Eraring Battery Energy Storage System

Preliminary Hazard Analysis (PHA)

IS365800_PHA | 02

13 October 2021

Origin Energy

SSD-15950052 EIS Appendix **M**

Preliminary Hazard Analysis - Eraring Battery Energy Storage System

Project No:	IS365800
Document Title:	Eraring BESS Preliminary Hazard Analysis (PHA)
Document No.:	IS365800-0001-GN-RSK-001
Revision:	02
Document Status:	Final
Date:	13 October 2021
Client Name:	Origin Energy
Client No:	SSD-15950052 EIS Appendix G
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File Name:	IS365800_Eraring BESS_Preliminary Hazard Assessment_Final 13102021

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Document history and status

Revision	Date	Description	Author	Reviewed	Approved
01	26/07/2021	Draft	I Boardman, N Wilkinson. D Pirsic	I Boardman	T Muddle
02	13/10/2021	Final	I Boardman, N Wilkinson. D Pirsic	I Boardman	T Muddle

Contents

Glossary of terms and abbreviations

Term	Definition
AS	Australian Standard
AHD	Australian height datum
BESS	Battery Energy Storage System
BMS	Battery Management System
CHAZOP	Control Hazard and Operability Study
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
EPS	Eraring Power Station
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
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

Executive Summary

Origin Energy Eraring Pty Ltd (Origin) is seeking regulatory and environmental planning approval for the construction and operation of a grid-scale Battery Energy Storage System (BESS) with a discharge capacity of 700 megawatts (MW) and storage capacity of 2,800 megawatt hours (MWh) located next to the Eraring Power Station (EPS) on existing Origin landholding (the Project).

The Secretary's Environmental Assessment Requirements (SEARs) issued for the Project includes the requirements to assess potential hazards and prepare a Preliminary Hazard Analysis (PHA) report in accordance with *Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis* (Department of Planning (DoP), 2011a) and *Multi-Level Risk Assessment* (DoP, 2011b).

The purpose of the PHA is to inform the development of the Project by identifying and assessing hazards that have the potential to impact community safety and documenting the measures that will be deployed to mitigate unacceptable risks.

PHA Methodology

This PHA is underpinned by a process involving hazard identification and risk assessment, back office research, advice from specialists and hazard analysis and risk assessment workshops. Hazards and risks were considered throughout the full Project lifecycle (construction, operation and decommissioning).

The Project

The Project concept design includes the installation of 700 MW lithium-ion battery capacity within land owned by Origin at EPS. This 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 typically be cooled by conventional cooling systems and physically separated from the adjacent enclosure. Enclosures would likely include electronics such as battery management systems and battery control 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.

Status of the Project Development

Origin is at an early stage of development of the Project having developed basic engineering concept studies and a functional and performance specification for the lithium-ion BESS. Origin has tendered the engineering, procurement, construction and commissioning of the BESS and has received preliminary technical and commercial offers which have helped to inform the Project; however, no selection of technology or detailed engineering has been performed at this stage. This has limited the PHA to a qualitative hazard and risk assessment underpinned by industry knowledge and experience of the Jacobs Project team.

Industry Practice

Jacobs found that BESS technology and standards are rapidly evolving as is the concept of best practice; however, with a good understanding of BESS technology failure modes and effects, acceptable standards of de-risking can be achieved by adopting sensible design principals which follow the hierarchy of control and are guided by the suite of evolving Australian and International standards.

Findings and Risk Assessment

Jacobs found that the highest identified Project risks relate to the consequences of a lithium-ion battery failure mode known as thermal runaway which 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 and it is evident that experienced battery manufacturers incorporate inherent design features and layers of protection into battery modules, battery management systems and enclosure designs to control the risk.

Origin is engaging with experienced technology suppliers; however, to the best of Jacobs' knowledge, there is insufficient evidence to demonstrate any fail safe lithium-ion BESS technology that is proven not to be potentially susceptible to thermal runaway and therefore the PHA has conservatively considered a fire as a credible event for risk and hazard management purposes. Origin's concept design and specifications 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 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 may be many layers of protection, that have not previously been available in battery designs, that would need to fail for an event to escalate. 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 site boundary. Manufacturers inherent design controls vary, and consideration of these would be undertaken during detailed safety in design processes during detailed design including fire risk assessment. Examples of known methods of additional control that are available in some technologies are individual module fire suppression and fire resistant layers within the modules to limit propagation. Cooling systems are also key to controlling the environment and dissipating heat;
- 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 the adoption of separation distances between battery enclosures included in Origin's concept requirements;
- A thermal runaway event in an enclosure causing uncontrolled buildup 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 buildup 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; and
- 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.

Overall, Jacobs consider the hazards and associated risks can be mitigated to so far as reasonably practical through adoption of controls in place within Origin's Project requirements and various recommendations made arising from the PHA.

Major recommendations

The major recommended actions mostly relating to the highest rated risks 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 fire risk assessment to inform the design and selection of the battery;
- Implement a design principle that assumes a thermal runaway event within an enclosure will occur in 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 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;
- Review findings from thermal runaway event incident investigations, to identify applicable lessons and improvements, and establish the Project design basis accordingly;
- Determine credible scenarios from a thermal runaway event once the technology and its size is 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.);
- Bushfire risk assessment is covered in detail other chapters of the Environmental Impact Statement (EIS), and the PHA recommends that heat maps from the detailed bushfire study be used to inform the design and determine adequate asset protection zones required to prevent conditions that could trigger thermal runaway in the specific technology selected;
- 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;
- 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; and
- Engage reputable and experienced design consultants knowledgeable in good industry standards to design the proposed grid connection infrastructure and undertake an electromagnetic field (EMF) study and assessment to confirm that EMF levels beneath the proposed transmission line are within public exposure guidelines.

Conclusions

The PHA concluded that at the current stage of development there are no unacceptably high Project development and operation related hazards that could result in significant offsite 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 a primary control for detecting and managing thermal runaway and confidence in these systems by suppliers is demonstrated by extended warranties that are available and placed on installations.

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

Origin's screening level refinement of BESS concepts obtained through formal tendered market enquiries has not identified any material concerns with locating the battery enclosures on the site while retaining the expected buffer from asset protection zones and maintaining reasonable separation distances between enclosures to avoid the potential spread of a fire. Recommendations are made to ensure that this is confirmed during the Project detailed design.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to document the findings of a Preliminary Hazard Analysis for the Eraring BESS Project in accordance with NSW Hazardous Industry Planning Advisory Papers as specified in the SEARS and in accordance with the scope of services set out in the contract between Jacobs and Origin Energy (‘the Client’). That scope of services, as described in this report, was developed with the Client.

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1. Introduction

1.1 Project overview

Origin Energy Eraring Pty Limited (Origin) owns and operates the Eraring Power Station (EPS) which is Australia's largest power station, having a capacity of 2,880 megawatts (MW). EPS is scheduled to be among 14 gigawatts (GW) of coal-fired generation plants to be retired within the next few decades (AEMO, 2020).

The retirement of the EPS will support Origin's carbon emission reduction goals and will align with the strategic transition away from coal in NSW. As such, Origin are now progressing an application to provide energy storage and key network services that would facilitate long term emissions reduction in the National Electricity Market (NEM) while supporting the delivery of secure and reliable electricity for consumers and businesses.

The Project is a State significant development (SSD) under the *State Environmental Planning Policy (State and Regional Development) 2011* (SRD SEPP) and as such the Project is subject to Part 4, Division 4.7 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) (refer to Section 3.1.1), which requires the preparation of an EIS in accordance with Secretary's Environmental Assessment Requirements (SEARs) and the approval of the Independent Planning Commission under circumstances described in SRD SEPP or the NSW Minister for Planning and Public Spaces.

1.2 Purpose and scope of the PHA

The purpose of the PHA is to inform the orderly development of the Project by identifying and assessing hazards that have the potential to impact community safety and documenting the measures that will be deployed to mitigate unacceptable risks. The scope of the PHA covers Project development and operation related hazards that could result in significant offsite effects.

This report is in response to the SEARS compliance requirements, specifically, *a Preliminary Hazard Analysis prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis (DoP, 2011a) and Multi-Level Risk Assessment (DoP, 2011b)* and further considers the DoP guidance notes provided with compliance requirements as included in Appendix A.

1.3 Project location

The Project will be situated on land zoned SP2 Infrastructure for electricity generating purposes and within an area previously disturbed by power station activities. No re-zonings or land acquisitions are required. The Project is located within, Lots 10 and 11 DP 1050120, Rocky Point Road Eraring, within the Lake Macquarie City Council (LMCC) LGA, as illustrated in Figure 1-1. Surrounding land use zoning and context is provided in Figure 1.2.

Project area
Electricity transmission line
Railway

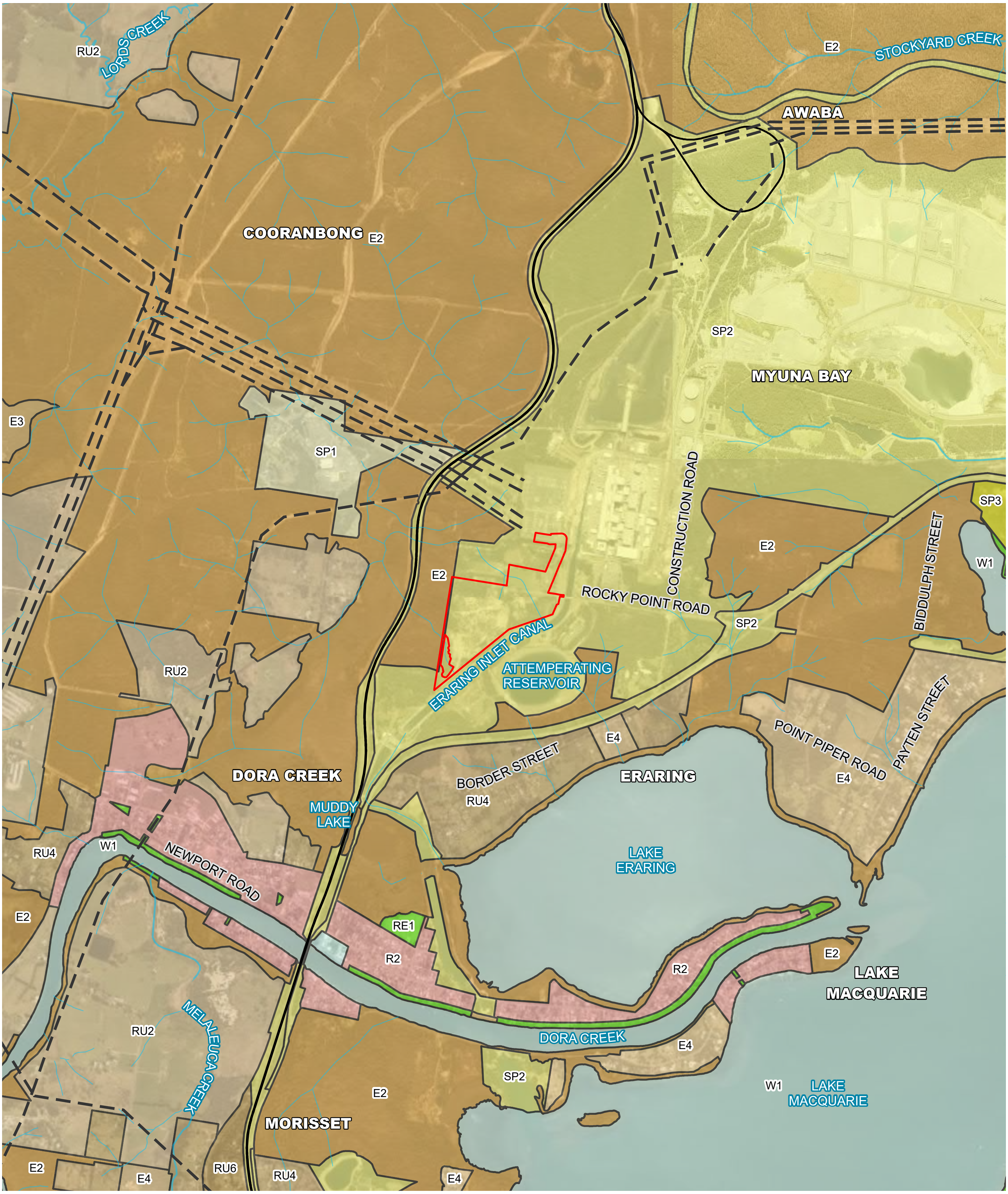
0 1 km

1:50,000 at A4
GDA94 MGA56

Data sources

Origin 2021
© Department Finance, Services and Innovation Dec 2020,
© Department of Customer Service 2020

Figure 1-1 Project location



Project area

Land zoning

- B1 Neighbourhood Centre
- E2 Environmental Conservation
- E3 Environmental Management
- E4 Environmental Living
- R2 Low Density Residential
- RE1 Public Recreation
- RU2 Rural Landscape
- RU4 Rural Small Holdings
- RU6 Transition
- SP1 Special Activities
- SP2 Infrastructure
- SP3 Tourist
- W1 Natural Waterways

Railway

Electricity transmission line

0 800 m

1:30,000 at A4

GDA94 MGA56

N

Data sources

Origin 2021,
Aerometrex 2020,
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Figure 1-2 Land zoning

Surrounding land external to the EPS consists of broadacre rural development and low-density residential properties. The largest commercial centre and population centre nearby is Charlestown (29.1 kilometres (km) north east), and the closest residential suburb is Dora Creek (1.2 km south). The Great Northern Railway alignment runs along the border of Dora Creek and Eraring suburbs, approximately 200 metres (m) west of the Project area.

The Project area is surrounded by the following features with the Origin landholding:

- EPS operations area, elevated TransGrid switchyard, coal yards and extensive EPS buffer lands to the north;
- Elevated attemperation reservoir to the east;
- Elevated EPS inlet canal to the south and east; and
- Mature vegetation within E2 environmental protection zoned land along a ridge line to the west.

The nearest private receptors to the Project area are located as follows:

- Rural residential dwellings approximately 600 m to the west on Gradwells Road beyond the Great Northern Railway;
- Dora creek township approximately 1.2 km to the south;
- Properties on Border Street approximately 600 m to the south which are screened by the EPS inlet canal and attemperation reservoir and beyond Wangi Road; and
- Dwellings to the north of Project area located over 4 km away beyond the EPS and mining operations.

1.4 Report structure

The report structure is as follows:

- Section 1 provides the Project background and purpose of the report;
- Section 2 provides the Project description;
- Section 3 provides a description of the assessment approach;
- Section 4 provides a summary of findings and recommendations;
- Section 5 provides the hazard and risk analysis and assessment; and
- Section 6 provides PHA conclusions.

2. Project description

2.1 Summary

Origin is seeking regulatory and environmental planning approval for the construction and operation of a grid-scale BESS with a discharge capacity of 700 MW and storage capacity of 2,800 MWh at the Project area. The Eraring BESS would be among the largest battery projects in NSW and Australia in terms of peak power output and discharge duration. The Project would provide energy storage and key network services that would facilitate long term emissions reduction in the NEM while supporting the delivery of secure and reliable electricity for consumers and businesses.

The Project would be situated within the Origin landholding associated with the EPS located on the western shore of Lake Macquarie. The EPS is approximately 40 km south of Newcastle and approximately 120 km north of Sydney in NSW. The total area of the Origin's landholding is approximately 1,200 hectares (ha), including EPS operational areas, Eraring Ash Dam and surrounding buffer lands consisting of bushland and grassland interspersed with roads and water management and electricity transmission infrastructure. The Project area is about 25 ha and is shown on Figure 2-1.

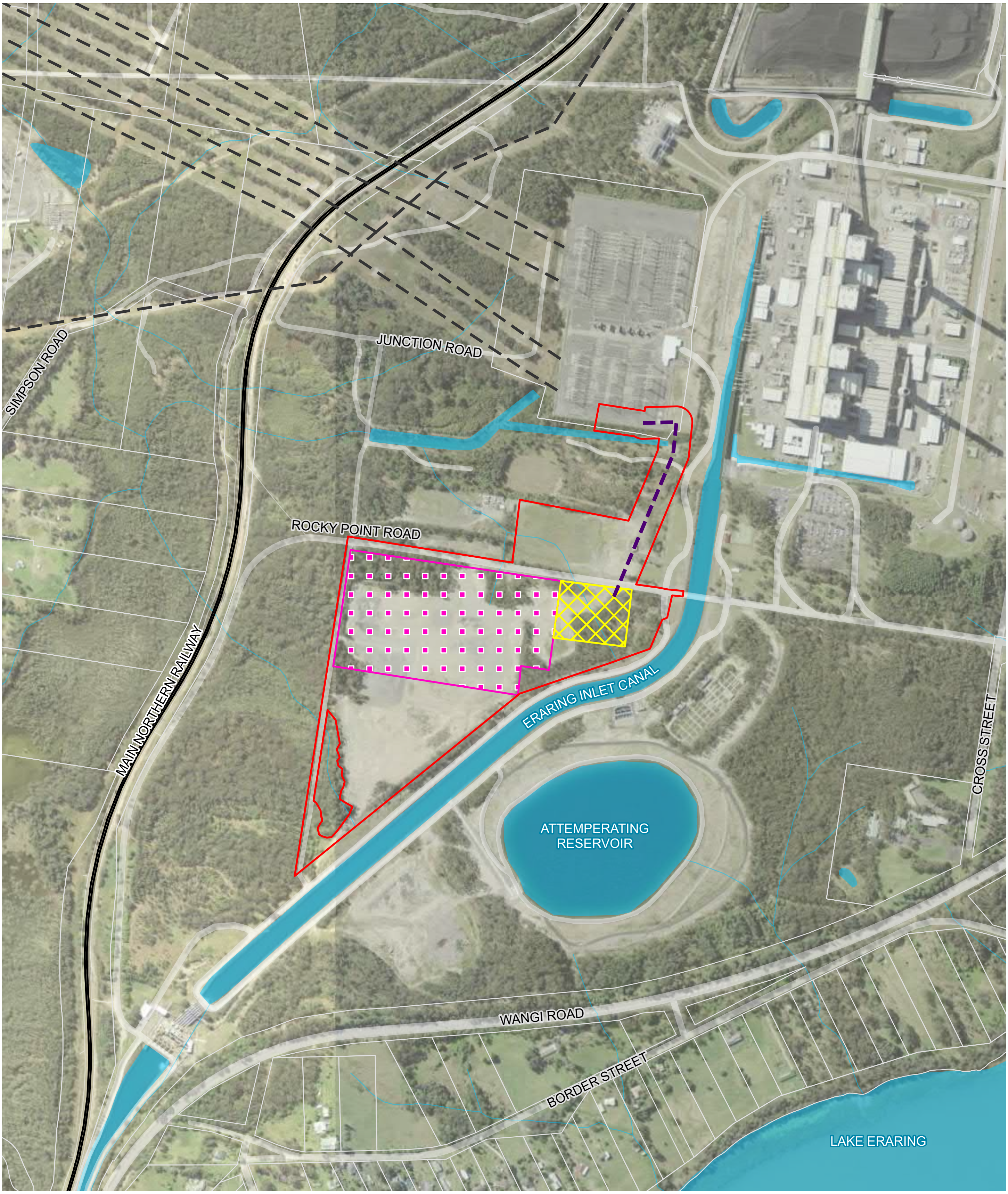
The Project would include the construction and operation of:

- BESS compounds comprising of rows of enclosures housing lithium-ion type batteries connected to associated power conversion systems (PCS) and high voltage (HV) electrical reticulation equipment;
- A BESS substation housing HV transformers and associated infrastructure;
- Approximately 400 metres (m) of overhead 330 kilovolt (kV) transmission line connecting the BESS substation to the existing 330 kV TransGrid switchyard; and
- Ancillary infrastructure and facilities including safety protection systems and site ancillary facilities such as laydown areas and site offices.

A full description of the Project is included in Section 3 of the EIS.

The BESS will be capable of providing energy Frequency Control Ancillary Services (FCAS), System Restart Ancillary Services (SRAS), as well as fast frequency response and synthetic inertia - security services currently under consideration in the NEM.

The Project maximum disturbance area is approximately 25 hectares (ha) in size with permeant infrastructure likely to cover half this area. Construction may require temporary compounds or laydown areas outside the permanent footprint but within the Project area and would be located in existing vacant areas of the Project area as illustrated in Figure 2-1.



Project area
Proposed 330kV transmission connection
Battery Energy Storage System
Substation
Electricity transmission line
Railway
Cadastre

0 300 m
1:10,000 at A4
GDA94 MGA56

Data sources

Origin 2021,
Aerometrex 2020,
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Figure 1-2 Project overview

2.2 Battery system

The BESS technology provider is not yet confirmed; however, the batteries are likely to consist of modular lithium-ion type racks, housed within battery enclosures containing protection, control and heating, ventilation and air conditioning.

Other infrastructure within the BESS compound will include:

- PCS comprising of inverters and battery transformers;
- HV reticulation including ring main unit (RMU), cables and switchboards; and
- Switch rooms and control rooms.

The PCS will be four-quadrant bidirectional type, with capability for both charge/ discharge in leading and lagging reactive power scenarios. The PCS will also have grid forming capability to allow islanded operation and SRAS where required.

2.3 Network connection

The Project would take advantage of the close proximity to the existing TransGrid owned 330 kV switchyard which has sufficient spare capacity for the size of the proposed BESS. The Project's connection will be electrically separate to that of EPS, so it can be operated independently of the EPS.

The following components are required to connect the BESS to the NEM:

- 33/330 kV transformers in a bunded transformer area;
- Overhead steel structure lattice towers complete with insulators and conductor(s) spanning the distance between the Project area and the existing TransGrid 330 kV switchyard;
- Associated protection and control systems.

Connection works into the TransGrid switchyard is targeting existing vacant connection bays but allowance is made for bench extension and installation of additional infrastructure.

2.4 Construction works

The construction methodology for the Project will be developed in more detail during the preparation of the detailed design. However, it is expected to involve:

- Installation and maintenance of environmental controls including drainage and sediment controls;
- Upgraded construction access track from existing internal access road to battery location;
- Vegetation clearing;
- Cut and fill to level areas and establish a hardstand pad and construction laydown areas;
- Structural works – slabs to support battery modules, power conversion systems and transformer structures;
- Delivery, installation and electrical fit-out of battery modules, power conversion systems and transformers;
- Installation of 330 kV overhead cabling from the battery transformers to the TransGrid switchyard;
- Testing and commissioning activities; and
- Removal of construction equipment and rehabilitation of construction areas.

2.5 Construction program

The Project's modular design provides significant deployment flexibility with the capacity to stage the 700 MW to meet market needs. The construction of the first stage of the BESS is expected to begin in 2022 (subject to approval) and have a duration of 18 months, with commercial operations possible by 2023. The indicative timeline for subsequent stages of the Project include:

- Stage 2 construction commencing 2023 and operations commencing 2025; and
- Stage 3 construction commencing 2026 and operations commencing 2027.

2.6 Operation

Operation will be 24 hours/365 days per week and will respond to market demand, fluctuating from discharge at full capacity for up to four hours or partial capacity for a longer duration. Maintenance activities will be ongoing (landscaping, asset protection zones, water management infrastructure, access tracks and inspection, testing and replacement of components). Operation life is expected to be between 20 to 30 years. Component replacements and/or upgraded may extend this timeframe.

2.7 Decommissioning

Following the end of economic life, above ground components would be removed and, where possible, re-purposed. Land rehabilitation will be undertaken where necessary to achieve acceptable conditions as far as reasonably practicable.

2.8 Additional description for PHA

The following description is provided for context and general awareness of a BESS that is typical of the concepts being considered by Origin and the basis on which the PHA has been assessed. A final layout and design has not been determined.

Origin has completed a RFT process from which the preferred technologies will be selected for the development of the first stage of the Project but ultimate technology selection is not complete and as such no detailed design is currently available. However, based on Origin's selection process a good understanding of available technology on offer is available. The Project description is typical of the concepts being considered by Origin and where necessary ranges are provided to accommodate options currently under consideration. It should be noted that the pace at which technology is developing in the battery storage space means that the option selected for early stages may not be replicated throughout subsequent stages. In general environmental performance, energy density and built-in controls are expected to improve such that reasonable worst case assumptions based on current technology would be unlikely to be exceeded and may be reduced.

The BESS compound is proposed to be installed in up to three stages and targets land within the Project area immediately south of Rocky Point Road. Significant flexibility is available within the BESS compounds for each stage to arrange power islands in different ways. This flexibility would facilitate necessary separation distances, asset protection and otherwise respond to constraints. Origin is considering various stage layouts and the detailed design of each stage would consider technology selection, design mitigation measures, layout and location to best balance environmental impacts, cost and achieve assessed performance outcomes. Visualisations depicting an aerial view of the BESS compound at full development is depicted in Photo 2-1.

Photo 2-1: Indicative aerial visualisation of Project at full development

Conceptually, the 700 MW – 2,800 MWh Project may comprise in the order of 2,000 to 8,500 battery enclosures, dependant on the selected supplier, containing battery modules with individual capacity of 0.3 to 1.4 MWh of energy storage. The largest enclosure type under consideration is be in the order of 2.5 m x 2.5 m x 2.8 m (length x width x height). When arranged in rows, all enclosures under consideration resemble a shipping container as depicted in Photo 2-2. 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.

Photo 2-2: Indicative visualisation of within BESS compound

The enclosures would likely be organised in rows and integrated with power conversion systems (inverter / transformers) servicing a number of enclosures to convert direct current from the battery to alternating current required within the electricity network. The rows of BESS enclosures would be physically separated and each enclosure substantially self-contained with local control and protection devices. Each enclosure would contain 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 typically be cooled by conventional cooling systems. Enclosures would likely include electronics such as battery management systems and battery control 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.

Power distribution feeding electrical power to a substation is expected to include both underground and above ground cabling. A transmission connection consisting of above ground 330 kV transmission lines to the electricity network would be run from the transformer bay to the TransGrid switchyard and require the establishment of an easement. Firefighting tanks, pumps and water reticulation may 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.

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. An area free of plant and equipment would surround the site to serve as an asset protection zone from the potential effects of bushfires. Access roads, lighting, security fencing and CCTV, small office and crib and ablution facilities would also feature at the site.

Battery enclosures being considered for the Project have secured internal access whereby operations or maintenance activities are substantially serviced form outside the enclosure. Life cycle maintenance includes routine maintenance inspections and routine changeout and repair of serviceable parts. Infrequently, battery enclosures and or modules within enclosures will be fully replaced.

3. Methodology

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

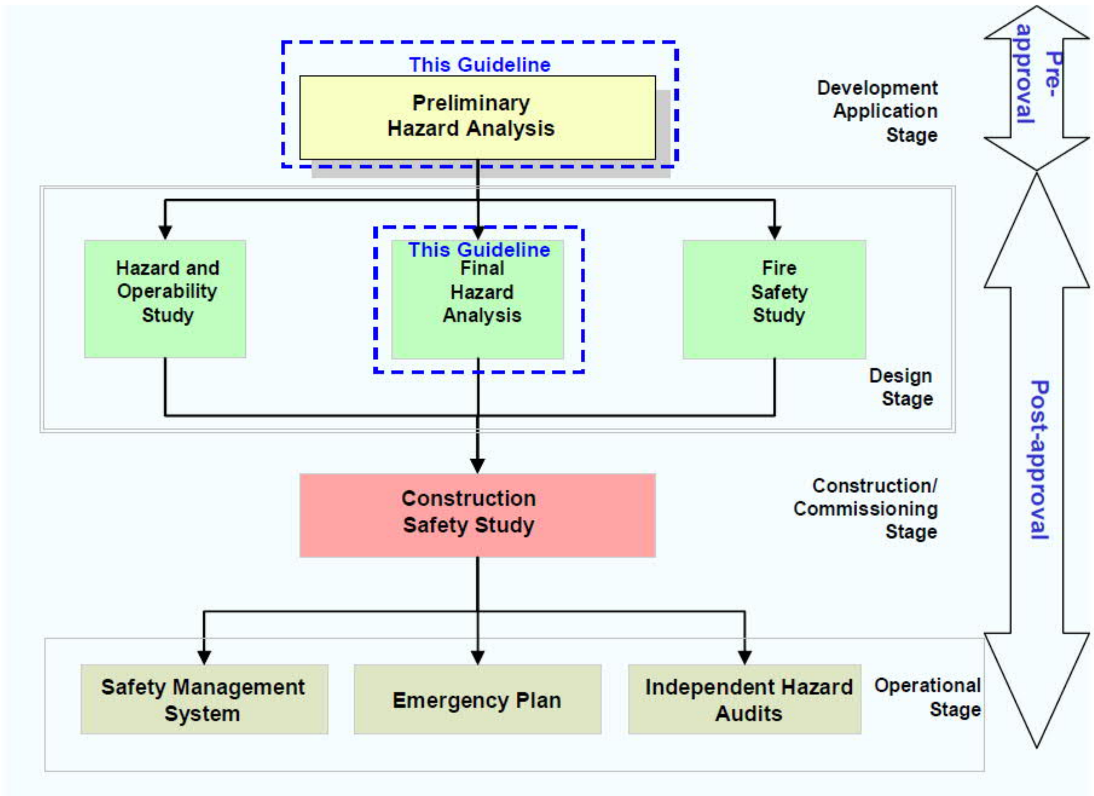


Figure 3-1: The hazard related assessment process (DoP, 2011a)

3.1.1 Process

The Project is at an early stage of development Project definition, the hazard identification process underpinning this PHA included back office research, investigation and consultation within Jacobs followed by two sessions of structured and independently facilitated workshops involving qualified and experienced personnel from Jacobs and representatives from Origin's Project and technical team (refer Appendix B for workshop outline and participating team member details). More detailed hazard and risk analysis including HAZOP will occur at later stages when the Project is better defined.

The analysis is structured to consider possible hazard scenarios that could result from Project construction and operation events, including abnormal events and the consequences of these to people, property and the biophysical environment. Safeguards and recommended actions identified throughout the PHA consider the hierarchy of control and formed a basis for challenging the effectiveness of actions.

3.2 Risk criteria

The PHA has used Origin's risk matrix and consequence and likelihood criteria for assessing the hazards identified. Jacobs consider these to be in line with a good industry standard and are appropriate for the stage of the Project, the level of definition and in keeping with the existing guidelines (DoP, 2011a). 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. Details of the specific criteria are provided in the sections below.

3.2.1 Consequence criteria

This PHA has used Origin's risk criteria for assessing the risks associated with identified hazards. The early stage of concept design of the Project and, as yet, no selected preferred technology or design has limited the analysis in most part to qualitative assessment based on the judgement and the industry experience of the Project analysis 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 People and Environment and Community categories as defined in Table 3-1 and Table 3-2. Origin's full risk matrix is shown in Appendix C for reference.

Table 3-1: People Consequence Criteria

PEOPLE - CONSEQUENCE CRITERIA	
Consequence	Criteria
Minor	Minor - A minor injury or illness resulting in first aid or no treatment
Moderate	Moderate - Injury or illness to one or more persons resulting in medical treatment or outpatient treatment (i.e. not requiring admission as an in-patient) excluding treatment for a serious injury or illness
Serious	Serious - Serious injury or illness to one or more persons not resulting in a permanent disability
Major	Major - Serious injury or illness to one or more persons, resulting in partial permanent disability
Critical	Critical - 1 - 3 fatalities or life threatening illness or total permanent disability to a small exposed group (<10 people)
Catastrophic	Catastrophic - Multiple fatalities >4 or life threatening illness or total permanent disability to a large exposed group (10 or more people)

Table 3-2: Environment and Community Consequence Criteria

ENVIRONMENT AND COMMUNITY - CONSEQUENCE CRITERIA	
Consequence	Criteria
Minor	Minor environmental or community impact - readily dealt with
Moderate	Moderate short term impacts to common regional species, habitats, ecosystems or area of cultural significance. Small scale impacts to cost of living, business viability or social wellbeing. Isolated examples of community tension
Serious	Serious medium term reversible impacts to low risk species, habitats, ecosystems or area/s of cultural significance. Moderate impacts to community cost of living, business viability or social wellbeing. Moderate levels of community tension.

ENVIRONMENT AND COMMUNITY - CONSEQUENCE CRITERIA	
Major	Long term reversible impacts to listed species, habitats, ecosystems or area/s of cultural significance. Significant impacts to community cost of living, business viability or social wellbeing. High levels of community tension.
Critical	Extensive long term partially reversible impacts to vulnerable species, unique habitats, ecosystems or area/s of cultural significance. Extensive reversible loss to community livelihood. Prolonged community outrage.
Catastrophic	Extensive permanent damage to endangered species, habitats, ecosystems or area/s of cultural significance. Extensive irreversible of community livelihood. Long term social unrest and outrage.

3.2.2 Likelihood criteria

The likelihood criteria used in this PHA is based on Origin's risk matrix and is shown in Table 3-3.

Table 3-3: Likelihood Criteria

LIKELIHOOD CRITERIA	
Likelihood	Criteria
Remote	Remote - <1% chance of occurring within the next year. Only occurs as a '100 year event ' or less frequent
Highly Unlikely	Highly Unlikely - <10% chance of occurring within the next year. Could occur within decades.
Unlikely	Unlikely - <30% chance of occurring within the next year. Could occur in the next few years.
Possible	Possible - <60% chance of occurring within the next year. Could occur within months to years.
Likely	Likely - <90% chance of occurring within the next year. Could occur within weeks to months.
Highly Likely	Highly Likely - Likely to happen multiple times a year

3.2.3 Risk matrix

The risk matrix used in the risk assessment is shown in Table 3-4.

Table 3-4: Risk Matrix

		LIKELIHOOD					
		1 Remote	2 Highly Unlikely	3 Unlikely	4 Possible	5 Likely	6 Highly Likely
CONSEQUENCE	6 Catastrophic	H5 - High	H6 - High	VH6 - Very High	VH7 - Very High	VH8 - Very High	VH9 - Very High
	5 Critical	M14 - Medium	M15 - Medium	H4 - High	VH3 - Very High	VH4 - Very High	VH5 - Very High
	4 Major	M11 - Medium	M12 - Medium	M13 - Medium	H3 - High	VH1 - Very High	VH2 - Very High
	3 Serious	L6 - Low	M8 - Medium	M9 - Medium	M10 - Medium	H1 - High	H2 - High
	2 Moderate	L4 - Low	L5 - Low	M4 - Medium	M5 - Medium	M6 - Medium	M7 - Medium
	1 Minor	L1 - Low	L2 - Low	L3 - Low	M1 - Medium	M2 - Medium	M3 - Medium

4. Findings and recommendations

4.1 Stage of development

Origin has developed basic engineering concept studies and developed a functional and performance specification for the lithium-ion BESS. Origin has tendered the engineering, procurement, construction and commissioning of the BESS and has received preliminary technical and commercial offers which have helped to inform the project description (refer to Chapter 2). Evaluation and shortlisting of offers are underway and Origin is currently working with shortlisted tenderers to finalise the selection of the preferred technology and design.

As such, this PHA focusses on known hazards associated with lithium-ion battery technologies and development aspects related to the Project area. At this stage of development, the PHA is substantially a qualitative assessment based on industry experience and judgement and identifies response actions that will 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 which 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; or
- 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.

Thermal runaway prevention, detection, and control is an important technology design consideration to battery technology manufacturers however the variations in factors such as battery chemistry, materials of construction and configuration and basic specifications leads to different and unique methods of safeguarding between suppliers. Battery Management Systems (BMS) 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 and more installations are commissioned and technology providers develop improved methods of managing and eliminating failure modes that have historically resulted in some escalated fire events related to thermal runaway. Different battery chemistries can have different potential energy releases during thermal runaway and approximately 20 battery fires are known to have occurred internationally over the period from their early technology pioneering developments. As such, the hazard and risk analysis has paid specific attention to the hazards and risks associated with these low likelihood events, and recommended action which targets an informed understanding of the extent of the hazard, and due consideration of the design controls and layers of protection once the project definition advances to a technology evaluation, selection and detailed design stage.

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. This includes appropriate selection and implementation of active and/or passive protections. Examples of known methods of additional control that are available in some technologies are individual module fire suppression and fire resistant layers within the modules to limit propagation. Cooling systems are also key to controlling the environment and dissipating heat.

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 adoption of Origin's design principle of maintaining separation of enclosures the extent of any hazard associated with the consequences of thermal runaway does not increase, albeit it the likelihood may increase marginally.

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 design safeguards and controls are commonly implemented in the sector.

With the technology developments since the early pioneering BESS projects and the emergence of global reputable technology suppliers providing industry standard warranties on technology, Jacobs consider that there is an elevated likelihood that current generation technology will be more reliable and less susceptible to extreme impacts from the manifestation of known failure modes.

4.4 Key hazard and risk findings

Jacobs found that the highest identified Project risks relate to the consequences of a lithium-ion battery failure mode known as thermal runaway which 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 and it is evident that experienced battery manufacturers incorporate inherent design features and layers of protection into battery modules, battery management systems and enclosure designs to control the risk.

Origin is engaging with experienced technology suppliers; however, to the best of Jacobs' knowledge, there is insufficient evidence to demonstrate any fail safe lithium-ion BESS technology that is proven not to be potentially susceptible to thermal runaway and therefore the PHA has conservatively considered a fire as a credible event for risk and hazard management purposes. Origin's concept design and specifications 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 may be many layers of protection, that have not previously been available in battery designs, that would need to fail for an event to escalate. 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 site boundary. Manufacturers inherent design controls vary, and consideration of these would be undertaken during detailed safety in design processes during detailed design including fire risk assessment. Examples of known methods of additional control that are available in some technologies are individual module fire suppression and fire resistant layers within the modules to limit propagation. Cooling systems are also key to controlling the environment and dissipating heat.
- 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 the adoption of separation distances between battery enclosures included in Origin's concept requirements

- A thermal runaway event in an enclosure causing uncontrolled buildup 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 buildup 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, and
- 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.

Overall, Jacobs consider the hazards and associated risks can be mitigated to so far as reasonably practical through adoption of controls in place within Origin's Project requirements and various recommendations arising from the PHA.

4.5 Other findings

- The PHA considered and reviewed a comprehensive identification of fourteen discrete causes for hazard incidents with a potential to impact people, property and the biophysical environment if appropriate safeguards are not put in place;
- 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;
- Origin's functional and performance specification which has been used to solicit preliminary BESS market supply and install enquiries, is of a reasonable industry standard and incorporates some requirements related to mitigation of hazards identified. The specification sets a sound base on which the PHA findings and recommendations will enable Origin to further engage with suppliers and contractors on matters to de-risk the Project as it progresses through the detailed design phase;
- Origin has adopted 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. 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 a low population density in the vicinity of the proposed development with the nearest residential suburb 1.6 km from the Project area and the nearest sensitive receptor 600 m from the Project area. Given the design principles adopted by Origin to mitigate the consequence of a credible event and the layers of protection likely to be available to avoid uncontrolled escalation of an event, the PHA considers it 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 will enable time to respond, if necessary, and to act to further mitigate or notify offsite receptors of any exposure to the hazard; and
- There are no unusual volumes of hazardous materials that are required to be stored at the site in support of a BESS operation for the Project.

Detailed hazard analysis and management plans are presented in Chapter 5. It is important to note that the number of recommended actions presented in the detailed plans is by no means a reflection of inadequacies in any aspect of the development approach to the Project. This number reflects the thoroughness in capturing both specific safeguards and reinforcing the importance of deploying standard industry practices throughout the development process (many of which already exist in Origin's specification) to underpin ongoing risk management and sizing up the exposure from the risk as new information becomes available.

4.6 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 fire risk assessment to inform the design and selection of the battery;
- Implement a design principle that assumes a thermal runaway event within an enclosure will occur in 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;
- Review findings from thermal runaway event incident investigations, to identify applicable lessons and improvements, and establish the Project design basis accordingly;
- Determine credible scenarios from a thermal runaway event once the technology and its size is 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.);
- Bushfire risk assessment is covered in detail other chapters of the EIS, and the PHA recommends that heat maps from the detailed bushfire study be used to inform the design and determine adequate asset protection zones required to prevent conditions that could trigger thermal runaway in the specific technology selected;
- 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
- 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; and
- Engage reputable and experienced design consultants knowledgeable in good industry standards to design the proposed grid connection infrastructure and undertake an EMF study and assessment to confirm that EMF levels beneath the proposed transmission line are within public exposure guidelines.

5. Hazard & Risk Analysis and Assessment

5.1 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 which is a risk assessment if no controls and safeguards are in place and target risk which is 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 so as 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 lesser risk;

3. Engineering controls – separate the hazard or design to protect or isolate people from the hazard;

4. Administration controls - implement procedures, training signage etc; and

5. Personal protective equipment.

Further, the Project team recognised that there is in most cases insufficient detail at this stage of the Project to reliably quantify such things as the volumes of hazardous by products in the case of a fire scenario and therefore some recommended actions relate to verifying this as the Project definition improves. Despite this, design principles are being adopted in Origin's specifications and technology evaluations which practically minimise hazardous by products in such an event. By way of example, the current concept includes an installation comprising a large number of independent battery enclosures, indicatively in the range 2,000 to 8,500 less than 1 MW units (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.

5.1.1 Lithium-ion battery technology failure modes and effects

Primary causes of thermal runaway identified include battery mechanical damage, defects and improper operation. Failure sequencing generally follows the generation of heat and overvoltage, production of off gas 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 Origin's requirements for the Project and additional recommendations:

5.1.1.1 Thermal runaway occurs because of battery defect

Ref. No:	Risk Area	Risk Issue	Causes
1.1	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 a defect in one battery module propagates to adjoining modules and escalates to an enclosure fire.
Risk Comments			
Defects can occur in manufacturing, installation or during operation if there are component malfunctions e.g. Cooling system loss.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.1.1 Specify the requirement for a system design that is able to reliably identify when thermal runaway is occurring within a short period of time and can initiate control actions. 1.1.2 Specify the requirement for full and complete remote monitoring and recording of all technical parameters that are necessary to assess the status of a module. Control actions and potential hazards that exist during a normal or abnormal operation. 1.1.3 Develop a complete maintenance plan, calibration routines, procedures and schedule for replacement, refurbishment or routine maintenance of cells or modules. 1.1.4 Specify that the contractor and suppliers must have a complete and comprehensive quality plan in place with a certified quality standard equivalent to ISO9001. The plan must be containing tangible and specific sub plans related to the technology, plant and equipment, e.g. demonstrate a review of the supply chain manufacturing to ensure that purchased cells are not counterfeit, and that the implementation of QA tests and procedures is compliant, that the manufacturers statistical failure rate is reasonable etc. Origin to review the QA plan. 1.1.5 Develop and implement an asset management plan that adheres to Original Equipment Manufacturer (OEM) operation and maintenance recommendations.	Serious	Highly Unlikely	M8 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.1.2 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	Thermal runaway due to an improper operation of one or a more battery module propagates to adjoining modules and escalates to an enclosure fire. Operation outside design specs e.g. charging or discharging, temperatures.
Risk Comments			
The BMS and battery control system is the primary design safeguard to prevent operation of the battery outside its limits that could result in overvoltage, elevated temperature or other factors that could initiate thermal runaway. 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; however, they are backed by warranties and guarantees in contracts. HVAC systems within each of the battery enclosures are used to control the temperature within the enclosure.			

Properly supervised commissioning including inspection and test plans and certificates during construction and commissioning are an important layer of protection. It could be reasonably expected that issues associated with this failure mode would be resolved during commissioning phase in a controlled environment.			
Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.2.1 Specify that the contractor must perform HAZOP and CHAZOP and that Origin and their representatives are in attendance. 1.2.2 Specify that the contractor must provide operation and maintenance manuals and training material including design and calibration settings and procedures. 1.2.3 Undertake design and operability reviews during the engineering phase. 1.2.4 Ensure that management of change processes are rigorously implemented during construction and operations.	Serious	Highly Unlikely	M8 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.1.3 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 improper operation of one or a more battery module propagates to adjoining modules and escalates to an enclosure fire.
Risk Comments			
Mechanical damage caused in battery modules has the potential to cause thermal runaway. Damage may occur during transport and handling of battery modules during construction and maintenance activities. Industry standard methods are available to monitor and identify if mechanical damage has occurred including shock sensors which are attached to battery components. It is typical for BESS suppliers to put strict procedures and warranty provisions in place which reject any batteries that show indications of mechanical shock. With these controls in place it is highly unlikely that the initiation of thermal runaway would be caused by mechanical damage. The site is not prominent to regularly frequented public access ways. During operations vehicles will include light vehicles, infrequent forklift, crane and heavy vehicle movements during battery change out operations. Lithium-ion batteries are transported in a semi charged state. There is a potential for accidents involving the transport of the batteries to site and mechanical damage caused during such an event. Shock sensors are typically used as an effective industry method of detecting potential mechanical damage and rejecting battery module installation. Maritime safety requirements exist for transport of lithium-ion batteries and Dangerous Goods code regulations for transportation. Lithium-ion batteries are a Class 9 Dangerous Good.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.3.1 Facility is a secured site with access controls and excludes members of the public and any untrained or unauthorised persons. All personnel operating vehicles or mobile plant within the facility shall be suitably qualified, trained and supervised. All maintenance activities in proximity to enclosures involving vehicles or mobile plant to be performed under safe methods of work processes. 1.3.2 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, PTW and safe work management systems etc. 1.3.3 Specify requirements for the responsible party to develop safe transport and	Serious	Unlikely	M9 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

shipping procedures (in line with OEM recommendations) and ensure that transport/shipping companies implement and audit compliance. 1.3.4 Specify security measures meeting requirements of appropriate standards e.g. AS1725.1. 1.3.5 Specify requirements for electronic site access control and remote CCTV security monitoring. 1.3.6 Ensure that the contractor has in place QA monitoring for any inadvertent mechanical damage (e.g. shock sensors) and procedures for acceptance or rejection of battery installations. 1.3.7 Develop and implement appropriate asset management plans during operation. 1.3.8 Specify that the contractor is required to prepare a risk assessed transport plan and Origin to review the plan.			

In an extreme scenario a fire within a battery module could propagate to other modules, extend throughout the enclosure and trigger conditions such as temperature that initiates thermal runaway in modules and in in adjacent modules. The following sections discuss the assessment of this failure event.

5.1.1.4 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 site boundary. 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. Based on preliminary tender design information the number of enclosures varies based on the technology offered. The order of magnitude range is 2,000 to 8,500 enclosures for stage 1 (700 MW capacity). Inherent safety in design principles have been applied to limit impact of cell failure (and consequently modules) so far as is reasonably practical (SFAIRP), but ultimate worst-case layer of protection to prevent any fire event escalating outside the initiating enclosure. For the design concepts which Origin is considering 'Enclosure' denotes a box boundary around the largest credible fire threat, a person cannot physically enter an 'enclosure'; analogous to a cupboard for battery cells that is accessed from the outside. The design is specified to minimise the threat of an enclosure fire or explosion, but in the unlikely event this should ever occur, to prevent a multi enclosure fire and therefore limit the products of combustion and there effect outside the site boundary. The Project Facility has been 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
1.4.1 Implement separation distances between enclosures to prevent the effect of thermal runaway in one enclosure causing thermal runaway on nearby enclosures. 1.4.2 Specify in the Contract documents that the selected battery technology must be designed, installed and operated in accordance with standards that meet or exceed requirements for fire performance test at installation level according to UL 9450A.	Major	Remote	M11 – Medium Jacobs consider this

1.4.3 Once technology is selected and design has advanced, undertake HAZOP and appropriate safety in design reviews to, amongst other things: • Confirm the enclosure materials and installation methods limit the threat of fire and explosion impacting personnel or equipment outside the enclosure, including adjacent enclosures • Review the technology monitoring systems and actions within the BMS and control systems are adequate to take direct action or alert conditions that could result in a fire. 1.4.4 Undertake design review of the contractor's design and confirm reasonable compliance with specified standards. 1.4.5 Confirm if selected technology can produce explosive gases, and if so, mitigate deflagration. 1.4.6 Implement controls that disallow the storage of flammable materials within a defined proximity of the battery enclosures . 1.4.7 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. 1.4.8 When the technology is selected/shortlisted, where appropriate, consult with NSW Hazards branch for guidance on emergency response measures and firefighting capability reasonably required for emergency response requirements. 1.4.9 When the technology is selected/shortlisted, undertake a fire safety study for the site to determine safe separation distances and quantify the extent of the smoke hazard from a single enclosure fire. Undertake a screening review of health exposures to inform the requirements (if any) to strengthen mitigations or responses actions (e.g. evacuation requirements in emergency response plans).			risk level to be mitigated to so far as reasonably practical

5.1.1.5 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
1.5.1 Specify that the systems enclosed environment has enough volume and ventilation to limit the potential for LEL being exceeded. 1.5.2 Specify the requirements for deflagration design that limits damage (should it occur). 1.5.3 Design electrical systems to AS3000. 1.5.4 Design and separation distances to give consideration for the maximum volume of gasses, deflagration design and mitigations, and the resulting aggregate potential for energy release, to limit impact to adjacent personal and equipment. 1.5.5 Design transformers including bunding and fire suppression in accordance with good industry standards. 1.5.6 Implement monitoring of transformers condition during operation.	Major	Highly Unlikely	M12 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.1.6 Bushfire triggers thermal runaway or asset damage

Ref. No:	Risk Area	Risk Issue	Causes
1.6	Health and Safety	Development adversely impacts offsite air quality in concentrations that affects community health and wellbeing during operations phase	Thermal runaway if initiated leads to battery fire generating toxic smoke which may drift across site boundary.
Risk Comments			
Excessive temperature from a bushfire event could cause safe temperature limits to be exceeded and initiation of thermal runaway to occur. A 10 m asset protection zone is expected based on preliminary bushfire study; however, this will be confirmed when particulars of the technology selection is known.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.6.1 Undertake a bushfire assessment. Determine safe convective and radiation heat flux buffers around the battery enclosures based on the specific characteristics of the technology chosen and to prevent initiation of thermal runaway. Determine and implement an appropriate asset protection zone. 1.6.2 Provide bushfire heat map to the integrator/constructor to confirm heat is not a concern for the technology, in particular, fire and thermal runaway. 1.6.3 Develop and implement a bushfire response plan, worker training and hot work controls at the site. 1.6.4 Implement vegetation management within the asset protection zone.	Major	Remote	M11 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

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

Ref. No:	Risk Area	Risk Issue	Causes
1.7	Health and Safety	Indent 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. Note: Battery enclosures are unable to physically entered; they are externally accessible only. Emergency response does not require entry into any enclosure or space with batteries. Poor knowledge, information or data available to assess the incident and deploy a safe and controlled response may result in an escalation of an event or injury.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target

1.7.1 Specify Facility requirements such that events do not escalate and are limited to the originating equipment, without requiring intervention by first responders (see Design Safeguards for 1.1 to 1.6 above). 1.7.2 Specify remote monitoring and operation to enable information on the status of enclosures to be available for response decision making 1.7.3 Specify Facility requirements so that occupied buildings or equipment able to be entered by personnel is separated from battery enclosures. 1.7.4 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 1.7.5 Ensure that critical design information for emergency response purposes is maintained up to date at a location remote from the site and readily accessible. (E.g. Maps, layouts, firefighting facilities, schematics etc)	Serious	Remote	L6 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.2 Surface water leaving the site has negative impact on protected 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 protected 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			
Site is brownfield, other forms of contaminant could be present in fill. The drainage system will be integrated with EPS drainage system and may impact current drainage design/sizing. A threatened frog population is located in waterways downstream of the Project area. Storage of oils and chemicals at site are expected to be minimal and below thresholds triggering special requirements under the Dangerous Goods regulations.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.8.1 Determine credible contamination and water flow events and volumes of contaminants to specify and design appropriate containment volumes for onsite ponds and retention devices to block discharge of water from the licenced discharge point if necessary. 1.8.2 Develop contingency plans that can be enacted during credible contamination events. 1.8.3 Develop emergency response plans in consultation with Emergency Services ensuring that drain and retention capacity is clearly identified and appropriate contingent actions are documented. 1.8.4 Verify the adequacy of the existing EPS drain sizing to accept drainage from the BESS site in all credible scenarios. 1.8.1 Specify industry standard approach and accepted industry reference for rainfall and runoff to assess pre and post development runoff and design for most credible severe event simulated. 1.8.2 Specify that the CEMP must address environmental protection measures to prevent spills and runoff from construction activities or as a result of adverse weather events. 1.8.3 Review the contractor CEMP. 1.8.4 Specify the requirement to undertake surface water runoff and flood modelling at the site to inform the earthworks design of the site.	Major	Highly Unlikely	M11 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

1.8.5 Specify relevant sediment management design requirements from the development consent conditions which the facility must comply with. 1.8.6 Specify requirements for sediment basins where surface water drainage modelling identifies the requirement. 1.8.7 Undertake design review to confirm compliance with all statutory and employer requirements.			

5.1.3 EMF from the transmission connection causes health impacts

<table>
<tr><td>Ref. No:</td><td>Risk Area</td><td>Risk Issue</td><td colspan="3">Causes</td></tr>
<tr><td>1.9</td><td>Health and Safety</td><td>The operation of the facility causes impacts which are detrimental to people's health and wellbeing</td><td colspan="3">Induced electrical and magnetic fields from the 330 kV interconnection.</td></tr>
<tr><td colspan="6">Risk Comments</td></tr>
<tr><td colspan="6">TransGrid policy requires that EMF is taken into account in the design and management of new facilities. The short section of Transmission line proposed for connection of the BESS to the network is expected to be unregulated and not necessarily be undertaken to TransGrid Standards; however, an EMF study is in line with good industry practice and is proposed be undertaken during the detailed design process which yet to be completed. The proposed transmission route is remote from any community residences and public accessways and is a short length contained within the Project area. Given these factors it is very unlikely that the project would have an impact on community sensitive receptors.

EMF hazards are induced through with AC currents notably the 330 kV transmission connection to the Project.
An EMF study is required to align with good industry standards.
There is a potential impact of induced coupling on existing transmission line conductors if close enough to the new line development. However, this is an aspect that would be considered during design and is not a factor that impacts community sensitive receptors in any way.

The Project may alter EMF at the Project area during operation and the potential exposure to workers.

Pipeline induced impacts e.g. acceleration of failure modes is also possible. There are no known critical pipelines or other infrastructure dissecting or in the vicinity of transmission route.</td></tr>
<tr><td colspan="3">Design Safeguards / Controls / Layers of Protection recommended actions</td><td>Consequence - Target</td><td>Likelihood - Target</td><td>Risk Level - Target</td></tr>
<tr><td colspan="3">1.9.1 Engage reputable and experienced design consultants familiar with good industry standard design requirements and undertake an EMF study and assessment to confirm that EMF levels beneath the proposed transmission line are within public exposure guidelines detailed in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines for limiting exposure to Time-varying Electric, Magnetic and Electromagnetic Fields and are in accordance with the current TransGrid design requirements.
1.9.2 Confirm that step and touch potential of infrastructure from induced voltages are limited within appropriate standard thresholds as part of the design process.
1.9.3 Consider EMF impacts to workers at the site during the design and implement appropriate health and safety management practices.</td><td>Moderate</td><td>Highly Unlikely</td><td>L5 – Low

Jacobs consider this risk level to be mitigated to so far as reasonably practical</td></tr>
</table>

5.1.4 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	Fuel spills from temporary storage and utility facilities Fuel supply and transfer spills and accidents Brownfield contamination in fill is transported into the groundwater by land disturbance Dust management - watering transports brownfield contamination Excavation and bulk earthworks and associated dewatering draws contaminated water
Risk Comments			
The Project development must not exacerbate or cause impact to EPS operation. The Centennial Mine is in close proximity to site, there is a potential incidental impact of the Project in respect to increased activity in the vicinity of the mine however this is a common risk with EPS operations and is currently managed.			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.10.1 Specify that all temporary fuel, chemicals and utility facilities (e.g. temporary power) at site must be stored and handled in accordance with relevant Australian Standards and good industry practices. Including bunding of all storage and transfer facilities. 1.10.2 Ensure that the CEMP addresses retention and testing of extracted water before discharging offsite. 1.10.3 Specify that all fuel and chemicals at site must be stored and handled in accordance with relevant Australian Standards and good industry practices.	Serious	Highly Unlikely	M8 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.5 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 bushfire. Arc flash. Vehicle movements create ignition source for flora e.g. grasses at the site.
Risk Comments			
Nil			

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.11.1 Specify that the contractor must develop and implement a vegetation management plan through the CEMP. 1.11.2 Specify the requirement for electrical design to include arc flash studies where appropriate.	Major	Remote	M11 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.6 Offsite Noise impacts from construction and operations activities

Ref. No:	Risk Area	Risk Issue	Causes		
1.12	Noise	Development adversely impacts offsite noise during Operations phase	Fans and changing load/charge discharge. Cumulative noise with EPS and Centennial Mine operations. Electrical noise - 50Hz transformers.		
Risk Comments					
Nil					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.12.1 Ensure that all equipment supply is specified with noise limits. 1.12.2 Undertake noise modelling and studies to confirm limits for near field noise limits. Specify limits complying with development consent and verify compliance through testing at commissioning.			Serious	Highly Unlikely	M8 – Medium Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.7 Incidental Hazards and Analysis

For completeness the following low risk incidental hazards identified in the PHA and the corresponding risk analysis are provided in the sections below.

5.1.7.1 Disruption to public rail network

Ref. No:	Risk Area	Risk Issue	Causes		
1.13	Community	Disruption to rail network	None identified.		
Risk Comments					
Development proximity to rail alignment approximately 200 m west of the Project area. Disruption due to impacts from and uncontrolled event such as fire or explosion.					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
None identified			Serious	Remote	L6 – Low Jacobs consider this risk level to be mitigated to so far as

			reasonably practical

5.1.7.2 Fire at temporary diesel generator during construction

Ref. No:	Risk Area	Risk Issue	Causes		
1.14	Air emissions	Development adversely impacts offsite air quality in concentrations that affects community health and wellbeing during Construction phase	Fire at temporary fuel supply or temporary diesel generator causes smoke which drifts across the site boundary.		
Risk Comments					
Nil					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.14.1 Design temporary and permanent fuel storage and handling (if constructed) to comply with AS and NFPA fire detection and firefighting facilities. 1.14.2 Minimise storage of fuels, chemicals or hazardous materials at the Project area.			Moderate	Highly Unlikely	L5 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.7.3 Construction workers exposed to contaminated substances at site

Ref. No:	Risk Area	Risk Issue	Causes		
1.15	Health and Safety	The operation of the facility causes impacts which are detrimental to people's health and wellbeing	Construction workers H&S during earthworks and civil works are exposed to unidentified brownfield contamination.		
Risk Comments					
A contamination assessment and report will be prepared for the Project area.					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.15.1 Include the contamination assessment report in the Technical specification for the works and specify requirements for the contractor to undertake a Project risk review taking into consideration the finding of the contamination assessment report for the activities being undertaken and Origin review.			Moderate	Highly Unlikely	L5 – Low Jacobs consider this risk level to be mitigated to so far as

			reasonably practical

5.1.7.4 Light pollution impacts offsite community

Ref. No:	Risk Area	Risk Issue	Causes		
1.16	Community	The operation of the facility causes impacts which are detrimental to people's health and wellbeing	Light pollution		
Risk Comments					
Nil					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.16.1 The need for night lighting is to be confirmed and if required installed in accordance with applicable guidelines for the minimising light spill from the Project.			Moderate	Highly Unlikely	L5 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.7.5 Fugitive dust blows across the site boundary

Ref. No:	Risk Area	Risk Issue	Causes		
1.17	Air emissions	Development adversely impacts offsite air quality in concentrations that affects community health and wellbeing during Construction phase	Fugitive dust blows across the site boundary		
Risk Comments					
Nil					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.17.1 Specify that the Contractor must demonstrate tangible mitigation and management actions to avoid nuisance dust at the site during construction. 1.17.2 Specify that good industry standard dust management plans and procedures must be documented or referenced in the CEMP. 1.17.3 Undertake review of the contractor's CEMP and monitor construction operations for compliance with plans and procedures.			Minor	Highly Unlikely	L2 – Low Jacobs consider this risk level to be mitigated to so far as

			reasonably practical

5.1.7.6 Construction and operations traffic causes community impacts

Ref. No:	Risk Area	Risk Issue	Causes		
1.18	Environment	Development adversely impacts offsite traffic during Operations phase	Volume of traffic cumulative with EPS and mining operations. Maintenance or battery change out.		
Risk Comments					
Traffic impact assessment undertaken					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.18.1 Implement recommendations of the traffic impact assessment. 1.18.2 Review contractor's design and logistics plan once available for consistency with traffic impact assessment and manage any changes accordingly.			Minor	Remote	L1 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.7.7 Import of contaminated material during construction

Ref. No:	Risk Area	Risk Issue	Causes		
1.19	Land use	Development adversely impacts offsite land use during construction phase	Contamination of imported fill.		
Risk Comments					
Contractor CEMP and QA plan to be reviewed to ensure this risk is appropriately dealt with.					
Design Safeguards / Controls / Layers of Protection recommended actions			Consequence - Target	Likelihood - Target	Risk Level - Target
1.19.1 Specify tracking and certification of fill removed and disposed from the site and transported to the site and verify.			Minor	Remote	L1 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

5.1.7.8 Subsidence of land

Ref. No:	Risk Area	Risk Issue	Causes
1.20	Land use	Development adversely impacts offsite land use during construction phase	Subsidence of land at the Project area.

Risk Comments
Subsidence is unlikely to cause offsite impact but may need to consider stability at the Project area with increased weight of battery modules on the site. There is a current mining licence granted underneath the Project area which is not being mined.

Design Safeguards / Controls / Layers of Protection recommended actions	Consequence - Target	Likelihood - Target	Risk Level - Target
1.20.1 Undertake a review of earthworks and fill stability giving consideration to facility loads.	Minor	Remote	L1 – Low Jacobs consider this risk level to be mitigated to so far as reasonably practical

6. Conclusions

The PHA concludes that at the current stage of development there are no unacceptably high Project development and operation related hazards that could result in significant offsite effects that are not manageable through application of inherent safety in design principles and safeguards.

Given the concept level definition of the Project, early engagement of suppliers and contractors and that the preferred technology is yet to be selected, Jacobs consider the recommended actions and safeguards to be appropriate and to 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 and separation distances of battery enclosures to reasonably limit impacts to adjacent enclosures are considered to be in line with good risk management practices for the technology.

Origin demonstrated a mature understanding of the hazards associated with the Project development and a commitment to risk mitigation and management throughout the development process.

Appendix A. Department of Planning guidance notes

The following guidance notes have been provided with the issued SEARS *a Preliminary Hazard Analysis prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guideline for Hazard Analysis (DoP, 2011a) and Multi-Level Risk Assessment (DoP, 2011b)*

Guidance for BESS-related PHAs

Since late 2020, the DoP has noted significant developments into research and standards for BESS. As such, we expect the PHA to consider these developments, ensuring that fire risks from these BESS have been appropriately considered in designing the SSD. Of particular note (not exhaustive) are:

- NFPA 855
- AS 5139
- IEC 62897
- UL 9540
- UL 9540A
- FM Global DS 5-33
- FM Global's Development of Sprinkler Protection Guidance for Lithium-Ion Based Energy Storage Systems.

Where certain aspects of the scope or requirements from the above publications may not align exactly, reasonable best practice should be considered in the designing the BESS while taking into account the principles from these publications. As such, the PHA should be prepared by a suitable specialist, ensuring appropriate technical judgement is taken in view of the above publications or reasonable best practice. Of particular importance is verification that the proposed BESS capacity would be able to fit within the land area designated for the BESS while taking into account separation distances between:

- BESS sub-units (racks, modules, enclosures, etc.) ensuring that a fire from a sub-unit do not propagate to neighbouring sub-units; and
- The overall BESS and other on-site or off-site receptors, ensuring fire safety.

Specifically for the Project, it should be verified that the proposed capacity of 700 MW will be able to fit the designated area of 12.5 ha as shown in the scoping report while taking into account spatial requirements for separation distances.

Appendix B. References

B.1 Reference Material

The following reference material has been used in conducting this PHA

- Grid-scale Energy Storage Hazard Analysis & Design Objectives for System Safety, SANDIA Report SAND2020-9360 – Sandia National Laboratories
- Origin's technical specification for preliminary market enquiry – Attachment 2C – Functional Specification
- AS/NZ 5139:2019 Battery Energy Storage Systems
- NFPA 855 Standard for the installation of Energy Storage Systems
- UL9450 Energy Storage System (ESS) Requirements
- UL9540A Test Methods.

Note: Although, presentation material is not currently available, two of the workshop participants attended a presentation in May 2021 hosted by the Institute of Engineers Australia titled Lithium-Ion Battery Energy Storage Systems. Fire Brigade Intervention and Design Consideration which provided insight to conventional thinking on BESS fires, intervention and design consideration. Origin's design principles appear consistent with the design considerations presented.

B.2 Hazard Analysis Workshop

A Hazard Analysis Workshop (the workshop) was undertaken to inform the PHA. The workshop was independently facilitated by Jacobs and specialists from both Jacobs and Origin attended. The workshop was held over two sessions, the first was to identify and document hazards associated with then development, the second session was to identify and documents actions and recommendations to mitigate the risks.

B.2.1 Purpose of the Workshop

The purpose of the workshop is as follows:

- Consult and gain input to a preliminary hazard analysis undertaken to support the development application for the Project by demonstrating that risk levels do not preclude approval
- Identify hazards associated with the Project that could potentially have an adverse impact on significant off site effects and community safety
- Review and document the mitigation actions and recommendations for the ongoing development of the Project.

B.2.2 Outcomes of the workshop

- A complete and comprehensive list of hazards and mitigation measures to enable the PHA report accompanying the EIS to be prepared.

B.2.3 Process

- A facilitated workshop using a hazard identification and risk assessment tool

B.2.4 Session 1 Preliminary Hazard Analysis and mitigation workshop

Meeting Summary

Total Number of Participants	8
Meeting Title	Eraring BESS - Preliminary Hazard Analysis and mitigation workshop
Meeting Start Time	6/17/2021, 10:00 AM
Meeting End Time	6/17/2021, 12:14 PM

B.2.5 Session 2 Action and safeguard review workshop

Meeting Summary	
Total Number of Participants	7
Meeting Title	Eraring BESS PHA finalisation
Meeting Start Time	6/28/2021, 9:58:04 AM
Meeting End Time	6/28/2021, 11:17:25 AM

B.3 Qualifications and experience of the hazard analysis team

An outline of the qualifications and experience of Jacobs Hazard Analysis team is included as follows:

B.3.1 PHA facilitator

Jacobs' PHA facilitator is a professional engineer with over 30 years of operations and maintenance and project leadership experience in multiple capital-intensive industries including power, chemical, and both upstream and downstream oil and gas processing. He specialises in operations and maintenance, asset management and life planning, risk management and the integration of new assets into a business. His career covers a wide range of operating, technical and business experiences and dealings at all levels of organisations. He has proven abilities in Project management both technical and business related over his career, including technical asset and business reviews, negotiating conditions of contract and the development of detailed business integration and transition plans for new power generation facilities. He has a capable technical and practical understanding of renewable power technologies, the NEM and planning and advising on commercial and Project structures for development of renewable power generation assets. This is underpinned by his extensive Project experience across a broad range of renewable energy technologies including solar, BESS, wind, hydro, biomass and energy from waste and services including such things as investment and divestment due diligence, facilitation of risk reviews, asset and lifecycle management, review and development of technical specifications, business documentation and agreement development. He has facilitated numerous hazard and risk processes over his career including PHA reports based on the NSW HIPAP guidelines. Examples include:

- Pumped Hydro hazard and risk review
- Carbon Capture and storage risk review
- Waste to Energy development risk review
- DC link risk review.

The facilitator is currently the Project Director for Owners Engineer Services for a 100 MW BESS development.

B.3.2 Jacobs Electrical Specialist

Jacobs' electrical specialist is a senior electrical engineer with over 30 years of experience in roles including Chief EIC, Lead Electrical and Owners Engineer on numerous HV power and energy related projects for various sectors including heavy rail, energy, mining, petrochemical and various specialised industrial sectors. He is competent in all phases of engineering design and engineering management including option and concept studies, FEED studies, EPCM and EPC projects, construction support and commissioning.

He has acquired and demonstrated diverse practical experience and competencies in HV substation, LV power distribution and protection systems, large scale PV generation applications, battery energy storage systems, and gas turbine and diesel generation Projects. He has specialist competencies in Electrical Engineering for Explosive Atmosphere, Root Cause investigations into electrical systems failures and regulatory/safety compliance.

His recent experience as Owners Engineer or electrical technical advisor for BESS projects include:

- Large Scale BESS Project – Multiple 250 MW, 250 MWh facilities to be located in Victoria, NSW, and SA. Specification development and tender evaluation
- BESS Project 100 MW, 150 MWh – Technical advisor and compliance and technical review of EPC design deliverables
- 50 MW/300 MWh BESS V Flow Battery – Technical advisor for inverter technology
- Feasibility study – BESS specifications, tender evaluation, and execution planning for integration of BESS technology for the replacement of GTG spinning reserve to reduce fuel consumption and emissions

B.3.3 Jacobs Renewables Specialist

Jacobs' renewables specialist has mechanical and electrical engineering qualifications with 20 years of experience in the electrical power sector and renewable energy industry with a focus on solar and battery storage. She has extensive experience in feasibility studies, concept design, technical specifications and tender evaluations through to construction, operation, performance analysis and due diligence of power plants. In addition, she has performed battery technology comparisons, compliance review and Safety in Design risk assessments for PV/BESS systems.

She has designed and project managed PV/BESS stand-alone power systems and has worked on renewable energy and energy efficiency Projects in Australia, UK, Germany, PNG, Fiji Islands, India, Pakistan and Mongolia.

B.3.4 Jacobs Environmental planning specialist

Jacobs' environmental planning specialist has qualifications in environmental science and urban and regional planning. He is a Technical Lead for Environmental Impact Assessment and Management for Jacobs in New South Wales with 12 years' experience providing environmental services in both environmental assessment and post approval delivery of environmental obligations for a diverse range of projects in New South Wales. He has an excellent understanding of State and Commonwealth planning and environmental legislation and has held key roles in projects spanning pre-feasibility constraints and opportunities assessments, planning approval strategy, development of environmental assessment documentation and post approvals management plans, and construction and operational environmental mitigation measure implementation and auditing.

He has performed key roles in planning and development of EIS inputs on two previous BESS projects and multiple other power generation projects including pumped hydro, thermal lant upgrades and wind farm projects.

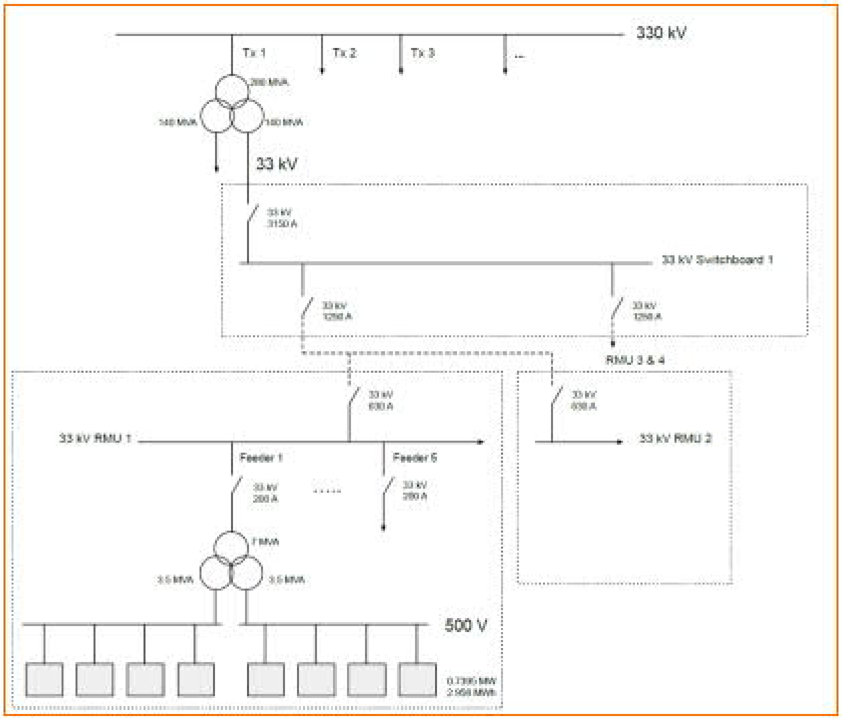
Origin's staff attending the Workshop included:

- Origin Project Director
- Origin Project Manager and Environmental specialist
- Origin Electrical Engineer

- Origin Engineer and lead for the development the technical specification.

B.4 Preliminary Single Line Diagram

The Project concept preliminary single line diagram is shown below.



Appendix C. Origin risk matrix, consequence and likelihood categories

Risk Matrix

CONSEQUENCE	IMPACT ON ORIGIN OPERATIONS: Getting Energy Right with Due Care		IMPACT ON ORIGIN OPERATIONS: Create Value			EXTERNAL RESPONSE: Decisions consider Our Customers, Communities and Planet	
	People	Environment and Community	EBIT	Cash flow	NPV	Stakeholder Perceptions	Laws, regulation and civil actions
6 CATASTROPHIC	Multiple fatalities ≥4 or life threatening illness or total permanent disability to a large exposed group (10 or more people)	Extensive permanent damage to endangered species, habitats, ecosystems or area/s of cultural significance Extensive irreversible loss of community livelihood. Long-term social unrest and outrage	>$200m	>$1b	>$1.5b	Multiple stakeholder groups confirming coordinated action, as reflected in media channels with significant reach and influence (eg. scheduled blockade or boycott covered in media for more than 1 week).	Criminal charges against any director or senior executive involving jail or loss of right to manage the company. Public inquiry – requiring considerable resources and Executive Leadership time. Loss of licence to operate an asset
5 CRITICAL	1 – 3 fatalities or life threatening illness or total permanent disability to a small exposed group (<10 people)	Extensive long term partially reversible damage to vulnerable species, unique habitats, ecosystems or area/s of cultural significance. Extensive reversible loss of community livelihood. Prolonged community outrage.	>$50m - $200m	>$250m - $1b	>$375m - $1.5b	Multiple stakeholder groups mobilising and encouraging others to take action, as reflected in media channels with significant reach and influence.	Criminal charges against any director, senior executive or senior manager not involving jail or loss of right to manage the company. Prolonged major litigation – exposure to significant damages / fines / costs. Suspension / restriction to operate an asset.
4 MAJOR	Serious injury or illness** to one or more persons, resulting in partial permanent disability	Long term reversible impacts to listed species, habitats, ecosystems or area of cultural significance. Significant impacts to community cost of living, business viability or social wellbeing. High levels of community tension.	>$20m - $50m	>$100m - $250m	>$150m - $375m	More than one stakeholder group's opinion or view influencing other stakeholders, reported through media channels with some reach and influence (eg. government comments in national media or in Parliament).	Criminal charges against any employee (not described above) Major litigation – exposure to damages / fines / costs.
3 SERIOUS	Serious injury or illness** to one or more persons **not** resulting in a permanent disability	Serious medium term reversible impacts to low risk species, habitats, ecosystems or area/s of cultural significance. Moderate impacts to community cost of living, business viability or social wellbeing. Moderate levels of community tension.	>$5m - $20m	>$25m - $100m	>$37.5m - $150m	More than one stakeholder group offering an opinion or view, reported through media channels with some reach and influence (eg. state based commentary lasting one 24 hour media cycle across internet, print, television, radio).	Non-compliance with conditions of licence to operate an asset or to conduct an activity. Litigation – exposure to damages / fines / costs.
2 MODERATE	Injury or illness to one or more persons resulting in medical treatment or outpatient treatment (i.e. not requiring admission as an in-patient) excluding treatment for a serious injury or illness	Moderate short term impacts to common regional species, habitats, ecosystems or area of cultural significance. Small scale impacts to cost of living, business viability or social wellbeing. Isolated examples of community tension.	>$1m - $5m	>$500k - $25m	>$750k - $37.5m	A single stakeholder group drawing attention to an incident, issue or approach, conveyed though media channels with potential reach and influence (eg. some social media complaints or local media reports).	Moderate non-compliance with external mandatory obligations or breach of contractual or other legal obligations (not described above). Litigation possible.
1 MINOR	A minor injury or illness resulting in first aid or no treatment	Minor environmental or community impact - readily dealt with	>$100k - $1m	<$500k	<$750k	A person or organisation within stakeholder group signaling an interest in an incident, event or approach, using channels with limited reach or influence (eg. letter of complaint/commendation).	Minor non-compliance with external mandatory obligations or breach of contractual or other legal obligations.

CONSEQUENCE	LIKELIHOOD: 1 REMOTE	2 HIGHLY UNLIKELY	3 UNLIKELY	4 POSSIBLE	5 LIKELY	6 HIGHLY LIKELY
	<1% chance of occurring within the next year. Only occurs as a '100 year event' or less frequent.	<10% chance of occurring within the next year. Could occur within decades.	<30% chance of occurring within the next year. Could occur within the next few years.	<60% chance of occurring within the next year. Could occur within months to years.	<90% chance of occurring within the next year. Could occur within weeks to months.	Likely to happen multiple times a year.
6 CATASTROPHIC	HIGH	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	VERY HIGH
5 CRITICAL	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH	VERY HIGH
4 MAJOR	MEDIUM	MEDIUM	MEDIUM	HIGH	VERY HIGH	VERY HIGH
3 SERIOUS	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH
2 MODERATE	LOW	LOW	MEDIUM	MEDIUM	MEDIUM	MEDIUM
1 MINOR	LOW	LOW	LOW	MEDIUM	MEDIUM	MEDIUM

Cash Flow - change from expectation over the life of the exposure. EBIT change from expectation over 12 – 18 month period

* Use the Cash Flow consequence category to assess and record the financial impact of risks, unless otherwise directed

** *Serious injury or illness* is defined as per our HSE Glossary