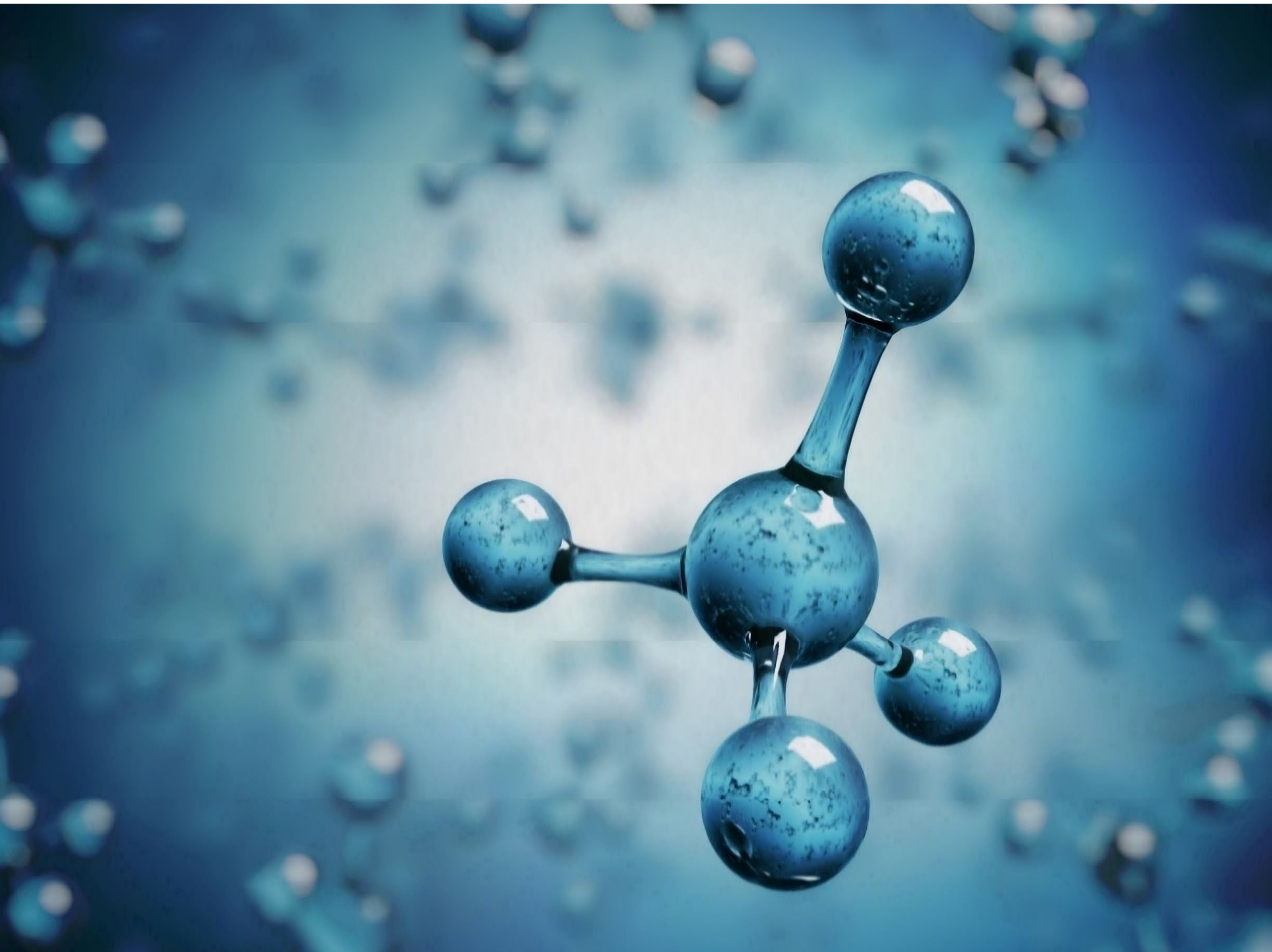
Lucas Heights Bioenergy Facility

Preliminary Hazard Analysis

LMS Energy Pty Ltd

October 2025

→ **The Power of Commitment**



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The Power of Commitment

Executive summary

The project

LMS Energy Pty Ltd (LMS) proposes to upgrade the landfill biogas management infrastructure at the Lucas Heights Resource Recovery Park (LHRRP), through installation of a new bioenergy facility (the project) to produce renewable energy from landfill biogas generated at the LHRRP.

The new bioenergy facility would be a like for like replacement of the existing power station, with improvements that comply with modern standards and regulations and forecasted bioenergy generation capacity requirements. The project ensures appropriate capacity to manage forecast peak recoverable biogas and renewable energy generation would effectively continue through the remaining landfilling and post closure periods for the landfill.

PHA results

This Preliminary Hazard Analysis (PHA) report has been prepared on behalf of LMS to support the environmental impact statement (EIS) for the project and responds to the Secretary's Environmental Assessment Requirements (SEARs) SSD-79933225 request for the preparation of a PHA covering the potential Hazards and Risks of the project.

The report includes a description of the project and potential hazards, identification of dangerous goods (DGs) expected to be transported, handled and stored on the project site, including the biogas (classified as a DG) transported within the biogas pipeline, and a description of any design measures and controls to minimise fire risk. Also included is a summary of DGs properties, preliminary risk screening of DGs as per the NSW *State Environmental Planning Policy (Resilience and Hazards)* (SEPP) and an assessment that reviews potential hazards that may arise during the construction, operation and maintenance of the development.

The results of the DG screening indicate that the proposed storage capacity of Dangerous Goods on-site, including biogas, a Class 2.1 flammable gas, do not exceed the thresholds within the SEPP requirements for dangerous good storage. The results of the transport screening indicate that the DGs movements are not expected to exceed the thresholds as there are expected to be minimal deliveries.

However, as the nearest land users, the Sutherland PCYC MiniBike club is located to the south-west of the project, and there will be open space parkland to the west following the completion of landfilling activities at the LHRRP, the project is considered potentially hazardous, requiring completion of a level 3 PHA to support the development application for the project. The new bioenergy facility will replace the existing power station and will be located to its east, placing it further from the Minibike club and future open space users than the current facility.

The hazard identification process identified that the worst-case credible scenarios included failure of the gas engine generator feed line and potential jet fires and explosions. Plausible scenarios were assessed, and the consequence and risk impacts deemed acceptable, subject to several risk reduction measures.

Recommended mitigation measures

Recommended mitigation and management measures identified in response to the PHA findings include:

1. Fire safety study to HIPAP No. 2 – A fire safety study during detailed design to HIPAP No. 2 should be included as a condition of development consent to cover the fire safety strategy and fire protection systems for the bioenergy facility, noting the provisions for biogas facilities outlined in the NCC documents E1D17 an E2D21.
2. Hot Work Permit System – A hot work permit system will be required on-site for any welding, cutting, or related activities.
3. Gas Cylinders and Cylinder Valve Covers – Where cylinder valve covers are fitted, such as for the LP Gas Cylinders, these are not to be removed during handling and storage. All gas cylinders are to be stored in accordance with AS4332- 2005 - *The storage and handling of gases in cylinders*.

4. Final Hazard Analysis – If substantial changes are made to the design, such as a large increase in the proposed pressure of the biogas fuel for the gas engines, LMS should conduct a final hazard analysis to reflect these changes. The FHA should include a revised estimate of the risk at the site boundary for worst case events.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.6, and the assumptions and qualifications contained throughout the report.

Key terms, acronyms and abbreviations

Term	Definition
ADG Code	Australian Dangerous Goods Code
ANSTO	Australian Nuclear Science and Technology Organisation
AS	Australian Standard
BMS	Burner Management Systems
Construction footprint	Defined as the area that would be directly affected by construction of the project. It includes: – the location of project infrastructure – the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the temporary construction workforce accommodation facility, construction compounds and laydown areas that would be used during construction.
CEMP	Construction Environmental Management Plan
CO_2	Carbon Dioxide
DG	Dangerous Good
DP	Deposited Plan
EPA	Environmental Protection Authority
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)
ERPG	Emergency Response Planning Guideline
FBR	Full Bore Rupture
FRNSW	Fire and Rescue NSW
FTE	Full Time Equivalent
GO	Garden Organics
IBC	Intermediate Bulk Container
km	kilometres
kW / m^2	kilowatt per square metre
kPag	kilopascals gauge
LFL	Lower Flammability Limit
LHRRP	Lucas Heights Resource Recovery Park
m	Metres
MW	Megawatt
MWh	Megawatt hours
NSW	New South Wales
PE	Polyethylene
PG	Packing Group
PHA	Preliminary Hazard Analysis
PLC	Programmable Logic Controller
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
POEO Clean Air Regulation	NSW Protection of the Environment Operations (Clean Air) Regulation 2022
QRA	Qualitative Risk Assessment
SDS	Safety Data Sheet

Term	Definition
SEARs	Secretary's Environmental Assessment Requirements
SEPP	*State Environmental Planning Policy*
SSD	State significant development
TX	Transformer
The project	The installation of a new, upgraded bioenergy facility at the Lucas Heights Resource Recovery Park (LHRRP) to replace the existing power station.
The proponent	LMS Energy Pty Ltd
The Regulation	Environmental Planning and Assessment Regulation 2000 (NSW)
UFL	Upper Flammability Limit
UN Number	United Nations Number (with reference to dangerous good identification)

Contents

Table index

Figure index

Appendices

1. Introduction

1.1 Overview

LMS Energy Pty Ltd (LMS) proposes to upgrade the biogas management infrastructure at the Lucas Heights Resource Recovery Park (LHRRP), by upgrading the existing power station (the project) to produce renewable energy from biogas generated at the LHRRP.

The new bioenergy facility would be a like for like replacement of the existing power station biogas generators within the existing power station site, with improvements that comply with modern standards and regulations and forecasted biogas generation capacity requirements. The project ensures appropriate capacity to manage forecast peak recoverable biogas and renewable energy generation would effectively continue through the remaining landfilling and post closure periods for the landfill.

1.2 Approval and assessment requirements

The project is a State Significant Development (SSD) and is subject to approval by the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

This report has been prepared by GHD Pty Ltd (GHD) as part of the environmental impact statement (EIS) to support the development application for the project. The EIS has been prepared to address the environmental assessment requirements of the Secretary of the NSW Department of Planning, Housing and Infrastructure (the SEARs).

The SEARs require that the project is assessed for the likely risks to public safety including fire and the use of dangerous goods (DGs) associated with the bioenergy facility. Specifically, including the dangerous goods transported within the biogas pipeline and any design measures and controls to minimise fire risk and exposure to future adjacent recreational land uses. This PHA assessment is carried out in accordance with Chapter 3 of the NSW *State Environmental Planning Policy* (SEPP) *(Resilience and Hazards) 2021*.

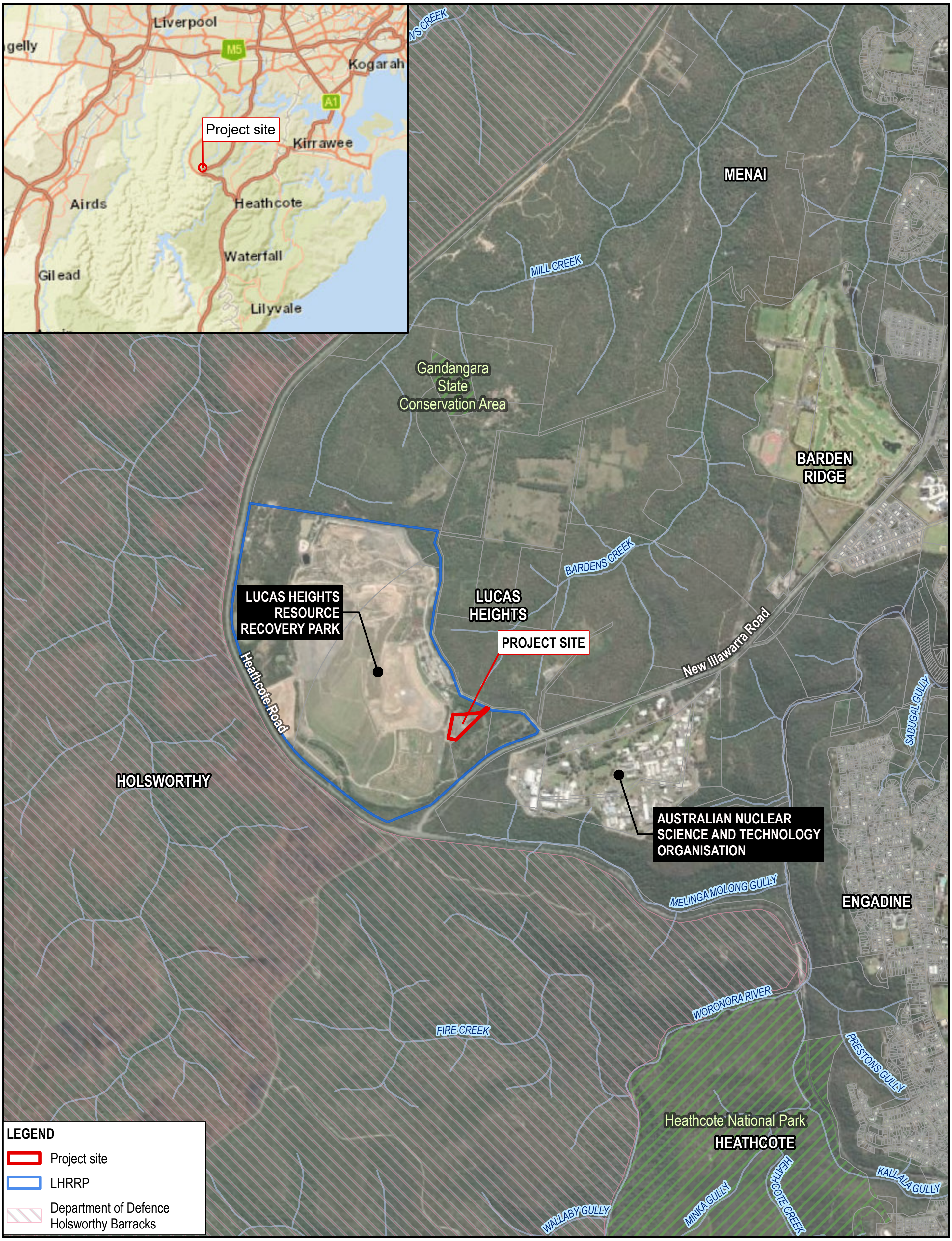
SEPP (Resilience and Hazards) requires a systematic approach to planning and assessing development applications for potentially hazardous and offensive development. SEPP (Resilience and Hazards) applies to any projects which fall under the policy's definition of a 'potentially hazardous industry' or 'potentially offensive industry'. For projects classified as a 'potentially hazardous or offensive industry' the policy establishes a comprehensive test by way of a Preliminary Hazard Analysis (PHA) to determine the risk to people, property and the environment at the proposed location and in the presence of controls.

1.3 The project

The project involves development of a new bioenergy facility to provide a modernised version of the existing power station servicing the LHRRP. The facility would have an output capacity of approximately 22 megawatts (MW). The facility would capture and recover biogas generated from the LHRRP landfill to generate electricity, which would be exported to the existing power network. Further information about the project is detailed in section 3.

The project's location is shown on Figure 1.1.

The bioenergy facility would be located on Lot 102 DP 1009354 (existing power station site) which has an area of approximately 1.80 hectares.



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

LMS Energy
Lucas Heights Bioenergy facility

Project No. 12649882
Revision No. 0
Date 17/09/2025

Regional context

FIGURE 1.1

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Data source: LPMA: DTDB/DCDB, 2019. World Imagery: Maxar
World Street Map: Esri, HERE, Garmin, NGA, USGS
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1.4 Secretary's Environmental Assessment Requirements

The specific SEARs addressed in this report are summarised in Table 1.1.

Table 1.1 Hazard and Risk SEARs

Requirement	Where addressed in this report
A preliminary risk screening completed in accordance with Chapter 3 of State Environmental Planning Policy (Resilience and Hazards) 2021 and Applying SEPP 33 [Ref. 1].	Sections 5, 5.2 and 5.3
A clear indication of class, storage and handling quantities and location of all dangerous goods and hazardous materials associated with the development, including the dangerous goods transported within the biogas pipeline.	Table 5.1
A description of any design measures and controls to minimise fire risk and exposure to future adjacent recreational land uses.	Table 6.1 and Table 6.2
Preliminary Hazard Analysis (PHA) prepared in accordance with Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis and Multi-Level Risk Assessment [Ref. 3], should the preliminary risk screening indicate that the project is "potentially hazardous".	All sections of this report

1.5 Purpose of this report

The purpose of this report is to complete an assessment of the hazards associated with the project that impact public safety. The report includes:

- a description of the project
- identification of DGs to be handled, transported and stored on the project site, including the dangerous goods transported within the biogas pipeline
- screening of DGs as per the requirements of SEPP (Resilience and Hazards)
- hazard identification and assessment of potential hazards and controls that may arise during the construction, operation and maintenance of the project, including quantitative risk assessment of high consequence hazards
- identification of controls to mitigate the identified impacts to minimise fire risk and exposure to future adjacent land uses.

The above addresses the specific components expected of the SEARs as listed in Table 1.1.

The methodology for the assessment is described in section 4.

1.6 Scope and limitations

SEPP (Resilience and Hazards) 2021, presents a systematic approach to planning and assessing proposals for potentially hazardous and offensive development for the purpose of industry or storage.

For development proposals classified as a 'potentially hazardous or offensive industry' the policy establishes a comprehensive test by way of a PHA to determine the risk to people, property and the environment at the proposed location and in the presence of controls.

The scope of this report includes identification of DG use, DG screening, hazard identification, a PHA and identification of mitigation measures. Excluded is any identification or assessment of hazards and risks associated with current operational activities beyond the development.

This report has been prepared by GHD for LMS Energy Pty Ltd and may only be used and relied on by LMS Energy Pty Ltd for the purpose agreed between GHD and LMS Energy Pty Ltd as set out in section 1.5 of this report.

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

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

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

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.7 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

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

The flare installation is being assessed independently as a modification to SSD 6835. Consideration of impacts associated with construction and operation of the flares will be assessed in the modification report and are hence excluded from the scope of this assessment. The cumulative effects of the bioenergy facility and flare installation will be considered as part of this EIS.

GHD has prepared the SAFETI risk model ("Model") for, and for the benefit and sole use of, LMS Energy Pty Ltd to support the development of the PHA and must not be used for any other purpose or by any other person.

The Model is a representation only and does not reflect reality in every aspect. The Model contains simplified assumptions to derive a modelled outcome. The actual variables will inevitably be different to those used to prepare the Model. Accordingly, the outputs of the Model cannot be relied upon to represent actual conditions without due consideration of the inherent and expected inaccuracies. Such considerations are beyond GHD's scope.

The information, data and assumptions ("Inputs") used as inputs into the Model are from publicly available sources or provided by or on behalf of the LMS Energy Pty Ltd, (including possibly through stakeholder engagements). GHD has not independently verified or checked Inputs beyond its agreed scope of work. GHD's scope of work does not include review or update of the Model as further Inputs becomes available.

The Model is limited by the mathematical rules and assumptions that are set out in the Report or included in the Model and by the software environment in which the Model is developed. Due to limitations of input data and SAFETI model detail / programming limits, the results of a QRA are approximate and reflect the constraints of the input data, assumptions, and model rule sets. The conclusions of a QRA are therefore sensitive to variations in the inputs or modelling assumptions. This is an unavoidable limitation of the technique. This study is reliant on the ability of the DNV SAFETI software to correctly model the data and settings for this exercise. GHD have not conducted an independent verification of the software and disclaims any responsibility for the performance of the SAFETI program.

The Model is a customised model and not intended to be amended in any form or extracted to other software for amending. Any change made to the Model, other than by GHD, is undertaken on the express understanding that GHD is not responsible, and has no liability, for the changed Model including any outputs.

1.7 Assumptions

The following assumptions have been made in the preparation of this report:

- DG quantities listed in this report are true and correct at the time of this assessment.
- Biogas is a Class 2.1 flammable gas, which have been taken to contain around 57% methane and 43% carbon dioxide, refer to section 6.3.1 for details.
- All equipment and systems are designed to be inherently safe.
- All equipment is maintained and operated as designed.
- Other DGs brought to site (not stored on site) during construction and for routine work are minimal and are not included in this assessment.
- The chemical data (UN number, DG classification) for DGs are based on available Safety Data Sheets (SDS).

Additional assumptions are detailed in section 7. Any changes to the assumptions used in this report would require a review of the screening results and the PHA and update as required.

1.8 Structure of this report

The structure of the report is outlined below.

- Section 1 – provides an introduction to the report and project
- Section 2 – describes the legislative and policy context of the report
- Section 3 – provides a brief outline of the proposed biogas process based on the LMS design
- Section 4 – describes the methodology used during the preliminary hazard analysis
- Section 5 – outlines the initial risk screening process in accordance with SEPP (Resilience and Hazards)

- Section 6 – describes the hazard identification (HAZID) process (including a HAZID desktop review) in accordance with SEPP (Resilience and Hazards)
- Section 7 – outlines the study assumptions
- Section 8 – summarises the preliminary hazard analysis and SAFETI modelling results as per the method described in section 4
- Section 9 – summarises the safety management systems which exist within the proposed design
- Section 10 – outlines the recommended mitigation measures based on previous sections
- Section 11 – summarises the evaluations and conclusions
- Section 12 – lists the references used in the report.

2. Legislative and policy context

2.1 SEPP (Resilience and Hazards)

State Environmental Planning Policy (Resilience and Hazards), 2021 (SEPP (Resilience and Hazards)), aims to manage risks and build resilience related to hazards. Development controls related to hazardous development and offensive industry, remediation of land and the approach to planning within coastal management areas are included. Section 3 outlines the development assessment process in relation to hazardous and offensive industries.

The Department of Planning, NSW, 2011, *Applying SEPP 33: Hazardous and Offensive Development Application Guidelines* continues to provide the process for assessing if developments are potentially hazardous or offensive under the SEPP (Resilience and Hazards) including threshold levels that trigger the potentially hazardous or offensive status. Applying SEPP 33 is the main guidance document that has been followed for this preliminary hazard analysis (PHA).

2.2 Hazardous Industry Planning Advisory Paper No. 4

The Department of Planning, NSW, 2011, *Hazardous Industry Planning Advisory Paper No 4 – Risk Criteria for Land Use Safety Planning* (HIPAP No. 4) sets out risk criteria for industries that are considered hazardous to comply to. This document is used when the SEPP (Resilience and Hazards) indicates a development is potentially hazardous [Ref 2].

2.3 Hazardous Industry Planning Advisory Paper No. 6

The Department of Planning, NSW, 2011, *Hazardous Industry Planning Advisory Paper No 6 – Guidelines for Hazard Analysis* (HIPAP No. 6) lists the process required for undertaking a PHA. This document is used when the SEPP (Resilience and Hazards) indicates a development is potentially hazardous [Ref 3].

3. Project description

3.1 Project overview

The project involves upgrading to the existing renewable energy infrastructure to deliver a modernised bioenergy facility at the existing power station site, supporting the operations of LHRRP. The upgraded facility would have a generation capacity of approximately 22 megawatts (MW).

The project would capture and recover biogas generated from the LHRRP landfill to generate electricity, which would be exported to the existing electricity network.

The project would allow operation of the existing power station, whilst the new bioenergy facility is being constructed. The proposed physical infrastructure and design outcomes for the project are provided in Table 3.1.

Table 3.1 Key project infrastructure and design outcomes

Project element	Description
Bioenergy facility generators	20 x 1.1 MW modular lean burn generator sets
Ancillary infrastructure	**New proposed infrastructure** – Transformers to step up the electrical output voltage from LV to HV to match the local grid voltage – Electrical metering, protection and communication equipment – Covered storage bund for chemical and coolant storage – HV Switchroom / Control room – Lightning poles – External lighting – Safety showers **Retained/ upgraded infrastructure** – Biogas delivery, metering, filtration and condensate removal system to remove moisture and particulate matter from the biogas – Lunchroom / Toilet – Offices / Workshop – Potable water pumps and tank(s) – Car parking for on site operators – Security fencing – Air compressors – External lighting – Waste oil and clean oil tanks **Buildings to be decommissioned** – Workshop x 2 – Existing generators – Existing flare facility – Cooling towers
Utilities connections	**Proposed new connections** – New underground high voltage (HV) electricity line to the Ausgrid 33 kilovolt (kV) distribution network as an extension of the connection from the existing electrical infrastructure to the Lucas Heights Zone Substation **Existing utilities connections** – Existing fibre connection to the Lucas Heights Zone Substation – Existing potable water connection from LHRRP
Hours of operation	– 6am to 6pm for operational staff – Remote operation 24 hours per day, 7 days per week outside of operational hours
Workforce	– 6 full time equivalent (FTE) staff during operation – 15 FTE staff during construction

3.1.1 Surrounding area

The project is located within the Sutherland Shire local government area about 30 kilometres southwest of the Sydney central business district within the suburb of Lucas Heights. Lucas Heights sits between the Royal National Park, Heathcote National Park and the Cubbitch Barta National Estate Area, which is managed by the Department of Defence as a part of the Holsworthy Barracks.

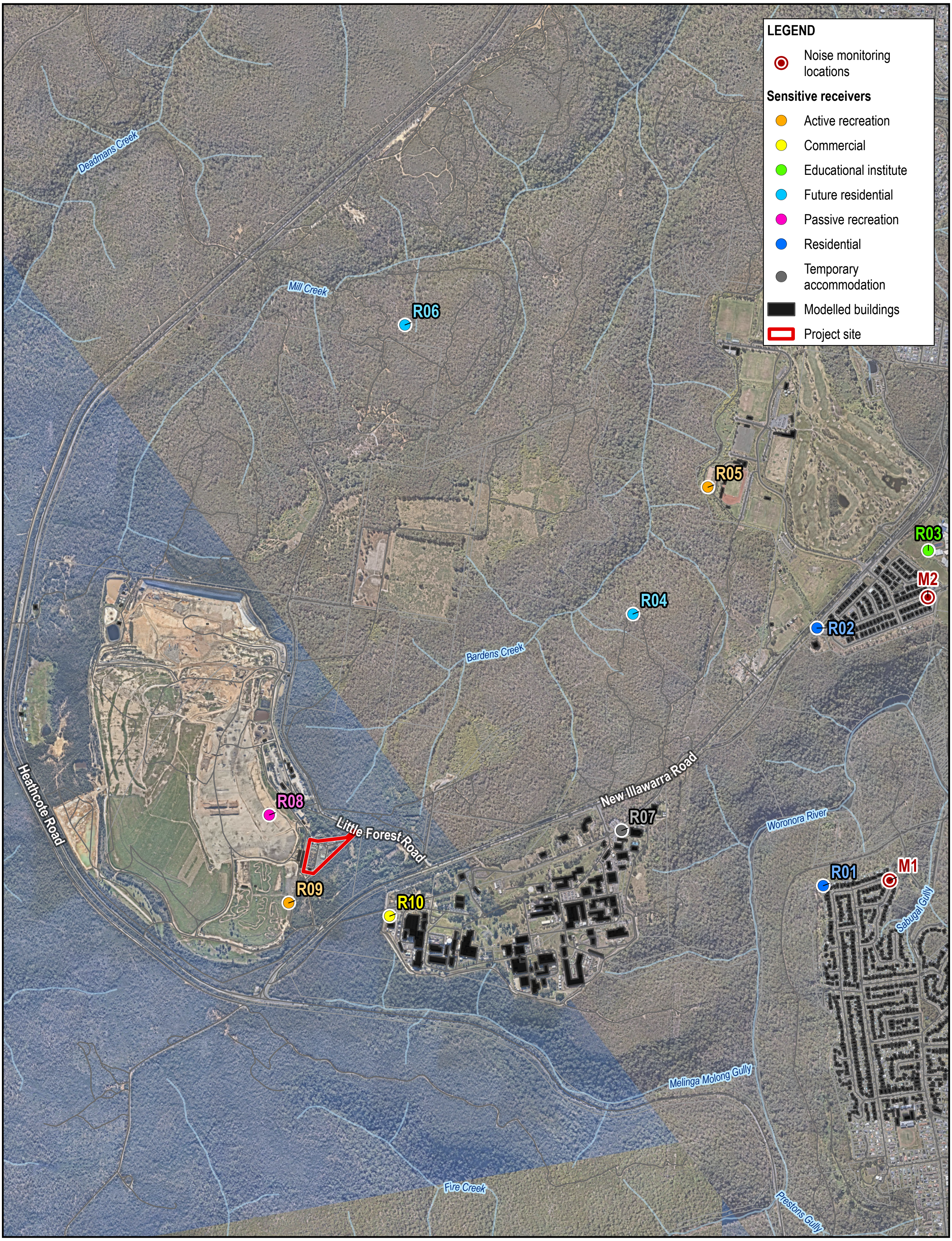
The surrounding area is largely undeveloped and supports substantial areas of vegetated land. There is also minimal heavy industry or commercial development in the area. Special land use activities are key features of the local area which include Defence activities, Australian Nuclear Science and Technology Organisation (ANSTO) and its associated facilities and the LHRRP.

The existing power station and flare is located on Lot 102 DP 1009354 with a separate access point south of the LHRRP entrance off Little Forest Road. Prior to construction of the new bioenergy facility, the existing flare and two workshops would be decommissioned.

A total of ten land users have been identified with the study area. These land users are listed in Table 3.2 and shown on Figure 3.1.

Table 3.2 Key land users

ID	Location	Land-use criteria	Source-to-receiver direction	Approximate distance
R01	Engadine residences	Residential (suburban)	ESE	2.2 km
R02	The Ridgeway residences	Residential (suburban)	NE	2.4 km
R03	Lucas Heights Community School	Educational institute	NE	3.0 km
R04	Gandangara	Existing: Passive recreation area Future: potential residential development	NE	1.7 km
R05	The Ridge Sports Complex	Active recreation	NE	2.3 km
R06	Gandangara North	Existing: Passive recreation area Future: potential residential development	NNE	2.3 km
R07	Lucas Heights Motel	Temporary accommodation	E	1.3 km
R08	Future parkland area	Passive recreation (post circa 2040)	NW	229 m
R09	Sutherland PCYC Minibike Club	Active recreation	SW	214 m
R10	ANSTO, Lucas Heights	Industrial	SE	376 m



Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Lucas Heights Bioenergy facility

Land users

Project No. **12649882**
Revision No. **0**
Date **16/09/2025**

FIGURE 3.1

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Data source: LPMA: DTDB/DCDB, 2019. Nearmap WMS Server: .
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3.1.2 Construction overview

If approved, construction of the project would likely commence in the first quarter of 2026 (Q1), with an estimated duration of 6-8 months (weather permitting).

Construction activities would include:

Early works (site establishment)

- site compound set-up including fencing to isolate the construction area from existing power station operations and set-up of environmental controls
- minor decommissioning of existing site sheds and flare compound
- minor civil works for site levelling and compaction

Mobilisation and structure installations (project construction)

- generator assembly and placement onto concrete pads using cranes
- installation of biogas delivery skids and placement onto concrete foundations
- ancillary connections (electricity through trenching) (gas, electrical, water, oil, compressed air)

Testing and commissioning

- test and commission of generators and ancillary equipment
- demobilisation.

3.1.2.1 Construction hours

Construction hours would be in accordance with the existing approved hours for construction at the LHRRP which are:

- Monday to Friday: 7am to 5pm
- Saturday to Sunday: 8am to 5pm.

Construction activities such as safety critical works, deliveries of oversized loads and emergency works may be undertaken outside the standard construction hours when the site contains minimal staff and to avoid peak traffic times.

3.1.3 Plant and equipment

Table 3.3 provides a list of the major pieces of plant and equipment expected to be required during the construction phase. The type and quantity of plant and equipment may vary depending on the construction staging and construction methods and would be determined by the construction contractor(s).

Table 3.3 Construction equipment

Construction equipment		
Excavators	Concrete trucks	Concrete pumps and agitators
Trucks	Vacuum trucks	Generators
Dozers	Front end loaders	Graders
Mobile cranes (various sizes)	Welding machines	Contractor service vehicles
Rollers	Semi-trailers	

3.1.3.1 Construction traffic

Traffic generation during construction is expected to comprise up to:

- 8 heavy vehicle movements per day
- 30 light vehicle movements per day.

Upon construction completion, all construction equipment would be demobilised and removed from the site.

3.1.3.2 Construction waste streams

Construction waste streams would include:

- minimal spoil – to be reused on site, where appropriate
- minimal waste concrete – may be reused on site or transferred off site for recycling
- minimal general waste from construction staff – to be taken off site with staff
- decommissioned plant and equipment.

Construction of the project would be undertaken in accordance with a Construction Environmental Management Plan (CEMP). The plan would detail mitigation measures to manage risks associated with the construction activities including waste management, generation of dust and noise, and control of construction traffic.

3.2 Bioenergy facility

3.2.1 Power generation system

Twenty 1.1 MW modular lean burn generator sets are proposed within the bioenergy facility. Each generator set would comprise a reciprocating lean burn gas engine purpose built for biogas combustion.

The generators are located in separate self-contained modules and the associated ancillary equipment installation includes high voltage switchgear for the export of the electricity generated to the local Ausgrid distribution network, as shown in Appendix A.

The custom designed generator enclosures would be fully insulated to attenuate noise, with engine exhaust emitted through stainless steel stacks located on top of the modules, approximately 10.2 m from ground level [Ref 9]. Each generator module would house all the components required to operate as a stand-alone unit and are specially designed as fully enclosed systems with integral bunds and fire, smoke and gas detection.

The modularised generator equipment is scalable both from a development perspective, and operationally, allowing flexibility to operate mixed modes (i.e. a combination of either flaring and/or generation) as required. This ensures the ability to combust the maximum available biogas, 24 hours per day and is seamless with programmable logic controller (PLC) controls and remote monitoring ensuring round the clock monitoring.

3.2.2 Key supporting infrastructure

3.2.2.1 Ancillary infrastructure

Ancillary infrastructure for the bioenergy facility would include the following:

- biogas delivery, metering, filtration and condensate removal system
- biogas quality monitoring
- electrical transformers
- site office/lunchroom and amenities, maintenance workshop/dry storage shed
- high voltage (HV) switch room/control room
- bunded storage for oil, coolant and chemicals
- internal all weather roads
- lightning protection and earth grid.

3.2.2.2 Biogas delivery infrastructure

The biogas management and extraction system for LHRRP connects to the existing power station. New connections to the generators would be established from the existing biogas network within the project site footprint.

Condensate collected at the facility would be returned to the LHRRP leachate management system via existing infrastructure.

3.2.2.3 Biogas monitoring

Biogas composition and heating value monitoring would be conducted using two gas analysers, one on each of the two low pressure biogas supply lines. The biogas flow would be metered in the same location.

The project would retain part of the existing biogas delivery infrastructure and add new biogas delivery skids to support biogas supply to the 20 new generators.

3.2.2.4 Electrical transformers

The bioenergy facility will include multiple step up transformers, each suitable for connection to two generators. The transformers shall be fitted with appropriate double HV bushings and LV terminations. All fittings on the transformers would be accessible with both the HV and LV compartments fitted.

3.2.2.5 Site office

The site has an existing workshop, site office and lunchroom which would be retained as part of the new facility.

3.2.2.6 High voltage switch room/ control room

The high voltage switch room will have fire and smoke detection. It will have a wall mounted Fire Indicator Panel and will be protected by a Inergen (IG-541) gas flooding system, comprising six bottles of inert gas agent which will displace oxygen to suppress electrical fires in the switch room.

3.2.2.7 Bulk oil storage

The current site operates with two 20,000 litre bunded oil tanks for clean oil and waste oil near the southern end of the site. The integrity and capacity of the existing bulk oil tanks for use in ongoing operations will be reviewed as part of detailed design and commissioning and if required replaced or supplemented with new bunded tanks at the same location with a combined capacity of up to 70,000 litres.

3.2.2.8 Chemical store

A modular chemical storage bund containing coolant is located adjacent the oil tanks. Minor chemicals would be stored appropriately in the existing workshop, in chemical storage cabinets where required.

3.2.2.9 Internal roadways, fencing and access

The bioenergy facility would be accessed via an existing entry/exit point at Little Forest Road. Rear access to the LHRRP is also provided on the eastern boundary. These access points are be linked by internal access roads. All existing internal access roads would be retained as part of the new facility. A new internal access road would be formed along the southern boundary.

The site has nine existing carparks which would be retained for further operations. Staff and visitors would use the main site entrance from Little Forest Road. The site is securely enclosed by a 2.4 metre high security fence.

3.2.3 Utility connections

3.2.3.1 Grid export connection

The facility would export electricity generated from biogas into the AusGrid network through a new 33 kilovolt (kV) underground connection to an existing AusGrid pole located on Lot 102 DP 1009354.

From the AusGrid pole, electricity would be transmitted via an existing 33 kV feeder to the Lucas Heights Zone Substation, approximately 750 m to the southeast at the ANSTO site.

3.2.3.2 Communications

An existing communications conduit extends to the site from the Ausgrid Lucas Heights Zone Substation.

3.2.3.3 Water management

A potable water supply is available to service the amenities and safety systems on site. The development requires minimal water inputs.

Domestic wastewater (blackwater and greywater) would be collected and disposed of via the existing wastewater management infrastructure which is a pumped septic system which returns to the ANSTO site.

Condensate (condensed water) knock out vessels will be retained from the existing power station. The condensate would be returned to the LHRRP leachate management system via existing infrastructure.

4. Method

The method to determine whether a project would be deemed potentially hazardous or potentially offensive and the required follow up assessments is provided in Table 4.1.

Table 4.1 SEPP (Resilience and Hazards) methodology for potentially hazardous or offensive industries

Issue	Methodology to determine if potentially hazardous/offensive	Follow up assessment if confirmed as potentially hazardous/offensive industry
Potentially hazardous industry	SEPP (Resilience and Hazards) risk screening process	Preliminary Hazard Analysis (PHA) required
Potentially offensive industry	Review of potential impacts to the amenity of the site or discharges, such as emissions (e.g. noise, air, pollution)	Meeting any licencing requirements issued by relevant authorities, e.g. Environmental Protection Agency (EPA) is required

The SEPP (Resilience and Hazards) process is discussed in sections 4.1 to 4.5.

4.1 Screening

SEPP (Resilience and Hazards) applies to any project which falls under the policy's definition of 'potentially hazardous industry' or 'potentially offensive industry'. If not controlled appropriately, some activities within these industries may create an offsite risk or offence to people, property or the environment thereby making them potentially hazardous or potentially offensive. SEPP (Resilience and Hazards) requires a screening process be undertaken and if the screening indicates that the project is potentially hazardous, then a PHA is required. The overall risk screening process is summarised in Figure 4.1.

If the project is potentially offensive, consideration to the quantity and nature of any discharges/pollution and the significance due to surrounding land use and the proposed controls, may require additional controls. It is noted that the objective of this project is to manage biogas from the neighbouring landfill site for production of renewable energy and the facility has been designed to minimise potentially offensive emissions to surrounding areas.

The risk screening process concentrates on the storage of specific dangerous goods (DGs classes that have the potential for significant offsite effects). The assessment involves the identification of classes and quantities of all DGs to be used, stored, or produced on site with an indication of storage locations. The quantities of DGs are then assessed against the SEPP threshold quantities. If any DG quantities exceed the threshold, the project is considered 'potentially hazardous'.

4.2 Hazard identification

Following screening, SEPP (Resilience and Hazards) requires a determination as to whether a project poses significant risk or offence. This requires identification of potential hazards to highlight any risks associated with the interaction of the project (as a whole) with the surrounding environment (i.e. a systematic process to identify any potential offsite impacts).

The HAZID process is a desktop qualitative assessment and involves documenting possible events that could lead to a possible off-site incident. The assessment then lists the potential causes of the incident, as well as identification of operational and organisational safeguards to prevent the incidents from occurring or mitigate their impact. The HAZID process identifies the scenarios relevant to a PHA if required.

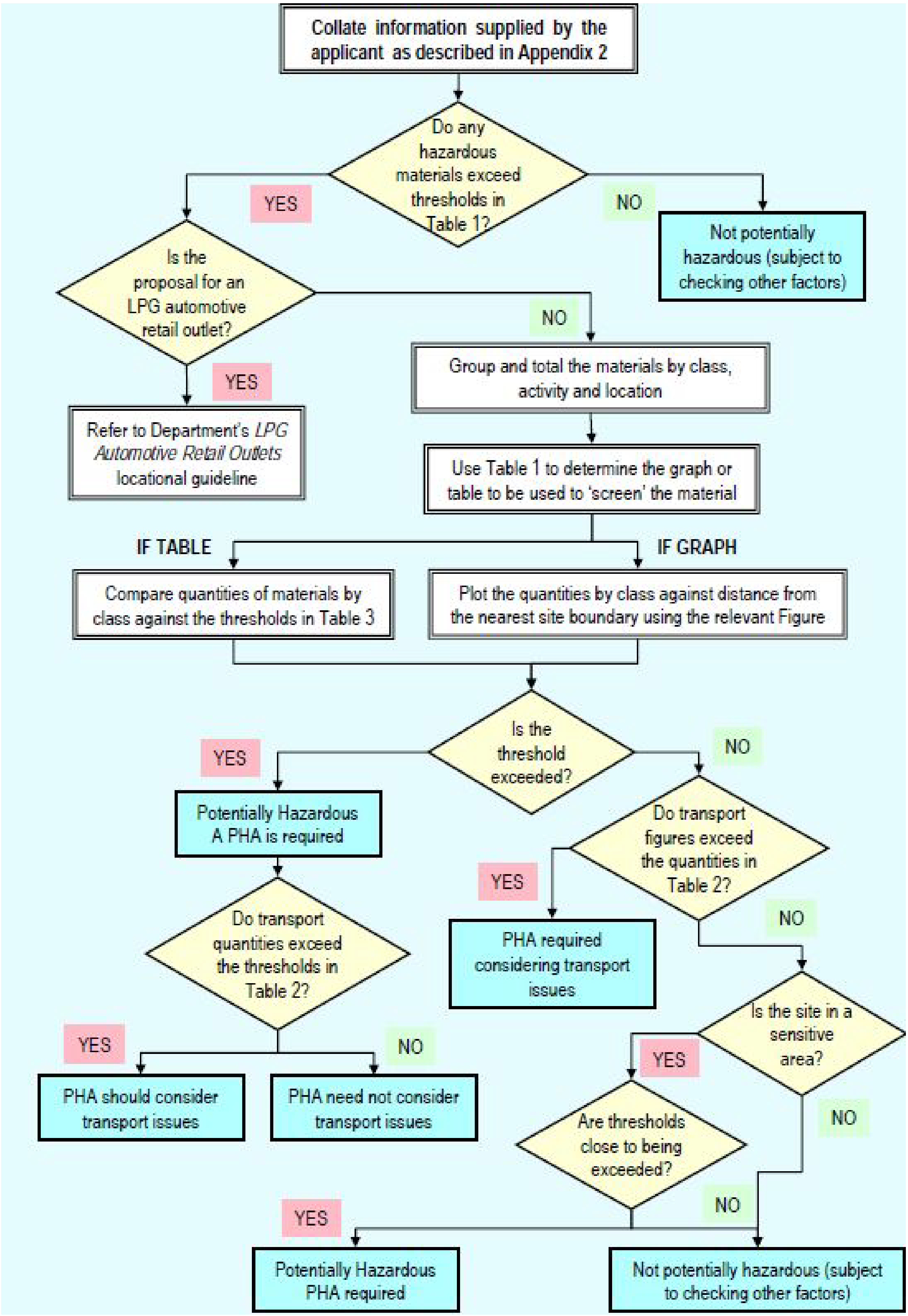

Figure 4.1 Applying SEPP 33 risk screening process [Ref. 1]

4.3 Leak frequency estimation

Frequency analysis involves estimating the likelihood of each of the failure cases that were defined in the hazard identification stage. Each failure case is broken down into equipment items. The leak frequency of each item is based on historical data.

The source of historical leak frequency data used for this study was the IOGP Process Release Frequencies Report [Ref 10]. It is based on the Offshore Oil and Gas industry and has been validated over time. It is comprehensive and widely used by other industries when there is no other reasonable data available. The statistical data for the event frequencies, together with the derived frequencies for the scenarios being considers are provided in Appendix C. It should be noted that the temperatures, pressures and other conditions at the facilities from which the leak frequency data has been obtained are significantly more severe than those which would be experienced at this project site, adding a level of conservatism to the results of the risk analysis.

4.4 Preliminary Hazard Analysis (PHA)

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

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

SEPP (Resilience and Hazards) identifies three levels of PHA. If a PHA is required, a judgement of the level of risk associated with the project is determined using the results of the screening and HAZID stages.

The three levels of PHA are:

- Level 1 – if low potential for harm is identified, a qualitative PHA is completed.
- Level 2 – if medium potential for harm is identified, a semi-quantitative PHA is completed.
- Level 3 – if high potential for harm is identified, a quantitative PHA is completed.

The level of PHA study required is discussed in Section 8.2 of the report.

4.5 Consequence and risk criteria

The identification of hazards and the quantification of the consequences outside the boundaries of a potentially hazardous development, and the assessment of that risk in terms of the nature of land uses in the vicinity provide the basis for compatible land use safety planning. Consequence criteria are required for a Level 2 PHA and a combination of consequence and risk criteria is used for a Level 3 PHA.

The consequence and risk criteria and results are presented in the following sections.

4.5.1 Heat radiation criteria

The effects of various heat radiation levels are summarised in Table 4.2 as per the NSW Hazardous Industry Planning Paper (HIPAP) No. 4 [Ref. 2].

Table 4.2 Heat radiation criteria

Heat radiation (kW/m^2)	Effect
4.7	Will cause pain in 15 to 20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	Significant chance of fatality for extended exposure. High chance of injury Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
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
35	Cellulosic material will pilot ignite within one minute's exposure Significant chance of fatality for people exposed instantaneously

4.5.2 Explosion overpressure criteria

The effects of various explosion overpressures are presented in Table 4.3 as per NSW HIPAP 4 [Ref. 2]. The overpressure levels reported in this assessment include 7 kPa, 14 kPa, 21 kPa and 35 kPa.

Table 4.3 Effects of explosion overpressure criteria [Ref. 2]

Explosion overpressure (kPa)	Effect
7	Damage to internal partitions and joinery but can be repaired Probability of injury is 10% No fatality
14	House uninhabitable and badly cracked
21	Reinforced structures distort Storage tanks fail 20% chance of fatality to a person in a building
35	House uninhabitable Wagons and plants items overturned Threshold of eardrum damage 50% chance of fatality for a person in a building and 15% chance of fatality for a person in the open

4.5.3 Individual risk criteria

Individual risk is a measure of the risk to an individual continuously exposed at a specific location within the effect zone of a hazardous incident. The individual risk criteria listed in Table 4.4 are suggested in HIPAP 4 [Ref. 2]. The risk level represents the frequency at which the relevant exposure type should not be exceeded.

Table 4.4 Individual fatality risk criteria

Risk levels (individual fatality risk per year)	Land Use	Limit of exposure at the following locations
0.5×10^{-6}	Sensitive	Hospitals, child-care facilities, and old age housing
1×10^{-6}	Residential	Residential developments and places of continuous occupancy such as hotels and tourist resorts
5×10^{-6}	Commercial	Commercial developments, including offices, retail centres and entertainment centres
10×10^{-6}	Recreational	Sporting complexes and active open space areas
50×10^{-6}	Industrial	Target for site boundary

The surrounding land users are discussed in section 3.1.1. The land use type with the lowest acceptable individual risk level adjacent to the new power generation site is currently the Sutherland PCYC MiniBike Club, which is classified as Recreational Land Use. The other immediately adjacent land users, the LHRRP landfill and the existing power station are Industrial sites. It is noted that the LHRRP is proposed to be transformed to open space parkland and the completion of land filling activities in around 2040 which is also classified as Recreational Land Use.

4.5.4 Societal risk

In the assessment of societal risk, multiple fatalities are considered instead of single fatalities as assessed in the individual fatality risk. The same basic consequence calculations used in individual fatality risk are used in the assessment of societal risk, where each incident outcome is considered in turn by combining the frequency (F) and the number (N) of people affected. The result is represented in the form of a Frequency-Number (FN) curve, which is a graph indicating the cumulative frequency (F) of ‘n’ or more fatalities (N) as shown in Figure 4.2. Selected values from the FN curve are given in Table 4.5 [Ref. 2].

Table 4.5 Societal risk criteria

No. of Fatalities (Consequence)	Intolerable Societal Risk Criteria (probability of N fatalities per year)	As Low as Reasonably Practicable (ALARP) Societal Risk Criteria	Negligible Societal Risk Criteria (probability of N fatalities per year)
10	$> 1 \times 10^{-4}$	Region between intolerable & negligible	$< 1 \times 10^{-6}$
1000	$> 1 \times 10^{-7}$	Region between intolerable & negligible	$< 1 \times 10^{-9}$

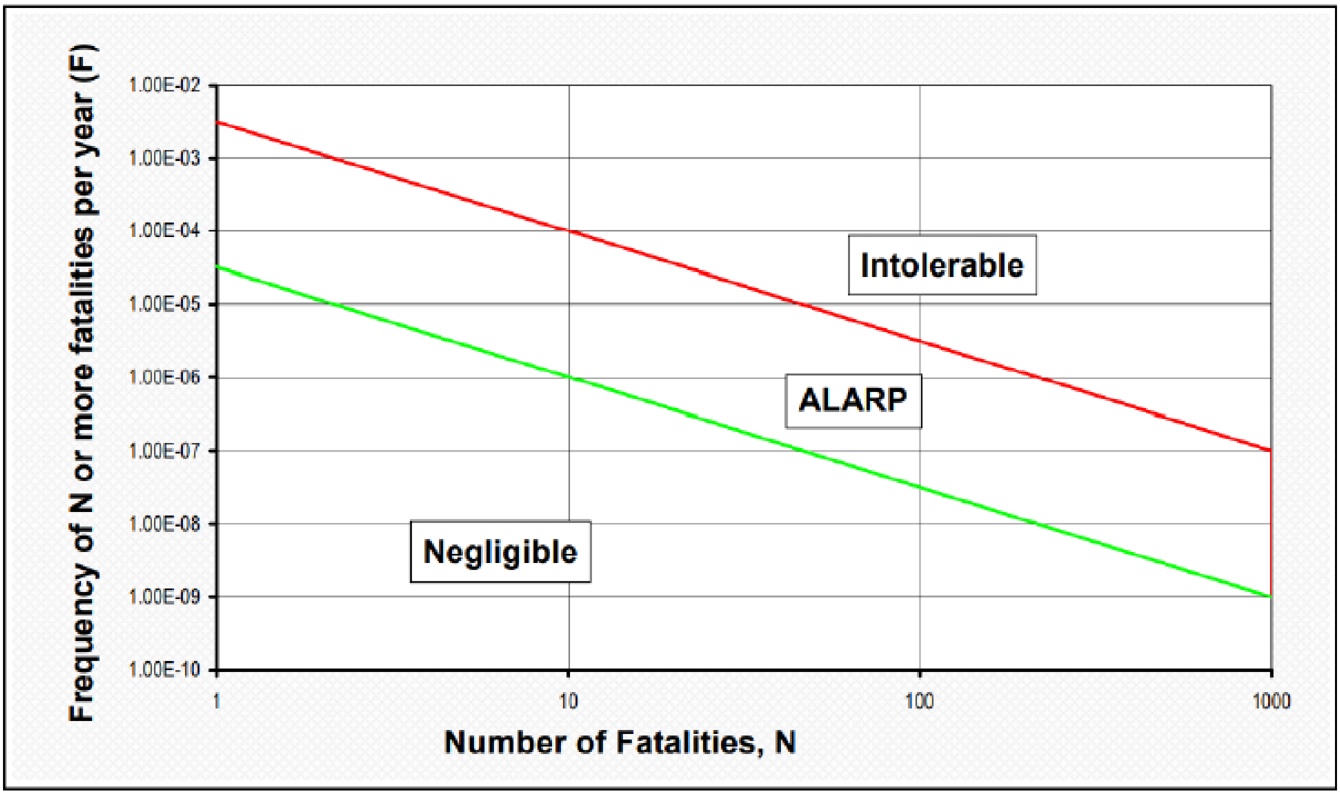

Figure 4.2 *Indicative societal risk criteria*

5. Preliminary risk screening

5.1 Dangerous goods

A detailed manifest of all dangerous goods (DGs) expected to be stored on-site, their quantity and method of storage and DG class is provided, as supplied by LMS, in Appendix B.

The current site operates with two 20,000 litre bunded oil tanks for clean oil and waste oil near the southern end of the site. The integrity and capacity of the existing bulk oil tanks for use in ongoing operations will be reviewed as part of detailed design and commissioning and if required replaced or supplemented with new bunded tanks at the same location with a combined capacity of up to 70,000 litres. Tanks would have short hoses for ease of handling.

A modular chemical storage bund containing coolant is located adjacent the oil tanks. Minor chemicals would be stored in the existing workshop to be retained on site.

It is assumed that no additional DGs would be stored onsite during operation of the project. If DGs are required for any operations or maintenance tasks during operations, such as spray lubricant or brake cleaner, it is assumed that these would be brought onsite in small quantities as required for the task and stored appropriately in the workshop. The storage screening results are shown in section 5.2.

5.2 Dangerous goods screening

5.2.1 Construction of the project

Construction of the project would be handled by LMS and any quantities of dangerous goods stored or transported to the site, such as diesel storage for on-site power generators or vehicle refuelling, would be covered in the Construction Environmental Management Plan (CEMP).

Any diesel stored or handled during the construction phase would be undertaken in accordance with AS1940:2017: *The storage and handling of flammable liquids*, and the requirements of WorkSafe NSW.

5.2.2 Operation

A summary of the operations phase dangerous goods classification, quantities, and thresholds is provided in Table 5.1 and Table 5.2 summarises the other main chemicals handled and stored on site during operation.

Table 5.1 Operations dangerous goods screening

Chemical / product	UN #	Expected storage quantity	DG class	Packing group	Combined storage threshold	Exceedance of SEPP (Resilience and Hazards) threshold
Biogas (Note 3)	1971 (Methane) 1013 (Carbon dioxide)	70 kg	2.1 2.2	NA	100 kg	Does not exceed threshold (Note 1)
Sulphur Hexafluoride (SF6)	1956	200 kg	2.2	NA	200 kg	Note 2
Waste oil	3082	Up to 40,000L	Class 9	NA	NA	Note 2
Clean oil – Motor oil, gear oil / Petroleum Oils	1268	30,000 L	Class C1/C2 (Note 4)	NA	NA	Note 4

Chemical / product	UN #	Expected storage quantity	DG class	Packing group	Combined storage threshold	Exceedance of SEPP (Resilience and Hazards) threshold
Transformer oil / Mineral oil	1993	33,000 L	Class C2	NA	NA	Note 4

Note 1. The combined storage does not exceed general screening threshold of 100 kg for biogas, a DG Class 2.1. However, as the nearest land users, the Sutherland PCYC MiniBike club is located immediately south-west of the project, and there will be a public park directly to the west in the future, the proximity and the relatively high quantity in relation to the threshold mean the project is considered potentially hazardous (refer Figure 6 Class 2.1 Flammable gases in Applying SEPP 33), requiring a level 3 PHA for the project.

Note 2. For the purpose of the SEPP (Resilience and Hazards) screening analysis, Class 2.2 and Class 9 Waste oils are excluded.

Note 3. Refer to Section 6.3.1 for composition and other details.

Note 4. If combustible liquids of Class C1 or C2 are present on site and are stored in a separate bund or within a storage area where there are no flammable materials stored, they are not considered to be potentially hazardous. If, however, they are stored with other flammable liquids, that is, Class 3 PGI, II or III, then they are to be treated as Class 3 PGIII, because under these circumstances they may contribute fuel to a fire.

Table 5.2 Summary of non-dangerous goods onsite

Chemical / product	Expected storage quantity
IG-541 – Gas Flooding agent (fire suppressant)	200 kg
Coolant – typically glycol and water	4000 L

5.3 Transport screening

5.3.1 Construction

Similar to the DG screening, construction of the project would be handled by the construction contractor and any quantities of dangerous goods, including those transported to the site, will be covered in the Construction Safety Management Plan (CSMP). At this stage in the project development, types and quantities of goods transported to the site are unknown, however they are expected to be minimal. It is therefore assumed that during construction, the expected vehicle movements will not exceed the SEPP (Resilience and Hazards) vehicle movement thresholds.

Should the DG types and quantities be updated, the transport screening review should be revisited.

5.3.2 Operation

Transport screening relates to the carriage of DGs to and from the proposed site. Table 5.3 shows the transport screening for the operation of the project. This includes the expected vehicle movements of each DG class and the vehicle movement thresholds according to Applying SEPP 33.

Table 5.3 Operations transport screening

Chemical / product	UN #	Expected vehicle movements (annual)	DG class	Packing group	Vehicle movements threshold (annual)	Vehicle movements threshold (weekly)	Exceedance of SEPP (Resilience and Hazards) threshold
Motor / Gear Oil	1268	12	C1/C2	NA	NA	NA	Note 1
Waste Oil	3082	12	9	NA	>1000	>60	Not Exceeded
Transformer Oil	1993	12	C2	NA	NA	NA	Note 1

Note 1. C1 or C2 combustible liquids are not dangerous goods under UN (United Nations) classification. They are defined as dangerous goods under workplace legislation. This also applies to goods too dangerous to be transported, and hence they are not considered in the transport screening analysis.

5.4 Summary of screening results

The results of the dangerous goods screening in section 5.2 indicate that the general screening thresholds outlined within Applying SEPP 33 are not exceeded for any class of DG. However, due to the proximity of land users and the relatively high storage quantity in relation to the threshold, means that the project is still considered a 'potentially hazardous industry'. Therefore, a PHA was completed under SEPP (Resilience and Hazards).

The results of the transport screening do not exceed the dangerous good movement thresholds as there are expected to be minimal deliveries. If changes occur to the proposed transport of dangerous goods, it is recommended that the screening process be repeated to determine any potential impact.

5.5 Summary of emissions

The expectation is that the current design requirements for the reduction of pollutant emissions (air quality and odour, noise and vibration) would be utilised. Assessments of noise, vibration, air quality and visual impacts from the project have been undertaken through the EIS.

Emissions to air from activities in NSW are regulated under the NSW *Protection of the Environment Operations Act 1997* (POEO Act), Protection of the Environment Operations (Clean Air) Regulation 2022 (POEO Clean Air Regulation), and Protection of the Environment Operations (General) Regulation 2022, Part 5.4 Air pollution.

An air quality assessment has been completed for the new bioenergy facility [Ref 6, Ref 7] and found, based on the modelling and assumptions used, compliance with the POEO Act and regulations.

Odour from the project site is not expected to cause any negative impacts to the surrounding environment during plant operation. Although there are some potential odour impacts from fugitive emissions of biogas from the landfill, these are expected to be consistent with what is currently experienced today. Implementation of the project will ensure management of biogas throughout the ongoing landfilling and post closure phases at the LHRRP and the implementation of the related flare system will provide full contingency for combustion of biogas generation for the landfill.

Noise pollution is regulated according to the Environmental Protection Authority (EPA's) *Noise Policy for Industry*. Hence, the noise level is predicted to be within the regulatory standards. This will be monitored to confirm assumptions during the commissioning stage.

Further details of the emissions can be found in the Noise and Vibration specialist report within the EIS.

The project is not currently considered an 'offensive industry'.

6. Hazard identification

6.1 Hazard identification (HAZID)

The results of the HAZID associated with the bioenergy facility is presented in Table 6.1. The HAZID was conducted as a desktop study and focused on the operational activities, and particularly the hazards of material stored or transported. The HAZID focused solely on hazard identification, likelihood is discussed in section 8.3 as part of the overall risk assessment.

Safeguards required to manage the risk scenarios that were identified to an acceptable level are also outlined in Table 6.1. The HAZID includes hazards associated with construction activities, however general worker construction risks will be captured in the CEMP.

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

– All plant and equipment are installed and operated in accordance with appropriate Australian Standards, codes and guidelines.
– Dangerous goods are stored in accordance with the Australian Dangerous Goods Code, relevant standards and guidelines, even if not a licensable quantity.
– All equipment and systems are designed to incorporate safety-in-design principles that aim to eliminate or minimize hazards through engineering controls and protective measures.
– Personnel are trained and competent to perform their assigned tasks.
– Personnel attend work free from the influence of drugs, alcohol and fatigue.
– Supervision arrangements are in place for all works performed at site.

The key risks with the potential to cause offsite impacts are discussed in more detail in section 6.4, including management strategies and controls.

6.2 Chemical management

Any chemicals brought on-site will be stored in accordance with the relevant Australian Standards. It is recommended that each chemical have appropriate labelling, separation where necessary, and disposal in accordance with Australian Standards. Emergency services require access to the safety data sheet (SDS) register of all chemicals that are located on-site. Additionally, appropriate safe work procedures should be implemented for the handling of all chemicals including transfer, storage, spill prevention, and clean up requirements.

6.3 Hazardous materials

The pipeline contains biogas, which is modelled as 57% methane and 43% carbon dioxide. Refer to section 6.3.1 for more details.

Dangerous goods, or hazardous materials, such as wastes and chemicals, stored or handled on the site include:

– biogas, as described in Section 6.3.1
– new and used motor lubrication oil for the CAT G3516 generators
– gas engine coolant, assumed to be a mixture of glycol and water
– Fire Suppression Gas (Inergen - IG-541) inside of the main switch room
– Sulphur Hexafluoride (SF_6) used as the insulating gas for the HV switchgear
– coolant, typically glycol and water
– transformer oil (Mineral Oil type).

The material health and environmental hazards and the controls and safeguards afforded by LMS to safeguard or mitigate these hazards are provided in Table 6.1.

6.3.1 Biogas from landfill

Biogas typically contains around 50% methane and 40% carbon dioxide, with around 9% nitrogen and 1% oxygen. It can also contain up to a few per cent of hydrogen, plus trace amounts of hydrogen sulphide, ammonia and other, potentially toxic or flammable substances.

Analysis results that suggest the biogas will contain around 57% methane and 37% carbon dioxide, with around 5% nitrogen and 0.9% oxygen. Trace amounts of hydrogen sulphide are expected around 170 ppm. While it is expected that up to 6% of the non-flammable gases are not carbon dioxide, it is assumed to be 57% methane and 43% carbon dioxide for the purpose of the risk and consequence modelling, to ensure a conservative assessment with respect to the biogas buoyancy and carbon dioxide toxicity as the biogas composition will likely change seasonally. While there may be some toxic trace components (i.e. hydrogen sulphide) these levels are not anticipated to increase the risk, this is further discussed in section 8.1.3.3.

6.3.1.1 Biogas properties

The predominant source of hazard from the project is associated with the potential for a loss of containment of biogas. This would generally only have the potential to cause injury or damage if there was ignition, resulting in a jet or flash fire (when in the open) or potentially an explosion (if it occurred in a sufficiently confined area).

Pure methane is a colourless, odourless, non-toxic, and non-corrosive gas and is lighter than air at temperatures greater than minus 110 °C. Pure carbon dioxide is a colourless and odourless gas which is heavier than air. The biogas mixture may or may not have an odour, depending on the presence and concentration of sulphur containing compounds.

The lower flammability limit (LFL) of pure methane is 5% and the upper flammability limit (UFL) is 15%. This means that if the concentration of methane in air is less than 5%, the gas mixture is too diluted to burn and if it is greater than 15% there is not enough oxygen for it to burn. Biogas containing approximately 57% methane and 43% non-flammable gases will have an LFL of 8.8% and an UFL of 26.3%.

The auto-ignition point for methane is 580 °C. This is the minimum temperature required for methane gas to ignite in air without a spark or flame being present.

Both methane and carbon dioxide pose asphyxiation hazards. Asphyxia is a possibility if the oxygen concentration in the atmosphere is less than 19.5%.

Non-ignited biogas has a density similar to ambient air and hence may not rise or sink substantially from the release elevation.

The biogas system operates at very low pressure – with slight vacuum pressure expected upstream of the blowers, and slight positive pressure in the order of 20 kPag downstream of the blowers and into the generator packages. This means the overall inventory (mass) of biogas in the piping and facilities is very low.

6.3.1.2 Fire and explosion factors

The factors involved in biogas releases leading to fire or explosion are:

- The piping or associated equipment must fail such that a release of biogas occurs. There are several possible causes of failure including corrosion, overpressure and damage by external sources.
- The released material must form a flammable mixture between the lower and upper flammability limits described above.
- The released material must contact an ignition source. This may be heat or sparks generated by mechanical damage, non-flame proof equipment, vehicles, open flames or very hot surfaces.
- Depending on the conditions of the release, including the volume of biogas, how rapidly it ignites and the degree of congestion or confinement, the event may be a jet fire, a flash fire or a vapour cloud explosion.
- For there to be a safety risk, people must be present within the harmful range (consequence effect distance) of the fire or explosion. How close the people are to the release will determine whether any injuries or fatalities result.

More information about these risks is provided below.

Jet fire

A jet fire risk is present if there is pressurised flammable gas. Jet fires result from the immediate ignition of the escaping fluid. Turbulence evoked by pressurised fluid escape entrains ambient oxygen and could create a mixture that lies within the biogas' flammability limits. The modelling software does not consider the effect of any obstructions that may be present, so the software models it as an unimpeded jet fire.

Flash fire

If a biogas release does not ignite immediately, a biogas cloud may form which could find an ignition source distant from the release location, leading to a flash fire or vapour cloud explosion. A flash fire is a slow deflagration of an unconfined, unobstructed biogas cloud producing negligible overpressure. Thermal effects are the main hazard, as flash fires typically have a heat flux of approximately 84 kW/m^2 for a duration of approximately 3 seconds.

Unlike a vapour cloud explosion, the negligible overpressure created by a flash fire does not accelerate the flame front and thus energy released from the combustion does not take the form of an explosive blast and consequent overpressure blast wave, which normally causes most of the damage.

Flash fire risks can only be expected from highly flammable materials or flammable materials heated significantly above ambient temperature to near or above their boiling point. Flash fire results are typically represented in cloud distances from the ignition location to the LFL. It is typically assumed that 100% fatality occurs within the LFL envelope, and 0.5 LFL represents the maximum distance in which a flammable cloud could be ignited.

Vapour cloud explosion

A vapour cloud explosion is an explosion occurring after the release of a large quantity of flammable biogas, which ignites following the formation of a flammable cloud within the upper and lower flammable limits in a confined area causing a damaging pressure wave.

A typical blast overpressure comprises several events, not all occurring simultaneously. Firstly, there is overpressure associated with the expansion of vapor upon release of the material and secondly, there is an accompanying increase in pressure resulting from the combustion/ignition of the material released.

The above is typically referred to as a delayed explosion and its occurrence downwind from the release location are highly dependent on prevailing weather conditions at the time of the release.

6.3.2 Transformers

The design shows that the transformers on-site are proposed to include one 3000 kVA rated 480V / 33 kV step-up transformer for every two gas engine generators, totalling ten off 480V / 33 kV transformers for the power generation. There will be one additional transformer on site for auxiliary loads.

The insulation oil used in these transformers is the primary fire risk. If the oil is ejected and ignited, it could result in a pool fire within the transformer bund, radiating heat to nearby structures such as the gas engine units, potentially causing escalation of the fire. Each step-up transformer contains around 3,000 L of mineral oil with all transformers being self-bunded.

Each transformer contains around 3000 litres of mineral oil. If the oil is ejected and ignited, it could result in a pool fire within the transformer bund, radiating heat to nearby structures such as the gas engine units, potentially causing escalation of the fire. The transformers and their installation will comply with the well-established safety requirements provided under AS2067, which include minimum separation distances for different transformer oil types and other fire safety management controls.

Based on the risk mitigations required by AS2067 and the typical controls used by LMS for current transformer installations, this scenario is not expected to cause off site consequences and has therefore not been included in the qualitative risk assessment (QRA).

Table 6.1 Hazards of materials stored or processed

Material/ quantity	Health hazards and physical properties	Environmental hazards	Potential for offsite impact	Controls/ safeguards provided
Biogas (from Landfill) includes: 57% methane, UN 1971, Class 2.1 and 43% carbon dioxide, UN 1013, Class 2.2 Other trace elements (e.g. hydrogen sulphide)	Biogas is a flammable gas, which may form explosive mixtures with air. May displace oxygen and cause asphyxiation, particularly in confined spaces. May contain toxic trace elements such as hydrogen sulphide. Lower explosive (flammable) limit: LFL ~8.8% Upper explosive (flammable) limit: UFL ~26.3% Avoid all possible sources of ignition (spark or flame). Do not pressurize, cut, weld, braze, solder, drill, grind or expose containers to heat or sources of ignition.	Methane produced from landfill is a greenhouse gas that contributes to global warming as defined by the Intergovernmental Panel on Climate Change (IPCC). Potential odour impacts from fugitive emissions of biogas.	Yes	– Polyethylene (PE) piping is installed underground for protection, all above ground piping that usually operates above atmospheric pressure is constructed from stainless steel – Pressure and temperature alarms and shutdowns, relieving system – All gas appliances provide in accordance with AS3814 - Industrial and Commercial Gas-Fired Appliances, which outlines key controls and safeguards to ensure safe and efficient operation of gas-fired equipment. These include robust safety requirements, proper installation guidelines, maintenance protocols, operational efficiency, and adherence to emission standards.
Gas Generator Lubrication Oil 30,000 L bulk oil tank 20 x Day tanks within Generator enclosures.	Classified as a C2 (Combustible liquid). Flash Point > 150 deg C. **Acute Effects** **Inhalation:** Material may be an irritant to mucous membranes and respiratory tract. **Skin contact:** Contact with skin may result in irritation. **Ingestion:** Swallowing can result in nausea, vomiting and irritation of the gastrointestinal tract. **Eye contact:** An eye irritant.	Avoid contaminating waterways. **Acute aquatic hazard:** This material has been classified as a Category Acute 3 Hazard. Acute toxicity estimate (based on ingredients): 10 - 100 mg/L **Long-term aquatic hazard:** This material has been classified as a Category Chronic 3 Hazard. Non-rapidly or rapidly degradable substance for which there are adequate chronic toxicity data available OR in the absence of chronic toxicity data, Acute toxicity estimate (based on ingredients): 10 - 100 mg/L, where the substance is not rapidly degradable and/or BCF ≥ 500 and/or log Kow ≥ 4.	No	– Storage of combustible liquids in accordance with relevant Australian Standards, including AS1940 – *The storage and handling of flammable and combustible liquids*, which includes use of double wall tank to contain tank leakage – Bushfire Emergency Response Plan – Control of ignition sources on site, including Permit to Work processes – Fire protection systems provided
Transformer Oil 3000 L for each of 11 x 33 kV transformer	Not a DG. May be fatal if swallowed and enters the airways, prolonged contact to skin may cause redness, irritation, and dry skin, and contact with eyes may cause irritation of the eyes and mucous membranes.	The product is not classed as being readily biodegradable by OECD test methods but is considered inherently biodegradable. Bioaccumulation is unlikely to be significant because of the low water-solubility of this product. It is also insoluble in water and will spread on the water surface.	Yes	– Transformer maintenance, including regular oil testing – Buckholtz relay – Self-bunding for all transformers – Fire protection systems provided
Waste Oil Max of 40,000 L bulk oil tank	Waste oils are deemed Class 9 – Miscellaneous materials.	Avoid spills entering drains or water ways.	No	– Storage of combustible liquids in accordance with relevant Australian Standards, including AS1940 – *The storage and handling of flammable and combustible liquids*, which includes use of double walled tank to contain tank leakage. – Waste oils to be disposed of by licensed waste contractor – Bushfire Emergency Response Plan – Control of ignition sources on site, including Permit to Work processes – Fire protection systems provided – Isolation Points

Table 6.2 HAZID Table

No.	Design Life Cycle Stage	Area of process	Hazard Event	Causes	Consequences (Health & safety; Environmental impacts)	Potential for offsite impact (Y/N)	Controls/safeguards provided	Comments/ Action
1	Operation & Maintenance	Generator engine stack	Venting of unignited biogas which is subsequently ignited	– Intermittent use of generator – Actual generator loads are lower than the operating load of the generator	– Release of unignited biogas from engine stack, resulting in a flammable biogas cloud igniting, causing property damage	No	– Personal Protective Equipment (PPE) including gloves, eye protection, suitable clothing and boots – Annual fire and evacuation training to be conducted	Event carried forward for further analysis in PHA
2	Operation & Maintenance	Generator enclosure	Biogas leak inside enclosure	– Physical impact to biogas piping or equipment – Overpressure of piping or equipment – Internal corrosion	– Displacement of oxygen resulting in asphyxiation – Toxic accumulation of hydrogen sulphide – Harm to personnel, potential for fatality	No	– Type B compliant generator enclosure such that slam shut operates at high speed to shut down the gas supply. – Methane gas detectors – Work permits and procedures for accessing and working inside generator enclosures.	Event carried forward for further analysis in PHA
3	Operation & Maintenance	Biogas Process Area	Pipework or flange leak or break from biogas piping in biogas receiving, metering, conditioning area.	– Physical impact to biogas piping or equipment – Overpressure of piping or equipment – Internal corrosion	– Jet / flash fire – An explosion is unlikely due to the low pressure and low level of confinement	Yes	– Above ground piping that usually operates under positive pressure is stainless steel, while the PE piping is only installed underground where it is protected – Electrical equipment selected in accordance with the hazardous area classification – Comprehensive emergency response plan – PPE including gloves, eye protection, suitable clothing and boots – Annual fire and evacuation training to be conducted	Event carried forward for further analysis in PHA
4	Operation & Maintenance	Generator (Caterpillar G3516)	Pipework or flange leak or break from biogas piping to generators.	– Physical impact to generator enclosure	– Jet/Flash fire/ or explosion inside generator containers causing container damage, projectiles, potential personnel injury or death – Escalation to neighbouring biogas engine generators and/ or transformers	Yes	– AS3814 Type B compliant gas train on generator packages – Most fuel gas conditioning equipment installed outside generator enclosure, limiting causes of gas release inside enclosure – Gas detection inside gas engine generator containers, with automatic shut down of fuel gas supply – Electrical equipment specified in accordance with the hazardous area classification – Comprehensive emergency response plan – Annual fire and evacuation training to be conducted – Biogas is flared when extraction exceeds gas engine generator available capacity or during generator outage or emergency	Event carried forward for further analysis in PHA
5	Operation & Maintenance	Generator Motor / Gear box oil	Loss of containment of clean or waste lubrication oil from clean oil (30,000 L tank), Waste oil (up to 40,000 L tank), 2 x 100 L oil tanks inside gas engine generator units.	– Physical impact Corrosion of storage tank Transfer pump failure Transfer hose/piping leak/ rupture	– Fire or explosion – Harm to personnel, potential for fatality – Environmental impacts (loss of vegetation, bushfire, loss of flora/fauna)	Yes	– Storage of flammable liquids in accordance with relevant Australian Standards AS 1940 – Bushfire emergency management and evacuation plan – Control of ignition sources on site, including Hot Work Procedures, with Hot Work Permits, designated Hot Work Bays, no hot work permitted on fire ban days – Pollution Incident Response Management Plan (PIRMP)	Event carried forward for further analysis in PHA
6	Operation & Maintenance	Transformers	Transformer oil fire in one of the 11 step up transformers	– Transformer oil overheating – Arc fault – Earth leakage – Fire spread from generators	– Usually limited to TX enclosure, but fires may be of long duration – Injury to personnel in the vicinity – Potential for environmental impacts if oil / firewater not contained	Yes	– Transformer maintenance, including regular oil testing – Buckholtz relay – Transformer Containment bund or enclosure – Fire protection systems – Designed to AS 2374.8:2000 – *Power Transformers – Application Guide, and to AS2067 - Substations and high voltage installations exceeding 1 kV a.c* – Suitable separation distances from transformers – Site specific emergency response plan, trained fire wardens, site first aiders, fire extinguishers, first aid kits – Pollution Incident Response Management Plan (PIRMP)	Event carried forward for further analysis in PHA

No.	Design Life Cycle Stage	Area of process	Hazard Event	Causes	Consequences (Health & safety; Environmental impacts)	Potential for offsite impact (Y/N)	Controls/safeguards provided	Comments/ Action
7	Operation & Maintenance	Transformers	Explosion of one of the 11 step up transformers	– Gases (e.g. hydrogen, then HCs) generated inside transformer enclosure due to oil degradation from overheating	– Overheating of transformer and explosion from overpressure – Personal injury / fatality – Asset Damage – Project area shut down	Yes	– Relief valve on transformer to vent off gases – High temperature trip – Designed to AS 2374.8:2000 – Power Transformers – Application Guide, and to AS2067 - Substations and high voltage installations exceeding 1 kV a.c – TX maintenance, including regular oil testing – Site specific Emergency Response Plan – Pollution Incident Response Management Plan (PIRMP)	Event carried forward for further analysis in PHA
8	Operation & Maintenance	Transformers, Switch Room, Near overhead or buried power lines/cables	Electrocution from high voltage (33 kV) system.	Contact with live electrical source, e.g.: – digging up cable – cranes contacting overhead cables – work in switchgear-room.	– Electrocution causing death	No	– Implement a Workplace Health and Safety (WHS) plan – Undertake a detailed Safety in Design process – Implement isolation procedures prior to maintenance of electrical equipment – Use a spotter for crane operation – Install fit for purpose electrical systems, designed to Australian standards – Supply and use of arc flash protective PPE – Secure Project area (fencing, gate person) – Site specific Emergency Response Plan – Unenergized site until commissioning – Clear identification of electrical hazards once Project area is engaged – Permit to Work and Lock-out-tag-out processes	No
9	Operation & Maintenance	Oil Storage area	Clean oil (30,000 L) or waste oil (up to 40,000 L) tank failure / leak causing environmental contamination or pool fire	– Vehicle impact to tank – Corrosion of tank – Drain valve or similar left open.	– Environmental contamination – Pool fire with potential for personnel injury	Yes (for environmental contamination)	– Site drainage to be designed to prevent oil spill from leaving site – Double walled, designed to appropriate standards – Tank to be designed to resist corrosion – Tank to be protected from vehicular impact – Filling, emptying, transfer and other operating procedures – Pollution Incident Response Management Plan (PIRMP)	No
10	Construction	All	Natural hazards	– Flooding – Earthquake – Lightning – High winds	– Asset damage – Personal injury – Site shutdown	No	– Design structures to appropriate codes and standards, including for wind and earthquake – Emergency Response Plan – Dust management and PPE measures – Lightning protection – Project area is not in flood zone – Weather monitoring	No
11	Construction & Operation	All	Bushfire	– Off-site bushfire – Construction activities e.g. hot works igniting adjacent bush.	– Water contamination – Personal injury	Yes (safety and environmental impact)	– Manage fuel for vehicles and machinery on site to appropriate standards – Onsite firefighting equipment – A Bushfire emergency management and evacuation plan will be prepared in consultation with the Rural Fire Service – Emergency Response Plan – Asset Protection Zones around the facility – Operational safety management plan (OSMP) – Operational environmental management plan (OEMP)	No

No.	Design Life Cycle Stage	Area of process	Hazard Event	Causes	Consequences (Health & safety; Environmental impacts)	Potential for offsite impact (Y/N)	Controls/safeguards provided	Comments/ Action
12	Construction	All	Subsidence	– Poor ground / soil material, ground movement, heavy rainfall – Inadequate design / construction cut and fill areas (new roads around inundation area). – Inadequate design and drainage, e.g. road culverts, retaining walls – Inadequate restoration of previous work areas (e.g. quarries, clay borrow areas, compound, workers accommodation)	– Asset damage – Personal injury – Poor water quality	No	– Geotechnical assessments and studies during design phase – Appropriate drainage design to control run-off	No
13	Construction	All	Vehicle interactions in project area	– Vehicle movements in vicinity of personnel	Personal injury	No	– Prepare traffic management plans including standard traffic rules and signage for construction and operation – Implement site speed limits – Provide designated pedestrian areas for construction and operation – Driver competency, licensed and inducted drivers	No
14	Construction	All	Loss of containment of chemicals, including dangerous goods	– Damage to storage containers, e.g. external impact, wear and tear	– Environmental damage – Personal injury	Yes (environmental impact)	– Store and separate chemicals in line with appropriate standards, stored in covered and bunded area – Implement a regular inspection and maintenance regime for chemical storage areas – Implement standard handling procedures – Provide spill kits to be used in the event of an incident involving release of chemicals/liquid contaminants – Provide PPE to all staff – Minimal quantities of DGs and other chemicals stored on site – Pollution Incident Response Management Plan (PIRMP)	No
15	Construction	All	Exposure to dust	– General construction activities – Decommissioning activities	– Health impacts – Third party complaints	Yes (health and environmental impact)	– CEMP – CSMP	No
16	Construction	All	Exposure to noise and vibration	– General construction activities – Decommissioning activities	– Health impacts – Third party complaints	Yes (health and environmental impact)	– CEMP – CSMP	No
17	Construction	All	Utility strike	– Excavation activities during construction striking biogas, water or power infrastructure – Decommissioning activities	– Asset damage – Personal injury – Supply outage	No	– Dial Before You Dig/services identification prior to excavation – Permit system – CEMP	No

6.4 Scenarios for PHA

From the HAZID table in Section 6.3, selected scenarios with the potential for offsite impact are discussed in the subsections below. The events which have appropriate controls to reduce the risks So Far as Is Reasonably Practicable (SFAIRP), with no offsite impact, do not require further assessment. The scenarios which may pose an offsite impact were carried forward for consequence and risk modelling in the PHA.

6.4.1 Release of unburnt biogas from a generator engine stack

Unburnt biogas can pass into the exhaust system such that it is released from a generator engine stack. Release of unburnt fuels from an engine stack can occur when the generator is left idle for extended periods of time (i.e. intermittent use of the generator) and when the actual load on the generator is lower than that it was designed for.

In the event that unburnt biogas is released from a generator engine stack, the height of release will be at a height of approximately 10.2 m. It is not expected that any ignition sources will be present at the height of the gas cloud, therefore no adverse consequences are expected. The risks are therefore reduced SFAIRP, and no further controls are required to manage them.

6.4.2 Pipework or flange leak or break in biogas lines

The biogas piping from the landfill site into the blowers generally operates at less than atmospheric pressure and hence is mainly constructed from polyethylene (PE). Most of this system is underground. The above ground metering/analyser runs and biogas conditioning skids are constructed of steel, providing increased mechanical strength.

The biogas piping from the blowers to the generators is predominantly made of PE and run underground for impact protection. Any above ground pipework, such as out of the biogas conditioning/blower skids, is constructed in accordance with AS5601 - *Australian and New Zealand Standard for Gas Installations.* Hence, the piping is generally well protected. However, the couplings between these two pipe materials, and other above ground flanges and fittings may be sources of leaks or failures.

The locations where loss of containment could occur from the biogas piping include:

1. The facility inlet piping
2. The generator biogas header
3. The generator inlet line
4. Within the generator enclosure.

The facility inlet header has not been modelled as it usually operates at less than atmospheric pressure and hence biogas would not be immediately released if piping integrity was lost. The consequences of loss of containment from the generator biogas header have been modelled. The possible effects of loss of containment of the biogas line inside the generator were modelled.

6.4.3 Loss of containment of clean or waste motor/gearbox lubrication oil

Clean oil and waste oil will be stored in atmospheric steel tanks designed to AS 1692 – *Steel tanks for flammable and combustible liquids* and operated and maintained to AS1940 – *Storage and handling of flammable and combustible liquids*. This includes the provision of safety management systems and controls such as minimising ignition sources and safety separation distances to other dangerous goods storages. All tanks will have double walls to contain spills.

To ignite the oil, it would have to be heated above its flash point or atomized under pressure and come into contact with a hot surface. Because lubricating oil in storage is at temperatures significantly lower than their flash points, and tank leaks are contained within the double walls, fires at or near oil storage tanks have a very low probability. Such fires are of localised effect, and given the controls, it is believed the risk is reduced to SFIARP, and hence these fire events have not been carried forward for modelling.

6.4.4 Transformer fire or explosion

The step up 33 kV transformers will be oil-filled with an oil capacity around 3,000 litres. Oil filled transformers can fail catastrophically due to arc winding or bushings failure, leading to an explosion in the transformer and ensuing oil fire. Safeguards against windings failure are oil monitoring and the Buchholz relay. The Buchholz relay serves as a critical protection device for oil filled transformers, primarily acting as a sensor for internal faults and gas buildup within the transformer. It detects issues like insulation failures, gas formation and oil leaks, triggering an alarm or tripping the transformer if a fault is detected.

Should the transformer fail or leak oil, the oil will be captured in the internal oil-catch bund. The internal bund will contain 110% of the volume of the transformer oil and excludes rainwater ingress. The additional 10% is an allowance for firefighting water and foam, in case of fire. As such fires are of localised effect, and given the risk is typically reduced to SFIARP, given the controls, these fire events have not been subject to consequence modelling.

7. Study assumptions

7.1 General modelling assumptions

The general assumptions and inputs for the consequence and risk modelling are listed in Table 7.1. Note that SAFETI does not consider site specific topography; therefore, all heights are measured from ground level (grade). The weather conditions are based on annual data at Lucas Heights (ANSTO), obtained from the Bureau of Meteorology (BOM), and includes conditions across the seasons [Ref 5].

Table 7.1 General modelling input parameters

Parameter	Value	Comment/Reference
Release location	Outside releases	All releases are outside unless otherwise specified
Terrain	Land	
Ambient temperature	17.6 ˚C	Bureau of Meteorology [Ref 5]
Surface temperature	17.6 ˚C	Bureau of Meteorology [Ref 5]
Relative Humidity	0.63	Bureau of Meteorology [Ref 5]
Surface roughness	50 cm	Parkland, bushes; numerous obstacles
Height of interest	1.5 m	Assumed to be the chest or face height of an average human

7.2 Atmospheric conditions

The Pasquill stability scheme detailed in Table 7.2 is commonly used to describe the amount of turbulence in the atmosphere for consequence and dispersion modelling.

Table 7.2 Pasquill weather stability class definitions

Class	Type	Descriptions
A	Unstable	Day time – sunny, light winds
B	Unstable	Day time – moderately sunny, light to moderate winds
C	Unstable / Neutral	Day time – moderate winds, overcast or windy and sunny
D	Neutral	Day time – windy and overcast Night time – windy
E	Stable	Night time – moderate winds with little cloud / light winds with more clouds
F	Stable	Night time – light wind, little cloud

Analysis of the wind data at the BoM monitoring station at Holsworthy Aerodrome was conducted to find the dominant atmospheric conditions. The most commonly occurring wind classes and speeds were identified for the consequence and risk modelling and are listed in Table 7.3. These weather conditions have been combined with wind directions to determine the wind probability used in the modelling, as shown numerically in Table 7.4.

Table 7.3 Modelled weather conditions

Weather condition designation	Stability class	Average wind speed (m/s)	Time of day
1.6/B	B	1.6	Day time
3/D	D	3.0	Day time
2.5/E	E	2.5	Night time
1.1/F	F	1.1	Night time

Table 7.4 Wind strength and direction probabilities for Lucas Heights

Direction	1.6/B	3.0/D	2.5/E	1.1/F
N	3.69%	0.11%	0.04%	4.62%
NNE	2.10%	0.09%	0.03%	0.76%
NE	1.46%	0.09%	0.08%	1.36%
ENE	2.17%	0.69%	0.17%	2.17%
E	2.82%	0.84%	0.18%	2.22%
ESE	2.06%	0.82%	0.18%	2.11%
SE	2.44%	1.31%	0.47%	2.43%
SSE	2.41%	1.83%	0.79%	2.76%
S	1.59%	1.13%	0.63%	2.45%
SSW	1.27%	0.59%	0.39%	2.95%
SW	2.26%	0.44%	0.39%	8.31%
WSW	4.52%	0.59%	0.26%	7.58%
W	4.89%	0.47%	0.17%	3.24%
WNW	3.06%	0.25%	0.05%	1.37%
NW	2.10%	0.12%	0.04%	0.97%
NNW	1.97%	0.05%	0.01%	0.63%

7.3 Population assumptions

Assumptions about the occupation of the surrounding environments are used when calculating the societal risk. The risk modelling does not allow input of nuances of population exposure such as working hours, weekdays versus weekends etc, but does allow different levels of population for 12 hour daytime and nighttime periods.

Table 7.5 Population Assumptions for Societal Risk Modelling

Population Assumptions	
LHRRP worker population	6 people
Occupancy	100% during the day and 0% during the night (Note 1)
Percentage indoors	55% during the day and 0% during the night (Note 1)
Recreational park density	25 people per day
Number of recreational parks	2 (worst case, when LHRRP is converted to open public space)
Occupancy	100% during the day and not applicable during the night (Note 1)
Percentage indoors	0% during the day and not applicable during the night (Note 1)

Note 1: Each 24 hour period is divided into one 12 hour daytime period and one 12 hour night-time period.

7.4 Biogas assumptions

The biogas has been modelled as a mixture of 57% methane and 43% carbon dioxide, as advised by LMS as per Section 6.3.1. The flammable limits of this mixture are:

– Lower flammable limit – 8.8% or 88,000 ppmv
– Upper flammable limit – 26.3% or 263,000 ppmv

7.5 Failure case definition

Failure cases were developed to represent the hazardous release scenarios. The cases were developed considering all possible mechanisms for loss of containment.

The loss of containment incidents that were considered in the consequence and risk modelling are:

- biogas pipework or flange leak or break inside a generator enclosure
- biogas pipework or flange leak or break on an above ground section of the generator biogas header
- biogas pipework or flange leak or break on an above ground section of a generator biogas inlet line.

The list of failure cases modelled, and their associated assumptions are shown in Appendix C.

8. Preliminary Consequence and Risk Modelling

8.1 Consequence analysis

The consequence modelling for these scenarios was performed using DNV's SAFETI version 9.0 commercial software package [Ref 4]. A summary of the model input parameters is presented in Appendix C. Appendix D provides details of the consequence model theory.

8.1.1 Loss of containment of biogas from the generator gas header

Loss of containment of biogas from the generator biogas header could result in a jet fire, fireball, flash fire or explosion event. Both a full bore rupture (300 mm leak) and line leaks (2, 6, 22 and 85 mm leaks) were modelled. The worst-case impacts arise in the event of a full bore rupture (FBR) of the generator biogas header line. The worst-case consequence results are summarised Table 8.1.

Table 8.1 Worst case consequences for a loss of containment of biogas from the generator biogas header

Jet fire				
Worst case scenario	Weather category	Thermal Radiation Intensity level (kW/m2)	Maximum distance downwind to intensity level (m)	
FBR	Category 3/D	4.7	45.1	
		12.6	36.1	
		23	32.8	
		35	27.8	
Fireball				
Worst case scenario	Weather category	Thermal Radiation Intensity level (kW/m2)	Maximum distance downwind to intensity level (m)	
FBR	All weather categories	4.7	23.7	
		12.6	13.4	
		23	8.6	
		35	5.6	
Flash fire				
Worst case scenario	Weather category	Distance to 0.5 LFL (m)	Distance to LFL (m)	Distance to UFL (m)
FBR	Category 1.6/B	28.8	9.4	Not reached at height of interest
Explosion				
Scenario	Weather category	Overpressure level (kPa)	Maximum distance downwind to overpressure level (m)	
FBR	Category 1.1/F	7	43.3	
		14	33.4	
		21	30.0	
		35	27.3	

Depending on the release direction, the jet fire radiation and explosion overpressure injury thresholds could extend beyond the boundaries of the facility, while the fireball and flash fire events did not have consequences that extend beyond the boundaries of the facility. The risks to the workers and surrounding populations are further explored in the risk analysis, refer to Section 8.3. Full consequence results are presented in Appendix E-1.

8.1.2 Loss of containment of biogas from a generator inlet line

Loss of containment of biogas from a generator inlet line could result in a jet fire, fireball, flash fire or explosion event

Since there are twenty generators, a potential loss of containment was modelled at two different locations to assist with the risk analysis. Both full bore rupture (150 mm leak) and line leaks (2, 6, 22 and 85 mm leaks) were modelled for both locations. The worst-case impacts arise in the event of a full bore rupture. Given the release inventory is the same, the consequence results are identical for each location, for the generators in the east and the generators in the west. The worst-case consequence results are summarised in Table 8.2.

Table 8.2 Worst case consequences for a loss of containment of biogas from a generator inlet line

Jet fire				
Worst case scenario	Weather category	Thermal Radiation Intensity level (kW/m2)	Maximum distance downwind to intensity level (m)	
FBR	Category 3/D	4.7	24.7	
		12.6	20.4	
		23	18.9	
		35	14.1	
Fireball				
Worst case scenario	Weather category	Thermal Radiation Intensity level (kW/m2)	Maximum distance downwind to intensity level (m)	
FBR	All weather categories	4.7	23.7	
		12.6	13.4	
		23	8.6	
		35	5.6	
Flash fire				
Worst case scenario	Weather category	Distance to 0.5 LFL (m)	Distance to LFL (m)	Distance to UFL (m)
FBR	Category 1.1/F	10.6	Not reached at height of interest	Not reached at height of interest
Explosion				
Scenario	Weather category	Overpressure level (kPa)	Maximum distance downwind to overpressure level (m)	
FBR	Category 1.1/F	7	21.4	
		14	16.5	
		21	14.9	
		35	13.6	

None of the events studied have consequences that extend beyond the boundaries of the facility. This is likely due to the smaller line size for a full bore of the generator inlet line when compared to the generator biogas header. The risks to the workers and surrounding populations are further explored in the risk analysis, refer to Section 8.3. Full consequence results are presented in Appendix E-2.

8.1.3 Loss of containment within generator enclosure

Biogas could be released within the generator enclosure as noted in Section 6.4.2 and Table 6.1. This loss of containment could potentially result in an explosion or asphyxiation within the generator enclosure. The calculation in Appendix C-3 was used to determine whether the amount of biogas released in this event was sufficient to cause an explosion or asphyxiation inside the enclosure. For biogas to build up inside the gas engine enclosure, several failures have to occur in addition to the gas release. These include failure of the ventilation and failure of the gas detection inside the enclosure. The gas detection will normally shutdown the gas engine generator and associated fuel gas supply if methane in excess of 10% LEL, which equates to around 1% biogas in air, is detected.

8.1.3.1 Explosion within generator enclosure

As calculated in Table C-11, in Appendix B, the average molar fraction of biogas inside the enclosure is conservatively estimated to be around 7.2%. Since the LFL of biogas in air is 8.8%, as per Section 6.3.1.1, this scenario does not result in flammable biogas concentrations within the generator enclosure. While it is possible that there may be a small volume of biogas/air mixture within the flammable range within the enclosure as the biogas is being released from the piping, it is not expected that ignition of the mass of methane in this area will result in significant heat radiation or overpressure consequences. The risk is therefore expected to be contained on-site and reduced SFAIRP and no further investigation into this loss of containment scenario has been included in this PHA.

8.1.3.2 Asphyxiation within generator enclosure

A release of biogas within the generator enclosure has the potential to displace oxygen such that personnel are exposed to an asphyxiation risk. Based on the release volume calculated in Appendix C-3 the oxygen levels are not expected to drop below 19%. IchemE outlines that at levels below 19% personnel will experience the first sign of hypoxia [Ref 11]. This may induce early symptoms for those with preexisting medical conditions. The asphyxiation risk calculation is outlined in Appendix C-3.

Given the Type B compliance of the generator and associated enclosure and the ventilation, it is likely that isolation will occur faster than the 20 seconds assumed in Appendix C-3 such that the asphyxiation risk is even lower than calculated. Therefore, this risk is expected to be reduced to SFAIRP and no further investigation into this loss of containment scenario has been included in this PHA.

8.1.3.3 Toxic exposure within generator enclosure

Analysis suggests that biogas contains trace amounts of hydrogen sulphide. Prolonged exposure to hydrogen sulphide has the potential to cause injury or fatality. The AEGL 3 limit for 10 minutes of exposure is 76ppm (i.e. this is the worst case scenario) [Ref 12]. Given the release volume calculated in Appendix C-3 the concentration of hydrogen sulphide is not expected to exceed 14 ppm. Based on AEGL values for hydrogen sulphide at this concentration 8 hours of exposure is required before the impact is disabling. This suggests that the risk is reduced SFAIRP and no further investigation into this loss of containment scenario has been included in this PHA. The toxic exposure risk calculation is outlined in Appendix C-3.

8.2 Summary of hazardous scenarios

Section 8.1 details the consequence of hazard scenarios which could lead to off-site impacts. The following scenarios were carried forward for a Level 3 PHA (quantitative analysis) to determine if the risk extended beyond the site boundary:

– Biogas pipework or flange leak or rupture on an above ground section of:
  - the generator biogas header
  - a generator inlet line.

For a loss of containment within the generator enclosure it was found that while it is possible that there may be a small volume of biogas/air mixture that is within the flammable range within the enclosure as the biogas is being released from the piping, it is not expected that ignition of the mass of methane in this area will result in significant heat radiation or overpressure consequences. The risk is therefore expected to be contained on-site and reduced SFAIRP and no further investigation into this loss of containment scenario has been included in this PHA.

8.3 Risk analysis

The risk modelling for these scenarios was performed using DNV's SAFETI version 9.0 commercial software package [Ref 4]. A summary of the distance to the various risk contours are presented in Table 8.3.

Table 8.3 Risk contour summary

Risk level	Scenario	Distance to contour (m)
Generator biogas header	1E-05 per year	n/a
	5E-06 per year	9.8
	1E-06 per year	10.5
	5E-07 per year	10.5
Generator header inlet - east	1E-05 per year	n/a
	5E-06 per year	9.6
	1E-06 per year	10.1
	5E-07 per year	10.1
Generator header inlet - west	1E-05 per year	7.0
	5E-06 per year	9.6
	1E-06 per year	10.1
	5E-07 per year	10.1

8.3.1 Individual risk

Individual risk is a measure of the risk to an individual at a specific location exposed to the effect zone of one or more hazardous incidents, by the summation of the likelihood of all events that could lead to that outcome at that location. This assessment of individual risk levels can be used to check that no individual is exposed to unduly high levels of risk. Analysis shows that the majority of the risk to an offsite land user is driven by full bore rupture at the generator east location, which is near the southern edge of the site. This is due to its proximity to the site boundary shared with the Sutherland PCYC MiniBike Club.

Figure 8.1 presents the multi-level individual risk contours for the bioenergy facility. It shows that there is no risk contour generated for a risk level of 5.0 x 10^{-05}, which is the HIPAP 4 individual fatality risk criteria for sensitive land users such as hospitals, child care centres and old age housing, as noted in Table 4.4. The highest risk contour calculated, which is 1.0 x 10^{-05}, does not extend beyond the site boundary into the surrounding recreational land. Therefore, the individual risk level is compliant with HIPAP 4 risk criteria.

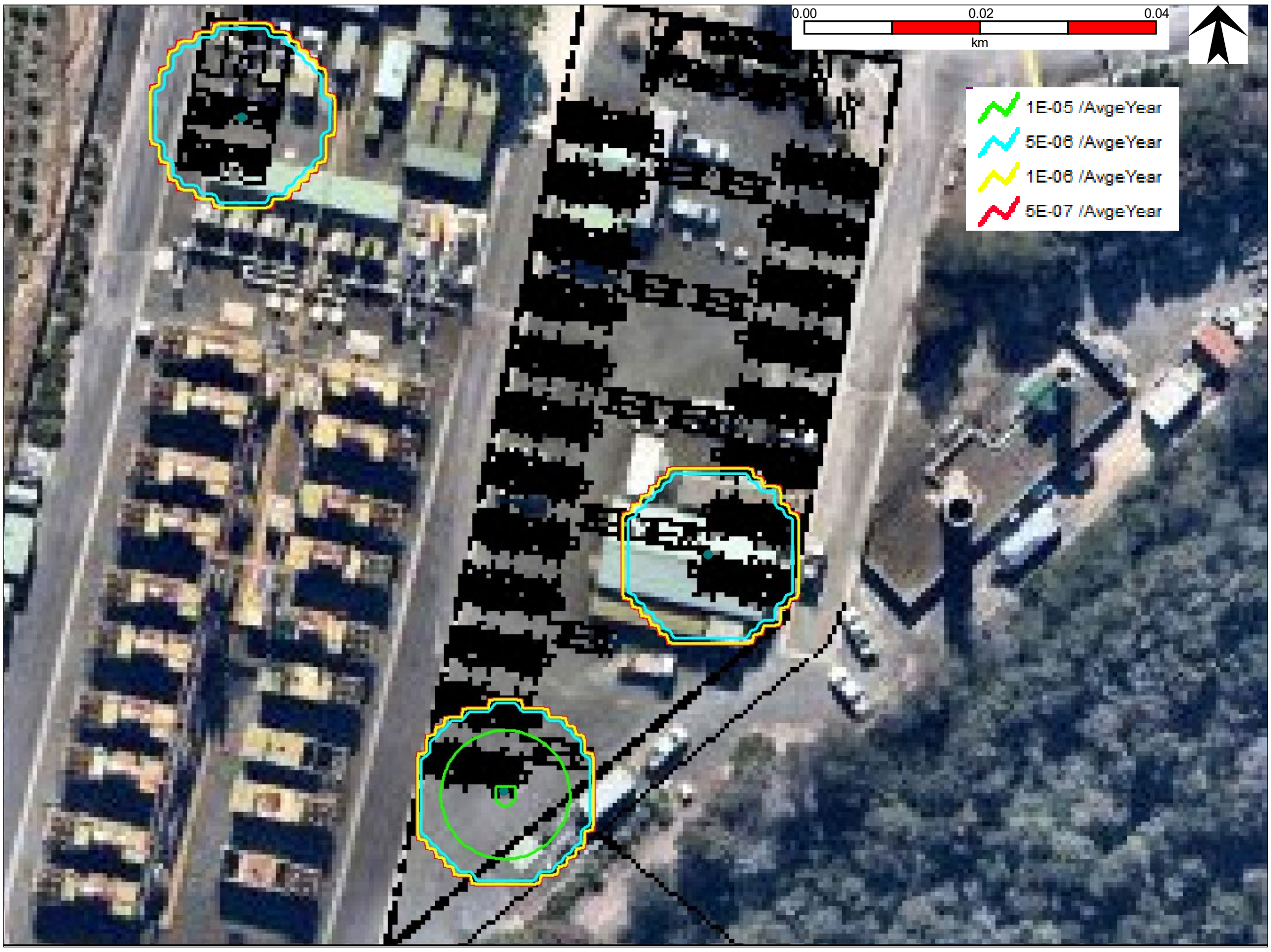

Figure 8.1 LHRRP risk contours

8.3.2 Societal risk

HIPAP 4 [Ref 2] states that societal risk looks at the tolerability of risks for hazards giving rise to societal concerns. It considers the fact that society is particularly intolerant of accidents that have a potential to create multiple fatalities, even though they are infrequent.

Whilst the frequency of a fatality is low, there is a possibility a singular person could be fatally impacted by a biogas release. Figure 8.2 shows that the societal risk at the bioenergy facility. On this graph, the green line indicates the upper boundary of the “negligible societal risk” region, while above the red line is the region showing “intolerable” societal risk, and the region below the two lines represents ALARP societal risk if it cannot be reduced further. The blue dot, which corresponds to a societal risk of 3.8×10^{-6} per year, is located well below the green line, within the negligible region, and as such the societal risks from the bioenergy facility are considered tolerable.

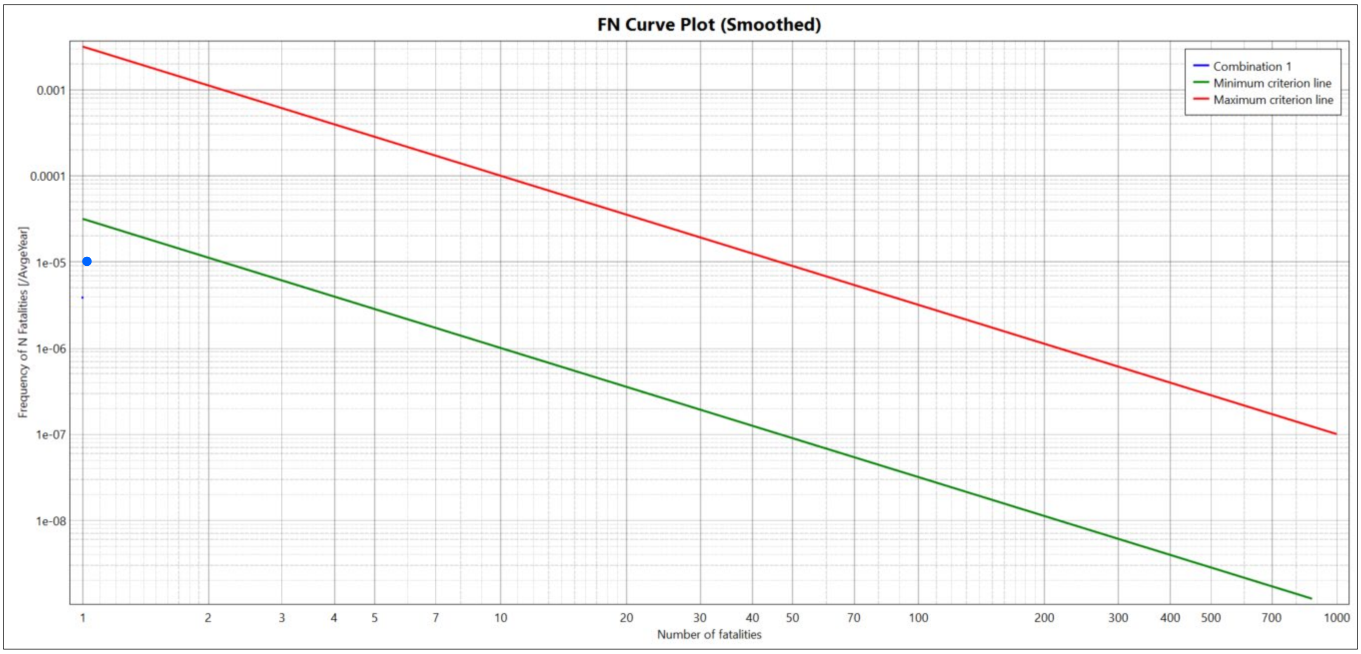

Figure 8.2 *Bioenergy Facility societal risk results (blue dot)*

9. Safety Management Systems

LMS will document comprehensive safety management systems for the site comprising:

- chemical and spill management systems (based on SDSs)
- fire prevention and protection systems summary
- bushfire assessment and bushfire emergency management and evacuation plan
- emergency planning
- site security
- traffic management
- welding and hot work.

9.1 Chemical and spill management

There will be bunded storage of chemicals on-site. It is recommended that any chemicals stored on site have appropriate labelling, separation where necessary and be disposed of in accordance with Australian Standards. Emergency services require access to the SDS register of all chemicals that are located on site.

Motor/gearbox lubrication oils and waste oils will be stored in above ground double walled tanks. All tanks and IBCs containing flammable liquids will be bunded or have double walls in accordance with AS 1940: 2022 – *The storage and handling of flammable and combustible liquids*.

Additionally, appropriate safe work procedures should be implemented for the handling of all chemicals including transfer, storage, spill prevention and clean up requirements.

9.2 Bushfire emergency management and evacuation plan

In addition to the on-site fire protection strategy developed with FRNSW, a bushfire assessment was prepared as part of the EIS. The bushfire protection measures include the following:

- Requirements for emergency access and egress including nomination of an alternative access route
- Formal preparedness procedures for staff and contractors to maintain awareness of and respond to escalating forecast fire danger including identification of firefighting equipment and fire water supply
- Formal pre-rehearsed procedures for staff and contractors to respond to a formal bushfire warning being issued by emergency services, including identification of escape routes and refuge areas
- Hot works management process/procedures, identification of people/positions authorised to permit hot works, identification of approved smoking areas, training of staff, storage of flammable chemicals/materials
- Systems/controls within the LMS plant to prevent spread of fire back to the landfill from the combustion of LFG at the power station
- Engine exhaust – height of stack and distance from vegetation/clearance zone for radiant heat
- Review and maintenance of asset protection zones.

9.3 Emergency planning

LMS will prepare a site-specific emergency response plan covering the site, which will include bushfire incident response procedures, lightning strikes and fire in adjacent facilities.

9.4 Site security

The site would be fenced with two-metre-high cyclone security fencing, with two barbed wire strands at the top of the fence.

9.5 Fire brigade access

All vehicles would enter the site via Little Forest Road.

Service roads throughout the site would be provided to allow access for service vehicles. The service road would provide a minimum 6 metres clearance for access by fire brigade and emergency services vehicles. Clearance will be confirmed with swept path analysis.

The project does not include a fire water tank but has access to the large fire water tank on the adjoining Cleanaway site.

9.6 Welding and hot work

Hot work activities on-site such as grinding, or welding are potential sources of ignition. For this reason, hot work permit systems and procedures are required around flammable gases, and combustible liquids and oils. These controls will form an important part of the fire prevention and protection systems onsite. Oxy acetylene - required for engineering repairs on the site will be stored in or close to the Site Workshop in accordance with AS 4839—2001: *The safe use of portable and mobile oxy-fuel gas systems for welding, cutting, heating and allied processes*.

10. Mitigation measures

Recommended mitigation and management measures were identified in response to the PHA findings include:

1. Fire safety study to HIPAP No. 2 – A fire safety study during detailed design to HIPAP No. 2 should be included as a condition of development consent to cover the fire safety strategy and fire protection systems for the Biogas facility, including any fire water storage on-site, and retention systems to contain fire water in any fire scenario.
2. Hot Work Permit System – A hot work permit system will be required on-site for any welding or cutting activities.
3. Gas Cylinders & Cylinder Valve Covers – Where cylinder valve covers are fitted, such as for the LP Gas Cylinders, these are not to be removed during handling and storage. All gas cylinders are to be stored in accordance with AS4332- 2005 - *The storage and handling of gases in cylinders*.
4. Final Hazard Analysis (FHA) – If substantial changes are made to the design, such as a large increase in the proposed pressure of the biogas fuel for the gas engines, LMS should conduct a final hazard analysis to HIPAP No.6. The FHA should include a revised estimate of the risk at the site boundary for worst case events.

11. Evaluation and conclusions

This report involved a preliminary risk screening of the project in accordance with the requirements of SEPP (Resilience and Hazards).

The results of the DG screening indicated that the proposed mass of biogas, which is a Class 2.1 flammable gas, did not exceed the general screening thresholds within the SEPP requirements for dangerous goods storage. However, as the nearest land users, the Sutherland PCYC MiniBike club, is located immediately southwest of the project, and there will be a public park directly to the west of the site in the future, it was deemed that the project is potentially hazardous and a level 3 PHA has been completed for this project.

The results of the transport screening do not exceed the dangerous good movement thresholds as there are expected to be minimal deliveries. If changes occur to the proposed transport of dangerous goods, it is recommended that the screening process be repeated to determine any potential impact.

Additionally, as the project is predicted to meet the relevant amenity licence requirements throughout the life of the project, it is not considered to be ‘offensive’.

Of the scenarios with the potential to cause offsite impacts, only modelling of the generator biogas header and generator inlet line loss of containment of biogas resulted in offsite impacts. A release of unburnt biogas from an engine stack was found to be at too high an elevation and had too small an extent to have offsite impacts. Furthermore, a release of biogas inside a generator enclosure was not expected to form an explosive mixture or pose an asphyxiation risk.

Depending on the wind direction, the jet fire radiation or explosion overpressure injury thresholds from a full bore rupture of the above ground section of biogas piping from the blowers to the generator biogas header could exceed the site boundary and extend onto the neighbouring Cleanaway landfill site/future public park, depending on the release direction. However, as the above ground piping section will be stainless steel and many other controls will be implemented, the probability of piping full bore rupture is very low. Furthermore, since the duration of any fire or explosion overpressure resulting from such a full bore rupture will be very short, the risk to any offsite land users is also extremely low. The more likely scenario for loss of containment is a leak from a flange or pipe fitting, resulting in a jet fire if ignited. The modelling showed that the consequences from this occurring are limited and will be contained completely onsite, regardless of the wind direction.

Risk modelling was conducted to confirm this. It found that both the individual and societal risks are well below the risk criteria specified in HIPAP 4 and as such the risks from activities at the LHRRP facility are considered tolerable.

The remaining risk scenarios assessed did not result in offsite impacts, so were found to be reduced SFAIRP by the controls existing in the design.

In summary, the PHA results for the biogas facility demonstrate that the offsite risks are managed to an acceptable level, subject to the risk management recommendations listed in section 10.

12. References

1. Applying SEPP 33: Hazardous and Offensive Development Application Guidelines, Department of Planning (DoP), NSW, 2011
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3. Hazardous Industry Planning Advisory Paper No. 6 – Guidelines for Hazard Analysis, Department of Planning (DoP), NSW, 2011
4. DNV 2021, PHAST Software Version 9.0: Component Library, DNV, London
5. Australian Government Bureau of Meteorology, Climate Statistics for Australian Locations: Goulburn Airport AWS, accessed 26/07/2021, < http://www.bom.gov.au/climate/averages/tables/cw_070330_All.shtml>.
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7. Astute Environmental Consulting, Project Bright Air Quality Assessment, Job:24-155, 25 October 2024.
8. LMS Energy, Lucas Heights Bioenergy Facility, Power Station Piping and Instrument Diagram, 20047-MP-002, Rev A (11 sheets)
9. LMS Energy, Lucas Heights Bioenergy Facility, Proposed Bioenergy Facility Site Layout, 20057-DA-050-01, Rev C
10. Drac, LMS Energy Project Bright, G3516 – Generator Enclosure General Arrangement, 00964-ME-GA-01, Rev H, and GA-04 Rev B
11. A consistent approach to the assessment and management of asphyxiation hazards, IChemE, 2008, **<**https://www.icheme.org/media/9748/xx-paper-53.pdf**>**
12. Acute Exposure Guideline Levels for Selected Airborne Chemicals, National Research Council, 2010, <https://www.epa.gov/sites/default/files/2014-11/documents/hydrogen_sulphide_final_volume9_2010.pdf>

Appendix A

Bioenergy Facility Layout

N

10 5 0 10 20
SCALE BAR (m)

SCALE 1:500 FOR A1 SIZE
SCALE 1:1000 FOR A3 SIZE
GDA94 / MGA ZONE 56
NEARMAP AERIAL IMAGE DATED 01/06/25

FOR INFORMATION

No	DATE	DRN	DESN	CHKD	APP	DESCRIPTION
D	15/09/25	SA	FL	–	–	FI – STORAGE SHED MOVED
C	08/09/25	SA	FL	–	–	FI – BUILDING POSITION CHANGES
B	07/08/25	SA	DM	–	–	FI – CSB ADDED
A	25/07/25	SA	DM	–	–	DIP – DESIGN IN PROGRESS

REVISIONS

DRAWING NUMBER	DESCRIPTION

REFERENCE DRAWINGS

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LMS ENERGY

DRAWN: S.A.
DATE: 25/07/25
DESIGN: D.M.
DATE: 25/07/25
APPRVD:
DATE:
A.B.N. 39 059 428 474

LUCAS HEIGHTS BIOENERGY FACILITY

POWER STATION
RELOCATED CONCEPT LAYOUT

SCALE	DRAWING NUMBER	SHEET	SHEETS	SIZE	REV
1:500	20057-DA-056-01		OF 01	A1	D

Appendix B

Dangerous Goods Manifest

Table B.1 Dangerous goods manifest for general materials

General					
Dangerous good name	**ADG Designation**	**Method of storage**	**Mass/volume**	**Substance**	**Method of Transport & Unloading**
Biogas	Landfill Gas	Process piping & equipment	TBA	Flammable Gas	NA
Waste Oil	Class 9 – Miscellaneous Material	Atmospheric steel tank with double walls	Up to 40,000L	Combustible oil	Truck / Approved waste contractor
Clean Oil	Class C1 or C2 Combustible liquid	Atmospheric steel tank with double walls	30,000L	Motor or Gear Oil / Petroleum Oils	Road Tanker / delivery hose
Sulphur Hexafluoride	Class 2.2 Non-flammable and non-toxic gas	Gas Insulated Switchgear	TBA	Non-flammable and non-toxic gas	Cylinder Dispensing / tray top truck
Diesel (Construction phase)	Class C1 – Combustible liquid	Various skid tanks	Typically, 10,000 L	Combustible fuel	Road Tanker / delivery hose
2 -stroke fuel	Class C2 – Combustible liquid	Plastic / steel pails	20 L	Combustible fuel	Packaged Goods / Tray top truck or van
Spray Paints (aerosols)	Class 2.1 liquified petroleum gas	Aerosol can	20 L	Paint	Packaged Goods / Tray top truck or van
CRC / WD-40 (aerosols)	Class 2.1 liquified petroleum gas	Aerosol can	20 L	Lubricant	Packaged Goods / Tray top truck or van
Brake Cleaner (aerosols)	Class 2.1 & 8 Corrosive	Aerosol can	20 L	Corrosive Substance	Packaged Goods / Tray top truck or van

Table B.2 Non-dangerous goods manifest for general materials

General					
Non-dangerous good name	**ADG Designation**	**Method of storage**	**Mass/volume**	**Substance**	**Method of Transport & Unloading**
Coolant – typically glycol and water	NA	IBCs	4000 L	Antifreeze (liquid)	Tray top truck / and IBC lift
IG-541 / Inergen – fire suppression gas	NA	Steel Cylinders	200 kg / 6 cylinders	Fire suppression gas containing 52% Nitrogen, 40% Argon and 8% CO_2	Cylinder Dispensing / tray top truck

Appendix C

Failure Case List and Assumptions

C-1 Loss of containment of biogas from the generator biogas supply header

To model the loss of containment of biogas from the generator biogas supply header scenario, the volume of biogas within the generator biogas header was estimated. This includes the outlets of both blowers, the underground biogas piping and the inlets (including the fuel gas train) to each of the 20 generators. These volumes are summarised and added in Table C.1.

Table C.1 Generator biogas supply header inventory

Line section	Size (ID, mm), estimated from P&ID [Ref 7]	Length of line section (estimated from site layout) [Ref 8]	Volume of section (m^3)
Blower outlet line into HEX	400	8 m x 2 blowers	2.01
Blower outlet line to underground piping	300	4 m x 2 blowers	0.57
Underground piping	450	150 m	23.86
Generation inlet line	150	8 m x 20 generators	2.83
Total volume of biogas			**29.3**

Due to a requirement for risk modelling for the loss of biogas from the generator biogas header scenario, a parts count was conducted to estimate the leak frequencies for the generator biogas header. This count does not include the individual generator biogas lines, which are counted in the next section. The count was based on the drawings provided for the LHRRP project and is summarised in Table C.2. Given we are unsure of the piping arrangement within the skid we have included both the shell and tube side of the heat exchanger to ensure that the model is conservative.

Table C.2 Generator biogas header parts count

Equipment type	Single unit	Total (2 units)
Heat exchanger (shell side)	1	2
Heat exchanger (tube side)	1	2
Instrument fitting (50 mm)	2	4
Flanges ANSI Raised Face – 300 mm	6	12
Flanges ANSI Raised Face – 400 mm	2	4
Valve (manual) – 300 mm	1	2
Process Piping – 300 mm	4	8
Process Piping – 400 mm	8	16

Based on the parts count the following leak frequences are listed in Table C.3.

Table C.3 Generator biogas header parts leak frequencies

Equipment type	Leak frequency per year				
	2 mm	6 mm	22 mm	85 mm	Full bore rupture
Heat exchanger (shell side)	2.40E-03	8.20E-04	2.80E-04	4.80E-05	2.40E-05
Heat exchanger (tube side)	1.64E-03	7.60E-04	3.60E-04	8.60E-05	6.60E-05
Instrument fitting (50 mm)	4.80E-04	2.00E-04	8.00E-05	0.00E+00	2.64E-05
Flanges ANSI Raised Face – 300 mm	1.56E-04	6.00E-05	2.28E-05	4.44E-06	1.56E-05
Flanges ANSI Raised Face – 400 mm	7.60E-05	2.60E-05	8.40E-06	1.36E-06	8.00E-06
Valve (manual) – 300 mm	5.80E-05	3.00E-05	1.60E-05	4.40E-06	4.40E-06
Process Piping – 300 mm	6.88E-05	3.36E-05	1.68E-05	4.16E-06	3.68E-06
Process Piping – 400 mm	1.30E-04	7.68E-05	4.80E-05	1.55E-05	2.08E-05
Total	**5.01E-03**	**2.01E-03**	**8.32E-04**	**1.64E-04**	**1.69E-04**

Other inputs for the loss of containment of biogas from the generator biogas header scenario are provided in Table C.4.

Table C.4 Generator biogas header leak/rupture modelling inputs

Parameter	Value	Unit	Reference / Comment
General parameters			
Temperature	40	˚C	The temperature may be over 50 ˚C from the blowers, but it is expected that some cooling will occur. 40 ˚C is considered conservative (as a lower temperature will result in more mass of biogas in the same volume).
Pressure	25	kPag	Conservative assumption based on client advised normal biogas pressure of 20 kPag.
Biogas volume	29.3	m^3	Calculated in Table C.1
Vessel type	Pressure vessel		Modelled as a pressure vessel as release from a pressure vessel is more conservative than release from a piping system.
Full bore rupture			
Model type	Leak		
Orifice size	300	mm	The rupture is taken to occur at near the junction of the above ground SS piping and the below ground PE piping.
Frequency	1.69E-04		
Line leak – 2 mm			
Model type	Leak		
Orifice size	2	mm	
Frequency	5.01E-03		
Line leak – 6 mm			
Model type	Leak		
Orifice size	6	mm	
Frequency	2.01E-03		
Line leak – 22 mm			
Model type	Leak		
Orifice size	22	mm	

Parameter	Value	Unit	Reference / Comment
Frequency	8.32E-04		
Line leak – 85 mm			
Model type	Leak		
Orifice size	85	mm	
Frequency	1.64E-04		

C-2 Loss of containment of biogas from a generator inlet line

To model the loss of containment of biogas from a generator inlet, the volume of biogas within the generator biogas header was estimated. Similar to the generator biogas header scenario, this includes the outlets of both blowers, the underground biogas pipeline and the inlets (including the fuel gas train) to each of the 20 generators. These volumes are summarised and added in Table C.5.

Table C.5 Flare system biogas inventory

Line section	Size (ID, mm), estimated from P&ID [Ref 7]	Length of line section (estimated from site layout) [Ref 8]	Volume of section (m^3)
Blower outlet line into HEX	400	8 m x 2 blowers	2.01
Blower outlet line to underground piping	300	4 m x 2 blowers	0.57
Underground piping	450	150 m	23.86
Generation inlet line	150	8 m x 20 generators	2.83
Total volume of biogas			**29.3**

Due to a requirement for risk modelling for the loss of biogas from the generator inlet scenario a parts count was conducted to estimate the leak frequencies for the generator inlet lines only. The parts in the blower discharges and biogas header are counted in the previous section. The count was based on the drawings provided for the LHRRP project, this count is summarised in Table C.6.

Table C.6 Generator inlet lines parts count

Equipment type	Single unit	Total (20 units)
Instrument fittings (50 mm)	3	60
Filter (Inlet > 150 mm)	1	20
Flanges ANSI Raised Face – 150 mm	5	100
Valves (manual) –- 150 mm	4	80
Process Piping – 150 mm	8	160

Based on the parts count the following leak frequences are listed in Table C.7.

Table C.7 Generator inlet line parts leak frequencies

Equipment type	Leak frequency per year				
	2 mm	6 mm	22 mm	85 mm	Full bore rupture
Instrument fittings (50 mm)	7.20E-03	3.00E-03	1.20E-03	0.00E+00	3.96E-04
Filter (Inlet > 150 mm)	2.40E-02	8.80E-03	3.00E-03	5.20E-04	2.60E-04
Flanges ANSI Raised Face – 150 mm	7.00E-04	3.10E-04	1.40E-04	3.20E-05	5.70E-05
Valves (manual) – 150 mm	1.36E-03	6.40E-04	3.04E-04	7.28E-05	5.76E-05
Process Piping – 150 mm	1.52E-03	6.24E-04	2.56E-04	5.12E-05	3.20E-05
Total	3.48E-02	1.34E-02	4.90E-03	6.76E-04	8.03E-04

Given the proximity of the two different sections of generators to the site boundary, two different release scenarios were considered for the generator biogas inlets, which are designated Generator East (12 generators) and Generator West (8 generators). The leak frequencies were proportioned based on the number of generators in each section. The groupings and release locations are show in Figure C.1.

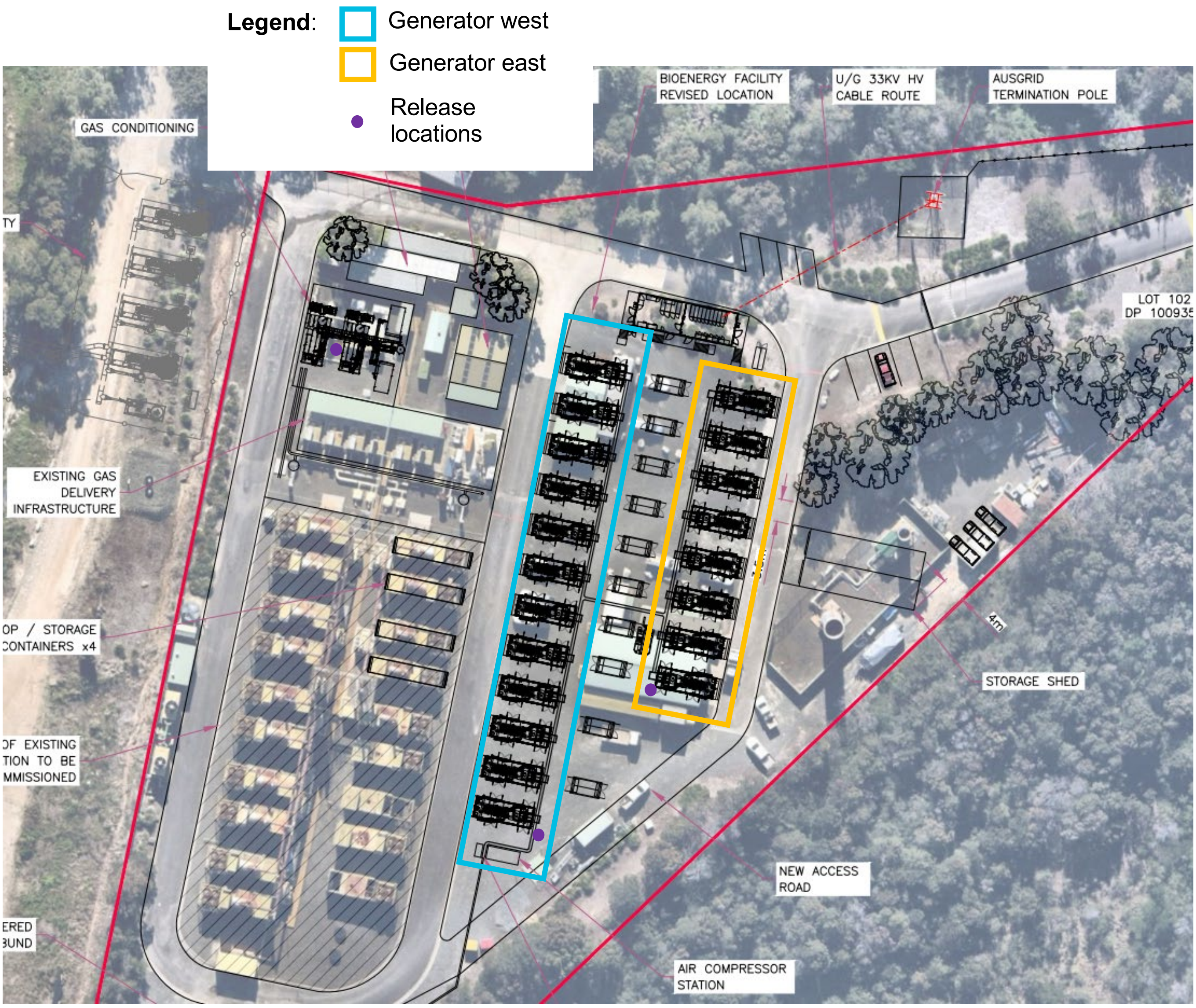

Figure C.1 *Generator inlet release locations*

Other inputs for the modelling of the loss of containment of biogas from the generator inlet lines are provided in Table C.8.

Table C.8 *Generator biogas inlet line modelling inputs*

Parameter	Value	Unit	Reference / Comment
General parameters			
Temperature	40	˚C	The temperature may be over 50 ˚C from the blowers, but it is expected that some cooling will occur. 40 ˚C is considered conservative (as a lower temperature will result in more mass of gas in the same volume).
Pressure	25	kPa	Conservative assumption based on client advised normal biogas pressure of 20 kPag.
Biogas volume	29.3	m^3	Calculated in Table C.3
Vessel type	Pressure vessel		Modelled as a pressure vessel as release from a pressure vessel is more conservative than release from a piping system.

Parameter	Value	Unit	Reference / Comment
Full bore rupture			
Model type	Leak		
Orifice size	150	mm	
Frequency – west	4.82E-04		
Frequency – east	3.21E-04		
Line leak – 2 mm			
Model type	Leak		
Orifice size	2	mm	
Frequency – west	2.09E-02		
Frequency – east	1.39E-02		
Line leak – 6 mm			
Model type	Leak		
Orifice size	6	mm	
Frequency – west	8.02E-03		
Frequency – east	5.35E-03		
Line leak – 22 mm			
Model type	Leak		
Orifice size	22	mm	
Frequency – west	2.94E-03		
Frequency – east	1.96E-03		
Line leak – 85 mm			
Model type	Leak		
Orifice size	85	mm	
Frequency – west	4.06E-04		
Frequency – east	2.70E-04		

C-3 Loss of containment within generator enclosure

Biogas could be released within the generator enclosure, potentially resulting in an explosion inside the enclosure. The calculation in Table C.9 was used to determine whether the amount of biogas released in this event was sufficient to cause an explosion inside the enclosure.

Table C.9 Generator enclosure release modelling inputs

Parameter	Value	Unit	Reference / Comment
Temperature	40	˚C	The temperature may be over 55 ˚C from the blowers, but it is expected that some cooling will occur. 40 ˚C is considered conservative as a lower temperature will result in more mass of biogas in the same volume.
Pressure	25	kPag	Conservative assumption based on client advised normal fuel gas pressure of 20 kPag.
Biogas density	1.4	kg/m^3	Calculated from temperature and pressure above.
Volume of biogas in feed pipe			
Length of pipe within generator enclosure.	6	m	Estimation from Generator Enclosure Internal General Arrangement [Ref 9]
Internal pipe diameter	140	mm	Approx ID of DN 150 Stainless steel piping. Line size and composition from LMS P&ID [Ref 7].
Volume within pipe at the time of loss of containment	0.09	m^3	Calculated
Biogas entering enclosure before isolation			
Time before isolation of generator fuel gas line occurs	20	s	Conservative assumption of time between biogas detection inside enclosure, or detection of low pressure in fuel gas train, and isolation of biogas supply.
Flow rate of biogas into generator	594	Am^3/h	
Additional biogas which flows into enclosure before isolation	3.3	m^3	Calculated from flowrate x time before isolation
Total volume of biogas released into enclosure	3.4	m^3	Initial piping volume + additional biogas which flows into enclosure before isolation
Total mass of biogas released into enclosure	**4.7**	**kg**	Piping volume x density
Molecular Weight of biogas	30	kg/kmol	
Moles of biogas released into enclosure	0.16	kmol	Mass of biogas released / molecular weight
Fraction of methane in air inside enclosure			
Total enclosure volume	92	m^3	9m x 3.2m x 3.2m – estimated from Generator General Arrangement drawings [Ref 9]
Amount of enclosure taken up by gas engine generator	50	%	Approximation based on Generator General Arrangement drawings [Ref 9]
Air volume inside enclosure	46	m^3	
Density of air inside enclosure	1.3	kg/m^3	
Molecular Weight of air	28.9	kg/kmol	
Moles of air in enclosure	2.07	kmol	Assumes that air is confined, i.e. no ventilation, which is very conservative as the generator walls will contain ventilation louvres.
Molecular fraction of biogas in air	7.2%		Moles of biogas / (Moles of air + biogas)

The Lower Flammability Limit (LFL) for biogas in air is 8.8%, meaning that this scenario does not result in a flammable biogas concentration within the generator enclosure.

A release within the generator enclosure could also pose an asphyxiation or toxic exposure risk. The calculation in Table C.10 was used to determine whether the amount of biogas released in this event was sufficient to cause asphyxiation or toxic injury based on the relevant criteria.

Table C.10 Generator enclosure asphyxiation risk

Parameter	Value	Unit	Reference / Comment
Biogas entering enclosure before isolation			
Total volume of biogas released into enclosure	3.4	m^3	Initial piping volume + additional biogas which flows into enclosure before isolation
Volume inside generator enclosure			
Total enclosure volume	92	m^3	9m x 3.2m x 3.2m – estimated from Generator General Arrangement drawings [Ref 9]
Amount of enclosure taken up by gas engine generator	50	%	Approximation based on Generator General Arrangement drawings [Ref 9]
Air volume inside enclosure	46	m^3	
Density of air inside enclosure	1.3	kg/m^3	
Molecular Weight of air	28.9	kg/kmol	
Moles of air in enclosure	2.07	kmol	Assumes that air is confined, i.e. no ventilation, which is very conservative as the generator walls will contain ventilation louvres.
Molecular fraction of biogas in air	7.2%		Moles of biogas / (Moles of air + biogas)
Volume of biogas released			
Total volume of biogas released into enclosure	3.4 m^3	m^3	Initial piping volume + additional biogas which flows into enclosure before isolation
Air composition			
Nitrogen	79.05	%	
Oxygen	20.95	%	
Biogas composition			
Methane	57.000	%	Based on biogas analysis provided by LMS
Carbon dioxide	42.983	%	
Hydrogen sulphide	0.017	%	Based on biogas analysis provided by LMS
Composition inside generator enclosure			
Void space inside generator enclosure	46.0	m^3	Initially occupied by ambient air.
Volume of biogas released into enclosure	3.4	m^3	
Volume of air remaining	42.6	m^3	Total volume less biogas volume
Volume of oxygen	8.9	m^3	Volume of air remaining * Oxygen %
% Oxygen inside generator enclosure	19.4	%	Volume of oxygen/ Volume occupied by gas
Volume of hydrogen sulphide	5.8E-04	m^3	Volume of biogas * Hydrogen sulphide %
Concentration (ppm) of hydrogen sulphide inside generator	12.5	ppm	(Volume of hydrogen sulphide/ Volume occupied by gas)*10^5

Appendix D

PHAST Consequence Model Theory

D-1 Discharge Modelling

If there is a hole in a pipeline, vessel, flange or other piece of process equipment, the fluid inside will be released through the opening, provided the process pressure or static head is higher than ambient pressure. The properties of the fluid upon exiting the hole play a large role in determining consequences, e.g., vapour or liquid, velocity of release etc. Figure D.1 illustrates an example scenario.

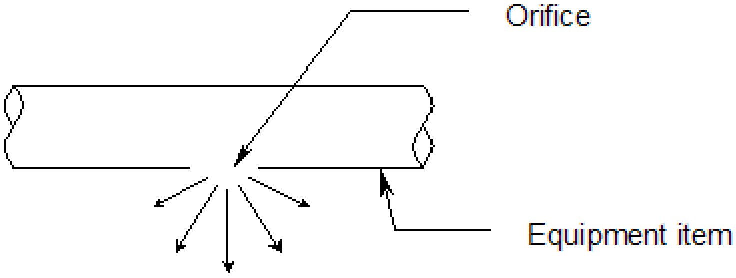

Figure D.1 Typical Discharge

The discharge can be considered to have two stages, the first is expansion from initial storage conditions to orifice conditions, the second from orifice conditions to ambient conditions.

The conditions at the orifice are calculated by assuming isentropic expansion, i.e., entropy before release = entropy at orifice. This allows enthalpy and specific volume at the orifice to be calculated.

The equations for mass flow rate ($\dot{m}$) and discharge velocity (u_0) are then given by:

$$\dot{m} = C_d A_o \rho_o \sqrt{-2(H_0 - H_i)}$$

And $$u_0 = C_d \sqrt{(-2(H_0 - H_i)}$$

Where:

– C_d = Discharge coefficients

– A_o = Area of the orifice

– ρ_o = density of the material in the orifice

– H_o = Enthalpy at the orifice

– H_i = Enthalpy at initial storage conditions

The discharge parameters passed forward to the dispersion model are as follows:

- release height (m) and orientation
- thermodynamic data: release temperature (single phase) (°C) or liquid mass fraction (two-phase), initial drop size (m)
- other data:
  – for instantaneous release: mass of released material (kg), expansion energy (J)
  – for continuous release: release angle (degrees), rate of release (kg/s), release velocity (m/s), release duration (s)

D-2 Dispersion

When a vapour leak occurs, some material will be released into the atmosphere. Upon being released it will start to disperse and dilute into the surrounding atmosphere. The limiting (lowest) concentration of interest is related to flammable and toxic limits for flammable and toxic substances respectively. The model used to determine extent of release is described below, along with some of the key input parameters.

The consequence modelling package PHAST utilises the Unified Dispersion Model (Witlox *et al*, 1999). This models the dispersion following a ground level or elevated two phase unpressurised or pressurised release. It allows for continuous, instantaneous, constant finite duration and general time varying releases. It includes a unified model for jet, heavy and passive two phase dispersion including possible droplet rain out, pool spreading and re-evaporation. SAFETI is built on the base models in PHAST.

D-3 Jet Dispersion

For a continuous, pressurised release, a vapour is released as a jet, i.e., high momentum release. The jet eventually loses momentum and disperses as a passive cloud. Figure D.2 below shows a typical release, and the various phases involved.

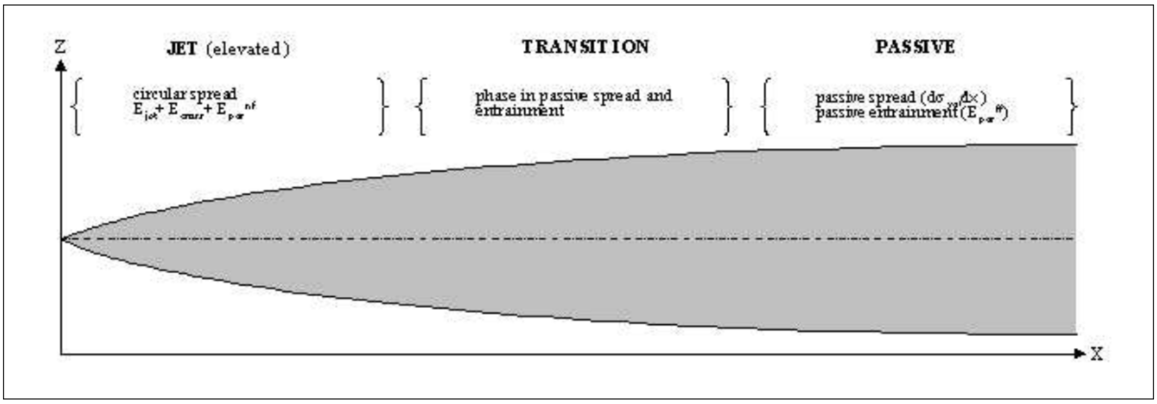

Figure D.2 Jet Dispersion

The cloud is diluted by air entrainment until it eventually reaches the lower limit of concern. During the jet phase, the mixing is turbulent, and much air is entrained. In the passive phase, less air is potentially entrained, and it occurs via a different mechanism to the turbulent jet phase. The calculation of the plume therefore depends on many factors, the key parameters being:

– Vapour released, specifically molecular weight
– Discharge conditions including phase(s) of release, velocity etc.
– Atmospheric conditions (a cloud will generally travel further in more stable conditions with lower wind speeds).

D-4 Flammable Effects

If the release is of a flammable material, it is possible for the release to be ignited. The type of fire which results (e.g. jet, pool fire, flash fire etc) depends on the physical properties of the release and whether the ignition is immediate or delayed. This chapter discusses the various flammable effects, which can occur.

D-4-1 Jet Fire

Jet fires are a result of high momentum releases. If a flammable release is ignited instantaneously, a jet fire will result. The flame will have a degree of 'lift off' as the flammable mixture has to dilute to be within the flammable limits. This section briefly discusses the model used for jet fires as well as key parameters in the calculation.

The jet fire calculation utilises the Chamberlain model (Chamberlain 1987). In this model, jet fires are modelled as a conical flame, with the ignited portion lift off, inclination and shape being determined by the material being released, the pressure at which it is being released and the hole size that it is being released through. These release parameters are the main inputs to the jet fire radiation calculations. Figure D.3 below shows a graphical representation of the jet fire model.

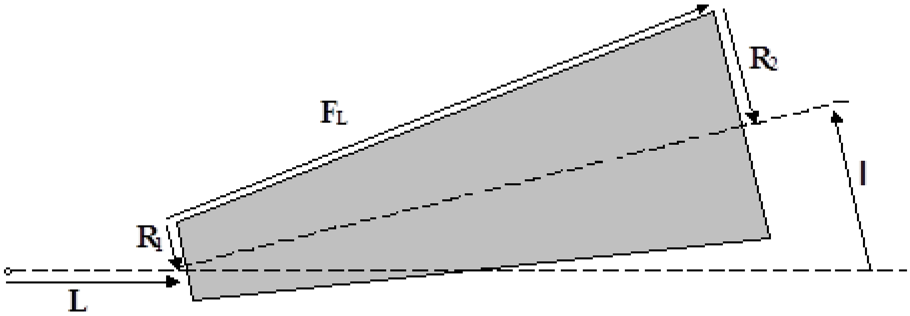

Figure D.3 Truncated Cone Jet Fire Model

Where:

L = Lift off
I = Flame Inclination
R_1 = Flame Base Radius
R_2 = Flame End Radius
F_L = Flame Length

The jet fire calculations model radiation from the entire surface of the ignited portion of the jet. This includes radiation from the cone forming the body of the flame, as well as from the ends of the cone. The amount of radiation that a nearby receiver is exposed to is determined by its distance from the flame surface, as well as by the orientation of the flame relative to the receiver. The key parameters in the calculation of the radiation exposure of a receiver are therefore the flame lift off, the flame inclination, and the dimensions of the ignited portion of the jet (i.e. flame length and end radii).

D-5 Multi Energy Explosion Model

The Multi Energy Model gives overpressure of an explosion as a function of distance from the explosion. The explosion is modelled as a sphere and overpressure is calculated based on scaled distance from the centre. This section explains the key parameters involved in the multi energy model.

The energy released by the explosion, E, is calculated as the product of the mass of fuel in the cloud and the heat of combustion. This assumes a stoichiometric mixture of fuel and air.

The distance scaling factor, S, is related to the energy released by the explosion and the atmospheric pressure by:

$$S = \left[\frac{E}{P_a}\right]^{1/3}$$

The scaled distance r is then given by:

$$r = \frac{d}{S}$$

where d is the actual distance of the receiver from the cloud centre.

To calculate overpressure a set of 10 curves is used. The actual curve used depends on the degree of confinement, with a confinement of 1 being least confined and 10 most confined. Process plants generally have a confinement factor of 3 or lower, though it needs to be assessed for each individual process. The graph showing the 10 curves is included in Figure D.4 below.

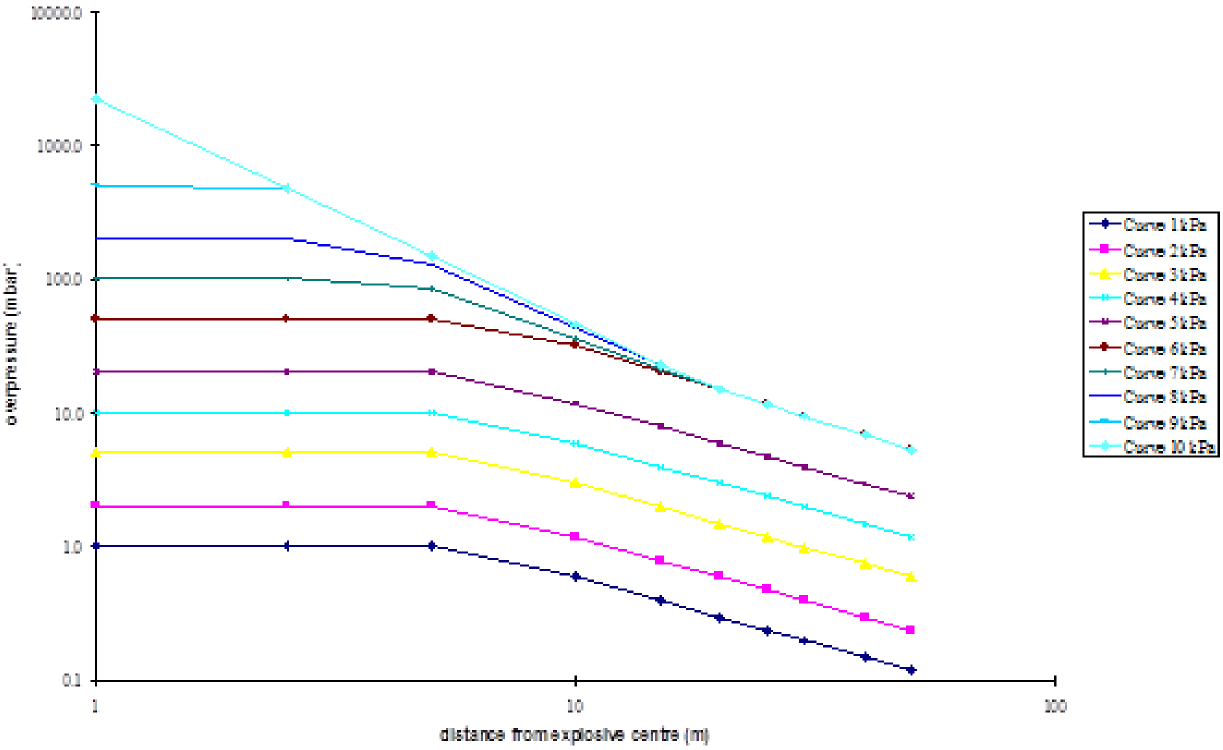

Figure D.4 *Multi Energy Curves*

Appendix E

Consequence Modelling Output

E-1 Generator header consequence results

Table E.1 Flash fire consequence results at 1.5m elevation

Scenario	Weather	Distance to UFL [m]	Distance to LFL [m]	Distance to 0.5 LFL [m]
Line leak - 2 mm	Category 1.6/B	n/a	n/a	n/a
	Category 3/D	n/a	n/a	n/a
	Category 2.5/E	n/a	n/a	n/a
	Category 1.1/F	n/a	n/a	n/a
Line leak - 6 mm	Category 1.6/B	Note 1	Note 1	Note 1
	Category 3/D	Note 1	Note 1	Note 1
	Category 2.5/E	Note 1	Note 1	Note 1
	Category 1.1/F	Note 1	Note 1	Note 1
Line leak - 22 mm	Category 1.6/B	Note 1	Note 1	Note 1
	Category 3/D	Note 1	Note 1	Note 1
	Category 2.5/E	Note 1	Note 1	Note 1
	Category 1.1/F	Note 1	Note 1	Note 1
Line leak - 85 mm	Category 1.6/B	Note 1	Note 1	Note 1
	Category 3/D	Note 1	Note 1	Note 1
	Category 2.5/E	Note 1	Note 1	Note 1
	Category 1.1/F	Note 1	Note 1	Note 1
Full bore rupture	Category 1.6/B	Note 1	9.4	28.8
	Category 3/D	Note 1	9.4	28.7
	Category 2.5/E	Note 1	10.3	27.6
	Category 1.1/F	Note 1	10.8	24.2

Note: 1. Not reached at height of interest

Table E.2 Jet fire consequence results at 1.5m elevation

Scenario	Weather	Flame length [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Line leak – 2 mm	Category 1.6/B	0.5	Note 1	Note 1	Note 1	Note 1
	Category 3/D	0.5	Note 1	Note 1	Note 1	Note 1
	Category 2.5/E	0.5	Note 1	Note 1	Note 1	Note 1
	Category 1.1/F	0.5	Note 1	Note 1	Note 1	Note 1
Line leak – 6 mm	Category 1.6/B	1.3	Note 1	Note 1	Note 1	Note 1
	Category 3/D	1.3	Note 1	Note 1	Note 1	Note 1
	Category 2.5/E	1.3	Note 1	Note 1	Note 1	Note 1
	Category 1.1/F	1.3	Note 1	Note 1	Note 1	Note 1
Line leak – 22 mm	Category 1.6/B	4.1	4.4	Note 1	Note 1	Note 1
	Category 3/D	4.4	4.7	Note 1	Note 1	Note 1
	Category 2.5/E	4.3	4.6	Note 1	Note 1	Note 1
	Category 1.1/F	4.0	4.3	Note 1	Note 1	Note 1

Scenario	Weather	Flame length [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Line leak – 85 mm	Category 1.6/B	12.4	14.3	11.9	8.0	6.6
	Category 3/D	13.3	15.4	13.3	12.1	9.0
	Category 2.5/E	13.0	15.0	12.9	10.3	7.9
	Category 1.1/F	12.1	13.8	11.3	7.2	6.1
Full bore rupture	Category 1.6/B	32.5	43.3	33.2	27.1	19.4
	Category 3/D	34.0	45.1	36.1	32.8	27.8
	Category 2.5/E	33.4	44.6	34.8	31.0	24.3
	Category 1.1/F	32.1	42.2	32.2	24.5	17.5

Note 1. Not reached at height of interest

Table E.3 Fireball consequence results at 1.5m elevation

Scenario	Weather	Fireball diameter [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Full bore rupture	Category 1.6/B	23.7	13.4	8.6	5.6	23.7
	Category 3/D	23.7	13.4	8.6	5.6	23.7
	Category 2.5/E	23.7	13.4	8.6	5.6	23.7
	Category 1.1/F	23.7	13.4	8.6	5.6	23.7

Table E.4 Explosion consequence results at 1.5m elevation

Scenario	Weather	Distance downwind to 7 kPa overpressure	Distance downwind to 14 kPa overpressure	Distance downwind to 21 kPa overpressure	Distance downwind to 35 kPa overpressure
Full bore rupture	Category 1.6/B	41.6	32.4	29.3	26.8
	Category 3/D	41.4	32.3	29.2	26.7
	Category 2.5/E	42.1	32.7	29.5	26.9
	Category 1.1/F	43.3	33.4	30.0	27.3

E-2 Generator inlet line consequence results

Table E.5 Flash fire consequence results at 1.5m elevation

Location	Scenario	Weather	Distance to UFL [m]	Distance to LFL [m]	Distance to 0.5 LFL [m]
Generator east	Line leak - 2 mm	Category 1.6/B	n/a	n/a	n/a
		Category 3/D	n/a	n/a	n/a
		Category 2.5/E	n/a	n/a	n/a
		Category 1.1/F	n/a	n/a	n/a
Generator west	Line leak - 2 mm	Category 1.6/B	n/a	n/a	n/a
		Category 3/D	n/a	n/a	n/a
		Category 2.5/E	n/a	n/a	n/a
		Category 1.1/F	n/a	n/a	n/a
Generator east	Line leak - 6 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator west	Line leak - 6 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator east	Line leak - 22 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator west	Line leak - 22 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator east	Line leak - 85 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator west	Line leak - 85 mm	Category 1.6/B	Note 1	Note 1	Note 1
		Category 3/D	Note 1	Note 1	Note 1
		Category 2.5/E	Note 1	Note 1	Note 1
		Category 1.1/F	Note 1	Note 1	Note 1
Generator east	Full bore rupture	Category 1.6/B	Note 1	Note 1	8.9
		Category 3/D	Note 1	Note 1	8.5
		Category 2.5/E	Note 1	Note 1	9.4
		Category 1.1/F	Note 1	Note 1	10.6

Location	Scenario	Weather	Distance to UFL [m]	Distance to LFL [m]	Distance to 0.5 LFL [m]
Generator west	Full bore rupture	Category 1.6/B	Note 1	Note 1	8.9
		Category 3/D	Note 1	Note 1	8.5
		Category 2.5/E	Note 1	Note 1	9.4
		Category 1.1/F	Note 1	Note 1	10.6

Note: 1. Not reached at height of interest

Table E.6 Jet fire consequence results at 1.5m elevation

Location	Scenario	Weather	Flame length [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Generator east	Line leak - 2 mm	Category 1.6/B	0.5	Note 1	Note 1	Note 1	Note 1
		Category 3/D	0.5	Note 1	Note 1	Note 1	Note 1
		Category 2.5/E	0.5	Note 1	Note 1	Note 1	Note 1
		Category 1.1/F	0.5	Note 1	Note 1	Note 1	Note 1
Generator west	Line leak - 2 mm	Category 1.6/B	0.5	Note 1	Note 1	Note 1	Note 1
		Category 3/D	0.5	Note 1	Note 1	Note 1	Note 1
		Category 2.5/E	0.5	Note 1	Note 1	Note 1	Note 1
		Category 1.1/F	0.5	Note 1	Note 1	Note 1	Note 1
Generator east	Line leak - 6 mm	Category 1.6/B	1.3	Note 1	Note 1	Note 1	Note 1
		Category 3/D	1.3	Note 1	Note 1	Note 1	Note 1
		Category 2.5/E	1.3	Note 1	Note 1	Note 1	Note 1
		Category 1.1/F	1.3	Note 1	Note 1	Note 1	Note 1
Generator west	Line leak - 6 mm	Category 1.6/B	1.3	Note 1	Note 1	Note 1	Note 1
		Category 3/D	1.3	Note 1	Note 1	Note 1	Note 1
		Category 2.5/E	1.3	Note 1	Note 1	Note 1	Note 1
		Category 1.1/F	1.3	Note 1	Note 1	Note 1	Note 1
Generator east	Line leak - 22 mm	Category 1.6/B	4.1	4.4	Note 1	Note 1	Note 1
		Category 3/D	4.4	4.7	Note 1	Note 1	Note 1
		Category 2.5/E	4.3	4.6	Note 1	Note 1	Note 1
		Category 1.1/F	4.0	4.3	Note 1	Note 1	Note 1
Generator west	Line leak - 22 mm	Category 1.6/B	4.1	4.4	Note 1	Note 1	Note 1
		Category 3/D	4.4	4.7	Note 1	Note 1	Note 1
		Category 2.5/E	4.3	4.6	Note 1	Note 1	Note 1
		Category 1.1/F	4.0	4.3	Note 1	Note 1	Note 1
Generator east	Line leak - 85 mm	Category 1.6/B	12.4	14.3	11.9	8.0	6.6
		Category 3/D	13.3	15.4	13.3	12.1	9.0
		Category 2.5/E	13.0	15.0	12.9	10.3	7.9
		Category 1.1/F	12.1	13.8	11.3	7.2	6.1

Location	Scenario	Weather	Flame length [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Generator west	Line leak - 85 mm	Category 1.6/B	12.4	14.3	11.9	8.0	6.6
		Category 3/D	13.3	15.4	13.3	12.1	9.0
		Category 2.5/E	13.0	15.0	12.9	10.3	7.9
		Category 1.1/F	12.1	13.8	11.3	7.2	6.1
Generator east	Full bore rupture	Category 1.6/B	18.8	23.3	18.6	14.3	9.8
		Category 3/D	20.0	24.7	20.4	18.9	14.1
		Category 2.5/E	19.6	24.3	18.8	17.5	12.1
		Category 1.1/F	18.5	22.7	17.9	12.7	8.9
Generator west	Full bore rupture	Category 1.6/B	18.8	23.3	18.6	14.3	9.8
		Category 3/D	20.0	24.7	20.4	18.9	14.1
		Category 2.5/E	19.6	24.3	18.8	17.5	12.1
		Category 1.1/F	18.5	22.7	17.9	12.7	8.9

Note: 1. Not reached at height of interest

Table E.7 Fireball consequence results at 1.5m elevation

Location	Scenario	Weather	Fireball diameter [m]	Distance downwind to intensity level 1 (4.7 kW/m2) [m]	Distance downwind to intensity level 2 (12.6 kW/m2) [m]	Distance downwind to intensity level 3 (23 kW/m2) [m]	Distance downwind to intensity level 4 (35 kW/m2) [m]
Generator east	Full bore rupture	Category 1.6/B	19.8	23.7	13.4	8.6	5.6
		Category 3/D	19.8	23.7	13.4	8.6	5.6
		Category 2.5/E	19.8	23.7	13.4	8.6	5.6
		Category 1.1/F	19.8	23.7	13.4	8.6	5.6
Generator west	Full bore rupture	Category 1.6/B	19.8	23.7	13.4	8.6	5.6
		Category 3/D	19.8	23.7	13.4	8.6	5.6
		Category 2.5/E	19.8	23.7	13.4	8.6	5.6
		Category 1.1/F	19.8	23.7	13.4	8.6	5.6

Note: 1. Not reached at height of interest

Table E.8 Explosion consequence results at 1.5m elevation

Location	Scenario	Weather	Distance downwind to 0.07 bar overpressure	Distance downwind to 0.14 bar overpressure	Distance downwind to 0.21 bar overpressure	Distance downwind to 0.35bar overpressure
Generator east	Full bore rupture	Category 1.6/B	20.7	16.1	14.6	13.3
		Category 3/D	20.5	16.0	14.5	13.3
		Category 2.5/E	20.9	16.2	14.7	13.4
		Category 1.1/F	21.4	16.5	14.9	13.6
Generator west	Full bore rupture	Category 1.6/B	20.7	16.1	14.6	13.3
		Category 3/D	20.5	16.0	14.5	13.3
		Category 2.5/E	20.9	16.2	14.7	13.4
		Category 1.1/F	21.4	16.5	14.9	13.6

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