NJM DESIGN

# Fire Safety Study (FSS)

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|---|---|
| Project Name: | WRESST – 576 Winton-Glenrowan Road, Winton |
| Job Number: | 10084 |
| Date: | 02 June 2026 |
| Client: | Winton Renewable Energy Stability and Storage Terminal Pty Ltd |
| Revision | 03 |

NJM DESIGN

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# 1 EXECUTIVE SUMMARY

NJM Design has been engaged by Winton Renewable Energy Stability and Storage Terminal Pty Ltd to undertake a Fire Safety Study (FSS) for the Winton Renewable Energy Stability and Storage Terminal (WRESST) located at 576 Winton-Glenrowan Road, Winton VIC adjacent to the existing Glenrowan Terminal Station.

The project 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 BESS supplier will be finalised during the detailed design stage.

Celero Infrastructure (the Proponent) proposes to develop a utility-scale Battery Energy Storage System (BESS Project), a capacity of up to 400 MW / 1600 MWh project located at 576 Winton-Glenrowan Road, Winton, Victoria.


***Figure 1: Winton RESST – General Location.***

The project includes:

- BESS units;
- Transformers and Inverters;
- 220 kV underground transmission connection;
- On-site substation;
- Internal access tracks (5m wide);
- Fire breaks and Water tanks;
- Retention basin;
- Security fencing and monitoring systems;

- Native vegetation removal;
- Earthworks;
- Landscaping/Screening.

The proposed project area, in relation to the Glenrowan Terminal Station and the map below shows the existing 220kV Transmission line which is overhead (Refer to the Figure 2).

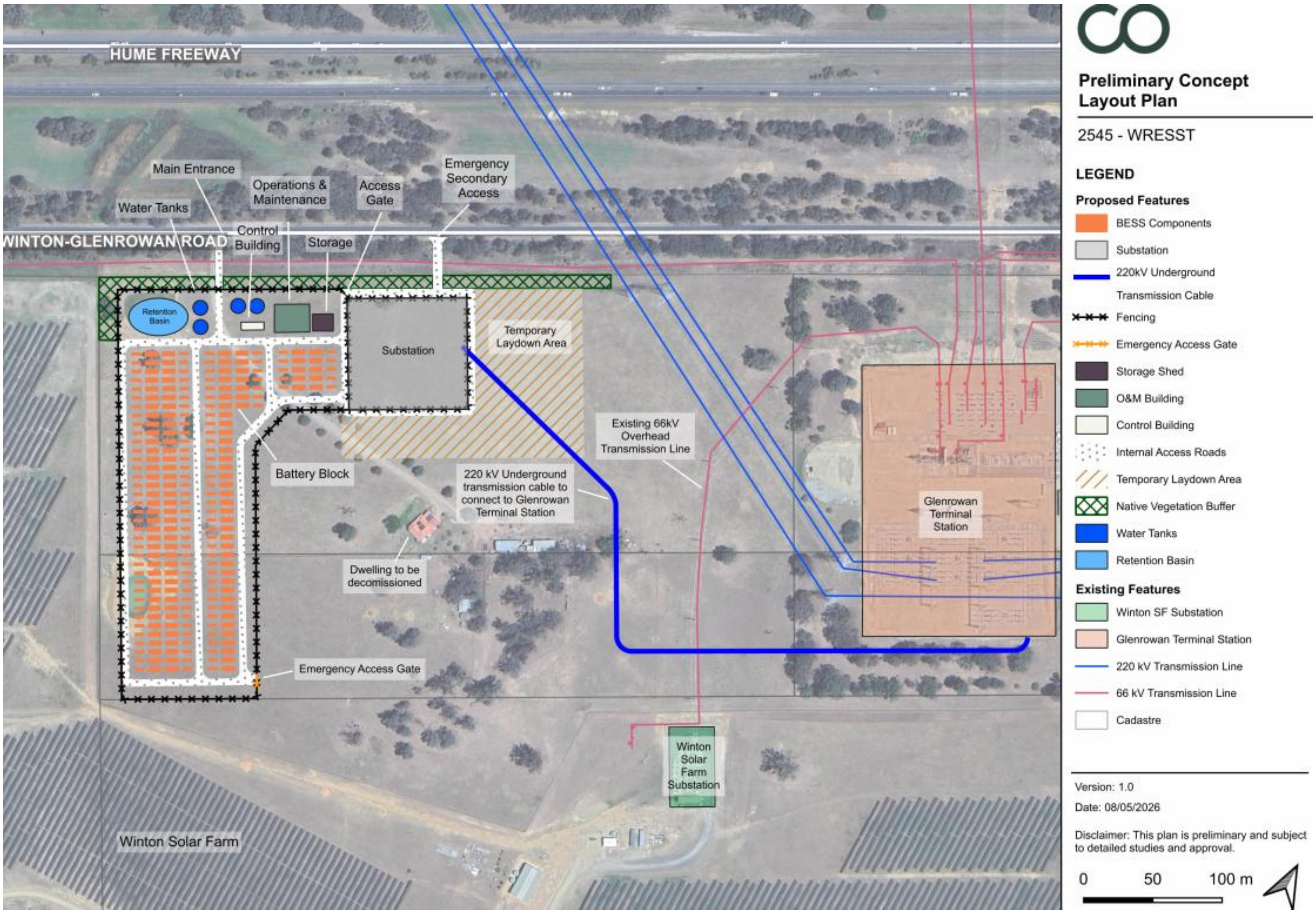


***Figure 2: Winton RESST – Cogency Layout Plan.***

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 layout. This includes the fire risks from the BESS 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, environment, legal and regulatory, community and property protection.

In particular the scope of work is to:

a. Provide a risk review consistent with fire risk assessment techniques for Hazardous industry planning advisory papers (HIPAP) [1].

b. Quantify severity of fires including heat radiation level at various distances from BESS and transformer fires and durations of the fire.

c. Put the risks into context via comparison with other accepted risks such as those from existing power infrastructure and surrounding buildings in the community.

d. Recommend mitigation measures if required.

e. Risks to equipment such physical damage, dust-build up and faults to monitoring systems are not included in this report and should be managed by the project separately.

A review of the below standards and reports as they relate to fire safety has also been undertaken.

a. CFA Design Guidelines and Model Requirements: Renewable Energy Facilities (Version 4.4, June 2025) [2].

b. Fire Safety Studies for Battery Energy Storage Systems (Version 1, June 2025) [3].

c. Best Practice Guide for Battery Storage Equipment - Electrical Safety Requirements, Version 1.0 – Published 06 July 2018.

d. NFPA 855, Standard for Stationary Energy Storage Systems (in development).

e. AS 2067:2016 has also been reviewed to place the risk of the BESS units in context with existing power utility infrastructure in the community [4].

f. FM Global Data Sheet 5-33 Factory Mutual Insurance Company. (2017). FM Global Property Loss Prevention Data Sheets 5-33. Factory Mutual Insurance Company.

g. AS 3000.

h. Building Code of Australia (NCC) 2022 [5].

i. AS 3959-2018 Construction of buildings in bushfire-prone areas [6].

j. Energy Safe Victoria (ESV) “Statement of Technical Findings - Fire at the Victorian Big Battery.

## 2 ABBREVIATIONS

| | |
|---|---|
| AC | Alternating Current |
| AS | Australia Standard |
| BAL | Bushfire Assessment Level |
| BESS | Battery Energy storage System |
| BFA | Bushfire Prone area |
| BMS | Battery Management system |
| CFA | Country Fire Authority |
| DC | Direct Current |
| ESV | Energy Safe Victoria |
| FAA | Federal Aviation Administration |
| FBIM | Fire Brigade Intervention Model |
| FM | Factory Mutual |
| HIPAP | Hazardous Industry Planning Advisory Paper |
| HRR | Heat release rate |
| HV | High Voltage |
| IFEG | International Fire Engineering Guidelines |
| LGA | Local Government Area |
| LFP | Lithium Phosphate |
| MV | Medium Voltage |
| NCC/BCA | National Construction Code/Building Code of Australia |
| NFPA | National Fire Protection Association |
| NSW | New South Wales |
| O&M | Operations and Maintenance |
| RESST | Renewable Energy Storage and Stability Terminal |
| SCBA | Self-contained breathing apparatus |
| SOC | State of charge |
| SUT | Set up Transformer |
| UL | Underwriters Laboratories |
| VBB | Victorian Big Battery |
| VIC | Victoria |
| WRESST | Winton Renewable Energy Storage and Stability Terminal |

# 3 MAIN FINDINGS AND RECOMMENDATIONS

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, the main Fire Engineering Requirements are as follows:

1. The BESS supplier must provide the results of a large-scale test in accordance with CSA TS-800:24 and/or UL9540A, and the laboratory/centre certifications.
2. The BESS units must have the following safety measures (not limited to):
   - Provision of a BMS (Mattery management system).
   - Smoke and heat detection.
   - Gas detection.
   - Fire alarm.
   - Door alarms.
   - Electrical safety measures (e.g., ground faults, high voltage, communication faults, etc.).
   - Automatic and manual stops that shutdown the battery.
   - Temperature controls.
   - Deflagration and ventilation systems / overpressure vents if required.
   - Lighting protection.
3. The proposed BESS layout must be reviewed to match the supplier's specifications and the large-scale tests.
4. The clearances between BESS units must not be less than 3.0m unless a large-scale test in accordance with CSA TS-800:24 and/or UL9540A is provided.
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. A Fire hydrant system as per AS 2419.1 must be provided throughout the facility for fire brigade intervention procedures. 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.
7. Transformers must comply with AS2067 separation distances for transformers and other surfaces, and the following:
   - Where transformers are oil-insulated, transformers shall use an FR3 (or similar) Ester oil where practical in lieu of the normal mineral oil. MV/SUT transformers will use FR3 oil type.
   - MV/SUT transformers, if not provided with enhanced protection, must not have an oil capacity of more than 38,000 litres (38 $m^3$) and must not be located to less than 1.5m from the non-combustible surfaces/equipment to comply with the requirements of the AS 2067.

- HV 220kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow.
- HV transformers must keep a clearance to other equipment and buildings as per with AS2067 (see figure below) subject to the final HV transformer specifications.

| 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 | [illegible] | [illegible] | 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 |



***Figure 3 – AS 2067:2016-Table 6.1 – Clearance for outdoor transformers*** [4]**.**

8. All buildings within the facility must comply with the performance requirements of the NCC where the DtS provisions are not satisfied:
    - All buildings (i.e., storge shed, O&M building, control building) must be separated from each other and other equipment by at least 6m as per the NCC DtS provisions, or
    - Where clearances between buildings are less than 6m, non-combustible and/or fire rated walls are recommended.

9. The firefighting water must be not less 288kl, sufficient for 4 hours supply based for 2 hydrants operating at the same time. The 288kl storage will be justified based on the BESS documentation, site layout and fire spread analysis.
10. Water storage of not less than 288kL must be provided at an entrance of the facility with a compliant hard stand and booster assembly in accordance with the latest CFA Guidelines Revision 4 [7] 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 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 FRV/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.
    - Signage must be provided to the alternative entrances of the facility, indicating the direction to the static water tank.
11. A firebreak of at least 10m wide must be designed and maintained as shown in Appendix A.
12. The five (5) metre perimeter road within the perimeter fire break must be maintained and designed to comply with the requirements of the CFA Design Guidelines for renewable Energy Facilities (this is compliant in the proposed layout in Appendix A).
13. The five (5) metre road within BESS isles (as shown in Appendix A) must be maintained to facilitate fire brigade intervention procedures.

14. The 2 two (2) alternative entrances on Winton Glenrowan Road must be maintained as shown in Appendix A and the following:
    - Maintain an emergency access gate for emergency services.
    - It is recommended to close the road loop around the proposed BESS units aisles as shown below.

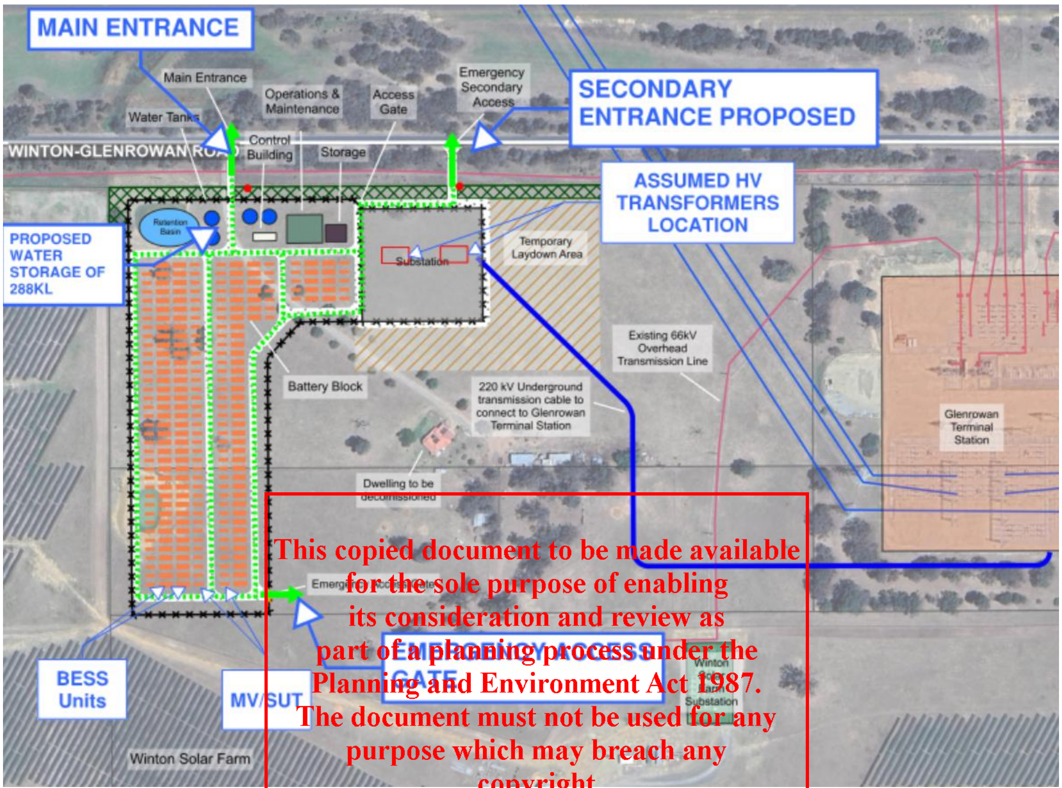




*Figure 4 – Entrances and roads within the BESS development.*

15. Access through the entrances must be provided by opening 003-key padlocks or intercom systems.
16. Each vehicle and heavy equipment 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 [7].
17. A containment and management plan of contaminated fire water runoff from the BESS is to be developed by the facility. The following measures are recommended:
    - HV 220kV transformers should have a bund with the capacity to hold the oil volume to account for water and overflow.
    - The Construction Techniques for Sediment Pollution Control (1991) and Managing soil disturbance: guidance sheet (2020) could be used to develop an Erosion and Sediment Control Plan (ESCP).
    - The plan must consider as part of the variables the storage of water designed for the fire hydrant system (e.g., 288kl is proposed in this FSS).
18. A fire rated wall must be provided between the HV transformers as per AS 2067 if required.
19. 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., SUT, 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., SUT, 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.



20. The development must develop a vegetation management plan.
21. An electrical hazards and risk assessment is to be performed by the facility (another consultant to address).
22. Develop a Fire Management Plan as required by the CFA Design Guidelines [7] for renewable Energy Facilities, which must contain at least the following content (figure below).

| Fire Management Plan Structure and Content | |
|---|---|
| A summary of fire hazards and risks to and from the site, specific to its location, infrastructure, activities and occupancy. | Based on sound hazard identification and risk management processes. This must include risks to firefighter safety during emergencies. |
| Description of control measures to prevent fire occurring and limit the consequences of fire at the facility. | Fire permits, ignition source controls, hot work permits, job hazard analyses, infrastructure/vehicle/equipment/road/fence/access maintenance, waste management, compliant dangerous goods storage and handling, vegetation/fuel reduction and management, peat management, Emergency Plan. |
| Description of control measures to prevent and reduce the consequences of external fire impacting the facility. | Bushfire monitoring, bushfire preparedness, reduced personnel presence/ activities/travel on days of Severe and above Fire Danger Rating, creation and management of fire breaks at the site perimeter and around infrastructure, vegetation/fuel reduction and management, Emergency Plan. |
| Details of equipment and resources to manage fire at the facility. | Fire detection and suppression systems, fire water supplies, automatic shut-down and isolation systems, monitored alarms, communications equipment, occupant warning systems, designated evacuation assembly areas, Emergency Information Container(s), Emergency Plan. |
| Policies and procedures that ensure all control measures are appropriate and effective, and remain so. | Performance standards for risk controls, specific activities to verify controls (servicing/maintenance, housekeeping inspections, external audits), review processes for risk control effectiveness. |
| Procedures for review of the Fire Management Plan. | Review triggers and schedule, organisational accountability for the Plan, allocated responsibilities (to persons or roles) for the ongoing review and development of the Plan. |

***Figure 5: Fire Management Plan Requirements as per CFA Design guidelines [7].***

# 4 SCOPE OF REPORT

## 4.1 GENERAL

Winton RESST facility is as presented in the plans in Appendix A. The project site area is approximately 26 hectares [8].

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 layout. 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, environment, legal and regulatory, 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 [3].
- 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 practical and advanced 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:

- Table of Assumptions provided by Cogency, dated 11 May 2026 [8].
- Best Practice Guide for Battery Storage Equipment - Electrical Safety Requirements, Version 1.0 – Published 06 July 2018.

- AS 2067-2016 [4] 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 [9].
- 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.

## 4.3 Project Stakeholders

The relevant stakeholders in accordance with NCC A2G2(4) for the WRESST – 576 Winton-Glenrowan Road, Winton project are detailed in Table 1:

***Table 1 – Design and Regulatory Stakeholders***

| Role | Organization |
|---|---|
| Client | Winton Renewable Energy Stability and Storage Terminal Pty Ltd |
| Manager/Developer | Celero Infrastructure |
| Fire Safety Engineer | NJM Design (Vic) Pty Ltd. |
| Fire Brigade | CFA |



## 4.4 Legislative Requirements

The primary objectives of the NCC, as summarised in the first edition of the International Fire Engineering Guidelines (IFEG) [10], 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) [11].
- Protection of neighbouring buildings – structures should not collapse onto adjacent property or spread fire due to flame extensions or radiation.

# 5 Risk Assessment Methodology

## 5.1 Introduction

Fire Safety Studies for Battery Energy Storage Systems (Version 1, June 2025) [3] is a guideline that, where a Fire Safety Study is requested by the CFA, must be followed.

The summary of the requirements in the proposed guideline and the sections that cover those requirements in this report are provided below.

***Table 2: CFA Guidelines requirements Table 2.***

| Guideline Parts | Relevant Report Sections |
|---|---|
| 1: Facility Description | ▪ Information, including general details and the site layout locality map, is outlined in Section 6.<br>▪ The project 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 BESS supplier will be finalised during the detailed design stage. |
| 2: Identify BESS Hazards | ▪ Section 8 addresses potential fire hazards associated with the BESS units.<br>▪ The BESS supplier must provide the results of a large-scale test in accordance with UL9540A and the laboratory/centre certifications.<br>▪ BAL assessment is presented in Section 9.2.7. |
| 3: Identify Consequences | ▪ The consequence of a fire in a battery and a transformer has been modelled and assessed in Section 9.2.<br>▪ Section 8 discusses past events and findings related to BESS fire hazards. |
| 4: Fire and Explosion Prevention | ▪ Section 3 include the outcomes of the risk assessment and the required fire safety measures to reduce fire risk.<br>▪ The BAL assessment is undertaken in Section 9.2.7, which also covers the required fire safety requirements. |
| 5: Fire Detection and Protection | ▪ The project has not defined the BESS provider at this stage, once it is finalized, the final fire detection and protection must be provided.<br>▪ Expectations for the BESS units' safety measures are listed in Section 3. |
| 6: Fire Water Demand and Supply | ▪ The required fire water for the site is assessed in Section 10.3, based on CFA Design Guidelines and Model Requirements: Renewable Energy Facilities (Version 4.4, June 2025) [2]. |

| Guideline Parts | Relevant Report Sections |
|---|---|
| 7: Fire Water Management | ■ A containment and management plan of contaminated fire water runoff from the BESS is to be developed by the facility (listed as a requirement in Section 3). |
| 8: Emergency Planning | ■ An emergency plan must be provided in accordance with AS 3745-2010: Planning for Emergencies in Facilities, and CFA's Design Guidelines and Model Requirements for Renewable Energy Facilities (listed as a requirement in Section 3). |
| 9: Recommendations and Implementation | ■ Conclusions and proposed fire engineering requirements are summarized in Section 3. |

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 Hazardous Industry Advisory Papers (HIPAPS) and the Fire Safety Studies for BESS [3].

The process is shown diagrammatically in Figure 6.



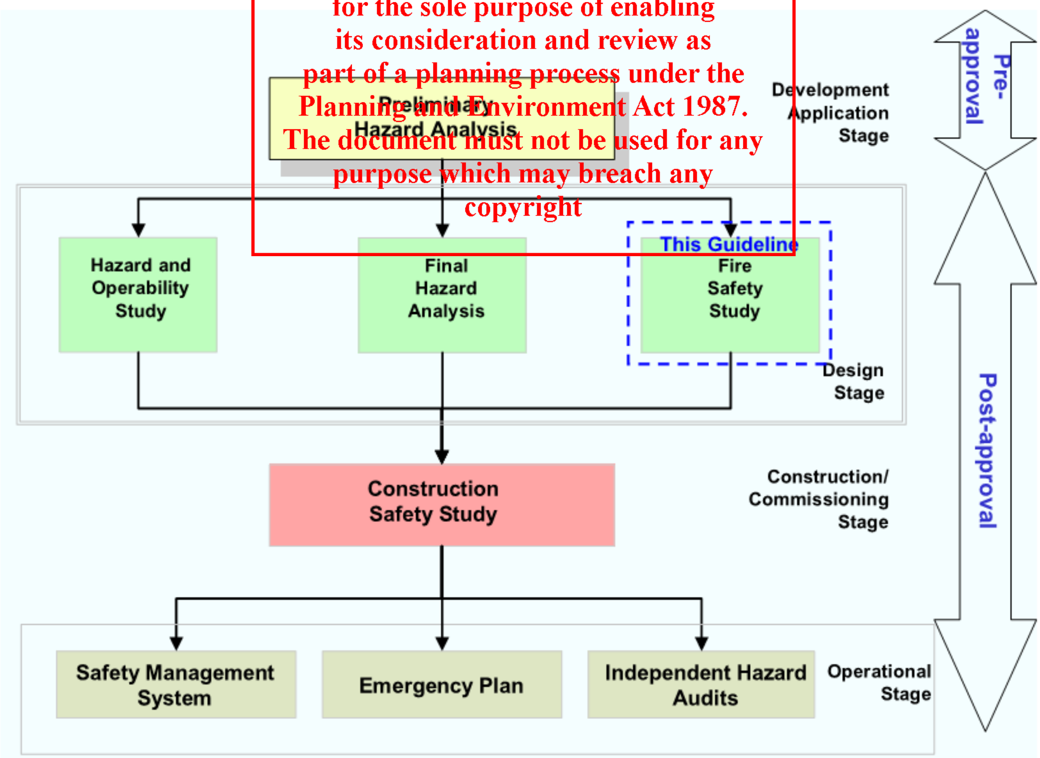


*Figure 6: The Hazards-Related Assessment Process*

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.–10 - 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 [3] (i.e., the development of this study), and the CFA Guidelines for Renewable Energies Revision 4 [2].

## 5.2 FIRE SPREAD ACCEPTANCE CRITERIA

- IEEE Std 979-2012 [12]:

Table B.3 of IEEE Std 979-2012 [12] gives some typical examples of the amount of radiant heat necessary to ignite common materials used in substations.

***Table 3: Typical radiant heat flux intensities (Table B.3IEEE Std 979-2012) [12].***

| Impact of radiant heat flux | Heat flux ($kW/m^2$) |
|---|---|
| Sufficient to cause damage to process equipment | 37.50 |
| Equipment failure | 35.00 |
| Damage to unprotected metal | 30.00 |
| Spontaneous ignition of wood | 25.00 |
| Cable insulation degrades | 20.00 |
| Pilot ignition of wood | 12.50 |
| Plastic melts | 12.50 |
| Pain threshold reached after 8s.<br>Second degree burns after 20s. | 9.50 |
| Possible failure of ceramic bushings | 5.00 |
| Skin burns | 5.00 |

Ausgrid Network Standard NS187 [13] parameters will be considered to assess the porcelain supports of ROI OHL Steelworks.

***Table 4: Radiant Heat Exposure Limits [13].***

| Item | Maximum allowable radiant heat flux (kW/m$^2$) | Comment |
|---|---|---|
| Porcelain bushing/Insulators | 12.50 | Damage may occur requiring replacement or in extreme case resulting in catastrophic failure. |

- AS 1530.4-2014 [14]:

Where other façade/lining materials are present in adjoining building or equipment, Table A3 of AS 1530.4-2014 [14] 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 [14].***

| Phenomena (Maximum for indefinite exposure for humans) | kW/m$^2$ |
|---|---|
| Pain after 10s to 20s | 4.00 |
| Pain after 3 s | 10.00 |
| Piloted ignition of cotton fabric after a long time | 13.00 |
| Piloted ignition of timber after a long time | 13.00 |
| Non-piloted ignition of cotton fabric after a long time | 25.00 |
| Non-piloted ignition of timber after a long time | 25.00 |
| Non-piloted ignition of gaberdine fabric after a long time | 27.00 |
| Non-piloted ignition of back drill fabric after a long time | 38.00 |
| Non-piloted ignition of cotton fabric after 5s | 42.00 |
| Non-piloted ignition of timber in 20s | 45.00 |
| Non-piloted ignition of timber in 10s | 55.00 |



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$^2$ at 2.0 m AFFL [15].

- 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$^2$ |
|---|---|
| BESS Units | 37.50 |
| MV/SUT transformers | 37.50 |
| HV transformers (Substation) | 5.00 |
| O&M Building, Control Building, other buildings | 13.00 |
| Storage containers | 13.00 |
| Vegetation | 13.00 |
| Fire Brigade | 3.00 |

# 6 FACILITY CHARACTERISTICS

## 6.1 FACILITY LAYOUT AND EQUIPMENT DESCRIPTION

### 6.1.1 General

The proposed Winton Renewable Energy Storage Stability Terminal (WRESST) is located at 576 Winton-Glenrowan Road, Winton, adjacent to the existing Glenrowan Terminal Station.

Celero Infrastructure (the Proponent) proposes to develop a utility-scale Battery Energy Storage System (BESS), a capacity of up to 400 MW / 1600 MWh project located in Winton, Victoria. The BESS units will connect to the Glenrowan Terminal Station via an underground 220kV transmission cable. The BESS development has the below layout distribution as shown in Figure 7 below.

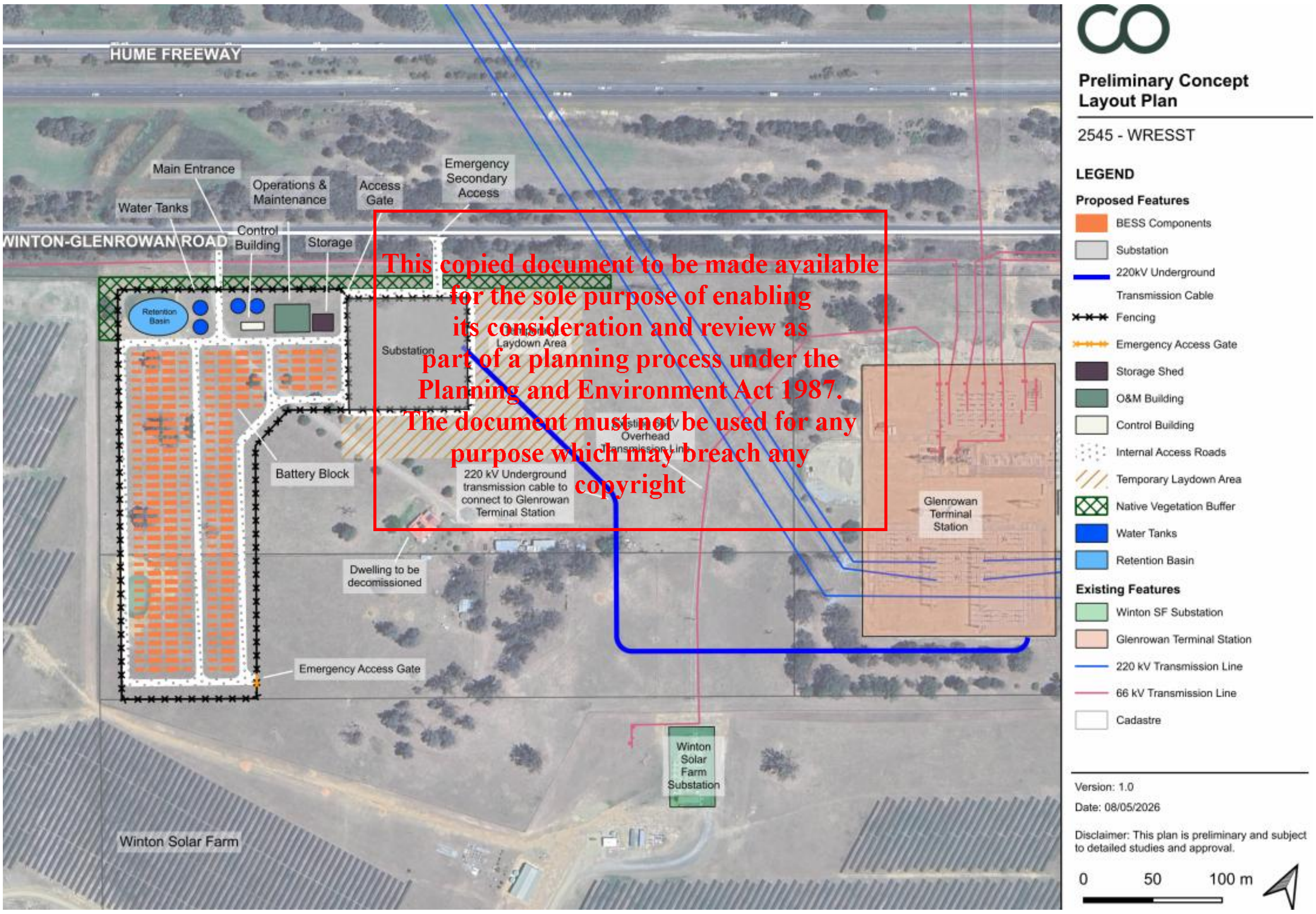


***Figure 7 – BESS layout.***

The proposed Winton Renewable Energy Storage Stability Terminal (WRESST) has the following equipment/facilities:

- BESS units;
- Transformers and Inverters;

- 220 kV underground transmission connection;
- On-site substation;
- Internal access tracks (5m);
- Fire breaks and Water tanks;
- Retention basin;
- Security fencing and monitoring systems;
- Native vegetation removal;
- Earthworks;
- Landscaping/Screening.

The facility has firebreaks no less than 10m wide to mitigate the risk of fire spread (Refer Appendix A).

As part of the fire-fighting measures, the site will also be provided with a water storage of not less than 288 kl, a fire hydrant system and portable fire extinguishers as per AS 2444.

The primary access to the site is via an unsealed entryway that connects to Winton-Glenrowan Road on the northern side. A secondary access point along Winton-Glenrowan Road is proposed [8] located approximately 158m away from the main entrance. An emergency gate has been provided located on the south-eastern side of the project area for local CFA/emergency services in the event of an emergency.

### 6.1.2 Dominant Occupant Characteristics

Based on the use of the project area, the occupant characteristics and attributes have been identified as part of the performance process and are summarised in Table 2 below.

***Table 7 - 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.<br>The site is expected to have 4 to 6 full time employees on site. |
| 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 extinguishers and summoning the fire Brigade. |

### 6.1.3 Location and adjacent allotments

The proposed Winton Renewable Energy Storage and Stability Terminal (WRESST) is located at 576 Winton-Glenrowan Road, Winton, adjacent to the existing Glenrowan Terminal Station.

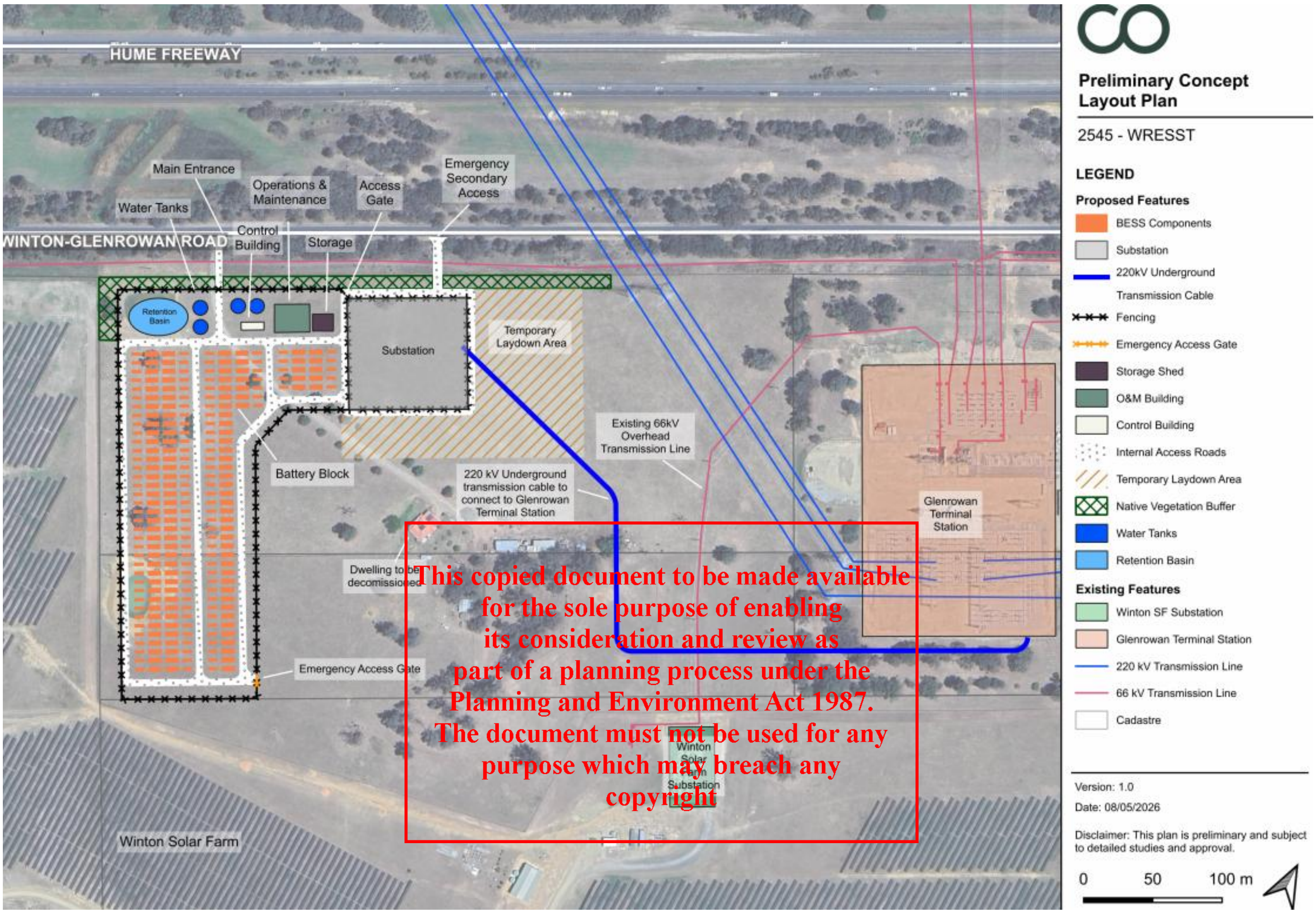



***Figure 8 – Winton RESST – Cogency Layout Plan.***

The new BESS development is located within a Farming Zone (FZ), the east adjoining existing Glenrowan Terminal Station is within a Special Use Zone (SUZ), Farming Zone (FZ) on the west and south sides, and Principal Road Network (TRZ3) on the north side (Refer to the Figure 9).

The site is bordered by the Winton Solar Farm to the south and west sides as depicted in Figure 8 above. There are 10 sensitive receptors within 2km of the proposed site (excluding dwelling on site) [8], and Winton Wetlands are located in proximity to the north-western of the site.

The site is located approximately 4.5km east of Winton and 9km west of Glenrowan towns. The site is within the Rural City of Benalla Local Government Area (LGA) [8].

### 6.1.4 Land zones

Land use for most of the surrounding area is agriculture and energy production. Adjacent to the western and southern boundary sits the Winton Solar Farm. To the eastern boundary is the existing Glenrowan Terminal Station, and the northern boundary is the Winton-Glenrowan Road.

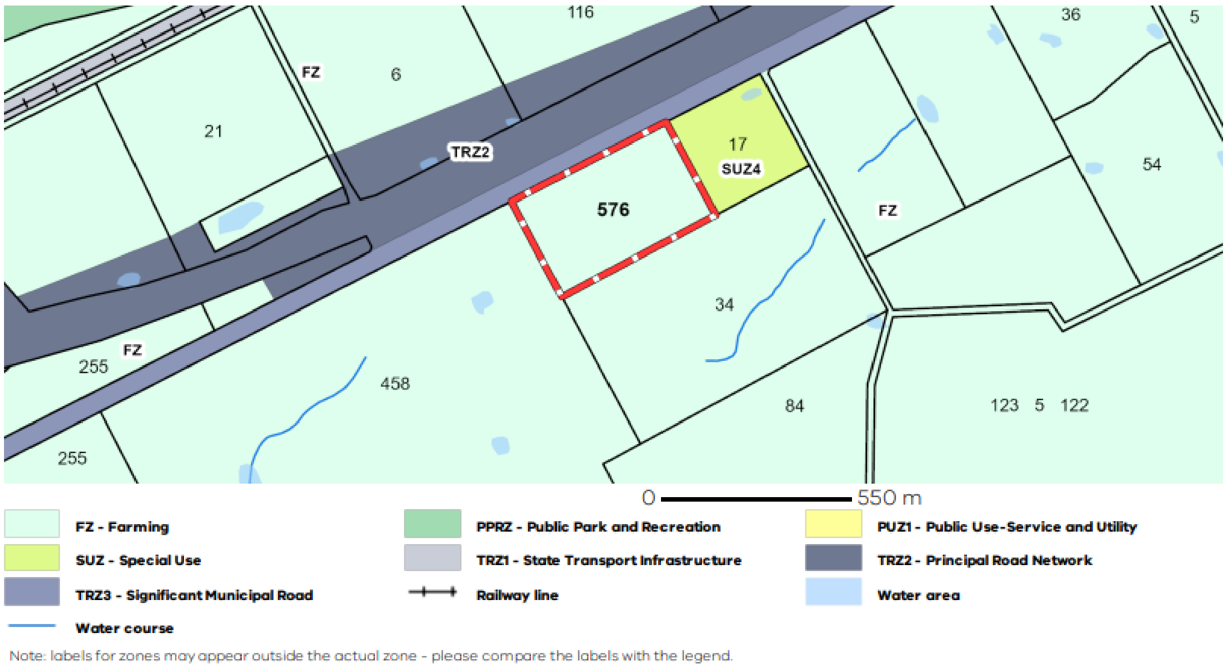


*Figure 9 – Development within a Farming Zone.*

The subject allotment is classified as a BFA (Bushfire Prone area) area in accordance with the VIC Planning portal (Refer to the Figure 10). Therefore, owners and management must maintain the land to minimize the risk of fire spread. It is noted that no Bushfire Management Overlay (BMO) nearby the project area.

Considering the above, the subject BESS will have a BAL Assessment in accordance to AS 3959-2018 – Construction of buildings in bushfire-prone areas [6].



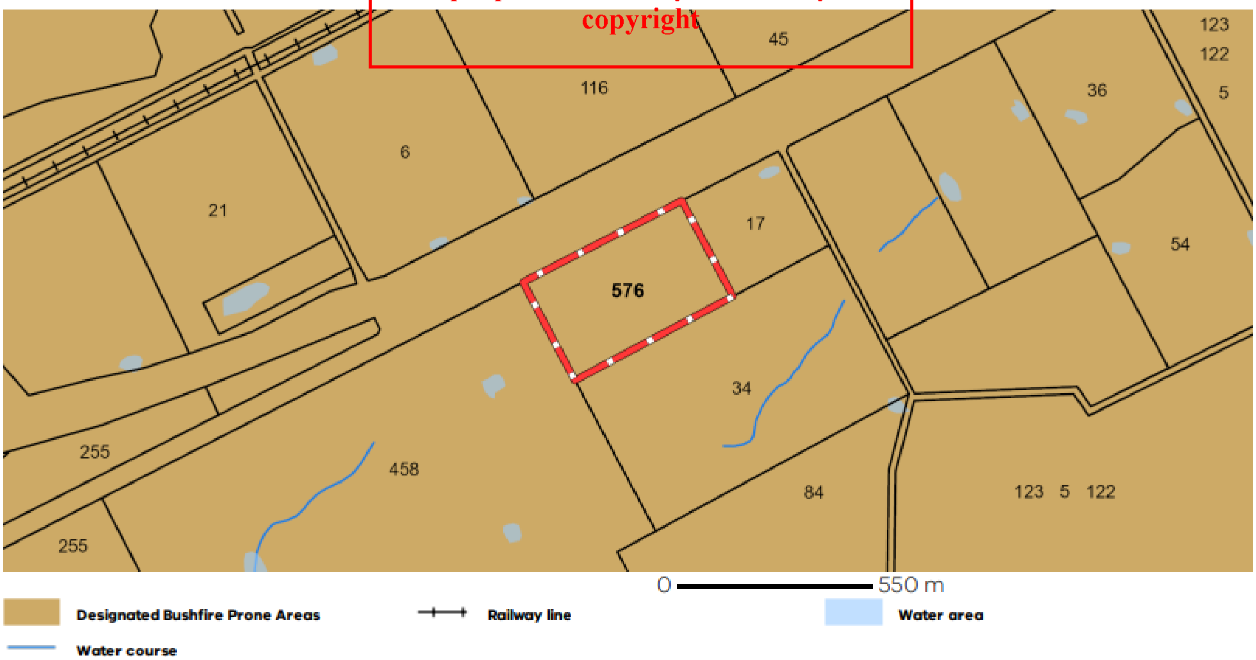


*Figure 10 – Site Zoning (Bushfire Prone Areas)*

Based on VicPlan as shown in Figure 11 below, the closest residential and industrial allotment from the WRESST is located at 3,723m and 7,667m, respectively.

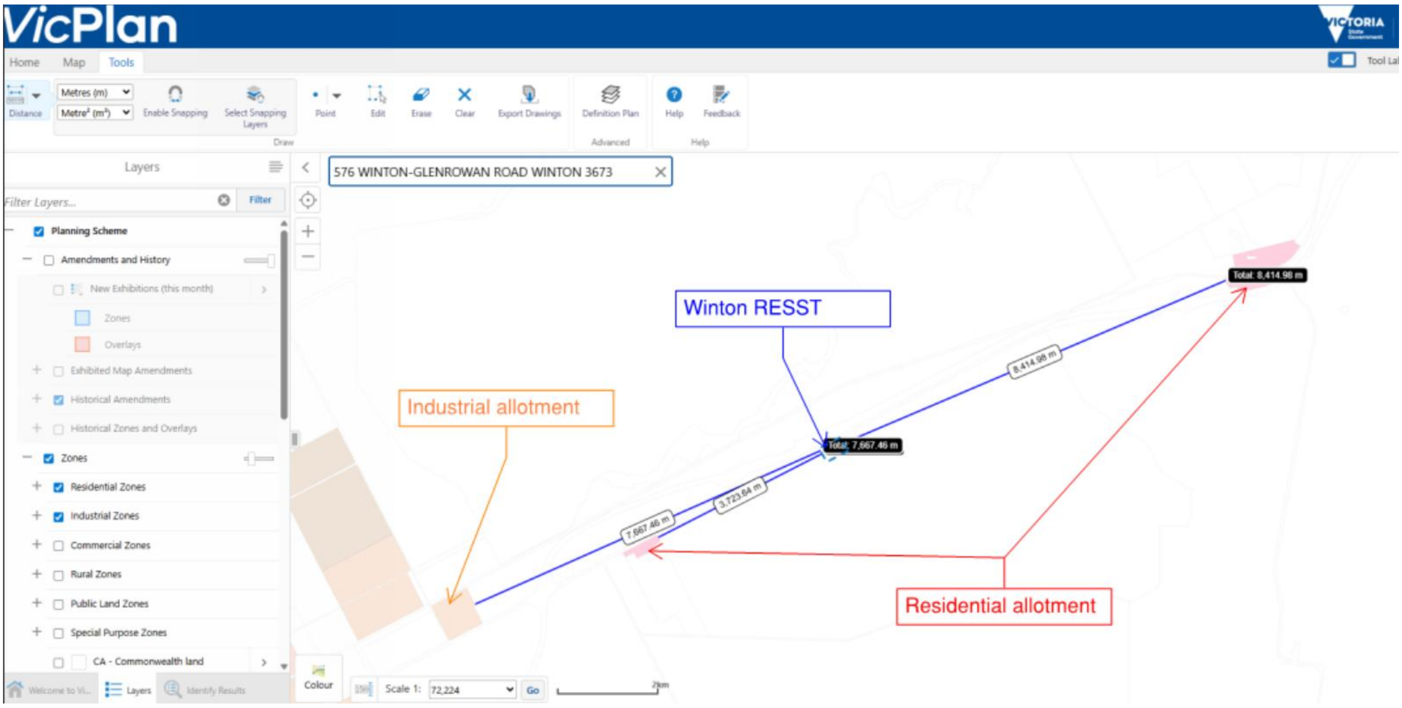


*Figure 11 – Distance to the closest residential and industrial allotment from WRESST site via VicPlan.*

### 6.1.5 Glenrowan weather conditions

The closest weather station to Glenrowan Terminal station is Wangaratta Aero [17]. In accordance with the available data, the average weather conditions are the following (Refer to the Figure 12):

- The average temperature is 22°C and the highest mean maximum temperature is 32.1°C for the month of January.
- The average relative humidity is 73%.
- Considering the December wind rose at 3 pm as the worst-case scenario, as shown in Figure 13, the wind statistics are as follows:
  - Wind is calm less than 0.5% of the time.
  - The strongest wind comes from the west with a speed of more than 40 km/hr (11.1m/s), approximately 26% of the time.
  - Wind predominantly comes from the west (26% of the time), followed by the north (15%), the south (8%), and the east (5%).
  - Average speed of the wind is 14.2 km/hr.

| Statistics | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | Years | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature** | | | | | | | | | | | | | | | |
| Mean maximum temperature (°C) | 32.1 | 31.0 | 27.7 | 22.5 | 17.4 | 13.9 | 13.0 | 14.6 | 17.7 | 21.5 | 25.9 | 29.3 | 22.2 | 38 | 1987 2024 |
| Mean minimum temperature (°C) | 14.4 | 13.7 | 10.9 | 7.0 | 4.3 | 2.9 | 2.5 | 3.0 | 4.6 | 6.5 | 9.6 | 11.9 | 7.6 | 38 | 1987 2024 |
| **Rainfall** | | | | | | | | | | | | | | | |
| Mean rainfall (mm) | 47.1 | 41.1 | 41.5 | 39.0 | 55.4 | 64.8 | 62.0 | 56.9 | 52.6 | 52.1 | 53.3 | 45.4 | 612.0 | 37 | 1987 2024 |
| Decile 5 (median) rainfall (mm) | 29.8 | 23.4 | 34.0 | 32.4 | 43.8 | 59.2 | 57.8 | 45.8 | 47.5 | 41.8 | 50.8 | 35.6 | | 38 | n/a n/a |
| Mean number of days of rain ≥ 1 mm | 4.5 | 3.5 | 3.9 | 4.5 | 6.7 | 9.1 | 10.1 | 9.4 | 7.3 | 6.2 | 5.4 | 4.9 | 75.5 | 37 | 1987 2025 |
| **Other daily elements** | | | | | | | | | | | | | | | |
| Mean daily sunshine (hours) | | | | | | | | | | | | | | | |
| Mean number of clear days | 10.7 | 11.3 | 13.8 | 10.8 | 6.1 | 5.5 | 5.2 | 5.6 | 7.0 | 8.9 | 8.7 | 11.5 | 105.1 | 12 | 1987 1999 |
| Mean number of cloudy days | 6.1 | 4.8 | 5.8 | 8.1 | 12.7 | 14.0 | 16.7 | 13.8 | 11.0 | 9.8 | 8.4 | 7.9 | 119.1 | 12 | 1987 1999 |
| **9 am conditions** | | | | | | | | | | | | | | | |
| Mean 9am temperature (°C) | 21.5 | 20.0 | 16.8 | 13.6 | 9.1 | 6.7 | 5.9 | 7.5 | 10.8 | 14.3 | 17.0 | 19.7 | 13.6 | 23 | 1987 2010 |
| Mean 9am relative humidity (%) | 54 | 61 | 67 | 74 | 90 | 92 | 93 | 88 | 79 | 67 | 62 | 54 | 73 | 23 | 1987 2010 |
| Mean 9am wind speed (km/h) | 9.8 | 7.7 | 6.9 | 6.3 | 5.0 | 5.5 | 5.6 | 7.6 | 9.0 | 9.9 | 9.9 | 10.7 | 7.8 | 23 | 1987 2010 |
| 9am wind speed vs direction plot | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | | |
| **3 pm conditions** | | | | | | | | | | | | | | | |
| Mean 3pm temperature (°C) | 29.9 | 29.1 | 26.2 | 21.5 | 16.8 | 13.3 | 12.2 | 13.5 | 16.4 | 20.0 | 24.0 | 27.2 | 20.8 | 23 | 1987 2010 |
| Mean 3pm relative humidity (%) | 28 | 32 | 33 | 42 | 56 | 67 | 67 | 61 | 55 | 46 | 38 | 30 | 46 | 23 | 1987 2010 |
| Mean 3pm wind speed (km/h) | 16.6 | 14.0 | 14.1 | 12.9 | 10.6 | 10.6 | 11.7 | 13.8 | 16.3 | 16.1 | 16.4 | 17.3 | 14.2 | 23 | 1987 2010 |
| 3pm wind speed vs direction plot | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | PDF | | |

*Figure 12: Wangaratta Aero weather statistics [17].*



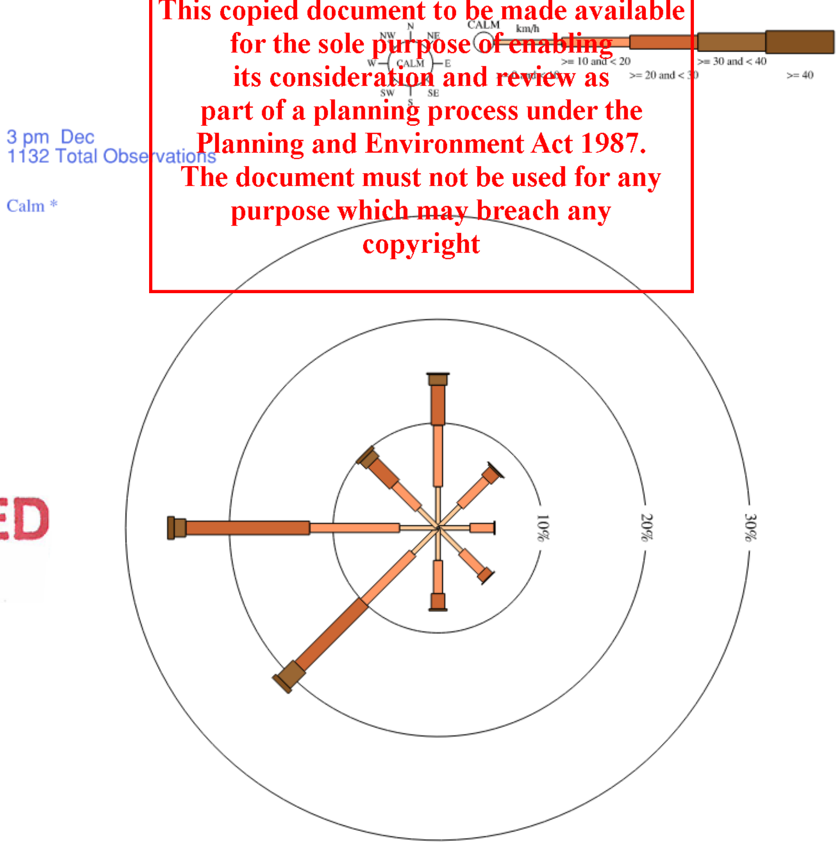




*Figure 13: Wind Rose for Wangaratta Aero weather station.*

# 7 FIRE BRIGADE

## 7.1 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 [11].

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.

## 7.2 FIRE BRIGADE STATIONS

The closest fire brigade station to the site is Winton Fire Station located approximately 4.7km (Refer to the Figure 14) away at 135 Winton-Glenrowan Road, Winton, VIC 3673.


***Figure 14 – Winton Fire Station relative to site.***

NJM DESIGN

## 7.3 Fire Brigade Access

The fire brigade will access the subject site from the north via an unsealed entryway that connects to Winton-Glenrowan Road. A secondary access point along Winton-Glenrowan Road is proposed [8] located approximately 158m away from the main entrance. An emergency gate has been provided located on the south-eastern side of the project area for local CFA/emergency services in the event of an emergency.

The access roads are not less than 5.0m wide, surpassing the requirements of the CFA Design guidelines [2].

The roads extend around and within the facility. The fire truck will run within the fence that encloses the facility.

The access/exits on the proposed locations of the facility will assure the fire brigade can access the site from at least one entrance if any other is obstructed.

It is recommended to close the road loop around the proposed substation as shown below.

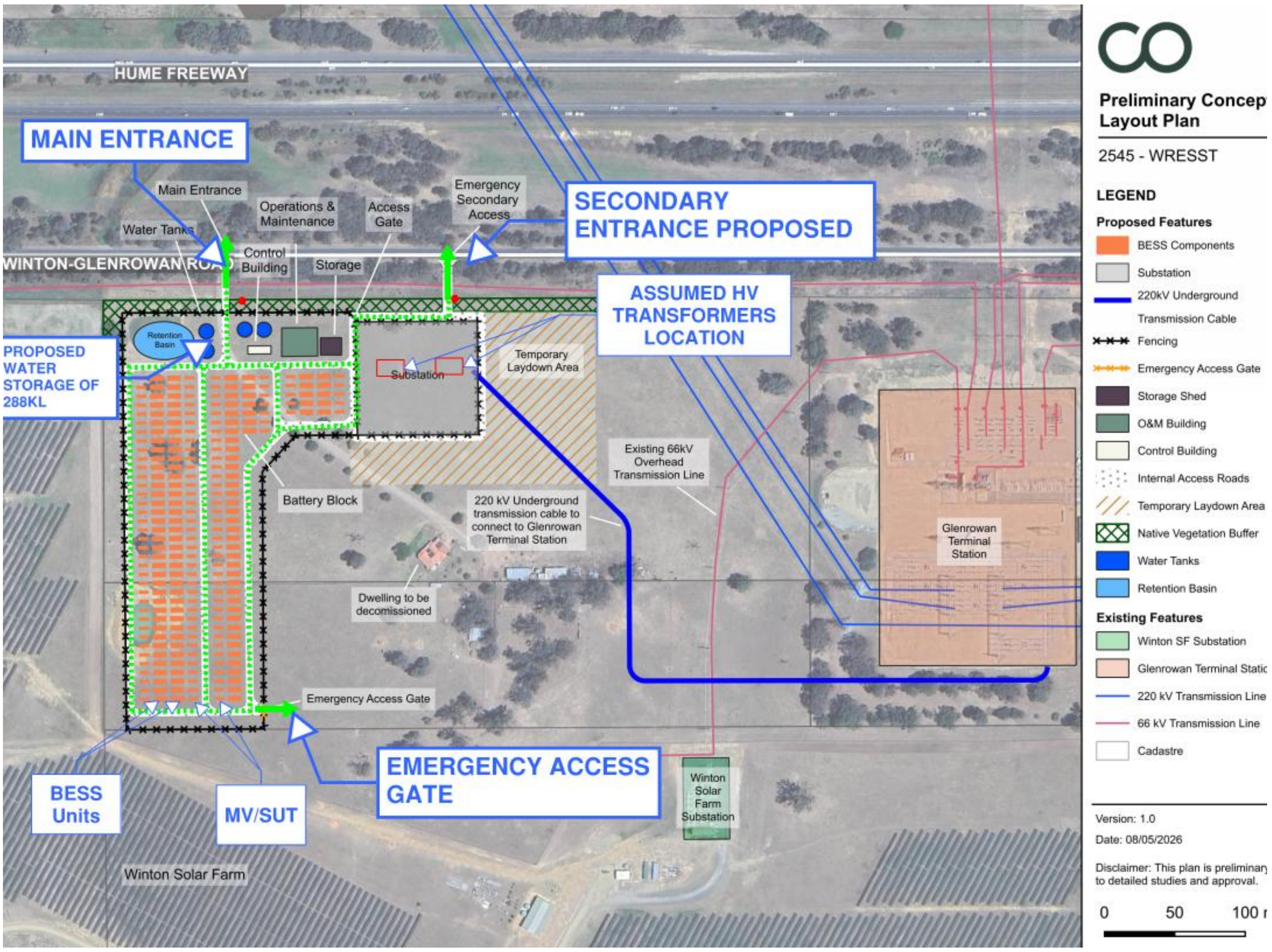


*Figure 15 – Entrances to site.*

## 7.4 General Fire Safety Strategy

Where an emergency occurs, the alarm is expected to be early detected by the safety measures of the BESS unit/transformer equipment (e.g., gas/heat/smoke/temperature detector, etc.), and a signal must be sent automatically to an Operation Centre which may be located on site and or remotely.

All equipment will be SCADA alarmed and will notify automatically the operators, who will proceed according to the Emergency Plan and the protocols provided by the equipment suppliers.

In the worst-case scenario where any of the equipment (i.e., SUT/MV transformers, HV transformers or Battery storage unit) reaches flashover, the fire brigade is expected to help control a safe perimeter around the fire and allow equipment on fire to self-extinguish if appropriate based on the equipment characteristics and assessment provided. The total burn out of the equipment on fire may be allowed without the need of direct water application based on the available information and assessment.

Fire spread is not expected given enough clearances between equipment, allotments and buildings; however the fire brigade is expected to help preventing any unexpected fire spread risk with the use of the fire trucks, fire hydrants, and the water supplied at the entrance of the site.

The attending personnel and vehicles will be equipped to commence the firefighting activities including investigations, set up and firefighting. The fire Brigade is provided with water supply at the main entrance, fire hydrants coverage, and roads within the facility.

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 or the staff monitoring the site remotely. When the fire brigade intervenes, they are expected to help control a safe perimeter around the fire.

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

When an emergency or warning signal is detected, the site must have an available Fire Management Plan which must indicate the roles, responsibilities and actions to take when an emergency signal is detected. The plan must comply with some of the following (not limited to):

- Determine who (roles and names) and actions to take to fix the matter.
- It must provide guidance to staff to determine when and how will contact the Fire Brigade so they can start the Fire Brigade intervention procedures when required.
- Indicate the expected role and strategy of the Fire Brigade (e.g., allow the BESS unit to burn out by itself and mitigate fire spread only, to extinguish fire and mitigate fire spread, maintain safe perimeter around the fire, etc.).

The Fire Management plan must be shared with the assigned Fire Brigade.

# 8 BESS Development Hazards

The Winton RESST will comprise a number of equipment components that have a risk of fire ignition, and hence a risk of fire and spread to the boundary or adjoining equipment.

The main fire hazards are given by the following equipment:

- BESS units.
- HV transformers at the Substation.
- Buildings (e.g., control buildings, etc).

Furthermore, given the location of the development, the risk of a bushfire will also be addressed.

The following section will explain past events and findings regarding the above fire risks.

## 8.1 Battery Hazards

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 or exposed to 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 the Appendix B including the Moorabool Fire.

## 8.2 Substations

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 16). Compared to the cable insulation, the probability of having transformer or transformer fluid as the object first ignited is much lower (20%).

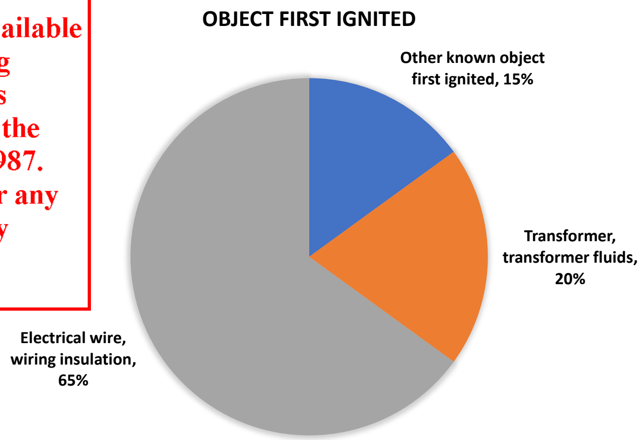


*Figure 16: Substation fires distribution.*

The EEP (Electrical Engineering Portal) [19] 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 17.

| 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 17 – Types and origins of Substations fires [19].*

Also, CIGRE [20] 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).

## 8.3 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 18.



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

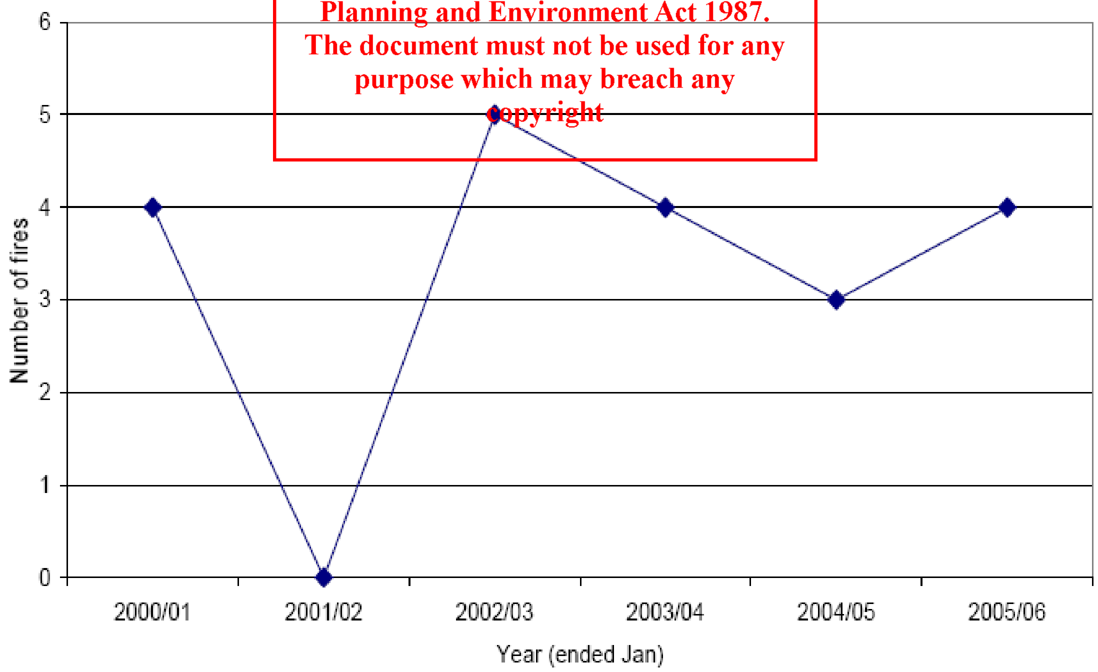


*Figure 18: Number of distribution substation fires in 2000/06 (Source NZFS FIRS).*

## 8.4 Leakage of the transformers' oil and contaminated water runoff.

Oil transformers and the water storage of 288kl have the risk of contaminated runoff water. The following measures are proposed:

- Transformers:
  - The 220kV transformers 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.
  - The Construction Techniques for Sediment Pollution Control (1991) and Managing soil disturbance: guidance sheet (2020), will be used to develop an Erosion and Sediment Control Plan (ESCP).
  - The plan must consider as part of the variables the storage of water designed for the fire hydrant system (e.g., 288kl is proposed in this FSS).

## 8.5 Flammable liquids or gasses

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



## 8.6 Release of contaminant gasses (i.e., pollution Co and $CO_2$).

The most common pollutants from a fire are CO (Carbon monoxide), $CO_2$ (Carbon dioxide), mix of multiple gasses and smoke from the equipment and oil's decomposition.

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

An analysis of this hazard is performed in this study, nonetheless it is recognized that given the location of the closest residential allotment (i.e., approximately 3,723m away), it is not expected that those communities will be affected by a fire at any of the equipment of the BESS facility.

## 8.7 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 3 of this document, and safety measures are to be added in the Emergency Management Plan.

It is recognized however that the site is provided masts for lighting protection, and the and the BESS units are expected to be provided with a lighting protection design.

# 9 Consequence on Incidents

## 9.1 BESS Fire Likelihood and Consequences

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.

From May 2, 2020, to Jan. 22, 2021, 21 ESS fires were reported across Korea from 1490 systems installed. This is a rate of 1.4%, i.e., rare based on table 2 from Appendix G of AS 5139.

Since 2011 to 2023, Electric Power Research Institute (EPRI) has recorded 81-88 incidents of BESS failures worldwide, and the following are the conclusions of the gathered statistics [21]:

- Battery storage failure incident rate dropped 97% between 2018 and 2023.
- Number of BESS units is increasing but failure rate is decreasing.
- EPRI defines failure incident as an occurrence which resulted in increased safety risk, caused by a BESS system or component failure rather than an exogenous cause of failure (e.g., wildfire impacting the BESS).
- Not all incidents resulted in a real fire incident (not registered how many were on fire).



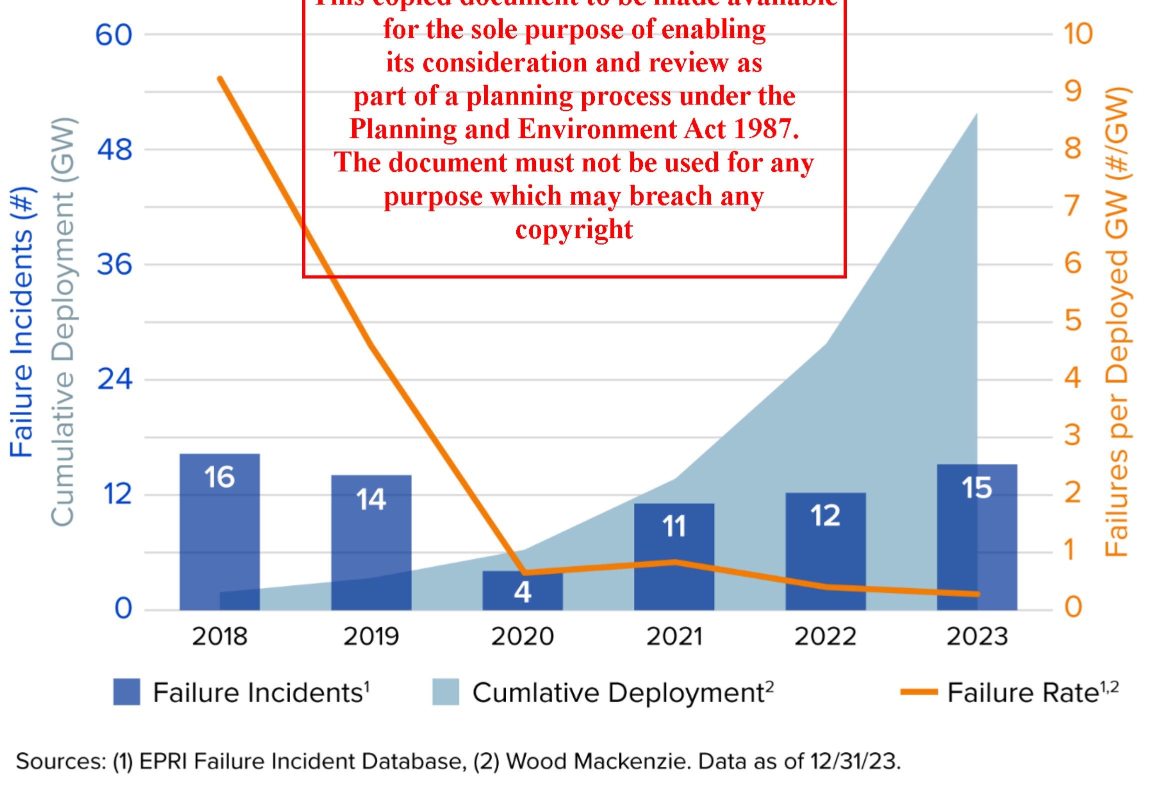


***Figure 19: Global Grid-scale BESS deployment and failure statistics [21].***

The likelihood of a fire is therefore considered to be rare. Accordingly, the risk of a fire would be rated as Very Low.

## 9.2 Consequence

The consequence of a fire in a battery and a transformer will be modelled and assessed as part of the fire engineering report.

It will be demonstrated that given the fire separation to the adjacent buildings, fire spread is not predicted to occur at a greater level than for NCC compliant buildings within the community. (Note this is based on units similar to those in the VBB fire and further assessment will be performed once the final BESS unit design is known).

### 9.2.1 220KV HV Substation.

In order to assess the impact of a transformer fire on other objects, the transformer fire was treated as a pool fire as it 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)*

Where:

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

As it 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 characteristics of the transformer of a typical 220kV substation, a bund of approximately 209m$^2$ with a fire of 262.7 MW (Figure 20) is estimated (the actual bund of the transformer will be reviewed later in the detailed design).

| | | | |
|---|---|---|---|
| Volume oil | 60000.00 | L | |
| | 60.00 | $m^3$ | |
| **Bund** | | | |
| Area TK & Radiator | 0.00 | | |
| L | 19.00 | m | |
| W | 11.00 | m | |
| H | 0.29 | m | |
| Ideal mass loss | 0.039 | $kg/sm^2$ | |
| A | 209.00 | $m^2$ | |
| V Bund | 60.00 | $m^3$ | |
| | | | |
| D | 16.31 | 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 | 1257.15 | $kW/m^2$ | |
| Ballast Factor | 1.00 | - | Without ballast = 1, with ballast = 0.2. |
| Q | 262.74 | MW | $\dot{Q} = A_f \dot{m}'' \chi \Delta h_c$ (Equation 3.5, *Enclosure Fire Dynamics)* |

***Figure 20: HRR Calculation substation.***

The FDS model boundary conditions are presented in Figure 21, and the fire scenario characteristics are as follows:

- Fire Origin: Transformer at substation HV.
- Fire growth: Instant.
- Weather conditions (refer to Section 6.1.5): Wind speed: 3.95m/s; Temperature: 22°C; Relative Humidity: 73%.
- Heat release rate: 262.7MW (Figure 20 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



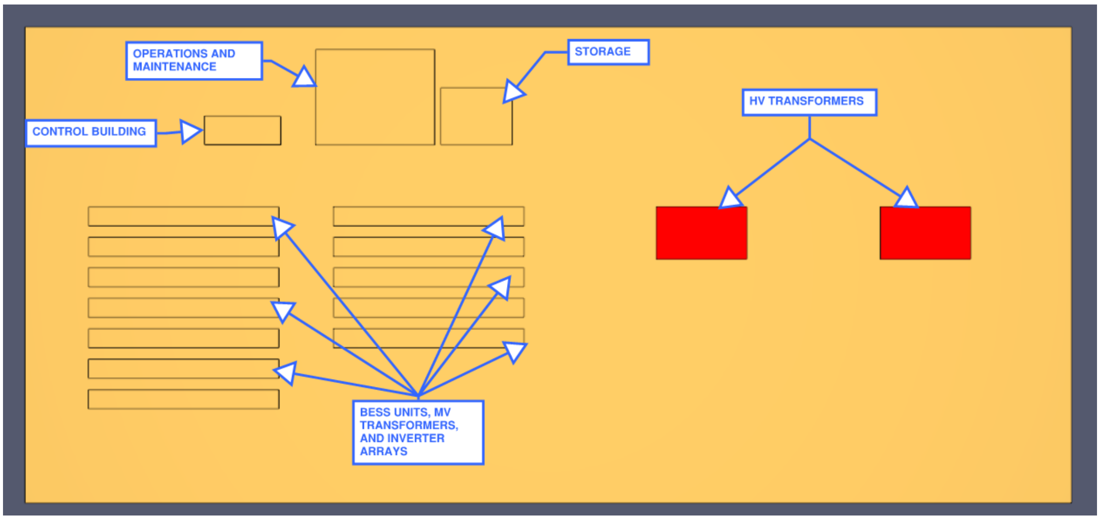


***Figure 21 – FDS Model.***

Given the location of the subject facility equipment, Table 8 below summarizes the heat flux received at the different locations within Winton BESS in accordance with the preliminary layout (refer to Figure 22 and Figure 23).

***Table 8 – Heat flux results based on HV Substation Fire.***

| Exposed equipment | Distance (m) | Incident Radiation (kW/m$^2$) | | |
|---|---|---|---|---|
| | | Wind (Figure 22) | No Wind (Figure 23) | Critical Criteria |
| Adjoining HV transformer within substation | 23.00 | 5.30 | 3.00 | 5.00 |
| BESS (the closest) | 32.50 | 3.00 | 3.00 | 37.50 |
| MV/SUT transformers | 23.00 | 5.30 | 3.00 | 37.50 |
| Closest Winton BESS fence/ Vegetation | 14.00 | 12.42 | 3.00 | 13.00 |
| Control Building | 74.00 | 3.00 | 3.00 | 13.00 |
| O&M Building | 41.00 | 3.00 | 3.00 | 13.00 |
| Storage Building | 24.00 | 3.00 | 3.00 | 13.00 |

The results indicate that, regardless of the presence of wind, the maximum heat flux levels at critical locations from a fire at the substation remain well below the critical heat flux for vegetation, equipment, and buildings. Hence, fire spread is not expected to occur.



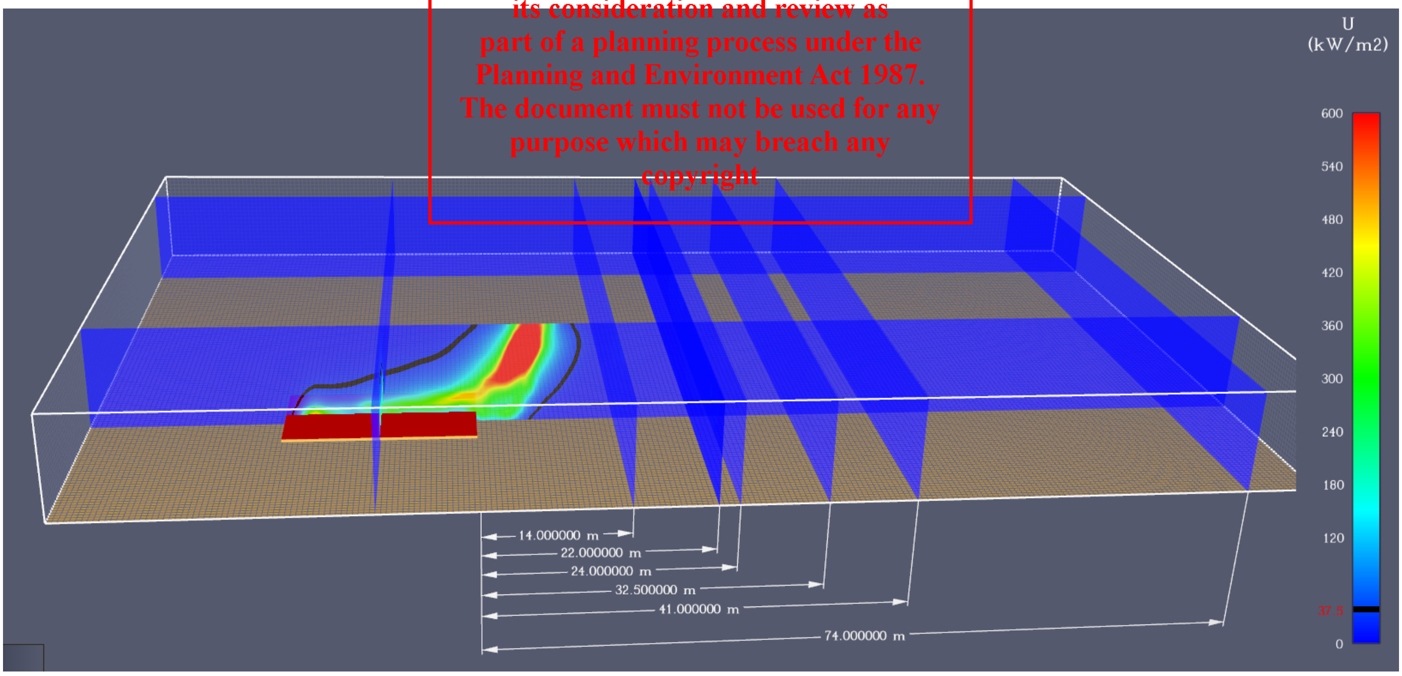


***Figure 22 – Radiant heat flux intensities with wind (HV-Transformer)***

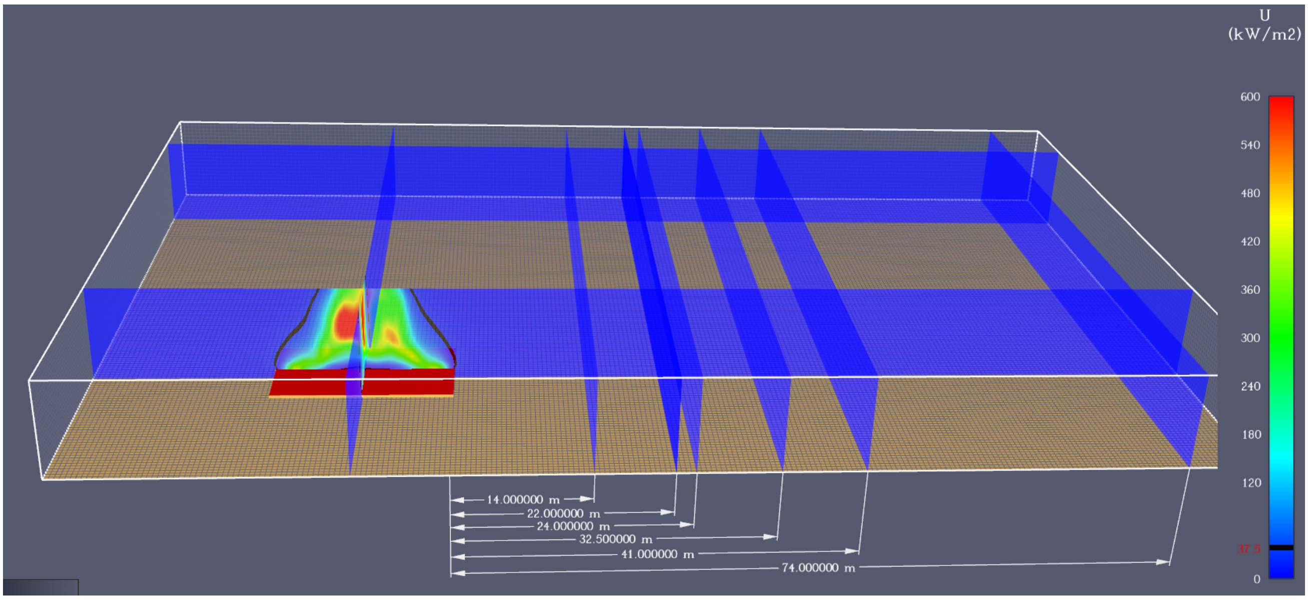


***Figure 23 – Radiant heat flux intensities with no wind (HV-Transformer).***

The results indicate that, with the presence of wind, the maximum heat flux levels at critical locations (adjoining HV transformer), from a fire at the substation are above the critical heat flux for equipment (5kW/m$^2$). Hence, fire spread or damage of equipment may occur to these locations with the presence of wind. In order to mitigate this risk, a fire rated wall will be provided between the transformer as per AS 2067 and proposed in Section 3.

Also, conditions are considered for fire brigade intervention purposes. Based on the results of the model, fire brigade operations may be impacted within a distance of 22.5 m from the HV transformer on the direction of the wind, due to a heat flux higher than 3.0 kW/m$^2$ (Figure 24).




***Figure 24 – Radiant heat flux higher than 3kW/m$^2$ with wind (Top View).***

### 9.2.2 MV/SUT transformers

The proposed MV/SUT transformers will have Natural Ester filled FR3 oil, an oil volume of not more than 38,000 L.

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, and therefore also compliance with AS2067.

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.

Table 10 below specifies that the proposed transformer must be located to not less than 1.5m if enhanced protection is not provided.

***Table 9: Distance assessment to MV/SUT transformers***

| Equipment to assess | Adjoining equipment | Required Distance (m) as per AS 2067 | Proposed Distance (m) | Compliant (Yes/No) |
|---|---|---|---|---|
| MV/SUT transformers with FR3 oil and without enhanced protection | MV/SUT transformer | ≥ 1.50 | 3.80 | Yes |
| | HV Substation transformers | ≥ 1.50 | 23.00 | Yes |
| | BESS units | ≥ 1.50 | 3.00 | Yes |
| | Closest building | ≥ 1.50 | 12.45 | 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.

### 9.2.3 Battery Fire - FDS Modelling

The proposed BESS units usually consist of a modular design with battery module bays, a customer interface bay, with a HVAC system and monitoring systems within an enclosure (e.g., IP66 enclosure).

As described in section 1.1, in accordance to Zhi Wang's report and the dimensions of the battery storage, if a BESS unit is on fire (BESS unit provider TBC), it will achieve an average heat release rate of approximately 6.0MW.

The battery fire is modelled based on the dimension in the preliminary architectural drawings (10m*4m*2m). Based on this configuration, a review of the BESS dimensions, and an assumed average of 200 kW/m², it is expected to reach an average heat release rate of approximately 8 MW.

***A flashover fire of the battery storage unit has been modelled in accordance with the layout shown in Appendix A. This is a conservative model considering that a fire of this scale is not expected to occur (i.e., where all sides of the BESS unit are on fire as shown in***

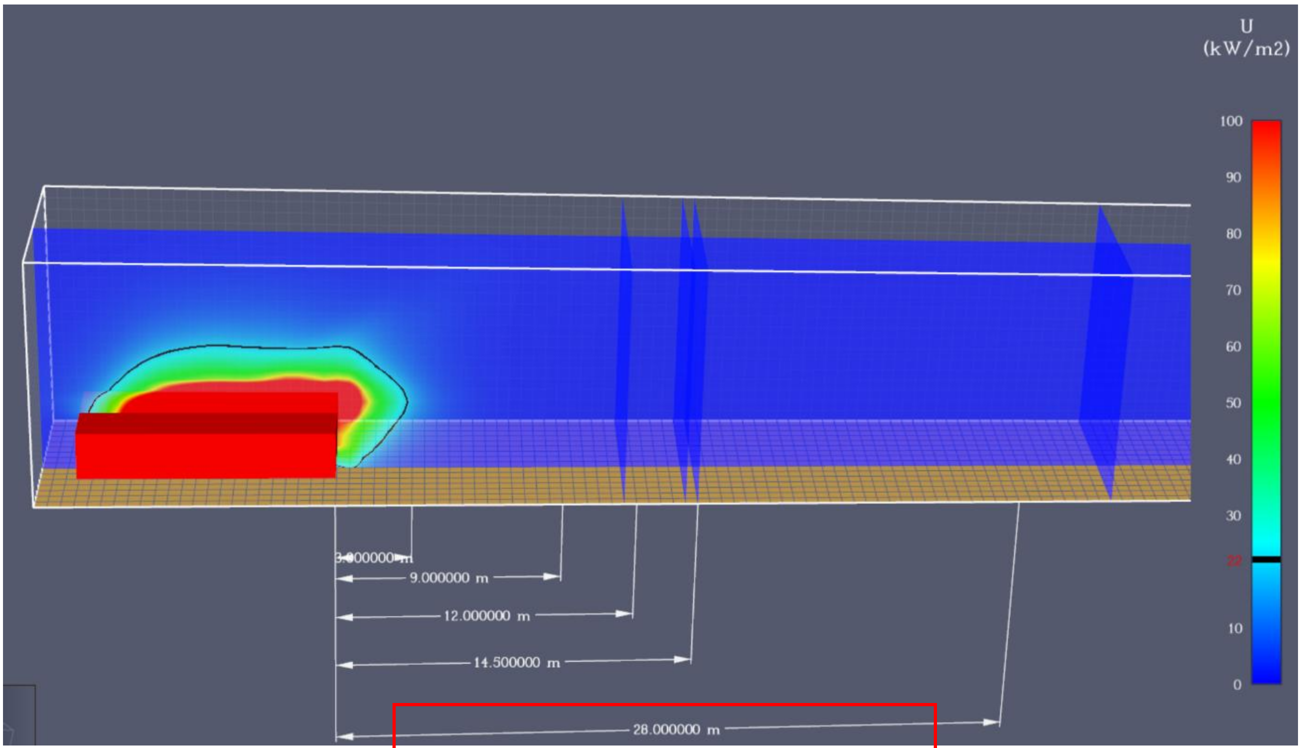


Figure 25).



It is noted that the Big Battery fire event in Victoria in 2021 and the Zhi Wang's report involved lithium-ion batteries, which have considerable fire safety disadvantages compared to the lithium iron phosphate batteries used by the equipment manufacturer. Lithium iron phosphate batteries are more thermal and chemically stable, stay cool in higher temperatures and have low energy density. Therefore, a lower HRR could be expected and the proposed HRR is considered a conservative measure.

Given the location of the equipment within the subject facility, Table 10 below summarizes the heat flux received at various locations (approximate distances) within Winton BESS.

***Table 10: Heat flux results (Red is not accepted).***

| Exposed equipment | Distance (m) | Incident Radiation (IR) ($kW/m^2$) | | |
|---|---|---|---|---|
| | | Wind | No wind | Critical Criteria |
| BESS Units (The closest) | 3.00 | 22.00 | 6.00 | 37.50 |
| MV/SUT Transformers | 3.00 | 22.00 | 6.00 | 37.50 |
| Control Building | 14.50 | 2.40 | 2.06 | 13.00 |
| Closest Winton BESS fence | 14.00 | 2.40 | 2.06 | 13.00 |
| HV Transformer | 32.50 | 2.06 | 2.06 | 5.00 |
| O&M Building | 11.65 | 2.85 | 2.06 | 13.00 |

Further assessment is required subject to information provided by the BESS supplier, who must provide results from a large-scale UL 9540A test to demonstrate that there is no fire spread between BESS units, however, the preliminary assessment indicate that the maximum heat flux levels received are below the critical heat flux for vegetation, equipment, and buildings. Hence, fire spread is not expected to occur.

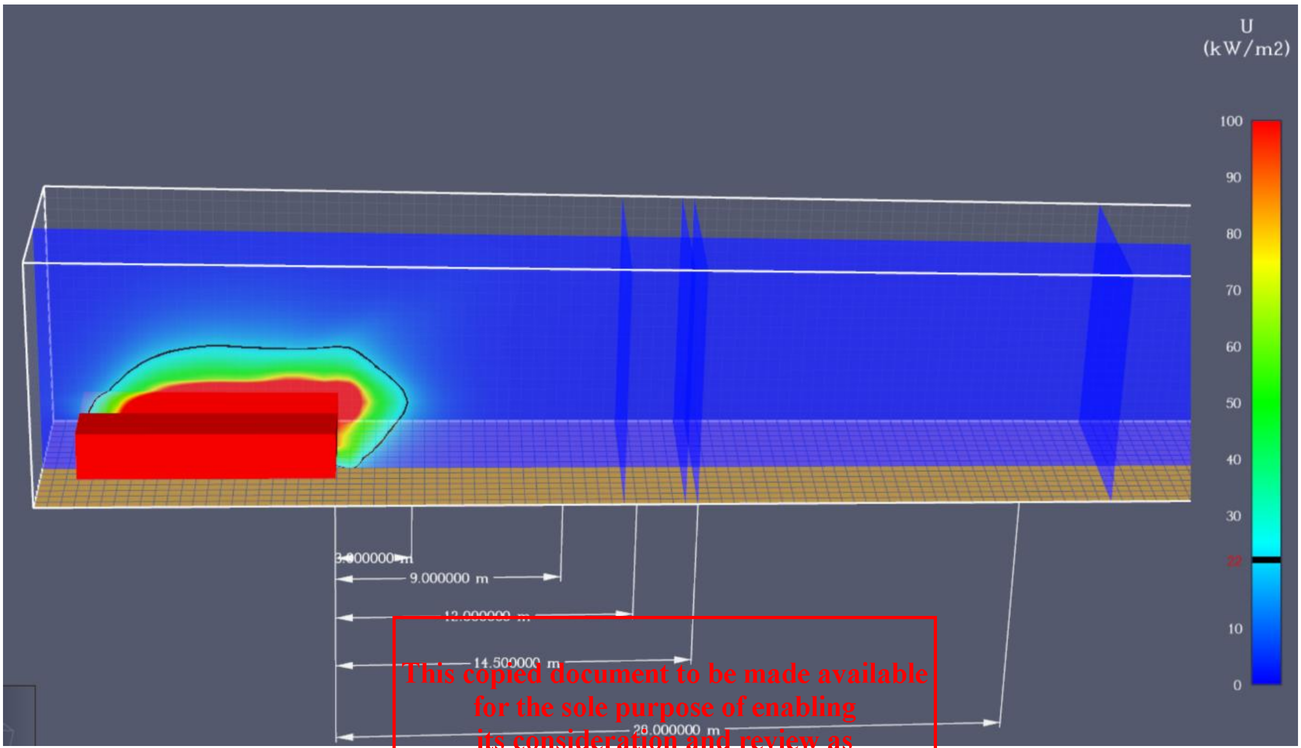




*Figure 25 – Radiant heat flux intensities with wind – BESS.*

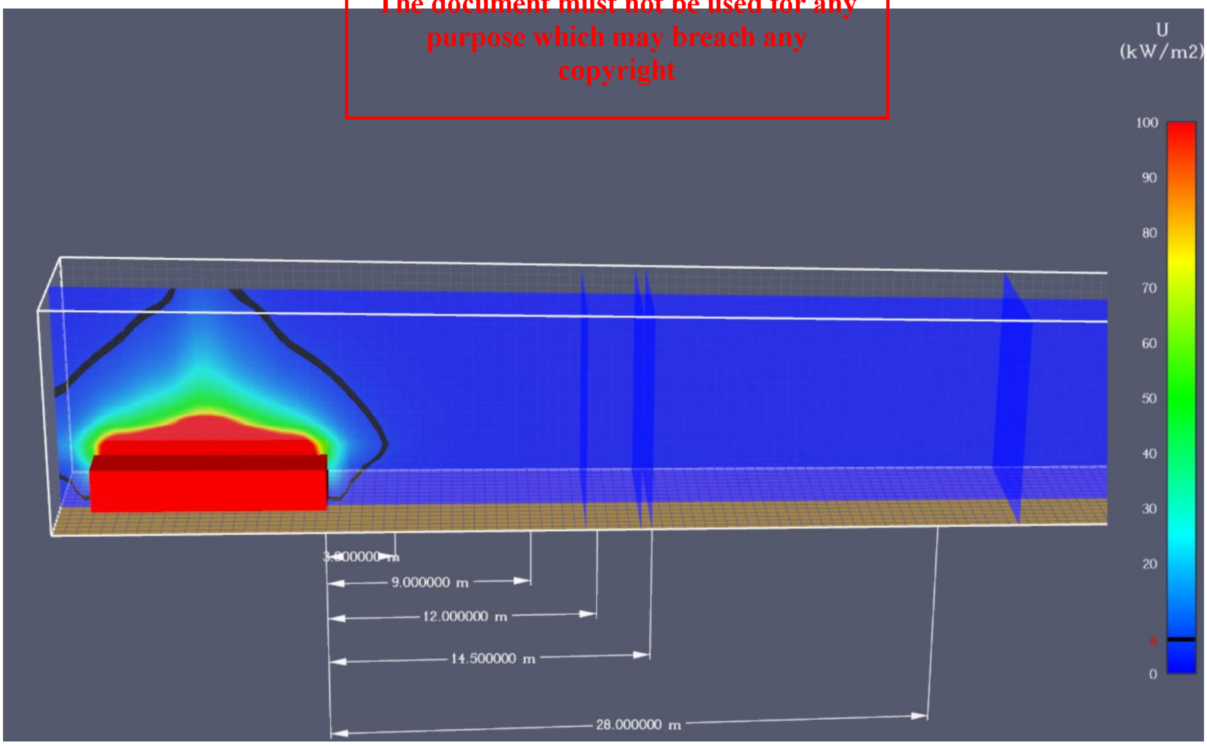


*Figure 26 – Radiant heat flux intensities without wind – BESS.*

Based on the results of the model, fire brigade operations may be impacted within a distance of 8m from the BESS fire due to a heat flux higher than 3.0 kW/m$^2$ (Figure 27).

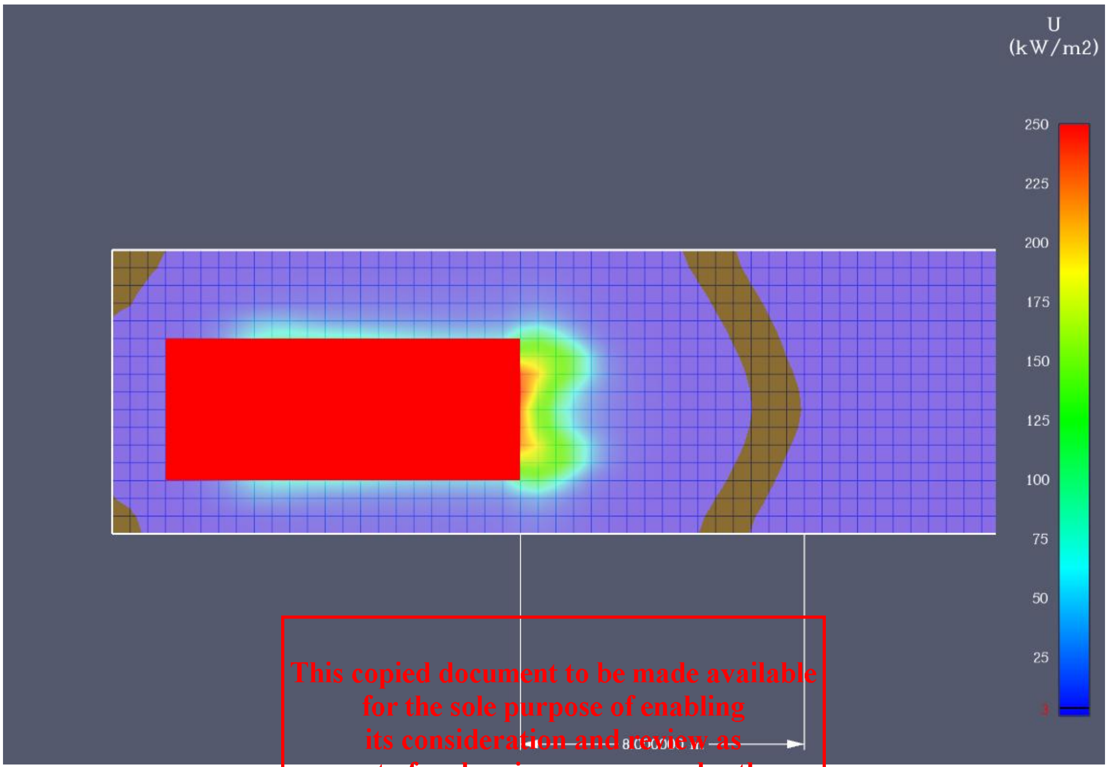


*Figure 27 – Radiant heat flux higher than 3kW/m$^2$ with wind (Top view).*



The above results however are subject to a flashover fire. In a real fire scenario, when a BESS unit releases gases or goes through a thermal runaway process, any of the multiple safety measures will be triggered to send a signal to the staff. Some of the fire safety measures that will be provided with at least the following (not limited to):

- Provision of a BMS (Mattery management system).
- Smoke and heat detection.
- Gas detection.
- Fire alarm.
- Door alarms.
- Electrical safety measures (e.g., ground faults, high voltage, communication faults, etc.).
- Automatic and manual stops that shutdown the battery.
- Temperature controls.
- Deflagration and ventilation systems / overpressure vents.
- Lighting protection.



### 9.2.4 Fire spread by thermal runaway

As described in Section 1.1, if a typical lithium-ion cell is exposed to a temperature of 150°C (300°F), the separator melting occurs and additional heating due to shorting between electrodes will occur and cell thermal runaway will initiate within minutes.

Therefore, a critical temperature of 150°C (300°F) is considered in the analysis of thermal runaway between BESS units.

A preliminary assessment is performed assuming a BESS unit is completely on fire (refer to previous section).

Temperatures to the outside of the adjoining BESS units were measured to be equivalent to the temperature of environment conditions.

Given a fire to any of the equipment existing in the subject facility as modelled in the previous Sections 9.2.1, 9.2.2 and 9.2.3 the temperatures and heat flux are summarized in Table 11 below.

***Table 11: Heat flux and Temperatures results (Red is not accepted).***

| Fire Source Feature | Distance to the closest BESS (m) | Incident Radiation (IR) (kW/m$^2$) / Temperature (°C) | | |
|---|---|---|---|---|
| | | Wind | No wind | Critical Criteria |
| BESS Units (The closest) | 3.00 | 22.00 kW/m$^2$ /202°C | 6.00 kW/m$^2$ /26°C | 37.5 kW/m$^2$/150°C |
| HV Transformers | 32.50 | 3.00 kW/m$^2$ /26.3°C | 3.00 kW/m$^2$ /22.5°C | 5 kW/m$^2$/150°C |

As shown in the table above, there is a possibility of thermal runaway occurring due to the high temperature and heat flux between the two BESS units, as shown in previous BESS fires events (refer to section 8.1).

However as mentioned above, further assessment is required, subject to information provided by the BESS supplier. The supplier must provide results from a large-scale test (CSA TS-800:24 and/or UL9540A) to demonstrate that there is no fire spread or thermal runaway between BESS units.



### 9.2.5 Adjacent Buildings from adjoining allotments

The batteries are located more than 32m from the equipment of the substation and at least 14m from the boundary fence.

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 and buildings from the boundary it is considered that the likelihood of a fire and the consequence are no worse than in the general community and no worst that a compliant NCC DtS building.

### 9.2.6 Fire in other Area of the facility

The facility contains a control room, storage containers, and an Operations & Maintenance building. The fire associated with these buildings are considered to be no greater than a small office type building.

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 facility of 3m and over, it is considered that the risk of fire spread is equivalent to that of a building with NCC compliant separation distances (3m to the boundary, or 6m to adjoining buildings within the same allotment, or less than 6m between building in the same allotment with firewalls and/or non-combustible walls) that are considered to represent the community acceptance level for fire spread.

### 9.2.7 Bushfire Attack Level (BAL) Assessment

The following BAL review has been performed in accordance with AS 3959-2018 [6], using the 6 step Simplified Procedure (Method 1) in Section 2 of the standard.

The closest BESS unit in the proposed Winton RESST project is approximately 14m from the site fence. The proposed project site is located on agricultural land. The adjoining allotments are shown in the figure below.

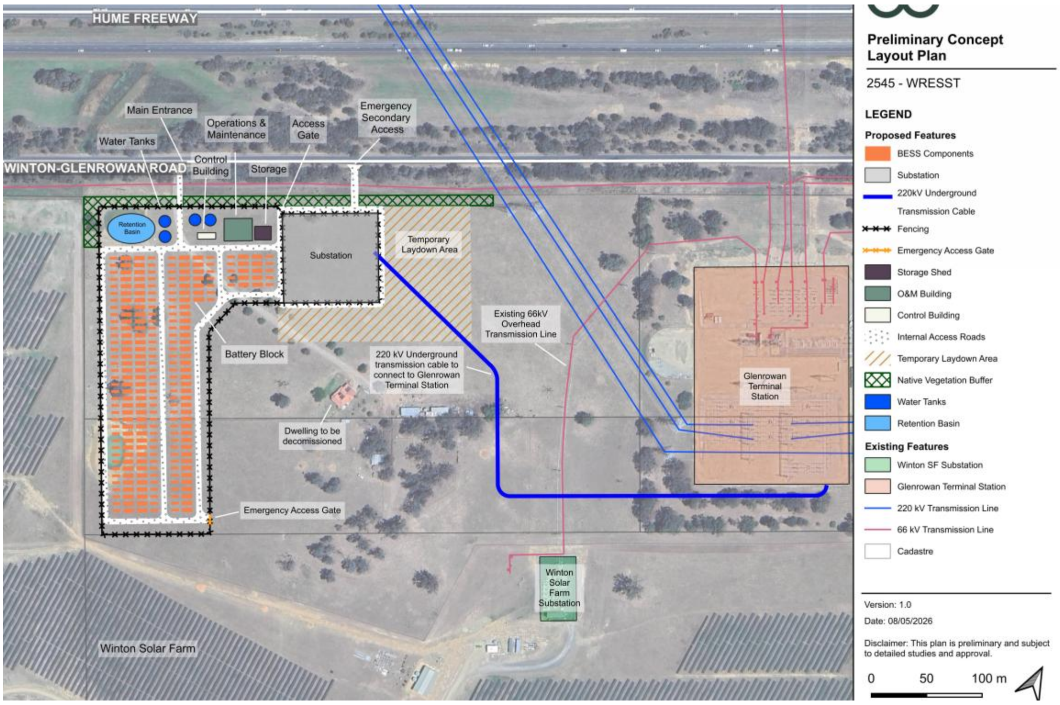


***Figure 28 – Preliminary Concept Layout Plan.***

The figure below shows the use of the land within 100m of the proposed development. There are solar farms to the western and southern sides, the Winton-Glenrowan road and managed vegetation to the north, and industrial energy developments to the western side.

The roadside vegetation to Winton-Glenrowan Road is managed and maintained vegetation and is exempted under the Clause 2.2.3.2 of AS 3959-2018. As per Clause 2.2.3.2 (d), the following vegetation shall be excluded from a BAL assessment: Strips of vegetation less than 20m in width (measured perpendicular to the elevation exposed to the strip of vegetation) regardless of length and not within 20m of the site or each other, or other areas of vegetation being classified vegetation. Hence, it is evident that the roadside vegetation to Winton-Glenrowan Road is in accordance with Clause 2.2.3.2 of AS 3959-2018.

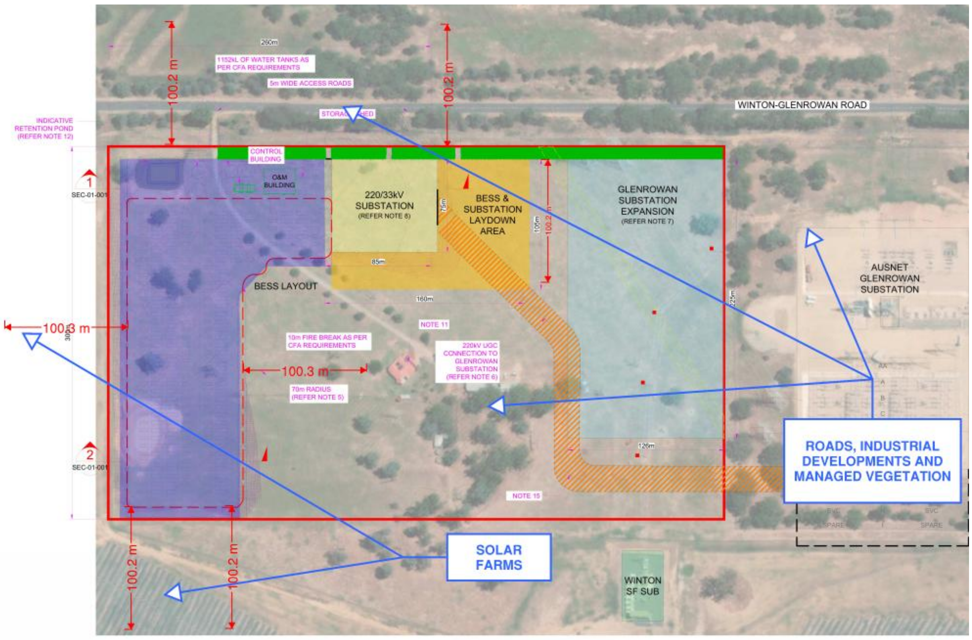


*Figure 29 – Use of land within 100m of the subject development.*

*Figure 30 – Solar Farm Aerial View from google maps.*

Therefore, there is no relevant vegetation to assess under the AS 3959-2018. The closest vegetation (forest) is located to south of the subject development at approximately 400m (figure below).


***Figure 31 – Clot vegetation to the south.***

Given that there are no buildings within 100m of the vegetation areas, no BAL construction requirements are required to be applied to the proposed buildings.

### 9.2.8 Consequence summary outcome

Given a catastrophic failure of any of the assessed equipment (i.e., HV transformers, MV/Step-up transformers, and Battery storage units), only the equipment on fire is expected to be lost and all surrounding equipment/buildings are expected to remain working, and fire spread to adjoining equipment/buildings/allotments is not expected given that the proposed clearances and safety measures are provided.

Further to the above, if any of that equipment stop working/fails due to a catastrophic fire, the battery blocks can continue operating once the fire has been extinguished, the emergency response procedures have been followed, and the site returns to safe operating conditions.

Based on the fire spread assessment performed in sections 9.2.1 to 9.2.6 above, and the continuous operation of the BESS, the consequence of a fire to the studied equipment can be rated as “Minor”.

# 10 Comparison with Relevant Standards

## 10.1 Best Practice Guide For Battery Storage Equipment - Electrical Safety Requirements, Version 1.0 – Published 06 July 2018

The guide provides safety criteria for battery storage equipment that contains lithium as part of the energy storage medium. Battery storage equipment is generally complete, pre-packaged, pre-assembled, or factory-built equipment within the one enclosure (except for master/slave configurations where there is a main unit and additional battery module units that can be connected together). This includes types that are:

- Battery module.
- Pre-assembled Battery System (BS) equipment.
- Pre-assembled integrated Battery Energy Storage System (BESS) equipment.

The introduction to the guide states "While this guide doesn't specifically cover equipment being used in commercial, industrial or other non-domestic/residential settings, or for systems with an energy storage capacity of over 200kWh, the general requirements and principles of this guide and risk matrix may be applied to offer some guidance in those situations, though there may be additional hazards in those circumstances that have not been identified in this guide."

It is therefore considered that the guide is not fully relevant to the current study but is used for Guidance.

The guide provides a number of methods to show full or partial compliance to the guide based on a series of tests. Many of the tests relate to non-fire risks and hence are not relevant to this assessment.

The main fire spread recommendations within the guide are the need for battery storage equipment to be housed in metal enclosures with a minimum thickness of 0.2mm. The subject design complies with this requirement. There is also the requirement for isolation devices and installation distances to be supplied with equipment, but no distances are specified.

Testing to various standards such as IEC 62619:2017 Secondary cells and batteries containing alkaline or other non-acid and electrolytes (or IEC 62619 Ed 1 2017), AS/NZS 4777.2:2015 Grid connection of energy systems via inverter requirements for inverter in equipment for connection to grid installations (applicable to pre-assembled integrated battery energy storage system equipment), etc., are expected to be conducted to the necessary degree in accordance with the manufacturers' specification when the battery assembly is finished.

## 10.2 AS 2067

Australian Standard AS 2067 [4] 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 AS 2067 Table 6.1 unless a fire rated wall is used to provide protection.

It is assumed the subject facility will have the following transformers:

- HV Substation: There will be 2 transformers that will use mineral oil, and their oil capacity is expected to be not more than 60,000 litres (60.0 m$^3$).
- MV/SUT transformers will be provided with less combustible liquid-insulated transformers.
- MV/SUT transformers, if not provided with enhanced protection, must not have an oil capacity of more than 38,000 litres (38 m$^3$) and must not be located to less than 1.5m from the non-combustible surfaces/equipment to comply with the requirements of the AS 2067.

| Transformer type | Liquid volume | Clearances to other transformers or equipment | Clearances to buildings | | |
|---|---|---|---|---|---|
| | | Horizontal clearance $G_1$ to other transformers or 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 |

***Figure 32: AS 2067:2016-Table 6.1 – Clearance for outdoor transformers*** [4].

Table 12 below summarizes 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 AS 2067.

***Table 12: Distance assessment.***

| Equipment to assess | Adjoining equipment | Required Distance (m) as per AS 2067 | Proposed Distance (m) | Compliant (Yes/No) |
|---|---|---|---|---|
| HV Substation transformers | All others | ≥ 23.0 | ≥ 23.0 | Yes |
| MV/SUT transformers with FR3 oil and without enhanced protection | MV/SUT transformer | ≥ 1.5 | 3.80 | Yes |
| | HV Substation transformers | ≥ 1.5 | 23.0 | Yes |
| | BESS units | ≥ 1.5 | 3.00 | Yes |
| | Closest building | ≥ 1.5 | 12.45 | Yes |

The above demonstrates that all the equipment have compliant distances between them in accordance with the Australian Standard AS 2067, except for the equipment (MV/SUT transformer, BESS units) that is located within 5m from the MV transformers if mineral oil is provided.

It was demonstrated that fire spread, or equipment failure is not expected at 3.0m distance from a MV transformer fire for BESS units or other MV transformer in section 9.2.2. Therefore, it is considered acceptable that the location of the BESS units and MV transformers to be less than 5m from the MV transformers (given MV/SUT transformers are provided with FR3 oil).

This is consistent with the fire spread assessment and results performed in Section 9.

## 10.3 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 6.1.4, 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) has been performed in Section 9.2.7 of this document.

*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 10.2 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 8 meters, and BESS units are to be separated as per large-scale tests. Hence fire spread from the site to the vegetation is not expected. This distance is considered to be acceptable based on the preliminary assessment within this report in section 9.

- 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 5.0m 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 6.1.4, 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) has been performed in Section 9.2.7 of this document.

*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)* [3] *to be undertaken.*

Response – This report is the FSS required. Section 5.1 describes how this document covers the requirements from the CFA's Fire Safety Studies for Battery Energy Storage Systems Guideline (v1, 2025) [3].

*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 6.1.4, 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) has been performed in Section 9.2.7 of this document.

*<u>Section 4.2.1 requires the following with respect to fire brigade vehicle access:</u>*

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

  Response - A 5.0 m 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 FRV 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 5.0 m 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 5.0 m. An alternative access/egress is provided to the site (refer to section 7.3 and Appendix A). There are no roads longer than 600m on this development.

- 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 fire brigade will access the subject site from the north via an unsealed entryway that connects to Winton-Glenrowan Road. A secondary access point along Winton-Glenrowan Road is proposed [8] located approximately 158m away from the main entrance. An emergency gate has been provided located on the south-eastern side of the project area for local CFA/emergency services in the event of an emergency.

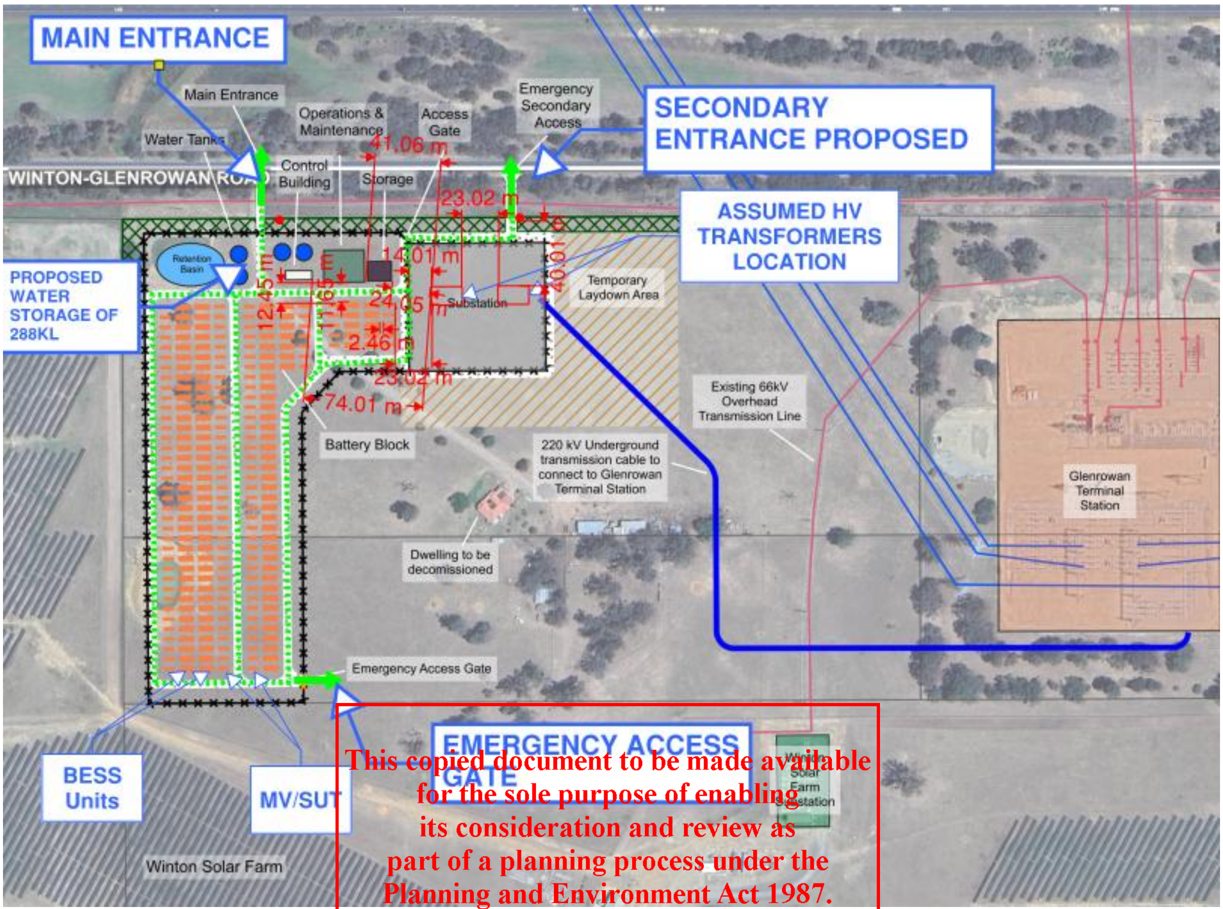




*Figure 33 – Alternative Access/Exit to the proposed layout.*

*<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 (Refer to Section 3 and Appendix A).

- Static water storage tank installations must comply with AS 2419.1-2021 [22]: Fire hydrant installations – System design, installation and commissioning.

  Response – Water storage of 288kL will be provided at the entrance to the facility with a compliant hardstand.

- 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 is 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 – Table 2.2.5(D) of AS 2419.1-2021 is extracted below:

**Table 2.2.5(D) — Number of fire hydrant outlets required to flow simultaneously — Open yards**

| Yard area, m² | Number of fire hydrant outlets |
|---|---|
| ≤ 3 000 | 1 |
| > 3 000 ≤ 9 000 | 2 |
| > 9 000 ≤ 27 000 | 3 |
| > 27 000 | 4 |

***Figure 34: AS 2419.1-2021 - Table 2.2.5(D) (Extracted) [22].***

The proposed layout has an aggregated area of approximately 22,800 m² (less than 27,000m²), as shown in figures below.

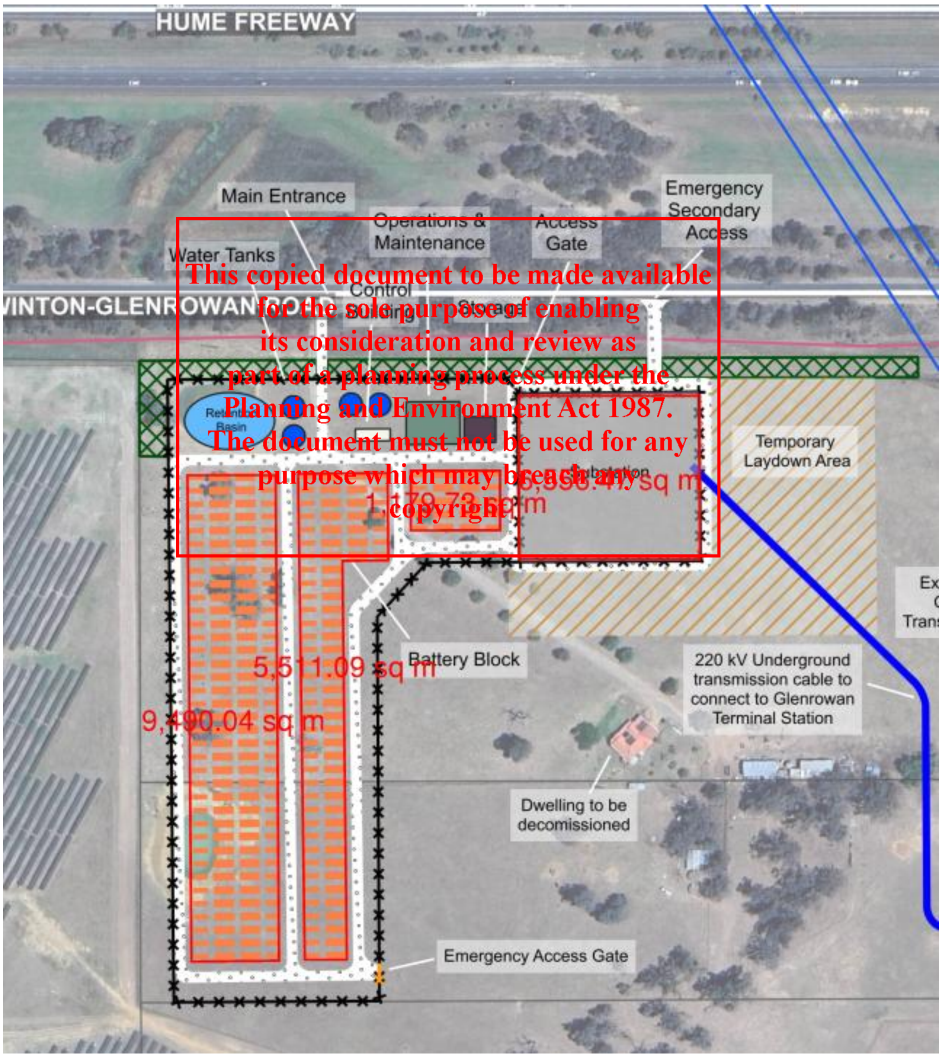


***Figure 35: Aggregated area for Layout.***

Based on the requirements of the CFA Design guidelines [2] which follow the quantities listed in the 2419.1-2021, given that water supply only is proposed, the water storage would be calculated based on 3 hydrants at 10 Liter/Second for 4 hours. This will result in a water storage of 432,000 Liters.

Given the current technology and statistics for BESS installations, it has been demonstrated that fire spread is not considered to occur between BESS equipment when they are separated more than 6m away and when the transformers comply with the requirements of the AS 2067. It has also been demonstrated that a BESS flashover and Transformer fire is not expected to spread to adjoining equipment.

The proposed layout has 4 areas (i.e., 3 BESS arrays and a Substation) that comply with these clearances; hence fire spread is not expected to occur. Therefore, it is proposed the "yard area" to be defined based on an average area of BESS yards not more than 9,000m$^2$.

Accordingly, the water storage would be calculated based on 2 hydrants at 10 Liter/Second for 4 hours. This will result in a water storage of 288,000 Liters. This also comply with the minimum requirements of the CFA Design guidelines [2].

As part of the performance solution to allow 288,000 Liters, the fire spread limitation was demonstrated in Section 9 of this document.

- (i) 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 – A Fire hydrant system as per AS 2419.1 must be provided throughout the facility, and hydrants will be located such that all infrastructure can be covered by at least 2 hydrants.

- (ii) 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.

- (iii) 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 than 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.



- (iv) 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.

*<u>Section 4.2.3 requires the following with respect to fire detection and suppression equipment:</u>*

- 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 (refer to Section 3).

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

*<u>Section 4.2.4 requires the following with respect to management of Landscape Screening and on-site vegetation:</u>*

- 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 6.1.4, 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) has been performed in Section 9.2.7 of this document.

*<u>Section 4.2.5 requires the following with respect to fire breaks:</u>*

- 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 options. The subject site is provided with a fire break of 10m. A bushfire assessment (i.e., BAL as per AS3959) has been performed in Section 9.2.7 of this document.



*<u>Section 4.2.6.4 requires the following with respect to management of Fire Water Runoff:</u>*

- 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 matter will be addressed as a condition on the planning permit that requires a Fire Management Plan, and it will be also a requirement from the Risk assessment. The plan must consider as part of the variables the storage of water designed for the fire hydrant system.

*<u>Section 4.3 recommends that battery energy storage systems are equipped with the following elements:</u>*

- 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 – In general it is considered that the latest commercial BESS comply with these requirements, however the review will be performed when a BESS supplier is identified.

## 10.4 Summary

Based on the provided assessment in this report it is concluded that:

- Fire spread to adjacent allotments is not expected, as the separation distances exceed the minimum requirements set by the NCC and relevant Australian Standards, confirmed by the fire spread analysis in Section 9. While fire spread between equipment is generally unlikely, there remains a potential risk between BESS units (i.e., thermal runaway, not fire spread) under windy conditions due to heat flux and high temperatures.
- Buildings' location must be reviewed in order to comply with the NCC DtS provisions.
- The layout and location of the BESS development ensures that buildings are well-distanced from vegetation negating the need for bushfire-specific construction.
- The safety measures listed in Section 3 of this report will mitigate to the degree necessary the risk of fire spread between allotments and equipment and will facilitate the Fire Brigade intervention procedure.

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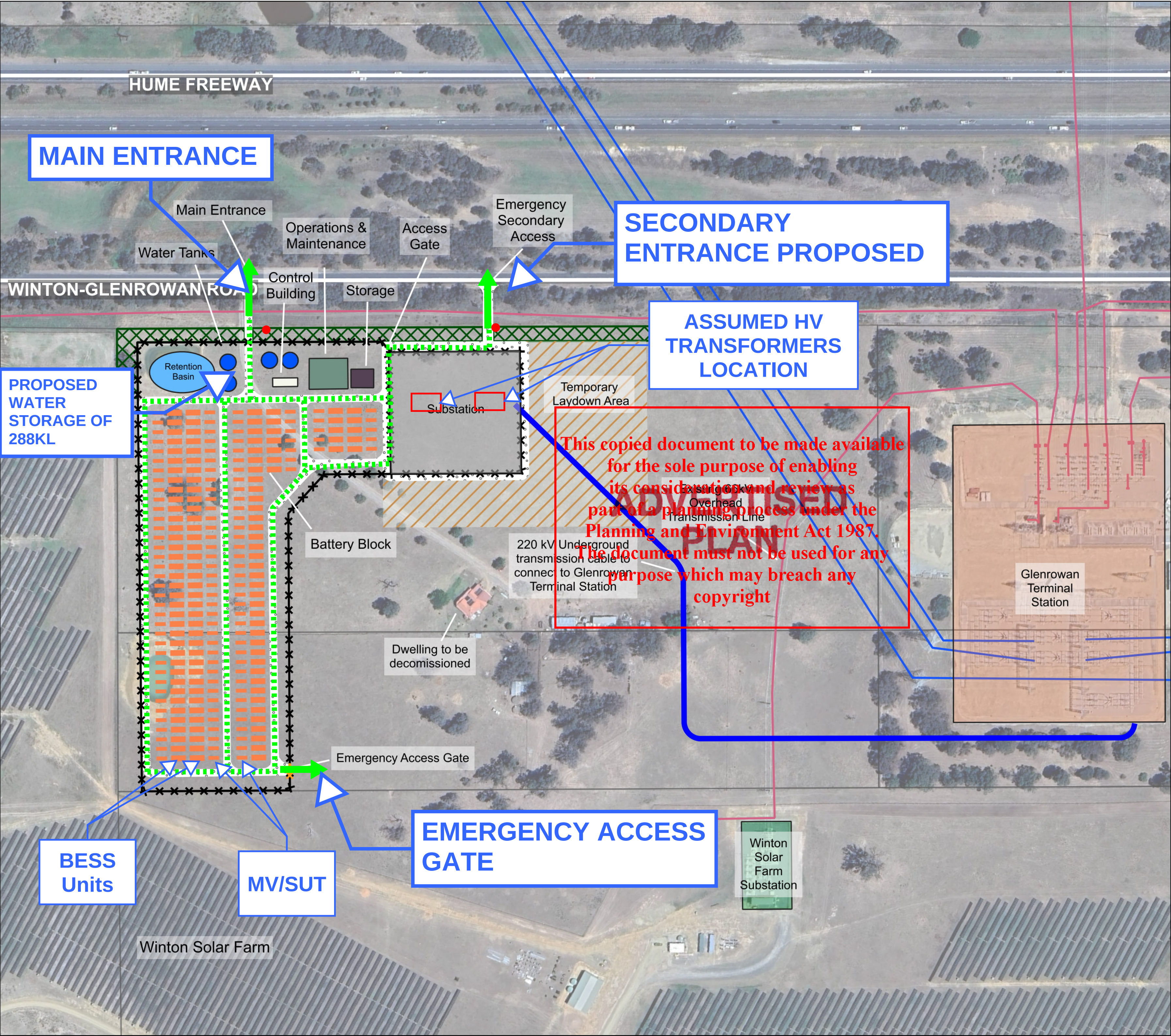
[21] EPRI (Electric Power Research Institute), "Insights from EPRI's Battery Energy Storage Systems (BESS) Failure Incident Database - Analysis of Failure Root Cause," 2024.

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

# Appendix A. PROPOSED FACILITY LAYOUT





**Preliminary Concept Layout Plan**

2545 - WRESST

**LEGEND**

**Proposed Features**

- BESS Components
- Substation
- 220kV Underground Transmission Cable
- Fencing
- Emergency Access Gate
- Storage Shed
- O&M Building
- Control Building
- Internal Access Roads
- Temporary Laydown Area
- Native Vegetation Buffer
- Water Tanks
- Retention Basin

**Existing Features**

- Winton SF Substation
- Glenrowan Terminal Station
- 220 kV Transmission Line
- 66 kV Transmission Line
- Cadastre

Version: 1.0

Date: 08/05/2026

Disclaimer: This plan is preliminary and subject to detailed studies and approval.

0 50 100 m

NJM DESIGN

# Appendix B. Past BESS Fires

## 1) Past BESS Fires

In order to obtain an understanding of the hazards associated with BESS facilities a summary of past fires is presented below.

### Incident Report – Bouldercombe BESS.

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

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".*

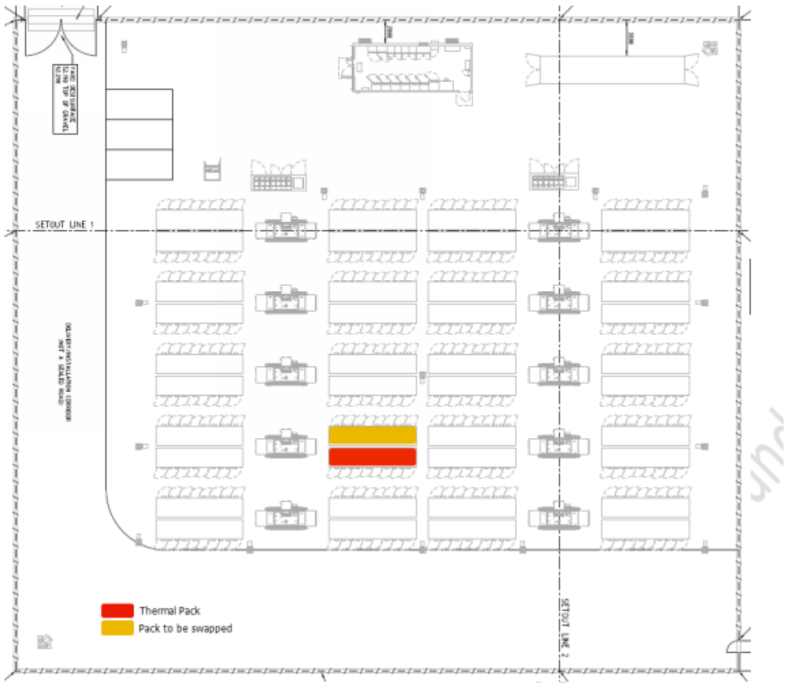



***Figure 36: Bouldercombe BESS Site Layout and Megapacks involved in the event.***

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.

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 (). 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*".

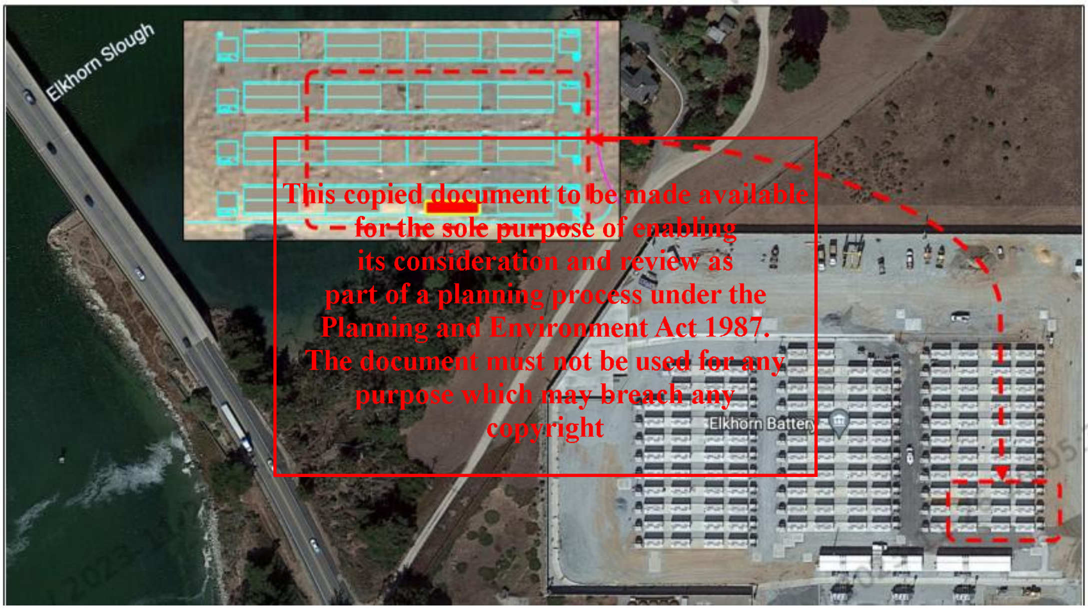




***Figure 37: Overview of Elkhorn BESS and Megapack on fire.***

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.

### 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.

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).

The wind conditions at the time of the VBB fire were 37 – 56km/hr which based on the wind data for the Glenrowan BESS location would only occur approximately 0% of the time, i.e., a probability of 0.

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.

### Drogenbos, Belgium – 11 November 2017 [18]

A fire broke out at Engie's Drogenbos test site in Belgium on November 11, 2017, during the commissioning of a lithium-ion battery system, causing significant damage to the Engie Ineo battery container. The firefighters arrived quickly at the site and rapidly extinguished the fire, which did not spread to other containers or parts of the site. Despite the fast response, the Engie Ineo lithium-ion battery system was damaged severely enough to be considered a "total loss." Two neighboring containers, containing battery systems from GE and Alphen, sustained only light external, peripheral, and easily repairable damage.

The fire was contained quickly, preventing it from spreading to the neighboring containers, which sustained only light, repairable damage. Despite the presence of fire detection and extinguishing systems, the fire could not be extinguished in time, raising concerns about the safety of lithium-ion batteries. While the cause of the fire remains uncertain, this incident underscores the critical importance of designing Battery Energy Storage Systems (BESS) with safety features that prevent a fire in one cell from overheating and causing a cascade failure to adjacent equipment—a crucial consideration to avoid widespread damage in future system designs.

### 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.

## 2) 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[6]. 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.

### Research and Testing of Lithium-Ion Batteries and BESS

Full-scale testing of a large, containerized lithium-ion battery energy storage system has yet to be conducted. However, other 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 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.

### FPRF/Exponent Hazard Assessment of Lithium-Ion Battery ESS



Exponent Inc. and the NFPA's Fire Protection Research Foundation conducted a full-scale fire test of a Tesla Powerpack – 100kWh lithium-ion BESS at 100% SOC[7]. 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.
- 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.

[6] 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.
[7] Blum, A. F., & Long, Jr., R. T. (2016). Hazard Assessment of Lithium-Ion Battery Energy Storage Systems. Quincy: National Fire Protection Association

- Temperatures at pods below the initiator pod showed temperature ranges between 26 and 82°C.
- External temperatures reached 21°C.
- Initiator pod was damaged, but other cells were not damaged.

###### 11.1.1.1.1 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[8]. 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.

###### 11.1.1.1.2 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.[9]

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.



[8] Mikolajczak, C. (2005). US FAA-Style Flammability Assessment of Lithium-Ion Cells and Battery Packs in Aircraft Cargo Holds. Exponent. Menlo Park: Exponent.
[9] ] 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.

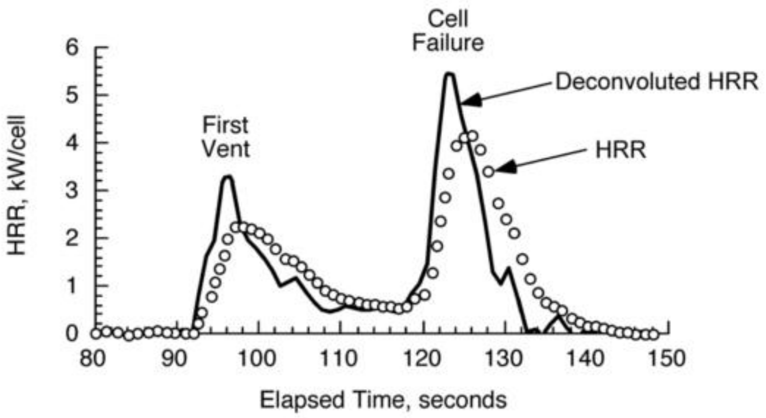



**Figure 2. Lithium-ion cell failure at 70% SOC exposed to 50 kW/m$^2$ irradiance in fire calorimeter; points are data from standard method; solid line is data corrected for instrument response**

***Figure 38: Results of a single group of batteries.***

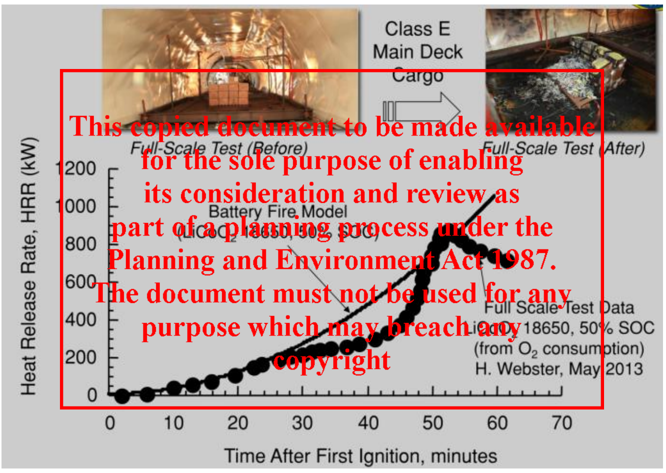





***Figure 39: Results of full-scale tests on 18650 batteries.***

The peak heat release rate is approximately 1MW.

#### 11.1.1.1.3 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[10]. 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 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.

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

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 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.

### 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.



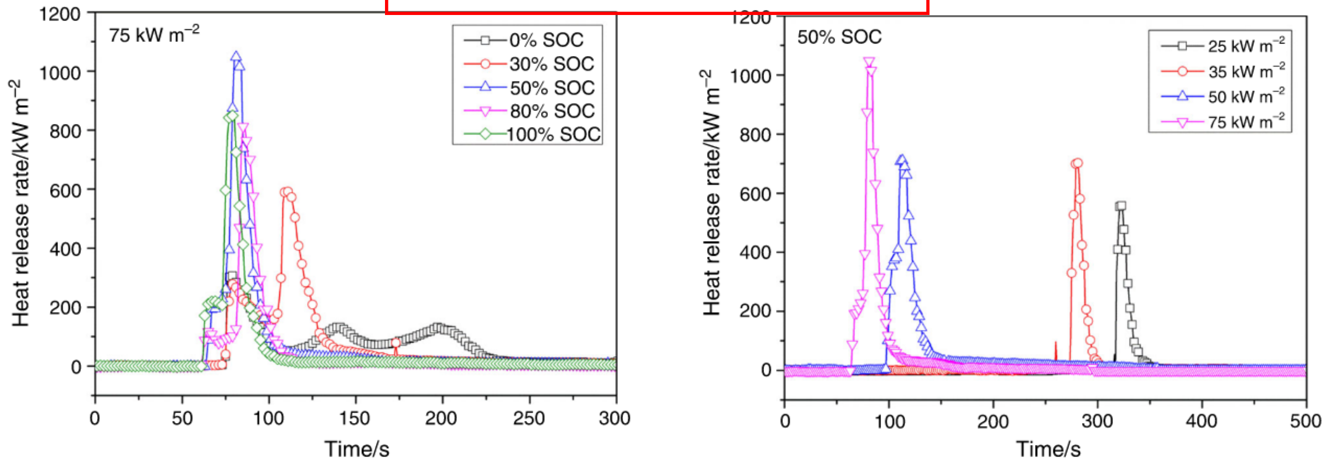



**Fig. 7** Heat release rate of batteries at different SOCs under an incident heat flux of 75 kW m$^{-2}$

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

***Figure 40: Tested heat release rates for Lithium-ion batteries.***