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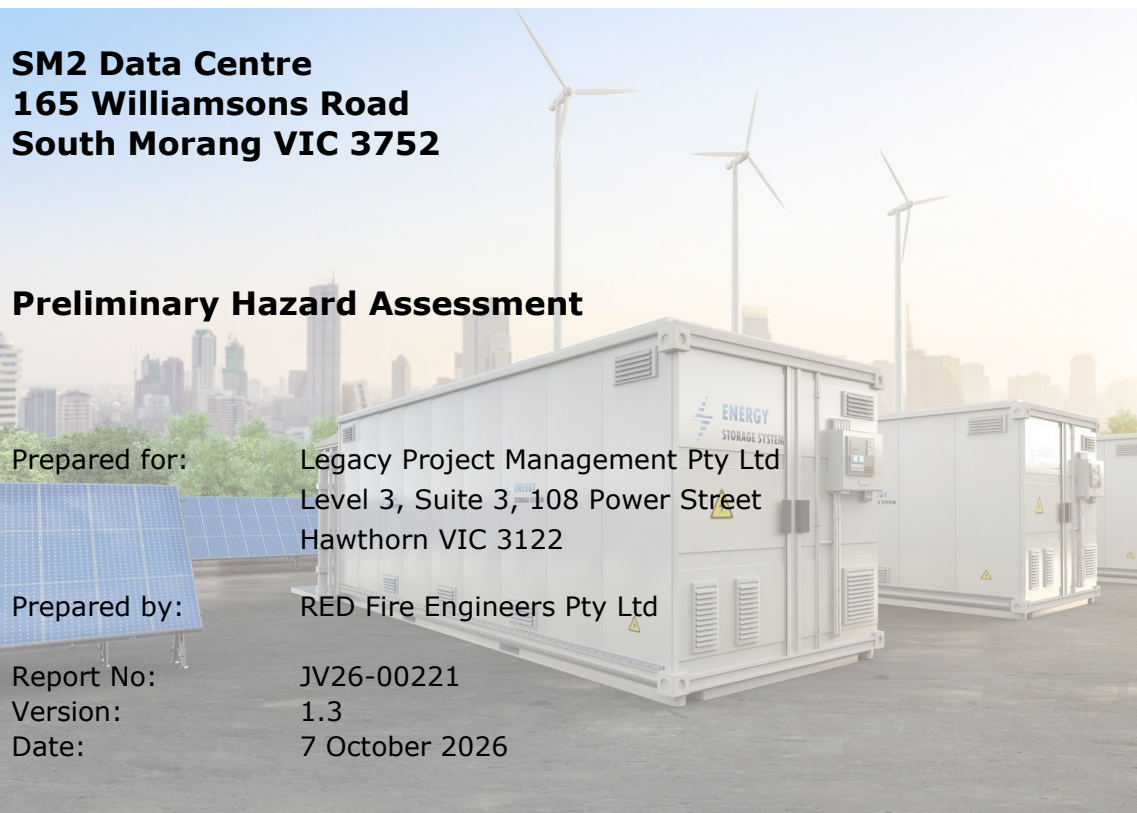
SM2 Data Centre
165 Williamsons Road
South Morang VIC 3752

Preliminary Hazard Assessment

Prepared for: Legacy Project Management Pty Ltd
Level 3, Suite 3, 108 Power Street
Hawthorn VIC 3122

Prepared by: RED Fire Engineers Pty Ltd

Report No: JV26-00221
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 Project address: 165 Williamsons Road South Morang VIC 3752
 Prepared for: Legacy Project Management Pty Ltd
 Prepared by: RED Fire Engineers Pty Ltd
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Summary of Main Findings and Recommendations

Appointment

RED Fire Engineers Pty Ltd has been appointed by Legacy Project Management Pty Ltd to develop a Preliminary Hazard Assessment (PHA) for the proposed SM2 Data Centre located at 165 Williamsons Road South Morang VIC 3752.

This project involves the development of a new data centre facility. The site consists of 23 data halls with a total IT capacity of approximately 200 MW. Twelve of this data halls have a floor area of 607.5 m² and IT capacity of approx. 6.8 MW, whilst the remaining have a floor area of 800.75 m² and IT capacity of approx. 9.1 MW.

The purpose of this PHA is to review potential hazards associated with the facility with a focus on offsite risks to community safety. In short, the focus of the PHA is on how loss of control (LoC) events (failures) on site can result in offsite hazards.

Methodology

The principal Victoria legislation associated with this PHA is:

- a) Occupational Health and Safety Act, 2004, No. 107, specifically section 37
- b) Occupational Health and Safety Regulation, 2017, No.2
- c) Environment Protection Act, 2017
- d) Environment Protection Regulations, 2021
- e) Dangerous Goods Act, 1985, No. 10189, specifically section 28
- f) Dangerous Goods (Storage and Handling) Regulations, 2022, No. 115 specifically Part 5 – Preparedness for incidents and emergencies, Division 3 – Equipment and planning

Whilst the project is located in Victoria, there is the no clear guideline on how to undertake a Preliminary Hazard Assessment in terms of dangerous goods or hazardous events. Therefore, PHA has been conducted in line with the NSW Hazardous Industry Planning Advisory framework (NSW Department of Planning, 2011), including the following general principles:

- a) Comprehensive, holistic, and systematic,
- b) Qualitative, quantitative, and site-specific,
- c) Complementary to other safety studies,
- d) Use consistent and well-documented methods and data,
- e) Review adequacy of safeguards, and
- f) Utilise all opportunities for risk reduction.

The development of this PHA has also considered the following documents:

- a) Assessment Guideline – Multi-level Risk Assessment
- b) HIPAP 3 – Risk Assessment
- c) HIPAP 4 – Risk Criteria for Land Use Safety Planning
- d) HIPAP 6 – Hazard Analysis
- e) HIPAP 10 – Land Use Safety Planning

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The report outlines proposed control measures to address these risks. Where the context of this site and its associated hazards alignment with the scope / intent of recognised standards these have been adopted. Where these Standards are not practicable or appropriate, requirements or Standards are adapted to account for the specific characteristics of the site.

The purpose of this PHA is to review the potential hazards associated with the facility described in Section 3 with a focus on offsite risks to community safety (societal hazards). This PHA is for understanding the risk levels of the proposed development, with the goal being to demonstrate that the risk levels do not preclude approval. The intent of this report is to assist WorkSafe Victoria to make a determination on whether or not to approve the project, on the basis of the use being a potentially hazardous industry with a demonstrated low off-site risk.

In line with the HIPAP methodology, a qualitative hazard identification (HAZID) process has been carried out in review of the process, site equipment, and potential stored materials. Subsequently, failure events have been identified and categorised, to identify which events may have significant offsite consequences. These events have then been carried forward for more detailed consequence analysis. In line with the Multi-Level Risk Assessment guidelines, a partially quantitative analysis has been carried out for these consequences, and where appropriate consequences have been carried forward for estimation of likelihood.

The hazards identified have been based on experience from similar data centre facilities, review of the design and consultation with the project design team.

Key Hazards & Consequences

The major hazardous events with potential offsite risk that were identified are summarised in Table 1. A fuller list of the hazards considered can be found in the Section 4.

Table 1 Hazards with potential offsite consequences

ID	Context	Source	Potential Results / Consequences
L3-GR	Toxic gas emission, HF, associated with thermal runaway / fire of Li-ion cabinets	Li-ion cabinets	Injury or death to personnel and the public

These hazards have been assessed further in FSS to determine their potential for posing a significant offsite risk. The potential consequences of hydrogen fluoride (HF) gas release resulted in it being carried forward for frequency analysis, with the likelihood being estimated using battery cell data and refinement of the consequence analysis. The likelihood analysis can be found Section 6.

It should be recognised that the modelling for the HF dispersion has considered a ground level release which is highly onerous. In the final design, the battery rooms are to be provided with ventilation shafts such that the HF would be released well above ground. When released above ground, the HF, which is lighter than air, would disperse more easily and is expected to remain above ground level. In other words, the actual design



would not result in as much potential exposure as has been produced in the models due to software limitations.

Following refinement of the consequence analysis it has been determined that L3-GR does not pose a significant offsite hazard.

Based on the analysis, the hazardous event resulting in the significant offsite AEGL-3 does not itself generate an F-N curve. In other words, the societal risk from this event based on a background population of 1,300 people per km² is too low to accurately plot on a societal risk curve. This means that the offsite consequences are extremely low.

To allow for visualisation and significant long-term population growth, the societal risk was re-assessed with the background population density increased by a full order of magnitude to 13,000 people per km². Only after this increase does the total risk from the site render on the F-N graph, with a maximum risk still two orders of magnitude lower than the typical acceptance criteria from HIPAP 4. In other words, even with 10x more people in the surrounding area, the societal risk of the site is still extremely low, and well below the acceptance criteria. Therefore, no significant off-site consequences are noted from this analysis with respect to HIPAP 4 acceptance criteria and the fire and blast hazards considered in this PHA.

Key Recommendations

Section 7 sets out key recommendations for the site in relation to this PHA and the HAZID carried out. It is assumed that measures required legislatively and typically applied standards of design, construction, operation, and management will be applied to the site.

The recommendations include a mixture of physical measures, management measures, and items which may require further study in future reports. Control measures were developed based on identified risks and aligned with relevant standards and best practices. These control measures were discussed and agreed with stakeholders through a draft PHA to confirm adoption or rejection of measures. Table 2 summarises the accepted control measures for the site. In the table, CMs indicated in blue are primarily preventative, and those indicated in green are primarily mitigative.

Some measures may be modified by the future FSS / FER, as further analysis and design development occurs.

Table 2 Accepted Control Measures

#	CM Title	CM Description
CM1	Safe Practices	An emergency response plan is to be developed for the site in addition to safe operational procedures and the like to instruct staff how to safely conduct business at the site.
CM2	Two-way communication	If/when operated unstaffed/from a remote station, two-way communication must be provided to site for responding staff/brigade. If the site is to operate unstaffed, the response time for a staff member in an emergency is to be considered in the emergency plan.
CM3	Portable Fire Extinguishers	PFE's to be provided as a minimum to NCC BCA and AS 2444, with additional fire extinguishers around small



#	CM Title	CM Description
		diesel storage (i.e. generator diesel tank) and outside of switchgear rooms with electrical hazards. Details/extent to be developed by the fire services engineer and in line with the future fire safety engineer's requirements.
CM4	Fire hose reel	Foam fire hose reels are to be provided only for the diesel tanks and diesel generator areas. Whether fire hose reels in general are provided elsewhere is subject to the building fire engineering by Orbe.
CM5	Fire Brigade	A large fire is to be responded to by the fire brigade. Associated with this control measure is a fire hydrant system that provides coverage and water supply for the site as set out in AS 2419.1:2021 for the entire site, with potential modifications to be subject to R129 consent and approval as the design is developed.
CM6	Fire truck access	Around the data centre building and to the substation, there shall be appropriate fire truck access and mobility. This shall meet all the requirements from the Fire Rescue Victoria guideline and/or R129 approval, recognising that the data centre building is a large isolated building.
CM7	Switch Room Fire Protection	HV/MV switch rooms associated with the substation are likely to have fire suppression, subject to Ausnet final design, as Ausnet is the design authority for that area. AusNet design is to consider automatic power isolation if appropriate. Building LV switch rooms typically are proposed either as fire separated (no suppression) or may have a double shock sprinkler/mist system with location detection.
CM8	Basement level fire suppression system for diesel storage	A suitable fire suppression system is to be provided to the basement diesel storage area. This may for example be a mist system or foam suppression system paired with detection, subject to further design development. All tanks are to be double skinned/self-bunded.
CM9	GenSet area fire suppression system	A suitable fire suppression system is to be provided to the GenSets. This may for example by a mist system or foam system, with details to be developed as the design progresses. The system must be approved/recommended for protection of generators. There is also to be fire separation around the generators, with the number of generators per fire compartmented area to be determined in detailed design.
CM10	Battery Room Fire Suppression System	A suitable fire suppression system is to be provided to battery rooms. This may for example be, a high-density sprinkler system, or mist system, paired with AS 1670.1 detection as well as specialist flammable gas detection such as Li-ion tamer or hydrogen gas detection.
CM11	Service and office area fire suppression system	A suitable fire suppression system is expected to be provided to the general areas such as office spaces and the like, other than specific areas with unique hazards. This may for example be standard sprinklers, in accordance with AS 2118.1: 2017. Removal of this system to general office areas however should not impact the findings of the PHA.
CM12	Data halls fire suppression system	A suitable fire suppression system is to be provided to the data halls. For example, a pre-action sprinkler system with aspirating detection throughout.
CM13	Fire Indicator Panel (FIP)	Fire detection and alarm systems, which meet AS 1670.1:2018, across the site, are to be connected to the main FIP (MFIP) via the FIP standard communication system.

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#	CM Title	CM Description
		Any departures are to be agreed with the fire safety engineer, and some areas are expected to have enhanced detection. The fire safety study is to consider whether specific battery management system (BMS) alarms should be fed to the MFIP, and if doing so can be done in accordance with AS1670.1 or AS 4418.2 where SCADA is used.
CM14	Fire and smoke detection and alarm system	AS 1670.1 compliant, or as agreed with the Fire Safety Engineer and FRV. The technology utilised is to be suitable for the application.
CM15	Automatic power shut off	The BMS for each battery system is to be capable of automatically isolating batteries at module or rack level on identification of faults/unsafe to operate conditions. This must include abnormally high temperature.
CM16	Low voltage management system	Residual Current Device (RCD), to be provided in accordance with AS 3000. Additional isolation to protect fire brigade may need to be considered in future design stages.
CM17	Site security	There are two parts to this control measure: a. The entire site is enclosed by a security fence, b. The site access gates are to be covered by CCTV. CCTV will include motion sensing and an alarm system to notify staff of personnel moving around the site. Additionally, the doors of the data centre and the switchboard and control room are to be monitored. On unauthorised access and alarm is to notify the site operator.
CM18	Fire fighter access	The site operator and after hours site authorised representatives are to be available to provide the fire brigade rapid access and support during an incident. This is to be further detailed in the FSS depending on whether the planned operation includes 24/7 on-site staffing or a mixture of on-site staffed hours and remote operation/management.
CM19	Spill kit arrangement	Appropriate spill kits are to be located near sources of dangerous goods, such as the diesel tanks and refuelling point.
CM20	First Aid kit	First Aid kits shall be provided on site, and located best to suit data centre operational and maintenance requirements. The operator is to review the requirements for first aid kits in line with their OHS responsibilities.
CM21	Personal Protective Equipment (PPE)	All PPE is to be fit for the task and potential exposure of staff. The operator is to define appropriate PPE for tasks and clearly describe them in invultuation processes, Standard Operating Procedures (SOPs), and/or Safe Working Method Statements (SWMS), as appropriate.
CM22	Site wide incident notification	Within buildings, audio notification devices shall comply with AS 1670.1:2018, i.e., a Building Occupant Warning System (BOWS). Horn systems may be used outside the area of the site; this is to be connected to the BOWS.
CM23	Management Plans	Associated with a future Fire Safety Study, the following management plans are to be developed and issued: a. Emergency Plan, b. Evacuation Plan, c. Emergency Information Book, and d. Dangerous Goods Manifest and Emergency Information
CM24	System monitoring	Site to have environmental sensors which can inform the site operator of at least temperature and wind (direction and speed), i.e., a weather station. All system sensor data to be shared with the site

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#	CM Title	CM Description
		operator, with notification related to potential / actual incidents. Details of notification to be developed as design progresses.
CM25	Site incident management	The site operator will need clear procedures for engaging and supporting emergency services during an incident. This would include when to call them, providing system data to them, and connecting them with the battery system operators/support.
CM26	Emergency Services	Access and procedures for when to call emergency services.
CM27	Site housekeeping	At least a monthly site inspection to remove unnecessary combustible material from the site.
CM28	Selection of Electrical Systems	Selection of all systems that are appropriate for the operations and the environment where they are to be located. This is to be shown by compliance with Standards. For example, where required rodent proof mesh or similar is to be provided to protect systems'.
CM29	Installation and maintenance of systems	Correctly qualified and experienced personnel are to be used to install and maintain the system.
CM30	Impact protection	Protection of external systems from vehicle damage is to be achieved by mechanical impact devices, such as bollards near the roads associated with the building and electrical system. These impact protection systems shall at least be located on the curves of the roads. An on-site speed limit is to be enforced to minimise risks of impact near equipment.
CM31	Lightning protection	Electrical systems and their associated cabling arrangements are to have lightning protection as required under AS 1768:2021.
CM32	Cyber attack protection	Planning and design should consider the possibility of damage / fire to systems and the diesel generators. Therefore appropriate cyber protection measures are to be taken.
CM33	Access to meteorological data	The site operator is to have access to regional meteorological data.
CM34	Response to a battery room incident	Within the battery rooms, if the detection systems (l-ion tamer or similar systems) activate then the site operator is to call the fire brigade (if not done within 300 s, then automatic call out is to occur), activate the site notification system, and isolate the affected battery room. If after hours, call out a site authorised representative to the site. Details of this are to be developed in consultation with FRV as the design progresses.
CM35	Non-combustible surfaces	Site electrical systems (e.g. at the substation) are to be surrounded by crushed rock or non-combustible ground out to the clearance set out in AS 2067:2016. The use of fire rated structure can limit this distance. This surface may include access roads and paved ways. This applies primarily to the AusNet 220kV/33kV Substation; however AusNet will have ultimate design authority for the substation.
CM36	Vegetation fuel load	Proximity to substation vegetation shall be in line with Ausnet requirements.
CM37	Drainage and contamination system	In the event of a battery room or diesel generator / tank fire, the entire contaminated fire water run-off needs to be collected and held in the detention system. The alignment of the drainage system, including closing off the connection to the town stormwater drainage system, is to occur automatically.
CM38	Arc Flash assessment	Arc flash report in accordance with industry practices.

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#	CM Title	CM Description
CM39	Fire rated data centre structures	Data halls, battery rooms, and the basement are to be fire rated structures.
CM40	Fire rated power transformer wall	The power transformer is to be encircled on three sides by fire and blast walls to protect the site and beyond. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation.
CM41	Bund transformer to contain oil	Transformer to be arranged so that any leak would be collected and held within the system, i.e., self-bunded or enclosure bund. Leak detection to be included; this may be a reduction in volume within the transformer. The bund and the structures to hold the transformer shall be able to withstand the pool fire event, in line with AS 1940: 2017. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation. Transformers in the actual building, i.e., data hall, are proposed to be dry-type.
CM42	Power transformer bund de-watering system	The power transformer bund size must comply with AS 2067 and AusNet requirements. This may include a requirement to consider rainfall simultaneous to a leak. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation.
CM43	Transformer Oil Selections	All High Voltage systems shall comply with AS 2067 or as agreed with Energy Safe Victoria and the relevant authority.
CM44	Diesel generators bunding	The diesel generators are to be contained within their own bunds. This bund shall be sufficient to contain the entire contents of the liquid in the system, as well as any spillage. In the current design they are fully enclosed and therefore the volume is nil for rain.
CM45	Diesel generator fire isolation	On detection of a fire within a diesel generator, the fuel supply is to be automatically shut off, via the MFIP.
CM46	Diesel tank selections	The diesel tanks and their arrangement to meet AS 1940:2017, or as agreed with relevant authority. This may include additional measures over and above AS 1940 compliance.
CM47	Diesel tank zoning bunding	Groups of diesel tanks to be encircled by bunding. This is in addition to the integral bunding provided by double skinned tanks.
CM48	Diesel pipework and pump monitoring	Diesel flow rate / pressure within the pipework or pumps to be monitored to detect system leaks.
CM49	Refuelling zone bunding	Refuelling zone to be encircled by a roll over bund.
CM50	Battery room explosion management system	Within the battery room an approved / compliant combustible concentration reduction system which includes an air inlet and outlet for combustible gases. This system to meet NFPA 69 with deflagration calculations to NFPA 68. The battery room is to be fitted with an approved AS 1940:2017 ventilation system designed for lighter and heavier than air volatile gases.
CM51	Battery room door swing	The battery room door if swinging outwards must be designed to not turn into a projectile or fragment when the room is subject to a partial volume deflagration assessment. This may be considered as part of an NFPA 68 partial volume deflagration assessment.
CM52	Cable	Outdoor cables across the site shall not be treated with flame retardant but shall be self-extinguishing, i.e., pass IEC 60332-1, or equivalent. Other approaches may be applied by the electrical designer so long as they comply with appropriate regulations.
CM53	Battery room deflagration control	The FSS must include review of the potential for a deflagration inside a battery room. It is expected that the FSS will rely on a partial volume deflagration assessment by the battery OEM. This may require the

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#	CM Title	CM Description
		<p>installation of deflagration panels, or stronger enclosures to the room.</p> <p>The FSS is also expected to consider a more onerous deflagration scenario for potential emergency services planning. Determining this information requires analysis of the specific batteries and therefore is carried forward to the FSS.</p>
CM54	Diesel fill point location	Diesel fill point shall be more than 50 m from the Ausnet HV powerlines.
CM55	Diesel Tank Rooms	<p>Several additional requirements are proposed to be applied and/or investigated for the diesel tank room in the basement:</p> <ul style="list-style-type: none"> • The tanks are to be positioned in groupings, it is expected that there may be 3-5 different groupings, • Each tank is to be double skinned, with its own integral bund. • Each grouping is to be provided with an additional bund, capable of holding not less than 110% the volume of the largest tank in the grouping, with additional allowance for the fire protection system to be determined. • Each grouping is to be within a separate, dedicated, fire rated room, with an FRL of not less than (240)/240/240. Where possible, the fire rated enclosure to these rooms is to consist of non-structural walls (e.g. non-load bearing walls), to provide additional separation of structure from the tanks. • The potential need to exceed the minimum concrete cover requirements of AS 3600 to achieve 240-minute FRLs is to be reviewed and may be implemented in design development. Whilst no formal FRL above 240 exists in AS 3600, this would be a way to effectively achieve an FRL greater than 240-minutes. • Each diesel tank room is to be provided with an automatic fire suppression system, specifically intended for use on pool fires. It is expected that this may be a mist system, foam system, or other suitable system. • Fire hydrant locations relative to diesel storage are to be coordinated and agreed with FRV, with the potential need for additional hydrant locations to support tactical operations.
CM56	Battery Room Ventilation Discharge Point	<p>The discharge point for the ventilation system from the battery rooms must be above ground level the exact location is to be determined as the design progresses.</p> <p>The intent being to discharge at high level.</p>

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1 Introduction

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1.1 Background

- 1.1.1 RED Fire Engineers Pty Ltd has been appointed by Legacy Project Management Pty Ltd to develop a Preliminary Hazard Assessment (PHA) for the proposed project.
- 1.1.2 This project involves the development of a new data centre facility. The site consists of 23 data halls with a total IT capacity of approximately 200 MW. Twelve of this data halls have a floor area of 607.5 m² and IT capacity of approx. 6.8 MW, whilst the remaining have a floor area of 800.75 m² and IT capacity of approx. 9.1 MW.
- 1.1.3 The purpose of this PHA is to review potential hazards associated with the facility with a focus on offsite risks to community safety. In short, the focus of the PHA is on how loss of control (LoC) events (failures) on site can result in offsite hazards.

1.2 Report Applicability

- 1.2.1 This report reviews the potential hazards associated with the facility as described in Section 3 with a focus on offsite risks to community safety (societal hazards) from events such as fire, explosion, or toxic release. The intent of this report is to assist the Fire Rescue Victoria to make a determination on whether or not to approve the Project on the basis of the use being a potentially hazardous industry with a demonstrated low offsite risks.
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- 1.2.2 As a PHA, this report provides analysis of the hazards but is based on preliminary information, therefore this report also provides recommendations for further reviews and analysis as the design progresses, where appropriate. Similarly, as a PHA, the focus of this report is on limiting the risks from the site to offsite receptors. The recommendations in this PHA may assist in management of safety of people and property onsite but have not been explicitly designed for these additional goals. Where necessary, this report provides recommendations to manage the risks appropriately in alignment with good practice and relevant safety legislation.
- 1.2.3 The aim of the PHA is to act as both a screening tool and initial hazard analysis for the site. The study aims to evaluate relevant safety measures in accordance with applicable regulations and standards. As this is a greenfield site, the assessment will identify potential fire risks and outline mitigation strategies to be incorporated into the design and operation of the facility.
- 1.2.4 The findings and opinions expressed within this report are based on the input information provided by Legacy Project Manager Pty Ltd and are applicable only to the detailed circumstances envisaged herein. The recommendations consider compliance with relevant legal and regulatory requirements their applicability in the current operational and legislative context.



- 1.2.5 This report is intended for use by Legacy Project Management Pty Ltd as a Preliminary Hazard Assessment for the specified site. The report must be updated if any changes to the site arrangement affect the information relied upon in the preparation of this report. This is to ensure that the recommendations remain consistent with current regulations and operational conditions.

1.3 Applicable Legislation

The principal Victoria legislation associated with this PHA is:

- a) Occupational Health and Safety Act, 2004, No. 107, specifically section 37
- b) Occupational Health and Safety Regulation, 2017, No.2
- c) Environment Protection Act, 2017
- d) Environment Protection Regulations, 2021
- e) Dangerous Goods Act, 1985, No. 10189, specifically section 28
- f) Dangerous Goods (Storage and Handling) Regulations, 2022, No. 115 specifically Part 5 – Preparedness for incidents and emergencies, Division 3 – Equipment and planning

Whilst the project is located in Victoria, there is the no clear guideline on how to undertake a Preliminary Hazard Assessment in terms of dangerous goods or hazardous events. Therefore, PHA has been conducted in line with the NSW Hazardous Industry Planning Advisory framework (NSW Department of Planning, 2011), with specific focus on the following documents:

- a) Assessment Guide for Multi-level Risk Assessment
- b) HIPAP 3 – Risk Assessment
- c) HIPAP 4 – Risk Criteria for Land Use Safety Planning
- d) HIPAP 6 – Hazard Analysis
- e) HIPAP 10 – Land Use Safety Planning

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1.4 Stakeholders and Documentation

- 1.4.1 The stakeholders and referral authorities associated with this project are listed in Table 3.

Table 3: Project stakeholders & Referral Authorities

Organisation	Role	Representative
Legacy Project Management (RED's client)	Project Manager & Developer	Will Fuller Jack Spargo
Focus Environment	Environmental Engineering Consultant	Jon Lawson
FRV	Referral authority	Alam Hossain
Planning Property Partners	Planning Consultants	Paul Little Julain McCluskey
ADP Consulting	Multidisciplinary Services Engineers	John Vollugi Rhys Baynham



Organisation	Role	Representative
Orbe	Fire Safety Engineer (NCC/Building)	Brock Perry
RED Fire Engineers	Fire & Risk Engineering Consultant	Anya Chekulaeva
	Fire & Risk Engineer	Ian Raymond Nate Lobel

1.4.2 The relevant documents and drawings on which this report is based are listed in Table 4.

Table 4: Relevant documentation

Organisation	Title	Project number/ ref	Date	Revision
Orbe	Fire Safety Study	-	Apr 26	1
Dover DC	South Morang Data Centres	-	Mar 26	-
Focus Environment	Dangerous Goods Storage and Planning	F0004061	02/07/25	-
Ewert Leaf	Site Analysis	M24062	11/08/26	B
	Site Plan			C
	Basement Floor Plan			B
	Ground Floor Plan			
	Level 01 Floor Plan			
	Level 02 Floor Plan			
	Roof Floor Plan			
	Sections			
	Program Areas			
Department of Transport and Planning	Development Facilitation Program PPA-1184, 165 Williamsons Road, South Morang	PPA-1184	17/07/26	-

1.4.3 Citations and references used throughout this report are listed in Section 8.

1.5 Assumptions & Limitations

- 1.5.1 The findings and opinions expressed within this report are based on the information provided by Legacy Project Management Pty Ltd and are applicable only to the detailed circumstances envisaged herein.
- 1.5.2 This report is intended for use by Legacy Project Management Pty Ltd to understand how offsite risks at this site can be managed in line with safety legalisation and associated code of practices plus relevant standards. The report must be updated if any changes to the site arrangement affect the information relied upon in the preparation of this report. This is to ensure that the recommendations remain consistent with current regulations and operational conditions.
- 1.5.3 This Preliminary Hazard Assessment is not intended to demonstrate that the operators OHS obligation have been discharged. However, it may naturally assist



in the overall development of the operator's approach to safety and in meeting their obligations. The application of a risk matrix framework may make this PHA more useful to operators in meeting such obligations. However, this document does not meet those obligations in full, nor does it discharge stakeholders or operators from their duty of care.

- 1.5.4 Whilst RED Fire Engineers has used reasonable care and judgement in performing the PHA, an incident with a severity exceeding the design inputs may still occur. It is impossible to have 'zero risk' or be 'risk free'. Regardless of what measures are applied, this does not and cannot eliminate all possibilities of a fire starting, and nothing in this report lays claim to achieving a zero risk, making the site risk free, or eliminating all fire and life risks from the project.
- 1.5.5 Any substitution of nominated safety measures, protection equipment and/or products nominated in this report without prior approval of RED Fire Engineers Pty Ltd may render this report invalid, and RED fire Engineers Pty Ltd should be contacted to assess the potential impact of the proposed substitution.

Assumptions	
All equipment on site is maintained for safe and efficient operations.	
All items / substances, especially dangerous goods, are correctly packed and stored at their appropriate location(s).	
All equipment on the site operated as designed.	
All essential fire safety measures on site have been and will continue to be maintained to the relevant Australian Standards and the local regulations.	
The outcome of this assessment is based on the information referenced in this report.	
This report excludes the analysis of premeditated risks including incendiary fires involving accelerants, explosives and/or multiple ignition sources, or acts of terrorism.	
No significant additional fuel loads, outside that noted in this report, are to be stored at this facility.	

- 1.5.6 The focus of the PHA process is on life safety, and on understanding the physical consequences of hazardous events. No consideration has been made for reputational damage, operational continuity, or any loss.

1.6 Glossary and Abbreviations

- 1.6.1 Table 5 provides a glossary and list of abbreviations used in this document.

Table 5: Glossary and Abbreviations

Abbreviation	Meaning	Definition
AC	Alternating Current	Electric current which periodically reverses direction.
BESS	Battery Energy Storage Systems	Systems used to store energy in batteries for later use. For this report, a BESS refers to a battery room and its contents.
BLEVE	Boiling liquid expanding vapour explosion	Is an explosion caused by the rupture of a vessel containing a pressurized liquid that has



Abbreviation	Meaning	Definition
		attained a temperature sufficiently higher than its boiling point at atmospheric pressure
BMS	Battery Management System	A system that monitors and manages battery performance and safety.
EWS	Emergency Warning System	A system designed to audibly and sometimes visibly alert people to emergencies and provide instructions for safety.
FIP	Fire Indicator Panel	A panel displaying the status of fire alarms and related systems.
FRL	Fire Resistance Level	The grading periods in minutes determined in accordance with Specifications 1 and 2 of the NCC, for the following criteria— a. structural adequacy; and b. Integrity; and c. Insulation, and expressed in that order. FRLs in this report are assumed to be determined in accordance with the NCC and AS1540.4.
FRV	Fire Rescue Victoria	Fire brigade in metropolitan Victoria
FSS	Fire Safety Study	A fire safety study's objective is to ensure that the existing or proposed fire prevention, detection, protection and fighting measures are appropriate for the specific fire hazard and adequate to meet the extent of potential fires for the subject development
HIPAP 2	Hazardous Industry Planning Advisory Paper No. 2	Guidelines for risk assessment and land use planning around hazardous industrial sites.
HRR	Heat Release Rate	The Heat Release Rate is the single most important variable in fire hazard analysis. It serves as the primary driver for all quantifiable fire effects, including compartment temperatures, smoke transport, and the activation of fire protection systems.
IRA	Initial Risk Assessment	The first evaluation of potential risks in a given context, often as part of safety planning.
LFP	Lithium Iron Phosphate	A type of lithium-ion battery known for to be higher stable.
LIB	Lithium-Ion Battery	A rechargeable battery type based on lithium-ion chemistry typically with a hydrocarbon based electrolyte.
LoC	Loss of Control	Loss of control refers to situations where an individual or organization fails to maintain safe operations, leading to increased risk of accidents, injuries, or other adverse outcomes.
O&M	Operation and Maintenance	Activities involved in operating and maintaining a system or facility.
PHA	Preliminary Hazard Assessment	is an exercise for the identification of hazards of a process facility and the qualitative or semi-quantitative assessment of the associated risk. A PHA provides information intended to assist managers and employees in making decisions for improving safety and reducing the



Abbreviation	Meaning	Definition
		consequences of unwanted or unplanned releases of hazardous materials. A PHA is directed toward analysing potential causes and consequences of fires, explosions, releases of toxic or flammable chemicals and major spills of hazardous chemicals, and it focuses on equipment, instrumentation, utilities, human actions, and external factors that might impact the process.
SFAIRP	So Far As Is Reasonably Practicable	SFAIRP asks what the available practicable precautions are and then tests which are reasonable based on the common law balance of the significance of the risk versus the effort and resources required to reduce it.
SQEP	Suitably Qualified and Experienced Person	A person with appropriate qualifications and experience for a specific task or responsibility.
URA	Updated Risk Assessment	A revised evaluation of risks, taking into account new information or changes in context.

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2 Scope of Report

2.1 Scope

- 2.1.1 The scope of this Preliminary Hazard Assessment (PHA) is limited to the potential hazards associated with the SM2 Data Centre. Specifically, this report considers fire, explosion, and toxic release risks that an incident on the site may pose to people in offsite areas.
- 2.1.2 As per Hazardous and Offensive Development Application Guidelines – Applying SEPP 33 (SEPP33-GL) the purpose of the PHA is to:
- Identify all potential hazards associated with the proposal;
 - Analyse all hazards in terms of their consequences (effects) to people and the biophysical environment and their likelihood of occurrence;
 - quantify the analysis and estimate the resultant risks to surrounding land uses and the environment; and
 - assess the risks in terms of the location, land use planning implications and existing criteria and ensure that the proposed safeguards are adequate and thus demonstrate that the operation will not impose an unacceptable level of risk.
- 2.1.3 Whilst SEPP33-GL, as quoted above, indicates the need to “quantify the analysis”, it is important to recognise that the detailed HIPAP documents and multi-level risk assessment guidelines clearly indicate that not all hazards require quantification, and accept that criteria for hazards described in the guidelines both qualitatively and quantitatively, with HIPAP 4: Risk Criteria for Land Use Safety Planning providing such criteria.
- 2.1.4 From the hazard identification process and discussions with the project team, Table 6 has been developed which has the agreed hazard locations/sources considered in this PHA. These may represent pieces of equipment, processes, storage of material or other potential hazard sources.

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Table 6 Hazard Sources

L#	Source Name
L1	External Factors
L2	Site Operations
L3	Battery Rooms
L4	Power Transformer
L5	Auxiliary Transformer
L6	Neutral / Earth Transformer
L7	Diesel Generator
L8	Diesel Tank
L9	Data Centre Power System
L10	Switchboard and Control Room

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2.2 Methodology

Identification of Hazards

- 2.2.1 This list of hazard sources has been agreed with the project team through the development of this document.
- 2.2.2 The hazard identification (HAZID) process is carried out through review of the site documentation, research of relevant equipment, processes, and chemicals, and consultation with the design team.
- 2.2.3 For this project, a draft PHA was developed with a HAZID table, as found in Section 4. The draft PHA was then issued to the client and design team for review.
- 2.2.4 Each hazard identified was given a specific HAZID for traceability and categorised based on the type of loss of control event.

Consequence Assessment

- 2.2.5 As the focus of a PHA is offsite hazards, each HAZID was identified and reviewed to determine whether that hazard was likely to have the potential for an offsite effect, and therefore require consequence analysis, or whether that hazard was primarily an on-site risk.
- 2.2.6 HAZIDs which had a potential for an offsite effect were then carried forward for consequence analysis.
- 2.2.7 Whilst the PHA focused on offsite hazards, it is recognised that avoidable risks should generally be avoided, including hazards which only pose an on-site risk. Therefore, these have been highlighted to the design team and are expected to be carried forward to other studies and design phases. Some of these hazards are specific and are expected to be addressed as part of the Fire Safety Study, others may be more general and be addressed through the general safety in design processes or designing systems to legislative requirements and standards.

Likelihood Analysis

- 2.2.8 Where the consequence analysis demonstrates that there is potential for a significant offsite hazard, the HIPAP framework requires the consideration of how often that event is expected to occur to determine the risk. This may be qualitatively or quantitatively.
- 2.2.9 In order to determine the risk to the site, this likelihood has to be established in some form, as risk is the product of the possibility of occurrence of an event and the consequence of that event. This process includes consideration of probabilities, likelihoods, and frequencies, as described separately within HIPAP 6.

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- 2.2.10 For this project, the first step of the likelihood analysis was to review the consequence analysis and the probability of wind conditions, as wind was the primary factor in determining if an offsite impact would occur. Subsequently, historical failure rate data for battery cells was used to determine likelihoods of failure, ultimately providing the probability of failure carried forward to risk analysis.

Risk Assessment

- 2.2.11 The off site risk assessment, produced from the consequence assessment and the likelihood analysis, against the relevant qualitative and quantitative criteria for risk to people, property and the biophysical environment. Generally, individual risk and risk to property to be presented in the form of risk contours.
- 2.2.12 Sensitivity analysis to the inputs of the risk assessment to be undertaken to demonstrate the impact on risk assessment based on small changes. In the risk assessment description major contributors to the risk assessment outcome to be noted,
- 2.2.13 The risk assessment is to be updated based on proposed control measures and description of the expected impact from the control measures.
- 2.2.14 Where quantitative criteria have been used in the risk assessment, the comparison is direct. Whilst qualitative criteria based risk assessment will be present with additional description and consideration of HIPAP 4, (NSW Department of Planning, 2011).
- 2.2.15 In complex site risk assessment, will include discussion on alternative control measures, locations, and site operations.

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3 Description of Facility

3.1 Locational Context

General Site Information

- 3.1.1 Figure 1 presents the proposed site locations and its surrounding areas. As can be noted to the north is residential properties, whilst to the south, east, and west are commercial properties. The site itself has two electricity transmission easements and a single water supply easement. Next to the site is the South Morang Terminal Station.
- 3.1.2 Figure 2 presents the site arrangements. As can be seen, in the northern section is the data centre and associated fire water tanks and pumps. Whilst to the south is the substation. This, and the other drawings are still high level and will be refined as the project matures.
- 3.1.3 Figure 3 presents the basement arrangement for the data centre. Of note on this floor are the 16 diesel fuel tanks, each with a capacity of 110 kL and their associated pumps. Additionally, it is planned that other engineering plant systems will be located on this floor, including 18 water tanks, each with a capacity of 500 kL.
- 3.1.4 Figure 4 presents the ground floor arrangement for the data centre. On this floor there is the office, which includes a loading bay and fire control room. There are seven data halls on this level. There are around 50 battery rooms on this level, in the mechanical service corridor. In the green area, generator set area (GenSet), there are 35 diesel generators.
- 3.1.5 To the right side of the data centre is the fire tank and fire pump's structure.
- 3.1.6 Figure 5 presents the 01 floor arrangement, which consists of 8 data halls, plus battery rooms and diesel generators. Figure 6 presents the 02 floor arrangement, which consists of 8 data halls, plus battery rooms and diesel generators. Figure 7 presents the roof floor arrangement, which consists of various plant spaces.
- 3.1.7 Figure 12 presents the section profile of the data centre, which shows that the basement has a height of 5.5 m, whilst the ground, 01, and 02 floors have a height of 7 m.
- 3.1.8 Across the 23 data halls there is expected to be around 5,000 server cabinets. With each cabinet energy density being 40 kW, then the total data hall energy load is 200 MW.

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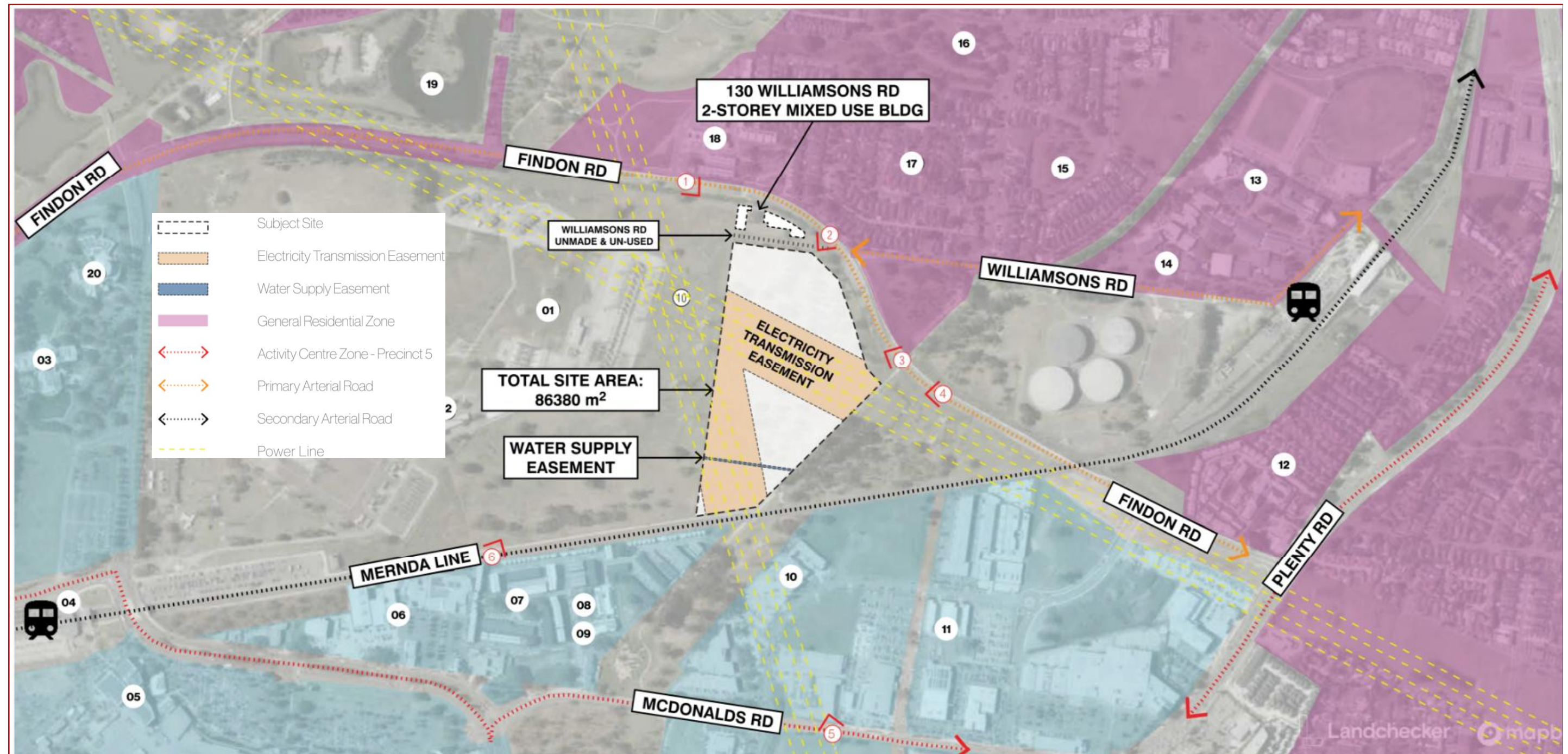
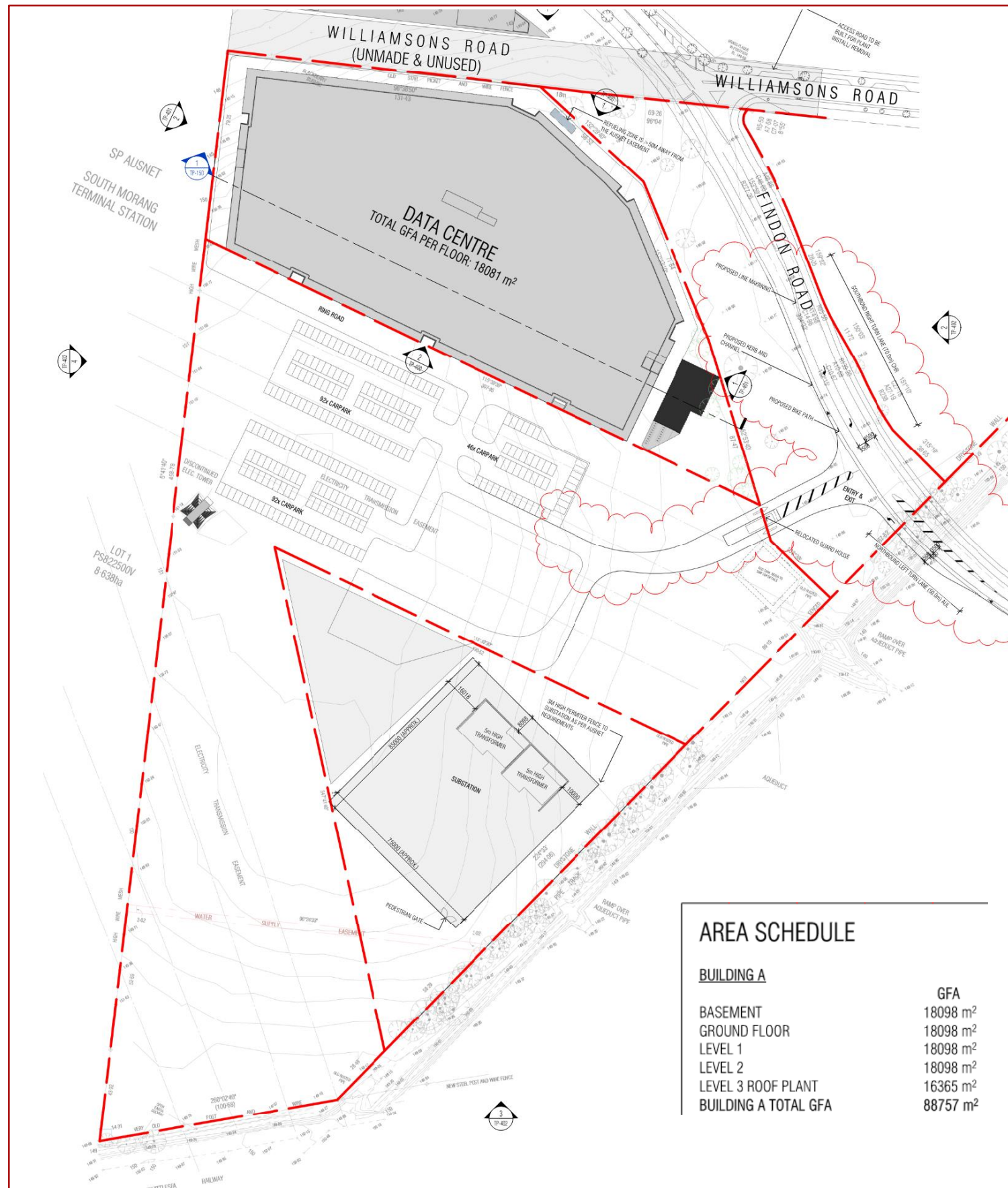


Figure 1: Site Analysis

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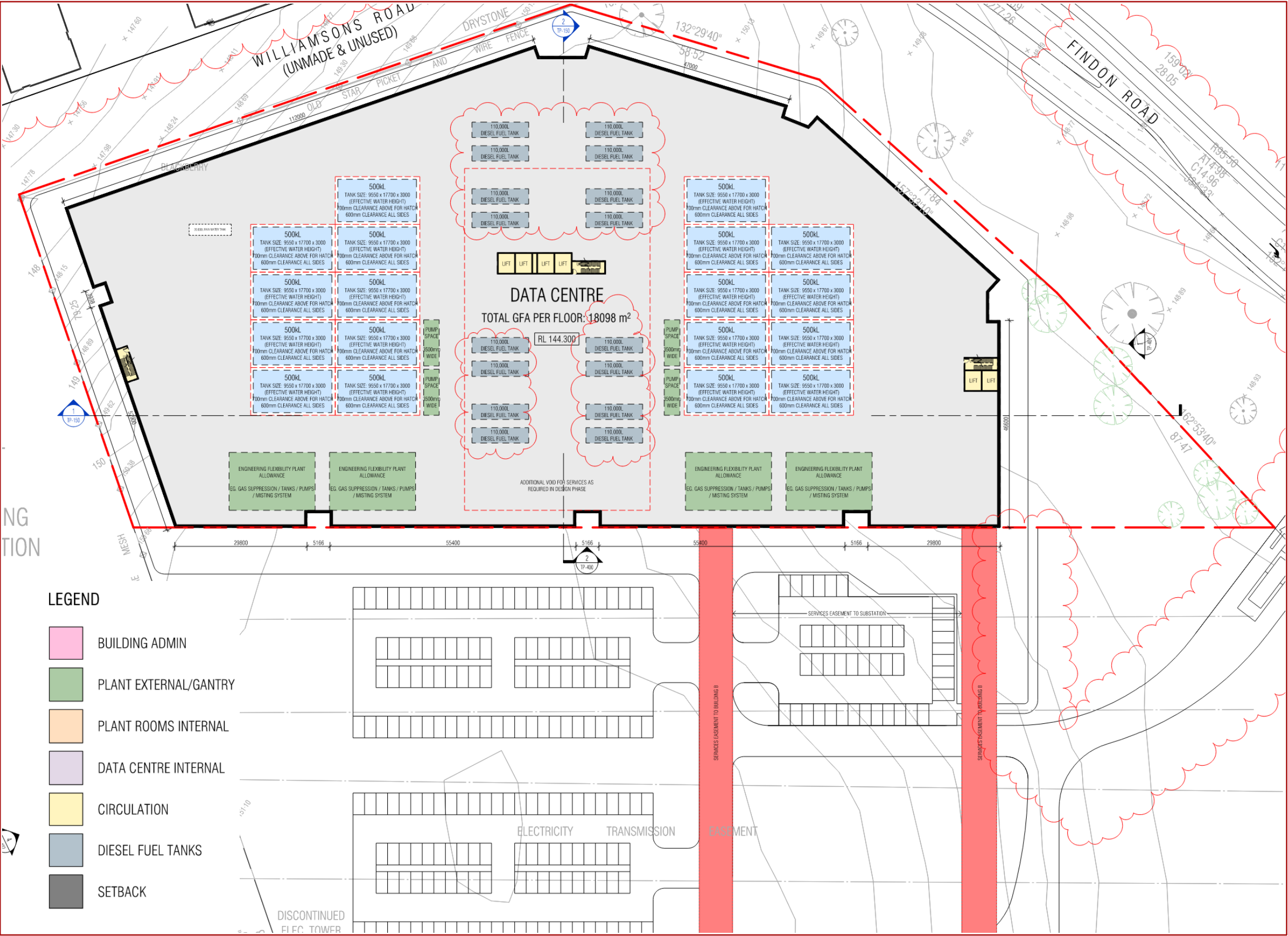
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Figure 2: Site Plan



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Figure 3: Basement Floor Plan

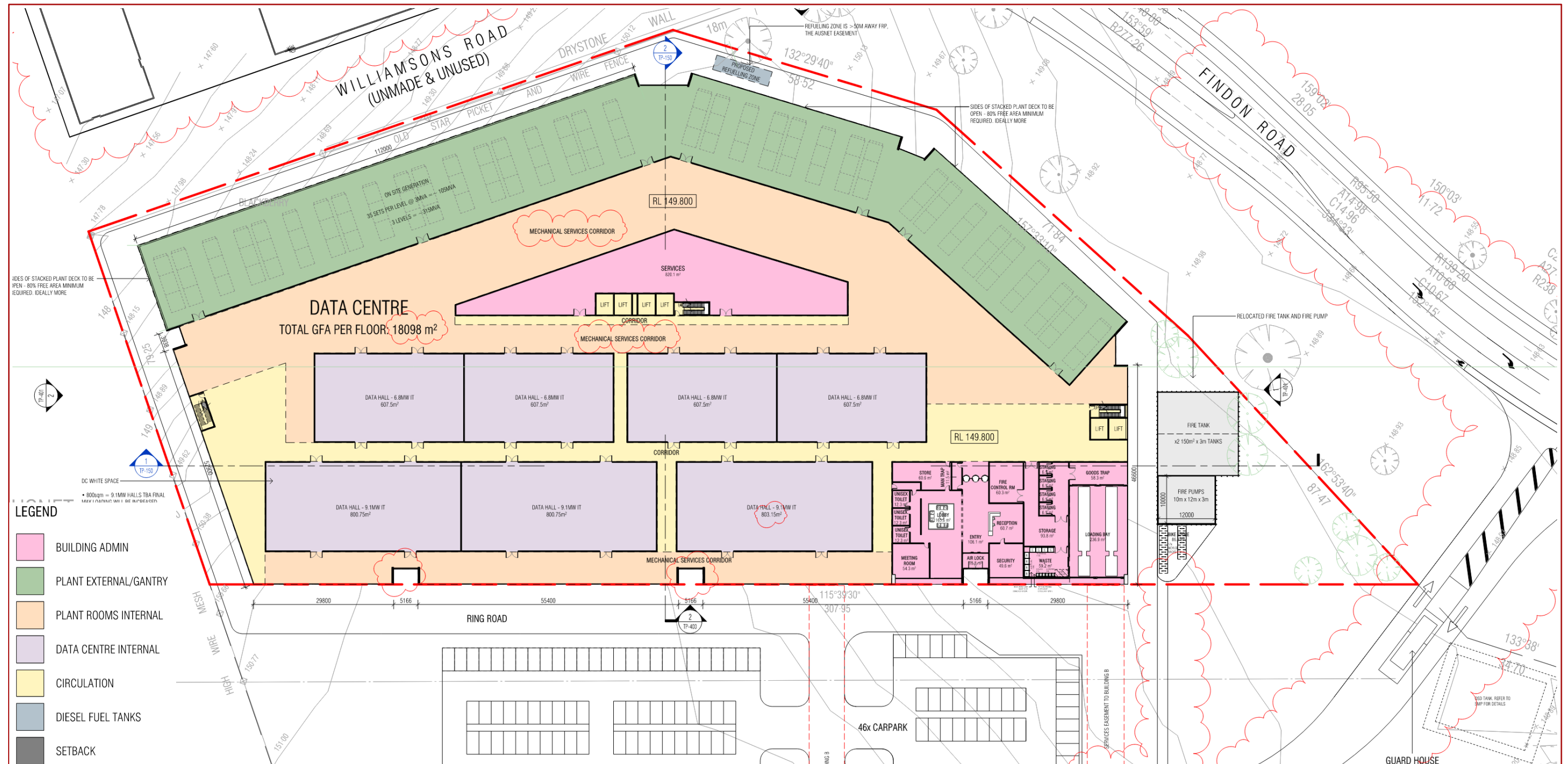


Figure 4: Ground Floor Plan

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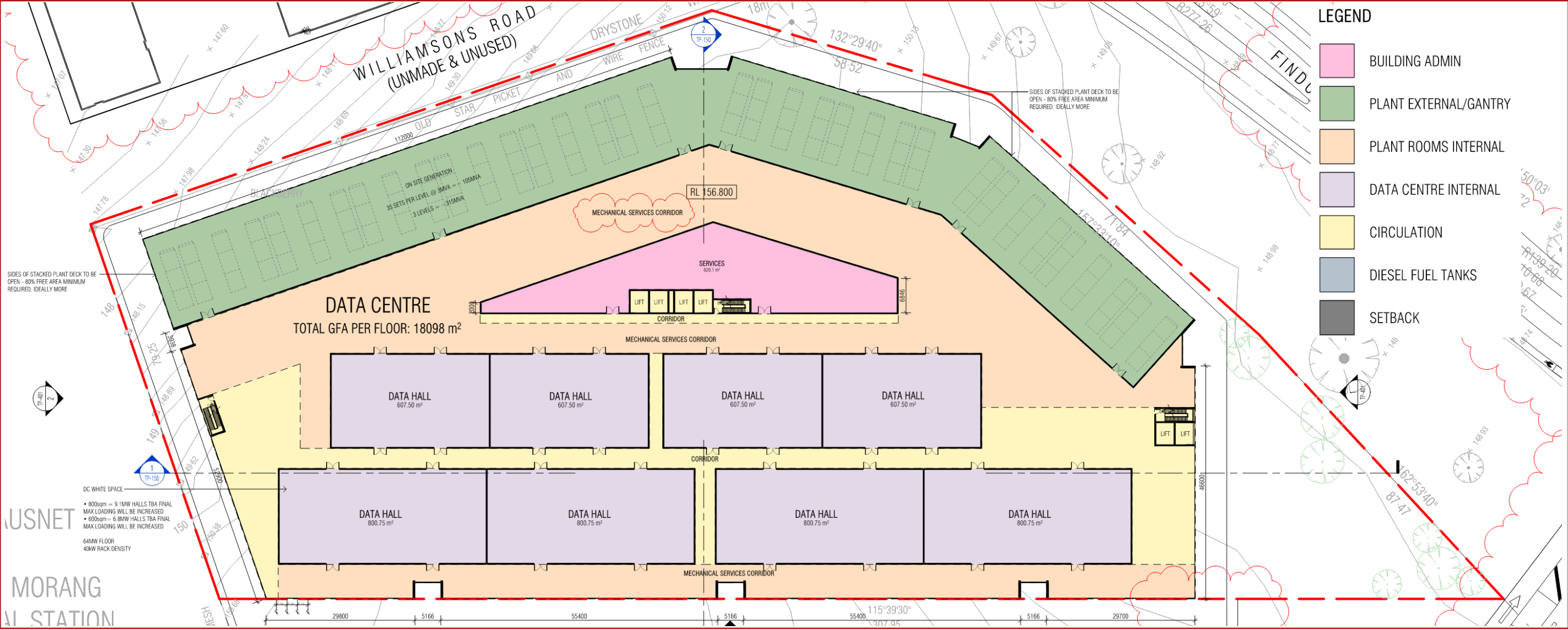


Figure 5: Level 01 Floor Plan

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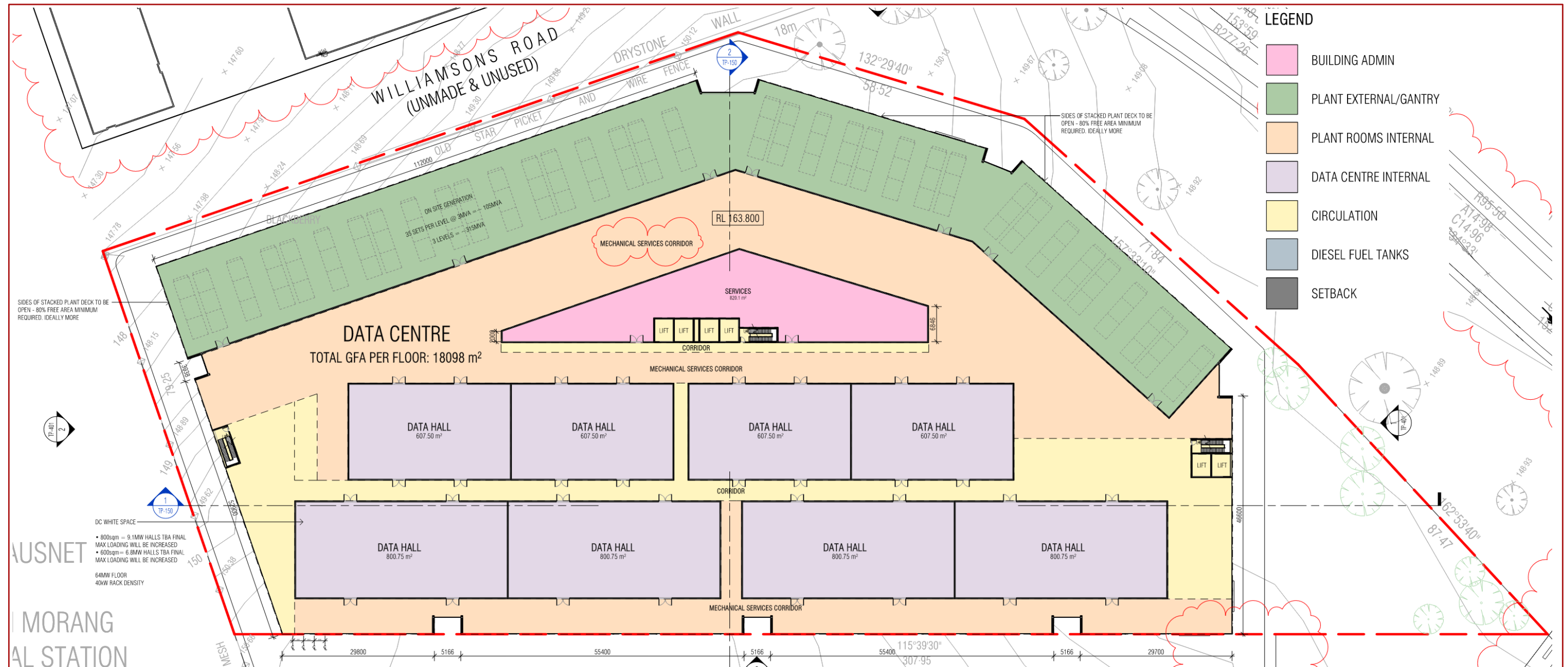


Figure 6: Level 02 Floor Plan

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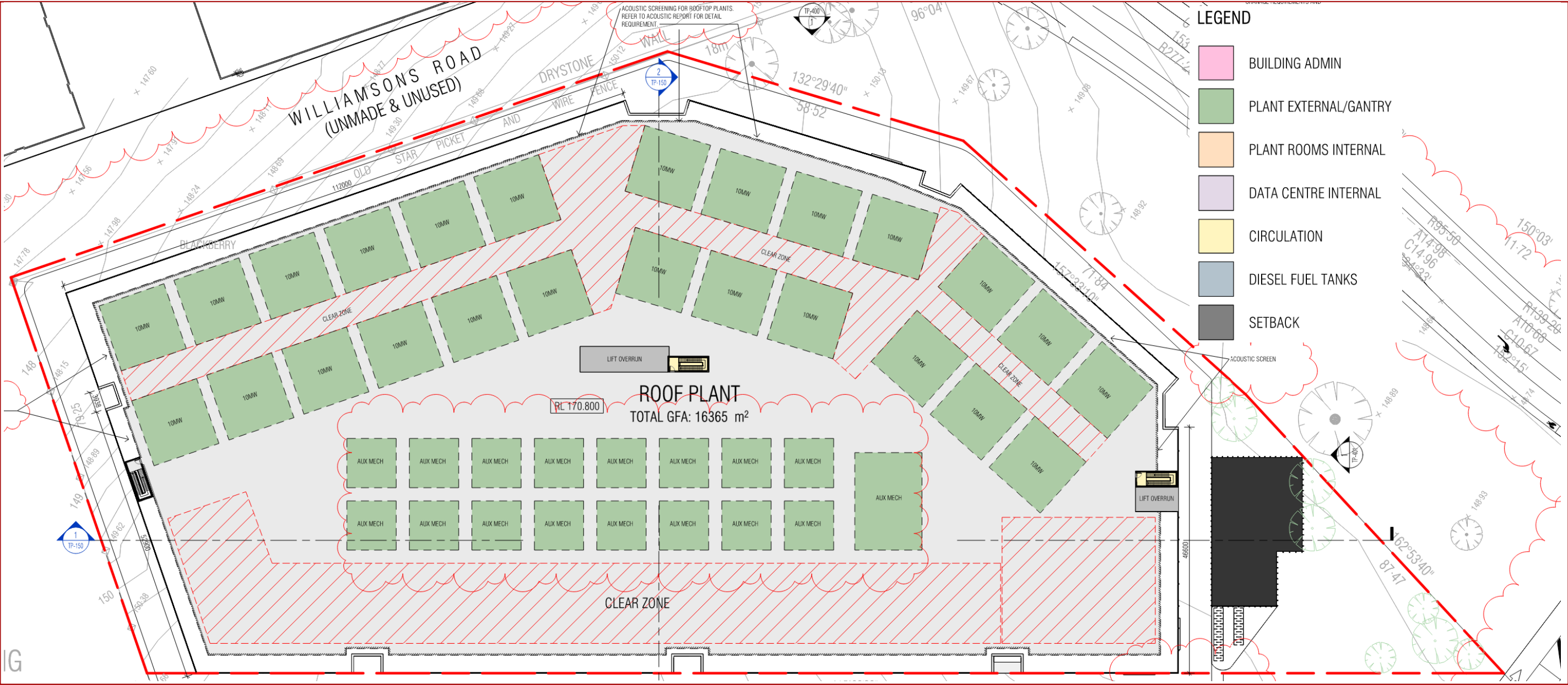


Figure 7: Roof Floor Plan

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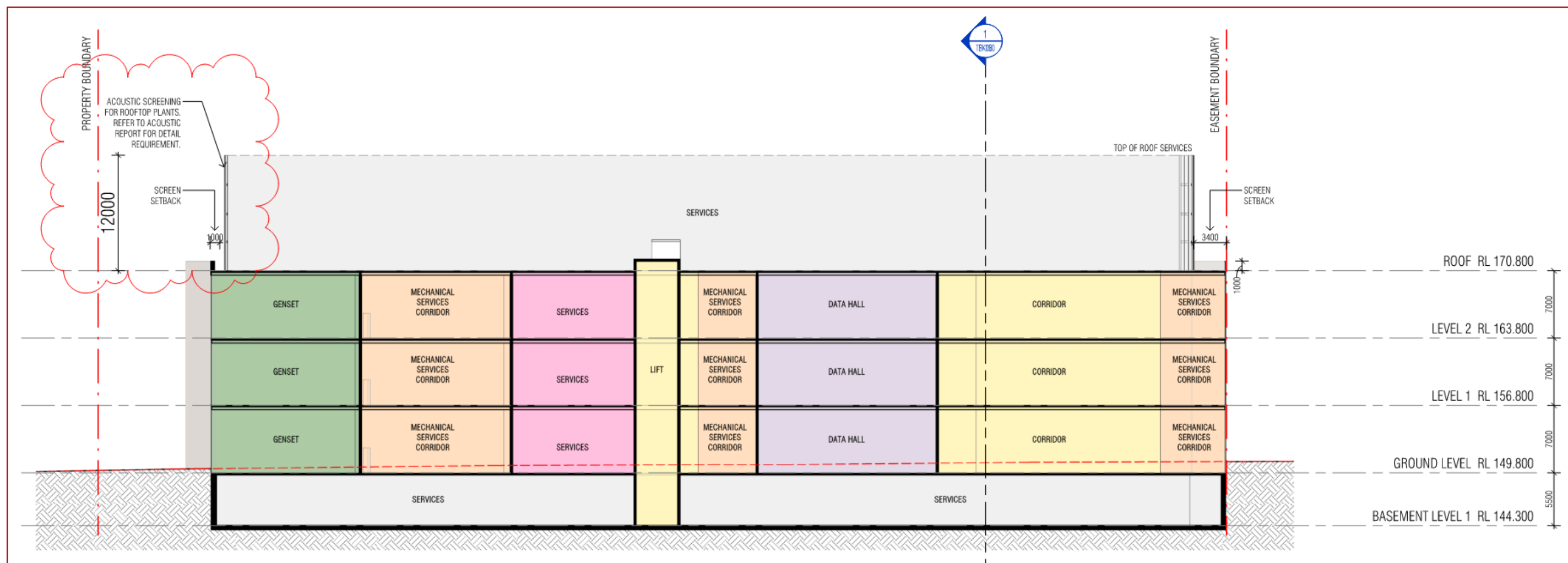


Figure 8: Data Centre Sections

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- 3.1.9 The mechanical service corridor on each level will house various service systems, including the across the three floors 154 battery room. This area may not be completely air sealed to the outside.
- 3.1.10 The GenSet area is opened on the external wall side of this area. Across the three floor there are 105 diesel generators.
- 3.1.11 Based on the preliminary report by Orbe, the project fire safety engineer, the data centre has a surface area of 18,098 m² and a volume of 470,065 m³. Under the BCA, 2025, (ABCB, 2025), would categorise this building as a Class 8. The size of the data centre means it's a large isolate building, as defined in clause C3D4, i.e., it's larger than 18,000 m² or 108,000 m³. Therefore, this building needs to have the following fire safety measures:
- Entire building protected by sprinklers. Noting the function of the building, this capability likely to be achieved by other fitted fire suppression systems, and
 - Perimeter road access around the entire building. This is expected to be achieved via the ring road and using Williamsons Road (unmade and unused).
- 3.1.12 Each battery room will have dimensions of 4 m x 4.5 m and 4 m in height. Within each battery room will contain one BESS cabinet / unit and associated power distribution system, a planned data centre power system.
- 3.1.13 Figure 12 presents the closest off-site receptor, the distances are presented in Table 7.

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Table 7: Off-site Receptor distances

Location Code	Emission Structures	Receptor	Distance (m)
A	Data centre	Residential property	70
B	Data centre	2-storey mixed use building	32.1
C	Power Transformer	Infinity Church	198

Site Processes

- 3.1.14 Unlike many other potentially hazardous industries, there is no manufacturing or material processing on site. The data centre provides data storage and analysis.
- 3.1.15 To support this process the site considers of substation, emergency diesel generators, and back up battery rooms for emergency power.

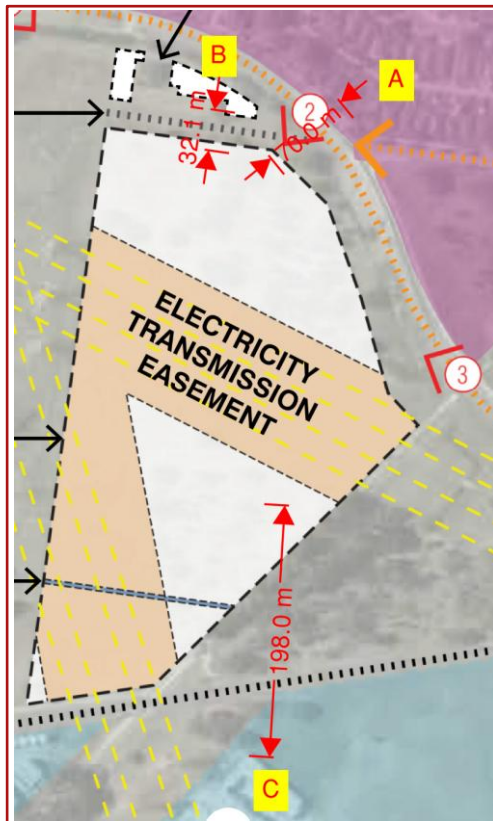
Site activity and staffing

- 3.1.16 The site is expected to normally operate with limited staff. During the working hours there will be staff to conduct maintenance operations. After hours staff will be available to response to operational incidences.

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3.1.17 Potentially, there could be around 200 occupants per level or a maximum occupancy of 600 across the building.



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Figure 9: Receptor to the site

Site Environment Inputs

3.1.18 The following provided information about the potential hazards associated with environmental events. These are preliminary and to be superseded / confirmed by the relevant specialists.

- a) Earthquake – (Burbidge, et al., 2012) presents updated earthquake hazard map for Australia. As this site is within Melbourne. This paper highlights that earthquake hazard in Melbourne is relatively low. Specifically, the hazard map shows a 0.08 AS 1170.4 Z-value and a 0.06 (G) 500 year Peak Ground Acceleration hazard value. The only viable control is to construct site buildings associated with site controls to meet AS 1170.4, with respect to the forementioned values. Where this is not possible manufacturer's instructions for footing / foundations are to be at least followed.
- b) Wind speed – Maximum recorded wind speed for South Morang is 103.7 km/h and was recorded on 29 Oct 2021 ^[1]. This is a rare event as the average wind speed is 8.7 km/h (2.4 m/s) over the last 5 years.
- c) Flood – As noted at flood risk tracker ^[2] the flood risk for the site is low for river flood and low for storm surge.

¹ From <https://wind.willyweather.com.au/vic/melbourne/south-morang.html> accessed on 02 Sep 26.

² From <https://floodrisktracker.steadfast.com.au/> accessed on 02 Sep. 26.



Hazard Locations

3.1.19 Figure 12 presents the hazards locations across the site.

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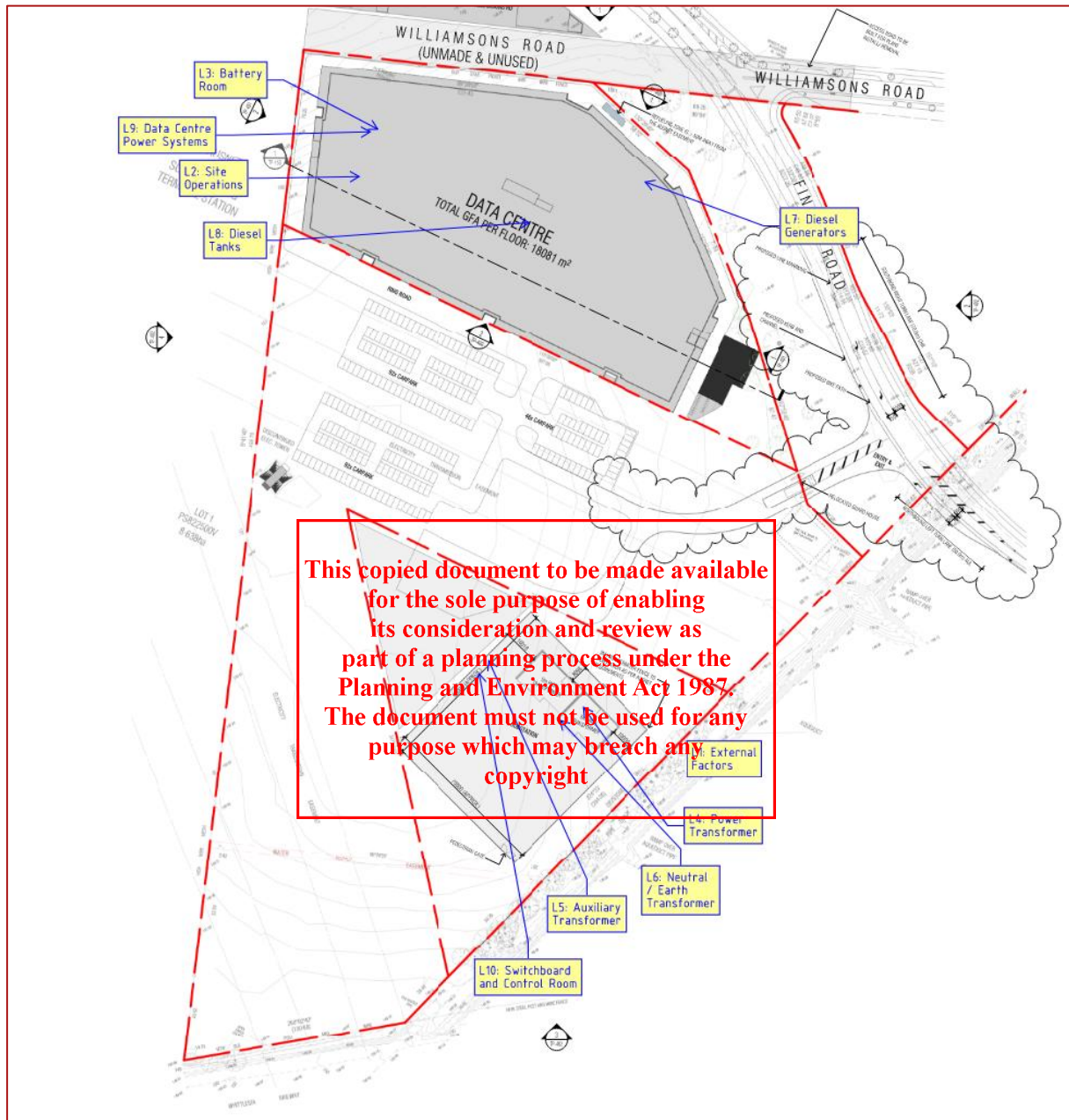


Figure 10: Hazard locations across the site

3.2 L1: External Factors

- 3.2.1 The site is located within the outer suburbs of Melbourne, therefore trespassing and vandalism are threats which could result in an incident at the site.
- 3.2.2 Additionally, there is a railway line on the eastern boundary, which could result in a large external fire event. Cyber attack site systems, such as the battery rooms or diesel generators, could result in an incident.



- 3.2.3 Bushfire and grass fires have been ruled out as a potential threat to the site due to the location.
- 3.2.4 There is limited risk of a boundary fire due to vehicle fire could result in an incident at the perimeter of the site.

3.3 L2: Site Operations

- 3.3.1 Operations across the site, including maintenance, can result in an incident at the site. The main focus of this location is the data halls within the data centre.

3.4 L3: Battery Rooms

- 3.4.1 There are 154 battery rooms. The energy storage capacity of each room is 300 kW, without selection of a product it is unknown how many cabinets are proposed yet.

3.5 L4: Power Transformer

- 3.5.1 The site will have two power transformers; each located in a bund that is 25.7 m x 17 m. Three side of this bund will have a fire and blast wall that is around 6 m in height.
- 3.5.2 The power transformer is expected to hold around 45,000 kg of combustible oil.

3.6 L5: Auxiliary Transformer

- 3.6.1 There will be at least two auxiliary transformers located within the substation.

3.7 L6: Neutral / Earth Transformer

- 3.7.1 There will be at least two neutral / earth transformers located within the substation.

3.8 L7: Diesel Generator

- 3.8.1 There are 105 diesel generators across three levels, i.e., 35 per level. Each diesel generator has a capacity of 3 MVA. Associated with each diesel generator is a day tank. This day tank is to have a nominal capacity of 1 kL.

3.9 L8: Diesel tank

- 3.9.1 The Diesel tank location includes the 16 tanks in the basement, plus the refuelling zone (outside of the building), pipework associated with the transfer of the diesel fuel, and the fuel pumps.
- 3.9.2 The capacity of each diesel tanks is 110 kL.

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3.10 L9: Data Centre Power System

- 3.10.1 The data centre power system relates to switchboards and associated systems that manage the power flow from the diesel generators and the battery rooms to data halls.

3.11 L10: Switchboard and Control Room

- 3.11.1 Within the substation there will be a switchboard and control room that manages the power flow from outside of the site to the data centre.

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4 Identification of Hazards

4.1.1 For the purposes of identifying the hazards at the site three key steps have been undertaken to identify the key loss of control events such as fire, toxic release, or explosion which may pose offsite sties. These are:

- 1) A review of expected chemicals/goods stored at the site to develop a manifest, if required.
- 2) A Hazard Log has been developed based on initial review of the site description and processes.
- 3) Finally, both of the above are vetted and endorsed by the project team, who are involved in the development of both items. This provides a well-rounded view of the potential fire safety hazards at the site.

4.1.2 The process of defining the hazard potential of a plant, process, or operation involves identifying hazards and estimating the potential consequences of credible incidents. In accordance with HIPAP 2 (NSW Planning, 2011), several additional factors must also be considered in selecting an appropriate system, including:

- a) Land use safety considerations: the impact of incidents on the surrounding land uses, and the sensitivity of these land uses,
- b) Infrastructure availability: such as water mains supply, area emergency planning, fire brigade response times and access,
- c) External factors: effects from surrounding and use (for example, other hazardous industries, bush fires, weather, etc), and
- d) Regulations: requirements of statutory bodies.

4.2 Material Manifest

4.2.1 No complete site manifest exists at this stage of the site development. What is known at this stage of the site development:

- a) 154 battery rooms each with a capacity of 300 kWh, which are Class 9 PG II and likely contain refrigerants for their cooling system,
- b) 1,760 kL of Diesel in basement tanks, Class 3 C1,
- c) 105 kL of Diesel in days tanks for the diesel generators, Class 3 C1,
- d) Approx. 120 kL transformer oil within the substation, Class 3 C2, and
- e) Refrigerant gas of approx. 20 kL, Class 2.1.

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4.3 Hazard Identification

- 4.3.1 The Hazard identification process involves reviewing the potential hazard sources on site and understanding how they may act as a source for different types of fire hazards. For the purposes of this fire safety study, various equipment or activities have been considered as potential hazard sources (also referred to as hazard locations in this report). Each of these locations has been considered against potential hazard types such as fire, blast, or toxic release. Then where relevant these have been combined to represent a specific Loss of Control (LoC) event, which is represented by a unique Hazard ID.
- 4.3.2 Table 8 presents a generic list of hazardous events, with generalised descriptions. This table is provided for background and greater understanding of the type of hazards which form LoCs across potentially hazardous industries. For simplicity’s sake, certain types of LoC events that are not relevant to the site have not been included, such as BLEVE, nor spill of toxic materials.

Table 8 Generic Hazard Types

Hazard Type	General Description	Typical Causes
General Hazard Source (G)	External or non-process hazard that may initiate or worsen another hazardous event.	Bushfire, grass fire, flood, lightning, storm, extreme heat, vandalism, trespass, cyberattack, malicious damage, vehicle impact, nearby industrial incident, loss of utilities.
Electromagnetic Fields (EMF)	Exposure to electromagnetic fields generated by electrical infrastructure and plant. Generally, an operational or occupational interface hazard rather than a conventional fire event, but may be considered where relevant to sensitive equipment, personnel, or emergency response.	High-voltage equipment, transformers, inverters, switch rooms, substations, cabling, earthing faults, proximity of workers/responders to energised assets.
Small Fire (SF)	A localised fire, typically limited to the object or immediate area of origin, with low initial escalation potential if promptly detected and controlled.	Overheated cables or terminals, arcing, minor electrical faults, small fuel/oil ignition, overheating bearings/motors, isolated cell failure in Battery equipment, small combustible waste ignition, equipment abuse, poor housekeeping.
Large Fire (LF)	A developed fire, involving one or more major items or areas, with potential for spread, escalation, structural damage, or off-site impacts. Not readily controllable without suppression/control systems or brigade intervention.	Escalation of a small fire, large flammable/combustible liquid release and ignition, battery room thermal runaway propagation, transformer fire, cable trench fire, inverter/skid fire, major equipment failure, bushfire exposure, vehicle fire, delayed isolation.
Explosion (EX)	A rapid release of energy resulting in overpressure, with or without fire, arising from combustion, pressure vessel failure, confined gas accumulation, or catastrophic equipment rupture.	Vapour cloud explosion, ignition of accumulated battery off-gases, arc flash/arc blast, transformer internal fault, pressure vessel failure, incompatible chemical reaction, ignition in enclosed plant spaces, poor venting, poor maintenance.
Small Leak (SL)	A minor loss of liquid or gas from equipment, storage, piping, hose, or fittings, generally localised and limited in quantity.	Gland/seal failure, loose fittings, flange seepage, pinhole corrosion, valve passing, instrument connection failure, minor tank or transformer seepage, small coolant/electrolyte/fuel leaks, poor maintenance, misuse of equipment.
Large Leak (LL)	A significant release of liquid from plant, storage, pipework, tanker, transformer, or fuel system, likely to continue until isolation or depletion and capable of causing pooling, contamination, or escalation.	Tank rupture, hose failure during transfer, pipe rupture, major gasket/flange failure, valve failure, impact damage, overfilling, catastrophic transformer failure, bund drain malfunction, collision, severe corrosion.
Small spill (SS)	A small uncontained liquid release to ground or hardstand, generally from handling, decanting, maintenance, or minor equipment failure, with limited spread and usually manageable by local spill response.	Minor overfill, drum/IBC tipping, poor decanting practices, seal leaks, sampling/maintenance activities, small fuel or oil release, minor electrolyte release, poor housekeeping.
Large spill (LS)	A substantial uncontained liquid release to ground or drainage system that may spread beyond local containment, create environmental harm, and increase fire/explosion risks where flammable liquids are involved.	Bulk tank failure, tanker unloading incident, transfer hose rupture, bund overtopping/failure, major transformer oil loss, large fuel tank rupture, collision, process, operator error.
Gas Release (GR)	Release of hazardous gas, vapour, smoke, or decomposition products from storage, process equipment, Battery failure, pressure systems, or fire conditions. May present toxic, flammable, asphyxiation, or explosion hazards.	Pressure relief venting, seal or flange failure, pipe rupture, cylinder manifold failure, Battery thermal runaway off-gassing, fire involving chemicals or cable insulation, overheating equipment, poor connection integrity, corrosion.

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- 4.3.3 A summary of potential hazards present, both internal and external, is presented in Table 9. These hazards are identified based on the following aspects: the nature and quantities of the materials involved, the characteristics of hazardous events (such as loss of containment), potential initiating events, ignition sources, and related factors. The possibility of the site being exposed to external hazards has also been considered. These hazards have been reviewed and agreed to by the project design team via the development of this document.
- 4.3.4 These hazards have also been categorised by 'Relevance'. A hazard which is not reasonably expected to occur is screened out as irrelevant, as are hazards that are out of scope (typically assessed by others), or have been predetermined not to pose an offsite risk by sitting below the SEPP33 screening levels. All other identified hazards may be reasonably expected to have a significant offsite impact and have been carried forward to consequence screening and/or analysis.
- 4.3.5 Although, Table 9 sets out all expected hazards associated with the site, only the hazards that impact beyond the site will be assessed in this PHA. All hazards will be assessed in the FSS.

Table 9 Identified Loss of Control Events (LoCs/Hazards)

ID	Context	Relevant?	Location / Source	Location & Type	Potential Causes	Potential Consequences
L1-G	These are external hazard sources which are specific possible triggers for many of the other specific LoCs. Examples include trespassers, railway, and cyber attacks.	Yes	External Factors (L1)	External Factors: General Hazard Source (L1-G)	Vandals and trespassers enter the site, i.e., unauthorised visitors. Rail accident at the boundary of the site. Unauthorised virtual access to the site.	Would range from minor damage to significant damage to the facility. Life safety similarly could range from minor to critical. Consequence will therefore be based on the consequence of the hazard locations below.
L2-SF	Electrical cable or computer systems fire, expected to be around 150 kW	Yes	Site Operations (L2)	Site Operations: Small Fire (L2-SF)	Poor installation and maintenance. Mechanical damage. High temperatures.	Small fire and toxic smoke. Hospitalisation for personnel and some computer infrastructure damaged
L2-LF	Fire spread from and via cables to involve a Data Hall	Yes	Site Operations (L2)	Site Operations: Large Fire (L2-LF)	Arson, mechanical damage, high temperatures	Loss of data hall or building. Death to personnel.
L2-EX	Source typically does not have an explosion potential in isolation.	No	Site Operations (L2)	Site Operations: Explosion (L2-EX)	N/a	N/a
L2-SL	No significant leak or spill potential.	No	Site Operations (L2)	Site Operations: Small Leak (L2-SL)	N/a	N/a
L2-LL		No	Site Operations (L2)	Site Operations: Large Leak (L2-LL)	N/a	N/a
L2-SS		No	Site Operations (L2)	Site Operations: Small spill (L2-SS)	N/a	N/a
L2-LS		No	Site Operations (L2)	Site Operations: Large spill (L2-LS)	N/a	N/a
L2-GR	Source does not typically produce an acutely hazardous gas cloud	No	Site Operations (L2)	Site Operations: Gas Release (L2-GR)	N/a	N/a
L3-SF	Localised battery room fire such as from a single or multiple cell thermal runaway	Yes	Battery Rooms (L3)	Battery Rooms: Small Fire (L3-SF)	Localised puncture / impact, overheating (failure of cooling system), electrical stress (overcharging / discharging), isolated manufacturing defect	Damage to the affected module / unit. Unlikely to have any offsite consequences.
L3-LF	Major failure of multiple systems leading to burnout of a full battery room	Yes	Battery Rooms (L3)	Battery Rooms: Large Fire (L3-LF)	Requires complete failure of the BMS and/or a significant event to overcome the cooling and protection measures in-built to the battery rooms	Loss of entire battery room . Significant fire and smoke produced. Potential for fire spread from the battery rooms. Significant thermal effects are likely. The potential for an explosion event and toxic gas emissions.
L3-EX	Significant failure leading to multiple cells venting to produce a vapour cloud explosion / release of battery electrolyte	Yes	Battery Rooms (L3)	Battery Rooms: Explosion (L3-EX)	Multiple cell failures likely due to cascading thermal runaway & finding an ignition source	Loss of entire battery room, potential damage to adjacent equipment and personnel if present. Depending on severity of the blast there is potential for an offsite hazard.
L3-SL	No significant leak or spill potential.	No	Battery Rooms (L3)	Battery Rooms: Small Leak (L3-SL)	N/a	N/a
L3-LL		No	Battery Rooms (L3)	Battery Rooms: Large Leak (L3-LL)	N/a	N/a
L3-SS		No	Battery Rooms (L3)	Battery Rooms: Small spill (L3-SS)	N/a	N/a
L3-LS		No	Battery Rooms (L3)	Battery Rooms: Large spill (L3-LS)	N/a	N/a
L3-GR	Major failure of multiple systems leading to venting of a full battery room . This could be thermal runaway with or without a fire. This scenario considers only the toxic effects.	Yes	Battery Rooms (L3)	Battery Rooms: Gas Release (L3-GR)	A gas release can occur without fire, if a sufficient number of cells enter thermal runaway and vent simultaneously, or as part of a fire	Potential for a significant release of hydrogen fluoride (HF) or other gases which pose a significant toxic risk. Gases can spread easily and could pose an offsite risk and risk to onsite personnel

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ID	Context	Relevant?	Location / Source	Location & Type	Potential Causes		Potential Consequences
L4-SF	Small oil leak occurs, which results in a small fire.	Yes	Power Transformer (L4)	Power Transformer: Small Fire (L4-SF)	Small hole in oil containment system and a hot surface.		Damage to the Transformer.
L4-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Yes	Power Transformer (L4)	Power Transformer: Large Fire (L4-LF)	Failure of the oil containment system and hot surface or other ignition source.		Fire spread beyond the Transformer.
L4-EX	Overheating of the transformer oil results in a BLEVE-type event.	Yes	Power Transformer (L4)	Power Transformer: Explosion (L4-EX)	Mechanical damage, over-current, etc		The explosion impacts the adjacent system and personnel nearby.
L4-SL	No major hazard in relation to the PHA. This would be covered under a fire that occurs after the leak.	No	Power Transformer (L4)	Power Transformer: Small Leak (L4-SL)	Corrosion or overheating.		Personnel, slips. No facility impact.
L4-LL		No	Power Transformer (L4)	Power Transformer: Large Leak (L4-LL)	Corrosion, overheating, or mechanical damaged.		Personnel, slips. No facility impact.
L4-SS		No	Power Transformer (L4)	Power Transformer: Small spill (L4-SS)	Over filling or poor fill up arrangement		Personnel, slips. No facility impact.
L4-LS		No	Power Transformer (L4)	Power Transformer: Large spill (L4-LS)	Poor fill up arrangement		Personnel, slips. No facility impact.
L4-GR	No specific gas released, general fire plume.	No	Power Transformer (L4)	Power Transformer: Gas Release (L4-GR)	N/a		N/a
L5-SF	Small oil leak occurs, which results in a small fire.	Yes	Auxiliary Transformer (L5)	Auxiliary Transformer: Small Fire (L5-SF)	Small hole in oil containment system and a hot surface.		Damage to the Transformer.
L5-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Yes	Auxiliary Transformer (L5)	Auxiliary Transformer: Large Fire (L5-LF)	Failure of the oil containment system and hot surface or other ignition source.		Fire spread beyond the Transformer.
L5-EX	Overheating of the transformer oil results in a BLEVE-type event.	Yes	Auxiliary Transformer (L5)	Auxiliary Transformer: Explosion (L5-EX)	Mechanical damage, over-current, etc		The explosion impacts the adjacent system and personnel nearby.
L5-SL	Small leak during operations	Yes	Auxiliary Transformer (L5)	Auxiliary Transformer: Small Leak (L5-SL)	Corrosion or overheating.		Personnel, slips. No facility impact.
L5-LL	Insufficient oil to be considered a large leak	No	Auxiliary Transformer (L5)	Auxiliary Transformer: Large Leak (L5-LL)	N/a		N/a
L5-SS	Small spill during refiling	No	Auxiliary Transformer (L5)	Auxiliary Transformer: Small spill (L5-SS)	Over filling or poor fill up arrangement		Personnel, slips. No facility impact.
L5-LS	Insufficient oil to be considered a large spill	No	Auxiliary Transformer (L5)	Auxiliary Transformer: Large spill (L5-LS)	N/a		N/a
L5-GR	Source does not typically produce an acutely hazardous gas cloud	No	Auxiliary Transformer (L5)	Auxiliary Transformer: Gas Release (L5-GR)	N/a		N/a
L6-SF	Small oil leak occurs, which results in a small fire.	Yes	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Small Fire (L6-SF)	Small hole in oil containment system and a hot surface.		Damage to the Transformer.
L6-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Yes	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Large Fire (L6-LF)	Failure of the oil containment system and hot surface or other ignition source.		Fire spread beyond the Transformer.
L6-EX	Overheating of the transformer oil results in a BLEVE-type event.	Yes	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Explosion (L6-EX)	Mechanical damage, over-current, etc		The explosion impacts the adjacent system and personnel nearby.
L6-SL	Small leak during operations	Yes	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Small Leak (L6-SL)	Corrosion or overheating.		Personnel, slips. No facility impact.
L6-LL	Insufficient oil to be considered a large leak	No	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Large Leak (L6-LL)	N/a		N/a
L6-SS	Small spill during refiling	Yes	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Small spill (L6-SS)	Over filling or poor fill up arrangement		Personnel, slips. No facility impact.
L6-LS	Insufficient oil to be considered a large spill	No	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Large spill (L6-LS)	N/a		N/a
L6-GR	Source does not typically produce an acutely hazardous gas cloud	No	Neutral / Earth Transformer (L6)	Neutral / Earth Transformer: Gas Release (L6-GR)	N/a		N/a
L7-SF	Diesel generator small fire - Localised small fire from small source or spillage.	Yes	Diesel Generators (L7)	Diesel Generators: Small Fire (L7-SF)	Degradation of gaskets or similar components over time, or mechanical damage, which results in the partial release of diesel. For ignition to occur, released oil must come into contact with an appropriate ignition source.		Damage to the affected module / unit. Potential for radiant heat between equipment. Potential for fire spread over a long period.



ID	Context	Relevant?	Location / Source	Location & Type	Potential Causes	Potential Consequences
L7-LF	Diesel generator large fire - major fire assuming full contents of diesel tank released	Yes	Diesel Generators (L7)	Diesel Generators: Large Fire (L7-LF)	Mechanical impact of tank or corrosion. For ignition to occur, released oil must come into contact with an appropriate ignition source.	Damage to the affected module / unit. Potential for fire spread between equipment due to size of fire.
L7-EX	Source typically does not have an explosion potential in isolation.	No	Diesel Generators (L7)	Diesel Generators: Explosion (L7-EX)	N/a	N/a
L7-SL	Small leak during operations	Yes	Diesel Generators (L7)	Diesel Generators: Small Leak (L7-SL)	Corrosion or mechanical impact	Personnel, slips. No facility impact.
L7-LL	Insufficient diesel to be considered a large leak	No	Diesel Generators (L7)	Diesel Generators: Large Leak (L7-LL)	N/a	N/a
L7-SS	Small spill during refilling	Yes	Diesel Generators (L7)	Diesel Generators: Small spill (L7-SS)	Over filling or poor fill up arrangement	Personnel, slips. No facility impact.
L7-LS	Insufficient diesel to be considered a large spill	No	Diesel Generators (L7)	Diesel Generators: Large spill (L7-LS)	N/a	N/a
L7-GR	Source does not typically produce an acutely hazardous gas cloud	No	Diesel Generators (L7)	Diesel Generators: Gas Release (L7-GR)	N/a	N/a
L8-SF	Small leak or spill results in a small fire	Yes	Diesel Tanks (L8)	Diesel Tanks: Small Fire (L8-SF)	Small leak / spill that reaches an ignition source	Hospitalisation of personnel and limit damage to the facility
L8-LF	Large leak or spill results in a large fire	Yes	Diesel Tanks (L8)	Diesel Tanks: Large Fire (L8-LF)	Large leak / spill that reaches an ignition source	Death to personal and noticeable damage to the facility.
L8-EX	Source typically does not have an explosion potential in isolation.	No	Diesel Tanks (L8)	Diesel Tanks: Explosion (L8-EX)	N/a	N/a
L8-SL	Small leak during operations	Yes	Diesel Tanks (L8)	Diesel Tanks: Small Leak (L8-SL)	Corrosion or mechanical impact	Personnel, slips. No facility impact.
L8-LL	Large leak due to take failure	Yes	Diesel Tanks (L8)	Diesel Tanks: Large Leak (L8-LL)	Corrosion, mechanical impact, or pipework failure.	Personnel, slips. No facility impact.
L8-SS	Small spill during refilling	Yes	Diesel Tanks (L8)	Diesel Tanks: Small spill (L8-SS)	Over filling or poor fill up arrangement	Personnel, slips. No facility impact.
L8-LS	Large spill during refilling	Yes	Diesel Tanks (L8)	Diesel Tanks: Large spill (L8-LS)	Poor fill up arrangement or pipework failure	Personnel, slips. No facility impact.
L8-GR	Source does not typically produce an acutely hazardous gas cloud	No	Diesel Tanks (L8)	Diesel Tanks: Gas Release (L8-GR)	N/a	N/a
L9-SF	Small electrical fire within the switchboard or associated systems	Yes	Data centre power system (L9)	Data centre power system: Small Fire (L9-SF)	Overheated switchboard or poor maintenance	Personnel can be expected to require hospitalisation, whilst the facility damage only the switchboard.
L9-LF	The switchboard or associated system is completely engulfed, and fire may spread	Yes	Data centre power system (L9)	Data centre power system: Large Fire (L9-LF)	Overheated switchboard, poor maintenance, or mechanical damage	Personnel can be expected to die whilst the fire spreads within the battery room.
L9-EX	An arc flash event associated with a switchboard.	Yes	Data centre power system (L9)	Data centre power system: Explosion (L9-EX)	Due to lead acid battery failure during charging or arc flash event in switchboard.	The explosion impacts the adjacent system and personnel nearby.
L9-SL	No significant leak or spill potential.	No	Data centre power system (L9)	Data centre power system: Small Leak (L9-SL)	N/a	N/a
L9-LL		No	Data centre power system (L9)	Data centre power system: Large Leak (L9-LL)	N/a	N/a
L9-SS		No	Data centre power system (L9)	Data centre power system: Small spill (L9-SS)	N/a	N/a
L9-LS		No	Data centre power system (L9)	Data centre power system: Large spill (L9-LS)	N/a	N/a
L9-GR	Source does not typically produce an acutely hazardous gas cloud	No	Data centre power system (L9)	Data centre power system: Gas Release (L9-GR)	N/a	N/a
L10-SF	Switch room small fire - localised small fire due to storage of combustibles.	Yes	Switchboard and Control Room (L10)	Switchboard and Control Room: Small Fire (L10-SF)	Overheated switchboard or poor maintenance	Personnel can be expected to require hospitalisation, whilst the facility damage only the switchboard.
L10-LF	Switchgear fire spreads across the room(s), or a lead-acid battery hydrogen explosion results in a large fire.	Yes	Switchboard and Control Room (L10)	Switchboard and Control Room: Large Fire (L10-LF)	Overheated switchboard, poor maintenance, or mechanical damage	Personnel can be expected to die whilst the fire spreads within the battery room.
L10-EX	An arc flash event associated with a switchboard or a hydrogen explosion associated with the lead-acid battery system located within the switchboard and control room.	Yes	Switchboard and Control Room (L10)	Switchboard and Control Room: Explosion (L10-EX)	Due to lead acid battery failure during charging or arc flash event in switchboard.	The explosion impacts the adjacent system and personnel nearby.
L10-SL	No significant leak or spill potential.	No	Switchboard and Control Room (L10)	Switchboard and Control Room: Small Leak (L10-SL)	N/a	N/a



ID	Context	Relevant?	Location / Source	Location & Type	Potential Causes	Potential Consequences
L10-LL		No	Switchboard and Control Room (L10)	Switchboard and Control Room: Large Leak (L10-LL)	N/a	N/a
L10-SS		No	Switchboard and Control Room (L10)	Switchboard and Control Room: Small spill (L10-SS)	N/a	N/a
L10-LS		No	Switchboard and Control Room (L10)	Switchboard and Control Room: Large spill (L10-LS)	N/a	N/a
L10-GR	Source does not typically produce an acutely hazardous gas cloud	No	Switchboard and Control Room (L10)	Switchboard and Control Room: Gas Release (L10-GR)	N/a	N/a

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5 Consequence Analysis

5.1 General

- 5.1.1 Following on from the HAZID process, each hazard has been qualitatively reviewed to determine if the hazard is likely to pose a significant offsite risk. Hazards which may pose an offsite risk have been carried forward for more detailed consequence analysis.
- 5.1.2 In some cases, a simple qualitative review of a hazard is enough to demonstrate that the hazard does not pose an offsite risk and therefore does not contribute to the offsite risk profile of the site. In other cases, further consequence analysis is proposed and carried out.

5.2 Consequence Analysis Table

- 5.2.1 Building on the HAZID word diagram from Section 4, Table 10 presents the hazards identified across the site together with a summary of the corresponding consequence analyses undertaken. Rows representing LoCs which were screened out in Section 4 have not been repeated. Modelling techniques referenced in the table are described in further detail following the table.
- Rows highlighted in **GREEN** do not reasonably pose an offsite risk or otherwise do not require further consequence analysis as explained within the table.
 - Rows in **YELLOW** are subject to further analysis due to offsite risk.
 - Rows in **LIGHT BLUE** are subject to further analysis in the FSS due to onsite risk. It is not intended to assess these as part of this PHA.
 - Some items require assessment but not in this document, they are included here for transparency.

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Table 10 Consequence analysis approach overview

ID	Context	Location & Type	Potential Consequences	Applicable Consequence Analysis
L1-G	These are external hazard sources which are specific possible triggers for many of the other specific LoCs. Examples include trespassers, railway, and cyber attacks.	External Factors: General Hazard Source (L1-G)	Would range from minor damage to significant damage to the facility. Life safety similarly could range from minor to critical. Consequence will therefore be based on the consequence of the hazard locations below.	No consequence modelling required, will use the worst outcome from the following.
L2-SF	Electrical cable or computer systems fire, expected to be around 150 kW	Site Operations: Small Fire (L2-SF)	Small fire and toxic smoke. Hospitalisation for personnel and some computer infrastructure damaged	No consequence modelling required as this is a small fire.
L2-LF	Fire spread from and via cables to involve a Data Hall	Site Operations: Large Fire (L2-LF)	Loss of data hall or building. Death to personnel.	No consequence modelling required, as data hall assumed engulfed in fire.
L3-SF	Localised battery room fire such as from a single or multiple cell thermal runaway	Battery Rooms: Small Fire (L3-SF)	Damage to the affected module / unit. Unlikely to have any offsite consequences.	No modelling required, consequence based on the requirement that UL9540A tested and UL9540 certified cells are used.
L3-LF	Major failure of multiple systems leading to burnout of a full battery room	Battery Rooms: Large Fire (L3-LF)	Loss of entire battery room . Significant fire and smoke produced. Potential for fire spread from the BESS cabinets. Significant thermal effects are likely. The potential for an explosion event and toxic gas emissions.	TBC for the FSS based on battery room design ³
L3-EX	Significant failure leading to multiple cells venting to produce a vapour cloud explosion / release of battery electrolyte	Battery Rooms: Explosion (L3-EX)	Loss of entire battery room, potential damage to adjacent equipment and personnel if present. Depending on severity of the blast there is potential for an offsite hazard.	EFFECTS modelling of hydrogen build-up and vapour cloud explosion. We will assume the volume of 1 battery room is filled with hydrogen gas to LEL, with no consideration of the unit's structural strength.
L3-GR	Major failure of multiple systems leading to venting of a full battery room. This could be thermal runaway with or without a fire. This scenario considers only the toxic effects.	Battery Rooms: Gas Release (L3-GR)	Potential for a significant release of hydrogen fluoride (HF) or other gases which pose a significant toxic risk. Gases can spread easily and could pose an offsite risk and risk to onsite personnel	EFFECTS Li-ion battery storage thermal-runaway model (Bugryniec et al., 2024). HF emission factor for LFP set to "High" (95th percentile, 223 mg/Wh). The entire unit over burn duration is assumed to be 90 minutes.
L4-SF	Small oil leak occurs, which results in a small fire.	Power Transformer: Small Fire (L4-SF)	Damage to the Transformer.	No consequence modelling required as this is a small fire.
L4-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Power Transformer: Large Fire (L4-LF)	Fire spread beyond the Transformer.	EFFECTS pool fire set within the bund. TBC for FSS ³
L4-EX	Overheating of the transformer oil results in a BLEVE-type event.	Power Transformer: Explosion (L4-EX)	The explosion impacts the adjacent system and personnel nearby.	No modelling required, consequence will be based on AS 2067 – e.g. design to comply with AS 2067.
L4-SL	Small leak during operations	Power Transformer: Small Leak (L4-SL)	Personnel, slips. No facility impact.	No consequence modelling required
L4-LL	Large leak during operation / incident	Power Transformer: Large Leak (L4-LL)	Personnel, slips. No facility impact.	No consequence modelling required
L4-SS	Small spill during refiling	Power Transformer: Small spill (L4-SS)	Personnel, slips. No facility impact.	No consequence modelling required
L4-LS	Large spill during refilling	Power Transformer: Large spill (L4-LS)	Personnel, slips. No facility impact.	No consequence modelling required
L5-SF	Small oil leak occurs, which results in a small fire.	Auxiliary Transformer: Small Fire (L5-SF)	Damage to the Transformer.	No consequence modelling required as this is a small fire.
L5-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Auxiliary Transformer: Large Fire (L5-LF)	Fire spread beyond the Transformer.	EFFECTS pool fire set within the bund. TBC-oil volume and type to be confirmed by the client for the FSS ³
L5-EX	Overheating of the transformer oil results in a BLEVE-type event.	Auxiliary Transformer: Explosion (L5-EX)	The explosion impacts the adjacent system and personnel nearby.	No modelling required, consequence will be based on AS 2067
L5-SL	Small leak during operations	Auxiliary Transformer: Small Leak (L5-SL)	Personnel, slips. No facility impact.	No consequence modelling required
L5-SS	Small spill during refiling	Auxiliary Transformer: Small spill (L5-SS)	Personnel, slips. No facility impact.	No consequence modelling required
L6-SF	Small oil leak occurs, which results in a small fire.	Neutral / Earth Transformer: Small Fire (L6-SF)	Damage to the Transformer.	No consequence modelling required as this is a small fire.
L6-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Neutral / Earth Transformer: Large Fire (L6-LF)	Fire spread beyond the Transformer.	EFFECTS pool fire set within the bund. {TBC-oil volume and type to be confirmed by the client for the FSS ³
L6-EX	Overheating of the transformer oil results in a BLEVE-type event.	Neutral / Earth Transformer: Explosion (L6-EX)	The explosion impacts the adjacent system and personnel nearby.	No modelling required, consequence will be based on AS 2067

³ This item is intentionally TBC. The intent is for it to be carried forward to the Fire Safety Study. It is not necessary to assess it as part of this PHA.

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ID	Context	Location & Type	Potential Consequences	Applicable Consequence Analysis
L6-SL	Small leak during operations	Neutral / Earth Transformer: Small Leak (L6-SL)	Personnel, slips. No facility impact.	No consequence modelling required
L6-SS	Small spill during refiling	Neutral / Earth Transformer: Small spill (L6-SS)	Personnel, slips. No facility impact.	No consequence modelling required
L7-SF	Diesel generator small fire - Localised small fire from small source or spillage.	Diesel Generators: Small Fire (L7-SF)	Damage to the affected module / unit. Potential for radiant heat between equipment. Potential for fire spread over a long period.	No consequence modelling required as this is a small fire.
L7-LF	Diesel generator large fire - major fire assuming full contents of diesel tank released	Diesel Generators: Large Fire (L7-LF)	Damage to the affected module / unit. Potential for fire spread between equipment due to size of fire.	EFFECTS pool fire set within the bund. TBC-oil volume and type to be confirmed by the client for the FSS ⁴
L7-SL	Small leak during operations	Diesel Generators: Small Leak (L7-SL)	Personnel, slips. No facility impact.	No consequence modelling required
L7-SS	Small spill during refiling	Diesel Generators: Small spill (L7-SS)	Personnel, slips. No facility impact.	No consequence modelling required
L8-SF	Small leak or spill results in a small fire	Diesel Tanks: Small Fire (L8-SF)	Hospitalisation of personnel and limit damage to the facility	No consequence modelling required as this is a small fire.
L8-LF	Large leak or spill results in a large fire	Diesel Tanks: Large Fire (L8-LF)	Death to personnel and noticeable damage to the facility.	Qualitative assessment
L8-SL	Small leak during operations	Diesel Tanks: Small Leak (L8-SL)	Personnel, slips. No facility impact.	No consequence modelling required
L8-LL	Large leak due to take failure	Diesel Tanks: Large Leak (L8-LL)	Personnel, slips. No facility impact.	No consequence modelling required
L8-SS	Small spill during refiling	Diesel Tanks: Small spill (L8-SS)	Personnel, slips. No facility impact.	No consequence modelling required
L8-LS	Large spill during refilling	Diesel Tanks: Large spill (L8-LS)	Personnel, slips. No facility impact.	No consequence modelling required
L9-SF	Small electrical fire within the switchboard or associated systems	Data centre power system: Small Fire (L9-SF)	Personnel can be expected to require hospitalisation, whilst the facility damage only the switchboard.	No consequence modelling required as this is a small fire.
L9-LF	The switchboard or associated system is completely engulfed, and fire may spread	Data centre power system: Large Fire (L9-LF)	Personnel can be expected to be impacted whilst the fire spreads within the battery room.	A model is be undertaken to show if there is any potential for fire spread within the context of the surrounding equipment. This is only required to be done for the FSS.
L9-EX	An arc flash event associated with a switchboard.	Data centre power system: Explosion (L9-EX)	The explosion impacts the adjacent system and personnel nearby.	No modelling required. Arc flash assessment.
L10-SF	Switch room small fire - localised small fire due to storage of combustibles.	Switchboard and Control Room: Small Fire (L10-SF)	Personnel can be expected to require hospitalisation, whilst the facility damage only the switchboard.	No consequence modelling required as this is a small fire.
L10-LF	Switchgear fire spreads across the room(s), or a lead-acid battery hydrogen explosion results in a large fire.	Switchboard and Control Room: Large Fire (L10-LF)	Personnel can be expected to die whilst the fire spreads within the battery room.	A model is be undertaken to show if there is any potential for fire spread within the context of the surrounding equipment. This is only required to be done for the FSS.
L10-EX	An arc flash event associated with a switchboard or a hydrogen explosion associated with the lead-acid battery system located within the switchboard and control room.	Switchboard and Control Room: Explosion (L10-EX)	The explosion impacts the adjacent system and personnel nearby.	No modelling required. Arc flash assessment.

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⁴ This item is intentionally TBC. The intent is for it to be carried forward to the Fire Safety Study. It is not necessary to assess it as part of this PHA.

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5.3 Tools & Methods

5.3.1 This section sets out a summary of the tools used for consequence analysis in the following subsections, their general inputs, limitations, and assumptions. Hazard specific inputs are within the relevant subsections, and further information on software tools are in the referenced appendix.

5.3.2 The following modelling software and calculation techniques have been used as part of this study:

- a) GEXCON EFFECTS
- b) GEXCON RISKCURVES⁵
- c) FIRE
- d) The Nuclear Regulatory Commission (NRC) Fire Dynamics Tools

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5.3.3 The majority of the consequence modelling has been undertaken using GEXCON EFFECTS, which applies methodologies from the TNO [6] "Yellow, Green, and Purple Books" to provide validated frameworks for fire, explosion, and toxic dispersion analysis. The following key assumptions have been applied to the consequence modelling:

- a) Source term characteristics (release rate, duration, inventory, phase, temperature, and pressure) must be defined by the user and significantly influence results.
- b) Terrain is simplified and generally treated as flat or homogeneous, with complex topographical features not explicitly represented.
- c) Meteorological inputs (wind speed, atmospheric stability class, ambient temperature, humidity) are assumed to be steady-state throughout the simulation.
- d) A true zero-wind condition cannot be modelled; dispersion requires a minimum non-zero wind speed (typically ~0.2 m/s) to maintain atmospheric turbulence and numerical stability within the software.
- e) Gas dispersion assumes ideal mixing behaviour and may not capture complex reactions, degradation, or particulate formation unless supported by the model.
- f) Pool formation and evaporation rates rely on flat surface conditions and do not reflect irregular containment or drainage.
- g) Obstructions and barriers are not fully modelled within the models
- h) Explosion modelling uses representative multi-energy assumptions and simplify real-world confinement conditions.
- i) Secondary hazards (projectiles, shrapnel, overpressure from enclosure rupture) are not inherently captured.
- j) Toxic dose calculations depend on the selected probit or concentration–time relationship and assume uniform exposure conditions.

⁵ Note RISKCURVES is only used for individual and societal risk assessments.

⁶ <https://www.gexcon.com/ebooks/>



5.3.4 GEXCON EFFECTS includes the model "Li-ion battery storage thermal runaway" to estimate the release of toxic substances during a battery thermal runaway. This empirical model relies on data from combustion experiments compiled by (Peter J. Bugryniec 2024).

- a) Thermal-runaway is treated as a gas release, not a chemically reactive or evolving multiphase system.
- b) A battery room fire cannot be modelled within the software, thermal radiation and fireball outputs are based on general combustion models, not battery-specific flame behaviour.
- c) HF is modelled as a pure toxic gas, with dispersion governed by standard atmospheric dispersion algorithms (e.g., dry plume, dense gas), without secondary reaction products.
- d) Battery module geometry is simplified, with the release represented as an orifice, vent, or area source, not a detailed cell-level failure mechanism.
- e) Constant release conditions are typically assumed, even though real thermal-runaway may vary significantly over time.
- f) No internal propagation modelling is included; EFFECTS does not simulate cascading cell failures or escalating heat output.

5.3.5 GEXCON RISKCURVES is a Quantitative Risk Assessment (QRA) software package used to evaluate the risk posed by hazardous facilities, dangerous goods storage, battery installations and chemical plants, pipelines, and similar major hazard facilities. It takes consequence modelling results (typically from EFFECTS) and combines them with event frequencies, population data, meteorological data, and ignition probabilities to calculate:

- a) Individual Risk Per Annum (IRPA),
- b) Location Specific Individual Risk (LSIR), contours,
- c) Societal Risk (F-N curves),
- d) Societal Risk Maps,
- e) Consequence Risk Assessments,
- f) Risk contribution and ranking analyses,
- g) Transport risk assessments,
- h) ALARP demonstrations, and
- i) Land-use planning studies.

5.3.6 Assumptions that RISKCURVES analysis is based on:

- a) Scenario Selection - Only selected hazardous scenarios are included,
- b) Frequency Data - Historical databases are assumed applicable to the installation,
- c) Population Assumptions - Population distributions are estimated, whilst occupancy factors are assumed,
- d) Meteorological Assumptions - Wind roses are assumed representative of long-term site conditions,
- e) Consequence Model Accuracy - Consequence footprints imported from EFFECTS or FLACS are assumed correct,

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- f) Vulnerability Assumptions - Probit models for injury and fatality are assumed valid,
- g) Ignition Assumptions - Ignition probabilities are estimated, and
- h) Exposure Assumptions - Receptors are assumed present according to assigned occupancy factors.

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5.3.7 Limitations that RISKCURVES is based on:

- a) Quality Depends on Input Data – Such as frequency of events, occupancy assumptions, population distribution, and weather data,
- b) Does Not Generate Consequences - RISKCURVES is primarily a QRA tool rather than a detailed consequence modelling package,
- c) Real Human Behaviour Is Simplified,
- d) Simplified Vulnerability Models - Fatality and injury predictions rely on published probit functions and dose-response relationships,
- e) Land Use Predictions - Future societal risk calculations depend on future population growth, future developments, and occupancy rates,
- f) Highly Sensitive to Event Frequency - Societal risk and IRPA outputs are often dominated by a small number of high-consequence scenarios,
- g) Transport Risk Simplifications, and
- h) Complex Site Effects May Require CFD to provide more accuracy assessment.

5.3.8 FiRE is an assessment tool used to simulate fire behaviour and evaluate its potential impacts on building occupants and structural elements. The software applies two-dimensional finite element analysis (FEA) with dynamic mesh generation to model complex heat-transfer processes with improved accuracy. FiRE provides advanced thermal-radiation assessment functionality, allowing direct interaction with building elevations and 3D panel selection to facilitate dose-based egress and tenability calculations.

5.3.9 The Nuclear Regulatory Commission (NRC) Fire Dynamics Tools (FDTs) are a set of Excel-based calculation methods for first principles fire hazard assessment. The tools use established fire-dynamics correlations from sources such as the SFPE Handbook and NFPA to estimate parameters including heat release rates, smoke layer formation, hot gas temperatures, and cable tray fire behaviour. Although developed for nuclear facilities, the methodology can be used for a high level screening analysis

5.3.10 The assumptions with these NRC sheets are:

- a) Calculations rely on empirical fire-dynamics correlations, providing simplified representations rather than detailed modelling.
- b) Analysis generally assumes steady or quasi-steady fire behaviour, without capturing rapid transients or suppression effects.
- c) Heat-release rates are user-defined and conservatively selected.
- d) Smoke and temperature predictions assume uniform mixing within the hot-gas layer.



5.4 Damage Thresholds

- 5.4.1 Each type of quantitative analysis carried out has a corresponding set of damages thresholds, related to life safety and the facility. This section sets out these values which are used across different assessments to determine the level of potential impact. These values are used in the analysis unless otherwise specified.
- 5.4.2 The damage thresholds are used to quantify the potential physical effects arising from hazardous events, including thermal radiation, overpressure and toxic exposure impacts. These thresholds provide a measure of the severity and extent of potential consequences but do not in themselves represent a measure of risk acceptability.
- 5.4.3 Risk acceptability will be assessed separately in the PHA in later section, using the criteria specified within HIPAP 4. Consistent with HIPAP methodology, consequence modelling results have been combined with event frequency analysis to calculate individual fatality risk and societal risk. Individual fatality risk contours and societal F-N curves have been developed and compared against the applicable HIPAP 4 criteria.
- 5.4.4 HF exposure in EFPEC is reported as different sets of contours, each with their own meaning and use for analysis. These contours are summarised in Table 11. All HF contours have been applied assuming occupants are outdoors. Indoor exposures are generally less, but these can be complicated to calculate and therefore in the initial assessment all contours are based on people being outdoors.

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Table 11: Summary of Toxic Exposure Contours

Toxicity Contour	Meaning / Intent
AEGL-3	AEGL-3 is define as an airborne concentration of a substance above which the general population could experience irreversible, serious, or long-lasting adverse health effects, or an impaired ability to escape. This is to be reported for three different durations of exposure, being 600 s, 1,800 s, and 3,600 s.
AEGL-2	AEGL-2 concentrations represent a level at which harmful health effects are expected and people exposed are likely to need to seek medical assistance. This is to be reported for three different durations of exposure, being 600 s, 1,800 s, and 3,600 s.
1% lethality	Exposure conditions resulting in a predicted 1% probability of fatality, determined using an accepted toxic-load and probit relationship that accounts for both concentration and exposure duration.

- 5.4.5 The assessment uses AEGL-2 and AEGL-3 contours as the primary consequence metric because the objective is to identify areas where members of the public may experience adverse health effects requiring emergency response actions such as shelter-in-place, restricted access or evacuation. AEGL criteria are recognised community exposure standards specifically developed for acute public



exposures and are therefore directly relevant to emergency planning and off-site consequence assessment.

- 5.4.6 The assessment also reports the 1% lethality contour derived from toxic-dose and probit modelling. This contour represents a fundamentally different endpoint, namely the area where the predicted probability of fatality is 1%. The 1% lethality contour is principally used for quantitative risk assessment and fatality-based land-use planning criteria, whereas AEGL-2 and AEGL-3 contours describe broader public health impact zones.
- 5.4.7 Accordingly, the AEGL and 1% lethality contours should be viewed as complementary rather than competing metrics. AEGL contours define potential health-effect zones for emergency planning purposes, while the 1% lethality contour defines the extent of potential fatality risk.
- 5.4.8 For blast modelling, the results are also to be reported in various sets of contours, each with their own meaning and use for analysis, these are as described in Table 12, which is partly replicated from HIPAP 6.

Table 12 Summary of Overpressure Contours

Overpressure Contour (kPa)	Description of Effects	Reference
3.5 kPa (0.5 psi)	<ul style="list-style-type: none"> 90% glass breakage No fatality and very low probability of injury 	HIPAP 6 – Table 2*
7 kPa (1 psi)	<ul style="list-style-type: none"> Probability of injury of 10%, no fatality. Repairable damage to internal partitions and joinery. 	HIPAP 6 – Table 2
14 kPa (2 psi)	<ul style="list-style-type: none"> House uninhabitable and badly cracked 	HIPAP 6 – Table 2
21 kPa	<ul style="list-style-type: none"> Reinforced structures distorted Failure of storage tanks. 20% chance of fatality to a person in a building. Often cause by debris, hence a significantly lower chance for occupants outdoors. 	HIPAP 6 – Table 2
35 kPa	<ul style="list-style-type: none"> Houses damaged beyond repair Wagons and plant items overturned. This is the threshold for eardrum damage. 50% chance of fatality for a person in a building and 15% chance for a person in the open. 	HIPAP 6 – Table 2
70 kPa	<ul style="list-style-type: none"> Threshold of lung damage. 100% chance of fatality for a person in a building or in the open. Complete demolition of houses. 	HIPAP 6 – Table 2

*HIPAP 6 has generally been referenced here instead of Appendix 9 of HIPAP 2, as the latter appears to have a printing error in the description of effects

- 5.4.9 For modelling focused on radiative heat fluxes, the key values for assessment are shown in Table 13.

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**Table 13 Heat Flux Criteria**

Heat Flux Contour (kW/m ²)	Description of Effects	Reference
35	Equipment failure, cellulosic material will ignite (piloted) within one minute exposure, significant change of instant fatality for people	Table B.3 from IEEE Std 979:2012 HIPAP 2 – Appendix 8
23	Likely fatality for extended exposure and chance of fatality for instantaneous exposure Spontaneous ignition of wood after long exposure Unprotected steel will reach thermal stress temperatures which can cause failure Pressure vessel needs to be relieved, or failure would occur	HIPAP 2 – Appendix 8
20	Inferred NCC acceptance criteria for fire spread between buildings based on Table C1V2 of NCC 2022 Volume One Cable insulation degrades	Table C1V1 from NCC Volume One 2022 Table B.3 from IEEE Std 979:2012
12.5 to 13	Piloted ignition of timber or fabric after long exposure. Significant chance of fatality for extended exposure and high chance of injury. Thin insulation backed steel may achieve thermal stress failure. Damage may occur requiring replacement of porcelain bushings/insulators Plastic melts	Table A.3 from AS 1530.4:2014 HIPAP 2 – Appendix 8 Table B.3 from IEEE Std 979:2012 Ausgrid Network Standard NS187
3	Hazardous operation conditions for firefighters where they may be expected to operate for short periods of time (up to 10 minutes)	Fire Brigade Intervention Manual

5.5 Environmental Inputs

5.5.1 This section summary of inputs that are used across multiple consequence analyses. These are provided here for simplicity, to avoid repetition.

5.5.2 For analysis considering wind speeds indicated in Table 14 are considered.

Table 14: Wind conditions considered

#	Wind Description	Speed
W1	Still conditions, no wind	0 m/s (0.2 m/s for EFFECTS)
W2	Average conditions	2.4 m/s from Para 3.1.18.

5.5.3 Wind direction is towards the closest system / adjacent equipment at the site, except for HF emission that is towards the closest off-site receptor. Note in Section 6, a wind rose is used to provide all directional HF dispersion for individual and societal risk. Whilst for consequence analysis of HF from a battery room, 7.5 m/s and 10 m/s is also assessed to determine impact of greater wind speeds.

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5.6 L3 Battery Rooms

- 5.6.1 Based on the initial screening, the hazards for the battery rooms requiring further analysis from the HAZID table only for gas release (HF).

L3-GR: Gas Release

- 5.6.2 Whilst lithium ion batteries (LIBs) produce many gases when undergoing thermal runaway or combustion, the primary gas of concern for this consequence analysis is hydrogen fluoride (HF) which is a highly toxic, corrosive, and lighter than air gas which is well studied and spreads easily. HF is produced in both fire and thermal runaway however all scenarios consider a thermal runaway-only event in terms of temperature. This is a conservative approach as given HF is already lighter than air, a fire would result in even lighter more buoyant HF gases which would more rapidly disperse resulting in dilution, and any concentrations of HF being at higher elevations, above occupied areas. The yields used however are from experiments including fire, which results in higher HF yields.
- 5.6.3 The determination of how much HF is provided from a cell is complex, as HF is the result of multiple chemical reactions dependent on water, and can be difficult to test for due to its high reactivity and corrosiveness. For the purposes of modelling in EFFECTS, the HF must be input in a quantity of mg/kWh of storage, and the energy per cell must also be input.
- 5.6.4 The Gexcon EFFECTS default values, considering a Low/Moderate/High/Very High options, are shown in Table 15. This table is from the Gexcon Technical Background document titled Li-ion Battery Storage Thermal Runaway, (Haaften, 2024). This reference describes how Gexcon has established these values based on several research papers which assess the amount of HF produced from cells. As HF results were not recorded in any of the fire tests, therefore, HF option of High has been selected. The cells are LFP type and therefore the high for LFP has been selected which is 223 mg/Wh, for each battery room with a capacity of 300 kWh.

Table 15: Default HF values from GEXCON Technical Background document

Chemical	Low (average) (mg/Wh)	Medium (68% percentile) (mg/Wh)	High (95% percentile) (mg/Wh)	Very High (99% percentile) (mg/Wh)
NMC				
HF	7.1	17.22	36.19	41.50
LFP				
HF	52.47	167.89	223.34	284.82

- 5.6.5 HF modelling is sensitive to the intensity of release due to it being easily dispersed. In other words, it is sensitive not only to the volume of gas released, but also to the timescale, with the same volume released over a shorter period being more onerous.



- 5.6.6 As the specific battery room has not been selected, generic fire behaviour of a battery room will be used to determine duration. A typical BESS unit comprising of multiple battery racks that has undergone a large scale fire test generally takes 6 hours to burn out. These BESS units generally contain four racks, which are similar in size to the battery rooms being used at this site. The burn out durations of the battery room could therefore be expected to take 90 - 120 minutes. To be conservative, 90 minutes will be used as this will provide a higher HF concentration.
- 5.6.7 This model has been conducted as a low momentum release at ground level based on Gexcon guidelines. In reality the HF emission would be out of a ventilation system which would dilute the HF as well as emit it with a velocity of around 5 m/s. Additionally, this emission would occur around 30 to 40 m above the ground. These differences make this consequence model very conservative. This is because as a requirement, each battery room must be provided with ventilation, and such ventilation would need to be discharged at the roof.
- 5.6.8 No sensitivity analysis has been conducted as the concentration used in this model is significantly higher than that expected. Therefore, any sensitivity analysis would be to reduce the HF concentration, which would result in a shorter reach of HF cloud. Additionally, this modelling will be redone in the fire safety study based on the product testing data.
- 5.6.9 The input parameters for the HF modelling are presented in Table 16.

Table 16: HF modelling input

Parameter	Value	Justification
Chemical name	Hydrogen Fluoride	Chemical of interest
Type of release	Low Momentum release	Recommended model from Gexcon
Energy capacity	300 kWh	The energy capacity of a single battery room in kWh
Mass flow rate of the source	0.0124 kg /s	Calculated flow rate based on the above
Duration of release	5,400 s (90 minutes)	Duration based on the above
Representative temperature	150°C	This is the temperature corresponding to the reported outflow rate. This value describes exit conditions at the representative flowrate.
Meteorological data	Pasquill	Stability class of wind
Pasquill stability class	F for no wind and avg wind / D for 7.5 m/s and 10 m/s	Pasquill class for wind speed
Reference height	10 m	Standard reference height of the wind conditions
Ambient temperature	20°C	Standard atmosphere
Ambient pressure	101.51 kPa	Standard atmosphere
Ambient relative humidity	50%	Melbourne humidity generally ranges between 44% to 64%



Parameter	Value	Justification
Roughness length description	Regular large obstacle coverage (suburb or forest)	Local environment
Receiver height	1.5 m	Head height

- 5.6.10 At this site the batteries are located within battery rooms, that are fire rated and fitted with a ventilation system. This ventilation system can be assumed to discharge the HF and air out at 5 m/s (vertically). The HF emission from the battery room would only be part of the of discharge which would be diluted and ejected well above ground level.
- 5.6.11 The analysis has been conducted for no wind, i.e., 0.2 m/s toward the closest receptor, and presented in Figures and . As can be observed the HF cloud would not impact any habitable buildings.
- 5.6.12 The analysis has been conducted for average wind, i.e., 2.4 m/s toward the closest receptor, and presented in Figures and . As can be observed the HF cloud will impact the residential buildings close to the site. Figures to show that as wind speed increases the range of the toxic environment decreases rapidly.
- 5.6.13 Extreme wind event has not been considered as this relates to gust, i.e., non-continuous event, and would disperse the HF faster. In other words, higher wind speed results in shorter downstream HF distribution downstream, but the HF is kept closer to the ground. Although much higher winds have been included in the analysis for completeness.
- 5.6.14 These contours show the extent of area expected to be exposed to AEGL-2/3 concentrations based on duration of exposure at intervals of 600 s (10 min), 1,800 s (30 min), and 3,600 s (60 min), plus 1% lethality.
- 5.6.15 The results of the modelling are summarised in Table 17. The model is based on a ground level release, recognising that releasing the HF at high level (as required in the final design) is expected to result in significantly reduced exposure relative to the modelled outcomes.

Table 17 HF Modelling Results

Wind Scenario	Maximum Distance (m)						
Duration Based Exposure Level	AEGL-2			AEGL-3			1% Fatality Dose
	600 s	1800 s	3600 s	600 s	1800 s	3600 s	
Still Conditions*	1	1	1	1	1	1	1
Average Wind (2.4 m/s)	137	264	327	95	181	225	136
7.5 m/s	26	48	59	18	34	42	19
10 m/s	23	42	51	16	29	36	16

*In still conditions the buoyancy of the plume results in immediate liftoff of gases meaning that little to no exposure is expected at ground level.

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L3-GR: Consequence Summary

- 5.6.16 Personnel / public within the HF emission cloud for a short period of time are not expected to suffer a significant injury although hospitalisation should be considered. If trapped or unaware of the incident death could occur, although that is more likely in very low wind speed conditions.
- 5.6.17 The only condition with significant offsite potential is the average wind, however this is measured based on a ground level release, for HF which is a lighter than air gas, given it would actually be ejected from the roof, the effects downwind would be minimal. In other words the modelled outcome are significantly more severe than the actual expected outcomes. The software used however most accurately reflects plume dynamics using the a release sub-model limited to ground level releases.
- 5.6.18 Facility damage from the HF emission is expected to be minor.

5.7 L4 Power Transformer

- 5.7.1 Based on the initial screening, the hazards for the Power Transformer requiring further analysis from the HAZID table only for large fire (loss of entire volume of oil within the unit).

L4-LF: Large Fire

- 5.7.2 Large fire event has been based on the entire volume of the oil within the Power Transformer, which has been assumed to be 45,000 kg. Additionally, to be conservative the oil is combustible.

- 5.7.3 The input parameters for the HF modelling are presented in Table 18.

Table 18: Site transformer pool fire modelling inputs

Parameter	Value	Justification
Chemical name	Fuel / bunker oil	Fuel in the transformer
Type of pool fire calculation	Two zone model Rew & Hulbert	Preferred model in EFFECTs for rectangular pool fire
Soot definition	Calculated / Default	Default values based on DIPPR database
Total mass release	45,000 kg	Size of oil supply
Temperature of pool	60°C	Oil assumes to have been heated before failure of the transformer
Type of pool shape	Rectangular	Shape of bund
Width of rectangular	21 m	Dimension of the bund
Length of rectangular	17.3 m	Dimension of the bund
Ambient temperature	20°C	Standard atmosphere
Ambient pressure	101.59 kPa	Standard atmosphere
Ambient relative humidity	50%	Melbourne humidity generally ranges between 44% to 64%



Maximum heat exposure (s)	300	It is expected that within 5 mins people would have moved away from this incident due to notification systems and management plans
Receiver height	1.5 m	Personnel head height

5.7.4 Figures 11 to 16 present the radiant heat analysis for the power transformer for no, average, and 10 m/s wind conditions.

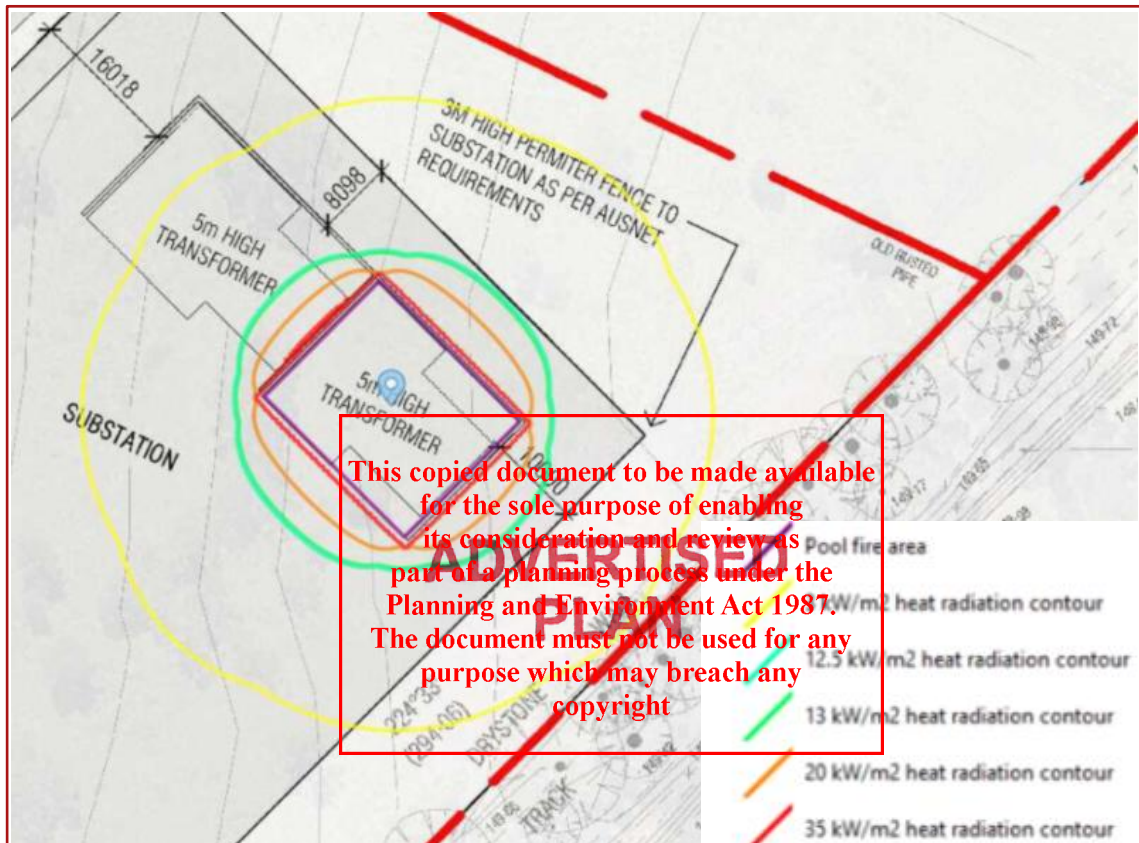


Figure 11: Radiant heat analysis from the Power Transformer – no wind top down

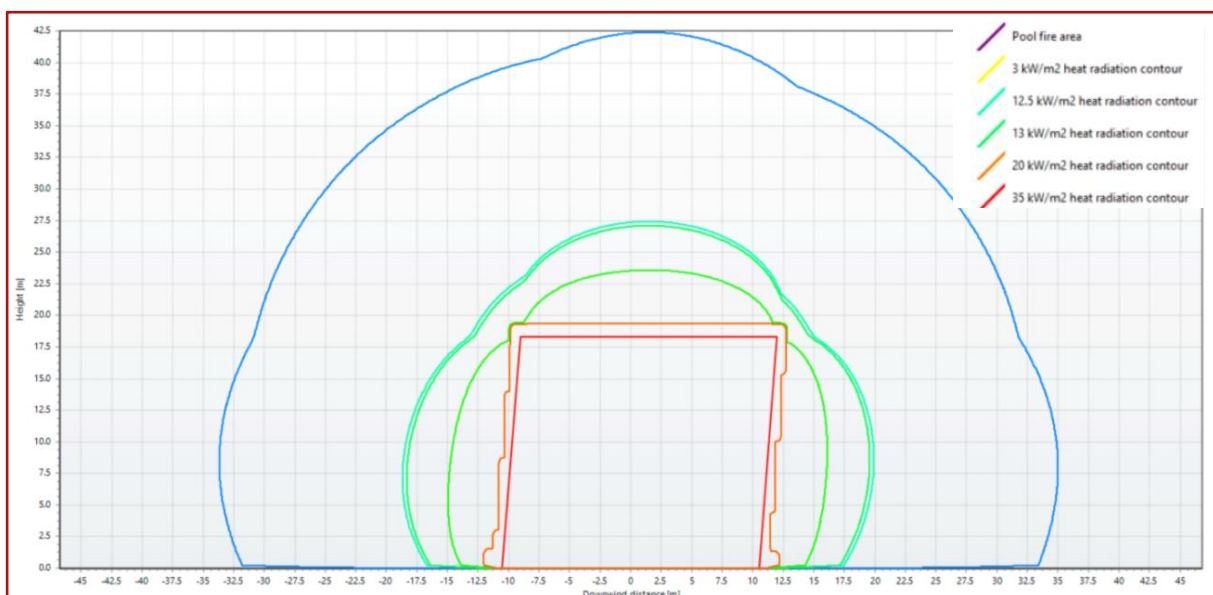




Figure 12: Radiant heat analysis from the Power Transformer – no wind elevation

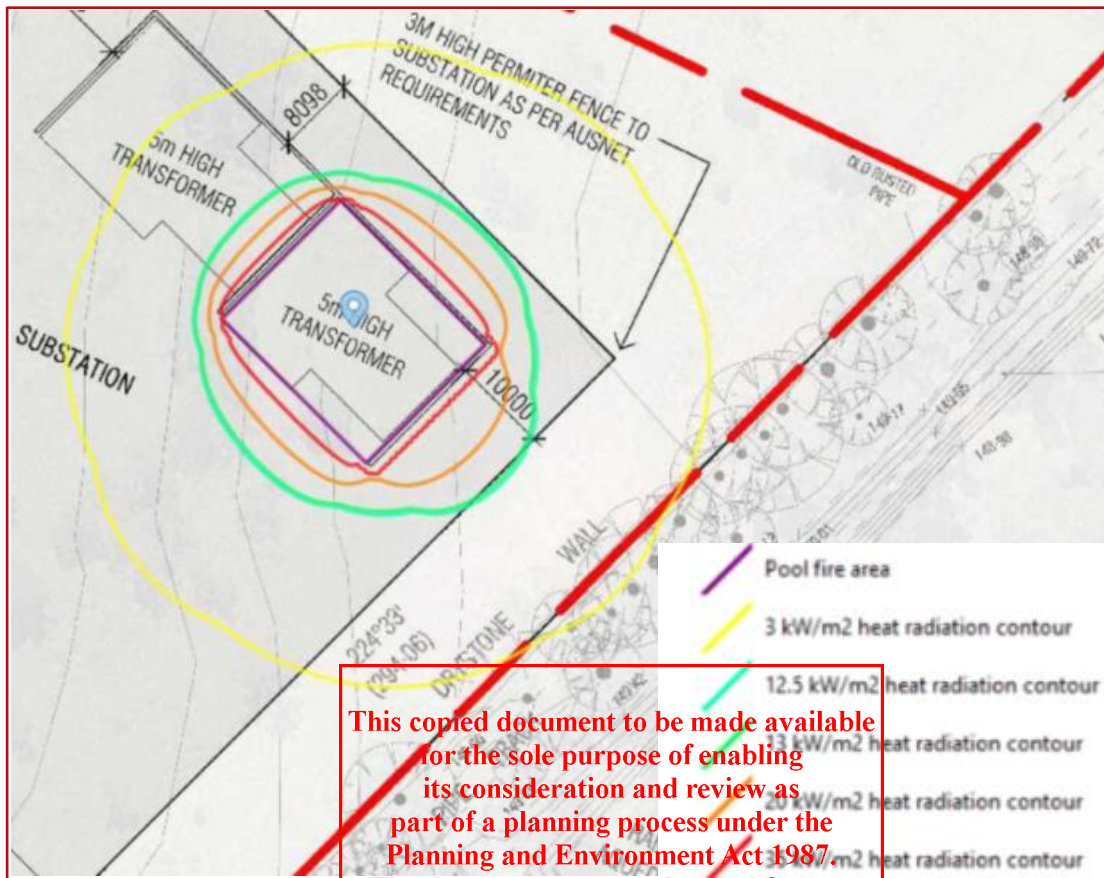


Figure 13: Radiant heat analysis from the Power Transformer – ave wind top down

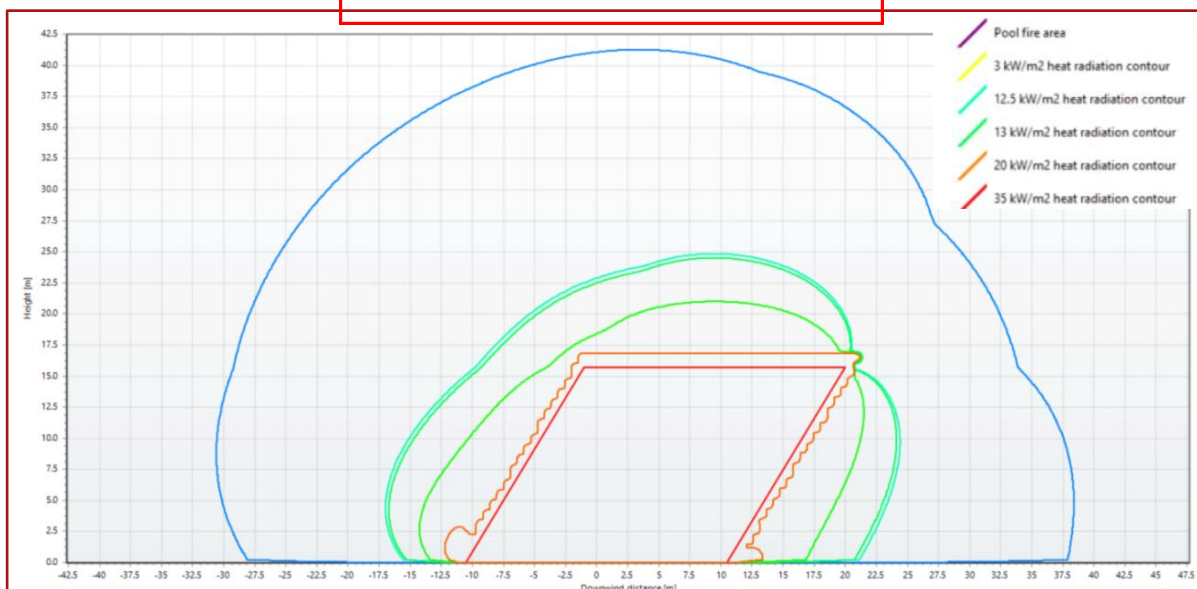


Figure 14: Radiant heat analysis from the Power Transformer – ave wind elevation

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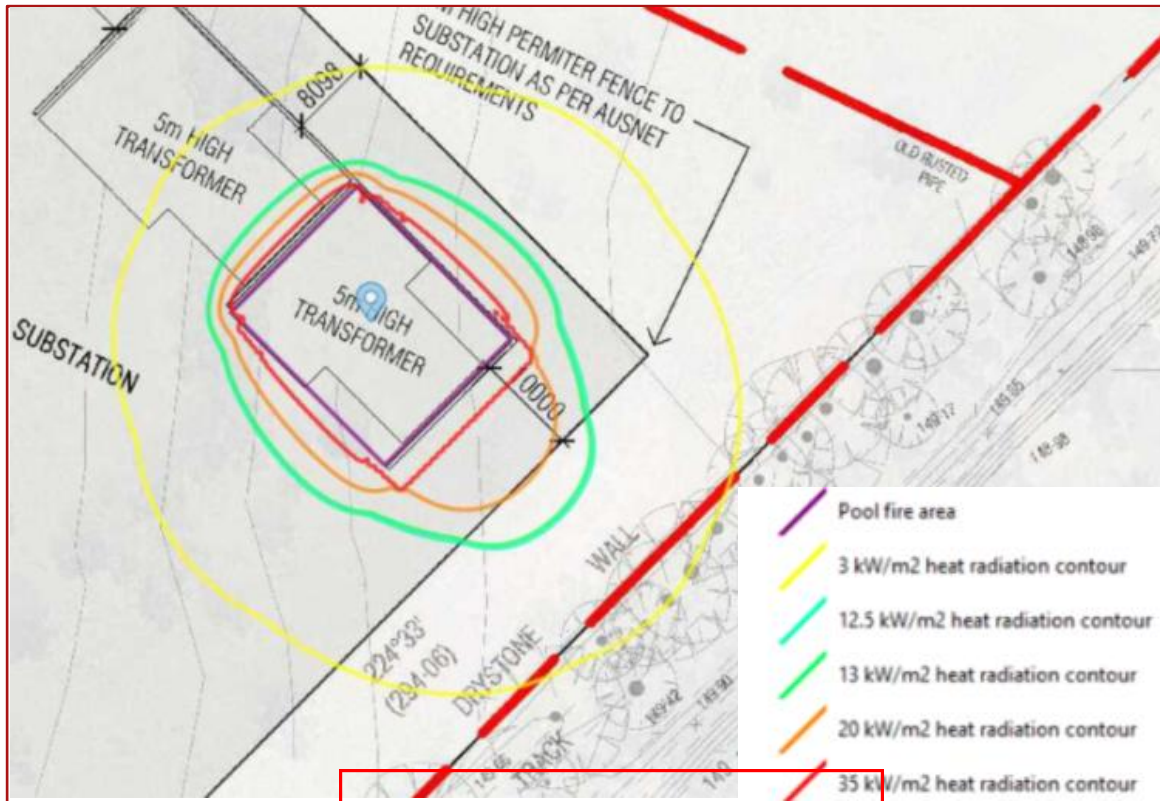


Figure 15: Radiant heat analysis from the Power Transformer – 10 m/s wind top down

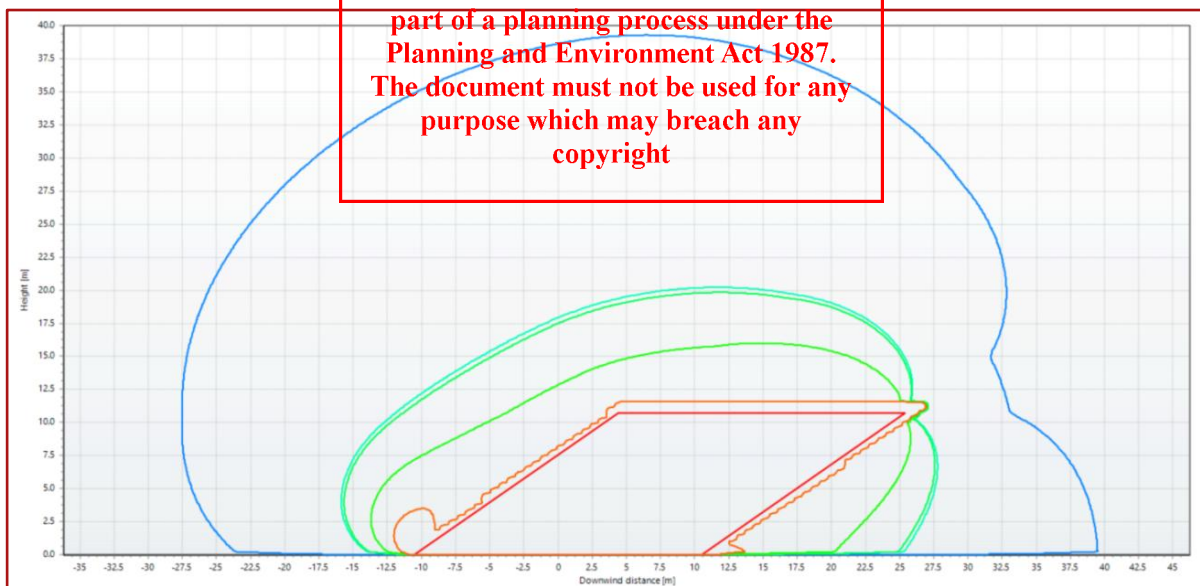


Figure 16: Radiant heat analysis from the Power Transformer – 10 m/s wind elevation

5.7.5 For all three scenarios the fire duration has been determined to be 3,643.1 s (1 hour and 43 s). The flame temperature has been determined to be 958°C and with a height of 18.3 m.

5.7.6 Table 19 provides a summary of the radiant heat reach for the scenarios.

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**Table 19: Radiant heat reach associated with event and wind conditions**

Criteria (kW/m ²)	Downwind (m)	Crosswind (m)
No wind		
1% lethality	48	98
3	34	67
12.5	18	33
13	18	33
20	15	26
35	12	19
Average wind		
1% lethality	51	94
3	38	65
12.5	22	34
13	21	33
20	17	27
35	12	21
10 m/s wind		
1% lethality	50	82
3	39	58
12.5	26	31
13	26	31
20	21	26
35	13	21

5.7.7 No sensitivity analysis has been conducted as three side of the power transformer bund are to be bound by a fire and blast wall, in accordance with AS 2067: 2016, (Standards Australia, 2016). In a sensitivity analysis the volume of oil could be changed, but that would only impact duration.

L5-LF: Consequence Summary

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5.7.8 Based on a fire and blast wall being fitted:

- Personnel close to the site transformer could suffer significant burns requiring hospitalisation, otherwise minor injuries are expected.
- The facilities, on site and off site, are not expected to suffer thermal damage but will lose its only site transformer.

5.8 L8 Diesel Tanks

5.8.1 Typically, the storage of large volumes of diesel such as proposed for this site would warrant a pool fire assessment to determine the potential offsite impacts of such a fire. This would be because large pool fires can result in significant thermal radiation/heat fluxes that can cross the site boundary. However, due to



the specific design of this building, such assessment is not necessary as explained below.

- 5.8.2 As the site is a vertically integrated data centre, rather than a low rise development, the tanks are inside the building, with no direct line of site to the outside. Without a line of sight, radiation from a tank fire can't reach the outside directly.
- 5.8.3 To further provide protection, whilst the design is still under a combination of the following measures is expected to be provided to the 15 x 110 kL tanks:
- The tanks are located partially below the natural ground level, in the basement storey which sits partly below ground.
 - The tanks are to be positioned in groupings, it is expected that there may be 3-5 different groupings,
 - Each tank is to be double skinned, with its own integral bund.
 - Each grouping is to be provided with an additional bund, capable of holding not less than 110% the volume of the largest tank in the grouping, with additional allowance for the fire protection system to be determined.
 - Each grouping is to be within a separate, dedicated, fire rated room, with an FRL of not less than (240)/240/240. Where possible, the fire rated enclosure to these rooms is to consist of non-structural walls (e.g. non-load bearing walls), to provide additional separation of structure from the tanks.
 - The potential need to exceed the minimum concrete cover requirements of AS 3600 to achieve 240 minute FRLs is to be reviewed and may be implemented in design development. Whilst no formal FRL above 240 exists in AS 3600, this would be a way to effectively achieve an FRL greater than 240-minutes.
 - Each diesel tank room is to be provided with an automatic fire suppression system, specifically intended for use on pool fires. It is expected that this may be a mist system, foam system, or other suitable system.
 - Fire hydrant locations relative to diesel storage are to be coordinated and agreed with FRV, with the potential need for additional hydrant locations to support tactical operations.

5.9 Consequence Summary

- 5.9.1 Based on the consequence analysis, a summary of off-site consequences is provided in Table 20. Where events have no off-site consequences, they are coloured **GREEN**, those with the potential for off-site injury only are coloured **YELLOW**, and those with the credible potential for off-site fatalities are coloured **RED**. Those in yellow and red are carried forward for frequency analysis. For this project, items in **PINK** are unique, representing those items that have a potential offsite consequence as modelled, whilst acknowledging that the model represents a more onerous outcome than the final design would permit.

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Table 20 Consequence Analysis Summary

ID	Context	Location & Type	Applicable Consequence Analysis	Summary of Off Site Consequence
L3-SF	Localised battery room fire such as from a single or multiple cell thermal runaway	Battery Room: Small Fire (L3-SF)	No modelling required, consequence based on the UL 9540A results.	No Impact
L3-LF	Major failure of multiple systems leading to burnout of a full battery room	Battery Room: Large Fire (L3-LF)	To be assessed in the FSS.	No Impact
L3-EX	Significant failure leading to multiple cells venting to produce a vapour cloud explosion / release of battery electrolyte	Battery Room: Explosion (L3-EX)	To be assessed in the FSS. EFFECTS modelling of hydrogen build-up and vapour cloud explosion.	No Impact
L3-GR	Major failure of multiple systems leading to venting of a full battery room . This could be thermal runaway with or without a fire. This scenario considers only the toxic effects.	Battery Room: Gas Release (L3-GR)	EFFECTS Li-ion battery storage thermal-runaway model (Bugryniec et al., 2024). HF emission factor for LFP set to "High" (95th percentile, 223 mg/Wh). The entire unit over burn duration is assumed to be 90 minutes.	Public off site could be impact by the HF cloud in some wind conditions, based on a ground level release. The actual design will include release at height, which would reduce offsite impacts.
L4-SF	Small oil leak occurs, which results in a small fire.	Power Transformer: Small Fire (L4-SF)	No consequence modelling required as this is a small fire.	No Impact
L4-LF	Loss of containment of the oil from the transformer, which results in a large fire.	Power Transformer: Large Fire (L4-LF)	To be assessed in the FSS. EFFECTS pool fire set within the bund.	No Impact
L4-EX	Overheating of the transformer oil results in a BLEVE-type event.	Power Transformer: Explosion (L4-EX)	No modelling required, consequence will be based on AS 2067	No Impact
L4-SL	Small leak during operations	Power Transformer: Small Leak (L4-SL)	No consequence modelling required	No Impact
L4-LL	Large leak during operation / incident	Power Transformer: Large Leak (L4-LL)	No consequence modelling required	No Impact
L4-SS	Small spill during refiling	Power Transformer: Small spill (L4-SS)	No consequence modelling required	No Impact
L4-LS	Large spill during refilling	Power Transformer: Large spill (L4-LS)	No consequence modelling required	No Impact

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6 Individual & Societal Risk Analysis

6.1 Introduction

6.1.1 Based on the consequence analysis, the following hazardous event has/have a potential significant off-site risk:

a) Battery Rooms

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6.1.2 These events have been carried forward for further analysis to determine the individual and societal risk they may pose. This is done by determining the number of people likely to be exposed to the event, and the frequency of the event. In some cases, this is a simple analysis of the area impacted and the likelihood the event, in other cases it requires further consideration of the probability and duration of the off-site area being occupied.

6.1.3 For instance, where an event only reaches a roadway off-site, in a remote area (no pedestrians), depending on the type of event both the probability and duration of occupation is necessary to determine the overall risk, in addition to the likelihood of the event itself occurring.

6.1.4 A risk curves model has been developed to show the individual fatality risk and the associated FN curves for off-site incidents. Figure 17 presents the population break down areas that surround the site and have been used in the modelling risk curve modelling. Table 21 sets out the daytime and night-time population parameters.

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Table 21: Population parameters

Population area	Daytime Population	Nighttime Population	Justification
Residential Area 1	70	70	Based on the proposed site of this new mixed use buildings ⁸
Residential Area 2	700	700	Based on approximate uses of the area and density
Residential Area 3	100	100	
Morang Service Reservoir	2	0	For typical maintenance workers potentially at the Reservoir
Commercial / Industrial Complex	50	2	Low capacity industrial area
Infinity Church	200	0	Based on maximum seating capacity of 220 persons. Assumed one (1) service per week
SM2 Data Centre	200	5	Based on typical data centre occupants
Terminal and Sub Station	8	0	Based on typical terminal and substation facilities

⁸ It is understood that this area is being redeveloped into a storage facility. Such change would be expected to reduce the population. Therefore, the existing population number has been used.



Population area	Daytime Population	Nighttime Population	Justification
Background	21,407	21,407	Based on census data ¹¹ and various estimates for this area of South Morang. The lowest value is 1,300 per km ² , therefore we also used a magnitude higher. In other words, a background population of 13,000 per km ² was used.

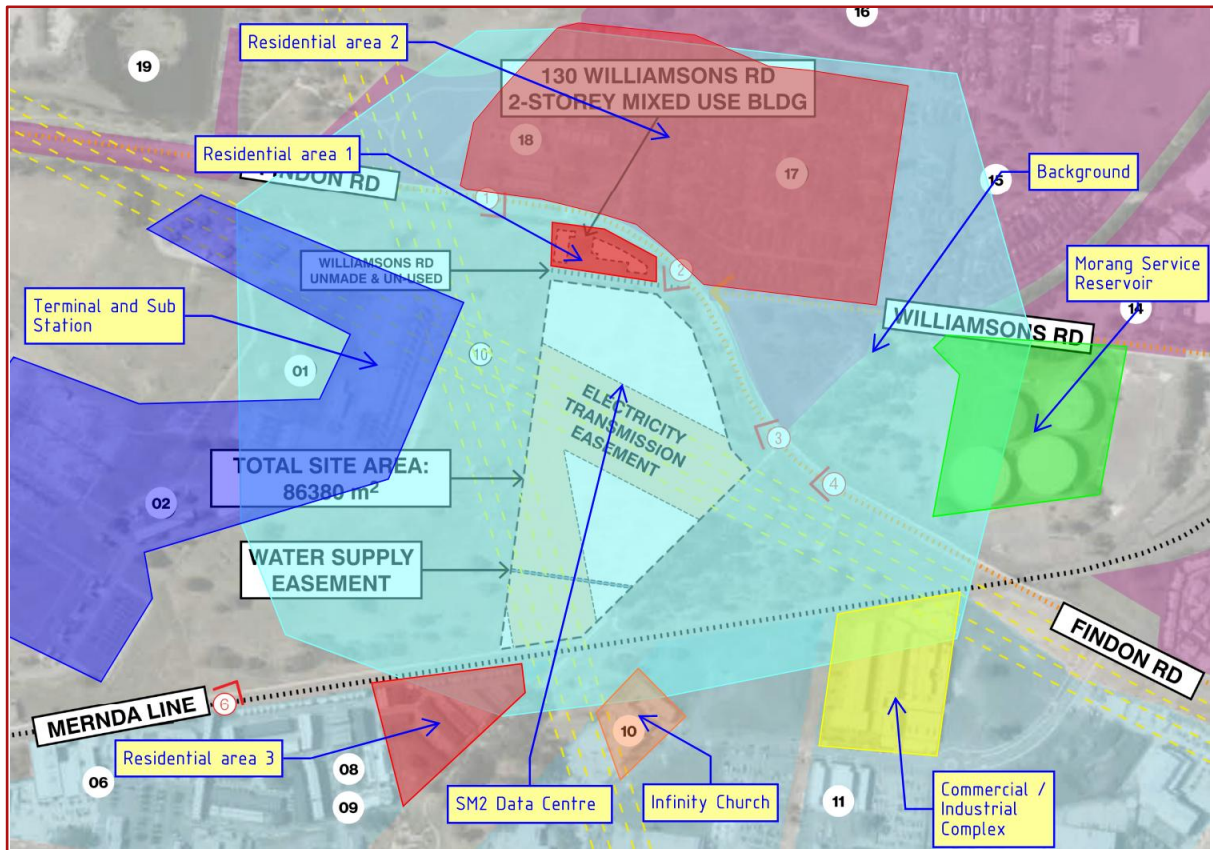


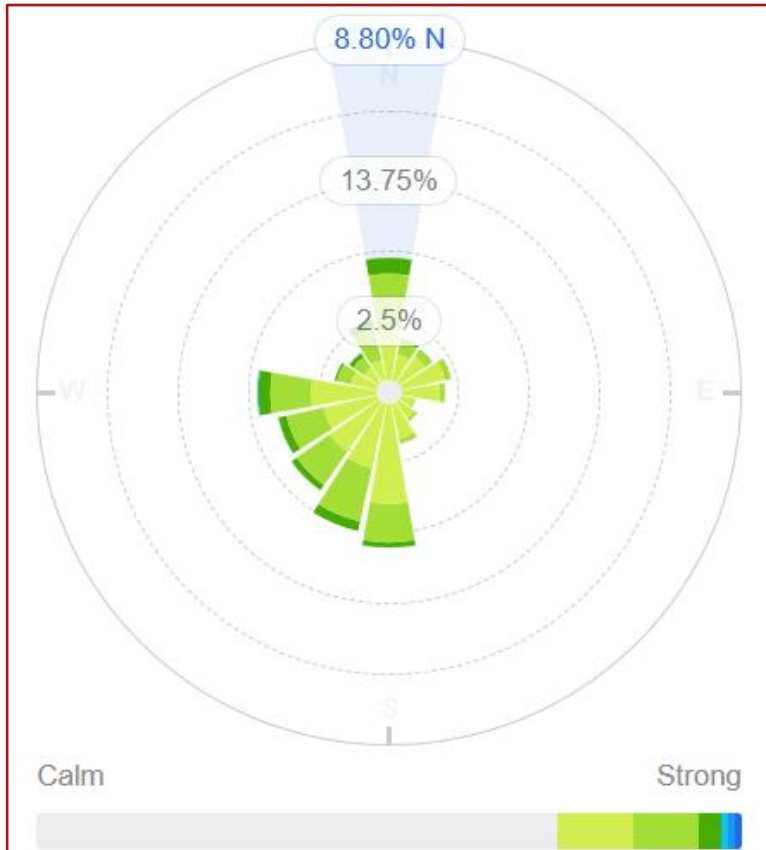
Figure 17: Population area surrounding the site

6.1.5 Figure 18 presents the last 5-year wind rose for the suburb South Morang. As can be noted that nearly 10% of the wind is northerly. The remaining wind blows mostly easterly to northerly, as well as southerly. Table 22 sets out the wind parameters used in RISKCURVES and shows similar characteristics to the wind rose, although it is from the Melbourne airport weather station.

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¹¹ <https://www.abs.gov.au/census/find-census-data/quickstats/2021/SAL22311> accessed 14 Sep 26



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Figure 18: Wind rose for South Morang ^[12]

Table 22: Wind inputs to RISKCURVES

Wind sector (from)	D5 Day (%)	B3 Day (%)	F2 Day (%)	D5 Night (%)
0	13.30	8.36	1.04	17.50
22.5	2.87	14.10	1.04	1.04
45	0.78	6.27	0.26	0.52
67.5	0.00	1.31	0.26	0.00
90	0.00	0.26	0.00	0.00
112.5	0.00	0.26	0.78	0.26
135	0.52	3.39	0.26	1.04
157.5	2.87	2.87	1.30	1.04
180	2.87	1.57	3.39	12.50
202.5	1.83	3.66	9.11	20.30
225	2.35	1.83	1.82	2.60
247.5	2.09	3.92	0.26	2.34
270	2.09	2.61	0.52	4.43
292.5	2.35	2.35	0.78	2.60
315	2.61	1.57	0.78	3.65
337.5	6.35	2.61	0.78	7.81

¹² From <https://wind.willyweather.com.au/vic/melbourne/south-morang.html> Accessed 09 Sep 26



6.2 L3-GR: Hydrogen Fluoride Gas Release from Battery Rooms

- 6.2.1 The results of the L3-GR consequence modelling show that an off-site area may be impacted by the HF gas release. The offsite impact is by the AEGL-3 levels or 1% lethality, which do pose a hazard to health and life, though the probability of fatality is considered low due to the exposure duration required.
- 6.2.2 The wind rose presented indicates that prevailing winds only occasionally travel toward the nearby residential areas.
- 6.2.3 The consequence modelling indicates that hydrogen fluoride (HF) gas generated during the assessed incident scenarios extends beyond the site boundary under all wind conditions other than still. The extent of the dispersion plume varies depending on the prevailing meteorological conditions. However, off-site impacts are predicted in all assessed scenarios.
- 6.2.4 The likelihood of any Li-ion battery fire comes from (Electric Power Research Institute, 2022), where it notes the failure rate for Li-ion batteries in a BESS arrangement, which could result in a fire, is 1 in 40 million per cell years.
- 6.2.5 The battery rooms has not been selected, but systems with this capability generally have around 200 Li-ion cells. Noting there are 154 battery room within the building, then the total number of Li-ion cells is 30,800. Therefore, the frequency would be 1 in 1,298 years. This fire event aligns with a single Li-ion cell going into thermal runaway. From the UL 9540A Li-ion module test it is known that it's unlikely that this event would result in a catastrophic battery room fire. Therefore, we consider technical specification violation (human error) by maintenance staff, which from (Alber, et al., 1995), is $1E-3$ per demand. In other words, this assumes that the cause of full unit failures is from manual incidents. Noting there are 154 battery rooms and access to these rooms does not need to occur regular, i.e., just over twice a year, then the overall risk is extremely low.
- 6.2.6 Figure 19, presents the individual risk curve for individual incident distribution for 1,300/km² background population. As can be noted $1E-6$ year¹³ contours just go beyond the boundary of the site and is not expected to impact Resident 1. As can be seen from the figure, the individual risk offsite is within the acceptance limit. Individual risk is independent of total population, and therefore doesn't change with an increased population, unlike societal risk.

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¹³ This relates to 1 in million years from HIPAP 4, (NSW Department of Planning, 2011).

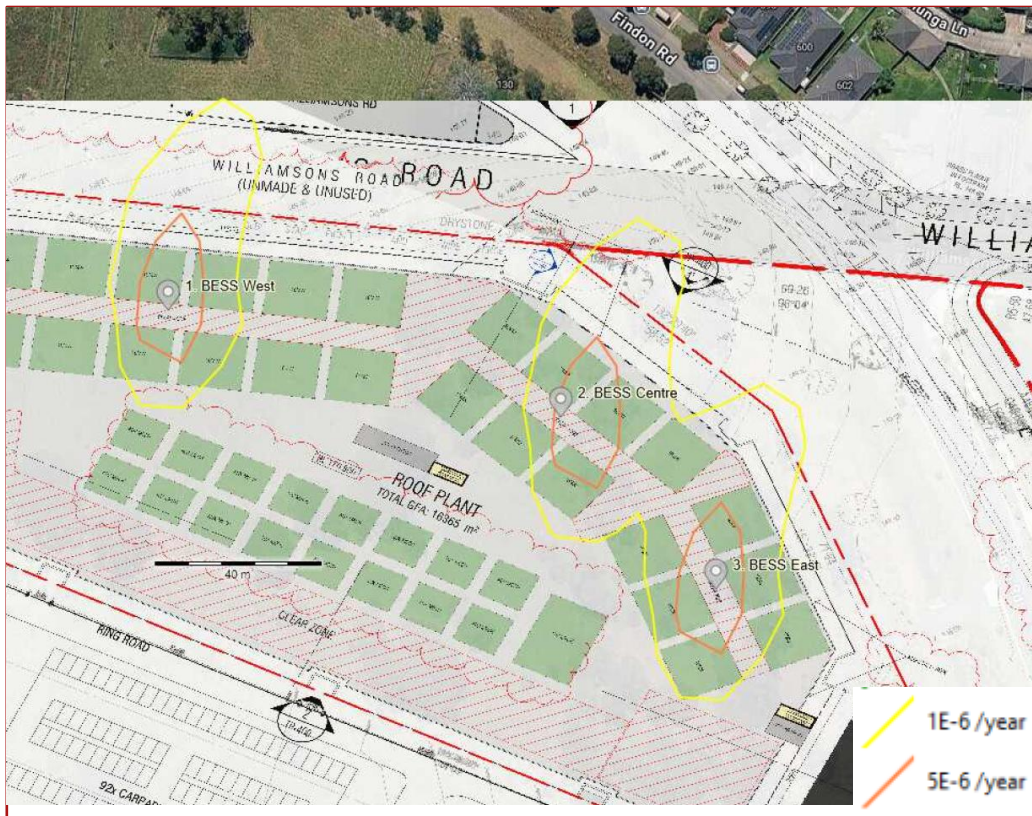


Figure 19: HF dispersion contours from the site, baseline background population – Yellow is the acceptance criteria

6.3 Cumulative societal risk

- 6.3.1 Using the baseline background data no F-N curve is generated, as the population impact is too small, and therefore the societal risk is too small to result in a F-N curve.
- 6.3.2 Figure 12¹⁴ presents the outcome of HF dispersion with the background population increased by an order of magnitude. As can be seen ALARP is satisfied. To achieve SFAIRP off site notification will be considered and detailed in the fire safety study.

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¹⁴ FN curve can only demonstrate that ALARP has been met and note that there are additional beneficial control measures can be applied.

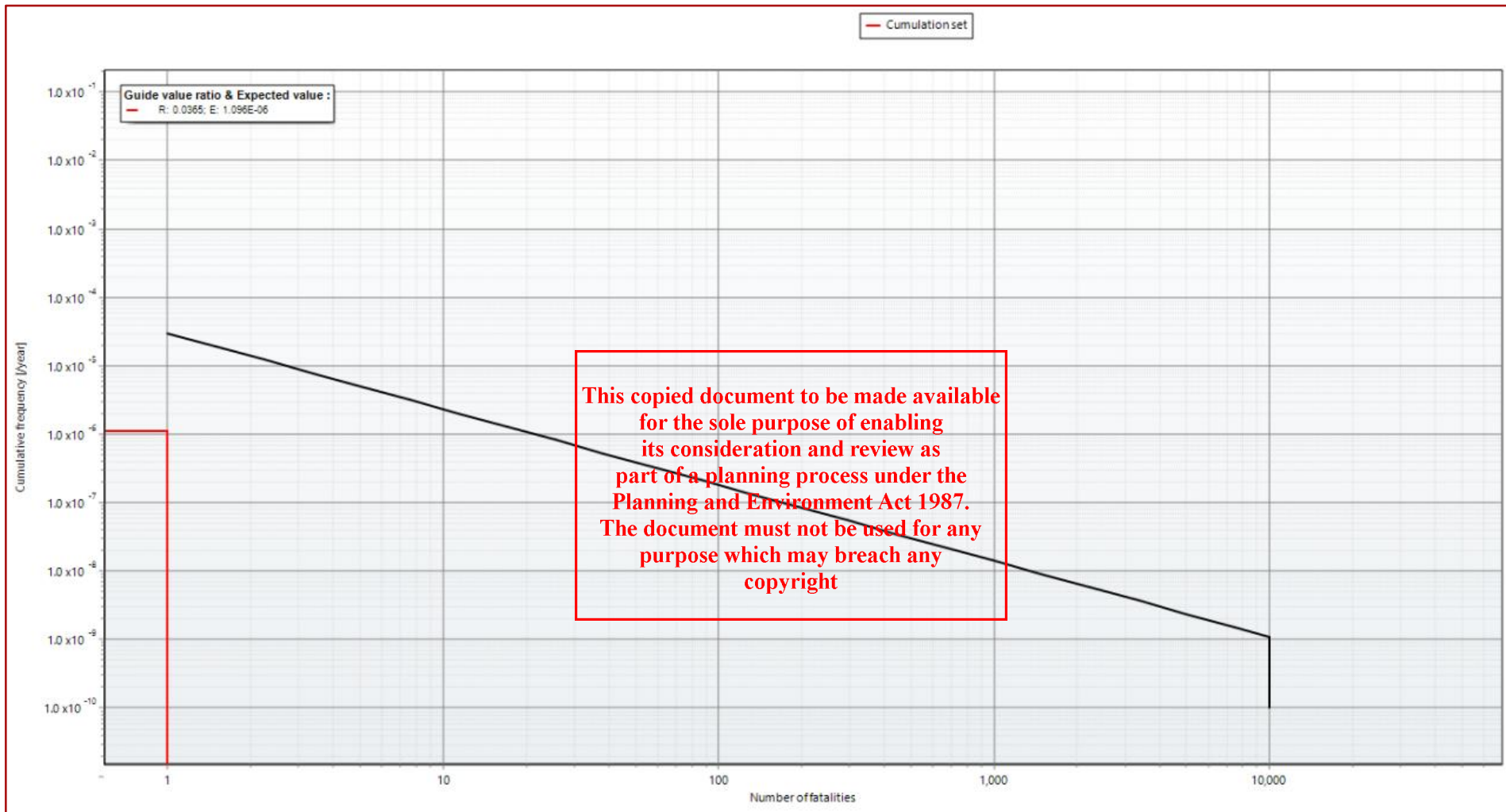


Figure 20: Society risk for battery room HF emissions with population artificially increased by an order of magnitude (13,000 people per km²)

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7 Recommendations

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7.1 Introduction

- 7.1.1 This section sets out the high level expected measures to be provided at the site. As a PHA, this is not an exhaustive list of recommendations / control measures. This PHA has been produced on the basis of the site having control measures typical of comparable sites and particularly having control measures which are already required as part of legislation including applicable Standards.
- 7.1.2 As an example, lightning protection is already a typically required feature of many buildings, especially if associated with significant electrical / electronic systems. This PHA assumes that lightning protection and grounding would be designed, installed, and maintained as appropriate to the relevant Australian Standards.

7.2 Summary of Individual and Societal risk

- 7.2.1 The acceptance criteria for fatality of commercial development are 1xE-6 per year from HIPAP 4 (NSW Department of Planning, 2011). This means all scenarios considered in this PHA are acceptable.

7.3 General Recommendations

- 7.3.1 The following general recommendations are expected for this Data Centre site; these are preliminary and will be reviewed in the FSS:

Table 23 Proposed Control Measures

#	CM Title	CM Description
CM1	Safe Practices	An emergency response plan is to be developed for the site in addition to safe operational procedures and the like to instruct staff how to safely conduct business at the site.
CM2	Two-way communication	If/when operated unstaffed/from a remote station, two-way communication must be provided to site for responding staff/brigade. If the site is to operate unstaffed, the response time for a staff member in an emergency is to be considered in the emergency plan.
CM3	Portable Fire Extinguishers	PFE's to be provided as a minimum to NCC BCA and AS 2444, with additional fire extinguishers around small diesel storage (i.e. generator diesel tank) and outside of switchgear rooms with electrical hazards. Details/extent to be developed by the fire services engineer and in line with the future fire safety engineer's requirements.
CM4	Fire hose reel	Foam fire hose reels are to be provided only for the diesel tanks and diesel generator areas. Whether fire hose reels in general are provided elsewhere is subject to the building fire engineering by Orbe.
CM5	Fire Brigade	A large fire is to be responded to by the fire brigade. Associated with this control measure is a fire hydrant system that provides coverage and water supply for the site as set out in AS 2419.1:2021 for the entire site, with potential modifications to be subject to R129 consent and approval as the design is developed.
CM6	Fire truck access	Around the data centre building and to the substation, there shall be appropriate fire truck access and mobility.



#	CM Title	CM Description
		This shall meet all the requirements from the Fire Rescue Victoria guideline and/or R129 approval, recognising that the data centre building is a large isolated building.
CM7	Switch Room Fire Protection	HV/MV switch rooms associated with the substation are likely to have fire suppression, subject to Ausnet final design, as Ausnet is the design authority for that area. AusNet design is to consider automatic power isolation if appropriate. Building LV switch rooms typically are proposed either as fire separated (no suppression) or may have a double knock sprinkler/mist system with location detection.
CM8	Basement level fire suppression system for diesel storage	A suitable fire suppression system is to be provided to the basement diesel storage area. This may for example be a mist system, or foam suppression system paired with detection, subject to further design development. All tanks are to be double skinned/self-bunded.
CM9	GenSet area fire suppression system	A suitable fire suppression system is to be provided to the GenSets. This may for example by a mist system or foam system, with details to be developed as the design progresses. The system must be approved/recommended for protection of generators. There is also to be fire separation around the generators, with the number of generators per fire compartmented area to be determined in detailed design.
CM10	Battery Room Fire Suppression System	A suitable fire suppression system is to be provided to battery rooms. This may for example be, a high-density sprinkler system or mist system, paired with AS 1670.1 detection as well as specialist flammable gas detection such as Li-ion tamer or hydrogen gas detection.
CM11	Service and office area fire suppression system	A suitable fire suppression system is expected to be provided to the general areas such as office spaces and the like, other than specific areas with unique hazards. This may for example be standard sprinklers, in accordance with AS 2118.1: 2017. Removal of this system to general office areas however should not impact the findings of the PHA.
CM12	Data halls fire suppression system	A suitable fire suppression system is to be provided to the data halls. For example, a pre-action sprinkler system with aspirating detection throughout.
CM13	Fire Indicator Panel (FIP)	Fire detection and alarm systems, which meet AS 1670.1:2018, across the site, are to be connected to the main FIP (MFIP) via the FIP standard communication system. Any departures are to be agreed with the fire safety engineer, and some areas are expected to have enhanced detection. The fire safety study is to consider whether specific battery management system (BMS) alarms should be fed to the MFIP, and if doing so can be done in accordance with AS1670.1 or AS 4418.2 where SCADA is used.
CM14	Fire and smoke detection and alarm system	AS 1670.1 compliant, or as agreed with the Fire Safety Engineer and FRV. The technology utilised is to be suitable for the application.
CM15	Automatic power shut off	The BMS for each battery system is to be capable of automatically isolating batteries at module or rack level on identification of faults/unsafe to operate conditions. This must include abnormally high temperature.
CM16	Low voltage management system	Residual Current Device (RCD), to be provided in accordance with AS 3000. Additional isolation to protect

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#	CM Title	CM Description
		fire brigade may need to be considered in future design stages.
CM17	Site security	There are two parts to this control measure: a. The entire site is enclosed by a security fence, b. The site access gates are to be covered by CCTV. CCTV will include motion sensing and an alarm system to notify staff of personnel moving around the site. Additionally, the doors of the data centre and the switchboard and control room are to be monitored. On unauthorised access and alarm is to notify the site operator.
CM18	Fire fighter access	The site operator and after hours site authorised representative are to be available to provide the fire brigade rapid access and support during an incident. This is to be further detailed in the FSS depending on whether the planned operation includes 24/7 on-site staffing or a mixture of on-site staffed hours and remote operation/management.
CM19	Spill kit arrangement	Appropriate spill kits are to be located near sources of dangerous goods, such as the diesel tanks and refuelling point.
CM20	First Aid kit	First Aid kits shall be provided on site, and located best to suit data centre operational and maintenance requirements. The operator is to review the requirements for first aid kits in line with their OHS responsibilities.
CM21	Personal Protective Equipment (PPE)	All PPE is to be fit for the task and potential exposure of staff. The operator is to define appropriate PPE for tasks and clearly describe them in evaluation processes, Standard Operating Procedures (SOPs), and/or Safe Working Method Statements (SWMS), as appropriate.
CM22	Site wide incident notification	Within buildings, audio notification devices shall comply with AS 1670.1:2018, i.e., a Building Occupant Warning System (BOWS). Horn systems may be used outside the area of the site; this is to be connected to the BOWS.
CM23	Management Plans	Associated with a future Fire Safety Study, the following management plans are to be developed and issued: a. Emergency Plan, b. Evacuation Plan, c. Emergency Information Book, and d. Dangerous Goods Manifest and Emergency Information
CM24	System monitoring	Site to have environmental sensors which can inform the site operator of at least temperature and wind (direction and speed), i.e., a weather station. All system sensor data to be shared with the site operator, with notification related to potential / actual incidents. Details of notification to be developed as design progresses.
CM25	Site incident management	The site operator will need clear procedures for engaging and supporting emergency services during an incident. This would include when to call them, providing system data to them, and connecting them with the battery system operators/support.
CM26	Emergency Services	Access and procedures for when to call emergency services.
CM27	Site housekeeping	At least a monthly site inspection to remove unnecessary combustible material from the site.
CM28	Selection of Electrical Systems	Selection of all systems that are appropriate for the operations and the environment where they are to be located. This is to be shown by compliance with Standards. For example, where required rodent proof mesh or similar is to be provided to protect systems'.

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#	CM Title	CM Description
CM29	Installation and maintenance of systems	Correctly qualified and experienced personnel are to be used to install and maintain the system.
CM30	Impact protection	Protection of external systems from vehicle damage is to be achieved by mechanical impact devices, such as bollards near the roads associated with the building and electrical system. These impact protection systems shall at least be located on the curves of the roads. An on-site speed limit is to be enforced to minimise risks of impact near equipment.
CM31	Lightning protection	Electrical systems and their associated cabling arrangements are to have lightning protection as required under AS 1768:2021.
CM32	Cyber attack protection	Cyber attacks could result in damage / fire to systems such as battery rooms and the diesel generators. Therefore, appropriate cyber protection measures are to be taken.
CM33	Access to meteorological data	The site operator is to have access to regional meteorological data.
CM34	Response to a battery room incident	Within the battery rooms, if the detection systems (lithium tamer or similar systems) activate then the site operator is to call the fire brigade (if not done within 300 s, then automatic call out is to occur), activate the site notification system, and isolate the affected battery room. If after hours, call out a site authorised representative to the site. Details of this are to be developed in consultation with PRV as the design progresses.
CM35	Non-combustible surfaces	Site electrical systems (e.g. at the substation) are to be supported by crushed rock or non-combustible ground surface in accordance with AS 2067:2016. The use of fire rated structure can limit this distance. This surface may include access roads and paved ways. This applies primarily to the AusNet 220kV/33kV Substation; however AusNet will have ultimate design authority for the substation.
CM36	Vegetation fuel load	Proximity to substation vegetation shall be in line with Ausnet requirements.
CM37	Drainage and contamination system	In the event of a battery room or diesel generator / tank fire, the entire contaminated fire water run-off needs to be collected and held in the detention system. The alignment of the drainage system, including closing off the connection to the town stormwater drainage system, is to occur automatically.
CM38	Arc Flash assessment	Arc flash report in accordance with industry practices.
CM39	Fire rated data centre structures	Data halls, battery rooms, and the basement are to be fire rated structures.
CM40	Fire rated power transformer wall	The power transformer is to be encircled on three sides by fire and blast walls to protect the site and beyond. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation.
CM41	Bund transformer to contain oil	Transformer to be arranged so that any leak would be collected and held within the system, i.e., self-bunded or enclosure bund. Leak detection to be included; this may be a reduction in volume within the transformer. The bund and the structures to hold the transformer shall be able to withstand the pool fire event, in line with AS 1940: 2017. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation. Transformers in the actual building, i.e., data hall, are proposed to be dry-type.
CM42	Power transformer bund de-watering system	The power transformer bund size must comply with AS 2067 and AusNet requirements. This may include a



#	CM Title	CM Description
		requirement to consider rainfall simultaneous to a leak. This applies to the AusNet substation, recognising that AusNet has ultimate design authority for the substation.
CM43	Transformer Oil Selections	All High Voltage systems shall comply with AS 2067 or as agreed with Energy Safe Victoria and the relevant authority.
CM44	Diesel generators bunding	The diesel generators are to be contained within their own bunds. This bund shall be sufficient to contain the entire contents of the liquid in the system, as well as rain event, in the current design they are fully enclosed and therefore the volume is nil for rain.
CM45	Diesel generator fire isolation	On detection of a fire within a diesel generator, the fuel supply is to be automatically shut off, via the MFIP.
CM46	Diesel tank selections	The diesel tanks and their arrangement to meet AS 1940:2017, or as agreed with relevant authority. This may include additional measures over and above AS 1940 compliance.
CM47	Diesel tank zoning bunding	Groups of diesel tanks to be encircled by bunding. This is in addition to the integral bunding provided by double skinned tanks.
CM48	Diesel pipework and pump monitoring	Diesel flow rate / pressure within the pipework or pumps to be monitored to detect system leaks.
CM49	Refuelling zone bunding	Refuelling zone to be encircled by a roll over bund.
CM50	Battery room explosion management system	Within the battery room an approved / compliant combustible concentration reduction system which This system to meet NFPA 69 with deflagration calculations to NFPA 68. The battery room is to be fitted with an approved AS 1940:2017 ventilation system designed for lighter and heavier than air volatile gases.
CM51	Battery room door swing	The battery room door if swinging outwards must be designed to not turn into a projectile or fragment when the room is subject to a partial volume deflagration assessment. This may be considered as part of an NFPA 68 partial volume deflagration assessment.
CM52	Cable	Outdoor cables across the site shall not be treated with flame retardant but shall be self-extinguishing, i.e., pass IEC 60332-1, or equivalent. Other approaches may be applied by the electrical designer so long as they comply with appropriate regulations.
CM53	Battery room deflagration control	The FSS must include review of the potential for a deflagration inside a battery room. It is expected that the FSS will rely on a partial volume deflagration assessment by the battery OEM. This may require the installation of deflagration panels, or stronger enclosures to the room. The FSS is also expected to consider a more onerous deflagration scenario for potential emergency services planning. Determining this information requires analysis of the specific batteries and therefore is carried forward to the FSS.
CM54	Diesel fill point location	Diesel fill point shall be more than 50 m from the Ausnet HV powerlines.
CM55	Diesel Tank Rooms	Several additional requirements are proposed to be applied and/or investigated for the diesel tank room in the basement: <ul style="list-style-type: none"> The tanks are to be positioned in groupings, it is expected that there may be 3-5 different groupings, Each tank is to be double skinned, with its own integral bund.



#	CM Title	CM Description
		<ul style="list-style-type: none"> Each grouping is to be provided with an additional bund, capable of holding not less than 110% the volume of the largest tank in the grouping, with additional allowance for the fire protection system to be determined. Each grouping is to be within a separate, dedicated, fire rated room, with an FRL of not less than (240)/240/240. Where possible, the fire rated enclosure to these rooms is to consist of non-structural walls (e.g. non-load bearing walls), to provide additional separation of structure from the tanks. The potential need to exceed the minimum concrete cover requirements of AS 3600 to achieve 240-minute FRLs is to be reviewed and may be implemented in design development. Whilst no formal FRL above 240 exists in AS 3600, this would be a way to effectively achieve an FRL greater than 240-minutes. Each diesel tank room is to be provided with an automatic fire suppression system, specifically intended for use on pool fires. It is expected that this may be a mist system, foam system, or other suitable system. Fire hydrant locations relative to diesel storage are to be coordinated and agreed with FRV, with the potential need for additional hydrant locations to support tactical operations.
CM56	Battery Room Ventilation Discharge Point	<p>The discharge point for the ventilation system from the part of a plating room must be above ground level the exact location is to be determined as the design progresses. The intent being to discharge at high level.</p>

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7.4 Relevant Standards / Guidance Documentation

- 7.4.1 This section sets out Standards that are likely to be relevant to the design of the battery rooms. Some such Standards are legislative requirements (e.g., AS/NZS 3000), others are expected to provide guidance in the detailed design of systems and may not be prescriptively or fully applied (e.g., FM 5-33). This is not an exhaustive list, and other relevant standards are expected to be applied in design of the site.
- 7.4.2 AS 1940:2017 – Safe Storage, Handling, and Management of flammable and combustible liquid. This standard sets out the current best (industrial) practices for the safe and effective management of class 3 dangerous goods across Australia.
- 7.4.3 AS/NZS 5139:2019 - Electrical installations – Safety of battery systems for use with power conversion equipment. This Standard is currently the mandatory Australian and New Zealand standard governing the safety, installation, and operation of battery energy storage systems (BESS) used in conjunction with inverters or other power conversion equipment. It sets out requirements to reduce electrical, fire, and chemical hazards associated with battery



installations—particularly lithium-ion and similar chemistries—across residential, commercial, and light industrial settings.

- 7.4.4 AS/NZS 3000:2018 - Electrical installations (known as the Australian/New Zealand Wiring Rules). This Standard sets out the requirements for the design, construction, and verification of all electrical installations. It provides the essential safety and performance framework for electrical systems across residential, commercial, and industrial environments.
- 7.4.5 AS 2067:2016 - Substations and High Voltage Installations Exceeding 1 kV a.c., is the third edition of the Australian Standard, published on 14 September 2016. It provides common rules for the design and construction of electrical power installations with nominal voltages above 1 kV a.c. and frequencies up to 60 Hz, incorporating lessons from previous editions and aligning with international standards such as IEC 61936-1:2010.
- 7.4.6 UL 9540A:2025 - Test Method for Battery Energy Storage Systems (BESS). This Standard is used for assessing fire propagation related to thermal runaway events in battery energy storage systems (BESS) such as battery rooms. UL 9540A provides a methodology for testing a system's safety-related behaviour when the design or installation conditions of a BESS exceed the limits set by the National Fire Protection Association (NFPA) 855.
- 7.4.7 NFPA 855:2026 - Standard for the Installation of Stationary Energy Storage Systems. This Standard provides mandatory requirements for the design, installation, operation, and maintenance of energy storage systems (ESS), including battery systems.
- 7.4.8 NFPA 68 - Standard on Explosion Protection by Deflagration Venting. NFPA 68 establishes requirements for the design, installation, and maintenance of venting systems intended to safely relieve pressure and direct combustible gases in the event of a deflagration (i.e. a subsonic combustion explosion) inside an enclosure.
- 7.4.9 NFPA 69:2024:2023 - Standard on Explosion Prevention Systems. NFPA 69 provides guidance and requirements for the design, installation, operation, and maintenance of systems intended to prevent explosions in enclosures and process equipment that may contain flammable gases, vapours, dusts, or hybrid mixtures.
- 7.4.10 FM Global Data Sheet 5-33 - Lithium-Ion Battery Energy Storage Systems. This data sheet describes loss prevention recommendations for the design, operation, protection, inspection, maintenance, and testing of stationary lithium-ion battery (LIB) energy storage systems (ESS) greater than 20 kWh.
- 7.4.11 CSA TS-800: 24 – The Large-Scale Fire Test (LSFT) is a comprehensive procedure designed to evaluate the fire hazards of Energy Storage Systems (ESSs), particularly those utilizing lithium-ion batteries. This test simulates a worst-case fire scenario in a BESS installation, assessing whether a fire can



escalate into a sustained enclosure fire and spread across adjacent cabinets. The test involves intentionally initiating a fire in an ESS enclosure to evaluate how fire might spread to nearby systems, which is crucial for large installations where multiple ESS units are placed in close proximity.

- 7.4.12 FRV GL-55 – A comprehensive framework for the design, installation, and operation of Battery Energy Storage Systems (BESS) within the fire district of Fire Rescue Victoria. It emphasizes the importance of fire safety in BESS installations, particularly those using lithium-ion technologies.

7.5 Further Studies

- 7.5.1 It is recommended that this site be subjected to a Fire Safety Study (FSS) for more detailed analysis of other site events and development of more detailed fire safety control measures. An FSS must also be carried out to develop a fire brigade intervention strategy and consult with the fire authorities to set out the appropriate response strategies for the site. This includes consideration of water runoff containment, as appropriate.
- 7.5.2 To further support the above recommendations, the local authorities including local fire brigades are to be informed of when commissioning activities are occurring to improve their readiness and familiarity of the site.

7.6 Conclusions

- 7.6.1 RED Fire Engineers Pty Ltd has been appointed by Legacy Project Management Pty Ltd to carry out a preliminary hazard analysis (PHA) for the proposed SM2 Data Centre located at 165 Williamsons Rd, South Morang, VIC, 3752.
- 7.6.2 In line with the HIPAP methodology, a qualitative hazard identification (HAZID) process has been carried out in review of the process, site equipment, and potential stored materials. Subsequently, failure events have been identified and categorised, to identify which events may have significant off-site consequences. These events have then been carried forward for more detailed consequence analysis. In line with the *Multi-Level Risk Assessment* guidelines, a partially quantitative analysis has been carried out for these consequences, and where appropriate consequences have been carried forward for estimation of likelihood.
- 7.6.3 On the basis that the recommendations in this study, including conducting a fire safety study which is to further develop recommendations, are implemented, commissioned, and undergo routine maintenance of fire safety control measures in accordance with manufacturer's recommendations and AS 1851:2012 (Standards Australia, 2012), or other relevant Standard(s), it is our professional opinion that the project is not a hazardous development and should be permitted to be established at the proposed location, with conditions for further assessment.

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- Standards Australia, 2021. *AS 2419.1, Fire hydrant installations, Part 1: System design, installation, and commissioning*, Canberra: Standards Australia.

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Appendix A.

Risk Management

Framework

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Appendix A Risk Management Framework

A.1 Introduction

- A.1.1 The level of risk which the hazards identified in this report present is determined using the risk matrix detailed in this appendix.
- A.1.2 This risk matrix has been developed from relevant legislation and WorkSafe Australia guidance as set out within this appendix. The risk matrix assesses the identified hazards and determines the risk rating based on different likelihood and consequence criteria. It includes likelihood and consequence descriptors for the risk category analysed, relevant to the hazards identified within this report.
- A.1.3 The application of this appendix and its risk matrix are for assessing appropriate measures to control the risk.

A.2 Legislation

- A.2.1 Across Australia safety at work is governed by the Work Health and Safety (WHS) Acts and Regulations ^[1]. These are all based off the Commonwealth legislation:
- a) Work Health and Safety Act, 2011 (Australia Government, 2018)
 - b) Work Health and Safety Regulations, 2011 (Australian Government, 2024)
- A.2.2 Within Victoria the legislation is:
- a) Occupational Health and Safety Act, 2004 (Victoria Government, 2024)
 - b) Occupational Health and Safety Regulations, 2017 (Victoria Government, 2019)
- A.2.3 The WHS legislation across Australia is similar, but not identical. Therefore, there are differences between the Commonwealth and other jurisdiction ^[2].
- A.2.4 All of these Acts and Regulations require risk to be undertaken with respect to 'So Far As Is Reasonably Practicable' (SFAIRP). Associated with the WHS Regulations are Codes of Practice (CoPs). A CoP is a practical guide to achieve the standard of health and safety required under the WHS Act and Regulations of their jurisdiction. The application of a specific CoP may limit the need for a risk assessment or provide criteria for the risk assessment. Additionally, standards, guides and codes, although not legally binding, are provided to assist with risk assessment undertaken and their criteria. Some examples of CoP that are relevant are:

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¹ In Victoria referred to Occupational Health and Safety (OHS) Act and Regulations. For convinces WHS will cover both the Work Health and Safety and Occupational Health and Safety within this Appendix.

² The differences between WHS legislation across Australian can be found here:
<https://www.safeworkaustralia.gov.au/doc/model-whs-act-cross-comparison-table>.



a) National:

- Code of Practice, How to Manage Work Health and Safety Risks, 2018 (Safe Work Australia, 2018)
- Code of Practice, Managing the Risk of Plant in the Workplace, 2023 (Safe Work Australia, 2023)
- Code of Practice, Managing Risks of Hazardous Chemicals in the Workplace, 2023 (Safe Work Australia, 2023a)
- Guide for Major Hazard Facilities: Safety Assessment, 2012 (Safe Work Australia, 2012)

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b) Victoria:

- How WorkSafe applies the law in relation to identifying and understanding hazards and risks, 2007 (WorkSafe Victoria, 2007)
- Code of practice for the storage and handling of dangerous goods, 2013 (WorkSafe Victoria, 2013)
- Overview of the safety case regime for a major hazard facility, 2019 (WorkSafe Victoria, 2019)
- Safety management system for a major hazard facility, 2021 (WorkSafe Victoria, 2021)
- Assessing and Controlling Risk: A Guide for Business, 1695.1, 2018, (Environment Protection Authority Victoria, 2018)

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A.2.5 Of these CoP, the CoP for the 'How to Manage Work Health and Safety Risks' sets out a framework of how risk is to be assessed / managed and therefore is the most relevant.

A.3 Implementation

A.3.1 The WHS legalisation calls up, Code of Practice, How to Manage Work Health and Safety Risks (Safe Work Australia, 2018). Under this CoP, the risk management process involves four steps, (Figure A.1):

- Identify hazards, i.e., what will cause a consequence at a specific location / system,
- Assess risks, specify the nature of the hazard that could occur, how serious the consequence could be, and then the likelihood of the incident occurring,
- Control risks, propose and implement control measures to eliminate or limit the harm with respect to SFAIRP, and
- Review control measures, ongoing review of the hazard, harm, and their associated control measures.

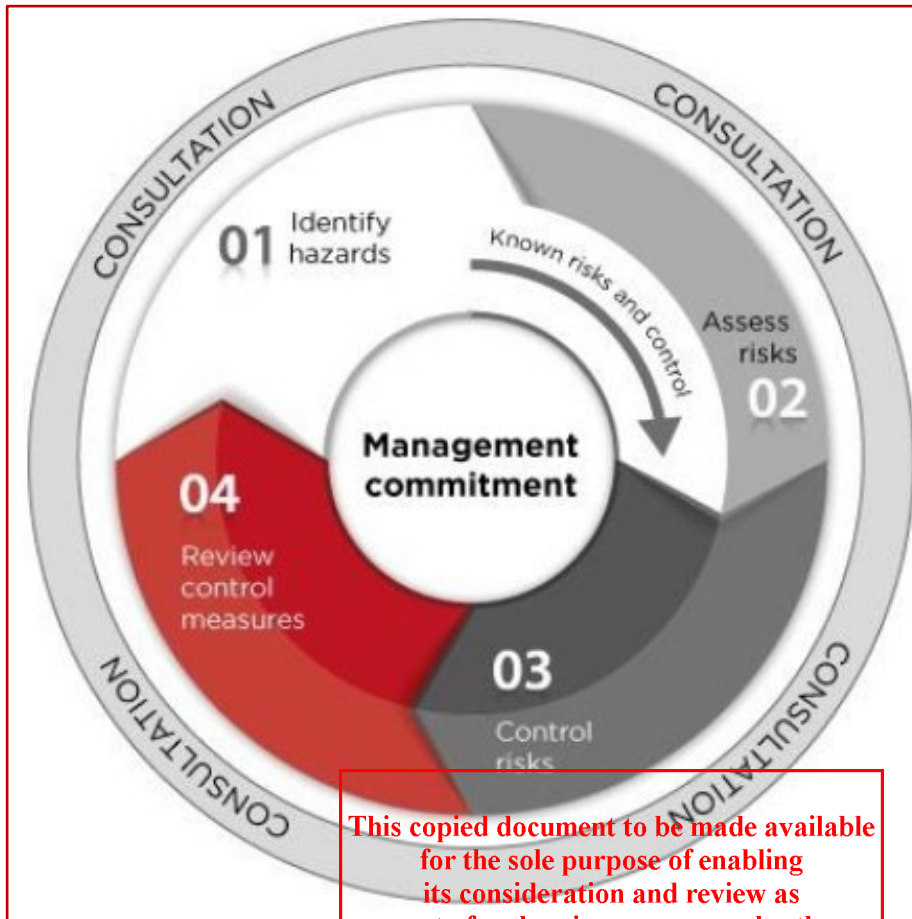


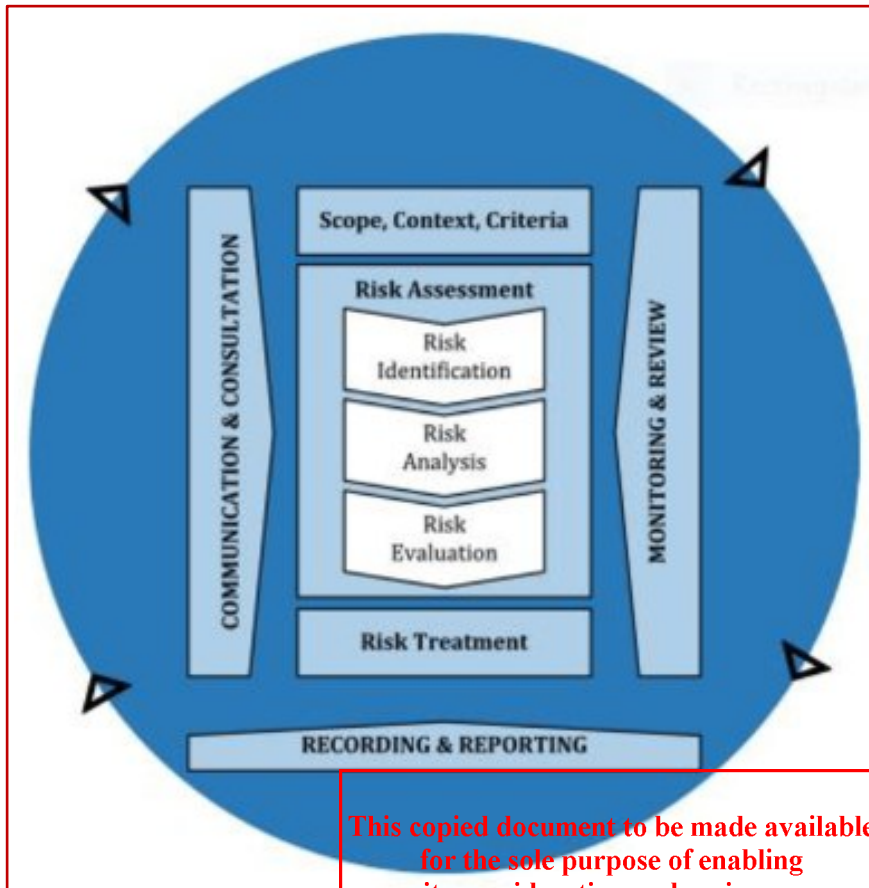
Figure A.1: Risk management process (Figure 1 from Safe Work Australia, 2018 (Safe Work Australia, 2018))

A.3.2 The risk assessment, provided with this document, by its very nature can only progress to the proposal of control measures. It is the responsibility of the business owner to implement and maintain all of these required control measures as well as conduct ongoing regular risk reviews. The control measures proposed in this report are only applicable to the situation and arrangement noted within this report. If the situation and arrangement change, then this report and its associated risk assessment are not valid.

A.3.3 The hazard assessment, i.e., steps 01 and 02 from Figure A.1, will be undertaken with consideration to AS ISO 31000:2018 (Standards Australia, 2018) risk management framework, see Figure A.2. In the context of developing this document a modified risk management process presented in Figure A.3 is used. Specifically, the following are noted:

- a) The potential magnitude of the consequence and the quality of the available information related to the hazard will influence the levels determined for likelihood and consequence.
- b) The risk analysis may be undertaken either solely or in combination of qualitative, semi-quantitative, or quantitative.

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Figure A.2: Default AS ISO 31000:2018 (Standards Australia, 2018) risk management process

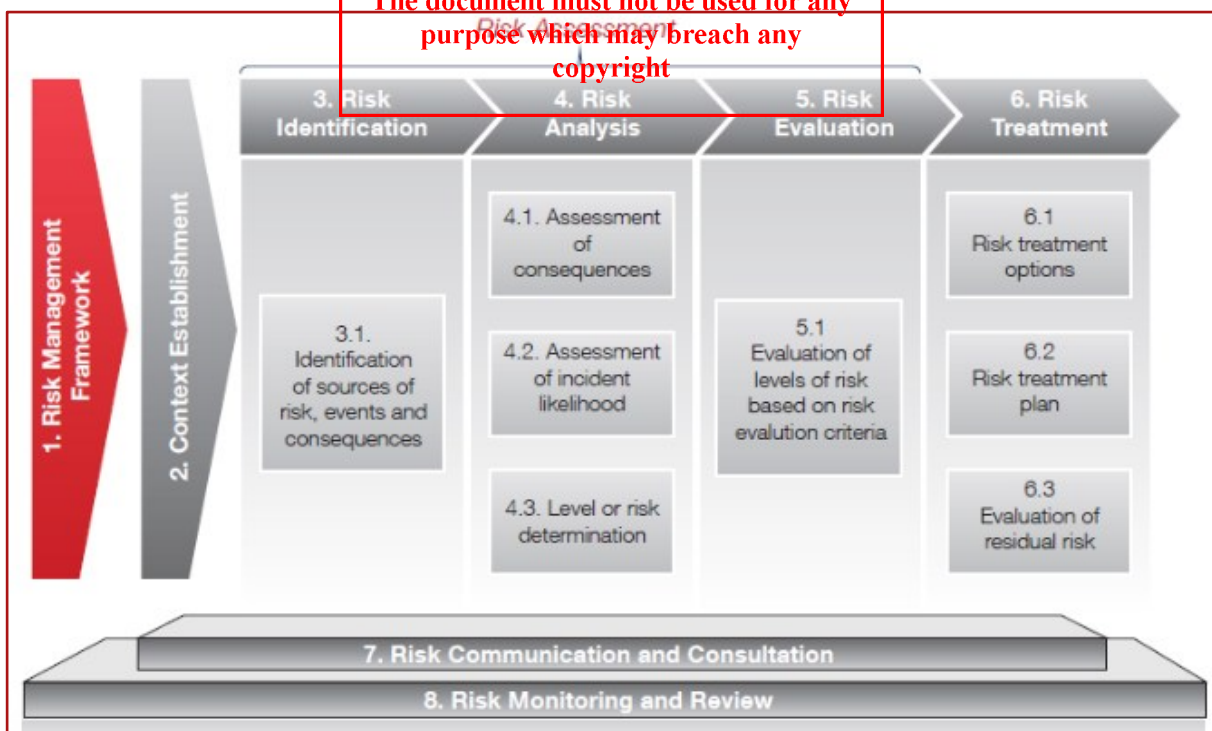
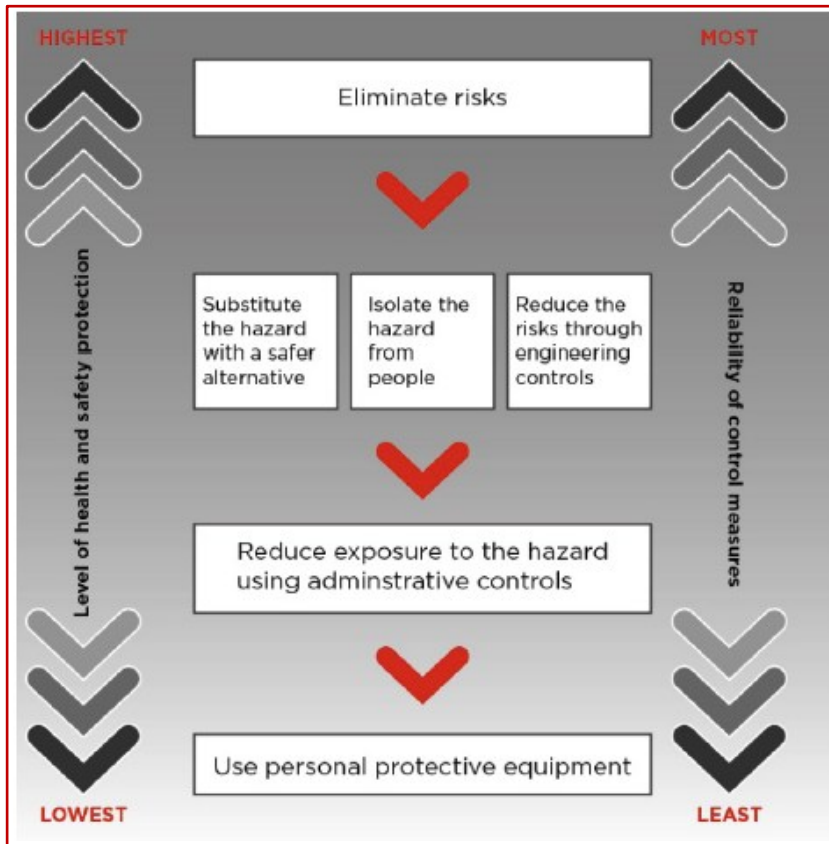


Figure A.3: Modified Risk Management process

A.3.4 Control measures will be developed with respect to the hierarchy of control measures, Figure A.4. As Elimination is unlikely, the focus will generally initially



be on isolation and engineering control, followed by administrative and personnel protective equipment.



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Figure A.4: Hierarchy of control measures (Figure 2 from Safe Work Australia, 2018 (Safe Work Australia, 2018))

A.3.5 Control measures will be considered and recommended until SFAIRP is considered to have been achieved, or in other words a reasonably practicable level of safety is met for the risk event under investigation via the required range of control measures. As set out in Code of Practice, How to Manage Work Health and Safety Risks (Safe Work Australia, 2018), reasonably practicable means that which is, or was at a particular time, reasonably able to be done to ensure health and safety, taking into account and weighing up all relevant matters including:

- the likelihood of the hazard or the risk concerned occurring,
- the degree of harm that might result from the hazard or the risk,
- what the person concerned knows, or ought reasonably to know, about the hazard or risk, and ways of eliminating or minimising the risk,
- the availability and suitability of ways to eliminate or minimise the risk, and
- after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.



- A.3.6 Control measures will be developed in consultation with the client and other relevant consultants, such as fire protection engineer. In determining what is reasonably practicable the following must be considered:
- a) All potential control measures are to be considered,
 - b) Then consider if it is reasonable to apply all of these proposed control measures. In other words, all control measures that can be applied should be implemented unless it is reasonable for some control measures not to be applied. An example of this could be a control measure which has the same influence on the hazard as another existing / proposed control measure, and
 - c) Where cost-benefit cannot support the implementation of a proposed control measure. It is the client's responsibility to demonstrate the excessive cost.
- A.3.7 Demonstrating reasonably practicable in this fashion is in line with the objectives of the WHS legislation.
- A.3.8 The risk matrix provided in the Risk Matrix section and its associated consequence table are used to determine the risk ranking for each identified scenario throughout this report. Code of Practice, How to Manage Work Health and Safety Risks (Safe Work Australia, 2018), does not specify a format or process that risk assessment is to be undertaken.
- A.3.9 The implementation of the Risk Matrix presented at Table A.3 is influenced by the type of documentation being developed.
- a) For a Fire Safety Study (FSS), this document will have been developed with consideration to HIAAP 2 (NSW Planning, 2011). Where preliminary / final hazard assessment ^[3] (PHA / FHA) has been developed for this project, the outcomes from these PHA / FHA will be included within this FSS, in the same format as used in the original PHA / FHA. In other words, where risk curves and the like have been developed and issued for this project, these risk tools will be used for the hazards that they refer to within this document. New fire specific risk not covered by these previous assessment(s) will be assessed against the fire matrix noted within this appendix.
 - b) For Fire Risk Assessment (FRA) and other risk reports, related to fire safety, relevant legalisation, codes, and guides will be considered. If the relevant legalisation or codes require a specific risk management process, then this would be applied instead of this risk matrix.
- A.3.10 The risk assessment begins with an initial risk assessment (IRA) of the scenario under consideration, developed using the risk matrix presented in Table A.3. In an IRA it is assumed that there are no control measures in place. Where manual

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³ From Hazard Industry Planning Advisory Paper No. 3, Preliminary Hazard Assessment is to identify all potential hazards, analyse these hazards effects on people and the environment, determine the probability of occurrence, and via the application of multi-level risk assessment quantify risk levels to surrounding land uses and the environment. Final Hazard Assessment is the same as a Preliminary Hazard Assessment, outside of the fact it is done later in the design / development of the site.



procedures could lead to the incident the likelihood is to be considered 'Almost Certain'.

A.3.11 An IRA will generally include two analyses, these being:

- a) The incident at the location of origin, and
- b) An IRA which relates to the spread of the incident to another location site after the original incident has occurred.

A.3.12 An updated risk assessment (URA) is conducted for the scenario under consideration after recommended control measures have been reviewed and selected. As with the IRA, two URAs will be conducted; these being for the incident at the location of origin and for the incident to spread.

A.3.13 As control measures may affect likelihood, consequence, or both, therefore additional URA's that focus on a reduced likelihood and then a reduced consequence scenario may be undertaken. With respect to WHS's focus on consequence the URA generally focusses on reduced consequence scenarios instead of reduced likelihood scenarios.

A.4 Risk Matrix

- A.4.1 To be able to rank the risk the likelihood and consequence levels have been developed considering a number of guidelines as outlined below. These levels are to be reviewed and concurred with all stakeholders.
- A.4.2 The likelihood presented in Table A.1 has been developed with consideration of:
- a) Table 10 in National Emergency Risk Assessment Guidelines (Australian Institute for Disaster Resilience, 2020),
 - b) Safe Work Australia, Guide for Major Hazard Facilities, 2012 (Safe Work Australia, 2012), and
 - c) Tables II and A-II from MIL-STD-882E System Safety (Department of Defense (USA), 2023).
- A.4.3 Specifically, the likelihood frequencies used in Table A.1 are based on the first five levels presented in Table 10 of National Emergency Risk Assessment Guidelines (Australian Institute for Disaster Resilience, 2020). Whilst the last level, i.e. Eliminated, presented in Table A.1 comes from II and A-II from MIL-STD-882E System Safety (Department of Defense (USA), 2023). This combination has been chosen as intervals up to 1,000 years and then greater is expected to provide an appropriate resolution for the occurrence of fire vulnerability associated with building and infrastructure.
- A.4.4 The consequence presented in Table A.2 has been developed with consideration of:
- a) Table 1 from Risk Management Framework (Western Parkland City Authority, 2022) for life safety,

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- b) Table 2 from NSW Health, Enterprise-wide Risk Management 2022 (New South Wales Government, 2022), and
 - c) Examples 27 and 33 from Safe Work Australia, Guide for Major Hazard Facilities, 2012 (Safe Work Australia, 2012).
- A.4.5 These three references all have similar consequences levels for life safety, such as multiple deaths relate to catastrophic. For the facility the consequence levels have been based on the last two referenced documents.
- A.4.6 The risk matrix in Table A.3 has been developed with consideration of:
- a) Table 3 from Risk Management Framework (Western Parkland City Authority, 2022),
 - b) Figure 2 in Assessing and Controlling Risk for Business (Environment Protection Authority Victoria, 2018), and
 - c) Table III, MIL-STD-882E System Safety (Department of Defense (USA), 2023).
- A.4.7 The risk matrix supports five levels of risk level, similar to Assessing and Controlling Risk for Business (Environment Protection Authority Victoria, 2018). In line with the MIL-STD-882E System Safety (Department of Defense (USA), 2023) the 'Very High' risk level relates to a consequence of 'Catastrophic' over a likelihood range of 'Almost Certain' to 'Occasional', plus a likelihood of 'Almost Certain' over a range of consequence 'Major' to 'Catastrophic'. Also in line with the MIL-STD-882E System Safety (Department of Defense (USA), 2023) the risk level for a consequence of 'Catastrophic' and likelihood of 'Rare' is 'Medium'. At the other end of the risk matrix, in line with all three reference documents, the risk level is 'Very Low' for consequence 'Minor' and likelihood 'Rare'. Within this risk matrix the consequence of 'Minor' for a likelihood of 'Almost Certain' has a risk level of 'Medium'. This arrangement aligns with the MIL-STD-882E System Safety (Department of Defense (USA), 2023) and Assessing and Controlling Risk for Business, (Environment Protection Authority Victoria, 2018). This leaves the central cells of the risk matrix that have been developed with the intent of a smooth transition from the previously mention end condition of this matrix.
- A.4.8 This risk matrix presented in Table A.3 is based on the likelihoods defined in Table A.1 and the consequences defined in Table A.2.
- A.4.9 The risk levels presented in Table A.3 are defined in Table A.4. Table A.4 also sets out the actions to be taken at each of these risk levels. These actions are based on Assessing and Controlling Risk for Business (Environment Protection Authority Victoria, 2018).

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Table A.1: Likelihood Levels

Name	Description	Average recurrence interval (ARI) / Site historical data	Annual Exceedance Probability (AEP)	Frequency (Indicative)
Almost Certain	Expected to occur several times a year under normal circumstances.	Less than 1 year / Has occurred 3 or more times in the last year or at least each year over the last 5 years.	63% per year or more	Once or more per year
Probable	Expected to occur at least once in a 10 year period or several times over a 100 year period.	1 to < 10 year / Has occurred at least once in the least decade or four or less times over the last 5 years.	10% to < 63% per year	Once per 10 years
Occasional	Expected to occur at least once in a 100 year period or several times over a 100 year period.	10 to < 100 year / Has occurred in the last two decades.	1% to < 10% per year	Once per 100 years
Improbable	Expected to occur at least once in a 1,000 year period or several times over a 1,000 year period.	100 to 1,000 year / An uncommon incident noted within the industry.	0.1% to < 1% per year	Once per 1,000 year
Rare	Not expected to occur any more than several times over a 10,000 year period.	1,000 year or more / May have not been reported across the industry sector.	Less than 0.1% per year	Once per 10,000 years
Eliminated	Incapable of occurrence. This level is only used when potential hazards are identified and later eliminated.	N/A	N/A	N/A

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**Table A.2: Consequence Levels**

Rating	Life Safety (Workers and the Public)	Facility
Minor	Minor injury or illness that is treatable in the workplace (first aid) or by a registered health practitioner, with no follow up treatment required.	Minimal damage resulting in negligible business, structural, and system impact.
Moderate	Injury or illness causing no permanent disability, which requires non-emergency medical attention by a registered health practitioner or at least ten minor outcomes.	Limited asset loss across the facility, which may include damage to system but no significant damage to structures.
Major	Serious injury or illness requiring immediate admission to hospital as an inpatient and / or permanent partial disability or at least ten moderate outcomes.	Serious asset loss and damage to the facility, which would include the destruction or significant damage to a single major structure.
Critical	Single fatality and / or permanent total disability or at least ten major outcomes.	Severe asset loss and damage to the facility, which would include the destroyed or significantly damaged to multiple major structures.
Catastrophic	Multiple fatalities or at least ten critical outcomes.	Total destruction or damage to the facility, including all or most building and associated systems. Potential for permanent loss of production.

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Table A.3: Risk Matrix

Likelihood	Consequence				
	Minor	Moderate	Major	Critical	Catastrophic
Almost Certain	Medium	High	Very High	Very High	Very High
Probable	Low	Medium	High	Very High	Very High
Occasional	Low	Medium	Medium	High	Very High
Improbable	Very Low	Low	Low	Medium	High
Rare	Very Low	Very Low	Very Low	Low	Medium
Eliminated	Eliminated				

Table A.4: Description of Risk Levels

Risk Level	Description	Action
Very High	Totally unacceptable level of risk.	Stop work and undertake action immediately.
High	Unacceptable level of risk.	Action plan immediately required to put controls in place to reduce risk level.
Medium	Could be acceptable if controls have been applied, if not practicable to lower the risk further by additional control measures.	Specific monitoring to be undertaken and additional control measures to be implemented if reasonably practicable. Regular review to be undertaken.
Low	May be considered acceptable level of risk, if not practicable to lower the risk further.	Attempt to lower or eliminate risk but higher risk levels take priority. Periodic reviews are to be undertaken.
Very Low	Generally considered acceptable.	Attempt to lower or eliminate risk but higher risk levels take priority.
Eliminated	Hazard no longer exists.	No action.

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Appendix B. Lithium- ion Fire Safety Considerations

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Appendix B Lithium-ion Fire Safety Considerations

B.1 Introduction

- B.1.1 This appendix provides a general understanding of the fire safety aspects associated with lithium-ion (Li-ion) cells and their associated batteries. In this appendix a Li-ion cell refers to just the cell itself, whilst Li-ion battery refers to a group of cells and other components such as battery management system (BMS) and thermal management systems.
- B.1.2 A description of a Li-ion cell is initially discussed and then the common uses / applications of Li-ion battery systems is presented. The focus of this appendix is on Battery Energy Storage System (BESS), but electric vehicles (EV) and portable Li-ion powered devices are also considered.
- B.1.3 Then the vulnerability of thermal runaway and fire is canvased, specifically how these events occur. Associated with this is the impact of different chemistry of the Li-ion cell. By-product emissions associated with thermal runaway and a fire are then presented.
- B.1.4 Finally, frequency of thermal runaway / fire is presented.

B.2 Li-ion Cell Arrangement

- B.2.1 Figure B.5 from (Ervo, et al., 2024) shows how a Li-ion cell discharges and charges. Lithium exists within the anode and cathode of the cells. The electrolyte moves the lithium ion depending on if the cell is under charging or discharging condition. As noted in (Underwriters Laboratories, 2023) and (Ervo, et al., 2024) a Li-ion cell comprises four primary components, these being:

- Anode,
- Cathode,
- Separator, and
- Electrolyte.

- B.2.2 (Waller, et al., 2020), (Best, et al., 2023), and (Kozich & Dairo, 2023) note there are three common forms of Li-ion cell, these are (and shown in Figure B.6):

- Cylindrical,
- Pouch, and
- Prismatic.

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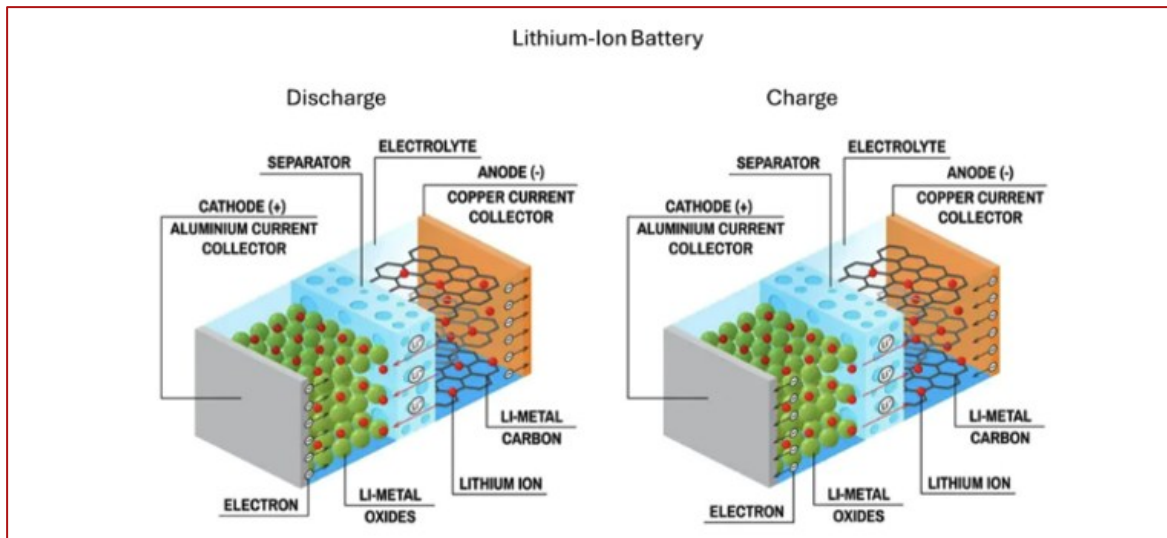


Figure B.5. Li-ion cell discharging and charging arrangement



Figure B.6: Li-ion cell common arrangements

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- B.2.3 There are various Li-cell chemistries, the two which will be focussed here are Lithium Iron Phosphate (LFP) and Nickel Manganese Cobalt (NMC). This is because these two chemistries are common for BESS and EVs. Brief discussion of byproducts of burning sodium ion batteries is provided.
- B.2.4 (Ervo, et al., 2024) notes that LFP cell degradation is limited due to the strong electrochemical stable iron phosphate bond. Whilst NMC is susceptible to changes in electrode structure as well as phase changes. Therefore, LFP are a far better option for long duration applications. Additionally, this results in LFP being more resistant to abuse, including mechanical abuse, than other Li-ion cell chemistry.
- B.2.5 Table B.5 provides a comparison between LFP and NMC Li-ion cells from (Ervo, et al., 2024) and (Hasselwander, et al., 2023). For clarity (Hasselwander, et al., 2023) data is provided in brackets. This comparison covers general aspects of the cells, their thermal stability, and performance differences. (Ervo, et al., 2024) should be consulted for further information.

**Table B.5: Summary comparison on LFP and NMC Li-ion cells**

Aspect	LFP	NMC
Cycle life and capacity fade	Longer cycle life and less capacity fade over time	Shorter cycle life and rapid capacity fade
Thermal stability and heat generation	Higher thermal stability and less prone to overheating	Less thermally stable since more susceptible to heat generation and thermal degradation.
Mechanical stability and structural change	Mechanically stable and minimal structural changes during cycling	Cells known to undergo structural changes such as cracking or particle disintegration.
Electrochemical stability and side reactions	More stable electrochemical environment with fewer side reactions that contributes to degradation	Prone to side reactions such as electrolyte decomposition
State of Charge (SoC) and Depth of Discharge (DoD) effects	SoC and DoD resilient with less degradation from deep cycling	Greater sensitivity to high SoC and deep DoD leading to degradation
Charge rate and charging protocol	Supports various rates of charge up to fast charging for the depth of charging it minimises degradation as part of a planning process under the Planning and Environment Act 1987. The document must not be used for any purpose which may breach any copyright	Fast charging leads to degradation of the cell
Environmental conditions	Performs well across broader temperature range and environmental conditions	Sensitive to environmental conditions, therefore, should be set up to support operations.
Chemical composition	Lithium iron phosphate is presented as a stable olivine structure	Lithium nickel manganese cobalt oxide with varying ratios of nickel, manganese, and cobalt
Operating temperature	-20°C to 60°C with higher thermal stability	-20°C to 55°C and sensitive to high temperatures
Thermal runaway threshold	Approx. 270°C, due to stable phosphate structure	Around 150°C – 200°C due to layered oxide structure
Heat generation and dissipation	Lower heat generation due to stable chemistry and efficient heat dissipation	Higher heat generation requires more robust cooling systems
Specific Heat Capacity	Higher, which helps in heat absorption and delay temperature raise	Lower that leads to quicker cell temperature increases
Thermal Management System	Less complex or extensive system required	More complex and advanced system are required

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Aspect	LFP	NMC
Lifecycle and Aging Effects	Less affected by thermal cycling and greater stability in performance over time	Sensitive to high temperatures leading to faster degradation
Safety Mechanisms	Inherently safer with a lower risk of thermal runaway	Often includes advance BMS with thermal monitoring and management to prevent overheating
End-use application	Suitable for applications where safety and thermal stability are priorities	Preferred in high-energy density applications where temperature control can be managed.
Energy density (Wh/kg)	90 – 160 (160 – 180)	150 – 260 (NMC-111: 150 – 180, NMC-532: 180 – 220, NMC-622: 220 – 260, NMC-811: 260 – 280)
Volumetric energy density (Wh/l)	(320 – 360)	(NMC-111: 300 – 450, NMC-532: 450 – 500, NMC-622: 550 – 650, NMC-811: 650 – 700)
Cycle life	1,000 – 2,000 (3,500)	1,000 – 2,000 (NMC-111: 1,500, NMC-532: 1,200, NMC-622: 1,200, NMC-811: 1,000)
Safety	Safer due to chemical and thermal stability	Less safe due to higher susceptibility to thermal runaway

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B.2.6 A Li-ion battery consists of one or more cells, wiring, BMS, thermal / management or cooling system (where required), and external contacts on the case. The BMS provides the following capabilities:

- Monitors the State of Charge (SoC) and State of Health (SoH) of the Li-ion battery so that it operates within its safe limits.
- Balancing the charge of the Li-ion cells, so that an even distribution occurs.
- Protects the battery and manages layers of safety from overheating, over-charging, and the like.
- Communicating data to monitoring and management site.

B.2.7 (Best, et al., 2023) notes that the charger plays a significant role in the performance and reliability of the Li-ion battery system. This is especially the case in small devices, where the charge may undertake some of the BMS actions whilst charging the device / Li-ion battery.

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B.2.8 Figure B.7 from (Best, et al., 2023) provides a list of common standards available to classify resistance of the Li-ion cell to different types of 'abuse'.

TEST TYPE	UN 38.3	IEC 62133-2	IEC 62281	IEC 62660-2	IEC 62619	UL 1642	UL 2054	UL 2271	UL 2580	ANSI C18.5	SAE J2464	JIS C8714
External Short Circuit	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Abnormal/Overcharge	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Forced discharge	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	
Crush		✓		✓		✓	✓	✓	✓		✓	✓
Impact	✓		✓		✓	✓	✓		✓	✓		
Shock	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Vibration	✓	✓	✓	✓		✓	✓	✓	✓			
Heating	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓
Temperature cycling	✓		✓	✓		✓	✓	✓	✓	✓	✓	
Altitude	✓	✓	✓			✓		✓				
Projectile						✓	✓	✓	✓			
Drop		✓	✓		✓			✓	✓		✓	✓
Penetration								✓	✓		✓	
Internal short circuit		✓			✓						✓	✓
Fire exposure						✓	✓		✓			

Figure B.7: Existing standards and methods of abuse to Li-ion cells

B.3 Uses and configurations of Li-ion Batteries

- B.3.1 Figure B.8 from (Kozich & Dairo, 2023) presents the major components within a BESS unit. BESS units generally have the most complex and developed Li-ion battery structure / support systems.
- B.3.2 EV are slightly less complex due to their smaller Li-ion battery capacity, which is generally between 30 – 1,000 V (AC) or 60 – 1,500 V (DC) (Fire Rescue New South Wales, 2024).
- B.3.3 Portable Li-ion batteries found in items such as mobile phones and laptops have simpler structures and the lowest quality battery cells compared to those used in electric vehicles and BESS units (Fire Rescue New South Wales, 2024).

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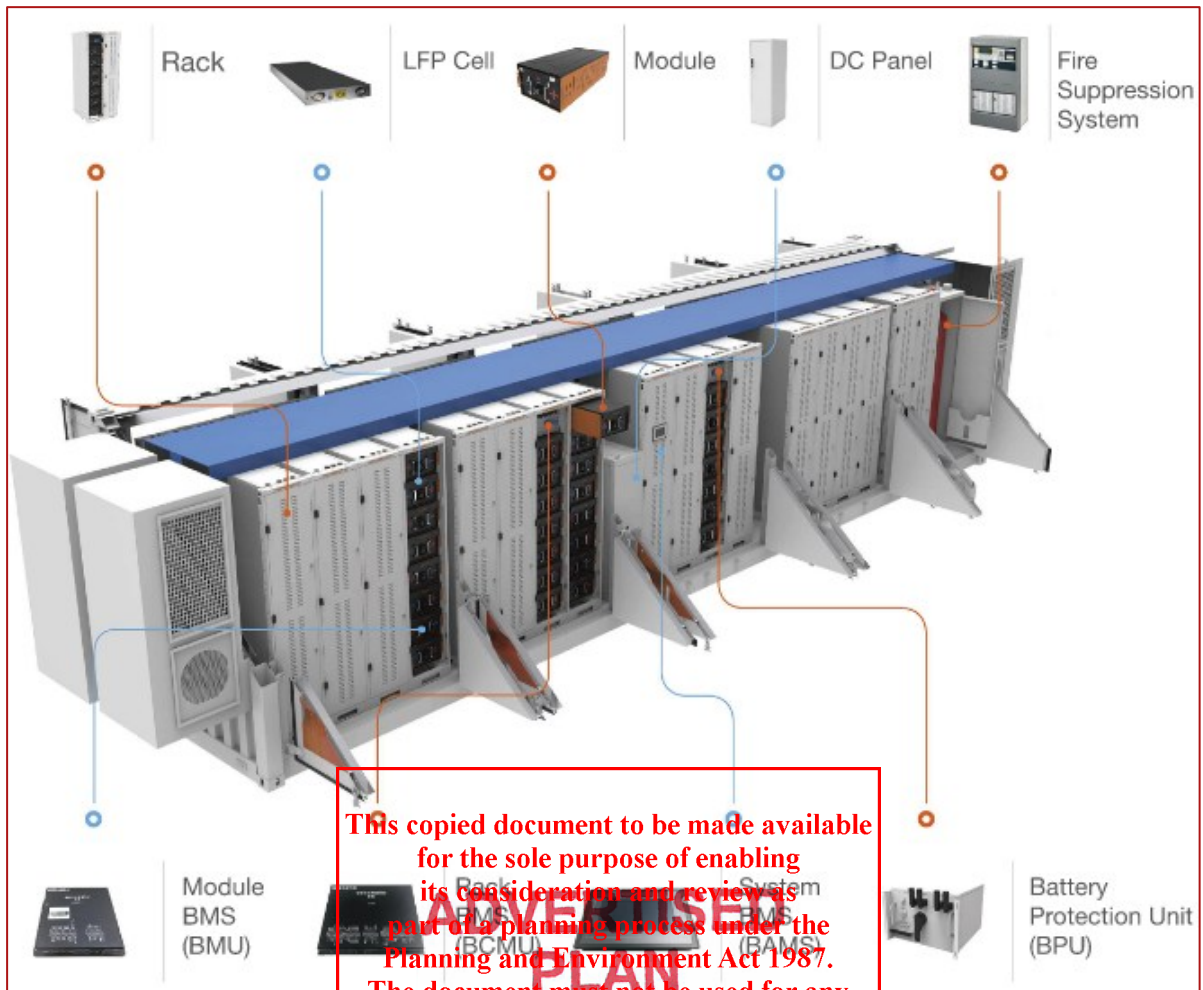


Figure B.8: Major components within a BESS unit

B.3.4 For E-bikes, E-scooters and similar devices, Table B.6 summaries the USA and European standards for E-bikes and E-scooter (Underwriters Laboratories, 2020).

Table B.6: Standards associated with E-bikes and E-Scooters

Aspect	E-Bikes	E-scooters and similar devices
Safety	<p>USA: UL 2849 – Electrical systems for E-Bikes</p> <p>EU: EN 15194 not as developed or complete as UL 2849</p>	<p>USA: UL 2272 – Electrical Systems of Personal E-Mobility Devices</p> <p>EU: EN 60335-1 covers hoverboards but UL 2272 more complete and wider coverage</p>
Battery Safety	<p>USA: UL 2271 – Batteries for use in Light Electric Vehicles (LEV) Applications</p> <p>EU: EN 15194:2017 refers to IEC/EN 62133 and EN 50604-1 for battery safety.</p> <p>IEC/EN 62133:2017 covers safety for secondary cells and batteries containing alkaline or other non-acid electrolytes.</p> <p>EN 50604-1 covers secondary lithium batteries for light electric vehicles.</p>	



B.4 Thermal Runaway and Fire

- B.4.1 (Electric Power Research Institute, 2022) notes that thermal runaway is an irreversible failure of a Li-ion cell that leads to the production of flammable gases. A thermal runaway can lead to:
- Ignition of unmixed flammable gases that results in a fire, or
 - Ignition of the flammable gases mixed with air within a confined environment that results in an explosion.
- B.4.2 Thermal runaway of a Li-ion battery does not always result in a fire. This can be seen in the Surprise, Arizona fire, where a rack of Li-ion cells went into thermal runaway within a sealed container. This generated an environment rich in flammable gases which lacked oxygen. When the fire fighters opened the door to the container, oxygen was introduced which led to an explosion (Electric Power Research Institute, 2022).
- B.4.3 Underwriters Laboratory (UL) highlights that a thermal runaway event is when the heat generated within a cell is greater than can be dissipated into the surroundings (Underwriters Laboratories, 2023). This can be caused by:
- Environmental – including excessive heat, charging in cold environment, and chemical exposure, such as sea water.
 - Mechanical – Li-ion cell exposed to dropping, crushing, indenting, shocking, vibrating, impacting, or penetrating.
 - Electrical Overcharge – The charging of the Li-ion cell done at a voltage above what it is designed for.
 - Electrical over-discharge – a cell's voltage falls below the discharge voltage limit governed by the cell design, which causes copper to dissolve from the anode and create paths for a short circuit.
 - External short circuit – Cell heated via joule or resistance heating to the point of thermal runaway occurring.
 - Design and Manufacturing – The cell / rack containing loose parts, electrode misalignment, burrs, tight tolerances, and contamination.
- B.4.4 It is noted that the SoC of the Li-ion cell determines the cell response in a failure event. Low SoC is unlikely to lead to flaming combustion.
- B.4.5 Figure B.9 from (Ervo, et al., 2024) presents a flow diagram for the factors which are connected to thermal runaway as well as fire or explosion outcome.

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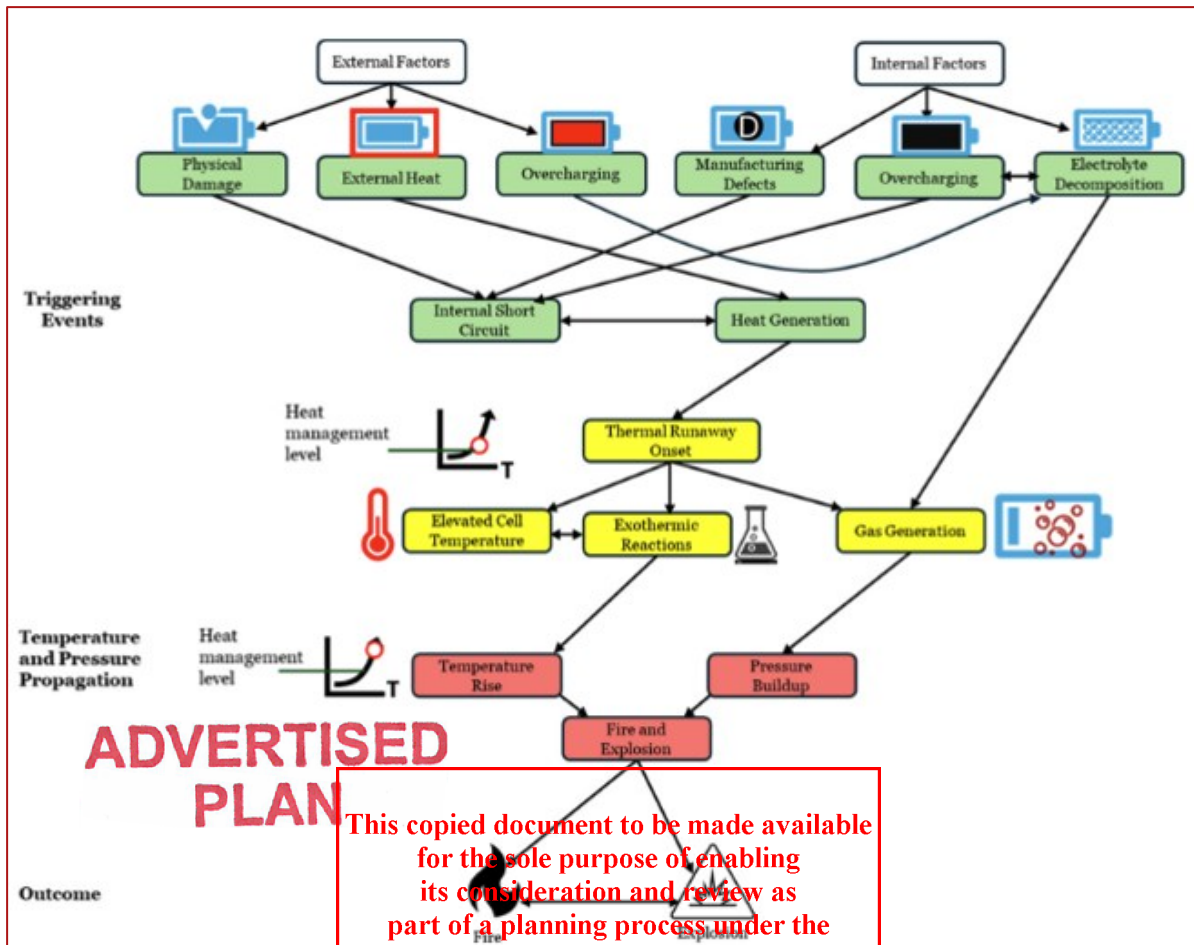


Figure B.9: Thermal runaway factors and connections to resulting fire or explosion

- B.4.6 In (Mylenbusch, et al., 2023) it is highlighted that a thermal runaway can result in a large-scale, short-duration subsonic deflagration (vapour cloud explosion). Although not a true explosion, such events can cause deaths, injuries, and equipment / structural damages. A deflagration can also be represented by a jet fire due to the energetic venting of gas from the Li-ion cell.
- B.4.7 (GHD, 2023) also notes the risk of cyber attack to Li-ion battery systems associated with BESS units. This is also a vulnerability to EV and similar systems.
- B.4.8 (Wang, et al., 2024) notes that the underlying degradation and gas-generation process within a Li-ion cell is similar to 'pyrolysis' of a common combustible solid. The notable difference is that thermal runaway within a Li-ion cell is self-sustained, whilst pyrolysis requires continuous thermal input.
- B.4.9 (Peng, et al., 2019) investigated thermal runaway of LFP Li-ion cell via the application of radiant heat. The cell that was used had a capacity of 60 Ah and was in a prismatic battery form. As noted in that article, thermal runaway of a Li-ion cell to fire can be considered to have five stages, these are:
- Stage 1: Solid electrolyte interphase (SEI) layers decompose and release at a temperature range 80 – 120°C. After this the lithium in the anode reacts with the electrolyte. At around 170°C the separator melts, which accelerates



the exothermic reaction. The battery expands due to increase internal pressure. At maximum expansion flammable gases are released from the cell. In the testing there was a spark to ignite these flammable gases. The time period to reach this ignition is related to the SoC and the incident heat flux, although the heat flux was the dominant factor.

- b) Stage II: The electrolyte keeps decomposing as well as the cathode. This results in the release of oxygen. The flaming combustion is steady, no jet fire.
- c) Stage III: The separator losses its entire integrity. Therefore, the cathode and anode have direct access to each other. This results in large number of short circuits. A large amount of gas is produced and ejected from the cell, which results in jet fires. The size of jet fires is related directly to the SoC.
- d) Stage IV: The fire becomes stable again, whilst flame height is at its largest. This is because the electrolyte is burning and therefore the heat release rate is also at its highest.
- e) Stage V: Flame weakens and extinguishes due to burn out. The burn out duration is inversely proportional to the SoC.

B.4.10 Table B.7 from (Peng, et al., 2019) provides the ignition time for different SoC and incident radiant heat.

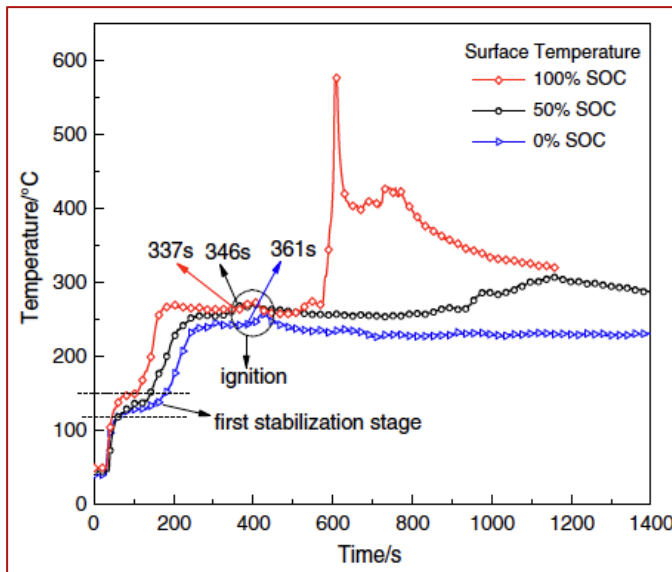
Table B.7: Ignition time for LFP Li-ion cell under different incident heat fluxes

SoC (%)	Ignition time (s)		
	6.5 (kW/m ²)	8.8 (kW/m ²)	11.1 (kW/m ²)
0	1107	590	361
50	1060	543	346
100	977	531	337

B.4.11 Figure B.10 from (Peng, et al., 2019) presents the different surface temperature of the LFP Li-ion cell due to different SoC during incident heat flux. Figure B.11 provides a comparison of surface temperature of a LFP Li-ion cell at 100% SoC undergoing different incident heat flux. As can be observed in this second case, the maximum temperature slightly decreases with decreasing incident heat flux, but the duration to reach the maximum surface temperature increases with lowering of the incident heat flux.

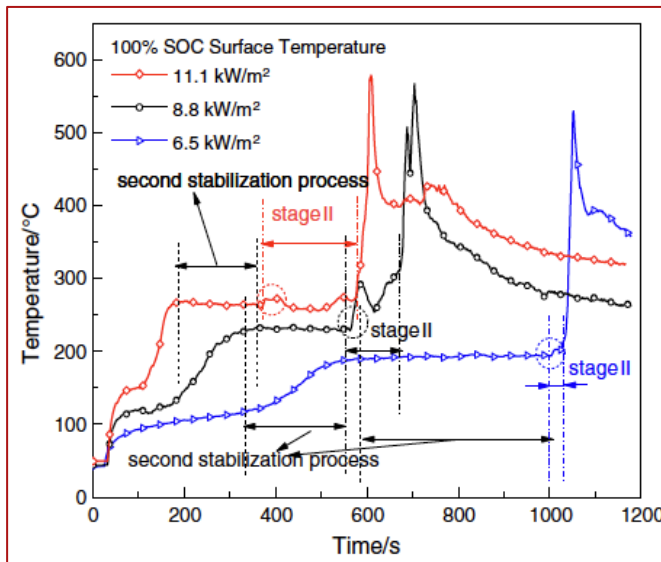
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Figure B.10: Surface temperature of LFP Li-ion cell at 0%, 50%, and 100% SoC under 11.1 kW/m² incident heat flux



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Figure B.11: Surface temperature curves for 100% SoC LFP Li-ion cell

B.4.12 This five-stage model will be the framework used in developing the fire safety strategy.

B.4.13 The following reviews published results for thermal runaway in Li-ion cell / batteries focus on LFP and NMC chemistry. What can be noted is that although general behaviours are common the exact temperature, duration and so on are often dependent on how the thermal runaway event is initiated.

B.4.14 (Sturk, et al., 2015) investigated both LFP and NMC Li-ion chemistries against realistic vehicle crash scenarios. From this work it is noted that it is hard / non-conservative to draw conclusion or expected response of a large complex Li-ion system based on single or small assembly Li-ion cell testing.

B.4.15 It was also noted that the charge state of individual Li-ion cells in a bunch impacts the bunch total heat release rate (Sturk, et al., 2015). Additionally,



where more Li-ion cells in a bunch are at 100% SoC leads to a longer duration to reach the peak heat release, which has a lower value compared to just one Li-ion cell at 100% SoC.

- B.4.16 (Wang, et al., 2019) investigates the fire behaviour of LFP and NMC Li-ion cells. It was noted that LFP generated more jet fires, whilst NMC were more likely to present as splash sparks, explosion, and gas / smoke ejections. Generally, it was observed that Li-ion batteries catch fire with an average surface temperature of 150°C. The maximum average surface temperature during the event were 535.3°C for LFP and 658.7°C for NMC. The normalised heat release was determined to be 2.304 kJ/g for LFP and 3.133 kJ/g for NMC.
- B.4.17 Additionally, the maximum surface temperature increase is of 18.04°C /s for LFP and 64.84°C/s for NMC (Wang, et al., 2019). The decomposition temperature of the Solid Electrolyte Interface (SEI) occurs between 80-120°C. Around 100°C combustible gases will be released due to electrolyte decomposition. The separator melts between 135 and 160°C, whilst the cathode decomposes above 200°C.
- B.4.18 Table B.8 provides a summary of fire parameters for various Li-ion cell chemistries, (Majeed, et al., 2024).

Table B.8: Characteristics parameter of a Li-ion fire

Li-ion cell chemistry	State of charge (%)	HRR kW	Maximum flame temperature (°C)	Time to ignition (s)
LFP – 50 Ah	50	35.95	894	975.8
LFP – 22 Ah, 3.7 V	66 or 100	12.3	943.1	536
LiNi _{0.5} Co _{0.2} Mn _{0.3} O ₂ / graphite cell	100	-	660	932
LFP – 243 Ah	100	88.5	895.8	2,336
NCM – 2 cells	100	-	Cell 1 – 636.8 Cell 2 – 693.2	Cell 1 – 392 Cell 2 – 159 after cell 1

- B.4.19 (Shen, et al., 2023) notes that during thermal runaway, the cell temperature at thermal runaway is just over 300°C for LFP, and between 549°C and 842°C for NMC.
- B.4.20 Figure B.12 from (Shen, et al., 2023) provides a brief description on thermal runaway between LFP and NCM.

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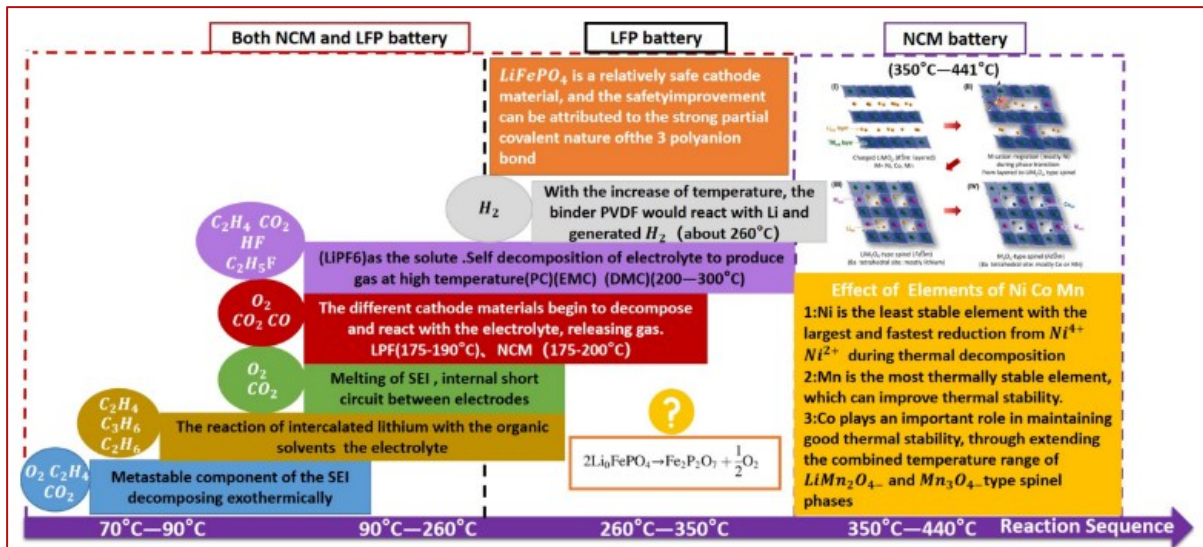


Figure B.12: Gas generation and phase changes associated with thermal runaway of LFP and NCM Li-ion cells

B.4.21 (Rappsilber, et al., 2023) provides a summary of various thermal runaway tests on Li-ion cell. From this review it is noted that the total heat release ranged between 2.0 and 112.0 kJ/Wh, and peak heat release rate ranged between 0.006 and 2.8 kW/Wh for a Li-ion cell.

B.4.22 (Saucer, et al., 2024) investigates thermal runaway effluent gas (TREG) associated with an EV in a garage. It was found that TREG could form an explosive atmosphere that would pose a threat to safety of life and the structure. Figure B.13 presents the impulse vs maximum overpressure associated with the bag experiments. For LFP chemistry the maximum overpressure was calculated to be 0.0046 kPa/L with an impulse 0.1535 kPa.ms/L.

B.4.23 In (Liu, et al., 2024) Li-ion cell was heated by heat flux at different locations of the cell, as shown in Figure B.14. Figure B.15 presents the outcome, which shows that bottom heat flux application resulted in the highest temperature rate, whilst heat flux applied to the side resulted in the fastest heat flux.

B.4.24 Figure B.16 shows that physical parameters change as a battery goes into thermal runaway (Liu, et al., 2024). As can be noted, temperature rises and plateaus, whilst gas emission initiates.

B.4.25 As noted in (Mayonado, et al., 2024), in UL 9540A testing and other destructive testing of Li-ion cells there can be a significant variation between heat release rate and then vent gas depending on the failure mode. The UL 9540A test does not meet the historically assessment conducted for fire or explosive hazards as well as does not represent the completely bound worst case failure scenarios. Specifically, the main limitations of the UL 9540A are the lack of:

- Full-scale fire testing,
- Testing fire suppression systems, and
- Testing of the explosive control system.

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B.4.26 Therefore, (Mayonado, et al., 2024) considers a full-scale propagating failure is a plausible event over the lifespan of the BESS site. (Mayonado, et al., 2024) also notes that in 2018, FM Global and NFPA conducted a BESS unit test of a single 125 kWh unit, which generated a 10 MW fire. In this testing it was demonstrated that a sprinkler of 0.3 gallons per minute per square foot (12.2 L/(min.m²)) was unable to extinguish the fire or stop propagation to adjacent unit within 3 feet (0.91 m).

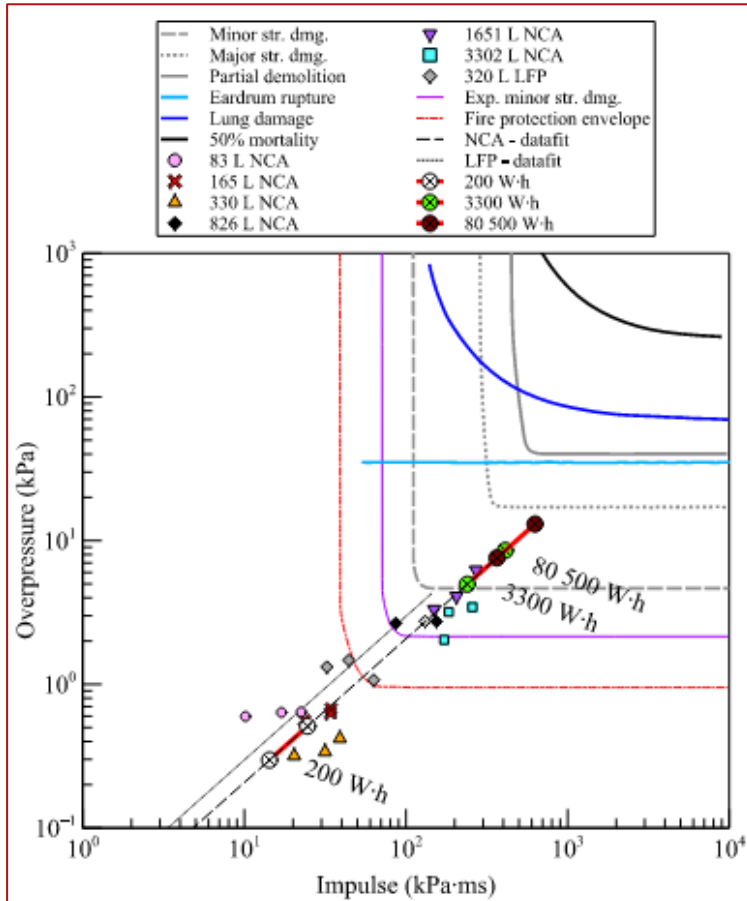


Figure B.13: Impulse vs maximum overpressure - bag experiments

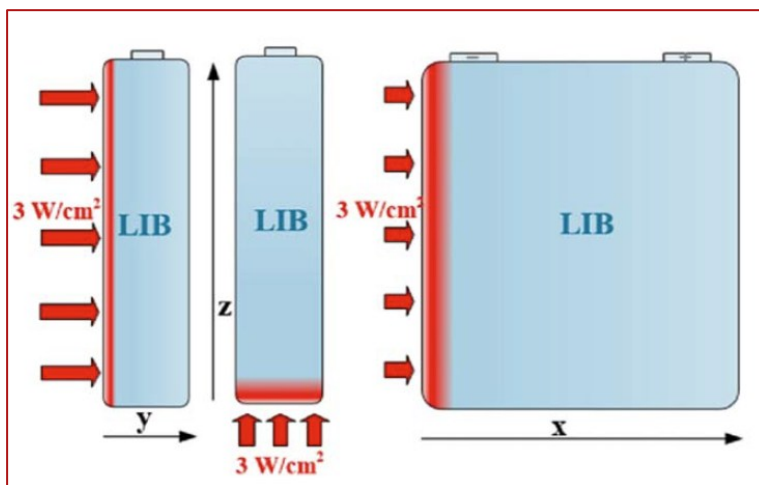


Figure B.14: Front, bottom, and side application of heat flux onto a Li-ion cell

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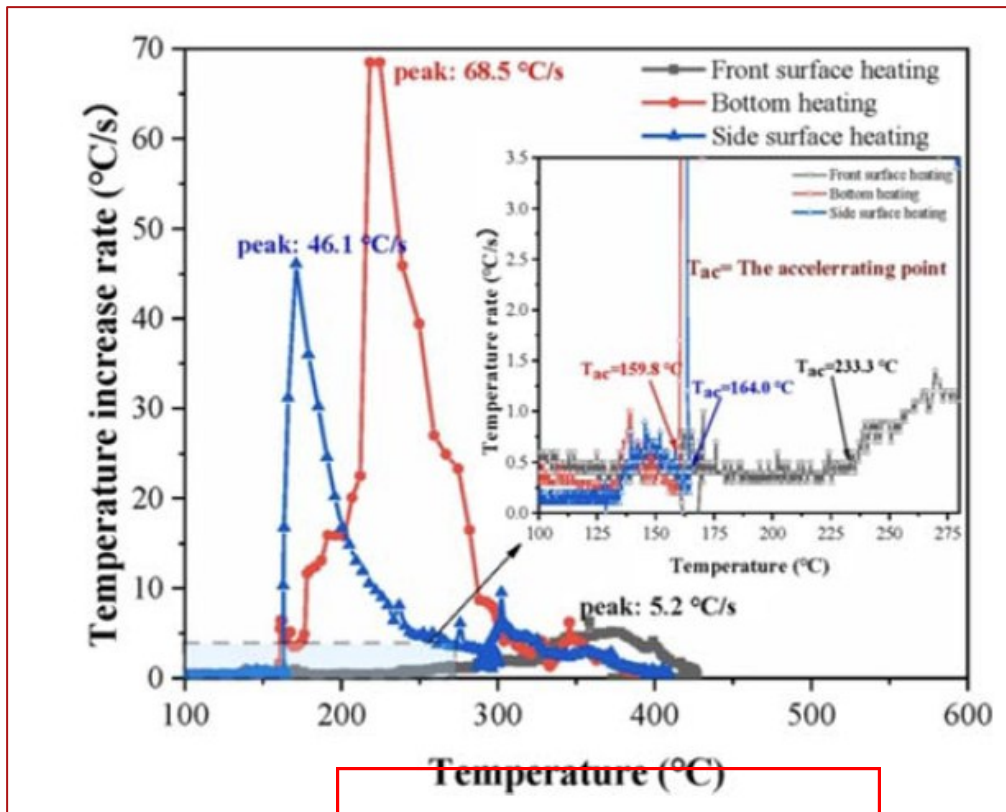


Figure B.15: Temperature rate change curves for different locations of heat application

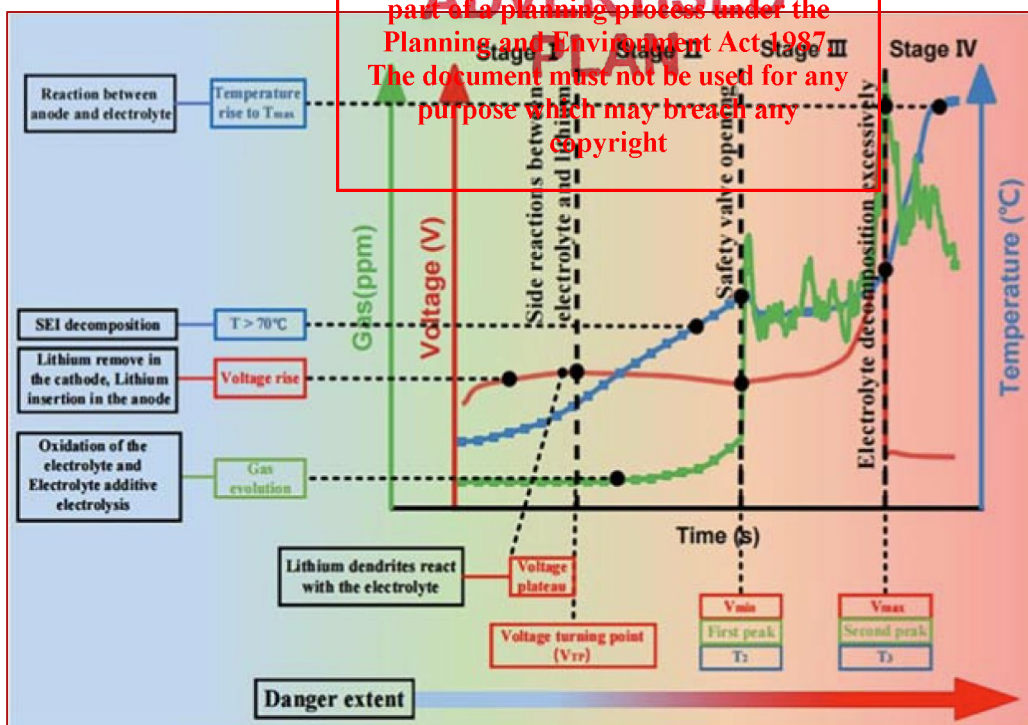


Figure B.16: Physical parameter response to an Li-ion cell going into thermal runaway

B.4.27 Figure B.17 from (Mayonado, et al., 2024) demonstrates that the arrangement of the cell can impact the heat release rate and therefore its ratio of total heat release to electrical energy of the Li-ion cell. As such the application of generic Li-ion cell to a BESS unit fire behaviour may not be accurate or conservative. As



an example, FM Global conducted a full-scale test and comparison between Li-ion cells with different configurations and cell chemistries. From this the ratio of total heat release to electrical energy of the unit was of the order 25, whilst on average the ratio was 9.

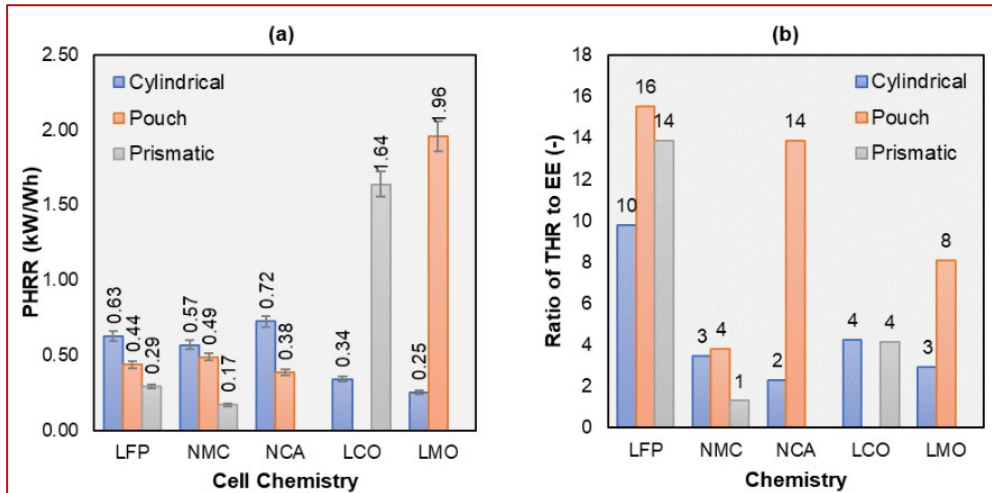


Figure B.17: Average heat release metrics across Li-ion Battery Chemistries and Form Factors: (a) Peak Heat Release Rate (PHRR) and (b) Total Heat Release (THR) ratio to Electrical Energy (EE) (Mayonado, et al., 2024) notes that a BESS unit fire has similar characteristics to a compartment fire in that there are phases of growth, fully developed, and decay.

B.4.28 A growth phase would likely start with one or a few Li-ion cells going into thermal runaway. These Li-ion cell(s) would need to generate sufficient heat energy, referred to as "Minimum Propagation Energy", to propagate this thermal runaway event to adjacent Li-ion cells. Additionally, the auto ignition temperature for the flammable gas mixture needs to be achieved.

B.4.29 Fully developed Li-ion unit fires demonstrate a fast or ultra-fast t^2 growth once flaming combustion has occurred. These fires within BESS units generally become oxygen-limited due to the rate of smoke and gas generated. Therefore, upper flammability limit can be exceeded for some flammable gases emitted (Mayonado, et al., 2024).

B.4.30 As the Li-ion cells which have entered thermal runaway burn out, decay of the fire event occurs. During this decay phase phenomena relates to 'stranded energy' and re-ignition' are outcomes of the chemical and electrical origins of thermal runaway. These phenomena and that flammable gases may be in concentration above the upper flammable limit means there is a significant backdraft hazard associated with this BESS unit. For this reason, systems that comply with NFPA 68 and NFPA 69 alone may not be suitable (Mayonado, et al., 2024).

B.4.31 In (Qi, et al., 2025) the critical surface temperature associated with thermal runaway was investigated. The outcome was for LFP (346°C) > sodium ion Battery (NIB) (292°C) > NCM523 (290°C) > NCM622 (281°C). It was also determined that NIB have the lowest thermal runaway trigger energy of 158 kJ, while LFP the highest 592.8 kJ.



B.5 By-Products

B.5.1 Across the Li-ion chemistries the following are common emitted gases:

a) Volatile gases

- Hydrogen (H₂)
- Short hydrocarbon, such as methane (CH₄), ethane (C₂H₆), ethylene (C₂H₄), and Propane (C₃H₈)
- Polycyclic aromatic hydrocarbons
- Acrolein (C₃H₄O)
- Benzene (C₆H₆)

b) Smoke

- Carbon dioxide (CO₂)
- Carbon Monoxide (CO)
- Soot
- Hydrogen cyanide (HCN)
- Nitrogen Oxides (NO_x)
- Sulfur Dioxide (SO₂)
- Ammonia (NH₃)
- Polychlorinated dibenzodioxins (PCDDs)

c) Acidic

- Hydrogen fluoride (HF)
- Phosphoryl fluoride (POF₃)
- Hydrogen Chloride (HCl)
- Hydrogen bromide (HBr)

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B.5.2 Table B.9 provides a summary of vented gas during thermal runaway for different Li-ion cell chemistry, from (Shahid & Agelin-Chaab, 2022).

B.5.3 (Shahid & Agelin-Chaab, 2022) proposed a linear relationship between Li-ion (NMC) cell capacity and volume of vented gas was developed, see Figure B.18.

B.5.4 Oxygen is not mentioned as a by-product with current Li-ion chemistries due to the low amount that is emitted. All that is noted comes from (Mylenbusch, et al., 2023) in that LFP chemistry do not emit O₂ below 450°C, whilst for NMC this occurs around 150 – 250°C.

B.5.5 As with temperature parameters for thermal runaway, the following review of papers on by-products related to Li-ion thermal runaway and fires presents a level of variability. This is because outside of chemistry, how the test was conducted can influence the outcome.

Table B.9: Comprising of gas emission during thermal runaway

Type	H ₂ (%)	CO (%)	CO ₂ (%)	CH ₄ (%)	C ₂ H ₂ (%)	C ₂ H ₄ (%)	C ₂ H ₆ (%)
------	--------------------	--------	---------------------	---------------------	-----------------------------------	-----------------------------------	-----------------------------------



LFP	23.34	4.5	25.39	5.9	0.08	3.26	1.29
NMC 1	12.39	30.3	13.22	10.5	0.0026	0.1	0.16
NMC 2	12.54	28.06	19.91	12.9	0.0027	0.16	0.21

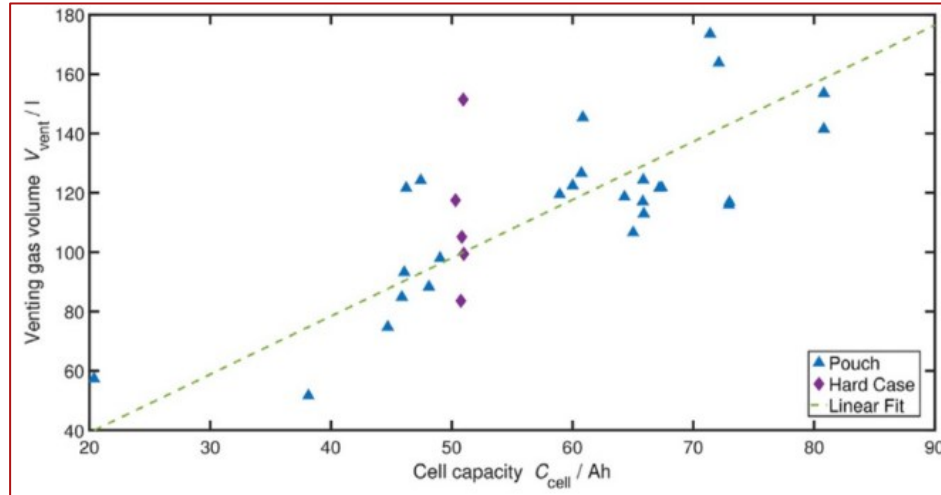


Figure B.18: Volume of vented gas compared to Li-ion cell capacity

- B.5.6 Figure B.19 from (Maloney, 2016) shows the total gas emissions from a Li-ion 18650 cell during thermal runaway, with respect to SoC, whilst Figure B.20 gives the breakdown for flammable gases.
- B.5.7 In (Shen, et al., 2023) it was observed that during thermal runaway LFP Li-ion cells emitted significantly more H₂ than NMC Li-ion cells, i.e., 50% vs 22%.
- B.5.8 (Rappsilber, et al., 2023) investigates the emission of HF from LFP Li-ion cells of different arrangements and SoC. The results are presented at Figure B.21.

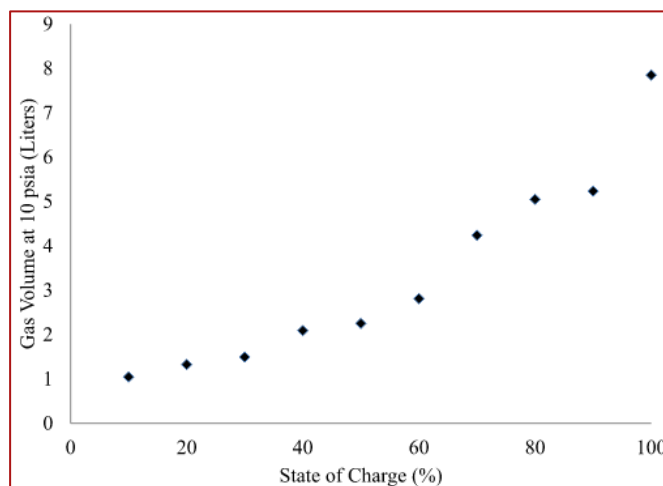


Figure B.19: Gas volume emitted from 18650 LiCoO₂ cell

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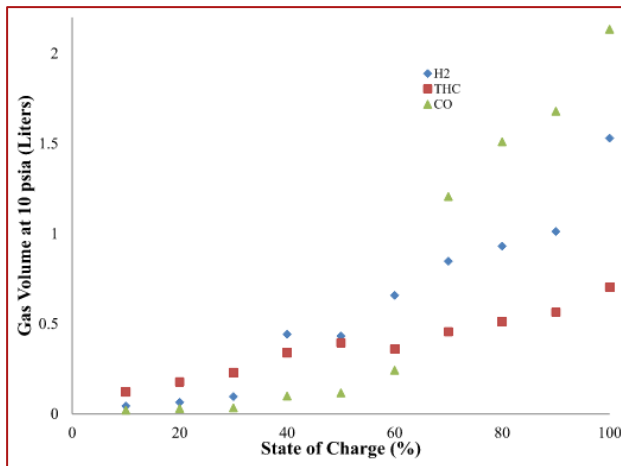


Figure B.20: Flammable gases emitted from LiCoO₂ 18650 cells, where THC is total hydrocarbons emissions

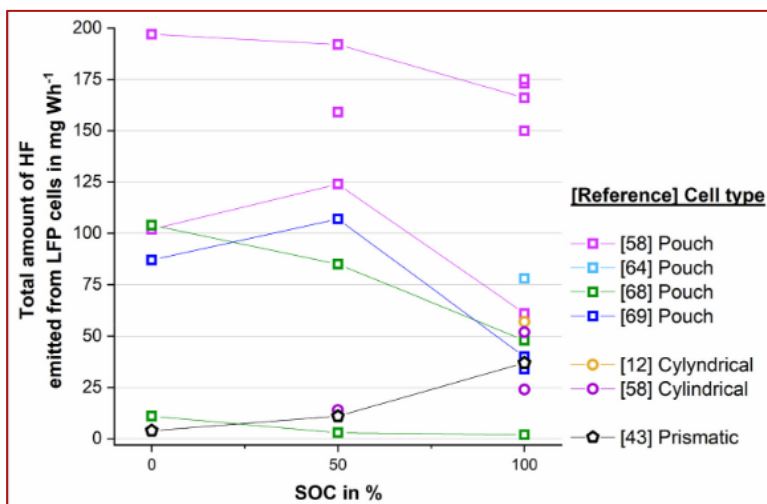


Figure B.21: HF released from LFP cells with respect to SoC and arrangement

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- B.5.9 (Bordes, et al., 2024) notes that during thermal runaway / fire events of a Li-ion cell / battery that potentially harmful components can be emitted. The emission of by-products from a Li-ion cell / battery may be anywhere within the full spectrum of physical states, i.e., liquids (electrolyte leak or ejection), gases, vapours, or solid aerosols. Often the emission of liquids / solids includes metals and their oxides, salts, or solvents. This is critical as water is often the only extinguishment medium that fire brigades have. Therefore, the potential environmental consequence of this contaminated water needs to be assessed.
- B.5.10 The assessment of the management of contaminated water is practical for fixed sites, such as BESS facilities. Whilst for EVs on the road, if contaminated water containment is to be undertaken, it may be necessary for the fire brigade to make ad-hoc arrangements for water containment during suppression activities, then alert the appropriate environmental authority to attend site to test and direct clean up activities.
- B.5.11 (Bordes, et al., 2024) conducted three similar tests on NMC Li-ion cell to determine the concentrations of emitted by-products. Table B.10 provides the outcome.

**Table B.10: Concentration of by-products from NMC cells**

By-product	Test 1	Test 2	Test 3
Halogen and Metals			
F ⁻ (mg/L)	142	91.6	93.7
CL ⁻ (mg/L)	33.4	36.5	203
Al (mg/L)	74.2	29.3	73.9
Co (mg/L)	0.42	12.8	7.07
Cu (mg/L)	0.3	0.26	4.18
Fe (mg/L)	5.92	4.59	0.3
Li (mg/L)	44.5	27.8	360
Mn (mg/L)	1.22	17.0	5.82
Na (mg/L)	15.6	16.3	26.2
Ni (mg/L)	3.25	49.0	40.1
P (mg/L)	201	113	5.8
Poly Aromatic Hydrocarbons			
Naphtalene (ng/L)	1279.2	279.2	3114.6
Acenaphtylene (ng/L)	2421.7	2405.1	1193.4
Methyl-1-naphtalene (ng/L)	26.8	459.4	667.1
Methyl-2-naphtalene (ng/L)	203.2	Below 10	2058.4
Acenaphtene (ng/L)	34.1	110.6	275.7
Fluorene (ng/L)	74.1	752.3	1055.0
Phenanthrene (ng/L)	360.9	3026.8	2581.6
Anthracene (ng/L)	10.6	330.5	303.3
Fluoranthene (ng/L)	57.7	1280.9	349.8
Pyrene (ng/L)	45.1	1279.8	20.5
Methyl-2-fluoranthene (ng/L)	7.3	45.1	21.3
B(a)A (ng/L)	24.8	185.7	131.8
Chrysene (ng/L)	32.5	212.3	40.8
Retene (ng/L)	104.9	170.7	19.8
B(e)P (ng/L)	7.5	306.3	50.4

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By-product	Test 1	Test 2	Test 3
B(j)F (ng/L)	Less than 20	106.3	Less than 20
B(b)F (ng/L)	34.6	259.6	5.8
B(k)F (ng/L)	8.3	81.0	8.2
B(a)P (ng/L)	13.0	163.9	20.8
D(a.h)A (ng/L)	Less than 2	36.7	4.5
Benzo(ghi)P (ng/L)	13.3	169.6	4.1
Indeno (ng/L)	35.2	162.1	11.8
Coronene (ng/L)	4	54	Less than 2
Organic Carbonates			
DMC (µg/mL)	n/a	n/a	n/a
EMC (µg/mL)	138	59	n/a
VC (µg/mL)	n/a	n/a	n/a
DEC (µg/mL)	n/a	n/a	n/a
FEC (µg/mL)	n/a	n/a	n/a
EC (µg/mL)	n/a	n/a	n/a
PC (µg/mL)	n/a	n/a	n/a

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B.5.12 Figure B.22 form (Mayonado, et al., 2024) demonstrate the impact of Li-ion cell chemistry and form on the total emission of gas in Litres.

B.5.13 Finally, from (Qi, et al., 2025), the dominant combustible gases from NCM622 and NCM523 are carbon monoxide, whilst for LFP and NIB hydrogen gas dominates, see Figure B.23.

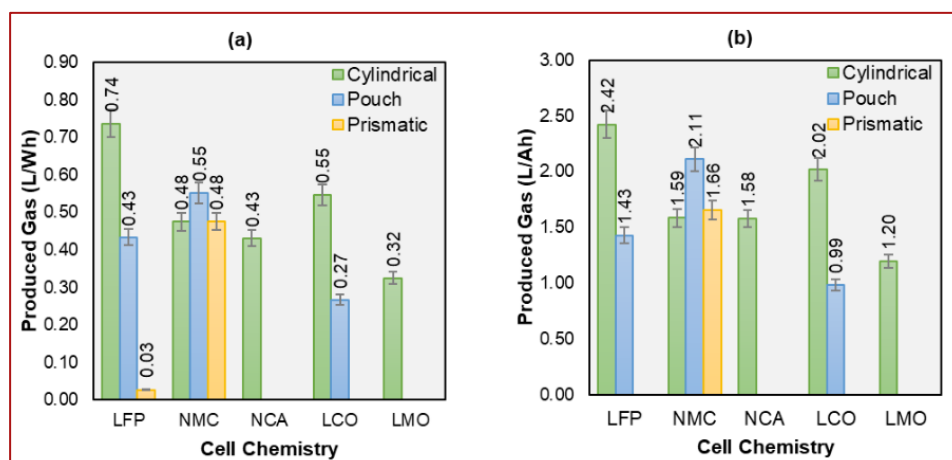
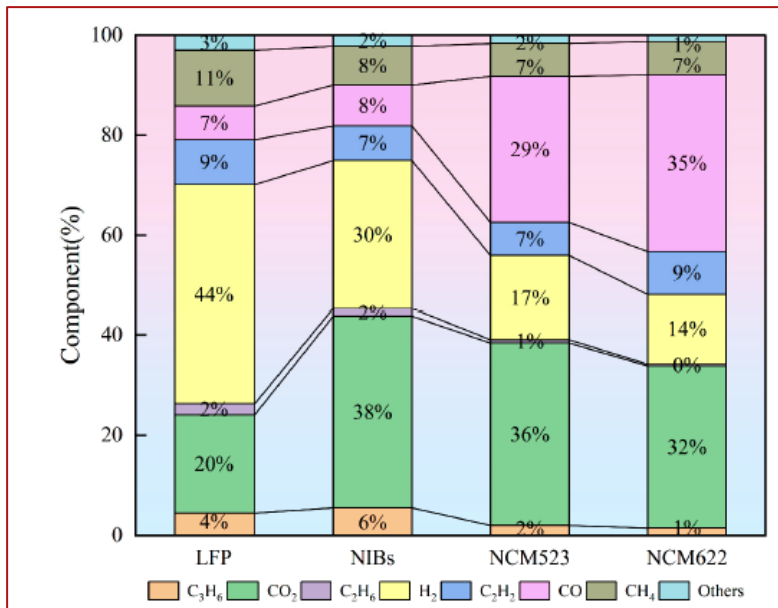


Figure B.22: Average total cell gas generation volumes across Li-ion cell chemistries and form factors: (a) reported unit of L/Wh and (b) reported unit of L/Ah



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Figure B.23: Normalised gas composition comparison for thermal runaway

B.6 Frequency

Criteria for Li-ion battery fire assessment

- B.6.1 (Fire Rescue New South Wales, 2024) notes that, when a site contains at least 25,000 kg lithium batteries in use, storage or handling, clause 361 of the NSW WHS Regulations, 2017 is to be implemented under the Planning and Environment Act 1987. To meet the requirements of clause 361 of the NSW WHS Regulation 2017, an emergency plan is to be developed in accordance with clause 43 of the NSW WHS Regulation 2017 and submitted to FRNSW. Additionally, an emergency services information package is to also be developed and issued to FRNSW.

- B.6.2 Currently in Australia this is the clearest guidance for when Li-ion battery systems need to be considered as a particular hazard. Therefore, when conducting a risk-based assessment the likelihood or the frequency of the incident occurring needs to be determined.

Frequency of incidents

- B.6.3 It is noted in (Electric Power Research Institute, 2024) that most BESS site failures relate to system integration rather than the BESS unit themselves. It is noted that system integration includes an up-to-date emergency response plan and regular drills that include the local first responders.
- B.6.4 Where an incident does relate to the BESS unit itself, this is more likely to occur during installation / construction of the site, see Figure B.24 from (Electric Power Research Institute, 2024).
- B.6.5 A well-documented example of fire during commissioning is the Victorian Big Battery fire. It was found to have been exacerbated by the "telemetry systems,



fault monitoring, and electrical fault safety devices [being] disabled or operate with only limited functionality. This prevented some of the safety features of MP-1 from actively monitoring and interrupting the electrical fault conditions before escalating into a fire event.” (Blum, et al., 2022).

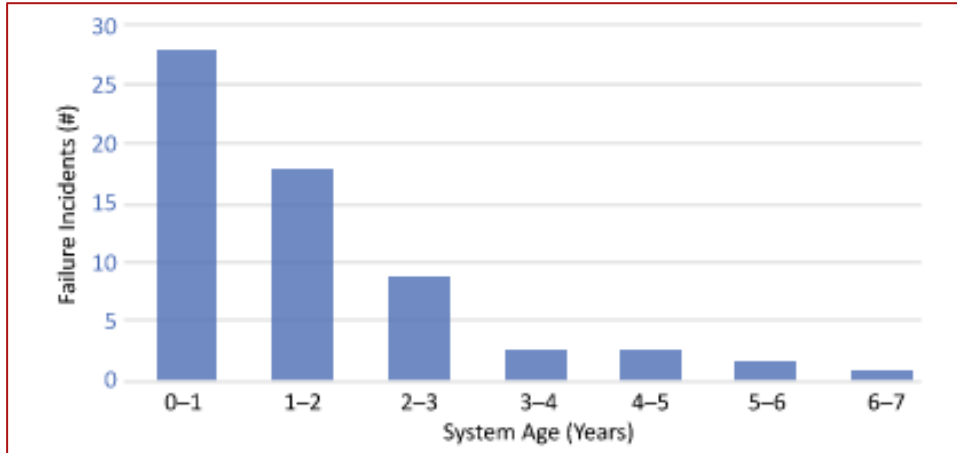


Figure B.24: Age of BESS facility at time of incident, ERPI data 2011 – 2024

B.6.6 This is best managed by a well-trained construction workforce, and ensuring critical componentry is operational and not isolated.

B.6.7 From (Electric Power Research Institute, 2022) it is noted that by 2022 there had been 56 stationary energy storage failures. This report then reviews Li-ion cells in use and compared against the failures to determine a failure rate of 1 in 40 million per Li-ion cell years. It should be noted that this statistic is based on part of older Li-ion cell chemistry which were more likely to experience thermal runaway / fire. It is noted that Six Sigma targets a failure rate of 1 in 3.4 million items (Mylenbusch, et al., 2023), therefore, the above failure rate is within a magnitude of that expected.

B.6.8 Figure B.25 from (Electric Power Research Institute, 2024) provides a breakdown of the failure / incidences at BESS sites.

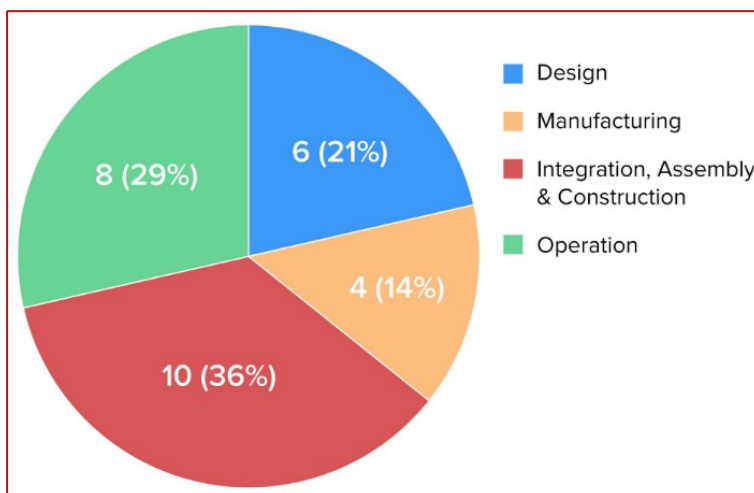


Figure B.25: Breakdown of BESS failures by root cause

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