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**Our ref: Nevertire Solar Farm Modifiation 4 Response to RFI re Hazards**

Date: 5 May 2022

Andy Nixey
Planning and Assessment Department of Planning and Environment
4 Parramatta Square, 12 Darcy Street
Parramatta NSW 2150

Dear Andy,

## Responding to requests for additional information regarding Hazards

I refer to the proposed Nevertire Solar Farm Modification 4 (SSD-8072-Mod-4). Further to our meeting on 7 April 2022, a request for additional information and comments from the Department of Planning and Environment Industrial Assessments on 7 April 2022 and our meeting on 20 April 2022, it is understood that the Department requires additional information to:

- Verify that the BESS could be accommodated within the area designated for the BESS, accounting for separation to prevent fire propagation; and
- Demonstrate that the fire risks from the BESS can comply with the Department's Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning' (HIPAP No.4).

In responding to the above, the PHA Memo prepared by SLR Consulting has been updated in April 2022 (refer Appendix A). Furthermore, additional comments from the Department have been considered as part of the updated PHA Memo.

Following further investigations into the area allocated for the BESS, the updated PHA Memo has indicated the following key items:

- the area allocated for the BESS would be more than sufficient to accommodate both of the BESS battery pack options (for example the 20-foot Tesla Megapack and 40-foot Kokam BESS pack options) being considered for the BESS facility
- the combination of sufficient separation distance and BESS unit safety systems are able to achieve the HIPAP 4 requirements for fire risk
- the codes and standards for BESSs and examination of the findings of the recent 2021 Victorian Big Battery fire have been considered in the PHA Memo

It is considered that the updated PHA Memo clarifies the misinterpretation of the BESS facility site layout, addresses and responds to the requests for additional information in that it verifies that the BESS could be accommodated within the area designated for the BESS, accounting for separation to prevent fire propagation.

In verifying the above, it is demonstrated that the fire risks from the BESS can comply with the Department's *Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning'* (HIPAP No.4).

Yours sincerely,
for RPS Manidis Roberts Pty Ltd

**Michelle Moodley**
Senior Consultant - Environment
michelle.moodley@rpsgroup.com.au
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# Appendix A
## Updated PHA Memo

# Memorandum

| | | | |
|---|---|---|---|
| **To:** | Ms Michelle Moodley | **At:** | RPS Australia Asia Pacific |
| **From:** | Dr Peter Georgiou | **At:** | SLR Consulting Australia Pty Ltd |
| **Date:** | 27 April 2022 | **Ref:** | 610.30353-M01-v3.0-20220427_excepted track changes |
| **Subject:** | Nevertire Solar Farm BESS<br>Response to RFI re Hazards | | |

**CONFIDENTIALITY**

*This document is confidential and may contain legally privileged information. If you are not a named or authorised recipient you must not read, copy, distribute or act in reliance on it. If you have received this document in error, please telephone our operator immediately and return the document by mail.*

Dear Michelle

As you are aware, SLR Consulting Australia Pty Ltd (SLR) prepared the Hazard and Risk Report (in the form of a Preliminary Hazard Analysis) to accompany Modification 4 (SSD-8072-Mod4) related to a proposed new Battery Energy Storage System (BESS) for the approved Nevertire Solar Farm.

Following submission of the modification, DPE (Department of Planning and Environment) have requested further information related to our above-mentioned report, specifically:

> - provide further information in the Preliminary Hazard Analysis for the Department to verify the separation distances between battery sub-units (containers, enclosures etc) are sufficient to ensure a fire does not propagate between the individual sub-units including:
>   - verification that the Battery Energy Storage System (BESS) would be accommodated within the area designated for the BESS, accounting for separation between BESS sub-units to prevent fire propagation; and
>   - demonstrating that the fire risks from the BESS can comply with the Department's Hazardous Industry Advisory Paper No. 4, '*Risk Criteria for Land Use Safety Planning*';

The enclosed responds to the above request for further information. In summary, SLR is confident that proposed BESS will satisfy the issues raised regarding adequate BESS unit separation and the fire safety requirements of Hazardous Industry Planning Advisory Paper (HIPAP) No.4.

Please do not hesitate to contact SLR if further information is required.

Yours sincerely

DR PETER GEORGIOU
Technical Director

Checked/ Authorised by: CS

# 1 BACKGROUND TO PROPOSED BESS

The approved (SSD-8072) 132 MW Nevertire Solar Farm (NSF) is a solar photovoltaic (PV) plant located approximately 1 km west of Nevertire and 90 km west of Dubbo, within the Warren Shire Council local government area (LGA).

Since development consent for the NSF was granted (July 2017), the development has been modified on three occasions (all approved) to revise the development footprint, facilitate a subdivision and amend the site facilities layout, and use an adjoining property for temporary access and parking during the construction phase.

Approval to export its full capacity into the NSW grid was granted in February 2020.

NSF’s owner, Elliott Green Power (EGP), has proposed a further modification to the project for the addition of a Battery Energy Storage System (BESS) facility to support and integrate with the NSF.

- It has been proposed to locate the BESS facility on 2.5 ha of land immediately adjacent to the NSF and the existing overhead transmission line easement.
- The proposed BESS would have a capacity of up to 50 MW / 100 MWh.
- The proposal would include battery storage containers, converters, ring main units (RMU), step-up transformers, high voltage (HV) underground feeders, connection to the NSF 22 kV switchboard and associated roads, tracks, fences and a control building.
- In relation to the lithium-based battery packs, and reflecting the rapid evolution of grid-scale renewable componentry, two options are being considered for the facility: up to 40 x 20-foot shipping container style 2.53 MWh (eg Tesla) battery energy storage packs or up to 26 x 40-foot 3.6 MWh (eg Kokam) packs.

## 1.1 Proposal Description

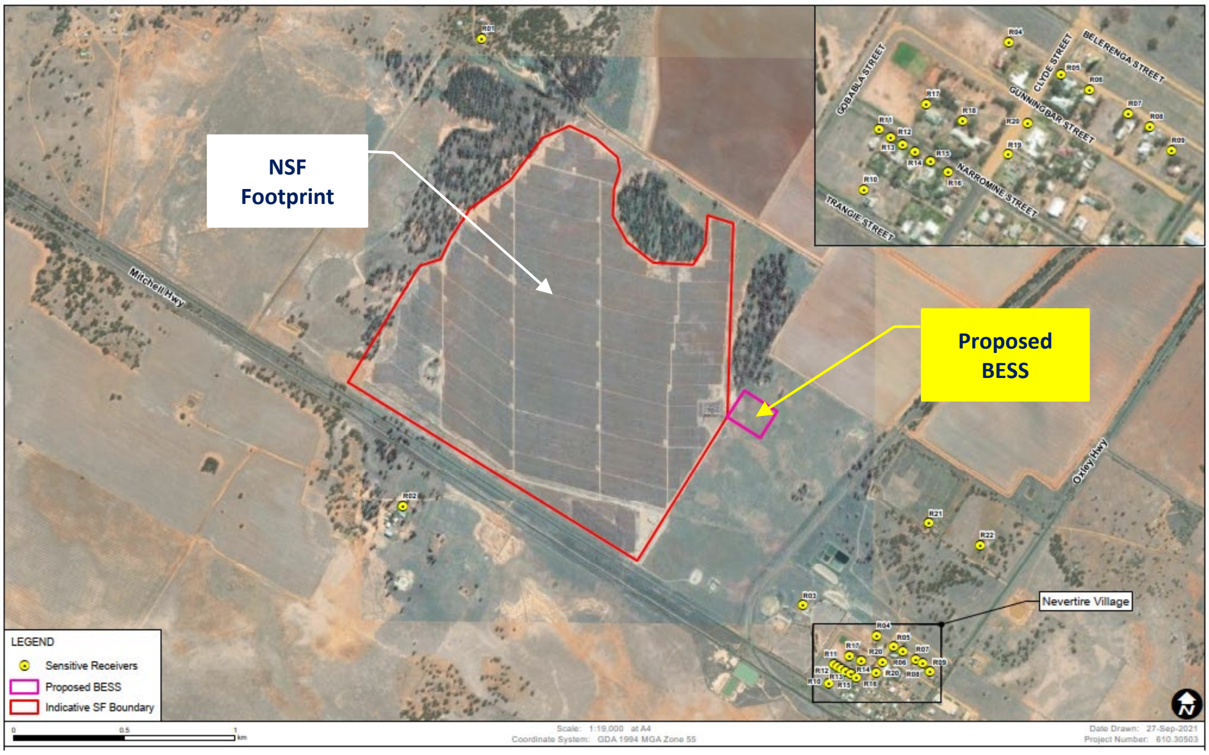
A locality map, including aerial view of the site is provided in **Figure 1**.

- The nearest sensitive receivers are located approximately 1 km from the proposed BESS site perimeter. They are the residential properties located in the village of Nevertire to the southeast of the proposal. Other rural residential properties are scattered around the site at similar and further distances.
- Nevertire Community Park is located within the village and has been identified as a passive recreation receiver.

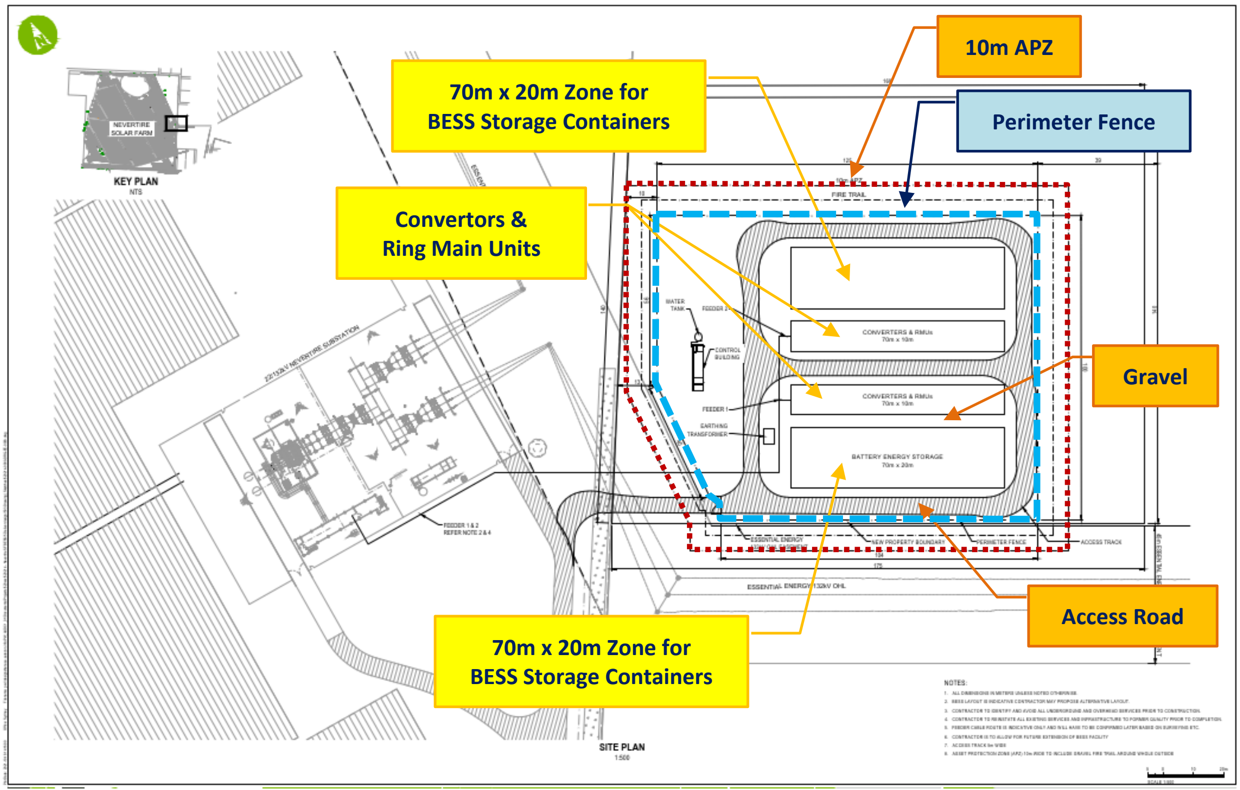
A facility layout plan is provided in **Figure 2**.

- The BESS battery packs will be located within two zones, 70 m by 20 m.
- The BESS battery packs would be separated from the zones dedicated to the Convertors and Ring Main Units as well as the facility’s Control Building and other infrastructure.
- The two BESS battery pack zones are set back (a) 10 m from their relevant Perimeter Fence, and (b) 20 m from the facility’s 10 m APZ. As the facility will operate in an unmanned mode, personnel would only be within the Perimeter Fence during inspection and maintenance activities.

## Figure 1 Locality Map




## Figure 2 Proposed BESS Layout



# 2 SUMMARY OF PREVIOUS HAZARD ASSESSMENT

SLR's previous assessment of the proposal was detailed in:

- SLR Report 610.30503-R02-v1.2-20211028.doc, *"Nevertire Solar Farm BESS, Preliminary Hazard Assessment"*, October 2021.

The assessment was prepared in accordance with:

- SEPP'33: Department of Planning NSW, 2011, *Applying SEPP 33* - Hazardous and Offensive Development Application Guidelines.
- MLRA: Planning NSW, 2011a *Multi-Level Risk Assessment*, New South Wales Government
- HIPAP 6: Planning NSW, 2011b *Hazard Analysis* – Hazardous Industry Planning Advisory Paper No 6, New South Wales Government

The assessment involved the following steps:

Step 1: Hazard identification;

Step 2: Hazard analysis (consequence and probability estimations); and

Step 3: Risk evaluation and assessment against specific criteria.

## 2.1 Key Outcomes

**Preliminary Risk Screening (PRS)**

- No dangerous goods are proposed to be used or stored at the facility and therefore the facility is not considered potentially hazardous with regards to dangerous goods in accordance with the thresholds pertaining to SEPP'33.
- The proposed 40 containerised battery energy storage system modules contain battery powerpacks consisting of lithium ion batteries. Lithium ion batteries lie within the Class 9 Miscellaneous Dangerous Substances and articles, which are excluded from the SEPP'33 screening process. However, the hazards associated with these batteries indicate progression to a Preliminary Hazard Analysis.
- No transport of dangerous goods has been proposed for the facility.

On the basis of the above, a more detailed assessment of the hazards associated with the proposed Lithium Ion batteries was undertaken via a Preliminary Hazard Analysis, in accordance with HIPAP 6.

**Preliminary Hazard Analysis (PHA)**

Following a review of surrounding land use, a series of potentially hazardous events and scenarios were considered to identify if further comprehensive qualitative analysis was required. The listing of all identified hazards has been included in this Memo – refer **Attachment A**.

Following an initial risk screening, the following potential hazards could not be eliminated through first review and require further examination:

- Hazards associated with lithium ion batteries in the BESS, specifically overheating and fire.
- Hazards associated with oils escaping from transformers.

# 3 UPDATED HAZARD ASSESSMENT

## 3.1 Previous BESS-Related Control Measures

In SLR's previous hazard assessment, a series of control measures were developed to maintain and contain BESS-related risks within the site boundary and reduce the risk to areas outside the site boundary.

These control measures have been included in this Memo as **Attachment B**.

It was concluded that the nominated control measures would be readily implemented as part of plant safety engineering and the comprehensive safeguards that global manufacturers have been developing the past few years.

The guidelines and standards used to develop the control measures are listed in **Section 4 – References**.

## 3.2 Updated Control Measures

Following review of SLR's previous hazard assessment, DPE requested further information covering the following:

- provide further information in the Preliminary Hazard Analysis for the Department to verify the separation distances between battery sub-units (containers, enclosures etc) are sufficient to ensure a fire does not propagate between the individual sub-units including:
  - verification that the Battery Energy Storage System (BESS) would be accommodated within the area designated for the BESS, accounting for separation between BESS sub-units to prevent fire propagation; and
  - demonstrating that the fire risks from the BESS can comply with the Department's Hazardous Industry Advisory Paper No. 4, '*Risk Criteria for Land Use Safety Planning*';

## 3.3 BESS Li-Ion Battery Energy Storage Packs

The proposed BESS would:

- have a capacity of up to 50 MW / 100 MWh and consist of lithium-based battery packs.

Two options are being considered for the battery packs:

- up to 40 x 20-foot shipping container style 2.53 MWh (eg Tesla) battery energy storage packs;

or

- up to 26 x 40-foot 3.6 MWh (eg Kokam) packs.

The specific Li-Ion battery pack option will be selected during the detailed design phase of the proposed facility.

The key aspects of BESS-related fire hazard encompass the following two broad areas.

**Risks Associated with Non-Battery Fire Events**

- Wiring Issues, eg short circuits.
- Electrical Safety System Failures, eg fuses, breakers, insulation, etc.
- Mechanical Interference, eg bugs, rodents, mishandling, etc.

**Thermal Runaway**

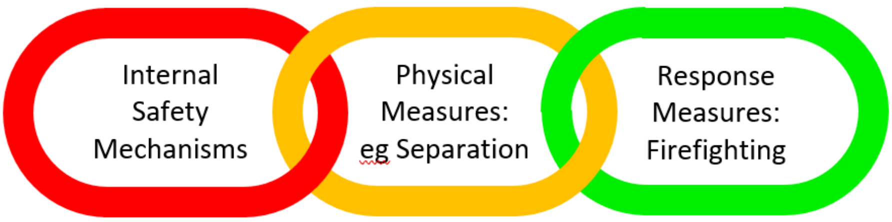
- Causes: manufacturer defect, overcharge, over-discharge, mechanical damage, environmental (too hot, too cold).
- Hazards Produced: heat, flame, off-gassing of mainly $H_2$ and CO, off-gassing of other toxic gases, deflagration/explosion risk.

**Strategy of Protection**

The key "links" in managing fire-related risks within a BESS facility are illustrated in the "Fire Response Chain" shown in **Figure 3**.

- **Link 1:** Globally manufactured, commercially available BESS units (battery packs, convertors, etc) come with a range of sophisticated in-built hazard reduction mechanisms to: firstly, avoid the onset of a fire event; secondly, detect a fire and "announce" it to relevant "stakeholders", and thirdly, contain and suppress the fire until external fire-fighting resources can be brought to bear to shut the fire down, if it has not already been contained.
- **Link 2:** In between the Link 1 automatic fire-management systems and the Link 3 intervention of fire-fighting resources are a series of physical measures, eg separation of BESS units, APZ zones, etc, designed limit the spread of a fire event until fire-fighting resources arrive to shut down the fire, if it has not already been contained.
- **Link 3:** Appropriate access for fire-fighting vehicles, availability of an adequate water supply for fire-fighting, emergency response planning, etc, form the last link aimed at being able to shut a fire down before it spreads beyond the BESS perimeter and into the surrounding community.

**Figure 3 Key Strategic Links in Managing BESS Fire-Related Risks – the Fire Response Chain**




While the DPE's request for further information covers mainly **Link 2** (refer **Figure 3**), this Memo also addresses the other two links as the "Fire Response Chain" depends on the strength of all three links. In particular:

- A strong **Link 1** places less onus on **Links 2 and 3**, and
- Strong **Links 1 and 2** place less onus on **Link 3**.

### 3.3.1 Link 1

It is worth re-stating that grid-scale BESS units provided currently by global manufacturers (eg Tesla's Megapack) typically contain a hierarchy of fire management controls which create layers of protection as illustrated in **Figure 4**.

- Electrical Protection is enabled via Current Interrupt Devices (CID) and Rack Level Fuse Protection.
- Mechanical protection is enabled via Pressure Relief Valves.
- LFP chemistry is preferred over NMC because of the higher onset temperature for Thermal Runaway (270°C for LFP versus 210°C for NMC). LFP also has a significantly lower self-heating rate than NMC chemistry batteries.
- BESS units typically come with a BMS (Battery Management System). The BMS monitors a range of variables related to the onset or incidence of a fire event (temperatures, over and under-voltage, over-currents, etc). The BMS will then trigger alarms, instigate internal fire suppression equipment and automatically disconnect each BESS unit in the event of a fire.
- A BMS's fire detection system would normally include: Thermal and Smoke Detectors, Explosive Gas Sensing and $H_2$ Detection for Thermal Runaway.
- Cabinet walls which are adjacent to other units are fire-rated to EI60, which would provide a 2-hour fire wall between adjacent units.
- The roof panels of BESS packs are typically designed for blast loading to minimise the impact of any potential deflagration/explosion, including roof panel rupture.
- Internal fire suppression systems would normally include a "dry pipe" sprinkler head and, for most modern units, heat-activated aerosols for non-battery fires or once internal temperatures exceed a given temperature limit (usually in the range 140°C to 150°C).

**Figure 4 Representative BESS Unit Fire Management Protection System (*courtesy: WÄRTSILÄ*)**

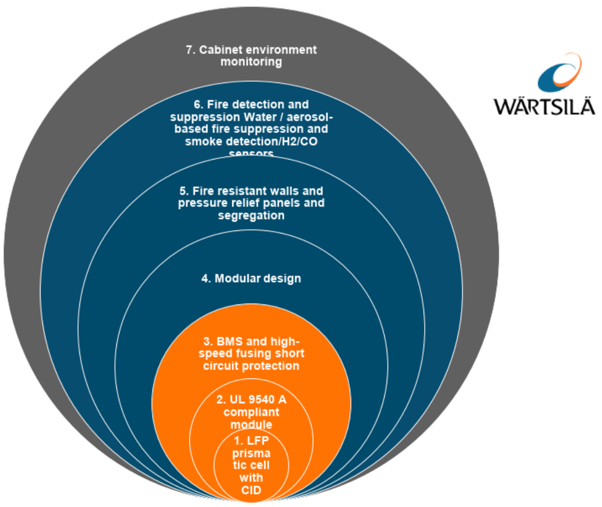



*Image:*
*Courtesy WÄRTSILÄ*

### 3.3.2 Link 1 – CASE STUDY IN BESS SAFETY DEVELOPMENT

Traditionally, the safety of engineering systems (civil, mechanical, electrical, etc) has evolved through three main avenues:

- R&D: especially in the early stages of development of a new product or system;
- Standards: compliance with standards provides an avenue for underpinning safety; and
- "Lessons Learned": typically, through failures, accidents, etc, where low probability failure mechanisms are discovered and mitigation measures developed to prevent their occurrence in the future. An example of this latter avenue discussed below is the Victorian Big Battery Fire of July 2021.

**Victorian Big Battery (VBB) Fire – 30 July 2021**

Neoen's VBB is a 300 MW/450MWh BESS facility located in Geelong, Victoria, fitted with 212 Tesla Megapacks, each measuring approximately: 7.2 m (length) x 1.6 m (width) x 2.5 m (height).

On Friday, 30 July 2021:

- A single Megapack (MP1) caught fire and spread to a neighbouring Megapack (MP2) during the installation and commissioning phase of the facility.
- At that time, approximately half of the Megapacks had been installed at the site and some were undergoing testing and commissioning.
- MP1 was NOT scheduled for testing that day and was shut down manually at around 7:20 am. When it was shut down, it was not displaying abnormal conditions to site personnel.
- At around 10:00 am, smoke was observed emitting from MP1 by site personnel, who then electrically isolated ALL the Megapacks on-site and called emergency services.
- Country Fire Authority (CFA) arrived shortly thereafter and set up a 25 m perimeter around MP1.
- They also began applying cooling water to nearby exposures (eg transformers) as recommended in Tesla's Lithium-Ion Battery Emergency Response Guide (ERG).
- At around Noon, the fire spread to the neighbouring MP2 installed 15 cm behind MP1. Wind was the dominant contributory factor in this case. At the time of the fire, sustained winds of over 50 km/hr impacted the site from the north. These 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.
- 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.
- The fire did not spread beyond MP1 and MP2, which 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 MP1 and MP2 failed "safely", ie they slowly burned themselves out with no explosions or deflagrations, as they are designed to do in the event of a fire, and as per the guidance in Tesla's ERG.
- By around 4:00 pm, 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 2 August 2021, at which time, the CFA handed the site over for a formal fire investigation to begin.

**Lessons Learned**

The VBB fire exposed a number of unlikely factors that, when combined, contributed to the fire initiation as well as its propagation from unit MP1 to MP2. This collection of factors had never before been encountered during previous Megapack installations, operation and/or regulatory product testing.

Below is a summary of the lessons learned from the incident and the new safety mitigation measures since implemented.

### Commissioning

- Key weaknesses identified: (i) limited supervision/monitoring of telemetry data during the first 24 hours of commissioning, and (ii) use of the keylock switch during commissioning and testing.
- These two factors prevented MP1 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 from 24 hours to 1 hour and to avoid utilizing the Megapack's keylock switch unless the unit is actively being serviced.

### Electrical Fault Protection Devices

- Key lessons learned covered the following: (i) coolant leak alarms not being active, (ii) the pyro disconnect being unable to interrupt fault currents when the Megapack is off via the keylock switch, and (iii) the pyro disconnect likely being disabled due to a power supply loss to the circuit that actuates it.
- These factors prevented MP1's pyro disconnect 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 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 almost certainly initiated by a coolant leak, potential unexpected failures of other internal components of the Megapack that could create similar damage to the battery modules have been explored.
- Accordingly, the 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.

### Fire Propagation

- Key lessons learned include: (i) the significant role external, environmental conditions (such as wind) can have on a Megapack fire, and (ii) the identification of a weakness in the thermal roof design (unprotected, plastic overpressure vents in the ceiling of the battery bays) that permitted 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 MP2 failed and became involved in the fire.

- This weakness had not been identified previously during product or regulatory testing as the relevant UL9540A tests are undertaken with wind speeds reaching only up to 20 kph. The fire therefore did not invalidate the Megapack's UL9540A certification, as the fire occurred as result of an environmental condition that is not captured by the UL9540A test method.
- 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 NOW COME STANDARD on all NEW Megapack installations.
- For EXISTING Megapacks, the vent shields can be easily RETROFITTED in the field.

### Megapack Spacing

- Investigation of the VBB fire concluded that NO changes were required to the installation practices of the Megapack ONCE the vent shield mitigation (as described above) was in place.
- Based on an analysis of MP2's telemetry data during the VBB fire, a Megapack's thermal insulation provides significant thermal protection in the event of a fire within an adjacent Megapack installed 15 cm away. The internal cell temperatures of MP2 only increased by 1°C, from 40°C to 41°C, 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, and NOT due to heat transfer via the 150 mm gap between Megapacks.
- With the new vent shield mitigation in place, the weakness has been addressed and since validated through unit level fire testing (ie tests involving the ignition of the Megapack's thermal roof).
- These tests have 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.

### Emergency Response

Lessons learned from the emergency response to the VBB fire include:

- Effective pre-incident planning is invaluable and can reduce the likelihood of injuries;
- Coordination with "Subject Matter Experts" (SMEs), either on site or remotely, can provide critical expertise and system information for emergency responders to draw upon;
- 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;
- The fire protection design approach of the Megapack was shown to be very robust;
- Victoria's EPA indicated that there was "good" air quality two hours after the fire, demonstrating that no long-lasting air quality concerns arose from the fire event;
- Water samples indicated that the likelihood of the fire having a material impact on firefighting water was minimal;
- Prior community engagement during the project planning stages proved to be invaluable as it enabled Neoen to quickly update the local community and address immediate questions and concerns. 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.

**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 (ie explosions) or resulted in any injuries to site personnel, the general public or emergency responders.
- It was isolated to the units directly involved and had minimal environmental impact.
- It did not adversely impact the electrical grid, and had appreciably short mission interruption.

### 3.3.3 Link 2

The key to **Link 2** (refer **Figure 3**) is to provide sufficient clearance between rows of adjacent BESS units (whether modular/cabinet type or containerised type) and between BESS units and the BESS enclosure perimeter.

- Typically, BESS battery packs have a minimum clearance distance to the nearest boundary of their enclosure of between 5 m to 6 m. This is based on the radiant heat flux from a theoretical BESS battery pack fire that might be experienced by site personnel.
- Rows of adjacent BESS battery pack units will also be separated by a minimum clearance which will vary in terms of the front and end walls and side walls. This is based on the radiant heat flux from a theoretical BESS battery pack fire that an adjacent BESS unit might experience in relation to its structural integrity.

**Minimum Clearance Distances from Fire Modelling**

The acceptance criteria used for fire modelling are given in terms of radiant heat flux limits and are related to personnel exposure and BESS unit structural integrity.

**Personnel Exposure**

- This applies to the separation distance of BESS units from the BESS enclosure fence perimeter.
- Following the requirements of HIPAP 4, this Memo has adopted the risk of personal injury as the governing criteria, since this risk level is more stringent than the risk of fatality.
- HIPAP 4 states that a radiation intensity of 4.7 kW/$m^2$ is considered high enough to trigger the possibility of injury for people who are unable to be evacuated or seek shelter. HIPAP 4 also suggests that a level of heat radiation of 4.7 kW/$m^2$ would cause injury after 30 seconds' exposure. On this basis, HIPAP 4 recommends a risk injury criterion of 50 in a million per year at a heat flux of 4.7 kW/$m^2$.
- Further support for this criterion is provided by API 521 6$^{th}$ Edition Table 12, which provides recommended limits regarding thermal radiation for personnel. 4.7 kW/$m^2$ is nominated as the limit for sterile radius around a heat source and as a short-term exposure limit (where emergency actions lasting 2-3 minutes can be carried out by personnel with appropriate clothing).

**BESS Unit Structural Integrity**

- This applies to the separation distance of BESS units from each other.
- HIPAP 4 states that a radiation intensity of 12.6 kW/$m^2$ can result in (i) a significant chance of fatality for extended exposure and a high chance of injury, (ii) the temperature of wood riding to a point where it can be ignited by a naked flame after long exposure, and (iii) thin steel, with insulation on the side away from the fire, reaching a thermal stress level high enough to cause structural failure.

Two approaches are available for determining the above minimum clearance distances for BESS units based on achieving the two nominated radiant heat flux limits of 4.7 kW/m$^2$ (personnel safety) and 12.6 kW/m$^2$ (structural integrity):

- Quantitative fire modelling; or
- Certified results with an appropriate test - the UL9540A Test Method represents industry best practice.

As noted previously, the choice of BESS unit has not yet been made.

**BESS Unit Separation Distances via Regulatory Guidelines**

Some information is available amongst international standards and guidelines regarding minimum separation distances between BESS packs and between BESS packs and surrounding personnel access areas.

For example, NFPA 855-2020 *Standard for the Installation of Stationary Energy Storage Systems*, (US) National Fire Protection Association (latest edition 2020) specifies:

- A minimum of 10 feet (3.05 m) separation to lot perimeters, public ways, buildings, stored combustible materials, hazardous materials, high-piled stock, and other exposure hazards not associated with the electrical grid.

AS/NZS 5139:2019 *Electrical Installations – Safety of Battery Systems for Use with Power Conversion Equipment* also provides guidance with respect to minimum separation distances from personnel and buildings and other equipment. The minimum separation distances (which range from 600 mm to 900 mm) do not apply in the present instance – the facility's BESS units will be located within their own 70 m x 20 m areas, isolated from personnel by the facility's Perimeter Fence as shown in **Figure 2**.

**BESS Unit Separation Distances via Quantitative Fire Modelling**

SLR has reviewed the literature of credible fire scenarios for comparable containerised BESS systems.

Guidance for example in relation to a fire event relevant to BESS units can be found in:

- AS 1530.4:2014, *"Methods for fire tests on building materials, components and structures – Fire resistance tests for elements of construction"*.

Other relevant international standards include:

- SFPE S.01, *Standard on Calculation Fire Exposures to Structures*, Society of Fire Protection Engineers; Gaitherburg MD, 2011.
- SFPE S.02, *Standard on Calculation Methods fo Predict the Thermal Performance of Structural and Fire Resistive Assemblies*, Society of Fire Protection Engineers; Gaitherburg MD, 2015.
- ISO 23932-1:2018, *Fire Safety Engineering – General Primciples – Part 1: General*.
- CIBSE Guide E, *Fire Engineering*, 3$^{rd}$ Edition, Chartered Institure of Building Services Engineers, UK, 2010.

The above standards provide parametric fire curves which can be used to estimate the upper bound of the likely fire temperatures relevant to a BESS unit.

These are typically in the range:

- 800-1,000°C at an "open" side of a containerised unit – a typical value found in the literature is 840°C, a standard upper limiting value used in fire simulations for fire spread between office buildings.
- 600°C at a "closed" side of a containerised unit – refer the SPFE and CIBSE Handbooks above, for a severe, fully developed fire in a containerised unit.
- 700-800°C for sides between an "open" and "closed" side.

Common assumptions made in the literature for BESS fire simulations include the following:

- BESS units are assumed to be a "black body" (worst-case from a fire spread point of view).
- Fire spread is via the Stefan-Boltzmann Law, with uniform heat loss.
- Emissivity factors in the range 0.9-1.0.

SLR's literature search of worst-case BESS fire simulations based on the above assumptions indicate the following approximate minimum separation distances:

- 6 m = minimum distance from either the front, end or side walls of any BESS battery pack to the associated enclosure fence perimeter (based on the 4.7 kW/m$^2$ criterion).
- 3 m = minimum distance between adjacent BESS battery pack side walls (based on the 12.6 kW/m$^2$ criterion).
- 4 m = minimum distance between adjacent BESS battery pack front and end walls (based on the 12.6 kW/m$^2$ criterion).

On the basis of the above, two possible configurations of BESS battery packs within a rectangular area have been assessed under the following assumptions:

- The available space consists of two, identical rectangular areas, 70 m x 20 m, the boundaries of which are a minimum 10 m from the nearest BESS enclosure Perimeter Fence (refer **Figure 2**).

Two BESS battery pack dimensions are possible

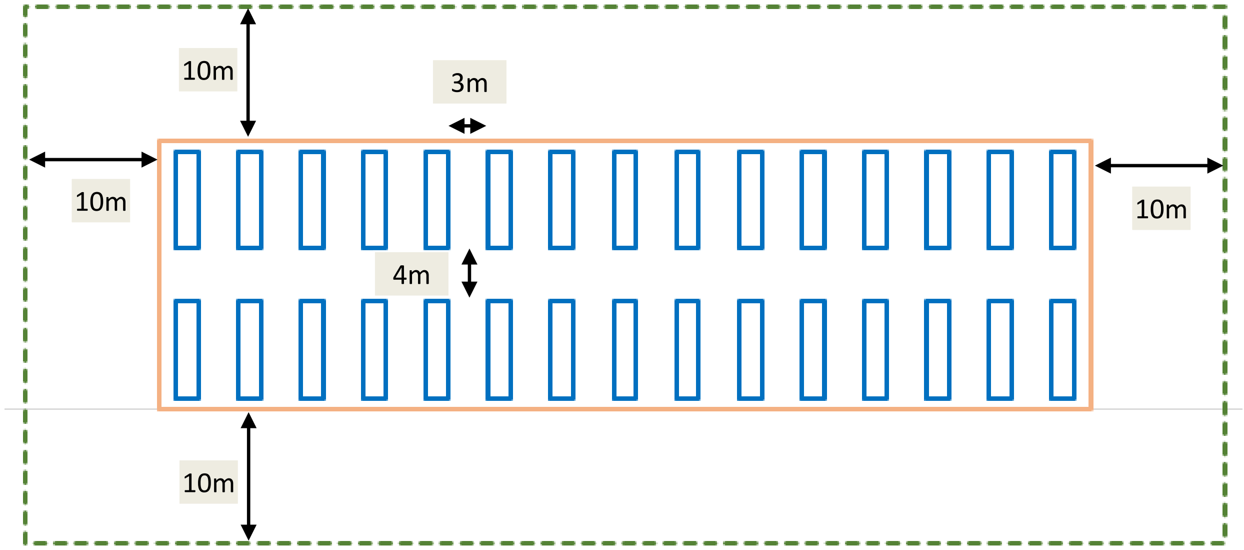
- For the 20-foot container option: Length = 7.2 m and Width = 1.7 m (eg Tesla Megapack)
- For the 40-foot container option: Length = 12.2 m and Width = 2.5 m (eg Kokam BESS pack)

**Configuration 1: 20-foot containers – refer Figure 5**

**Figure 5** demonstrates that:

- A total of 30 x 20-foot BESS battery packs would fit within each 70 m x 20 m rectangular area.
- This would enable a total of 60 x 20-foot packs within the entire facility.
- The area within the facility allocated for the BESS battery packs can comfortably accommodate the targeted/proposed BESS installation.

**Figure 5 Possible BESS Battery Pack Configuration for the 20-foot Option**

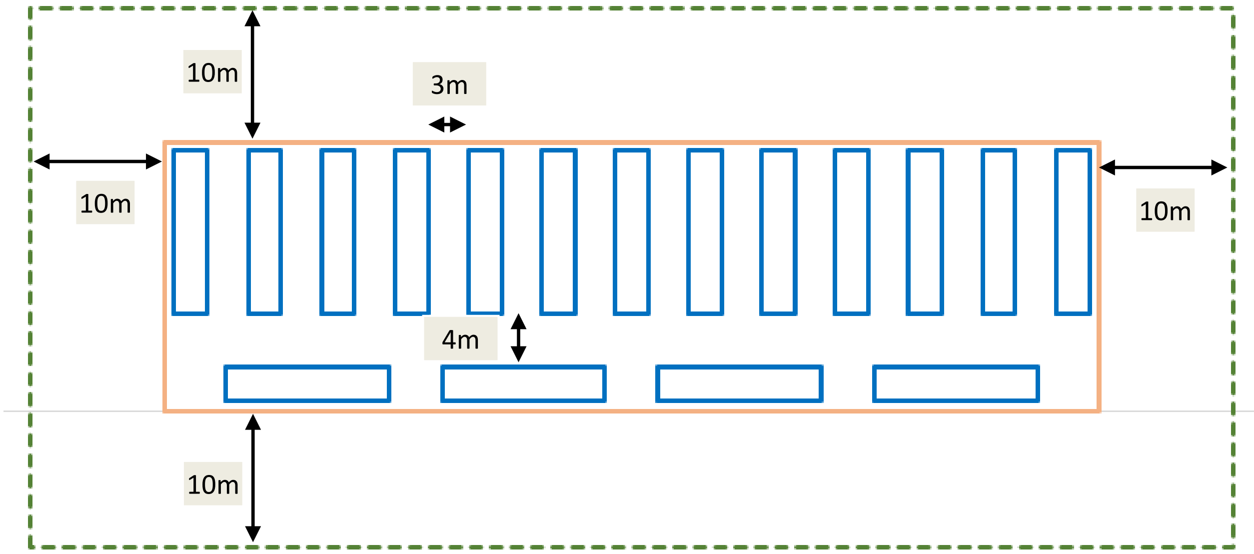



**Configuration 2: 40-foot containers – refer Figure 6**

**Figure 6** demonstrates that:

- A total of 17 x 40-foot BESS battery packs would fit within each 70 m x 20 m rectangular area.
- This would enable a total of 34 x 40-foot packs within the entire facility
- The area within the facility allocated for the BESS battery packs can comfortably accommodate the targeted/proposed BESS installation.

**Figure 6 Possible BESS Battery Pack Configuration for the 40-foot Option**




On the basis of the (conservative) fire scenario analysis results obtained from the literature, the proposed pair of 70 m by 20 m BESS battery pack areas (refer **Figure 2**) will be MORE THAN SUFFICIENT to accommodate both of the BESS battery pack options being considered for the facility, the 20-foot and 40-foot options.

**BESS Unit Separation Distances via Certified Tests – UL9540A**

The standard certification test for establishing (amongst a number of design parameters) the minimum fire-related clearances for commercially available BESS containerised units is UL9540A:

- UL 9540A ANSI/CAN/UL *Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage System*

A number of the potential BESS container manufacturers being considered for the Proposal (including the Tesla Megapack) have carried out their fire testing under UL9540A.

In fact, UL has established a database of its BESS container fire tests and provides FREE ACCESS to this database:

- Refer … https://www.ul.com

The Tesla Megapack UL9540A test results indicate that:

- A separation distance between the sides and backs of Tesla Megapacks of 6 inches (~15 cm) was sufficient in terms of preventing a fire from spreading from one unit to another.

**Figure 6** shows some actual installations involving Tesla Megapacks. Of particular interest is the Angleton installation, where the following can be seen:

- The single row of 10 Tesla Megapack PAIRS of containers required a total length of approximately 56 m.

This implies that the two 70 m by 20 m BESS battery pack enclosures (refer **Figure 2**) designated for the Proposal would be sufficient to accommodate EVEN MORE than the “theoretical” installation design shown in **Figure 5**.

Again, using actual UL9540A fire test results, the proposed pair of 70 m by 20 m BESS battery pack areas (refer **Figure 2**) will be MORE THAN SUFFICIENT to accommodate both of the BESS battery pack options being considered for the facility, the 20-foot and 40-foot options.

**Achieving the risk level recommended in HIPAP 4**

As noted previously, the HIPAP 4 risk criteria heat flux levels are associated with an occurrence of 50 in a million per year. This is achieved via a combination of the following:

- The “credible” fire scenarios discussed above (and associated safe separation distances) were developed using the maximum expected temperature inputs as suggested by AS 1530.4-2014 *Methods for Fire Tests on Building Materials, Components and Structures. Part 4 Fire-Resistance Tests for Elements of Construction.* Thus, the modelled fires used the upper bound of any plausible fire event.
- The layers of protection provided by global BESS manufacturers (eg Tesla, Wartsila, etc) that have been developed over recent years, have successively reduced the incidence of (i) an electrolyte-instigated fire, and (ii) a battery cell thermal runaway fire.

The combination of sufficient separation distance and BESS unit safety systems are able to achieve the HIPAP 4 requirements for fire risk.

## Figure 7 Example Tesla Megapack Installations

**Hornsdale Battery (SA)**

**Angleton (Texas)**

### 3.3.4 Link 3

A separate Bushfire Assessment Report has been prepared for the Proposal by BEMC, covering:

- **Asset Protection Zones, Landscaping and Construction Standards**: including non-combustible fencing to be installed and located 10 m from the BESS and related infrastructure and a 10 m APZ around the external boundary fence, to be managed as an inner protection zone (IPA)
- **Access:** from Mitchell Highway to the BESS with fire trail access around the BESS compound perimeter fence
- **Water Supply:** including a supply pipe from the existing static water tank associated with the control room, positioned outside the BESS compound to enable responding fire fighters to access this water supply.
- **Bush Fire Emergency Management and Operations Plan** (to be developed).

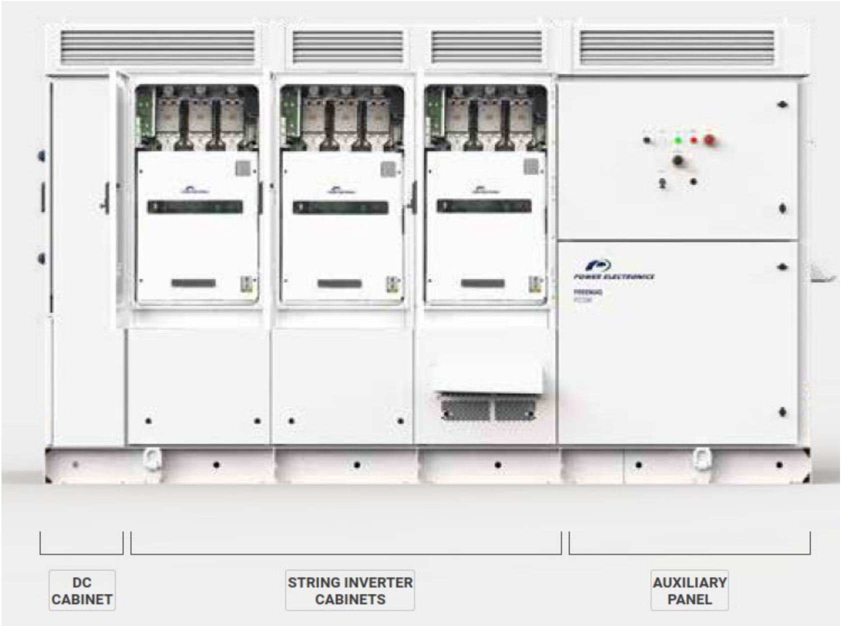
It was concluded that the above measures would enable the Proposal to comply with the performance criteria in Planning for Bushfire Protection (2019).

## 3.4 BESS Convertors

To date, the only specific item of BESS plant that has been selected is the BESS Power Conversion System, Model/Make: POWER ELECTRONICS Freemaq PCSK.

- The Freemaq PCSK is compatible with all battery technology and manufacturers and, in addition to its AC/DC conversion capabilities, offers grid support functions such as Peak Shaving, Ramp Rate Control, Frequency Regulation, Load Leveling and Voltage Regulation.
- Freemaq PCSK units are designed for concrete pads or piers, open skids and are integrated into full container solutions.
- 3.8 MW Freemaq PCSK units are 12 ft (3.66 m) long - refer **Figure 3**.
- The chosen Freemaq PCSK units have been in operation (not just for solar facilities) for more than three years and feature a Variable Speed Drive colling system (iCOOL3) that has been certified to IP55 protection for an outdoor convertor. This avoids the need to employ complex liquid cooling systems with the historical risks that such systems have evidenced (albeit infrequently) in the past (complex maintenance, leaks, etc).
- Freemaq PCSK units also feature a unique, autonomous heating system to prevent condensation, key to delivering continuous availability and reducing maintenance.
- Freemaq PCSK units are supported by the Freesun-APP, which provides continuous monitoring of the unit. The units come with built-in wifi, allowing remote connectivity (via the Freesun-APP) to any smart device for detailed updates and information regarding all critical data being recorded within the units - energy registers, production and “events”.
- Freemaq PCSDK units all have “Anti-Islanding” that combines passive and active detection methods enable compliance with IEC 62116 and IEEE 1547.
- Finally, the units carry Certification to UL1741, CSA 22.2 No.107.1-16, IEC 62109-1 and IEC 62109-2.

## Figure 8 3.8 MW Freemaq PCSK Unit



# 4 CONCLUSIONS

This Memo has responded to DPIE's request for further information in relation to hazards associated with the proposed BESS facility at the approved Nevertire Solar Farm, in particular:

- The separation distances between adjacent BESS sub-units and between BESS sub-units and their enclosure perimeter;
- Verification that the proposed BESS capacity of the Proposal (50MW/100MWh) can be accommodated within the enclosures provided; and
- HIPAP 4 fire risk issues have been adequately addressed.

**Summary of Memo Outcomes 1**

Following a literature search of credible fire scenario modelling relevant to BESS units, it was concluded that:

- The proposed pair of 70 m by 20 m BESS battery pack areas (refer **Figure 2**) will be MORE THAN SUFFICIENT to accommodate both of the BESS battery pack options being considered for the facility, the 20-foot and 40-foot options.

**Summary of Memo Outcomes 2**

Following a web-based search of certified fire tests to UL9540A, it was again concluded that:

- The two proposed 70 m by 20 m BESS battery pack enclosures for the facility (refer **Figure 2**) would be able to accommodate both of the BESS battery pack options being considered for the facility, the 20-foot and 40-foot options.

It is recommended that this Memo be updated once the specific choice of BESS container and battery pack is made to confirm the above conclusions.

# REFERENCES

AS1768:2020 *Lightning Protection*

AS 5139 *Electrical Installations - Safety of Battery Systems for Use with Power Conversion Equipment*

Commonwealth Government, 2020, *Australian Code for the Transport of Dangerous Goods by Road and Rail* (ADG Number 7.7).

Department of Planning NSW, 2011, *Applying SEPP 33* - Hazardous and Offensive Development Application Guidelines.

Ditch, Ben & Zeng, Dong. (2019). *Development of Sprinkler Protection Guidance for Lithium Ion Based Energy Storage Systems* (FM Global Research Technical Report).

FM Global *Property Loss Prevention Data Sheets 5-33, Electrical Energy Storage*

IEC 62485-1:2015 *Safety requirements for secondary batteries and battery installations - Part 1: General safety information*

IEC 62485-2:2010 *Safety requirements for secondary batteries and battery installations - Part 2: Stationary Batteries*

IEC 62619:2017 *Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications*

IEC 62897 *Stationary Energy Storage Systems with Lithium Batteries - Safety Requirements*

IEC 62933:2018 *Electrical Energy Storage (ESS) Systems*;

NFPA 855: 2020 *Standard for the Installation of Stationary Energy Storage Systems*;

NFPA, 2016 *Hazard Assessment of Lithium Ion Battery Energy Storage Systems*. Fire Protection Research Foundation and the National Fire Protection Association.

Planning NSW, 2011a *Multi-Level Risk Assessment*, New South Wales Government

Planning NSW, 2011b *Hazard Analysis* – Hazardous Industry Planning Advisory Paper No 6, New South Wales Government

UL 1973 *Batteries for Use in Light Electrical Rail Applications and Stationary Applications*

UL 9540 *Standard for Lithium Batteries*;

UL 9540 *Standard for Energy Storage Systems and Equipment*;

UL 9540A ANSI/CAN/UL *Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage System*

# Attachment A

## Hazard Identification

### Details of the hazardous events, causes, consequences and controls assessed for the proposed BESS modification

| Hazardous Incident / Event | Possible Cause | Possible Consequences | Prevention / Protection Safeguards |
|---|---|---|---|
| Bushfire | Bushfire external to site causes fire to spread onto BESS | Damage to the BESS and the solar farm | Implementation of a fire break around the site<br>Implementation of a fire management plan or the like<br>Coordination with local fire authorities |
| Fire starting on site | Fire starting on site, cause other than starting in containerised module | Damage to the BESS and the solar farm | Implementation of a fire management plan or the like<br>Coordination with local fire authorities |
| Explosion / Thermal Runaway reaction – powerpacks in containerised modules | Thermal runaway reaction occurs in powerpack from overcharging or fire<br>Faulty powerpacks | Localised damage to containerised modules.<br>Gas / vapour release from containerised modules<br>Fire unlikely to spread between containerised modules (NFPA, 2016) | Equipment and systems will be designed and tested to comply with international and/ or Australian standards and guidelines (see **References**).<br>Implementation of a fire management plan or the like |
| Exposure of equipment to high voltage | Short circuit/ or equipment failure | Equipment failure and injury or fatality to personnel | Equipment and systems will be designed and tested to comply with international and/ or Australian standards and guidelines (see **References**).<br>BESS BMS fault detection and safety shut-off systems provided<br>Emergency Response Plan to cover all site hazards |

| Hazardous Incident / Event | Possible Cause | Possible Consequences | Prevention / Protection Safeguards |
|---|---|---|---|
| Damage to batteries from vehicle collision | Light vehicle strike to batteries | Damage to battery cells<br>Electrical risks | Use of perimeter fence around battery facility<br>Use of internal access roads with appropriate turning circles<br>Limit of speed limit within fenced facility<br>Earthing system installed as per normal electrical facilities |
| Transformer Oil Leakage | Corrosion of tank base or leakage of oil tank | Leakage of transformer oil to environment<br>Potential for pool fire in oil | Use of fully bunded oil storage for transformers in accordance with AS1940<br>Regular tank inspections included in inspection requirements |
| Security Breach | Security breach into battery storage facility for theft of components | Theft of equipment or risk to personnel | Installation of security fencing around entire facility and also battery facility separately<br>Installation of CCTV security system to monitor key areas<br>Inspections to monitor for security breaches |
| Damage due to lightning strike | Lightning striking facility and causing damage | Lightning strike causing damage to facility or personnel | Completion of a lightning risk assessment in accordance with AS1768<br>Include lightning protection measures if deemed necessary |
| Flooding of facility causing damage | High rainfall and flooding to site | Damage to electrical equipment<br>Restricted access to site | Where possible install electrical equipment elevated above ground level<br>Ensure suitable site access and egress at different locations |
| Exposure to Electromagnetic Fields (EMF) | Electric fields and magnetic fields from operating electrical equipment and transmission lines | Personnel exposed to elevated EMF levels | Equipment and systems will be designed and tested to comply with international and/ or Australian standards and guidelines (see **References**).<br>Follow industry guidance with respect to minimising exposure to EMF. |

# Attachment A

## Control Measures Detailed in SLR Report 610.30503-R02-v1.2-20211028

| Major Incident | Description | Potential Outcomes | Frequency Estimate | Likely Consequences | Controls | Residual Risk Level |
|---|---|---|---|---|---|---|
| Fire | Fire on site or bushfire impinges on BESS | Localised damage to containerised modules.<br>Unlikely to spread to between containerised modules (NFPA, 2016) | Rare | Damage to individual containerised modules | Equipment to comply with international and Australian standards and guidelines (see **References**)<br>Fire management plan or the like, be in place | Low |
| Explosion / Thermal Runaway reaction – powerpacks in containerised modules | Thermal runaway reaction occurs in powerpack from overcharging or fire | Localised damage to containerised modules.<br>Gas / vapour release from containerised modules<br>Unlikely to spread between containerised modules (NFPA, 2016) | Rare | Damage to individual containerised modules | Equipment to comply with international and Australian standards and guidelines (see **References**)<br>Fire management plan or the like, be in place | Low |

| Major Incident | Description | Potential Outcomes | Frequency Estimate | Likely Consequences | Controls | Residual Risk Level |
|---|---|---|---|---|---|---|
| Transformer failure and fire | Transformer catastrophically fails | Transformer oil spills and fire | Rare | Leakage of transformer oil to environment<br><br>Localised fire | Equipment to comply with international and Australian standards and guidelines (see **References**)<br>Use of fully bunded oil storage for transformers in accordance with AS1940<br>Regular tank inspections included in inspection requirements<br>Fire management plan or the like, be in place | Low |
| Electrical Hazards – short circuit /equipment failure | Exposure to high voltages | Electrocution | Rare | Injury / death | Equipment to comply with international and Australian standards and guidelines (see **References**)<br>Site operating procedures in place to avoid workers coming in contact with electrified systems | Low |