The distortion corrected photograph is imported into 3ds Max as a background. The Virtual Camera is placed at the coordinates supplied by the surveyor, and set to match the physical camera settings and lens used. The Virtual Camera is then aligned in 3 axis (xyz) to match the background photograph with the previous geolocated point cloud and feature surveys. The Virtual Camera settings are then iterated using fine adjustments to pan, tilt, roll, camera position and fine tuning of effective focal length until optimal alignment of the surveyed points with the photograph is achieved.

**9.1.1. MODELING - PROPOSED BUILT FORM**

The proposed Built Form 3D base model was modelled by the architects and provided to Orbit Solutions as an FBX/3DS/IFC/SKP file, which was then imported into 3ds Max.

The imported 3D model was optimised to remove extraneous detail, e.g. internal furniture, fixtures, fittings, plants, entourage etc.

Geometry cleanup was then performed to remove co-planar faces and any other possible issues that may cause rendering artifacts.

The optimized 3D model of the Proposed Built Form is then checked against the supplied CAD documentation to ensure consistency between drawings and model. Where discrepancies were found, clarification is sought from legal team.

Besides this cleanup process, there is no addition or deletion of geometry that would significantly alter the form of the supplied 3D model. Where the Architectural Documentation shows additonal details (such as solar panels, pre-cast panel joints, metal cladding seams, downpipes, etc) that were not included in the supplied 3D model, these would be modelled by the Orbit team member after consultation with the legal team and Architect.

**9.1.2. MATERIALS & FINISHES**

Geometry, materials and lighting effects are a simulation of realworld conditions. Consideration was given to the fact that the supplied reference photos for materials and finishes were taken under varied lighting conditions, often indoors under neutral lighting conditions. Where possible, manufacturer's specifications and additional reference photos under various lighting conditions are collected to provide a more accurate representation.

**9.1.3. LIGHTING SIMULATION**

Physically-accurate lighting conditions was simulated with a Sun/ Sky system that can closely match the daylighting conditions visible in the photographs. Metadata recorded with each photograph (date/time/ exposure settings) along with field notes taken on-site is inputed into the daylighting system for each camera location.

**9.1.4. MODELING - PROPOSED LANDSCAPING**

Every effort has been made to accurately represent the planting per the provided species schedule in the landscape plan but is dependent on availability of assets (seasonal, spread, etc). Regard is also given to the physical constraints of the context for each instance.

Landscape assets are accessed from a stock library when possible or custom modelled in Exlevel or GrowFX where required to most closely represent the references provided.

Landscape models represent trees at 80% maturity in accordance with any provided planting schedule and/or additional instructions. Groundcover and shrubs are shown at 100% of their mature size.

**9.1.5. POST-PRODUCTION & LAYOUT**

The 3D model comprising the proposed built form and landscape is rendered out in 3D Studio MAX / VRAY for composition in Adobe Photoshop with the original photograph of the existing conditions.

Photoshop tools are used to paint or alter elements of the existing conditions that will be demolished or replaced, such as existing vegetation, crossovers and signage. The unaltered photograph is shown for comparison.

White / grey hatch may be shown where existing elements are to be removed/ demolished and no proposed elements obscure these areas.

The finalised exported images are then published through InDesign to an A3 booklet output in PDF format.

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# PALMERSTON

## Battery Energy Storage System
## Noise Impact Assessment

**Prepared for:**

Akaysha Energy Pty Ltd c/o Cogency Australia
11-13 Pearson Street Cremone VIC 3121

**SLR Ref: 640.30604-R01**
**Version No: -v1.1**
**April 2023**

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## BASIS OF REPORT

This report has been prepared by SLR Consulting Australia Pty Ltd (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Akaysha Energy Pty Ltd c/o Cogency Australia (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

## DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 640.30604-R01-v1.1 | 21 April 2023 | Benjamin French | Gustaf Reutersward | Gustaf Reutersward |
| 640.30604-R01-v1.0 | 14 April 2023 | Benjamin French | Gustaf Reutersward | Gustaf Reutersward |
| 640.30604-R01-v0.2 | 3 April 2023 | Benjamin French | Gustaf Reutersward | Gustaf Reutersward |
| 640.30604-R01-v0.1 | 24 March 2023 | Benjamin French | | |
| | | | | |

# EXECUTIVE SUMMARY

This technical report is an attachment to the Palmerston BESS Development Application submission on behalf of Akaysha Energy Pty Ltd.

SLR Consulting Pty Ltd (SLR) was engaged by Akaysha Energy Pty Ltd c/o Cogency Australia to conduct a noise assessment of a proposed 100 MW / 200 MWh battery energy storage system (BESS) at 1440 Saundridge Road Cressy, Tasmania to support a Development Application submission under the *Land Use Planning & Approvals Act 1993.*

The project is located on rural farmland approximately 2.5 km east northeast from Poatina, Tasmania.

Evaluation of noise impacts on sensitive receptors has been undertaken in accordance with the *Environmental Management and Pollution Control Act 1994*, *Environmental Management and Pollution Control (Noise) Regulations 2016* and the *Environment Protection Policy (Noise) 2009.*

Unattended noise monitoring was conducted between 25 January to 2 February 2023 at a location representative of the existing ambient environment. The measurement was used to determine appropriate noise goals in general accordance with the *Noise Measurement Procedures Manual*, borrowing elements from the NSW *Noise Policy for Industry, 2017*.

The key project impacts in relation to noise is as follows:

- **Noise from construction activities:** Due to the short duration of construction activities and the distances between the proposed site and the closest receptors construction noise impacts are relatively minimal. Scheduling construction activities in accordance with the Prohibited Hours as defined in the Regulations, community engagement and best practice noise management controls, regular maintenance, broadband reversing beepers etc. will further minimise residual risk of harm to nearby receptors.
- **Noise from operational activities:** The closest receptor is located approximately 770 m south-east of the BESS. A 2 dBA exceedance is predicted at night-time at this receptor with no additional mitigation. Mitigation options are presented in this report, and compliance with the EPP (Noise) noise goals is expected to be achievable through implementation of one or a combination of noise mitigation options comprising: low noise BESS fans and/or silencing treatment, noise barriers and operational control measures such as load locking equipment during the night period. Measures are to be finalised during the detailed design phase of the project.

It is recommended to update the noise model during detailed design to ensure compliance is maintained. Confirmation of compliance will be verified by post commissioning noise measurements.

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## APPENDICES

# 1 Introduction

Akaysha Energy Pty Ltd is proposing to develop a 1.5 ha, 100 MW / 200 MWh battery energy storage system (BESS) at 1440 Saundridge Road Cressy, Tasmania.

SLR Consulting has been engaged by Akaysha Energy Pty Ltd c/o Cogency Australia to conduct a noise assessment to support the development application of the proposed Palmerston BESS under the *Land Use Planning & Approvals Act 1993*.

# 2 Project Area

The proposed site is on rural farmland approximately 2.5 km east northeast from Poatina, and immediately northwest of the Palmerston Substation.

The BESS will also include the construction of a 220 V – 33 kV substation to feed into the Palmerston Substation. The new substation will be located to the north of Palmerston Substation, between the existing substation and the proposed BESS site. The 33 kV reticulation infrastructure linking the BESS to Palmerston Substation will be buried within 20 m wide easements, as shown in **Figure 1**.

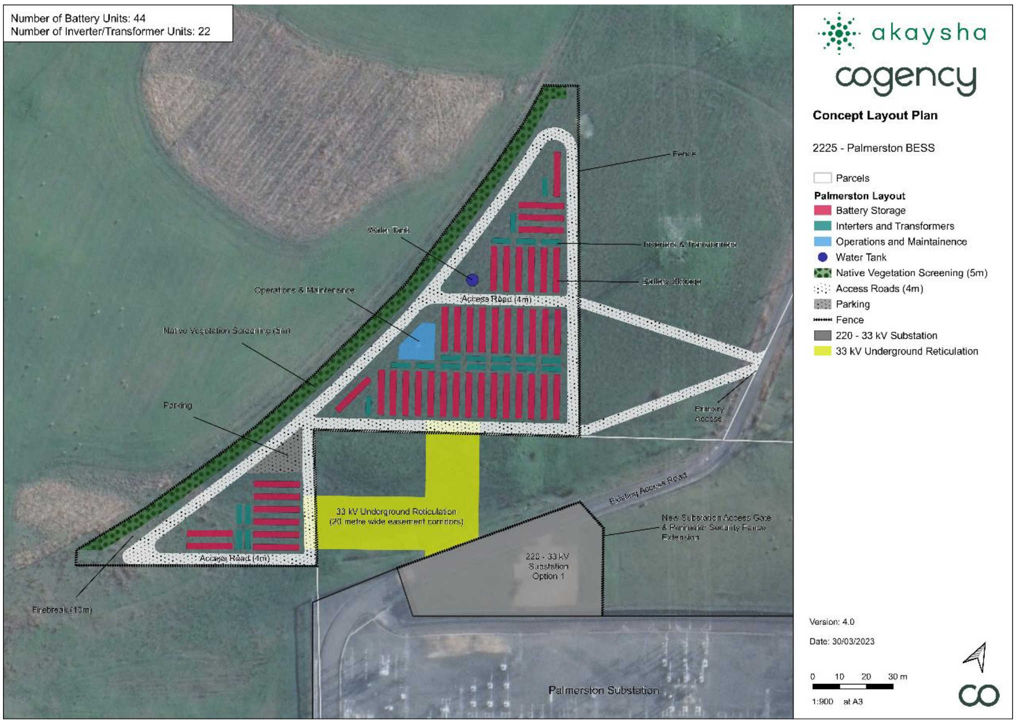
Eleven noise sensitive receptors were identified within a 2 km radius of the site boundary. **Figure 2** shows the site layout and the identified receptors.

Five receptors are understood to be part of the Palmerston farming property (project hosts), and four receptors are part of the Woodside farming property. These receptors are numbered Palmerston 1 to 5 and Woodside 1 to 4 respectively, the remaining two receptors on Poatina Road and Saundridge Road are labelled according to their addresses. **Table 1** summaries the receptor locations (GDA 2020 Zone 55) and the distance to the centroid of the project site.

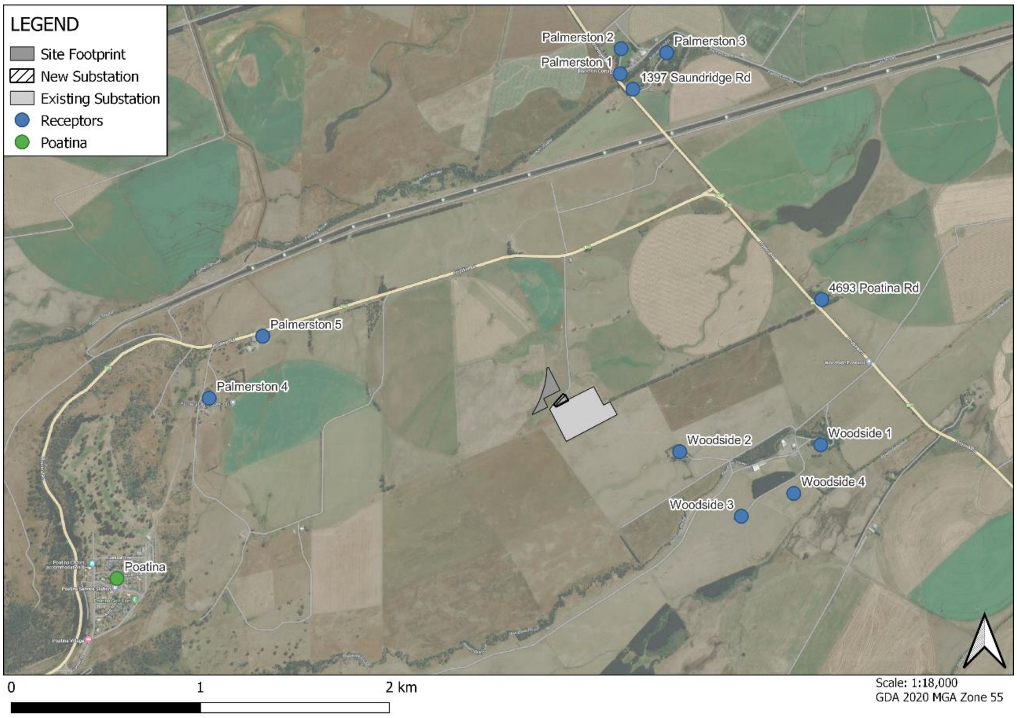
**Table 1 Noise sensitive receptors**

| Receptor | Easting | Northing | Distance to project centroid (m) |
|---|---|---|---|
| Palmerston 1 | 499401.234 | 5375622.227 | 1,720 |
| Palmerston 2 | 499406.2111 | 5375755.037 | 1,850 |
| Palmerston 3 | 499647.2066 | 5375734.343 | 1,900 |
| Palmerston 4 | 497227.3848 | 5373906.619 | 1,790 |
| Palmerston 5 | 497511.0915 | 5374234.992 | 1,530 |
| Woodside 1 | 500461.9635 | 5373659.686 | 1,470 |
| Woodside 2 | 499716.3618 | 5373623.711 | 770 |
| Woodside 3 | 500042.1132 | 5373281.777 | 1,220 |
| Woodside 4 | 500319.5873 | 5373402.921 | 1,410 |
| 1397 Saundridge Rd | 499468.5556 | 5375540.76 | 1,660 |
| 4693 Poatina Rd | 500467.5226 | 5374428.659 | 1,530 |

## Figure 1 Concept layout plan




## Figure 2 Project area and sensitive receptors within 2 km.



# 3 Project Criteria

In Tasmania, the *Environmental Management and Pollution Control Act 1994* (Act), *Environmental Management and Pollution Control (Noise) Regulations 2016* (Regulations) and the *Environment Protection Policy (Noise) 2009* (EPP Noise) regulates noise from industry. The objectives of the EPP Noise are to implement the Act and to protect the acoustic environment that are conductive to:

- The wellbeing of the community including its social and economic amenity, or
- The wellbeing of an individual, including the individual's
  - Health and
  - Opportunity to work and study and to have sleep, relaxation and conversation without unreasonable interference from noise.

The EPP Noise provides acoustic environment indicator levels, adopted from the World Health Organisation publication *Guidelines for Community Noise, 1999*. A selection of project relevant indicator levels is shown in **Table 2**. Note that these environment indicator levels are indicative, and not mandatory noise levels.

### Table 2 Acoustic environment indicator levels

| Specific Criteria | Critical Health Effect(s) | $L_{eq}$ [dBA] | Time base [hours] | $L_{max}$ fast [dBA] |
|---|---|---|---|---|
| Outdoor Living Area | Serious annoyance, daytime and evening | 55 | 16 | - |
| | Moderate annoyance, daytime and evening | 50 | 16 | - |
| Dwelling, Indoors | Speech intelligibility & moderate annoyance, daytime and evening | 35 | 16 | - |
| Inside bedrooms | Sleep disturbance, night time | 30 | 8 | 45 |
| Outside bedrooms | Sleep disturbance, window open (outdoor values) | 45 | 8 | 60 |
| Industrial, commercial, shopping and traffic area, indoors and outdoors | Hearing impairment | 70 | 24 | 110 |

The Northern Midlands Council has published general guidelines on noise but does not have specific noise criteria for industry.

Although the acoustic indicator levels in **Table 2** are not mandatory noise limits, they can be used to form a basis for design targets.

It is noted that the background determination methodology in the Tasmanian Environment Division's document *Noise Measurement Procedures Manual* is very similar to the Rating Background Level prescribed in the NSW's *Noise Policy for Industry, 2017 (NPfI)* [1]. It is proposed to adopt the NSW procedure for defining noise targets as it is more conservative and appropriate than the WHO Acoustic Environment Indicator levels.

[1] The main difference between procedures is the NSW procedure uses a 15 min assessment period, the Tasmanian procedures uses 10 minute periods. For the purposes for assessment, the Tasmanian Background Noise Level procedure detailed Part B Section 14 of the *Noise Measurement Procedures Manual* and the NSW *Noise Policy for Industry* RBL procedure are interchangeable. The 15 minute period was used for this assessment.

According to the NSW NPfI, project noise targets are the minimum of:

- Recommended Amenity Noise Levels:
  - 50/45/40 dBA for day/evening/night respectively, and
- Project Intrusiveness Noise Levels:
  - Which is the maximum of:
    - Rating Background Level + 5 dB, or
    - 40/35/35 dBA for day/evening/night respectively (rural residential settings)

For example, when background levels are low, i.e. RBL + 5 < 35 dBA, the night time noise targets are set to 35 dBA according to the minimum Project Intrusiveness Noise Levels. When background levels are high (RBL + 5 > 40 dBA), the noise targets are limited to 40 dBA according to the Amenity Noise Level.

For sleep disturbance assessments, the NSW Noise Policy for Industry recommends noise targets of:

- $L_{AFmax}$ = 52 dBA or
- $L_{AFmax}$ = RBL + 15 dBA, whichever is greater.

## 3.1 Construction Noise

The aforementioned Act, Regulations and EPP Policy also control construction noise. Part 2, Section 6 of the Regulations specifies:

1) *A person must not operate equipment, or a machine specified in Schedule 1 on -*

    a. *Any residential premises; or*

    b. *Any site where construction, or demolition, that is not the construction or demolition of a public street, is taking place –*

*If the noise emitted by the equipment, or machine, when so operated is, or likely to be, audible in a habitable room in any residential premises, other than the residential premises referred to in paragraph a. whether or not the doors and windows of that habitable room are opened or closed.*

**Table 3** presents the prohibited hours of use for mobile machinery, forklift trucks and portable equipment, operation of such equipment is prohibited within these periods if it is likely to be audible in a habitable room. Operation of construction equipment outside of the prohibited hours of use is unlimited, provided the EPP Noise is upheld, i.e. best practice environmental management to reduce noise emissions to the greatest extent that is reasonably practical, dominant or intrusive noise characteristics of an activity should be reduced to the greatest extent that is reasonably practical etc.

**Table 3 Schedule 1 – Prohibited hours of use: Mobile machinery, forklift truck or portable equipment**

| Day of Operation | Prohibited hours of use |
|---|---|
| Monday to Friday | Before 7 am and after 6 pm |
| Saturday | Before 8 am and after 6 pm |
| Sunday or public holiday | Before 10 am and after 6 pm |

# 4 Existing Noise Environment

Unattended noise monitoring was conducted at 4740 Poatina Road (Woodside 1), located 1,470 m southeast of the proposed BESS. The monitoring was conducted from Wednesday 25 January 2023 to Thursday 2 February 2023. The monitoring equipment was located outdoors in acoustic free-field conditions. Photos of the installed equipment[2] are shown in **Appendix A**.

Noise monitoring was conducted in accordance with AS 1055:2018 *Acoustics- Description and measurement of environmental noise*. Background levels were determined in general accordance with the *Noise Measurement Procedures Manual, Second Edition July 2008*.

Weather data was obtained from the nearest Bureau of Meteorology weather station at Cressy (Brumby's Creek), approximately 10.6 km northeast of the monitoring location. Data potentially affected by rain or wind has been excluded from the analysis.

## 4.1 Results

**Table 4** presents the measured representative daily background levels for day, evening and night periods at the monitoring location. Day periods are defined in the Tasmanian Environment Division of the Department of Environment, Parks, Heritage and the Arts *Noise Measurement Procedures Manual, 2nd Edition July 2008.* The background noise levels are taken as the median of all 10 percentile $L_{90,\ 10\ min}$ values calculated over the monitoring period. Detailed graphs showing 15-minute $L_{10}$, $L_{90}$ and $L_{eq}$ levels with observations from the Cressy weather station are presented in **Appendix A**.

**Table 4 Woodside 1 background noise results**

| Date | 10th percentile of $L_{90,\ 10\ min}$ dBA | | |
|---|---|---|---|
| | Day (7am to 6 pm) | Evening (6 pm to 10 pm) | Night (10 pm to 7 am) |
| Wed, 25 Jan | - | (38) | 33 |
| Thurs, 26 Jan | 33 | 33 | 33 |
| Fri, 27 Jan | 34 | 37 | 34 |
| Sat, 28 Jan | (36) | 34 | 33 |
| Sun, 29 Jan | (34) | 35 | 34 |
| Mon, 30 Jan | 35 | 37 | 33 |
| Tue, 31 Jan | 34 | (34) | 33 |
| Wed, 1 Feb | 34 | 33 | 32 |
| Thurs, 2 Feb | 33 | - | - |
| **Median** | **34** | **34** | **33** |

Note: numbers shown in red text and parentheses have been excluded from the analysis due to adverse weather (i.e. wind or rain)

[2] ARL316 noise monitor, serial number: 16-207-045. Calibration status current (calibration due: 11 May 2024)

## 4.2 Discussion

The Environment Division adopts the World Health Organisation acoustic environment indicator levels in the EPP Noise as an indicator of environments conductive to health and wellbeing. The indicator levels are 50 dBA ($L_{eq}$) for day and 45 dBA ($L_{eq}$) for night, with an additional 60 dBA ($L_{max}$) criterion for sleep disturbance. These levels are significantly higher than the measured backgrounds; adopting these as targets would allow the project to drastically alter the existing ambient environment.

Therefore, it is proposed to apply the NSW Noise Policy for Industry minimum assumed rating background noise level (RBL). The minimum rating background level noise levels is applied when the measured backgrounds are very low, this is common for rural situations, as is the case here.

Project intrusiveness noise levels are defined as RBL + 5 dB. Similar to the WHO environment indicator levels, these are not directly used as regulatory limits but are used to assess potential noise impacts.

The NSW minimum Project Intrusiveness Noise Level are shown in **Table 5** along with the minimum measured background levels + 5 dB, the minimum intrusiveness levels, recommended amenity noise levels and the derived project noise targets.

It is noted that the receptors close to the proposed site may also receive noise from existing industry (i.e. the Palmerston Substation), therefore it is proposed to share the noise limit with the Palmerston Substation by reducing the noise targets down by 3 dB, which is also equivalent to the minimum intrusiveness noise levels.

**Table 5 Project noise targets**

| Time of Day | Measured Background Level, dBA | Background Level + 5 dB, dBA | Minimum Intrusiveness Noise Levels, dBA | Recommended Amenity Noise Levels (rural residential), dBA | Project Noise Targets[1], $L_{Aeq}$,dBA |
|---|---|---|---|---|---|
| Day | 34 | 39 | 40 | 50 | **40** |
| Evening | 34 | 39 | 35 | 45 | **36** |
| Night | 33 | 38 | 35 | 40 | **35** |

Note 1: Due to the presence of Palmerston Substation, project noise goals have been reduced by 3 dB down to the Minimum Intrusiveness Noise Levels

In order to protect existing ambient environment, it is proposed to adopt the more stringent noise targets of **40/36/35 dBA ($L_{eq}$) for day/evening/night** respectively.

For sleep disturbance, it is also proposed to adopt the more stringent NSW Noise Policy for Industry noise target of **52 dBA ($L_{AFmax}$)**.

# 5 Acoustic Investigation

This acoustic investigation assesses construction and operational noise impacts to the closest receptors. The following two construction scenarios were modelled:

- BESS Earthworks & Hardstand – involving bulk earthworks and hardstand construction of the BESS infrastructure and substation site

- BESS Infrastructure installation – construction of the BESS facility substation and auxiliary buildings

One operational scenario was modelled, with the assumption that all battery & inverters are operating at 100% capacity for the entire duration of the assessment period and noise levels assessed against the night time noise criterion. This is considered the most conservative noise assessment scenario.

## 5.1 Noise Modelling

A 3D noise model was constructed within the modelling software SoundPLAN 8.2 to predict noise levels at the nearby sensitive receivers.

Noise modelling was conducted using the ISO 9613-2[3] algorithms incorporated in the noise modelling software. The ISO 9613-2 algorithm predicts the A-weighted sound pressure levels under meteorological conditions favourable to propagation from sources of known sound power levels. This enhanced propagation is equivalent to downwind propagation or a moderate ground-based temperature inversion. The model also includes attenuation due to air absorption, ground attenuation and shielding.

## 5.2 General Modelling Assumptions

The following general assumptions are made based on best-practice modelling method to suit the project:

- The reflection-order of other buildings was set to three (3), indicating that the noise model allowed for three (3) reflections off façades.
- Source heights were set according to the source item.
- Receivers were set 1.5 m above ground level.
- All equipment is assumed to be in operation for the entire 1 hour assessment period.
- Ground topography within 5 km of the proposed site was sourced from publicly available 1 m elevation data published by the Tasmanian Government.
- Ground absorption is modelled by a single number parameter between 0 (hard – reflective) and 1 (soft – absorptive). The infrastructure hardstand was modelled as hard ground, all other ground surfaces were modelled with a ground absorption parameter of 0.6, suitable for rural farmland.

## 5.3 Construction Noise Assessment

Construction activities are proposed to be undertaken during daytime hours only. Stages of the construction includes:

1. Earthworks, including compaction and drainage and construction of hardstand pads for the BESS and adjoining substation infrastructure.
2. Infrastructure deliveries and installation, installation of transformers and construction of onsite buildings.

[3] ISO 9613-2:1996 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation*

### 5.3.1 Sound Power Levels

Sound power levels of typical mobile plant and equipment, taken from SLR's noise database of field measurements and BS 5228-1:2009[4] are summarised in **Table 6**. For a worst-case assessment it is assumed that all equipment is operating continuously over the assessment period, due to sequencing of equipment usage that often occurs on site, this is expected to represent a conservative approach.

The construction scenarios were modelled as area sources covering the infrastructure study area. The overall sound power level is distributed over this area.

**Table 6 Construction equipment sound power levels**

| Scenario | Equipment | Quantity | SWL, per item, $L_{Aeq,}$ | Overall, $L_{Aeq,}$ |
|---|---|---|---|---|
| Earthworks + Hardstand | Excavator | 2 | 104 | 123 |
| | Dozer | 1 | 108 | |
| | Grader | 1 | 104 | |
| | Dump Truck | 2 | 102 | |
| | Vibratory Roller | 1 | 105 | |
| | Concrete Truck | 4 | 104 | |
| | Concrete Pump | 4 | 102 | |
| | Concrete Poker | 4 | 97 | |
| | Rock Breaker | 1 | 121 | |
| | Chain Trencher | 1 | 102 | |
| | Rock Saw | 1 | 113 | |
| | Water Truck | 1 | 111 | |
| | Diesel Generator | 4 | 94 | |
| | Diesel Pump | 2 | 97 | |
| Infrastructure Delivery and Construction | Trucks | 2 | 102 | 115 |
| | Powered Hand Tools | 4 | 102 | |
| | Forklift or Telehandler | 1 | 102 | |
| | 20 t Franna crane | 1 | 98 | |
| | Diesel Generator | 4 | 94 | |
| | Diesel Pumps | 2 | 97 | |

## 5.4 Operational Noise Assessment

### 5.4.1 Sound Power Levels

Sound pressure measurements of battery units were supplied by Powin (representing an indicative BESS), which have been used to determine sound power levels noise, with noise spectra estimated based on similar equipment. All items are assumed to be in operation for the entire assessment period. The inverters are also assumed to operate at 100% capacity (i.e. maximum fan speed) 24 hours each day. **Table 7** summaries sound power levels for the key operational equipment.

[4] *Code of Practice for Noise and Vibration Control on Construction and Open Sites – Part 1: Noise*

The spectrum for the high voltage transformer was adopted from refence data by Bies and Hanson (11.16). Noise spectra are shown in **Table 8**.

**Table 7 Indicative equipment sound power levels**

| Qty | Item | Sound Pressure Level (SPL), $L_{eq}$ dBA | Overall Sound Power Level (SWL), $L_{eq}$ dBA |
|---|---|---|---|
| 22 | Inverter | 77 to 80 dBA at 1 m | 92 dBA per unit |
| 44 units (7 segments per unit + battery management system) | Battery enclosure | 62 to 67 dBA at 1 m per segment | 79 dBA per segment |
| 1 | 100 MW HV Transformer | N/A | 94 dBA per unit |

**Table 8 Nominative noise spectra**

| Item | Octave Band Centre Frequency, Hz -linear weighting, dBZ | | | | | | | | dBA |
|---|---|---|---|---|---|---|---|---|---|
| | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k | |
| Inverter | 93 | 93 | 92 | 91 | 84 | 83 | 82 | 78 | **92** |
| Battery enclosure segment | 77 | 78 | 78 | 77 | 75 | 71 | 67 | 61 | **79** |
| HV Transformer | 96 | 98 | 94 | 94 | 88 | 83 | 78 | 71 | **94** |

# 6 Assessment Results

## 6.1 Construction Noise Results

**Table 9** presents the construction noise results for the assessed scenarios. It is anticipated that construction works would occur during the day-time period. Construction noise will be audible from several receptors, however predicted levels at all receptors are less than the WHO Acoustic Environment Indicator Level for moderate annoyance (50 dBA $L_{eq,\ 16\ hours}$).

Noise contour plots for these scenarios are shown in **Figure 3** and **Figure 4**.

**Table 9 Construction noise results**

| Receptor | Predicted Noise Level, $L_{eq}$, dBA | |
|---|---|---|
| | Earthworks and hardstands | Infrastructure construction |
| Palmerston 1 | 37 | 29 |
| Palmerston 2 | 38 | 29 |
| Palmerston 3 | 37 | 28 |
| Palmerston 4 | 39 | 31 |
| Palmerston 5 | 38 | 30 |

| Receptor | Predicted Noise Level, $L_{eq}$, dBA | |
|---|---|---|
| | Earthworks and hardstands | Infrastructure construction |
| Woodside 1 | 41 | 33 |
| Woodside 2 | 48 | 40 |
| Woodside 3 | 42 | 34 |
| Woodside 4 | 40 | 32 |
| 1397 Saundridge Rd | 38 | 29 |
| 4693 Poatina Rd | 42 | 34 |

## Figure 3 Construction results – Earthworks and Hardstand

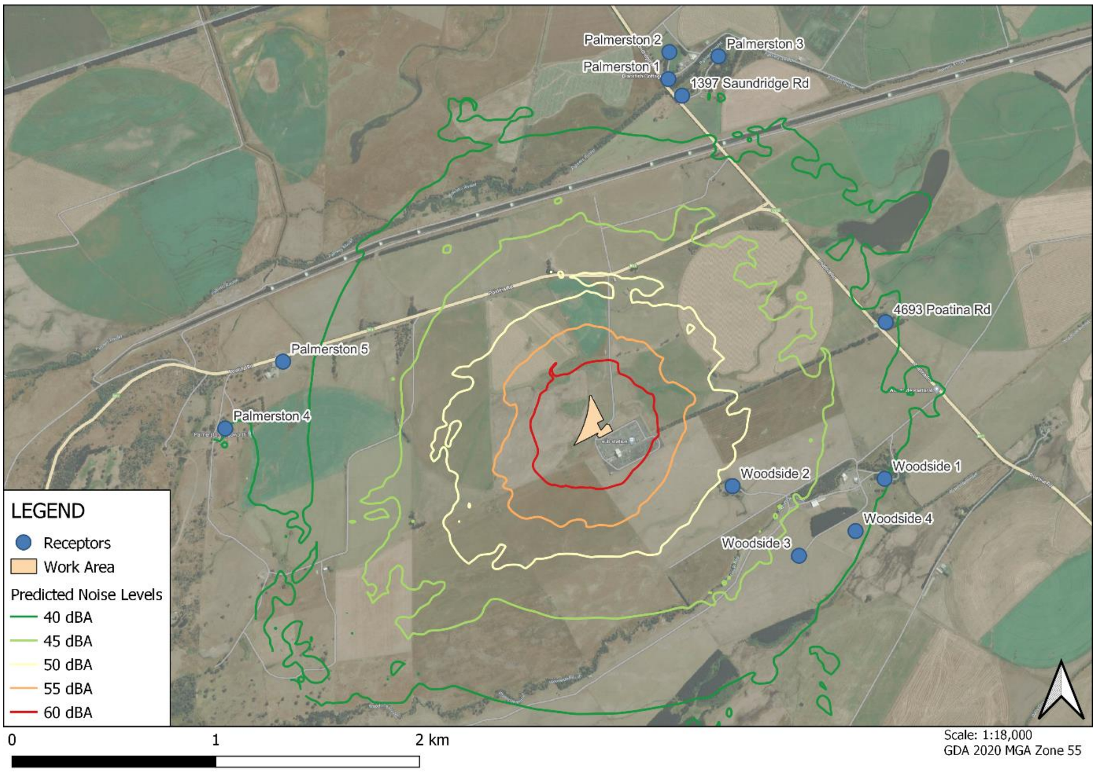
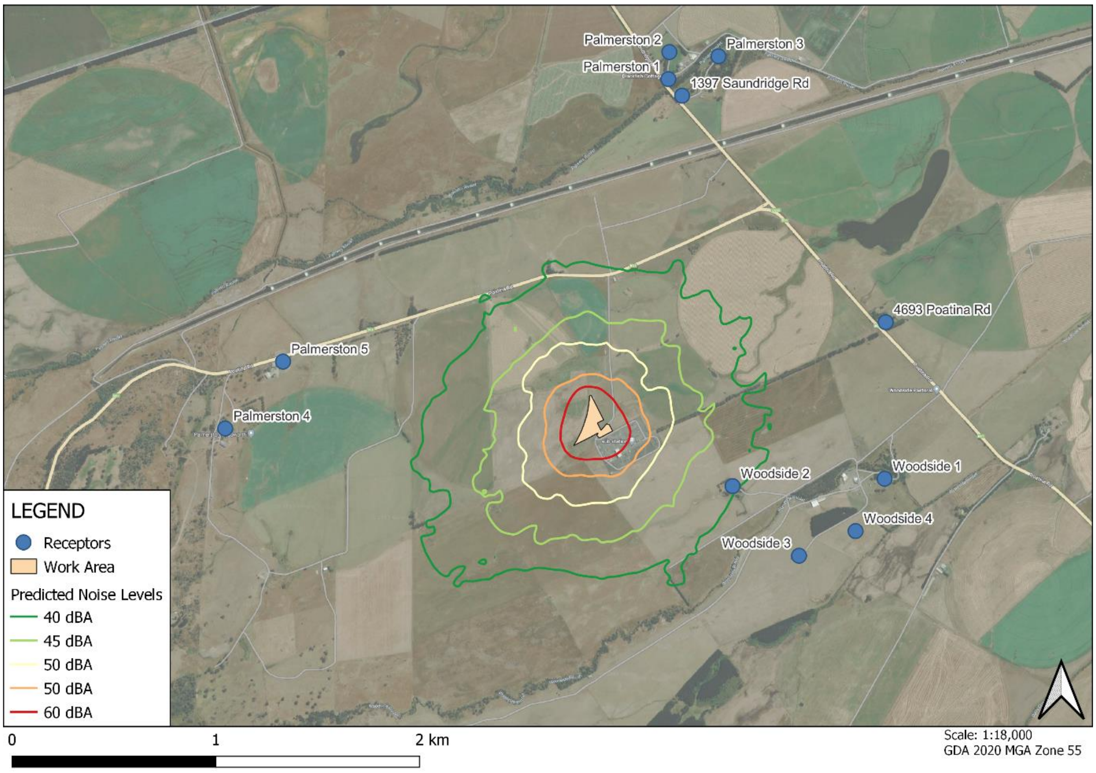


**Figure 4 Construction results – Infrastructure**




## 6.2 Operational Noise Results

**Table 10** shows the predicted source contributions and overall noise levels at the identified sensitive receptors compared with the night-time noise goal. It can be seen in **Table 10** that the contribution of the proposed substation is negligible compared with the contributions of the batteries and inverters.

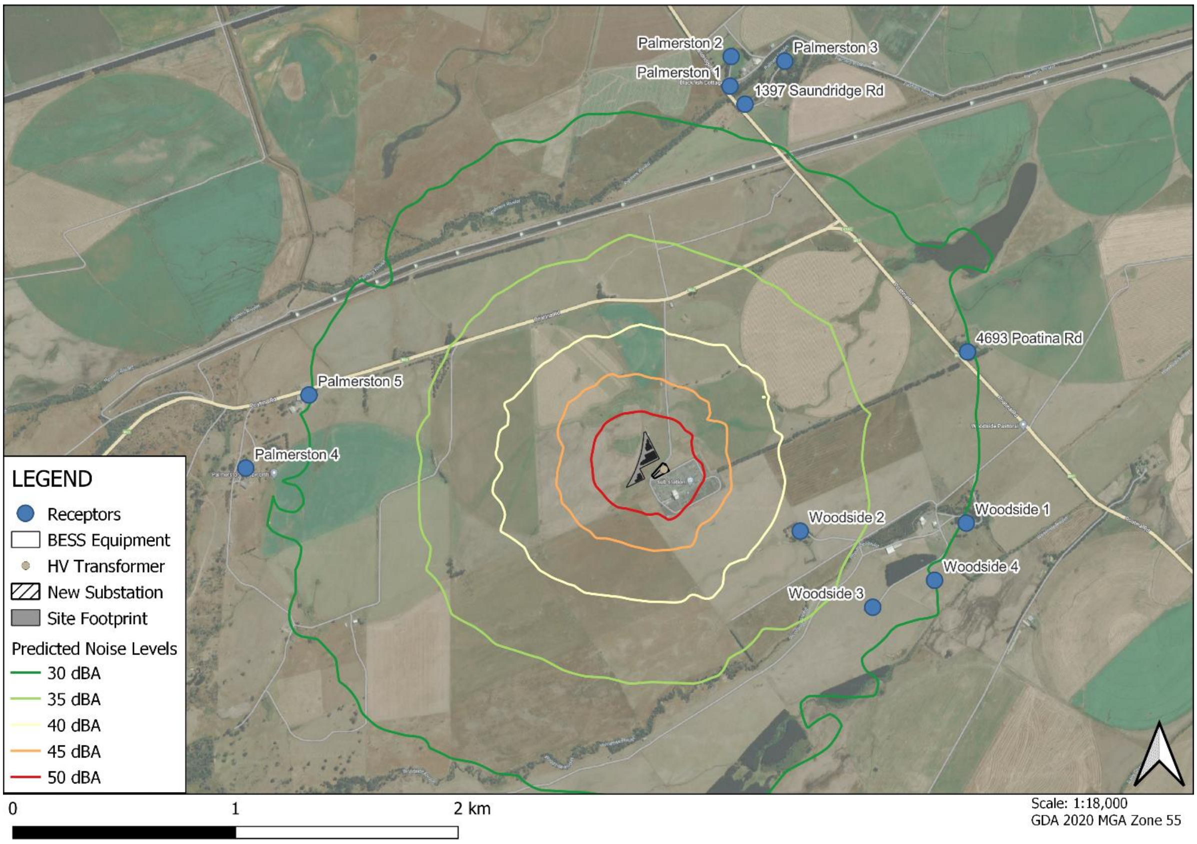
The night-time noise target is predicted to be exceeded at one location, Woodside 2, by 2 dBA. Mitigation options are detailed in the following section. **Figure 5** shows the predicted operational noise contours.

**Table 10 Operational noise results**

| Receptor | Source contribution, $L_{eq}$, dBA | | | | Night time noise target, dBA | Exceedance, dBA |
|---|---|---|---|---|---|---|
| | Battery enclosures | Inverters | Substation | Overall | | |
| Palmerston 1 | 25 | 25 | < 20 | 28 | 35 | - |
| Palmerston 2 | 24 | 24 | < 20 | 27 | 35 | - |
| Palmerston 3 | 24 | 24 | < 20 | 27 | 35 | - |
| Palmerston 4 | 25 | 26 | < 20 | 29 | 35 | - |
| Palmerston 5 | 27 | 27 | < 20 | 30 | 35 | - |
| Woodside 1 | 27 | 27 | < 20 | 30 | 35 | - |

| Receptor | Source contribution, $L_{eq}$, dBA | | | | Night time noise target, dBA | Exceedance, dBA |
|---|---|---|---|---|---|---|
| | Battery enclosures | Inverters | Substation | Overall | | |
| Woodside 2 | 35 | 33 | 22 | **37** | 35 | **2** |
| Woodside 3 | 29 | 29 | < 20 | 32 | 35 | - |
| Woodside 4 | 27 | 25 | < 20 | 29 | 35 | - |
| 1397 Saundridge Rd | 25 | 25 | < 20 | 28 | 35 | - |
| 4693 Poatina Rd | 27 | 27 | < 20 | 30 | 35 | - |

## Figure 5 Operational noise contours



## 6.3 Noise Mitigation Options

The proposed site is located directly adjacent to a centre-pivot irrigation field. It is not feasible to move the site further north or northwest, away from Woodside 2.

Reducing the amount of plant and thus BESS capacity will reduce noise levels. A reduction of 2 dBA will require reducing onsite plant by approximately 40% which is not considered feasible.

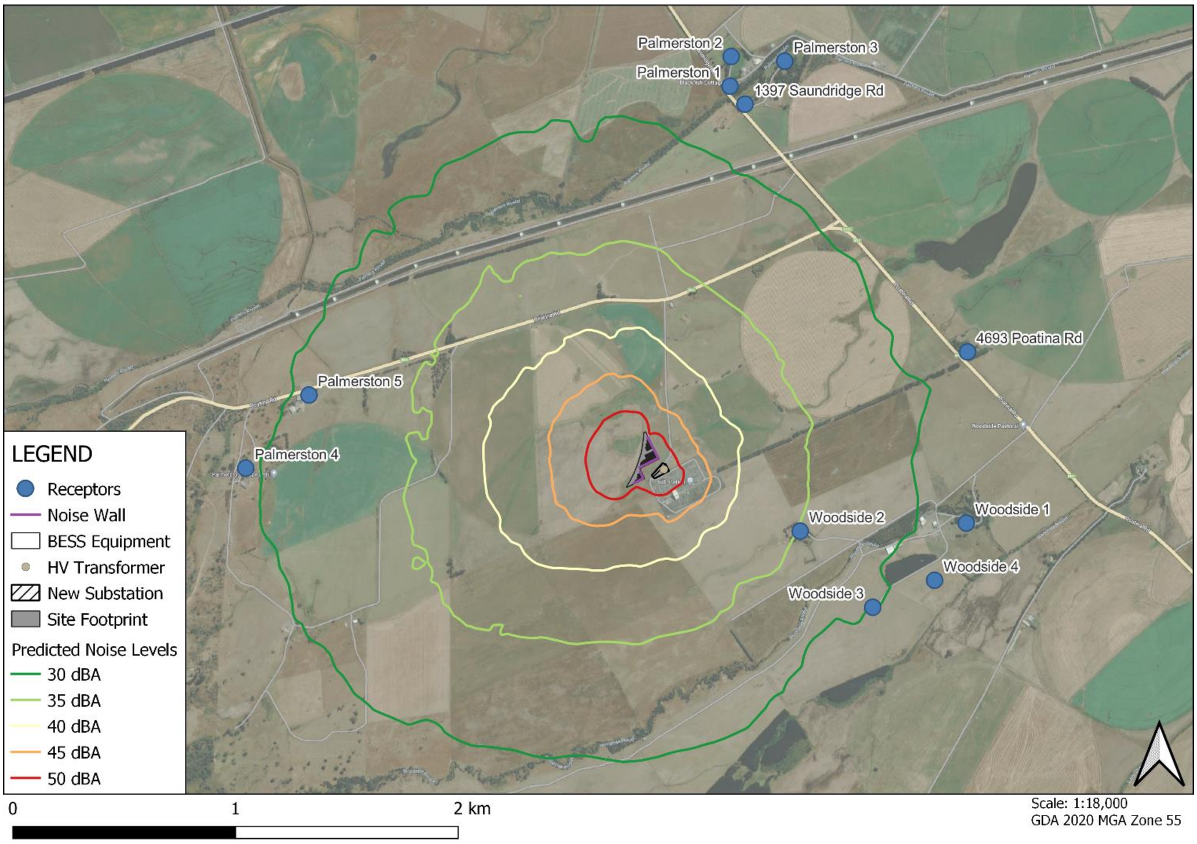
The modelled battery enclosures and inverters did not include fan silencing treatment. Applying attenuators to the battery and inverter fan units and specifying low noise fans can serve to reduce noise emissions from the BESS facility. This is anticipated to be subject to a detailed review including mechanical and acoustic optimisation during the detailed design stage.

A 2 dBA reduction in sound power level in the battery units and inverters is required to comply with the night-time noise goal. This can be easily achieved with fan silencer attenuation treatment. Reductions on individual inlet and outlet sound power levels of up to 9 dBA has been observed for other manufacturer “silenced” units on similar inverters.

Noise barriers were also considered. Noise barriers are most effective when they are installed as close to the source or receiver as possible, the effectiveness of noise barrier attenuation is constrained by the offset requirements from the outermost BESS units for maintenance access. Similarly, the distribution of noise emitting plant over a relatively large area reduces noise barrier effectiveness. Noise model results indicate that a 5 m noise barrier along the eastern and southern sides of the site will achieve compliance at Woodside 2. **Figure 6** shows predicted noise contours with the noise barrier.

At receptor mitigation may also be considered by negotiating with the impacted landowner to apply acoustic treatment to the dwelling, typically with glazing upgrades to exceed internal noise levels.

## Figure 6 Noise mitigation option – 5m noise wall



# 7 Discussion

## 7.1 Construction Noise

Construction of the BESS facility will be audible from several receptors from time to time, however noise impacts are minimised due to the work being temporary and conducted outside of the prohibited hours as defined in the Act.

The Australian Standard AS2436-2010 *Guide to Noise Control on Construction, Maintenance and Demolition Sites* sets out numerous practical recommendations to assist in taking all reasonable and practicable measures to prevent or minimise noise impacts.

All construction works will be completed under a Construction Environmental Management Plan (CEMP).

Noise control strategies to be considered are listed below:

- Ensure construction works to occur outside of the prohibited hours as defined in the Act (see **Table 3** for a summary of the prohibited hours).
- Notification of receptors of the proposed works schedule and potential noise impacts and relevant contacts for queries or complaints.
- Incorporate clear signage at the site including relevant contact numbers for community enquiries.
- The lowest noise emitting plant and equipment that can economically and efficiently undertake the work should be selected where possible.
- Maintain regular maintenance of equipment to keep it in good working order and operating at the lowest feasible noise level.
- Use less intrusive broadband reversing beepers on mobile plant where possible.
- Equipment operators are to be made aware of noise impacts and techniques to minimise emissions through training/instruction, examples include:
  - Avoid dropping materials from height into bins, trucks and receptacles.
  - Operate mobile plant and power tools in a quiet, efficient manner where possible.
  - Switch plant off when not in use
- Machines/tools found to produce excessing noise compared with industry best practice should be removed from service until repairs or modification can be made, or the machine/tool is replaced.
- Where possible avoid tonal reversing/movement alarms on machinery and replace with broadband (non-tonal) alarms or ambient noise-sensing alarms.
- Use dampened bits on impulsive tools (e.g. ratchet drivers) to avoid 'ringing' noise.

## 7.2 Operational Noise

Unmitigated operational noise levels are predicted to marginally exceed the night time noise goal at one receptor by 2 dBA. Mitigation options include attenuation treatment on the battery units and inverters and/or construction of a noise wall on the eastern and southern sides of the site.

Furthermore, it is important to note that the operational noise assessment presented in this report is to be considered a conservative approach, i.e., inverters and battery cooling systems and HV transformers operating at 100% capacity all the time combined with atmospheric conditions favourable to noise propagation. Whilst it is possible for the BESS facility to operate at close to 100% full load during the night period[5], it is far more likely that the maximum charging load will occur when the spot price is typically the lowest, generally during the midday period. Similarly the maximum discharge load would likely occur during peak demand and when spot price is highest, typically around 6.30 pm (day/evening period).

If the BESS was not operating at 100% during the night period (i.e. cooling fans operating at 40% to 50%), the resulting noise emission reduction would satisfy the night time noise goal at the closest sensitive receptor.

Given the conservative 100% load assumption of the noise model and the indicative BESS layout and equipment selection, it is considered premature to provide detailed design for silencing treatment/noise barriers at this stage of the design.

All plant will be reviewed during detailed design to ensure that compliance with the noise goals can be achieved through the selection of equipment and site layout and post commissioning noise measurements will be undertaken to confirm compliance with the EPP Noise.

# 8 Conclusions

This noise assessment report was prepared to support a development application for the Palmerston BESS development. This report presents applicable noise criteria, based on background noise measurements, assessment methodology, results and management strategies to demonstrate the feasibility of achieving compliance with the day, evening and night time noise goals.

Construction noise impacts are controlled by limiting works to day periods and a combination of training/equipment maintenance and community engagement.

An exceedance of up to 2 dBA at the closest sensitive receptor was predicted for worst case night-time operations. Mitigation options were presented to demonstrate the feasibility of achieving compliance with the noise goal of 35 dBA at night.

All plant, equipment and the design layout will be reviewed during the detailed design stage to ensure that compliance with the noise goals is achieved as the acoustic performance of plant and site layout is refined, followed by post commissioning noise measurements to confirm compliance.

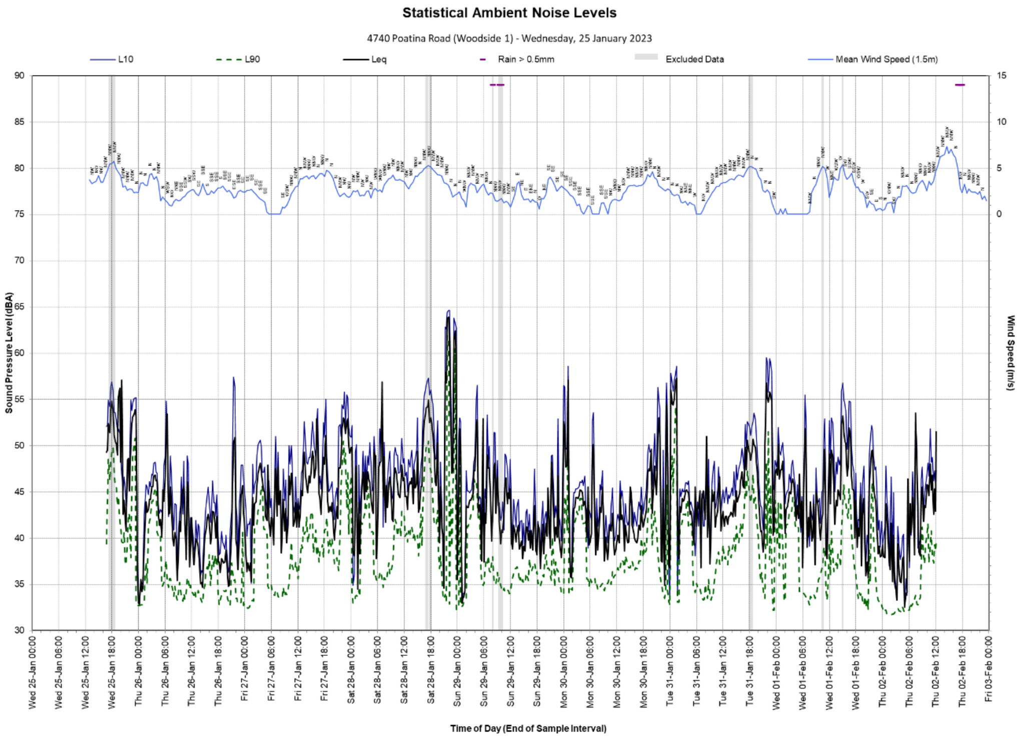
[5] Some BESS capacity is required to be kept in reserve as part of the regulatory requirements with the Transmission Network Service Provider (TNSP). Hence, the BESS is unlikely to ever operate at 100%.

# Appendix A:

## Monitoring Results

**Figure 7 Unattended noise monitor - 4740 Poatina Road 'Woodside 1'**

**Figure 8 Woodside 1 unattended monitoring results**



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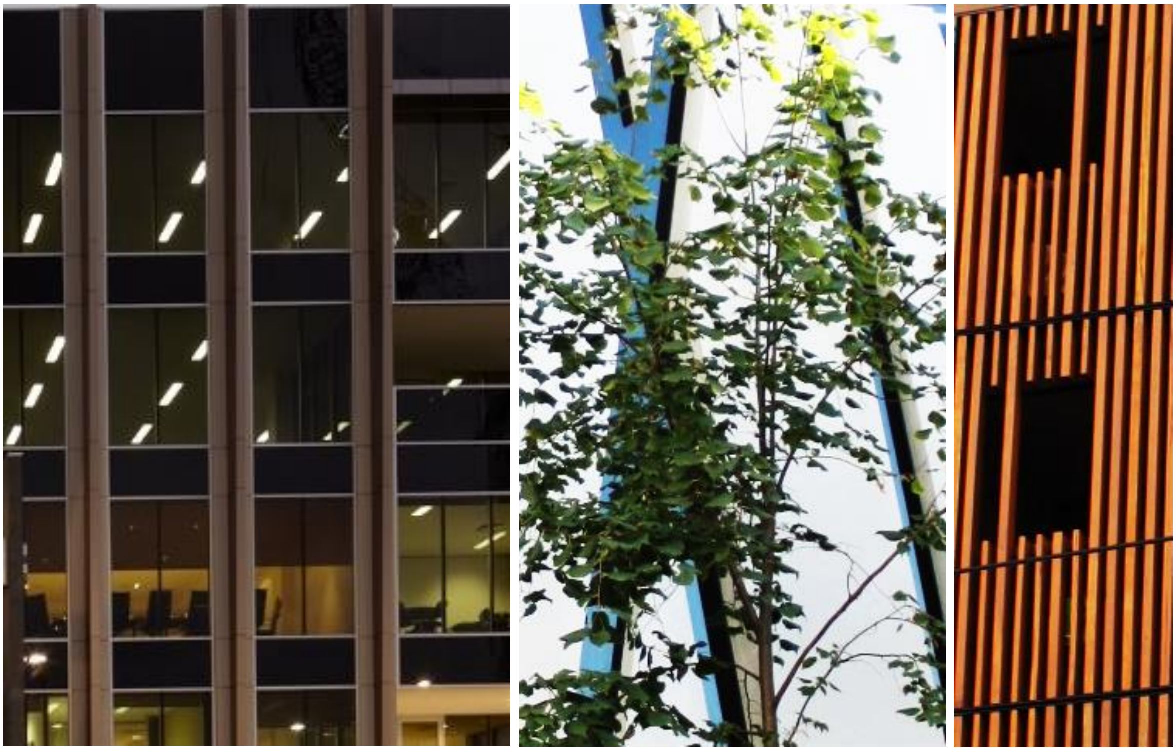
# Fire Hazard and Risk Assessment

## PALMERSTON BESS (Battery Energy Storage System)



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**Project Name:** Palmerston BESS

**Project Number:** 8198

**Report Name:** Fire Hazard and Risk Assessment

**Client:** Akaysha Energy

| Revision | Issue Date | Document Control | | | |
|---|---|---|---|---|---|
| 01 | 27 June 2023 | Issue: | Fire Hazard and Risk Assessment (FHRA) | | |
| | | | Written by: | Reviewed by: | Approved by: |
| | | Name: | Javier Piedrahita PE0003748 | Ian Moore PE0003103 | Javier Piedrahita PE0003748 |
| 02 | 13 July 2023 | Issue: | Fire Hazard and Risk Assessment (FHRA) | | |
| | | | Written by: | Reviewed by: | Approved by: |
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# 1 EXECUTIVE SUMMARY

## 1.1 GENERAL

NJM Design has been engaged by Akaysha Energy to undertake a fire hazard and risk assessment for the 1.5ha, 100MW/200MWh Battery Energy Storage System (BESS) located at 1440 Saundridge Road, Cressy TAS. The site is adjacent to the existing Palmerston Substation.

The objective of this report is to identify primary fire risks associated with the implementation and function, location, proposed fire systems and fire brigade intervention of the BESS units. 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.

In particular the scope of work is to:

a. Provide a risk review consistent with fire risk assessment techniques for Hazardous industry planning.
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.

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

a. AS 5139 Electrical Installations – Safety of battery systems for use with power conversion equipment
b. Best Practice Guide for Battery Storage Equipment - Electrical Safety Requirements, Version 1.0 – Published 06 July 2018
c. NFPA 855, Standard for Stationary Energy Storage Systems (in development),
d. AS2067 has also been reviewed to place the risk of the BESS units in context with existing power utility infrastructure in the community.
e. Design Guidelines and Model Requirements: Renewable Energy Facilities, Country Fire Authority, March 2022.
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. AS3000.
h. Building Code of Australia (BCA) 2019 Amendment 1.
i. Energy Safe Victoria (ESV) “Statement of Technical Findings - Fire at the Victorian Big Battery.

## 1.2 FIRE ENGINEERING REQUIREMENTS

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

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

1. A firebreak of at least 10m wide must be designed and maintained as shown in Appendix A (this is compliant in the proposed layout in Appendix A).

2. A four (4) metre perimeter road within the perimeter fire break (as shown in Appendix A) must be designed and must comply with the requirements of the CFA Guidelines for renewable Energy Facilities [1] (also refer to Section 7.5) (this is compliant in the proposed layout in Appendix A and structural characteristics must be verified by the designer).
3. A Fire hydrant system must be provided in accordance with AS 2419.1-2005: Fire hydrant installations, Section 3.3: Open Yard Protection and any additional requirements of the Fire Brigade (also refer to Section 7.5). Furthermore, location of hydrants must be located as follows (refer to section 6.2):
    a. Be located not less than 8.0m from the small transformers/inverters (refer to section 6.2).
4. Develop a Fire Management Plan as required by the CFA Guidelines for renewable Energy Facilities [1] (refer to Section 7.5), which must contain the following content (figure below).

| Table 1: Fire Management Plan Requirements | |
|---|---|
| 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 Management 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 Management 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 Management 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 (serving/maintenance, housekeeping inspections, external audits), review processes for risk control effectiveness. |
| Procedures for review of the Plan. | Review triggers and schedule, organisational accountability for the Plan, allocated responsibilities (to persons or roles) for the ongoing development and review of the Plan. |

***Figure 1: Fire Management Plan Requirements as per CFA guidelines***

5. Smaller transformers (i.e., inverters and transformers) located in accordance with the proposed layout in Appendix A, must comply with the following:
    a. Have an oil capacity of not more than 3,800 litres (3.8 $m^3$).
    b. Be provided with enhanced protection in accordance with AS2067.
    c. Where transformers are oil-insulated, transformers must use an FR3 (or similar) Ester oil in lieu of the normal mineral oil.
6. Energy segments units must be provided with at least a smoke detection system.
7. The water storage tank is required to allow for 2 hydrants at 10L/s each for four hours, i.e., 288kL.

## 1.3 CONCLUSIONS

Based on the results of the assessment it is concluded that:

1. The design of the BESS units is acceptable and covers all fire initiation and fire spread risks to an acceptable level.
2. Based on the AS5139 Risk Methodology the risk of a fire would be considered Very Low, given that the consequence is Minor and the likelihood is very low.
3. The proposed installation procedures and Units have design and requirements that address the issues raised by the Victorian Big Battery (VBB) fire (refer to Appendix B).
4. The risk of fire development and spread is no worse than that posed by existing utility infrastructure in the community or the adjacent buildings in the community.
5. Fire spread to adjacent allotments would not be predicted to occur, based on that the distances from the subject site surpass the clearances specified by the NCC and the Australian standards. This is confirmed by the fire spread analysis performed in Sections 6.2, 6.3, 6.4 and 6.5.
6. Fire spread between Battery Storage Units is not expected if a Battery Storage Units reaches flashover, however flashover is not expected to happen due to the fire safety measures and E-Stops (i.e., safety sensors), which will shut down the Battery Storage Unit to delay a possible battery-runaway failure and warn staff to perform the required maintenance before a battery catches of fire.

   The fire safety measures available by the providers usually are the following:

   - Heat detection.
   - Gas detection.
   - Smoke detection.

   And the E-Stops (i.e., safety sensors) will include:

   - Hydrogen sensor (signals H2 concentration reached set point).
   - Trouble (loss of AC power or low battery voltage).
   - Fire alarm (signals smoke and/or heat).
   - Fire supervisory (signals tampering, low air, and high air).
   - Door alarm (signals door is open).
7. Given the subject site layout, fire spread from a Battery Storage Unit row is not expected to adjoining transformers or adjacent Battery Storage Unit rows.
8. Fire brigade intervention is considered not to be affected by a fire based on the preliminary fire modelling results presented within this report. There will be multiple hydrants to attack a transformer or battery fire given the provision of hydrants and access roads outside of the critical area around the transformers and battery (refer to CFA Guideline in section 7.5).
9. If one of the site entrances were to be obstructed by a fire, it is expected the fire brigade will be able to access through the alternative entrance on the east side of the development. The south-west corner of the BESS is proposed to have a single access given that a BESS fire in the south-west corner is not expected to extend up to the single access to block the access (the access road is located at 20m approximately from the Energy Segments, whilst a BESS fire is not expected to extend more than 2.4m, hence the access road is not expected to be blocked).
10. The firefighting water will be sufficient for 4 hours supply based on at least 2 hydrants. The hydrants will be located such that all areas can be covered by at least 2 hydrants.

11. The other parts of the infrastructure such as the transformers and control room do not present a significant fire risk or higher hazard than other small buildings in the community that do not require particular fire safety provisions.
12. The adjoining allotments are private land with modified grassland. AS3959-2018 considers this grassland as a low threat and hence the development does not require specific construction specifications.
13. Based on the analysis performed in Section 7.5, it is considered that the design and layout of the BESS complies with the CFA guidelines, hence providing an acceptable level of fire safety to personnel, fire brigade and adjacent properties.

# 2 SCOPE

## 2.1 GENERAL

A review of the design to applicable standards has been undertaken as well as a comparative risk assessment to existing power utility infrastructure and industrial facilities in the same setting.

An assessment of the likelihood of ignition and fire spread from a battery unit was undertaken. This assessment included the investigation of the likely heat release rate (HRR) of a fire and its impact on an adjacent building as a result of radiant heat transfer.

It is beyond the scope of this fire risk assessment to assess the likely spread at ground level of firefighting water run-off.

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.

## 2.2 BASIS OF THE STUDY

The development of the study was based on the following information:

- Cogency concept plan layout, version 4.0, dated 30/03/2023.
- Review of other BESS fires and installations in particular the Victorian Big Battery fire and the ESV findings.
- CFA Design Guidelines and Model Requirements: Renewable Energy Facilities (Version 3, March 2022).
- Tamar Fire Management Area Bushfire Risk Management Plan 2021, version 1.0, dated in February 2021 [2].

No Tasmanian Fire Brigade Guidelines have been identified relating Battery Energy storage systems (BESS).

# 3 Risk Assessment Methodology

## 3.1 Introduction

This Fire Hazard and Risk Assessment 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).

The process is shown diagrammatically in Figure 2.

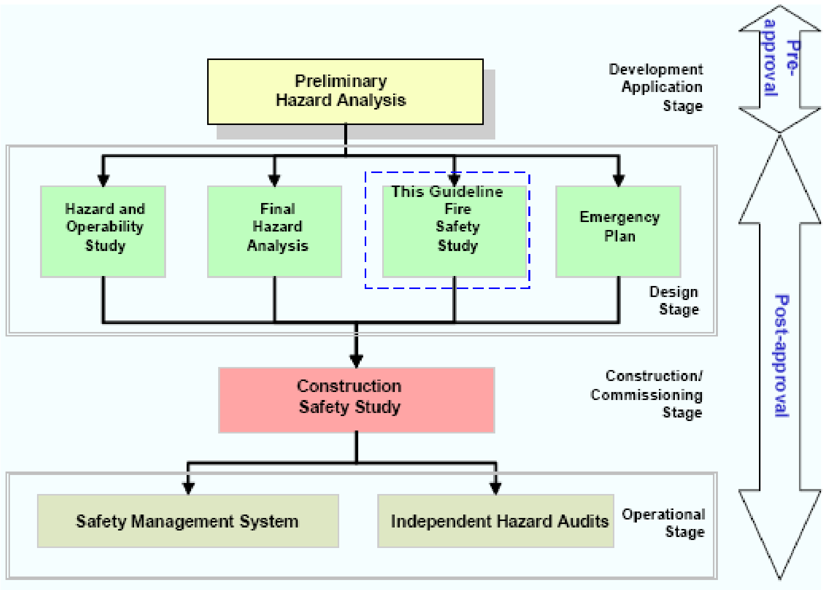


*Figure 2: The Hazards-Related Assessment Process*

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.

## 3.2 RISK MANAGEMENT

The hazards identified as part of this assessment have been assessed using the below risk criteria and ranking based on past HIPAP studies and industry practices undertaken by the author.

The effectiveness of the existing controls was rated using the following criteria (Table 1).

***Table 1: Risk Control Effectiveness***

| Level | Descriptor | Control Rating Guidance Description |
|---|---|---|
| 1 | Excellent | The system is effective in mitigating the risk. Systems and processes exist to manage the risk and management accountability is assigned. The systems and processes are well documented and understood by staff. Regular monitoring and review indicate high compliance with the process. |
| 2 | Good | Systems and processes exist which manage the risk. Some improvement opportunities have been identified but not yet actioned. Formal documentation exists for key systems and processes in place to manage the risk that is reasonably understood by staff. |
| 3 | Fair | Systems and processes exist which partially mitigates the risk. Some formal documentation exists, and staff have a basic understanding of systems and processes in place to manage the risk. |
| 4 | Poor | The system and process for managing the risk has been subject to major change or is in the process of being implemented and its effectiveness cannot be confirmed. Some informal documentation exists; however, staff are not aware or do not understand systems or processes to manage the risk. |
| 5 | Unsatisfactory | No system or process exists to manage the risk. |

The following table was used to rate the likelihood of different risks occurring (Table 2) that has been extracted from Appendix G of AS5139:

***Table 2: Example likelihood of occurrence rating***

| Likelihood rating | Definition of likelihood of occurrence rating |
|---|---|
| Almost certain | Probability of occurrence: greater than 90 % |
| | Expected to occur whenever system is accessed or operated |
| | The event is expected to occur in most circumstances |
| Likely | Probability of occurrence: 60 % – 89 % |
| | Expected to occur when system is accessed or operated under typical circumstances |
| | There is a strong possibility the event may occur |
| Possible | Probability of occurrence: 40 % – 59 % |
| | Expected to occur in unusual instances when the system is access or operated |
| | The event may occur at some time |
| Unlikely | Probability of occurrence: 20 % – 39 % |
| | Expected to occur in unusual instanced for non-standard access or non-standard operation |
| | Not expected to occur, but there is a slight possibility it may occur at some time |
| Rare | Probability of occurrence: 1 % – 19 % |
| | Highly unlikely to occur in any instance related to coming in contact with the system or associated systems |
| | Highly unlikely, but it may occur in exceptional circumstances, but probably never will |

## 3.3 CONSEQUENCE RATING

The following table was used to rate the consequence of different risks occurring (Table 3).

The consequence for each risk was considered in relation to its cumulative effect in the period under review.

***Table 3: Consequence rating Appendix G AS5139***

**Table G.1 — Typical risk consequence table**

| Consequence/ impact category | Consequence/impact rating definitions | | | | |
|---|---|---|---|---|---|
| | Catastrophic | Major | Moderate | Minor | Insignificant |
| Health and safety | Any fatality of staff, contractor or public | Non-recoverable occupational illness or permanent injury | Injury or illness requiring medical treatment by a doctor | Injury requiring first aid | No or minor injury |
| | | Injury or illness requiring admission to hospital | Dangerous/reportable electrical incident | Circumstances that lead to a near miss | |
| Environmental | High, long term or widespread impact (spill, emission, or habitat disturbance) to sensitive environment | Substantial impact — large spill or emission requiring Emergency Services attendance | Moderate impact — Spill or emission not contained on site with clean up needed | Minor cleanup/rectification — spill or emission not contained on site | Small spill or emission that has no impact on site or installation |
| | Environmental agency response with significant fine | Recovery of environment likely but not necessarily to pre-incident state | Death or destruction of protected flora or fauna | Environment expected to fully recover to pre-incident state | Clean up requires no special equipment and has no potential impact |
| | Long term recovery of environment to pre-incident state not likely | Any spill into sensitive area (wet tropics, fish habitat, potable water supply) | Environment likely to recover to pre-incident state in short to medium term | Environmental nuisance (short-term impact) caused by noise, dust, odour, fumes, light | |
| Legal and regulatory | Breach of licences, legislation or regulations leading to prosecution | Breach of legislation or regulations leading to: (a) contravention notice from authorities; or (b) court order; or (c) fine over $1000 | Breach of legislation, regulations leading to: (a) warning notice; or (b) fine of up to $1000; or (c) enforceable undertakings | Breach of legislation regulations, policies or guidelines leading to an administrative resolution | No issues |
| Asset impact | Equipment destruction, repair not possible, asset repair greater than original cost of works | Equipment damage repaired at a cost of between 50 % and 100 % of original cost of works | Equipment damage repaired at a cost of between 15 % and 50 % of original cost of works | Equipment damage repaired at a cost of between 2 % and 15 % of original cost of works | Simple equipment damage with no or same day repair at a cost of less than 2 % of original cost of works |

## 3.4 RISK CRITERIA

The likelihood and consequences of a risk occurring were used to determine the risk rating of either catastrophic, major, moderate, minor or insignificant. The matrix below was used to provide a visual method of categorising risks based on their risk rating.

To determine the risk rating, the Likelihood rating is added (+) to the Consequence rating. The addition of the two numbers produces a continuum number that is a number from 2 through to 10. (Table 4).

***Table 4: Risk matrix rating***

| Consequence (how serious) | Likelihood (how often) | | | | |
|---|---|---|---|---|---|
| | Rare | Unlikely | Possible | Likely | Almost certain |
| Catastrophic | Medium | High | High | Extreme | Extreme |
| Major | Medium | Medium | High | High | Extreme |
| Moderate | Low | Medium | Medium | High | High |
| Minor | Very low | Low | Medium | Medium | Medium |
| Insignificant | Very low | Very low | Low | Medium | Medium |

The risk treatment options, which are available for the treatment of risks, are based on five main concepts:

***Table 5: Risk Treatments***

| | | |
|---|---|---|
| **Avoid:** | Do not proceed with the activities that create the risk. | |
| **Treat:** | Find and implement measures that ensure the risk is monitored and mitigated. Control involves reducing the likelihood and/or consequence. | |
| | Change the likelihood: | Reduce the likelihood of an adverse event occurring through preventative measures. E.g., Training, Awareness, Procedures, Asset Management. |
| | Change the Consequences: | Reduce the size of the losses associated with undertaking an activity. E.g., Emergency response, Contingency and Disaster recovery plans. |
| **Share:** | Risks are shared with suppliers, business partners or other organisations Not considered applicable for the subject facility. | |
| **Transfer:** | Risk or part of a risk is transferred to another party. Even though the risk may have been transferred, it should be noted that it still exists. Not considered applicable for the subject facility. | |
| **Retain:** | Retention of a risk, primarily where no other options exist, or it is not commercially feasible to treat it in any other way. Only really acceptable for Low to Medium risks | |

## 3.5 FIRE SPREAD ACCEPTANCE CRITERIA

- IEEE Std 979-2012:

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

IEEE Std 979-2012
IEEE Guide for Substation Fire Protection

**Table B.3—Radiant heat flux level and damage**

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

***Figure 3: Typical radiant heat flux intensities-based IEEE Std 979-2012 [3]***

- AS 1530.4-2014:

Where other façade/lining materials are present in adjoining building or equipment, Table A3 of AS 1530.4-2014 [4] contains a listing of heat flux required for radiant ignition for piloted and unpiloted ignition. The heat flux ($q_{cr}$) level for non-piloted ignition is taken as 25 kW/m$^2$. Refer to Figure 4.

Typical radiant heat flux intensities to cause various phenomena are tabulated in Table A3.

**TABLE A3**

**TYPICAL RADIANT HEAT INTENSITIES FOR VARIOUS PHENOMENA**

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

***Figure 4: Typical radiant heat flux intensities based on AS 1530.4-2014***

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.

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# 4 BESS Facility Description

## 4.1 Location

The Palmerston BESS is located at Cressy Tasmania (1440 Saundridge Road,Cressy TAS 7302), to the north of the existing Palmerston Substation as shown below (Figure 5).

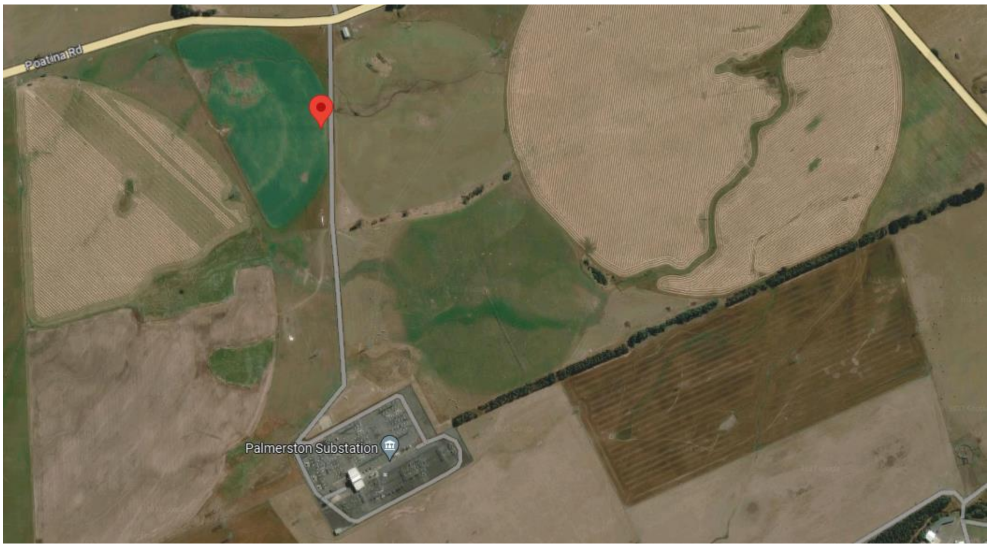


***Figure 5: Site Location***

The subject Palmerston BESS is bounded by the existing Palmerston Substation to the south (10m to 24m apart), and by private lands to the north, west and east sides (separated by not less than 4m roads from each other).


***Figure 6: Site geography***

### 4.1.1 Land Zones

The site and its surroundings are private lands (Figure 7) in accordance with the Bushfire Risk Management Plan 2021, and are either modified lands or native grasslands (Figure 8) that are part of the Fire Management Area [2].

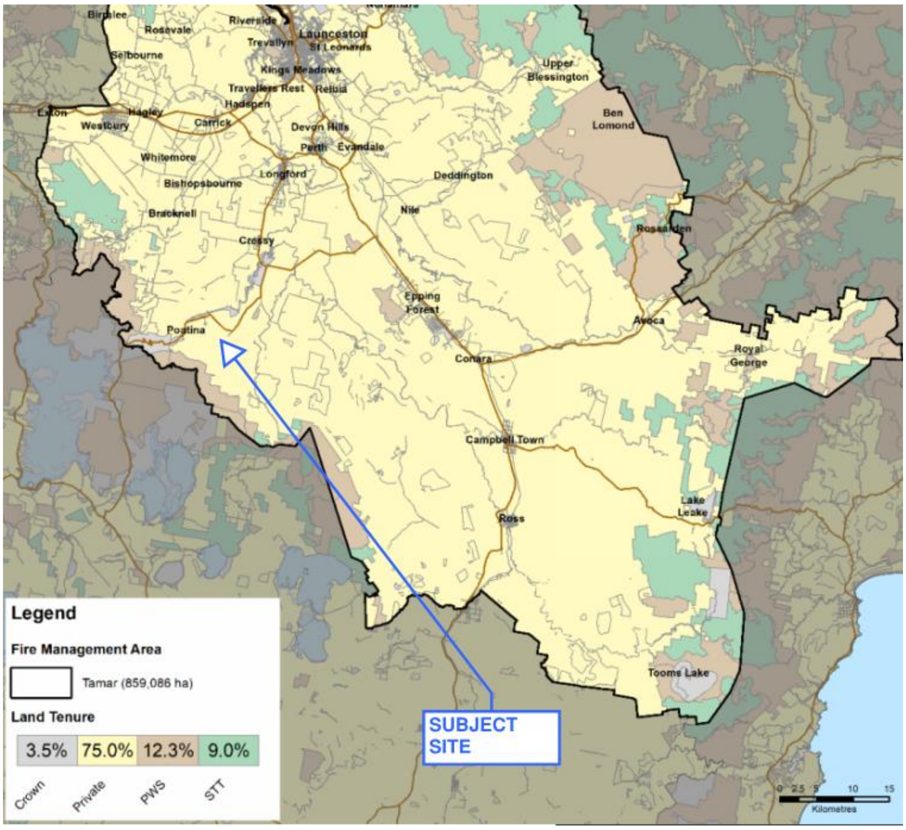


*Figure 7:Cressy Private Lands*

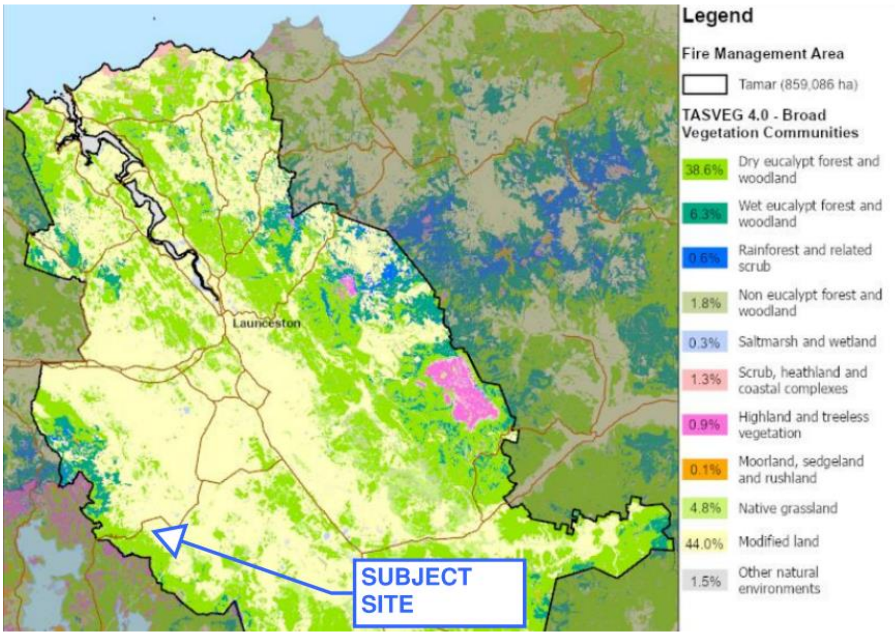


*Figure 8:Native Grasslands*

#### 4.1.2 Cressy weather conditions

In accordance with the available data, the average weather conditions on site are the following, based on the Launceston Airport Climate statistics:

- The maximum average temperature es 16.9°C and the highest temperature can reach up to 24.1°C.
- The mean relative humidity is 86.2%.
- Average speed of the wind is 15 kmph (4.16 m/s), and it remains calm 40% of the time.

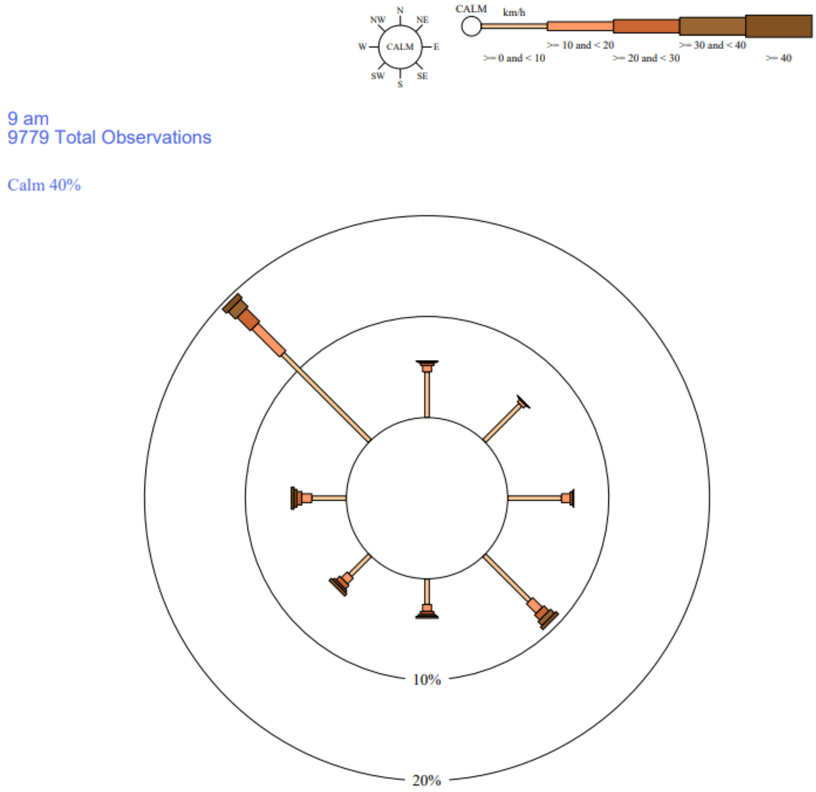


***Figure 9 – Palmerston wind statistics***

### 4.2 FACILITY LAYOUT

#### 4.2.1 General

Palmerston BESS facility is as presented in the plans in Appendix A.

The equipment part of the new facility is the following:

- Battery storage arrays.
- Inverters and transformers.
- A room for operation and maintenance purposes.
- An open carpark.
- Water tanks.

As part of the layout and safety measures, there are 10m wide firebreak on the northwest boundary and 4m wide road access as shown in Appendix A. The battery array has the below layout distribution.

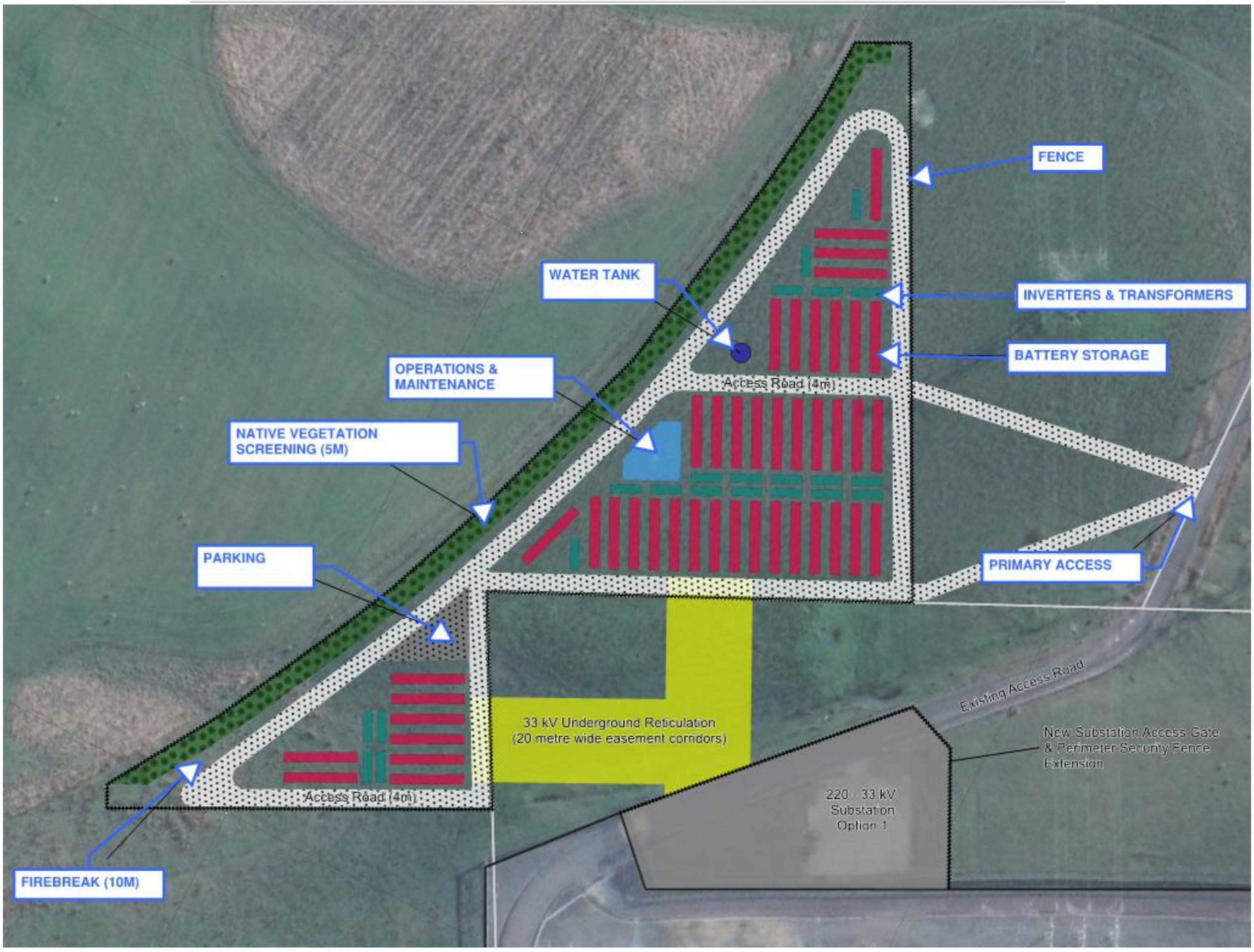


***Figure 10 - BESS array layout***

The facility will be enclosed within a security fence.

#### 4.2.2 Adjacent Properties

The immediate allotments are private lands to all sides which are part of the Fire Management area (Figure 7 and Figure 8). A fire can occur and spread due to a grassfire; hence a bushfire assessment is addressed in Section 6.4.

The existing Palmerston Substation to the south has equipment that is not less than30m away from the proposed development. Given the distance the risk of fire spread between the allotments is not expected.

Given the results of the fire modelling, fire spread beyond the unit of fire origin or facility is not predicted to occur. The surrounding land use is also not predicted to result in fire spread to the facility (refer to Section 6.5 of this document).

### 4.3 FIRE BRIGADE

#### 4.3.1 Fire Brigade Stations

The closest fire brigade station is Cressy Fire Brigade, located at 16.2km away (Figure 11). The fire brigade will access the subject site from the north via Poatina Road.

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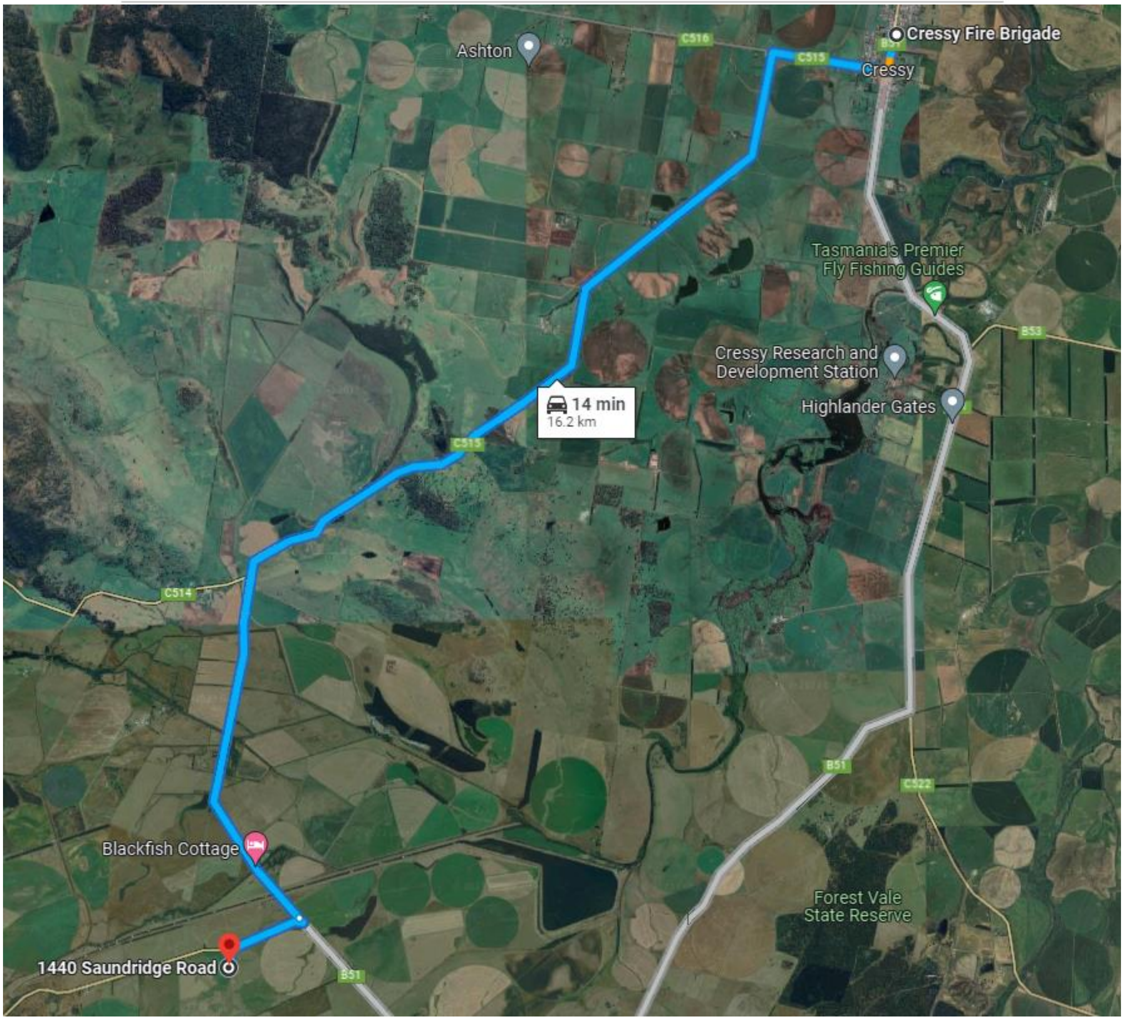


***Figure 11: Cressy Fire Station***

### 4.3.2 Fire Brigade Access

The allotment has 2 access roads on the east side and the southwest corner is to have an access road from the north (refer to Appendix A and Figure 12 below). Two alternative access roads are provided to facilitate the fire brigade intervention procedures, and to assure access to all site in case one of the access road is obstructed.

The access roads are not less than 4m wide as required by the CFA guidelines.

The water tank and main facilities for fire brigade intervention purposes are located on the west side of the allotment next to one of the internal roads so the fire brigade intervention is facilitated (see Figure 12 and Appendix A).

Attack fire hydrants are to be located around the fire track such that all areas can be fully covered in accordance with AS 2419.1-2005.

There is a 4m wide road around each BESS section to make sure the fire brigade can reach a fire from either side.

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***Figure 12: Main site access***

The hardstand surface that is required by AS 2419.1–2005 to be provided to serve feed and attack fire hydrants as well as fire brigade booster connections will be designed in accordance with CFA Guideline (section 7.5) and FRV Guideline 13, Version7, August 2017, i.e.:

- To withstand a uniformly distributed load over the entire area of 7 kPa or 0.7 tonnes/m$^2$ and a continuous water discharge from a fire brigade appliance. (This is to prevent the pumper from being undermined by water issuing from the appliance over an extended period.)
- Shall 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.

Further provisions for the fire brigade intervention procedures in accordance with the CFA Guideline are addressed in Section 7.5.

# 5 FIRE HAZARDS

The subject Palmerston BESS 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:

- Battery storage arrays.
- Inverters and transformers.

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.

## 5.1 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 and exposed in fire, this can trigger thermal runaway and lead to a fire and explosion.

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

### 5.1.1 Past BESS Fires

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

#### 5.1.1.1 Victorian Big Battery fire

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

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 Palmerston BESS location would only occur approximately 3% of the time, i.e., a probability of 0.03.

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.

#### 5.1.1.2 S&C Electric Lithium-Ion ESS fire in Wisconsin

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

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

#### 5.1.2 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.[1] Any internal production of oxygen will affect cell internal reactivity, cell internal temperature, and cell case temperature, but plays no measurable role in the flammability of vent gases.

##### 5.1.2.1 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.

###### 5.1.2.1.1 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[2]. Two tests were conducted, one with an external ignition source of 400 kW and another with an internal ignition by heater cartridges. The internal test set individual cells into thermal runaway to simulate an internal failure, and the external test led the internal cells into failure through heat exposure.

---

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

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

The results of the external ignition test determined the following:

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

The internal ignition test gave the following results:

- A fire in the Powerpack resulted in internal temperatures exceeding 1,093°C.
- Temperatures at pods below the initiator pod showed temperature ranges between 26 and 82°C.
- External temperatures reached 21°C.
- Initiator pod was damaged, but other cells were not damaged.

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

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

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

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

#### 5.1.2.1.3 FAA Energetics of Lithium-Ion Battery Failure

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

To analyse the hazard of lithium-ion batteries undergoing a thermal runaway event in an aircraft, a pallet load of 18650 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 ESS due to the number of batteries in a confined compartment.

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

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

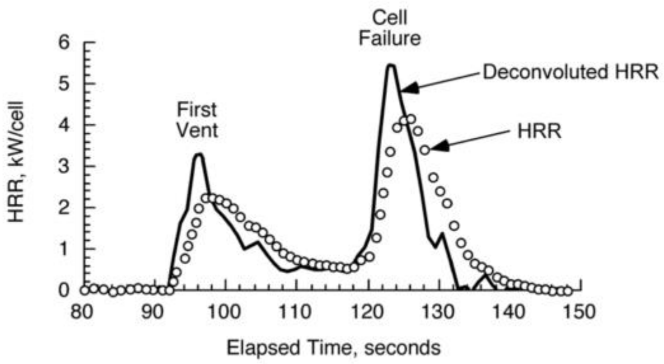


**Figure 2. Lithium-ion cell failure at 70% SOC exposed to 50 kW/m² irradiance in fire calorimeter; points are data from standard method; solid line is data corrected for instrument response**

***Figure 13: Results of a single group of batteries***

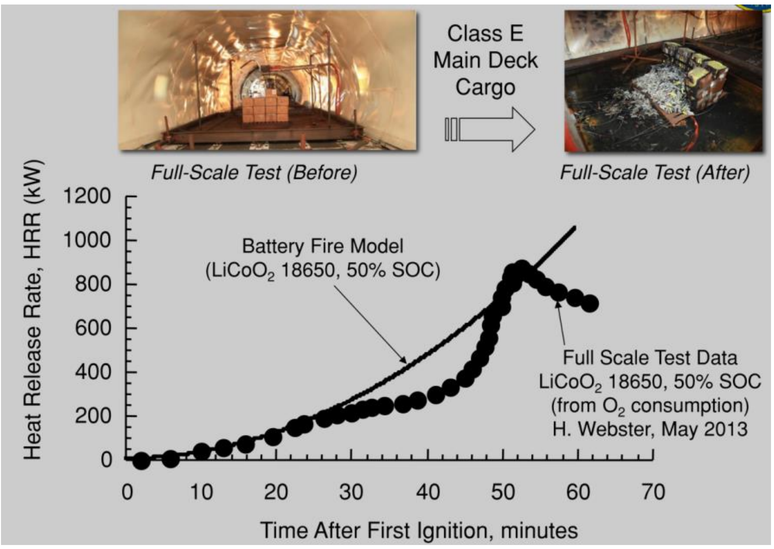


***Figure 14: Results of full-scale tests on 18650 batteries***

The peak heat release rate is approximately 1MW.

#### 5.1.2.1.4 DNV GL Considerations for ESS Fire Safety

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

[5] 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.

#### 5.1.2.2 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.

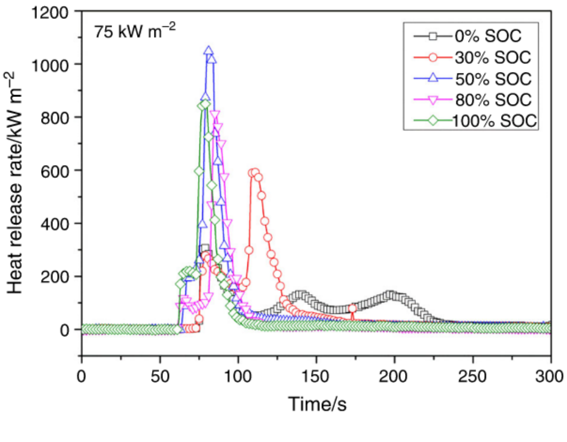


**Fig. 7** Heat release rate of batteries at different SOCs under an incident heat flux of 75 kW m$^{-2}$

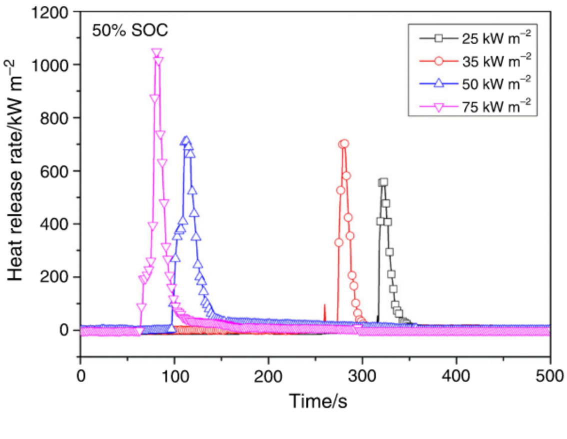


**Fig. 8** Heat release rate of batteries with 50% SOC under different incident heat fluxes

***Figure 15: Tested heat release rates for Lithium-ion batteries***

Based on the above review it is considered that each unit of the subject site will have an average heat release rate of approximately 6.2MW, considering that each units' dimensions are 2.44m x 1.72m x 3.23m (i.e., superficial area of 31m$^2$) (see Appendix A) and an average of 200kW/m$^2$.

## 5.2 TRANSFORMERS

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

- The last Australian CIGRE reliability report in 1995 came up with a failure rate for a failure causing a fire as 0.01%, i.e., $1x10^{-4}$/yr. This was for transformers above 60 kV.
- A more recent survey (not a formal survey) covering 1800 transformer tanks from 6 utilities over 7 years calculated a risk of causing a fire as 0.09%, i.e., 9 x $10^{-4}$/year (re CIGRE transformer Technology Conference 2008, presentation on Risk of Transformer fires by Arne Petersen).
- With regard to the Victorian transmission system for transformers 220 kV and above, there has only been one fire in 32 years giving a rate of 0.021%, $2.1x10^{-4}$/yr.
- The New Zealand Ministry of Commerce, now known as the Ministry of Economic Development (MED), is a government department responsible for the government ownership of public properties. The number of distribution substations and the population in New Zealand are provided in their annual statistics reports. The statistical data on the number of distribution substations in New Zealand was obtained from the MED between 1946 and 1995. Since the statistical data after 1995 was not available, the number of distribution substations between 1995 and 2006 is estimated based on the growth rate measured in the previous 50 years. The NZFS FIRS database during the 6 years period from January 2000 to January 2006 indicated 24 fire incidents, 20 fire incidents were related to distribution substations and 4 fire incidents are related to power or terminal substation. The 4 fires related to power or terminal substations were indicated to originate in switchgear areas or transformer vaults as shown in Figure 16.

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

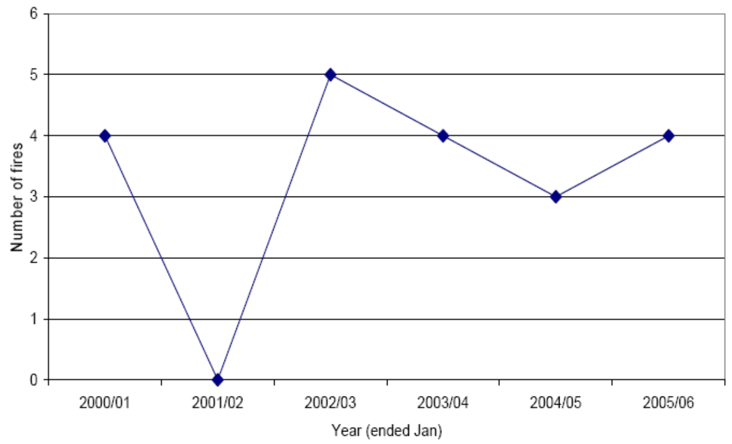


***Figure 16: Number of distribution substation fires in 2000/06 (Source NZFS FIRS)***

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# 6 RISK ASSESSMENT

## 6.1 LIKELIHOOD

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 AS5139 above.

The likelihood of a fire is therefore considered to be Rare.

Accordingly, the risk of a fire would be rated as Very Low.

## 6.2 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 unit design is known).

Given the expected equipment in the Palmerston BESS, the small transformer could produce a fire of 12.33MW (Figure 19). It is considered that the presence of the BESS unit will not present a more significant fire to the community than already exists.

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 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 Smokeview 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.

### 6.2.1 Smaller transformers

Small transformers and inverters are located between each array of batteries. The transformers have a galvanised steel bund at the base of the skid.

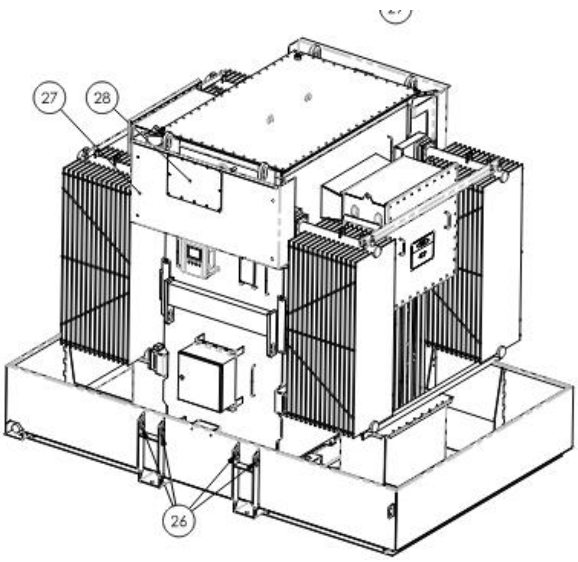


***Figure 17: Transformer showing bund at the base.***

Inverters and small transformers will use FR3 fluid oil, and their oil capacity is expected to be not more than 2,000 litres (2.0 $m^3$).

Preliminary fire and smoke modelling (with and without wind conditions) of similar transformers with an oil volume of 4,000 Litres and a bund area of 15$m^2$ have shown a heat release rate of 12.33MW (Figure 18 and Figure 19).

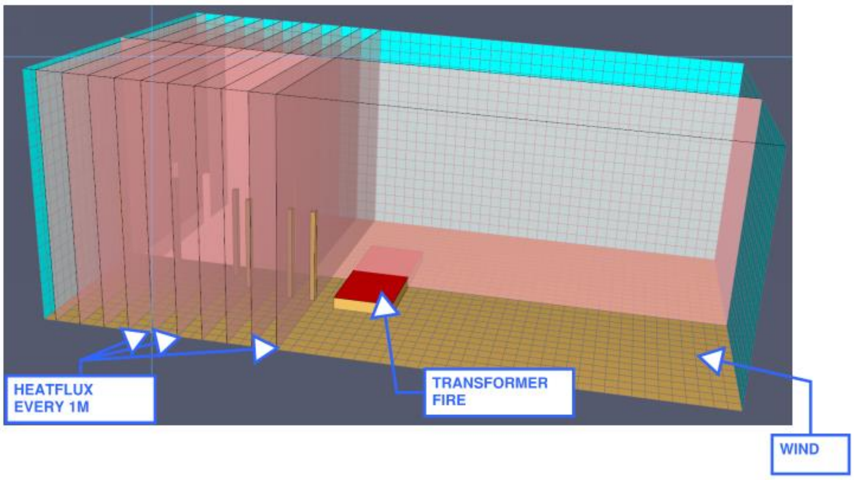


***Figure 18: Preliminary fire and smoke modelling***

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| | | | |
|---|---|---|---|
| Volume oil | 4000.00 | L | |
| | 4.00 | $m^3$ | |
| **Bund** | | | |
| L | 6.00 | m | |
| W | 2.50 | m | |
| H | 0.27 | m | |
| Ideal mass loss | 0.039 | $kg/sm^2$ | |
| kb | 0.70 | $m^{-1}$ | |
| $X_x$ | 0.70 | Combustion efficiency | |
| X | 2.19 | | Distance between centre of source and target |
| A | 15.00 | $m^2$ | |
| V Bund | 4.00 | $m^3$ | |
| | | | |
| D | 4.37 | m | |
| m" | 0.037 | $kg/m^2.s$ | $\dot{m}'' = \dot{m}''_{\infty}(1 - e^{-k\beta D})$ (Equation 3.6, *Enclosure Fire Dynamics*) |
| Hc | 3.160E+07 | J/kg | |
| q | 822.20 | $kW/m^2$ | |
| Q | 12.33 | MW | $\dot{Q} = A_f \dot{m}'' \chi \Delta h_c$ (Equation 3.5, *Enclosure Fire Dynamics*) |
| Qc | 8633.1 | kW | |
| Density Oil | 890.00 | $kg/m^3$ | |
| Mass Oil Theoretical | 3560.00 | kg | |
| Duration Theoretical | 106.42 | Minutes | |
| | 1.77 | hours | |
| Mass oil Bund | 3560.00 | kg | |
| Duration Bund | 106.42 | Minutes | |
| | 1.77 | hours | |

***Figure 19: HRR Calculation small transformers***

Table 6 below lists the distance of the closest equipment/building to the small transformers (assuming a fire will occur to the transformer shown below):

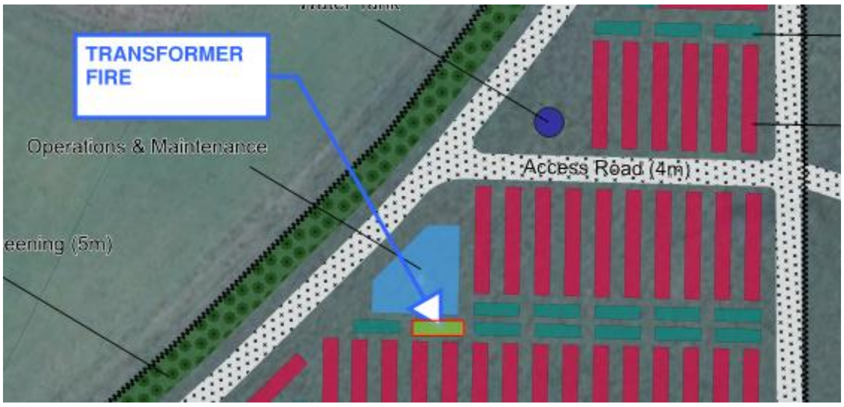



***Figure 20: Transformer fire location***

***Table 6: Distance between equipment***

| Equipment to assess | Adjoining equipment | Distance (m) |
|---|---|---|
| Transformer | Transformer/Inverter | 2.3 |
| | Battery array | 1.1 |
| | Maintenance Rooms | 1.1 |

Table 7 below summarizes the average heat flux received at different distances from a fire in the small transformers and the switch gears.

***Table 7: Heat flux results (Red is not acceptable)***

| Distance (m) | Incident Radiation (kW/m²) | |
|---|---|---|
| | No wind (Figure 21) | Wind 4.16m/s (Figure 22) |
| 1.0 | 21 | 48 |
| 2.0 | 17 | 47 |
| 3.0 | 12 | 21 |
| 4.0 | 6 | 14 |
| 5.0 | 5 | 9 |

The results indicate that when wind is not present, the maximum heat flux levels received at further than 1.0m are lower than the critical heat flux to damage process equipment (i.e., 37.5kW/m²) (Figure 21).

However, when the wind is present, there is a risk of fire spread within 2.0m, heat flux levels are above the critical heat flux to damage process equipment (Figure 22).

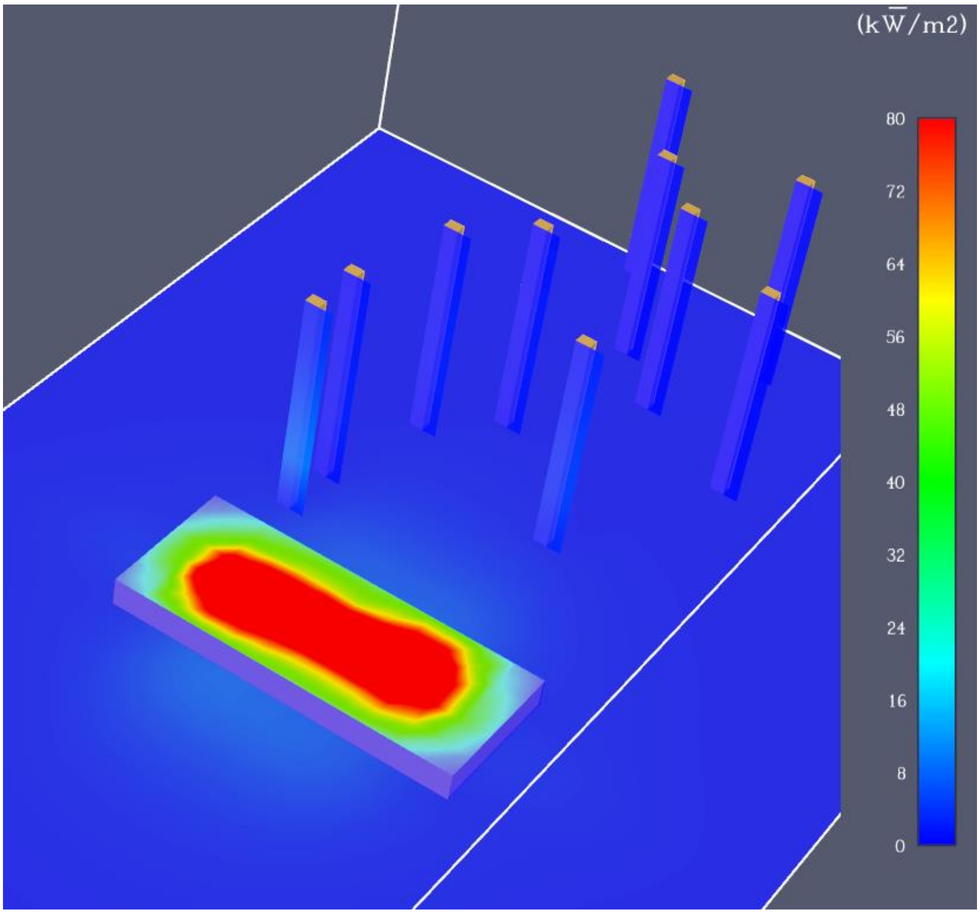



***Figure 21: Radiant heat flux intensities without wind***

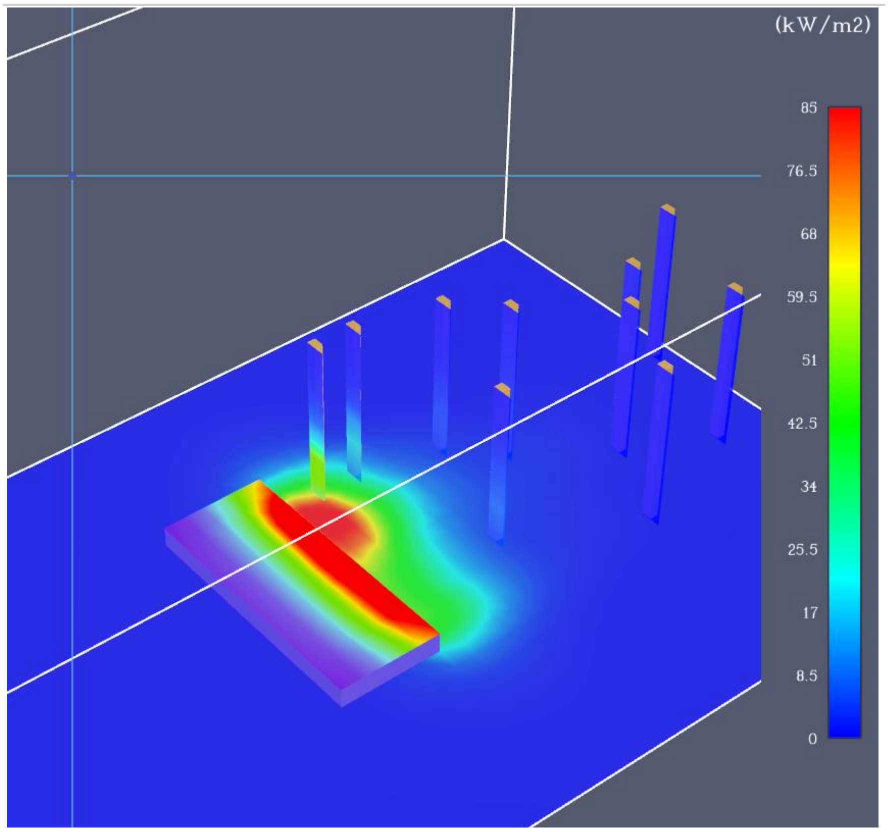



***Figure 22: Radiant heat flux intensities with wind***

The above results consider the worst-case scenario where the transformer reaches flashover, however the transformer counts with protection that will advise staff about any issues that will mitigate the risk of fire. Furthermore, considering the above results where fire can damage process equipment and structures within 2.0m:

- The operations and maintenance room's walls that face the transformers and batteries will have non-combustible façade materials and brick veneer to prevent fire spread.
- The inverter/transformers will be separated from each other and from the battery storage units at least 1.5m.
- The 4.0m radius is not extended given the wind remains with a lower speed most of the time (refer to Section 5.1.1).

Also, the fire brigade operations may be impacted within a distance of 8m from the transformer due to a heat flux higher than 3.0 kW/m$^2$ (Figure 23) with wind conditions (the black area has a heat flux higher than 3.0 kW/m$^2$).

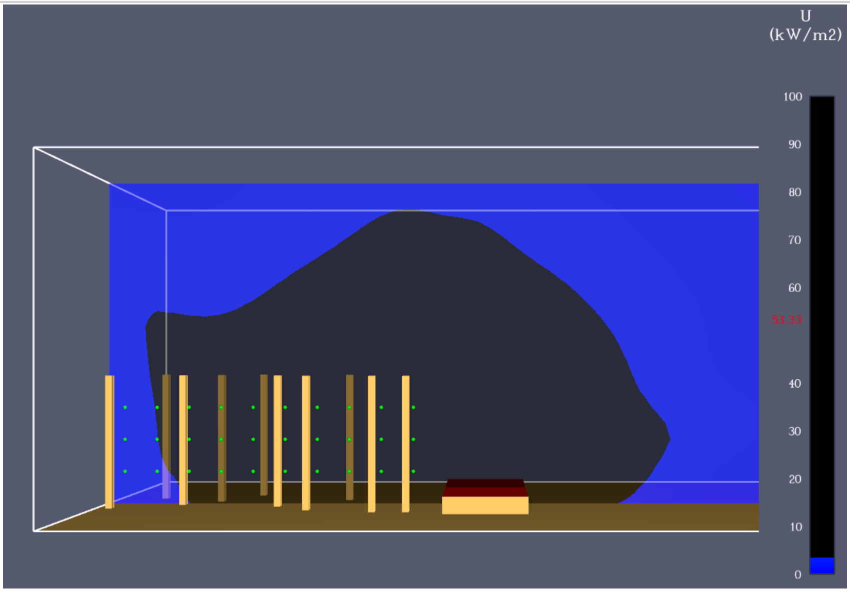



***Figure 23: Radiant heat flux higher than 3kW/m²***

It is noted that compared to a real fire scenario in the subject allotment, the presented results are conservative given the size of the fire. The expected heat flux in a real fire scenario will be lower than shown in the preliminary modelling at the different distances from the transformer.

### 6.2.2 Battery Storage Unit Fire

The battery storage units consist of a modular design that contains batteries, thermal management equipment, air conditioning and essential safety systems.

As described in section 5.1.2.2, in accordance with Zhi Wang's report and the dimensions of the battery storage, if a storage unit is on fire, it will achieve an average heat release rate of approximately 6.2MW.

A flashover fire within a battery storage unit has been modelled in accordance with layout shown in Appendix A.

Each energy segment has varied compartments. The main 3 compartments for this assessment are the batteries stored within the lower compartment, HVAC (Heating, Ventilation, and Air Conditioning) units on top, and a ladder tray (Figure 24).

The HVAC units have an air intake grid at the top and an exhaust on the roof of the battery storage unit (Figure 24). Given a fire, the air ducts between compartments will allow fire and smoke to spread throughout the battery storage unit without restriction due to their buoyant nature. Other possible holes/connection between inner compartments will be assumed to be part of the air conditioning system for modelling purposes and are not modelled.

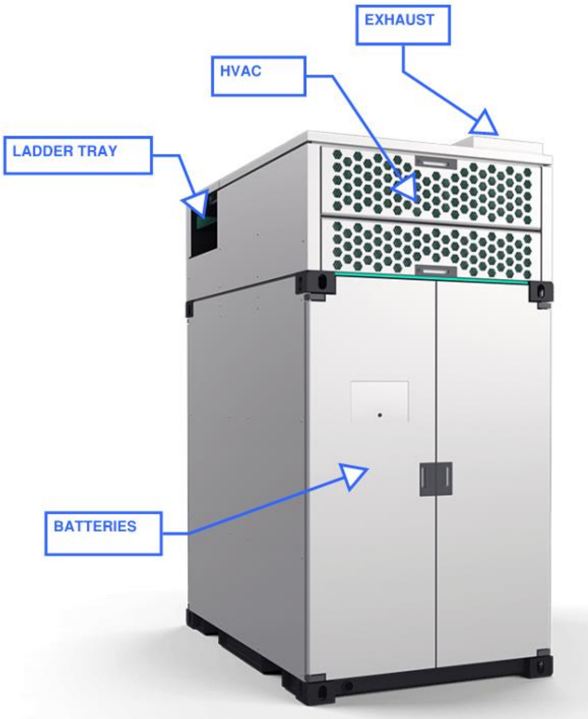



***Figure 24: Battery storage unit.***

The model and the scenario described above, demonstrated the fire spread between battery storage units is not expected if flashover occurs:

- When flashover occurs, flames and smoke will vent mainly through the exhaust on top and the grid at the front top of the battery storage unit (Figure 25). The heat flux level at the next row of battery storage units (i.e., 13.7kW/m$^2$ shown in Figure 28) is below the threshold for non-piloted ignition (i.e., 25kW/m$^2$) and damaged to unprotected metal (i.e., 30kW/m$^2$) as permitted by the of IEEE Std 979-2012 [3] (refer to section 3.5 and Figure 27 and Figure 27).

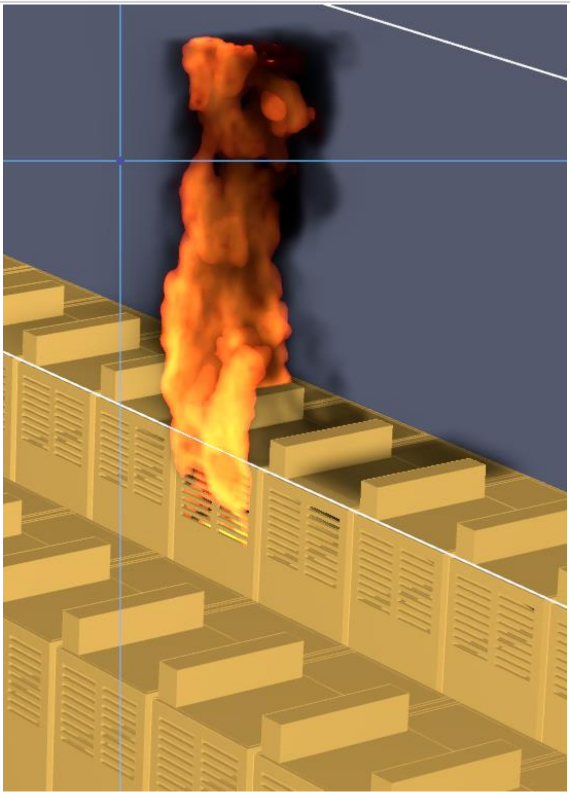


*Figure 25: Heat flux at next Battery storage Units row (2.4m apart).*

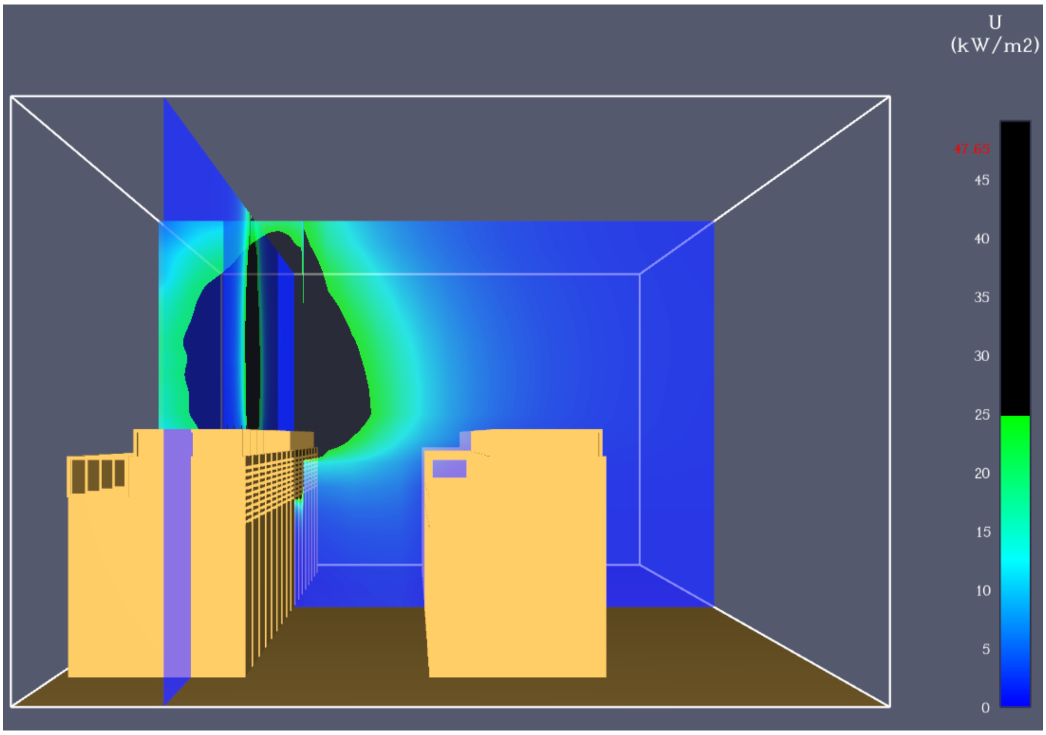



*Figure 26: Heat flux thresholds (lateral view).*

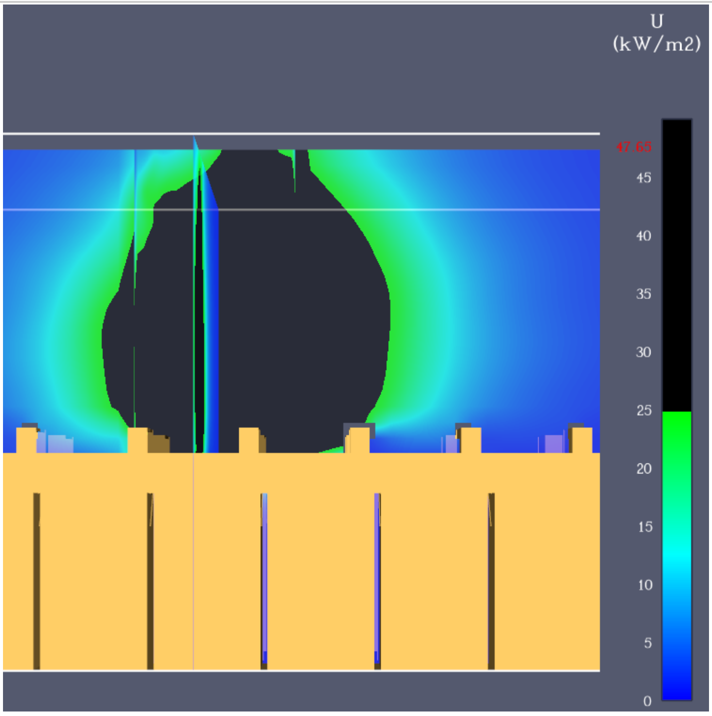



*Figure 27: Heat flux thresholds (front view).*

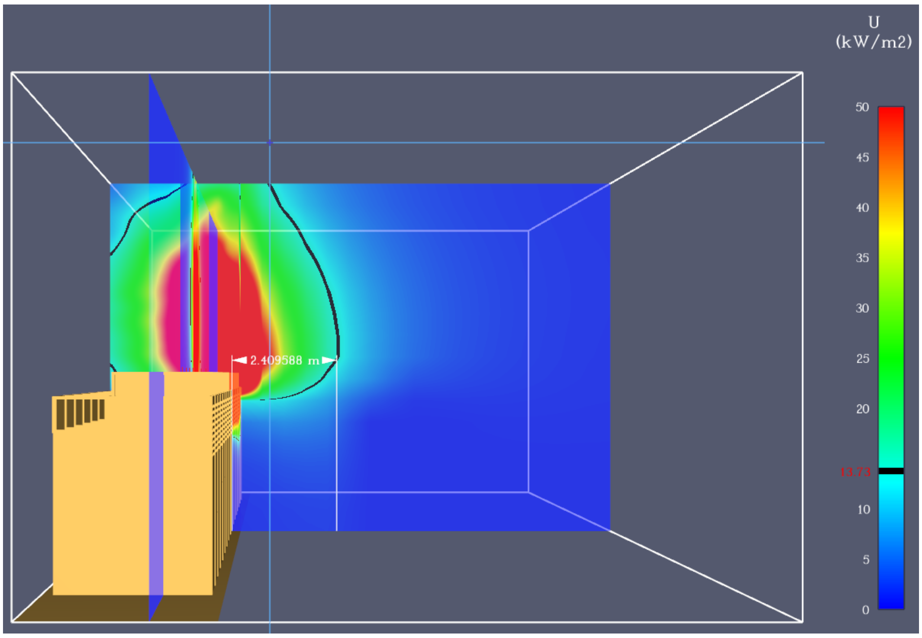



*Figure 28: Maximum Heat flux.*

- Although fire spread is not expected, some smoke spread between battery storage units is expected through the ladder tray area, as it has a ventilation grid connected to the area of the HVACs. The smoke spread is not expected to affect or stop the operation of the adjoining segment units given the buoyant effect of smoke, temperature of smoke, and the location of the smoke detectors, which are located at the lower battery compartment of the energy segment.

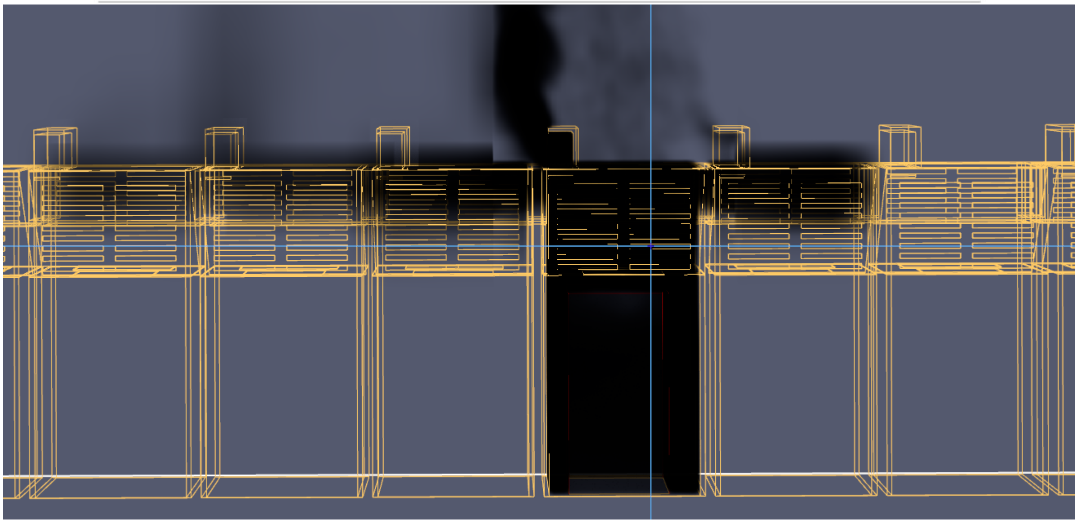


***Figure 29: Smoke spread between battery storage units.***

- Considering the smoke spread above, heat flux through the ladder tray area is also assessed with a threshold of 20kW/m$^2$ in accordance with of IEEE Std 979-2012 [3] (refer to section 3.5) due to the presence of cables. The model suggests that heat flux higher than 20kW/m$^2$ will happen intermittently in a small section of the adjoining energy segments.

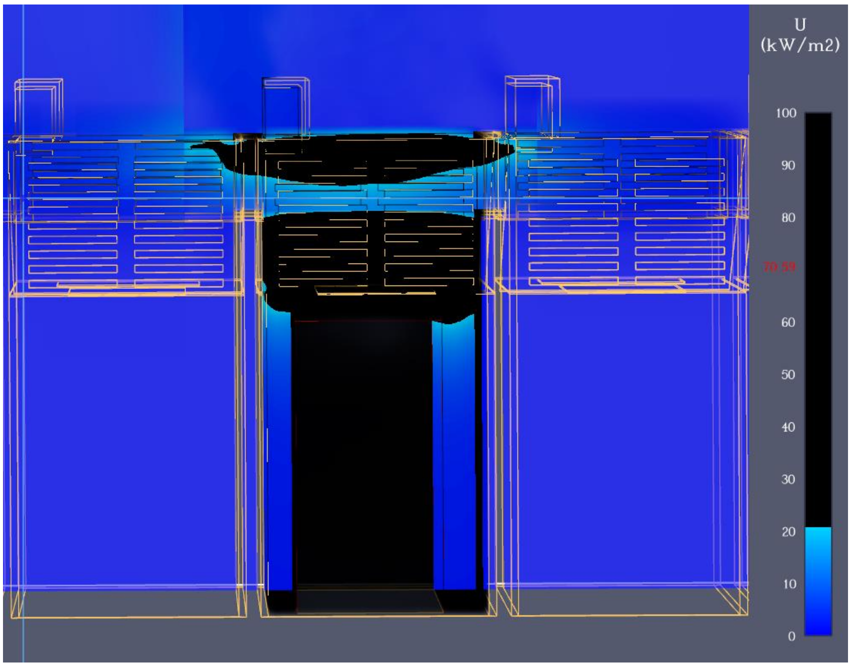



***Figure 30: Heat flux through the ladder tray area.***

The above results however are subject to a flashover fire. In accordance with the Thermal runaway tests of the batteries, a battery will release gases between 41 and 49 minutes. At this stage the smoke detector is expected to detect the smoke and shut down the energy segments as part of the fire safety system. A signal is sent so staff will proceed with the required maintenance procedures to stop the thermal runaway of the battery and prevent a potential fire and smoke spread.

## 6.3 ADJACENT BUILDINGS/ALLOTMENTS

The adjacent buildings allotment are private grassland areas and are expected to be industrial facilities that have either a compliant fire rated wall or a 3m set back from the boundary in accordance with the NCC DtS provisions.

The batteries are set back at least 6.0m 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 from the boundary it is considered that the likelihood of a fire and the consequence are no worse than in the general community.

## 6.4 FIRE IN OTHER AREA OF THE FACILITY

The facility contains a room for operation and maintenance purposes. The fire associated with these buildings are considered to be no greater than a small office type building. The room is located approximately 15m from the boundary.

Based on the International Fire Engineering Guidelines the likelihood of an office fire is $6.2 \times 10^{-3}$ per year and a fire size of approximately $250 kW/m^2$. Accordingly, the peak fire size is predicted to be 37MW assuming adequate ventilation.

Given the separation distances to the battery units and other areas of over 4.0m it is considered that the risk of fire spread is extremely low and significantly less than that for a building with NCC compliant separation distances (3m to the boundary) that are considered to represent the community acceptance level for fire spread.

## 6.5 BUSHFIRE ATTACK LEVEL (BAL) ASSESSMENT

The following BAL review has been performed in accordance with AS3959-2018, using the 6 step Simplified Procedure (Method 1) in Section 2.

The adjoining allotments located approximately 6m from the relevant equipment are private lands that have managed grassland, as shown in Figure 7 taken from the Bushfire Risk Management Plan 2021.

(1) ***FDI Classification:***

In accordance with AS3959-2018 Table 2.1, Victoria has an average FDI of 100.

(2) ***Vegetation classification:***

The vegetation classification has been done based on pictures above.

Given that the adjoining allotments have managed grassland located at 25m at 0 degrees slope, the vegetation is classified as Group G Grassland (figure below).

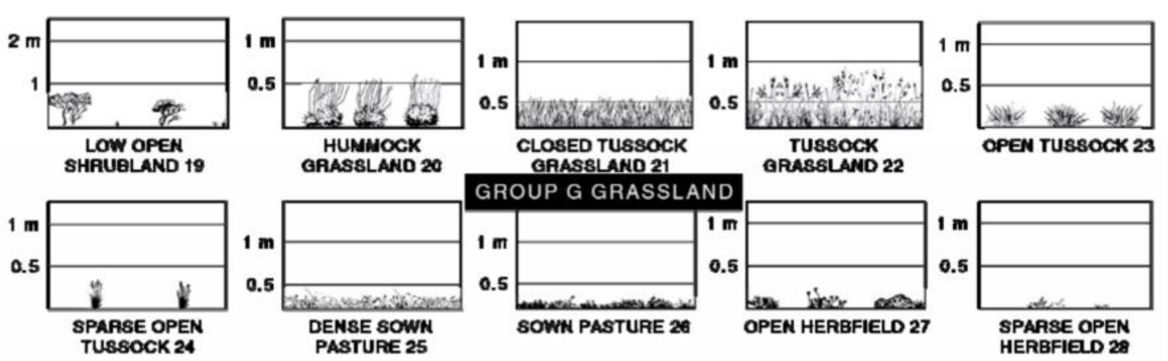



***Figure 31: Grassland types.***

(3) ***Distance of site from the vegetation:***

The grassland is located at least 6.0m from the equipment.

(4) ***Effective slope:***

The grassland is slope is 0 degrees.

(5) ***BAL Determination:***

In accordance with AS3959-2018, Section 2.2.3.2(f) the grassland is classified and regarded as a low threat (i.e., BAL-LOW), given the flammability, content and low fuel load.

(6) ***Construction provisions:***

Given the above, AS3959-2018 does not suggest or require any construction provisions to be included as part of the design (refer to Appendix C).

# 7 COMPARISON WITH RELEVANT STANDARDS

## 7.1 AS 5139 ELECTRICAL INSTALLATIONS – SAFETY OF BATTERY SYSTEMS FOR USE WITH POWER CONVERSION EQUIPMENT

AS NZS 5139 2019 specifies requirements for general installation and safety requirements for battery energy storage systems (BESSs), where the battery system is installed in a location, such as a dedicated enclosure or room, and is connected with power conversion equipment (PCE) to supply electric power to other parts of an electrical installation.

Clause 2.2.3 indicates a BESS as having the following components.

a) Power Conversion Equipment (PCE).

b) Battery Interface and Connection.

c) Battery System.

Table 3.1 classifies various batteries by the hazard type as reproduced below:

**Table 3.1 — Hazard classifications by battery type**

| Battery chemistry | Electrical hazard | Energy hazard | Mechanical hazard | Fire hazard: level 1 or 2 | Explosive gas hazard | Chemical hazard | Toxic fume hazard |
|---|---|---|---|---|---|---|---|
| Lead acid | ✓ | ✓ | ✓ | Level 2 (Note 2) | ✓ | ✓ | ✓ |
| Nickel alkaline | ✓ | ✓ | ✓ | Level 2 (Note 2) | ✓ | ✓ | ✓ |
| Lithium ion | ✓ | ✓ | ✓ | Level 1 (Note 1) | ✓ (Note 3) | N/A | ✓ |
| Flow | ✓ | ✓ | ✓ | N/A | ✓ (Note 4) | ✓ | ✓ (Note 4) |
| Hybrid ion | ✓ | ✓ | ✓ | N/A | N/A | N/A | ✓ |

**Key**

N/A = not applicable

NOTE 1 Lithium ion pre-assembled battery system equipment or pre-assembled integrated BESS equipment conforming to the *Best Practice Guide: battery storage equipment — Electrical Safety Requirements* are N/A for this hazard classification.

NOTE 2 Lead acid and nickel alkaline based batteries with cases that conform to V0 specification in accordance with relevant product standards are N/A for this hazard classification. Refer to Clause 3.2.6.2.

NOTE 3 Lithium chemistries that release hydrogen under fault conditions should be considered an explosive gas hazard, e.g. lithium manganese.

NOTE 4 Flow batteries having an acidic water-based solution have a significant risk of producing explosive gases and toxic fumes.

NOTE 5 Where the table or the notes state N/A that is only related to the classification level for Table 3.1, so as to assist in clarifying action required to be taken as outlined in Sections 4, 5 and 6. This is based on accepted knowledge, additional actions or other measures in place to minimize the risks so far as is reasonably practicable for the identified hazard, and it is not intended to necessarily indicate any particular hazard does not exist for the particular battery type.

Lithium-Ion batteries would have a fire hazard level of 1. It is also noted that a BESS unit that complies with the Best Practice Guide is not covered by the standard.

Requirements and assessment from AS NZS 5139 2019 are listed below:

- Clause 3.2.6.1 states that "battery systems and BESS's shall be installed in such a manner that, in the event of a fire originating within the battery system or battery energy storage system, the spread of fire will be kept to a minimum."

  The likely risk of fire spread was modelled as part of the fire engineering assessment in Section 6. However, given the separation between rows of battery storage units is not less 2.4m, it is considered that the proposed facility complies, and fire spread is not expected.

- Note 5 to clause 3.2.6.3 Lithium-Ion Batteries states:

  NOTE 5: Lithium-ion pre-assembled battery system equipment or pre-assembled integrated BESS equipment conforming to the BEST Practice Guide: battery storage equipment – Electrical Safety Requirements are considered to minimize the risks so far as is reasonably practicable for the identified hazard and are not applicable for this fire hazard classification (see Table 3.1).

- Clause 4.2.1 requires that a risk assessment be performed. This fire risk assessment report complies with this requirement.

- Section 4.2.4 relates to a BESS in a room and is not applicable to the facility. However, the clause refers to the need for separation from combustible materials and refers to the need for separation of 300mm from the wall. Given the separation distances to other buildings and adjacent allotments, it is considered that the facility complies.

- Clause 4.3.4 requires that where the BESS is installed within a building with a fire indicator panel that a detector be placed in the room with the BESS. It is considered that the monitoring of the devices linked to the operator who can call the brigade is an acceptable detection system.

- Clause 4.3.8 states that where an alarm system is installed within a BESS it shall be installed so that on an alarm it causes an action to be initiated to correct the fault.

  The alarms within the BESS are monitored by the Battery Management System (BMS) that monitors current, voltage, resistance and temperature as well as a Local Control System (LCS). The LCS receives information from the BMS and relays it to United Energy instantaneously. The design is therefore considered to comply with clause 4.3.8.

- Clause 5.2.4 Protection against the spread of fire requires that the equipment shall not contribute to the spread of fire in accordance with AS3000 Clause 1.5.12 which states:

  **1.5.12 Protection against the spread of fire**

  **Protection shall be provided against fire initiated or propagated by components of the electrical installation.**

  Electrical equipment shall be selected, installed and protected such that the equipment will not—

  (a) obstruct escape routes, either directly or by the products of combustion; or

  (b) contribute to, or propagate a fire; or

  (c) attain a temperature high enough to ignite adjacent material; or

  (d) adversely affect means of egress from a structure.

  NOTES:

  1 Clause 2.9.2.5 (h) contains requirements for the placement of switchboards in or near fire exits and egress paths.

  2 Clauses 2.9.7, 3.9.9 and Appendix E contain requirements dealing with the prevention of the spread of fire.

  The fire spread was assessed in Section 6 in accordance with the current layout. It demonstrated the fire spread will be limited due to the possible sizes of the fires and the distances between equipment. The layout also provides alternatives paths to egress the allotment, hence a fire is not expected to prevent the evacuation from the site.

- Clause 6.3.4.4 requires that the BESS have a BMS that monitors all potential and controllable fault conditions that could result in fire. It is considered that the subject units have a BMS and various alarm monitoring devices that comply with the clause. Where the BMS monitors excessive temperatures or minimum temperatures or overcurrent the system is shut down and charging of the batteries disconnected as required by Clause 6.3.4.5 to 6.3.4.8.

- The BESS is required by the standard to be ventilated to avoid the building up of flammable and explosive gases which the subject unit is.

Appendix G of the standard provides information on conducting a risk assessment with respect to BESS units.

The likelihood table is provided in Table G.2 below:

**Table G.2 — Example likelihood of occurrence rating**

| Likelihood rating | Definition of likelihood of occurrence rating |
|---|---|
| Almost certain | Probability of occurrence: greater than 90 % |
| | Expected to occur whenever system is accessed or operated |
| | The event is expected to occur in most circumstances |
| Likely | Probability of occurrence: 60 % – 89 % |
| | Expected to occur when system is accessed or operated under typical circumstances |
| | There is a strong possibility the event may occur |
| Possible | Probability of occurrence: 40 % – 59 % |
| | Expected to occur in unusual instances when the system is access or operated |
| | The event may occur at some time |
| Unlikely | Probability of occurrence: 20 % – 39 % |
| | Expected to occur in unusual instanced for non-standard access or non-standard operation |
| | Not expected to occur, but there is a slight possibility it may occur at some time |
| Rare | Probability of occurrence: 1 % – 19 % |
| | Highly unlikely to occur in any instance related to coming in contact with the system or associated systems |
| | Highly unlikely, but it may occur in exceptional circumstances, but probably never will |

Based on a review of the hazards as identified in Section 5 of this report all the hazards are considered to be Rare, i.e., probability of occurrence less than 1% or $1x10^{-2}$ per year.

The level of consequence is given in Table G.1.

**Table G.1 — Typical risk consequence table**

| Consequence/ impact category | Consequence/impact rating definitions | | | | |
|---|---|---|---|---|---|
| | Catastrophic | Major | Moderate | Minor | Insignificant |
| Health and safety | Any fatality of staff, contractor or public | Non-recoverable occupational illness or permanent injury | Injury or illness requiring medical treatment by a doctor | Injury requiring first aid | No or minor injury |
| | | Injury or illness requiring admission to hospital | Dangerous/reportable electrical incident | Circumstances that lead to a near miss | |
| Environmental | High, long term or widespread impact (spill, emission, or habitat disturbance) to sensitive environment | Substantial impact — large spill or emission requiring Emergency Services attendance | Moderate impact — Spill or emission not contained on site with clean up needed | Minor cleanup/rectification — spill or emission not contained on site | Small spill or emission that has no impact on site or installation |
| | Environmental agency response with significant fine | Recovery of environment likely but not necessarily to pre-incident state | Death or destruction of protected flora or fauna | Environment expected to fully recover to pre-incident state | Clean up requires no special equipment and has no potential impact |
| | Long term recovery of environment to pre-incident state not likely | Any spill into sensitive area (wet tropics, fish habitat, potable water supply) | Environment likely to recover to pre-incident state in short to medium term | Environmental nuisance (short-term impact) caused by noise, dust, odour, fumes, light | |
| Legal and regulatory | Breach of licences, legislation or regulations leading to prosecution | Breach of legislation or regulations leading to: (a) contravention notice from authorities; or (b) court order; or (c) fine over $1000 | Breach of legislation, regulations leading to: (a) warning notice; or (b) fine of up to $1000; or (c) enforceable undertakings | Breach of legislation regulations, policies or guidelines leading to an administrative resolution | No issues |
| Asset impact | Equipment destruction, repair not possible, asset repair greater than original cost of works | Equipment damage repaired at a cost of between 50 % and 100 % of original cost of works | Equipment damage repaired at a cost of between 15 % and 50 % of original cost of works | Equipment damage repaired at a cost of between 2 % and 15 % of original cost of works | Simple equipment damage with no or same day repair at a cost of less than 2 % of original cost of works |

The battery area is not continuously occupied and the risk of a fire and occupants being present is low. The batteries are spaced well apart such that a person could turn and walk away from a fire. Accordingly, it is considered that a moderate health and safety consequence could occur in the event of a fire.

The batteries are separated from each other and the adjacent allotments such that fire spread is not predicted to occur to involve adjacent occupancies.

The site will have drainage and retention such that any impact is retained on site.

The overall consequence ranking is considered to be minor to moderate.

The resultant risk matrix is provided in table G.3:

**Table G.3 — Risk matrix table**

| Consequence (how serious) | Likelihood (how often) | | | | |
|---|---|---|---|---|---|
| | Rare | Unlikely | Possible | Likely | Almost certain |
| Catastrophic | Medium | High | High | Extreme | Extreme |
| Major | Medium | Medium | High | High | Extreme |
| Moderate | Low | Medium | Medium | High | High |
| Minor | Very low | Low | Medium | Medium | Medium |
| Insignificant | Very low | Very low | Low | Medium | Medium |

Based on the results of the quantitative assessment contained in this report a fire within the BESS is unlikely to result in further fire spread. Accordingly, the consequence is considered to be minor.

Based on a review of the above standard it is considered that the BESS unit would essentially comply with the standard and present a Very Low risk.

## 7.2 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 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 the equipment but not distances are specified.

Testing to various standards such as 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.

## 7.3 NFPA 855, STANDARD FOR STATIONARY ENERGY STORAGE SYSTEMS (IN DEVELOPMENT)

NFPA 855 is under development but details with battery systems within containerized systems.

The standard follows the US Building Code NFPA 1 – Life Safety Code and The International Fire Code in recommending the siting and location of outdoor containerized BESS as shown below.

"**Separation: Stationary storage battery systems located outdoors shall be separated by a minimum 5 feet (1.5m)** from the following:

- Allotment boundaries.
- public ways.
- Buildings.
- Stored combustible materials.
- Hazardous materials.
- High-piled stock.
- Other exposure hazards".

The subject facility complies with the above requirement as shown in the layout in Appendix A.

## 7.4 AS2067

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

The minimum separation distances are specified in AS2067 Table 6.1 unless a fire rated wall is used to provide protection.

***Table 8: AS 2067 Table 6.1***

**MINIMUM VALUES FOR SEPARATING OUTDOOR TRANSFORMERS**

A1

<table>
<tr><th>Transformer type</th><th>Liquid volume<br>(L)</th><th colspan="2">Clearance $G_1$ to other transformers or fire resistant surfaces<br>(m)</th><th colspan="2">Clearance $G_2$ to combustible building surface<br>(m)</th></tr>
<tr><td rowspan="6">Oil-insulated transformers (O)</td><td>100 ≤1000</td><td colspan="2">1</td><td colspan="2">6</td></tr>
<tr><td>>1000 ≤2000</td><td colspan="2">3</td><td colspan="2">7.5</td></tr>
<tr><td>>2000 ≤20 000</td><td colspan="2">5</td><td colspan="2">10</td></tr>
<tr><td>>20 000 ≤45 000</td><td colspan="2">10</td><td colspan="2">20</td></tr>
<tr><td>>45 000 ≤60 000</td><td colspan="2">15</td><td colspan="2">30</td></tr>
<tr><td>>60 000</td><td colspan="2">23</td><td colspan="2">30</td></tr>
<tr><td rowspan="3">Less combustible liquid-insulated transformers (K) without enhanced protection</td><td>100 ≤1000</td><td colspan="2">1</td><td colspan="2">6</td></tr>
<tr><td>>1000 ≤3800</td><td colspan="2">1.5</td><td colspan="2">7.5</td></tr>
<tr><td>>3800</td><td colspan="2">4.5</td><td colspan="2">15</td></tr>
<tr><td rowspan="3">Less combustible liquid-insulated transformers (K) with enhanced protection</td><td colspan="5">Clearances $G_1$ and $G_2$ to building surface or adjacent transformers</td></tr>
<tr><td colspan="2">Horizontal<br>(m)</td><td colspan="3">Vertical<br>(m)</td></tr>
<tr><td colspan="2">0.9</td><td colspan="3">1.5</td></tr>
<tr><td rowspan="4">Dry-type transformers (A)</td><td colspan="2" rowspan="2">Fire behaviour class</td><td colspan="3">Clearances $G_1$ and $G_2$ to building surface or adjacent transformers</td></tr>
<tr><td colspan="2">Horizontal<br>(m)</td><td>Vertical<br>(m)</td></tr>
<tr><td colspan="2">F0</td><td colspan="2">1.5</td><td>3.0</td></tr>
<tr><td colspan="2">F1/F2</td><td colspan="2">None</td><td>None</td></tr>
</table>

The subject facility will have insulated transformers with less combustible liquids and enhanced protection. The subject facility will have small transformers that will be located at the end of each row of battery storage units (shown in figure below and Appendix A).

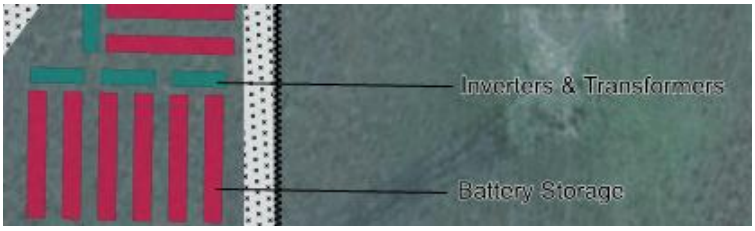



***Figure 32: Inverter and transformers***

It is understood that the transformers' specification specifies FR3 (or similar) Ester oil in lieu of the normal mineral oil. This oil would have a flash point of approximately 330°C compared to 145°C for standard oil and hence is less likely to result in a fire.

The smaller transformers are not expected to have more than 2,000 litres (2.0 m$^3$).

Table 9 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 AS2067.

***Table 9: Distance assessment***

| Equipment to assess | Adjoining equipment | Required Distance (m) | Proposed Distance (m) | Compliant (Yes/No) |
|---|---|---|---|---|
| Transformer | Transformer/Inverter | ≥ 0.9 | 1.5 | Yes |
| | Battery array | ≥ 0.9 | 1.5 | Yes |
| | Maintenance Rooms | ≥ 0.9 | 1.5 | Yes |

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

Regarding the building, the operations and maintenance room's walls that face the transformers and batteries will have non-combustible façade materials and brick veneer to prevent fire spread (Note that the brick veneer has an inherent FRL of at least 60 minutes).

## 7.5 Design Guidelines and Model Requirements: Renewable Energy Facilities, Country Fire Authority (CFA), March 2022

*Section 4.2 of the Guide states that the bushfire risk is required to be addressed according to the Victorian Planning Provisions.* Given the location of the site is within a bushfire management zone and a bushfire assessment has been performed in Section 6.5 of this document, hence it is considered that requirement has been achieved.

*Section 4.2 also recommends a fire study to Hazardous Industry Planning Advisory Paper 2: Fire Safety Study Guidelines (2011) be undertaken.* This report is considered to satisfy this recommendation.

*Section 5.3 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 small transformers are considered to be adequately separated.

- 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 at least 6.0m. The batteries are arranged such each row of the battery array is separated 2.4m from each other. These distances are considered to be acceptable based on the preliminary assessment within this report in section 6.2.

- 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 and 2 alternative access roads on the east side of the development. There is a 4m wide road around and within the facility and the batteries to facilitate access.

- 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 - The facility is in a relatively flat area free of vegetation. The closest vegetation is classified as grassland based on AS3595. AS3595 allows grassland to be excluded from the analysis.

*Section 6.1 indicates the following are low risk location attributes:*

- Grassland.
- No continuous other vegetation types within 1-20km 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 BMO applies (also refer to section 6.5).

It is considered that the subject facility complies with the above requirements and can be considered as a low-risk site.

*Section 6.2 requires the following with respect to fire brigade vehicle access:*

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

  Response - A 4.0m wide road is provided around and within the site.

- Roads must be of all-weather construction and capable of accommodating a vehicle of fifteen (15) tonnes.

  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 4m wide as required.

- 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 (12.5% or 7.1°) entry and exit angle.

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

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

  Response – All the perimeter roads are not less than 4.0m. The layout will allow alternative egress and access.

- 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 site has alternative access roads from an existing road on the east side of the allotment.

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

  Response – Hydrants will be clearly marked, and a block plan provided at the booster point.

- Static water storage tank installations must comply with AS 2419.1-2005: Fire hydrant installations – System design, installation and commissioning.

  Response – Water tanks with agreed supply (4 hours based on at least two hydrants operational) will be provided at the entrance to the facility with a compliant hard stand and booster assembly.

- 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 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, a ten (10) 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 an 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.

  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: a) A fire hydrant system that meets the requirements of AS 2419.1-2005: Fire hydrant installations, Section 3.3: Open Yard Protection, and Table 3.3: Number of Fire Hydrants Required to Flow Simultaneously for Protected Open Yards. Except, that fire hydrants must be provided and located so that every part of the battery energy storage system is within reach of a 10m hose stream issuing from a nozzle at the end of a 60m length of hose connected to a fire hydrant outlet.

Response – Table 3.3 of AS2419 is reproduced below:

**TABLE 3.3**

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

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

NOTE: Where more than one external fire hydrant, each with two valve-controlled outlets is installed and more than one outlet is required to flow, then one outlet on each of the most hydraulically disadvantaged fire hydrants has to achieve the required flow and pressure.

If the number of outlets required to flow exceed the number of fire hydrants installed, then simultaneous flow from each of the two outlets on the most hydraulically disadvantaged fire hydrant will be necessary.

Where only one external fire hydrant with two valve controlled outlets is installed and 2 outlets are required to flow, then simultaneous flow from each of the two outlets will be necessary.

The facility is approximately 11,200m$^2$ within the security fence. Two battery arrays are separated from each other not less than 6.0m apart and each group of battery array is approximately not more than 3,300m$^2$ (Figure 32). Accordingly, 2 hydrants running are required by the standard.

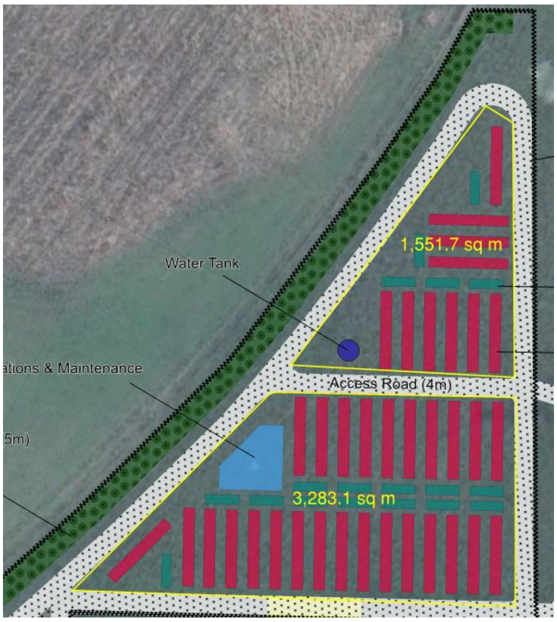



***Figure 33: Arrays of battery Storage units.***

The water storage tank is therefore required to allow for 2 hydrants at 10L/s each for four hours, i.e., 288kL.

All batteries are able to be reached by at least two hydrants.

- 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.

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

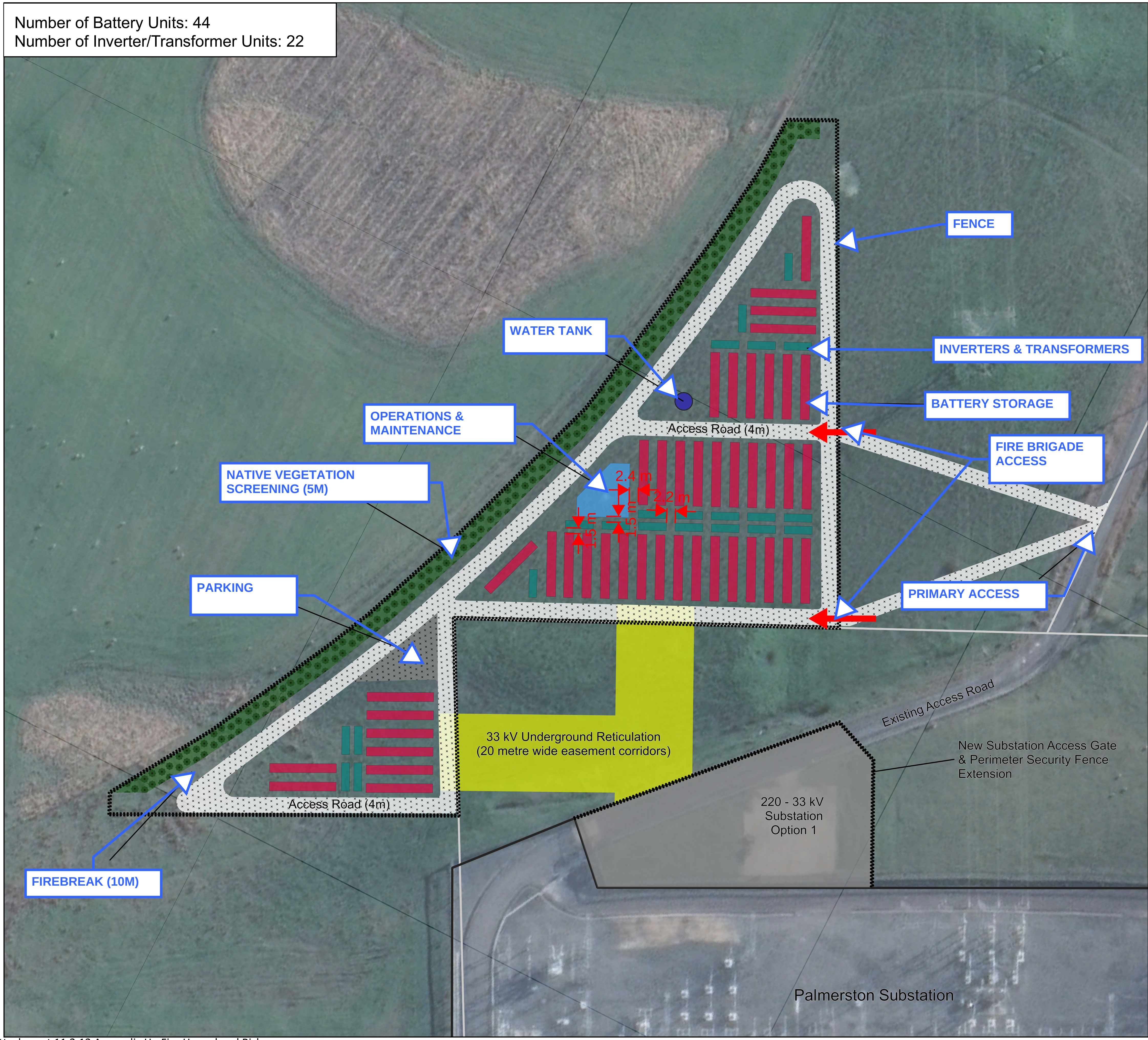
  Response – The battery units will incorporate a battery management system as well as an alarm system within the facility to enable early warning of faults. The battery containers will contain venting or pressure relief to prevent explosions.

## 7.6 SUMMARY

It is considered that the BESS facility complies with the various requirements from the standards and guidelines with respect to location, layout bushfire protection, materials of construction, monitoring systems etc.

# Appendix A. PROPOSED FACILITY LAYOUT

Number of Battery Units: 44
Number of Inverter/Transformer Units: 22




akaysha

cogency

**Concept Layout Plan**

2225 - Palmerston BESS

Parcels

**Palmerston Layout**

- Battery Storage
- Interters and Transformers
- Operations and Maintainence
- Water Tank
- Native Vegetation Screening (5m)
- Access Roads (4m)
- Parking
- Fence
- 220 - 33 kV Substation
- 33 kV Underground Reticulation

Version: 4.0

Date: 30/03/2023

0 10 20 30 m

1:900 at A3

CO

# Appendix B. VBB Fire Investigation

January 25, 2022

# Victorian Big Battery Fire: July 30, 2021

REPORT OF TECHNICAL FINDINGS

ANDY BLUM, PE, CFEI
SENIOR FIRE PROTECTION ENGINEER

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PAUL ROGERS, PRINCIPAL FOUNDER
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## Background

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

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

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

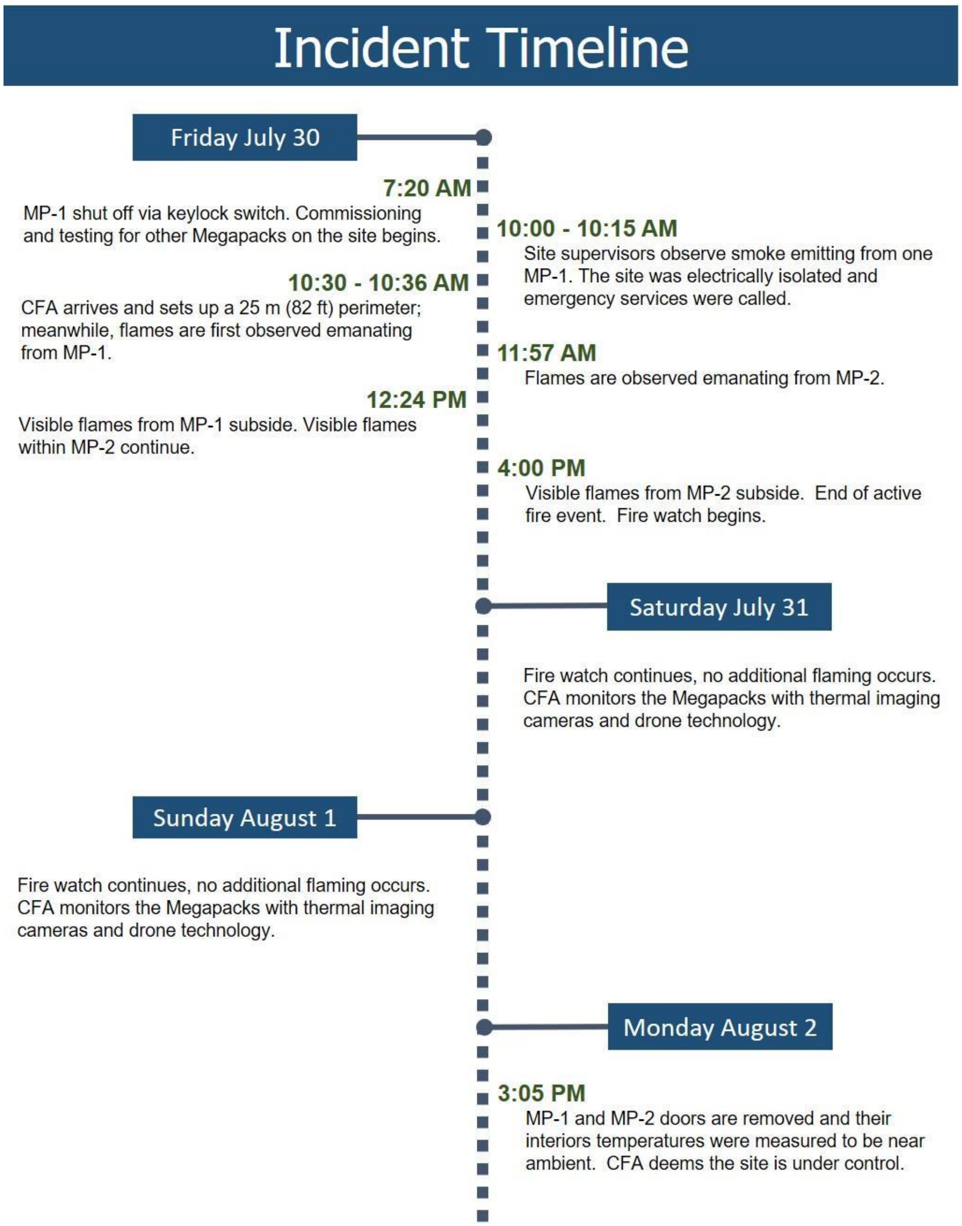
This report summarizes those investigations and analyses and has been prepared by Fisher Engineering, Inc. (FEI) and Energy Safety Response Group (ESRG), two independent engineering and energy storage fire safety consulting firms. In addition, this report provides a list of lessons learned from the fire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

## Incident Timeline

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

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

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




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

# Investigation

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

## Fire Cause Investigation

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

### Fire Origin and Cause Determination

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

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

### Contributory Factors

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

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

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

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

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

## Fire Propagation Investigation

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

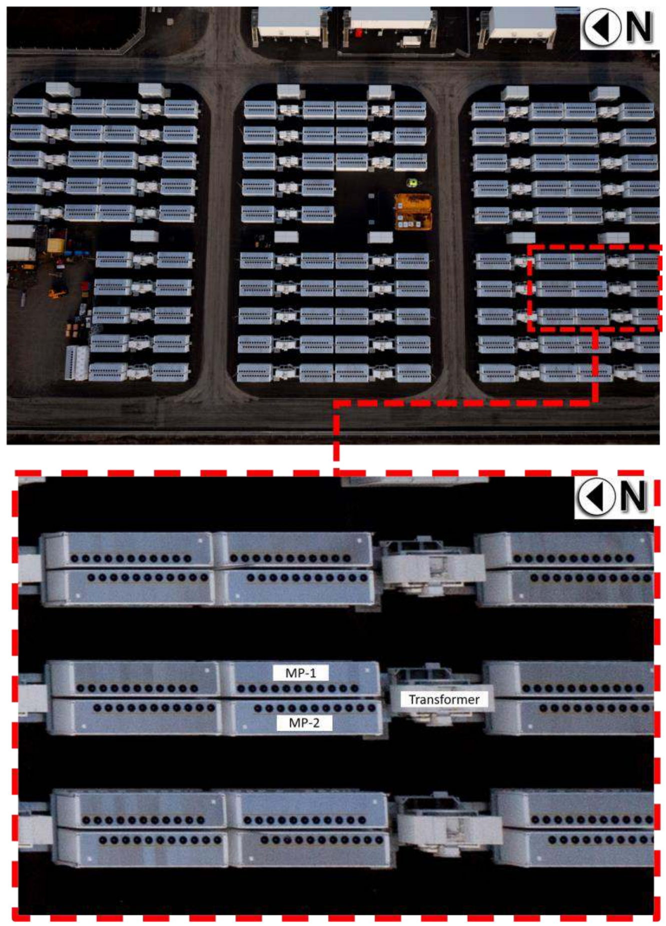



*Figure 1 VBB Megapack layout (top) and area of fire origin (bottom)*

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

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

## Fire Propagation Determination

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

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

## Contributory Factors

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

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

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

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

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

## Mitigations

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

Procedural Mitigations:

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

Firmware Mitigations:

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

Hardware Mitigations

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

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

## Emergency Response

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

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

### Key Takeaways

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

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

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

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

## Environmental Concerns

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

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

## Community Concerns

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

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

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

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

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

### Overhaul and Remediation

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

## Lessons Learned

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

### 1. Commissioning Procedures

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

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

### 2. Electrical Fault Protection Devices

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

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

## 3. Fire Propagation

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

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

## 4. Megapack Spacing

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

## 5. Emergency Response

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

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

# Appendix C. AS3959: Construction Requirements