Technical Report – BESS Preliminary Hazard Analysis

Virya Energy

Yanco Delta Wind Farm
15 September 2022

Executive Summary

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure. The generating capacity of the wind farm is approximately 1,500 megawatts (MW).

This Preliminary Hazard Analysis (PHA) assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) relating to potential hazards associated with the BESS and will assist the Minister for Planning to make a determination on whether or not to approve the Project. This report provides an assessment of potential hazards that have the potential to impact community safety and documenting the measures that would be deployed to mitigate unacceptable risks.

BESS

The Project would involve the construction and operation of a grid-scale BESS with a discharge capacity of 800 megawatts (MW) and storage capacity of 800 megawatt hours (MWh). The BESS along with the central primary substation would cover a footprint of up to 15 hectares. The BESS would consist of battery modules and components, and ancillary infrastructure. It would connect to the substations and the grid via underground and/or overhead cables. Whilst the battery technology and/or supplier has not yet been determined, for the purposes of this assessment, the predicted layout and assessed potential risks for the development has been modelled against a lithium-ion (Li-ion) battery. Li-ion is considered a commercially mature technology and has been widely deployed at scale for similar applications.

The BESS would include a larger number of individual small capacity battery enclosures containing racked battery modules. A battery module is typically a standalone component, which, depending on the technology chosen, may be as small as the size of a briefcase. Each enclosure would be physically separated from the adjacent enclosure and typically would be air or liquid cooled. Enclosures would likely include electronics such as battery management systems, battery control systems, fire suppression systems and cabling. Multiple enclosures would connect to an inverter that converts direct current (DC) electricity to alternating current (AC) for distribution and ultimate transmission to the electricity network.

Assessment methodology

This PHA has been prepared in accordance with Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning (DoP, 2011), *Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis* (Department of Planning (DoP), 2011a) and *Multi-Level Risk Assessment* (DoP, 2011b). The PHA is underpinned by a process involving hazard identification and risk assessment, back-office research, advice from specialists. Hazards and risks were considered throughout the full Project lifecycle (construction, operation and decommissioning).

Given the selection of technology or detailed engineering is still to be determined, the PHA has been carried out using a qualitative hazard and risk assessment underpinned by industry knowledge and Project team experience.

Findings and risk assessment

The nominated capacity of the BESS would be able to be accommodated within the area assessed. This was based on a review of current technologies including standard sizing of BESS enclosures, separation distances and balance of plant. The following is a summary of the highest assessed risks and a summary of the key controls:

- A thermal runaway event in a single battery enclosure causing pollution is assessed as a credible hazard:
  - In conventional designs, there are many layers of protection, that have not previously been available in battery designs. These would need to fail for an event to escalate. Further, some manufacturers provide advanced fire suppression systems within their containerised solutions
  - A previous incident at the Victoria Big Battery (VBB) site in Geelong, was investigated and additional commissioning processes, sensors and alarms have been recommended to better identify and respond to failures of internal components. The Project design would be consistent with these recommendations
  - The risk can be reasonably mitigated through monitoring and reporting of early signs of the failure and the design of direct and automatic control and shutdown actions in the battery management system. Further, the adoption of a large number of smaller battery enclosures reduces the amount of pollution caused if an event escalates and is considered unlikely to cause any harmful concentrations if pollution in the form of smoke crosses the Project area as has been found following the investigation by the Environment Protection Authority (EPA) on the VBB incident. Manufacturers inherent design controls vary, and consideration of these would be undertaken during detailed safety in design
  - Due to the nature of the location of the installation i.e., low population density (All dwellings are a minimum of 4.5 kilometres from either BESS option and the closest town to the Project is Jerilderie, which is located a minimum of 35 kilometres to the south-east from the BESS), the likelihood and consequence of airborne hazards would be lower due to dispersion
  - A thermal runaway event in one battery enclosure which triggers thermal runaway in adjacent battery enclosures whereby increasing the volume of pollution is assessed as a credible hazard
  - The risk is reasonably mitigated by thermal insulation built into the containerised solution, passive compartmentation and the adoption of separation distances between battery enclosures.
- A thermal runaway event in an enclosure causing uncontrolled build-up of off-gas to explosive limits and igniting with deflagration / explosion of battery enclosure(s) is assessed as a credible hazard:
  - The risk can be reasonably mitigated through design controls noted earlier to contain the propagation of thermal runaway and the design of deflagration and normal venting of enclosures to avoid build-up of gases above unsafe limits.
- Escalation of thermal runaway event due to poor information or knowledge of appropriate methods of response is assessed as a credible risk:
  - The risk can be reasonably mitigated through robust communications and information transfer.
- Surface water containing contaminants leaving the Project area and having a negative impact on biota in waterways downstream of the development is assessed as a credible hazard:
  - The associated risk can be reasonably mitigated by standard industry design and controls of site drainage and containment. This is further discussed in the Surface water quality and groundwater technical report (Jacobs, 2022a).

Overall, the hazards and associated risks can be mitigated to so far as reasonably practical through adoption of controls based on the latest manufacturer technical solutions which are considered 'state of the art' and various recommendations made arising from the PHA.

Key recommendations

The major recommended actions, mostly relating to the highest rated risks, are summarised as follows:

- Suppliers and designers to demonstrate robust designs to prevent, monitor and (where unable to eliminate the possibility) control thermal runaway and undertake specialist safety in design assessments, such as fire risk assessments to inform the design and selection of the battery technology
- A fire safety study to be carried out in consultation with Fire and Rescue NSW (FRNSW) and to the satisfaction of the operational requirements of FRNSW
- Implement a design principle that assumes a thermal runaway event within an enclosure would occur during the lifetime of the asset and, therefore, limits deflagration energy release and prevents the spread of fire to adjacent enclosures by adopting appropriate design controls, such as suitably designed enclosures and separation distances
- Undertake detailed Hazard and Operability Studies (HAZOP) and design review of the selected designs with specific attention on the inherent design features that detect, control and prevent thermal runaway
- Determine credible scenarios from a thermal runaway event once the technology and its size are determined, to quantify the amount of potential hazardous by-products that must be managed and establish the Project design basis accordingly (e.g., amount of combustion and pollution, fire water requirement for containment (if applicable), volumes of retention dams etc.)
- Implement a robust quality plan and inspections throughout the supply chain and during construction, focused on aspects that provide layers of protection to prevent battery modules being installed that have manufacturing defects or mechanical damage. This should include factory and site acceptance testing
- Develop and implement suitable asset management plans to ensure proper maintenance of the facility in line with manufacturers' recommendations and good industry practice throughout the operations phase
- Engage reputable and experienced design consultants knowledgeable in good industry standards to design the proposed grid connection infrastructure
- Make provisions for training and education of operations staff and emergency response services to understand the technology to safely manage potential incident responses.

Conclusion

At the current stage of development there are no high risks related to the Project construction and operation that could result in significant off-site effects that are not manageable through application of inherent safety in design principles and the adoption of appropriate standards and quality systems.

Inherent design features built into suppliers' battery units are the primary controls for detecting and managing thermal runaway. The adoption of design principles for containment within enclosures, maintaining separation distances of battery enclosures to prevent thermal runaway being triggered by an adjacent BESS fire, and limiting the size and capacity of individual BESS enclosures significantly reduces the severity of a fire or deflagration incident.

The risk of exposure to hazards would be relatively low given the low population density and reasonable separation from the closest sensitive receptor. However, this would be further confirmed once more information is available during the Project detailed design phase to quantify volumes of potentially hazardous by-products (e.g., smoke) and their effects.

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Glossary of terms and abbreviations

Term	Definition
AS	Australian Standard
AHD	Australian height datum
ALARP	As Low as Reasonably Practicable
APZ	Asset Protection Zone
BESS	Battery Energy Storage System
BMS	Battery Management System
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
CCTV	Closed Circuit Television
CEMP	Construction environment management plan
CSSI	Critical state significant infrastructure
CTMP	Construction traffic management plan
DG	Dangerous Goods
DoP	Department of Planning (NSW)
EIS	Environmental impact statement
EMF	Electromagnetic field
EPA	Environment Protection Authority NSW
KV	Kilovolt
LEL	Lower Explosive Limit
MW	Megawatt
MWh	Megawatt hour
NFPA	National Fire Prevention Association
NSP	Network Service Provider
NSW	New South Wales
OEM	Original Equipment Manufacturer
PTW	Permit to Work
QA	Quality Assurance
RL	Reduce level
RMU	Ring Main Unit
SEARs	Secretary's Environmental Assessment Requirements
SES	State Emergency Service NSW
SFAIRP	So Far As Is Reasonably Practical
SSI	State significant infrastructure
SSD	State significant development
TIA	Traffic impact assessment

Term	Definition
WTG	Wind Turbine Generator

1. Introduction

1.1 Background

Virya Energy is proposing to construct, operate and maintain the Yanco Delta Wind Farm (the Project). Approval is sought under Division 4.7 of Part 4 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Project would involve the construction, operation and maintenance of a wind farm with up to 208 wind turbine generators (WTGs), a battery energy storage system (BESS) and associated electrical infrastructure. The generating capacity of the wind farm is approximately 1,500 megawatts (MW). The Project would be located within the South-West Renewable Energy Zone (REZ), 10 kilometres north-west of the town of Jerilderie, within the Murrumbidgee Council and Edward River Council Local Government Areas (LGAs) (refer to **Figure 1-1**).

The Project area is defined as the property boundaries of Project landowners (i.e. landowners that have entered into agreements with Virya Energy to have WTGs or associated infrastructure on their properties).

1.2 Project description

The Project would include the following key features:

- Up to 208 WTGs to a maximum tip height of 270 metres
- Generating capacity of approximately 1500 MW
- BESS, approximately 800 MW/800 megawatt hours (MWh) (type yet to be determined)
- Permanent ancillary infrastructure, including operation and maintenance facility, internal roads, hardstands, underground and overhead cabling, wind monitoring masts, central primary substation and up to eight collector substations
- Temporary facilities, including site compounds, laydown areas, stockpiles, gravel borrow pit(s) and concrete batch plants.

An indicative Project layout is provided in **Figure 1-2**.

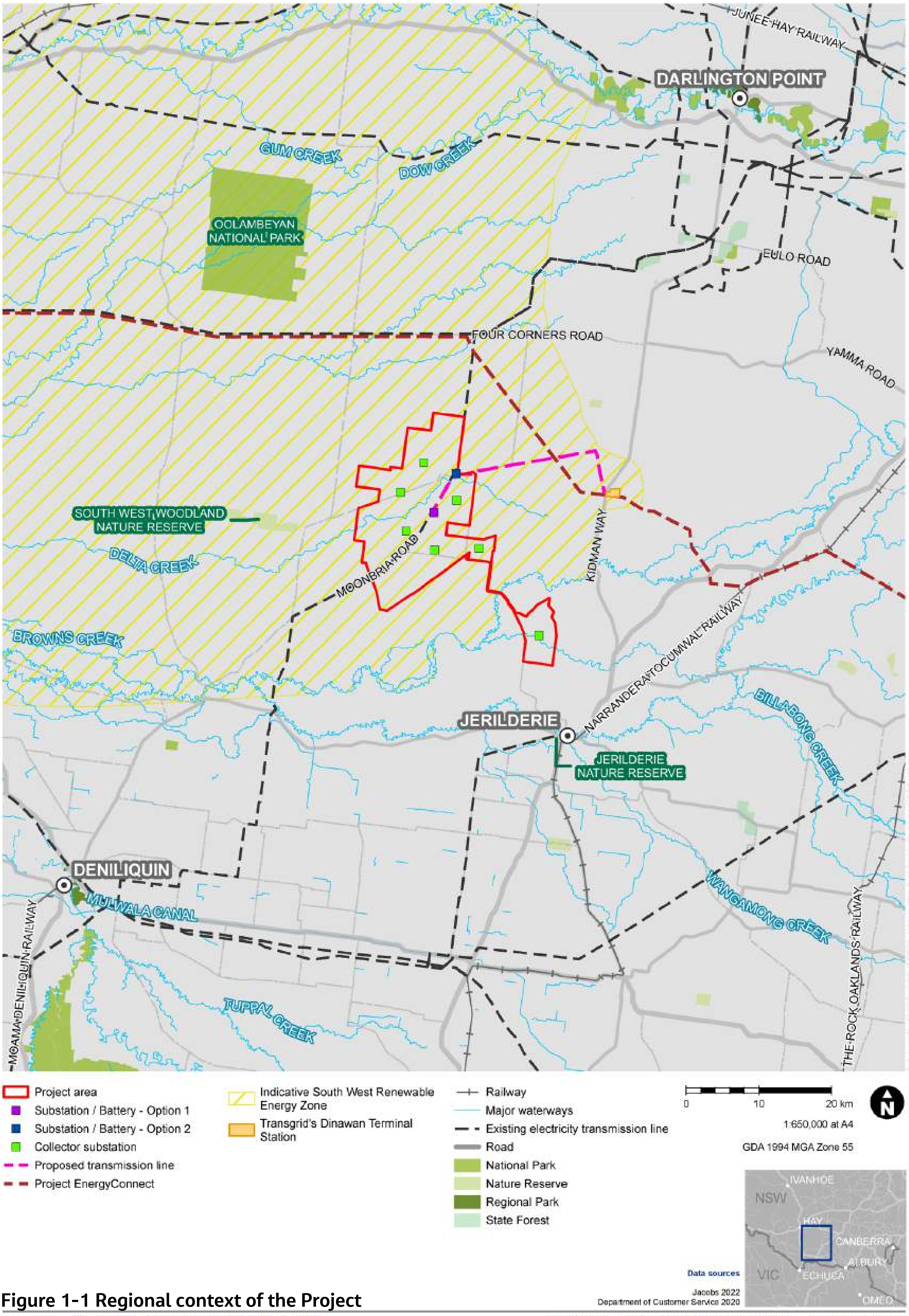

Figure 1-1 Regional context of the Project

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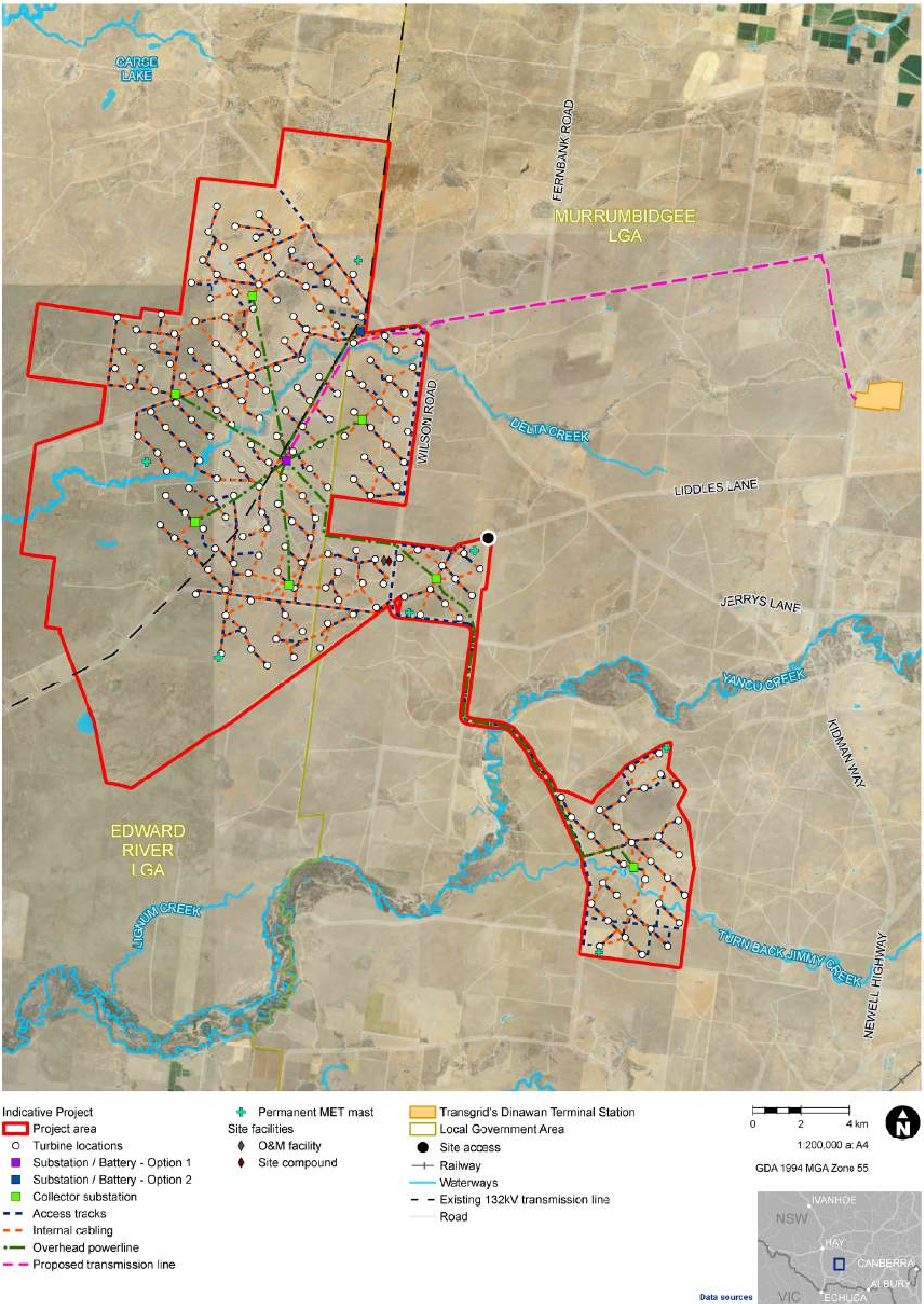

Figure 1-2 Indicative Project layout

Jacobs | NSW Spatial | Buildings & Infrastructure | Eastern Asia Pacific | www.jacobs.com

1.3 Secretary's Environmental Assessment Requirements

This assessment forms part of the environmental impact statement (EIS) for the Project. The EIS has been prepared under Division 4.7 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSD-41743746) relating to preliminary hazards and will assist the Minister for Planning to make a determination on whether or not to approve the Project.

Table 1-1 outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to preliminary hazards

Secretary's Requirement	Where addressed in this report
Hazards and Risks – including:	
• Battery Storage: – a preliminary risk screening completed in accordance with the State Environmental Planning Policy (Resilience and Hazards) 2021	The preliminary risk screening is provided in **Section 5.1**.
– a Preliminary Hazard Analysis (PHA), prepared in accordance with the Hazardous Industry Planning Advisory Paper No. 6, 'Hazard Analysis' and Multi-level Risk Assessment (DoP, 2011). The PHA must consider all recent standards and codes and verify separation distances to on-site and off-site receptors to prevent fire propagation and compliance with Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning (DoP, 2011);	This report. Standards and codes are described in **References**.

1.4 Structure of this report

The structure and content of this report are outlined in **Table 1-2**.

Table 1-2 Structure and content of this report

Chapter	Description
Chapter 1 Introduction	Outlines key elements of the Project, SEARs and the structure of this report (this Chapter)
Chapter 2 Project description	Provides a description of the proposed Project, estimated design parameters, technology assumptions, integration into the overall WTG scheme, construction, operation and decommissioning
Chapter 3 Assessment methodology	Provides a description of the assessment methodology for this assessment
Chapter 4 Findings and recommendations	Summarises the findings and provides key recommendations from the review
Chapter 5 Hazard analysis	Detailed hazard assessment including State Environmental Planning Policy (Resilience and Hazards) 2021 risk screening summary

Chapter	Description
Chapter 6 Environmental management measures	Summarises the findings of this report
Chapter 7 Conclusions	
References	Provides details of external resources used

2. Project description

2.1 Summary

The BESS would have capacity of up to 800 MW / 800 MWh and would consist of battery modules and components as well as ancillary infrastructure. The BESS would connect to the proposed substations and the grid via proposed underground and/or overhead cables.

Storage of energy can add significant benefits to renewable energy generation as it allows for the dispatch of energy in accordance with market demand and can overcome potential issues associated with intermittency of output. The BESS would provide firming capability for the wind energy being produced by the Project and would provide energy storage and key network services that would facilitate long term emissions reduction in the National Electricity Market while supporting the delivery of secure and reliable electricity for consumers and businesses. The BESS would cover a footprint of up to fifteen hectares and would be built next to the central primary substation. Two indicative locations for the BESS are shown in **Figure 1-2**.

A main compound would be erected and used throughout construction. The construction compound would be up to one hectare and would include a site office, car park area, storage and equipment laydown areas. It would be located in existing vacant areas of the Project area.

2.2 Project location

The Project would be located in the South-West REZ in New South Wales (NSW), approximately10 kilometres north-west of the town of Jerilderie, within the Murrumbidgee Council and Edward River Council Local Government Areas (LGAs). The largest population centres nearby are Wagga Wagga, about 150 kilometres east of the Project, followed by Deniliquin located 70 kilometres south-west of the Project.

The Project would connect to Transgrid's Dinawan Terminal Station, scheduled for completion in 2025, as part of Project EnergyConnect. The REZs are identified as strategically advantageous for energy generation, storage and transmission due to their exceptional renewable energy resources and geographic proximity to existing infrastructure.

There is low population density and homogenous agricultural land use within and surrounding the Project area and, as a result, the number of sensitive receivers would be minimised (there are three dwellings within the Project area, all owned by Project landowners). All landowner dwellings are a minimum of two kilometres from any proposed WTGs. The Project is highly compatible with existing pastoral land uses, as minimal impact to current agricultural activities are expected during both construction and operation

2.3 Battery system

The BESS technology type or provider has not been confirmed. However, for the purposes of this assessment, it has been assumed that the batteries are likely to consist of modular lithium ion (Li-ion) type racks, housed within battery enclosures containing protection, control and heating, ventilation, fire suppression systems and air conditioning (please see **Figure 2-1**).

Other infrastructure within the BESS compound would include:

- Rows of enclosures housing batteries connected to associated power conversion systems (PCS) and high voltage (HV) electrical reticulation equipment
- A BESS substation housing HV transformers and associated infrastructure
- Ancillary infrastructure and facilities including safety protection systems and site ancillary facilities such as laydown areas and site offices.

2.4 Electrical integration

The BESS substation would be connected to the grid through Dinawan Terminal Station. The grid interconnection voltage level would be either 330kV or 500kV. This would be finalised during detailed design.

The 800MW/800MWh BESS would be divided into BESS groups of 100MW/100MWh each. The concept design is based on a typical BESS and PCS model. Each of the BESS group consists of 24 PCS and 48 BESS containers where the output/input voltage would be stepped up/down from 0.8kV to 33kV. The voltage would be further stepped up to 330 (or 500) kV for grid interconnection.

The interconnector would consist of few major components such as transmission line and HV substation. **Table 2-1** provides a high-level overview on the configuration and technical details for a HV substation.

Table 2-1 Configuration and technical details for a HV substation

Criteria	Details
Configuration	One and a half breaker configuration
Rated Voltage	362 kV (550 kV)
Normal Operating Voltage	330 kV (500 kV)
Rated Frequency	50 Hz
Lightning Impulse Withstand Level	1175 kV_p (1550 kV_p)
Switching Impulse Withstand Level	950 kV_p (1175 kV_p)
Number of Feeders	1) 2 x Overhead Line Feeders (550MW each) 2) 5 x 33/330 (500)kV 120MVA Transformer Feeders 3) 2 x Busbar Voltage Transformers

2.5 Construction works

The construction workforce for the Project (including WTG's) is anticipated to consist of up to 300 people per day during peak construction (Year 2). Outside of peak construction (Year 1 and Year 3), the workforce is anticipated to consist of up to 150 people per day.

The Project would involve the recruitment and training of a construction workforce. The construction methodology for the BESS would be developed in more detail during detailed design and in line with the construction program for the overall Project. Once the site establishment and early enabling works have been completed, construction for the BESS compound is expected to involve:

- Piling and foundation works – prior to delivery onsite of containerised battery modules, ancillary cables and equipment
- Detailed excavation of cable trenches with conduit placement, backfilling and compaction – upon completion of piling works. Formwork, reinforcement placement and concrete pour works (FRP) would make-up activities for an engineered ground slab upon which containerised battery modules would be placed
- Positioning of containerised battery modules would be slung into position via mobile cranes with timing linked with batch shipping activities
- Final installation activities – including cable pulling and tie-ins, as well as control and monitoring system installations.

2.6 Construction program

If successful in obtaining planning approval and grid connection agreement, the construction of the Project would begin in 2024/2025. The expected construction duration of the Project would be 36 months. Commercial operations of the first commissioned WTGs would commence in 2026/2027, in line with and dependent on the completion and commissioning of the Dinawan Terminal Station and Project EnergyConnect. Further information on the Project program and schedule can be found in the Project EIS.

2.7 Operation

The BESS would provide firming capability for the wind energy being produced by the Project. Operation would be 24 hours a day, 365 days a year. Maintenance activities would be ongoing (landscaping, asset protection zones, water management infrastructure, access tracks and inspection, testing and replacement of components). Operational lifespan for a BESS is typically between 10 to 15 years, however, component replacements, upgrades and or extended warranties may extend this timeframe in accordance with the 30-year design life of the wind farm.

The Project would involve the recruitment and training of an ongoing operations and maintenance workforce

2.8 Decommissioning

Following the end of economic life, above-ground components would be removed and, where possible, re-purposed or recycled. Below ground infrastructure, would generally remain to avoid further disturbance. Some infrastructure, such as access tracks and laydown areas, may be of benefit to the landowners and may be retained in situ following an agreement with the landowners.

During decommissioning, existing access tracks would generally be used for equipment access and removal of materials from the Project area. The dismantled infrastructure components would generally be sold as parts or scrap materials.

Disturbed areas would be rehabilitated to meet the intended final land use and be comparable with pre-construction conditions in consultation with landowners.

2.9 Additional description for PHA

The following description is provided for context and general awareness of a BESS that is typical of the concepts to be considered by Virya Energy and the basis on which the PHA has been assessed. A final layout and design would be determined during detailed design.

Conceptually, the 800 MW/800 MWh Project may comprise in the order of 384 battery enclosures, dependent on the selected supplier. Enclosure types under consideration are in the order of 7 to 10 m x 2.5 m x 2.35 m (length x width x height). When arranged in rows, all enclosures under consideration resemble a shipping container as depicted in **Figure 2-1**. Each enclosure would house racks of lithium-ion type batteries, internal cooling, fault and fire detection and energy management systems. The battery enclosures, inverters and transformers would be provided with internal bunding and environmental controls for hazardous substances management suitable for the selected technology in accordance with applicable guidelines.

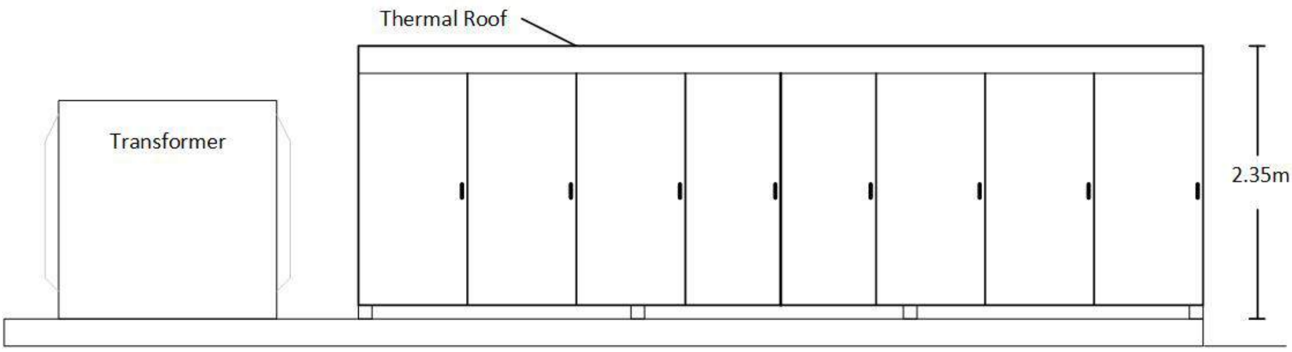

Figure 2-1 Indicative visualization of BESS containerised solution

For the PHA, the assessment has considered an external containerised solution which would either be integrated with power conversion systems (PCS) or interface to them as a separate standalone containerised solution (refer to **Figure 2-2**). The PCS would interface to a number of enclosures to convert direct current from the battery to alternating current. Each enclosure would include electronics such as fire safety systems, battery and rack management systems as well as protection systems. Battery modules would typically be air or liquid cooled. Multiple enclosures would connect to a PCS that converts direct current DC electricity to alternating current AC for distribution and ultimate transmission to the electricity network.

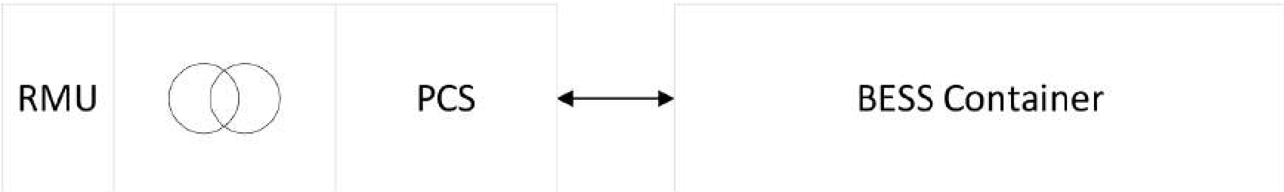

Figure 2-2 Indicative layout with external PCS type arrangement

Firefighting tanks, pumps and water reticulation would be located at the site, as well as surface water drains and retention ponds. Quantities of refrigerant may be used as a cooling agent contained in process piping and HVAC and refrigerant systems servicing the battery enclosures. The volumes and composition are estimated not to exceed screening thresholds representative of a material hazard at the site. Battery enclosures may also require a water feed depending on the fire safety system selected (refer to **Figure 2-3**).

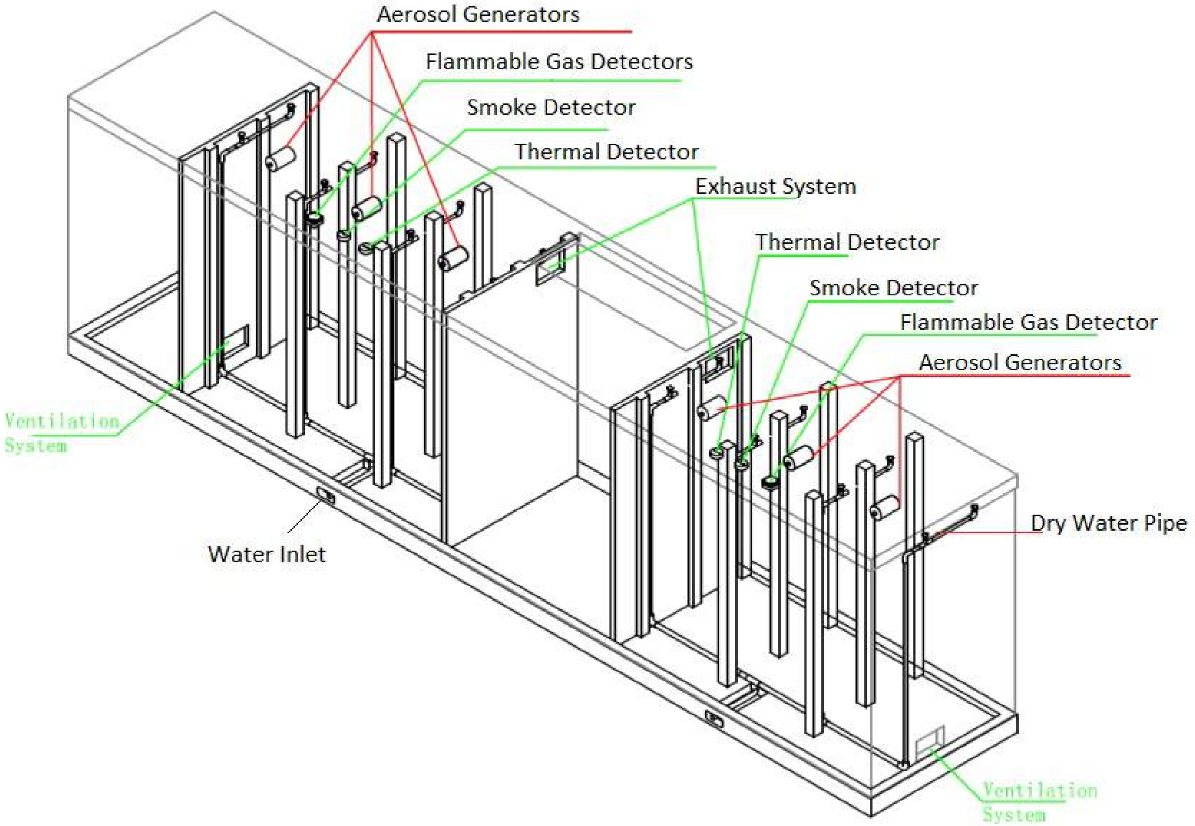

Figure 2-3 Indicative fire suppression system (Aerosol or Water based) within a BESS container[1]

During construction, earthworks would be undertaken to level the site and civil foundations put in place to support the BESS enclosures, transformers, and ancillary equipment. Access roads, lighting, security fencing and CCTV, small office and crib and ablution facilities would also feature at the site.

[1] Image: Sungrow

3. Assessment methodology

3.1 Relevant guidelines

This PHA has been prepared in accordance with:

- Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning (Department of Planning (DoP), 2011a)
- Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis (DoP, 2011b), and
- Multi-Level Risk Assessment (MLRA) (DoP, 2011c). The MLRA, sets out three levels of risk analysis that may be appropriate for a PHA. This guidance document was consulted to determine the level of analysis required for this study.

Figure 3-1 below depicts the hazards related assessment process used for the Project.

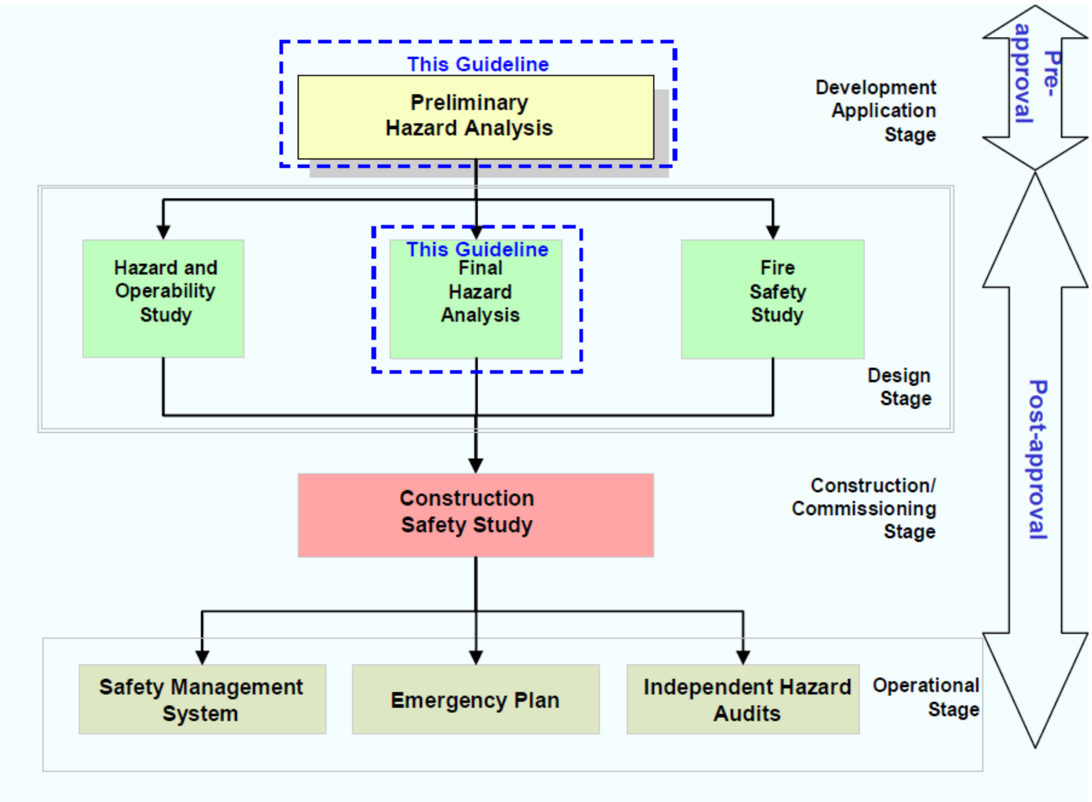

Figure 3-1 The hazard related assessment process (DoP, 2011b)

3.2 Process

The Project is at an early stage of development. The PHA has been prepared to support the EIS for the Project. The overall purpose of this PHA is to address the hazards and risks associated with the Project, notably associated with the following:

- Risk from material reactions and as a consequence, fires associated with electrical infrastructure and flammable material – This includes spontaneous ignition from a thermal runaway event at the BESS
- Environmental risk from spills causing land contamination
- Health and safety risk to the community, staff and contractors.

The analysis is structured to consider possible hazard scenarios that could result from Project construction and operation. This includes abnormal events and the consequences of these to people, property and the biophysical environment. Safeguards and recommended actions identified throughout this PHA consider the hierarchy of control and forms a basis for challenging the effectiveness of actions to reduce the associated risks to as low as reasonably practicable.

Project definition and the hazard identification process that underpins this PHA includes review of other credible PHA's for similar sized projects, literature and recommendations from battery hazard assessments and similar battery incident investigations for events such as the fire on the Victoria Big Battery (VBB). A Jacob's standard risk matrix for the assessment. A more detailed hazard and risk analysis, including HAZOP would occur during the detailed design phase of the Project.

This PHA should be read in conjunction with the associated technical reports as listed in **References** where additional mitigation measures have been provided.

3.3 Consequence criteria

As described above, the Project is at an early stage of concept design. This PHA is, therefore, limited, in most part, to qualitative assessments based on the judgement and the industry experience of the Project team.

As the PHA is principally concerned with the Project development and operation related hazards that could result in significant offsite effects, the consequence categories are limited to Health and Safety, Environment and Community categories as defined in the risk matrix as per **Table 3-1**.

Table 3-1 Risk matrix

Consequence					
Health & Safety	First aid treatment	Medical treatment required	Serious injury requiring urgent treatment	Permanent and serious disablement	Fatality
Environment & Community	E: Onsite release, containable with minimal damage. Localised impact on energy usage. C: Workforce concern.	E: Onsite release with some damage, no offsite damage. Numerous and/or widespread but small-scale impacts on energy and waste. Remediation in terms of days. C: Local community concern	E: Offsite release, no significant environmental damage. Remediation in terms of weeks. C: Regional concern	E: Major offsite release, short to medium term environmental damage. Remediation in terms of months. C: Widespread community outcry. Regional concern	E: Major offsite release, long term environmental damage. Remediation in terms of years. C: Extreme community outcry. National concern.
Consequence Target	**1**	**2**	**3**	**4**	**5**
Remote Once every 50 - 100 years	1	2	3	4	5
Highly unlikely Every 10 - 50 years	2	4	6	8	10
Unlikely Every 3 - 10 years	3	6	9	12	15
Likely Every 1- 3 years	4	8	12	16	20
Highly Likely At least once a year	5	10	15	20	25

Risk response	
15-25 – Extreme	Unacceptable level of risk - Controls must be implemented to reduce the risk. Seek HSE team input and EDO approval before proceeding
9-14 – High	Unacceptable level of risk - Controls must be implemented to reduce the risk. Seek HSE team input and EDO approval before proceeding
5-8 – Medium	Implement controls to reduce risk As Low As Reasonably Practicable. If risk is still Medium after implementation - Line management must approve before proceeding
1-4 – Low	Controls are acceptable. Requires monitoring

3.4 Risk criteria

The PHA has used the risk matrix and consequence criteria for assessing the hazards identified as set out in **Chapter 5**. This is considered to be in line with a good industry standard and are appropriate for this stage of the Project, the level of definition and in keeping with the existing guidelines (DoP, 2011b). Once technology selection has been made and further details of the specific design safeguards are known, more quantitative risk assessment can be undertaken to confirm the quantum of relevant hazards.

3.4.1 Risk screening

The purpose of risk screening, as per the MLRA guideline document, is to determine whether the proposed Project should be considered as potentially hazardous; defined as the following (*DPIE, HIPAP 3 Risk Assessment Appendix 1*):

> *Potentially hazardous industry' means a development for the purposes of an industry which, if the development were to operate without employing any measures (including, for example, isolation from existing or likely future development on other land) to reduce or minimise its impact in the locality or on the existing or likely future development on other land, would pose a significant risk in relation to the locality:*
>
> *(a) to human health, life or property; or*
> *(b) to the biophysical environment, and includes a hazardous industry, and a hazardous storage establishment.*

The MLRA sets out three stages in the assessment process, namely:

- Preliminary screening
- Risk classification and prioritisation
- Risk analysis and assessment.

The risk screening process in the MLRA considers the type and quantity of hazardous materials storage and the distance of the storage area to the nearest Project boundary. It also includes the expected number of transport movements associated with hazardous material and other types of hazards.

Hazardous materials are defined within the guidelines as substances that fall within the classification of the Australian Dangerous Goods Code (ADGC)

Other types of hazards are evaluated following the definitions in the MLRA, and include material incompatibility, reactivity and instability; hazardous wastes; hazardous activities or process conditions; known past incidents (and near misses) in similar industries; and environmental sensitivity in the local area.

3.4.2 Level of Analysis

The guidelines set out criteria for using the results of the screening, classification and prioritisation steps to determine which of three levels of further analysis is appropriate, including:

- **Level 1 – Qualitative**. Primarily based on the hazard identification techniques. There are no potential events with significant off-site consequences and societal risk is negligible
- **Level 2 – Partially quantitative**. Using hazard identification and the focused quantification of key potential off-site risk contributors. The frequency of occurrence of risk contributors having off-site consequences is low
- **Level 3 – Quantitative**. Based on the full and detailed quantification of risks, consistent with HIPAP No. 6 - Hazard Analysis. There are significant off-site risk contributors, and a Level 2 analysis is unable to demonstrate that the risk criteria would be met.

A qualitative assessment is deemed sufficient for the Project at the concept design stage.

4. Findings and recommendations

4.1 Stage of development

The basic engineering concept study for this PHA is based on a 800 MW/800 MWh lithium-ion (Li-ion) battery. As such, this PHA focusses on known hazards associated with lithium-ion battery technologies and development aspects related to the Project area. Lithium-ion is the most commercially mature technology for the size of the proposed Project. At this stage of development, the PHA is substantially a qualitative assessment based on industry experience and judgement. It identifies response actions that would verify the adequacy of the design controls as the Project transitions through its development phases.

4.2 Technology failure modes

Lithium-ion batteries are susceptible to a failure mode called thermal runaway. This can result in a self-sustaining fire within a battery energy storage medium. Thermal runaway can be caused by:

- Battery mechanical damage
- Defects with the battery unit
- Improper operation.

Failure sequencing generally follows the creation of heat from an overvoltage or short circuit event, formation of off gas, smoke and subsequently fire. A battery would produce a lot of smoke before thermal runaway occurs. Smoke detectors, therefore, are key instruments used to transmit detection to the Battery Management System (BMS).

Thermal runaway prevention, detection, and control is an important technology design consideration of battery technology manufacturers. The variations in factors such as battery chemistry, materials of construction, configuration and basic specifications, however, leads to different and unique methods of safeguarding between suppliers. Battery Management Systems including detection and control devices are a principal method of avoiding operating conditions which could lead to thermal runaway. Quality systems and testing in manufacturing, transport, and commissioning are examples of principal controls in avoiding mechanical damage and defect failure mechanisms.

4.3 Technology and historical context

BESS technology is rapidly maturing as more installations are commissioned, and technology providers develop improved methods of managing and eliminating failure modes that have historically resulted in some events leading to thermal runaway. Different battery chemistries can have different potential energy releases during thermal runaway. As such, the hazard and risk analysis has paid specific attention to the hazards and risks associated with these potential scenarios, and recommended actions which targets an informed understanding of the extent of the hazard. Due consideration should be paid to the design controls and layers of protection once the Project definition advances to a technology evaluation, selection and detailed design stage. These should also apply to the transportation, commissioning and setting to work of the BESS units.

The approach from different BESS suppliers to thermal runaway varies in the inherent design methods and technology adopted to monitor and manage events and each technology providers solution should be considered in its own right. However, lessons learned from recent case studies such as the VBB fire on monitoring and control during periods of inactivity should also be considered. This includes appropriate selection and implementation of active and/or passive protections on receipt of goods onsite.

At present, there are few operating large-scale installations globally with the scale of storage and dispatch capacity that is anticipated for the Project. However, it is important to note that with the common design principle of maintaining separation of enclosures, the extent of any hazard associated with the consequences of thermal runaway does not increase. With the exception of the battery enclosures, BESS facilities largely include enabling plant and equipment that is common to conventional power plants. The associated hazards are well understood, and similar design safeguards and controls must be built into the design.

With the advancement of technology, there would be an elevated likelihood that current generation technology would be more reliable and less susceptible to extreme impacts from the manifestation of known failure modes.

4.4 Emergency Response

A comprehensive fire safety study would be undertaken in consultation with Fire and Rescue NSW (FRNSW) which will include an assessment of the capabilities of the local fire and rescue services. A key understanding of the technology and the appropriate response would be invaluable to containment of an incident and limit further impact on the environment. ERP's would be in place and available to emergency responders.

4.5 Key hazard and risk findings

The highest identified Project risks relate to the consequences of a lithium-ion battery failure mode known as thermal runaway. This can cause a single battery module fire that has the potential to initiate further thermal runaway in adjacent battery modules. The failure mode is common to lithium-ion technology, occurs infrequently and is well understood by experienced battery manufacturers. Despite some thermal runaway events occurring globally since the early adoption of the technology, the industry's understanding of design controls has improved. It is evident that, as a result, experienced battery manufacturers incorporate inherent design features and layers of protection into battery modules, battery management systems and enclosure designs to control the risk.

There is insufficient evidence to demonstrate any fail-safe lithium-ion BESS technology not potentially susceptible to thermal runaway. Therefore, this PHA considers a fire as a credible event for risk and hazard management purposes. The concept design for the Project, along with the recommendations of the PHA, adopt sensible and specific controls to mitigate the risk associated with such an event to as low as reasonably practical.

The following is a summary of the findings of assessed risks and a summary of the key controls:

- A thermal runaway event in a single battery enclosure causing pollution is assessed as a credible hazard. In conventional designs there are many layers of protection, that have not previously been available in battery designs, that would need to fail for an event to escalate, reference to the recorded incident at the Victoria Big Battery (VBB) site in Geelong, Australia, whereby additional commissioning processes, sensors and alarms have been recommended to better identify and respond to failures of internal components. Further, some manufacturers provide advanced fire suppression systems within their containerised solutions
- The PHA concludes that the risk can be reasonably mitigated through monitoring of early signs of the failure and design of direct and automatic control and shutdown action in the battery management system. Further, the adoption of a large number of smaller battery enclosures reduces the amount of pollution caused if an event escalates and is considered unlikely to cause any harmful concentrations if pollution in the form of smoke cross the Project area as has been found following the investigation by the Environment Protection Authority (EPA) on the VBB incident. Manufacturers inherent design controls vary, and consideration of these would be undertaken during detailed safety in design
- A thermal runaway event in one battery enclosure which triggers thermal runaway in adjacent battery enclosures whereby increasing the volume of pollution is assessed as a credible hazard. The risk is reasonably mitigated by thermal insulation built into the containerised solution, passive compartmentation and the adoption of separation distances between battery enclosures

- A thermal runaway event in an enclosure causing uncontrolled build-up of off-gas to explosive limits and igniting with deflagration/explosion of battery enclosure(s) is assessed as a credible hazard and can be reasonably mitigated through design controls noted earlier to contain the propagation of thermal runaway and the design of deflagration and normal venting of enclosures to avoid build-up of gases above unsafe limits
- Escalation of thermal runaway event due to poor information or knowledge of appropriate methods of response is assessed as a credible risk and can be reasonably mitigated through robust communications and information transfer, training and education and involvement of operations staff and emergency response services to understand the technology and safely manage responses
- Surface water containing contaminants leaving the Project area and having a negative impact on biota in waterways downstream of the development is assessed as a credible hazard and the associated risk can be reasonably mitigated by standard industry design and controls of site drainage and containment This is further discussed in the Surface water quality and groundwater technical report (Jacobs, 2022a)
- Based on a review of current technologies including standard sizing of BESS enclosures, separation distances and balance of plant, the nominated capacity of the BESS would be able to be accommodated within the area assessed.

Overall, the assessment considers the hazards and associated risks can be mitigated to so far as reasonably practical through adoption of controls in place with the Project requirements and various recommendations arising from the PHA.

4.6 Other findings

- A small number of the hazards are unique to lithium-ion BESS technology and associated with abnormal or emergency events while the remainder are common industry causes which are regularly managed through proven design methods. For unique hazards, individual failure modes have been analysed
- The specification of industry standards and requirements that are most relevant and applicable to the Project and for the hazards and risks which require management have been adopted. This approach recognises that, as with technology, the industry standards are rapidly maturing. Although an Australian Standard exists (AS5139) and its intent is understood, it is more relevant to domestic battery installations and is therefore not a specific requirement of the specification for the Project
- There is low population density in the vicinity of the Project. There are three dwellings within the Project area, all owned by Host Landowners. All dwellings are a minimum of 4.5 kilometres from either BESS option and the closest town to the Project is Jerilderie, which is located a minimum of 35 kilometres to the south-east from the BESS. Given the design principles recommended to mitigate the consequence of a credible event and the layers of protection likely to be available to avoid uncontrolled escalation of an event, it is considered highly unlikely that a significant offsite impact scenario would emerge through the life of the Project. In this unlikely event, design safeguards to minimise the spread and extent of event would enable time to respond, if necessary, and to act to further mitigate or notify offsite receptors of any exposure to the hazard
- There would be no unusual volumes of hazardous materials stored in the Project area in support of BESS operation for the Project.

Detailed hazard analysis and management plans are presented in **Chapter 5**.

4.7 Key recommended actions

The key recommended actions are summarised as follows:

- Specify requirements for suppliers and designers to demonstrate robust designs to prevent, monitor and (where unable to eliminate the possibility) control thermal runaway and undertake specialist safety in design assessments such as a fire risk assessment to inform the design and selection of the battery technology
- Implement a design principle that assumes a thermal runaway event within an enclosure would occur during the lifetime of the asset and therefore limits deflagration energy release (and prevents the spread of fire to adjacent enclosure by adopting appropriate design controls such as suitably designed enclosures and separation distances)
- Undertake detailed HAZOP and design review of the selected designs with specific attention on the inherent design features that detect, control and prevent thermal runaway
- A fire safety study to be carried out in consultation with Fire and Rescue NSW (FRNSW) and to the satisfaction of the operational requirements of FRNSW
- Determine credible scenarios from a thermal runaway event once the technology and its size are determined to quantify the amount of potential hazardous by-products that must be managed and establish the Project design basis accordingly (e.g. amount of combustion and pollution, fire water requirement for containment)
- Implement a robust quality plan and inspections throughout the supply chain and during construction, focused on aspects that provide layers of protection to prevent battery modules being installed that have manufacturing defects or mechanical damage. This should include factory and site acceptance testing
- Develop and implement suitable asset management plans to ensure proper maintenance of the facility in line with manufacturers' recommendations and good industry practice throughout the operations phase
- Make provisions for training and education of operations staff and emergency response services to understand the technology to safely manage potential incident responses.

5. Hazard & risk analysis and assessment

5.1 State Environmental Planning Policy (Resilience and Hazards) 2021 - risk screening summary

Based on the State Environmental Planning Policy (Resilience and Hazards) 2021, a risk screening has been carried out in relation to the storage of hazardous materials, transport of hazardous materials and other types of hazards. These are presented in **Table 5-1** to **Table 5-3**.

The outcomes of the risk screening for the PHA are summarised below:

1) The expected storage of hazardous materials associated with the Project would not exceed the relevant risk screening threshold
2) The expected transport of hazardous materials associated with the Project would not exceed the relevant risk screening threshold.

Based on the above, the Project would not be considered potentially hazardous (by DPE's definition). However, as DPE also requires assessment of other types of hazards, the following potential hazards are assessed further:

1) Uncontrolled thermal runaway reaction or decomposition within the Li-ion batteries in the BESS potentially leading to propagation to other infrastructure (covered in **Section 5.2.1**)
2) Environmental impact or health and safety impact from exposure if there is a spill of pollutant from the battery enclosures, transformers or landing gantries, e.g. cooling medium or oil. This risk may be mitigated during detailed design.

Based on the below tables, State Environmental Planning Policy (Resilience and Hazards) 2021 thresholds are not exceeded for any material.

Table 5-1 SEPP 2021 risk screening summary – Storage of hazardous materials

Hazardous Material	DG Class	Category	Proposed Quantities	SEPP threshold	Project would exceed threshold?
Li-ion batteries	Dangerous goods (DG) Class 9	Miscellaneous DG	Unknown at concept design stage	DG Class 9 material is excluded from screening process	No
Coolant (HVAC)	Not expected to be a DG	Not expected to be combustible or toxic	Unknown at concept design stage	Non-DG material is excluded from screening process	No
Refrigerant (compressed gas/liquid within battery racks)	Expected to be DG Class 2.2	Non-flammable, Non-toxic	Unknown at concept design stage	DG Class 2.2 material is excluded from screening process	No
Inert gas for fire suppression system within the battery containerised solution	Expected to be DG Class 2.2	Non-flammable, Non-toxic	Unknown at concept design stage	DG Class 2.2 material is excluded from screening process	No

Hazardous Material	DG Class	Category	Proposed Quantities	SEPP threshold	Project would exceed threshold?
Oil and other petroleum products	Not a DG	Combustible liquid C1 (AS1940)	Unknown at concept design stage	Combustible liquid is excluded from the screening process	No

Table 5-2 SEPP 2021 risk screening summary – Transport of hazardous materials

Hazardous Material	DG Class and Packaging Group	Category	Applicable Vehicle Movement	SEPP threshold (vehicles carrying dangerous goods)	Project exceeds threshold
Li-ion batteries	DG Class 9	Miscellaneous dangerous goods			No
Coolant (HVAC)	Not expected to be a DG	Not expected to be combustible or toxic			No
Refrigerant (compressed gas/liquid within battery racks)	Expected to be DG Class 2.2	Non-flammable, Non-toxic		>1000 annual >60 peak weekly	No
Oil and other petroleum products	Not DGS	Combustible liquid C1 (AS1940)	<60 weekly <1000 annually		No

Table 5-3 SEPP 2021 risk screening summary - Other types of hazards

Other types of Hazards	Applicable (Yes/No)	Screening Result	Project exceeds threshold
Any incompatible materials (hazardous/non-hazardous)?	No	No incompatible materials identified for the Project	No
Any hazardous waste?	Yes	No significant quantities of hazardous waste identified for the operation of the Project	No
Type(s) of activities the DG's and otherwise hazardous materials are associated with (storage, processing, reaction), if different to the above?	No	No significant hazardous activities associated with DGs identified for this Project	No

Other types of Hazards	Applicable (Yes/No)	Screening Result	Project exceeds threshold
Incompatible, reactive or unstable materials and process conditions that could lead to uncontrolled reaction or decomposition	Yes	Thermal runaway reaction associated with Li-ion batteries has occurred in other similar industry	Yes, potential exists for a thermal runaway reaction in a battery cell
Storage or processing operations involving high or low temperatures and/or pressures?	No	No high/low temperatures and/or pressures identified as associated with Project infrastructure. HVAC/Liquid cooling systems would be utilised during operation	No
Details of known past incidents (and near misses) involving hazardous materials and processes in similar industries	Yes	Thermal runaway reaction associated with Li-ion batteries has occurred in other similar industry	Yes, potential exists for a thermal runaway reaction in a battery cell
Environmental Risk i.e. water courses, threatened species?	No	The Project would result in disturbance to vegetation, EECs and potential loss of habitat. These risks will be mitigated through the implementation of management measures detailed in the EIS for the Project.	Yes, potential exists for impacts to the environment however limited potential based on the implementation of mitigation and management measures
Is any exposure to the risk to the environment reversible?	Yes	The risk of environmental pollution is being considered within the design	Yes, subject to detailed design

5.2 Hazard Identification, consequence and likelihood analysis

The tables presented in this section detail specific hazards and risks, the credible causes of the risk and the recommended safeguards and action plan. Risk is discussed as current risk (a risk assessment if no controls and safeguards are in place) and target risk (a risk assessment if recommended controls and safeguards, are implemented).

Throughout the analysis, consideration was given to actions in the context of the hierarchy of controls to build confidence that the effectiveness is maximised. In order of increasing effectiveness of the control, the hierarchy is:

1) Elimination – removal of the hazard or danger completely
2) Substitution – minimise the hazard by substituting (entirely or partly) with something with a lower risk
3) Engineering controls – separate the hazard or design to protect or isolate people from the hazard
4) Administration controls – implement procedures, training, signage or similar
5) Use of personal protective equipment (PPE).

There is, in most cases, insufficient detail at this stage of the Project to reliably quantify items such as the volumes of hazardous by-products in the case of a fire scenario. Therefore, some recommended actions relate to verifying this as the Project definition improves. Despite this, design principles are being adopted for the Project's specifications and technology evaluations which would minimise hazardous by-products in such an event. By way of example, the Project concept includes an installation comprising a large number of independent battery enclosures, indicatively in the range of 384 (varying dependent on the technology providers design) which are physically separated from one another to mitigate the risk of a fire event spreading and increasing the exposure of hazardous by-products. As such, the design principle is one of containment of fire to a single battery enclosure accepting that the total elimination of fire risk is unlikely.

5.2.1 Lithium-ion battery technology failure modes and effects

Primary causes of thermal runaway identified include battery mechanical damage, defects and improper operation such as overcharging. Failure sequencing generally follows the generation of heat and if not controlled, smoke and fire.

The following sections discuss the assessment of events that could trigger thermal runaway and captures both existing control actions implemented throughout the Project and additional recommendations:

5.2.1.1 Thermal runaway occurs because of battery defect

Ref. No:	Risk Area	Risk Issue	Causes
1.1	Health and Safety, Operations	A thermal runaway event escalates to a fire causing smoke and pollution that impacts operation of the facility and offsite air quality and sensitive receptors	Thermal runaway due to a defect in a battery module which propagates to adjoining modules and escalates to an enclosure fire.
Risk Comments			
Defects can occur in manufacturing, transport, installation or during operation if there are component malfunctions such as cooling system loss. However, due to the nature of the location of the installation i.e. low population density (All dwellings are a minimum of 4.5 kilometres from either BESS option and the closest town to the Project is Jerilderie, which is located a minimum of 35 kilometres to the south-east from the BESS), the likelihood and consequence of airborne hazards would be lower due to dispersion.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Manufacturing or transportation damage to the BESS ▪ BESS containers must undergo factory and site acceptance testing to confirm correct operation within design limits. ▪ The responsible parties must develop safe transport and shipping procedures (in line with OEM recommendations and UN 38.3) Monitoring of critical alarms during storage and or commissioning ▪ The BESS telemetry system must be activated and connected to the site telemetry on receipt of BESS containers onsite (as minimum; internal temperatures, fault alarms, etc must be transmitted). If required, temporary power supplies should be installed to ensure all critical safety systems remain active. Electrical fault and Protection Devices ▪ Built in safety systems should be designed such that they are able to identify, respond, contain, and isolate issues within the battery modules due to failures of other internal components. Fire Propagation ▪ Although BESS containers are designed to provide substantial thermal protection in the event of a fire. To limit heat transfer to adjacent enclosures, the design must ensure sufficient spacing/heat barriers between BESS containers.	3	Highly Unlikely	6 – Medium Risk level considered to be mitigated to so far as reasonably practical

Emergency Response ▪ Include the local fire and rescue department in the design phase of the project to ensure that there is sufficient onsite safeguards/infrastructure in place in the event of a fire and that the local fire and rescue are familiar with the site facilities. ▪ Develop and implement an asset management plan that adheres to Virya Energy and Equipment Manufacturer (OEM) operation and maintenance guidelines and recommendations. Environment ▪ In the event of a fire, air quality should be monitored within an agreed and accepted range from the site. The outputs of which should be reported to the EPA.			

5.2.1.2 Thermal runaway because of improper operation of the battery

Ref. No:	Risk Area	Risk Issue	Causes
1.2	Health and Safety	A thermal runaway event escalates to a fire causing smoke and pollution that impacts offsite air quality and sensitive receptors	Fire related to thermal runaway due to improper operation of one or more battery modules, propagates to adjoining modules and escalates to an enclosure fire. Operation outside design specification, for example – rapid charging or discharging.
Risk Comments			
Safety is a serious issue in lithium-ion battery technology. Most of the metal oxide electrodes are thermally unstable and can decompose at elevated temperatures, releasing oxygen that can lead to a thermal runaway. To minimize this risk, lithium-ion batteries are equipped with a monitoring unit to avoid overcharging and over-discharging. Usually, a voltage balance circuit is also installed to monitor the voltage level of each individual cell and prevent voltage deviations among them. The BMS monitors, controls, and where necessary shuts down battery operation if critical operating parameters are exceeded, some of these controls are proprietary to battery manufacturers and are backed by warranties and guarantees in contracts i.e. operational data must be submitted periodically for warranty validation. OEM supervised commissioning, test and inspection plans, during construction and commissioning are an important layer of protection as well as periodic cell calibration. It could be reasonably expected that issues associated with this failure mode could be managed if these guidelines are followed accordingly.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Test and Commissioning ▪ All test, commissioning and O&M procedures must be submitted to the Owners Engineer with sufficient time for review and approval during the construction phase in anticipation of COD. ▪ Test and commissioning must be performed by the OEM or authorised (and qualified) supplier and must be witnessed by the Owner/Owner's representative. ▪ Test records and test certificates must be submitted to the Owner/Owner's representative for review and approval. All operation and maintenance manuals and training material including design and calibration settings and procedures must be provided before take-over.	3	Highly Unlikely	6 – Medium Risk level considered to be mitigated to so far as reasonably practical

Operations and Maintenance ▪ Periodic test and calibration must be adhered to. The results of which must be submitted to the OEM and Owner/Owner's representative for review. ▪ O&M reports must be submitted to the Owner as specified in the O&M contract for review. ▪ Any software revisions, updates or operational changes must follow a change management process approved by the Owner and OEM.			

5.2.1.3 Thermal runaway occurs because of mechanical damage

Ref. No:	Risk Area	Risk Issue	Causes
1.3	Health and Safety	A thermal runaway event escalates to a fire causing smoke and pollution that impacts offsite air quality and sensitive receptors	Thermal runaway due to mechanical damage possibly due to transportation, blade throw or similar impact.

Risk Comments

Mechanical damage caused in battery modules has the potential to cause thermal runaway. Damage may occur during transport, construction and operation. Industry standard methods are available to monitor and identify if mechanical damage has occurred including shock sensors which are attached to battery components.

Lithium-ion batteries are transported in a semi charged state and/or potentially within a pre-assembled enclosure (i.e. a BESS containerised solution). There is a potential for accidents involving the transport of the batteries to site and mechanical damage caused during such an event. A site acceptance test should be carried out on receipt of goods and any defects raised as non-conformances for replacement.

Maritime safety requirements exist for transport of lithium-ion batteries and DG code regulations for transportation. Lithium-ion batteries are a Class 9 Dangerous Good.

During operations vehicles would include light vehicles, infrequent forklift, crane and heavy vehicle movements during battery change out operations. BESS containers may require to be housed within a barn type arrangement for further protection. Findings and recommendations within the Blade Throw Report should be considered in the design of the BESS compound.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Transportation to site ▪ Specify requirements for the responsible party to develop safe transport and shipping procedures (in line with OEM recommendations and UN 38.3) and ensure that transport/shipping companies implement and audit compliance. ▪ Each container must undergo a site acceptance test including a mechanical inspection and connection to the onsite SCADA for the monitoring of critical alarms. Ensure that the contractor has in place QA monitoring for any inadvertent mechanical damage and procedures for acceptance or rejection of battery installations. Installation ▪ Specify installation of appropriate controls at the site during construction and operations phase to control vehicle movements and mitigate likelihood and consequence of impacts with enclosures. May include traffic flow and speed controls, bollards and barriers and safe work management systems. ▪ Specify security measures meeting requirements of appropriate standards e.g. AS1725.1. ▪ Specify requirements for electronic site access control and remote CCTV security monitoring. ▪ Consider a 'Barn' type of housing for the BESS scheme which would provide additional protection.	3	Highly Unlikely	6 – Medium Risk level considered to be mitigated to so far as reasonably practical

5.2.1.4 Thermal runaway propagation from one battery enclosure to another

Ref. No:	Risk Area	Risk Issue	Causes
1.4	Health and Safety	A thermal runaway event escalates to a fire causing smoke and pollution that impacts offsite air quality and sensitive receptors	Thermal runaway in one battery enclosure extends to multiple battery enclosures causing increased pollution with the potential to cross the Project area. The event may be triggered from radiant heat and temperature rise initiating thermal runaway in nearby enclosure modules.

Risk Comments

Excessive temperature from a thermal runaway event in one module could cause safe design temperature limits to be exceeded in other modules and initiation of thermal runaway.

Inherent safety in design principles have been applied to limit impact of cell failure (and consequently modules) so far as is reasonably practical (SFAIRP). For the design concept, an 'Enclosure' denotes a box boundary around the largest credible fire threat.

The design is specified to minimise the threat of an enclosure fire or explosion. The enclosures thermal insulation can provide significant thermal protection in the event of a fire. Further, each containerised solution is fitted with either a water-based or aerosol-based fire suppression system. However, in the unlikely event this should ever occur, to prevent a multi enclosure fire and therefore limit the products of combustion, adequate spacing as per the manufacturers specified guidelines as well as allowing sufficient spacing for a transportation corridor should be observed. The range of an ordinary water tank fire truck is generally greater than 30m, and the system layout can be designed accordingly.

The Project shall be specified to require battery equipment to be supplied and installed to meet the current version of NFPA requirements and demonstrate UL 9540A validation for fire containment to prevent escalation. AS1539 applicability is limited in respect to industrial scale BESS. It is used for guidance on intent, where appropriate.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Design verification, enclosure layout and spacing ▪ Adequate separation distances shall be implemented as per the OEM's recommended guidelines between enclosures to prevent the effect of thermal runaway in one enclosure causing thermal runaway on nearby enclosures. ▪ Verify that the specified battery design and recommended separation distances have been certified in accordance with standards that meet or exceed requirements for fire performance test at installation level according to UL 9450A. ▪ The design must undergo a HAZOP and appropriate safety in design reviews. ▪ Consult with FRNSW to undertake a fire safety study for the site for guidance on emergency response measures and firefighting capability reasonably required for emergency response requirements. Commissioning ▪ Specify that the contractor must determine, demonstrate and implement thermal runaway controls and safe separation distances of enclosures to prevent secondary thermal runaway on adjacent enclosures.	3	Highly Unlikely	6 – Medium Risk level considered to be mitigated to so far as reasonably practical

5.2.1.5 Thermal runaway escalates to a battery deflagration/explosion event

Ref. No:	Risk Area	Risk Issue	Causes
1.5	Health and Safety	Development adversely impacts offsite air quality in concentrations that affects community health and wellbeing during operations phase	Explosion of battery module from build-up of explosive gases to LEL range and uncontrolled ignition.

Risk Comments
Thermal runaway can cause the build-up of explosive gases which can cause an explosion hazard if able to build up to the explosive limit concentrations and ignited. Small quantities of refrigerant gas are present in electrical battery racks.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
BESS Enclosure ▪ The BESS enclosure design shall be specified to have sufficient volume and ventilation (over pressure vents) to limit the potential for LEL being exceeded. ▪ Adequate separation distances shall be implemented as per the OEM's recommended guidelines between enclosures to prevent the effect of thermal runaway in one enclosure causing thermal runaway on nearby enclosures. Monitoring and Control procedures ▪ The BESS FSS will provide a notification to the site SCADA system to notify the plant operator of a thermal runaway event. ▪ The BESS control system will initiate a shutdown and isolation procedure to the BESS module, rack and container. ▪ The BESS shall be equipped with either a sprinkler based or aerosol-based fire suppression system as well as overpressure vents to prevent a build-up of explosive gases.	3	Highly Unlikely	6 – Medium Risk level considered to be mitigated to as far as reasonably practical

5.2.1.6 Bush fire triggers thermal runaway or asset damage

Ref. No:	Risk Area	Risk Issue	Causes
1.6	Health and Safety	Thermal runaway if initiated leads to battery fire generating toxic smoke which may drift across the Project area.	Excessive temperature from a bush fire event could cause safe temperature limits to be exceeded and initiation of thermal runaway to occur.

Risk Comments
A bush fire onsite could create could cause safe temperature limits to be exceeded initiating a thermal runaway event. Bushfire protection measures have been developed for construction and operational phases of the Project, based on guidance from PBP (RFS, 2019a). Adoption of the measures described here is expected to reduce, to an acceptable level, both the risk of bush fire ignition by construction and/or operation of the assets and the risk that bushfires in the landscape pose to the assets. Permanent bushfire protection measures are proposed in the bush fire risk technical report (Jacobs 2022b). Further, BESS enclosures include a FSS and a safety shutdown system internally.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
BESS Compound ▪ An asset protection zone has been proposed (20m) around the BESS compound. ▪ The area within the BESS compound should be back filled with crusher run or similar and be free of vegetation. ▪ A water supply (for fire & rescue services should be installed in strategic locations around the BESS compound. ▪ Consider findings and recommendations within the Bush fire risk technical report (Jacobs 2022b) and implement an appropriate asset protection zone around enclosures.	1	Highly Unlikely	2 – Low Risk level considered to be mitigated to so far as reasonably practical

5.2.1.7 Incident or injury to emergency services personnel responding to an incident

Ref. No:	Risk Area	Risk Issue	Causes
1.7	Health and Safety	Incident or emergency first responders are injured during incident management	- Explosion of battery module - Contact with live electrical components - Contact with fire - Contact with hazardous substances or materials - Smoke inhalation
Risk Comments			
The availability of information about the site and status of plant and equipment is critical in assessing the response to an incident. Emergency response does not require entry into any enclosure or space with batteries. Battery containers are remotely monitored and can be remotely shutdown. Battery containers have built in fire suppression systems and therefore should not require to be accessed in case of a fire.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Incident management plan ▪ Specify facility requirements such that events do not escalate and are limited to the equipment, without requiring intervention by first responders. ▪ Specify remote monitoring and operation to enable information on the status of enclosures to be available for response decision making. ▪ Specify Facility requirements so that occupied buildings or equipment able to be entered by personnel is separated from battery enclosures. ▪ Specify Facility requirements for the design to consider one or more methods for emergency services to establish the environment within a building or enclosure is safe, without being exposed to ensuing hazards ▪ Ensure that critical design information for emergency response purposes is maintained and up to date at a location remote from the site and readily accessible. (i.e. Maps, layouts, firefighting facilities, schematics etc)	3	Remote	3 – Low Risk level considered to be mitigated to so far as reasonably practical

5.2.2 Surface water leaving the site has negative impact on surrounding biota

Ref. No:	Risk Area	Risk Issue	Causes
1.8	Environment	Development adversely impacts offsite flora and fauna during operations phase	Surface water containing contaminants leaving the Project area and having a negative impact on surrounding biota in waterways downstream of the development. Credible event includes a firefighting event, abnormal weather events. Contaminants may include sediment or oils and chemicals used at site.

Risk Comments

Construction of the Project would involve a range of activities including vegetation clearing and subsequent mulching, earthworks, trenching, concrete works and the establishment of a construction compound. These construction activities present a potential risk to downstream water quality if appropriate management measures are not implemented, monitored and maintained throughout the construction phase.

Material impact from water-run-off from fire hoses during an incident into a catchment.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
▪ Implement construction phase management procedures to minimize impact on any downstream water ways. ▪ Implement temporary drainage around site during the construction phase. ▪ Consult with FRNSW and consider the findings within the site drainage system design. ▪ Consider findings and recommendations within the Surface water quality and groundwater technical report (Jacobs, 2022a) and implement environmental management measures.	3	Highly Unlikely	6 – Medium Risk level to be mitigated as far as reasonably practical

5.2.3 EMF from the transmission connection causes health impacts

Ref. No:	Risk Area	Risk Issue	Causes
1.9	Health and Safety	The operation of the facility causes impacts which are detrimental to people's health and wellbeing	Induced electrical and magnetic fields from the plant and 330/500 kV interconnection.

Risk Comments

EMF hazards are induced through with AC currents notably the 330/500 kV transmission connection to the Project. It has been determined in the EMF Technical Paper that the expected EMF levels from the project infrastructure would comply with the relevant Australian and international standards and guidelines, specifically the ICNIRP reference levels, within and at the perimeter of the Project area. As such, mitigation measures have not been considered in the assessment. This is an aspect that would be considered during design and is not a factor that would impact community sensitive receptors in any way.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
▪ Consider findings and recommendations within the Electromagnetic interference assessment technical report (Jacobs, 2022c) and implement prudent avoidance measures to reduce public exposure to magnetic fields generated by the windfarm within the detailed design.	1	Highly Unlikely	2 – Low This risk level to be mitigated as far as reasonably practical

5.2.4 Ground water contamination during construction and operations

Ref. No:	Risk Area	Risk Issue	Causes
1.10	Water Systems	Development adversely impacts ground water during Construction phase	Contamination from accidental leaks or spills of chemicals and fuels. Vegetation clearing and subsequent mulching, earthworks, trenching, concrete works and the establishment of a construction compound. Use of access tracks and the use of the operation and maintenance facility which could result in increased runoff, erosion and sedimentation and accidental leaks and spills.

Risk Comments
Management measures would be required to avoid, minimise and manage any short-term impacts on downstream receivers (waterways and drainage lines) as a result of construction and operation of the Project.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
Material stockpile during construction ▪ Establish a construction environmental management plan (CEMP) ▪ Stabilise stockpiled materials including excavated soil such that material could not erode during high rainfall or windy events. ▪ Construction of hardstand areas and access roads to minimise soil compaction. ▪ Construction of a site wide drainage system to capture any surface water runoff during operations. ▪ Consider findings and recommendations within the Surface water quality and groundwater technical report (Jacobs, 2022a) and implement environmental management measures.	1	Highly Unlikely	2 – Low This risk level to be mitigated as far as reasonably practical

5.2.5 Fire caused from site operations spreads offsite

Ref. No:	Risk Area	Risk Issue	Causes
1.11	Health and Safety	Fire caused by other plant and equipment associated with the BESS development	Transmission line failure/Collapse causing bush fire. Arc flash. Vehicle movements create ignition source for flora e.g. grass at the site.

Risk Comments
A Bush fire risk technical report (Jacobs, 2022b) has been drafted as part of the EIS and bush fire is a credible risk. The report includes recommendations for permanent bush fire protection measures which would be considered within the BESS layout and design.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
▪ Establish a firebreak (a fuel reduced area surrounding the Project area) which can provide a defendable space for fire attack and reduce the likelihood of fire crossing into or out of the Project area. ▪ Consider findings and recommendations within the Bush fire risk technical report (Jacobs, 2022b) and implement environmental management measures.	1	Remote	1 – Low This risk level to be mitigated as far as reasonably practical

6. Environmental management measures

A summary of the recommendations and management measures detailed in **Section 4.7** and **Chapter 5** are provided in **Table 6-1**. These measures have been developed to specifically manage potential hazards associated with the BESS which have been predicted during construction and operation of the Project.

Table 6-1 PHA management measures

Impact	Reference	Environmental management measure	Responsibility	Timing
Hazards	PHA1	A detailed Hazard and Operability Study and design review of the selected designs will be carried out with specific attention on the inherent design features that detect, control and prevent thermal runaway.	Proponent/ Contractor	Detailed design
Thermal Runaway	PHA2	Requirements for suppliers and designers will be specified to demonstrate robust designs to prevent, monitor and (where unable to eliminate the possibility) control thermal runaway and undertake specialist safety in design assessments such as a fire risk assessment to inform the design and selection of the battery technology.	Proponent/ Contractor	Detailed design
Thermal runaway	PHA3	A design principle will be implemented that assumes a thermal runaway event within an enclosure would occur during the lifetime of the asset and therefore limits deflagration energy release (and prevents the spread of fire to adjacent enclosure by adopting appropriate design controls such as suitably designed enclosures and separation distances).	Proponent/ Contractor	Detailed design
Thermal runaway	PHA4	Credible scenarios will be determined from a thermal runaway event once the technology and its size are determined to quantify the amount of potential hazardous byproducts that must be managed and establish the Project design basis accordingly (e.g. amount of combustion and pollution, fire water uses for containment (if applicable), volumes of retention dams etc.).	Proponent/ Contractor	Detailed design
Quality control	PHA5	A robust quality plan will be implemented and inspections will be carried out throughout the supply chain and during installation, including factory and site acceptance testing.	Proponent/ Contractor	Detailed design, commissioning
Hazards	PHA6	Suitable asset management plans will be developed and implemented to ensure proper maintenance of the facility in line	Proponent/ Contractor	Prior to operation

Impact	Reference	Environmental management measure	Responsibility	Timing
		with manufacturers' recommendations and good industry practice throughout Project operation.		
Fire safety	PHA7	A fire safety study will be prepared in consultation with Fire and Rescue NSW and to the satisfaction of their operational requirements.	Proponent/ Contractor	Detailed design
Emergency response	PHA8	Provisions will be made for training and education of operations staff and emergency response services to understand the technology to safely manage potential incident responses.	Proponent/ Contractor	Prior to operation

7. Conclusions

There would be no unacceptably high Project risks that could result in significant off-site effects that are not manageable through application of inherent safety in design principles and safeguards. Further, there is low population density surrounding the Project area and, as a result, the number of affected sensitive receivers would be minimised should there be an incident leading to an incident such as a fire. All dwellings are a minimum of 4.5 kilometres from either BESS option and the closest town to the Project is Jerilderie, which is located a minimum of 35 kilometres to the south-east from the BESS, therefore, the likelihood and consequence of airborne hazards would be lower due to dispersion.

Given the concept level definition of the Project, and that the preferred technology is yet to be selected, the recommended actions and safeguards will enable a more quantitative assessment to be undertaken as the Project advances.

Battery thermal runaway and consequential hazards are considered the highest negative consequence potential; however, design principles which require early warning of such events, small module sizes to limit the quantity of hazardous by products, separation distances of battery enclosures to reasonably limit impacts to adjacent enclosures and integrated fire detection and fire suppression systems is considered in line with good industry risk management practices for the technology.

While there are hazards associated with the Project, the Proponent is committed to risk mitigation and management throughout design, construction, operation and decommissioning.

References

Department of Planning (DOP), 2011a. *Hazardous Industry Advisory Paper No. 4, 'Risk Criteria for Land Use Safety Planning'.*

Department of Planning (DOP), 2011b. *Hazardous Industry Advisory Paper No. 6, 'Hazard Analysis'.*

Department of Planning (DOP), 2011c. *Multi-Level Risk Assessment.*

Jacobs, 2022a. *Yanco Delta Wind Farm – Surface water quality and groundwater technical report.*

Jacobs, 2022b. *Yanco Delta Wind Farm – Bush fire risk technical report.*

Jacobs 2022c. *Yanco Delta Wind Farm – Electromagnetic interference assessment technical report*