ARUP

Squadron Energy

Sapphire Solar Farm

Fire Safety Study

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Background

Sapphire Solar Farm Pty Ltd (the Proponent) has obtained development approval for the Sapphire Solar Farm (SSF) project (the Project). The Project involves the construction, operation and eventual decommissioning of a utility-scale photovoltaic (PV) solar farm and battery energy storage system (BESS) on an approved development footprint of 458.5 ha in the Kings Plains region of the Inverell Shire Local Government Area (LGA), 30 km east of Inverell in northern New South Wales (NSW). Construction and operation will occur in stages, with the 30 MW BESS to be constructed in Stage 1, and the expansion of the BESS (solar PV component) comprising later stage(s). The Project was granted development consent by the NSW Department of Planning and Environment (DPE) under the Environmental Planning and Assessment Act (EP&A Act) on 16 August 2018, with modification being granted on 19 April 2021 covering administrative mapping changes. It was granted consent by the Minister for the Environment (in accordance with the Environment Protection and Biodiversity Conservation Act (EPBC Act) on 15 October 2018.

The development approval is therefore subject to the consent conditions:

- NSW EP&A Act Development Consent SSD8643-8643-MOD -1; and
- Commonwealth EPBC Act Approval 2017/8121.

This document is the Fire Safety Study (FSS) required by Condition 23 in Schedule 3 of SSD-8643-MOD -1. It builds on the preliminary hazard assessment (PHA), completed as part of the SSF Environmental Impact Statement (EIS), which formed part of the project Development Application in January 2018 and has been prepared considering then relevant State Environmental Planning Policy 33 (SEPP 33) guidelines[1]:

- *Applying SEPP 33: Hazardous and Offensive Development Application Guidelines (NSW DPIE 2011a);*
- *Hazardous Industry Planning Advisory Paper No 2 (HIPAP 2): Fire Safety Study Guidelines (NSW DPIE 2011b);*
- *Hazardous Industry Planning Advisory Paper No 4 (HIPAP 4): Risk Criteria for Land Use Safety Planning (NSW DPIE 2011c); and*
- *Hazardous Industry Planning Advisory Paper No 6 (HIPAP 6): Hazard Analysis (NSW DPIE 2011d).*

An additional revision to this study incorporates lessons learned from the Geelong Big Battery Fire and further information on the selected technology.

Findings

A summary of the findings and recommendations of this FSS are:

- There is no off-site risk due to DGs being on site, therefore further analysis of DG-related incidents was not required.
- All vegetation within 20 m of the BESS is cleared, and a material such as gravel used to ensure clearance is maintained.

[1] Note that SEPP 33 has now been updated and is part of more complete State Environment Planning Policy (Resilience and Hazards) 2021. The guidance materials and HIPAP papers for SEPP 33 are still the relevant guidance materials for potentially hazardous industry.

- Vegetation in the area around the BESS is maintained at a level that will prevent any external fire from reaching an intensity which would adversely impact on the BESS across the 20 m separation distance.
- The gas detection and smoke detection system designs should be reviewed by a suitably qualified fire services engineer.
- All equipment shall be capable of operating at the maximum anticipated ambient temperature.
- Row-to-row separation distance between GridSolv Quantum[2] battery enclosures (herein referred to as ‘Quantum Enclosures’) is not less than 3 m. Quantum Enclosures that are electrically connected to the same power ACC/DCC cabinet are separated by a distance in the order of 0.1 m.
- The BESS Integrator and Operator should have a commissioning plan in place that minimizes down time of monitoring and control data transmission.
- Installation should be certified to all relevant Australian Standards (e.g. AS 3000 series) where possible.
- A non-intervention firefighting response will be adopted, this is supported by the fire test of the Quantum Enclosures.
- Installation of other infrastructure on the BESS site should be in accordance with their relevant Australian Standards and should be separated from the Quantum Enclosures by not less than 5 m or the requirements of aforementioned standards, whichever is greater.
- The control building should be located no closer than 11 m from the nearest Quantum Enclosure and should be constructed in accordance with NCC BCA. It is recommended that the external walls be fire-rated walls to provide increased resilience to the building in a fire event. Fire rating to be to BCA requirements or at least 60/60/60 when tested from the outside, whichever is greater.
- Fire extinguishers should be provided as first aid fire fighting to ancillary areas within the BESS site, where first aid fire fighting is appropriate. Locations and fire extinguisher types to comply with AS 2444:2001.
- The BESS Integrator should provide a site-specific Emergency Response Plan (ERP) in collaboration with the BESS Manufacturer for use by the Owner/Operator and Fire Service. This should be done in accordance with HIPAP 1.
- Discussions should include the local fire service, a fire engineer familiar with the technology, owner/operator, and BESS Integrator’s subject matter expert during the development of the ERP.
- Preparation of the Emergency Services Information Package (ESIP) shall be in line with FRNSW safety guideline.

[2] Gridsolv Quantum is a product of Wärtsilä

Key Terms and Definitions

Term	Definition
AS	Australian Standards
BMS	Battery Management System
BESS	Battery Energy Storage System
CATL	Contemporary Amperex Technology Co., Limited (Battery Manufacturer)
DG	Dangerous Good
DPE	Department of Planning and Environment
EIS	Environmental Impact Statement
EMS	Energy Management System
ERP	Emergency Response Plan
ESIP	Emergency Services Information Package
FHA	Final Hazard Analysis
FRNSW	Fire and Rescue New South Wales
FIP	Fire Indicator Panel (often called Fire Detection Indicating and control Panel)
FSS	Fire Safety Study
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
HV	High Voltage
HVAC	Heating, Ventilation and Air Conditioning
IEC	International Electrotechnical Commission
LV	Low Voltage
MW	Megawatt, unit of power
MWh	Megawatt hour, a unit of energy
NEM	National Electricity Market
NSW	New South Wales
NFPA	National Fire Protection Association
NSW RFS	New South Wales Rural Fire Service
PHA	Preliminary Hazard Analysis
PCU	Power Control Unit

Term	Definition
PV	Photovoltaic
SEPP	State Environmental Planning Policy
SSF	Sapphire Solar Farm
SWF	Sapphire Wind Farm
UL	Underwriter Laboratories, a product testing and certification organisation
UN	United Nations

List of Codes, Standards and Best Practices

Standard	Standard Name
AS 1670.1:2018	Fire detection, warning, control and intercom systems – System design, installation and commissioning. Part 1: Fire
AS 1670.5: 2016	Fire detection, warning, control and intercom systems – System design, installation and commissioning. Part 5: Special hazards systems
AS 1940:2017	The storage and handling of flammable and combustible liquids
AS 2419.1:2021	Fire hydrant installations. Part 1: System design, installation and commissioning
AS 2444:2001	Portable fire extinguishers and fire blankets — Selection and location
AS 3000:2018	Electricity Wiring Rules
AS 5139:2019	Electrical installations – Safety of battery systems for use with power conversion equipment
EN 1364-1:2015	Fire resistance tests for non-loadbearing elements – Part 1: Walls
EN 62477-1:2022	Safety requirement for power electronic converter systems and equipment
IEC 62109-1:2010	Safety of power converters for use in photovoltaic power systems – Part 1: General requirements
IEC 62109-2:2011	Safety of power converters for use in photovoltaic power systems – Part 2: Particular requirements for inverters
IEC 62133-2:2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety Testing for Lithium-Ion Batteries
IEC 62619:2022	Secondary cells and batteries containing alkaline or other non-acid electrolytes – safety requirements for secondary lithium cells and batteries, for use in industrial applications
ISO 13501-2: 2016	Fire classification of construction products and building elements – Part 2: Classification using data from fire resistance tests, excluding ventilation services
NCC BCA	National Construction Code, Volume 1, Building Code of Australia
NFPA 72:2022	National Fire Alarm and Signaling Code
NFPA 855:2023	Standard for the Installation of Stationary Energy Storage Systems
UL 1973:2022	Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications
UL 9540A:2019	Standard for Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems

1. Introduction

1.1 Background

The Proponent has obtained development approval for Sapphire Solar Farm (SSF) (planned infrastructure map depicted in Figure 2. The project involves the construction, operation and decommissioning of a utility-scale photovoltaic (PV) solar farm and battery energy storage system (BESS) on an approved development footprint of 458.5 ha at Kings Plains, within the Inverell Shire Local Government Area (LGA) 30 km east of Inverell in northern New South Wales (NSW). The Project was granted development consent by the Department of Planning and Environment (DPE) under the Environmental Planning and Assessment Act (EP&A Act) on 16 August 2018. It was granted consent by the Minister for the Environment (according to the EPBC Act) on 15 October 2018. The area layout and BESS layout can be seen in Figure 4 and Figure 5, respectively.

The development approval is therefore conditional on the consent conditions:

- NSW EP&A Act Development Consent SSD-8643-MOD -1; and
- Commonwealth EPBC Act Approval 2017/8121.

Since then, the BESS technology has been selected and an update to the fire safety study is needed.

1.1.1 Project Staging

It is intended that SSF will be constructed and operated in stages.

The development consent for the SSF provides for a BESS capacity of 60MW. Stage 1 will involve the construction and operation of a 30MW (BESS). Subsequent stage(s) of the SSF will be the construction, operation of the solar PV component of the project and expansion of the BESS facility to the full 60MW capacity.

The BESS layout provided in Figure 5 with a higher resolution version of the layout is provided in Appendix A,, this shows the layout for the 60MW BESS, with the option of additional Quantum Enclosures shown in grey, and the Quantum Enclosures for the Stage 1 BESS (30MW) in black.

Commissioning of Stage 1 is planned for 2024-2025.

Stage 1 will include establishment of electrical cables between the battery and existing TransGrid substation and construction of a site compound. Access to the BESS will be via Western Feeder Road, to the SWF main access gate and then use the existing internal access roads of Sapphire Wind Farm (SWF).

1.2 Scope and Purpose of this Report

This report is the Fire Safety Study (FSS) on the proposed SSF to satisfy Condition 23 in Schedule 3 of the Development Consent (SSD-8643-MOD -1) which states:

Prior to the commencement of construction of the development, or unless otherwise agreed by the Secretary, the Applicant must prepare a Fire Safety Study for the development, in consultation with Fire & Rescue NSW, and to the satisfaction of the Secretary.

The study must:

(a) be consistent with the Department's Hazardous Industry Planning Advisory Paper No. 2, 'Fire Safety Study Guidelines'; and

(b) report on the implementation status of the relevant mitigation measures listed in the EIS.

Following the Secretary's approval, the Applicant must implement the measures described in the Fire Safety Study.

It builds on the preliminary hazard assessment (PHA) completed as part of the SSF Environmental Impact Statement (EIS) which formed part of the project Development Application in January 2018 and has been prepared considering the relevant SEPP 33[3] guidelines:

- *Applying SEPP 33: Hazardous and Offensive Development Application Guidelines* (NSW DPIE 2011a);
- *Hazardous Industry Planning Advisory Paper No 2 (HIPAP 2): Fire Safety Study Guidelines* (NSW DPIE 2011b); and
- *Hazardous Industry Planning Advisory Paper No 2 (HIPAP 4): Risk Criteria for Land Use Safety Planning* (NSW DPIE 2011c).

The purpose of this FSS is to ensure that existing or proposed fire prevention, detection, protection and fighting measures are appropriate for the site-specific fire hazards at the SSF and to report on the application of the mitigation measures presented in the PHA that was appended to the SSF EIS. A FSS is part of the hazard assessment documentation that provides additional detail to what is presented in the PHA. This is illustrated in Figure 1.

In accordance with HIPAP 2 (NSW DPIE 2011b):

- This FSS encompasses the entire SSF site and all fire-related potential hazards;
- The fire protection and strategies presented are based on the worst-case scenario;
- The study considers both the aspects of a fire system: the physical components, and the operational and strategic planning aspects; and
- The study considers all effects of fire at SSF. This includes flame, radiant heat and explosion effects, as well as toxic materials, gases and contaminated fluids

The structure of this FSS is:

- Section 2: describes the project setting and components
- Section 3: identifies the fire hazards presented by SSF
- Section 4: presents the fire event modelling and consequences
- Section 5: presents the fire prevention and mitigation strategies

[3] Note that SEPP 33 has now been updated and is part of more complete State Environment Planning Policy (Resilience and Hazards) 2021. The guidance materials and HIPAP papers for SEPP 33 are still the relevant guidance materials for potentially hazardous industry.

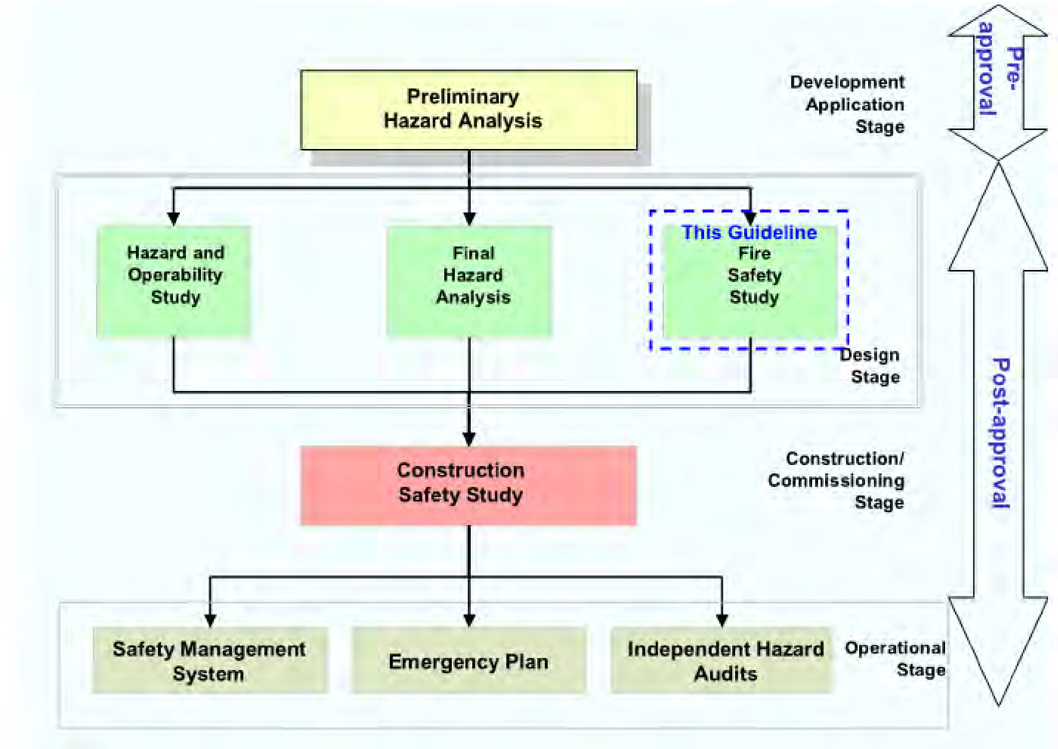


Figure 1: The Hazards-Related Assessment Process outlined in HIPAP 2 (NSW DPIE 2011b)

1.2.1 Report Updates

February 2021

This report was updated in February 2021 in order to reflect changes to the project. These changes include the staging of the project and technological and design modifications. None of the proposed changes increase the relevant risk levels or alter any of the conclusions of previous versions of this report. Therefore, this version of the report is substantially similar to previous versions, although references may be made to the project changes.

November 2022

This report has been updated in November 2022 to reflect the selected BESS technology and the information provided on it. Additionally, lessons learned from recent BESS fire and explosion events have been incorporated.

April 2023

This report was updated in April 2023 in order to address minor comments and finalise the report for issue to FRNSW for review.

July 2023

This report was updated in July 2023 in response to the FRNSW review of the FSS dated 25 May 2023 and agreed actions from meeting between Squadron Energy and FRNSW on 27 June 2023. Updates include documenting the utilisation of a non-intervention firefighting response and to include a summary on the fire test results of the Quantum Enclosures.

September 2023

This report was updated in September 2023 in response to further FRNSW comments review of the FSS dated 11 August 2023 and agreed actions from meeting between Squadron Energy, Arup and FRNSW on 14 September 2023. Updates include higher resolution plans, additional information/ detail, a summary of the report against the new FRNSW Technical Information Fire Safety Guideline (refer Appendix D) and provision of the referenced reports to FRNSW for their review[4].

1.3 Lessons Learned from Previous BESS Incidents

As electricity networks are decarbonizing, lithium-ion BESSs have been incorporated into networks to provide balance between energy supply and demand. Lithium-ion batteries have been around since the 1990s; but the rate of technological advancement has been so rapid that code and standard development has struggled to keep up. Additionally, as with many industries, there are challenges when scaling-up; what works for a single battery cell will not necessarily be effective for hundreds of thousands of battery cells packaged into a BESS.

1.3.1 Arizona, USA 2019

On 22nd of April 2019, a BESS explosion occurred in Arizona, USA at a public utility that had been using a 2 MWh BESS for 2 years. Thermal runaway occurred in a cell and cascaded to adjacent cells and modules in a rack. The BESS was outfitted with a total flooding clean agent fire suppression system; however, the system was incapable of stopping thermal runaway. Due to the nature of the suppression system, the ventilation system was turned off to hold the clean agent as per its design; therefore, there was no means to exhaust the flammable off-gases. No pre-incident planning was done for the site and the emergency response plan (ERP) had no guidance on extinguishing, ventilation, or entry procedures. When the fire department did finally enter the container, the fresh air introduced enough oxygen to cause an explosion, injuring serval firefighters and destroying the BESS.

The incident investigation by DNV GL included a statement from 3M, the manufacturer of Novec 1230, that clean agent fire suppression could not prevent or suppress cascading thermal runaway in lithium-ion battery systems. However, such systems could be effective in an initial confined fire.

1.3.2 Geelong, Victoria 2021

On 30th of July 2021, a fire broke out at the 450 MWh BESS project in Geelong, Victoria, Australia. Thermal runaway occurred in one of the 212 Tesla Megapacks while the system was being commissioned. The fire spread to a neighbouring Megapack but did not propagate any further. The Megapack had undergone UL9540A fire testing to establish separation distances to minimize propagation of thermal runaway to adjacent units. However, several factors led to a larger fire than expected, but thankfully no explosion.

Fisher Engineering found that a leak in the liquid cooling system caused arcing of the power electronics that led to thermal runaway. The commissioning procedures had the BESS unit switched off via a keylock switch, effectively a lock-out tag-out, but that caused many of the safety systems (telemetry, fault monitoring, electrical fault safety devices) to be disabled or have limited functionality. Detection of fire and onset and escalation of thermal runaway was unknown because telemetry data (e.g. temperatures, fault alarms) was not being transmitted to Tesla's off-site control facility due to the commissioning procedure.

Lastly, the wind conditions on the day, 20-30 knots, caused flames exiting the roof of the originating Megapack to directly impinge on the neighbouring Megapack's thermal roof; something the UL9540A testing would not have shown due to the low wind conditions permitted in the test procedure. Tesla's ERP and the facility's subject matter experts instructed the fire brigade to let the unit burn out and only apply cooling water to nearby exposures of the unit on fire. Cooling efforts lasted approximately 6 hours, followed by fire watch for almost 72 hours; highlighting the importance of a detailed ERP, availability of subject matter experts and pre-incident planning with the fire service.

[4] Note these are subject to NDAs as such are not appended to this report.

1.3.3 Bouldercombe, Queensland 2023 [5] [6] [7]

On 26th September 2023, a fire broke out at at 7.45pm at the Bouldercombe Battery Project which is owned and operated by Genex Power. The battery is one of 40 lithium Telse Megapack 2.0 units at the site. The site was unoccupied at the time. Several crews attended however the site has a non-intervention strategy and were advised to let the fire burn out.

Police said work is being done to douse the surrounding batteries at the Bouldercombe site and could continue for several days. The extent of this activity is at this time unknown due to the information coming from new reports only.

At the time of issuing this report, the site has been disconnected from the grid and the fire was on going but remained contained within the battery unit of fire origin. QFES remain on site (one truck) and are monitoring the temperatures and "making sure the visible fire doesn't spread".

[5] https://www.news.com.au/technology/gadgets/firefighters-told-not-to-put-out-tesla-inferno-at-queensland-site/news-story/12cd1a6559c184bc8be1c3d83cda3206

[6] https://www.abc.net.au/news/2023-09-27/tesla-battery-fire-at-queensland-renewable-energy-project/102905302

[7] https://reneweconomy.com.au/fire-erupts-in-tesla-megapack-battery-module-at-bouldercombe-storage-facility/

2. Project Setting and Component Description

The layout of the SSF development footprint is shown in Figure 2 and consists of 8 areas for solar PV panels (in orange), a BESS area, the existing SWF operations and maintenance (O&M) facility, construction laydown areas, and construction compounds are all linked by cable routes and access roads (both new and existing).

The project will be connected to the electricity network via the TransGrid Substation that provides the network connection point for the Sapphire Wind Farm (SWF).

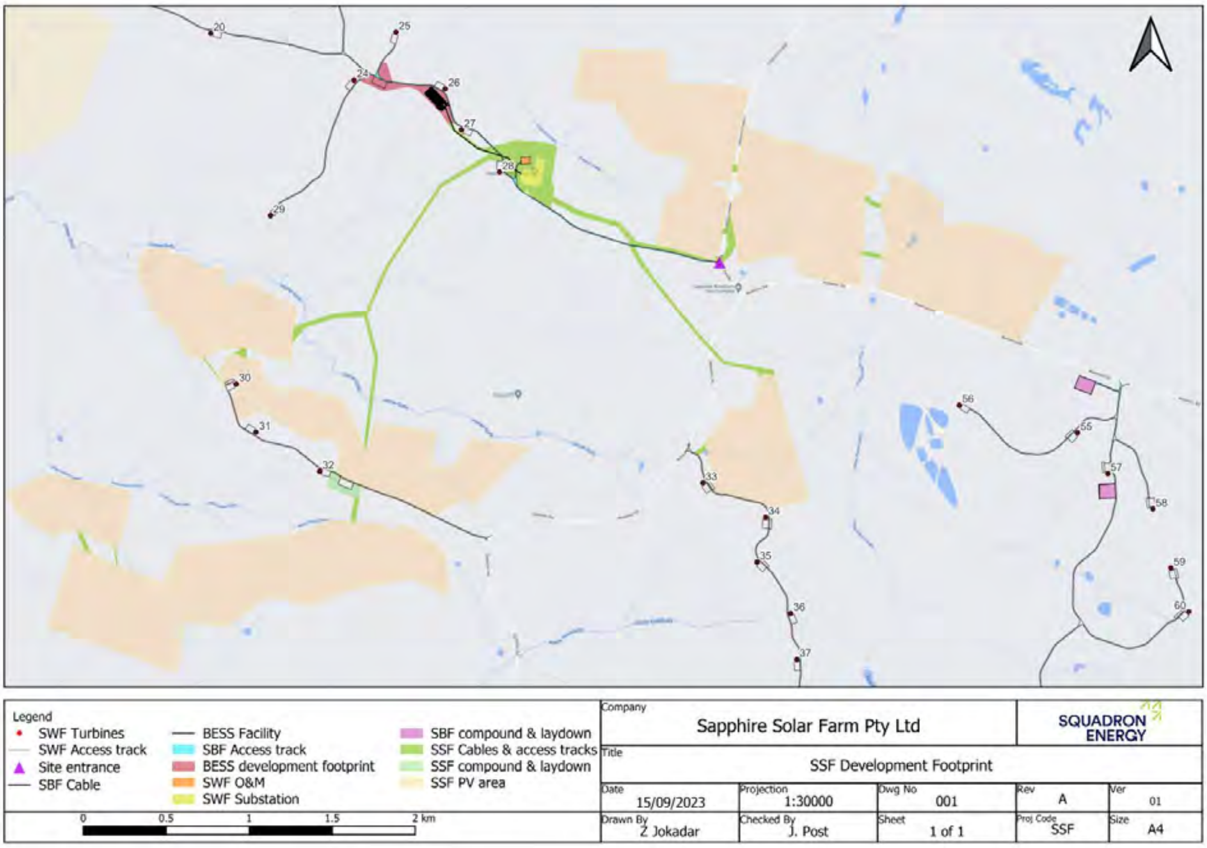


Figure 2: Project layout showing development footprint (refer Appendix A for a higher resolution plan)

2.1 Project Setting

The SSF site ('the Site') is located on land 30 km east of Inverell, in the Inverell Shire LGA, in northern New South Wales. The Site can generally be accessed from Gwydir Highway via Waterloo Road, or from Kings Plains Road via the Western Feeder and Waterloo Road (although the consent conditions identify the project haulage route being from the east via Gwydir Highway and Waterloo Road) (refer to Figure 3). The Site encompasses some land also utilised by the SWF. The Site comprises predominantly cleared agricultural land used for grazing and cultivation with some scattered trees. Some areas having previously been the site of open-cut sapphire mining and quarrying have since been returned to agricultural grasslands.

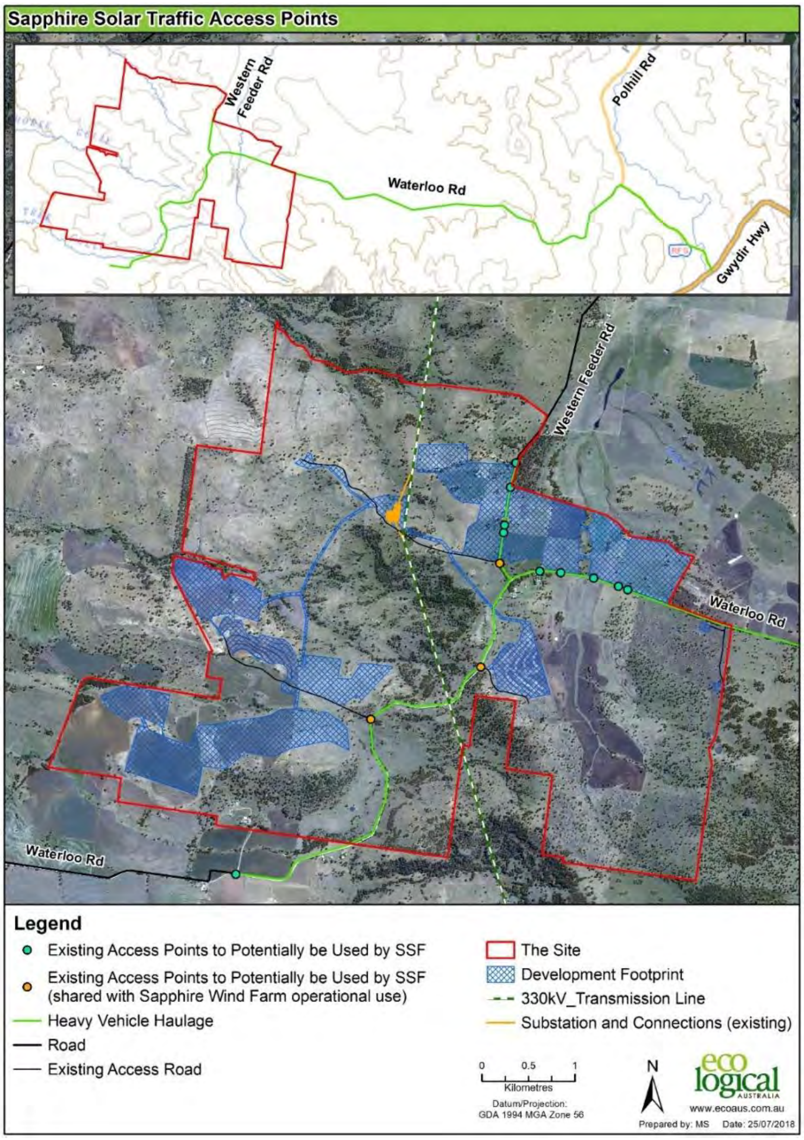


Figure 3: SSF Site Access (refer Appendix A for additional plans showing site access)

2.1.1 Surrounding Land Use

The development footprint and surrounding land is agricultural land zoned RU1 Primary Production under the *Inverell Shire Local Environmental Plan 2012* and has a very low population density. There are 12 residences within 2 km of the site. Five are associated with SSF by their owner's hosting infrastructure and seven residences are non-associated.

2.1.2 Site Layout

The area layout of the prosed battery site can be seen in Figure 4. The area consists of grassland with sparce vegetation spread across the immediate vicinity. Figure 5 shows the 60MW BESS layout, a higher resolution version of the layout is provided in Appendix A. The BESS site consists of rows of the proposed Quantum Enclosures, the transformers, back up diesel generator, control building and storage container. It should be noted that the number of Quantum Enclosures per row is conceptual only and is for the 60MW capacity. The 30MW capacity will comprise of two Quantum Enclosures per row.. During detailed design minor adjustments to the layout may be required, however, these changes will not influence the results of the fire safety study.

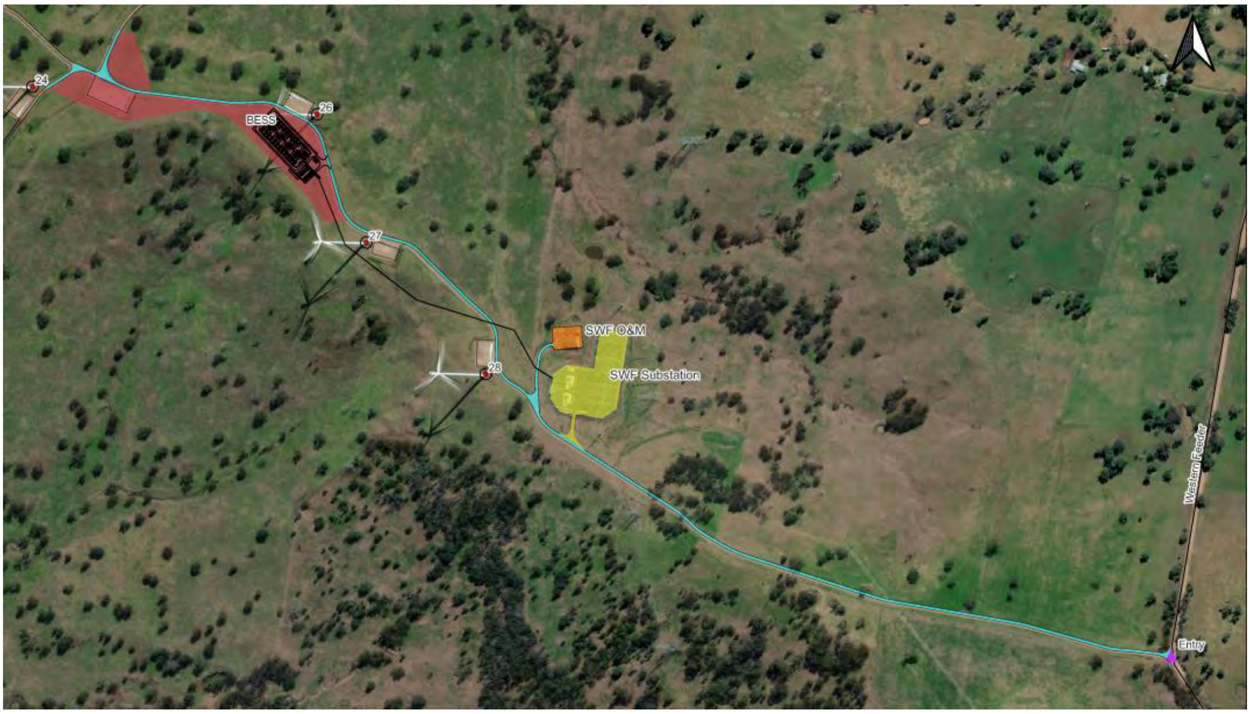


Figure 4: Area Layout (refer Appendix A for a higher resolution plan)

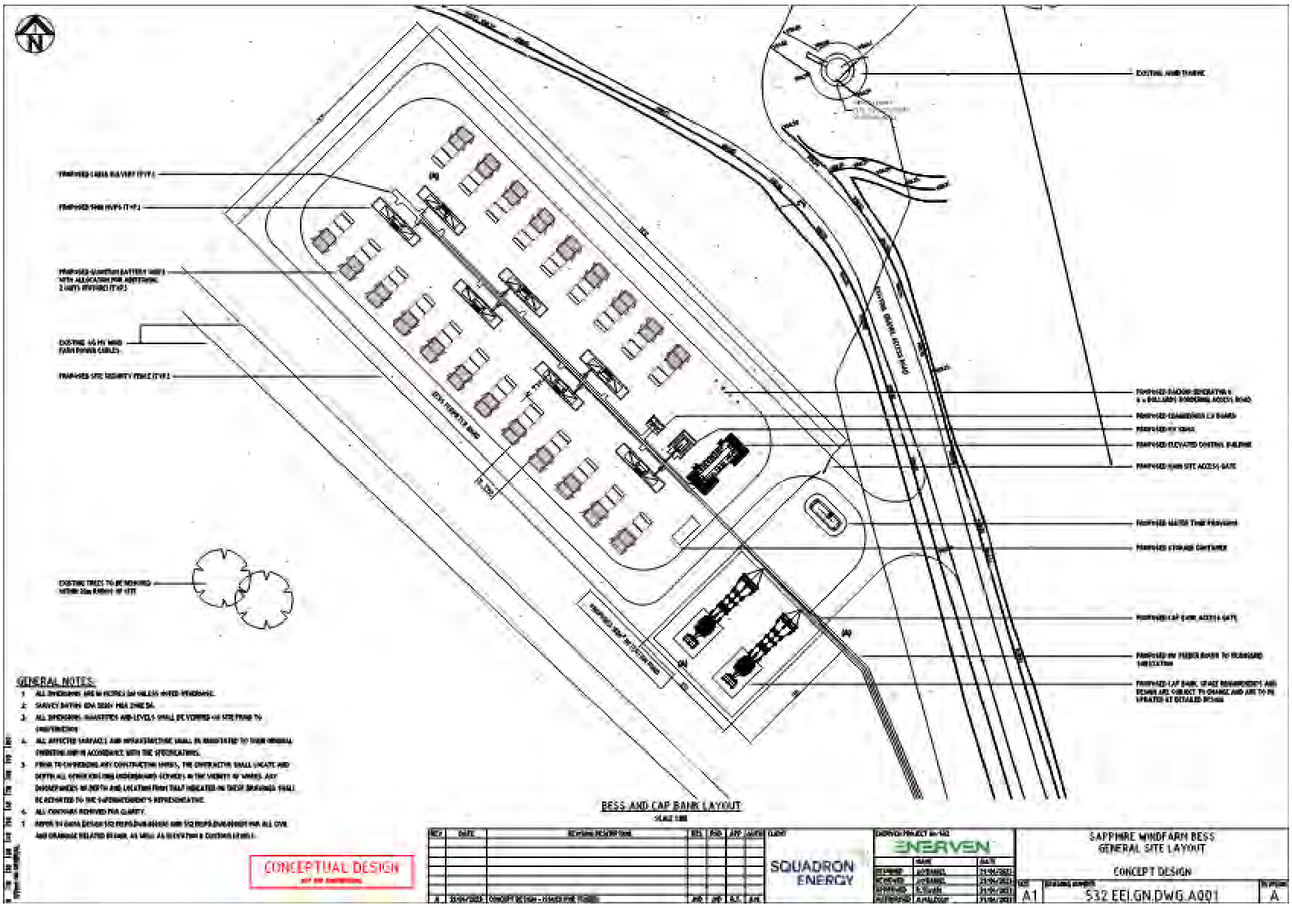


Figure 5: BESS Layout dated 29-Dec-2022 (refer Appendix A for a higher resolution plan)

2.2 Project Components

This section describes the project components that would require firefighting intervention in the event that control measures fail, specifically the PV panel arrays and the BESS. Furthermore, the associated Energy Management System, control building and workforce are discussed.

It is noted that the existing TransGrid substation, situated approximately 643 m southeast of the BESS and adjacent to the existing SWF's O&M building. The substations is operated by TransGrid and adheres to its independent fire prevention and mitigation protocols.

Both the TransGrid substation and the SWF's O&M building fall outside the scope of this analysis, however are considered with respect to the overall fire hazard analysis of the BESS site in that they are not expected to be exposed to a fire event on the BESS site, nor contribute to a fire on the BESS site due to its substantial separation distance, refer Table 1.

2.2.1 Dangerous Goods and Hazardous Chemicals

The dangerous goods (DGs) and hazardous chemicals present at the SSF Site include:

- Transformer oil (class 3); and
- Lithium-ion batteries (class 9)

The coolant in the BESS's liquid cooling system is a water/glycol mix that is not classified as a dangerous good per ADGC. The transformer oil is not "stored" in the conventional sense, but is in circulation in the transformer cooling equipment, while the batteries themselves are fundamentally a piece of operational equipment.

There is no off-site risk due to DGs being on site, therefore further analysis of DG-related incidents was not required.

2.2.2 PV Panel Arrays

The land is currently agricultural grassland used for grazing and cultivation in a varied pattern throughout the year and from year to year. The PV panel array is proposed to be a single-axis tracking system with rows aligned in a north-south orientation, with tracker to tracker east-west spacing of 4 m to 15 m. The ground below the PV panel array will be a grassland which will be maintained with a high percentage of ground cover, but with a low height above the ground (via mechanical slashing or grazing). The physical components of the PV panel array will be designed to allow grazing. The PV panels and racking generally consist of steel piers with panels composed of glass, silicon and polymer films connected with plastic-insulated electrical cables.

As shown in Figure 2 the development footprint is comprised of a series of discontinuous PV panel areas. As part of the EIS process and consistent with Condition 23 in Schedule 3 of the Development Consent (SSD-8643-MOD -1), PV panel areas will be surrounded by a defendable space of 20 m, which will be managed as grassland.

2.2.3 BESS

The BESS location is adjacent to an existing gravel access road constructed for the SWF. This access road is located along an approximately 350 m wide ridge with the land descending to the north-east and south-west (refer to Figure 4). The proposed BESS area is relatively flat, with good road access and significant distances from major off-site infrastructure as shown in Table 1. These distances form a critical layer of protection for off-site populations in the event of a major incident at the SSF.

Table 1: The distance from the eastern end of the BESS to the nearest major infrastructure and residences

Location	Distance from Battery Storage Location
Site Boundary SSF[8]	280 m
Site Boundary SWF[9]	1,500 m
Nearest Residence	1,686 m
Nearest Road	1,600 m
Nearest non-involved landholding	1,600 m
Transgrid substation	643 m
SWF O&M building	589 m
Nearest wind turbine	68 m

The proposed BESS is a lithium-ion, solid state battery system with lithium iron phosphate ($LiFePO_4$) cells housed in modules, which are placed into a racking arrangement, inside the Quantum enclosure. The battery cells and modules are manufactured by CATL and have undergone UL9540A thermal runaway testing. CATL's battery modules meet the European safety standards IEC 62619 and EN 62477-1 and the American standard, UL 1973. There are up to 6 CATL modules in a Wärtsilä (BESS Integrator) rack.

Up to 4 Wärtsilä racks are incorporated into each Quantum Enclosure. Figure 6 shows the Wärtsilä Quantum Enclosure exterior and interior. The 60MW build out will comprise 70 Quantum enclosures, each storing a maximum of 1.12MWh of electrical energy. The Quantum Enclosures are designed to meet NFPA 855, a more applicable standard to grid-scale outdoor energy storage systems than AS 5139.

The Wärtsilä GridSolv Quantum Enclosure has the following features:

- External doors, such that maintenance staff can access the battery racks and auxiliary equipment without entering the enclosure;
- Ventilation fan for flammable gas ventilation
- Deflagration panels on the roof;
- 60-min fire rated side walls designed to ISO 13501-2 and tested in accordance with EN 1364-1;

Doors on the front and rear of the enclosure are insulated with non-combustible mineral wool; and

- Option to link up to 8 enclosures, which can be controlled from a single ACC/ DCC cabinet, which connects the battery strings to the inverter and provides an interface for auxiliary power and communications.

[8] Noting the BESS is within the SSF site boundary.

[9] Noting the BESS is within the SWF site boundary.

Figure 6: Sample BESS Enclosure Exterior Rendering and Interior Photograph

The doors, roof, and deflagration panel on the roof are of similar construction to the side walls and expected to perform comparably in a fire, however as these specific components have not been tested or certified to EN 1364-1, they have not been designated a 60-min fire rating. The performance of the whole Quantum Enclosure assembly in a fire even is detailed in section 4.2.

The project uses SMA's Medium Voltage Power Solution (MVPS) that consists of two inverters, one oil cooled transformer, medium- and low-voltage switchgears, and accessories for consumption and control. The inverter complies with IEC 62109-1 and IEC 62109-2. The MVPS is delivered on a skid or in a rugged pre-configured 40 ft container, as shown in Figure 7. The MVPS complies with AS 3000. The MVPS will also be outfitted with a fast stop switch, full hermetic protection of transformer's heat detectors, and trip protection.

Figure 7: Medium Voltage Power Solution (One per every 2 BESS rows)

During charging, electricity flows from the existing TransGrid substation through underground cabling via the MVPS to each enclosure. The electricity flow is controlled by the Energy Management System (EMS) and Battery Management System (BMS). During discharge, this process is reversed: electricity flows from the battery cells, back to the substation. The output of the BESS is reticulated through unit transformers to 33 kV and then through the SWF HV transformers to connect to the NEM's 330 kV Queensland and New South Wales interconnector.

The BESS design has a myriad of safety features. Starting at the cell, the $LiFePO_4$ chemistry provides inherent safety by having a higher thermal runaway onset temperature than other chemistries like nickel manganese cobalt (NMC). Each cell has a vent that can relieve pressure in a cell. Sensors are incorporated into the modules to monitor individual cell voltage, current, temperature and state of charge.

Each rack of modules has a BMS, which monitors overcharging and current surges, maintains voltage levels and communicates with the EMS that executes shutdown sequences (through the BMS) in the event of, overheating or other unplanned events. Short circuit devices are fitted at the rack level in the switchgear, to limit the current peak and energy of any such event. A glycol/water liquid cooling system is integrated into each rack to maintain the cells in the enclosure within safe and optimal operational temperature limits (< 21°C). Each rack may also be isolated with DC switches. Refer, section 5.2 and Appendix B for a more detailed description of the BMS' various warning and fault conditions.

The Quantum Enclosure contains additional humidity and temperature sensors, as well as, smoke and gas detection systems, to detect off gases or smoke that could be indicative of a thermal runaway or fire event. When smoke is detected within the Quantum Enclosure, it should report to the local fire detection panel at the ACC/ DCC cabinet which will initiate a shutdown sequence for the effected enclosure.

A site master panel will receive the signals from all the ACC/DCC cabinets, the panel will be located in the control building on the BESS site An annunciator panel will also be located in the control building, the control building is currently located ~12 m from the nearest Quantum Enclosure, based on the bespoke fire test detailed in section 4.2 the control building is unlikely to be affected by a fire event within a Quantum Enclosure. The control building will be constructed in accordance to the National Construction Code - Building Code of Australia (NCC BCA) including provisions associated with protection from other fire source features on the site. .

Each Quantum Enclosure is a rigid metal and insulated cabinet. The sides of the enclosures have a fire rating of 60 minutes providing passive fire protection and limiting spread between adjacent enclosures. The front and back doors with chillers integrated into them are insulated. A ventilation fan to exhaust gas during a thermal runaway event. A deflagration panel to redirect gases, smoke and flame during a hazardous event. Each unit is to be bonded to site level earth/grounding.

Each row of Quantum Enclosures can be further controlled by the ACC/ DCC cabinet. The DCC section has two types of surge protection: Type 1 and Type 2. While the ACC section has Type 2 surge protection devices. Type 1 overcurrent protection is mounted on the line side of the main service entrance and protects against external power surges including lightning. Type 2 is mounted on the load side and limits transient voltage and protects the sensitive electronics. The ACC/DCC cabinet also houses process stop buttons that force a manual shutdown of the Quantum Enclosure. The intended users of the stop buttons are trained BESS operators and maintenance personnel.

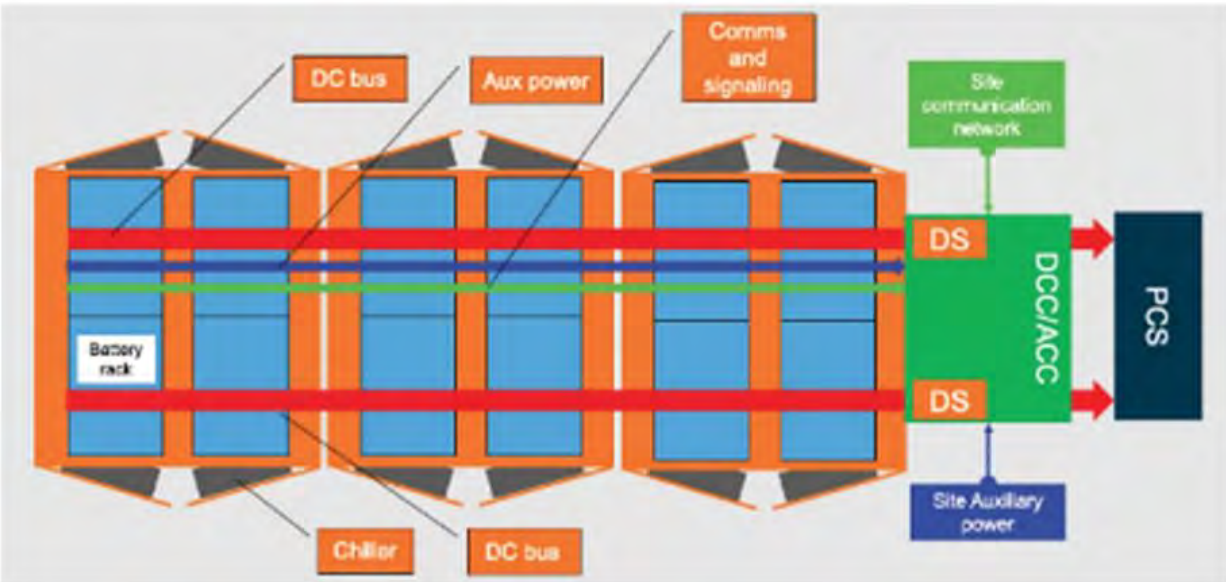


Figure 8: Schematic of the GridSolv interconnections

2.2.4 Operation and Maintenance Facility

A control building for low voltage electrical equipment including protection panels will be constructed in the vicinity of the BESS. The control building is identified in Figure 5 and in the high resolution plan in Appendix A. Additionally, spare parts will be stored in a dedicated container in the BESS area, also identified in Figure 5 and in the high resolution plan in Appendix A.

One BESS Operator/Technician will be co-located with the on-site operational staff of the Sapphire Wind Farm during normal working hours, this is remote from the BESS site located 589 m to the southeast, as noted in Table 1, refer to Appendix A for additional site plans.

The operations manager would be likely be located offsite, but is expected to be able to reach the site within one (1) hour of being notified of an emergency. Remote operational monitoring will include a 24/7 remote control room that monitors performance and alarms. The operation of the BESS is also remotely controlled by the EMS.

The BESS site itself is predominantly unoccupied unless technicians or contractors have specific tasks/works to undertake at the site. Field service technicians and contractors will handle annual and bi-annual planned maintenance, as well as corrective maintenance that is outside the planned maintenance.

2.2.5 Workforce

Staff numbers on site will be approximately 200 during construction and up to 10 maintenance staff during the operational phase of the project. Staff will typically be on site during daylight hours, with 24-hour remote monitoring of system integrity and security.

3. Fire Hazard Identification

3.1 Materials and Quantities

A list of specified dangerous goods and hazardous materials at the SSF is presented in Table 2. The table shows the quantity and location of the materials present as well as their classification according to the ADGC and Hazardous Chemical (HAZCHEM) Codes.

HIPAP 2 (NSW DPIE 2011b) calls for average and maximum quantities to be shown. As the materials will be stored in small quantities if at all, the average and maximum figures would be materially the same value. Therefore, only a single value is shown for all materials.

The materials listed in Table 2 are constantly in use either as a coolant for the equipment or the batteries themselves.

The critical hazards on the site, and those that would require firefighting intervention should control measures fail, are not related to the storage of DGs or other hazardous materials but rather to the PV panel arrays, BESS[10] and the substation. As described in Section 2.2, the substation is outside of the scope of this FSS and is not discussed here.

Table 2: List of potentially hazardous materials at SSF

Chemical Name	Class	UN No.	HAZCHEM Code	Inventory Average	Storage Type	Location Reference
Lithium-ion batteries	9	3480	4W	980tonnes	In use	BESS
Mineral oil	NA	NA	NA	13,370 kg	In use	Transformer oil
R134a	2.2	3159	2TE	15.5 kg	In use	Refrigerant
R410A	2.2	3163	2TE	201.6 kg	In use	Refrigerant
SF6	2.2	1080	2TE	43.4 kg	In use	Refrigerant
Basf Glysantin G30 Glycol	NA	NA	NA	4620 kg	In use	Refrigerant

3.2 Hazardous Incident Scenarios

Hazardous Incident Scenarios were identified using a variety of methods, including:

- a hazard identification (HAZID) process;
- a site visit to the SSF, including a site inspection of the BESS location;
- information received from the preferred battery original equipment manufacturer (OEM) suppliers identified in the procurement process;
- prior battery fire studies in the literature and from industry;
- liaison with relevant NSW Government Agencies including:

[10] A non-intervention strategy is proposed, refer 5.3 for further details.

- Department of Planning and Environment;
- Fire and Rescue NSW (FRNSW);
- New South Wales Rural Fire Service (NSW RFS); and

- the PHA previously completed for the SSF as part of the EIS process.

The SSF PHA identified the following types of potential hazards (not all fire related) at the facility:

- Fire (flammable liquid);
- Explosion (flammable gas);
- Toxic gas leak;
- Electrocution; and
- Crushing.

Not all of the potential hazards listed above are related to fire and detailed analyses were included in the PHA. This FSS is concerned only with fire and explosion consequences. HIPAP 2 (NSW DPIE 2011b) advises that a word diagram should be used as part of the reporting of hazard identification. The word diagram produced for the PHA (reproduced and refined in Table 3 in accordance with HIPAP 6 (NSW DPIE 2011d)) outlines some possible causes, consequences and mitigation measures for specific hazard events. This analysis does not address likelihood; however, most of the hazards are appropriately controlled by the mitigation measures already in place.

A critical hazard in lithium-ion batteries is thermal runaway. Triggered by a fault (for example an electrical short-circuit or battery cell electrical shunt) which can induce high-current flows inducing high temperatures and potentially an exothermic reaction perpetuating thermal runaway, which may result in a fire. The heating and fire can then heat neighbouring cells, propagating the effect. If a fire results, it can cascade from cell to cell, module to module, rack to rack and in extreme cases, enclosure to enclosure. This is supported by the fire testing summarised in section 4.2 which demonstrated no fire spread from a Quantum Enclosure to adjacent Quantum Enclosures during testing.

The thermal runaway hazard is mitigated by a series of safety measures, occurring at the cell, module, BMS, rack and enclosure levels of the BESS. Standards for lithium-ion batteries include thermal runaway testing at the cell level and module level; and install standards in some international jurisdictions assess the system or enclosure level, although these standards do not yet exist in Australia. Regardless, this is the most significant hazard identified and is thus the basis for the fire modelling performed in this study.

The Quantum enclosure is fitted with a BMS for each rack, and other monitoring equipment that, in the event of severe abnormal conditions or identified battery faults within the enclosure will execute a shutdown sequence through the EMS. The EMS utilises information received from the BMS, as well as sensors and equipment within the enclosure itself.

Furthermore, the possibility of the Quantum enclosure releasing gaseous emissions, due to an overcharge or thermal event, presents an explosion and toxicity hazard for maintenance personnel. Whilst the likelihood of this event is minimal, the consequences are significant and as such this hazard and the two resulting potential consequences were considered in further detail in the PHA. Results are therefore presented in this report.

Table 3: Hazard identification word diagram

Event	Cause	Consequence	Mitigation Measures
Thermal Runaway in battery cell	• Electrical fault (e.g. short circuit) • External heat source (e.g. bushfire, arson) • High ambient temperature • Mechanical failure allowing rapid chemical mixing in cell (e.g. crush, penetration, fall, internal structure failure) • Excessive charge/discharge current • Excessive voltage during charging • Frequent temperature excursions in cells • Charge imbalance across cells connected in series • Over-discharge, inducing very low voltage • BMS/safety mechanism failure • Coolant leak or liquid-cooling system failure resulting in short circuit or heating of cell • Battery aging/degradation cause by the above	• Fire engulfing single cell, which can then spread to whole module • Fire, spreading to other modules in the rack • Fire, spreading out of racking to other battery racks • Fire, spreading out of enclosure to other enclosures	• BMS, particularly for voltage balancing, charge/discharge rate limiting and safety shutoff mechanisms • Cell temperature and voltage are monitored, and current is monitored in the switchgear. Readings outside of safe limits will cause the BMS to disconnect the string/rack. • Backup power supply for liquid cooling system • aR class fuses integrated into the battery rack switch gear • Specific battery design to minimise thermal runaway risk (e.g. electrolyte additives, $LiFePO_4$ rather than LCO/NMC chemistry) • Integrated protective circuitry to provide safety in case of internal short circuit failure, as part of certification procedure for lithium-ion cell testing • Containerised system to prevent escalation • Integrated rack and battery bank level BMS. • Smoke and hydrogen gas detectors can trigger a safety relay that stops operation of the inverter and cuts power to the battery rack switchgear. • System sizing and battery capacity consider degradation over time • Pressure relief vent in each battery cell
Electrical connection failure/short	• Improper installation • Faulty equipment/untested to industry standards • Failure of safety devices	• Excess heat leading to fire • Electrocution of maintenance staff • Damage to BMS, with potential to disrupt larger system	• BMS detects voltage or current outside of safe range and disconnects the faulty string/rack • Surge protection between the feeder and ground protects against a voltage spike. • It is not possible to operate the BESS without the GEMS being in operation.

Event	Cause	Consequence	Mitigation Measures
BMS failure	• Improper installation • Faulty equipment/untested to industry standards • Operation beyond supplier specified parameters • Software failure • Incoming electrical surge	• Thermal Runaway and fire • Electrocution	• Robust BMS with back safety measures installed in accordance with appropriate regulation, refer section 2.2.3. • Integrated rack and battery bank level BMS. • Routine inspection and maintenance
Release of battery cell liquid electrolyte	• Puncture, crush or fall event for battery or stack • Onsite explosion and resulting projectile ruptures battery pack • Battery penetrated by gunshot fired from surrounding farmland • Car collision with container/s	• Potential for electrolyte to form a pool fire • Potential for electrolyte to evaporate, build up in container and explode	• Protected by enclosure against most small arms • No shooting signs at site boundary as deterrent • Access to the site is controlled • The BESS area is fenced off • Ventilation fan to exhaust flammable gas in case of thermal runaway • Deflagration panel in enclosure's roof in case of gas/pressure build up
Fall of battery racking/stack	• Improper installation of batteries, both in container and placement of containers • Faulty equipment/untested to industry standards • Improper operational procedures	• Crush operational stuff • Potential for toxic material leakage	• Quantum Enclosure is a no-entry design, whereby accessibility is only from the door restricting operator from entering. • Install in line with appropriate standards and manufacturer's instructions
Flammable gas release from battery	• Overcharging/discharging • Damage to cell • Heat exposure	• Potential for explosion if gas is allowed to build up and source is present • Potential for explosion to send small projectiles flying, presenting a hazard to maintenance staff • Toxic gases presenting risk to maintenance staff/fire-fighting staff (specifically carbon monoxide, hydrogen fluoride)	• BMS to control overcharge/discharge and overvoltage. If outside of safe operating range, the rack is disconnected. • Short circuit devices (aR class fuses) limit short circuit current peak and energy • Integrated protective circuitry to provide safety in case of internal short circuit failure, as part of UL1973 listing. • UL9540A testing showed control of fire/explosion in a module. • Deflagration panel in container's roof in case of gas/pressure build up • No access to inside of container.
External impact	• Car collision with container/s • Potential wind turbine failure	• Crush and penetration of multiple cells, overheating, leading to fire	• Access to the site is controlled • Fencing installed around the BESS area.

Event	Cause	Consequence	Mitigation Measures
			• In terms of the wind turbine falling, a geotechnical report has been undertaken to warrant the safety of the foundations.
Vandalism and/or ingress (animals, people, insects)	• Access and/or damage by unauthorised personnel • Access and/or damage by animals or insects	• Damage to BMS, batteries, auxiliary electronics or safety systems • Potential hazard to vandals/animals • Potential for damage to battery system to create fire/toxic materials hazards	• Batteries enclosed in cabinet with a no-entry design. • BESS is fenced off to prevent access • Site boundary fenced to prevent accidental ingress • On site security protocols (monitored by 24-hour monitoring system with incident response protocols) • O&M Facility and flammable material stores are approximately 589 m away from the battery facility (Figure 4). This distance is considered sufficiently remote that it does not warrant detailed calculations.
External fire engulfs Quantum Enclosures	• Bushfire • Wind condition exceeding UL9540A test limits causes flame tilt from a fire in an adjacent container • Substation/transmission line/PV/Wind infrastructure failure and subsequent fire initiation, spreading through surrounding grassland to Battery System	• Large amount of chemical energy in battery system engulfed by external fire is released, exacerbating fire • Some of the battery container's walls carry a 1-hour fire rating. If the battery container is engulfed in flames, it will cause damage to the power electronics resulting in a short-circuit. A short-circuit will lead to an increase in battery cell temperature and as previously identified, this condition will lead to enforcing the battery protection due to abnormal temperature.	• Containers well-sealed with 1-hr fire rated walls • Cleared 20m exclusion zone around battery system. • Bushfire management plan includes management of surrounding grasslands. • Separation distance between Quantum Enclosures and other fire source features, including, control building, backup generator and SWF flammable materials stores O&M. • Separation between Quantum Enclosures to limit heat transfer based on UL9540A testing and manufacturer's specifications. • Deflagration panel on roof provided with insulation to limit heat penetrating the Quantum Enclosure. • Site-wide isolation through GEMS. • Refer section 3.3

Event	Cause	Consequence	Mitigation Measures
Sustained heatwave	• Sustained environmental radiative heat output	• Cell overheating and thermal runaway if liquid-cooling system is not operational or sufficient	• Liquid-cooling system, with backup power source • Inspection and testing protocol for cooling system during assembly and end-of-line testing • Alarms and sensors to identify a coolant leak • Temperature monitoring and shutoff with BMS control
Water ingress	• Leaks in container during rain events	• Short circuit, leading to electrocution or fire	• Container certified to relevant standards • Container checked for leaks as part of maintenance regime • Container is IP55 rated
High levels of humidity	• Weather events • Liquid-cooling system does not de-humidify, or even adds moisture content over time (condensing type)	• Short circuit, leading to electrocution or fire	• Humidity sensors in each enclosure • Cooling system utilises insulated piping • Each enclosure has a dehumidifier, and container software management systems to measure humidity levels inside container • Cooling system is pressure tested at the Quantum FAT
Electrical fire from PV panels	• Improper installation • Wiring fault	• Fire within PV array • Potential for grassfire	• Defendable space around the PV panels • Wiring and installation standards

3.3 Other Fire Hazards on BESS Site

There are other fire hazards on site not associated with the BESS, given the associated fire safety measures associated with these other areas of the BESS site, a fire event is not expected to impact the BESS. As such, the consequences have not been specifically assessed in section 4.

The fire hazards within these areas these have been assessed and addressed as follows:

Table 4: Mitigation of other fire hazards on the BESS site

Area	Separation Distance Note 1	Additional Mitigation of Fire Hazard Note 2
Control building	11.9 m	Building shall comply with NCC BCA. It is recommended that the external walls be fire-rated walls to provide increased resilience to the building in a fire event. Fire rating to be to BCA DtS requirements or at least 60/60/60 when tested from the outside, whichever is greater.
Storage Container	5.0 m Note 3	Constructed of steel.
Backup Generator	8.0 m	Diesel storage associated with Generator shall comply with AS 1940:2017. Generator shall comply with relevant Australian Standards.
Capacitor Bank	>20.0 m	Capacitor Bank shall comply with relevant Australian Standards.
MV Kiosk	10.5 m	MV Kiosk shall comply with relevant Australian Standards.
Changeover LV Board	6.1 m	Changeover LV Board shall comply with relevant Australian Standards.
MVPS	5.0 m Note 3	Fire safety features as per section 2.2.3

Note 1: Separation distance to the nearest row of Quantum Enclosures, if during detailed design it is determined that there is an Australian Standard requirement for a great separation distance this shall be adhered to.

Note 2: The fire rating provided to the Quantum Enclosures provides the primary mitigation measure with respect to fire spread to and from the other areas on the BESS site.

Note 3: Refer section 4.2.2.

4. Consequences of Incidents

The consequences of the hazard scenarios identified during the HAZID process were assessed in the PHA. The results of the fire event assessments are provided below.

4.1 PV Panel Array

4.1.1 PV Panel Array Fire Scenario

The fire risk associated with PV panel arrays is no different to any other electrical installation. Research commissioned by the Department for Communities and Local Government (DCLG) in the UK and carried out by BRE Global indicates that "there is no reason to believe that the fire risks associated with PVs are any greater than those associated with any other electrical equipment" (Shipp et al., 2013). Fire incidents associated with PV arrays were generally related to installation faults.

4.1.2 PV Panel Array Fire Spread

The PV panel array causes no additional risk of a fire spreading to the rest of site and potentially having off site consequences. The panels are constructed almost exclusively from non-combustible materials (such as glass, steel and concrete). Fire spread is appropriately mitigated by the separation provided by the surrounding roadways.

4.2 BESS

4.2.1 Fire Test Study Summary

A bespoke fire test was conducted by Fire & Risk Alliance, LLC (FRA) for the Gridsolv Quantum Enclosure on 2 February 2023.[11] The tests focus was on fire propagation of heat and fire onto adjacent enclosure. The test evaluated the results of a forced full scale fire in the enclosure. The adjacent enclosures were spaced 100 mm away from each side of the initiating enclosure.

The test demonstrated that in the event of an enclosure failure where the initiating enclosure ignites and becomes fully involved, the modules in the adjacent enclosures do not reach failure conditions. The thermal data indicating that the external wall temperatures on all enclosures remained at or below 160°C and the North and South Target enclosures experienced temperatures lower than 120°C towards the top of the container and below 100°C at lower elevations. This was further confirmed by visual observation sighting no fire propagation occurred.

The test duration was 8.5 hours without any outside intervention before suppression activities were undertaken due to the expiration of the burn permit.

Gas measurements were also conducted, and it was found that high levels of gases were measured above the initiating enclosure, whereas, at a height of a standing person, the concentration of those gases dropped off significantly. In terms of the toxicity, these types of gases are detrimental to occupants – carbon gases (CO and CO_2) being asphyxiant gases, induces anoxia (lack of oxygen) condition whilst fluoride gases (HF and POF_3) are toxic gases and corrosive to the skin upon contact. In the early stages of a fire event gas concentrations are not going to at disabling or lethal levels in the immediate vicinity to the fire affected enclosure, and given the remote nature of the site, the concentration of toxic gases in the air will rapidly dissipate to non-lethal exposure levels. To reduce the risk of exposure there is a non-intervention fire fighting response proposed for staff and fire fighters, part of the fire fighting strategy should also include an exclusion zone and remaining upwind of a fire event where practicable.

[11] Fire & Risk Alliance, LLC, "Quantum Cube Bespoke Unit Testing Summary Report," Fire & Risk Alliance, LLC, 2023.

4.2.2 BESS Fire Modelling

A fire event in a Quantum Enclosure was modelled. In order to assess the worst credible case for off-site risk, it was assumed that all fire prevention measures had failed, and an enclosure had caught fire. Two fire configurations were considered: a single door being open and the more credible scenario in which all doors are closed. Note, this is considered an extreme case based on the fire test results as documented above.

The radiative heat flux emitted was calculated using the Stefan-Boltzmann Law:

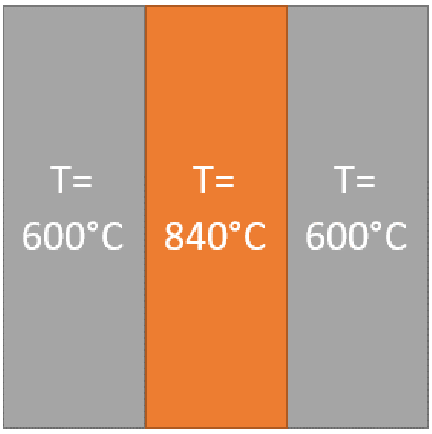
$$j^*_{emitter} = \varepsilon\sigma T^4$$

where j^* is the radiant emittance, ε is the emissivity of the container, σ is the Stefan-Boltzmann constant and T is the surface temperature. The heat flux received was calculated using the view factor method. Further description of this methodology and all equations used are presented in Appendix C.

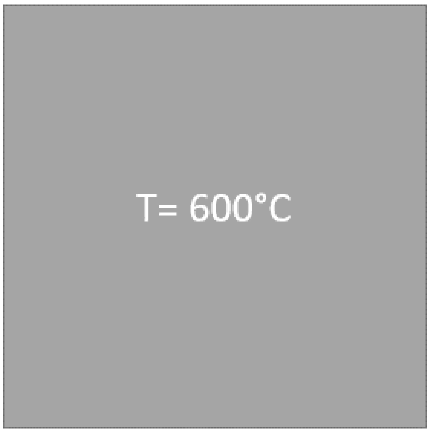
The following assumptions formed the basis for the modelling:

- The temperature of the open door was set at 840°C (flame temperature). This is representative of an emitting heat flux of 84kW/m² which is used for fire spread design between buildings such as offices (Approved Document B) (HMCLG, 2010). While the enclosures do contain batteries, which would have combustible contents and some plastic materials, the overall structure of the enclosure is to be non-combustible and the majority of racking within the space is constructed of non-combustible metal. This results in a comparable fuel load. 840°C is also within the flame temperature range recommended for use for fires based on the Fire Engineering Design Guide. While adiabatic flame temperature is based on the chemistry of a flame, within a compartment the overall compartment dynamics and air ratio influence the temperature of a flame;
- The temperature of the closed doors and container walls was set at 600°C, which is generally the temperature at which flashover begins in a compartment as per the SFPE Handbook and CIBSE Guide E. This represents a severe fully developed fire throughout the container. While a flashover fire may reach higher temperatures than 600°C, given that the enclosure has 60-minute rated fire walls, it is unlikely that the external surface temperatures would reach 600°C or beyond;
- The emissivity of the container was taken to be 0.9. This represents a conservative emissivity for a severe fire and a good radiator;
- The open door was assumed to be the dimensions (width and height) of one rack within the enclosure;
- The heat flux from the emitting surface was assumed to be uniform;
- No heat loss was assumed to intermediate media (i.e. to air or smoke); and
- The basis of the fire modelling is to consider the worst-case conditions. It is a consequence-based assessment. In this context historical wind data does not affect the consequence assessment. Further as detailed above the fire modelling ignores that integrity and insulation rating of the containers, providing further conservativeness.

The two scenarios are represented pictorially in Figure 9.



Scenario 1: Single door open



Scenario 2: All doors Closed

Figure 9: Pictorial representation of the two fire modelling scenarios.

The results of the modelling are presented in Figure 10. The Purple line shows 12.6 kW/m^2 which, according to HIPAP 4 (NSW DPIE 2011c), has the following effects:

- Significant chance of fatality for extended exposure. High chance of injury
- Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure
- Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure

The risk of a fatality as a direct result of an enclosure fire is limited to people within 2 m (door closed) or 3 m (door open).

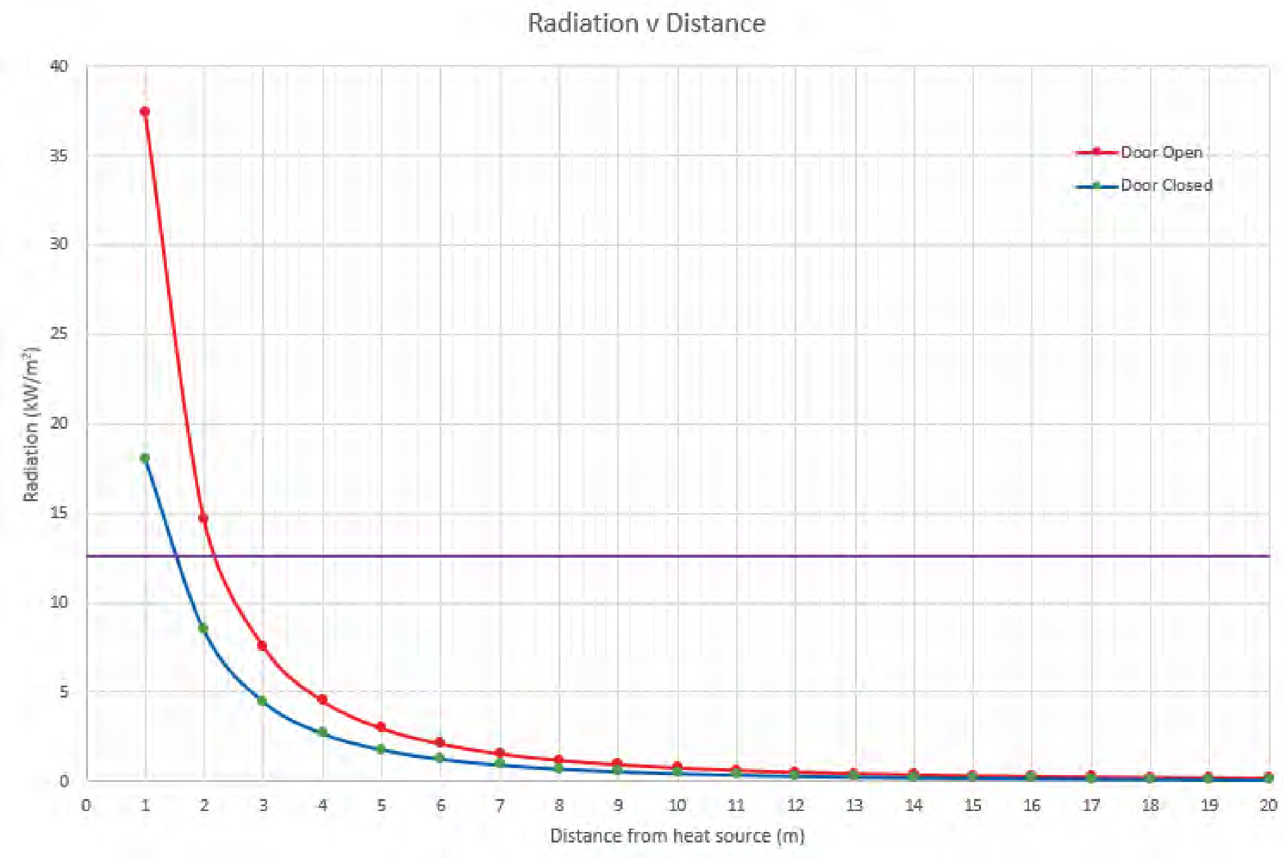


Figure 10: The results of the fire modelling, showing heat flux radiation plotted against distance. The Purple line is set at 12.6 kW/m²

The closest equipment to the enclosures are the MVPSs approximately 5 m away. The maximum anticipated heat flux from an enclosure on an MVPS is less than 5.0 kW/m^2. This heat flux is less than the electrical equipment exposure limits defined by Ausgrid (11-15 kW/m^2). Exposure protection should not be needed to keep this adjacent equipment safe unless there is flame impingement.

4.2.3 Fire Spread

In order to mitigate against the risk of fire spread from the BESS to the rest of the site and potentially off-site, a 20 m clear zone is to be installed around the BESS, with all vegetation cleared and gravel or a similar material placed on the ground.

The results of the analysis above suggest that in the event of an entire enclosure catching fire, the 12.6 kW/m^2 radiation contour would extend approximately 2 m (door closed) to 3 m (door open) and at 20 m, the heat radiation would be below 1 kW/m^2, which is comparable to the effect of direct sunlight, and insufficient to cause ignition.

The fire modelling demonstrates that the 20 m separation zone is sufficient to prevent fire spread from the BESS to the remainder of the site and to off-site receptors. The separation zone is also required to ensure that that external fire events do not impact the BESS.

The separation distance between rows of enclosures at 3.1 m is sufficient to mitigate the risk of fire propagation via radiant heat from row to row in the BESS. The UL9540A test report provided, testing at the cell and module level. The results show that thermal runaway was contained within the module. However, since flammable gases were vented, it was UL's recommendation for a unit, containing the modules, to undergo further testing. As such, bespoke testing was undertaken as per section 4.2.1. The UL9540A testing flowchart is show in Figure 11 for context.

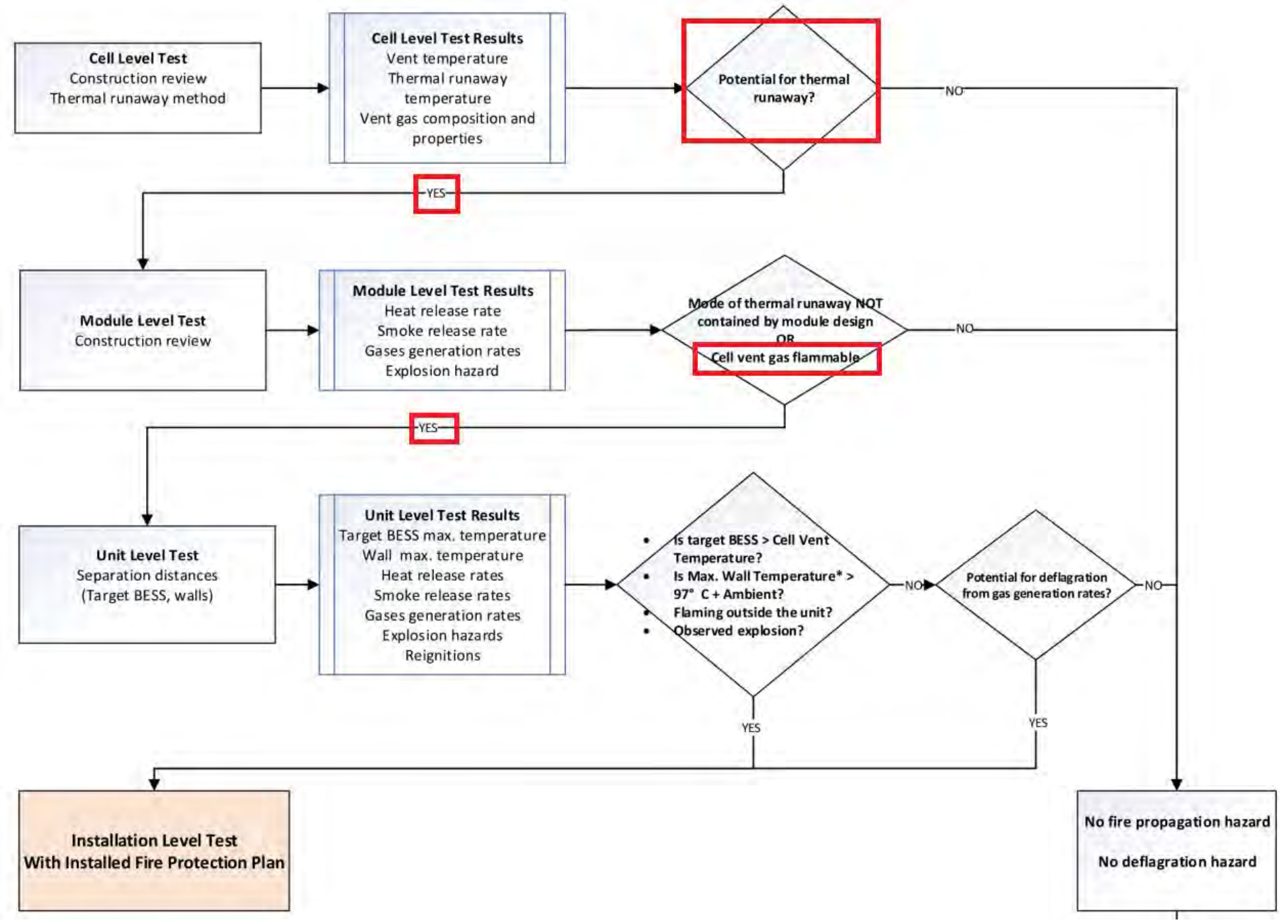


Figure 11: UL9540A Testing Flowchart (Credit: Underwriter's Laboratories)

Wärtsilä had a 3rd party conduct a fire modelling study to evaluate the risk of fire propagation which is discussed in more detail in Section 4.2.5.

4.2.4 Gas Explosion

A confined vapour cloud explosion (VCE) was identified as a consequence of an event in Section 3.2. The UL9540A, for the cell and module level testing, gives the composition of gases generated, shown in Table 5. The vapours emitted during a thermal runaway event can be flammable and toxic.

Table 5: Gas composition in UL9540A test results

Material	Gas composition by mass (%) in Cell Test	Gas composition by volume (%) in Module Test
Carbon Monoxide	11	27
Carbon Dioxide	33	10
Hydrogen	36	35
Methane	10	-
Ethylene	5	-
Ethane	1	-
Dimethyl Carbonate	2	-
Other Hydrocarbons	2	28*
*Module Level testing uses a Flame Ionization Detector to measure Total Hydrocarbons		

The explosion consequence is very unlikely as identified in the PHA. Vented flammable gases would need to disperse and mix and then find an ignition source to cause a confined VCE. Each enclosure has a ventilation fan to actively ventilate the enclosure before an explosive concentration is reached and a passive deflagration panel that should relieve the developed pressure from an explosion and release it into the surrounding environment in a controlled manner.

Wärtsilä had a 3rd party perform a ventilation analysis for the enclosure. The battery manufacturer's UL 9540A test data indicated a peak gas release rate of 218 lpm (3.63 l/s). Based on the results of the FDS analysis the Quantum ventilation fan maintains the gas concentration below the battery gas LEL during the duration of the event.

Wärtsilä had a 3rd party perform a deflagration analysis for the enclosure. The battery manufacturer's UL9540A test data informed the design. The cell level testing indicated a burning velocity of 64 cm/s and maximum pressure (P_{max}) of 103 psig. The module level testing indicated that 394 L of gas was produced. The deflagration analysis performed by Fire & Risk Alliance, LLC reviewed two scenarios:

1. Release of flammable gas from failure of a single battery module
2. Release of flammable gas that would fill the full volume of the enclosure

The maximum pressures observed in the FLACS modelling were 0.77 to 0.87 psi. Applying a critical burst/deployment pressure of 0.7 psi for the deflagration panel quickly reduces the pressures in the enclosure and limits the duration of pressure impulse and magnitude.

HIPAP 4 (NSW DoP 2011c) suggests that 7 kPa is an appropriate cut-off for significant injury or fatality to individuals. Anderson et al. showed that ISO shipping containers sustained "minor" damage at 2 psi overpressure approx. 14 kPa) and "significant" damage at 5 psi overpressure approx. 35 kPa). The deflagration panel deployment at 0.7psi should minimize significant damage to the surroundings and the enclosure.

No off-site consequences are expected due to the release of vented flammable gases.

4.2.5 Wärtsilä Heat Flux Summary

Wärtsilä contracted a 3rd party, Fire & Risk Alliance, to perform computational fluid dynamics modelling for the Quantum enclosure to understand the effect of flaming activity within the enclosure and to adjacent enclosures. Ten scenarios were considered ranging from a fire limited to the enclosure of origin that is ventilation controlled to a fire burning after a deflagration event with 0 – 50 mile per hour wind conditions.

The analysis utilised the UL9540A testing data for a module. One scenario considered is very similar to the Geelong Big Battery fire in a deflagration has occurred causing flames to escape the top of the enclosure and high wind speeds causing flame-tilt onto an adjacent enclosure. The modelling found the roof of the adjacent enclosure was exposed to temperatures of 600 °C, exposing the topmost modules in the adjacent enclosure to a heat flux of 42 kW/m^2. Follow-up scenarios incorporated rockwool insulation to the underside of the deflagration panel and the heat flux was able to be reduced to 5-8 kW/m^2.

As a result of the analysis Wärtsilä has incorporated additional insulation to the deflagration panels. This minimises the chance of thermal runaway in an adjacent enclosure from the incident heat flux through the top of the deflagration vent. The testing also showed the ability of the fire-rated side walls and insulated front and back to minimize the transmittance of heat into adjacent enclosures, allowing for 0.1 m of side-to-side separation between enclosures.

5. Fire Prevention and Mitigation Measures

The fire prevention and mitigation strategy for the SSF contains multiple layers of fire control and fire defence, following a typical risk control hierarchy. They are described below against each of the two key parts of the project.

5.1 PV Panel Array

Grass will be managed beneath the panels to reduce the height of grasses. Vegetation clearing from the development will not result in cleared logs and branches remaining below the panels.

5.1.1 PV Panel Array Fire Spread Prevention

As described in Section 2.2.1, as part of the EIS process and consistent with Condition 23 in Schedule 3 of the Development Consent (SSD-8643-MOD -1), the perimeter of each of the PV panel areas will be surrounded by a 20 m defendable space managed as a grassland.

5.2 BESS

The fire prevention and mitigation strategy for the BESS contains multiple layers of defence. The first control measure is the BMS, which ensures the batteries are operating within normal conditions. If that should fail and a battery begins to operate outside defined parameters, controls are in place to detect and prevent, and then finally mitigate increases in temperature, and ultimately fire propagation.

5.2.1 Battery Management System (BMS)

The BMS works to ensure that the performance of each battery is within normal operating range. The BMS is the communication interphase between the battery modules and the EMS in terms of individual battery voltage, current, temperature and state of charge.

The BMS typically includes features such as:

- Overcharge protection;
- Surge protection;
- Voltage level maintenance; and
- Trip switching in the event of, overheating, or unplanned electrical events.

5.2.2 Temperature Control

Each enclosure is fitted with its own liquid cooling system to maintain each CATL module's average temperature to less than 21°C. The chiller systems are provided with backup power from an onsite diesel generator. Further, the temperature sensors located inside the modules can detect elevated temperatures in any of the cells and initiate shutdown sequences for the affected module, through the EMS. Other cabinet environmental monitoring includes temperature and humidity sensors.

The liquid cooling system in use in the enclosures must be rated for use in local weather conditions, including prolonged direct sunlight exposure; and will have a maximum operational temperature of 45°C. The record high temperature in Inverell is 41.9 °C and the record low temperature in Inverell is -9.5 °C. Climate change scenarios over the life of the plant have not been assessed due to inherent uncertainty; however, maximum high temperatures may be expected to increase in future under such projections. All equipment should be suitable for operation at the maximum anticipated ambient temperature and direct sunlight.

As the system is liquid cooled, incorporation of a leak detection system into the chiller via for instance low pressure detection, should be included in the overall enclosure design. Additionally, the BESS OEM should ensure that the cooling system is pressure tested, at site, to detect any leaks prior to commissioning. Notwithstanding any testing prior to delivery by the battery manufacturer or integrator.

5.2.3 Shutdown Mechanisms

The BESS is equipped with both automatic and manual shutdown capabilities.

Automatic Shutdown

Protection features are built into the BESS such that if a critical fault occurs the BESS will automatically shutdown. The BMS has a number of warning and fault conditions, a high level summary of relevant conditions are summarised in Appendix B

The equipment and conditions inside the BESS enclosures are continuously monitored. The EMS monitors alarms, temperature, humidity and enclosure door status.

If the BESS is operating outside of permissible limits (warning condition), the BESS Technician can initiate a shutdown if deemed appropriate.

Manual Shutdown

Each ACC/ DCC cabinet is equipped with process stop button that is hardwired and will send a fast shutdown command to the inverter for an entire row of Quantum Enclosures. The process stop buttons to drive a safety relay which will cease power exchange between the row of Quantum Enclosures and the grid, and to isolate an entire row of Quantum Enclosures from the DC Bus.

Each Quantum Enclosure can be manually isolated at the rack-level via an isolation device.

The entire BESS can be isolated through the GEMS panel.

Other safety systems should not be disabled or impaired by these isolation devices. Wärtsilä has confirmed that if auxiliary power in the Quantum Enclosure is not cut, chillers and their controls and monitoring along with smoke detection, hydrogen gas detection, and temperature and humidity sensor readings will continue to be transmitted to the EMS.

Manual shutdown mechanisms are to be deployed by the BESS Operator or technicians.

5.2.4 Enclosure Fire Detection & Suppression

As learned from the Arizona BESS explosion, clean agent fire suppression including Novec 1230, is unable to stop a cascading thermal runaway event in batteries. Previous versions of the GridSolv Quantum had an aerosol fire suppression system; however, Wärtsilä recognizes that this type of suppression cannot stop a thermal runaway event and can contribute to a larger accumulation of flammable gas. Based on the 2023 edition of NFPA 855, Wärtsilä will no longer offer the aerosol suppression system as a standard option in the enclosure. As such, it is assumed that this project will acquire Quantum Enclosures without a suppression system.

A non-intervention firefighting response will be adopted, this is supported by the fire test for the Quantum Enclosures and modules, as summarised in Section 4.2.1, which demonstrated that in the event of an enclosure fire, the fire does not propagate between enclosures.

Each enclosure also has hydrogen gas detectors, and a photoelectric smoke detector. When smoke is detected within the enclosure it should report to the local fire detection panel at the ACC/ DCC cabinet which will initiate a shutdown sequence for the effected enclosure. Additionally, the audio-visual fire alarm on the ACC/ DCC cabinet should notify those in the immediate surroundings of the problem.

The design of the smoke detection system complies with NFPA 72 as that is the standard referenced by NFPA 855. The design of the gas detection system complies with NFPA 72 for the same reason as above. The site master panel and annunciator panel, located in the control building, will likely comply with Australian standards (AS 1670). . A suitably qualified services engineer should review the gas and smoke detection system design to ensure compatibility across design codes. The ERP should outline the detection/alarm stages and corresponding actions.

The control building will be designed to comply with the NCC BCA requirements, it is recommended that over and above these requirements the external walls be fire-rated walls to provide increased resilience to the building in a fire event. Fire rating to be to BCA DtS requirements or at least 60/60/60 when tested from the outside, whichever is greater.

The enclosure's fire and gas detection systems will ensure prompt awareness of a fire or thermal runaway event at the site master panel. Additionally, the annunciator panel, will provide fire services valuable information when responding to an event, with respect to non-intervention activities such as monitoring the extent of exclusion zones. The intent is the BESS operator or a BESS technician will relay information on the annunciator panel to the fire brigade.

The ventilation fan in the Quantum Enclosure will exhaust flammable gas as an active means of protection and a passive deflagration panel on the roof will vent should a deflagration event occur. These layers of protection mitigate the risk of an event like Arizona occurring.

5.2.5 BESS Fire Spread Prevention

The following fire prevention strategies are recommended:

- All vegetation within at least 20 m of the BESS shall be cleared, with gravel or a similar material laid to prevent both an external fire impacting the BESS and a fire within the BESS spreading to the wider site and off site; and
- Vegetation shall be maintained across the remainder of the development footprint at a level that will prevent any external fire reaching an intensity which would adversely impact on the BESS across the 20 m separation distance. Specifically, the slopes near the BESS should be well maintained.

NFPA 855, a globally recognized standard for BESSs, considers remote locations to be more than 30.5 m from exposure hazards. However, based on the analysis discussed in Section 4.2.3, 20 m is adequate.

5.2.6 BESS Commissioning

The Geelong Big Battery Fire occurred during commissioning, it was discovered after the fact that numerous safety features were disabled or had limited functionality when the unit was isolated for commissioning. An emergency response plan (ERP) should be developed that considers these safety features, with requirements set in Section 5.6. It is imperative that a commissioning plan be drafted, it is recommended that it include:

1. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
2. A listing of the specific BESS and associated components, controls and safety-related devices to be tested, a description of the tests to be performed and the functions to be tested.
3. Conditions under which all testing will be performed, which are representative of the conditions during normal operation of the BESS.
4. Documentation of the owner's project requirements and the basis of design necessary to understand the installation and operation of the BESS.
5. Verification that required equipment and systems are installed in accordance with the approved plans and specifications.
6. Integrated testing for all fire and safety systems.
7. Testing for any required thermal management, ventilation or exhaust systems associated with the BESS installation.
8. Preparation and delivery of operation and maintenance documentation.
9. Training of facility operating and maintenance staff.
10. Identification and documentation of the requirements for maintaining system performance to meet the original design intent during the operation phase.
11. Identification and documentation of personnel who are qualified to service, maintain, and decommission the BESS, and respond to incidents involving the BESS, including documentation that such service has been contracted for.

12. A decommissioning plan for removing the BESS from service, and from the facility in which it is located. The plan shall include details on providing a safe, orderly shutdown of energy storage and safety systems with notification to stakeholders prior to the actual decommissioning of the BESS. The decommissioning plan shall include contingencies for removing an intact operational Quantum Enclosure from service, and for removing an Quantum Enclosure from service that has been damaged by a fire or other event.

The commissioning protocols should minimize down time of monitoring and control data transmission.

5.3 First Aid Fire Protection

There are no fire hose reels proposed to the BESS site as there is no reticulated water supply to the BESS site.

Fire Extinguishers are proposed to the ancillary risks to the BESS, where first aid fire fighting is considered appropriate, such as the control building, MV Kiosk and backup generator.

Selection of fire extinguishers will be in accordance with AS 2444:2001 and appropriate to the hazard. For example, foam extinguishers are required to for the diesel storage associated with the back up generator for compliance with AS 1940, where possible all other extinguishers should be appropriate for Class E as well as any additional risks.

5.4 Fire Brigade Provisions

The SSF will be serviced by the New South Wales Rural Fire Service (NSW RFS). RFS may call for assistance from Fire and Rescue NSW (FRNSW), who handle hazardous materials emergencies. Both the NSW RFS and FRNSW have stations in Inverell and Glen Innes, approximately 37 km from the SSF access point. The nearest fire stations are shown in Figure 12 and Table 6. Access to site is via Waterloo Road or Western Feeder, with the site entrance located at approximately 29°42'15.8"S, 151°25'26.5"E.

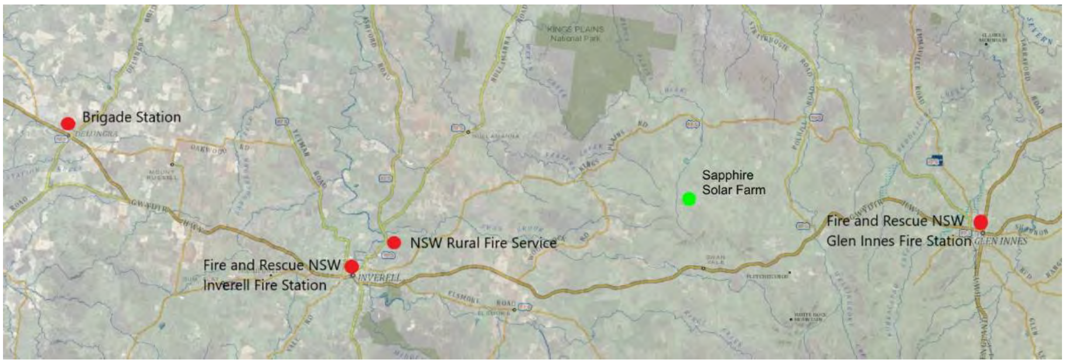


Figure 12: Location of nearby fire stations (image source: SIX Maps)

Table 6: Local Fire Service Information

Station Name	Address	Distance	Contact Details
NSW Rural Fire Service: Inverell	52 Burtenshaw Rd, Inverell NSW 2360, Australia	38 km	+61 2 6721 0446
Fire and Rescue NSW: Inverell	59 Evans St, Inverell NSW 2360, Australia	37 km	+61 2 6721 0015
NSW Rural Fire Service: Glen Innes	181 Bourke St, Glen Innes NSW 2370, Australia	37 km	+61 2 6732 7046
Fire and Rescue NSW: Glen Innes	202 Bourke St, Glen Innes NSW 2370, Australia	37 km	+61 2 6732 5379
Delungra Fire Brigade	Railway St, Delungra NSW 2403, Australia	74 km	+61 1800 679 737

5.4.1 Site Movement

The site contains solar arrays, wind turbines, the TransGrid 330 kV substation and the BESS, connected by roadways (both sealed and unsealed) trafficable by vehicles, this road is expected to meet Fire and Rescue NSW fire safety guideline "Access for fire brigade vehicles and firefighters" given heavy vehicles use the roads to access the wind turbines. The SWF O&M building is adjacent to the substation and located such that emergency services vehicles attending the site through the main access point on Waterloo Rd are not required to drive past the BESSs.

As outlined in section 5.6, protocols with respect to communication with the fire brigade and access to site are to be worked through during the Emergency Response Plan (ERP) development process. An example of what the protocols may entail are:

- Internal site protocols to determine when fire brigade is called out (manual call out).
- Fire brigade would be met at the SWF site entrance by the BESS operator or approved delegate and escorted through the site.
- The site entrance (if closed) would display contact numbers for site operators/ alternative the local fire brigade may have been provided the relevant contact numbers.
- Because of the non-intervention strategy, if there is an extended delay in accessing the site, a fire event is expected to be contained within the area of fire origin until it burns out due to fuel depletion.
- Attending fire brigade to review exclusions zones around the fire event (internal site protocols to include initial exclusion zones)
- As it is envisaged that fire brigade would be accompanied the following information would be provided to them by the attending BESS operator or approved delegate.
  If responding to a BESS incident, a control building will be located at the eastern end of the BESS area that will house protection panels for the capacitor bank, BESS area, CCTV, SCADA and HVAC systems. All alarms (internal and external) will be via the SCADA, either DNP3 or Modbus. To provide safe emergency service access to the control building, it is located a safe distance from the Quantum Enclosures and it has been recommended that the external walls of the control building be fire rated to provide additional resilience.
  Squadron Energy and Wärtsilä propose an annunciator panel be located in the control building at a safe distance from the BESSs to provide information to the fire brigade on fire alarm status in the Quantum Enclosures. Additional information on the status of individual Quantum Enclosures can be obtained from the SCADA system.

The perimeter of the solar array area must include a defendable space that permits unobstructed vehicle access as per Consent Condition 25.

5.4.2 Firefighting Water Considerations

With respect to BESS fire events a non-intervention approach is adopted. This is supported by the bespoke unit testing as summarised in Section 4.2 , which did not utilise cooling water and demonstrated fire spread between the Quantum Enclosures was unlikely to occur. Further, the Geelong fire event utilized a passive/ non-intervention approach whereby cooling water was sprayed for exposure protection of equipment like transformers.

There is however firewater for firefighting is provided for the protection of ancillary assets and grass fires. The greater SSF site is to be provided with a 20 kL potable fire water tank consistent with the consent conditions. This water tank is to be provided near the main access point to the Sapphire site, so that the fire brigade should have easy access to it direct from the main road, to support use for grass fires.

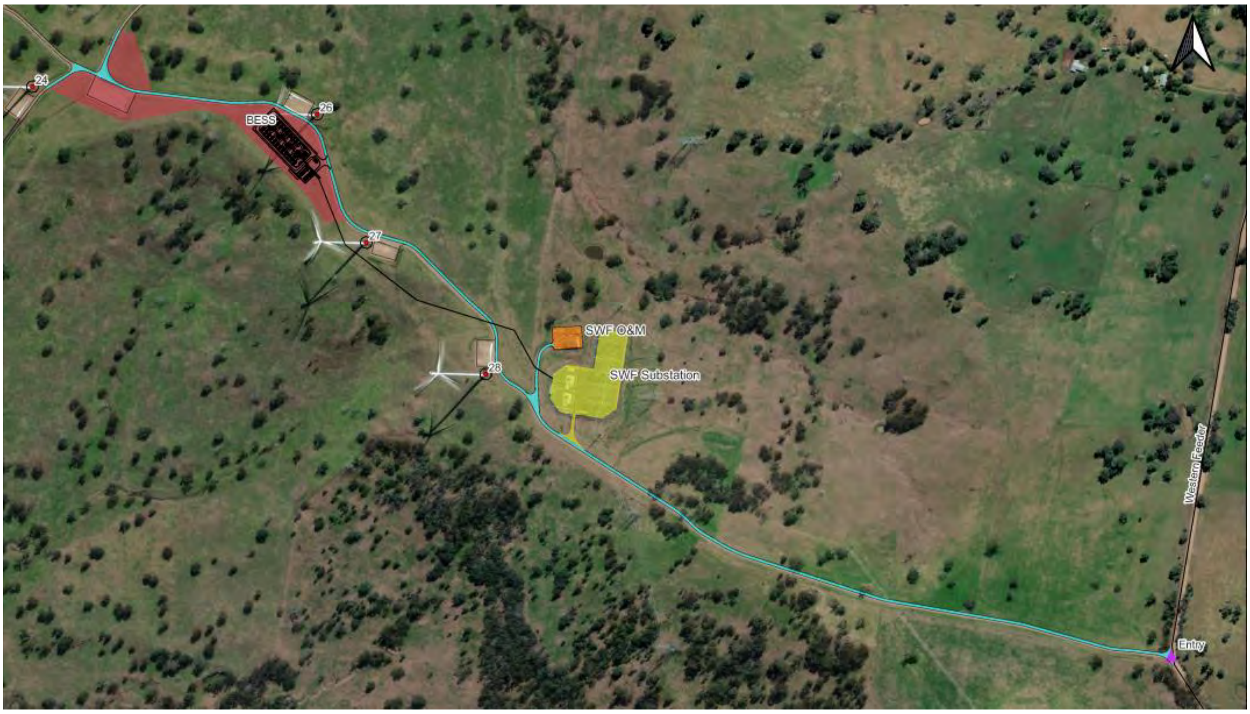


Figure 13: Propose SWF site fire water tank at the 'Entry' (in Magenta) (refer Appendix A for a higher resolution plan)

A 20 kL tank is considered appropriate for ancillary fires within the BESS site, based on one (1) hose stream at 10 L/s from a tanker truck, which is consistent with AS 2419.1:2021 for the size of the control building, there is sufficient water for 30 mins of firefighting.

Furthermore, in the event that the fire brigade do not attend site or a fire event is left to burn out, the fire is not expected to spread beyond the area of fire origin due the separation distances (refer Table 4). The closest equipment to the Quantum Enclosures are the MVPSs approximately 5 m away. The maximum anticipated heat flux from a Quantum Enclosure on an MVPS is less than 5 kW/m^2, based on the calculation methodology presented in Section 4.2. This heat flux is less than the electrical equipment exposure limits defined by Ausgrid (11-15 kW/m^2), and less than the heat flux required to cause ignition of fabric in the presence of a spark (10kW/m^2) as per the Guide to the BCA. Exposure protection should not be needed to keep this adjacent equipment safe unless there is flame impingement.

There is no fire water containment proposed to the BESS site, as there is non-intervention strategy in place.

5.5 Post-Fire Incident Actions

Due to the characteristics of thermal runaway and the compartmented nature of the enclosures, there is a small potential that after an initial thermal runaway event/fire that the initiating cause is not fully removed, and batteries could re-heat themselves and reignite.

In order to mitigate against this potential, the following actions are to be taken following a fire event in an enclosure:

- Upon visual conclusion of the fire event, fire watch should continue until thermal imaging confirms the temperature of the enclosure has returned to ambient.
- Following the above period, if it is safe to do so, the batteries/battery racks are to be removed from the enclosure and isolated. The batteries may be isolated for inspection and checking. Batteries, especially if damaged are to be isolated outside in a clear area with no combustibles (e.g. on a hardstand or gravel pad). In this case they may be monitored and maintained in this clear area isolation for a few days to a week to warrant against reignition.
- If the batteries may not be removed immediately due to danger of fire, heat, electrification or other dangers or damage:

  - A non-intervention fire brigade response shall be taken,
  - If possible, reinstate a temporary gas or smoke detection system to the enclosure, and/or
  - Provide on-site monitoring of the enclosure for at least a week or until feasible to decant the battery modules from the enclosure to an isolated area.
- Before any enclosure or battery is reinstated and connected back to the energy grid, all fire safety systems within the enclosure are to be fully reinstated including detection systems and connection back to the main GEMS system.

The BESS Integrator should provide the site a site-specific ERP (see Section 5.6 for requirements) in collaboration with the Battery Manufacturer for use by the Owner/Operator and Fire Service.

5.6 ERP Requirements

The Emergency Response Plan (ERP) requirements are discussed in this section in accordance with HIPAP 1 (*Emergency Planning*).

The ERP should outline the non-intervention firefighting approach, which is supported by the fire test results that indicate fire propagation does not result between Quantum Enclosures.

According to HIPAP 1 *a site-specific emergency plan minimises the effect of accident inside and outside a facility*, in this case the BESS site. It is a collection of procedures that are clearly defined, systematically developed, and carefully monitored. It is implemented by personnel with adequate training and resources. An emergency plan should be:

- Specific to the facility and the major hazards identified in a risk assessment;
- Effective in addressing the consequences of a major accident both on-site and offsite; integrated into the sites ERP;
- Developed in consultation with employees, emergency services and people likely to be affected by the consequences of a major accident, including other closely located facilities;
- Understood by employees, visitors and other people likely to be affected;
- Subject to testing, review and update at appropriate intervals; and

The ERP should include, but is not limited to:

- Procedures in the event of fire with respect to the attending fire brigade.
    - When and how to contact the fire brigade.
    - Providing critical information during the initial call, and then in subsequent communications.
    - How to communicate with them remotely and on site.
    - Site access protocols.
    - Expected actions for the attending fire brigade given the non-intervention strategy e.g. setting up exclusion zones.
- Plans showing locations of site entry points, and key infrastructure.
- Plans showing locations of fire extinguishers.

The ERP process should also determine if the tactical fire plan is required, any additional signage requirements, the content to be contained within the Emergency Services Information Package (ESIP), and if any additional briefing materials are required for the local RFS.

Additional signage may include:

- Signage to site access points so they are clearly identifiable and not obstructed (e.g. 'Emergency vehicle access – do not block').
- Appropriate signage warning of hazards, how to contact the site operator, the location of critical information for emergency responders.
- Any signage is to be permanently affixed, weather resistant if external, high contrasting, clearly visible and readable at an expected viewing distance.

The main consideration in planning is the ultimate protection of people, property, and the environment from adverse impact during an emergency. The key to a good management plan is that it is dynamic and interactive, with ongoing review through continual monitoring and consultation. This cyclical nature is summarised below in Figure 14

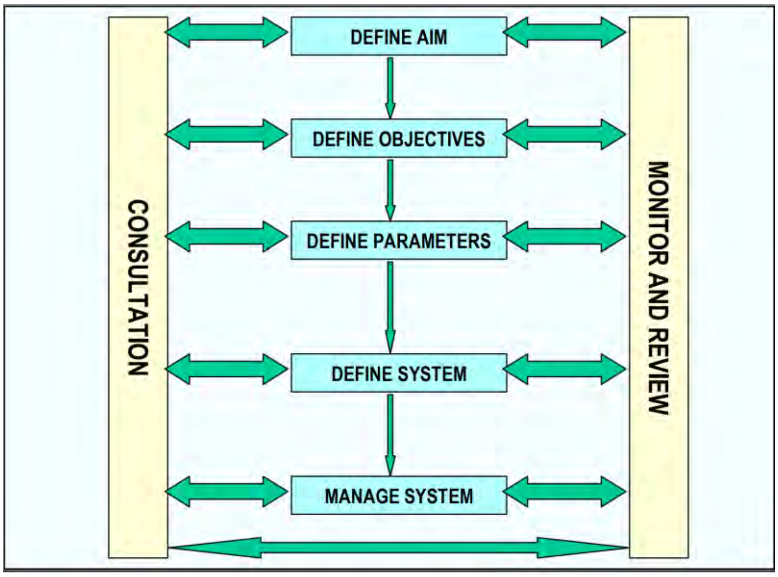


Figure 14: Emergency Planning Process

HIPAP 1 is split into five sections that detail all aspects related to emergency planning and the need for it. Specifically, in Section 3, it explains all issues that need to be addressed when preparing an emergency plan. In Appendix 2 of the paper, there is a 33-point checklist that summarises the components of a site-specific emergency plan.

In addition preparation of an Emergency Services Information Package (ESIP) shall be in line with FRNSW safety guidelines.

The ERP and ESIP shall be prepared prior to commissioning of the BESS.

6. Conclusion

The risk of fire and explosion at the SSF has been assessed according to HIPAP 2 (NSW DIPE 2011b). The risk of off-site impacts as a result of fire or explosion at the site is appropriately controlled by the measures in place, subject to the following recommendations:

- There is no off-site risk due to DGs being on site, therefore further analysis of DG-related incidents was not required.
- All vegetation within 20 m of the BESS is cleared, and a material such as gravel used to ensure clearance is maintained.
- Vegetation in the area around the BESS is maintained at a level that will prevent any external fire from reaching an intensity which would adversely impact on the BESS across the 20 m separation distance.
- The gas detection and smoke detection system designs should be reviewed by a suitably qualified fire services engineer.
- All equipment shall be capable of operating at the maximum anticipated ambient temperature.
- Row-to-row separation distance between Gridolv Quantum[12] battery enclosures (herein referred to as 'Quantum Enclosures') is not less than 3 m. Quantum Enclosures that are electrically connected to the same power ACC/DCC cabinet are separated by a distance in the order of 0.1 m.
- The BESS Integrator and Operator should have a commissioning plan in place that minimizes down time of monitoring and control data transmission.
- Installation should be certified to all relevant Australian Standards (e.g. AS 3000 series) where possible.
- A non-intervention firefighting response will be adopted, this is supported by the fire test of the Quantum Enclosures.
- Installation of other infrastructure on the BESS site should be in accordance with their relevant Australian Standards and should be separated from the Quantum Enclosures by not less than 5 m or the requirements of aforementioned standards, whichever is greater.
- The control building should be located no closer than 11 m from the nearest Quantum Enclosure and should be constructed in accordance with NCC BCA. It is recommended that the external walls be fire-rated walls to provide increased resilience to the building in a fire event. Fire rating to be to BCA requirements or at least 60/60/60 when tested from the outside, whichever is greater.
- Fire extinguishers should be provided as first aid fire fighting to ancillary areas within the BESS site, where first aid fire fighting is appropriate. Locations and fire extinguisher types to comply with AS 2444:2001.
- The BESS Integrator should provide a site-specific Emergency Response Plan (ERP) in collaboration with the BESS Manufacturer for use by the Owner/Operator and Fire Service. This should be done in accordance with HIPAP 1.
- Discussions should include the local fire service, a fire engineer familiar with the technology, owner/operator, and BESS Integrator's subject matter expert during the development of the ERP.

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[12] Gridsolv Quantum is a product of Wärtsilä

- Preparation of the Emergency Services Information Package (ESIP) shall be in line with FRNSW safety guideline.

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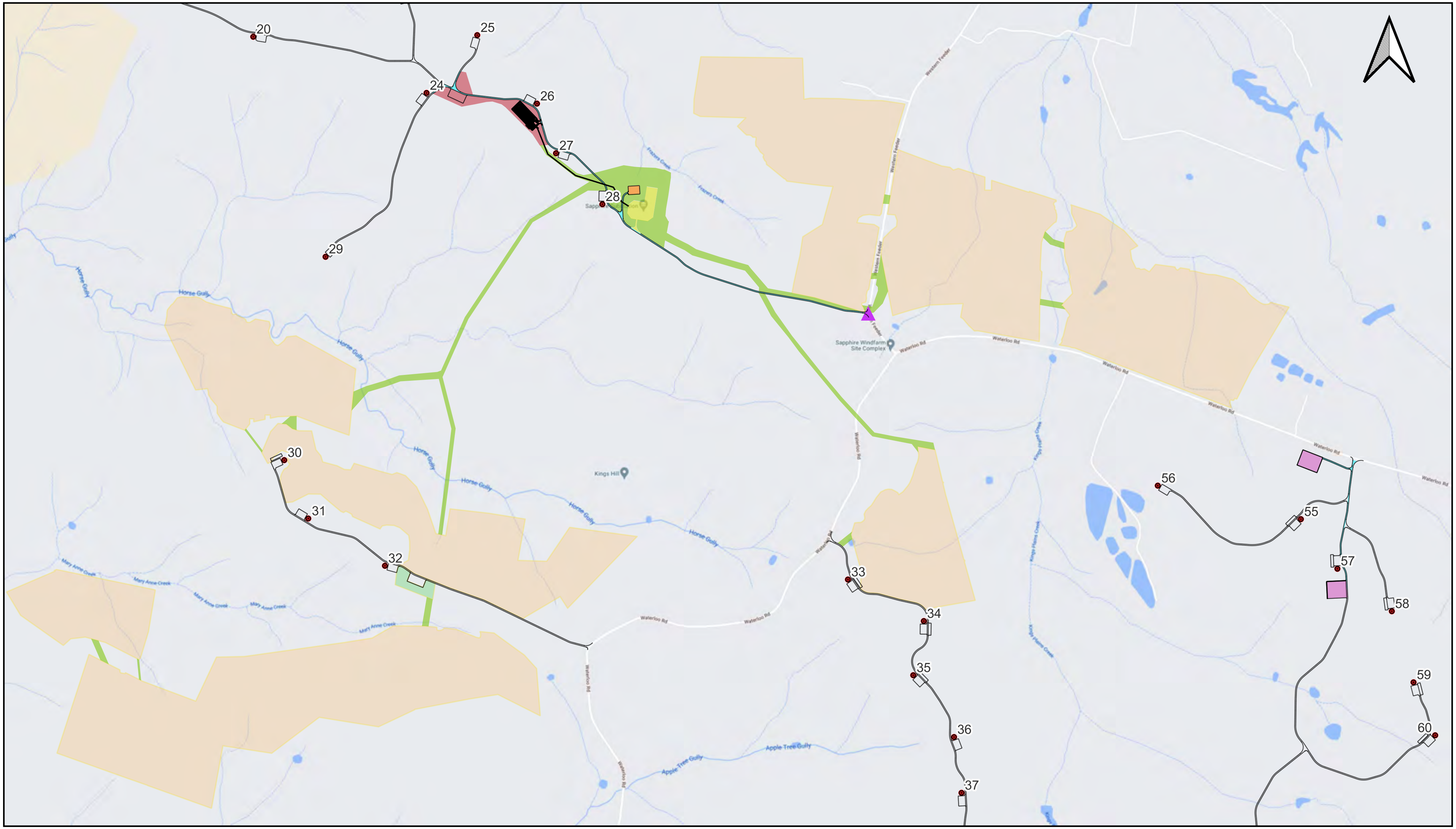
Appendix A

Additional Site Plans



Legend

- SWF Turbines
- SWF Access track
- Site entrance
- SBF Cable
- BESS Facility
- SBF Access track
- BESS development footprint
- SWF O&M
- SWF Substation
- SBF compound & laydown
- SSF Cables & access tracks
- SSF compound & laydown
- SSF PV area

0 0.5 1 1.5 2 km

Company	Sapphire Solar Farm Pty Ltd				SQUADRON ENERGY
Title	SSF Development Footprint				
Date 15/09/2023	Projection 1:30000	Dwg No 001	Rev A	Ver 01	
Drawn By Z Jokadar	Checked By J. Post	Sheet 1 of 1	Proj Code SSF	Size A4	

Legend

- SWF Turbines
- SWF Access track
- Site entrance
- SBF Cable
- BESS Facility
- SBF Access track
- BESS development footprint
- SWF O&M
- SWF Substation
- SBF compound & laydown

0 0.5 1 1.5 2 km

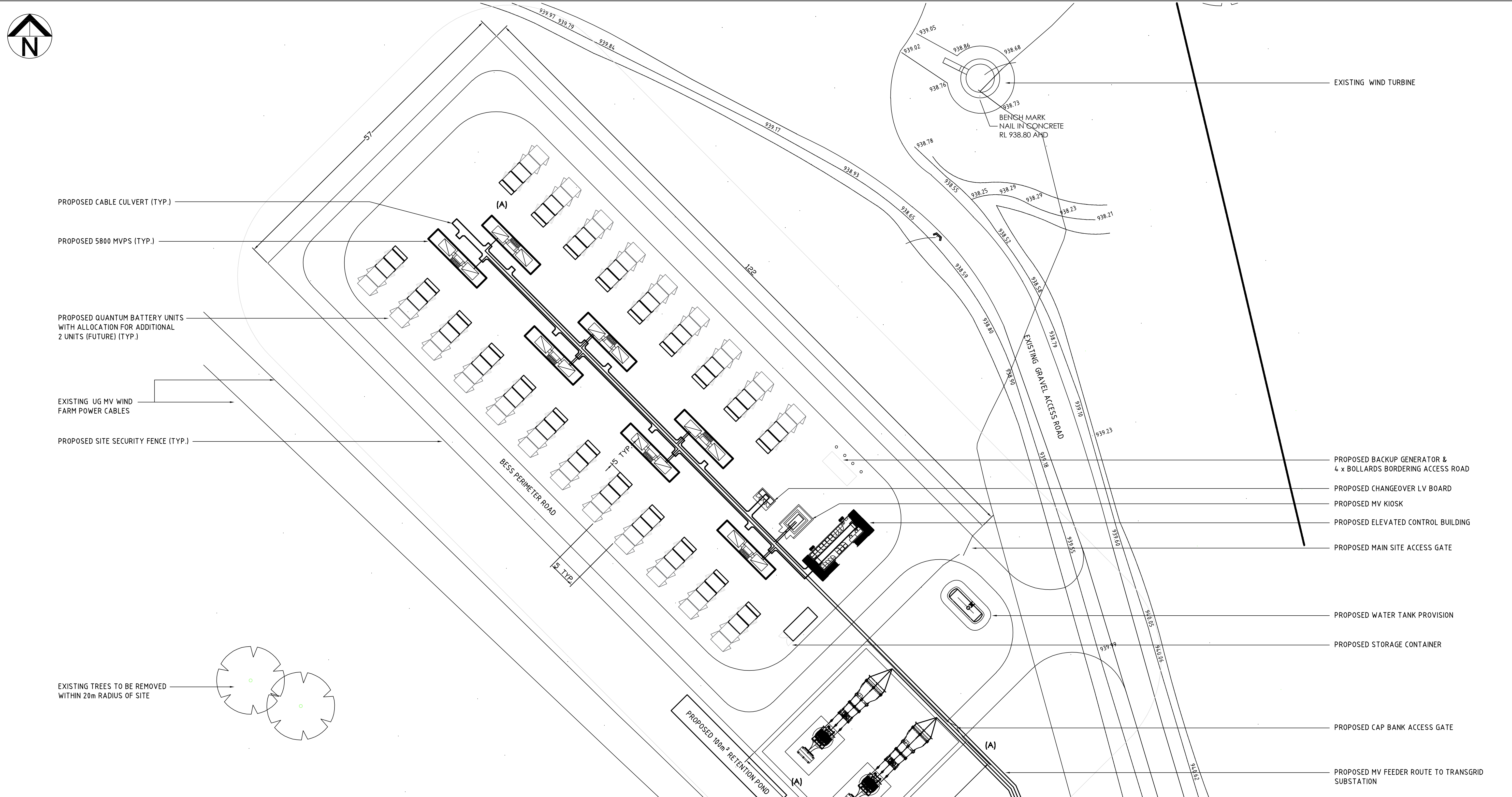
Company: Sapphire Solar Farm Pty Ltd				SQUADRON ENERGY	
Title: SBF Development Footprint					
Date: 15/09/2023	Projection: 1:23000	Dwg No: 001	Rev: A	Ver: 01	
Drawn By: Z Jokadar	Checked By: J. Post	Sheet: 1 of 1	Proj Code: SSF	Size: A4	

Legend

- SWF Turbines
- SWF Access track
- Site entrance
- SBF Cable
- BESS Facility
- SBF Access track
- BESS development footprint
- SWF O&M
- SWF Substation

0 0.2 0.4 0.6 0.8 1 km

Company: Sapphire Solar Farm Pty Ltd				SQUADRON ENERGY
Title: BESS Access				
Date: 15/09/2023	Projection: 1:10000	Dwg No: 001	Rev: A	Ver: 01
Drawn By: Z Jokadar	Checked By: J. Post	Sheet: 1 of 1	Proj Code: SSF	Size: A4



BESS AND CAP BANK LAYOUT

SCALE 1:100

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN METRES (m) UNLESS NOTED OTHERWISE.
2. SURVEY DATUM: GDA 2020/ MGA ZONE 56.
3. ALL DIMENSIONS, QUANTITIES AND LEVELS SHALL BE VERIFIED ON SITE PRIOR TO CONSTRUCTION.
4. ALL AFFECTED SURFACES AND INFRASTRUCTURE SHALL BE REINSTATED TO THEIR ORIGINAL CONDITION AND IN ACCORDANCE WITH THE SPECIFICATIONS.
5. PRIOR TO COMMENCING ANY CONSTRUCTION WORKS, THE CONTRACTOR SHALL LOCATE AND DEPTH ALL OTHER EXISTING UNDERGROUND SERVICES IN THE VICINITY OF WORKS. ANY DISCREPANCIES OF DEPTH AND LOCATION FROM THAT INDICATED ON THESE DRAWINGS SHALL BE REPORTED TO THE SUPERINTENDENT'S REPRESENTATIVE.
6. ALL CONTOURS REMOVED FOR CLARITY.
7. REFER TO GAMA DESIGN 532.EEI.PD.DWG.0001(A) AND 532.EEI.PD.DWG.0001(B) FOR ALL CIVIL AND DRAINAGE RELATED DESIGN, AS WELL AS ELEVATION & CONTOUR LEVELS.

0 10 20 30 40 50 60 70 80 90 100
100mm ON ORIGINAL

CONCEPTUAL DESIGN
NOT FOR CONSTRUCTION

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
A	21/06/2023	CONCEPT DESIGN - ISSUED FOR TENDER	JOD	JOD	R.T.	A.M.

CLIENT: SQUADRON ENERGY

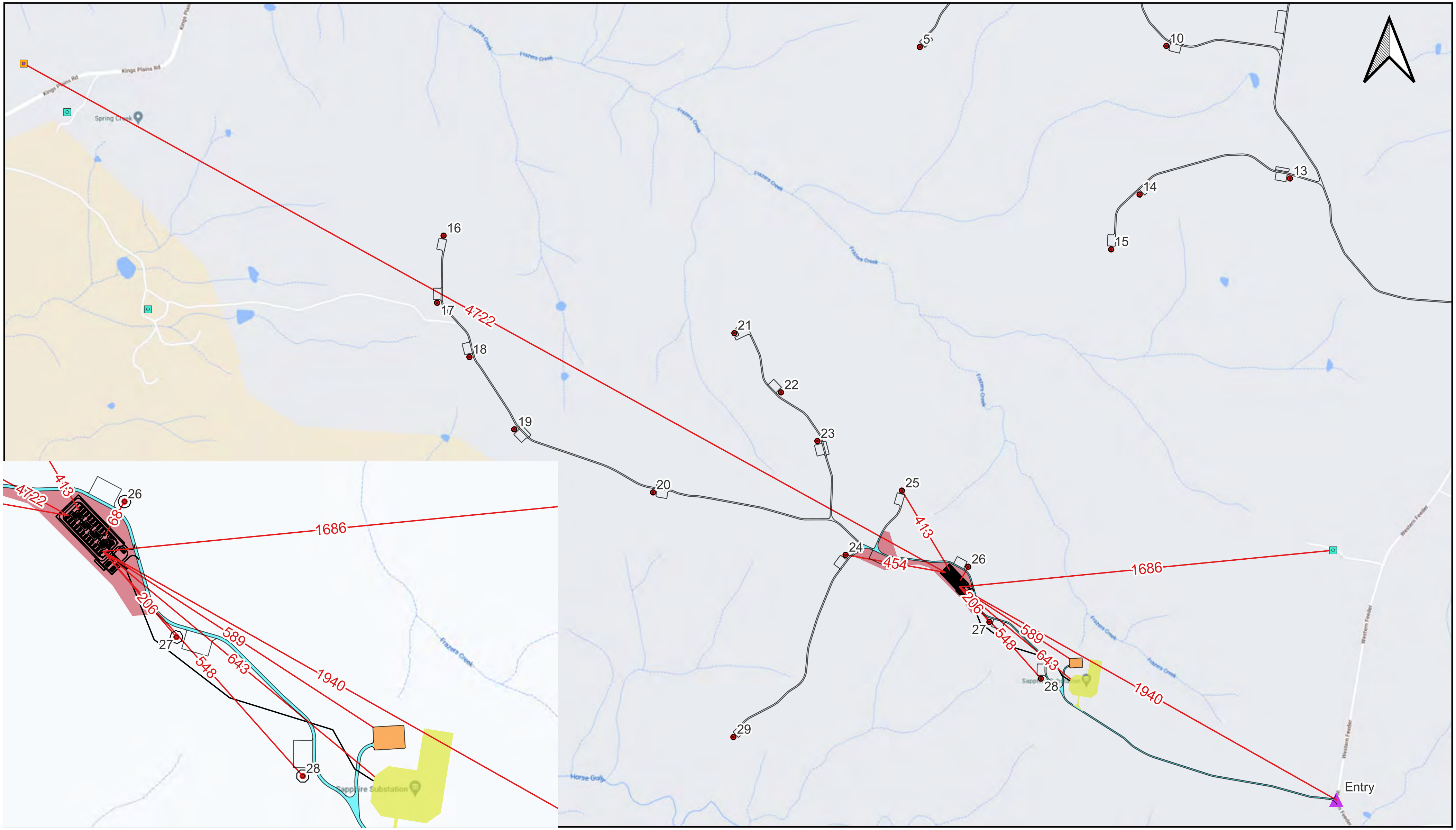
ENERVEN PROJECT No: 532
ENERVEN

	NAME	DATE
DESIGNED	J.O'DANIEL	21/06/2023
REVIEWED	J.O'DANIEL	21/06/2023
APPROVED	R.TIWARI	21/06/2023
AUTHORISED	A.MALCOLM	21/06/2023

SAPPHIRE WINDFARM BESS
GENERAL SITE LAYOUT

CONCEPT DESIGN

SIZE	DRAWING NUMBER	REVISION
A1	532.EEI.GN.DWG.A001	A



Legend
- SWF Turbines
- SWF Access track
- Resident
- Not Associated
- Associated
- Site entrance
- SBF Cable
- BESS Facility
- SBF Access track
- BESS development footprint
- SWF O&M
- SWF Substation

0 | 0.5 | 1 | 1.5 | 2 km

Company				
Sapphire Solar Farm Pty Ltd				SQUADRON ENERGY
Title: BESS distance to Constraints				
Date: 15/09/2023	Projection: 1:27000	Dwg No: 001	Rev: A	Ver: 01
Drawn By: Z Jokadar	Checked By: J. Post	Sheet: 1 of 1	Proj Code: SSF	Size: A4

Appendix B

BMS Functions

The following is extracted from the BMS specification, the intention is not to list all the functions within the BMS but to summarise key warnings and faults that may be relevant to the prevention/ mitigation of thermal runaway and associated fire event.

Warnings in general do not shutdown the originating device. When a warning is indicated, the operator should investigate the cause of the warnings and resolve the condition to prevent warnings from escalating into faults. Warning indicators will be cleared automatically when warning conditions are resolved.

Warnings conditions:

- Over current charge/discharge
- Large voltage difference of single cell
- Large temperature difference within rack
- Rack voltage
- Aux power
- Fan warning
- Abnormality on module temperature sampling
- High voltage circuit break

Faults cause the originating device to shut down. Faults are latched, as such, even after the fault conditions are resolved, fault indicators will not be cleared automatically.

Fault conditions:

- Cell extreme temperature
- Cell extreme voltage
- Relay close failure, Relay stuck fault
- Inner communication fault
- Abnormality on Current value
- Abnormal fault on single cell voltage sampling
- Over current
- MCAN communication interruption fault

Appendix C

Heat Radiation Calculations

A fire event in a battery enclosure was modelled. In order to assess the worst credible case off-site risk, it was assumed that all fire prevention measures had failed, and a container had caught fire. Two fire configurations were considered:

1. a single door being open, and
2. the more credible scenario in which all doors are closed.

The radiative heat flux emitted was calculated using the Stefan-Boltzmann Law:

$$j^*_{emitter} = \varepsilon \sigma T^4$$

where j * is the radiant emittance, ε is the emissivity of the container, σ is the Stefan-Boltzmann constant and T is the surface temperature. The heat flux received was calculated using the view factor method:

$$j^*_{receiver} = 4\emptyset j^*_{emitter}$$

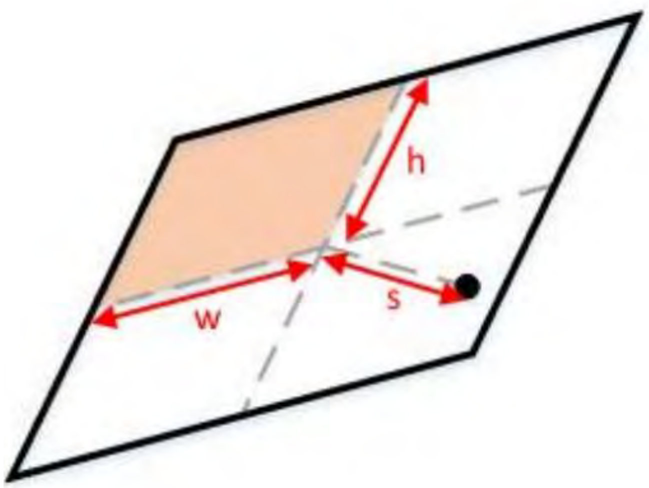
The view factor, Ø, is given by the equation

$$\emptyset = \frac{1}{2 * \pi} * \left(\frac{a}{(1+a^2)^{\frac{1}{2}}} \tan^{-1} \frac{b}{(1+a^2)^{\frac{1}{2}}} + \frac{b}{(1+b^2)^{\frac{1}{2}}} \tan^{-1} \frac{a}{(1+b^2)^{\frac{1}{2}}} \right)$$

The parameters a and b are given by the following equations, where h is half the height of the surface, w is half the width of the surface and s is the perpendicular distance from the surface to the point of interest:

$$a = \frac{h}{s} ; b = \frac{w}{s}$$

This is represented graphically as follows:



Appendix D

Fire Safety Guideline Technical Information Comparison

The "Fire Safety Guideline Technical Information – Large scale external lithium-ion battery energy storage systems – Fire safety study considerations" was issued after the development of this FSS, which was first issued in 2018. To demonstrate the FSS covers all the considerations raised in the guideline a comparison table has been prepared:

FRNSW guideline reference	Description	Report reference
5.1 Assessment of potential consequences of credible incidents	An assessment of consequences of a failure event involving LiBESS and the potential for propagation and secondary incidents	Section 1.3 Lessons Learned From Previous BESS Incidents Section 3. Fire Hazard Identification Section 4. Consequences of Incidents Section 5.4 Post-Fire incident actions
5.2 Defining the fire safety strategy	The development of the FSS that relates to the strategy and approach that will be adopted to achieve the required level of safety and performance.	Section 2: Project setting and component description Section 5 Fire Prevention and Mitigation measures
5.3 Electrical hazards posed to firefighters	Large -scale LiBESS including supporting infrastructure are considered to constitute a electrical hazard when involved in an incident	Section 3.2 Hazardous Incident Scenarios Section 5.3 Fire Brigade Provisions Note: No exposure to electrical hazards due to a non- intervention strategy
5.4 Fire Brigade Intervention	Providing safe access for Fire Brigade personnel should it be deemed appropriate for intervention by the FRNSW commissioner.	Section 5.3 Fire Brigade Provisions Section 5.5 ERP requirements Note: Non- intervention strategy
5.5 Implemented fire safety systems	The implementation of fire detection and protection measures that may be required to ensure that the necessary level of safety and performance has been achieved for the site	Section 5 Fire Prevention and Mitigation measures
5.6 BESS unit separation	The separation of large scale LiBESS containers or racks by way of either appropriately fire-rated physical barriers or distance containing supporting analysis or evidence to demonstrate that the objective of the FSS have been satisfied.	Section 4.2 BESS (Consequence of Incidents) Section 5.2.5 BESS Fire Spread Prevention
5.8 Environmental impacts	A LiBESS involved in a thermal runaway incident may produce by-products that are hazardous to the environment, consideration for toxic smoke plume and its subsequent impact on the surrounding environment and communities.	Section 4.2 BESS (Consequence of Incidents)
5.9 Post-Incident clean-up and disposal	Supporting management and procedures documentation to be provided for the handling and removal of the LiBESS and any by-products which form as part of firefighting intervention	Section 5.4 Post-Fire Incident Actions Section 5.5 ERP requirements