FLUENCE
A Siemens and AES Company

Fire Safety Study Report

LIBESS PROJECT

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Planager
Risk Management Consulting

FIRE SAFETY STUDY

LIDDELL BATTERY ENERGY STORAGE SYSTEM

Liddell Power Station
New England Highway
Muswellbrook NSW 2333

Prepared for	Fluence
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FSS, AGL Energy Liddell Battery Energy Storage System

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Disclaimer

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The analysis of fire safety within BESS', including the consequences of generation of heat, overpressure or toxic combustion gases during a fire event, is limited to the available data and current hazards analyses on similar / applicable BESS'. Much of the available information is still recent and subject to ongoing research, with only few industrial sized BESS' having been developed in Australia at the time of this report, and with the applicable Australian and International Codes of Practice only a few years into their implementation. As such, the analysis in this report represents the current understanding of the subject matter but is subject to the limitations of available data at the time of this report.

Further, the report is based on the assumption that communication with Fluence by the suppliers of the battery solutions would occur as and if more understanding comes to light in relation to the safety of their products in the specific and with BESS' in general, resulting in an update of the fire safety strategy at the BESS and update of this report. Planager shall not be responsible in any way in connection with erroneous information or data provided to it by the Fluence or any third party, or for the effects of any such erroneous information or data whether or not contained or referred to in this document.

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Summary of main findings and recommendations

Introduction

AGL is an electricity generator and retailer operating in Australia. AGL Macquarie (***AGL-M***) owns and operates the Bayswater Power Station (Bayswater) which is approved to generate up to 2,740 megawatts (***MW***), the 2,000 MW Liddell Power Station (Liddell), the 50 MW Hunter Valley Gas Turbines (now decommissioned) and associated ancillary infrastructure systems.

AGL-M has received Development Consent from the NSW Department of Planning and Environment[1] (referred to here as the Department of Planning, or ***DoP***) for the Liddell Battery and Bayswater Ancillary Works Project, including the Liddell Battery Energy Storage System, which will be owned and operated by AGL Liddell BESS Pty Ltd (***AGL-LB***).

Conditions B2 and B3 of the Development Consent state that a Fire Safety Study (***FSS***) be developed and implemented, as follows:

B2. Prior to commencing construction, the Applicant must prepare a Fire Safety Study for the development, to the satisfaction of FRNSW and the Planning Secretary. The study must:

(a) be consistent with the:

(i) Department's Hazardous Industry Planning Advisory Paper No. 2 'Fire Safety Study' guideline and relevant Australian Standards and International Guidelines; and

(ii) NSW Government's Best Practice Guidelines for Contaminated Water Retention and Treatment Systems; and

(b) describe the final design of the battery energy storage system and verify that the final design is consistent with all findings and recommendations in the Preliminary Hazard Analysis dated 25 March 2021.

B3. The Applicant must implement the measures described in the Fire Safety Study approved by the Planning Secretary.

Fluence Energy Pty Ltd (Fluence) has been contracted by AGL-LB to design, supply BESS equipment and maintain the infrastructure and equipment associated with the Liddell BESS.

The Liddell BESS Substation, located adjacent to the north of the BESS, is used to transform the medium voltage output from the BESS to high voltage (330 kV) before transporting it to the existing Transgrid Switching Station.

[1] Now the Department of Planning, Housing and Industry

Fluence has requested Planager Pty Ltd (Planager) to prepare this FSS to present the proposed fire safety strategy for the operations and facilities associated with the site including the BESS and the Liddell BESS Substation.

The FSS scope is as follows:

- The works that are within Fluence's remit, i.e. the Liddell BESS, including battery storage enclosures and associated inverters and transformers
- The Liddell BESS Substation (33/330 kV) to which the BESS is connected, and which is located adjacent to the BESS to the north of the site.

The specifications and key design features detailed in the report are summarised in Table E.1.

Table E.1 Specifications and key design features

Project Element	Description
Performance requirements	• Useable energy capacity at point of connection (***PoC***): 1000 MWh. • Real power charge capacity at PoC: 500 MW • Real power discharge capacity at PoC: 500 MW • BESS discharge cycle rate: 365 cycles per year • BESS discharge duration: 2 h
Battery technology	Enclosures: Fluence Gen 6 Cubes Cells: Envision Dynamics Technology (Jiangsu) Co. Ltd ESS 4L H3L7 280A prismatic lithium iron phosphate (LFP) cells Modules: Envision Automative Energy Supply Corporation EACH-1P52S-280Ah modules in a 1P52S configuration Racks: Envision Automative Energy Supply Corporation AESC EACH-1P416S-280Ah rack system
BESS Facility	Battery infrastructure: • Nominally 1548 × battery enclosures arranged in 172 rows (9 Cubes per row). Each battery enclosure housing two (2) liquid cooled racks of LFP battery modules, Direct Current (***DC***) protection module, and associated control systems • Nominally 86 × Power Conversion Systems (***PCS***) inclusive of 86 Core transformers and 172 Inverter • Nominally 43 × Outdoor Core Telco Enclosures (OCTE), one for each 4 Core/PCS units • Nominal 22 off 33kV Ring Main Units (RMU) • Nominal 12 off 33kV Kiosk hosing 33kV switchgear and 33kV/0.45V Auxiliary transformers • Nominal 43 outdoor LV distribution boards Additionally: • Two (2) Switchgear rooms

Project Element	Description
	• Control room • Operations and Maintenance (O&M) building • Workshop and Storage building • Ancillary infrastructure including 2 x water tanks for bushfire protection purposes, lightning protection, security fencing and closed-circuit television (CCTV).
Liddell BESS Substation and connection	• Two Main Step-Up Transformers 320MVA, inclusive of oil spill tank and fire wall between transformers and fire walls to protect bay equipment, refer to Figure 2-4 • Auxiliary Services building • Nominal 4 × 33kV dedicated buried feeder cables that will be directly connected between the BESS and the Liddell BESS Substation
	• Nominal 2 × buried earthing continuity conductors that will connect the BESS facility earth grid to the Liddell BESS Substation earth grid. • Nominal 2 × multi-core optic fibre cables and any additional signalling required by the Network Service Provider (**NSP**).

The following works, although included in the Project approval, are outside of the scope of the FSS:

- The overhead high voltage transmission line from the Liddell BESS Substation to the existing Transgrid Switching Station
- The Bayswater Ancillary Works (BAW).

The report has been prepared in accordance with the Hazardous Industry Planning Advisory Paper No 2 (***HIPAP2***) *Fire Safety Study Guideline* by the DoP and the FRNSW Fire Safety guideline, *Large-scale external lithium-ion battery energy storage systems – Fire safety study considerations*.

The FSS documents the fire safety strategy at the BESS and the Liddell BESS Substation from the following three (3) perspectives:

- Minimising the risk of a fire occurring
- Minimising the risk of a fire spreading within the BESS and the Liddell BESS Substation
- Minimising the risk of a fire spreading outside of the BESS and the Liddell BESS Substation.

Summary of the fire safety strategy

The BESS and the Liddell 33kV BESS Substation have a relatively low fire potential with no flammable material stored, handled or produced and a high degree of control of the batteries, including highly automated shut-down and application of fire suppressants.

The fire prevention and protection measures at the BESS and the Liddell 33kV BESS Substation reflect the current state of the art for such facilities. Further, the firefighting strategy, in case of a battery fire, involves automatic initiation of fire suppressants inside the battery Cubes.

The fire safety strategy includes the provision of appropriate separation distances (or clearances) to minimise the risk of fire propagation.

The distances between battery-related equipment are shown on the block layout in Figure E.1.

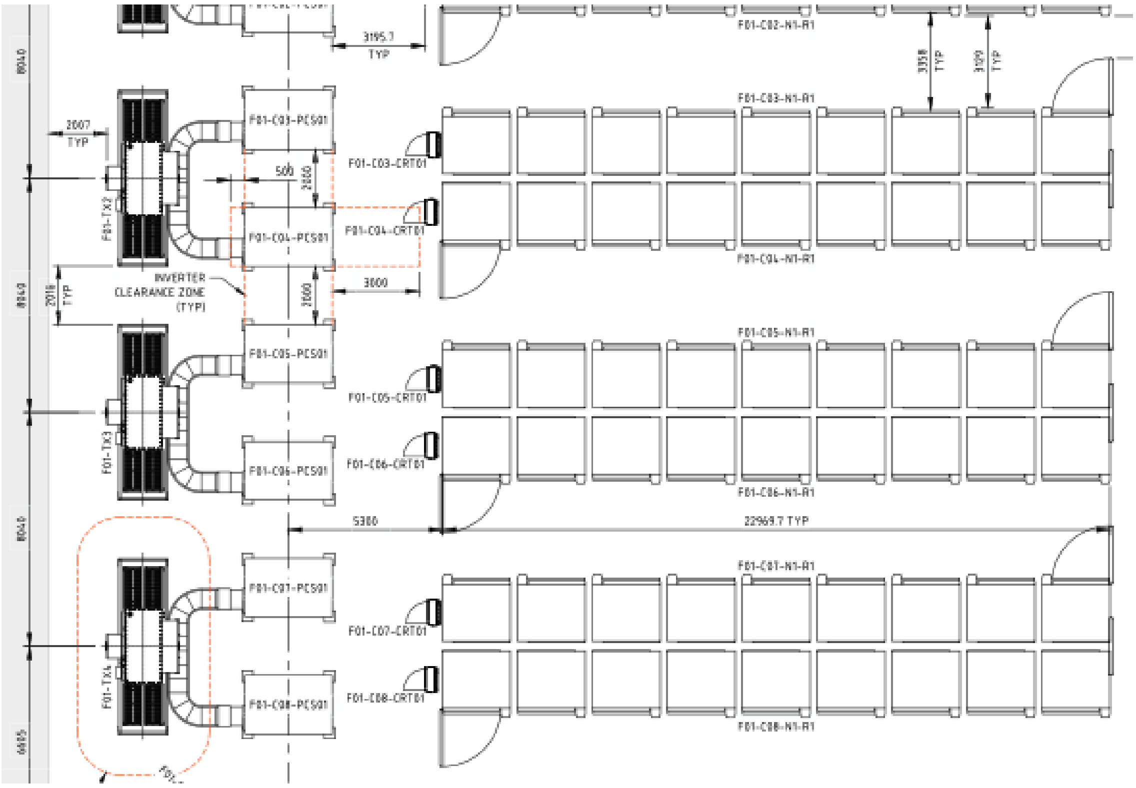


Figure E.1: Block layout

For battery-related equipment the separation distances meet the following requirements:

- The distance between rows of battery enclosures (Fluence Cubes):
  - Exceeds the distance used in the large scale fire tests which was sufficient to prevent fire propagation under test conditions
  - Exceeds the distance to the heat radiation endpoint for propagation to non-combustible material (HIPAP4, 23 kW/m^2) obtained by fire modelling for the maximum credible wind speed at the site
  - Meets the requirements of NFPA 855
- The closest distance between a battery enclosure and an inverter (the nearest battery-related equipment) exceeds the modelled distance to the heat radiation endpoint for

propagation to non-combustible material from an enclosure fire and the separation required to prevent propagation from an inverter fire

- The closest distance between an inverter and a MV transformer exceeds the separation required to prevent propagation from an inverter fire or a MV transformer.

For the Liddell BESS substation, clearances around the HV transformers are in accordance with AS 2067:2016. Clearances include:

- A minimum separation of 40 m to other buildings and facilities not protected by fire walls
- A 20 m buffer around the perimeter of the substation, including between the substation and the BESS.

For non-battery related infrastructure where other fires may occur the clearances to other infrastructure exceed the requirements in NFPA 850-2020 and in AS 2067:2016 Table 6.1 in all circumstances as shown in Table E.2.

Firewater would be supplied from the raw water supply via two storage tanks located between Site Entrances A and B to the south of the boomerang pond. Firewater can be used by fire services to fight bushfires and other fire in adjacent areas. However, with the APZ between the site and the nearest bushland, it is unlikely that firefighting would be required to save the assets on the BESS site from a bushfire.

If a major fire did occur at the BESS and the Liddell BESS Substation, despite the extensive preventative and protective features available for this development, the APZ is likely to prevent the initiation of a fire in the surrounding bushland from heat radiation from the fire. Ember attack may still occur.

Given that the toxic combustion products from a BESS fire are likely to be similar to those from a building fire, such as one involving construction plastics, current understanding is that the consequences to the nearest residential areas are unlikely to be severe and, while the fire is likely to evolve smoke and soot, the fire plume is likely to be similar to that from a fire involving plastics in a house or building.

Table E.2: General fires: clearances between infrastructure

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
Switchroom 1 & 2	To house the 33kV main switchboards, with two switchboards in each room. While the rooms will not be habitable, technicians will conduct maintenance work inside	At the north of the BESS, between the battery-related infrastructure and the Liddell BESS Substation. There is an access road between the nearest Cores and the buildings.	25 metres to battery related infrastructure 60 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Control room	To house the control and monitoring equipment of the BOP and BESS systems. While it will not be habitable, technicians will conduct maintenance work inside	At the north of the BESS, between the battery-related infrastructure and the Liddell BESS Substation. There is an access road between the nearest Cores and the buildings.	25 metres to battery-related infrastructure 60 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
O&M building	To provide space for onsite personnel, including kitchen and toilet facilities. The building will usually be unoccupied, but can accommodate up to 16 people for meetings etc	In the north west corner of the BESS site, adjacent to site entrance A.	100 metres to battery-related infrastructure 175 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
				60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Car park	To provide parking for staff, contractors, visitors, deliveries etc	Adjacent to the O&M building to the south east	80 metres to battery-related infrastructure 155 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between other exposure hazards not associated with electrical grid infrastructure and an outdoor energy storage system as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Workshop and storage building	To provide storage of critical spares and a workshop for maintenance activities	To the west of the battery-related infrastructure area, across an internal access road	20 metres to battery-related infrastructure 124 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Firewater	To provide water for firefighting (non-electrical fires only)	Firewater tanks located between Site Entrances A and B	40 metres to battery-related infrastructure 55 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between other exposure hazards not associated with electrical grid infrastructure and an outdoor energy storage system as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
				60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Liddell 33 kV BESS Substation	To transform the medium voltage output from the BESS, into high voltage (330kV).	At the north of the facility. There is a 20m buffer zone between the substation and the BESS	> 60 metres from battery-enclosures > 20 metres from all BESS infrastructure (transformers are > 50 metres from BESS infrastructure)	Meets or exceeds the clearance requirements of AS 2067:2016 Substations & High Voltage Installation

Recommendations

Recommendation	Status	Implementation
1. Ensure all recommendations from the bushfire threat assessment are fully considered.	accepted	The bushfire threat assessment, including recommendations, has been considered in the detailed design of the BESS
2. Operators should consider training people working within the facility in the use of fire extinguishers to contain small fires before they can develop into something more serious.	accepted	This will be considered once the construction phase is completed
3. The developers consult with DoP, FRNSW and RFS to ensure the proposed static firewater supply solution is acceptable, including the source of the water, the capacity and position of the firewater tanks	accepted	Consultation has taken place, and the firewater tank design is currently underway
4. Provide a means of rapid isolation (e.g. automatic valve) on the outlet of the attenuation pond so that contaminated run-off can be contained and tested before disposal	accepted	This FSS has been provided to the designers for consideration on how to achieve this
5. Although fires involving Cubes, inverters or transforms do not require active fire services intervention, in the event of any fire on site (at the BESS or the BESS Substation), an appropriate site representative should be available to provide advice to FRNSW, as soon as possible on site and by phone in the interim. Contact details should be included in the ESIP.	accepted	24/7 remote monitoring and response processes are aimed at minimising delays in responding to emergencies, independent of the SLA timeframes. Contact details will be included the ESIP.
6. Include the emergency isolation procedure in the Emergency Response Plan.	accepted	This will be included in the ongoing development of emergency plans
7. The Fire Safety Study should be updated if any changes to the site layout or to the battery modules, ESS designs or model are proposed	accepted	Management of change process will include updating of the FSS when necessary

Clause No.	Description	Addressed in this report	Reference in this report
5 Developing the fire safety study			
5.1 Assessment of potential consequences of credible incidents			
5.1.1	A fundamental objective of a FSS is that the hazard potential of a plant and/or operation is defined by a process of hazard identification and subsequent estimation of the potential consequences of credible incidents. Underestimation of the potential consequence of a credible incident is likely to result in failure of the fire safety system and subsequent propagation and escalation of an incident.	The consequence assessment in the FSS is based on a comprehensive hazard identification (HAZID) process which is based on a desk-top review of National and International information and research covering BESS facilities. The factors considered in the HAZID are discussed in the FSS and the results presented in an appendix.	Factors: Section 3 HAZID: Appendix 1
5.1.2	A failure event involving LiBESS may eventuate from a number of internal and external mechanisms including mechanical-, thermal- and electrical abuse or failure, and may result in the expulsion of chemical components, propagation of chemical vapours and/or a thermal runaway event and fire and/or explosion.	The failure events considered in the HAZID include internal and external causes covering thermal, mechanical and electrical events, manufacturers' defects, damaged/faulty equipment, maintenance errors, malicious acts and natural events such as bushfire. The types of hazards associated with the Facility are summarised in the report. Potential consequences identified include generation of heat, toxic gases and toxic combustion products; thermal runaway; deflagration/overpressure; generation of hydrogen; escalation/propagation; environmental pollution, and injury and fatality resulting from exposure to these consequences.	HAZID: Appendix 1 Hazardous scenarios: Section 3.3, including Table 3-3. Consequence analysis: Section 4

Clause No.	Description	Addressed in this report	Reference in this report
5.1.3	FRNSW consider a credible incident to be one in which a fire propagates within a LiBESS system or unit, with active fire safety systems disabled, and involves the full BESS unit / container.	The analysis of credible consequences in the FSS focuses on the conditions under which a fully involved fire event within a battery enclosure (Fluence Cube) could occur and the potential for propagation of this fire beyond this enclosure of origin (incident enclosure). The fire scenario assumes all protective functions and lower-level passive controls have failed, and as such is considered a worst-case scenario. The choice of worst case credible incident is supported by the results of large scale fire testing undertaken on the enclosures to be used at the Facility.	Enclosure fire: Section 4.1 Large scale fire testing: Section 2.5
5.1.4	When undertaking consequence analysis of an incident, both the direct impacts of an incident and the potential for propagation and secondary incidents should be addressed. This includes management of chemical components or by-products released during an incident and the environmental impacts of toxic water-run off that may be used to mitigate an incident.	Both direct and potential escalation scenarios such as propagation and secondary incidents have been considered in the HAZID and addressed in the consequence analysis. The choice of quantitative and qualitative analyses (both methodologies recognised in HIPAP 2) have been justified. Measures to manage potential direct impacts of an incident and the potential for propagation and secondary incidents, including toxic/pollutant water run-off resulting from fires, are discussed in the report.	HAZID: Appendix 1 Consequence analysis: Section 4 Water management (including toxic run-off): Section 6.3
5.1.5	Where a hazard analysis study (i.e., preliminary hazard analysis, final hazard analysis, or a hazard and operability study) has been undertaken for the site in question, this should be used to inform the FSS.	The FSS has been informed by the following: Nilsson K. and Lewis A., Preliminary Hazard Analysis for Liddell Battery and Bayswater Ancillary Works NSW, 25 March 2021	PHA: Reference 2

Clause No.	Description	Addressed in this report	Reference in this report
5.1.6	Whilst the emphasis of this section is the assessment of consequences of a failure event involving LiBESS and the potential for propagation and secondary incidents, the FSS must still consider the broader potential for all credible incident scenarios at the facility.	The HAZID is comprehensive and considers the entire site, including the BESS, the substation and associated buildings. The credible incident scenarios considered in the FSS cover fire or arc flash at medium/high voltage equipment (transformers, inverters etc) and general fires, e.g. building fires in addition to fires/explosions involving battery enclosures. The potential for propagation and secondary incidents, has been considered quantitatively and qualitatively as appropriate (see para 5.1.4)	HAZID: Appendix 1 Hazardous scenarios: Section 3.3, including Table 3-3. Consequence analysis: Sections 4.2 and 4.3
5.2 Defining the fire safety strategy			
5.2.1	Within the context of a FSS, the fire safety strategy relates to the strategy and approach that will be adopted to achieve the required level of safety and performance. An effective fire safety strategy aims to minimise the likelihood, severity, and extent of an incident.	The functional specification for the Project includes Safety In Design as one of the functional requirements. The Safety In Design philosophy is focused on the elimination or minimisation of risks to as low as reasonably practical (ALARP) as early in the lifecycle of a project as possible. An effective fire safety strategy, utilising an appropriate hierarchy of controls, is recognised by AGL and Fluence in the functional specification for the Project as an important part of the Safety In Design process. The fire safety strategy is defined and described in the FSS in terms of the layers of protection afforded by the strategy.	Overview of fire safety strategy: Section 5.1 including Figure 5-1 Fire safety strategy: Section 5

Clause No.	Description	Addressed in this report	Reference in this report
5.2.2	Special consideration should be given to developing a fire safety strategy that is effective in minimising potential for propagation and escalation of an incident with reference to the credible incidents outlined in Section 5.1 Assessment of potential consequences of credible incidents. An example of an element of a fire safety strategy that may be adopted is the separation of BESS containers or racks by way of either appropriately fire-rated physical barriers or distance. Where possible, preference should be given to the implementation of strategies that are supported by higher-order risk controls (i.e., elimination and/or engineering controls, etc.).	The fire safety strategy at the Facility combines a range of measures to prevent, detect, alert and respond to fire incidents. These measures are aimed at minimising the potential for propagation and escalation of an incident, including an incident that involves an entire Fluence Cube (i.e. the identified worst credible incident). Hierarchy of control principles have been applied and detailed in the form of layers of protection.	Fire safety strategy: Section 5
5.2.3	Supporting analysis and/or evidence should be provided within the FSS to justify the selection, appropriateness, and efficacy of the selected fire safety strategy. This should include all calculations and analyses and contain justification of all inputs and methods used. Where testing is relied upon, detailed test reports need to be provided which detail who undertook the tests, the test methodology and results obtained. Testing should be witnessed and verified by parties who are independent from the battery manufacturer / supplier.	Supporting analysis and/or evidence is included within the FSS to justify the selection, appropriateness, and efficacy of the selected fire safety strategy. The Fluence Cubes have undergone UL 9540A and large scale fire testing: the methodologies and results of this testing are described in detail in the FSS. The testing has also been assessed by independent third parties and the findings have been used to inform the FSS.	Fire safety strategy: Section 5 Testing: Section 2.5
5.2.4	The fire safety strategy should consider the likelihood of occupants being present within the BESS unit / container.	Fluence Cubes are unoccupiable and cannot physically be entered by personnel when the battery racks are fitted. Doors mounted on the front of the enclosures enable all battery modules and other equipment to be accessed from outside the enclosures.	Battery and enclosure design: Section 2.4
5.2.5	FRNSW does not support the adoption of fire safety strategies that are either partially or wholly reliant on fire brigade intervention to achieve an acceptable level of safety, given that:	The overarching aim of the fire safety strategy is to remove the need for intervention by emergency services, in recognition BESS facilities pose significant risks to emergency responders.	Fire safety strategy: Section 5

Clause No.	Description	Addressed in this report	Reference in this report
	• Intervention of a fire brigade at an incident is considered to constitute application of a low-order administrative type risk control and is not in line with the so far as is reasonably practicable principle in managing risk, given higher-order controls are available and may be implemented in a reasonably practicable manner • Large-scale LiBESS including supporting infrastructure may constitute a chemical or electrical hazard such that intervention activities and/or firefighting operations may pose unacceptable risks to the safety of attending firefighters • The rapid intervention of a permanent full-time fire brigade cannot be relied upon as it is subject to resource availability and proximity to the incident. • Potential for significant variation in the weight of response, capability, equipment, and level or training of attending fire brigade resources.	This includes the demonstration of no escalation (propagation) in a major fire event via large scale fire testing and subsequent modelling for worst case credible on-site wind weather conditions.	Emergency management: Section 7
5.3 Electrical hazards posed to firefighters			
5.3.1	Large-scale LiBESS including supporting infrastructure are considered to constitute an electrical hazard when involved in an incident, given that: • It may not be possible to determine the state of charge of an affected unit. • High voltages may still be present, even at low states of charge. • There is potential for energy to be stranded within an affected unit. • FRNSW currently does not have the equipment or capability to be able to detect live direct current (DC) power.	The overarching aim of the fire safety strategy is to remove the need for intervention by emergency services, in recognition BESS facilities pose significant risks to emergency responders, including those associated with electricity. The procedure for isolation of electricity is described in the FSS and includes the recognition that while the Facility and equipment can be isolated from the grid connection, electrochemical energy will continue to be stored within battery enclosures and UPS systems.	Isolation of utilities – electricity: Section 7.2.1

Clause No.	Description	Addressed in this report	Reference in this report
	• It may not be possible to isolate the input to- or output from an affected unit, particularly where isolation controls (automated or otherwise) have been adversely affected by exposure to radiant heat. • The affected and surrounding units may experience a degradation of the ingress protection (IP) rating as a result of exposure to radiant heat.		
5.3.2	A FRNSW incident commander may determine that no intervention activities or firefighting operations will be undertaken where it is considered that there is unacceptable risk posed to the safety of firefighters.	The overarching aim of the fire safety strategy is to remove the need for intervention by emergency services, in recognition BESS facilities pose significant risks to emergency responders, including those associated with electricity. The facility layout and BESS infrastructure are designed to minimise the risk of fire propagation and the fire response strategy for the electrical infrastructure on site is to leave fires involving this infrastructure to burn out without intervention from emergency responders.	Cooling/firefighting water: Section 6 Emergency management: Section 7
5.3.3	Signage should be provided at appropriate locations (based upon a site assessment), including but not limited to all entrances to the facility and the main control room, warning of the potential electrical and chemical hazards present. Whilst the scope of AS 5139 is limited to a battery with a maximum capacity of 200 kWh, Section 7 of the standard contains useful guidance that can be used for labels and safety signage.	A danger sign restricting access will be positioned at every entrance to the Facility. Electrical equipment will be fitted with signs warning of electrical hazards and of process stop procedures where appropriate.	Signage: Section 5.2.9
5.4 Fire brigade intervention			
5.4.1	Section 5A General functions of Commissioner of the Fire and Rescue NSW Act 1989 imposes specific statutory functions on the Commissioner of FRNSW, specifically that:	See para 5.2.5 (Defining the fire safety strategy) and para 5.3.2 (Electrical hazards posed to firefighters)	

Clause No.	Description	Addressed in this report	Reference in this report
	1) It is the duty of the Commissioner to take all practicable measures for preventing and extinguishing fires and protecting and saving life and property in case of fire in any fire district. (and) 2) It is the duty of the Commissioner to take all practicable measures— a) for protecting and saving life and property endangered by hazardous material incidents, and b) for confining or ending such an incident, and c) for rendering the site of such an incident safe. In the event of a fire or hazardous material incident involving large-scale LiBESS, FRNSW may be required to undertake intervention activities and firefighting operations in order to fulfil statutory obligations, as such, consideration to the safety of first responders conducting intervention activities must be considered.		
5.4.2	A potential incident at a BESS facility may be deemed a "hazardous material incident" in accordance with Section 3 of the Fire and Rescue NSW Act 1989. Substantial Hazardous Material response resources may be required to determine an appropriate intervention and mitigation strategy in the event of an incident.	The location and response time for fire services detailed in the FSS includes the closest HAZMAT resources.	Fire services: Section 7.2
5.4.3	Intervention activities and firefighting operations at an incident involving large-scale LiBESS will be undertaken in a manner similar to that for large-scale electrical infrastructure (e.g., substations, electrical switchyards, etc.). FRNSW personnel may not enter the affected BESS compound or compartment until an electrical company representative is in attendance on site and has confirmed power is isolated. The electrical company representative may also be required to provide safety and technical advice to a FRNSW incident commander to assist in determining what intervention activities and firefighting operations can be safely undertaken.	In the event of an incident, the remote operators will notify the site on-call representative who will attend the site to provide safety and technical advice to a FRNSW incident commander to assist in determining what intervention activities and firefighting operations can be safely undertaken. The procedure for isolation of electricity is described in the FSS and includes the responsibility for isolation rests with the operators of the Facility.	Fire services: Section 7.2

Clause No.	Description	Addressed in this report	Reference in this report
5.4.4	As previously noted, a FRNSW incident commander may determine that no intervention activities or firefighting operations will be undertaken where it is considered that there is unacceptable risk posed to the safety of firefighters.	See para 5.3.2.	
5.4.5	An Emergency Plan is to be developed for the site in accordance with Hazardous Industry Planning Advisory Paper No 1 (HIPAP No. 1) Emergency Planning. The findings of the FSS should inform the development and content of the Emergency Plan. This should include, but not be limited to: a. Details on how the owner / operator is alerted to abnormal operation, fault or hazard in a BESS. b. Details on how fire services are notified of an incident. This should be described as part of the fire safety strategy. Upon detection of a fire in a BESS or on the site via an automatic detection system, notification of the fire services should be automatic. c. Detail effective communication strategy with remote operator representative for incident duration. d. Suitable arrangements for attendance on site by an appropriately qualified representative during any incident. e. Details on how battery status and information is relayed to emergency services, including items such as deployment of deflagration panels, etc..	Emergency planning is detailed within the FSS.	Emergency plans: Section 7.3
5.4.6	Detail the required level of personal protective equipment (PPE) including any breathing apparatus (BA) requirements for emergency services.	Emergency plan includes emergency and safety equipment, including firefighting equipment. Based on the potential for the production of toxic gases, FSS states that fire fighters should always wear	Emergency plans: Section 7.3 Need for breathing apparatus: Section

Clause No.	Description	Addressed in this report	Reference in this report
		protective equipment and breathing apparatus in the field when getting close to burning or smoking battery fires.	4.1.2 (Toxic combustion products in the fire plume)
5.4.7	The following FRNSW guidelines should also be utilised as part of the fire safety strategy and documentation requirements for the site: a. FRNSW Fire safety guideline – Hazardous chemicals manifest b. FRNSW Fire safety guideline – Emergency services information package and tactical fire plans The most recent versions can be found on the FRNSW website.	There are no hazardous chemicals on site whose quantities exceed Schedule 11 of the WHS regulations. As required under Conditions of Consent), Fluence will develop an emergency services information package and tactical fire plans as part of their emergency planning obligations. These are to be developed in line with the requirements of the *FRNSW Emergency services information package and tactical fire plans guideline.*	Emergency services information package and tactical fire plans : Section 7.4
5.5 Implemented fire safety systems			
5.5.1	The implementation of fire detection and protection measures may be required to ensure that the necessary level of safety and performance has been achieved for a site.	Fire detection and protection measures are implemented within the BESS, substation and buildings.	Fire safety strategy: Section 5.
5.5.2	The analysis of requirements for fire detection and protection measures should be informed by the assessment of potential consequences of credible incidents for the site. This should also align with the objectives of the fire safety strategy for the site, particularly those relating to the management and mitigation of the severity of an incident, and prevention of propagation and escalation of an incident, including the potential off-site and environmental impacts.	The fire safety strategy at the Facility combines a range of measures to prevent, detect, alert and respond to fire incidents. These measures are aimed at minimising the potential for propagation and escalation of an incident, including an incident that involves an entire Fluence Cube (i.e. the worst credible incident as determined by consequence analysis in the FSS).	Fire safety strategy: Section 5.

Clause No.	Description	Addressed in this report	Reference in this report
5.5.3	Supporting analysis and evidence is required to be provided within the FSS to justify the suitability and efficacy of proposed fire detection and protection measures for the site. This evidence is required to demonstrate that the specified performance of individual measures and the collective system is adequate to satisfy the objectives of the fire safety strategy.	The fire safety strategy, including analysis and evidence to justify the proposed fire detection and protection measures is detailed in the FSS.	Fire safety strategy: Section 5.
5.5.4	All fire detection and protection measures that are relied upon to satisfy the objectives of the fire safety strategy should be automatic in nature (i.e., not require manual operation by an operator or attending emergency service). Supporting evidence is required to be provided within the FSS to demonstrate that individual measures and the collective system have sufficient capacity to operate at the required level of performance for the full duration of an incident.	The fire safety strategy includes comprehensive, automatic fire detection and alarm and automatic shutdown systems.	Automatic fire detection and alarm: Section 5.2 (Layer of protection 5) Automatic shutdown system: Section 5.2 (Layer of protection 4)
5.5.5	Adequate redundancy should be provided to all fire detection and protection measures that are relied upon to satisfy the objectives of the fire safety strategy. Emergency power supply to essential systems is one key consideration.	The fire detection and protection measures include redundancy as an important consideration. Redundancy measures include but are not limited to multiple, independent fire detection in battery enclosure and manual as well as automatic fire suppression and shutdown systems. Battery enclosures and FIPs are fitted with sufficient battery back-up power to maintain data collection and critical functions and the site has duplicated battery systems and UPS..	Fire safety strategy: Section 5 and Table 2-5

Clause No.	Description	Addressed in this report	Reference in this report
5.5.6	Where the fire safety strategy does not rely on direct fire attack on a LiBESS system or unit, a fire hydrant system should still be provided for the purpose of addressing other credible fire scenarios (e.g. within auxiliary buildings and infrastructure) and protection of LiBESS units from all potential fire sources. The specific requirements of the fire hydrant system, in terms of locations of hydrants, water supply, etc., should be based on the level of risk of the facility. Coverage by street hydrants is not considered adequate for such a facility.	There is no hydrant system. Two dedicated water tanks fitted with 65mm and 150mm Storz fittings to allow for connection by FRNSW and NSW RFS appliances supplies firewater to the site.	Cooling/firefighting water supply: Section 6.1
5.5.7	Provision should be made for monitoring of the Alarm Signalling Equipment (ASE) where a fire detection system is provided as part of the fire safety system for a site and a readily available response from a permanent fire brigade is available.	Fire services call out is manually triggered by personnel remotely monitoring operations in the 24/7 manned AGL Dispatch Centre.	Fire services – alert and call-out: Section 7.1.2 Cause and effects matrices: Appendix 6
5.6 BESS unit separation			
5.6.1	As identified in Section 5.2 Defining the fire safety strategy, the separation of large-scale LiBESS containers or racks by way of either appropriately fire-rated physical barriers or distance may be adopted as a fire safety strategy for a site.	The BESS enclosures include fire-rated physical barriers and are physically separated to prevent fire propagation.	Separation by distance: Section 5.2.3 (Layer of protection 7)
5.6.2	Where such a strategy is adopted, the FSS is required to contain supporting analyses or evidence to demonstrate that the objectives of the fire safety strategy have been satisfied, namely that the provided separation is adequate to prevent propagation and escalation of an incident. Where active and/or passive measures are provided to support the implementation of this strategy, evidence is required to be	The enclosures have undergone Large Scale Fire (LSF) testing with active fire protection measures disabled, to demonstrate that the passive measures used to prevent propagation from a burning enclosure are sufficient. This testing is described in the FSS.	Large scale fire testing: Section 2.5

Clause No.	Description	Addressed in this report	Reference in this report
	provided in the FSS that demonstrates their ability to maintain the required level of performance for the full duration of an incident.		
5.6.3	Where separation is provided by way of a physical barrier that is constructed of a material with a fire resistance level as determined in accordance with AS 1530.4:2014 Methods for fire tests on building materials, components and structures - Fire-resistance tests for elements of construction, an assessment is required to be undertaken to demonstrate that the fire severity associated with the design fire of the worst credible incident (i.e., the design fire severity) does not exceed that associated with the 'standard time versus temperature curve' as prescribed within Section 2.11 of AS 1530.4:2014. Failure to accurately quantify the design fire severity such that it is underestimated or exceeds that associated with the standard fire curve may result in the fire resistance performance of materials relied upon for separation being exceeded and subsequent failure of the fire safety system.	The roof, walls and floor of the Cubes are thermally insulated using rock wool (conforms to ISO 1182:2020 *non-combustible material* and to ASTM E 84 *Class A grade*	Physical protection: Section 5.2.1 (Layer of protection 6)
5.6.4	Where separation is provided by way of distance, an assessment is required to be undertaken to demonstrate that propagation of the incident will not occur to adjacent and surrounding racks, containers, and/or associated infrastructure. The assessment is required to consider the combined effects of exposure to convective and radiant heat on a receiving body from the worst credible fire for the full duration of an incident.	The results of the LSF testing are confirmed by consequence modelling in the FSS. The modelling considers a worst case credible fire scenario based on the LSF results and uses these results to fine tune model parameters. The modelling is also extended to consider on-site conditions as discussed in para 5.6.5.	Heat radiation from a Cube fire: Section 4.1.1
5.6.5	The impacts of environmental conditions (e.g., wind effects) must also be assessed. This should include assessment of flame tilt, etc.	The fire modelling examines if the worst-case credible fire as defined by LSF testing would also be the worst case scenario at the BESS for the weather conditions (in particular, wind speeds) that are typical for the site. The case where a door to the enclosure (probably the	Heat radiation from a Cube fire: Section 4.1.1

Clause No.	Description	Addressed in this report	Reference in this report
		weakest side of the enclosure) was left open or was otherwise breached is also modelled. Flame tilt is assessed.	
5.7 BESS unit ventilation and flammable and toxic gases			
5.7.1	A LiBESS may produce large volumes of flammable, corrosive and toxic vapours and gases when involved in a thermal event as a result of thermal decomposition of battery components and electrolytes, pyrolysis of combustible materials, and incomplete combustion of volatiles within smoke. Flammable vapours and gases when confined within a compartment or a container are deemed to have the potential to result in a hazardous atmosphere. Any person exposed to these vapours or gases is considered to be at risk of harm.	Combustion products were captured and quantified from within the Initiating Cube and in the duct placed above it. and quantified in the LSF test with the maximum gas concentrations measured above the Initiating Units compared with flammability limits (LFL) and toxic exposure limits (ERPGs). Evaluation of consequence from ignition of flammable gases is quantitative and the model has been verified using results from LSF testing. Evaluation of toxic gas dispersion is qualitative, as toxic combustion modelling from a fire in a battery enclosures is not proven as yet and could potentially be misleading and not helpful. The qualitative approach is allowed in HIPAP2 Section 2.3, which states that consequences of incidents are to be estimated but does not state that the estimation must be quantitative. Further, HIPAP2 Section 2.3 requires justification of all models and assumptions used to estimate consequences, and with the current limited large scale experimental data available in the public domain, to support consequence modelling, the use of traditional software products for HF and other toxic combustion	Beyond Design Basis Test: Section 2.5.5 Toxic combustion products in the fire plume: Section 4.1.2

Clause No.	Description	Addressed in this report	Reference in this report
		gas generation has not as yet (to our knowledge), been validated for the BESS industry. While simple consequence modelling may be done, its limitations need to be understood. Without proper validation of the software tools for toxic dispersion for BESS fires, Planager do not believe that it is useful or prudent to report on such modelling as part of a FSS. While further research into this area would certainly be useful, it is outside of the scope of this FSS. Therefore, a precautionary approach to potential toxic exposure is recommended in the FSS, including: - evacuating persons not involved in emergency response from the site - fire fighters to wear protective equipment and breathing apparatuses in the field when getting close to burning or smoking battery fires - decisions regarding evacuation of the local community to be at the discretion of the emergency services and should be based on real-time atmospheric monitoring. We believe that the existing approach undertaken in the FSS is appropriate given the limitations discussed above, and that it meets HIPAP2 requirements.	
5.7.2	Ignition of the flammable gases produced during a thermal runaway event may result in a deflagration or explosion. This is noted to have caused or contributed to injury and death to attending emergency services at past incidents.	The ignition of the flammable gases produced during a thermal runaway event resulting in a deflagration or explosion has been considered in the FSS (see para 5.7.5)	Pressure build-up of gases and deflagration: Section 4.1.3.

Clause No.	Description	Addressed in this report	Reference in this report
			Deflagration panels: Section 5.2.2
5.7.3	The design of the fire safety system for any facility containing large-scale LiBESS is required to demonstrate that consideration has been given to the management of flammable, corrosive and toxic vapours and gases that may be produced during a thermal runaway event.	The fire safety system includes provision for deflagration venting of gases (should ignition occur) produced during thermal runaway	Deflagration panels: Section 5.2.2
5.7.4	Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment, a FSS must assume that there is potential for a hazardous atmosphere to be generated unless suitable evidence is provided that demonstrates otherwise. A subsequent analysis of potential consequences is required to be undertaken to inform the analysis of requirements for detection and protection such that suitable measures can be selected for implementation.	See para 5.7.1	
5.7.5	Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment and it is determined that there is potential for a flammable atmosphere to be generated from a thermal runaway incident, the consequence assessment is required to consider how an ignition of the atmosphere resulting in a deflagration or explosion will impact on surrounding racks or units, supporting infrastructure, and any other surrounding elements or structures.	The consequences of a build up of pressure due to thermal runaway are discussed in the FSS. The battery enclosures fitted with roof mounted deflagration panels to provide pressure relief in the event of an overpressure incident and direct the force of the explosion upwards, away from personnel and other infrastructure.	Pressure build-up of gases and deflagration: Section 4.1.3. Deflagration panels: Section 5.2.2
5.7.6	Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment that is occupiable by a person, signage should be provided at appropriate locations including but not limited to the entrance to the respective compartment or container,	The BESS enclosures are not occupiable and are located outside.	Battery and enclosure design: Section 2.4

Clause No.	Description	Addressed in this report	Reference in this report
	warning that in the event of an incident involving the LiBESS there is potential for a hazardous atmosphere to be present.		
5.7.7	Where a large-scale LiBESS is proposed to be located within an enclosing container or compartment that is occupiable by a person, a visual warning device should be provided at the entrance to the compartment or container that is to activate upon the activation of any provided detection or protection measures, with associated signage provided stating that a fire safety measure has activated and warning that there is potential for a hazardous atmosphere to be present.	While the BESS enclosures are not occupiable, a local horn/strobe (visual and audible) is used to identify the Cube which is affected by an event. The horn/strobe would be activated locally at the Cube upon CO detection (specific sound and strobe) and fire detection (fire alarm sound and strobe) via the F-stop system at the Core.	Detection and alarm: Section 5 Table 5-1 (Layer of protection 5)
5.8 Environmental impacts			
5.8.1	A LiBESS involved in a thermal runaway incident may produce by-products that are hazardous to the environment.	The Project (and FSS) recognise that in the event of fire, burning batteries and transformers will produce contaminants. The contaminants from battery systems may include traces of metals, contaminants from burning plastics and contaminants from the battery glycol/water heat exchange system. The developments transformers may also leak oil during operations or during a fire event.	Contaminated firewater containment: Section 6.3
5.8.2	When undertaking any consequence assessment relating to a thermal runaway incident, consideration must be given to the potential for the generation of a toxic smoke plume and its subsequent impact on the surrounding environment and communities. This should include demonstrating that toxic gas emissions during such a fire will not impact neighbours, first responders or passers-by, under worst-case weather conditions specific to the site.	See para 5.7.1	

Clause No.	Description	Addressed in this report	Reference in this report
5.8.3	Any Emergency Plan for the site should detail the required level of personal protective equipment (PPE) including any breathing apparatus (BA) requirements for emergency services.	Emergency plan includes emergency and safety equipment, including firefighting equipment.	Emergency management plans: Section 7.3
5.8.4	Where a fire safety strategy is adopted that relies on the application of water (or water-based agents) to suppress a fire, provision must be made for the containment of all contaminated firefighting water for the entire expected duration of the incident. Any provided containment system must ensure that contaminated firefighting water is not able to enter local waterways or groundwater.	The site includes a 3500m^3 stormwater attenuation pond designed to serve two purposes – stormwater attenuation for standard operations and contamination detention during emergency situations.	Contaminated firewater containment: Section 6.3
5.8.5	Where a containment system is proposed to be connected to a reticulated stormwater system, provision must be made for the isolation of the system by way of automatically operated valves that close upon activation of an associated fire safety measure.	The means to isolate the system is yet to be finalised. The FSS includes the following recommendation - Recommendation 4: Provide a means of rapid isolation (e.g. automatic valve) on the outlet of the attenuation pond so that contaminated run-off can be contained and tested before disposal. Fluence have accepted this recommendation.	Contaminated firewater containment: Section 6.3
5.8.6	Whilst not a requirement of a FSS, it is recommended that any Emergency Plan developed for the site identify local catchment areas and drainage pathways such that appropriate measures may be implemented in the event that the capacity of the provided containment system is exceeded.	Noted.	
5.8.7	Appropriate consideration should also be given to Planning for Bushfire Protection (2019).	A bushfire hazard assessment against the requirements of Planning for Bushfire Protection (PBP, 2019) has been undertaken for the site. These results are reported in the *Bushfire Threat Assessment Fluence Energy Liddell Power Station* and referenced in the FSS.	Separation by distance - Asset Protection Zone: Section 5.2.3

Clause No.	Description	Addressed in this report	Reference in this report
5.9 Post-incident clean-up and disposal			
5.9.1	Whilst not a requirement of a FSS, it is recommended that supporting management and procedures documentation for the site provide details of the following: • Following an incident, how LiBESS will be handled and removed (including transportation) from site. It is noted that this is the responsibility of the facility owner and/or operator and that FRNSW is not responsible for aiding or facilitating such actions. • A procedure for the removal and disposal of contaminated firefighting water.	Noted	
5.10 Reference standards and codes			
5.10.1	HIPAP No.2 states "The principle of a fire safety study is that the fire safety 'system' should be based on specific analysis of hazards and consequences and that the elements of the proposed or existing system should be tested against that analysis. This should always produce a better outcome than the application of generalised codes and standards alone" (DPIE 2011).	Noted. The FSS has been developed in accordance with HIPAP2. The consequence analysis has been performed by an independent consultancy (Planager). The fire safety strategy proposed by Fluence has been tested/critiqued against this analysis.	The FSS has been developed in accordance with HIPAP2
5.10.2	The provisions within applicable codes and standards may be adopted where it can be demonstrated that the requirements of HIPAP No.2 have been adequately satisfied.	Applicable codes and standards have been used in the development of the BESS and HV equipment and associated fire safety strategy by Fluence and are included in the hazard identification. Where these are demonstrably sufficient to meet the requirements of HIPAP2 (e.g. AS 1940 for oil fires, AS 2067 for substations, AS 60076 AS/IEC 60076.1 for power transformers etc) they have been referenced in the FSS.	Codes and Standards: Section 8 Hazard Identification: Appendix 1

Glossary and Abbreviations

ACC/DCC	Auxiliary control cabinet/DC combiner cabinet
AEGL	Acute Exposure Guideline Levels: Used by emergency planners and responders worldwide as guidance in dealing with rare, usually accidental, releases of chemicals into the air. AEGLS are expressed as specific concentrations of airborne chemicals at which health effects may occur. They are designed to protect the elderly and children, and other individuals who may be susceptible.
AESC	Automative Energy Supply Corporation
AGL-LB	AGL Liddell BESS Pty Ltd
APZ	Asset Protection Zone, between the BESS and neighbouring bushland
AS	Australian Standard
ASE	Automatic Signalling Equipment
BCA	Building Code of Australia
BESS	Battery Energy Storage System, a form of energy storage system relying on electrochemical batteries to store energy. A BESS consists of battery enclosure(s), a power conversion system (PCS), and associated auxiliary equipment (AC switchgear, meters, relays, and telecommunications equipment)
BMS	Battery Management System, protects the battery from harmful operation and maximises its lifespan by constantly controlling and monitoring the battery's parameters such as voltage, current, temperature, state-of-charge and state-of health, and ensuring they are within operating specifications
CCTV	Closed Circuit Television
Cell	(Battery) electrochemical cell. Cells arranged into modules, where each module contains 52 cells.
CID	current interrupt device
CO	carbon monoxide
CO_2	carbon dioxide (gas)
Cube	Fluence Gen 6 Cube battery enclosure
DC	Direct Current
DCP	Dry Chemical Powder
DCPM	Direct Current Protection Module
DG	Dangerous Goods

DPHI	Department of Planning, Housing and Infrastructure (NSW)
enclosure	A discrete energy-storage unit that includes batteries within battery racks, a cooling system, communication interface and other equipment and accessories necessary to maintain health and long-term operation in an outdoor environment. Enclosures are interconnected to form rows of nine (9) enclosures. The enclosure is the fundamental building block of the ESS plant layout
ERP	Emergency Response Plan
ERT	Emergency Response Team
ESD	Emergency Shut Down
ESMS	Energy Storage Management System
ESS	Energy Storage System. ESS technologies can be classified into five categories based on the form in which energy is stored: Mechanical, Electrochemical (using batteries), Thermal, Electrical and Chemical. The Liddell BESS is an electrochemical ESS.
Facility	Liddell BESS, including battery storage enclosures and associated inverters and transformers, and the Liddell BESS Substation (33 kV) to which the BESS is connected, cabling within the BESS auxiliaries, access and APZ
FACP	Fire Alarm Control Panel
FAT	Factory Acceptance Test (or Testing)
FIP/FRP	Fire Indicator Panel/First Responder Panel
FPE	Fire Protection Engineer
FRNSW	Fire and Rescue, NSW
FRV	Fire Rescue Victoria
FSS	Fire Safety Study
HCl	hydrogen chloride (gas)
HCN	hydrogen cyanide (gas)
HF	hydrogen fluoride (gas)
HMI	Human Machine Interface
HIPAP	Hazardous Industry Planning Advisory Paper (DoP's guideline document)
HIPAP2	Hazardous Industry Planning Advisory Paper Number 2 *Fire Safety Study*
HRV	Heavy rigid vehicle
HV	High Voltage
HVAC	Heating, Ventilating, and Air Conditioning

IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
IP	Ingress Protection ratings, defined in international standard EN 60529 (British BS EN 60529:1992, European IEC 60509:1989), and used to define levels of sealing effectiveness of electrical enclosures against intrusion from foreign bodies (tools, dirt etc) and moisture
IPA	Inner protection area
kg	kilogram
kV	kilovolt
kW	kiloWatt
kWh	kiloWatt hour
L	litre
LEL	Lower Explosive Limit
LFP	lithium iron phosphate
LGA	Local Government Area
Li-ion	Lithium-ion
LV	Low Voltage
m	metre
Manual call point	an electromechanical device, forming part of a fire detection and alarm system, that allows occupants to trigger the alarm manually in the event of a fire
MOSOC	maximum operating state of charge
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Megawatt
MWh	Megawatt-hour
NEM	National Energy Market
NFPA	National Fire Protection Association (US)
NYSERDA	New York State Energy Research & Development Authority
OCTE	Outdoor Core Telco Enclosures
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
PA	Public Address

PCS	Power Conversion System, converts alternating current (AC) to direct current (DC), and vice versa, to allow power flow between the BESS and the grid
PG	Packing Group
PHA	Preliminary Hazard Analysis
PM	Preventative Maintenance
ppm	parts per million
rack	Physical rack which is made up of eight (8) battery modules connected in series. Each enclosure houses two (2) racks connected in parallel amounting to 16 battery modules per enclosure.
RFS	NSW Rural Fire Services
row	Up to nine (9) enclosures are connected to form a row. Each row is connected to an Outdoor Core Telco Enclosures (***OCTE***), Power Conversion System (***PCS***) and Core (low to medium voltage) transformer
runaway	Occurs when excessive heat is generated and accumulated within the battery, e.g. due to poor system design, installation or mishandling, leading to the build-up of heat and flammable (and possibly toxic) gas such as simple hydrocarbons (e.g. methane), HCl, HBr, HCN and CO
SAT	Site Acceptance Test (or Testing)
SDS	Safety Data Sheet
SOC	State-of-Charge
SOP	standard operating procedure
thermal runaway	See “runaway”
TNO	the Netherlands Organisation
UL	Underwriters Limited
UPS	Uninterrupted Power Supply
WHS	Work Health and Safety

Report

1 INTRODUCTION

1.1 BACKGROUND

AGL is an electricity generator and retailer operating in Australia. AGL Macquarie (***AGL-M***) owns and operates the Bayswater Power Station (Bayswater) which is approved to generate up to 2,740 megawatts (***MW***), the 2,000 MW Liddell Power Station (Liddell), the 50 MW Hunter Valley Gas Turbines (now decommissioned) and associated ancillary infrastructure systems.

AGL-M has received Development Consent from the NSW Department of Planning and Environment[2] (referred to here as the Department of Planning, or ***DoP***) for the Liddell Battery and Bayswater Ancillary Works Project (***the Project***). The Project is a State Significant Development (SSD-8889679) and includes the following:

The Liddell Battery Energy Storage System (***BESS***): A grid connected BESS with capacity of up to 500 MW and 1 GWh. The development of the battery system is required for the transition from thermal power generation to renewable generation. The operation of the Liddell BESS will be complementary to the ongoing operation of Bayswater.

Decoupling works: Alternative network connection arrangements for the existing Transgrid 330 kV kilovolt (***kV***) Switching Station that provides electricity to infrastructure required for the ongoing operation of Bayswater and associated ancillary infrastructure and potential third-party industrial energy users.

Bayswater Ancillary Works (*BAW*): Works associated with the ongoing operation of Bayswater which includes (but is not limited to), upgrades to ancillary infrastructure such as pumps, pipelines, conveyor systems, roads and assets to enable maintenance, repairs, replacement, expansion or demolition.

The Liddell BESS will be owned and operated by AGL Liddell BESS Pty Ltd (***AGL-LB***).

[2] Now the Department of Planning, Housing and Industry

Conditions B2 and B3 of the Development Consent state that a Fire Safety Study (***FSS***) be developed and implemented, as follows:

B2. Prior to commencing construction, the Applicant must prepare a Fire Safety Study for the development, to the satisfaction of FRNSW and the Planning Secretary. The study must:

(a) be consistent with the:

(i) Department's Hazardous Industry Planning Advisory Paper No. 2 'Fire Safety Study' guideline and relevant Australian Standards and International Guidelines; and

(ii) NSW Government's Best Practice Guidelines for Contaminated Water Retention and Treatment Systems; and

(b) describe the final design of the battery energy storage system and verify that the final design is consistent with all findings and recommendations in the Preliminary Hazard Analysis dated 25 March 2021.

B3. The Applicant must implement the measures described in the Fire Safety Study approved by the Planning Secretary.

Fluence Energy Pty Ltd (Fluence) has been contracted by AGL-LB to design, supply BESS equipment and maintain the infrastructure and equipment associated with the Liddell BESS.

The Liddell BESS Substation, located adjacent to the north of the BESS, is used to transform the medium voltage output from the BESS to high voltage (330 kV) before transporting it to the existing Transgrid Switching Station.

Fluence has requested Planager Pty Ltd (Planager) to prepare this FSS to present the proposed fire safety strategy for the operations and facilities associated with the site including the BESS and the Liddell BESS Substation.

The report has been prepared in accordance with the Hazardous Industry Planning Advisory Paper No 2 (***HIPAP2***) *Fire Safety Study Guideline* (Ref 1) by the DoP and the FRNSW Fire Safety guideline, *Large-scale external lithium-ion battery energy storage systems – Fire safety study considerations*.

1.2 Scope

The FSS scope as follows:

- The works that are within Fluence's remit, i.e. the Liddell BESS, including battery storage enclosures and associated inverters and transformers
- The Liddell BESS Substation (33/330 kV) to which the BESS is connected, and which is located adjacent to the BESS to the north of the site.

Together, these are referred to as *the facility* in this FSS.

The overhead high voltage connection (***transmission line***) from the Liddell BESS Substation to the existing Transgrid Switching Station will be owned and built by Transgrid to relevant codes and standards. This work is outside of the scope of this FSS, as is the The Bayswater Ancillary Works (BAW), which was also included in the Project approval. Neither of these works is expected to have a bearing on the fire safety strategy described in this report.

The FSS is based on design information, as available in the documentation provided to Planager prior to installation and operation of the BESS on the site. In line with Consent Condition B2 (b), the scope of this FSS includes verification that the final design is consistent with all findings and recommendations in the Preliminary Hazard Analysis[3] (***PHA***, Ref 2).

The FSS does not verify compliance of the fire system to the Standard to which they have been installed. Implementation of the findings in the FSS form part of Fluence's/AGL-LB safety assurance responsibilities for the Project.

1.3 Aim

The aim of the FSS is to demonstrate that the fire safety strategy for the BESS is appropriate for the specific fire hazards associated with the Site, as developed at the detailed design stage of the Project.

The FSS is a document which enables and assists stakeholder consultation with Fire Rescue NSW (***FRNSW***), NSW Rural Fire Services (***RFS***) and the DoP.

Emergency planning is also an important element of the safety assurance process, and FSS provides input into the facility's Emergency Response Plan.

1.4 Recommendations arising from the PHA

The PHA dated 25 March 2021 (Ref 2) conducted for the Project included a list of safety commitments and a number of recommendations regarding the detailed design stage of the Project. The recommendations arising from the hazard analysis are listed below. A verification that the final design of plant and operations in the scope of this FSS[4] is consistent with the findings and recommendations in the Preliminary Hazard Analysis is provided in Section 9:

PHA1. A detailed bushfire threat assessment is conducted for the Project, including establishment of an APZ, in consultation with the Rural Fire Service (RFS)

PHA2. The separation distance between infrastructure within the Battery is determined in accordance with Codes and Standards and manufacturer's recommendations so that the

[3] The Preliminary Hazard Analysis included then proposed *Bayswater Ancillary works*, which are not part of the present Project and hence outside of the scope of this FSS

[4] i.e. the Bayswater Ancillary works is not included

preferred strategy of allowing a fire in one battery enclosure or inverter to burn without the risk of propagating to other infrastructure can be maintained without the need for external firefighting

PHA3. The separation distance within the Battery is determined in accordance with Codes and Standards and manufacturer's recommendations to allow safe escape in case of a fire

PHA4. All relevant requirements in the new AS5139 (2019) are adhered to at the Battery. Adherence to requirements in international standards are also considered, for example to the US NFPA 855(2020) Code. Further, consider procurement of a battery system that is certified to UL 1642, UL 1973, IEC 61427-2 and IEC62619

PHA5. The need for active firefighting requirements at the Battery and at the waste storage area is determined in consultation with RFS and the DoP, e.g. in the form of firewater tanks and connections to the RFS. Detailed firefighting response and any need for firewater containment should be assessed and reported (e.g. in the format of a Fire Safety Study) post development approval, for review by the DoP, NSWFR and the RFS

PHA6. The health and safety associated with EMF on the site and the potential exposure to EMF are considered for AGL-LB staff and contractors as part of AGL-LB's obligations for their health and wellbeing under the WHS Regulations

PHA7. Measures to prevent a leak from occurring at the brine pipeline, the emergency diesel generators and at the Battery, and for secondary containment should a leak occur, is addressed in the detailed design phase for the Project

PHA8. The register of commitment (Appendix 1 of the PHA) is integrated into the management for the Project. This includes integration of 84 individual commitments, including for the design, installation and maintenance of the BESS (further details in Section 9).

1.5 Report organisation

The report is organised as follows:

- The description of the site is provided in Section 2
- The fire hazards are discussed in Section 3, and an estimate of consequences of fires is provided in Section 4
- The fire safety strategy for the site is presented in Section 5
- Firewater demand and containment is discussed in Section 6
- Emergency response is discussed in Section 7
- Significant Codes and Standards are listed in Section 8
- Status of recommendations in the PHA are provided in Section 9

- Conclusions and recommendations are provided in Section 10
- References made to input information and reports, research, reviews etc. are provided in Section 11.

1.6 METHODOLOGY

The FSS has two elements:

- The study of fire safety at the facility, which is based on the fire safety strategy developed for the BESS, as provided by Fluence, and the safety assessments and fire modelling undertaken by Planager on behalf of Fluence.
- The report, which summarises the fire safety strategy on site and justifies design and operational decisions made by AGL-LB and Fluence. It facilitates discussions with the relevant stakeholders and development of further hazard and risk related studies and plans.

1.7 KEY ELEMENTS OF THE STUDY

The key elements of the FSS as detailed in HIPAP2 (Ref 1) are:

- Identification of fire hazards and the consequences of possible fire incidents
- Listing of available fire prevention and protection (mitigation) strategies and measures and highlighting of any gaps as identified, including analysis of the requirements for fire detection and protection and identification of the specific measures to be implemented
- Evaluation of firefighting or fire cooling water supply and demand
- Evaluation of volumes of contaminated firefighting water against available containment
- Evaluation of first aid fire protection requirements, and
- Preparation and submission of a report inclusive of any recommendations.

These elements are shown in the flow diagram, from HIPAP2, in Figure 1-1.

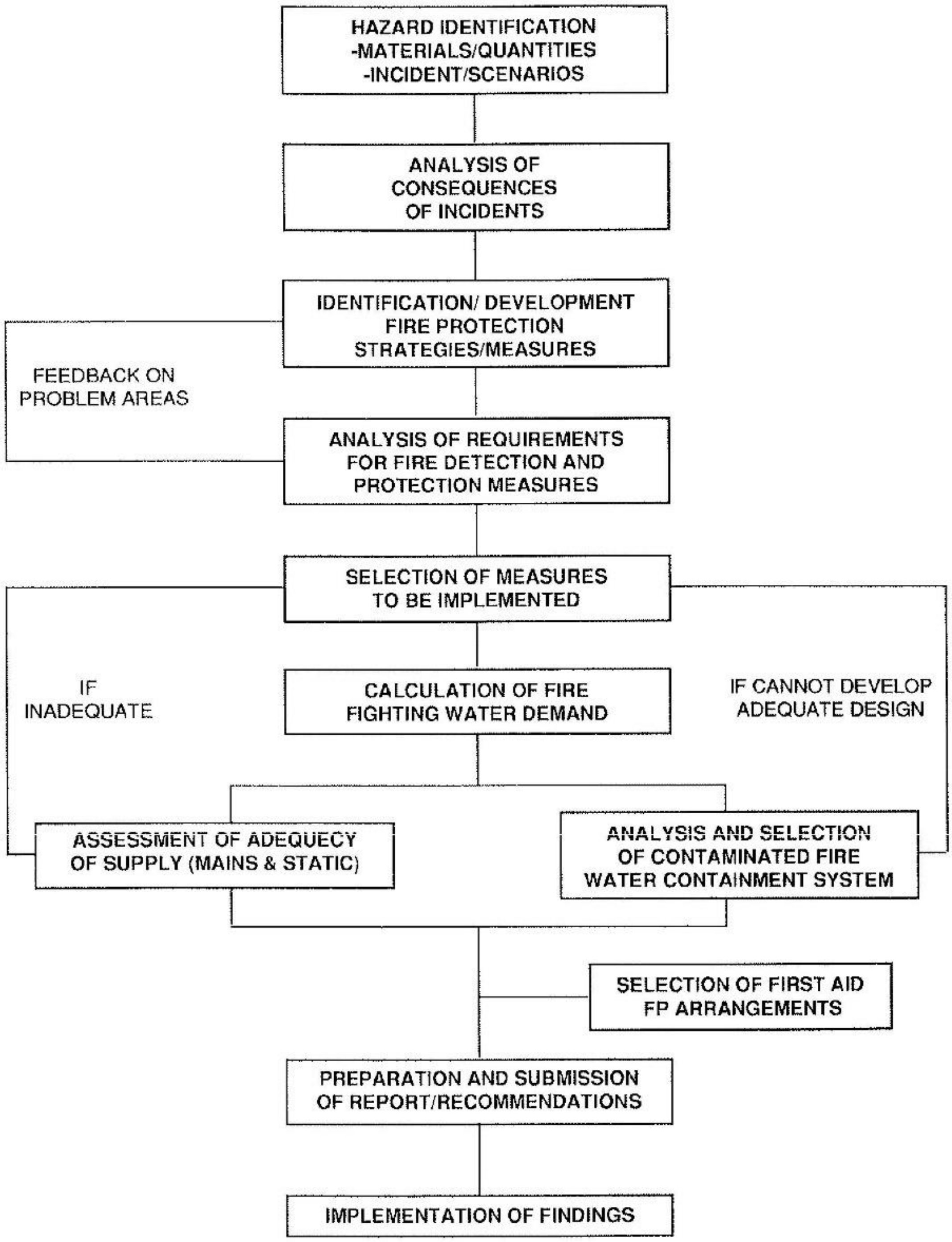


Figure 1-1: Flow diagram for a fire safety study (HIPAP2)

2 DESCRIPTION OF THE FACILITY

2.1 SITE LOCATION

Liddell and Bayswater are located approximately 15 kilometres (km) south-east of Muswellbrook, 25 km north-west of Singleton, and approximately 165 km west-northwest of Sydney, New South Wales (NSW). The total area of the AGL-LB landholding is approximately 10,000 hectares (ha), including Bayswater, Liddell, Ravensworth, Lake Liddell, Lake Plashett and surrounding buffer lands.

The works associated with the Project are almost entirely within the AGL-LB landholding except for minor works to the switchyard and where AGL-LB infrastructure crosses road reserves, Crown land or Council property. The majority of the AGL-LB landholding has been previously disturbed during the construction and operation of Liddell and Bayswater and historic agricultural activity.

The New England Highway (NEH) runs between Liddell and Bayswater, with access from the highway provided by means of a dedicated road network designed to service the power stations. The Northern Railway Line runs to the east of the AGL-LB landholding.

The Project lies within the catchment area of the Upper Hunter Valley (Upper Hunter), which is the largest coastal catchment within NSW. The largest tributary of the Hunter River is the Goulburn River which joins the Hunter River approximately 25 km to the west of the Project. The Hunter River flows to the west and then around the south of the Project. The Hunter River is located about 13 km from the Project.

The project location within the general area is shown in Figure 2-1. An overall site plan showing the BESS development area and construction laydown areas is provided in Figure 2-2.

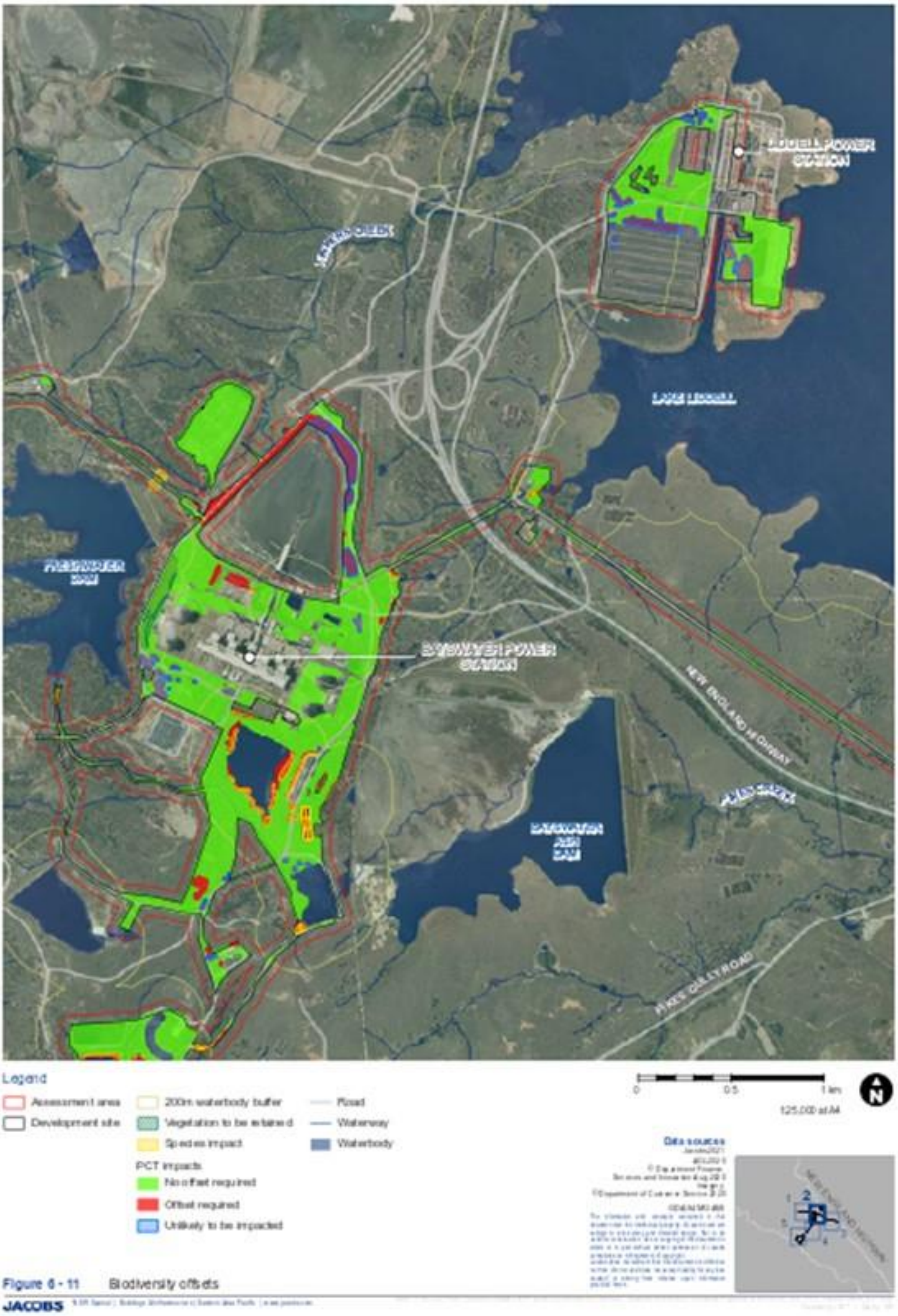


Figure 2-1: Project location

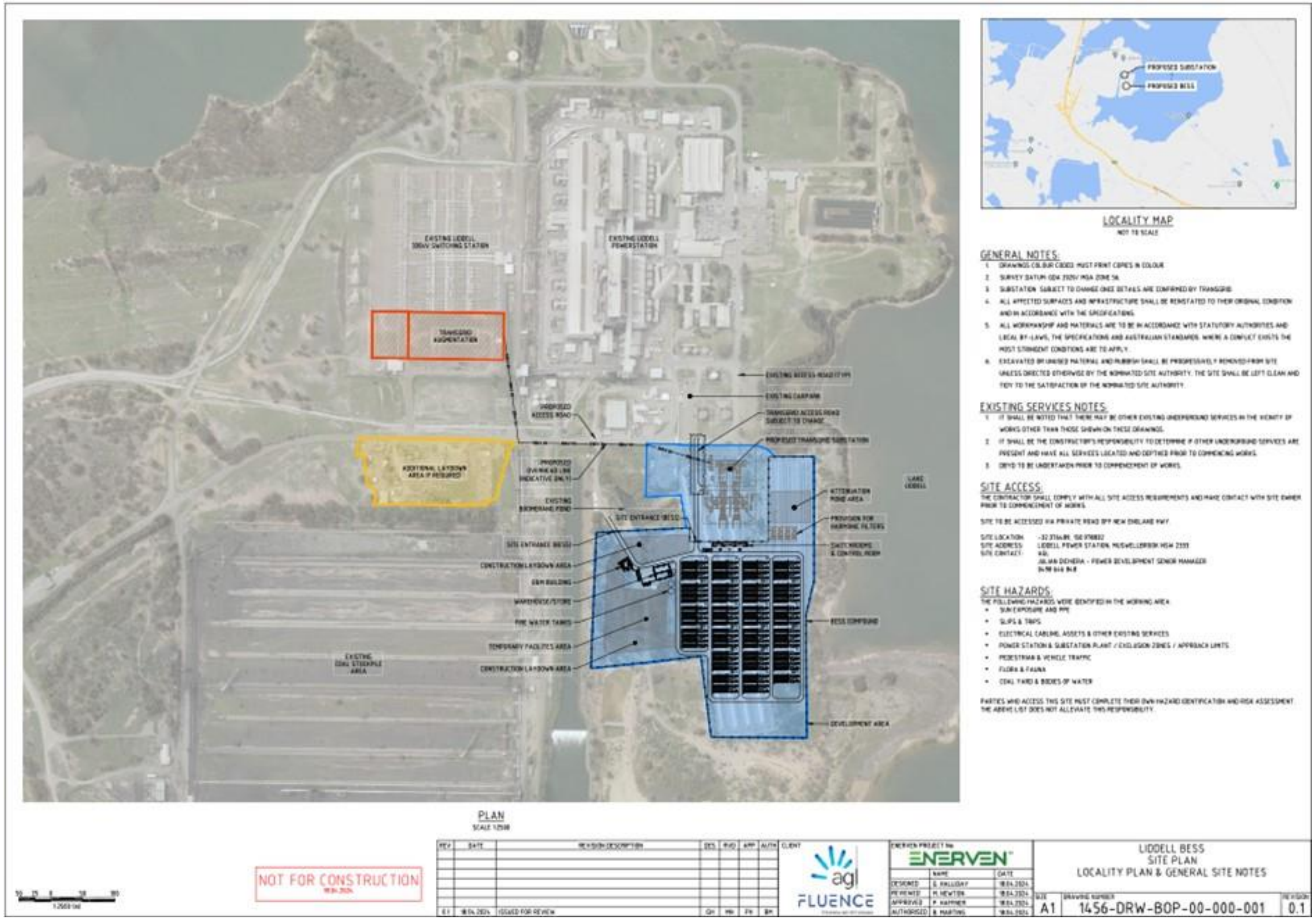


Figure 2-2: BESS development area

2.2 SITE LAYOUT

A site layout is given in Figure 2-3. An A3 version of this layout is also given in Appendix 2. The layout shows the following:

- Back-to-back doubled rows of Cubes with nine (9) Cubes per row. Each row of Cubes is connected to a Power Conversion System (***PCS***) and an Outdoor Core Telco Enclosure (***OCTE***, one per two doubled rows), and Core (low to medium voltage) transformer (one per doubled row)
- 33kV ring main units
- Medium voltage (MV) kiosks (BESS auxiliary supply)
- Two switchgear rooms and a control room located adjacent to two switchroom transformers and a back- up diesel generator
- Operations and Maintenance (O&M) building
- Workshop and storage building
- Two (2) firewater tanks filled using the raw water supply
- 4-6 m wide entry and internal access roads
- BESS area boundary fence
- Liddell BESS Substation 330/33kV with 330kV overhead transmission line to the existing Transgrid Switching Station (the transmission line and the existing Transgrid Switching Station are not included in the FSS scope) including two (2) main step-up-transformers (330/33kV)

The BESS block layout is show in Section 2.4. The Liddell BESS Substation layout is shown in Figure 2-4.

Figure 2-3: Site layout

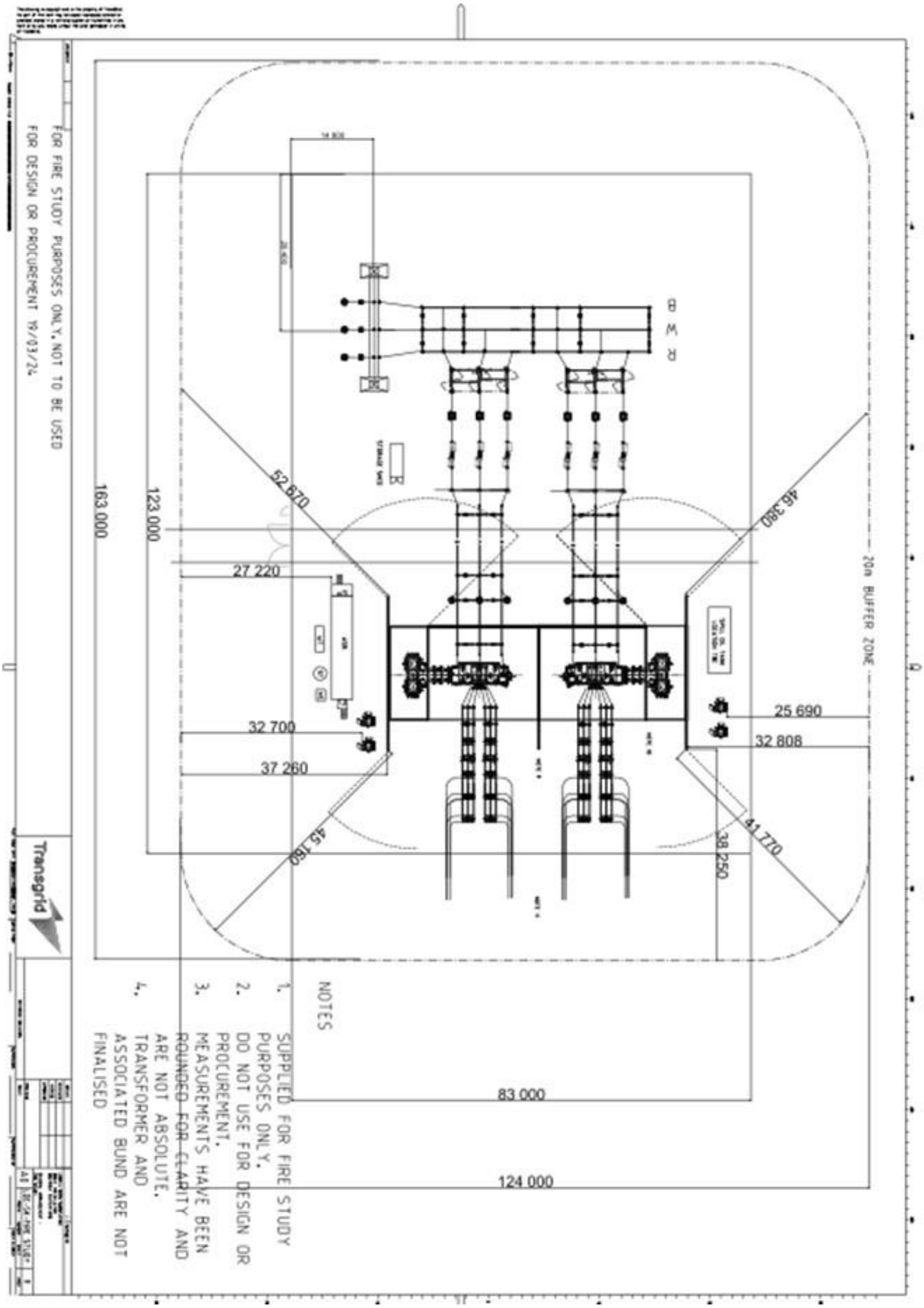


Figure 2-4: Liddell BESS Substation layout

2.3 SITE INFRASTRUCTURE

The tables in the following sections summarise details of the site's infrastructure.

2.3.1 Locational details

Table 2-1: Locational details (source: EIS, Ref 3)

Project Element	Description
LGA	Muswellbrook and Singleton
Location	AGL-LB landholding located approximately 15 km south-east of Muswellbrook, 25 km north-west of Singleton, and approximately 165 km west north west of Sydney in NSW
Zoning	SP2 Infrastructure (Power Station) under the Muswellbrook Local Environment Plan 2009 (Muswellbrook LEP) and RU1 – Primary Production under Singleton Local Environmental Plan 2013 (Singleton LEP).
Existing environment	The Project is located within an area dominated by mining and power generation. The landscape local to Liddell is heavily influenced by industrial activity. Local land use is dominated by large-scale infrastructure associated with Bayswater and Liddell and open cut mining activities at Ravensworth Mine Complex, Mount Arthur Coal, Hunter Valley Operations, Liddell Coal Mine and the former Drayton Mine. Agricultural clearing for the purposes of grazing is also present within and surrounding the AGL-LB landholding. There are limited social infrastructure and sensitive receivers in the locality of the facility. The closest social infrastructure is the Lake Liddell Recreation Area with a dwelling located approximately 2 km from the facility. The closest residential area is the Antiene subdivision, which is located approximately 4 km north of the facility.
Bushfire prone land	The land associated with the facility is partly designated as a bushfire prone area (Ref 4)
Footprint	The approximate footprints of the various elements associated with this FSS are: • Liddell BESS and associated infrastructure: 16 ha (approx. 350 × 465 m) • Liddell BESS Substation: 1 ha (83 × 123 m).

2.3.2 Access and security

Table 2-2: Access and security

Project Element	Description
Access	Access to and from the facility is provided by slip-lanes from the New England Highway into an existing site access road. Two independent entrances are available into the BESS site. A further two gates provide access between the BESS and the Liddell BESS Substation.
Lighting	Sufficient lighting will be supplied for operational requirements (design is yet to be finalised).
Security	The facility will be enclosed by security fencing. The fence will typically be 2.7m high overall with 2.1m chainmesh and 4 strands of barbed wire at 140mm spacing. CCTV cameras will be strategically located throughout the facility. Restricted access to the site via a 24/7 manned security gate at the main entrance to the BESS. Various locations within the site including into the substation will be controlled by an Automatic Control System.

Access within the BESS

Access within the facility will be facilitated by internal access roads (4 to 6 m in width), around the perimeter of the site and between battery arrays (Cores) and transformers in the Liddell BESS Substation. These roads have been designed for the movement of heavy rigid vehicles[5] expected during construction, operation and maintenance of the facility. Road pavements will be capable of accommodating 15 tonne vehicles.

The roads will also be designed to meet the width and turning radius requirements for a general fire appliance in accordance with FRNSW guidelines (Ref 5).

2.3.3 Specifications and key design features

Summaries of the specifications and key design features of the BESS and the Liddell BESS Substation are provided in Table 2-3 and Table 2-4 . A summary of key safety features of the Cubes, inverters and transformers is given in Table 2-5.

[5] As per AS2890.2:2018 section 2.2(c), the description of the HRV is 12.5m in length with 4-axle twin steer with wheelbase as shown in Figure 2.1.

Table 2-3: Specifications and key design features: BESS

Project Element	Description
Performance requirements (Ref 6)	• Useable energy capacity at point of connection (***PoC***): 1000 MWh. • Real power charge capacity at PoC: 500 MW • Real power discharge capacity at PoC: 500 MW • BESS discharge cycle rate: 365 cycles per year • BESS discharge duration: 2 h
BESS Facility	Battery infrastructure: • Nominally 1548 × battery enclosures arranged in 172 rows (9 Cubes per row). Each battery enclosure housing two (2) liquid cooled[6] racks of Lithium-ion[7] (***Li-ion***) type battery modules, Direct Current (***DC***) protection module, and associated control systems • Nominally 86 × Power Conversion Systems (***PCS***) inclusive of 86 Core transformers and 172 Inverter • Nominally 43 × Outdoor Core Telco Enclosures (OCTE), one for each 4 Core/PCS units • Nominal 22 off 33kV Ring Main Units (RMU) • Nominal 12 off 33kV Kiosk hosing 33kV switchgear and 33kV/0.45V Auxiliary transformers • Nominal 43 outdoor LV distribution boards Additionally: • Two (2) Switchgear rooms • Control room • Operations and Maintenance (O&M) building • Workshop and Storage building • Ancillary infrastructure including 2 x water tanks for bushfire protection purposes, lightning protection, security fencing and closed-circuit television (CCTV).

Table 2-4: Specifications and key design features: Liddell BESS Substation

Project Element	Description
Liddell BESS Substation and connection	• Two Main Step-Up Transformers 320MVA, inclusive of oil spill tank and fire wall between transformers and fire walls to protect bay equipment, refer to Figure 2-4 • Auxiliary Services building • Nominal 4 × 33kV dedicated buried feeder cables that will be directly connected between the BESS and the Liddell BESS Substation

[6] Coolant is a water:glycol mix

[7] lithium iron phosphate - LFP

Project Element	Description
	• Nominal 2 × buried earthing continuity conductors that will connect the BESS facility earth grid to the Liddell BESS Substation earth grid. • Nominal 2 × multi-core optic fibre cables and any additional signalling required by the Network Service Provider (**NSP**).

Table 2-5: Key safety features

Element	Summary
Management of battery conditions	Each Cube's Battery Management System (***BMS***) provides a range of safety measures including: • Preventing overcharging and current surges • Maintaining voltage levels and ensuring the automatic cut-out in the event of electrical shorts • Preventing overheating and other unplanned events.
Thermal management	**Fluence Cubes**: Temperature is controlled using door mounted heating, ventilation and air conditioning (***HVAC***) and chiller units. **Inverters**: Temperature is controlled using forced air cooling system. **BESS inverter transformer:** (Non-Mineral) Oil natural air natural (KNAN) cooling **Main Step-Up Transformers 320MVA:** Transformers will be fitted with a duplicate transformer differential protection scheme. Hot winding, hot oil temperature and other mechanical trips are under No. 2 Protection (Alstom P645).
Fire protection system	**Fluence Cubes**: Each Cube has a fire protection system that includes gas (carbon monoxide) and fire detection (multi-sensor), fire alarm (strobe and horn), and fire suppression (thermally activated solid aerosol). The suppression system is designed to address a non-battery fire before it spreads to the batteries. The Li-ion battery cells, modules and Cubes are non-propagating as per UL 9540A and BDBT (see Section 2.5). OCTE: Each cabinet contains gas (carbon monoxide) and fire detection (multi-sensor) and a Fire Indicator Panel (***FIP***). The FIPs are connected to a series of master FIPs. **Main Step-Up Transformers 320MVA:** Protection relays are fitted in the switchgear and transformers to protect against over-currents and short circuits. The relay in the transformer alarms on fault detection tripping the switchgear. The transformer tanks are fitted with oil-level, overpressure and overtemperature detectors and trips.
Physical safety features	Fluence Cubes: • A Fast-stop (F-Stop) system which operates at Cube and Core level • Modules, Cubes, Inverters etc are appropriately Ingress Protection (IP) rated to prevent ingress of water/dust • Cubes are fitted with lockable disconnect switch, open door sensors, gas spring dampers (to prevent the doors from opening and closing too quickly) and sliding door locks

Element	Summary
	• Tethered deflagration panels are fitted on the roof of each Cube • Separation of ≥3 m to adjacent rows of Cubes Main Step-Up Transformers 320MVA: • 20m buffer zone around the Liddell BESS Substation • Each transformer is surrounded by fire walls on three sides and there is a separate fire-rated compartment for the cooling system. • An underground tank fitted with a flame trap is used to contain spilled oil. • Earthing and lightning protection throughout the site • Oil containment at each Core transformer at the BESS of sufficient capacity to contain 110% of the oil volume • Oil containment tank (below ground) at the Liddell BESS Substation to contain HV transformer oil spillages • Stormwater flow management to ensure stormwater is discharged from the site in a manner that meets all planning requirements
Water supply	Two (2) aboveground firewater tanks filled from the raw water supply
Uninterruptible power system (**UPS**)	Fluence Cubes: Each Cube and Core Fire Indicator Panel (**FIP**) is fitted with sufficient battery back-up power to maintain data collection and other critical functions. **Site wide:** Duplicated 125Vdc battery systems and duplicated 230V AC uninterruptible power supplies (UPS) for safety shutdown and reliable operation of any PCS, BMS, SCADA, protection system, control, monitoring, protection and indication of High and Low voltage plant/equipment.

2.3.4 Facility operations

The facility will operate on a 24 hour per day, seven days per week basis.

BESS

The BESS will be designed to operate one full cycle (charge/discharge) 365 times per year.

The Fluence Operating System (F.OS) provides 24/7 remote operating capabilities and can be accessed:

- Remotely using a web browser to connect to the customer network
- Locally using a computer set up by the commissioning team at the installed system site
- Via an internal customer VPN.

The F.OS adheres to the National Institute of Standards and Technology cybersecurity framework. It features 256-bit encryption, multi-factor authentication, enterprise-class network security software, and secure, role-based user access. Data is backed up in a virtual private cloud, encrypted in transit and transferred over secure, site-to-site VPN tunnels (Ref 7).

The BESS will normally be controlled remotely from the AGL Dispatch Centre (DC). The control and monitoring system features audible and visual alarms and other notifications to guide rectifying action by the remote operator. The alarm design and operating philosophy will be compliant with ANSI/ISA 18.2, IEC 62682 and AGL's Alarm Management Standard. Engineered controls will be implemented to manage alarming and ensure compliance to these standards. The possibility of alarm flooding, defined in AGL's Alarm Management Standard as an alarm rate that exceeds 10 alarms in a 10 minute interval, will be assessed during detailed design, and, if necessary, measures will be adopted to manage alarm levels and frequency to a level that is acceptable for management by a single control room operator (Ref 8). During operations, the occurrence of alarm floods will be monitored and analysed with unacceptable levels (defined as the alarm system in flood for more than 1% of the time), a trigger to improve the alarm system and/or process operation.

The Facility will be connected via a SCADA panel to the Australian Energy Market Operator (**AEMO**) Automatic Generation Control (**AGC**) system and while in AGC mode will respond to the remote AGC setpoint from AEMO and NSP.

While the Facility is designed to be an unmanned operation, minimal manning will be provided from the existing AGL Dispatch Centre workforce consistent with ensuring safe and reliable operation.

In normal operation, the BESS may be on standby mode ready for peak load dispatch. During peak demand, the operating battery/inverter units will be started and ramped up at the maximum unit ramp rates to meet the demand. The system will be designed such that the total response time (from signal initiation by AGC/other modes to power despatch at the PoC) will not exceed 250 milliseconds.

Liddell BESS Substation

The function of the Liddell BESS Substation is to transform the medium voltage output from the BESS, which operates one full cycle (charge/discharge) 365 times per year, into high voltage (330kV).

All signals from the Liddell BESS Substation are sent to Transgrid for remote monitoring as the site is normally unmanned. The control and monitoring system features audible and visual alarms and other notifications to guide rectifying action by the remote operator. The Facility will be connected via a SCADA panel to the Transgrid remote operated control room. While the Facility is designed to be an unmanned operation, minimal manning will be provided from time to time, from the existing Transgrid workforce consistent with ensuring safe and reliable operation.

In normal operation, the Liddell BESS Substation may be on standby mode ready for peak load dispatch from the BESS. During demand, the transformers will automatically be started up.

2.4 Battery and Enclosure Design

The energy storage system comprises of discrete energy storage enclosures (Cubes) that include batteries mounted in racks, battery management system, data acquisition system and the associated equipment required to maintain safe operation in an outdoor environment. Cubes are connected via nodes (the smallest dispatchable part of the system) to form Cores. Each Core is self-contained and includes, in addition to Cubes:

- Outdoor Core Telco Enclosure (OCTE) containing the main Core-level ethernet switch, the Core-level fire panel and the Fast-stop (F-Stop) system
- Core transformer, which boosts low voltage (LV) AC from the PCS to MV AC for connection to the power grid directly or through a HV transformer
- Power conversion system (PCS) comprising an inverter that converts DC to AC to supply energy from the batteries to the grid and converts AC to DC to charge the batteries form the grid.
- Cube row termination (CRT), an electrical enclosure that standardises the connection of the Fluence Cubes to the PCS.

Multiple Cores may be connected to a common AC power bus to form an Array.

A block layout showing separation distances between Cubes and between Cubes and the other equipment in the Cores will be used at Liddell is shown in Figure 2-5. This is an extract of Drawing 1456-DRW-BOP-30-601-001 Rev 0.3. An A3 version of the complete drawing is included in Appendix 2.

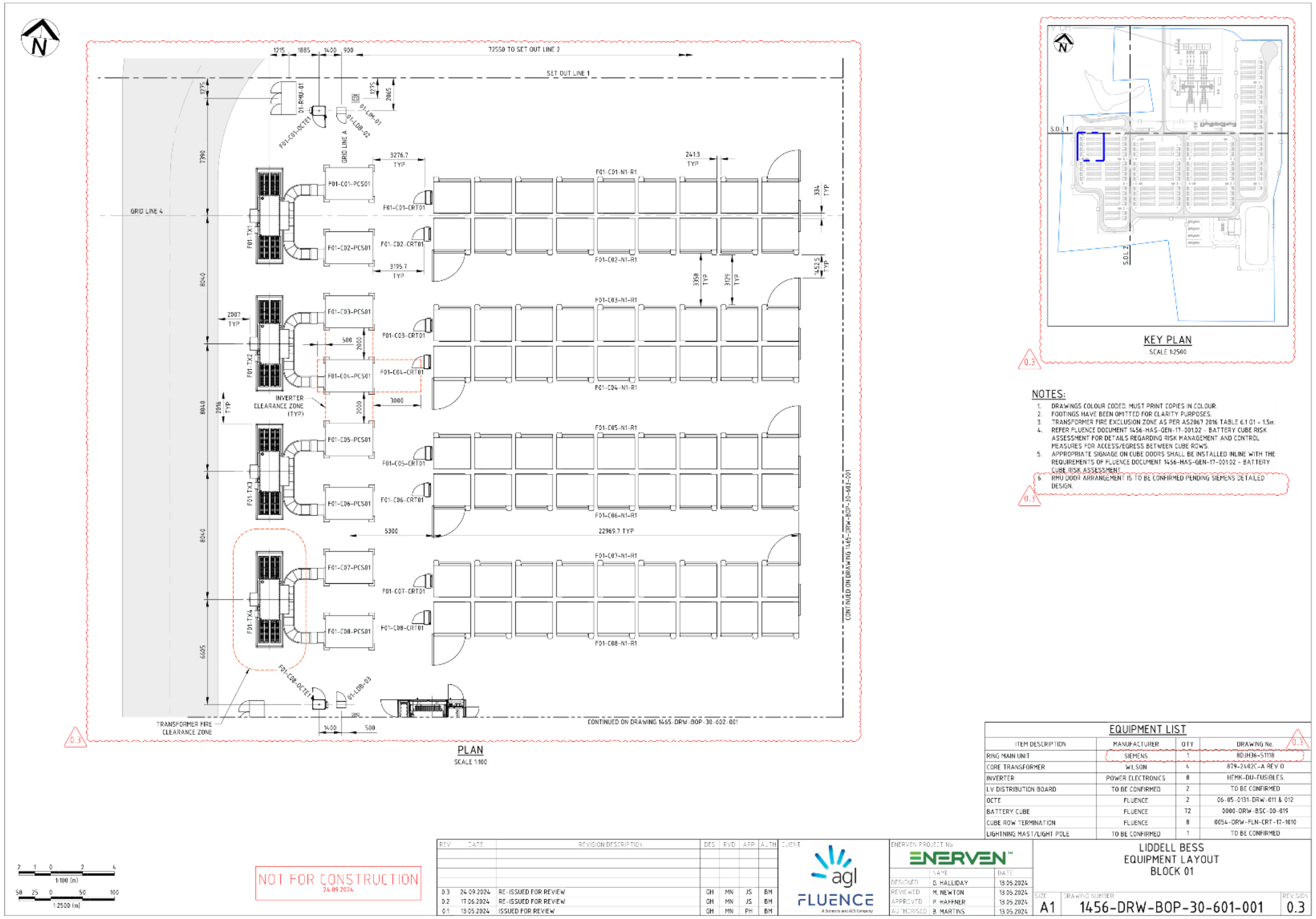


Figure 2-5: Block layout

The details of the design are summarised in Table 2-6.

Table 2-6: Fluence Cube technology

Title	Description
Battery cells	Lithium ion (LI-ion) design manufactured by Envision Dynamics Technology (Jiangsu) Co. Ltd. The Liddell BESS uses ESS 4L H3L7 280A prismatic lithium iron phosphate (LFP) battery cells. Each cell is rated for a nominal capacity of 280 Ah and a nominal voltage of 3.2 V, giving a nominal energy capacity of 896 Wh (Ref 9) and is fitted with an off-gas vent designed to relieve internal pressure in the event of a thermal runaway.
Battery modules	The battery cells are held in Envision Automative Energy Supply Corporation (**AESC**) EACH-1P52S-280Ah modules in a 1P52S configuration (52 cells per module connected in series). The module housings are of metal construction consisting of aluminium sides and a stamped steel lid; they are liquid cooled using an aluminium cooling plate at the base of the module (Ref 10). Each module is rated for a nominal capacity of 280 Ah and a nominal voltage of 166.4 V giving an energy capacity of 46.6 kWh. The module has an ingress protection (***IP***) rating of IP67 which provides complete protection from dust intrusion and virtually all ingress of water (Ref 9).
Module dimensions and weight	808 mm (W) × 1180 mm (L) × 240 mm (H) Weight = 350 kg
Battery racks	The Envision AESC EACH-1P416S-280Ah rack system consists of 8 modules connected in series. Each rack has a nominal voltage of 1331.2 V and a nominal energy capacity of 372 kWh. The other main components of the rack system include the Direct Current Protection Module (***DCPM***) located at the top of the rack, hose, high voltage (HV) and low voltage (LV) cables and a rack bracket. The DCPM comprises high voltage (HV) and low voltage (LV) electrical connectors, LED indicators, a disconnect switch and a communication interface. The DCPM provides visual indication of contactor status, overcurrent protection from the shared primary DC bus, a communication interface between pack BMS and module BMSs, lockable disconnect switch to isolate the battery pack from the DC bus for servicing and a connection between the battery pack and shared DC bus via electrically controlled contactors (Ref 9).
Enclosures	The Fluence Gen 6 Cube is a rigid metal, ground mounted, liquid-cooled enclosure which is designed for an outdoor environment. The Cubes are designed to be installed in rows and connected to form Cores. Each Cube holds two (2) battery racks. A door on the front of the Cube provides access to the battery modules, door mounted chiller, uninterruptible power supply (***UPS***) and other controls (Ref 10). The Cubes are IP55 rated (Ref 11) Deflagration panels mounted on the top of, and tethered to, the enclosures are designed to minimise structural and mechanical damage and the safety risk to operators or first responders (Ref 12).
Enclosure Dimensions and weight	2566 mm (W) × 2160 mm (D) × 2549 mm (H) Weight = 8360 kg without coolant

Title	Description
Enclosure nominal energy	745 kWh
Storage capacity	≥ 2 h
Max enclosures/row	18 back-to-back in doubled rows (9 enclosures per single row)
Cooling medium and technology	The Fluence Cube provides thermal management through door mounted heating, ventilation and air conditioning (***HVAC***) and chiller units. The HVAC can be controlled remotely and uses R-134a refrigerant. The closed-loop, liquid cooling chiller uses 50:50 ethylene glycol:water and R-410 refrigerant (Ref 9). Each Cube contains (Ref 9) the following weight of refrigerant and coolant: • R-134a: 220 g • R-140: 2400 g • Ethylene glycol/water: 40.4 kg

The external and internal aspects of the Fluence Cubes are shown in Plate 1 and Plate 2 respectively.

Plate 1: Fluence Cube: external view (Ref 9)

Plate 2: Fluence Cube: internal view

Plate 2 shows the door mounted chiller system (labelled 1); two racks each with 8 modules, side by side (one rack labelled 2) and the Direct Current Protection Module (***DPCM***) at the top of a rack (labelled 3).

2.5 LARGE-SCALE FIRE TESTING

A series of tests has been undertaken to investigate the potential for battery equipment to experience fire propagation in the event of a thermal runaway event. These were completed in accordance with UL 9540A:2019 – *Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems.* UL9540A tests were successfully performed at module, rack and Quantum Enclosure (unit) level. In each case, the UL9540A tests demonstrated that a thermal runaway event would be contained within the initiating module.

Additionally, above the requirements of current standards, a further fire test was undertaken at Cube level in a Beyond Design Basis Test (BDBT). The purpose of the test was to evaluate the battery response to conditions more severe than the conditions required by UL 9540A unit level testing. The test involved initiating thermal runaway in all 52 cells of a battery module within the BESS unit. The BDBT is discussed in detail in SAFE Laboratories and Engineering Corp. (SAFE Labs), *Beyond Design Basis Burn Test, Fluence AESC-LFP* (Ref 10).

The tests and their results are summarised in Table 2-7 and described in further detail in the Sections 2.5.1 through to 2.5.4.

Table 2-7: Summary of fire testing for the Liddell Cube

Test	Laboratory	Test date	Location	Test report #	Findings	Reference
UL 9540A cell level	UL-LLC	29 Jul-5 Aug 2021	Changzhou, China	4790027966	Module level test required	Ref 13
UL 9540A module level	UL-LLC	2 Dec 2022	Changzhou, China	4790637679.1	Unit level test required	Ref 14
UL 9540A unit level (Cube)	CSA Group Cleveland	15 Apr 2023	North Carolina, USA	80149894	Test successful	Ref 15
BDBT	Safe Labs	17 Apr 2023	North Carolina, USA	-	Test completed without fire propagation	Ref 10

In addition to the fire tests described above, as a precautionary approach, the results of a previous large-scale fire test, referred to as the *Bespoke Burn test,* are included in this report. This large scale fire test, which was conducted by DNV Energy in September 2022 (Ref 16), involved the same Cube (Fluence Gen6) but set up with CATL-LC battery modules rather than the Envision AESC modules which will be installed at the Liddell BESS. The tests and their results are summarised in Table 2-7 and described in further detail in Section 2.5.6. During the test the fire breached the enclosure (Cube). While the test does not exactly relate to the Cube proposed for the Liddell BESS development, with the limited fire test data available, it is not possible to rule out a similar outcome at the Liddell BESS, and the outcome of the breached fire is regarded as a more severe (worst case) fire scenario in this FSS. This is further explained in Section 2.5.7.

Table 2-8: Summary of another large scale fire testing which breached the Fluence Cube (considered as the worst case fire scenario)

Test	Laboratory	Test date	Location	Test report #	Findings	Reference
Bespoke fire test	Safe-Labs	12 Sept 2022	Sanford, NC	DNV 10347021-ROC-R-01	Fire breached the Cube enclosure at the door seals. Test completed without fire propagation to other Cubes	Ref 16

2.5.1 UL 9540A test: Overview

The Envision AESC battery cell and module, and the Fluence battery enclosure (Cube) have undergone propagation testing following the UL 9540A methodology. This process involves triggering a single cell within a battery module into thermal runaway using externally applied heat.

The UL 9540A test method evaluates the BESS system at four levels: cell, module, unit and installation, in the following hierarchy:

- Cell level testing heats sample cells to determine the potential for thermal runaway within an individual cell
- Module level testing is required if, during cell level testing, it is observed that thermal runaway is induced in the cell and the composition of vent gases exceeds 25% of the lower flammable limit (LFL) for flammable gases
- Unit level testing is required if, during module level testing, it is observed the module design is unable to contain thermal runaway, or the cell vent gas is flammable
- Installation level testing is required if, during unit level testing, flaming is observed outside the initiating BESS unit, the surface temperature of the modules in the adjacent BESS unit(s) exceeds the temperature at which cell level gas venting occurred, surface wall temperatures increase more than 97°C from ambient, and explosion hazards are recorded.

2.5.2 UL 9540A test: Cell level

Standardised cell testing on the ESS 4LH3L7 280A LFP battery cell was undertaken on behalf of Envision AESC by UL-LLC Company Ltd.

As discussed in the UL 9540A – cell level report (Ref 13), the verification testing consisted of five separate tests using different cell samples; all of which were conducted under similar parameters. The test cells were conditioned using two cycles of charge and discharge and then stabilised at 100% SOC prior to testing. Flexible film heaters were used to heat the test cells at an average heating rate of 4.3°C to induce thermal runaway. For Test 5, the cell was placed in a sealed battery gas composition chamber.

The results indicated that thermal runaway was induced at an average temperature of 239°C and that average cell vent temperature was 160°C. Vent gases with a flammable gas concentration of greater than 25% of the LFL were produced in Test 5.

The results indicated that further testing at module level was required.

2.5.3 UL 9540A test: Module level

Module testing examines the module design, heat release rate, gas generation, external flaming and flying debris hazards. Standardised testing on the EACH-1P52S-280Ah module containing ESS 4LH3L7 280A battery cells was undertaken on behalf of Envision AESC at module level, again by UL-LLC Company Ltd (Ref 14).

As discussed in the UL 9540A – module level report (Ref 14), the module test was executed to replicate the EACH-1P52S-280Ah module battery cell assembly configuration. The initiating cell (line 2 cell 7) was selected for its central location within the module which enabled thermal stress to be transmitted to adjacent cells in two different directions. Thermal runaway was induced in a similar manner to the cell level test. Cells in proximity to the initiating cell were monitored using thermocouples.

During the test, the initiating cell vented 46 minutes after the start of the test and thermal runaway in this cell occurred at 60 minutes. Eight minutes after the initial thermal runaway, the runaway propagated to two adjacent cells (Line 2 Cell 6 and Line 2 Cell 8). No further propagation was observed. The testing also showed module off-gas venting, but no flaming of vent gases was observed. These results indicated that further testing at unit level was required.

2.5.4 UL 9540A test: Unit (Cube) level

UL 9540A unit level testing assesses the design of the unit, heat release rate, gas generation, external flaming, flying debris hazards, unit and wall surface temperatures, heat flux at the target wall, and reignition. Testing is conducted with BMS, Energy Storage Management System (***ESMS***), fire protection system, and explosion protection systems disabled, and the protection provided by these systems is not evaluated during the testing.

Unit-level testing was undertaken on the Gen 6 Cube on behalf of Fluence at Safe Labs' testing facility in Sanford, North Carolina, USA. The tests were conducted by CSA Group Cleveland. The results of this testing are reported in the unit level test report (Ref 15).

The same Cube set up was used for the UL 9540A test and the BDBT (results of the BDBT are discussed in Section 2.5.5). The tests were conducted outdoors with barriers (in the form of shipping containers) surrounding the test area to prevent drafts impinging on the units. The unit level configuration and test site are shown in Figure 2-6 and Plate 3, and included one *Initiating Unit* where thermal runaway was forced, three Target Units, and a Test (Instrumented) Wall. The Initiating and Target Units, and the Test Wall were equipped with numerous temperature and heat flux sensors. Table 2-9 lists the separation distances between Cubes and between Cubes and the Test Wall, both used in testing and specified by the manufacturer (Fluence). The arrangement of Cubes and the separation distances are analogous to those for the Liddell BESS.

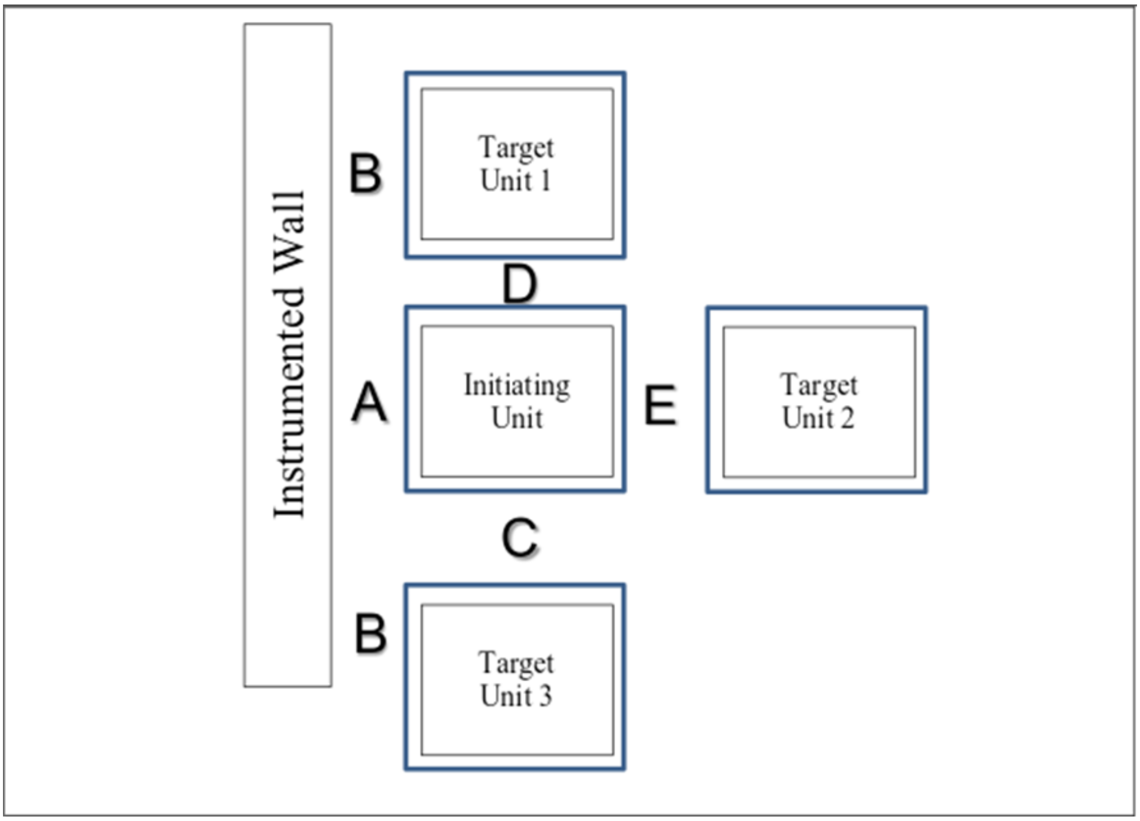
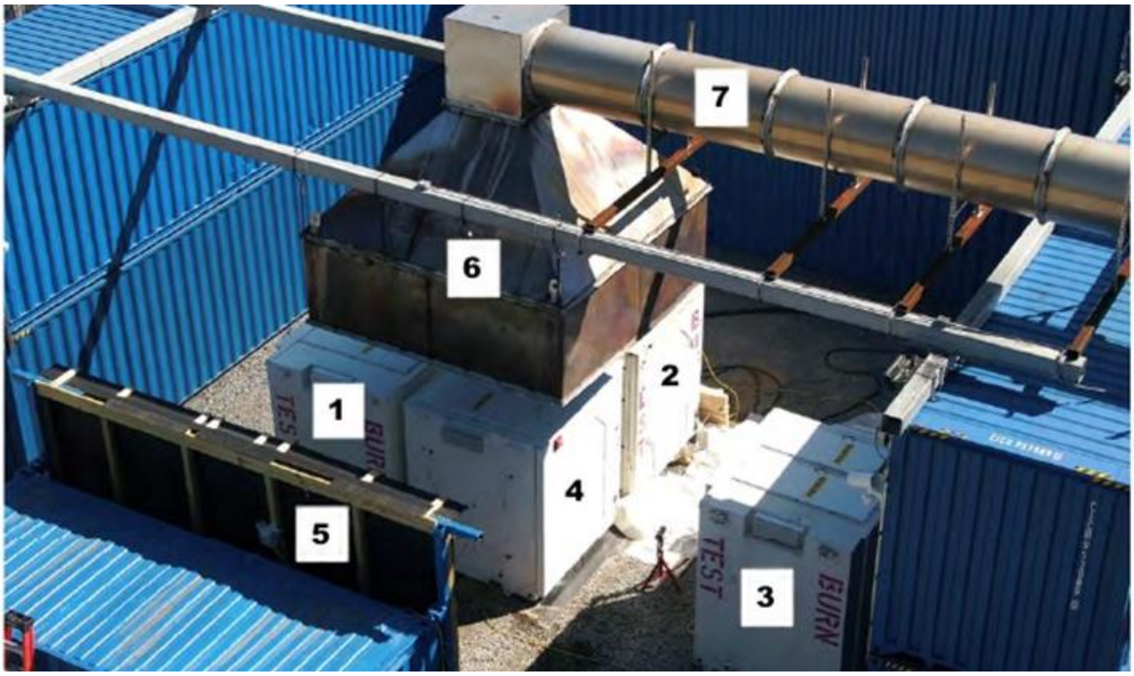


Figure 2-6: Diagram showing unit level test set-up (Ref 15)

Table 2-9: Unit tests: separation distances

Location	Distance (mm)	
	Required by manufacturer	Measured by testing company
A: Initiating Unit to Test Wall	3048	3048
B: Target Units 2 & 3 to Test Wall	3048	3048
C: Initiating Unit to Target Unit 3	2134	2146
D: Initiating Unit to Target Unit 1	178	191
E: Initiating Unit to Target Unit 2	178	175

Plate 3: Unit level test set-up: UL 9540A test (Ref 15)



Notes:	1. Target Unit 1	2. Target Unit 2	3. Target Unit 3	4. Initiating Unit	5. Target Wall
	6. Hood over Initiating Unit		7. Ductwork to scrubbers and CEMS		

Plate 4: Unit level test set-up: BDBT (Ref 10)

In Plate 4, the hood used to collect emitted gases for analysis using the continuous emission monitoring system (***CEMS***) can be seen lowered over the Initiating Cube. This equipment was not used during the UL 9540A test.

The Initiating Unit was fully populated with two racks of Envision prismatic lithium iron phosphate battery modules. Each rack shelf (eight per rack) housed a single module containing 52 cells with a nominal voltage rating of 166.4V per module and nominal capacity rating of 280Ah. The total energy capacity of the Initiating Unit was 745kWh. The test was conducted with the fire detection system active but with no fire suppression system.

The Initiating Unit was charged to maximum operating state of charge (***MOSOC***) 4 hours prior to the test. The voltage level of modules was measured to ensure that the test was conducted with MOSOC.

Figure 2-7 shows the positions of the initiating call within the initiating module (Cell 20) and the module (left-hand side rack, sixth module from the top). The interior thermocouple positions are also shown in the figure. Four thermocouples were also placed around the interior edge of the Initiating Unit door. Sets of four thermocouples were also placed on the five exterior surfaces (top, front, back, left side, right side) of the Initiating Unit: each set comprised of two drilled through high temperature thermocouples and two outside mounted thermocouples.

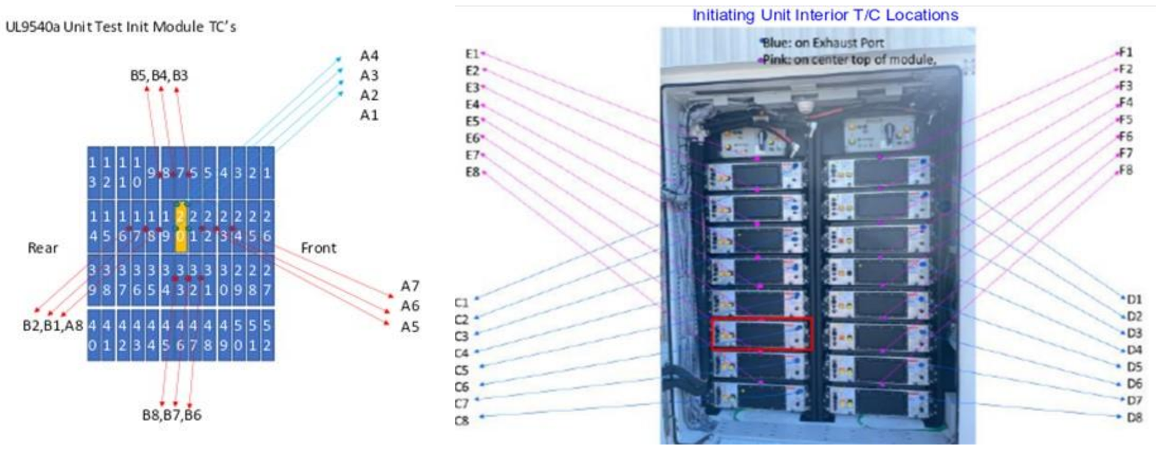


Figure 2-7: Test configuration showing locations of initiating cell, initiating module and interior thermocouples (Ref 15)

A portable probe positioned within the Initiating Unit enabled gases to be sampled from within the Cube and analysed by the CEMS (see Section 2.5.5).

A heat flux transducer was placed at the Target Wall facing the door of the Initiating Unit. This position was estimated to receive the greatest heat flux during potential propagation of thermal runaway within the Initiating BESS Unit. Three other heat flux transducers were placed at the Target Units facing the Initiating Unit, although these are not required for UL 9540A testing.

Due to logistical concerns (issues with supply), the Target Units used live alternate LFP modules to stand in for Envision modules. The alternate modules were liquid cooled in a similar fashion to those manufactured by Envision AESC and contained 280 Ah battery cells. The modules in the Target Units were charged to approximately 30% SOC (Ref 10).

In the test, temperature sensors were installed internally within the Target Units in locations close to the side of the of the Cube which faced the Initiating Unit, and on the Target Wall, across from the Initiating Unit.

The test was initiated using flexible film heaters to heat the initiating cell (Cell 20, see Figure 2-7) at a rate of 6°C/min until thermal runaway was induced. The test ran for a duration of 19 hours and 48 minutes.

Cell to cell thermal runaway was limited to three cells - one initiating cell (Cell 20) and two adjacent cells (Cells 19 and 21), one on each side of the initiating cell. The damage to the initiating module is shown in Plate 5. Plate 6 shows the interior of the Initiating Unit after the test. These images indicate that while there was significant damage to the module, the damage to the Cube was minimal.

Plate 5: Initiating module: after the test, lid removed

Plate 6: Initiating Unit: interior after the test

The temperature profiles recorded in the initiating and surrounding cells within the battery module are presented in Figure 2-8. The data show the initiating cell temperature peaks at approximately 750°C when thermal runaway initiated. Internal temperatures within the Initiating Unit, beyond the initiating module, remained below 60°C for the duration of the test. Initiating Unit external temperatures and Target Unit temperatures remain below 40°C. Temperatures measured at the Target Wall reached a peak of 45°C.

The maximum heat flux measured by the gauge positioned at the Target Wall opposite the Initiating Unit was 0.18 kW/m^2, this was within the UL 9540A required heat flux limit of

1.3 kW/m^2. This measurement also exceeded the maxima measured by the other heat flux gauges.

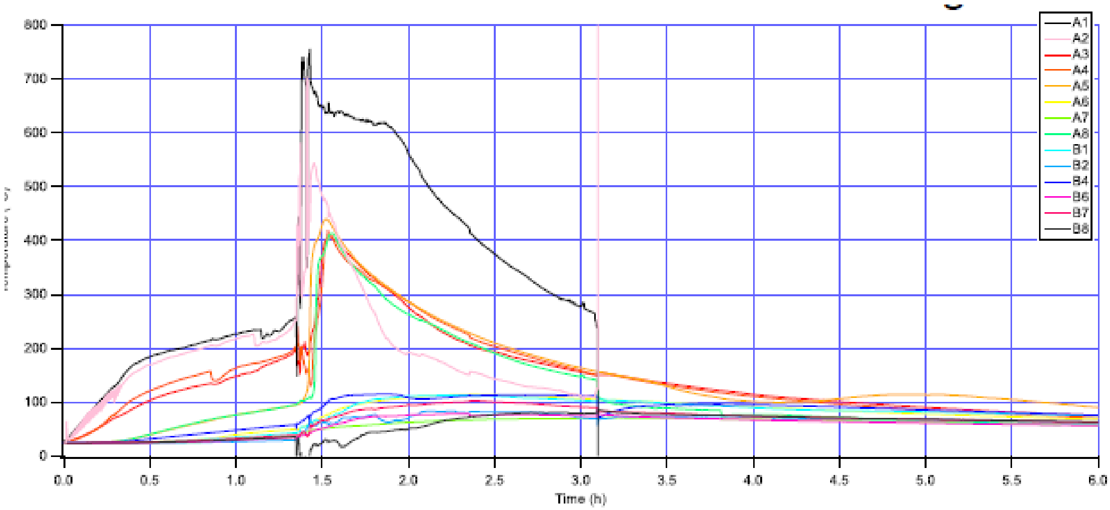


Figure 2-8: Temperature profile - initiating and surrounding cells within the initiating battery module (UL 9540A unit test, Ref 15)

Physical damage was limited to within the initiating module. No damage was observed outside of the Initiating Unit. The maximum temperatures measured on the surface of the target modules were below the temperature needed to induce cell venting. There was no evidence of external flaming or flying debris at the conclusion of the test.

The UL 9540A unit level test criteria was satisfied, and installation level testing was not required.

2.5.5 Beyond Design Basis test

This large-scale burn test was designed to evaluate the battery response to conditions that are more severe than the conditions required by UL 9540A unit level testing. The test was considered a beyond design basis test (***BDBT***) as it involved initiating thermal runaway in all 52 cells of a battery module within a BESS unit (Cube).

In common with the UL 9540A unit level test, the BDBT assessed the design of the Cube, external flaming, flying debris hazards, internal Cube and external wall temperatures, heat flux at the Target Wall, and reignition. The BDBT also measured heat flux levels experienced by the Target Units and monitored gas emissions from the Initiating Unit via the CEMS.

Testing was conducted with BMS, ESMS, fire protection system, and explosion protection systems disabled, and the protection provided by these systems was not evaluated during the testing.

The testing was undertaken on the Gen 6 Cube on behalf of Fluence by Safe Labs at their testing facility in Sanford, North Carolina, USA. The results of this testing are reported in the BDBT report (Ref 10).

The BDBT followed the UL9540A Unit-level test and was performed at the same facility two days later, using the same test setup (see Figure 2-6 and Plate 4). The test configuration, components and sensor set-up were the same as those used for the UL 9540A Unit level test except for the following:

- During the BDBT, a stainless-steel hood was positioned over the Initiating Unit to capture evolved gases (to be analysed by the CEMS)
- The initiating heaters were different. Instead of heating a single cell, four stainless-steel strip heaters were used to produce nearly simultaneous thermal runaway of multiple cells within the initiating module
- The module that was partially damaged in the UL 9450A unit level test (i.e. the initiating module for that test) was replaced and the replacement module charged to 100% SOC to match the SOC of the other 15 modules in the Initiating Cube. The position of the Initiating module remained unchanged between the two tests (left hand rack, sixth from the top; see Figure 2-7).

After the Initiating module was reinstalled, the liquid cooling system was filled using a mixture of ethylene glycol and water (50:50) according to installation instructions. Although the cooling system was filled, the chillers and pump were not energised or operating during the test.

The Initiating Unit bus bars were connected to the adjacent Target Unit bus bars using flexible jumpers. The DCPMs at the top of the two racks in each of the four units were left open so the unit bus bars were not energised.

Instrumentation

The following instrumentation and data acquisition equipment was used during the BDBT:

Weather station: to monitor environmental conditions

Continuous Monitoring Emission System (CEMS): to measure various gases evolved during the burn test and comprising Fourier-Transform Infrared Spectrometer (FTIR); High Temperature Flame Ionization Detector (HFID); Oxygen detector; Gas Chromatograph with Thermal Conductivity Detector (GC-TCD); Gas Chromatograph with Mass Spectrometer (GC-MS), and smoke obscuration measurement.

The CEMS was set up to monitor gases sampled from inside the Initiating Unit (obtained using a portable probe) and from the duct connected to the hood positioned over the Initiating Unit.

Heat flux transducers: to measure the heat flux in various locations in the test area. Two water-cooled heat flux transducers were placed between the Target Units 1 and 2 and the Initiating unit, at the initiating module elevation. Two additional non-water-cooled heat flux transducers were installed inside of Target Units 2 and 3, on battery modules expected to receive the highest heat exposure. Two more water-cooled transducers were installed on the Target Wall and in the aisle between the Initiating Unit and the Target Unit 3. These heat flux locations are shown in Figure 2-9.

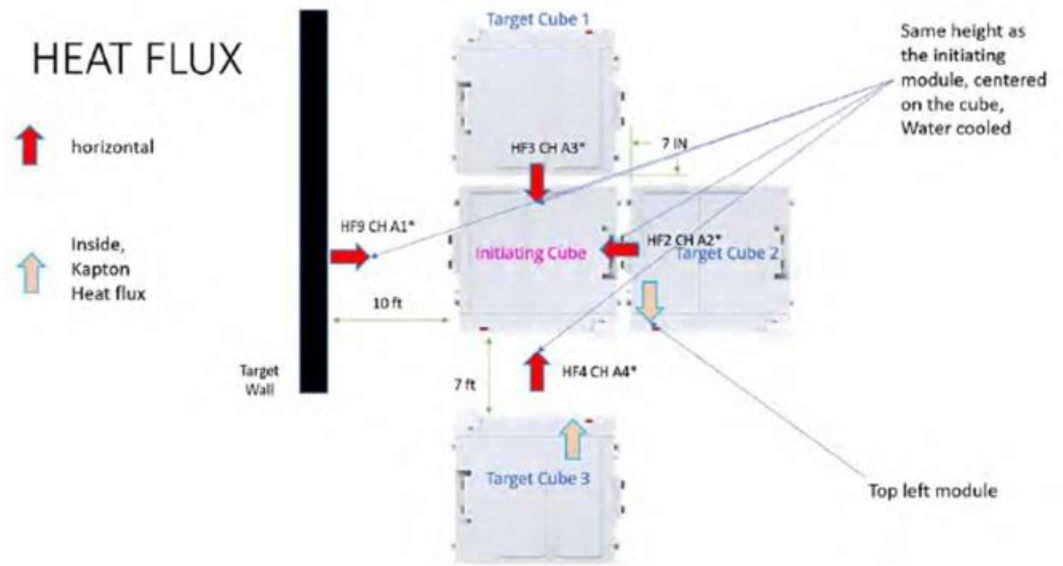


Figure 2-9: Heat flux transducer locations

Thermocouples: a total of 132 type K thermocouples were used to monitor temperature throughout the test, including but not limited to locations that complied with the UL 9540A unit level test. Thermocouples were installed as follows:

- Initiating module cells in the positions shown in Figure 2-7 and on each of the four heaters used to induce thermal runaway
- Initiating Unit in the internal positions shown in Figure 2-7. Four thermocouples were also placed around the interior edge of the Initiating Unit door. Sets of four thermocouples were also placed on the five exterior surfaces (top, front, back, left side, right side) of the unit: each set comprised of two drilled through high temperature thermocouples and two outside mounted thermocouples
- Target Wall in the positions shown in Figure 2-10
- Target Units in the internal positions shown in Figure 2-11 to Figure 2-13. Four thermocouples were positioned externally on all Target Units on the side nearest the Initiating Unit. A further eight thermocouples were positioned externally on Target Unit 2 on the front edges (Ref 15).

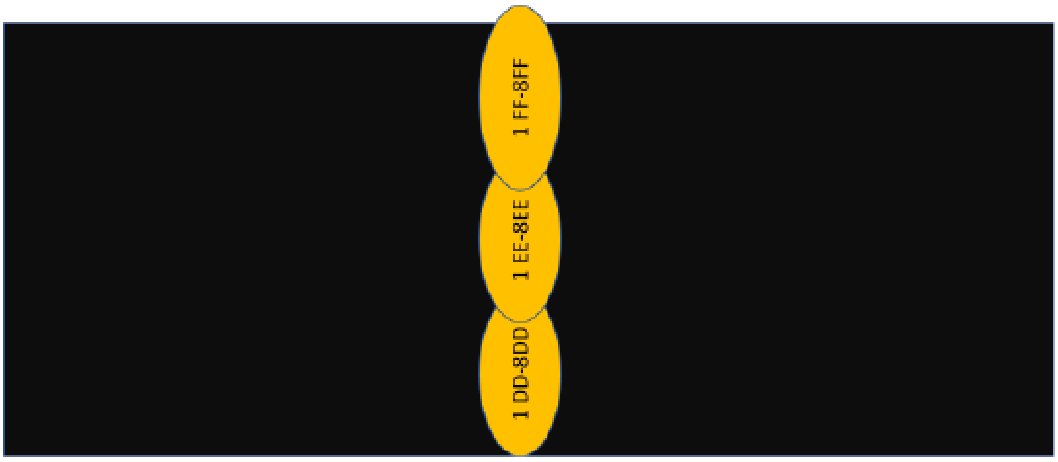


Figure 2-10: Target Wall: thermocouple positions

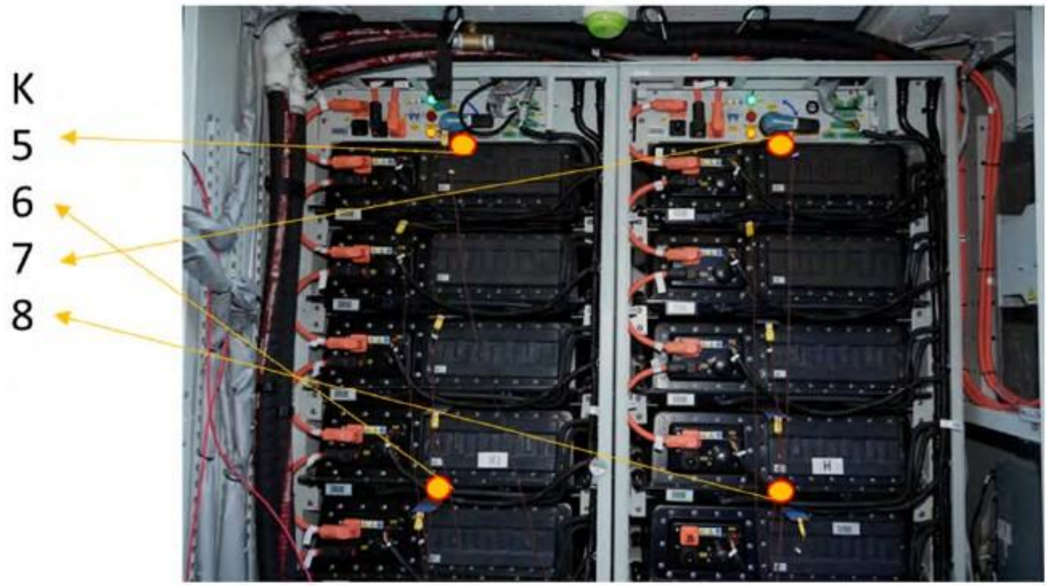


Figure 2-11: Target Unit 1: thermocouple positions

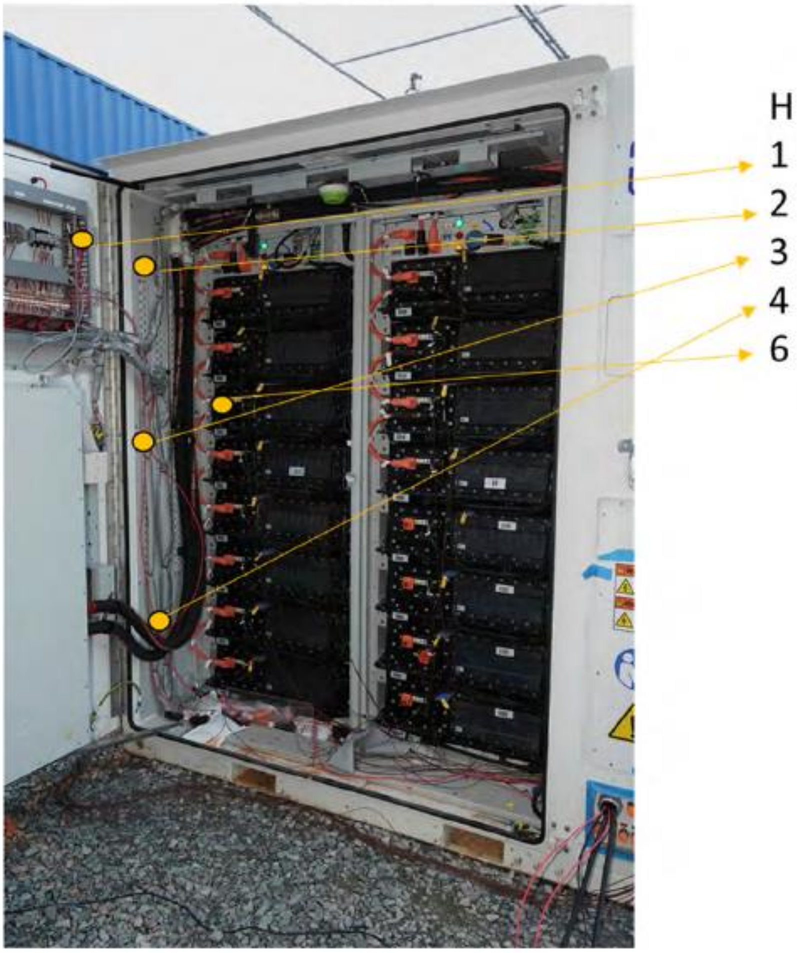


Figure 2-12: Target Unit 2: thermocouple positions

Figure 2-13: Target Unit 3: thermocouple positions

Video cameras: 10 video cameras were used during the test. Five red, green, blue (RGB) cameras were placed around the test area, directed towards the Initiating and Target Units. Two additional RGB cameras were placed inside of the Initiating Unit. One RGB camera was placed in a Target Unit. Two thermal imaging cameras were placed outside the Initiating Unit and directed towards it. This provided real-time thermal imaging of the Initiating Unit. The camera positions are shown in Figure 2-14.

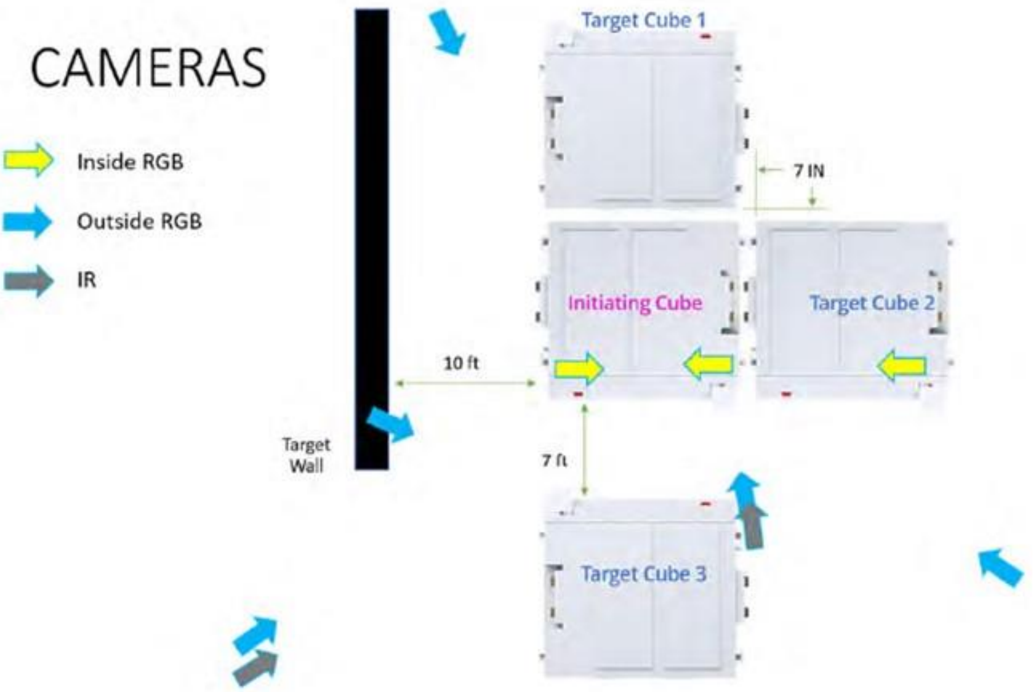


Figure 2-14: Video camera locations

Heater voltage and current: Once the heaters were energised, their voltage and current were measured continuously until the heaters were damaged beyond use and disconnected.

Initiating method

Four 2.25kW strip heaters (9kW combined) were used to initiate thermal runaway of multiple cells inside the initiating module, mounted inside the module on either side, between the outer row of cells and the module side wall. The heaters were in contact with both the outer row of cells and the aluminium wall. The heaters on each side (comprising two heaters connected in parallel) were controlled separately. At the start of the test, the controllers were set to ramp the temperature at a rate of 4°C/min until either the heater overcurrent protection opened, or the temperature reached 600°C. Once thermal runaway was confirmed, the heaters were disconnected.

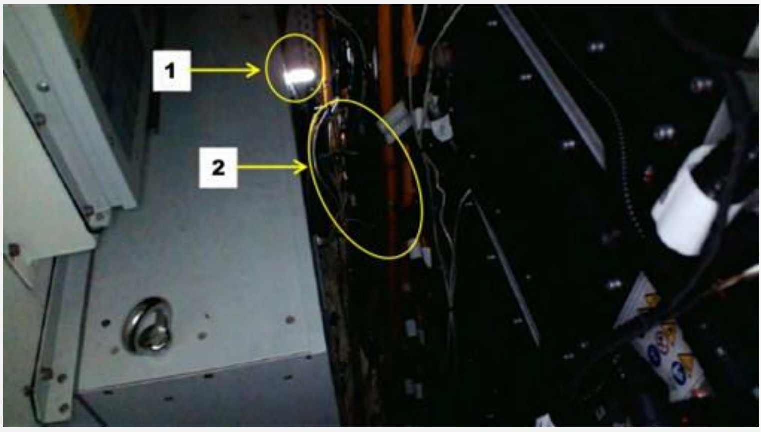
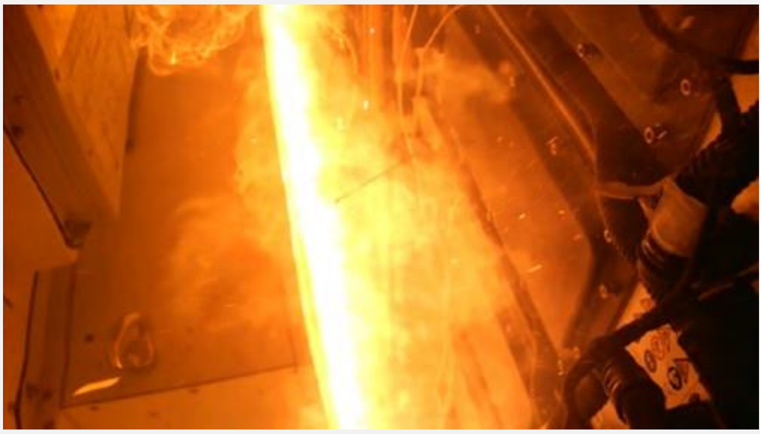
Test data

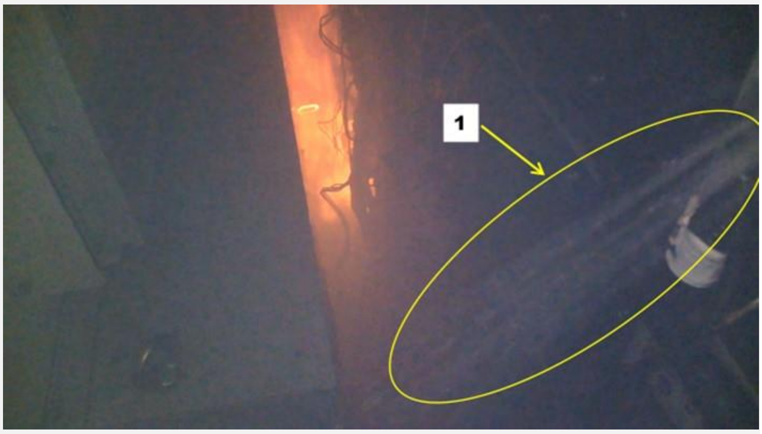
Summary: The test was started at 10.21 am (0:00). The first cells in the initiating module entered thermal runaway approximately two hours after the start of the test. While all cells within this module eventually entered thermal runaway, there was no evidence of propagation to cells in other modules within the Initiating Unit. Observable events lasted for approximately six hours, after which the temperatures slowly returned to ambient and the gas concentration inside the cube slowly progressed towards normal.

Note: During the test, gases were emitted from the cable penetrations used in connecting data acquisition equipment placed inside the Initiating Cube. These penetrations would normally be sealed during field installation however, off gases could also be emitted through the meshed area on the Cube door if an internal fire were to occur during normal operation.

Weather: At the start of the test, the outdoor temperature was 65°F (18°C) with 35% relative humidity (RH) and a 7 mph (3 m/s) wind speed. Wind gusts were below 12 mph (5 m/s) during the beginning of the test and less than 2 mph (1 m/s) by early afternoon.

Timeline:

Time	Event	Image
0:00	Heaters turned on 1. light from internal camera 2. initiating module	
1:53	First cell experiences thermal runaway: inside the Initiating Unit, the temperature rises rapidly, and flames are visible. The flames self-extinguish within one minute	

Time	Event	Image
1:53	Coolant lines (marked as 1.) leaking within the Initiating Unit. Flames visible in background	
1:53	First signs of gas exiting Initiating Unit (marked as 1.)	
1:53	Internal cameras are obscured by smoke for the duration of the test	

<table>
<tr><th>Time</th><th>Event</th><th>Image</th></tr>
<tr><td rowspan="3">1:54
–
2:44</td><td rowspan="3">Eight episodes of gas escaping through cable penetrations observed. Durations are between 1 and 7 min.

(images chosen to show typical amounts)</td><td>

1:54 – duration = 3 min</td></tr>
<tr><td>

2:15 – duration = 7 min</td></tr>
<tr><td>

2:31 – duration = 1 min</td></tr>
<tr><td>2:48</td><td colspan="2">No more gases are visible exiting the Initiating Unit. Hydrogen levels inside the Cube measured at 13%</td></tr>
<tr><td>13:12</td><td colspan="2">Measured hydrogen levels inside the Cube are 7%</td></tr>
</table>

Temperature measurements: Temperature data was captured for 24 hours after the start of the test, but all temperatures showed cooling trends after the first few hours. No subsequent thermal events occurred after the first 6 hours of the test. The following figures which plot temperatures (°C) versus elapsed time from the start of the test (hours) show temperature profiles obtained in the following locations:

Initiating Module: Figure 2-15 shows the temperatures measured by the thermocouples placed inside the Initiating Module in proximity to the cells (data obtained from the two thermocouples used in the control of the heater temperatures are not shown). All thermocouples showed temperatures consistent with thermal runaway over a period of approximately one hour (Ref 10)

Initiating Unit: Figure 2-16 shows all temperatures measured inside the Initiating Unit, except those internal to the initiating module (see Figure 2-15). The thermocouples acquiring this data were located on the outside of the modules, in the centre of each module lid (see Figure 2-7 for thermocouple positions).

Target Units and Target Wall: Figure 2-17, Figure 2-18 and Figure 2-19 show the temperature data collected by the thermocouples in the Target Units. Figure 2-20 shows the temperature data collected by the thermocouples placed on the Target Wall.

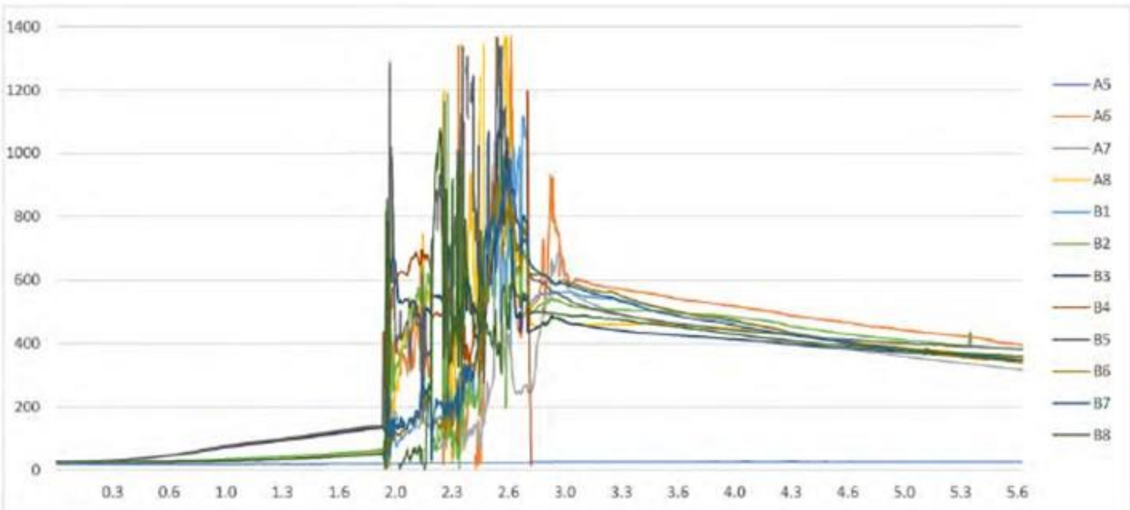
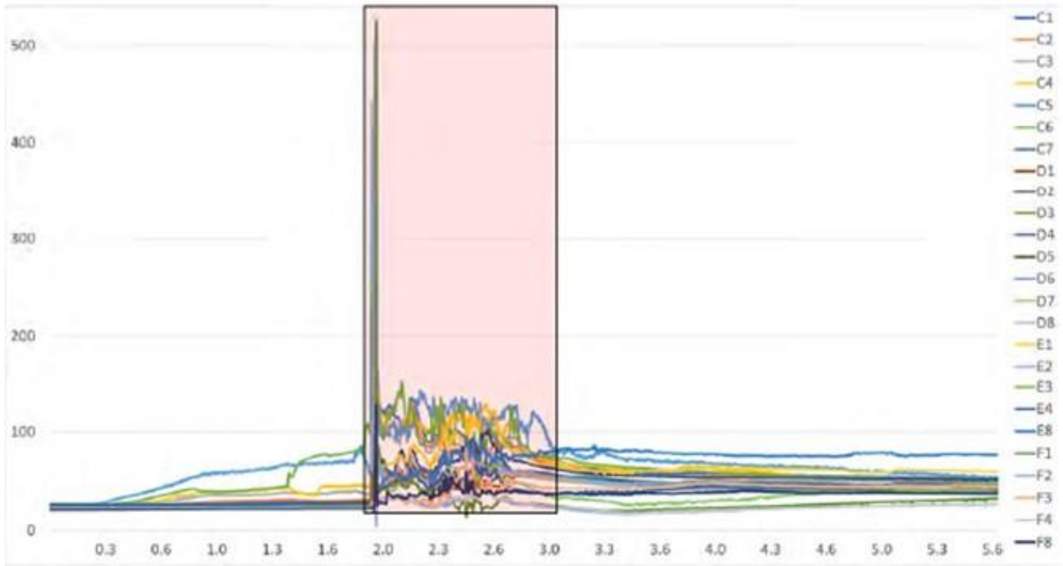


Figure 2-15: Initiating Module: internal temperature profiles during BDBT



Note: the red box shows the time during the test where gases were observed outside of the Initiating Unit (as described in the timeline above).

Figure 2-16: Initiating Unit: internal temperature profiles during BDBT

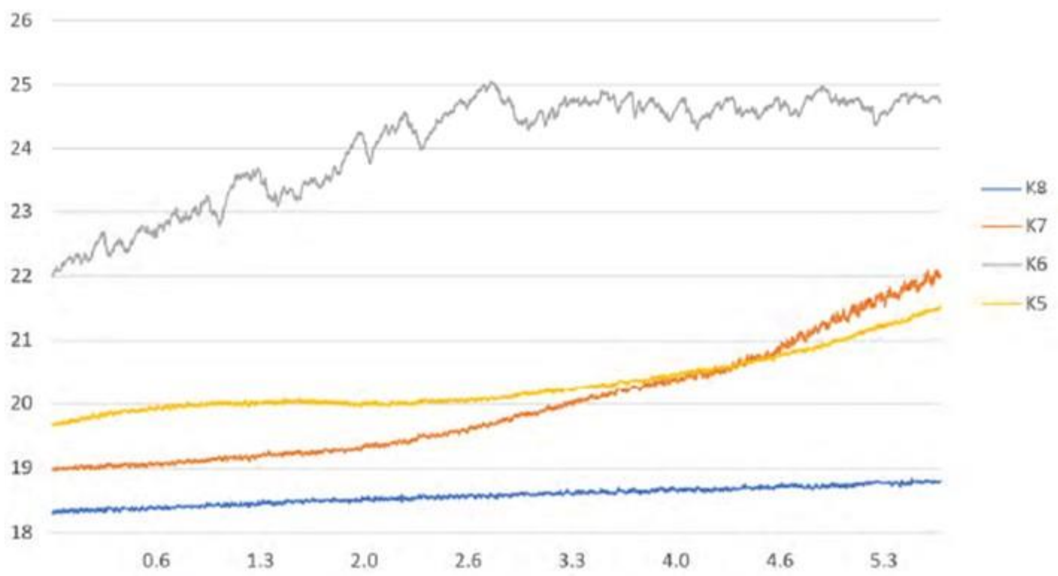


Figure 2-17: Target Unit 1: internal temperature profiles during BDBT

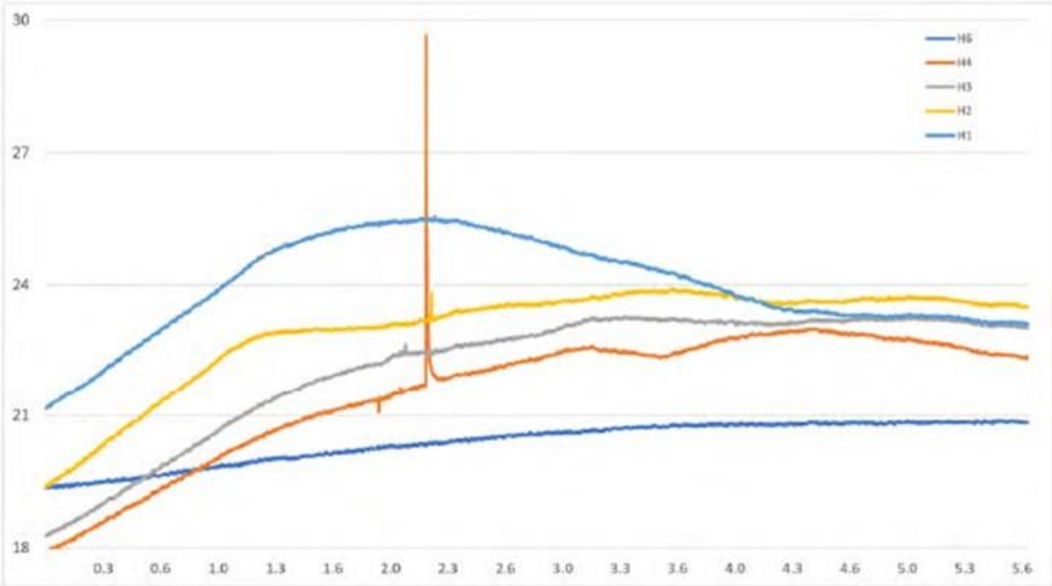


Figure 2-18: Target Unit 2: internal temperature profiles during BDBT

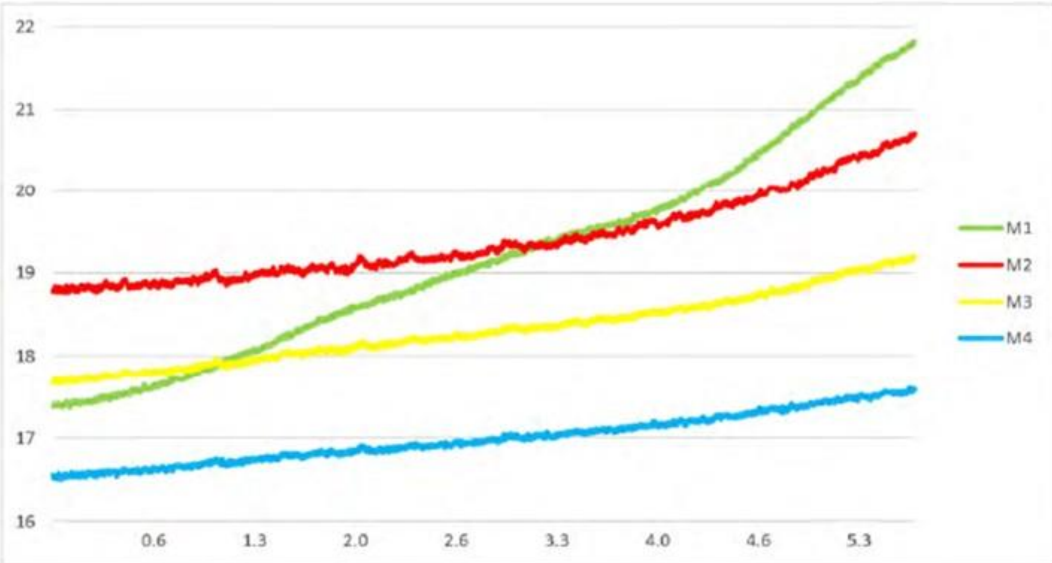


Figure 2-19: Target Unit 3: internal temperature profiles during BDBT

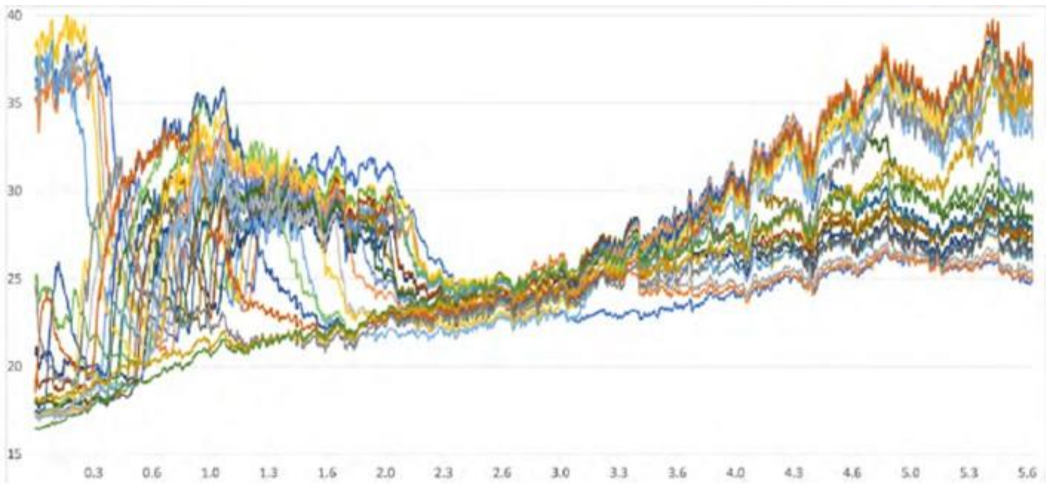


Figure 2-20: Target Wall: temperature profiles during BDBT

Heat flux: The heat flux data was affected more by the sunlight than the events taking place in the Initiating Unit. The heat flux profiles are shown in Figure 2-21. The data collected from the heat flux transducers showed the following:

- Target Unit 1 external transducer: indicated two brief rises at approximately the same time that visible flames were observed in the Initiating Unit. The magnitude was approximately 0.225 kW/m^2 higher than the heat flux due to direct sunlight
- Target Units 2 and 3 internal and external transducers: exhibited no elevated heat flux levels
- Target Wall transducer: exhibited no elevated heat flux levels beyond that associated with exposure to direct sunlight.

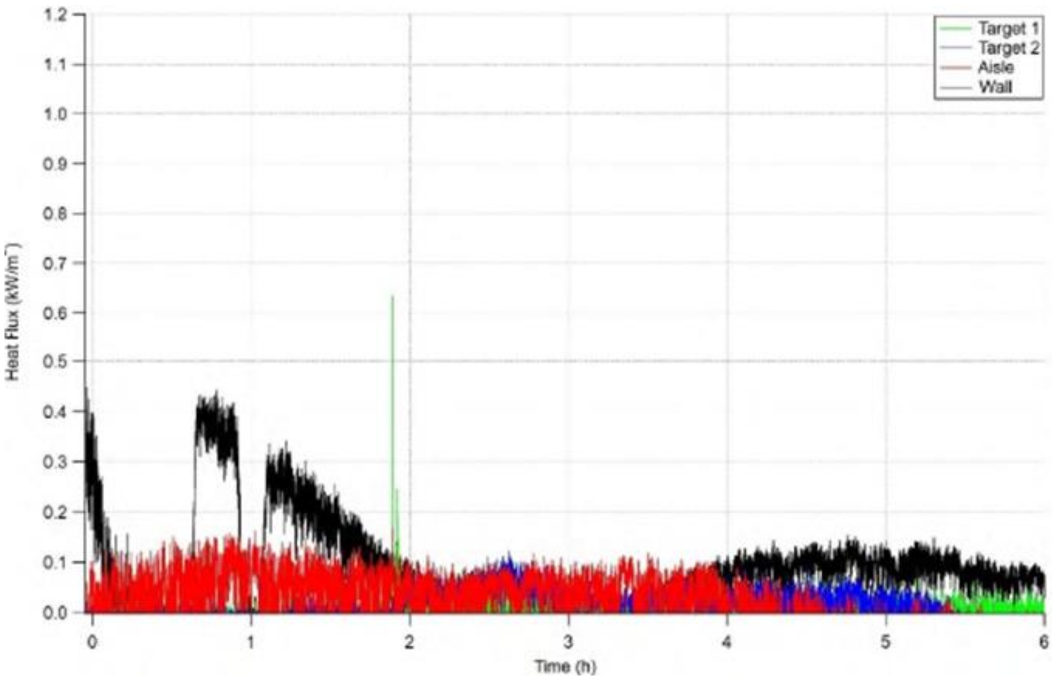


Figure 2-21: Heat flux data collected from external transducers during BDBT

CEMS: During testing, the location for gas analysis was switched between the interior of the Initiating Unit (Cube) and the duct connected to the hood positioned over this unit (Duct). The data collected from these two positions during the BDBT is summarised in Figure 2-23.

Gas composition profiles obtained in the first three hours of testing are shown in Figure 2-23 (Cube, first two hours) and Figure 2-24 (Duct, third hour). The graphs show gas concentrations (ppm) as a function of time.

Sampling started within the Cube and alkyl carbonate gases[8] were the first gases detected just before the first cells in the initiating module audibly vented. Approximately five minutes after that, flames ignited, and oxygen levels rapidly dropped to 5%. The flames were brief and self-extinguished in less than one minute. At this time, ethylene (C_2H_4), hydrogen fluoride (HF), hydrogen cyanide (HCN), acetylene (C_2H_2), phosphoryl fluoride (POF_3), carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), methanol (MeOH), and hydrogen (H_2) were detected inside the Cube in addition to alkyl carbonates as shown in Figure 2-23.

When the sampling point was switched to the Duct, approximately two hours after the start, alkyl carbonates, C_2H_4, CO_2, CO[9], CH_4 and H_2 were detected in concentrations lower

[8] Electrolytes used in lithium-ion batteries often contain alkyl carbonates and their detection is attributed to cell venting events (Ref 10).

[9] As much as 40 ppm of carbon monoxide was detected but this same amount of carbon monoxide was detected within the duct prior to the test when blank samples were collected (Ref 10).

than those in the Cube (Figure 2-24). Within an hour after the detection of flames in the Cube, the amounts of these gases in the Duct sample had decreased to negligible levels except for H_2 which continued to rise for several hours before decreasing, although remaining much less than the levels detected with the Cube.

Hydrogen levels in the Cube also remained high. After sampling from the Cube resumed, three hours after the start of the test and one hour after flame detection, the H_2 level had climbed to above 13%. Levels of the other gases remained high but less than those measured earlier. Four hours after the start of the test, all gases were found to be decreasing within the Cube although the H_2 concentration did not fall below 4% (LFL) until almost 25 hours after the start of the test (almost 23 hours after flame detection).

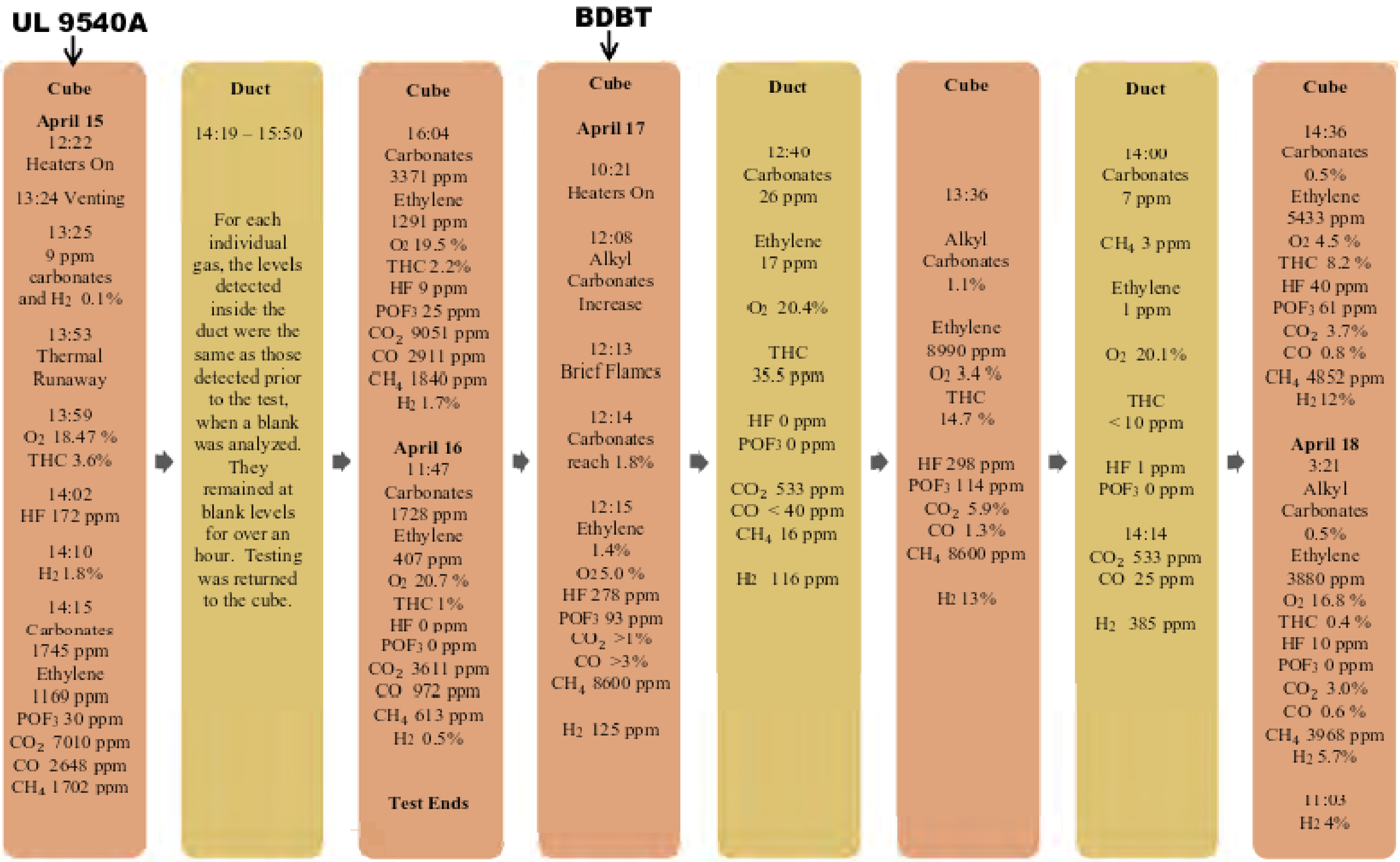


Figure 2-22: Summary of gas analysis results: UL 9540A unit level test and BDBT

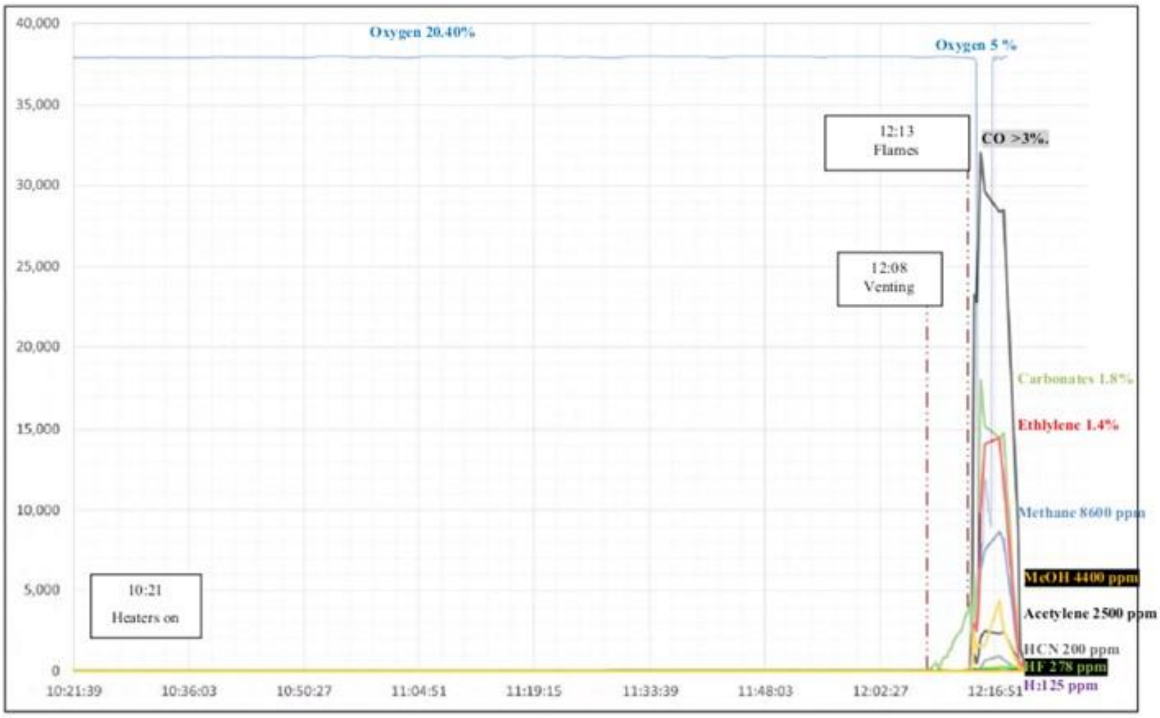


Figure 2-23: Gas analysis within Initiating Unit (Cube): BDBT (first two hours of testing)

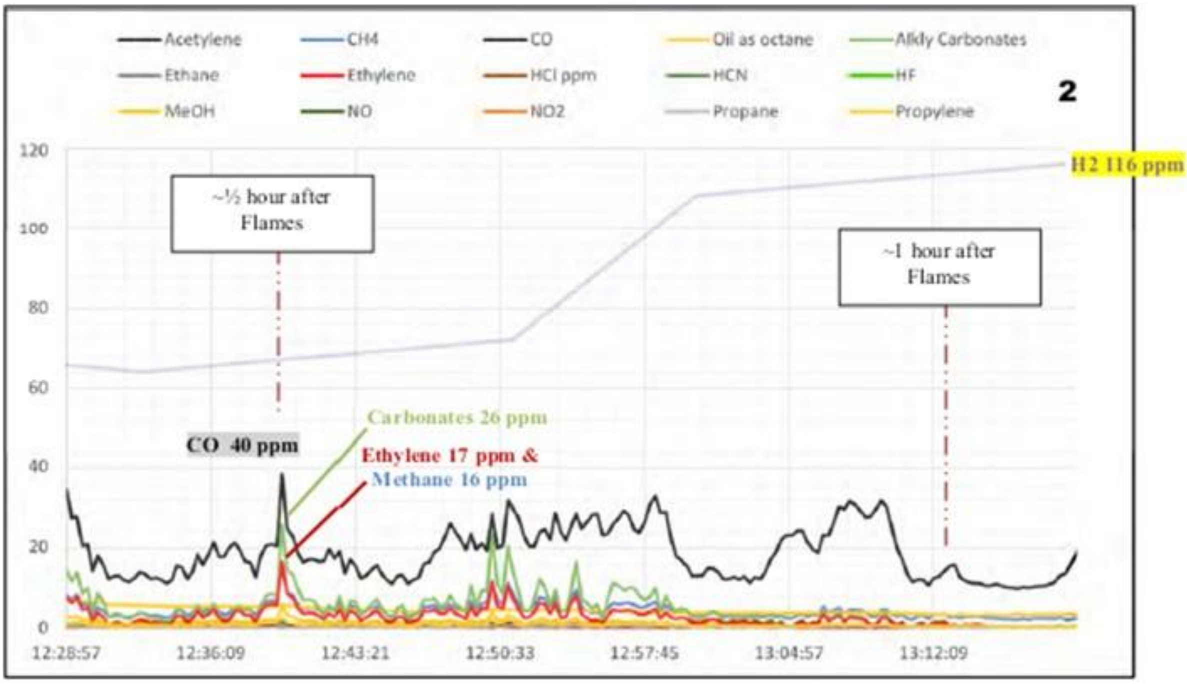


Figure 2-24: Gas analysis within Duct: BDBT (third hour of testing)

Damage

Due to the combination of electrical energy and elevated hydrogen and hydrocarbons measured within the Initiating Unit, it was allowed to sit undisturbed for 8 days. The unit was then allowed to ventilate for several hours. No thermal or electrical events occurred while opening the door or after the door was open.

From the outside, there was no significant damage to the Initiating Unit or the Target Units as shown in Plate 7. The most notable exception was the soot staining on the fire blanket in front of the Initiating Unit. This occurred as smoke and gases vented from the Initiating Unit through the cable penetrations.

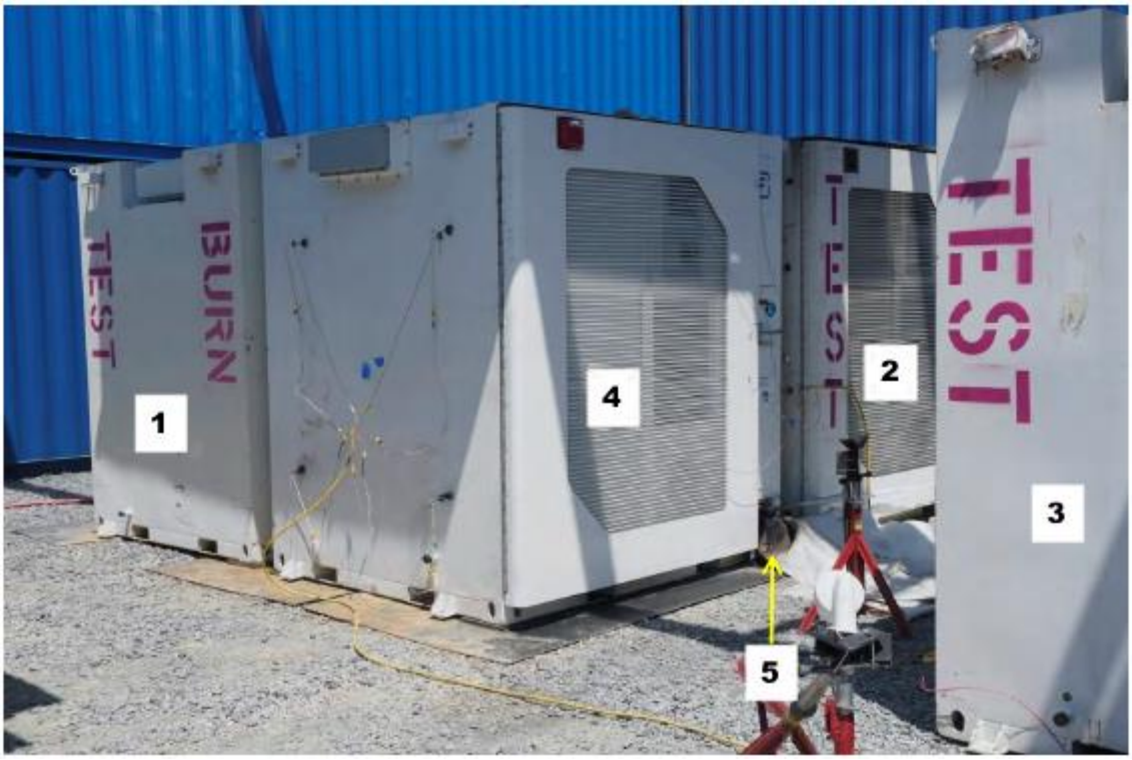


Plate 7: Initiating and Target Units after the BDBT

As shown in Plate 8, inside the Initiating Unit there was heat and smoke damage throughout the Cube, which was much greater than that sustained during UL 9540A unit level testing. The damage was greatest at and near the Initiating Module, as shown in Plate 9. Even in this area, module housings remained mostly intact.

Plate 8: Inside the Initiating Unit after the BBDT

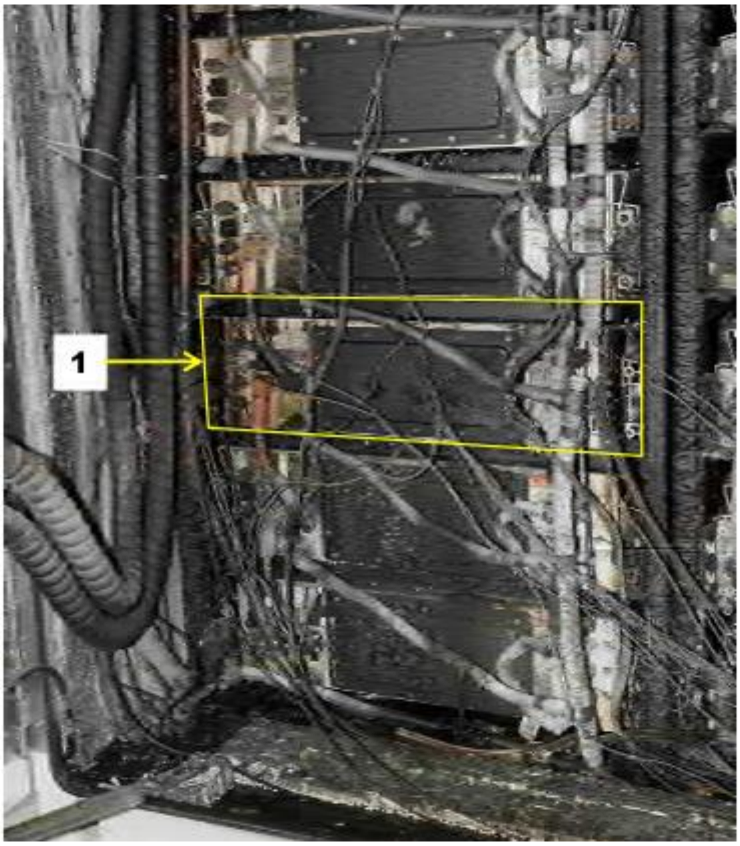


Plate 9: Damage to Initiating Module (1) and surrounding areas

After the Initiating Unit door was opened, the module voltages were recorded. All but the initiating module still had near 100% SOC open circuit voltages. The initiating module voltage was zero. The cells in all modules except those in the module directly above the initiating module were still isolated from the equipment ground. Despite the loss of isolation in this module, none of the cells experienced thermal runaway.

Conclusions

While all 52 cells within the initiating module experienced thermal runaway, there was no evidence of module-to-module propagation within the Initiating Unit. There was also no evidence of deflagration or detonation within the Initiating Unit.

There was no propagation between the Initiating Unit and the Target Units.

2.5.6 Previous large-scale test on Fluence Cubes (Bespoke Burn test)

A previous large-scale fire test, referred to here as the *Bespoke Burn test*, was conducted by DNV Energy in September 2022, and involved the same Cube (Fluence Gen 6) but set up with CATL-LC battery modules rather than the Envision AESC modules which will be installed at the Liddell BESS). The scope of work, assumptions and limitations, test approach, methodology, results, conclusions, and recommendations are documented in the report produced by DNV (Ref 16) and summarised in the FSS for the Broken Hill BESS (Ref 17).

The test used the same layout configuration as the BDBT, with one Initiation Cube and three Target cubes physically spaced in to the same separation distances. In common with the BDBT, the active fire suppression systems in the Cubes were disabled during testing.

The test used electrical heaters to trigger all 52 cells of a single CATL module into thermal runaway. While the BDBT used strip heaters to heat the module, in this test ceramic furnace heaters with a combined power output of 11.4kW (approximately 25% higher than the output of the heaters in the BDBT) were used. A heat up ramp rate of 5°C/min was used compared to the 4°C/min used in the BDBT. The heaters were shut off approximately one and a half hours into the test when smoke was observed emanating from the Cube door, then switched on again approximately half an hour later but with the ramp controls bypassed.

The test progressed very slowly, with smoke emitting from the initiation Cube after 4 hours and an external fire igniting after about 6.5 hours, which burned for another 6.5 hours. During this test, smoke and fire evolved from the front door of the Initiating Cube, specifically from the air conditioning and chiller openings and around the right-side seal of the door, and eventually spread to the deflagration panel and the busbar opening on the top of the Initiation Cube.

As shown in Figure 2-25, episodes of wind during the Bespoke Burn test caused the fire to tilt towards the adjacent Target Cube on the right-side of the Initiation Cube, resulting in flame impingement on this Cube, and damaging the left front corner as shown in Figure 2-26. The fire also burnt in the gap between the Initiation Cube and this Target Cube. This was the most severe damage sustained by any of the Target Cubes.

Figure 2-25: Flames tilting across the directly adjacent Cube due to wind in the Bespoke Burn test

Figure 2-26: Damage sustained to Cubes in the Bespoke Burn test

Throughout the test, the measured module temperatures inside all three Target Cubes remained well below the temperatures that could cause cell venting or thermal runaway and there was no physical evidence of propagation between the Initiation Cube and any of the Target Cubes.

The testers concluded that:

- The testing demonstrated that the Fluence Cube design can prevent propagation of thermal runaway to adjacent Cubes
- All temperatures observed near battery modules and cells in the adjacent Target Cubes stayed well below critical temperatures
- No firefighting was necessary to cool down the adjacent Cubes to prevent Cube-to-Cube propagation.

2.5.7 Implications for fire scenario modelling

Given the similarities in testing methodology between this Bespoke Burn test and the BDBT, the reasons for the difference in the results (with the Initiating Cube remaining intact in the BDBT and flames emanating from the enclosure in the Bespoke Burn test) are unclear. There are some differences between the tests, in particular the different modules used (CATL in the Bespoke Burn test and Envision AESC in the BDBT) and the heating device power outputs and heating rates, but there is insufficient evidence to draw a firm conclusion about the effects of these differences. Therefore, to ensure that a worst-case credible fire scenario is considered in the modelling of Cube fire (see Section 4.1), two scenarios are considered in this FSS:

- Despite a fire within the Cube, the enclosure remains intact (in line with the results of the BDBT) so that adjacent receptors may be exposed to heat from the surface of the enclosure but not to flame impingement
- The Cube is breached during the fire (in line with the results of the Bespoke Burn test) so that adjacent receptors may be exposed to heat from the surface of the enclosure and the emanating flames and potentially to direct flame impingement.

3 FIRE HAZARD IDENTIFICATION AND CONTROLS

3.1 INPUT INFORMATION AND METHODOLOGY

The hazard identification in the FSS is based on a desk-top review of National and International information and research covering BESS facilities. The following factors were considered:

- External factors and neighbouring land use (refer to Section 2)
- Project infrastructure, location, workforce, and Project specific information received from the battery OEM suppliers, Fluence (refer to Section 2)
- Proposed operation and maintenance activities and potential threats including materials and energies (refer to Sections 2 and 3.2)
- Known events that have occurred elsewhere
- Liaison with relevant NSW Government Agencies
- Review of Standards and Codes of practice, including relevant Australian Standards and NFPA Codes for BESS (Section 8)
- Review of research report into Li-ion battery safety, including the program conducted by DNV on behalf of the New York State Energy Research & Development Authority (NYSERDA) and Consolidated Edison (Ref 18), the large-scale battery tests conducted by FM Global (Ref 19) and the research by the Victoria University in conjunction with the Maritime Division, Defence Science & Technology Group (Ref 20)
- Review of publicly available information of BESS incidents and accidents.

3.2 POTENTIALLY HAZARDOUS MATERIALS

The potentially hazardous material and Dangerous Goods (***DGs***) storage associated with the BESS is summarised in Table 3-1, and the potentially hazardous properties are detailed in Table 3-2. None of the materials are listed in Schedule 15 of the Work, Health and Safety Regulations.

Table 3-1: Storage of Dangerous Goods and other potentially hazardous material

Hazardous material	DG Class and Category	UN number	HAZCHEM Code	Quantities
Lithium ion (Li-ion) batteries Contain: - Li-ion phosphate - Li hexafluoro phosphate	DG Class 9 Miscellaneous dangerous goods	3480	2Y	Total 3034-3468 tonnes of LFP on the BESS distributed in a number of separated locations: 1.96-2.24 tonnes of LFP per Cube The Li-ion cells use lithium iron phosphate ($LiFePO_4$) as the cathode material and include a volatile hydrocarbon-based liquid and dissolved lithium salt (which is a source of lithium ions), such as lithium hexafluorophosphate. Each battery module weighs 350kg and contains 35-40% LFP There are eight (8) battery modules in a rack and Cubes contain two racks. There are 1548 Cubes across the BESS.
Transformer oil - BESS Core transformer - BESS auxiliary transformer - Substation transformers	Combustible liquid C1 (AS 1940:2017 amendment 2:2021)	N/A	N/A	Total 464 kL combustible oil distributed in a number of separated locations: (a) Total BESS: 3825 L per unit 329 kL total (86 units) 1400 L per unit 2.8 kL total (2 units) (b) Total Liddell BESS Substation: - 66kL per unit 132 kL total (2 units)
Coolant: 50:50 mix of water and ethylene glycol	Pure ethylene glycol is a Combustible liquid Water/ethylene glycol mixture is not combustible	N/A	N/A	Total 116kL coolant across the BESS distributed in a number of separated locations (75L per 1548 Cubes)

Hazardous material	DG Class and Category	UN number	HAZCHEM Code	Quantities
Chiller: R-140A[10]	DG2.2	2857[11]	2TE	Total 3,785kg refrigerant gases across the BESS distributed in a number of separated locations (2.4kg per 1548 Cubes, Ref 11)
HVAC: R-134A[12]	DG2.2	3159	2TE	Total 340kg refrigerant gases across the BESS distributed in a number of separated locations (0.22g per 1548 Cubes, Ref 11).
Fire suppression unit: Potassium nitrate (75% w/w)	DG Class 5.1	3268[13] 1486		Each Cube is fitted with a thermally activated fire suppression cannister containing solid potassium nitrate in blended form. Total 1,548kg KNO_3 across the BESS distributed in a number of separated locations (Charge weight per cannister = 1kg)
Li-ion batteries contain graphite, lithium-ion phosphate, lithium hexafluorophosphate, carbonates (di-ethyl, di-methyl, ethyl-methyl, propylene, ethylene), acetylene, hexafluoro propylene- vinylidene fluoride copolymer (Ref 11)				

[10] R-140A refrigerant is a mixture of difluoromethane, pentafluoro-ethane (UN 3163)

[11] Refrigerating machine

[12] R-134A refrigerant is 1,1,1,2 tetrafluoro-ethane (UN 3159)

[13] Safety device

Table 3-2: Summary of main materials hazards

Material	Description and potential hazards
Li-ion batteries and electrolyte	Li-ion batteries are stable under normal conditions and do not exhaust vapours. The cell electrolyte is largely absorbed in the electrodes such that there is no free or spillable electrolyte. Persons handling a Li-ion battery on a day-to-day basis should not be exposed to any hazardous vapours, gases or harmful electrolyte. In case of severe mechanical damage (e.g., severe crushing) some electrolyte may leak out of the affected battery cells but is expected to evaporate rapidly (Ref 21). Batteries may fail in a thermal runaway reaction[14] if exposed to damaging conditions, at which point they may generate combustible gases and other hazardous compounds. In an enclosed or localised area, these gases may accumulate, causing pressure damage, and, if ignited, they can explode, causing severe equipment damage. Exposure to the consequences from a battery fire or explosion may lead to injury or death. Human exposure to hazardous voltage or arc-flash at the battery is also possible, resulting in injury.
Coolant	The coolant is a mixture of ethylene glycol and water (50:50). Pure ethylene glycol is a combustible liquid (Ref 22) but water-glycol mixtures at this concentration is generally not regarded as combustible – however, the SDS specifies that the material will burn although it is not easily ignited. Should water be driven off in a fire situation, combustible ethylene glycol would participate in the fire by adding to the fire load. Combustion products are a complex mixture of airborne solids, liquids, and gases including carbon monoxide, carbon dioxide, and unidentified organic compounds will be evolved when this material undergoes combustion. Combustion may form oxides of potassium.
Refrigerant	Two refrigerants are used within the Cube: R-140A (a mixture of difluoro-methane and pentafluoro-ethane) is used in the rack chilling system and R-134A (1,1,1,2 tetrafluoro-ethane) is used in the Cube climate control (HVAC) system. These refrigerants are held as compressed gases under pressure. The refrigerant unit may explode if heated. Contact with compressed gases may cause frost bite. Exposure is harmful (all routes).
Oil	Oil is used and handled at the transformers and insulating oils. If a spill of oil reaches surface water, petroleum products can kill aquatic wildlife.
Fire suppression agent: Potassium nitrate (KNO_3)	Potassium nitrate is a white, odourless crystalline solid which is chemically stable under normal conditions. It is an oxidising agent and undergoes violent to explosive reaction with many compounds including organic and/or combustible materials, some metals and their compounds and with (strong) reducing agents. It decomposes on exposure to heat releasing oxygen. It is a skin, eye and respiratory irritant.

[14] Runaway reaction in a Li-ion battery cell, should it occur, can result in the generation of excessive heat inside or outside the cell which keeps on generating more and more heat. The chemical reactions inside the cell in turn generate additional heat until there are no reactive agents left in the cell.

Material	Description and potential hazards
	To produce the fire suppression agent, potassium nitrate is blended with dicyandiamide (non-hazardous) and phenolic resin. The phenolic resin is a skin and eye irritant and may also cause respiratory irritation. The blended components are pressed into a highly stable moulded form. This is contained within a sealed, double-walled stainless steel cannister, minimising its hazard potential. The sealed fire suppression cannisters present no ecological hazards. Upon thermal activation, the chemicals are not discharged from the unit but are fully consumed by an internal chemical reaction. The fire suppression aerosol produced upon ignition has a very low global warming potential and no ozone depleting potential
Note: The materials listed above are the only DG / potentially hazardous materials to be stored on site, except for small amounts of materials for maintenance activities (e.g. solvents and thinners), which will be stored in approved DG cabinets. Adherence with relevant Australian Standards is generally sufficient to manage the fire risk associated with small amounts of potentially hazardous chemicals stored in DG cabinets to SFAIRP levels and this FSS does not discuss these materials further.	

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3.3 FIRE HAZARDOUS SCENARIOS

An overview of the types of hazards associated with the BESS is provided in Table 3-3.

Table 3-3: Types of hazards associated with the BESS

Element	Hazard type							Refe-rence
	Electrical	Energy	Fire	Explosive	Chemical/ pollution	Toxic fume	EMF	
Fluence Cubes Li-ion batteries	✓	✓ Note 1	✓ Note 2	✓ Note 3	-	✓ Note 4	✓	AS 5139 / NFPA 855
Coolant	-	-	✓ Note 5	-	✓ Note 6	✓ Note 4	-	SDS
Chiller, HVAC				✓ Note 9				
Oil fires in inverters, transformers	-	✓ Note 1	✓ Note 7	-	✓ Note 6	✓ Note 4	✓	AS 1940
Electrical fires in transformers, inverters, switchgear, cabling	✓	✓ Note 1	✓ Note 2	-	-	✓ Note 4		
General fires in buildings			✓ Note 8			✓ Note 4		

Notes:

1. Arc flash incident potential including as an ignition source
2. Fire may be caused by overheating (incl. thermal runaway for batteries), vibration, shock, impact, external short circuit, overcharge, forced discharge due to internal or external cause
3. The battery cell / module fire may release hydrogen under fault conditions which is an explosive gas hazard (Ref 23)
4. A battery fire may evolve toxic combustion products including flammable hydrocarbons, carbon monoxide and toxic vapours of HCl, HF and HCN. A fire involving the coolant chemical and transformer oil may evolve toxic and corrosive fumes. A fire involving plastics and other combustible construction material e.g. in electrical cabling or building material/contents may evolve toxic combustion material
5. Ethylene glycol is a combustible liquid (Ref 22) and may be driven off in a fire increasing the fire load and heat radiation
6. Failure to contain a spill (coolant, transformer oil or any firefighting medium) has a potential to cause off-site pollution
7. Fire may be caused by vibration, shock, external short circuit (including due to lightning strike, impact etc.)
8. Fire in buildings may be caused by malfunction of electrical equipment or heaters, arson etc.
9. Fire or heat exposure to the refrigerant unit may cause it to disintegrate releasing overheated compressed (non-flammable) gases with ejection of material

The following fire hazardous events have been determined for the BESSs:

- *Fire or explosion at the Fluence Cube (battery enclosure):* A fire or explosion may occur within the Li-ion batteries which are located inside the battery enclosure in the BESS Facility. Potential precursors are overheating (including thermal runaway), vibration, shock, impact, external short circuit, overcharge, forced discharge (Ref 2).

  Overheating may be caused by:

  - by an upset condition within the battery module itself or from adjacent battery modules within the Fluence Cube (internal event)
  - from an external source such as a neighbouring Fluence Cube, a bushfire or fire in the general compound area (external event).

  Fire may generate damaging heat which may cause injury or propagation to adjacent infrastructure and the fire may generate toxic combustion products.

  The coolant used in the battery enclosures may, once the water has been driven off by the heat of the fire, participate in the fire by adding heat load and may evolve toxic combustion products.

- *Fire or arc flash at medium and high voltage equipment (transformers, inverters):* Fires involving combustible oil at the transformers can pose a serious fire hazard if not managed. Arc flash incidents may occur in electrical equipment including transformers and switchgear.

- *General fires, e.g. building fires:* Fire involving combustible construction material or plastics (e.g. associated with electrical cabling) may occur within the Control and Switch rooms, Operations and Maintenance building and Workshop and Storage building. There is also a potential for arc flash.

The details of the fire hazardous events above are provided in the *Hazard Identification Word Diagram* in Appendix 1, including causes, potential consequences (assuming all controls fail) and a summary of the preventative and mitigative controls to be included in the BESS.

In addition to the potential hazards listed above, mechanical hazards are associated with each of the BESS enclosures due to falling over / tripping / seismic, and lack of lifting or securing – such hazards are outside the scope of the FSS except as a potential precursor to a fire (as detailed Appendix 1) and are detailed in the PHA (Ref 2).

4 CONSEQUENCES OF FIRE

The potential fire incidents identified in Section 3 relate to the following:

- Fire involving a Cube, including generation of heat radiation, overpressure effects and toxic combustion products
- Fire involving medium and high voltage equipment, including heat radiation and overpressure effects from arc flash
- General fires in buildings including those housing electrical equipment and cabling.

The consequences of fire scenarios have been evaluated as follows:

- *Quantitatively* viz. heat radiation levels resulting from a battery fire
- *Qualitatively* viz. overpressure effects and toxic gas generation from a battery fire and arc flash
- *Qualitatively* viz. heat radiation from other infrastructure (e.g. transformer oil, low/medium/high voltage equipment and cabling) fires and arc flash.

The objectives of the consequences analysis are to:

- Identify and characterise the quantities and locations of hazardous chemicals and energies that could be released during a fire event within the BESS
- Conduct simple heat radiation calculations for a Cube (battery enclosure) fire to estimate the distances to the heat radiation endpoints for a representative fire scenario within the BESS
- Evaluate hazards associated with toxic fire plume and explosion overpressure from a Cube fire
- Evaluate hazards associated with heat radiation from a fire involving other infrastructure within the facility
- Determine potential impacts and safety risks at the nearest sensitive receptors
- Provide information to teams working within the BESS and the Liddell BESS Substation, and to emergency response teams to allow for an estimate of the potential for impact on people and the surrounding community.

The thermal (heat) radiation, overpressure and toxic endpoints can be predicted based on the types and quantities of flammable and toxic materials involved or generated in a fire, with the effects associated with a range of exposure levels as presented in Table 4-1.

In this FSS, the distances to the listed thermal radiation levels associated with a Cube fire are quantified; all other effects are discussed qualitatively.

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Risk Management Consulting

Table 4-1: Hazardous endpoints assessed in this Fire Safety Study

Heat radiation	Potential effect (actual effect depends on duration of exposure)			Reference
23 kW/m^2	Potential propagation to non-combustible material. Likely fatality for extended exposure and chance of fatality for instantaneous exposure			HIPAP4 (Ref 24)
12.5 kW/m^2	Potential propagation to combustible material. Significant chance of fatality for extended exposure. High chance of injury			
4.7 kW/m^2	Injury may occur if a person is exposed. Will cause pain in 15-20 seconds and injury after 30 seconds' exposure			
Overpressure	**Potential effect**			**Reference**
21 kPa	Reinforced structures distort, storage tanks fail. 20% chance of fatality to person in building			HIPAP4 (Ref 24)
14 kPa	Houses uninhabitable and badly cracked			
7 kPa	Damage to internal partitions & joinery. 10% probability of injury, no fatality			
Toxic exposure to material[15]	**Acute Exposure Guideline Level (AEGL) – 60 minute exposure, in ppm Potential effect (actual effect depends on duration of exposure)**			**Reference**
	AEGL 1	**AEGL 2**	**AEGL 3**	
HBr	1	40	120	ALOHA (Ref 23), ACC (Ref 25), US EPA (Ref 26)
HCl	1.8	22	100	
HF / POF_3 [16]	1	25	44	
HCN	2	7.1	15	
CO	N/A	83	330	
EO	N/A	45	200	
Formaldehyde	0.9	14	56	
NH_3	30	160	1100	
NO_x as NO_2	0.5	12	20	
	Notable discomfort, irritation etc.; not disabling and transient / reversible effects	Irreversible / serious, long-lasting adverse effects / impaired ability to escape	Life-threatening health effects or death	
Ignition	**Level %**	**Lower Flammable Limit**		**Reference**
LFL[17] H_2 HCN CO CH_4 Other HCs	 4% 5.6% 12% 4.4% 2% to 3%	Potential ignition of flammable vapours and gases		From SDSs

[15] List of the predominant materials with toxic / corrosive properties identified via CEMS

[16] AEGL levels for POF3 is not available. POF3 is highly reactive and likely to rapidly transform to HF (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5577247/)

[17] List of the predominant materials with flammable properties identified via CEMS

4.1 Fluence Cube fire

The consequences from a fire event in the BESS have been modelled as a fire at a Cube, and are detailed in the following Sections of the report:

- Heat radiation associated with a fire at a Cube: Section 4.1.1
- Toxic combustion products resulting from a Cube fire: Section 4.1.2
- Build-up of pressures and explosion within a Cube: Section 4.1.3

4.1.1 Heat radiation from a Cube fire

A. Purpose and method

The analysis focuses on the conditions under which a fully involved fire event within a Cube could occur and the potential for propagation of this fire beyond this enclosure of origin (incident enclosure).

The fire scenario assumes all active fire safety systems are in a failed state or have been disabled and that the Cube is fully involved in the fire. This is considered a worst-case scenario in line with *the Fire safety guideline - Technical information for Fire Safety Studies of Large-scale external lithium-ion BESSs* (Ref 27).

In general, fires would propagate to neighbouring infrastructure if the heat radiating from the fire reaches sufficient intensity at the target. The potential for propagation of a fire incident to other equipment has been analysed by contemplating three theoretical scenarios by which a BESS fire has a potential to escalate, as general to any battery enclosure:

a. Heat radiation levels are not sufficient to initiate a fire outside the incident enclosure (i.e. no propagation between enclosure, or an enclosure and other equipment); or
b. Heat radiation levels are not sufficient to initiate a fire in an enclosure in an adjacent row but are sufficient to promote propagation to a neighbouring enclosure in the same row; or
c. Heat radiation levels are sufficient to promote propagation beyond a single row of enclosures, posing a potential risk to assets beyond the row of burning enclosures.

If tests and/or modelling demonstrate that propagation is unlikely to occur, then it is unlikely that a fire in an enclosure would escalate from the theoretical scenario *a.* through to scenarios *b.* and *c.* above.

In lieu of a time-proven industry library for battery combustion modelling, fire modelling needs to be developed to, as far as possible, reflect site location, layout, and selected equipment of the BESS.

For the Liddell Project, the results of the following two large-scale fire tests are used to calibrate the fire model:

- BDBT (Ref 10), as described in Section 2.5.5 of this Fire Safety Study. The experimental design and layout tested in the BDBT exactly match the Liddell BESS and therefore represent the strongest possible calibration data for the heat radiation model.
- Bespoke Burn test (Ref 16 and Ref 17), as described in Section 2.5.6. The experimental design and layout in the Bespoke Burn Test predominately match the Liddell BESS, the main difference being the choice of battery modules, with CATL battery modules fitted in the Cubes used for the Bespoke Burn Test instead of the Envision AESC modules which will be installed at Liddell.

The underlying assumption in the fire model development is that there is sufficient combustible material in the Cube to sustain a major fire for a significant amount of time (many minutes or hours). This has been found to be the case in a number of large-scale tests (e.g. Refs 18 and 19), and reflected in the BDBT (Ref 10) and the Bespoke Burn test (Ref 16).

Potential for propagation is assessed using the heat radiation levels listed in HIPAP4 (see Table 4-1).

The following two scenarios are examined:

Scenario 1 – Cube Intact: Heat radiation emitted from the unbreached Cube, as experienced during the BDBT (Ref 10), with the walls, roof, and door of the Initiating Cube remaining intact throughout the test.

Scenario 2 – Breached Cube: Heat radiation emitted from a Cube, as experienced during the Bespoke Burn test (Ref 16), with the door of the Cube open or otherwise breached. In this case the external flames would extend from ground level to a height above the roof of the Cube which would be governed by the intensity of the fire.

The Cube could also be breached if the deflagration panels operated, and the flame emerged through an open panel located in the roof of the Cubes at a height of 2.55m above ground. In this case the heat radiation levels experienced by receptors such as adjacent Cubes or responding personnel would be less than for the case where the fire emanated from the door because the intact wall of the Cube would mask the radiant heat from the part of the flame within the Cube, below the roof of the Cube. Hence the modelling for the Breached Cube also encompasses flame emanation through the deflagration panel, as a less severe scenario.

B. Fire model development

The development of the fire model is in three steps, as follows:

- *Step 1:* Determine the fire characteristics and behaviour measured during large-scale fire testing

- *Step 2:* Develop a fire model which is calibrated, as closely as possible, with the fire characteristics observed during the large-scale tests

  The fire model uses the Effects® consequence calculation software model, following the methodologies in TNO's *Yellow* Book (Ref 28) which is internationally recognised for such studies. Further details on the Effects® consequence assessment software are provided in Appendix 3.

- *Step 3:* Determine representative site-specific weather conditions. If the site will experience more severe (worst case credible) weather conditions than those experienced during large-scale testing, calculate the effects that these conditions will have on fire behaviour.

These steps are discussed in detail below.

Step 1: The fire characteristics during the large-scale fire, including flame dimensions and effect of wind and sun, are determined, to understand the fire which occurred during the conditions of the test.

- Flame dimensions: Flame height is an important parameter during fire modelling since wind could tilt the flame towards a target and the longer the flame the more likely the flame would impinge on that target. Hence, when developing the fire model, the flame height needs to correlate well with the test results. Once a good correlation is achieved, the resulting heat radiation values can then be compared with those measured during the Bespoke Burn test to determine if the fire model provides a reasonable representation of the fire behaviour in the test.

  BDBT: The flame remains within the Cube, and the model for the *Cube intact scenario* is developed, with no flame emanating from the Cube, to reflect the BDBT outcome.

  Bespoke Burn test: The flame emanated from the Cube, e.g. via the door, as shown in the photographs in Figure 4-1 The flame height of the worst-case fire during the Bespoke Burn test was about 4 metres from ground, with a width of approximately 1 metre. These flame dimensions are used in the development of the Breached Cube fire model. A schematic representation of the fire scenario, assessed as a "wall of fire" emanating from the Cube, is shown in Figure 4-2.

Figure 4-1: Flames extending above the roof line of the Cube in the Bespoke Burn test

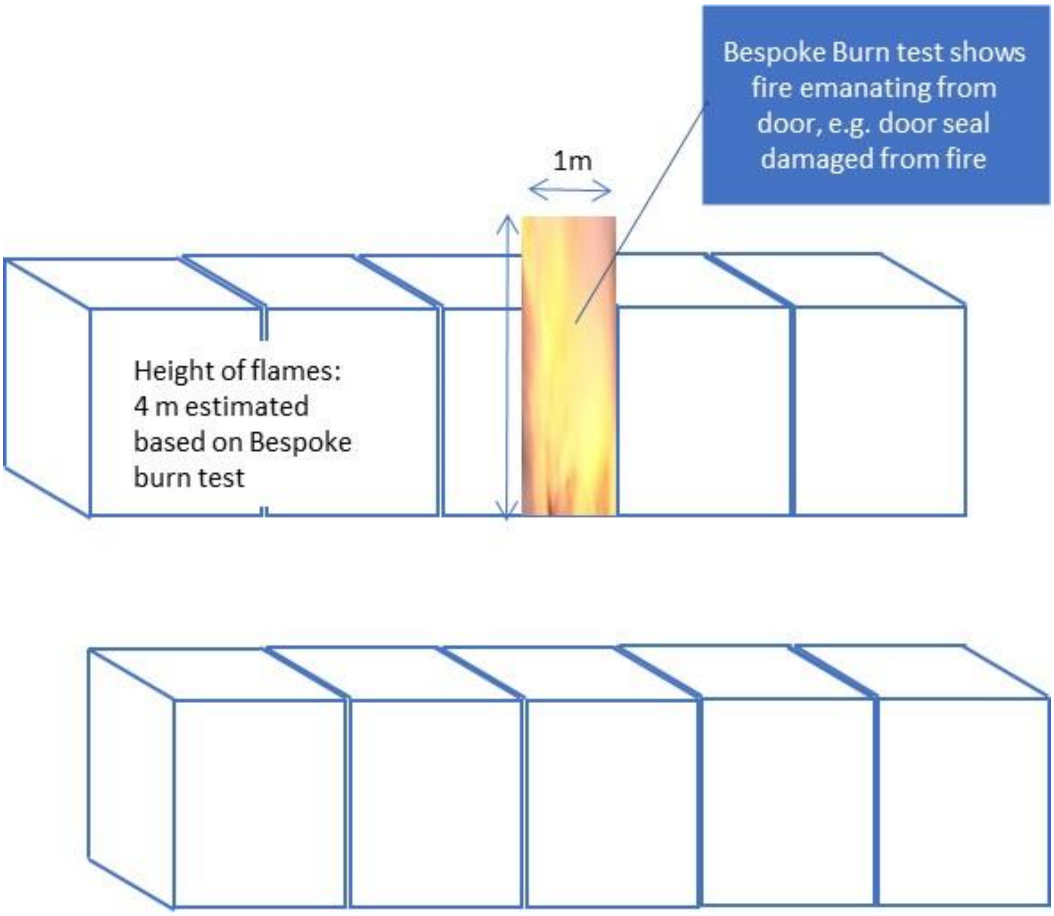

Figure 4-2: Representation of a *Breached Cube* fire scenario

- Flame temperature:

  BDBT: Temperatures up to about 160°C were measured inside the Initiating Unit (see Figure 2-16) with the highest temperatures within either of the Target Units reaching 26°C (Target Unit 2, Figure 2-18), and the temperature of the Wall reaching 40°C (Figure 2-20).

  Bespoke Burn test: Temperatures in the range of 400°C to 700°C were measured (during sustained fire with some peaks of up to 900°C for relatively short duration (less than 10 minutes), see Figure 4-3.

  The temperature used in the *Breached Cube* model is chosen based on the results from the DNV Bespoke Burn test (Ref 16), of 700°C for sustained peak temperature and compared with the 900°C for short duration peak temperature (see Figure 4-3 below).

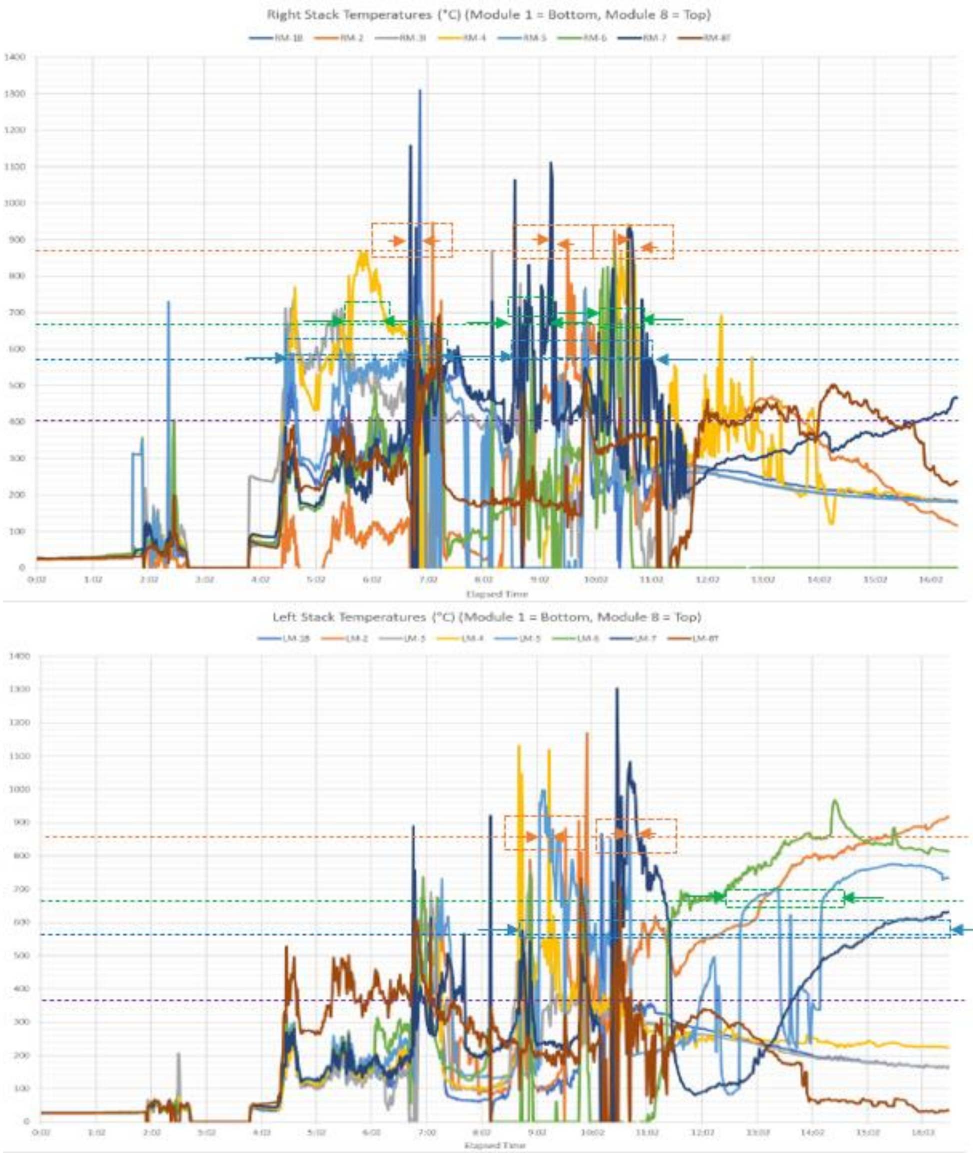

Figure 4-3: Temperatures within the Initiation Cube, Right and Left Module, extract from Bespoke Burn test (Ref 17), with durations of peak temperatures represented on the test results

- Heat radiation and effect of wind and heat from the sun:

  General: Wind can affect the flame emanating from a Cube by tilting the flame in the direction of the wind and by causing flame drag which causes the flame to spill over the edge of the enclosure. Figure 4-4 shows a schematic representation of a fire with diameter D, flame height L, and flame base D' which is elongated due to the effect of wind, and with the angle of the tilt represented by θ.

  As per the results of experimental and actual battery fires, in the case of a battery fire inside an enclosure, it is assumed that the base of the flame would be protected from the wind by the walls of the enclosure with only the top of the flames affected by wind tilt and drag, as represented in the figure below.

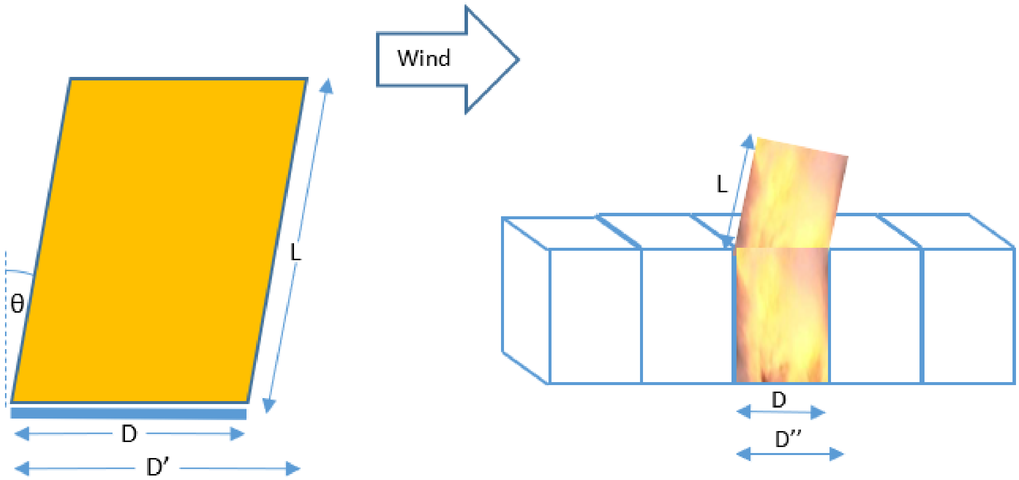

Figure 4-4: Effect of wind on flame tilt and drag

Taking into account the effects of wind on the flame, including deflection of flames, is complex and requires consideration of a number of factors including the flame tilt and flame drag from the wind. In this study, the flames are assumed to tilt in the direction of the wind (which is assumed to be directed towards the target of either a facing row of Cubes or across the roof of a neighbouring Cube or row of Cubes) with the base at the ground of the Cube which is on fire.

BDBT: The wind speed changed during the BDBT test (Ref 10), with wind gusts up to 5.4 m/s at the beginning of the test (in the morning), reducing to less than 1 m/s in the early afternoon (Ref 10). The BDBT report does not correlate heat radiation measurements with wind speeds. Instead, the report confirms that the two brief rises in heat radiation (up to a maximum of about 0.7 kW/m^2), as measured at the Target 1 sensor, approximately corresponds to visible flames being observed inside the Initiating Unit (via the camera in the Cube), and that this heat radiation was approximately 0.225 kW/m^2 higher than the heat radiation due to direct sunlight. The BDBT report also confirms that the Target Wall transducer, measuring a maximum 0.43 kW/m^2 at any time, exhibited *no elevated heat flux levels beyond that associated with exposure to direct sunlight* (Ref 10).

The heat radiation levels, measured at Targets 1 and 2, at the Aisle and at the Target Wall, are provided in Table 4-2. Conservatively, the maximum heat radiation at Target 1 is used to represent the no/low wind situation for the *Cube intact* fire scenario.

Table 4-2: Maximum heat radiation measured during the BDBT, used for the *Cube intact* fire scenario

Distance of sensors from Initiating Unit	Maximum heat flux (kW/m²) at wind gusts ≤12mph [≤5.4m/s]	Maximum heat flux (kW/m²) at wind gusts ≤2mph [≤1m/s]
	@ beginning of test	@ early afternoon
0.18 m at Target 1	0.7 (reported as *visible flames being observed in the Initiating Unit*, Ref 10)	0.1
0.18 m at Target 2	0.1	0.1
2.13 m at the Aisle	0.1	0.1
3.05 m at the Target Wall	0.43 (reported as *similar to exposure to direct sunlight*, Ref 10)	0.1

With the above results, no fire model is required to determine the effect of sustained fire in different wind weather conditions - further discussions in Section 4.1.1C.

Bespoke Burn test: The Bespoke Burn test measured heat-flux in six (6) locations, but the testers only deemed as accurate two of the sensors, one at 2.1 metres distance from the burning Cube, measuring up to 5 kW/m², and one at 1.1 metres distance, measuring up to 14 kW/m² (Ref 16, summarised in Ref 17). The maximum heat radiation at each target which has been used to represent the no-wind situation for the *Breached Cube* (door open) fire scenario, is provided in Table 4-3.

Table 4-3: Maximum heat radiation (Bespoke Burn tests), used to develop *Breached Cube* fire scenario

Distance of sensor from Initiating Unit	Maximum heat flux measured (kW/m²)
1.1 m	14 (flames visible outside Cube)
2.1 m	5 (flames visible outside Cube)

The Bespoke Burn test report (Ref 16) does not correlate wind speed and wind direction with the measured heat flux. From photographic and video evidence, the test appears to have been carried out during mainly calm wind conditions (the flame coming out of the Cube remains relatively upright for much of the test), with episodes of wind which caused the fire to tilt towards the adjacent Target Cube, resulting in flame impingement on this Cube.

The heat radiation is expected to increase when the wind causes the flame to tilt towards a target, and to decrease as it pushes the flame away. The maximum heat flux is likely to have been measured as the wind tilts the flame towards the target.

With no available correlation between heat radiation, wind speed and wind direction, the model is developed assuming the maximum heat flux measured during the test corresponds to a low/no wind situation. This is likely to be a conservative assumption as the maximum heat flux measurements are more likely to correspond to the situation where the flame is tilted towards the Target.

Step 2: Effects® is used as a basis for the fire model. The Effects® fire model requires the selection of a combustible material whose physical and chemical properties are used in the calculations. As described in Appendix 3, Effects® includes two databases containing the properties of more than a thousand representative materials. Of the materials available in these databases, methyl acrylate, a raw material used in the production of acrylic fibres and resins amongst other things, gave the best correlation with the results of the Bespoke Burn test.

The Effects® model was set up so that it calculated heat radiation, flame temperature and flame height which, as far as possible, correlate with those measured during the large-scale tests, under no/low wind speed conditions. The results of the modelling are presented in Table 4-4 (BDBT) and Table 4-5 (Bespoke Burn test, as modelled in the Broken Hill FSS, Ref 17).

Table 4-4: Cube Intact: BDBT test values versus best fit Effects® modelled values, any wind condition

Fire characteristics	BDBT	Values as modelled by Effects® (low/no wind conditions)	
Flame temperature	400-700°C sustained and 900°C short (peak) duration	700°C	900°C
Height of flames	4 metres	5 metres	
Heat radiation at 1.1 metres	14 kW/m²	14 kW/m²	26 kW/m²
Heat radiation at 2.1 metres	5 kW/m²	7 kW/m²	14 kW/m²

Table 4-5: Breached Cube: Bespoke Burn test values versus best fit Effects® modelled values for no/low conditions

Fire characteristics	Bespoke Burn test	Values as modelled by Effects® (low/no wind conditions)	
Flame temperature	400-700°C sustained and 900°C short (peak) duration	700°C	900°C
Height of flames	4 metres	5 metres	
Heat radiation at 1.1 metres	14 kW/m²	14 kW/m²	33 kW/m²
Heat radiation at 2.1 metres	5 kW/m²	7 kW/m²	17 kW/m²

The heat radiation profile for the burning Cube, as modelled in Effects® during low/no wind conditions, is presented in Figure 4-5 below, for the 700°C and the 900°C flames in the blue and orange curves respectively.

The data points that were considered as accurate from the Bespoke Burn test are also included, as the two grey dots.

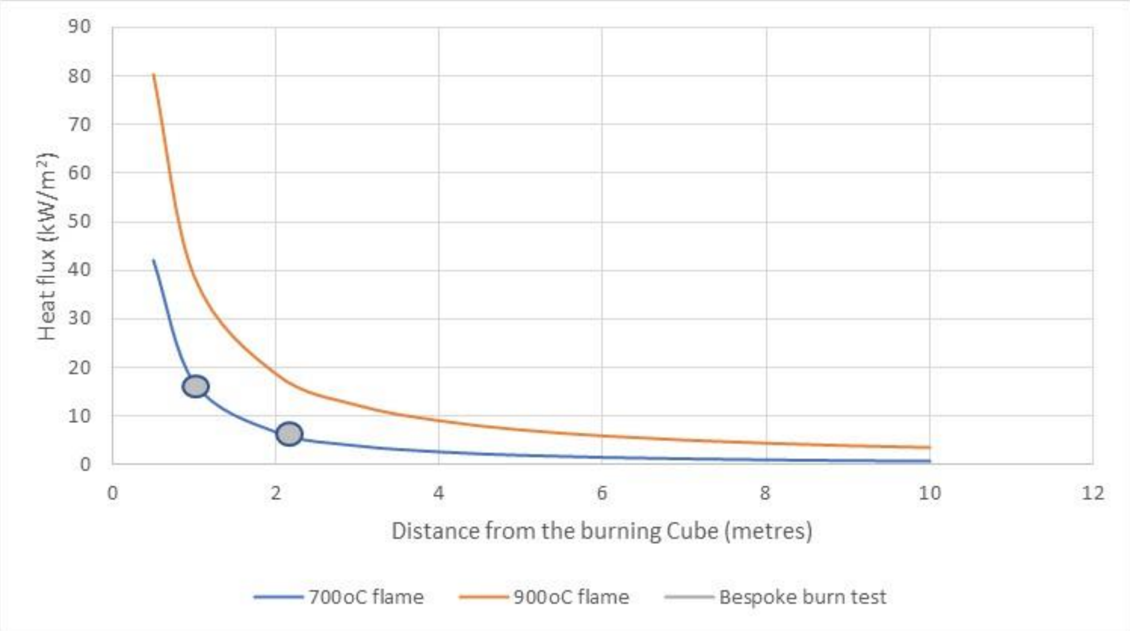

Figure 4-5: Heat radiation for the Fluence Gen6 Cube assuming no shielding of the fire in the front and roof of the enclosure (View Factor calculation method, no/low wind)

Analysis of the 700°C flame: The values modelled in the Effects® software for the 700°C flame follow closely those observed and measured during the Bespoke Burn test (Ref 16), including:

- Effects® calculates the flame height as 5 metres versus the observed maximum 4 metres in the Bespoke Burn test, indicating a similar but conservative result for the fire model
- Effects® calculated the heat radiation at 1.1 metres as 14kW/m^2, i.e. the same as the Bespoke test; and at 2.1 metres as 7kW/m^2, which is somewhat higher than the Bespoke test results of 5kW/m^2. These results indicate a similar but somewhat conservative result for the fire model.

Analysis of the 900°C flame: In the case for the 900°C flame, while maintaining similar flame height values as those observed in the Bespoke Burn test, the heat radiation results did not correlate to the levels measured during the Bespoke Burn test (Ref 16), as discussed below:

- The Effects® model calculates the flame height as 5 metres versus the 4 metres observed in the Bespoke Burn test, indicating a similar but conservative result for the fire model
- The calculated versus measured heat radiation at target, as follows:
- 1.1 metres distance: calculated as 26kW/m^2 versus measured as 14kW/m^2
- 2.1 metres distance: calculated as 14kW/m^2 versus measured as 5kW/m^2.

  The results indicate that the model set up to replicate a 900°C flame temperature gives a poor comparison with the actual test results.

Of note, the Effects® software calculates the surface heat emission as 45 kW/m^2 and the atmospheric transmissivity as 99%. These values are noted here for interest only but no data is available in the Bespoke Burn test so the calculated values cannot be compared with the test results.

Step 3: Use the model to predict fire behaviour under representative (including worst-case credible) weather conditions at the BESS site (Liddell).

For this FSS, wind speed data was obtained from the EIS for the Project, citing the Air Quality Impact Assessment conducted as part of the Bayswater Water and Other Associated Operational Works Project (Ref 29), including wind rose data. The Air Quality Assessment in turn sourced the wind data from the AGL Macquarie meteorological station referred to as AGL08 which is located to the north of the ash dam augmentation area, at between 3 and 4 kilometres away from the Project area at a similar elevation of approximately 150 m AHD. The annual wind rose in 2017 at AGL08 weather station is shown in Figure 4-6. Further details on the meteorological conditions are provided in Appendix 3.

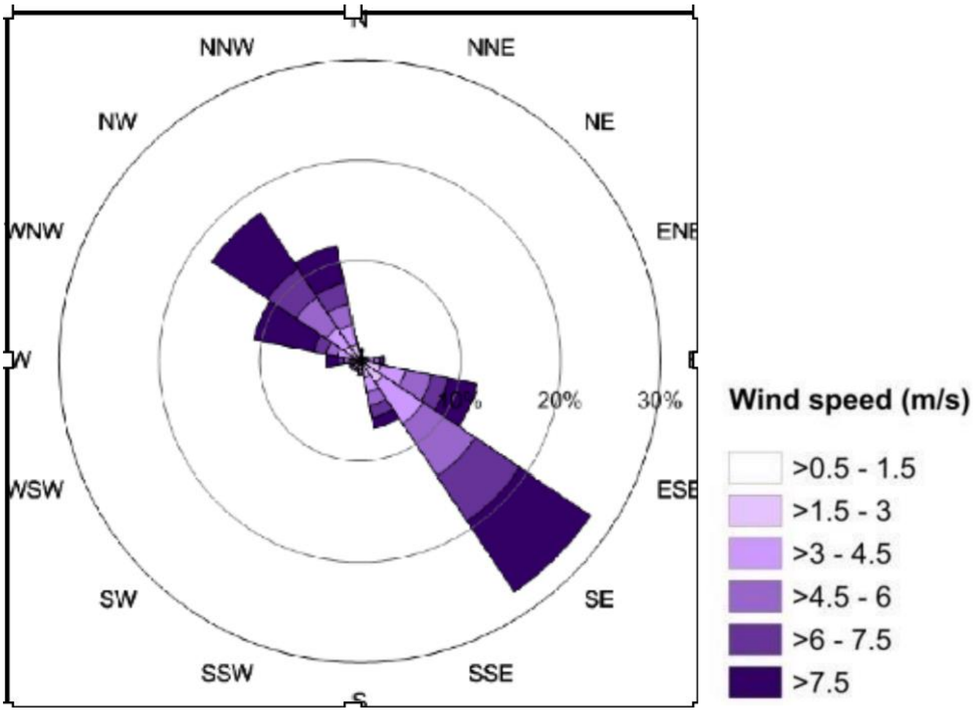

Figure 4-6: Annual wind rose, AGL Macquarie AGL08 meteorological station, 2017 (Ref 29)

Analysing the wind speeds in the wind rose above, Table 4-6 lists the speeds that were considered in the heat radiation modelling as representing a site-specific *worst case credible* and *typical* situation for the *Breached Cube* fire scenario.

Table 4-6: Wind speed ranges, AGL Macquarie AGL08 meteorological station, 2017 (Ref 29)

Wind speed range (metres per second)	Approximate percent of data points, estimated from wind rose	Wind speed set to represent site specific scenario
0 - 3 m/s	<10%	2 m/s, as *typical night time*
3 – 7.5 m/s	>60%	5 m/s, as *typical daytime*
>7.5 m/s	30%	10 m/s, as *worst case credible*
TOTAL	100%	

Notes:

- In the calculations, the wind is assumed to direct the flame towards the target 100% of the time
- The percentages of wind speed condition are determined from reading the graphical representation of the wind rose and are approximate only. They are noted here for information only, but are not used in the calculations
- The wind rose shows that wind speeds above 7.5 m/s are not unusual in this area, and a worst-case credible wind speed of 10 m/s was selected for use in the modelling, representing about 30% of the time annually
- Further, that wind speeds ranging from calm up to 7.5 m/s are more common, say 70% of the time annually, and a wind speed of 5 m/s was selected for typical day time wind conditions

  Night time wind speeds are likely to be lower than during the day and would result in lower heat radiation at the target (for the case assumed in the FSS, where the wind pushes the flame towards the target). Typical night time wind speed is considered to be included as part of the model development, which was set up assuming low/no wind situation

In the calculations, the wind is assumed to be directed towards the target 100% of the time; the flame is assumed to be emanating from the front of the Cube with the base on the ground; and the flame is assumed to be protected from tilting by the Cube walls up to the point where the flame protrudes above the Cube roof, at which point it is assumed to be tilting towards the target.

C. Heat radiation modelling results

The Effects® model, set up to provide a reasonable correlation between the calculated results and those observed and modelled during the large-scale tests, has been used to determine the heat radiation results presented in Table 4-7and in Table 4-8, and the profiles presented in Figure 4-8 and for the following wind speeds:

- *Typical night time conditions*, represented by low/no wind speed
- *Typical day time conditions*, represented by wind speed of 5 m/s and
- *Worst-case credible conditions*, represented by wind speed of 10 m/s.

Cube Intact:

The fire remains within the Cube and the flames would be shielded within the enclosure by the walls and roof of the Cube. Hence, it is not likely that higher wind speeds would significantly affect the fire characteristics. Therefore, the heat radiation measured during the *Cube Intact* scenario (i.e. as seen in the BDBT) is considered the worst-case credible scenario for the case where a fire inside the Cube does not result in the activation of the deflagration panels or in sufficient damage to the enclosure to breach the containment, regardless of weather conditions including wind speed.

Table 4-7: Cube Intact: Distance to heat radiation end point values

Heat radiation (700°C flame)	Potential effect (actual effect depends on duration of exposure) at heat radiation end point value)	Distance, as measured radially from the Cube, depending on wind speed During worst case credible wind conditions at the Liddell location
23 kW/m^2	Potential propagation to non-combustibles; likely fatality	Heat radiation level is not expected to be reached anywhere outside of the Cube
12.5 kW/m^2	Potential propagation to combustibles; significant chance of fatality	Heat radiation is not expected to be achieved outside of the Cube
4.7 kW/m^2	Injury may occur if a person is exposed	Heat radiation is not expected to be achieved outside of the Cube
3 kW/m^2	Unlikely to cause excessive discomfort	Heat radiation is not expected to be achieved outside of the Cube

Breached Cube:

The effect of wind on the heat radiation profile was modelled using the fire model developed for the Breached Cube. The results are presented as heat radiation contours surrounding an individual, representative Cube in Figure 4-7.

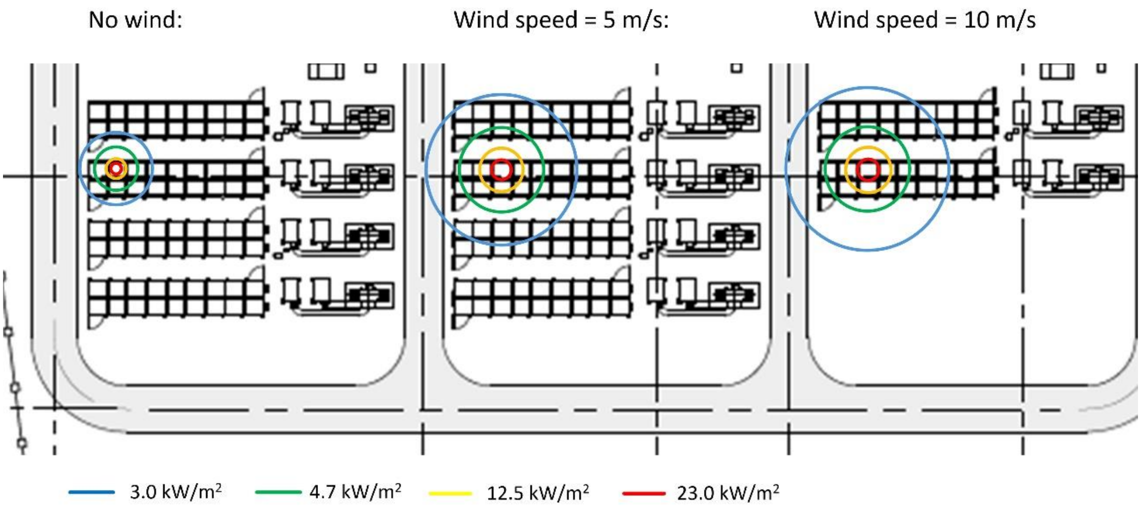

Figure 4-7: Effect of wind on heat radiation contours for the Fluence Gen 6 Cube, 700°C sustained fire

The heat radiation distances are also presented as heat radiation transects in Figure 4-8 and numerically in Table 4-8. The distances are presented as the distance from the front of the Cube towards the target (the Cube in the facing row of Cubes), with the heat radiation levels corresponding to the end point levels in HIPAP4 (refer to Table 4-1).

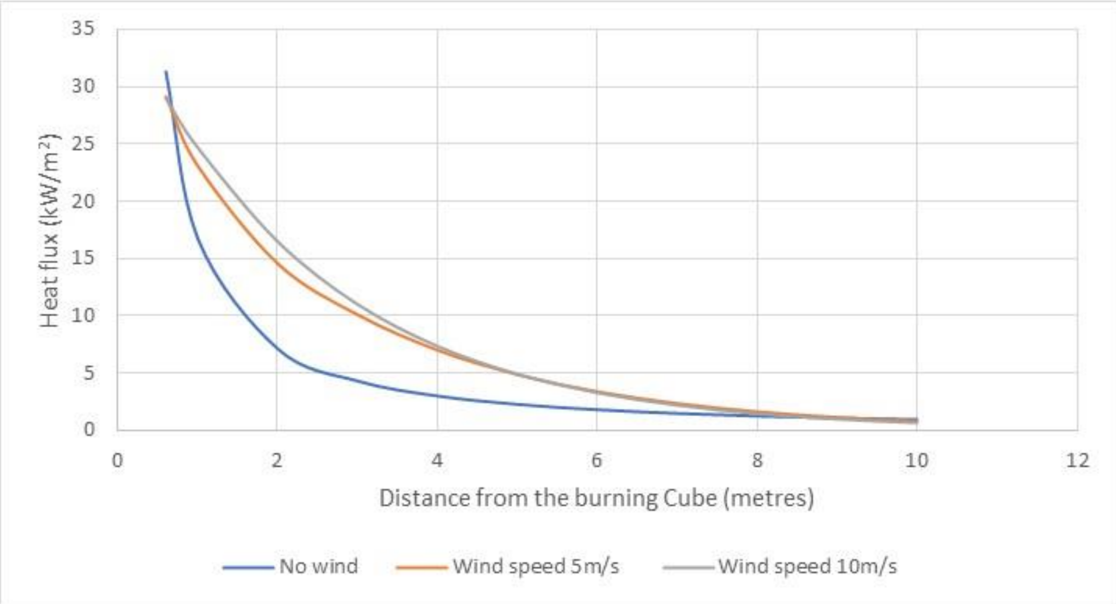

Figure 4-8: Effect of wind on heat radiation profiles for the Fluence Gen 6 Cube, 700°C sustained fire

Table 4-8: Breached Cube: Distance to heat radiation end point values, View Factor calculation method), 700°C flame

Heat radiation (700°C flame)	Potential effect (actual effect depends on duration of exposure) at heat radiation end point value	Distance, as measured radially from the Cube, depending on wind speed		
		No wind	Wind 5m/s	Wind 10m/s
23 kW/m^2	Potential propagation to non-combustibles; likely fatality	0.7 m	1.3 m	1.4 m
12.5 kW/m^2	Potential propagation to combustibles; significant chance of fatality	1.3 m	2.9 m	3.0 m
4.7 kW/m^2	Injury may occur if a person is exposed	2.8 m	5.6 m	5.6 m
3 kW/m^2	Unlikely to cause excessive discomfort	4.8 m	10.0 m	10.8 m

The following results apply for the 700°C fire, which represents the sustained fire conditions seen during the Bespoke Burn test:

- *Propagation for non-combustible material and likely fatality:* The distance to the 23 kW/m^2 heat radiation level, which is considered for potential propagation for non-combustible material and likely fatality, as per HIPAP 4, is calculated to be less than 2 metres in all cases.
- *Propagation for combustible material and possible fatality:* The distance to the 12.5 kW/m^2 heat radiation level, which is considered for potential propagation for combustible material and significant chance of fatality, as per HIPAP 4, is calculated to be less than 3 metres in all cases.
- *Injury:* The distance to the 4.7 kW/m^2 heat radiation level, which is considered for injury potential, as per HIPAP 4, is calculated to be less than 6 metres in all cases.

- *Unlikely discomfort:* The distance to the 3 kW/m^2 heat radiation level, which is considered as a heat radiation that is unlikely to cause discomfort, and which is therefore, at times, used to justify locations of fixed firefighting equipment such as fire hydrants, is calculated to be less than 11 metres in all cases. There is no fixed firefighting equipment located within this distance.

The Fluence Cubes are positioned back-to-back in double rows with doors facing doors across the aisle in adjacent double rows. The aisle (internal access way) is a minimum of 3 metres wide. Thus, a fire at a partially opened or damaged door in a Cube (shown to be a weak point in the Bespoke Burn test, Ref 16) would be oriented towards the door side of the Cube in the adjacent row, where there are potential weak points such as ventilation openings or gaps in the door, and combustible material may be exposed to the heat from a fire. The heat radiation end point for combustible material, of 12.5kW/m^2 (Ref 24) is therefore used to evaluate the potential for propagation.

The following can be seen from the results

- At a distance of 3 metres, the heat radiation from a fully developed fire in one Cube modelled as Breached Cube, as calculated at the closest Cube(s) in a row facing the fire would be less than 5 kW/m^2, assuming typical night time conditions (defined here as low or no wind) and a sustained fire (700°C flame).

  In typical day time wind conditions (defined here as 5 m/s wind speed), the heat radiation at this distance would be 10 kW/m^2.

  In worst case credible wind conditions (defined here as 10 m/s), the heat radiation at this distance would be 12 kW/m^2.

- For short durations (up to 10 minutes) the flame temperature may reach 900°C, in which case the heat radiation at 3 metres from the Cube on fire may reach 20kW/m^2 (for 5 m/s winds) and 26kW/m^2 (for 10m/s winds). While the heat radiation at the 900°C flame would exceed the 23kW/m^2 level where potential propagation may occur, the flame only burns for a short duration at this temperature and, while it may cause visual (e.g. sooting) damage to the neighbouring Cube, it is unlikely to cause fire propagation.

- Adjacent Cubes within rows are separated by a 0.241 metre air gap (see Table 5-2). At this distance the heat radiation from a fully developed fire in one Cube to the next Cube in the row would be greater than 23 kW/m^2 assuming no passive fire protection (i.e. disregarding fire resistance of the walls or roof of the Cubes). In such a case, propagation from a fully involved fire in a Cube to a neighbouring Cube in the same row is theoretically possible, unless adequate protective measures are in place to prevent fire spread.

The measures in place to prevent fire propagation to adjacent Cubes, in addition to separation, include (see Section 5):

- The Cubes are constructed from non-combustible material which have been shown to withstand fires for several hours

- The roof, walls and floor of the Cubes are thermally insulated using rock wool which conforms to ISO 1182:2020 as *non-combustible material* and to ASTM E 84 as Class A grade (which is the represents the highest rating achievable)
- The battery racks within the Cubes are normally liquid cooled, i.e. the neighbouring Cube is likely to be cooled in a fire scenario involving its neighbour.

For the scenario where an internal Cube fire breaches the containment afforded by the enclosure, the Bespoke Burn (Ref 16) tests confirmed that a fire in a battery cell, module or Cube would be unlikely to propagate to nearby cells, modules, or Cubes. In particular, temperature measurements undertaken during the Bespoke Burn testing showed the following:

- The temperature measured on the inside side wall of the Initiation Cube on the side where the trigger module was located and the fire was burning on the outside of the Cube (Figure 4-1), reached a maximum of 900°C for short periods of time and 900°C during a sustained fire. The highest temperature reached on the outside of this wall was less than 250°C.
- The highest temperatures measured by the thermocouples located in the battery modules in neighbouring Cubes were in the Target Cube where flame impingement occurred. The maximum temperature reached was in the top module of the rack closest to the Initiation Cube and was approximately 110°C (at the same time, the BMS measured a battery cell temperature of 53°C). These temperatures are significantly lower than the venting temperature of about 150°C and the thermal runaway temperature of about 250°C determined in the UL 9540A testing.

D. Conclusion, Fluence Cube fire

The BDBT and the Bespoke Burn test results show no evidence of propagation beyond a single Cube, even where a neighbouring Cube is subject to direct flame impingement during the fire.

The fire modelling during more severe weather conditions (wind speeds) confirm that the same results are likely to apply.

This confirms that the passive protective measures are effective in preventing fire spread and in protecting the batteries from the calculated heat radiation levels, including in the case where the wind tilts the flames across the roof of an adjacent Cube.

The bushfire threat assessment (discussed in Section 5.2) recommends buffer zones of 26 m or more to protect facility assets (i.e. battery units, inverters and transformers) from the effects of bush fire and vice versa. As the heat radiation level beyond about 10 m from the fire is calculated to be less than 3 kW/m^2 (see Table 4-8), no offsite consequences are expected beyond a 26 m buffer. Generation of embers etc. is still possible, and the BESS will be designed and constructed to withstand ember attack.

4.1.2 Toxic combustion products in the fire plume

A. Introduction

Evaluation of toxic gas generation and dispersion in a major fire is difficult in general terms. HIPAP2 Section 2.3 requires justification of all models and assumptions used to estimate consequences. Quantifying the dispersion of gases emanating from a BESS fire is especially problematic since this is a new technology and there are very few historical records on actual fires as yet. Only limited large-scale experimental data are available in the public domain, to support fire modelling. The use of traditional software products for HF and other toxic combustion gas generation has not, as yet, been validated for the BESS industry and source terms for dispersion modelling (generation rates for HF and other toxic combustion products[18]) have not been defined with any confidence. While simple fire modelling can be done, its limitations need to be understood.

Hence, given the need for justification and the limitations to the accurate quantification of toxic dispersion from BESS fires discussed above, the approach used in this FSS has been to develop a qualitative understanding of the release of toxic combustion products during a Li-ion battery Fluence Cube fire, based on the research that has been done in this area to date and on the results of gas measurement during the BDBT. This provides a general understanding of the nature of the toxic combustion products and may be used, with caution, to provide guidance on appropriate locations for evacuation areas.

It is also noted that atmospheric monitoring was undertaken at two locations during the Victorian Big Battery fire incident at Geelong (which occurred on 31/7/2021) and subsequent response. This monitoring did not identify air quality outside limits. The learnings from the Victorian BESS fire indicate that at least on a windy day there was only limited toxicity in the fire plume emitted from the fire. While a toxic smoke warning was initially issued by the Fire Rescue Victoria (**FRV**) to people downwind of the fire, there appears to have been no real threat to the community from the toxic gases in the smoke, as confirmed by atmospheric monitoring[19].

In the event of a major fire at the BESS, evacuation of the local community, including any people on the power station site, would be at the discretion of the emergency services and would be based on real-time atmospheric monitoring undertaken by their HAZMAT team.

B. Fire scenario

The gas composition evolved from the cell and Unit (Cube) levels tests is discussed in Section 2.5.5, with the toxic and flammable gases being listed in Table 4-1, together with the levels which may be hazardous to human health.

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[18] For example, the data obtained is limited to concentrations of combustion products, without measuring the rate in which they are generated. A source term cannot be defined based on concentrations.

[19] Refer to EPA AirWatch data Moorabool Sites and to various news articles online at the time of the fire

The maximum gas concentrations measured, for a number of significant combustion gases, are listed in Table 4-1 together with the flammability limits (LFL) and toxic exposure limits.

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Table 4-9: Maximum gas concentrations measured in the BDBT

Chemical compound	Flammability Limits (%)	Toxic exposure limits (ppm)			Maximum concentration measured during the BDBT (ppm)		Flammability limit exceeded (YES / NO)		Toxic limit exceeded (YES / NO)	
		AEGL1	AEGL2	AEGL3	Inside Cube	In duct[20]	Inside Cube	In duct[20]	Inside Cube	In duct[20]
CH_4	4.4%	N/A			8,600 ppm (0.86%)	16 ppm	YES	NO	N/A	
CO	12%	N/A	83	330	>30,000 ppm (3.0%)	<40 ppm	NO	NO	YES	NO
CO_2	N/A	Asphyxiant – unlikely to be relevant in context			>59,000 ppm (5.9%)	3611 ppm	N/A		NO	NO
H_2	4%	N/A			130,000 ppm (13%)	385 ppm	YES	NO	N/A	
Isobutylene	18,000ppm (1.8%)	Unlikely to be relevant in context			147,000 ppm (14.7%) as THC	36 ppm as THC	YES	NO	N/A	
Methanol	60,000ppm (6%)	Unlikely to be relevant in context							N/A	
HCl	N/A	1.8	22	100	Note 1	<1 ppm	N/A		Possibly, AEGL1	NO
HCN	10%	2	10	25	Note 1	<1 ppm	NO	NO	Possibly, AEGL1	NO
HF	N/A	1	25	44	278	1 ppm	N/A		YES	YES, AEGL1
POF_3	N/A	AEGL levels not available. POF3 is highly reactive and likely to rapidly transform to HF[21]			114 ppm	0 ppm	30		YES	NO
Formaldehyde	7%	0.9	14	56	Note 1		NO	NO	NO	NO
HBr	N/A	1	40	120	Note 1		NO	NO	Possibly AEGL1	NO

[20] During testing, the location for gas analysis was switched between the interior of the Initiating Unit (Cube) and the duct connected to the hood positioned over this unit (Duct). The data collected from these two positions during the BDBT is summarised in Figure 2-23.

[21] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5577247/

Chemical compound	Flammability Limits (%)	Toxic exposure limits (ppm)			Maximum concentration measured during the BDBT (ppm)		Flammability limit exceeded (YES / NO)		Toxic limit exceeded (YES / NO)	
		AEGL1	AEGL2	AEGL3	Inside Cube	In duct[20]	Inside Cube	In duct[20]	Inside Cube	In duct[20]
NH_3	150,000ppm (15%)	30	160	1100	Note 1		NO	NO	NO	NO
NO_x / NO_2	N/A	0.5	12	20	Note 1		N/A		Possibly AEGL1	NO
Ethylene oxide	26,000ppm (2.6%)	N/A	45	200	Note 1		NO	NO	NO	NO
Carbonyl sulphide	120,000ppm (12%)	N/A	55	150	Note 1		NO	NO	NO	NO
Alkyl carbonates (not spec.)	Not available		N/A		18,000ppm (1.8%)	26	TBC	TBC	TBC	TBC

Note 1: The BDBT report (Ref 10) does not give concentration. Figures 40 to 50 do not show any significant concentrations measured in duct or Cube

Note 2: N/A signified both not applicable and not available

Note 3: YES signifies limit is exceeded, as reported in the BDBT, or likely to be exceeded in the conditions of the BDBT

Note 4: NO signifies limit is not exceeded, as measured during the BDBT, or is no likely to be exceeded in the conditions of the BDBT, as read off the Figures 40 to 50 in the BDBT report. May be exceeded in other fire conditions

Note 5: Possible AEGL 1 means, insufficient data is available in the BDBT report to rule out the possibility of AEGL1 limit being exceeded. Other AEGL levels unlikely to be exceeded from reading of graphs in Figures 40 to 50 in the BDBT report

The results show the following:

- Toxic gas concentrations inside the Cube are likely to exceeded limits which are regarded as hazardous to human health in a fire similar to the one during the BTBT. This highlights the need to ensure no personnel access the Cube in or after the fire event until safe conditions have been declared (see Section 7)
- Toxic gas concentrations measured outside of the Cube (as indicated by the measurements taken in the duct) are not likely to exceeded limits which are regarded as hazardous to human health, with the exception of hydrogen fluoride (HF) where the measured gas concentration, of 1 ppm, is equal to the AEGL limit. Hence, HF concentrations may exceed AEGL1 levels near the Cube.

Asphyxiant gases such as CO_2, released into a confined environment, can displace the oxygen in the air. In the case of a fire at a BESS, located in the open, this does not constitute a credible health hazard.

The combustion products are typical of fires involving plastics and other construction material.

DNV research (Ref 18) into the emissions from battery fires concluded as follows (with Figures 4 and 5 quoted by DNV reproduced in Figure 4-9 below):

> *The average emissions rate[22] of a battery during a fire condition is lower per kilogram of material than a plastics fire, as shown in Figure 5. However, the peak emissions rate (during thermal runaway of a Li-ion battery, for example) is higher per kilogram of material than a plastics fire, as shown in Figure 4. This illustrates that a smouldering Li-ion battery on a per kilogram basis can be treated with the same precautions as something like a sofa, mattress, or office fire in terms of toxicity, but during the most intense moments of the fire (during the 2-3 minutes that cells are igniting exothermically) precautions for toxicity and ventilation should be taken.*

The DNV research further goes on to say that: *The randomized failure rate limits the toxicity and heat release rate of the fire.*

[22] Emissions concentration in ppm averaged over total minutes of burn time

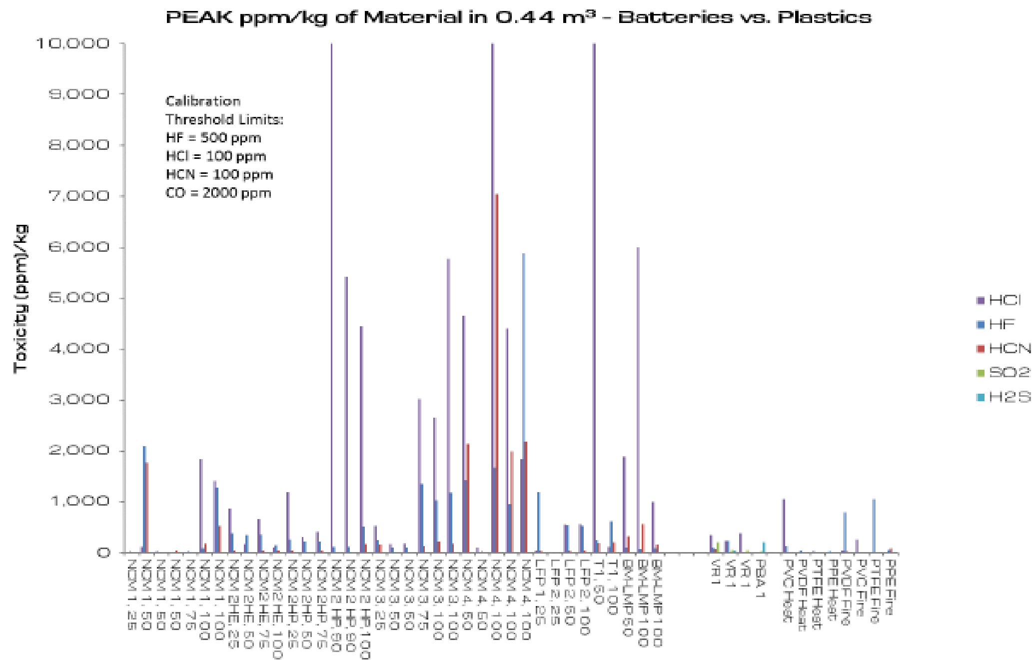


Figure 4 **Peak ppm per kg (in a 0.44 m³ volume) for all batteries tested as compared to plastics.**

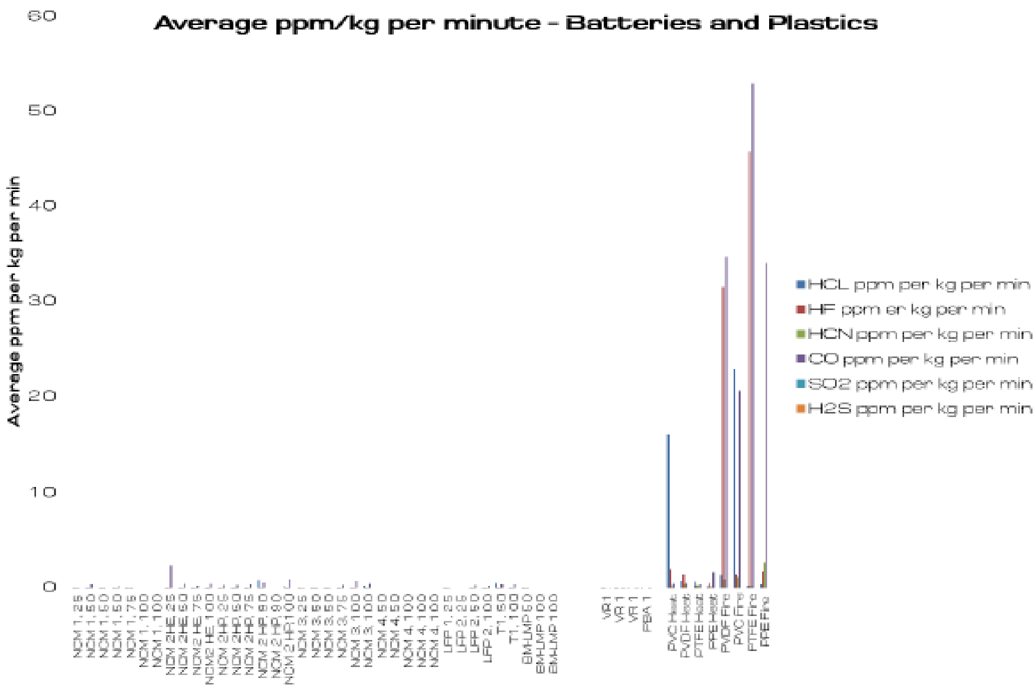


Figure 5 **Average emissions per kg per minute of test mass for plastics vs. batteries.**

Figure 4-9: Comparison between BESS fire and plastics fire, as extracted from DNV Considerations for ESS Fire Safety, 2017

The research by Chalmers University, Sweden (Ref 30) found that HF gas could be generated in BESS fires which would pose a threat, particularly in a confined or semi-confined space. In an open air, outdoor BESS, as is the case for the Liddell BESS Facility, the concentrations of toxic gas generated may pose a hazard in the near field.

For practical reasons, fire fighters should always wear protective equipment and breathing apparatus in the field when getting close to burning or smoking battery fires.

C. Effects associated with exposure to toxic combustion products from a BESS fire

The health effects associated with exposure to some of these gases are summarised in Table 4-10.

Table 4-10: Health effects associated with exposure to the toxic gases that may be produced in a Quantum Enclosure fire

Toxic gas	Health effects	Reference
Carbon monoxide (CO)	When CO is inhaled, it bonds with haemoglobin in the blood, displacing oxygen and forming carboxyhaemoglobin (COHb) and resulting in a lack of oxygen to the body cells. Symptoms of mild CO poisoning include headache, fatigue, nausea, dizziness, confusion, and irritability. Continued exposure can lead to vomiting, loss of consciousness, brain damage, heart irregularity, breathing difficulties, muscle weakness, and death.	US EPA
Hydrochloric acid gas (HCl)	HCl is corrosive to the eyes, skin, and mucous membranes. Acute inhalation exposure may cause coughing, hoarseness, inflammation and ulceration of the respiratory tract, chest pain, and pulmonary oedema.	US EPA
Hydrofluoric acid gas	Acute inhalation exposure to gaseous HF can cause severe respiratory damage including severe irritation and lung oedema. Other symptoms include irritation of the eyes, nose and upper and lower respiratory tracts, tearing of the eyes, sore throat cough, chest tightness and wheezing.	US EPA
Hydrogen cyanide	HCN is a systemic chemical asphyxiant, interfering with the body's use of oxygen. It has whole-body (systemic) effects, particularly affecting those organ systems most sensitive to low oxygen levels: the central nervous system (brain), the cardiovascular system (heart and blood vessels), and the pulmonary system (lungs). Exposure to HCN can be fatal.	NIOSH - CDC

D. Findings

Given the findings in the aforementioned research (Refs 18, 30) and in the gas measurement conducted during the large-scale tests (Refs 10 and 16), fumes and smoke may be generated in a major BESS fire, some of which may be toxic. The fumes may be released from the opening of the deflagration panel in the roof of the Cube or via other openings (vent, seals, door).

The smoke plume generated by the fire would be at a temperature that is significantly higher than ambient and, with the limited confinement in an open BESS layout, most of the combustion products are likely to be carried up to an altitude where they would be dispersed to below hazardous levels, without harm to people in the vicinity. In line with the findings in the DNV research (Ref 18), the fire plume is predicted to be similar to that generated from a fire involving a sofa, mattress, or office fire in terms of toxicity, but during the most intense moments of the fire, precautions for toxicity and ventilation should be taken (DNV cites that this is confined to the 2-3 minutes that cells are igniting exothermically – however, such ignition is likely to be random and staggered in case of a large battery fire and needs to be expected to occur at any time).

The Liddell BESS battery equipment located is outdoors, and without any covered areas, allowing for the dispersion of combustion products.

Despite the low likelihood of harm from toxic combustion products, emergency responders should take a precautionary approach and always don protective equipment and breathing apparatus before approaching a burning or smoking Cube (or other electrical fire). Those on site or near a fire who are not involved in providing emergency response and who are not wearing appropriate breathing apparatus should be evacuated away from the incident area. Advice regarding the use of PPE, including breathing apparatus, and evacuation will be included in the emergency planning documentation for the BESS.

Given that the toxic combustion products from a BESS fire are likely to be similar to those from a building fire, such as one involving construction plastics or general furnishing (sofa, mattress, Ref 18), current understanding is that the consequences to people's health and safety is unlikely to be severe at the nearest off-site occupied locations (such as at the main road).

E. Implications for firefighting

Given the limitations to the accurate quantification of toxic dispersion from BESS fires, a precautionary approach to potential toxic exposure is recommended, including:

- Evacuating persons not involved in emergency response from the site
- Wearing protective equipment and breathing apparatus in the field when getting close to burning or smoking battery fires
- Basing decisions regarding evacuation of the local community on real-time atmospheric monitoring.

4.1.3 Pressure build-up of gases and deflagration

The UL 9540A battery module and unit tests (as discussed in Section 2.5) confirmed that no flying debris or explosion was triggered during thermal runaway testing. During both cell, module and unit level testing, where a battery cell is forced into thermal runaway, no fire or explosion occurred, and no propagation was observed between the adjacent modules or Units (Cubes).

However, tests involving other Li-ion batteries show that a flashover event associated with a thermal runaway can occur under some circumstances, and that the explosion hazard may not be related to the battery itself, but the gases it generates.

Such incidents have been seen particularly within indoor installations of Li-ion batteries.

The Cube where the battery racks are installed outdoors and are fitted with a roof mounted deflagration panel to provide pressure relief in the event of an overpressure incident (see Section 5.2). This is a panel which is secured with breakaway washers and pins, which acts as a passive burst disc, and does not rely on any action or system to activate. If the deflagration panel were prevented from opening, the resulting overpressure may cause loss of integrity of the battery Cube and ejection of material which could cause further damage and propagation to nearby Cubes and injury to personnel within the Facility.

The following summarises the findings:

- If overpressure were to occur, this may cause damage to the battery enclosure and ejection of material. If ejected debris encounters plant or personnel, this may cause damage to other equipment or injury to personnel within the Facility.
- There is the possibility of an instantaneous release of toxic gases for the situation where a deflagration panel opens.

4.1.4 Fire passing into directly adjacent Cubes via the deflagration panels

In the Victorian Big Battery fire incident at Geelong (31/7/2021), flames emanated from the enclosure vents. The theoretical potential exists for the flames to tilt across the roof of an enclosure and cause propagation to neighbouring enclosures. Heat radiation incident to the roof area of adjacent enclosures is theoretically possible in any BESS. However, fire propagation is prevented as follows in the Liddell BESS:

- The Liddell enclosures do not have roof-mounted ventilation, fans, heat exchange systems, louvers or openings as were present in the VBB case
- The deflagration panels are fully sealed, secured and constructed in non-combustible fire rated material with insulation preventing flames entering adjacent Cubes
- The smoke detectors in the Cube would shut down the row of enclosures, including those that are adjacent to that Cube
- There is a level of segregation provided by only installing a maximum of two racks in each Cube.

Furthermore, the battery cell chemistry used in Liddell BESS batteries is more stable and less energy dense than that used in the batteries involved in the Victorian Big Battery fire and, the batteries are thus less susceptible to thermal runaway, and in the event of a fire will not burn as fiercely as was experienced in the Victorian fire.

4.2 Medium and High Voltage Equipment Fire

4.2.1 Inverter and transformer fires

A. Inverter fires

The inverters at the BESS are compliant with UL 1741: *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources,* a safety standard for inverter and power converter equipment used in renewable energy systems, including battery systems. This standard includes the requirement that, should a fire occur inside an inverter, the inverter's enclosure with all the doors and covers closed is capable of containing the fire and so preventing its spread.

There is minimal risk of an inverter fire propagating to adjacent infrastructure and equipment, and such a fire can be left to self-extinguish without fire fighter intervention.

B. Transformer oil fires

Transformer oil and cellulose insulation burn to mostly carbon dioxide (CO_2) if sufficient air is present, with generation of toxic and flammable carbon monoxide (CO) if the air supply is restricted. Other toxic and corrosive gases may also be released - such as nitrogen and sulphur oxides - from burning of cable insulation.

Smoke from transformer oil fires consist of very fine solid particles and condensed water vapour. In many cases smoke reaches harmful levels before the temperature does. This is especially so when fire occurs indoors or in confined areas.

Smoke particles can cause damage to the respiratory system and may impair vision if they lodge in eyes with the potential to impair the ability to escape the transformer fire.

Prevention from propagation from a transformer oil fire is achieved through a combination of separation distances to adjacent infrastructure, firewalls, and clearances around transformers in accordance with AS 2067:2016 *Substations & High Voltage Installation*, as detailed in Section 2.3.3, including:

- Firewall between the two high voltage Main Step-Up transformers
- Firewalls between transformers and bay equipment
- Minimum separation to other buildings and facilities not protected via fire walls: 40 metres
- As per Transgrid requirements, there is a 20 metre buffer around the Liddell BESS Substation.

The fire clearance zones defined in AS 2067 are shown in Figure 4-10 for the MV transformers.

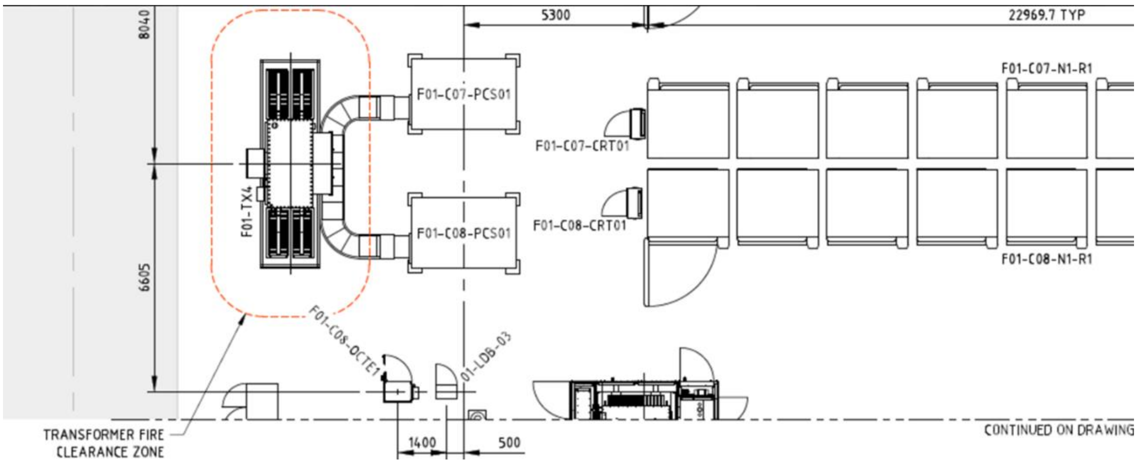


Figure 4-10: Fire clearance zones for MV transformers

Prevention from environmental pollution from an oil spill at any of the HV and MV transformers is via bunding 110% of the maximum oil volume in each Core (MV) transformer and via an underground oil spill containment tank fitted with a flame trap for the substation (HV) transformers.

The risk of harm from a transformer oil fire is known and understood and is generally managed by following the requirements in Codes and Standards.

4.2.2 Fire initiated from an arc flash

The electrical equipment at the Facility has sufficient energy to cause an arc flash in the case of a short circuit or fault. Arc flashes can be dangerous since they can cause serious burns and electrocution. Arc flash temperatures can exceed 12,000°C and are therefore capable of melting metal or causing fires and explosions.

The intensity and the resultant harm to workers and other personnel nearby is dependent on various factors including voltage, arcing current, arcing time, the amount of energy available, the distance from the arc, the location of the arc and barriers in place that may direct the arc in a particular direction (Ref 31).

The HV electrical equipment has a higher risk of severe arc flash than do lower voltage equipment. Arcing faults may cause catastrophic failure within the electrical equipment unless the fault conditions are quickly removed, e.g. through automated shutdowns and trips.

Injury and damage from arc flash is managed by following Australian Standards requirements including the Australian Energy Council *Electrical Arc Flash Hazard Management Guideline*, AS/NZS 3000:2018 *Electrical installations*; AS/NZS 4836:2011 *Safety Near Low-voltage Electricals*; and AS 2067:2016 *Substations and high voltage installations exceeding 1 kV a.c.,* and by reference to various industry Codes e.g. including the Best Practice Guide (Ref 31).

4.3 General fires at the Facility

General fires may occur at the facility including incidents within buildings and vehicles. Building layouts and elevations are included in Appendix 2 and a summary of building details, including fire protection measures is provided in Appendix 4.

Separation distance (or clearance) is a generally accepted strategy for minimising the risk of fire propagation from one structure to another. If adequate clearance cannot be achieved then other measures may be required, such as active or passive fire protection.

Table 4-11 shows the (non-battery related) infrastructure where general fires may occur, together with the clearance provided to adjacent infrastructure. The clearances exceed the requirements in NFPA 850-2020 and in AS 2067:2016 Table 6.1 in all circumstances.

Table 4-11: General fires: clearances between infrastructure

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
Switchroom 1 & 2	To house the 33kV main switchboards, with two switchboards in each room. While the rooms will not be habitable, technicians will conduct maintenance work inside	At the north of the BESS, between the battery-related infrastructure and the Liddell BESS Substation. There is an access road between the nearest Cores and the buildings.	25 metres to battery related infrastructure 60 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Control room	To house the control and monitoring equipment of the BOP and BESS systems. While it will not be habitable, technicians will conduct maintenance work inside	At the north of the BESS, between the battery-related infrastructure and the Liddell BESS Substation. There is an access road between the nearest Cores and the buildings.	25 metres to battery-related infrastructure 60 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
O&M building	To provide space for onsite personnel, including kitchen and toilet facilities. The building will usually be unoccupied, but can accommodate up to 16 people for meetings etc	In the north west corner of the BESS site, adjacent to site entrance A.	100 metres to battery-related infrastructure 175 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
				60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Car park	To provide parking for staff, contractors, visitors, deliveries etc	Adjacent to the O&M building to the south east	80 metres to battery-related infrastructure 155 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between other exposure hazards not associated with electrical grid infrastructure and an outdoor energy storage system as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Workshop and storage building	To provide storage of critical spares and a workshop for maintenance activities	To the west of the battery-related infrastructure area, across an internal access road	20 metres to battery-related infrastructure 124 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between buildings and an outdoor energy storage system) as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding 60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Firewater	To provide water for firefighting (non-electrical fires only)	Firewater tanks located between Site Entrances A and B	40 metres to battery-related infrastructure 55 metres to Liddell BESS Substation transformers	Exceeds the requirement for minimum 3 metres between other exposure hazards not associated with electrical grid infrastructure and an outdoor energy storage system as per NFPA 855-2020 paragraph 4.4.3.3 Clearance to Exposures. Exceeds the requirements for all dimensions listed for oil insulated transformers exceeding

Infrastructure	Use	Location	Clearance	Adherence to Codes and Standards to manage propagation risk SFAIRP
				60,000 L of liquid volume as AS2067:2016 table 6.1 (30m)
Liddell 33 kV BESS Substation	To transform the medium voltage output from the BESS, into high voltage (330kV).	At the north of the facility. There is a 20m buffer zone between the substation and the BESS	> 60 metres from battery-enclosures > 20 metres from all BESS infrastructure (transformers are > 50 metres from BESS infrastructure)	Meets or exceeds the clearance requirements of AS 2067:2016 Substations & High Voltage Installation

Fires involving cabling, plastics (e.g. PVC, PVDF, PTFE, PPE) and some other building materials may evolve toxic material. Toxic combustion products from plastics fires include HCl, HF, HCN and CO (Ref 18). This also relate to fires within other buildings and rooms within the BESS, including the electrical buildings.

The risk of harm from a building fire is known and understood and is generally managed by following the requirements in Codes and Standards including the National Construction Code (NCC). Fire safety at the buildings and its adherence to the requirements in the NCC is listed in Appendix 4.

5 FIRE SAFETY STRATEGY

5.1 OVERVIEW

The functional specification for the facility (Ref 32) includes Safety In Design as one of the functional requirements. The Safety In Design philosophy is focused on the elimination or minimisation of risks to as low as reasonably practical (ALARP) as early in the lifecycle of a project as possible. An effective fire safety strategy, utilising an appropriate hierarchy of controls, is recognised by AGL-LB in their functional specification for the Project as an important part of the Safety In Design process.

The fire safety strategy at the Liddell BESS combines a range of measures to prevent, detect, alert and respond to fire incidents.

These measures are aimed at minimising the potential for propagation and escalation of an incident, including an incident that involves an entire Fluence Cube (i.e. the fire incidents discussed in Section 4).

Without reliance on intervention or active controls, passive controls alone have been shown in testing and modelling to contain the worst credible incident.

The overarching aim of the strategy is to remove the need for intervention by emergency services, in recognition that BESS facilities pose significant risks to emergency responders.

An overview of the relationship between the fire safety strategy for the Cubes and site-wide measures is given in Figure 5-1.

The details of the strategy are discussed in the following sections:

- Section 5.2: Fluence Cube: layers of protection and general site measures
- Section 7: Emergency management.

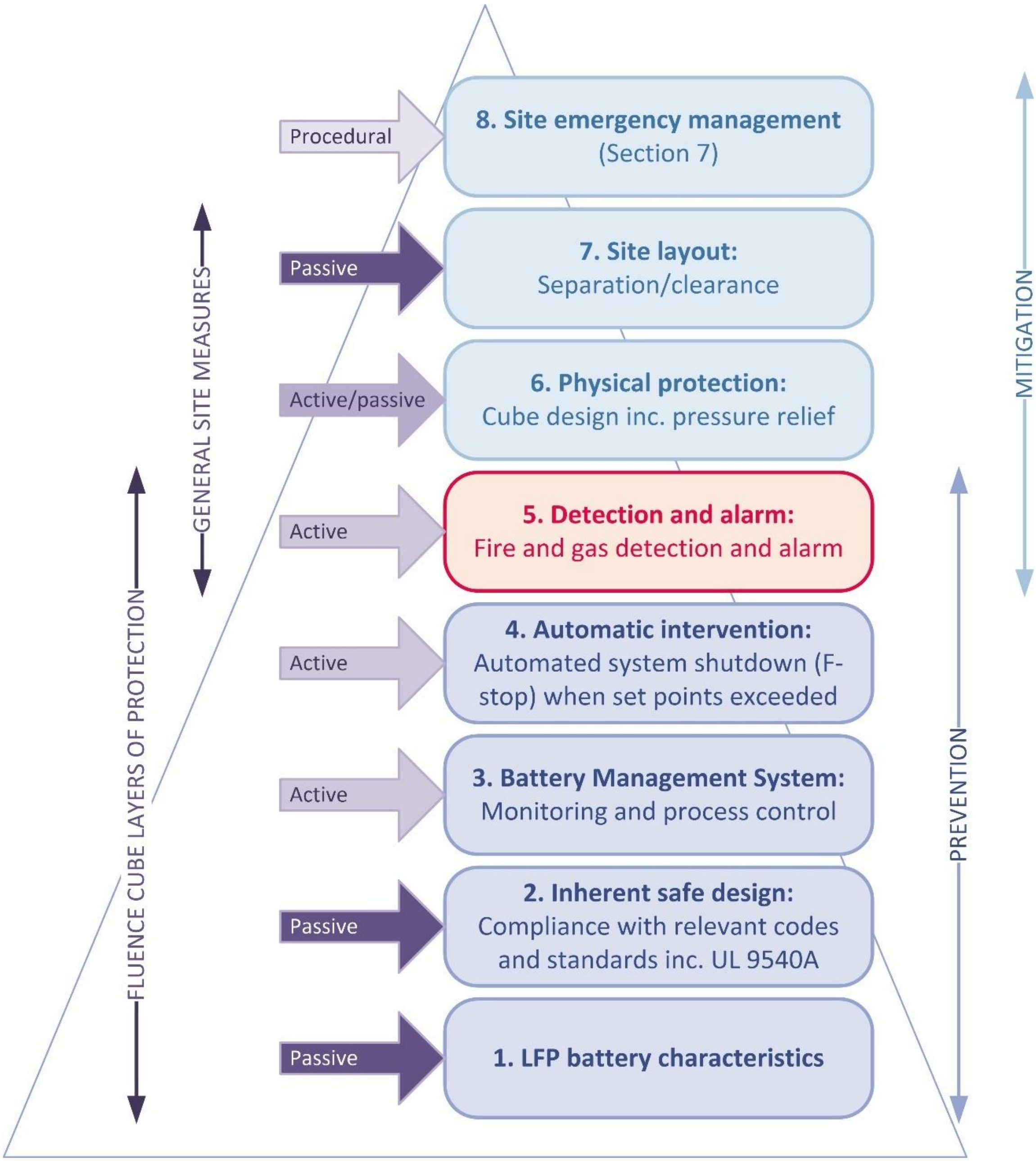


Figure 5-1: Overview of fire safety strategy

5.2 Fluence Cube and General Site Measures

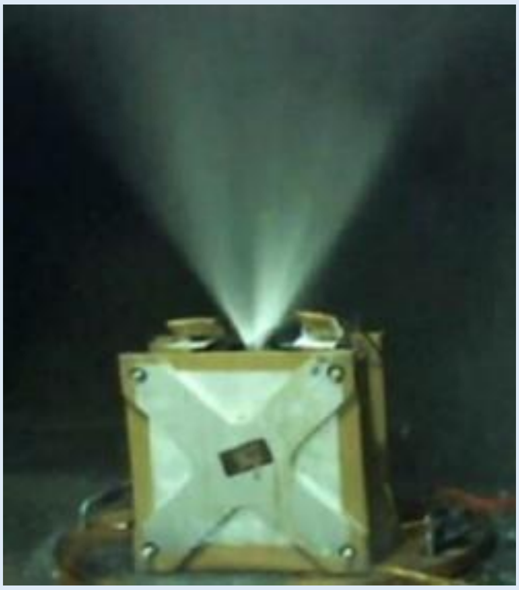
The Fluence Cube is a discrete energy-storage unit that includes batteries, a battery management system, a data acquisition system, and other equipment and accessories necessary to maintain system health and operate the ESS long-term in an outdoor environment.

A single Fluence Cube contains the battery, a battery management system (BMS), a controller, auxiliary panel, safety equipment, and HVAC components.

Layer of protection 1: LFP battery characteristics

Each Cube is fitted with Envision AESC LFP prismatic battery cells rated at 280 Ah, arranged in modules in a 52S1P (52 cells connected in series).

The risk of fire and thermal runaway in the Envision AESC battery cells and modules is minimised through the choice of cell chemistry, and cell and module design and construction.

Key controls:	
Battery cell: • Li-ion chemistry is lithium iron phosphate (LFP), which is currently known as relatively stable in terms of thermal runaway potential under normal and abnormal operating conditions • Prismatic metal casing (aluminium) which resists deformation and provides a heat sink • Cells are designed to vent from the top cap providing directional, pressure relief[23] away from other cells within the module Battery module: • Modules are designed to vent from the front plate providing directional, pressure relief away from other modules within the rack • IP rating of 67 provides complete protection from dust intrusion and prevents virtually all ingress of water (Ref 9) Fluence Cube: • Thermal management of cells/modules using liquid cooling	 Plate 10: Cell venting during UL 9540A testing (Ref 13)

[23] Photos in the UL certification show cells venting through centre aperture in top plate.

Layer of protection 2: Inherent safe design

The Envision AESC battery cells comply with UL 1973 (the Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications) which specifies detailed requirements that the manufacturers of ESS must meet to qualify for safety certification.

UL 9540 compliance:

The Fluence Gen 6 Cubes have been designed to contain a fire within the unit itself and to stop a fire potentially spreading from unit to unit. If thermal runaway was to occur within a battery cell, module or rack, it has been demonstrated in UL 9540A testing that such an event would remain confined with no propagation to other areas in the enclosure or to other enclosures. As discussed in Section 2.5 the Cubes passed all the performance criteria for the unit level test.

In addition, the BDBT (see Section 2.5.5) showed that forcing a complete battery module with a Cube into thermal runaway is not sufficient to cause module-to-module propagation within the enclosure.

UL 9540A unit level results:

- Thermal runaway:
  Cell to cell thermal runaway was limited to the initiating cell and two adjacent cells
- Cell venting:
  The maximum recorded temperature on the surface of the target modules were below the temperature required to induce cell venting
- Physical damage:
  No physical damage was observed beyond the initiating module in the initiating unit.
  No damage was observed to the target units
- External flaming/explosion/flying debris:
  There was no evidence of external flaming, explosions or flying debris.

Layer of protection 3: Battery Management System (BMS)

The battery system is designed, built, and tested to operate within certain specified normal operating conditions. Process monitoring through the BMS is integrated across all levels from battery cell to Core. The BMS monitors and controls parameters such as temperature, current and voltage to ensure batteries are operating optimally and within design specifications.

The BMS is a multi-level distributed architecture consisting of a Battery Administrator Unit (BAU), Battery Control Unit (BCU) and Battery Management Unit (BMU). The BAU is the control core of the BMS and enables information aggregation and remote debugging and provides the interface between the BMU and the PCS/EMS or external controller.

BAU functionalities (Ref 9):

- Battery charge and discharge management
- Thermal management
- Real time estimation of SOC
- BMS system self-check and fault diagnosis alarm, safety protection for abnormal and fault conditions
- Data storage, transmission, and processing

Layer of protection 4: Automatic intervention on abnormal conditions

A battery can be compromised by mechanical damage, a manufacturing defect, over-charging, over-voltage, an internal or external thermal event, or through an electrical fault. These abnormal conditions can cause a fire with a battery module.

A small fire can be prevented from propagating to other areas through automatic detection and shutdown based on early warning systems. The BMS detects and manages faults and potential operational upset conditions that could otherwise lead to problems such as thermal runaways and/or fire. On detection of unsafe (fault) conditions, the BMS issues alarms and triggers the Fast-Stop (F-Stop).

The BMS monitors and protects the battery from:

- Overcharging/overvoltage
- Over-discharging
- Overtemperature
- Under-temperature
- Imbalance

5.2.1 Fast-Stop (F-Stop)

The Fast-Stop forms part of the Core safety system as shown in Figure 5-2 and Figure 5-3. When abnormal conditions are detected in the Cube, the detection system automatically initiates a system fast-stop that stops power flow throughout the Core.

The F-Stop can also be initiated manually using push buttons located on each Cube and each Core. The manual F-Stops are coloured red and are located on the right side of the doors on the Cubes and OCTEs as shown Plate 11 (Cube on left, OCTE on right of image). While the F-stop cannot be triggered remotely, the operator in the remote control room can initiate an orderly core shut down by accessing the array controller user interface.

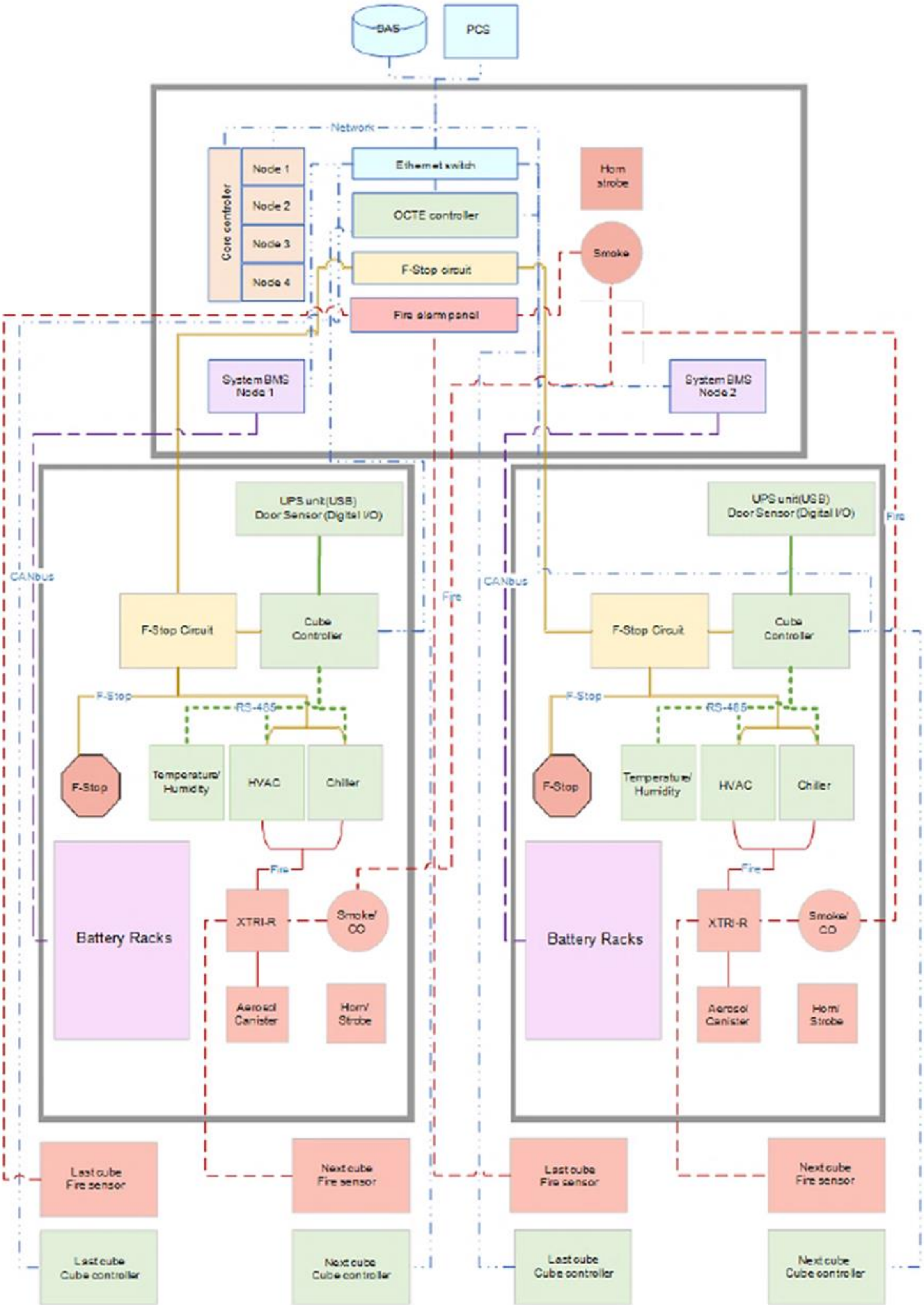


Figure 5-2: Core safety system topology showing two Cube rows (Ref 12)

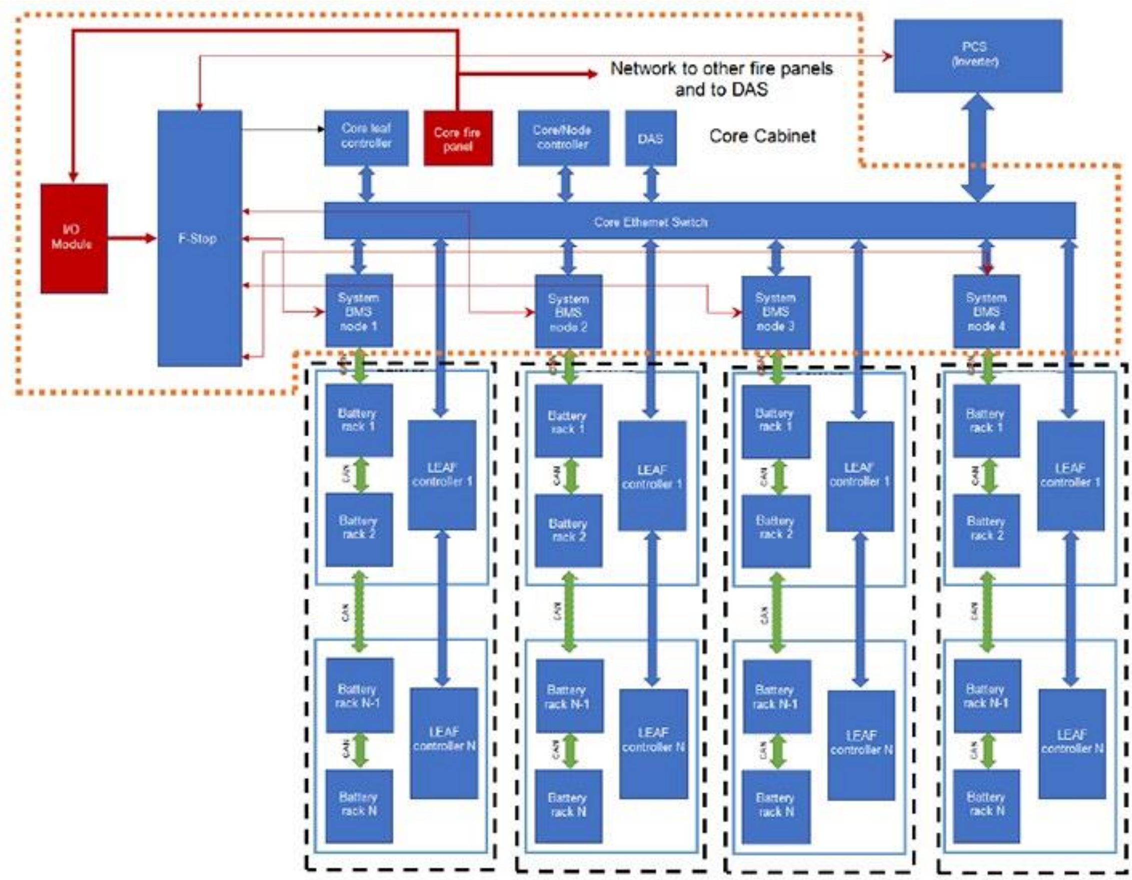


Figure 5-3: Core level logic flow (Ref 12)

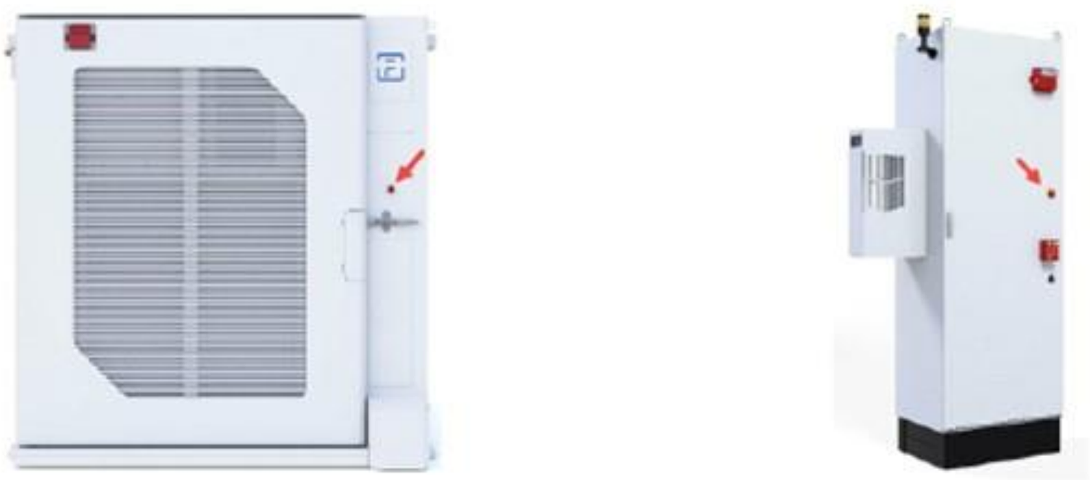


Plate 11: Location of manual F-Stop buttons

The following actions can trigger the F-Stop in a Cube:

- Cube F-Stop is pressed (manual initiation)
- Core F-stop is pressed (manual initiation)
- Smoke or CO is detected in the Cube (automatic initiation)

- Fire suppressant aerosol cannister is discharged (automatic initiation).

When the F-Stop is triggered in a Cube, the following actions are initiated (Ref 12):

- Chiller and HVAC units in the affected Cube are tripped
- Master BMU and DCPM units are tripped after a one second delay, disconnecting the battery racks in the Cube
- Core F-Stop is triggered.

The following actions can trigger the F-Stop in a Core:

- Core F-stop is pressed (manual initiation)
- Cube F-Stop is pressed (manual initiation)
- Core fire panel trip (automatic initiation)
- BMS triggers F-Stop (automatic initiation).

When a Core-level F-Stop is initiated, the power converter is stopped and the batteries in all Cubes are disconnected (by opening the DCPM/BCU contactors. Data collection continues and the Chiller and HVAC units in unaffected Cubes continue to operate to maintain battery temperature.

The F-Stop does not de-energise the batteries and they remain charged to whatever level they were prior to initiation of the F-Stop (Ref 33).

Layer of protection 5: Detection and alarm

Early detection and alarm are at the heart of preventing the growth of a fire within the BESS.

Cube and Core level

The Fluence Battery Energy Storage System Gen6 is protected by the Siemens fire detection system Cerberus Pro (Ref 34). Each Cube and OCTE is fitted with a multi-sensor fire detector with integrated carbon monoxide (CO) sensor. The detector monitors smoke, temperature and CO levels within the unit. CO levels are used to detect an off-gas event in battery cells prior to a thermal runaway. If smoke, high levels of CO (>30 ppm) or a temperature above 95°C are detected the fire suppressant system, and a white strobe and horn located on the unit are automatically activated. The fire suppressant, strobe and horn systems are not dependent on external power or control. A Core F-Stop is also automatically initiated.

The condensed fire suppressant aerosol unit discharges an ultra-fine suspension of particles that act on non-battery components within the Cube (Ref 12). The suppressant can contain or extinguish a non-battery fire before it spreads, but it is not designed to extinguish a battery fire. Even when a suppression system is discharged during a thermal runaway event, batteries continue to produce flammable gas. Each incident varies depending on the battery size, system chemistry, and state of charge. The automatic fire suppression system is discussed further in Section 5.2.7.

An overview of the safety system control topology (showing two Cube rows), including the detection and alarm system at Cube and Core level is given in Figure 5-4.

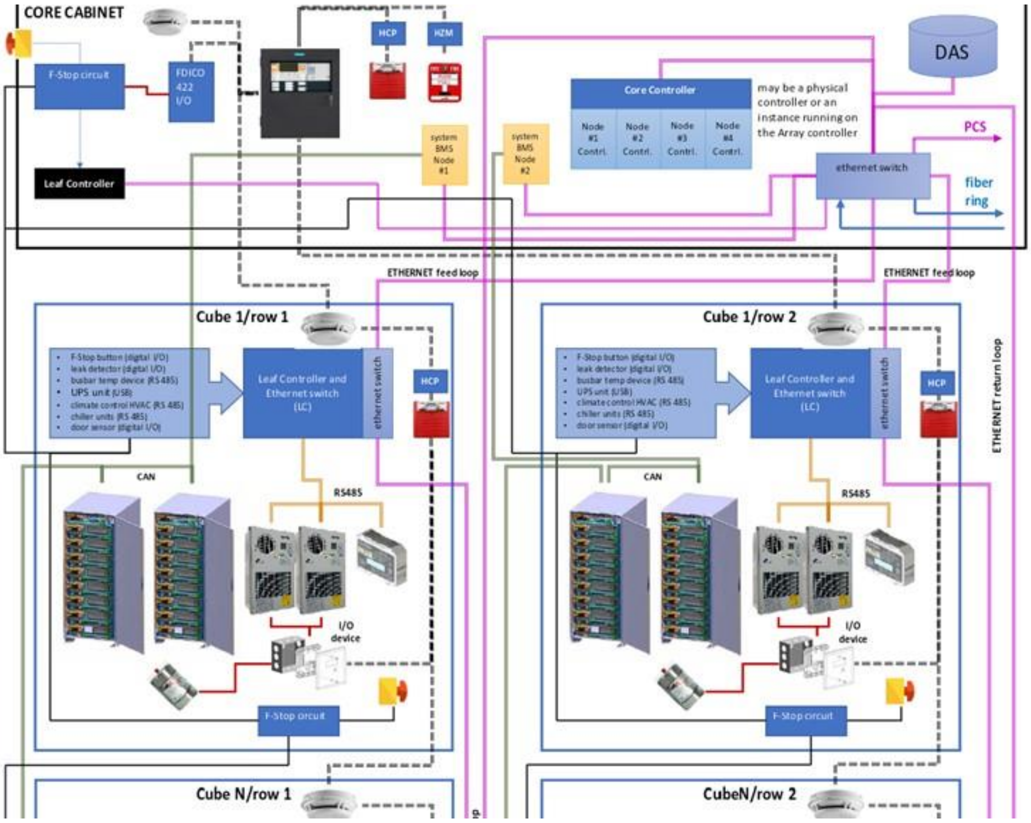


Figure 5-4: Cube and Core fire detection and alarm

Details of the Cube and Core level detection and alarm system are summarised in Table 5-1.

Site

Details of the automatic fire detection and alarms for the transformers, inverters and buildings are summarised in Table 5-1.

Table 5-1: Automatic detection and alarm systems

System / Equipment	Application
Cube and Core	Primary detection in individual battery cell voltage and temperature monitoring to detect cell failures, connected to automatic shutdown on detection of operation of battery cell outside of safe operating window.
	Secondary fire detection through multi-criteria detector for carbon monoxide (CO), smoke, and temperature. Detection via busbar temperature sensor, humidity sensor, power outage and leak detection within the Cube. Alarm is sent to the Core FIP located in the OCTE.

System / Equipment	Application
	A detection of a runaway in a battery (through the CO sensor), and of a fire (through smoke and temperature detection) triggers a full shutdown of an entire Core including each Cube connected to the Core (via the F-stop system at the Core). Neighbouring Cores would remain operational.
	A local horn/strobe (visual and audible) is used to identify the Cube which is affected by an event. The horn/strobe would be activated locally at the Cube upon CO detection (specific sound and strobe) and fire detection (fire alarm sound and strobe) via the F-stop system at the Core.
	A release of the fire suppression agent inside a Cube discussed in Section 5.2.7 is connected to the F-stop system in the Cube and stops the Cube's HVAC and chiller units[24]. This triggers the strobe & horn at the affected Cube only.
Transformers	Transformers have a two-stage safety system. The transformers have temperature alarms to the control system at high level, and then have an electrical protection trip to the whole RMU feeder and Cubes associated with that feeder when they detect a PRD or high-high temperature fault.
Inverters	Thermal model inverter trips are transmitted to the Control Room via the software relay.
Buildings	Buildings are provided with fire and smoke detection and alarm systems (e.g. Early Smoke Detection Apparatus, VESDA).
Liddell BESS Substation	Smoke and fire detectors connected to the substation FIP are installed in the Auxiliary Services building. Alarms register remotely in the Transgrid control room.

The automatic fire detection system is to be maintained in accordance with manufacturer's recommendations.

Layer of protection 6: Physical protection

If a thermal runaway did occur at the module and rack level, and assuming this escalated to a fire, the extent of that fire is minimised by limiting the amount of combustible material exposed to the fire. The Fluence ESS is a modular design which segregates the battery capacity into separated, fire-resistant Cubes.

Provided the fire or explosion does not compromise the integrity of the Cube, the fire would remain confined within the enclosure and propagation to other areas is unlikely.

[24] Under a potential pre-thermal-runway scenario, the chiller units would continue cooling the battery as much as possible. Under a smoke or fire scenario the HVAC and chiller units are stopped because the chiller and HVAC units are the heaviest electrical loads in the Cube and may potentially be the cause of the smoke and/or fire.

Key controls:

- The Cubes act as discrete battery enclosures which are sealed and independently controlled
- Cube climate control (HVAC) maintains internal temperature and humidity within design specifications
- Cube doors are fitted with gas spring dampers and a sliding door lock
- Vent on each battery cell provides cell-level, directional pressure relief
- Deflagration panels are fitted into the roof of each Cube (see Section 5.2.2)
- The roof, walls and floor of the Cubes are thermally insulated using rock wool (conforms to ISO 1182:2020 *non-combustible material*[25] and to ASTM E 84 *Class A grade*[26])
- Lightning masts are installed on site, designed and installed in compliance with AS 1768:2021
- A DC arc flash assessment of the Fluence Gen 6 ESS (Ref 35), undertaken in support of UL 9540 certification, has determined arc flash hazards (according to NFPA 70E and CSA Z462). This risk assessment has identified the arc flash incident energy level, the restricted approach boundary, and the required arc flash personal protective equipment.

5.2.2 Deflagration panels

Deflagration panels are passive devices engineered to direct the force of an explosion. Two (2) deflagration panels, designed according to NFPA 68:2018, are fitted to the roof of each Cube to direct the forces upwards, should an explosion occur. The panels are attached using breakaway washers and pins and are tethered to the Cube to prevent them flying free and causing damage.

The panels have been designed following the calculation methodology set out in NFPA 68 and using gas concentration, flow rate and volume data from UL 9540A cell and module level testing. In Cube testing, explosions were not created until concentrations exceeded the likely gas concentrations based on UL 9540A testing (Ref 12). Upon ignition, the deflagration panels successfully directed the force of the explosion upwards, and the Cube structure remained intact.

Layer of protection 7: Site layout

The effect to the environment around an enclosure from a thermal or pressure event is minimised by the site layout.

Key controls:

- The minimum separation distance between rows of Cubes is sufficient to minimise fire propagation between rows and to provide access and to provide escape in the case of an emergency
- An APZ as recommended in the bushfire threat assessment minimises the risk of propagation of a fire or explosion at the BESS to nearby vegetated areas

[25] Testing agency: Institute of Civil Engineering and Building Technology, Korea

[26] Testing agency: SGS US Testing Company INC

5.2.3 Separation by distance

In addition to the physical separation provided by segregating the batteries within fire resistant enclosures, site layout is used as a means of preventing fire propagation:

- Between Cubes
- Between Cubes and other site equipment and infrastructure
- Between the site infrastructure and the surrounding environment to manage bushfire risk, in the form of an Asset Protection Zone (APZ).

Separation between Cubes

The Cubes at the Liddell BESS will be installed in double rows of back-to-back enclosures with nine (9) cubes in each row. A typical layout is shown in Figure 2-5.

While it is noted that the Facility is outside the scope of AS/NZS 5139:2019 *Electrical installations - Safety of battery systems for use with power conversion equipment*[27], the minimum clearance requirements as per the Standard are depicted in Figure 5-5, for information only. Included are also the requirements specified in the National Fire Protection Association (***NFPA***) 855:2020 *Standard for the Installation of Stationary Energy Storage Systems* - while not legally binding in Australia, the NFPA requirements are included for illustrative purposes.

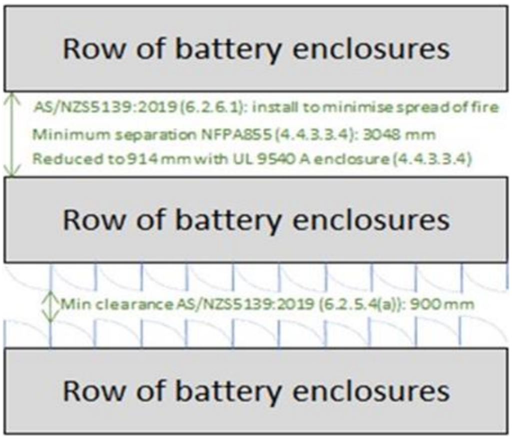


Figure 5-5: Code requirements (AS/NSZ 5139) minimum required clearances between rows of enclosures, with those from NFPA 855 also included for illustrative purposes

Clearance for unimpeded access: AS/NZS 5139:2019 (paragraph 6.2.5.4a[28]) sets the minimum requirement for clearance for unimpeded access on the working side of the battery enclosure to 900 mm with the doors open. As shown in Figure 2-5, the Fluence Cubes at the BESS are installed in rows with a minimum separation distance of 3.048 m between the rows. This is sufficient to provide a clearance of approximately 1.2 m with a Cube door open, meeting the

[27] BESS comes under exclusion 1 pertaining to critical power requirements

[28] Clearance can be reduced to 600mm in circumstances not applicable to the Liddell BESS

requirement of unimpeded access on the working side of the battery enclosure set out in AS/NZS 5139.

Separation to prevent fire propagation: AS/NZS 5139:2019 (paragraph 3.2.6.1) specifies that the BESS shall be installed such that, in the event of a fire originating within the BESS, the spread of the fire shall be kept to a minimum. No detailed guidance as to the actual separation distance required for an outdoor major BESS is provided in AS/NZS 5139.

With the scope of AS/NZS 5139:2019 limited to a maximum energy capacity of 200 kWh and noting that a grid-scale NEM connected BESS comes under AS/NZS 5139 scope exclusion 1, pertaining to critical power requirements, it is necessary to refer to international Codes for guidance in the development of a large-scale BESS.

One such code is the NFPA 855:2020 *Standard for the Installation of Stationary Energy Storage Systems.* NFPA 855 has become internationally recognised in the area of fire safety for large-scale energy storage systems, and, while the requirements do not cover all battery configurations and are not binding in Australia, reference to the guidance in the NFPA Code is made here to inform the present assessment of separation distance, as follows:

- NFPA 855 (para 4.4.3.3) Clearance to Exposures sets the separation distance of 10 feet (3.048 metres) between battery enclosures and other buildings; stored combustible materials; hazardous materials; and other exposure hazards not associated with the electrical grid etc.
- NFPA 855 (para 4.4.3.3.4) allows the clearances to exposures other than buildings to be reduced to 3 ft (914 mm) where large-scale fire testing of the ESS in accordance with UL 9540A[29] demonstrates that a fire within the ESS enclosure will not generate radiant heat flux sufficient to ignite stored materials or otherwise threaten the exposure.

As shown in Figure 2-5, the Fluence Cubes at the BESS are installed in doubled rows with a minimum separation distance of 3.048 m between the rows on the door side. This is sufficient to:

- Exceed the clearance to exposures requirement of NFPA 855 for UL 9540A fire tested installations
- Minimise the risk of propagation to adjacent rows as discussed in Section 4.1.1.

In the large-scale fire tests (UL 9540A BESS unit level and the BDBT), three Target Cubes were used in addition to the Initiating Cube to investigate the potential for propagation between adjacent Cubes. In both tests the Cubes were physically spaced to represent the typical configuration for the intended installation.

[29] or equivalent test standard.

These separation distances are given in Table 5-2, together with the separation distances between adjacent Cubes at the BESS.

Table 5-2: Separation distances between adjacent Cubes

Separation between Initiating Cube and:	Distance: UL 9540A unit level test	BDBT	Liddell BESS
Cube in front	7 ft (2.13 m)	7 ft (2.13 m)	3.048 m
Cube behind	7 in (0.18 m)	7 in (0.18 m)	≥ 0.18 m
Cube to the side	7 in (0.18 m)	7 in (0.18 m)	0.241 m

Given that no fire propagation was observed between the Initiation Unit and Target Units in the unit level tests (a result confirmed by the consequence calculations in Section 4.1.1 which use meteorological conditions comparable to those experienced the Liddell site) and that the distances between Cubes at the Liddell BESS equal or exceed those used in the tests, the separation distances between adjacent Cubes are sufficient to minimise the risk of propagation between enclosures.

Separation between Cubes and other equipment and infrastructure

As discussed above, NFPA 855:2020 (para 4.4.3.3) sets a separation distance of 10 feet (about 3 metres) between battery enclosures and other buildings; stored combustible materials; hazardous materials; and other exposure hazards not associated with the electrical grid etc.

As measured from the site layout drawing (Figure 2-3 and the larger scale drawing in Appendix 2) and recorded in Table 4-11, the clearances between Cubes and other infrastructure all exceed the separation distances in NFPA 855:2020 (para 4.4.3.3).

Asset Protection Zone

A bushfire threat assessment against the requirements of Planning for Bushfire Protection (PBP, 2019, Ref 36) and the Muswellbrook Local Environment Plan (2009) has been undertaken for the Liddell BESS site, including the Liddell BESS Substation. These results are reported in the *Bushfire Threat Assessment Fluence Energy: Liddell Power Station* (Ref 4).

The assessment found that the principal bushfire hazard arises to the southwest of the site, where the vegetation is classed as dry sclerophyll forests/grassy woodlands and includes some dense trees bordering the BESS site in the southwest corner. To the north, there is existing marsh and wetland type vegetation, and, to the east, there is existing understory of both native and exotic plants and trees. The vegetation hazard to the east and north is counteracted by Lake Liddell which surrounds the project site to the east, south, and west (Ref 4).

Table 5-3 provides a summary of the data inputs used for the Bushfire Attack Level (BAL) analysis undertaken in the bushfire hazard assessment, together with the findings.

Table 5-3: Data inputs and results for BAL analysis (Ref 4)

Criteria	Direction from site: North	East	South	West
PBP 2019 Appendix 1 Vegetation Structure (Keith, 2004)	Cleared for development/ Central Hunter Ironbark grassy woodlands	Central Hunter Ironbark grassy woodlands	Central Hunter Ironbark grassy woodlands	Cleared for development/ Central Hunter Ironbark grassy woodlands
Minimum separation distance from the asset to the predominant vegetation (m)	26≤100	26≤100 (Woodland) 16-23 (Remnant vegetation)	26≤100	26≤100
Separation distance from the proposed assets to the predominant vegetation (m)	32.2	≥ 26 (Woodland) 16 (Remnant vegetation)	13	13
Effective slope	Flat	Upslope 0-5°	Upslope 0-5°	Flat
Construction of building in bushfire-prone area (AS3959-2018)	Must meet BAL: 12.5	Must meet BAL: 12.5 (Woodland) 19 (Remnant vegetation)	Must meet BAL: 12.5	Must meet BAL: 12.5

The assessment concluded that construction should adhere to BAL 12.5 standards, requiring a minimum separation of 26 m from woodland vegetation and 23 m from remnant vegetation to mitigate potential risks from ember attack and radiant heat. For areas where a separation distance of between 16 and 23 m from vegetation classified as remnant vegetation to onsite assets can be achieved, construction must comply with BAL 19 standards. PBP (2019) does not supply minimum setbacks for this specific type of development. However, based on access for firefighting and the vulnerability of the asset, the bushfire threat assessment report (Ref 4) recommends:

- At the commencement of building works and in perpetuity the Project Site shall be managed as an inner protection area (IPA) as outlined within PBP 2019 and the NSW Rural Fire Service's document *Standards for Asset Protection Zones*, including installation and maintenance of a minimum IPA of 26m width between the BESS and unmanaged vegetation. This IPA should act as APZs for the BESS and be maintained as such.

The APZs provide a buffer to avoid flame contact and radiant heat that could pose a threat to life and to the integrity of the facility's assets. This buffer will also reduce the chances of a fire escaping from the site and entering surrounding bushland.

5.2.4 Bushfire protection

The bushfire threat assessment (Ref 4) recommends the establishment of buffer zones (APZ) as discussed in Section 5.2.3 above.

The bushfire threat assessment also recommends the provision of a supply of water for combating bush/brush fires. This is discussed further in Section 6.1.1.

In addition, the report lists the following measures for consideration to protect infrastructure and equipment from the effects of bushfires:

- Establish a current Bushfire Management Plan which considers all new infrastructure and equipment as required
- All services are to be installed in accordance with Chapter 6 of PBP (2019)
- All decommissioned infrastructure (such as fuel oil tanks) to be inspected and compliant prior to construction
- All existing hazards (such as contaminated pockets of land) to be assessed formally and ensure no further bushfire hazard to proposed development
- All overhanging branches, limbs over project boundary by 2 m are to be removed and maintained
- All debris, dead vegetation and any other existing piles are to be removed. No timber or flammable material to be kept on site
- All grasslands within the Project Site are to be monitored and maintained
- Vegetation near non-perimeter and perimeter roads are to be maintained
- An Emergency Management and Evacuation Plan should be developed for the development prior to occupation
- All new construction should be to the AS3959-2018 Construction Standard of BAL 12.5.

Recommendation 1. Ensure all recommendations from the bushfire threat assessment (Ref 4) are fully considered.

Other measures which will protect infrastructure and equipment from the effects of bushfires are:

- Fluence battery energy storage equipment does not rely on air circulation within the battery enclosure. External air/ember contact the inside of the Cubes would be within the front-mounted refrigeration system, with the heat exchange components and grills being constructed of non-combustible materials. Ember attack is therefore not expected to pose a threat to the battery equipment.

5.2.5 Manual call points (fast-stop buttons and fire buttons)

Manual F-stop buttons are discussed in Section 5.2.1.

There will be a manual call point (break glass alarm) located in the Master Fire alarm panel which will allow occupants to trigger the alarm manually in the event of fire. The manual call points will sound the alarm even when the automated fire alarm system is malfunctioning or damaged.

The manual F-stop buttons and call points are to be inspected in accordance with manufacturer's recommendations.

5.2.6 Fire indicator panels

Each OCTE includes a core fire indicator panel (FIP) which protects the OCTE and its connected Cubes (Ref 34). Each row of Cubes is wired by a separate detector loop.

The Fire Command Centre (***FCC***) is an indoor enclosure located in the control room which houses the master FIPs (Ref 34). The master panels are dedicated panels linked to a panel network of a maximum of 15 core FIPs with a global view. The master panels are used as global access points to get information on the fire detection system of the entire site. The FCC is equipped with one multi-sensor fire detector, one manual pull station and a combined alarm device (sounder / light beacon) outside the cabinet.

All alarms, CO events or faults from Cubes, OCTEs and the FCC are displayed on the master panels. These master panels further act as interfaces for signal transmission to Fluence's Data Acquisition System (DAS), and to a Digital Alarm Communicator Transmitter (***DACT***) used for automatic notification of the fire service.

As shown in the Cause and Effect diagrams in Appendix 6 each Core FIP receives the following system inputs:

- Cubes:
  - Automatic fire detector (multi-sensor)
  - Carbon monoxide (CO) detector
  - Special extinguishing medium alarm
- OCTE:
  - Manual fire alarm – call point
  - Automatic fire detector (multi-sensor)
  - FACP primary 240VAC power failure

- System device wiring trouble/fault
- Open circuit/ground fault

The Core FIP carries out the following functions:

- Activates the F-Stop system
- Activates a horn/strobe (visual and audible) upon CO detection (specific sound and strobe) and fire detection (fire alarm sound and strobe) and manual pull station both at the affected Cube and at the Core
- Transmits the emergency signalling system to the master FIP.

The FIP at each OCTE includes a backup battery to provide for up to 24h monitoring of all devices, including enough power to provide at least 5 minutes power to all horn/strobe units operating at the same time, or 1h power for 4 horn/strobe units (one unit on the Core + 3 units on potentially affected Cubes), or 3h power to two horn/strobe units (one unit on the affected Cube and one unit on the Core). The UPS is fed from a 24V DC supply.

At the Liddell BESS substation, there will be a FIP located within the Auxiliary Services building which receives signals from the building's smoke and fire detectors. Alarms register at the remote Transgrid control room and automatically alert fire services.

Testing of the FIPs will be in accordance with the manufacturer's recommendations.

5.2.7 Automatic fire suppression system

There is no automatic fire suppression system proposed for the Liddell BESS Substation.

The Fluence Cubes are fitted with a thermally activated, independent condensed aerosol fire suppression system (manufactured by Stat-X) which is designed to activate at 95°C. The extinguishing agent in the FSS is potassium nitrate (KNO_3) which, on release from the cannister in a fire, acts as an oxidiser disrupting the combustion chain reaction and thus extinguishing the fire. The KNO_3 particles bind with the free radicals that sustain the fire's combustion process, producing potassium hydroxide and water.

Calculations have been undertaken by the FSS manufacturer to determine the required cannister size.

The cannisters are also fitted with an auxiliary contact to provide information to the Core FIP upon release of the agent. FSS release at a Cube triggers a F-Stop of the entire Core.

It is recognised that the suppression systems can extinguish a fire but may not stop thermal runaway or off gassing if the battery cells are damaged. Even if the fire has been extinguished and hold times have been met, the gas detection system would still be monitored locally or remotely via the SCADA in case of any subsequent events. The fire safety strategy does not rely on the Cube suppression system as shown in large scale fire testing which were performed successfully (no propagation beyond the Initiating Cube) with the suppression system disabled.

Inspection of the fire suppression cannisters are inspected to ensure that there are no signs of damage or leakage will be in accordance with the manufacturer's recommendations.

Automatic fire suppression systems (e.g. Inergen system) will be installed in the Switchrooms and the Control Room.

5.2.8 Public address systems

No Public Address (***PA***) system is proposed for the Facility.

The site has mobile phone coverage.

5.2.9 Signage

Access roads and areas within the facility will be identified by signage matching the address/grid system in a manner that is appropriate for day and night navigation. A site layout showing the locations of site infrastructure (ESS equipment, buildings, Liddell BESS Substation etc.) will be positioned at the main entrance as part of the ESIP (see Section 7.4).

A danger sign restricting access as shown in Plate 12 will be positioned at every entrance gate to the facility, to alert emergency responders to the hazard.

Plate 12: Access signage

Warning signs are displayed on the Fluence Cubes as shown in Plate 13.

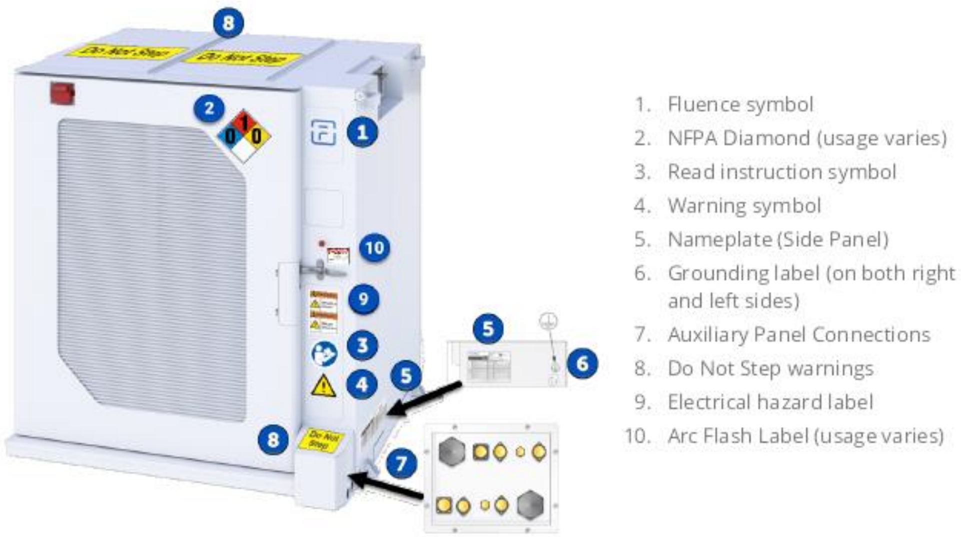


Plate 13: Warning signage on Fluence Cube

All temporary and permanent safety signage and markings for the Project will comply with AS 1319-1994. Signs warning of the following hazards will be posted as appropriate on relevant equipment/infrastructure throughout the facility:

- Electrical: arc flash and electrical shock hazards
- Fire: fire hazard and respiratory hazard – when smoke or fire is present
- Battery: toxicity and corrosive material hazards, respiratory hazard, fire and gas explosion risk, and caution – thermal runaway fire
- Coolant and refrigeration: low temperature, toxicity and respiratory hazard.

In addition, signage regarding PPE requirements and location of safety equipment will be posted at appropriate locations around the facility.

Smoking is not permitted anywhere within the BESS aside from designated area(s). No smoking signs will be installed at site entrances.

5.2.10 First-aid fire protection – fire extinguishers

Portable fire extinguishers and fire blankets to be provided and placed to meet AS2444 requirements and will be located throughout the facility to provide first response firefighting facilities including, but not necessarily limited to, the locations shown in Table 5-4.

Table 5-4: Portable fire extinguishers

Equipment location	Type	Number
All buildings	General purpose (A, B, E) CO_2	As per AS2444 requirements
Mobile plant and equipment	General purpose (A, B, E)	As per AS2444 requirements
Fuelling locations (tbd) and standby diesel generator	General purpose (A, B, E)	As per AS2444 requirements
Auxiliary Services building (Liddell BESS substation)	General purpose (A, B, E)	As per AS2444 requirements

Recommendation 2. Operators should consider training people working within the facility in the use of fire extinguishers to contain small fires before they can develop into something more serious.

Extinguishers are to be maintained in accordance with AS 1851:2012.

6 COOLING/FIREFIGHTING WATER

Using water for fire response on energised sites such as a BESS can create hazards for emergency services. Therefore, the BESS has been designed such that water is not relied upon as fire response to prevent escalation. The facility layout and BESS infrastructure are designed to minimise the risk of fire propagation and the fire response strategy for the electrical infrastructure on site is to leave fires involving this infrastructure to burn out without intervention from emergency responders. The only fires that may, at the sole discretion of first responders, receive the application of cooling/firefighting water are a bush/brush fire, or other structure fire such as in the buildings if not extinguished by site personnel using the available first aid firefighting equipment (portable fire extinguishers).

6.1 SUPPLY

6.1.1 Firewater supply

Water for firefighting will be supplied by two above ground firewater tanks. The firewater tanks will be located to the south of the Operations and Maintenance Building as shown in Figure 6-1. The tanks will be filled using the raw water supply. Refer to Recommendation 3.

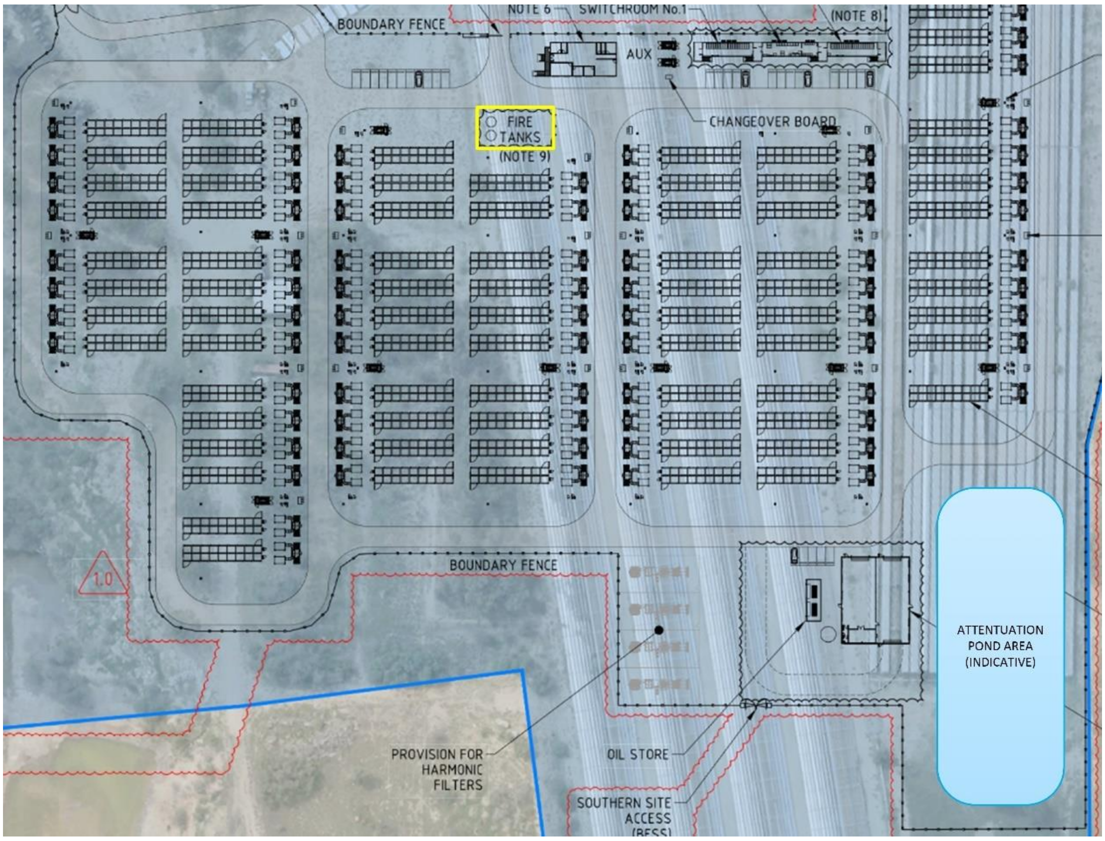


Figure 6-1: Location of dedicated firewater tanks and attenuation pond

The bushfire threat assessment (Ref 4) recommends the following acceptable solutions referenced from PBP 2019 for the provision of an aboveground static water supply:

- where no reticulated water supply is available, water for firefighting purposes is provided in accordance with Table 5.3d
- a connection for firefighting purposes is located within the IPA or non-hazard side and away from the structure
- 65 mm Storz outlet with a ball valve is fitted to the outlet
- ball valve and pipes are adequate for water flow and are metal
- supply pipes from tank to ball valve have the same bore size to ensure flow volume
- a hardened ground surface for truck access is supplied within 4 m
- above-ground tanks are manufactured from concrete or metal; raised tanks have their stands constructed from non-combustible material or bushfire-resisting timber (see Appendix F of AS 3959)
- unobstructed access can be provided at all times
- tanks on the hazard side of a building are provided with adequate shielding for the protection of firefighters
- all exposed water pipes external to the building are metal, including any fittings
- hose reels are constructed in accordance with AS/NZS 1221:1997 and installed in accordance with the relevant clauses of AS 2441:2005. (NSW RFS, 2019).

Table 5.3d of PBP 2019 (Ref 36) lists the water supply requirements for non-reticulated developments or where reticulated water supply cannot be guaranteed. While developments such as BESS are not included explicitly, the table gives a water supply requirement of 20 000 L for large rural/lifestyle lots greater than 10 000 m^2 in size. This will be considered as a minimum capacity for the BESS firewater tanks.

Recommendation 3. The developers consult with DoP, FRNSW and RFS to ensure the proposed firewater supply solution is acceptable, including the source of the water, the capacity and position of the firewater tanks.

6.1.2 Towns water

There is no site connection to towns water. Potable water for kitchen and amenities use will be supplied using rain water collection.

There are no hydrants available for use by emergency services, so any water required to combat a building or other small fire on site would need to be supplied from the firewater supply or from emergency services water tankers, should such a fire not be extinguished using the available portable fire extinguishers.

6.2 DEMAND

6.2.1 Fixed sprinklers and deluges

There are will not be any sprinkler systems within the facility including within any of the buildings on site.

6.2.2 Cooling/firefighting water

Estimating a realistic figure for firewater demand for a full-scale fire is problematic as there are many variables, e.g. weather conditions, availability of specialist firefighting resources that have the potential to have a significant effect on the amount of water required. In these circumstances, emergency services would tailor their response to make best use of the available resources including water supply.

Cooling/firefighting water is not designed to be applied at the BESS, inside the enclosures or inside of other infrastructure that forms part of the BESS as forced access to the interior of battery systems, inverters and transformers may be difficult or inadvisable for first responders, due to the hazards associated with water in electrical systems, and international deflagration and re-ignition incidents that have occurred during emergency response to BESS. Water would therefore only be required to combat bush/brush and small building fires. As discussed in Section 6.1.1, the water required for these fires will be supplied via the two dedicated firewater tanks which will be filled using the raw water supply and sized appropriately (see Recommendation 3).

6.3 CONTAMINATED FIREWATER CONTAINMENT

There is potential for residues after a fire and hence a potential for contaminated fire (cooling) water run-off. Contamination may include traces of metals, contaminants from burning plastics and contaminants from the coolant. Firewater run-off from a fire in the transformers may contain oils, greases and solid (carbonaceous) matter.

Without proper containment, this run-off could cause environmental pollution and become a potential hazard to people in the area.

Run-off from the BESS would flow into the attenuation pond, planned to be of 3500m^3 capacity, which is located between the Workshop and Storage Building and the eastern boundary of the site, as shown in Figure 6-1. The attenuation pond is designed to manage a peak outfall flow rate and during and following a rain event the water will continually flow downstream.

This pond will be managed to comply with the following:

- Managing Urban Stormwater, Soils and Construction, Volume 1 (Landcom, 2004)

- any EPL licence conditions which may be held for operations

Further, procedures outlining the management of stormwater runoff will include (but not be limited to):

- Routine and pre-discharge sampling and analysis to confirm absence of contaminants exceeding applicable criteria
- Pre-discharge confirmation of compliance with water quality performance criteria able to be analysed in real time
- The methodology for dewatering including use of amphibian friendly flocculants and pH balancing agents
- Supervision requirements
- Staff responsibilities and training
- Approvals required before any dewatering activity commences

Recommendation 4. Provide a means of rapid isolation (e.g. automatic valve) on the outlet of the attenuation pond so that contaminated run-off can be contained and tested before disposal.

Options for disposal of contaminated water would be dependent on water quality post testing at a NATA accredited laboratory. Disposal would either be by discharging the water over land within the site boundary or by pumping into trucks and transportation to a licenced facility.

6.3.1 Guidelines and requirements

The HIPAP 2 *Fire Safety Study* guidelines issued by the DoP (Ref 1) specify that a minimum of 90 minutes of firewater supply is required. FRNSW considers that this minimum supply requirement is not a basis for determining the adequacy of the firewater retention capacity as this should be based on the fire-fighting water requirements for the worst-case fire scenario.

The worst-case fire scenarios at the facility will be a bush/brush fire or a fire in one of the buildings. The planned, available retention capacity of 3500 ML in the attenuation pond is adequate.

7 EMERGENCY MANAGEMENT

7.1 EMERGENCY ALERT AND EVACUATION

Potential emergencies such as fire, explosion, release of hazardous material, bomb threat or an earthquake may require that personnel evacuate portions of, or the entire facility.

The evacuation signal for the BESS site is provided by a handheld air horn operated by the Chief Fire Warden or Fire Wardens as required.

Upon hearing the evacuation signal, all personnel are required to ensure that nearby personnel are aware of the emergency; secure any work that might otherwise become a hazard (if safe to do so); evacuate the area immediately and proceed to the designated on-site evacuation muster point and make their presence at the assembly area known to their supervisor.

All persons are responsible for reporting any missing persons to Fluence Emergency Management Team (***EMT***), who will relay this information immediately to local Emergency Response where applicable. All employees must wait in the assembly area unless directed otherwise by the Chief Warden or emergency services.

The evacuation procedure is included in the Liddell BESS Emergency Response Plan.

The Liddell BESS Substation will be unmanned.

7.2 FIRE SERVICES

Alert and call-out: Fire services will be notified manually using triple zero (000) by the operators remotely monitoring the BESS SCADA system.

Overview Cause and Effects matrices for the fire system inputs and for the BESS (Cubes and Cores) are provided in Appendix 6. The following upset conditions register as a critical alarm on panels located on-site and in the remote 24/7 monitoring centre and would alert operators to a potential emergency requiring fire services callout:

- Cube's F-Stop button pressed
- Insulation monitoring device detects low resistance (below threshold)
- Automatic fire/smoke detection (BESS, building or BESS Substation)
- Aerosol canister release in Cube
- CO detected in Cube
- Power outage in one Cube
- Power outage at a Core.

All alarms and CO events from the various devices are organised in zones and addressed in a site wide addressing system. The site-wide system can be displayed on the Core panels inside the corresponding Outdoor Core Telco Enclosures and on the master panels in the Fire Control Centre.

It is the responsibility of the Chief Warden to ensure that emergency services have been notified and to brief emergency responders on the type, scope and location of the emergency and on the progress of any evacuation.

The BESS is monitored 24/7 by operators in the remote control centre as well as the site staff having remote digital access. The Liddell BESS Substation SCADA is also monitored 24/7. In the event of process alarms, warnings and, if escalated, fire alarms the site on call representative will be notified. According to the service contract for the BESS, in the event of a critical incident such as the breakdown of core equipment the on call representative will respond within four hours.

Recommendation 5. Although fires involving Cubes, inverters or transforms do not require active fire services intervention, in the event of any fire on site (at the BESS or the BESS Substation), an appropriate site representative should be available to provide advice to FRNSW, as soon as possible on site and by phone in the interim. Contact details should be included in the ESIP.

Additionally, the fire services will be automatically notified via the Liddell BESS Substation via the substation FIP and manually notified by the operators in the remote Transgrid control room, should a fire occur within the substation.

Location and response time: The closest fire service is Fire and Rescue NSW Muswellbrook Fire Station which is approximately 18 km away from site. The closest RFS station is located at Hebden, approximately 15 km away. The local RFS control centre is located at Muswellbrook.

The closest HAZMAT FRNSW response would be called from Newcastle.

FRNSW fire stations are equipped with trained personnel and resources for dealing with hazmat incidents: each fire station receives hazardous materials awareness training and equipment to combat minor spills of hydrocarbons, gas leaks and emergency decontamination procedures[30].

First responders would be able to arrive at the BESS within about 20 minutes from receipt of the call with HAZMAT response over an hour from call.

The FRNSW and RFS would need to be escorted on site by Liddell BESS site operations.

[30] https://www.fire.nsw.gov.au/page.php?id=9191

Site access for emergency vehicles: Emergency vehicles can access the BESS via the slip-lanes from the New England Highway into an existing site access road. Alternate access is provided as described in Table 2-2.

As discussed in Section 2.3, the roads within the site have been designed and constructed to allow access for HRV, including specialist fire appliances.

7.2.1 Isolation of utilities – electricity

As per the Emergency Response Plan, de-energization of system(s) will be initiated under instruction of the Chief Warden, or other approved representative, or as requested by fire agencies.

Recommendation 6. Include the emergency isolation procedure in the Emergency Response Plan.

Primary systems can be disconnected via F-Stops with physical isolations lock-out tag-out of switchgear by trained operators.

Local isolation of battery enclosures can be competed from field can also be initiated by pressing the F-Stop buttons located at the Cubes and the OCTEs. The operation and maintenance manuals will carry all the required information related to starting, stopping, emergency shutdown in detail.

While the BESS and equipment can be isolated from the grid connection, electrical chemical energy will continue to be stored within battery enclosures and UPS systems.

7.3 Emergency management plans

To comply with Consent Condition B5, which states that a comprehensive set of emergency plans and procedures must be developed for the Liddell BESS, prior to the start of construction, Fluence have drafted the *Liddell BESS Emergency Response Plan* (Document Control Number: 0775-HAS-GEN-90-003).

The stated purpose of this plan is to describe the site emergency response and evacuation procedures to be followed by personnel at the AGL Liddell Battery Energy Storage System (BESS) located within the Liddell Power Station, NSW. This plan is intended to work together with the site owner's (AGL) Emergency Response Plan, to enable coordinated, quick, and effective responses to emergencies that might arise during project construction. As the Project progresses, this document will be revised to cover the commissioning phase of the Project.

Emergency responses will be managed by Fluence or an external emergency-response authority (e.g., police, fire, ambulance). The emergency response plan has been developed specifically for the Liddell BESS site and conforms to the requirements of the NSW Work Health and Safety Regulation 2017. Australian Standard AS 3745 – AMDT 2-2018 Planning for Emergencies in Facilities has also been referenced.

The plan is consistent with Hazardous Industry Planning Advisory Paper No. 1 - *Emergency Planning* and NSW RFS *Planning for Bushfire Protection*. The Emergency Response Plan includes, but is not limited to:

- External and key internal emergency contacts
- Site layout plan
- Emergency roles and responsibilities including general requirements, communication and training for:
  - Chief/Deputy warden
  - Emergency Response Team (wardens)
  - First aiders
  - Project Manager
  - Employees and contractors
- Access for emergency responders
- Training, including emergency drills
- Evacuation assembly areas
- Emergency notification requirements for different levels of emergency
- Emergency equipment including fire suppression and first aid equipment
- Emergency procedures including alarms, emergency services notification, site evacuation and natural disaster (including bushfires)
- Fire hazards, risks and controls including guidance on battery fire management
- After emergency actions and regulatory authority and company notification
- Testing and review

The plan also contains guidance on the management of bushfire emergencies based on the RFS fire danger ratings.

The Emergency Response Plan will cover the construction and commissioning phases of the Project. Once the BESS is handed over to the Operators, appropriate operational emergency management documentation will be developed by Fluence (as the organisation responsible for operations and maintenance) in conjunction with AGL, prior to operations commencing.

An Emergency Response Manual for the Liddell BESS Substation will be prepared using Transgrid's Substation Emergency Response Manuals Template (MNA-SUN-TEM-053). This will provide a site-specific emergency response procedure that is aligned to Transgrid's Corporate and Regional Emergency Management Plan (CREMP).

7.4 Emergency services information package (ESIP) and tactical fire plans (TFPs)

As required by FRNSW, AGL-LB must develop an emergency services information package and tactical fire plans as part of their emergency planning obligations. These are to be developed in line with the requirements of the FRNSW *Emergency services information package and tactical fire plans* guideline.

As stated in the guideline, the function of an ESIP is to provide firefighters and other emergency services with information that they require to effectively manage a fire or other emergency incident, and to provide guidance to the FRNSW incident commander on specific, safety critical tasks such as evacuation and emergency shutdown. The ESIP should be complete, self-contained and portable.

The ESIP and tactical fire plans are yet to be develop, but in line with the guideline they will contain:

- Site overview
- Emergency and other contacts
- A site layout plan showing emergency assembly points and the location of emergency equipment
- Evacuation overview
- Tactical checklists listing the tasks that will need to be undertaken to manage the hazard scenarios that have been identified for the Facility
- A hazardous chemicals list
- Firefighting guidance, including management of electrical hazards, toxic and flammable gas emissions from LFP batteries and thermal runaway
- Tactical fire plans: TFPs are colour coded drawings that visually display the installed fire safety systems and other essential features that are critical in managing a fire or other emergency incident.

Once developed, copies of the ESIP including TFPs will be available on site at designated emergency site access point.

Recommendation 7. To meet the requirements of FRNSW, the ESIP and TFPs must be developed prior to commencement of commissioning activities.

7.4 First Responder Safety Guide

Fluence have developed a safety guide (Ref 37) to provide general information on the Fluence battery energy storage system and guidance on hazards and managing fires emergencies arising from those hazards.

The Safety Guide contains the following three sections which cover:

1. Overview:

- Equipment examples
- Battery types
- Thermal runaway
- Safety systems

2. Hazards:

- Chemical and toxicity hazards
- Electrical hazards
- Fire and explosive hazards

3. Fire management:

- Before entering the site
- Site emergency action plan
- Fire management tactics
- Protection of exposures
- Fire decay

8 SIGNIFICANT CODES AND STANDARDS

The statutory framework, codes and standards that apply to ensuring the safety of a BESS installed in Australia are listed below.

Type	Title
Acts and Regulations	NSW Work Health and Safety Act 2011 and Regulation 2017
	NSW Environmental Planning and Assessment Act 1979 and Regulations 2000
	NSW Electricity Supply Act 1995, Electrical Supply (General) Regulation 2014 and Electricity Supply (Safety and Network Management) Regulation 2014
Governmental Policy and guidelines	Fire Safety guideline, 2011 (HIPAP2, Ref 1)
	Planning for Bushfire Protection, 2019
Australian Standards	AS/NZS 5139:2019 Electrical installations — Safety of battery systems for use with power conversion equipment
	AS 1939:1990 Degrees of protection provided by enclosures (IP Code)
	AS/IEC 62619:2017 Safety requirements for secondary lithium cells and batteries, for use in industrial applications
	AS 61508:2011 Functional safety of electrical/electronic/programmable electronic safety-related system
	ASC/ESC 5000 The Australian Battery Guide by the Energy Storage Council
	AS/NZS 1170.2:2011 (R2016) Structural design actions - Wind actions
	AS 1307.2:1996 (R2015) Surge arresters Metal-oxide surge arresters without gaps for a.c. systems
	AS 1603:2018 Automatic Fire Detection and Alarm Systems AS 1670.1:2018 Fire detection, warning control and intercom systems: System design, installation and commissioning, Part 1: Fire AS 1670.3:2018 Fire detection, warning control and intercom systems: System design, installation and commissioning, Part 3: Fire alarm monitoring AS 1670.4:2018 Fire detection, warning control and intercom systems: System design, installation and commissioning, Part 4: Emergency warning and intercom systems AS 1670.5:2016 Fire detection, warning control and intercom systems: System design, installation and commissioning, Part 5: Special hazards systems AS 1670.6:1997 Fire detection, warning control and intercom systems: System design, installation and commissioning, Part 6: Smoke alarms AS 4428 suite of standards:1998-2020 Fire detection, warning, control and intercom systems
	AS/NZS 1851:2012 Maintenance of fire protection equipment AS/NZS 1850:2009 Portable fire extinguishers AS 2444:2001 Portable fire extinguishers and fire blankets: Selection and location

Type	Title
	AS/NZS 1768:2007 Lightning protection
	AS 2067:2016 Substations and high voltage installations exceeding 1 kV a.c.
	AS 2374.1:2003 Power transformers Part 1: General
	AS 3000:2018 Australian Wiring Rules
	AS 3008:2017 Electrical installations – Selection of cables
	AS/IEC 60076.1:2014 Power transformers general EN 50588-1:2015 Medium power transformers 50Hz
	AS/IEC 61869.2:2021 Instrument transformers, Part 2: Additional requirements for current transformers AS/IEC 61869.3:2021 Instrument transformers, Part 3: Additional requirements for inductive voltage transformers
	AS/IEC 62271 suite of standards:2008-2023 HV switchgear and control gear
	AS/NZS 1429.1:2000 Electric cables - Polymeric insulated for working voltages 1.9/3.3 (3.6) kV up to and including 19/33 (36) kV
	AS 1824.2-1995 Insulation coordination (phase-to-earth and phase-to-phase, above 1 kV) Application guide
	AS 1940:2017 amendment 2:2021 The storage and handling of flammable and combustible liquids IEC 60296:2020 Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment
Other, for Buildings and site	National Construction Code, 2019 AS/NZS 1680.2.4:2017 Interior lighting - Industrial tasks and processes AS 2293.1:2018 – Emergency escape lighting and exit signs for buildings AS 1668.1:2015 The use of ventilation and air conditioning in buildings - Fire and smoke control in buildings AS 1668.2:2012 - The use of ventilation and air conditioning in buildings - Mechanical ventilation in buildings
Other Codes, for reference	NFPA 855:2019 Standard for the Installation of Stationary Energy Storage Systems NFPA 68:2018 Standard on Explosion Protection by Deflagration Venting
	IEC 61439-2:2020 Low-voltage switchgear and control gear assemblies - Part 2: Power switchgear and control gear assemblies
	IEC 62477-1:2022 Safety requirements for power electronic converter systems and equipment - Part 1: General
	IEEE 80 – 2013 Guide for Safety in AC Substation Grounding IEEE 293 – 2018 Recommended Practice for Seismic Design of Substations
Testing and evaluating BESS	UL 9540 Standard for Energy Storage Systems and Equipment, for the basis for documenting and validating the safety of an ESS as an entire system or product UL 9540 A Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems, for a test method for evaluating thermal runaway propagation in battery ESS

9 STATUS OF DESIGN VERSUS FINDINGS AND RECOMMENDATIONS IN THE PRELIMINARY HAZARD ANALYSIS

In accordance with Condition B2(b) in the instrument of approval, a verification that the final design is consistent with all findings and recommendations in the Preliminary Hazard Analysis dated 25 March 2021. Only those findings and recommendations that are relevant for the scope of the present FSS are covered here, i.e. the BESS and the Liddell BESS Substation. Those recommendations that relate to the Bayswater ancillary works are not included.

Recommendation and finding in the PHA dated 25 March 2021	Detailed design status	Verified as consistent with PHA (YES / NO)
PHA1. A detailed bushfire threat assessment is conducted for the Project, including establishment of an APZ, in consultation with the Rural Fire Service (RFS)	A detailed bushfire threat assessment is conducted for the Project, including establishment of an APZ. This is discussed in Section 5.2.3 and 5.2.4. Recommendation 3 in this Fire Safety Study relates to further consultation with RFS.	YES
PHA2. The separation distance between infrastructure within the Battery[31] is determined in accordance with Codes and Standards and manufacturer's recommendations so that the preferred strategy of allowing a fire in one battery enclosure or inverter to burn without the risk of propagating to other infrastructure can be maintained without the need for external firefighting	Table 4-11 lists the clearances between the battery Cores and other infrastructure with the facility together with compliance to relevant Codes and Standards	YES
PHA3. The separation distance within the Battery is determined in accordance with Codes and Standards and manufacturer's recommendations to allow safe escape in case of a fire	While it is noted that the BESS is outside the scope of AS/NZS 5139 (2019), paragraph 6.2.5.4a[32] sets the minimum requirement for clearance for unimpeded access on the working side of the battery enclosure to 900 mm with the doors open. This is adhered to in the BESS, with a minimum of 1.2 m with doors opened.	YES

[31] The term *Battery* was used in the Environmental Impact Statement and the PHA to define the BESS

[32] Clearance can be reduced to 600mm in circumstances not applicable to the Liddell BESS

Recommendation and finding in the PHA dated 25 March 2021	Detailed design status	Verified as consistent with PHA (YES / NO)
PHA4. All relevant requirements in the new AS5139 (2019) are adhered to at the Battery. Adherence to requirements in international standards are also considered, for example to the US NFPA 855(2020) Code. Further, consider procurement of a battery system that is certified to UL 1642, UL 1973, IEC 61427-2 and IEC 62619	The BESS is outside the scope of AS/NZS 5139 (2019) and hence not relevant to the FSS. Separation distances between ESS infrastructure and between the ESS and other infrastructure and equipment comply with US NFPA 855(2020). The Li-ion battery cells, modules and Cubes are non-propagating as per UL 9540A and BDBT.	YES
PHA5. The need for active firefighting requirements at the Battery and at the waste storage area is determined in consultation with RFS and the DoP, e.g. in the form of firewater tanks and connections to the RFS. Detailed firefighting response and any need for fire water containment should be assessed and reported (e.g. in the format of a Fire Safety Study) post development approval, for review by the DoP, NSWFR and the RFS	As discussed in Section 6.	TBC
PHA6. The health and safety associated with EMF on the site and the potential exposure to EMF are considered for AGL-LB staff and contractors as part of AGL-LB's obligations for their health and wellbeing under the WHS Regulations	This is outside of the scope of the FSS	N/A
PHA7. Measures to prevent a leak from occurring at the Battery, and for secondary containment should a leak occur, is addressed in the detailed design phase for the Project	This is outside of the scope of the FSS	N/A
PHA8. The register of commitment (Appendix 1 of the PHA) is integrated into the management for the Project. This includes integration of 84 individual commitments, including for the design, installation and maintenance of the BESS	Evaluation is provided in Appendix 5.	YES

10 Conclusions and Recommendations

The BESS site has a relatively low fire potential with no flammable material stored, handled or produced and with a high degree of control of the batteries, including automated shut-down.

The fire prevention and protection measures at the BESS reflect the current state of the art for such facilities. The firefighting strategy involves automatic initiation of fire suppressants inside the battery Cubes, which, together with appropriate separation between Cubes and other equipment and infrastructure mitigates the need for active firefighting intervention by emergency services should a fire occur in a battery enclosure.

Firefighting water for non-electrical fires is provided by two aboveground firewater tanks filled using the raw water supply.

If a major fire did occur on the BESS, despite the extensive preventative and protective features available for this development, the APZ is likely to prevent the initiation of a fire in the surrounding bushland from heat radiation from the fire. Ember attack may still occur, however the site infrastructure, including the Cubes, are of design and construction that minimises the likelihood of fire starts from embers.

Given that the toxic combustion products from a BESS fire are likely to be similar to those from a building fire, such as one involving construction plastics or mattresses, current understanding is that the consequences to surrounding land use, including to residential areas, are unlikely to be hazardous and, while the fire is likely to evolve acrid smoke and soot causing hazard to people nearby on the site, the fire plume is likely to be similar to that from a fire involving a house or building.

A precautionary approach to potential toxic exposure is recommended, including:

- evacuating persons not involved in emergency response from the site
- fire fighters should wear protective equipment and breathing apparatus in the field when getting close to burning or smoking battery fires
- decisions regarding evacuation of the local community should be at the discretion of the emergency services and should be based on real-time atmospheric monitoring.

The Fire Safety Study has demonstrated that the fire safety strategy at the BESS is appropriate for the specific fire hazards associated with the site, as developed at the detailed design stage of the Project.

Recommendations

The recommendations are summarised in Table 10-1.

Table 10-1 Summary of recommendations

Recommendation	Status	Implementation
1. Ensure all recommendations from the bushfire threat assessment are fully considered.	accepted	The bushfire threat assessment, including recommendations, has been considered in the detailed design of the BESS
2. Operators should consider training people working within the facility in the use of fire extinguishers to contain small fires before they can develop into something more serious.	accepted	This will be considered once the construction phase is completed
3. The developers consult with DoP, FRNSW and RFS to ensure the proposed static firewater supply solution is acceptable, including the source of the water, the capacity and position of the firewater tanks	accepted	Consultation has taken place, and the firewater tank design is currently underway
4. Provide a means of rapid isolation (e.g. automatic valve) on the outlet of the attenuation pond so that contaminated run-off can be contained and tested before disposal	accepted	This FSS has been provided to the designers for consideration on how to achieve this
5. Although fires involving Cubes, inverters or transforms do not require active fire services intervention, in the event of any fire on site (at the BESS or the BESS Substation), an appropriate site representative should be available to provide advice to FRNSW, as soon as possible on site and by phone in the interim. Contact details should be included in the ESIP.	accepted	24/7 remote monitoring and response processes are aimed at minimising delays in responding to emergencies, independent of the SLA timeframes. Contact details will be included the ESIP.
6. Include the emergency isolation procedure in the Emergency Response Plan.	accepted	This will be included in the ongoing development of emergency plans
7. The Fire Safety Study should be updated if any changes to the site layout or to the battery modules, ESS designs or model are proposed	accepted	Management of change process will include updating of the FSS when necessary

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Planager
Risk Management Consulting

Appendix 1

Hazard Identification Word Diagram

FSS, AGL Energy Liddell Battery Energy Storage System

Planager
Risk Management Consulting

Appendix 1 – Hazardous Identification Word Diagram

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
1. Fire in the Cube (battery enclosure) caused by internal event: *Thermal event*: Electrical fire within the Cube or excessive heating in the cell (overcharge/ over-discharge) *Thermal event*: Fire in combustible material within the Cube *Mechanical event*: Piercing, impact, crushing, vibrations (maintenance / testing / installation, and then put into operation) *Electrical event*: Overcharging or over-discharging battery, exceeding cell rating	Generation of heat, toxic gases and toxic combustion products Thermal runaway reaction inside the cell Can evolve to rapid flashover and potentially deflagration if combustion products are not vented If the negative electrode gets in contact with water or humidity, hydrogen gas can be formed which may ignite Possible escalation to involve other battery racks in the Cube, adjacent Cubes with more and more heat and toxic combustion products evolved Possible injury from heat and toxic combustion products	*Prevention:* - Safety In Design incl. equipment & systems designed & tested to comply with relevant Standards and guidelines incl. Factory Assurance Testing and Site Assurance Testing (**FAT** and **SAT**) - Selection of battery cell chemistry to minimise runaway, heat insulation at cell level - Equipment procured from supplier (Fluence) with proven track-record, installed by reputable contractors following AGL's requirements for contractor management, permits, control of modification, Induction etc. - Siting & design minimises mechanical impact incl. traffic management (speed limits, barriers, warning signs), robust outer casing of Cubes, fenced & secured area, CCTV cameras - Battery rack cooling using liquid coolant (50:50 ethylene glycol and water) and chiller - HVAC system provides additional cooling inside Cube *Detection and automatic shut-down:* - BMS including voltage control, charge/ discharge current control and temperature monitoring with automatic safety shut-off function in case of safe limits exceeded - Electrical protection against ground faults, short circuits, surges (fuse / circuit breaker) and lightning protection (to AS 2067, AS/NZS 1768, AS/NZS 3000) - Preventative Maintenance (PM) tests (e.g. thermography or other) as per scheduled maintenance in line with manufacturer's specifications to identify precursor of malfunction, carried out by or on behalf of AGL - Each Cube fitted with multi-criteria detector (CO, smoke, temperature) with I/O interface between Core level fire panel, fire suppression system, HVAC and chiller cooling system (all devices UL and EN/IEC listed per applicable Codes and Standards) and horn/strobe device to identify affected Cube - Each Core is fitted with a fire panel, horn/strobe device to identify the Core containing the affected Cube and manual pull station. Core level devices are in the Core telco enclosure.

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
	Possible environmental pollution from firefighting / cooling water	- Automatic F-stop system at Cube and Core level *Protection and limitation to prevent escalation:* - Each Cube is fitted with an independent, thermally activated fire suppression system (FSS), - The roof of each Cube roof is fitted with 2 tethered deflagration panels designed using data from UL 9540A - Cubes are lockable with fitted disconnect switch and open-door sensor which is closed via gas spring damper and sliding door lock. If access is required, then it is done under a Permit - Fire resistance of Cube through use of non-combustible construction material and fire resistant sides, roof and floor (via rock wool) - Minimising generation of toxic combustion products through use of non-combustible construction material - Site layout includes separation distances between nodes to minimise escalation between Cubes - Facility is located in an open area, minimising the risk of accumulation / ingress of toxic combustion products *Emergency response:* - Automatic activation of local emergency shutdown (F-stop) - Access/egress within BESS allows for emergency services access and evacuation - Emergency Management Plan and Emergency Response Procedures
2. Fire in a Cube (battery enclosure) caused by external event: *Thermal event:*	As above	*Prevention* - As per Scenario 1. plus: - APZ defined to prevent escalation to nearby bushland - Wind design: Cubes are designed to withstand a max. windspeed of approximately 220km/h

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
Site fire including at adjacent Cube/Core, bushfire Environmental conditions outside safe envelope *Mechanical event:* Damage from excessive wind / flood / security breach / vehicle impact or damage *Electrical event*: Short-circuit due to water ingress (rain, flood, firewater) or lightning strike		- Flood and storm water: Site drainage system designed to control and manage flows to protect Site infrastructure, Site soil and water management plan, concrete pads elevate Site infrastructure above ground level to manage mitigate effects of a probable maximum flood event - Water ingress: Cubes are IP55/NEMA 3R rated, roof is sloped, doors fitted with integrated drip edge - Security breach: Security fence installed on Site perimeter, all access to site is controlled, CCTV - Impact: limited Site access, internal access roads, reduced Site speed limits - Water ingress: Cubes, inverters are IP55/NEMA 3R rated, Cube roof is sloped, doors fitted with integrated drip edge - Lightning protection will be installed in accordance with the Australian Standards requirements AS 1768:2021 *Lightning protection.* *Detection and automatic shut-down:* - As per Scenario 1. *Protection and limitation to prevent escalation* - As per Scenario 1. plus: - APZ defined to prevent escalation to nearby bushland *Emergency response:* - As per Scenario 1.
3. Fire or arc flash at transformers, inverters: Fire involving oil in the due to ignition of spilled liquid (burst tank, overfilling etc.) or overheating	Generation of heat and harmful / irritant combustion products Arc flash may produce pressure wave, intense light, noise and heat	*Prevention:* - Equipment and systems designed and tested to comply with the relevant international standards and guidelines; procured from reputable suppliers; and installed by reputable contractors following AGL's internal requirements for contractor management (incl. Contractor management, permits, control of modifications, induction of all personnel prior to work etc.) - Maintenance and isolation procedures (e.g. lock-out/tag-out) - Preventative maintenance schedule established and monitored (including of insulation)

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
Damage from external event (e.g. bushfire, wind, lightning) Damage from internal event e.g. arc flash[33] Damaged / faulty switchgear, transformer, cables	Possible escalation to involve nearby combustible material Possible injury/fatality from heat generation and exposure to toxic combustion products Environmental pollution from release of pollutant Propagation to adjacent infrastructure (e.g. oil storages) and domino effects and further fire, release of toxic combustion products Exposure to intense light and noise	- Transformers and inverters are in located designated area - Combustible transformer oil is not readily ignited - Switchgear and earthings / earths are designed, manufactured and tested according to Code requirements - Electrical switching procedures - Electrical protection against ground faults, short circuits, surges (fuse / circuit breaker) and lightning protection (to AS 2067, AS/NZS 1768, AS/NZS 3000) - Circuit breakers - Flood and stormwater: as per Scenario 2 - Water ingress: Inverters and transformers are IP55/NEMA 3R rated. - Lightning protection: as per Scenario 2 *Detection and automatic shutdown:* - Preventative maintenance and condition monitoring (e.g. insulation, replacement of faulty equipment) including oil analysis as per maintenance schedule and continuous online monitoring of a number of parameters of the transformer (with alarm if safe limits are exceeded, for operator response). Regular visual inspection. - Dedicated circuit breakers, earth switch and disconnector *Mitigation:* - Warning signs (arc flash boundary) - MV Inverter transformers installed with 110% oil containment

[33] Note: An arc produced by flow of electrical current through ionized air after initial flashover or short circuit, resulting in a flash that can cause significant heating and burn injuries to occur. Arc flash may result in rapid rise in temperature and pressure in the air between electrical conductors, causing an explosion known as an arc blast

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
		- Separation distance to adjacent infrastructure in accordance with Code requirements. APZ established and maintained - Use of appropriate PPE for flash hazard *Emergency response:* - Fire Management procedures and Emergency Response Plan - Access/egress within BESS allows for emergency services access and evacuation
Fire involving oil in the transformers due to ignition of spilled liquid or overheating in the transformer	Generation of heat and harmful / irritant combustion products Possible escalation to involve nearby combustible material Possible injury/fatality from heat generation and exposure to toxic combustion products Environmental pollution from firefighting / cooling water	*Prevention (of loss of containment and of ignition):* - Oil overflow interceptor and water displacement mechanism - Water level sensor - Combustible oil is not readily ignited *Detection and automatic shutdown:* - Transformer alarm due to pressure relief device or the winding/oil temperature trip activation sent to FIP and triggers Core F-Stop *Mitigation:* - Transformers are bunded with 110% oil capacity containment - Bunds are fitted with oil separators - Separation distance to adjacent infrastructure in accordance with Code requirements *Emergency response:* - Fire Management procedures and Emergency Response Plan

Possible threats	Potential consequences (un-mitigated)	Preventative and mitigative safeguards
4. General fires, e.g. involving combustible construction material or plastics associated with electrical cabling, e.g. initiated by electrical fires, failure to manage hot work, malicious act, failure of preventative maintenance etc. Includes fires within the buildings.	Generation of heat and harmful / irritant combustion products Possible escalation to involve nearby combustible material Possible injury/fatality from heat generation and exposure to toxic combustion products Environmental pollution from firefighting / cooling water	*Prevention:* - Compliant wiring to ensure conductors can sustain some levels of short circuit - High speed fuses used - Preventative maintenance - Housekeeping - Security - Design to Code requirements - Permit To Work process in place for hot work *Detection:* - Smoke detection in the O&M room and the Auxiliary Services building *Emergency response:* - Extinguishers - Access/egress within buildings allows for emergency services and evacuation - Fire Management Plan and Emergency Response Plan - APZ defined to prevent escalation to nearby bushland

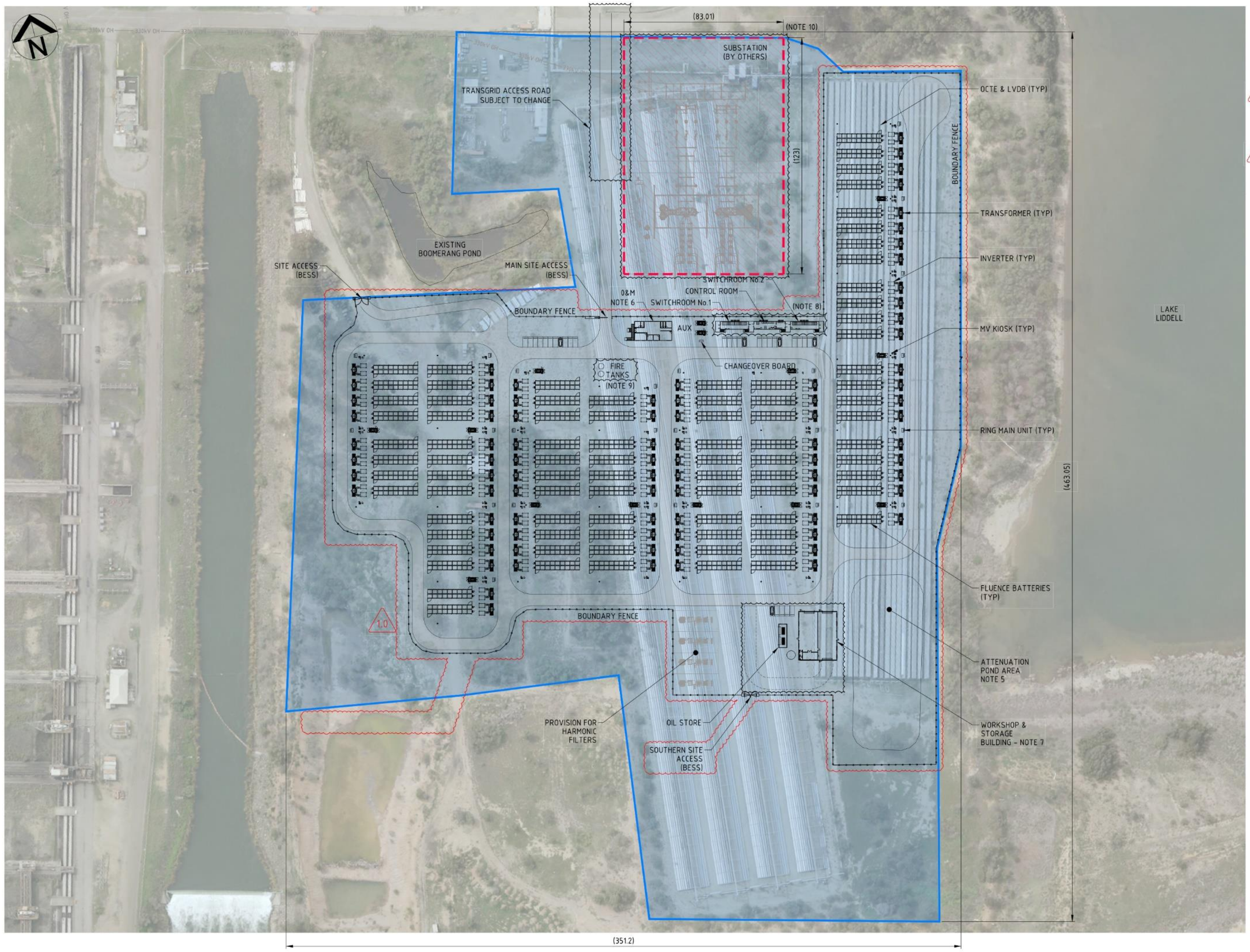
Appendix 2

Site drawings

FSS, AGL Energy Liddell Battery Energy Storage System

Appendix 2 – Site drawings

1. Site layout
2. Liddell BESS Substation layout
3. Block layout plan
4. Buildings
5. Fire services plan



PLAN

SCALE 1:1000

NOTES:

1. DRAWINGS COLOUR CODED. MUST PRINT COPIES IN COLOUR.
2. ALL DIMENSIONS ARE IN METRES (m) UNLESS NOTED OTHERWISE.
3. SURVEY DATUM: GDA 94/MGA ZONE 56.
4. ALL DIMENSIONS, QUANTITIES AND LEVELS SHALL BE VERIFIED ON SITE PRIOR TO CONSTRUCTION.
5. ACCESS ROADS AND ATTENUATION POND AREA SHOWN INDICATIVELY REFER CIVIL DESIGN FOR DETAILS.
6. O&M BUILDING DETAILS TO BE CONFIRMED FOLLOWING VENDOR DRAWINGS.
7. WORKSHOP & STORAGE BUILDING SIZE TO BE CONFIRMED FOLLOWING CONFIRMATION OF SPARE PARTS LIST.
8. SWITCHROOM AND CONTROL BUILDINGS TO BE CONFIRMED FOLLOWING VENDOR DESIGN.
9. FIRE WATER TANKS AND ASSOCIATED EQUIPMENT TO BE CONFIRMED FOLLOWING DETAILED DESIGN.
10. TRANSGRID SUBSTATION FOOTPRINT TO BE CONFIRMED FOLLOWING RECEIPT TRANSGRID DESIGN.

LEGEND:

- BESS AREA BOUNDARY FENCE
- SUBSTATION FENCE (TRANSGRID)
- 330kV OH — PROPOSED 330kV OVERHEAD LINE (BY OTHERS)
- DEVELOPMENT BOUNDARY
- ACCESS ROADS (NOTE 5)
- SUBSTATION BENCH

20 10 0 20 40
1:1000 (m)

ISSUED FOR USE
30.09.2024

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
1.0	30.09.2024	ISSUED FOR USE	GH	MN	JS	BM
0.3	20.08.2024	RE-ISSUED FOR REVIEW	GH	MN	JS	BM
0.2	17.06.2024	ISSUED FOR REVIEW	GH	MN	JS	BM
0.1	18.04.2024	ISSUED FOR REVIEW	GH	MN	PH	BM

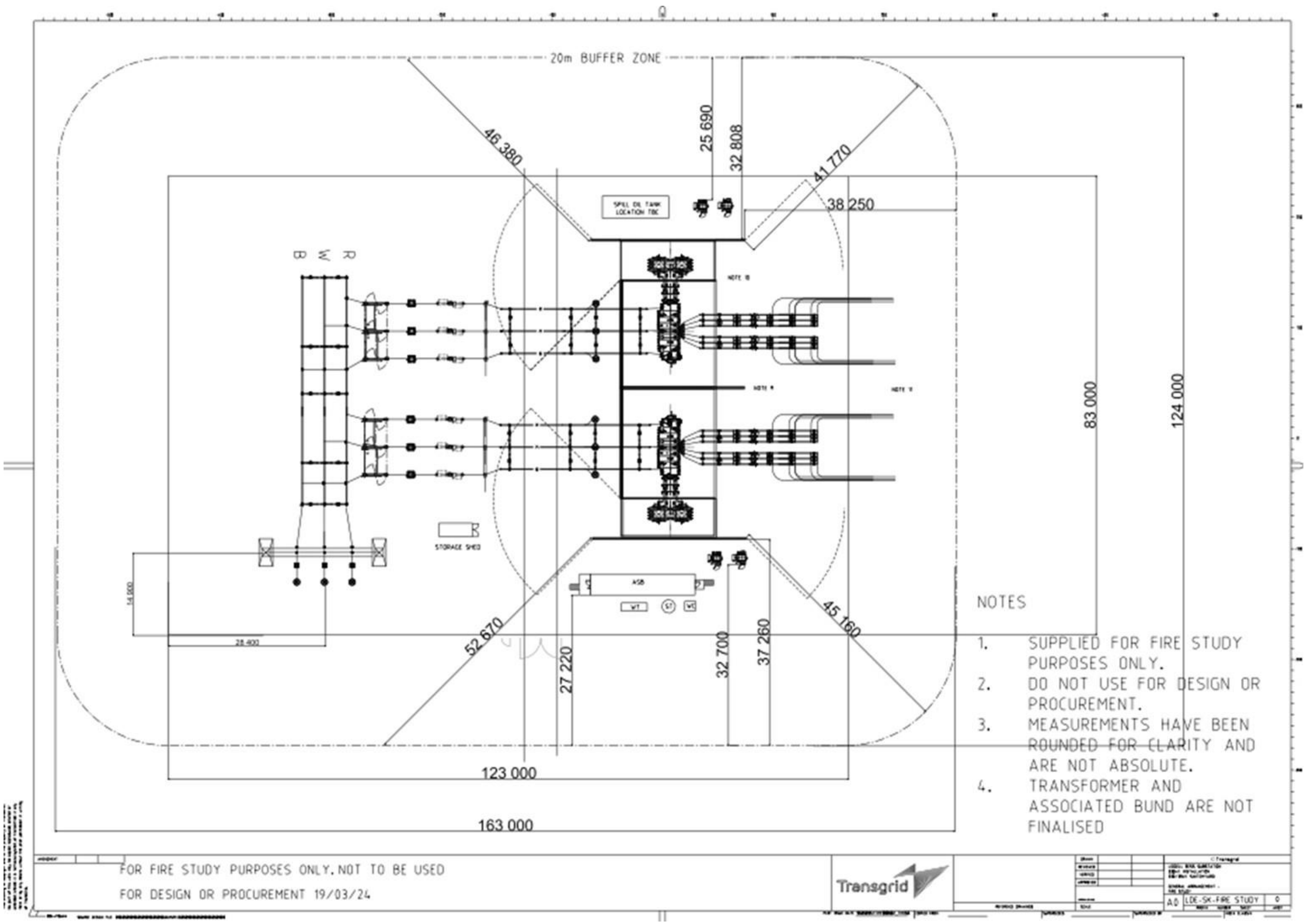
CLIENT: agl / FLUENCE (A Siemens and AES Company)

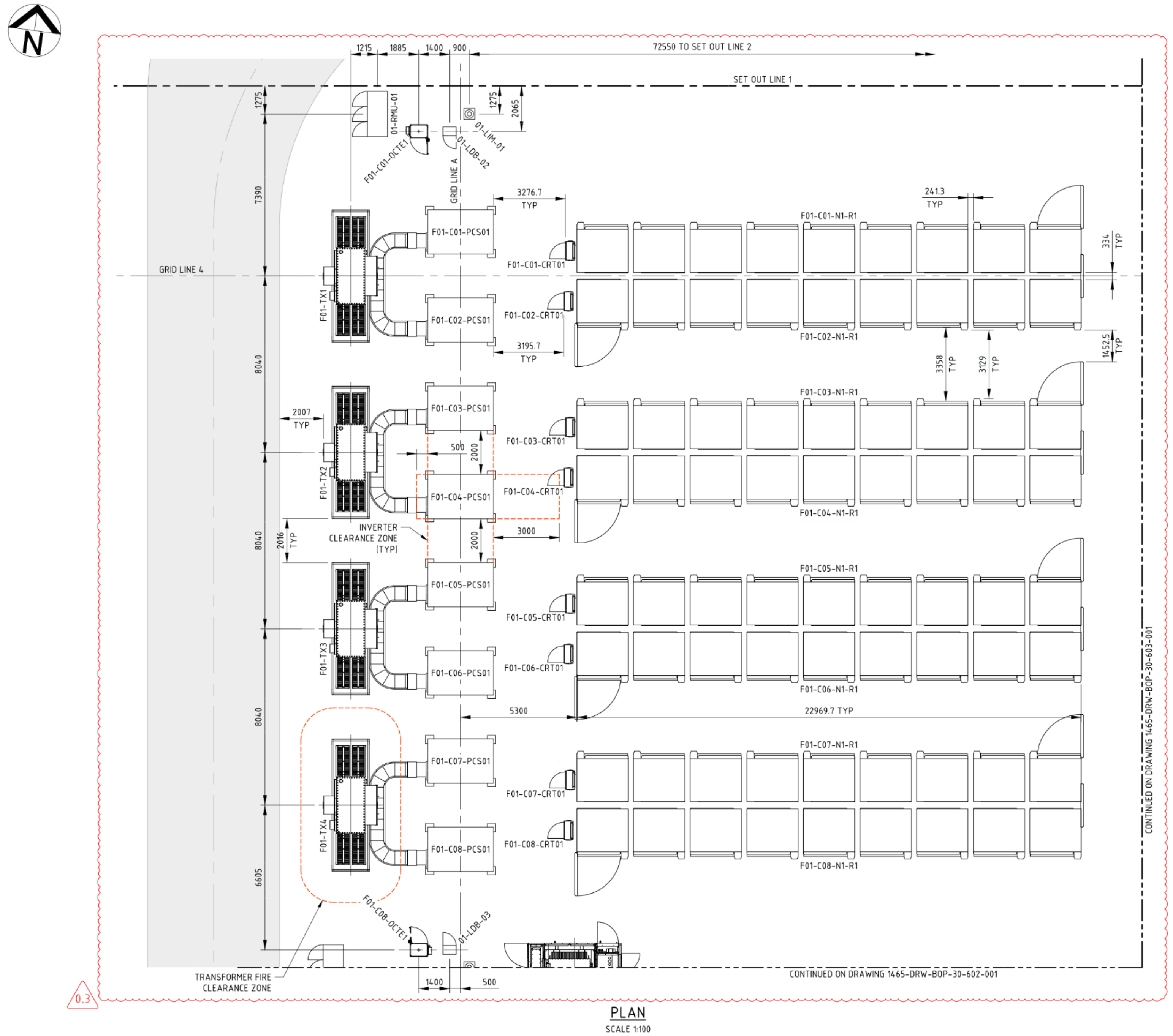
ENERVEN PROJECT No: ENERVEN™

	NAME	DATE
DESIGNED	G. HALLIDAY	18.04.2024
REVIEWED	M. NEWTON	18.04.2024
APPROVED	P. HAFFNER	18.04.2024
AUTHORISED	B. MARTINS	18.04.2024

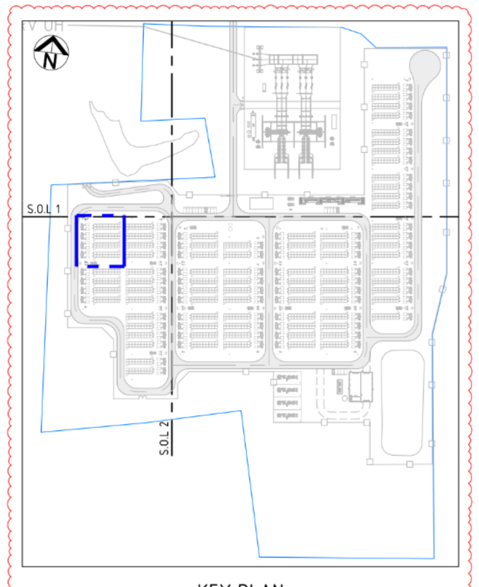
LIDDELL BESS
SITE PLAN
SATELLITE OVERVIEW

SIZE: A1 | DRAWING NUMBER: 1456-DRW-BOP-00-000-002 | REVISION: 1.0


20m BUFFER ZONE
46 380
25 690
32 808
41 770
38 250
SPILL OIL TANK LOCATION TBC
R
W
B
STORAGE SHED
83 000
124 000
52 670
27 220
32 700
37 260
45 160
123 000
163 000
NOTES
1. SUPPLIED FOR FIRE STUDY PURPOSES ONLY.
2. DO NOT USE FOR DESIGN OR PROCUREMENT.
3. MEASUREMENTS HAVE BEEN ROUNDED FOR CLARITY AND ARE NOT ABSOLUTE.
4. TRANSFORMER AND ASSOCIATED BUND ARE NOT FINALISED
FOR FIRE STUDY PURPOSES ONLY. NOT TO BE USED
FOR DESIGN OR PROCUREMENT 19/03/24
Transgrid
A0
LDE-SK-FIRE STUDY



PLAN
SCALE 1:100



KEY PLAN
SCALE 1:2500

NOTES:

1. DRAWINGS COLOUR CODED. MUST PRINT COPIES IN COLOUR.
2. FOOTINGS HAVE BEEN OMITTED FOR CLARITY PURPOSES.
3. TRANSFORMER FIRE EXCLUSION ZONE AS PER AS2067 2016 TABLE 6.1 G1 = 1.5m.
4. REFER FLUENCE DOCUMENT 1456-HAS-GEN-17-001.02 - BATTERY CUBE RISK ASSESSMENT FOR DETAILS REGARDING RISK MANAGEMENT AND CONTROL MEASURES FOR ACCESS/EGRESS BETWEEN CUBE ROWS.
5. APPROPRIATE SIGNAGE ON CUBE DOORS SHALL BE INSTALLED INLINE WITH THE REQUIREMENTS OF FLUENCE DOCUMENT 1456-HAS-GEN-17-001.02 - BATTERY CUBE RISK ASSESSMENT.
6. RMU DOOR ARRANGEMENT IS TO BE CONFIRMED PENDING SIEMENS DETAILED DESIGN.

EQUIPMENT LIST

ITEM DESCRIPTION	MANUFACTURER	QTY	DRAWING No.
RING MAIN UNIT	SIEMENS	1	8DJH36-51118
CORE TRANSFORMER	WILSON	4	879-2402C-A REV 0
INVERTER	POWER ELECTRONICS	8	HEMK-DU-FUSIBLES
LV DISTRIBUTION BOARD	TO BE CONFIRMED	2	TO BE CONFIRMED
OCTE	FLUENCE	2	06-05-0131-DRW-011 & 012
BATTERY CUBE	FLUENCE	72	0000-DRW-BSC-00-019
CUBE ROW TERMINATION	FLUENCE	8	0054-DRW-FLN-CRT-17-1010
LIGHTNING MAST/LIGHT POLE	TO BE CONFIRMED	1	TO BE CONFIRMED

1:100 (m)
1:2500 (m)

NOT FOR CONSTRUCTION
24.09.2024

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
0.3	24.09.2024	RE-ISSUED FOR REVIEW	GH	MN	JS	BM
0.2	17.06.2024	RE-ISSUED FOR REVIEW	GH	MN	JS	BM
0.1	13.05.2024	ISSUED FOR REVIEW	GH	MN	PH	BM

CLIENT: agl FLUENCE (A Siemens and AES Company)

ENERVEN PROJECT No: ENERVEN

	NAME	DATE
DESIGNED	G. HALLIDAY	13.05.2024
REVIEWED	M. NEWTON	13.05.2024
APPROVED	P. HAFFNER	13.05.2024
AUTHORISED	B. MARTINS	13.05.2024

LIDDELL BESS
EQUIPMENT LAYOUT
BLOCK 01

SIZE: A1
DRAWING NUMBER: 1456-DRW-BOP-30-601-001
REVISION: 0.3

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS OTHERWISE NOTED.
2. BUILDING DESIGN SHALL INCORPORATE CRANE LIFTING POINTS AND BE SUITABLE FOR ROAD TRANSPORT.
3. FLOOR TO CEILING HEIGHT SHALL BE 3000mm.
4. ALL CABLE ENTRIES SHALL BE BOTTOM ENTRY THROUGH FLOOR PENETRATIONS/GLAND PLATES.
5. BUILDING TO HAVE GUTTERS AND DOWN PIPES FITTED.
6. EXTERIOR COLOURS TO BE DETERMINED.
7. ACCESS RAMP & PLATFORM TO HAVE HANDRAILS, ETC AS REQUIRED.
8. WATER TANK REQUIREMENT TO BE DETERMINED.

ELECTRICAL NOTES:

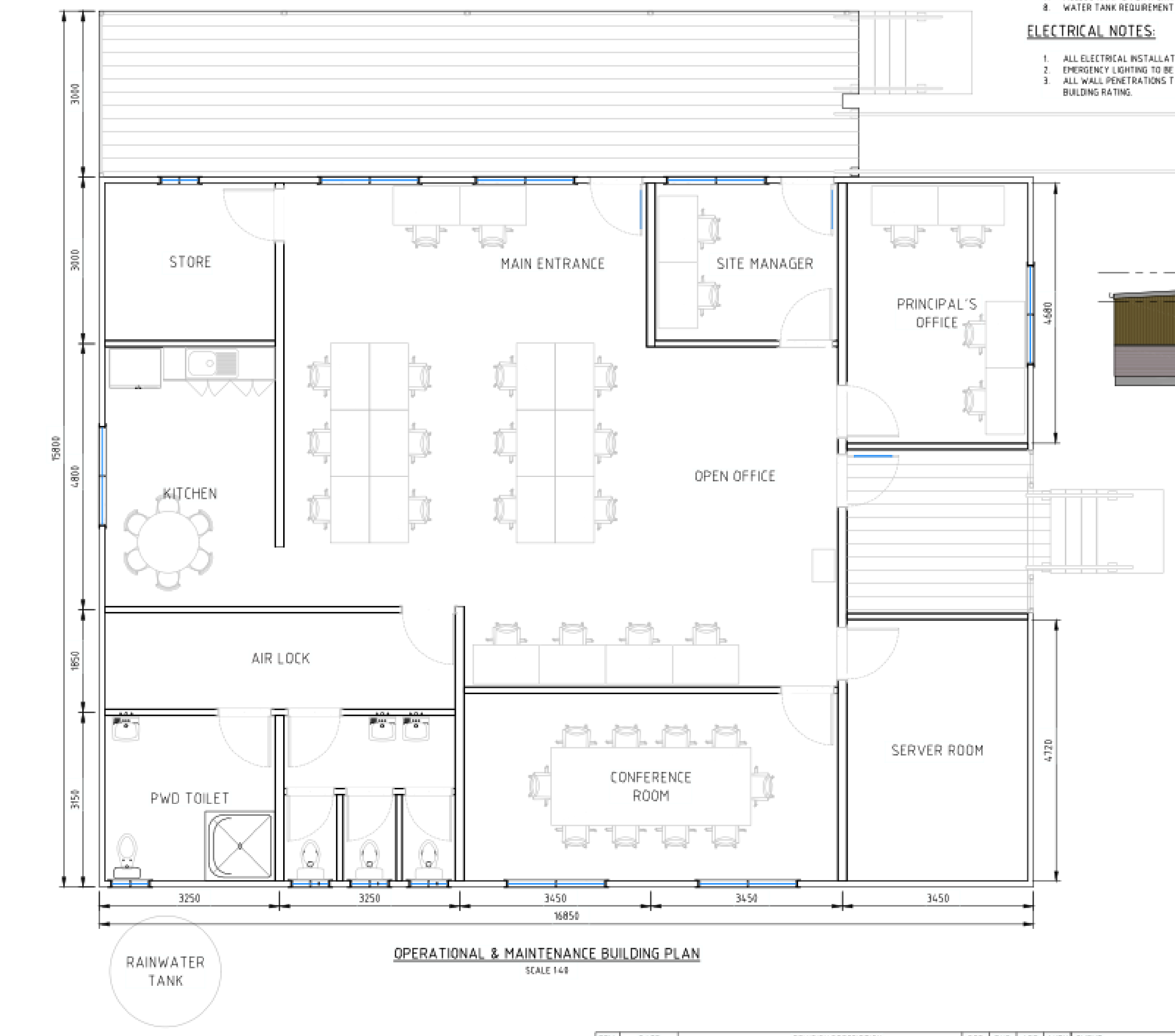
1. ALL ELECTRICAL INSTALLATIONS TO BE IN ACCORDANCE WITH AS3000.
2. EMERGENCY LIGHTING TO BE IN ACCORDANCE WITH AS2293.
3. ALL WALL PENETRATIONS TO USE GROMMETS AND BE SEALED TO RETAIN BUILDING RATING.

AIR CONDITIONING NOTES:

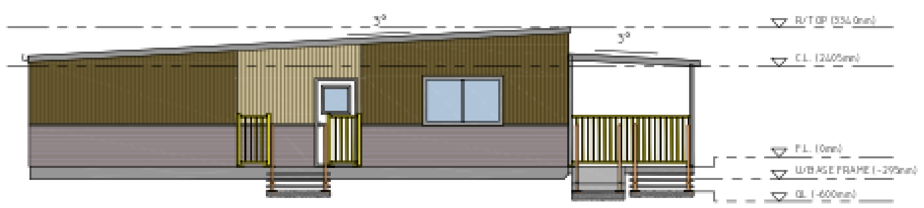
1. AIR CONDITIONING REQUIRED IN EACH ROOM TO BE SIZED FOR 25°C.
2. DRAIN PIPE TO BE 20mm Ø MINIMUM.
3. REMOTE CONTROLS TO BE INSTALLED NEXT TO ENTRY DOOR.
4. OUTDOOR UNITS TO BE INSTALLED AT THE 'REAR' OF BUILDING.
5. ALL WALL PENETRATIONS TO USE GROMMETS AND BE SEALED TO RETAIN BUILDING RATING.

FIRE SERVICE NOTES:

1. INSTALLATION OF SMOKE DETECTORS AS PER AUSTRALIAN STANDARDS.
2. FIRE SERVICE CABLING TO BE RUN WITHIN WALL CAVITY.



OPERATIONAL & MAINTENANCE BUILDING PLAN
SCALE 1:40



OPERATIONAL & MAINTENANCE BUILDING
EAST ELEVATION
SCALE N.T.S.

500 0 500 1000 1500
1:40 (mm)

NOT FOR CONSTRUCTION
27.03.2024

CLIENT DRG NO: 1456-DRW-BOP-00-697-001

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
0.1	27.03.2024	ISSUED FOR REVIEW	GH	MN	PH	

CLIENT: agl FLUENCE

ENERVEN PROJECT No: ENERVEN

	NAME	DATE
DESIGNED	G. HALLIDAY	27.03.2024
REVIEWED	M. NEWTON	27.03.2024
APPROVED	P. HAFFNER	27.03.2024
AUTHORISED		

LIDDELL BESS
BUILDING LAYOUT
OPERATIONS & MAINTENANCE BUILDING

SIZE	DRAWING NUMBER	REVISION
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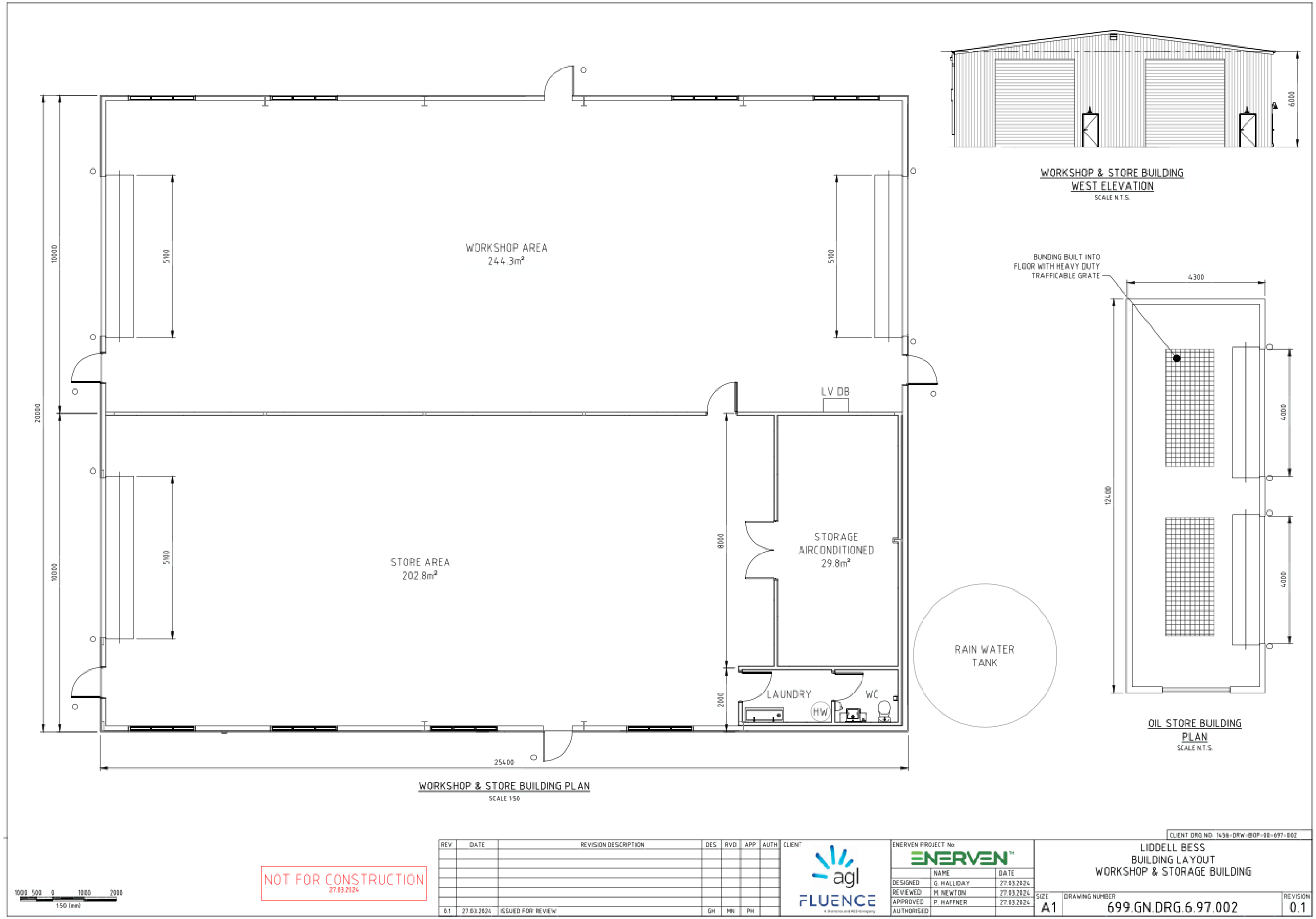
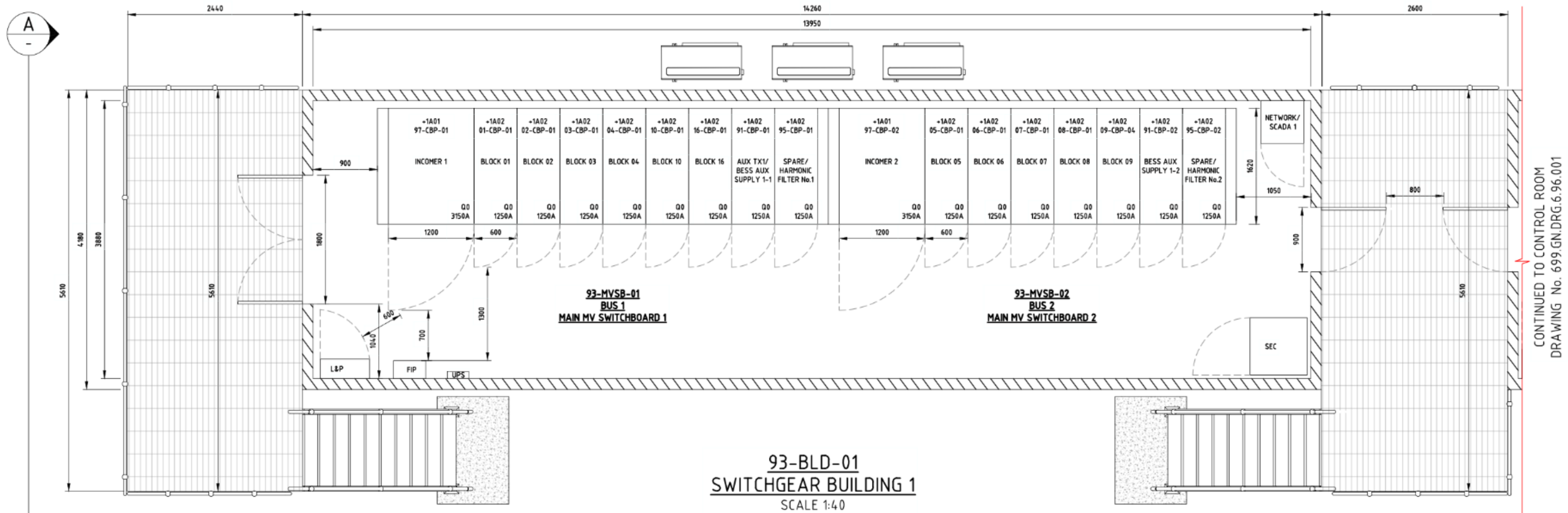
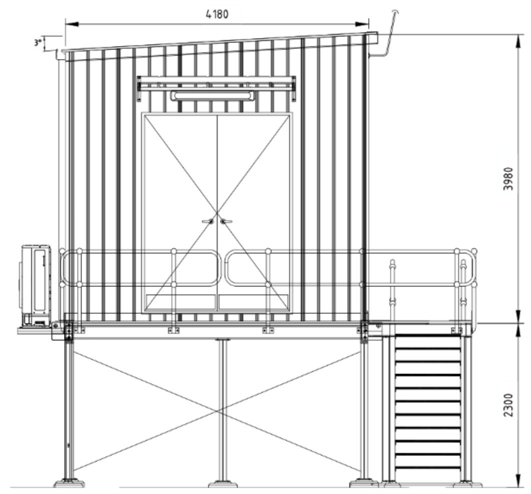
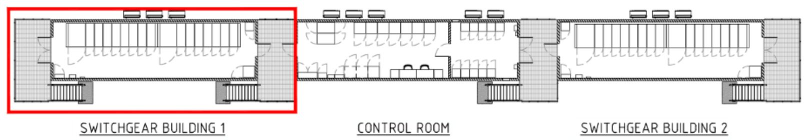

WORKSHOP & STORE BUILDING
WEST ELEVATION
SCALE N.T.S.
6000
WORKSHOP AREA
244.3m²
STORE AREA
202.8m²
STORAGE
AIRCONDITIONED
29.8m²
LV DB
LAUNDRY
WC
HW
RAIN WATER
TANK
20000
10000
10000
5100
8000
2000
25400
WORKSHOP & STORE BUILDING PLAN
SCALE 1:50
BUNDING BUILT INTO
FLOOR WITH HEAVY DUTY
TRAFFICABLE GRATE
4300
12400
4000
4000
OIL STORE BUILDING
PLAN
SCALE N.T.S.
NOT FOR CONSTRUCTION
27.03.2024
1:50 (mm)
CLIENT DRG NO. 1456-DRW-BOP-00-697-002
REV | DATE | REVISION DESCRIPTION | DES | RVD | APP | AUTH
0.1 | 27.03.2024 | ISSUED FOR REVIEW | GH | MN | PH
CLIENT
agl
FLUENCE
ENERVEN PROJECT No.
ENERVEN
NAME | DATE
DESIGNED | G. HALLIDAY | 27.03.2024
REVIEWED | M. NEWTON | 27.03.2024
APPROVED | P. HAFFNER | 27.03.2024
AUTHORISED
LIDDELL BESS
BUILDING LAYOUT
WORKSHOP & STORAGE BUILDING
SIZE A1
DRAWING NUMBER 699.GN.DRG.6.97.002
REVISION 0.1



93-BLD-01
SWITCHGEAR BUILDING 1
SCALE 1:40



SECTION A
SCALE 1:40



BUILDING
CONTEXT PLAN
NOT TO SCALE

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES (mm) UNLESS NOTED OTHERWISE.
2. DOOR HEIGHTS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING HEIGHT MEASURED ABOVE ADJACENT FINISHED FLOOR.
3. DOOR WIDTHS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING WIDTH.
4. DOORS TO BE METAL FRAMED, FOAM FILLED, SHEETED WITH COLORBOND AND REINFORCED TO SUIT DOOR HARDWARE. DOOR HARDWARE TO BE LOCKWOOD 1800 SERIES LEVEL HANDLES WITH SATIN CHROME FISNISH, OR EQUIVALENT.
5. ALL DOORS FITTED WITH LOCKS WITH CONTROL ROOM DOOR KEYED DIFFERENTLY TO HV SWITCHROOM DOORS.
6. ALL DOORS TO BE FITTED WITH INTERNAL PANIC BAR RELEASE MECHANISM TO ALLOW EASY EXIT ACCESS FROM THE HV SWITCHROOM VIA BOTH EGRESS PATHS.
7. BUILDING INTERNAL FLOOR TO CEILING HEIGHT IS NOMINALLY 3.3m, TO ALLOW FOR CABLE LADDER ABOVE GIS SWITCHGEAR TO FACILITATE TOP ENTRY OF MULTICORE CABLES IF REQUIRED.
8. MV SWITCHGEAR IS BASED UPON STANDARD 600mm WIDE GIS. BASEFRAME AND FLOOR SUPPORT SHALL BE COMPLIANT WITH SWITCHGEAR MANUFACTURER'S DEFLECTION AND INSTALLATION REQUIREMENTS.
9. WHEN FINAL SWITCHGEAR IS INSTALLED A BARRIER TO PREVENT ACCESS BEHIND PANELS SHALL BE INSTALLED.
10. FOR BUILDING EQUIPMENT LAYOUT DRAWING REFER TO:-
    - 699.GN.DRG.6.93.001 FOR SWITCHGEAR BUILDING 2
    - 699.GN.DRG.6.96.001 FOR CONTROL ROOM
11. ALL EQUIPMENT DIMENSIONS ARE TYPICAL AND WILL BE CONFIRMED ONCE PROCUREMENT IS FINALISED.
12. AIR CONDITIONER ALLOWANCE AND LOCATION IS TYPICAL AND TO BE CONFIRMED BY BUILDING MANUFACTURER.

500 0 500 1000 1500
1:40 (mm)

NOT FOR CONSTRUCTION
27.03.2024

EQUIPMENT IDENTIFICATION

ITEM	DESCRIPTION	NOM. DIMENSIONS
+1A01	33kV SWITCHGEAR INCOMER PANEL	1200W x 1620D x 2500H
+1A02	33kV SWITCHGEAR FEEDER PANEL	600W x 1620D x 2500H
L&P	LIGHT AND POWER (L&P)	690W x 275D x 1200H
FIP	FIRE INDICATION PANEL (FIP)	450W x 250D x 1500H
SEC	SECURITY PANEL (SEC)	800W x 800D x 2000H
UPS	UPS DISTRIBUTION BOARD	256W x 100D x 200H
NETWORK/ SCADA 1	NETWORK BESS SCADA PANEL (24RU)	600W x 600D x 1200H

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
0.1	27.03.2024	ISSUED FOR REVIEW	JB	GH	PH	

CLIENT: agl FLUENCE A Siemens and AES Company

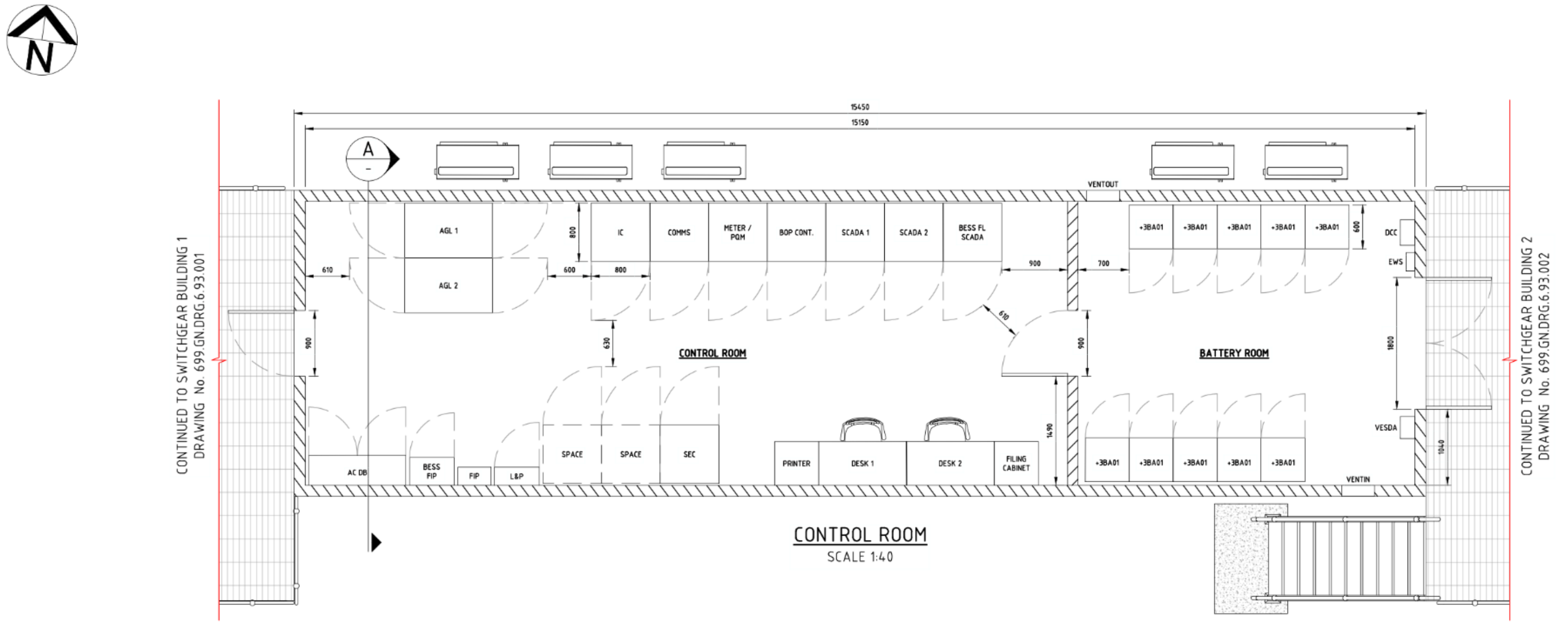
ENERVEN PROJECT No: ENERVEN

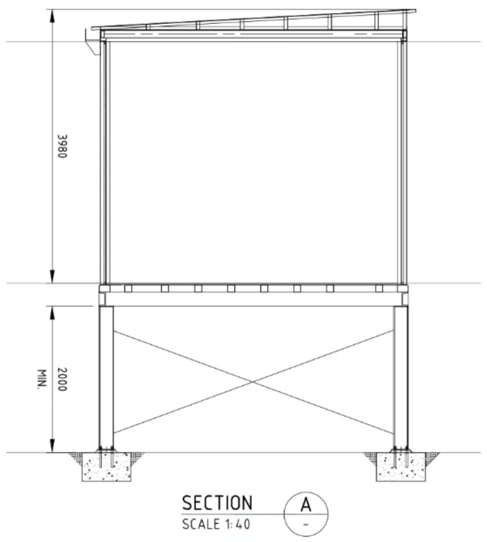
	NAME	DATE
DESIGNED	J. BRADBURY	27.03.2024
REVIEWED	G. HALLIDAY	27.03.2024
APPROVED	P. HAFFNER	27.03.2024
AUTHORISED		

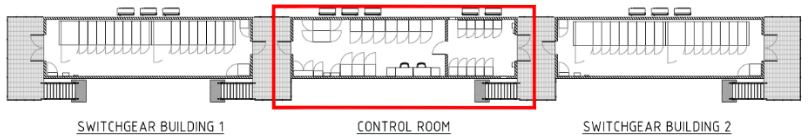
CLIENT DRG NO: 1456-DRW-BOP-00-693-001

LIDDELL BESS
BUILDING LAYOUT
SWITCHGEAR BUILDING 1

SIZE: A1 | DRAWING NUMBER: 699.GN.DRG.6.93.001 | REVISION: 0.1







BUILDING CONTEXT PLAN
NOT TO SCALE

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES (mm) UNLESS NOTED OTHERWISE.
2. DOOR HEIGHTS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING HEIGHT MEASURED ABOVE ADJACENT FINISHED FLOOR.
3. DOOR WIDTHS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING WIDTH.
4. DOORS TO BE METAL FRAMED, FOAM FILLED, SHEETED WITH COLORBOND AND REINFORCED TO SUIT DOOR HARDWARE. DOOR HARDWARE TO BE LOCKWOOD 1800 SERIES LEVEL HANDLES WITH SATIN CHROME FISNISH, OR EQUIVALENT.
5. ALL DOORS FITTED WITH LOCKS WITH CONTROL ROOM DOOR KEYED DIFFERENTLY TO HV SWITCHROOM DOORS.
6. ALL DOORS TO BE FITTED WITH INTERNAL PANIC BAR RELEASE MECHANISM TO ALLOW EASY EXIT ACCESS FROM THE HV SWITCHROOM VIA BOTH EGRESS PATHS.
7. BUILDING INTERNAL FLOOR TO CEILING HEIGHT IS NOMINALLY 3.3m, TO ALLOW FOR CABLE LADDER ABOVE PANELS TO FACILITATE TOP ENTRY OF MULTICORE CABLES IF REQUIRED.
8. MV SWITCHGEAR IS BASED UPON STANDARD 600mm WIDE GIS. BASEFRAME AND FLOOR SUPPORT SHALL BE COMPLIANT WITH SWITCHGEAR MANUFACTURER'S DEFLECTION AND INSTALLATION REQUIREMENTS.
9. WHEN FINAL SWITCHGEAR IS INSTALLED A BARRIER TO PREVENT ACCESS BEHIND PANELS SHALL BE INSTALLED.
10. FOR BUILDING EQUIPMENT LAYOUT DRAWING REFER TO:-
    - 699.GN.DRG.6.93.001 FOR SWITCHGEAR BUILDING 1
    - 699.GN.DRG.6.93.002 FOR SWITCHGEAR BUILDING 2
11. ALL EQUIPMENT DIMENSIONS ARE TYPICAL AND WILL BE CONFIRMED ONCE PROCUREMENT IS FINALISED.
12. AIR CONDITIONER ALLOWANCE AND LOCATION IS TYPICAL AND TO BE CONFIRMED BY BUILDING MANUFACTURER.

EQUIPMENT IDENTIFICATION

ITEM	DESCRIPTION	NOM. DIMENSIONS
+3BA01	BATTERY SYSTEM PANEL (TBC)	600W x 600D x 2500H
L&P	LIGHT AND POWER (L&P)	600W x 250D x 600H
FIP	FIRE INDICATION PANEL (FIP)	450W x 250D x 1200H
IC	INTERFACING CUBICLE	800W x 800D x 2000H
COMMS	FIBRE & COMMS PANEL	800W x 800D x 2000H
METER/PQM	METERING AND PQ PANEL	800W x 800D x 2000H
BOP CONT	BOP CONTROL CUBICLE	800W x 800D x 2000H
SEC	SECURITY PANEL (SEC)	800W x 800D x 2000H
SCADA 1	SCADA PANEL 1	800W x 800D x 2000H
SCADA 2	SCADA PANEL 2	800W x 800D x 2000H
BESS FL SCADA	BESS SCADA PANEL (FLUENCE)	800W x 800D x 2000H
BESS FIP	BESS FIRE INDICATION PANEL	610W x 380D x 1330H
AC DB	DISTRIBUTION BOARD	1200W x 400D x 2200H
DCC	DC BUS COUPLER	TBA
EWS	EYE WASH STATION	TBA
VESDA	DC VESDA 1 AND VESDA 2	TBA
VENTIN	NATURAL VENTILATION - INLET	TBA
VENTOUT	NATURAL VENTILATION - OUTLET	TBA
AGL 1	CLIENT SERVER CUBICLE 1	750W x 1200D x 2000H
AGL 2	CLIENT SERVER CUBICLE 2	750W x 1200D x 2000H

500 0 500 1000 1500
1:40 (mm)

NOT FOR CONSTRUCTION
27.03.2024

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
0.1	27.03.2024	ISSUED FOR REVIEW	JB	GH	PH	

CLIENT: agl, FLUENCE (A Siemens and AES Company)

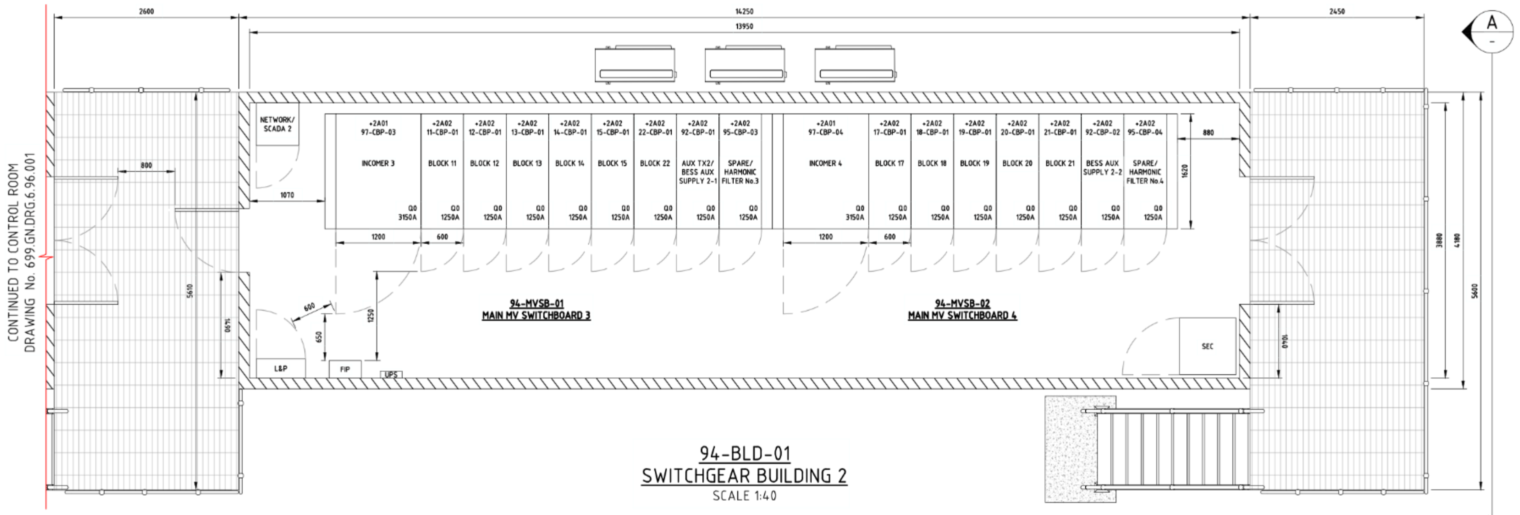
ENERVEN PROJECT No: ENERVEN

	NAME	DATE
DESIGNED	J. BRADBURY	27.03.2024
REVIEWED	G HALLIDAY	27.03.2024
APPROVED	P. HAFFNER	27.03.2024
AUTHORISED		

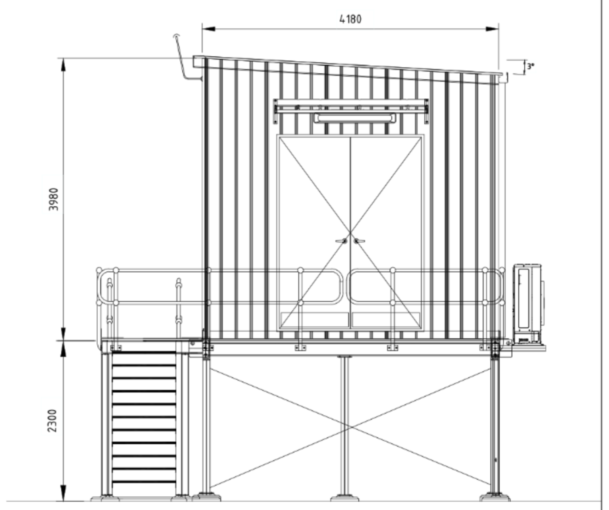
CLIENT DRG NO: 1456-DRW-BOP-00-696-001

LIDDELL BESS
BUILDING LAYOUT
CONTROL ROOM

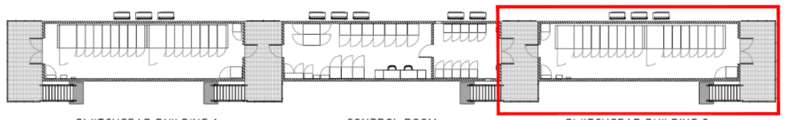
SIZE: A1 | DRAWING NUMBER: 699.GN.DRG.6.96.001 | REVISION: 0.1



94-BLD-01
SWITCHGEAR BUILDING 2
SCALE 1:40



SECTION A
SCALE 1:40



BUILDING
CONTEXT PLAN
NOT TO SCALE

GENERAL NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES (mm) UNLESS NOTED OTHERWISE.
2. DOOR HEIGHTS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING HEIGHT MEASURED ABOVE ADJACENT FINISHED FLOOR.
3. DOOR WIDTHS SHOWN ARE THE APPROXIMATE MINIMUM CLEAR OPENING WIDTH.
4. DOORS TO BE METAL FRAMED, FOAM FILLED, SHEETED WITH COLORBOND AND REINFORCED TO SUIT DOOR HARDWARE. DOOR HARDWARE TO BE LOCKWOOD 1800 SERIES LEVEL HANDLES WITH SATIN CHROME FISNISH, OR EQUIVALENT.
5. ALL DOORS FITTED WITH LOCKS WITH CONTROL ROOM DOOR KEYED DIFFERENTLY TO HV SWITCHROOM DOORS.
6. ALL DOORS TO BE FITTED WITH INTERNAL PANIC BAR RELEASE MECHANISM TO ALLOW EASY EXIT ACCESS FROM THE HV SWITCHROOM VIA BOTH EGRESS PATHS.
7. BUILDING INTERNAL FLOOR TO CEILING HEIGHT IS NOMINALLY 3.3m, TO ALLOW FOR CABLE LADDER ABOVE GIS SWITCHGEAR TO FACILITATE TOP ENTRY OF MULTICORE CABLES IF REQUIRED.
8. MV SWITCHGEAR IS BASED UPON STANDARD 600mm WIDE GIS. BASEFRAME AND FLOOR SUPPORT SHALL BE COMPLIANT WITH SWITCHGEAR MANUFACTURER'S DEFLECTION AND INSTALLATION REQUIREMENTS.
9. WHEN FINAL SWITCHGEAR IS INSTALLED A BARRIER TO PREVENT ACCESS BEHIND PANELS SHALL BE INSTALLED.
10. FOR BUILDING EQUIPMENT LAYOUT DRAWING REFER TO:-
    - 699.GN.DRG.6.93.001 FOR SWITCHGEAR BUILDING 1
    - 699.GN.DRG.6.96.001 FOR CONTROL ROOM
11. ALL EQUIPMENT DIMENSIONS ARE TYPICAL AND WILL BE CONFIRMED ONCE PROCUREMENT IS FINALISED.
12. AIR CONDITIONER ALLOWANCE AND LOCATION IS TYPICAL AND TO BE CONFIRMED BY BUILDING MANUFACTURER.

EQUIPMENT IDENTIFICATION

ITEM	DESCRIPTION	NOM. DIMENSIONS
+2A01	33kV SWITCHGEAR INCOMER PANEL	1200W x 1620D x 2500H
+2A02	33kV SWITCHGEAR FEEDER PANEL	600W x 1620D x 2500H
L&P	LIGHT AND POWER (L&P)	690W x 275D x 1200H
FIP	FIRE INDICATION PANEL (FIP)	450W x 250D x 1500H
SEC	SECURITY PANEL (SEC)	800W x 800D x 2000H
UPS	UPS DISTRIBUTION BOARD	256W x 100D x 200H
NETWORK/ SCADA 2	NETWORK BESS SCADA PANEL (24RU)	600W x 600D x 1200H

500 0 500 1000 1500
1:40 (mm)

NOT FOR CONSTRUCTION
27.03.2024

CLIENT DRG NO: 1456-DRW-BOP-00-693-002

REV	DATE	REVISION DESCRIPTION	DES	RVD	APP	AUTH
0.1	27.03.2024	ISSUED FOR REVIEW	JB	GH	PH	

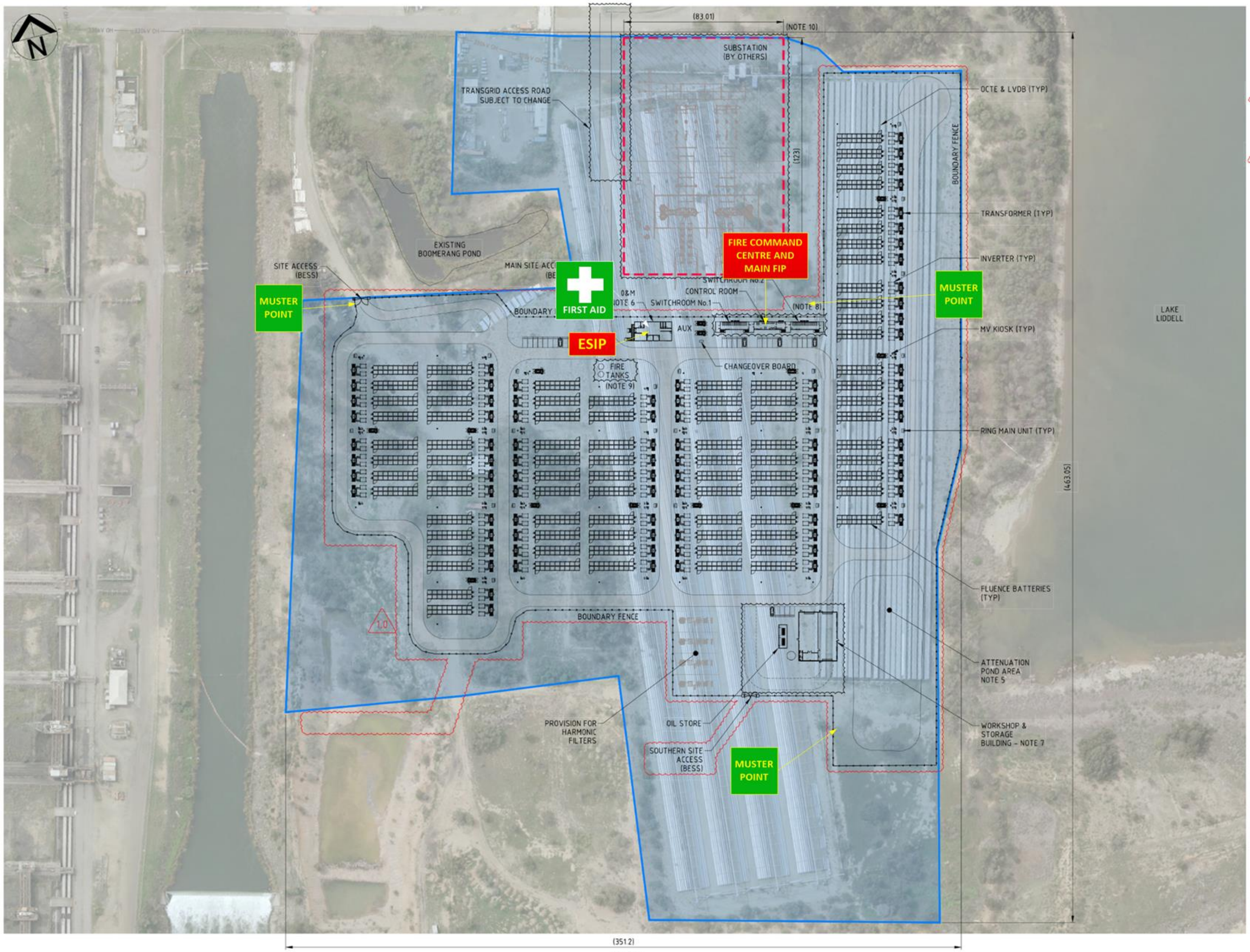
CLIENT: agl FLUENCE A Siemens and AES Company

ENERVEN PROJECT No: ENERVEN™

	NAME	DATE
DESIGNED	J. BRADBURY	27.03.2024
REVIEWED	G. HALLIDAY	27.03.2024
APPROVED	P. HAFFNER	27.03.2024
AUTHORISED		

LIDDELL BESS
BUILDING LAYOUT
SWITCHGEAR BUILDING 2

SIZE: A1
DRAWING NUMBER: 699.GN.DRG.6.93.002
REVISION: 0.1


N
TRANSGRID ACCESS ROAD SUBJECT TO CHANGE
SUBSTATION (BY OTHERS)
(83.01)
(NOTE 10)
(123)
OCTE & LVDB (TYP)
BOUNDARY FENCE
TRANSFORMER (TYP)
INVERTER (TYP)
EXISTING BOOMERANG POND
SITE ACCESS (BESS)
MAIN SITE ACC
FIRST AID
FIRE COMMAND CENTRE AND MAIN FIP
MUSTER POINT
MUSTER POINT
CONTROL ROOM
SWITCHROOM No.1
(NOTE 8)
AUX
ESIP
MV KIOSK (TYP)
LAKE LIDDELL
FIRE TANKS (NOTE 9)
CHANGEOVER BOARD
RING MAIN UNIT (TYP)
(463.05)
FLUENCE BATTERIES (TYP)
BOUNDARY FENCE
ATTENUATION POND AREA NOTE 5
PROVISION FOR HARMONIC FILTERS
OIL STORE
WORKSHOP & STORAGE BUILDING - NOTE 7
SOUTHERN SITE ACCESS (BESS)
MUSTER POINT
MUSTER POINT
(351.2)

PLAN

Appendix 3

Effects® modelling

FSS, AGL Energy Liddell Battery Energy Storage System

Appendix 3 – Effects® modelling

The Effects® model (by TNO) was set up to deliver heat radiation and flame temperature results that, as far as possible, correlate with the following large-scale test results:

- The BDBT for the Cube Intact fire scenario (Ref 10)
- The Bespoke fire test for the Breached Cube fire scenario (Ref 16).

The assessment was set up in two steps, with the purpose of the first step to determine the fire characteristics and behaviour measured during the large-scale fire; and the purpose of the second step to develop a fire model which is calibrated, as closely as possible, with the fire characteristics observed during the large-scale tests.

While other modelling parameters were observed, such as flame temperature and height of the fire, these were secondary to the calibration against the heat radiation.

A fully developed fire involving a battery enclosure will involve energy released during combustion of combustible materials and electrical energy emitted during the fire. FM Global, in their large-scale research into battery fires (Ref 9) estimated that about 26% of the energy released from the fire is from the electrolyte; 67% from the plastic material; and 7% as associated with the electrical energy.

To develop the fire model to run on the Effects® software, the first step is to select a material which corresponds as closely as possible to the actual fire.

In Effects®, there are two chemical databases available (YAWS and DIPPR), pre-programmed with chemical and physical properties of over 1,500 materials. The databases contain over 100's of thousands of data records covering physical, thermophysical, thermodynamic, transport, safety, and environmental properties together with interactive tables containing a plotting tool showing properties as a function of variables such as temperature, pressure, and concentration. Additionally, the user can prepare their own specific material or mixtures.

In this step, Planager tested 100s of the pre-programmed materials in both databases, with the closest fit between Bespoke test results and Effects® model results found for methyl acrylate, which is a raw material used for the production of acrylic fibres, fibre processing agents, moulding resins, adhesives, paints, coatings, and emulsions.

With the findings in the FM Global research above, this material appears to fit in relatively well with expectations and was therefore selected as the basis for the Effects® modelling.

The model was then calibrated to provide a best fit between the Effects® model's output, in particular heat radiation and flame temperature, and the Bespoke test measured data.

This step involved varying the flame diameter, the combustion rate and the fraction combustion heat radiated (%) for best fit against heat radiation and flame temperature.

Meteorological conditions are important for determining the likely and the worst case credible wind weather conditions. The key meteorological requirements of are, typically, hourly records of wind speed, wind direction, temperature, atmospheric stability class and mixing layer height. A minimum one year of hourly data is usually required, which means that almost all possible meteorological conditions, including seasonal variations, are considered in the model simulations.

For this FSS, wind speed data was obtained from the EIS for the Project, citing the Air Quality Impact Assessment conducted by Jacobs as part of the Bayswater Water and Other Associated Operational Works Project (Spencer L, *AGL Macquarie Pty Ltd Bayswater Water and Other Associated Operational Works Project, Air Quality Impact Assessment, Jacobs*, 4 December 2019), including wind rose data. The Air Quality Assessment in turn sourced the wind data from the AGL Macquarie meteorological station referred to as AGL08 which is located to the north of the ash dam augmentation area, at between 3 and 4 kilometres away from the Project area at a similar elevation of approximately 150 m AHD. The annual wind rose in 2017 at AGL08 weather station is shown in Figure 4-6 in the body of the report.

The closest meteorological station to the Project area is that operated by AGL Macquarie, referred to as AGL08 which is located to the north of the ash dam augmentation area at an elevation similar to the key Project areas of approximately 150 m AHD.

Meteorological data from four recent years (1 Jan 2015 to 6 Jun 2018) was initially analysed to identify trends from year-to-year and also to identify a representative year for use in the dispersion modelling. The most complete data was 2017 and this is the data chosen for this FSS.

Appendix 4

Building fire protection

FSS, AGL Energy Liddell Battery Energy Storage System

Appendix 4 – Building details

Building	Function	Building Class	Occupancy	Size	Construction
Switchroom 1 & 2	To house the 33kV main switchboards, with two switchboards in each room.	8	Normally unoccupied	Single storey 14.4 × 4 m floor area = 57.6m^2	Prefabricated non-combustible materials, with thermally insulated walls and ceilings. Metal cladding will protect the building from environmental intrusions
Control room	To house the control and monitoring equipment of the BOP and BESS systems.	8	Normally unoccupied	Single storey 21 × 4 m floor area = 84m^2	Prefabricated non-combustible materials, with thermally insulated walls and ceilings. Metal cladding will protect the building from environmental intrusions
O&M building	To provide space for onsite personnel, including kitchen and toilet facilities.	5	Normally unoccupied but can accommodate to 16 people	Single storey 15 × 16.8 m floor area = 252m^2	Prefabricated non-combustible materials, with thermally insulated walls and ceilings. Metal cladding will protect the building from environmental intrusions Fire rated to BAL 12.5
Workshop and storage building	To house the site's spare parts holdings, tools and maintenance equipment, hazardous substances/dangerous goods	8	Normally unoccupied	Single storey 20 × 25.4 m floor area = 508m^2	Prefabricated non-combustible materials, with thermally insulated walls and ceilings. Metal cladding will protect the building from environmental intrusions Fire rated to BAL 12.5
Auxiliary Services Building	To house auxiliary services	8	Normally unoccupied	Single storey	Prefabricated non-combustible materials.

Building	Ventilation	Hazard	Fire systems	Additional information
Switchroom 1 & 2 Control room	An HVAC system will be installed to manage heat loads within the building, integrated into the fire system to shut off in case of fire detection.	Electrical Bushfire Arson	Building materials are rated for a 2-hour fire rating (120/120/120), equipped with fire and smoke detection equipment, VESDA and an FIP interfacing with the Master FIP Automatic fire suppression system (TBD)	APZ Emergency power to fire system Secured site and building
O&M building	Ducted air conditioning (HVAC)	Electrical Cooking facilities Bushfire Arson	Fire and smoke detection equipment and an FIP interfacing with the Master FIP Emergency lighting and exit signage for safe egress Integrated EWIS system Fire extinguishers	Multiple means of egress from building APZ Emergency power to fire system Secured site and building No storage of flammable material (other than paper)
Workshop and storage building	Natural in main sections Climate-controlled storage room for storage of spare parts that require certain temperature and humidity conditions	Electrical Bushfire Arson	Fire and smoke detection equipment and an FIP interfacing with the Master FIP Emergency lighting and exit signage for safe egress Integrated EWIS system	Segregated hazardous substances/dangerous goods storage area APZ Emergency power to fire system Secured site and building
Auxiliary Services Building	TBD	Electrical Bushfire Arson	Ionisation smoke and heat detectors; VESDA system FIP interfacing with the site FIP	Secured site and building APZ Emergency power to fire system Secured site and building

Appendix 5

Evaluation of PHA commitments

Appendix 5 – Evaluation of PHA commitments

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
Prevention	General - applies to all elements of the Project	1. All equipment and systems designed & tested to comply with the relevant national / international standards and guidelines	Operations and Maintenance (O&M) instructions will be provided for equipment associated with the development
		2. Equipment to be procured from reliable and internationally recognised supplier with proven track-record	Fluence confirm that all BESS equipment used and installed is compliant to IEC standards
		3. Battery to be procured from supplier with no thermal runaways	Batteries, modules, racks and enclosure have passed to UL 9540 A testing. Large scale test confirms no propagation
		4. Equipment installed by contractors following AGL's internal requirements for contractor management, permits, control of modifications etc.	Outside of the scope of the FSS
		5. All installation and maintenance to be performed by trained personnel using SWMS	Outside of the scope of the FSS
		6. Induction of all personnel prior to works commencing	Outside of the scope of the FSS
		7. Electrical isolation protocol will be in place during construction and installation (PTW)	Maintenance and isolation procedure (e.g. deenergize equipment) will be in place
		8. Hot work permits will be in place during construction and installation (PTW)	AGL-LB have a commitment to workplace health and safety and have numerous policies and procedures to achieve a safe workplace. These include a Permit to Work (PTW) system.
		9. Bushfire Management Plan in place	Bushfire Management forms part of the site ERP

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
		10. Training of personnel for preventing and dealing with bushfire risk	Bushfire Management forms part of the site ERP
		11. Preventative maintenance practices in place including maintenance schedules and calibration of equipment, instruments and sensors	Operations and Maintenance (O&M) instructions will be provided for equipment associated with the development
		12. Impact barriers installed as required to prevent damage from vehicles, heavy machinery etc.	Defined road ways in the BESS
		13. Warning signs etc. installed as per Code and Standards requirements including DG signage	Section 5.2.9 in the FSS deals with warning signs
		14. Earthing of electrical equipment including HV equipment	Earthing will be as per relevant Australian Standards
		15. Lightning protection mast installed (Substations)	Lightning protection will be as per relevant Australian Standards
		16. Switch rooms and the Battery are housed in dedicated enclosure(s) which will be constructed in accordance with relevant standards and above flood level	Building design and protection as per Appendix 4 in the FSS
Prevention	Specific to EMF	25. Optimising equipment layout and orientation to ensure minimal EMF generation	Outside of the scope of the FSS
		26. Balancing phases and minimising residual current	
		27. Location siting of HV/MV equipment in remote areas - Exposure to personnel is short duration in nature (transient)	

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
		as all permanently occupied buildings are located well away from HV/MV plant and equipment	
		28. Incidental shielding (i.e. the Battery building/enclosure, switch room)	
		29. Warning signs	
		30. Exposure to EMF considered for AGLM Staff and contractors as part of health and safety management practices	
Prevention	Security measures	31. The entire site is secured; the Battery will be located within a secure fenced area. Impact protection from vehicles e.g. in the form of guard posts or other equivalent measures where relevant	Security is discussed in Section 2.3.2 of the FSS
		33. Onsite security protocols	Security is discussed in Section 2.3.2 of the FSS
		34. Warning signs	Security is discussed in Section 2.3.2 of the FSS
		35. During construction, the areas will be manned and temporary fences will be installed	Outside of the scope of the FSS
Detection and shut-off	General	36. Inspection rounds formally established	Operations and Maintenance (O&M) instructions will be provided for equipment associated with the development

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
		37. Thermography and other Non-Destructive Testing (**NDT**) as per scheduled maintenance to identify precursor of malfunction	Operations and Maintenance (O&M) instructions will be provided for equipment associated with the development
		38. Alarms available to provide hazard warning on operations upset conditions. Control room attended 100% of the time in normal operation (most likely this will be the AGLM Control Room in Melbourne, with communication to personnel, as required).	Alarms are discussed throughout the FSS. Continuous (100%) monitoring of BESS conditions is discussed in Section 3.2.4 of the FSS
Detection and shut-off	Specific to the battery	39. Battery Management System (BMS) including voltage control, charge/ discharge current control and temperature monitoring to battery manufacturer's specifications	Discussed in Section 5 in the FSS
		40. Automatic safety shut-off function in case of safe limits exceeded	
		41. HVAC system installed if required (may be water cooled)	
		42. Secondary detection in enclosure (e.g. smoke / heat), with information transferred to the BESS control room so that, if there is a fire/ smoke/ high temperature the module is isolated with associated shut-downs	
		56. Warning signs (electrical hazards, arc flash)	Section 5.2.9 in the FSS deals with warning signs

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
Protection and limitation to prevent escalation	General - applies to all elements of the Project	57. Separation distances established between each element of the Project (including between infrastructure at the Battery) to minimise risk of escalation in accordance with Codes and Standards and manufacturer's recommendations	Section 5.2.3 (Separation by distance) in the FSS discusses separation
		58. Separation distances to the surrounding bushland established in accordance with *Planning for Bush Fire Protection* and *AS3959 Construction of buildings in bushfire prone areas* (this includes establishment of an appropriate APZ)	APZ is evaluated in the Bushfire assessment and summarised in Section 5.2.4 of the FSS
		59. Vegetation management within the APZ to be scheduled as a maintenance task	APZ is evaluated in the Bushfire assessment and summarised in Section 5.2.4 of the FSS
		60. Security protocol for the site; fencing at the Battery	Security is discussed in Section 2.3.2 of the FSS
Protection and limitation to prevent escalation	Specific to the Battery	61. The Battery housed in a dedicated enclosure with appropriate fire rating (minimum 1 hour). Only restricted personnel allowed	Discussed throughout the FSS and particularly in Table 2.5
		62. Visible annunciation fitted to the battery enclosure to indicate potentially hazardous conditions associated with the Battery (e.g. at entry door and inside the enclosure to allow escape)	Table 2.5 of the FSS discusses the safety systems relating to the battery enclosure door. Audible alarms are summarised in Table 5-1
		63. Battery enclosure venting to reduce concentrations inside enclosure as per requirements in Codes and Standards	Not used in the Fluence solution

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
		64. Explosion venting or venting of toxic or flammable gases, if required, as per Codes and Standards and in accordance with manufacturer's instructions	Section 5.2.2 of the FSS discusses explosion venting and panels
		65. Battery fire protection system inside and outside of the enclosure to Standard requirements	Battery fire protection system inside the BESS is discussed throughout the FSS. Outside the BESS, discussed in Section 5.2.10
		66. Escape from battery enclosure an escape through the Battery in accordance with Code requirement (note: Code stipulates that any toxic combustion products or gas released from other fault conditions will be evacuated from the enclosure such that people will be able to escape from the enclosure and not be exposed at adjacent egress routes (during the time deemed necessary to evacuate from that area))	Battery enclosures cannot be entered during operation. PTW would apply entry is required when racks are removed
Protection and limitation to prevent escalation	Specific to the Decoupling works	67. Management System including voltage control, charge/discharge current control and temperature monitoring. Automatic safety shut-off function in case of exceeding safe limits as per AS2067.	The BMS is discussed in Section 5.2 of the FSS.
		68. Protective walls, barriers or solid covers as per AS2067 requirements	Protective walls in the substation, as discussed in Table 2.5
		69. Use of appropriate PPE for flash hazard	Outside of the scope of the FSS

Type of safeguard	Element	Register of commitments made in the PHA: Preventative and protective safeguards	Status at the detailed design stage: Preventative and protective safeguards
		70. Smoke and heat detectors	Discussed in Section 5.2 in the FSS
		71. Fire protection system (enclosure) - fire suppression system to be determined during design e.g. deluge initiated through fusible link / fusible bulb or other, fire extinguisher(s)	Discussed in Section 5.2.7 in the FSS
		72. Use of appropriate PPE	Outside of the scope of the FSS
		73. Key locked cabinets and electrical rooms	Discussed in Appendix 4 for buildings. For enclosures, discussed in Table 2.5
Overall	Management	83. The risk of seismic activity is to be integrated into the design for this Project	Outside the scope of the FSS.
	PHA recommendation	PHA Recommendation #4: All relevant requirement in AS5139 (2019) are adhered to. Adherence to the requirements in internationals standards e.g. NFPA 855. Further, consider procurement of a battery system that is certified to UL1642, IEC 1973, IEC 61427-2 and IEC 62619	All BESS equipment used and installed is compliant to IEC standards

Appendix 6

Cause and Effects matrices

FSS, AGL Energy Liddell Battery Energy Storage System

Appendix 6 – Cause and Effects matrix

FIRE SYSTEMS INPUT AND EFFECTS

		CUBE								OCTE				FIRE COMMAND CENTRE			
	EFFECT / CAUSE	Shutdown of the affected Cube	Chillers Shutdown	HVAC Shutdown	Cube Horn/ Strobe in affected cube	Core Horn/Strobe on OCTE in affected core	Cube F-STOP Shutdown in affected cube	Deflagration Panels	Comments	Control Panel Alarm/Trouble Buzzer & LED	Activate Relay for F-STOP interface	Core F-STOP Shutdown	Activate Audible/Visual Devices	Activate Control Panel Alarm Buzzer & IED	Activate Audible/Visual Devices	Transmit Alarm/trouble Signal to central station via DAS (24H MONITORING)	Activate Dialer module for Fire brigade interface
CUBE	**CO detector in Cube 30 ppm – via Multi-Detector**				X	X	X		F-STOP ACTIVATED BUT THE AUXILIARY RUNS		X	X	X				
	Excess Pressure Buildup in Cube							X									
	Smoke or Heat detected via Multi-Detector or sensors	X	X	X	X	X	X		HVAC, CHILLER FOR AFFECTED CUBE IS SHUTDOWN	X	X	X	X				
	Aerosol canister released – 95 °C temp switch on canister	X	X	X	X	X	X					X					
	Cube F-STOP	X	X	X			X		HVAC, CHILLER FOR AFFECTED CUBE IS SHUTDOWN		X	X	X				
	Core F-STOP located at Core cabinet						X		FAST STOP ENTIRE CORE		X	X	X				

	EFFECT / CAUSE	CUBE								OCTE				FIRE COMMAND CENTRE			
		Shutdown of the affected Cube	Chillers Shutdown	HVAC Shutdown	Cube Horn/ Strobe in affected cube	Core Horn/Strobe on OCTE in affected core	Cube F-STOP Shutdown in affected cube	Deflagration Panels	Comments	Control Panel Alarm/Trouble Buzzer & LED	Activate Relay for F-STOP interface	Core F-STOP Shutdown	Activate Audible/Visual Devices	Activate Control Panel Alarm Buzzer & IED	Activate Audible/Visual Devices	Transmit Alarm/trouble Signal to central station via DAS (24H MONITORING)	Activate Dialer module for Fire brigade interface
OCTE	**Automatic fire detector**				X	X				X	X		X	X	X		
	FACP Primary 240VAC Power Failure									X							
	System Device Wiring Trouble/Fault									X							
	Open Circuit/Ground Fault									X							
FIRE COMMAND CENTRE	**Manual Fire Alarm - Call Point**													X	X	X	X
	Automatic fire detector													X	X	X	X
	FACP Primary 240VAC Power Failure															X	

		CUBE								OCTE				FIRE COMMAND CENTRE			
EFFECT / CAUSE		Shutdown of the affected Cube	Chillers Shutdown	HVAC Shutdown	Cube Horn/ Strobe in affected cube	Core Horn/Strobe on OCTE in affected core	Cube F-STOP Shutdown in affected cube	Deflagration Panels	Comments	Control Panel Alarm/Trouble Buzzer & LED	Activate Relay for F-STOP interface	Core F-STOP Shutdown	Activate Audible/Visual Devices	Activate Control Panel Alarm Buzzer & IED	Activate Audible/Visual Devices	Transmit Alarm/trouble Signal to central station via DAS (24H MONITORING)	Activate Dialer module for Fire brigade interface
	System Device Wiring Trouble/Fault															X	
	Open Circuit/Ground Fault															X	

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BESS CAUSE AND EFFECTS

EFFECT / CAUSE	Alarm	Trip	Warning	Shutdown of Cube/Node	Shutdown of Chillers and HVAC units in Cube	Shutdown of PCS	DC contactors open	Alarm Level	Note
Cube's F- Stop button pressed	X	X		X	X	X	X	Critical	Both chillers and both HVAC units stop in affected Cube only (hardwired trip). For other Cubes in Core: HVAC and chiller continue normal operation (no change) The associated Core is shutdown. Trip MBMU (master BMU) centrally via HW and trip DCPM unit via CAN bus
Cube leak detector (if equipped)	X		X					Warning	
Core F-Stop main relay voltage drop	X	X		X		X	X		
One or two HVAC units fail	X		X	X		X		N/A	
Humidity Control			X					Warning	HVAC units: Cube controller commands HVAC units to control humidity Chiller units: No action
Door sensor	X							Alarm	
Insulation monitoring device	X		X	X		X		Critical	When the IMD detects the insulation resistance of DC and AC below the threshold, the inverter status will show as being faulted with fault code 45. When this happens, the dispatch setpoint to the batteries will be 0. The IGBT switching stops in the Inverter

EFFECT / CAUSE	Alarm	Trip	Warning	Shutdown of Cube/Node	Shutdown of Chillers and HVAC units in Cube	Shutdown of PCS	DC contactors open	Alarm Level	Note
Fire alarm (smoke or aerosol canister release) in Cube	X		X	X		X		Critical	Only the chillers and HVAC in the affected Cube are shutdown. All other chillers and HVAC in the core continue to run to cool the batteries down. F-stop is activated. Trip MBMU (master BMU) centrally via HW and trip DCPM unit via CAN bus
CO detected in Cube	X		X	X		X	X	Critical	The associated core is shutdown. F-stop is activated
Excessive Cube internal temperature Tair > 40°C persisting for more than 2h	X			X		X		Warning	Utility Running at the Node controller level. If the signal " Node High Temp Active " is 1 then the Node Controller to start Node shut-down sequence. Partial load operation applies for the Core (N-1 Nodes), to the extent that the PCS has more than one Node. If only one Node, stop entire Core
Power outage in one Cube (Detected by the Cube Controller's communication to the UPS unit)	X	X		X		X		Critical	Core controller to Initiate shut-down sequence for the Core of the identified power loss
Power outage at Core	X	X		X		X		Critical	Core controller to Initiate shut-down sequence for the Core of the identified power loss