODULE	N/A
NO. OF BATTERY UNITS	480
BATTERY UNIT STORAGE CAPACITY (kWh)	5,000
POWER CONVERSION SYSTEM (PCS) OEM	TBC
PCS UNIT MODULE	N/A
NO. OF PCS UNITS	120
PCS DERATED POWER CAPACITY (kVA @ 40°C)	5,000

LEGEND :

SYMBOL	DESCRIPTION
	PROPERTY BOUNDARIES
	INVESTIGATION AREA
	BESS FACILITY FENCE
	INTERNAL ROAD (6m WIDTH)
	500kV BESS CONNECTION
	500KV TRANSMISSION LINE
	EXISTING 500KV TRANSMISSION LINE TO BE REDIRECTED
	500KV TRANSMISSION TOWER
	EXISTING 500KV TRANSMISSION EASEMENT (60m WIDTH)
	500kV CUT-IN TERMINAL FUTURE EXPANSION

ADVERTISED PLAN

REV	DATE	BY	DESCRIPTION	CHK	APPD
A	18.11.25	CW	CONCEPT ISSUE	AM	NH

REFERENCE COORDINATION DRAWINGS

DESCRIPTION	DRAWING NO.	REV	CHK

SURVEY DATUM
HORIZONTAL DATUM: VERTICAL DATUM:

SCALES
0 50 100 150
Full Size 1:5000 ; SCALE (m)

A3 ORIGINAL
DO NOT SCALE THIS DRAWING
APPROVED
SIGNED:
DATE: RPEQ:

wsp
Level 11, 567 Collins Street, Melbourne
Tel: +61 3 9622 9700
wsp.com

CLIENT:

PROJECT: MURCHS CORNER BESS
500 MW / 2000 MWH

TITLE: BESS LAYOUT & CONNECTION

DRAWING STATUS: PRELIMINARY ISSUE
NOT FOR CONSTRUCTION

DESIGNED:	CHECKED:	APPROVED:
C. WYNN-WILLIAMS	A. MIRZAEI	N. HIDE
PROJECT No: PS226195	DRAWN: C. WYNN-WILLIAMS	DATE: 18.11.2025

DRAWING No: PS226195-WSP-ELE-1000 REV: A

Appendix B. CFA Design Guidelines and Model Requirements: Renewable Energy Facilities, Country Fire Authority (CFA), June 2025 (v4.4)

Section 2.2.2 of the Guide states that the bushfire risk is required to be addressed according to the Victorian Planning Provisions.

Response - As per Section 5, the subject BESS is part of a Farming zone (FZ) and is classified as a Bushfire Prone area. Given the location of the BESS site, a bushfire assessment (i.e., BAL as per AS 3959:2018) is not required given the type of vegetation and use of the land.

Section 3.3.3 states that for BESS facilities the following hazards be addressed:

- Electrical hazards, such as battery faults; overcharging; rapid discharge; loss of remote monitoring systems; internal short circuits; overheating; water ingress; lightning strike (leading to thermal events/runaway).

  Response - The batteries will be monitored such that if there is a fault or electrical runaway the system will be shut down.

- Chemical hazards, such as the inherent hazards of the stored dangerous goods; spills and leaks of transformer oil/diesel spills/leaks, refrigerant gas/coolant; chemical reactions from ignition.

  Response - No dangerous goods are indicated to be stored on the site. The MV/SUT Transformers will be assessed at a later stage and the HV Transformers have been reviewed in Section 0 in accordance with AS 2067.

- Potential fire spread due to proximity of batteries (and containers/enclosures) to each other, on-site infrastructure and vegetation (including screening vegetation).

  Response - The battery units are separated from adjacent properties by over 15 meters, and the BESS units must be tested as per UL9540 and/or CSA TS-800:24. Hence fire spread from the site to the vegetation is not expected.

- Mechanical damage to battery containers/enclosures due to vehicular impact.

  Response - The facility has a security fence such that only maintenance vehicles can access the site. There is a not less than 4.5m wide road around and within the facility and the batteries.

- Landscape hazards, such as bushfire/grassfire ignition from fire within the facility, or external ignition of site infrastructure from embers, radiant heat and flame contact.

  Response - As per Section 5, the subject BESS is part of a Farming zone (FZ) and is classified as a Bushfire Prone area. Given the use of the land and lack of vegetation, a BAL assessment as per AS 3959:2018 is not required given the type of vegetation and use of the land.

Section 3.3.5 also recommends a fire safety study for large scale battery energy storage systems (BESS) over 1MWh based on CFA's Fire Safety Studies for Battery Energy Storage Systems Guideline (v1, 2025) [2] *to be undertaken.*

  Response – This report achieves this requirement.

Section 4.1 indicates the following are low risk location attributes:

- Grassland.
- No continuous other vegetation types within 1-20 km of the project site.

- Generally flat topography, some undulation may be present.
- Slopes are less than 5 degrees.
- Good road access with multiple routes available to and from the project site.
- No Bushfire Management Overlay applies.

  Response - As per Section 5, the subject BESS is part of a Farming zone (FZ) and is classified as a Bushfire Prone area. Given the use of the land and lack of vegetation, a BAL assessment as per AS 3959:2018 is not required given the type of vegetation and use of the land.

Section 4.2.1 requires the following with respect to fire brigade vehicle access:

- Construction of a four (4) metre perimeter road within the perimeter fire break.

  Response - A not less than 4.5m wide road is provided around and within the site. Hence the provided roads are compliant.

- Roads must be of all-weather construction and capable of accommodating a vehicle of fifteen (15) tonnes (e.g., no compacted earth).

  Response - Roads will be constructed to satisfy CFA Guidelines, i.e., the emergency vehicle access road around the facility is considered as being a hardstand and therefore shall also be designed to withstand a point load of 15 tonnes (or 150kN) so that it can withstand an aerial appliance at any location within the boundaries of the hardstand.

- Constructed roads should be a minimum of four (4) metres in trafficable width with a four (4) metre vertical clearance for the width of the formed road surface.

  Response - Roads are not less than 4.5m wide, surpassing the required width.

- The average grade should be no more than 1 in 7 (14.4% or 8.1°) with a maximum of no more than 1 in 5 (20% or 11.3°) for no more than fifty (50) metres.

  Response - The site is relatively flat and complies with the above.

- Dips in the road should have no more than a 1 in 8 (12.5% or 7.1°) entry and exit angle.

  Response - The site is relatively flat and complies with the above, however the road design must assure this requirement is achieved.

- Roads must incorporate passing bays at least every 600 metres, which must be at least twenty (20) metres long and have a minimum trafficable width of six (6) metres. Where roads are less than 600 metres long, at least one passing bay must be incorporated.

  Response – All the perimeter roads are not less than 4.5m, and alternative access/egress is provided. The site has no roads more than 600m long, hence bays are not required.

- Road networks must enable responding emergency services to access all areas of the facility, including fire service infrastructure, buildings, and battery energy storage systems and related infrastructure.

  Response – Access roads are present around and within the facility such that all areas can be accessed.

- The provision of at least two (2) but preferably more access points to the facility, to ensure safe and efficient access to and egress from areas that may be impacted or involved in fire. The number of access points must be informed through a risk management process.

  Response – The subject site has 2 alternative access/egress gates to the western side of the facility.

<u>Section 4.2.2 requires the following with respect to firefighting water supply:</u>

- Water access points must be clearly identifiable and unobstructed to ensure efficient access.

  Response – Signage will be provided to indicate the location of the water tanks.

- Static water storage tank installations must comply with AS 2419.1-2021 [14]: Fire hydrant installations – System design, installation and commissioning.

  Response – Compliant. Water storage of 600kL will be provided near the entrance to the facility with a compliant hardstand and signage.

- The static water storage tank(s) must be an above-ground water tank constructed of concrete or steel.

  Response – It is considered the design will comply with this requirement.

- The static water storage tank(s) must be capable of being completely refilled automatically or manually within 24 hours.

  Response – This matter will be addressed as a condition on the planning permit that requires a Fire Management Plan.

- The static water storage tanks must be located at vehicle access points to the facility and must be positioned at least ten (10) metres from any infrastructure (solar panels, wind turbines, battery energy storage systems, etc.).

  Response – Complies.

- The hard-suction point must be provided, with a 150mm full bore isolation valve equipped with a Storz connection, sized to comply with the required suction hydraulic performance.

  Response – It is considered the design will comply with this requirement.

- Adapters that may be required to match the connection are: 125mm, 100mm, 90mm, 75mm, 65mm Storz tree adapters with a matching blank end cap to be provided.

  Response – It is considered the design will comply with this requirement.

- The hard-suction point must be positioned within four (4) metres to a hardstand area and provide a clear access for emergency services personnel.

  Response – Complies.

- An all-weather road access and hardstand must be provided to the hard-suction point. The hardstand must be maintained to a minimum of 15 tonne GVM, eight (8) metres long and six (6) metres wide or to the satisfaction of the CFA.

  Response – It is considered the design will comply with this requirement.

- The road access and hardstand must be kept clear at all times.

  Response – It is an ongoing practice that must be part of the Fire Management Plan.

- The hard-suction point must be protected from mechanical damage (e.g., bollards) where necessary.

  Response – It is considered the design will comply with this requirement.

- Where the access road has one entrance, an eight (8) metre radius turning circle must be provided at the tank.

  Response – The access road is continuous around the site from the tank location such that turning is not required and vehicles can drive in and out of the site.

- An external water level indicator must be provided to the tank and be visible from the hardstand area.

  Response – It is considered the design will comply with this requirement.

- Signage indicating ‘FIRE WATER’ and the tank capacity must be fixed to each tank.

  Response – It is considered the design will comply with this requirement.

- Signage must be provided at the front entrance to the facility, indicating the direction to the static water tank(s).

  Response – It is considered the design will comply with this requirement.

- For facilities with battery energy storage systems, the fire protection system must include at a minimum: b) Where no reticulated water is available, a fire hydrant system that complies with AS 2419.1-2021 must be provided:

  - (i) The fire water supply must be of a quantity no less than 288,000L or as per the provisions for Open Yard Protection of AS 2419.1-2021 flowing for a period of no less than four hours at 20L/s, whichever is the greater.

  - (ii) The quantity of static fire water storage to be calculated from the number of hydrants required to flow from AS 2419.1-2021: Fire hydrant installations, Table 2.2.5(D).

  Response – Fire water supply of 288,000L is provided. Calculations and water requirements are described in Section 8.4.

  - (iii) Fire hydrants must be provided and located so that every part of the battery energy storage system is within reach of a 10m hose stream issuing from a nozzle at the end of a 60m length of hose connected to a fire hydrant outlet.

    Response – It will comply when it is designed.

  - (iv) The fire water supply must be located at vehicle entrances to the facility, at least 10m from any infrastructure (electrical substations, inverters, battery energy storage systems, buildings).

    Response – The proposed layouts comply with this requirement as shown in Appendix A.

  - (v) The fire water supply must be reasonably adjacent to the battery energy storage system and shall be accessible without undue danger in an emergency. (E.g., Fire water tanks are to be located closer to the site entrance that the battery energy storage system).

    Response – The proposed layouts comply with this requirement as shown in Appendix A. The water tanks are located at the main entry of the subject site.

  - (vi) The fire water supply must comply with AS 2419.1-2021: Fire hydrant installations - Section 5: Water storage tanks.

    Response – This is compliant as assessed above. Water storage of 288,000 Liters will be provided.

- Requirements for Battery Energy Storage Systems (Decentralized) are not included in this document, given that the subject site is not considered a decentralized BESS.

Section 4.2.3 requires the following with respect to fire detection and suppression equipment:

- For on-site buildings and structures, according to the requirements of the National Construction Code.

  Response – Buildings at the facility are considered to comply with the DtS provisions where possible and are considered to achieve the performance requirements of the NCC.

- For storage of dangerous goods, according to the requirements of any Australian Standards for storing and handling of dangerous goods.

  Response – No dangerous goods are indicated to be stored on the site.

- For electrical installations, a minimum of two (2) suitable fire extinguishers must be provided within 3m-20m of each PCU.

  Response – Buildings at the facility are considered to comply with the DtS provisions where possible and are considered to achieve the performance requirements of the NCC. It includes the provisions for the fire protection and extinguish systems (i.e., portable fire extinguishers, water supply).

- In all vehicles and heavy equipment, each vehicle must carry at least a nine (9)-litre water stored-pressure fire extinguisher with a minimum rating of 3A, or other firefighting equipment as a minimum when on-site during the Fire Danger Period.

  Response – This will be required as part of the fire safety requirements for the subject site; hence it is considered to be compliant.

Section 4.2.4 requires the following with respect to management of Landscape Screening and on-site vegetation:

- Any proposed or existing vegetation must be considered in the Risk Management Plan for its potential to intensify and propagate fire within and away from the site.

  Facilities must be designed so that the radiant heat flux (output) from vegetation does not create the potential for ignition of on-site infrastructure or other vegetation.

  Response – As per Section 5, the subject BESS is part of a Farming zone (FZ) and is classified as a Bushfire Prone area. Given the use of the land and lack of vegetation, a BAL assessment as per AS 3959:2018 is not required.

Section 4.2.5 requires the following with respect to fire breaks:

- A fire break must be established and maintained around the perimeter of the facility, commencing from the boundary of the facility or from the vegetation screening inside the property boundary, and around the perimeter of control rooms, electricity compounds, substations and all other buildings on-site. The width of fire breaks must be a minimum of 10m, and at least the distance where radiant heat flux (output) from the vegetation does not create the potential for ignition of on-site infrastructure.

  Response – It complies with the proposed layout. The subject site is provided with a fire break of not less than 10m.

Section 4.2.6.4 requires the following with respect to management of Fire Water Runoff:

- CFA recommends that infrastructure is provided for the containment and management of contaminated fire water runoff from battery energy storage systems. Infrastructure may include bunding, sumps and/or purpose-built, impervious retention facilities. A fire water management plan may include the containment and disposal of contaminated fire water.

  Response – This is part of the requirements of this document and must be provided by the facility.

Section 4.3 recommends that battery energy storage systems are equipped with the following elements:

- Battery management/monitoring systems for monitoring the state of battery systems to ensure safe operation.
- Detection systems for smoke, heat (thermal), fire and toxic gas (off-gassing) within battery containers.
- Suppression systems for fire within battery containers.
- Systems to prevent heat/fire spread within battery containers (such as thermal barriers, shut-down separators, isolation systems, cooling systems).
- Systems to prevent explosion within battery containers (such as ventilation, pressure relief and exhaust systems).
- Warning and alarm systems within the battery containers, and/or the facility, to enable early warning for faults, operation of the battery energy storage system above 'normal'/safe parameters, smoke, off-gassing, and fire.

  Response – It is considered that the latest commercial BESS comply with these requirements (also see section 5.1.1), however the review will be performed when a BESS supplier is identified.

Appendix C. STATISTICS

Below are described some of the main events that have contributed to the design of the latest fire safety measures to the BESS technology, enhancements to prevent catastrophic events.

1. Victorian Big Battery Fire

The Energy Safe Victoria (ESV) "Statement of Technical Findings - Fire at the Victorian Big Battery" provides a summary of the key findings into the fire (refer to Appendix D).

On 30 July 2021, the Victorian Big Battery (VBB) experienced a fire that involved two Battery units during commissioning.

The root cause of the fire was found to be a leak within the cooling system that caused a short circuit that led to a fire in an electronic component. This resulted in heating that led to a thermal runaway and fire in an adjacent battery compartment within one unit, which spread to an adjacent second unit.

The contributing factors into the fire were reported to be:

- The supervisory control and data acquisition (SCADA) system took 24 hours to 'map' to the control system and provide full data functionality and oversight to operators. The unit that caught fire had been in service for 13 hours before being switched into an off-line mode when it was no longer required as part of the commissioning process. This prevented the receipt of alarms at the control facility.
- A key lock was operated correctly to switch the unit to off-line service mode (which was no longer required for ongoing commissioning), but this caused:
  - Telemetry systems for monitoring the condition of the (now out of service) unit to shut down and so remove visibility of the developing event.
  - The battery cooling system to shut down.
  - The battery protection system to shut down, including the high voltage controller (HVC) that could have operated a pyrotechnic fuse to disconnect the faulty battery unit.

The lessons learnt from the fire were reported to be:

- Each cooling system is to be fully functional, and pressure tested when installed on site and before it is put into service.
- Each cooling system in its entirety is to be physically inspected for leaks after it has been functionally, and pressure tested on site.
- The SCADA system has been modified such that it now 'maps' in one hour and this is to be verified before power flow is enabled to ensure real-time data is available to operators.
- A new 'battery module isolation loss' alarm has been added to the firmware; this modification also automatically removes the battery module from service until the alarm is investigated.
- Changes have been made to the procedure for the usage of the key lock during commissioning and operation to ensure the telemetry system is operational.

- The high voltage controller (HVC) that operates the pyrotechnic fuse remains in service when the key lock is isolated.

The over pressure vents in the roof of the units involved in the VBB fire were seen as the main fire propagation method and a weakness in the fire spread prevention. (The effect of vents on possible fire spread scenarios versus the consequence of an overpressure event if they were not installed will be assessed as part of the detailed assessment of the final unit design).

It was recommended in the report that one of the hardware mitigation measures is the installation of newly designed, thermally insulated steel vent shields within the thermal roof of all units.

The fire did not spread beyond the two units and no members of the public or emergency services were indicated to have suffered significant injuries.

2. S&C Electric Lithium-Ion ESS fire in Wisconsin

The fire occurred in the S&C Electric facility in 2016. Within this facility, energy storage systems are designed, assembled, and operated before being deployed. The fire was initially assumed to have initiated with the lithium-ion batteries, however, the investigation later determined that the fire started in the battery manufacturer's DC power and control compartment – not the batteries themselves. The DC power and control unit that started the fire was part of a larger system that was being assembled – therefore the safety features normally integrated into an ESS were not yet installed in this particular fire event.

The units at the proposed site will be fully functional at the time of delivery and installed and commissioned at the time of installation including safety systems.

3. Incident Report – Bouldercombe BESS

The Bouldercombe BESS is a 50MW and 100 MWh battery comprised of 40 individual Megapack 2 (MP) energy storage systems (Figure 27).

The report provided by Tesla Energy Products stated the following:

"*On Tuesday September 26, 2023, a single Megapack caught fire and was left to fully consume itself over approximately 48hrs without the need for water/fire suppressant to be applied by First Responders as per Tesla's Industrial Lithium-Ion Battery Emergency Response Guide. No workers were at risk of harm and the battery failed in a safe manner, as the system is designed to do in the event of a fire*".

"*A second Megapack (MP2TG122340001W76), installed directly behind the initiator Megapack, was found to have signs of secondary heat effects and was removed. The total impact to the site was 2 out of the 40 MPs on site*".

The incident demonstrated that given a fire to a Megapack, fire will be limited to the affected Megapack only and fire will not spread to adjoining Megapacks, transformer or structures, however heat may damage some of the components of the Megapack at the back.

The Bouldercombe BESS had a normal operation despite of the event due to the provision of safety and redundancy systems, the loss of the 2 megapacks did not affect the normal operation of the BESS development.

In regard to the root cause of the fire, the analysis determined a load-side AC fault occurred leading to fault cascading within the Megapack. Further studies and tests are being performed in order to assess further electrical faults of the Megapack.

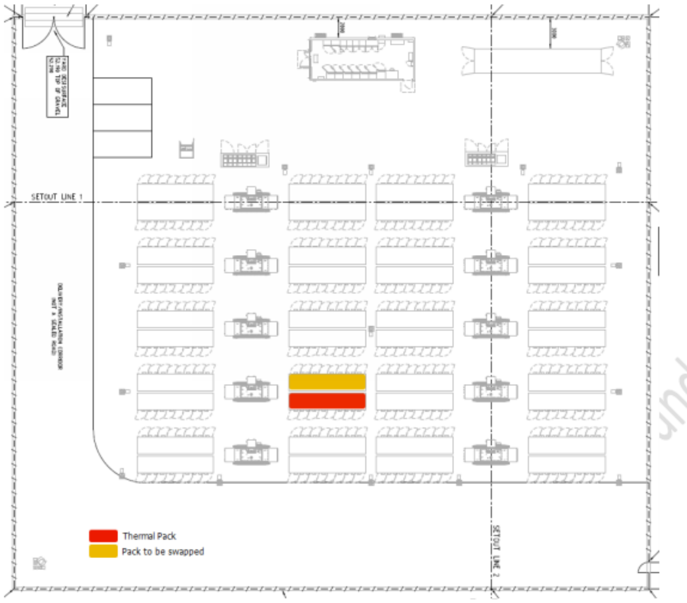


Figure 27: Bouldercombe BESS Site Layout and Megapacks involved in the event.

4. Elkhorn BESS Fire of September 20, 2022. Public Report of Technical findings.

The Elkhorn BESS is located at the Moss Landing Electric Substation in Monterey County, California, and it has the capacity to store and dispatch up to 730 megawatt hours (MWh) of energy.

The facility is provided with the first version of the Megapack (also referred to as the Megapack 1 to distinguish it from second-generation of Tesla BESS called the Megapack 2).

In September 2022, a fire occurred to a single Megapack as shown in the picture below (Figure 28). In summary, "*The fire proceeded in accordance with its design and consumed itself. It burned as a flaming fire for about 6 hours, and then generated visible smoke and off-gas for another 12 hours. As per the instructions in Tesla's Lithium-Ion Battery Emergency Response Guide (ERG), which were incorporated into the PG&E Pre-Fire Plan, the Megapack was allowed to burn and consume itself while being monitored by first responders at a safe distance*".

Figure 28: Overview of Elkhorn BESS and Megapack on fire.

The above demonstrated that where a Megapack is on fire, fire is not expected to spread to adjacent Megapacks or adjoining structures, and fire will be limited to the affected Megapack.

The Root Cause Analysis of the incident identified the following causes:

- Significant water ingress, which allowed electrical shorts to initiate the thermal runaway of the battery cells.
- There were additional confounding factors that influenced the fire event during the Pre-Incident time frame, that is, the two days prior to the fire event. These included: (1) Auto-Safe Discharge; (2) Tesla Monitoring Alarm; and (3) Playbook Guidance.

Given the Root Cause Analysis above, the enclosure, manuals and software for the Megapack 2 and Megapack 2XL were updated accordingly to mitigate the risk of ignition of the Megapack.

5. Thermal Runaway / Fire within a battery

One of the reasons lithium-ion cell thermal runaway reactions can be very energetic is these cells have very high-energy densities compared to other cell chemistries. The other reason that lithium-ion cell thermal runaway reactions can be very energetic is because these cells contain flammable electrolyte, and thus, not only do they store electrical energy in the form of chemical potential energy, but they also store appreciable chemical energy (especially compared to cells with water-based electrolytes) in the form of combustible materials.

Self-heating of lithium-ion graphitic anodes in the presence of electrolyte initiates at temperatures in the 70 to 90°C range. Thus, if a cell is brought to this initiating temperature in an adiabatic environment, it will eventually self-heat to the point thermal runaway initiates. For a typical 100% charged cell brought to its self-heating temperature, thermal runaway will occur after approximately two days if the cell is well insulated. Should initial temperature be higher, time to thermal runaway will be shorter. For example, if a typical lithium-ion cell is placed into an oven at more than 150°C (300°F), such that separator melting occurs, additional heating due to shorting between electrodes will occur and cell thermal runaway will initiate within minutes. However, if heat is allowed to escape, time to thermal runaway may be longer, or the cell may never achieve thermal runaway.

Measurement of cell case temperatures during thermal runaway experiments have been performed by laboratories such as UL. For fully charged cells, these temperatures can reach in excess of 600°C case temperatures. The temperature rise is driven by reactions of the electrodes with electrolyte and release of stored energy. Some cathode materials will decompose and may change their crystalline structure which may result in the release of small quantities of oxygen that can participate in reactions internal to the cell (e.g., oxidation of the aluminium current collector).

This fact has led to a misconception that lithium-ion cells burn vigorously because they "produce their own oxygen." This idea is incorrect. No significant amount of oxygen is found in cell vent gases.[1] Any internal production of oxygen will affect cell internal reactivity, cell internal temperature, and cell case temperature, but plays no measurable role in the flammability of vent gases.

[1] Lithium-Ion Batteries Hazard and Use Assessment, Final Report, Celina Mikolajczak, PE, Michael Kahn, PhD, Kevin White, PhD ,Richard Thomas Long, PE, Exponent Failure Analysis Associates, Inc., July 2011 National Fire Protection Association, Fire Protection Research Foundation.

5.1. Research and Testing of Lithium-Ion Batteries and BESS

Full-scale testing of a large, containerized lithium-ion battery energy storage system has been conducted. Testing has been conducted to provide insight into the fire hazards associated with lithium-ion battery energy storage systems. A few of the larger-scale testing and research reports will be summarized below:

- FPRF/Exponent Hazard Assessment of Lithium-Ion Battery Energy Storage Systems.
- FAA (Federal Aviation Administration) Fire Hazards of Lithium-Ion Batteries – testing of pallet load of lithium-ion batteries in an aircraft cargo hold.
- DNV GL/Con-Edison Considerations for ESS Fire Safety.
- Fire Protection Engineering Analysis to Tesla BESS units. Fisher Engineering. Project reference 22035, dated 23/01/2023 [15].
- Tesla Megapack 2 and 2 XL – Destructive Fire Test and Fire Modelling Report. Fire & Risk Alliance. Revision 0 dated 15/04/2024 [16].

5.2. FPRF/Exponent Hazard Assessment of Lithium-Ion Battery ESS

Exponent Inc. and the NFPA's (National Fire Protection Association) Fire Protection Research Foundation conducted a full-scale fire test of a Tesla Powerpack – 100kWh lithium-ion BESS at 100% SOC[2]. Two tests were conducted, one with an external ignition source of 400 kW and another with an internal ignition by heater cartridges. The internal test set individual cells into thermal runaway to simulate an internal failure, and the external test led the internal cells into failure through heat exposure.

The results of the external ignition test determined the following:

- A fire in the Powerpack resulted in internal temperatures exceeding 1,093°C, and external temperatures reached 232°C.
- Flames were observed coming out of the exhaust vent and out of the BESS front door.
- Flames several feet high were observed from the exhaust vent of the Powerpack.
- Heat flux of approximately 25kW/m^2 measured 1.8m from front of BESS.
- All batteries and electronics of the BESS were damaged.

The internal ignition test gave the following results:

- A fire in the Powerpack resulted in internal temperatures exceeding 1,093°C.
- Temperatures at pods below the initiator pod showed temperature ranges between 26 and 82°C.

[2] Blum, A. F., & Long, Jr., R. T. (2016). Hazard Assessment of Lithium-Ion Battery Energy Storage Systems. Quincy: National Fire Protection Association

- External temperatures reached 21°C.
- Initiator pod was damaged, but other cells were not damaged.

5.3. US FAA-Style Flammability Assessment of Lithium-Ion Cells and Battery Packs in Aircraft Cargo Holds

The exponent conducted flame attack tests on single prismatic batteries and prismatic battery packs inside a cargo hold [3]. The result of this testing provides insight into battery behaviour under fire conditions as well as temperature profiles of the fire events.

Key findings from these small-scale tests include the following:

- Frequent battery case rupture events were observed in the prismatic battery pack testing.
- Direct flame impingement on small, unpackaged quantities of prismatic battery packs can lead to thermal runaway of individual cells and venting of gases. The vent gases are generally ignited by the pre-existing flame, increasing the total heat flux produced by the fire.
- Testing of 4 cell li-ion battery packs produced ceiling temperatures between 400°C and 600°C.

5.4. FAA Energetics of Lithium-Ion Battery Failure

The Federal Aviation Administration (FAA) has worked to quantify the hazard of lithium-ion batteries under a fire event since a fleet of the Boeing 787 Dreamliner were grounded as a result of hazards associated with LIB fires. In addition to the fire events, large numbers of lithium-ion batteries are being shipped as cargo on aircraft. Although the failure of a single cell is a low probability event (1/1,000,000), the large quantity of batteries on aircraft and the severe impact of an event on the survivability of the aircraft make the risk a safety concern to the passengers.[4]

To analyse the hazard of lithium-ion batteries undergoing a thermal runaway event in an aircraft, a pallet load of 18,650 cylindrical batteries were forced into thermal runaway within a cargo hold of an aircraft. This test showed that all of the batteries became involved in the fire. This testing provided data regarding lithium-ion battery fires and heat release rate curves providing insight into the growth function of a fire involving multiple packs of lithium-ion batteries. This study is applicable to quantifying a fire event in a BESS due to the number of batteries in a confined compartment.

The results indicated the heat release rate per battery cell was approximately 5kW.

[3] Mikolajczak, C. (2005). US FAA-Style Flammability Assessment of Lithium-Ion Cells and Battery Packs in Aircraft Cargo Holds. Exponent. Menlo Park: Exponent.
[4]] Lyon, R. E., Walters, R. N., Crowley, S., & Quintiere, J. G. (2015). Fire Hazards of Lithium-Ion Batteries. Federal Aviation Administration. Atlantic City: Federal Aviation Administration.

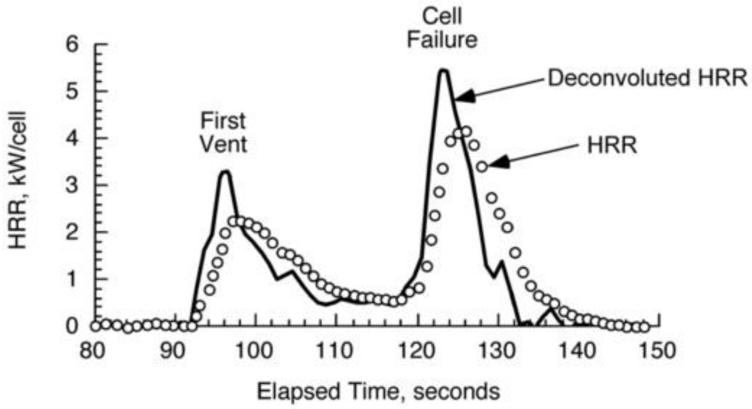


Figure 2. Lithium-ion cell failure at 70% SOC exposed to 50 kW/m² irradiance in fire calorimeter; points are data from standard method; solid line is data corrected for instrument response

Figure 29: Results of a single group of batteries.

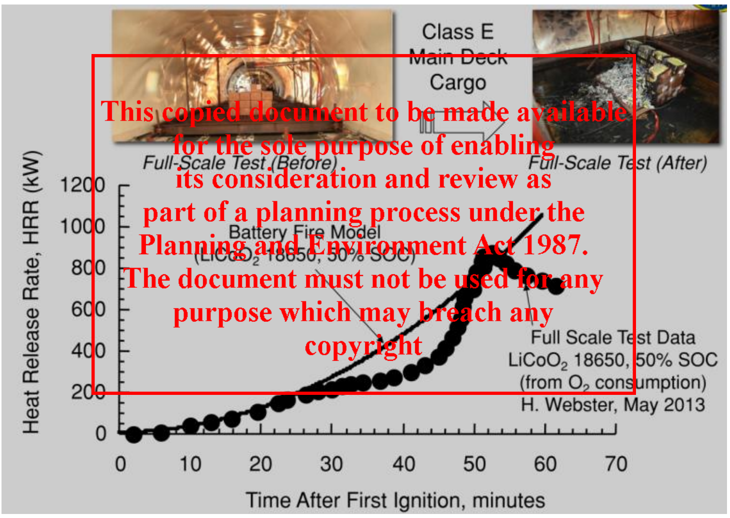


Figure 30: Results of full-scale tests on 18650 batteries.

The peak heat release rate is approximately 1MW.

5.5. DNV GL Considerations for ESS Fire Safety

DNV GL and Rescue Methods were contracted by Con-Edison Power and the New York State Energy Research and Development Authority (NYSERDA) to address a series of frequently asked questions regarding BESS Fire Safety[5]. This work included testing of lithium-ion batteries of various chemistries as individual cells and battery modules. The individual cells were exposed to a 4-kW radiant heat source until they vented inside DNV GL's Large Battery

[5] DNV GL. (2017). Considerations for ESS Fire Safety. Dublin: DNV GL

Destructive Testing Chamber. For the module testing, modules between 7.5 and 55 kWh were ignited inside a partially closed metal container by direct flame impingement from a propane torch. The module testing provided data concerning the effect of oxygen, toxicity, and heat release rate of the fire.

A few key findings from this testing are discussed below:

- Batteries are more volatile at higher states of charge (SOC).
- Mass loss rate is proportional to SOC. Average mass loss rate: 18% mass loss over 41.7 min.
- If flames are visible and temperature is rising, the ESS is likely to have multiple batteries and/or modules involved in the fire. Rising temperatures within the ESS is an indication of increasing risk.
- The batteries themselves emit flammable gases.
- Recommended Ventilation Rate Correlation of 0.095 - 0.15 l/s/Wh.
- HRR (Heat release rate) produced variable results. The range was between 2.5 – 80 kW/kg, depending on volume of gases, duration of release, rate of ignition, and gaseous mixture.
- Partially burned systems can continuously emit flammable gases as long as the cells retain their heat – even if the fire has been extinguished.

5.6. Rate of Heat Release

The Rate of Heat Release for the battery units is dependent on the state of charge as well as the size of the batteries and the incident heat flux.

It was reported in "Fire behaviour of lithium-ion battery with different states of charge induced by high incident heat fluxes", by Zhi Wang that the peak heat release rate of a battery unit is approximately 700kW/m^2 to 1050kW/m^2 and an average of approximately 150 – 200kW/m^2.

Note these are individual small batteries and not part of a BESS unit and the area is the surface area of the batteries. Based on the size of the units in the VBB fire as reported by the ESV investigation (7.5m x 1.6m x 2.5m) and assuming the front and the top of the unit are burning based on the location of the ventilation, the heat release rate is predicted to be 4.5MW to 6MW.

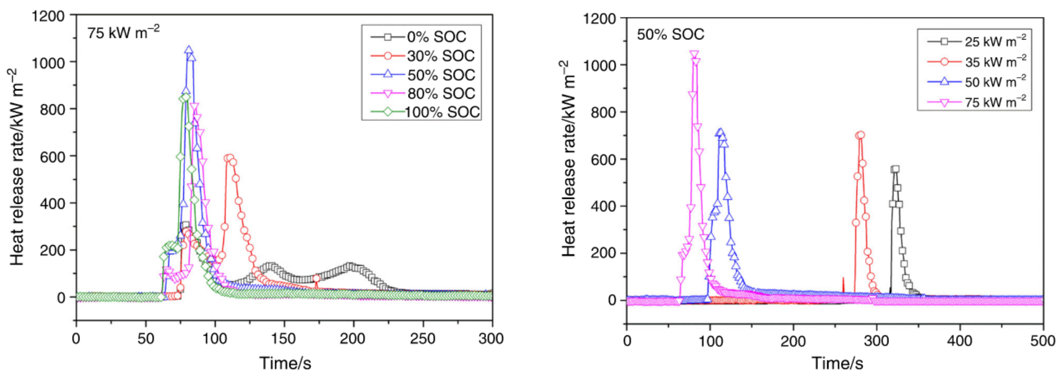


Fig. 7 Heat release rate of batteries at different SOCs under an incident heat flux of 75 kW m^{-2}

Fig. 8 Heat release rate of batteries with 50% SOC under different incident heat fluxes

Figure 31: Tested heat release rates for Lithium-ion batteries.

Based on the above review and an average of $200kW/m^2$, it is considered that each CATL BESS Container will have an average total heat release rate of approximately 12.8MW, considering that total dimensions are 6.058m x 2.896m x 2.438m (i.e., superficial area of $64m^2$) [15].

Appendix D. VBB Fire Investigation

January 25, 2022

Victorian Big Battery Fire: July 30, 2021

REPORT OF TECHNICAL FINDINGS

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Background

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

On Friday, July 30th, 2021, a single Megapack at VBB caught fire and spread to a neighboring Megapack during the initial installation and commissioning of the Megapacks. The fire did not spread beyond these two Megapacks and they burned themselves out over the course of approximately six hours. There were no injuries to the general public, to site personnel or to emergency first responders as the Megapacks failed safely (i.e., slowly burned themselves out with no explosions or deflagrations), as they are designed to do in the event of a fire. Per the guidance in Tesla's Lithium-Ion Battery Emergency Response Guide[2] (ERG), emergency responders permitted the Megapack to burn and consume itself while nearby exposures were being monitored at a safe distance. The total impact to the site was two out of the 212 Megapacks were fire damaged, or less than 1% of the BESS.

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

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

Incident Timeline

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

1 https://victorianbigbattery.com.au/
2 https://www.tesla.com/sites/default/files/downloads/Lithium-Ion_Battery_Emergency_Response_Guide_en.pdf
3 The keylock switch is a type of "lock out tag out" switch on the front of the Megapack that safely powers down the unit for servicing.

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

Incident Timeline

Friday July 30

7:20 AM
MP-1 shut off via keylock switch. Commissioning and testing for other Megapacks on the site begins.

10:00 - 10:15 AM
Site supervisors observe smoke emitting from one MP-1. The site was electrically isolated and emergency services were called.

10:30 - 10:36 AM
CFA arrives and sets up a 25 m (82 ft) perimeter; meanwhile, flames are first observed emanating from MP-1.

11:57 AM
Flames are observed emanating from MP-2.

12:24 PM
Visible flames from MP-1 subside. Visible flames within MP-2 continue.

4:00 PM
Visible flames from MP-2 subside. End of active fire event. Fire watch begins.

Saturday July 31

Fire watch continues, no additional flaming occurs. CFA monitors the Megapacks with thermal imaging cameras and drone technology.

Sunday August 1

Fire watch continues, no additional flaming occurs. CFA monitors the Megapacks with thermal imaging cameras and drone technology.

Monday August 2

3:05 PM
MP-1 and MP-2 doors are removed and their interiors temperatures were measured to be near ambient. CFA deems the site is under control.

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

Investigation

A multi-entity fire investigation commenced on August 3, 2021. The VBB fire investigation process involved analyzing both the root cause of the initial fire in MP-1 as well as the root cause of the fire propagation into MP-2. The investigations included on-site inspections of MP-1 and MP-2 by the CFA, Energy Safe Victoria[4] (ESV), Work Safety Victoria[5] (WSV), local Tesla engineering/service teams and a local third-party independent engineering firm. In addition to the on-site work immediately after the incident, the root cause investigations also included data analysis, thermal modeling and physical testing (electrical and fire) performed by Tesla at their headquarters in California, USA and their fire test facility in Nevada, USA.

Fire Cause Investigation

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

Fire Origin and Cause Determination

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

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

Contributory Factors

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

1. The supervisory control and data acquisition (SCADA) system for a Megapack required 24 hours to setup a connection for new equipment (i.e., a new Megapack) to provide full telemetry data functionality and remote monitoring by Tesla operators. Since VBB was still in the installation and commissioning phase of the project (i.e., not in operation), MP-1 had only been in service for 13 hours prior to being switched off via the keylock switch on the morning of the fire. As such, MP-1 had not been on-line for the required 24 hours, which prevented this unit from transmitting telemetry data (internal temperatures, fault alarms, etc.) to Tesla's off-site control facility on the morning of the fire.
2. The keylock switch for MP-1 was operated correctly on the morning of the fire to turn MP-1 off as the unit was not required for commissioning and testing that morning; however, this action caused telemetry systems, fault monitoring, and electrical fault safety devices[6] to be disabled or operate with

[4] Victoria's energy safety regulator
[5] Victoria's health and safety regulator
[6] These elements include, among other devices, fuses at the cell and module level for localized fault current interruption and a battery module pyro disconnect that severs the electrical connection of the battery module when a fault current is passing through the battery module.

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

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

Fire Propagation Investigation

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

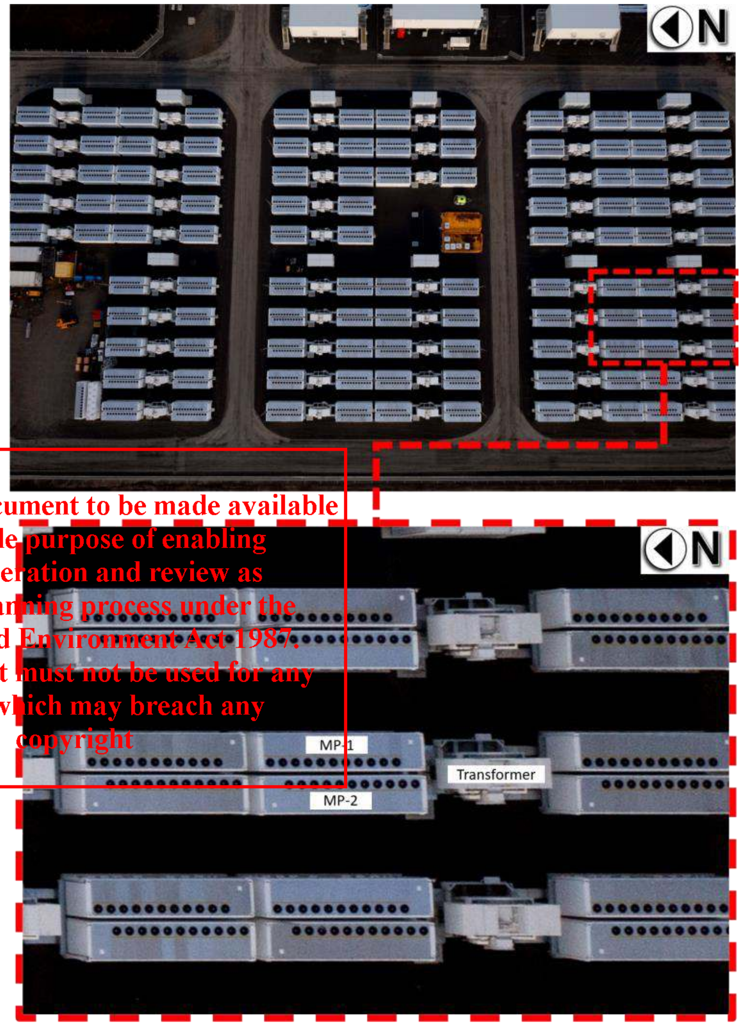

Figure 1 VBB Megapack layout (top) and area of fire origin (bottom)

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

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

Fire Propagation Determination

Flames exiting the roof of MP-1 were significantly impacted by the wind conditions at the time of the fire. Wind speeds were recorded between 20-30 knots[9] which pushed the flames exiting the roof of MP-1 towards the roof of MP-2. This direct flame impingement on the top of the thermal roof of MP-2 ignited the internal components of MP-2, most notably, the plastic overpressure vents that seal the battery bay[10] from the thermal roof. Once ignited, the overpressure vents provided a direct path for flames and hot gases to enter into the battery bays, thus exposing the battery modules of MP-2 to fire and/or elevated temperatures. Exposed to temperatures above their thermal runaway threshold of 139°C (282°F), the cells within the battery modules eventually failed and became involved in the fire.

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

Contributory Factors

The wind was the dominant contributory factor in the propagation of fire from MP-1 to MP-2. At the time of the fire, a 20-30 knot (37-56 km/hr, 23-35 mph) wind was recorded out of the north. The wind conditions at the time of the fire pushed the flames exiting out of the top of MP-1 towards the top of MP-2 leading to direct flame impingement on the thermal roof of MP-2. This type of flame behavior was not observed during previous product testing or regulatory testing per UL9540A. In UL9540A unit level testing, the maximum wind speed permitted[12] during the test is 10.4 knots (19.3 km/hr, 12.0 mph); whereas, wind conditions during the VBB fire were two to three times greater in magnitude. As such, the wind conditions during the VBB fire appear to have identified a weakness in the Megapack's thermal roof design (unprotected, plastic overpressure vents in the ceiling of the battery bays) that allows Megapack-to-Megapack fire propagation. This weakness was not identified previously during product or regulatory testing and does not invalidate the Megapack's UL9540A certification, as the cause of fire propagation was primarily due to an environmental condition (wind) that is not captured in the UL9540A test method.

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

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

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

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

Mitigations

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

Procedural Mitigations:

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

Firmware Mitigations:

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

Hardware Mitigations

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

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

Emergency Response

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

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

Key Takeaways

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

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

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

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

Environmental Concerns

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

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

Community Concerns

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

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

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

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

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

Overhaul and Remediation

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

Lessons Learned

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

1. Commissioning Procedures

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

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

2. Electrical Fault Protection Devices

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

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

3. Fire Propagation

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

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

4. Megapack Spacing

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

5. Emergency Response

Lessons learned from the emergency response to the VBB fire include: (1) effective pre-incident planning is invaluable and can reduce the likelihood of injuries; (2) coordination with SMEs, either on site or remotely, can provide critical expertise and system information for emergency responders to draw upon; (3) the effectiveness of applying water directly to adjacent Megapacks appears to provide limited benefits; however, water application to other electrical equipment, with inherently less fire protection built into their designs (such as transformers), can be a useful tactic to protect that equipment; (4) the fire protection design approach of the Megapack has inherent advantages over other BESS designs in terms of safety to emergency responders; (5) the EPA indicated that there was “good” air quality 2 hours after the fire demonstrating that no long-lasting air quality concerns arose from the fire event; (6) water samples indicated that the likelihood of the fire having a material impact on firefighting water was minimal; (7) prior community engagement during the project planning stages is invaluable as it enabled Neoen to quickly update the local community and address immediate questions and concerns; (8) early, factual and where possible, face-to-face engagement with the local community is essential when a fire event is unfolding to keep the general public informed; (9) an executive stakeholder steering committee from the key organizations involved in the emergency response can help ensure that any pubic communications are timely, efficient, coordinated and accurate; and (10) effective coordination between stakeholders at the site allowed for rapid and thorough handover process after the incident, the swift and safe decommissioning of the damaged units and the site’s quick return to service.

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