EnergyCo

Waratah Super Battery – Munmorah

Appendix F - Hazard and Risk Assessment

November 2022

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Project name	Waratah Super Battery Technical Advisor
Document title	Waratah Super Battery | Hazard and Risk Assessment
Project number	12582669
File name	12582669-REP-App F-Preliminary Hazard Analysis Report.docx

Status Code	**Revision**	**Author**	**Reviewer**		**Approved for issue**		
			Name	**Signature**	**Name**	**Signature**	**Date**
S4	0	F. Duncan	G Marshall		D Chubb		2/11/2022

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The Power of Commitment

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1. Introduction

Energy Corporation of NSW (EnergyCo) propose to develop a lithium-ion battery energy storage system at the site of the former Munmorah Power Station. The battery energy storage system (BESS) would be supported by connecting transmission and related infrastructure to connect the proposed battery to the National Energy Market (NEM). Additional ancillary infrastructure would also be required to support the project including access roads, site services, an administration building, maintenance building and storage yard, and signage and site security.

The proposed BESS would be located on a site within the former Munmorah Power Station at Colongra on the Central Coast of New South Wales (NSW).

The proposed battery energy storage system, connecting transmission and related infrastructure, and ancillary infrastructure is referred to as 'the project' or 'the Waratah Super Battery'.

1.1 Purpose of this report

This report assesses the potential hazards and risks associated with the construction, operation, and decommissioning and rehabilitation of the project and provides mitigation measures to reduce potential hazards and risks associated with the Waratah Super Battery.

The report has been prepared in accordance the SEARs (refer to Appendix A of the EIS).

1.2 Scope and limitations

This report: has been prepared by GHD for Energy Corporation of NSW and may only be used and relied on by Energy Corporation of NSW for the purpose agreed between GHD and Energy Corporation of NSW as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Energy Corporation of NSW arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Energy Corporation of NSW and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The following limitations were identified for the hazard and risk assessment prepared for the Waratah Super Battery:

– *Uncertainties in the final specification of the selected supplier of the BESS, requiring indicative industry specifications to be referenced.*
– *Uncertainties in the final layout of the BESS units, requiring indicative industry layouts to be referenced.*

2. Government plans, policies, and guidelines

The project has been declared Critical State Significant Infrastructure (CSSI) in accordance with Section 5.13 of *the Environmental Planning and Assessment Act 1979* (EP&A Act) and Schedule 5 of the Planning System's State Environment Planning Policy (SEPP). The Minister for Planning is the consent authority, and the project is to be assessed in accordance with the provisions of Division 5.2 of the EP&A Act.

The hazard and risk assessment was prepared with reference to the following plans/ policies/ guidelines:

- NSW State Environment Planning Policy (Resilience and Hazards), 2021 (Resilience and Hazards SEPP).
- NSW Department of Planning and Environment, Hazardous Industry Planning Advisory Paper No 4 – risk criteria for land use safety planning, 2011.
- NSW Department of Planning and Environment, Hazardous Industry Planning Advisory Paper No 6 – guidelines for hazard analysis, 2011.
- NSW Department of Planning and Environment, Multi-level risk assessment, 2011.
- International Commission on Non-Ionizing Radiation Protection, Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic Fields (1 Hz – 100 kHz), 2010.
- UL 9540 – Standard for safety of energy storage systems and equipment, 2021.
- AS 2067 – Substations and high voltage installations exceeding 1 kV a.c., 2016.
- AS/ NZS 5139 – Electrical installations - Safety of battery systems for use with power conversion equipment, 2019.
- NFPA 855: Installation of stationary energy storage systems, 2020.

3. Methodology

The Resilience and Hazards SEPP applies to any project which falls under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. If not controlled appropriately, some activities within these industries may create an offsite risk or offence to people, property or the environment thereby making them potentially hazardous or potentially offensive. The Resilience and Hazards SEPP requires a screening process be undertaken and if the screening indicates that the project is potentially hazardous, then a preliminary hazard analysis (PHA) is required. If the project is potentially offensive, after considering the quantity and nature of any discharges and the significance of the offence likely to be caused and having regard to surrounding land use, then measures are required to reduce or minimise the offensive impacts.

3.1 Risk screening

The risk screening process typically concentrates on the storage of specific dangerous good classes that have the potential for significant offsite effects. Specifically, the assessment involves the identification of classes and quantities of all dangerous goods to be used, stored or produced on site with an indication of storage locations. The quantities of dangerous goods are then assessed against the Resilience and Hazards SEPP threshold quantities.

3.2 Hazard identification

Following screening, the Resilience and Hazards SEPP requires a determination of whether the project poses significant risk. Hazard identification highlights any risks associated with the interaction of the project (as a whole) with the surrounding environment. This is a systematic process to identify any potential offsite impacts. The aim of the hazard identification process is to show the project does not pose any significant risk.

The hazard identification is a desktop qualitative assessment and involves documenting possible events that could lead to a possible off-site incident. The assessment then lists all potential causes of the incident, as well as identification of operational and organisational safeguards to prevent the incidents from occurring or to mitigate the impact.

The hazard identification process is conducted for all lifecycle stages of the project.

3.3 Preliminary hazard analysis

For development projects classified as 'potentially hazardous industry', a PHA is required to be completed to determine the risk to people, property and the environment at the proposed location and in the presence of controls. Criteria of acceptability are used to determine if the development project is classified as a 'hazardous industry'. If this is the case, the development project may not be permissible within most industrial zonings in NSW.

The PHA prepared for this project identifies the potential hazards, analyses these hazards in terms of their impact to people and the environment and their likelihood of occurrence, quantifies the resulting risk to surrounding land uses and assess the risk to demonstrate that the project will not impose an unacceptable level of risk.

The Resilience and Hazards SEPP identifies three levels of PHA. If a PHA is required, a judgement of the level of risk associated with the project is determined using the results of the screening and hazard identification stages. The three levels of PHA are:

– Level 1 – if significant but not serious potential for harm is identified, a qualitative PHA is completed.
– Level 2 – if medium potential for harm is identified, a semi-quantitative PHA is completed.
– Level 3 – if high potential for harm is identified, a quantitative PHA is completed.

4. Existing environment

The project site sits within the former Munmorah Power Station at Colongra on the Central Coast of NSW. Munmorah Power Station operated for a period of approximately 50 years prior to its closure in June 2012. In 2016, Munmorah Power Station and its surrounding land area was transferred to Generator Property Management Pty Ltd (GPM). GPM is a government-owned company with, amongst other things, responsibility for decommissioning, demolition and remediation of power station sites remaining in public ownership in NSW. GPM remains responsible for decommissioning, demolition, and remediation of Munmorah Power Station.

The project site has an area of approximately 14 hectares and is relatively flat. It is mostly cleared (except for some small patches of native vegetation) and heavily disturbed from its previous use as a coal stockpile area for the former Munmorah Power Station.

Infrastructure immediately surrounding the project site includes:

– Telecommunications tower immediately to the north-west.
– Colongra Power Station, approximately 250 metres to the north-east.
– Transmission lines and electrical distribution infrastructure to the north, including Munmorah Substation.
– Former Munmorah Power Station and associated lands to the north-west and north.

Within the locality of the project site are the residential suburbs of Doyalson, San Remo, Buff Point, Budgewoi and Halekulani with the latter being approximately 600 metres distant (and the others farther away). Other public areas of interest are:

– Hammond Canal which is a man-made canal that links Lake Munmorah to Budgewoi Lake, approximately 300 metres north-west of the project site.
– Koala Park, approximately 400 metres north-west of the project site.
– Colongra Swamp Nature Reserve, approximately 650 metres to the north-east of the project site.
– Lake Munmorah, approximately 1.2 kilometres to the south-east of the project site.
– Budgewoi Lake, approximately two kilometres to the south-west of the project site.

5. Risk screening

5.1 Construction

Construction of the project would require the use of chemicals and dangerous goods (e.g., paint, solvents, diesel, general oils and lubricants, cleaning products). There would be minimal storage of these chemicals, and no stockpiling would occur during construction of the project. None of the dangerous good thresholds would be exceeded during construction of the project, as per the Resilience and Hazards SEPP. This element of the project lifecycle is not considered potentially hazardous and significant off-site impacts are not anticipated.

Impacts from offensive aspects of the project from construction noise and vibration and dust are referenced in other sections of the EIS.

5.2 Operation

Excluding the lithium-ion batteries, operation of the project would require minimal use of chemicals and dangerous goods. Lithium-ion, refrigerant, coolant, and transformer oil (contained within the transformers only) would be contained within the battery energy storage system. These materials would not be stored onsite apart from what is inside the battery modules. Lithium-ion batteries are a Class 9 dangerous good (miscellaneous dangerous goods and articles) under the Resilience and Hazards SEPP. Transformer oil is a Class C2 dangerous good (combustible liquid) under Resilience and Hazards SEPP. Neither Class 9 or C2 dangerous goods have a SEPP threshold, so none of the dangerous good thresholds would be exceeded during operation of the project, as per the Resilience and Hazards SEPP. However, based on industry knowledge of the battery storage technology, and considering that large battery energy storage systems are a relatively new technology, the project has been considered ‘potentially hazardous’ and a Level 2 PHA has been prepared for the project.

The nature of a BESS operation is not pre-disposed to emissions, and the project would not release a quantity of pollutant emissions during normal operation to be considered potentially offensive. An assessment of noise and vibration from the operation of the project has been undertaken with findings provided Section 6.6 of the EIS.

5.3 Decommissioning

Decommissioning of the project would require the use of chemicals and dangerous goods (e.g., diesel, general oils and lubricants, cleaning products). There would be minimal storage of these chemicals, and no stockpiling would occur during decommissioning of the project. None of the dangerous good thresholds would be exceeded during decommissioning of the project, as per the Resilience and Hazards SEPP. This element of the project lifecycle is not considered potentially hazardous and significant off-site impacts are not anticipated.

Impacts from offensive aspects of the project from decommissioning and rehabilitation noise and vibration and dust are referenced in other sections of the EIS.

6. Preliminary hazard analysis

6.1 Hazard identification

The results of the desktop hazard identification are provided in Table 6.1, including safeguards. The safeguards are required to ensure the risk scenarios that were identified are contained or at least controlled to an acceptable level.

In undertaking the hazard identification study the following assumptions were made:

– All plant and equipment is installed and operated in accordance with appropriate Australian Standards, codes and guidelines.

– Dangerous goods are stored in accordance with the Australian Dangerous Goods Code, relevant standards and guidelines even if not a licensable quantity.

– All equipment and systems are designed to be inherently safe.

Table 6.1 Hazard identification

Life cycle stage	Hazard	Cause and consequence	Safeguard	Considered in hazard analysis
Construction	Vehicle interactions on public roads	Transport of equipment to site results in a traffic accident leading to a fatality.	Construction Management Plan	No
	Vehicle interactions within the project area	Movement of heavy mobile equipment on site results in a traffic accident leading to a fatality.		No
	Natural hazards	Extreme weather event, such as flooding, earthquake, lightning or bushfire results in equipment damage and/ or construction delays leading to additional costs.		No
	Fire	Hot works activities result in a small fire within the project area leading to equipment damage and/ or construction delays and additional costs.		No
	Loss of containment of chemicals, including dangerous goods	Spill from human error or equipment failure results in environmental damage leading to fines.		No
	Contact with chemicals, including dangerous goods	Spill from human error or equipment failure results in injury leading to first aid or hospitalisation.		No
	Contact with electricity	Human error or equipment failure results in injury leading to hospitalisation.		No
Operation	Vehicle interactions within the project area	Movement of heavy mobile equipment on site results in a traffic accident leading to a fatality.	Safety Management System	No
	Natural hazards (flooding, earthquake, lightning, bushfire)	Extreme weather event, such as flooding, earthquake, lightning or bushfire results in equipment damage.		No

Life cycle stage	Hazard	Cause and consequence	Safeguard	Considered in hazard analysis
	Loss of containment of chemicals, including dangerous goods	Spill from human error or equipment failure results in environmental damage leading to fines.		No
	Contact with chemicals, including dangerous goods	Spill from human error or equipment failure results in injury leading to first aid or hospitalisation.		No
	Contact with electricity	Human error or equipment failure results in injury leading to hospitalisation.		No
	Impact damage of lithium-ion battery assemblies	Handling error during maintenance and/ or replacement activities results in equipment damage.		No
	Electrical installations	Presence of multiple pieces of electrical equipment results in exposure to electric and magnetic fields (EMF).		Yes
	Thermal runaway of lithium-ion batteries	Manufacturing fault, overcharging or overheating within containers results in a large fire leading to injury or fatality.	Battery Management Plan	Yes
Decommissioning	Vehicle interactions on public roads	Disposal of equipment off site results in a traffic accident leading to a fatality.	Decommissioning Management Plan	No
	Vehicle interactions within the project area	Movement of heavy mobile equipment on site results in a traffic accident leading to a fatality.		No
	Natural hazards	Extreme weather event, such as flooding, earthquake, lightning or bushfire results in decommissioning delays leading to additional costs.		No
	Fire	Hot works activities result in a small fire within the project area leading to decommissioning delays and additional costs.		No
	Loss of containment of chemicals, including dangerous goods being removed	Spill from human error or equipment failure results in environmental damage leading to fines.		No
	Contact with chemicals, including dangerous goods during removal	Spill from human error or equipment failure results in injury leading to first aid or hospitalisation.		No
	Contact with electricity during isolation and removal	Human error or equipment failure results in injury leading to hospitalisation.		No

6.2 Hazard analysis

Two hazards were identified that required further analysis. The hazards and the associated analysis are discussed in detail within this section.

6.2.1 Lithium-ion batteries

Lithium-ion batteries are regulated as Class 9 miscellaneous dangerous goods and articles. Lithium-ion batteries contain electrolyte and lithium in various forms, along with other metals. Lithium-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in a non-rechargeable lithium battery. The electrolyte, which allows for ionic movement, and the two electrodes are the constituent components of a lithium-ion battery cell.

Lithium-ion batteries can pose unique safety hazards since they contain a combustible or flammable electrolyte and may be kept pressurised. If a battery cell is charged too quickly, it can cause a thermal runaway from overvoltage, or dendrite formation (short circuit), leading to potential fires and explosions. Because of these risks, testing standards are more stringent than those for acid-electrolyte batteries, requiring both a broader range of test conditions and additional battery-specific tests. There are also different types of battery chemistry associated with lithium-ion batteries. There is an industry-wide trend to change to the iron phosphate from the conventional magnesium-cobalt-aluminium oxide chemistries due to an order of magnitude or better reduction in thermal runaway risk. The reason for the risk reduction is that iron phosphate lithium batteries have a high chemical and thermal stability and a high temperature tolerance so provide a higher level of safety.

Historically, there have been consumer product battery-related recalls by some companies, including the Samsung Galaxy Note 7 and hoverboards, both recalled for battery fires. Investigations indicate that the key causes for the fires were either the use of non-certified batteries or manufacturing defects (Battery University, 2019).

There are several hazard management options for thermal runaway of lithium batteries. For example, these may include, but are not limited to, lithium chemistry utilised, fusible separators which slow down conduction over certain temperatures, pressure relieving mechanisms, and separation of the anode and cathode to minimise dendrite formation and short circuits.

There are a number of options for containerised lithium-ion batteries, such as ABB PowerStore (ABB, 2020) and Tesla Powerpack (Tesla, 2017) and others that could be used for the project. A final decision on the exact supplier would be determined during the detailed design and procurement phases. General data from associated equipment guides have been utilised and referenced for the following consequence and likelihood calculations.

The refrigerant used in the batteries is typically a dangerous goods Class 2.2 by virtue of the pressure at which it is stored, but with release and partial combustion, could form small quantities of fluorinated hydrocarbons or hydrofluoric acid in the immediate area of the fire (Tesla, 2017). This could cause a localised environmental impact from acidified fire-fighting water that would need to be contained and disposed of in a suitable manner.

Existing situations were reviewed for situations where lithium-ion batteries are located in relatively confined regions with limited ventilation or where lithium-ion batteries provided a thermally based ignition/ toxic release. Whilst these examples are diverse, they have fundamental similarities to typical battery energy storage systems and solar farm installations that assist with consequence understanding.

The release, dispersion, and flammable effect for lithium-ion batteries has been tested with smaller battery assemblies for consumer / retail equipment due to thermal events associated with hoverboards, e-cigarettes or mobile phones (Battery University, 2019). Some events have happened at a larger commercial scale, including a 2 MW battery array in the USA which injured a team of firefighters (FM Global, 2019). Another known event occurred with a US navy test submarine, where thermal runaway apparently happened during charging. The battery size was approximately one megawatt hour. The submarine was closed off and cooled from the outside with water until the reaction had run to completion (Cavas, 2008)

Most recently, the Victorian Big Battery experienced a fire during commissioning. The findings (ESV, 2021) found that fire escalation was due to environmental conditions (such as high wind) not being considered in testing and a weakness in the thermal roof design. Additionally, during commissioning several monitoring and protection systems were switched to off-line service mode, which allowed the initial fault to go undetected and resulted in the total loss of two battery units. The fire response was to allow the on-fire units to burn themselves out, whilst keeping the remaining units cool with water deluge.

A cabinet of batteries within a container could exhibit some similar features of release, such as a gaseous release from electrolyte, refrigerant or coolant. Depending on the materials, heated chlorinated and fluorinated hydrocarbons could be released into the container space. Evidence has shown that the separation distances between cabinets will reduce escalation potential, and slow down propagation of a thermal event from one battery cabinet to adjacent equipment. Additionally, separation of containers will also limit escalation potential.

6.2.1.1 Hazard scenarios

The key hazard for battery systems is thermal runaway. There are a number of causes of thermal runaway and the following scenarios were identified as being worthy of further analysis:

– Scenario 1: Latent battery failure caused by a manufacturing fault.
– Scenario 2: Overcharging.
– Scenario 3: Overheating within containers.

Thermal runaway from hot joints is considered to be incorporated into the battery failure fault rate in scenario one. Thermal runaway from operational or maintenance handling damage is considered to be minimal and incorporated into the risk of scenario three.

6.2.1.2 Consequence assessment

The conditions in Table 6.2 were used in the consequence determination. Any one of the three scenarios could result in a thermal runaway, so the consequence is relevant for all three scenarios listed in Section 6.2.1.1.

Table 6.2 Consequence determination assumptions

Parameter	Symbol	Value	Comment
Assumed average container surface temperature during thermal runaway reaction	T_1	400 °C	Trigger temperature for thermal runaway is lower (about 70-80 °C) The individual cells may exceed 600 °C [1]
Surrounding air temperature	T_2	22 °C	Average outside air temperature for Norah Head [2]
Height of containerised battery unit	L_1	2.896 m	Height of an ABB PowerStore [3]
Height of an average person	L_2	1.8 m	Average height of a person

It was estimated that the heat experienced between the batteries and a person in range during a fire, can be estimated by the radiation between two parallel plates/ flat surfaces. This calculation estimated the net radiant heat exchanged between two plates using Figure 6.1.

[1] Tesla, 2017, Lithium-ion battery emergency response guide – Tesla Powerpack system, Powerwall and sub-assembly, all sizes, pages 7 and 9
[2] Bureau of Meteorology website, summary statistics for Norah Head AWS, accessed August 2022 **Climate statistics for Australian locations (bom.gov.au)**
[3] ABB, 2020, e-mesh PowerStore modular: flexible and scalable energy storage system, page 4

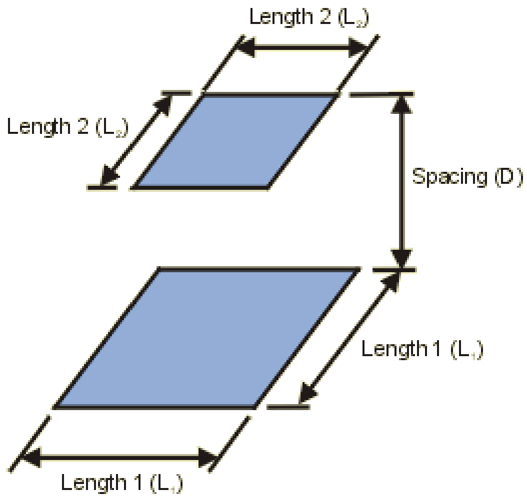

Figure 6.1 *Radiant heat exchanged between two plates*

Details of the calculations are based on radiation between parallel square surfaces of different edge lengths follow.

The heat flow q from the plate[4] is calculated as:

q = 56.69 x 10^{-9} x VF(1-2) x L12 x (T14 – T24)

Where

56.69 x 10^{-9} is the average Stefan-Bolzmann constant

L1 is the length of plate 1

L2 is the length of plate 2

T1 is the plate 1 temperature

T2 is the plate 2 temperature

D is the distance between plates (values provided in Table 6.3 to give differing radiated heat values)

The view factor VF(1-2) (also known as radiation shape factor, angle factor, and configuration factor) is defined as:

$$VF_{(1-2)} = \frac{1}{\pi \left(\frac{L_1}{D}\right)^2}(A + B + C)$$

[4] Rosenow, W. M., J. P. Hartnett, Y. I. Young, Handbook of Heat Transfer, 3rd Ed., McGraw-Hill Handbooks, New York, 1998. p. 7.3 - 7.19, 7.81

Where:

$$A = \ln \frac{\left[\left(\frac{L_1}{D}\right)^2\left(1+\left(\frac{L_2}{L_1}\right)^2\right)+2\right]^2}{\left(y^2+2\right)\left(x^2+2\right)}$$

$$B = \sqrt{y^2+4}\left[y \tan^{-1}\frac{y}{\sqrt{y^2+4}} - x \tan^{-1}\frac{x}{\sqrt{y^2+4}}\right]$$

$$C = \sqrt{x^2+4}\left[x \tan^{-1}\frac{x}{\sqrt{x^2+4}} - y \tan^{-1}\frac{y}{\sqrt{x^2+4}}\right]$$

Where X and Y are defined as:

X = R x (1 + e)

Y = R x (1 – e)

R = L1 / D

Note: R must be greater than 0.2 for this calculation.

e = L2 / L1

Given the complex equation, the website referenced[5] iteratively uses distances to provide the indicated radiated heat outputs, as listed in Table 6.3. The radiated heat distances are relevant for all three thermal runaway hazard scenarios.

Table 6.3 Summary of heat radiation consequences

Release Scenario	Maximum Distance Downwind of Release to Heat Radiation		
	4.7 kW/m^2 (heat radiation level that can cause injury)	**12.6 kW/m^2 (heat radiation level that can cause fatality)**	**23 kW/m^2 (heat radiation level that can cause property damage)**
Single container battery thermal runaway event (container reaches 400 °C)	4.11 m	2.06 m	1.05 m

The release events are worst case as they assume no intervention to limit the release. For the release scenarios, some level of intervention would be expected. Additionally, the battery units are containerised, so, whilst a fire may start within the container, the container walls will also inhibit a proportion of the radiated heat. As such, the zones of effect can be considered conservative.

Separation distance between containers is important to limit the potential for overheating adjacent containerised batteries. The most relevant guidance for BESS separation distances comes from the United States of America. As the layout of the units has not been finalised, the design should align with guidance on separation distances as set out by the most recently released codes, as shown in Table 6.4. The 2021 Victorian Big Battery fire highlight the importance of having a functioning battery monitoring system throughout all life-cycle periods (including commissioning). Additionally, the findings from the Victorian Big Battery fire indicate that appropriate thermal testing, such as the inclusion of a variety of environmental conditions, is needed when determining final BESS layout.

[5] Maya HTT, accessed August 2022, Radiation between parallel square surfaces of different edge length, **https://thermal.mayahtt.com/t4.1mwiz/radiate/pa-sqpl/pa-sqpl.htm**

Table 6.4 BESS separation distance references

Standard/ Code	Separation distance reference	Comments
NFPA 855 – Standard for the Installation of Stationary Energy Storage Systems 2020	1 m to adjacent ESS units and adjacent walls 3 m from buildings, roads, boundary, hazardous or combustible materials 3 m clearance of combustible vegetation	-
AS 5139 – electrical installations (safety of battery systems for use with power conversion equipment) 2019	0.6 m between equipment	Less relevant because standard focus is on battery system and all other equipment within a battery system room, not specifically between units
UL 9540 – Standard for Safety of Energy Storage Systems and Equipment 2021	1 m to adjacent ESS units and adjacent walls (reduced distances require a large-scale fire test via valid thermal testing process)	UL 9540A (Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems) found to be invalid with high winds (VBB findings 2022)
Fisher Engineering Inc and Energy Safety Response Group, 2022, Fire report of technical findings from the Victorian Big Battery Fire	These units had a spacing of 0.15 m to the sides and back of each unit with 2.4 m in front of each unit, after using UL 9540A. Fire escalation was determined to be due to environmental conditions (such as high wind) not being considered in UL 9540A and a weakness in the thermal roof design. Additionally, during commissioning several monitoring and protection systems were switched to off-line service mode, which allowed the initial fault to go undetected and resulted in the total loss of two battery units.	Fire escalated between units separated by 0.15 m Highlights importance of a functioning battery monitoring system

The radiant heat distances calculated in Table 6.3 align with the guidance from the codes outlined in Table 4, although, to protect the general public from injury, a distance of four metres or more from the boundary is recommended.

6.2.1.3 Likelihood estimation

The likelihood of the three thermal runaway scenarios identified occurring during operation of the project could be different, so all three are assessed. The results of the frequency analysis for the three scenarios are summarised in Table 6.5 to Table 6.8. The assignment of the frequency and probability values has been made based on industry failure frequencies, specialist risk management judgement, and the quantified consequences.

It is important to note that the determination of 'absolute values' for assigned probabilities is less important than consistently using 'comparative' or 'relative' values. The overall aim is to provide a ranking to compare with risk criteria.

Table 6.5 Scenario 1: Latent battery failure frequency

ID	Parameter	Value	Reference
A	Batteries per rack	18	ABB Design specs
B	Racks per container	2	ABB Design specs
C	Number of containers	2,800	Project specs
D	Total number of battery units	100,800	Calculated = A*B*C
E	Manufacturing fault rate (failure per battery per year)	1/100,000	Assumed – includes battery faults and connection / joint faults using lithium iron phosphate chemistry
F	Latent battery failure frequency (per year)	1.1	Calculated = D*E
G	Percentage of faults leading to thermal runaway	30 %	Professional estimation

ID	Parameter	Value	Reference
H	Effectiveness of fusible separators in preventing thermal runaway	95 %	Professional estimation
I	Thermal runaway from latent battery failure frequency (per year)	0.015	Calculated = F*G*(1-H)
J	Thermal runaway from latent battery failure (years)	66	Calculated = 1/I

Table 6.6 Scenario 2: Overcharging

ID	Parameter	Value	Reference
K	Storage capacity per battery (hrs)	4	ABB Design specs
L	Number of charges per container per year	365	Assumed
N	Total number of charges for all containers per year	1,022,000	Calculated = L*C
O	Charging failure rate (failure per charge per year)	1/10,000,000	Assumed – driver is circuit and protective components but includes checks and battery management systems – both voltage, current and thermal sensing
P	Thermal runaway from charging failure frequency (per year)	0.102	Calculated = N*O
Q	Thermal runaway from charging failure (years)	9.8	Calculated = 1/P

Table 6.7 Scenario 3: Overheating within containers

ID	Parameter	Value	Reference
R	HVAC systems per container	2	ABB Design specs
S	Total number of HVAC units	5,600	Calculated = R*C
T	HVAC fault rate (failure per battery per year)	1/10,000	Assumed
U	HVAC failure frequency (per year)	0.56	Calculated = S*T
V	Percentage of faults leading to thermal runaway	50 %	Professional estimation
W	Effectiveness of fusible separators in preventing thermal runaway	95 %	Professional estimation
X	Thermal runaway from latent battery failure frequency (per year)	0.014	Calculated = U*V*(1-W)
Y	Thermal runaway from latent battery failure (years)	71	Calculated = 1/X

Table 6.8 Total frequency for thermal runaway events

ID	Parameter	Value	Reference
Z	Combined thermal runaway frequency (per year)	0.13	Calculated = I+P+X
AA	Combined thermal runaway events (years)	7.6	Calculated = 1/Z

6.2.1.4 Risk assessment

Combining the consequence assessment with the frequency estimation provides the risk of thermal runaway events occurring. The onsite and offsite risk assessment results are shown in Table 6.9 and Table 6.10.

Table 6.9 Risk assessment results – onsite

ID	Parameter	Value	Reference
AB	Frequency of thermal runaway event (per annum)	0.13	Calculated = Z
AC	Probability of person impacted	1/240	Assumed – using consequence combined with layout (area divided into 10 sections) and someone in the field for an hour per day
AD	Probability impact results in fatality	1/100	Conservative professional estimation
AE	Probability impact results in injury	9/10	Conservative professional estimation
AF	Probability impact results in property damage	100 %	Conservative professional estimation
AG	Frequency of fatality (per annum)	5.5×10^{-06}	Calculated = AB*AC*AD
AH	Frequency of injury (per annum)	4.9×10^{-04}	Calculated = AB*AC*AE
AI	Frequency of property damage (per annum)	0.13	Calculated = AB*AF

Table 6.10 Risk assessment results – offsite

ID	Parameter	Value	Reference
AJ	Frequency of thermal runaway event (per annum)	0.13	Calculated = Z
AK	Probability of person and or property impacted	0	Assumed – using consequence and proposed location of BESS
AL	Frequency of fatality (per annum)	0	Calculated = AJ*AK
AM	Frequency of injury (per annum)	0	Calculated = AJ*AK
AN	Frequency of property damage (per annum)	0	Calculated = AJ*AK

The risk criteria for land use and safety planning within HIPAP 4 (Department of Planning, 2011) include onsite and offsite fatality values, as well as offsite injury and property damage values. The HIPAP 4 fire and explosion risk criteria are summarised in Table 6.11.

Table 6.11 HIPAP 4 Risk Criteria

Impact	Onsite Criteria	Offsite Criteria
Fatality (12.6 kW/m^2 & 21 kPa)	5.00×10^{-05}	1.00×10^{-06}
Serious injury (4.7 kw/m^2 & 7 kPa)	–	5.00×10^{-05}
Property damage (23 kw/m^2 & 14 kPa)	–	5.00×10^{-05}

The assessment of risk of fatality, injury and property damage for any thermal runaway event against HIPAP 4 risk criteria is summarised in Table 6.12. There are no expected offsite impacts given the proposed location, and as such the risk of injury, fatality or property damage is negligible and complies with HIPAP 4. The onsite fatality risk also complies with HIPAP 4.

Table 6.12 Risk criteria compliance for thermal runaway events

Event	Frequency per year	Interval years	Compliance
OFFSITE property damage	0	0	Complies
OFFSITE serious injury	0	0	Complies
OFFSITE fatality	0	0	Complies
ONSITE fatality	5.5×10^{-06}	183,000	Complies

6.2.1.5 Management recommendations

In order to ensure no offsite impact occurs, the BESS should be located at least 4.5 m from the facility border to ensure compliance with HIPAP guidelines. The current design has an asset protection zone between the BESS and the boundary much greater than 4.5 metres. Also, the greater the distance between the BESS and the site boundary, the better the facility can manage the BESS fire hazard whilst allowing for future growth and expansion of battery storage capacity.

The project would manage potential fire risks through mitigation, as outlined in a battery management plan. Specific management of potential bushfire risk will occur as per recommendation in other sections of the EIS.

Offsite health effects from smoke, which could include small quantities of fluorinated hydrocarbons or hydrofluoric acid are considered low given the lack of combustible material available for a prolonged fire event and the low residential density in the area. A strong wind may have the ability to carry the smoke laterally beyond the site. Additionally, the fluorinated hydrocarbons and hydrofluoric acid could cause a localised environmental impact from acidified fire-fighting water that should be contained and disposed of in a suitable manner.

A battery management plan should be developed and implemented to capture the following key battery safety requirements (Occupational Safety and Health Administration, 2019, Battery University, 2017 and Tesla, 2017):

- Batteries will be stored as per manufacturer specifications.
- Installation of equipment will be in accordance with manufacturer's instructions and by qualified personnel.
- Ensure lithium-ion batteries and associated equipment are tested and certified to ISO 9001, with internal verification processes such as receipt and filing of certification details.
- Compliance to AS/ NZS 5139:2019 (Electrical installations – Safety of battery systems for use with power conversion equipment).
- Verification of installation quality and operational values is required for each battery container.
- A BESS commissioning plan is developed and includes confirmation that Battery Management System (BMS) is activated and operating during commissioning.
- The battery system will be insulated, containerised and bunded.
- Installation of bollards/ protective barriers around key areas.
- The location of the BESS should be at least 4.5 m from the core development area boundary, based on preliminary radiant heat contours for public injury, and confirmed by appropriate modelling (thermal and other).
- Separation distances between battery containers should be confirmed by the BESS designer/ supplier through appropriate thermal testing/ modelling and comply with AS 2067 (Substations and high voltage installations exceeding 1 kV a.c.). Industry guidance recommends at least 1 metre where possible or a 1-hour minimum fire barrier should be installed if separation distances cannot be achieved.
- Ensure lithium-ion batteries includes protections and circuit controls, such as
  - Integrated circuit control systems to avoid voltage drift.
  - Current sensing circuits to avoid short circuiting.
  - Built-in positive temperature coefficient to protect against current surges.
  - Circuit interrupt device that opens at excess pressure.
  - Safety vent to release gases on excessive pressure build-up.
  - Separator that inhibits ion-flow when exceeding a certain temperature threshold.

- BMS to properly manage the batteries state of change, including battery balancing devices, to avoid deterioration and individual cell over/ under voltage during operation.
- Ensure lithium-ion batteries and associated equipment are located within a temperature controlled and ventilated location that does not exceed the manufacturer temperature range specification.
- Thermal sensing of the cells to avoid over heating of cells.
- An inspection and maintenance regime for the batteries, HVAC and associated equipment.
- A hot joint monitoring program for battery terminals and connections.
- The lithium-ion batteries storage area will be protected from flooding, based on the annual exceedance probability for the area and subsequent suitable selection of freeboard.
- Avoidance of damaging lithium-ion batteries. Regularly inspect them for signs of damage, such as bulging/cracking, hissing, leaking, rising temperature, and smoking.
- The lithium-ion batteries will have a fire detection and suppression system.
- A protocol in place for damaged batteries that will include the following actions:
  - Immediately remove a battery from service and place it in an area away from flammable materials if any sign of damage is present.
  - Before moving a damaged battery, wait a period of time to observe if there is any smoke, as this may be an indication that a thermal reaction is in progress. A damaged battery will also be monitored after removal for evidence of smoke, flame, leakage of electrolyte, leakage of coolant, or signs of heat.
- Follow manufacturer's guidance on how to extinguish small battery fires, which could include using dry chemical extinguishers, foam fire extinguishers, powdered graphite, dirt, or sand. If the fire of a burning lithium-ion battery cannot be extinguished, allow the container to burn out on its own in a controlled and safe manner, using water to cool the outside container.
- A battery emergency response plan to be enacted in the event of a BESS fire. This will be regularly reviewed and tested to ensure relevance.

As generic data on lithium-ion batteries was used to assess quantities and consequence impacts, a review and confirmation that the risk assessment calculations are still valid is required once detailed design is finalised.

6.2.2 EMF

EMF are part of the natural environment. Electric fields are present in the atmosphere and static magnetic fields are created by the earth's core. EMF is also produced wherever electricity or electrical equipment is in use. Transmission lines, electrical wiring, household appliances, and electrical equipment all produce power frequency EMF.

An electronic field is the force that fills the space around every electric charge, including any powered electrical appliance or conductor (e.g. transmission line). Electric fields are measured in volts per metre (V/m) or kiloVolt per metre (kV/m). They occur both naturally and from power generation and are produced every time electricity flows or there is an electrical force. The higher the voltage/ force the stronger the electric field. Electric fields are strongest closest to the source and their level reduces quickly with distance. Most materials act as a shield or barrier to electric fields.

Fields of different frequencies interact with the body in different ways. In Australia, transmission lines and other electrical devices and infrastructure, including substations, operate at a frequency of 50 hertz. This frequency falls within the Extremely Low Frequency (ELF) range of 0 to 300 hertz adopted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has adopted the ICNIRP Guidelines for Limiting Exposure to Time-varying Electric and Magnetic Fields (1hz – 100khz) (2010) (ICNRP Guidelines). The ICNIRP Guidelines express limits in terms of 'Reference Levels' and 'Basic Restrictions' under general public and occupational exposure conditions for ELF EMF. ARPANSA has developed its own standard for EMF greater than 100 kHz, which also aligns with ICNIRP's Guidelines for the same frequency range.

A summary of the ICNIRP Guidelines for exposure to ELF EMF (below 100 kHz) is provided in Table 6.13.

Table 6.13 ICNIRP Guidelines for exposure limits below 100 kHz

Exposure characteristics	Electric field strength (kiloVolt per metre – kV/m)		Magnetic flux density (Tesla – T)	
	Occupational	General public	Occupational	General public
1 Hz - 25 Hz	20	5	0.025/f	0.005/f
25 Hz - 300 Hz	500/f	250/f	0.001	0.0002
300 Hz - 3 kHz	500/f	250/f	0.3/f	0.08/f

Where f = frequency in Hz

Using the Australian frequency for transmission lines, the exposure limits specific to high voltage (HV) overhead power lines is displayed in Table 6.14.

Table 6.14 Exposure limits for overhead high voltage power lines (50 Hz)

Exposure characteristics	Electric field strength (volt per metre – V/m)	Magnetic flux density (milliGauss – mG)
Occupational		
Whole working day	10,000	10,000
General public		
Up to 24 hours per day	5,000	2,000

6.2.2.1 Hazard scenarios

They key hazard for electrical installations is EMF. During operation, the following sources of EMF would be present on the project site:

– Proposed onsite switchyard.
– New proposed 330 kV transmission lines (two) to connect into the Munmorah Substation.

6.2.2.2 Consequence assessment

The layout of the switching yard and the selection of equipment which would be undertaken during detailed design would be in line with the design of similar substations located throughout Australia. The principles of prudent avoidance would be implemented, and careful positioning and selection of equipment is likely to result in exposure levels at the boundary of the substation being similar to existing background levels. Fencing around the switching yard (and wider site) would ensure that members of the public would be at negligible risk of exposure from the substation. Access to the switching yard would only be available to suitably trained workers.

While the rest of the electrical equipment to be located on site would generate magnetic fields, due to their voltage levels and substantial distance to the nearest sensitive receivers they are likely to comply with limits for both public and occupational exposure. Exposure levels are likely to be close to background levels at the property boundary. Security fencing to be erected around the site would also prevent access to the site by members of the public and, therefore, limiting their exposure.

The proposed route for the overhead transmission line would run along the north-eastern boundary of the former Munmorah Power Station. It would be approximately 650 metres long. The route does not go through residential areas.

TransGrid (2020) have indicated that the magnetic flux from typical HV transmission lines, such as those seen on the transmission line for the project, are:

– 10 – 200 mG directly under a HV transmission line for people doing ground-based activities.
– 2 – 50 mG at the edge of a HV transmission line easement (typically 22.5 to 35 metres from the centre line) for people doing ground-based activities

These magnetic fields are well below the levels contained within the interim guidelines on limits of exposure (see Table 6.14).

The new overhead transmission line would have an easement width of around 45 metres. Houses, buildings, and other substantial constructions would be prohibited within the proposed easement. Regardless of route selection, the transmission line would operate in the same way as existing power lines in the area and would present a minimal EMF risk to the general public or workers.

As the consequence impact is not considered significant, no further discussion is needed within the PHA.

6.2.3 Cumulative risk

The proposed location of the BESS is located within a power generator precinct, with the Colongra Power Station and the Munmorah Substation located in proximity to the BESS. As with the BESS, the power station and the substation will have fire and explosion hazards. Like the BESS, the power station and the substation risk profiles are anticipated to be focused within their respective boundaries and therefore the cumulative risk is not expected to increase for the area. Additionally, the nature of the fire and explosion hazards and the separation of each facility is not predicted to result in any knock-on effects.

7. Mitigation measures

Mitigation measures proposed to avoid or minimise potential hazards and risks during construction, operation, and decommissioning and rehabilitation of the project are listed in Table 7.1. These measures would be included in the issue-specific environmental management sub-plans for the Waratah Super Battery.

Table 7.1 Mitigation measures – hazards and risk

No.	Risk	Mitigation measure	Timing
HR1	BESS thermal runaway event	Select lithium iron phosphate chemistry for the battery type. Design and selection of all battery equipment should implement items listed in Section 6.2.1.5.	Design
HR2	EMF exposure	Design and selection of electrical equipment to minimise EMF levels and comply with the ICNIRP exposure levels. Install fit for purpose electrical systems.	Design
HR3	Construction/ decommissioning accident	Prepare a construction management plan, and when needed, a decommissioning plan, to manage construction/ decommissioning-related risks, including traffic management, designated pedestrian areas within the core development site and bushfire management. Develop safe work method statements to guide construction/ decommissioning activities, including crane operation, installation of electrical equipment and chemical handling procedures. Provide appropriate Personal Protective Equipment (PPE) to all staff	Construction/ decommissioning
HR4	BESS thermal runaway event	Prepare a battery management plan, including fire safety study to incorporate the items listed in in Section 6.2.1.5.	Operation

8. Conclusion

This PHA addressed the hazard and risk component associated with the project. Specifically, an assessment of potential hazards and risks associated the BESS for the project.

The PHA involved a preliminary risk screening of the project in accordance with the requirements of the Hazards and Resilience SEPP. While the results of the dangerous goods and transport screening indicated that the project does not exceed any of the thresholds within the Hazards and Resilience SEPP requirements, due to the potential for explosion and fire associated with the operation of the lithium-ion battery storage, the project was considered "potentially hazardous".

The initial hazard identification process considered hazards during construction, operation, and decommissioning. Fire started because of construction and/or decommissioning activities is considered a plausible event, as is the interaction with heavy machinery. Both will be managed through the preparation of a construction management plan, and when required, a decommissioning management plan.

During operation, fires started at the BESS are a credible risk and may pose off-site impacts. Given the risk, a Level 2 PHA is an appropriate level of examination and has been included in this report. A Level 2 PHA uses a semi-qualitative approach based on comprehensive hazard identification to demonstrate that the activity does not pose a significant risk.

The PHA determined that the risk arising from the three BESS thermal runaway fire scenarios does not exceed the individual fatality or injury risk criteria specified in the NSW Department of Planning and Environment's 2011 publication HIPAP No. 4 – Risk Criteria for Land Use Safety Planning.

The project presents a minimal EMF risk to the general public and workers as the EMF levels are well below the levels contained within the ICNIRP guidelines.

The PHA demonstrates that the project could be designed, constructed, operated, and decommissioned in a manner that would meet relevant regulations, standards and policies. Therefore, the project does not pose any significant risk or offence.

It is recommended that management procedures and safeguards as listed in Section 7 be implemented to incorporate practices that will prevent risk scenarios occurring.

Any changes to the assumptions used in this report should result in a review of the PHA and update as required.

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