Biogas Capture, Storage and Combustion Guidelines for Meat Processing Plants

Version 2

PROJECT CODE:	**2016 (A.ENV.1027)**
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DATE SUBMITTED:	**15th Feb 2017**

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

ABBREVIATIONS

Term	Meaning
AIT	auto-ignition temperature
ALARP	as low as reasonably practicable
AMPC	Australian Meat Processor Corporation
AS	Assets
AT	methane analyser
AWL	above water level
CAL	covered anaerobic lagoon
CPU	central processing unit
EN	environment
ESV	EnergySafe Victoria
F	frequency (for risk calculation)
FCV	flow control valve
FA	flame arrestor
FMEA	Failure Modes and Effects Analysis
FT	flow meter
H_2S	hydrogen sulphide gas
HAZID	hazard identification
HAZOP	hazard and operability study
HDPE	high density polyethylene
MAOP	maximum allowable operating pressure
LEL	lower explosive limit
LFL, 1/2LFL	lower flammable limit, half the LFL.
LOC	Loss of Containment
OTTER	Office of the Tasmanian Economic Regulator
PE	people
PES	programmable electronic system
PL	plant
PLC	programmable logic controller
S	severity (for risk calculation)
SCADA	supervisory control and data acquisition
SMP	Safety Management Plan
TOW	top of (CAL) wall
WHS(NUL)	Work Health and Safety (National Uniform Legislation)

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1 INTRODUCTION

1.1 Background

Biogas is the product of anaerobic biological breakdown of organic substances. Anaerobic ponds or lagoons (the terms are interchangeable) are a common treatment step of wastewater produced from the meat industry. The technology is simple and inexpensive to operate while significantly reducing the wastewater organic loading. The by product, biogas, is both a valuable fuel and a greenhouse gas. Captured biogas can be used to fuel a boiler or for co-generation. The burning of the biogas also significantly reduces methane emissions. Hence, the covering of the anaerobic ponds has recently become popular.

The collection and handling of biogas in a covered anaerobic lagoon (CAL) from the bacterial degradation of meat processing wastewater is accompanied by a number of hazards, the most significant of which include:

- Toxicity due to the presence of hydrogen sulphide gas (H_2S) which is a minor component of biogas
- Flammability of biogas when mixed with air in the appropriate proportions
- Suffocation by biogas due to the exclusion of air, especially in confined spaces

1.2 Aims

The aims of this guide are to:

- Inform the meat processing industry and associated regulatory bodies of the hazards and risks associated with the production, storage, transport and use of biogas produced in anaerobic systems treating industry wastewater
- Provide recommendations for the mitigation of these risks using ALARP principles
- Provide a consistent approach for the industry across Australia
- Provide technical material helpful for companies in preparing their risk management documentation

1.3 Scope

Since 2007 there has been a rapid introduction of covered anaerobic lagoon technology (and its associated variants) into the red meat processing industry in Australia to replace traditional anaerobic ponds which were open to the atmosphere – albeit often through a relatively thick natural floating crust. Consequently, a need has arisen to provide informative and careful advice on the hazards of this new technology and how the risks associated with these hazards can be appropriately mitigated.

The guide is focused on the identification of hazards and mitigation of the risks associated with biogas capture from CAL technology treating meat processing wastewater and downstream storage and transport of the biogas for use in a range of gas appliances.

The Guide is also relevant for other biogas-producing anaerobic treatment technologies such as in-vessel reactors and where anaerobic solid digestion may be used.

The terms applying to biogas and biogas-fuelled devices can be complex. Appendix 1 contains a glossary of commonly used technical terms relevant to biogas and frequently used in regulatory material.

The Guide does not seek to cover the design, installation or operation of biogas-fuelled gas devices such as flares, boilers or cogeneration equipment. These devices and their installation are regulated in most Australian States by regulations which reference Australian Standards.

An additional resource of interest is the updated AMPC publication 'Waste Water Management in the Australian Red Meat Processing Industry' manual (2017). This contains a section describing the management of anaerobic ponds which is complementary to this Guide.

2 OVERVIEW OF ANAEROBIC TECHNOLOGY

2.1 Anaerobic technology suitable for the meat processing industry

Anaerobic bacterial processes have been integral to the treatment of strong but biodegradable industrial wastewater for many decades. The meat processing industry has utilised anaerobic systems widely due to the excellent anaerobic biodegradability of its wastewater and the highly robust and cost-effective nature of these processes. The main technology variants are briefly covered below.

2.1.1 Uncovered anaerobic ponds

Uncovered anaerobic ponds have long been used in the meat industry for wastewater treatment. These ponds treat the wastewater using the same biological activity as covered anaerobic lagoons (CALs), but are covered by a naturally formed crust consisting of floating fats and fine cellulosic particles, which may eventually host grass and reeds (refer to Image 1). These crusts can be quite thin where primary treatment is of a high standard, or may be over a metre thick where pre-treatment is cursory.

Image 1: A naturally crusted anaerobic pond processing wastewater from a large meat plant.

The biogas produced by these ponds escapes through fractures or vents in the crust. Consequently, it is emitted into the atmosphere largely untreated, although the crust often deodorises it to a substantial extent. The loss of this biogas deprives the facility of a substantial source of energy-rich fuel. Uncovered anaerobic ponds can contribute 50% or more of the Scope 1 greenhouse emissions (according to NGER) from Australian meat processing plants.

It is worth noting that these ponds generate similar quantities of biogas to CALs and that there have been few instances of problems (such as fires, etc.) with the release of biogas into the open despite numerous anaerobic ponds existing at many meat processing plants in Australia.

Anaerobic sludge slowly accumulates in the system over time, although at a far lower rate than in aerobic systems with the same organic load. Uncovered anaerobic ponds may require periodic sludge removal to maintain the available system volume and avoid high suspended solids in the effluent. Sludge removal is a feature to all anaerobic treatment systems.

2.1.2 Covered anaerobic lagoons (CALs)

Image 2: Twin 20 ML CALs treating wastewater from a mixed species Australian meat processing facility

CALs are a variant of anaerobic pond technology in which the surface of the pond is covered with a synthetic geomembrane which traps the biogas for collection and use (refer to Image 2). The first CALs were installed in Australian red meat processing plants in the mid-1990s, for example at the Australia Meat Holdings Aberdeen facility and a trial CAL at Southern Meats Goulburn. Significant difficulties usually associated with crusts building up under the cover led to only a gradual implementation of this technology.

The introduction of the carbon pricing mechanism in 2012 provided an economic driver for the adoption of CALs since they provide a cost-effective means for emissions abatement relative to other GHG abatement technologies. They offer other benefits including:
Negligible offensive odour
Potential to use the energy-rich biogas for boiler fuel and/or cogeneration to offset purchases of external forms of energy
Improved visual amenity compared to natural ponds
As of late 2016 there were approximately 30 CAL installations in Australian red meat processing plants and/or rendering facilities totalling 450 ML of treatment volume. Of this, eleven installations comprising the majority of the volume (350 ML) were commissioned since 2010.

2.1.3 Vessel-based anaerobic reactors

High rate anaerobic reactors (digesters) have been popular for the treatment of highly soluble, biodegradable industrial wastewater since the 1980s. However, the high suspended solids and oil and grease content of meat processing wastewater and its particulate nature has meant that most of these high rate anaerobic reactor systems have typically performed poorly where applied to meat processing facilities.

A low rate type of in-vessel anaerobic reactor that can be adapted to meat processing sites is based on the Anaerobic Contact (AC) system. They are essentially an anaerobic form of an activated sludge process in which the wastewater is fed into a mixed reaction tank where high concentrations of microbial sludge are maintained by the recirculation of settled sludge from the downstream clarifier. This permits high levels of activity. The AC-treated wastewater flows out of the tank into a degassing chamber, which is needed to remove the high levels of dissolved biogas in the water. From the degassing chamber the mixture enters a typical clarifier where the bacterial sludge is settled out. Most is returned to the upstream reaction tank to maintain high bacterial levels. Excess sludge is wasted in a similar manner to activated sludge plants.

The organic loading rate remains relatively low (< 2 kg COD/m^3.d) despite the high bacterial levels since hydrolysis of particulate COD remains the rate limiting step. As a result, the tank size required is large and generally not cost competitive with CALs for larger meat plants. The advantage of this system is the mixing of the reaction tank allows good contact between bacteria and COD and minimises problems caused by accumulating scum, although this remained a challenge with this technology and resulted in many installations abandoning it in the UK. The design and operation of a large full scale AC plant in the US is described by Stebor at al. (1990).

Nevertheless, there are few examples of successful low rate vessel reactor systems in Australia. One example is the 3 ML reactor at BDC, Bunbury WA. Newer higher rate technologies are emerging such as the anaerobic membrane bioreactor (AnMBR) and Anaerobic Flotation Reactor, but remain unproven at full-scale in the industry.

2.2 Description of typical CAL in the meat industry

2.2.1 Components of a covered anaerobic Lagoon

Figure 1 shows a typical CAL in the meat industry.

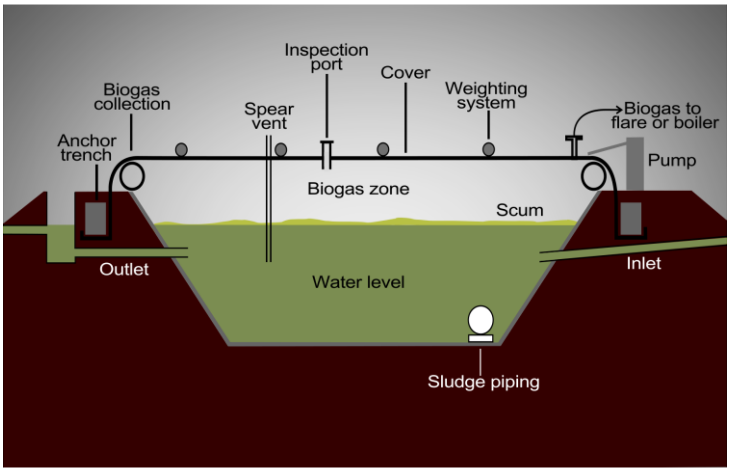

Figure 1: Schematic of typical covered anaerobic lagoon

Most Australian meat industry CALs have been constructed to operate at low positive pressures under the cover. This allows biogas accumulation under the cover during normal operation resulting in its inflation above the water level. The widely-reported CAL at Oakey Meat Processing Plant is a negative pressure CAL which is designed to operate at slight negative pressure under the cover with little or no inflation under normal operation. The benefits and challenges of each type need to be understood and affects the design of some components.

The CAL typically consists of the following components:

- **Impermeable liner**
  CALs typically have a high-density polyethylene (HDPE) membrane overlain on a geotextile to prevent wastewater leakage into the subsoil. The liners are usually fixed into place with an anchor trench using the weight of earth or concrete fill to prevent movement.
- **Cover**
  Typically, HDPE is used for the construction of the CAL cover, although a variety of other plastic materials have also been used (MLA, 2009). The cover is fixed in place by a variety of methods depending on the fabricator. An anchor trench approach is the most common rather than attachment of the cover to a concrete ring beam.

- **Wastewater inlet and outlet pipes**
  The pipework is designed to allow the wastewater to enter and leave below the pond surface. The inlet pipework is designed to prevent short circuiting through the pond volume. The outlet pipework minimises floating solids carry-over.
- **Biogas collection and discharge**
  For CALs operating under positive pressure a ring main around the lagoon perimeter and under the cover is often used to collect the biogas, although alternate concepts are used. A single discharge point in the ring main is common. This discharge exits the CAL either through the cover or liner. For negative pressure CALs, the biogas collection may need assistance by floats which support parts of the cover off the water to provide channels by which the biogas can access the biogas main.
- **Biogas release valves**
  It is imperative that the CAL has biogas safety release mechanisms for instances where biogas is unable to exit through the conventional biogas take-off point. Examples include blockages or prolonged flare shutdown. A variety of safety release designs have been used. These range from simple pipe spears which lift out of the liquid as the cover expands, to more sophisticated mechanisms using water seals, or weighted flaps. Safety valves generally operate to allow biogas to escape to atmosphere when a preset pressure under the cover is exceeded.
- **Inspection ports**
  Inspection ports allow access to the pond for visual inspection and instrument access during CAL operation.
- **Weighting and stormwater removal system**
  These two systems work together to minimize stress to the pond cover. The weighting system performs two functions; it firstly minimizes wind forces on the cover by reducing the height of cover elevation exposed to the wind and secondly provides low spots for water accumulation. The stormwater removal system pumps the water away from where it accumulates. Excessive amounts of accumulated stormwater may displace large amounts of CAL treatment volume and may block pipes or biogas flow under the cover.
- **Sludge removal**
  Sludge removal systems may be installed to periodically remove accumulated sludge.

2.2.2 Components of a biogas capture system

The role of the biogas capture system is two-fold:

1. To capture and incinerate all biogas generated by the CAL to ensure the methane content of the biogas is converted by burning into carbon dioxide. Methane has a global warming potential of 21 times carbon dioxide. Consequently, incinerating the biogas largely eliminates Scope 1 emissions from the CAL (especially since the carbon dioxide produced counts as a zero emission).
2. To ensure that all gaseous compounds with an offensive odour (H_2S especially) are oxidised to odourless components.

The incineration of biogas can be accomplished several ways, but the most common methods in the Australian red meat processing industry are:

- **Flaring**
  In which case the useful energy of the biogas is lost
- **Burning in a boiler**
  This method recovers the thermal energy of the biogas while simultaneously accomplishing the roles above. Emission abatement is increased in this method by the displacement of fossil fuels to equivalent energy content.
- **Burning in a cogeneration engine**
  In this mode, biogas energy is converted into electrical energy (at about 35 – 40% efficiency). Significant heat recovery is also possible by use of heat exchangers to recover thermal energy either from the exhaust gases, or water jacket cooling or both. However, many meat processing plants are already hot water rich.

Figure 2 illustrates a typical biogas train.

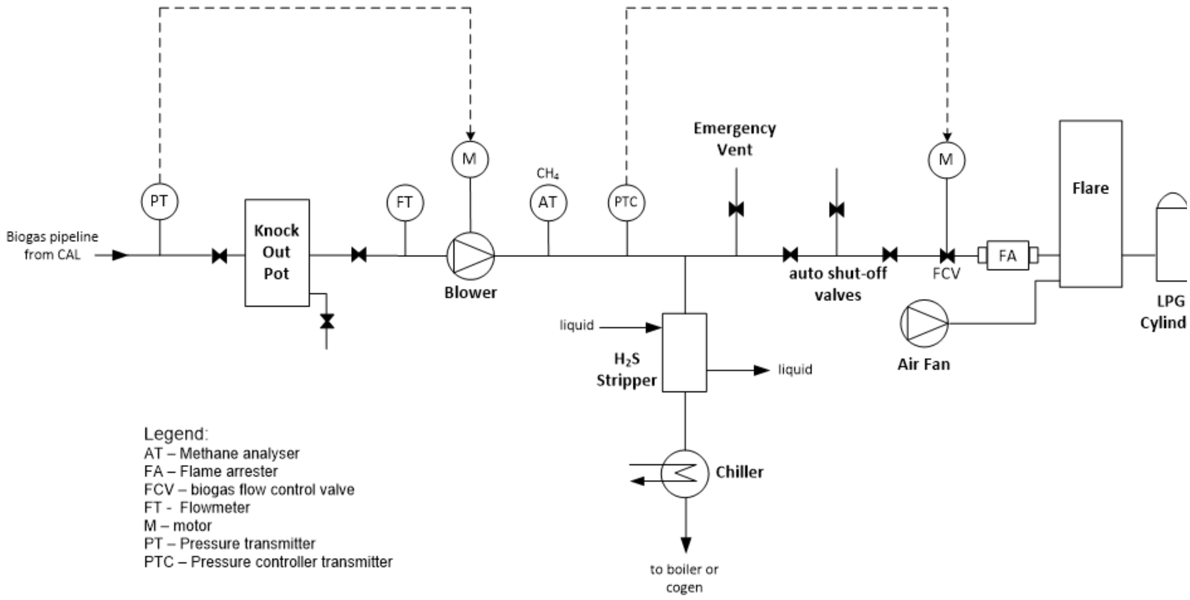

Figure 2: Schematic of typical biogas train and flare system

A typical biogas train usually contains the following elements:

- **Biogas pipeline**
  This conveys biogas from the CAL cover to the flare.
- **Knockout pot**
  This is generally a stainless-steel vessel situated at the lowest point of the biogas pipeline to collect water condensing from the water-saturated biogas as it cools. The water can be safely drained at this point. This protects the downstream blower and instruments from damage.
- **Gas blower**
  The blower provides positive pressure to convey biogas to the flare for incineration.
- **Measuring devices**
  Typically, these include a biogas flowmeter (FT) and methane analyser (AT) with output logged to the facility SCADA system.
- **Flow control valve (FCV)**
  A PLC system typically controls biogas flow to the flare through the automated flow control valve. In many cases, the valve is controlled according to the pressure under the CAL cover permitting the flare to operate at a number of biogas flow settings. Alternately, the blower operation can be modulated.
- **Slam shut valve**
  A fast-acting safety valve system which shuts off the biogas supply in the event the flare is not functioning or loses flame. The number of valves is set by Australian Standard based on energy flow. Meat industry systems typically use two valves for the larger installations.
- **Flame arrestor (FA)**
  This safety device prevents a flame front running back through the biogas supply line.
- **Flare**
  The flare is a device which incinerates the biogas safely. There are two main types of flare available. Regulatory agencies may dictate the selection and should be consulted prior to purchase.

    - Fully enclosed - This flare type controls the air supply to the biogas burner to ensure a hot flame for maximum odour and methane destruction. The flare is completely enclosed in a refractory shield.
    - Candlestick - This flare is a simple Bunsen-burner type flare consisting of a vertical biogas tube with burner on top. The air supply is unlimited. This type of flare may have a metal shroud around the burner to prevent wind extinguishing the flame (which otherwise requires constant re-priming of the flare). This flare is less sensitive to biogas supply, but usually generates a cooler flame associated with less complete odour and methane destruction.

- **Priming system**
  The priming system which usually consists of a LPG cylinder to feed the flare priming system in case of the need for flare re-ignition.

Where the biogas is used for cogeneration in a biogas engine, or diverted for boiler fuel, the flare exists as a contingency element of the system only.

2.2.3 Biogas storage

Biogas storage is necessary to hold biogas generated over the weekend for use during production times. This requirement is met in different ways depending on the type of CAL.

1. Storage under the CAL Cover (see Image 3). Positive pressure CALs can store significant quantities of biogas under the cover due to their large footprint and (usually) large freeboard. A typical meat industry CAL may hold 5,000 m^3 of biogas between the CAL water level and the top of the CAL wall, which is of the order of a day's production for a medium-large meat processing plant. The downside of this is that the CAL cover is mechanically worked harder than a negative pressure cover due to the frequent changes in cover inflation and its exposure to wind impacts. There have been no reports of problems in Australian CALs with cover deterioration to date.

2. Separate gas storage (see Image 4). Negative pressure CALs must transfer biogas to a separate storage vessel to mitigate the mismatch between production and demand. This imposes additional capital and operating costs to the installation. The upside is that cover life may be enhanced.

Image 3: Inflated CAL, Teys, Beenleigh

Image 4: 'Golf bubble', NB Foods, Oakey

2.2.4 Biogas conditioning

Biogas sent to a purpose-built biogas flare does not require conditioning for combustion. Prior to consumption of the biogas for other uses such as boiler or cogeneration fuel, biogas conditioning is recommended. This typically includes:

- **Stripping of Hydrogen Sulphide**
  Hydrogen Sulphide (H_2S) is corrosive to motors and above a low threshold concentration, reducing the level of this contaminant is commonly required. The methods vary, but at the high biogas flows typical from meat industry CALs, some sort of stripping tower is used.
- **Dehumidification**
  The biogas is saturated with water which is undesirable for boiler and cogeneration engines. It is common to chill the biogas to remove the excess moisture by condensation.

More detail is found in Section 3.4.

3 BIOGAS AND BIOGAS UTILISATION

3.1 Biogas properties

Biogas comprises largely of methane and carbon dioxide, the products of anaerobic digestion of organic material, and is saturated with water. Typical quantities of water in saturated biogas are 30 – 50 g/m^3 biogas. Small amounts of nitrogen, oxygen and hydrogen sulphide are also commonly present in biogas produced at meat processing facilities. Siloxanes, dust and hydrocarbons may also be present in biogas generated from landfill, but it is rare in biogas generated from meat processing wastewater. Typical biogas compositions are presented in Table 1.

Table 1: Typical biogas composition from meat processing

Compound	Formula	Typical % by dry volume
Methane	CH_4	55 to 75%
Carbon dioxide	CO_2	20 to 45%
Hydrogen sulphide	H_2S	200 to 10,000 ppm

Biogas is generally a colourless, odorous and flammable gas that is lighter than air. Specific biogas properties depend on its composition. The biogas heating value is proportional to the methane percentage with heat values for methane and carbon dioxide being 37.8 MJ/m^3 and 0 MJ/m^3 respectively. For example, the heating value of biogas consisting of 70% methane is 26.5 MJ/m^3.

The auto ignition temperature is high and ranges from 595°C to 750°C depending on the methane percentage and environmental conditions. This makes methane less easy to ignite than, for example, common commercial gases which are propane or butane-rich.

Hydrogen sulphide (H_2S) presence causes odour and toxicity issues with the effects dependent on the concentration. Table 2 shows the symptoms caused by H_2S exposure that increase in severity as the concentration increases. Most measurements of H_2S at Australian beef processing plants suggest relatively low H_2S contamination (less than 2,000 ppm), but this is still sufficiently toxic to seriously affect humans who come in contact with it. Levels as high as 8% v/v have been measured in biogas from an Australian facility (MLA, 2011).

Table 2: Symptoms for humans at increasing H_2S exposure (MSDS, 2011)

H_2S (ppm)	Symptoms
10 - 20	Eye irritation
50 - 100	Eye damage
100 - 150	Paralysis of olfactory nerve (ie loss of sense of smell)
320 - 530	Pulmonary oedema
>800	Lethal dose to 50% of humans after 5 minutes of exposure
>1000	Immediate collapse with loss of breathing even after inhalation of a single breath

Image 5: Biogas Warning Sign

Table 3 lists the key biogas properties, the contributing component and the relevant consequence. The hazardous biogas properties of flammability and toxicity are highlighted on the warning sign at an Australian meat processing plant (refer to Image 5).

When biogas is burnt the carbon, emissions are reduced by approximately 97% and the odour is destroyed. The negative aspects of burning biogas are light pollution from unshrouded candlestick flares and the possibility of low levels of pollutants from incomplete combustion. However, a well-designed enclosed flare allows almost complete combustion with minimal light pollution.

Table 3: Key biogas properties

Compound	Components	Typical % by dry volume
Flammable	Methane	Methane is flammable between 5% and 15% in air. Biogas is a useful fuel source however uncontrolled emissions in the presence of ignition sources must be avoided.
Odorous	Hydrogen sulphide	50% of humans can detect the characteristic 'rotten egg' odour of hydrogen sulphide above 0.0047ppm. Biogas is highly odorous as it generally contains >200ppm H_2S in addition to other unpleasant odour compounds.
Water-saturated	Humid CAL environment	Lowers thermal value of biogas (MJ/m^3) Biogas pipelines prone to condense large quantities of water Increases corrosion in biogas systems
Colourless	Methane and carbon dioxide	There is no visual warning of the presence of biogas.
Lighter than Air	Methane	Methane has a specific density of 0.68 kg/m^3 compared to 1.18 kg/m^3 for dry air at standard temperature (15°C) and pressure (101.325 kPa). The density difference causes most biogas leaks to rapidly dissipate upwards into the atmosphere.
Toxic	Hydrogen sulphide, carbon monoxide & absence of oxygen	At hydrogen sulphide concentration > 1,000ppm (very common in the meat industry) inhalation of a single breath of pure biogas would result in immediate collapse with loss of breathing. Asphyxiation by biogas itself due to the absence of oxygen is a further threat.
High global warming potential	Methane	Methane has 21 times more warming potential than the equivalent mass of carbon dioxide.

3.2 Uses and requirements for different biogas options

There are five main uses worldwide for biogas produced as a result of large scale anaerobic treatment of wastewater or waste solids. This excludes the use of biogas to heat the anaerobic reactor contents, which is generally not required for Australian red meat processing wastewater due to its already optimal temperature. The uses of biogas in the Australian meat processing industry comprise:

1. Flaring
2. Boiler fuel
3. Cogeneration of electricity and hot water

Table 4 summarises the primary requirements in terms of biogas quality and key issues for each of the options.

Table 4: Primary requirements of biogas quality and key issues

Use	Minimum CH_4 content vol%	Maximum H_2S ppm	Moisture removal	Scale dependant	Carbon abatement (tCO_{2-e} / tCH_4 used)	CAPEX	OPEX	Dependence on external market
Flare	30%	NA	minimal	no	20.4[E]	low	low	none
Boiler	30%	1,000[A]	minimal	yes	23.6[F]	med – high	low	none
Cogeneration	60%	200[B]	required	yes	25.2+[G]	high	high	high if export
Gas Grid	87%	≤30 [C]	required	yes	21.0+[F]	high	med-high	high
Vehicle Fuel	96%	5 - 25[D]	required	yes	21.0+[F]	high	med-high	high

A A limit on H_2S levels is advisable to reduce maintenance costs caused by corrosion.
B Most gas engine manufacturers void their warranty if greater than this limit.
C European quality limits as total sulphur, (mg S/nm^3) for feed-in gas.
D European vehicle fuel, 5-25 mg/nm^3. Wellinger & Lindberg (2005).
E Based on global warming potential of methane of 21 CO_{2-e} and 97% carbon abatement achieved by burning.
F Minimum abatement achieved by burning plus the displacement of purchased gas.
G Minimum abatement achieved by burning plus the displacement of purchased electricity.

3.3 Biogas utilisation technologies

The Review of Biogas Cleaning (MLA 2012) recommended the following actions prior to purchasing biogas equipment:

- Biogas quality should be considered at the initial stages of concept development.
- Potential equipment suppliers should be consulted to confirm the biogas quality requirements (e.g. technical reference information).
- Biogas sampling should be undertaken to identify the concentrations of constituents which could potentially have an adverse process and mechanical impacts. This is not always possible – for example for greenfield sites.
- If deemed required, technology options for contaminant removal (viz. water and hydrogen sulphide) should be investigated and assessed considering the specific site preferences and considerations (noting the advantages and disadvantages present).

3.3.1 Flaring

Biogas flares are used to safely incinerate the biogas, reduce carbon emissions and destroy odour. Water removal in a knockout pot is the only form of pre-treatment required prior to flaring. Where the biogas is used for cogeneration in a biogas engine, or diverted for boiler fuel, the flare exists as a contingency element of the system only. There are two main types of flare available:

3.3.1.1 *Fully enclosed*

This flare type (Image 6) controls the air supply to the biogas burner to ensure a hot flame for maximum odour and methane destruction. The flare is completely enclosed in a refractory shield. It usually has a limited turndown.

Image 6: Fully enclosed flare treating CAL biogas

3.3.1.2 *Candlestick flare*

This flare is a simple bunsen-burner type (Image 7) consisting of a vertical biogas pipe with burner on top. The air supply is unlimited. This type of flare may have a metal shroud around the burner to prevent wind extinguishing the flame (which otherwise requires constant re-priming of the flare). This flare is less sensitive to biogas supply, but usually generates a cooler flame associated with less complete odour and methane destruction. While candlestick flares are low cost, their lack of complete combustion of biogas and light pollution problems may cause non-compliance issues where these are stringent.

Flares are the cheapest option for biogas combustion due to their minimal need for biogas conditioning, low operating costs and moderate capital costs while still achieving excellent carbon abatement. However, a fully enclosed flare for a large meat processing facility may cost upwards of $250,000 in Australia.

Safety risks are managed through the purchase of approved (by Australian authorities) flares with relevant safety mechanisms, installation by appropriately certified technicians and through their typically remote, open air location.

Image 7: Candlestick flare at night

3.3.2 Boiler fuel

Using the natural energy of the biogas in onsite boilers adds to the benefit gained by burning of the biogas. The use of biogas for boiler fuel is increasingly widely used in the Australian red meat industry.

The total carbon abatement achieved by burning 1 tonne of methane in a boiler as opposed to releasing it to atmosphere is of the order of 23.6 tonne of $CO_{2\text{-}e}$. Burning the methane contributes to the largest proportion of the carbon abatement with a further 3.2 tonne $CO_{2\text{-}e}$ saved by displacing purchased natural gas. Greater carbon abatement may be possible if the biogas displaces coal which has 72% greater rate of carbon emissions than LPG for the same energy content.

Cost savings achieved by using the biogas to substitute natural gas as boiler fuel are significant, with large Australian meat processing facilities reporting savings of the order of $0.75 – 1.25 million per year. In addition, where the allocation of natural gas pipeline capacity is restricted, the surplus NG freed up through the use of biogas is available for facility expansion. The required conditioning of biogas for boiler feed is generally minimal. The main issue is to avoid corrosion from the elevated H_2S levels in the biogas.

Boiler suppliers generally do not state stringent H_2S limits for the biogas feed to the boiler. The Review of Biogas Cleaning report suggests that levels in the range of 1,500 – 2,000 ppm H_2S generally does not require H_2S removal. This is typically at the usual concentration in biogas from meat processing CALs.

Corrosion can occur in the flue exhaust of boilers, particularly if a boiler economiser is used, as sulphurous acid can form from the reaction of sulphur dioxide and water if the exhaust gas temperature drops below the dew point. Therefore, boiler economisers should be operated to maintain a flue gas temperature greater than 200^{o}C to minimise the risk of corrosion, or if several boilers are available, the biogas may be burnt in the boiler without an economiser.

3.3.3 Co-generation

Biogas energy is transformed into electricity and heat by cogeneration at a small number of Australian meat processing or independent rendering plants. Electricity can be either used for onsite requirements or exported to the electricity grid. It is important to carefully and diligently lock in contracts with electricity suppliers. There has been some difficulty achieving good commercial outcomes and even when accepted the electricity export price is often significantly less than the import tariffs.

Carbon abatement by cogeneration includes that achieved by burning the biogas plus the reduction in electricity demand from use or export of the electricity generated. The Scope 2 emissions would reduce by 4.81 tonne $CO_{2\text{-}e}$ per tonne CH_4 burnt assuming an electrical conversion efficiency of 35%. Further carbon abatement may be possible if the waste heat from the gas engines can be utilized to generate hot water for the facility and replace hot water boiler fuel. In many Australian meat processing plants where high temperature rendering is used, there is already generally sufficient hot water available and no benefit in producing more.

A wide range of technologies exist to convert biogas into electricity and heat including gas engines, microturbines and fuel cells. Currently, gas engines and microturbines are the technology of choice. Fuel cells require extensive biogas conditioning.

The various characteristics and costs of these technologies are presented in Table 5.

Table 5: Comparison of biogas power generation in stationary appliances

Parameter	Biogas Engine	Microturbine
Unit capacity (kWel)	110-3,000	30-300
Plant size	Small to medium	Small
Electrical efficiency (%)	30 - 42	25 - 30
Thermal efficiency (%)	40 - 50	30 - 35
Overall system efficiency (%)	70 - 80	55 - 65
Power/heat ratio production control	Not possible	Very good
Biogas purification requirement	Medium	Medium
Emissions NO_X	High 500-700 mg/Nm^3	Low
Alternative fuel source	Liquid gas	Natural gas, kerosene, fuel oil
Investment cost(€/kWel)	400 – 1,100	600 – 1,200
Operation and maintenance cost (€/kWel)	0.01 – 0.02	0.008 – 0.015

Source: Wellinger et al 2013

All of these technologies require more rigorous biogas conditioning to reduce moisture and H_2S content. Refrigeration successfully removes moisture. Options for H_2S removal are the same as for boiler but generally require a higher degree of control and removal efficiency. Manufacturers will often void the warranty if H_2S concentration exceeds 200 ppm. However most of the engines can be operated without biogas purification if the level of sulphur is low enough (100 ppmv).

In general, as the H_2S concentration in the biogas increases, so do the maintenance costs.

As the electrical efficiency in both cases is low it is important that there is a thermal demand in close proximity to the facility where possible. For red meat processing plants operating high temperature render plants, this is a difficult issue since they generally have sufficient hot water available. Effective use of recovered heat generated by the engine jacket and exhaust gas (for example by recovering hot water for process heat, preheating of boiler feed etc) can enhance the economics of CHP (Wellinger et al 2013).

Biogas co-generation is generally only suitable in medium to large scale meat processing facilities. A certain minimum limit of biogas production would be required to justify the capital and operating expense. However, there is the possibility of third party lease/operate options associated with cogeneration. There are significant safety issues associated with biogas cogeneration, especially where the engines are located in enclosed buildings. These risks can be suitable mitigated by interlock and suitable alarming devices and suitable building construction. These are discussed in the Biogas Guideline for red meat processing plants.

3.3.4 Export gas options

Biogas conditioning and export for vehicle fuel or to the gas grid is currently not adopted within Australia. Larger European biogas producers have entered this market. In this scenario, the biogas is cleaned extensively and scrubbed to remove carbon dioxide (see

Table 4) to achieve methane contents above 85% v/v.

The main advantages of export gas options occur where onsite uses are non-existent (which is rare since for most meat processing plants the biogas derived from wastewater treatment rarely makes up more than a small fraction of total demand). The main disadvantage is the extensive biogas conditioning required to meet the stringent quality requirements and the challenge of negotiating commercial supply contracts with large gas industry players.

For most meat processing facilities, this option is unlikely to be worthwhile

3.4 Biogas cleaning

3.4.1 Contaminants in biogas

Recent excellent reviews of technologies for biogas cleaning and conditioning are provided by MLA (2012) and Wellinger et al, (2013). Specifically, the Review of Biogas Cleaning (MLA 2012) covers potential biogas contaminants in meat processing-derived biogas, their likely impact and optimal conditioning regimes in detail.

Supplier information and literature values have been summarised in Table 6, which provides a summary of the major adverse effects attributed to various components and impurities found in biogas generated from a wide variety of processes.

Table 6: Adverse effect of various biogas components and impurities for different end use options

Biogas component	Flare	Boiler	Reciprocating gas engine	Microturbine
Methane (CH_4)	>50%	>50%	>60%	>55%
Hydrogen sulphide (H_2S)	Not specified	Not specified	<250 ppm	<5,000 ppm
Water (H_2O)	Free water removal	Free water removal	<80% relative humidity	<55% relative humidity
Ammonia (NH_3)	Not specified	Not specified	<25 ppm	<200 ppm
Chlorine (Cl_2)	Not specified	Not specified	<40 ppm	250 ppm
Fluorine (F_2)	Not specified	Not specified	<40 ppm	1,500 ppm
Siloxanes	Not specified	Not specified	<2 ppm	<0.005 ppm
Dust	Not specified	Not specified	50mg/10kWh	20 ppm
Particle size	Not specified	Not specified	<3µm	<10 µm

Fortunately, the main contaminants of concern for biogas generated from meat processing anaerobic systems are only:

- Water
- Hydrogen sulphide
- The other contaminants listed in Table 6 are usually not an issue since they are either not detected in meat processing biogas (e.g. siloxanes), or are found at levels below the threshold of concern. Nevertheless, if the biogas is intended for gas engines or microturbines it is wise to assay the biogas initially to ensure impurities are at satisfactorily low levels since there may be site specific issues in play

The presence of relatively high levels of water and hydrogen sulphide are of most concern and some degree of biogas conditioning is needed when utilising it for higher grade uses. This depends on the process used, as highlighted in Table 7.

Table 7: Typical biogas treatment requirements

Process Equipment	**Hydrogen sulphide (H_2S)**	**Water (H_20)**
Flare	No	Yes – free water removal (e.g. knock-out pot)
Boiler	No	Yes – drying via chiller
Reciprocating gas engine	Yes	Yes – drying (e.g. refrigeration)
Microturbine	No	Yes – drying (e.g. refrigeration)

3.4.2 Impact & removal of water in biogas

Biogas is saturated with H_2O when produced from the anaerobic wastewater treatment process and large amounts of water may condense from the biogas when cooled (for example in the biogas pipeline on cool nights). The presence of water promotes the corrodibility of the biogas components; including H_2S, carbon dioxide (CO_2) and oxygen (O_2).

Biogas flares are generally unaffected. For other equipment, wet biogas is troublesome. For reciprocating gas engines, water condensation in combustion chambers can wash the lubricating oil off cylinder walls, resulting in higher wear and tear. Water can also accumulate at any low sections of pipe causing biogas flow restrictions, if the piping system is not designed with correct falls and condensate removal.

Free water and condensate in the biogas from the anaerobic system is removed initially using a 'knock-out pot' (as shown in Figure 3) with a condensate drain. Additional water removal can be achieved through refrigeration of the biogas using chillers, which cools the biogas to below the dew point temperature, forcing the water to condense. This is typically sufficient for most biogas uses.

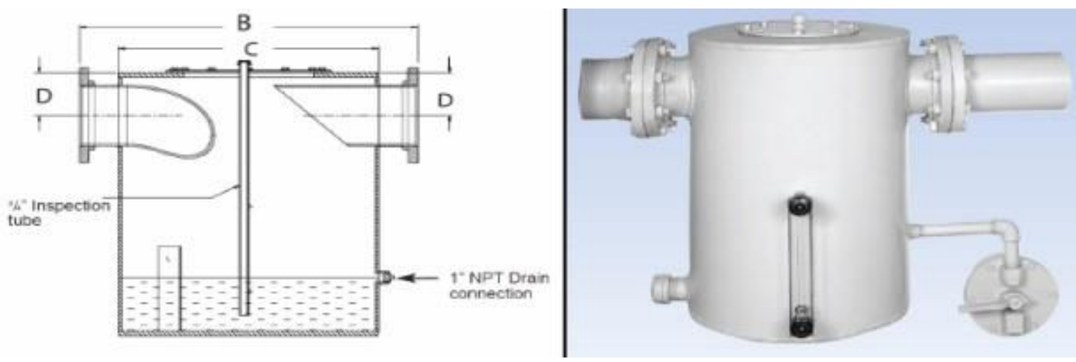

Figure 3: Schematic diagram & picture of a typical knock-out pot (Varec)

3.4.3 H_2S removal technologies

A biogas sampling program undertaken at a number of meat processing plants identified H_2S concentrations between 1,000-1,500 ppm, which is known to cause corrosion of process equipment.

Measurements at a number of sites by Johns Environmental has found similar concentrations, although there have been exceptions with one meat processing CAL reported to produce biogas with H_2S at levels up to 8%v/v.

Sulphur dioxide (SO_2), formed from H_2S during the combustion of biogas, can lead to the production of Sulphurous (H_2SO^3) and Sulphuric (H_2SO_4) acid from the reaction with H_2O when combustion exhaust gases are cooled below the dew point. There have been several occurrences of economisers in boilers being rapidly and severely corroded when the boiler was fed biogas. The lubricating oil of gas reciprocating engines can also become contaminated with Sulphur and require more frequent changing. This can severely increase operating costs for these devices and decrease their service life.

In practice, it appears that:

- No biogas conditioning other than a knock out pot is needed for biogas flares
- Drying of biogas by refrigeration is recommended for use of biogas in boilers. Generally, no biogas conditioning to remove H_2S is required
- For biogas gas engines, both conditioning to reduce water and H_2S is required
- For microturbines, there is little or no Australian experience with this equipment using meat processing biogas

Capital and operating costs for the most common methods used to reduce H_2S concentrations in biogas at various flow rates commonly observed for meat processing plants are presented in Figure 4, with accuracy of estimates around ±30%. These costs are taken from the Review of Biogas cleaning report (MLA, 2012). More detail on the conditioning technologies is found in that report.

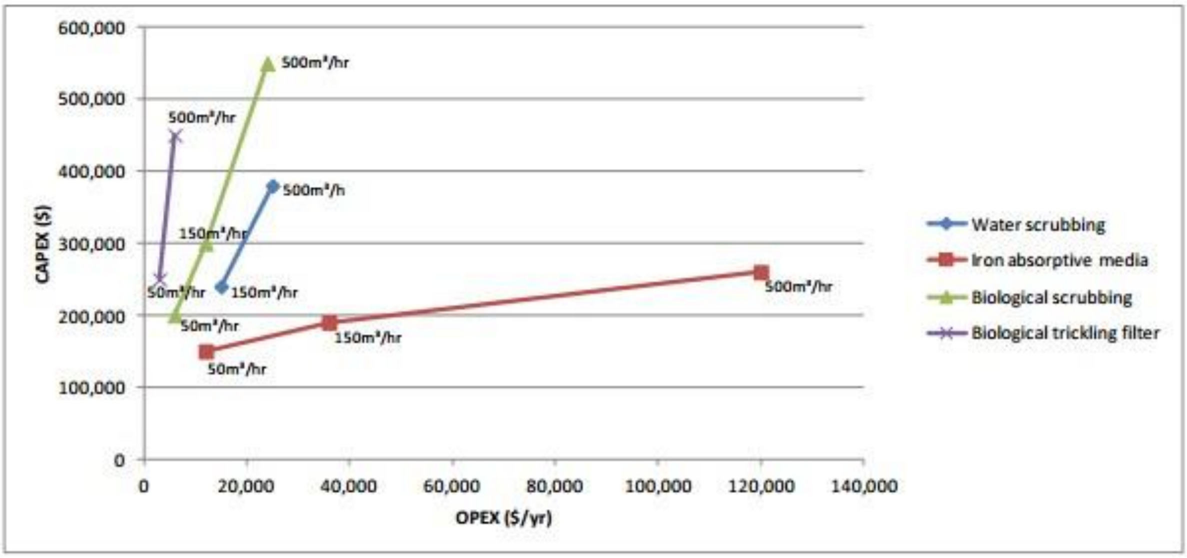

Figure 4: Costs for H_2S reduction processes

From an economic perspective, it is important to assess the cost of repair and replacement of corroded equipment with the cost benefit of conditioning the biogas through removal of hydrogen sulphide. In some instances, with appropriate selection of use, technology and materials of construction, it may be better to accept the higher maintenance bill.

4 BIOGAS REGULATION

4.1 Regulatory approvals for CALs

In addition to the usual requirements for planning approvals often associated with general wastewater plant installations (such as development approvals and environmental licence amendments) which typically vary from State to State, there are specific regulations which apply to biogas and its production, storage, transport and use on a meat processing site.

In Australia, biogas and the certification of biogas equipment (including associated LPG gas bottles) falls under a regulatory framework which varies significantly from State to State. Biogas regulation tends to be viewed through State-idiosyncratic lenses including:

- Dangerous goods regulations, or
- Fuel gas regulations, especially in States with a history of coal mining incidents, or
- WHS regulations with their emphasis on duty of care and ALARP (As low as reasonably practicable) approach to risk management

For people, new to managing biogas risks, this variance in approach and knowing which State authority regulates biogas can be very confusing and makes it challenging to find the appropriate advice. Table 8 summarises the relevant legislation, enforcing authority and relevant direct contact details for each Australian state or territory. It is important to contact these departments directly prior to commencing work to ensure regulations information is current.

It must be noted also that State environmental authorities may impose specific conditions regarding biogas combustion equipment in the plant's environmental licence or permit.

There are various aspects of regulation involved with industrial biogas facilities. These can be sub-divided into three groups:

1. Regulations governing the manufacture and installation of gas equipment including flares, LPG flare pilot ignition systems, boilers and gas-fired cogeneration equipment. These are collectively termed Type B appliances. Typically, the vendor of such equipment will have obtained the necessary approvals and require appropriately trained personnel to install the equipment.
2. Workplace health and safety or more specific, non WHS regulations concerning hazards associated with biogas production, storage, transport and use at a specific site. Typically, these will be the responsibility of the site and will apply during construction and normal operation.
3. Environmental regulations concerning emissions from gas fuel (e.g. biogas) burning. These will be site-specific and may involve exhaust emission quality parameters being applied to the site through the environmental licence.

4.2 Disclaimer

The guideline is provided as an advisory document for meat processing personnel and their supporting services who are considering the design, construction, operation or decommissioning of biogas-producing anaerobic wastewater treatment technologies. The content is not intended to replace the need to adopt good engineering practice principles or to be aware of the changes in regulations subsequent to the date of the Guideline, which may require additional measures to be taken.

Table 8: Relevant regulatory authority for each State

State	Current Regulation	Relevant Authority	
Qld	Petroleum and Gas (Production and Safety) Regulations 2004	Petroleum & Gas Inspectorate, Safety & Health Division, Department of Natural Resources and Mines	Ali Jarrahi Petroleum Gas Senior Inspector (specialising in biogas) (07) 3330 4241 ali.jarrahi@dnrm.qld.gov.au
NSW	Gas Supply (Gas Appliances) Regulation 2012	Department of Fair Trading	Energy and Utilities Unit (02) 9895 0722 gassafety@finance.nsw.gov.au
Vic	Gas safety (gas installation) regulations 2008	Energy Safe Victoria	Iganzio Cannizzo Senior Gas Engineer (03) 9271 5429 Iganzio.cannizzo@energysave.vic.gov.au
Tas	Gas Act 2000 and Gas Safety Regulations 2014	Consumer, Building and Occupational Services, Department of Justice, Tasmania	Andrew Ayton Manager of Gas Safety (03) 6477 7150 andrew.ayton@justice.tas.gov.au
SA	Gas Act 1997	Office of the Technical Regulator, Department State Development, South Australia	Tom Sika Manager Gas Installation and Appliance Safety (08) 8226 5790 tom.sika@sa.gov.au
WA	Gas Standards (Gas Supply and System Safety) Regulations 2000 Gas Standards *(*Gasfitting and Consumer Gas Installations*)* Regulations 1999	Energy Safety, Department of Commerce,	Anthony Smith Principal Engineer for Gas Utilisation (08) 6251 1955 anthony.smith@admirs.wa.gov.au
WA	Dangerous Goods Safety (storage and handling of non-explosive) regulations 2007	Resource Safety Division, Department of Mines and Petroleum	Iain Dainty Principal Dangerous Good Officer 08 9358 8001 dgsb@dmp.wa.gov.au
NT	Dangerous Goods Regulations (Gas and Explosives) Work Health and Safety (National Uniform Legislation) Act	NT Worksafe	Anthony Waite Manager for Major Hazard Facilities/Competent Authority (08) 8999 5037 anthony.waite@nt.gov.au

Care needs to be taken to ensure that the regulatory situation has not changed since the publication of this Guideline.

5 BIOGAS SAFETY GUIDELINES

These safety guidelines offer general advice regarding the siting, design and operating practices associated specifically with CALs. In many cases, individual meat processing facilities have developed site specific safety practices that improve on and may be different or more stringent than those outlined in this Section.

5.1 General siting and exclusion zones

For many facilities, the large size of the CAL and its association with wastewater treatment requires the CAL and associated equipment to be located distant from food processing operations and residents. This section outlines recommendations concerning the positioning of CALs and related equipment on the industrial site.

- Where practicable CALs should be located on the site well away from other major ignition sources (boilers and byproducts facilities with hot surfaces), traffic and/or areas where people are working to safeguard infrastructure and personnel against the potential hazards arising from the nature of biogas. A minimum distance of 50 metres is recommended subject to site limitations.
- As much as practicable, ignition sources should be minimised near the CAL and biogas train. These include:
    - Vehicles
    - Electrical equipment
    - Hot work (grinding and cutting operations)
    - Open flames (cigarettes, matches, etc.)
- Where electrical equipment is required (for example stormwater removal, sludge or effluent pumps, motors and controls), it should be sited outside the hazardous areas associated with the CAL. Hazardous areas associated with the CAL must be classified according to the relevant Australian Standard 60079.10.1:2009 (at the time of writing). Electrical equipment situated within the hazardous areas must meet the requirements for the zone identified, or be relocated outside the extent of the zone. In practice, most release sources associated with CALs under normal operation fall into hazardous area Zone 2 category with small zone dimensions relative to the dimensions of the CAL. Control panel enclosures should be rated IP55 minimum.
- An exclusion zone of at least 3 metres is recommended around the CAL and associated inlet and outlet pits so as to prevent public and animal access. Animals, especially kangaroos and dingos have been known to severely damage CAL covers. The exclusion zone should be secured using a security fence. Security mesh is recommended and the fence should be at least 1800 mm in height. Exclusion of children is critical even though most CAL sites are usually remote from residences. All access points should be locked.
- Safety signs should be erected near the main entry point to inform of the hazards and required safety measures within fenced area (refer to
- Image 8). Recommended signage includes:
    - No entry – Authorised personnel only
    - Exclusion of ignition sources (naked flames, smoking, etc)
    - Biogas properties and hazards
    - Deep tanks

- The biogas pipeline must be clearly identified with signage to prevent damage by third parties.
- Tall objects such as light stands, power poles and trees should be positioned at a suitable distance to eliminate the possibility of their falling on the cover during storms or due to the failure of the supporting structure.
- Vegetation should be controlled in the surrounding areas to reduce the fire risk to the cover in the case of bushfire or where a fire event occurs nearby. Where ember attack is a realistic possibility, consideration might be given to fire suppression systems to protect the CAL cover (e.g. sprinkler systems).

Image 8: Suitable safety signs on exclusion zone

5.2 Design for cover protection

The cover is the integral part of the CAL that captures the biogas. It is imperative that the cover is not compromised. Holes in the cover will not only allow loss of biogas to the atmosphere but also create a potentially hazardous environment. The cover design should include features that reduce the likelihood of damage.

- The biogas collection system under the cover is employed to capture the biogas and transfer it to the biogas train. Meat processing CALs have a propensity to accumulate scum under the cover despite best practice pre-treatment. Biogas collection piping should be at least 500 mm above the maximum operating water level so that the risk of scum, foam or mousse entering the collection system is minimised. Gassy mousse resulting from incomplete breakdown of incoming organic load is particularly mobile and troublesome and can frequently occur during startup of CAL systems.
- Overpressure release systems prevent cover over-inflation in the event that biogas cannot be withdrawn via the biogas train for any reason. Cover over-inflation may lead to it tearing from its fixings, or become subject to excessive wind forces. It is recommended to provide an overpressure release mechanism. Several options have been used in Australia including:
    - Safety spears (Image 9). While these are simple, they are vulnerable to blockage by scum under the cover which may nullify their effectiveness and imposes additional stress on the cover. They are best placed well within the cover perimeter to avoid biogas release at angles near horizontal to the ground.
    - Hydrostatic release valves (Image 10) use a depth of liquid, typically water, to prevent biogas release below a set pressure. For most applications, 100 mm water head is sufficient to maintain less than 100 Pa.g pressure under the cover. The advantages of this device are simplicity, it is unlikely to be compromised by scums and gas release occurs remote from the CAL. The disadvantage is the requirement for constant topping up of the liquid and the small margin of error (especially on hot summer days), which can lead to excessive biogas release.

Image 9: Safety spears.

Image 10: Hydrostatic release valves

- Weighted or mechanically operated flaps (Image 11) release can be used instead of spears to avoid penetration below the cover. They are best placed well within the cover perimeter to avoid biogas release at angles near horizontal to the ground.

Image 11: Weighted operated flap, Kilcoy Pastoral Company, Kilcoy

- Cover seam welds should use split head wedge and/or extrusion welding techniques to join HDPE sheets to permit non-destructive weld testing to ensure gas tightness during construction.
- Penetrations through either the CAL liner or cover should be reinforced to minimise the risk of tearing. This is particularly true of penetrations such as inlets, outlets and safety spears where the protruding element under the cover may become bound into undercover scum and crust leading to excessive stress on the supporting welds due to differential movement of the cover and crust.
- Stormwater removal systems (Image 12) should be designed to remove large volumes of accumulated stormwater on the cover surface, which can potentially strain cover fixings and stretch the cover. In some instances excess stormwater can depress the cover to block inlets, outlets or access of biogas to the undercover biogas collection system.

Image 12: Typical stormwater removal system.

- It is recommended to avoid installing electrical items on covers such as stormwater pumps unless fitted with temperature cut-outs.
- Partitions fixed to the underside of the cover (such as hanging curtains or baffles) are not advised. These have a tendency over time to fold and lift up under the cover where they may block access by biogas to overpressure devices or the collection system.
- A hazardous area analysis consistent with AS/NZ 60079.10.1:2009 Explosive atmospheres – Classification of areas is recommended to assess the extent of suitable zones of separation of potential biogas release points from identified hazards. Where possible and appropriate, larger exclusion distances should be provided for potential ignition sources to minimise the possibility of flash fires in the event of major releases from covers.

5.3 Biogas train design

The biogas train includes biogas piping, blower, instrumentation, gas conditioning equipment and all biogas combustion units as shown in Figure 2.

Biogas pressures are typically low for meat processing industry CALs. Biogas pressure upstream of the blower and under the CAL cover is usually less than 0.1 kPa. In some cases, it may be under negative pressure for some covers. Upstream of the blower, a typical biogas delivery pressure to the flare using centrifugal blowers is still low at less than 5 kPa. Higher pressures may be used for delivery to gas boilers and cogeneration gensets.

A hazardous area analysis is recommended for the biogas pipeline to the point of connection with the biogas flare and skid as per item 8 of Section 5.2. Where the biogas train and flare is a Type B device with a certificate of compliance, the flare vendor will have generally conducted their own assessment.

5.3.1 Biogas system: CAL to blower

1. A manual isolation valve is recommended in the biogas pipeline adjacent to the CAL to permit isolation of the biogas train from the CAL.
2. In laying out pipe runs and equipment, due recognition should be given to potential gas releases and ignition that could lead to damage by flame on nearby objects. Typical lateral impact distances due to thermal radiation from a small jet fire (ignition of biogas leak from pipeline) are small (of the order of 3 metres or less).
3. Consideration should be given in design to isolation strategies, particularly where long biogas pipe runs are planned.
4. Consideration should be given to fire escalation if flames cause grass fires and these propagate. Open areas should have hazards minimized to reduce escalation.
5. Stainless steel pipeline (Image 13) construction is recommended for above ground biogas piping as it has good corrosion resistance and fire protection properties. Australian Standard AS 4645.2:2008 Steel pipe systems provides guidance for design and construction of gas piping systems, although in the context of higher gas pressures (up to 1,050 MAOP).

Image 13: Above ground stainless steel biogas pipe

6. PVC and HDPE may be considered for biogas piping, but generally it is required to be underground as protection against fire risk (from external fires). Australian Standard AS 4645.3:2008 Gas Distribution Network: Plastics pipe systems provides guidance for design and construction of gas piping systems, although in the context of higher gas pressures (up to 700 kPa).
7. With plastic piping care is needed regarding the impact of high biogas temperatures. Under Australian conditions, biogas temperatures may be higher than the permitted temperature

tolerance. For most HDPE pipes the operating temperature tolerance is up to 65°C, but AS 4645.3:2008 limits PE80B and PE100 pipes to operating temperatures of less than 40°C. Any biogas recirculation system must take into account heat added through the recirculation blower. Table 9 provides a comparison of features between HDPE and Stainless Steel pipework.

8. When working with plastic piping, there is a need to beware of static electricity discharges especially when working on the pipeline. Ensure good earthing practice (see AS 5601.1-2010).

Table 9: Comparison of HDPE and stainless steel for biogas piping

Consideration	HDPE	Stainless Steel
Cost	Cheaper	
Maximum operating temp (°C)	65°C. Some grades lower.	Not an issue
Corrosion resistance	Excellent	Excellent
Insulation properties	Excellent	Poor – increases biogas condensation in pipeline
Fire vulnerability	High. Some States prohibit above ground use.	Low
Field fabrication	Straightforward	Difficult

9. Consideration must be given to handling significant amounts of condensate drainage in the pipeline due to the high degree of humidification of the biogas, which is often at elevated temperature under the cover. Condensate volume may increase substantially during periods of flare outage due to biogas cooling in above ground stainless steel piping. The pipe should grade back to the CAL or a knock out pot at a constant minimum slope of 2% to prevent accumulation.

10. A suitably designed knockout pot (Image 14) must be installed at low points in the biogas pipeline to remove condensate and to ensure hazards such as mousse (due to CAL biological dysfunction) or scum captured by the biogas collection system under the cover does not enter the blower. These units must be manufactured from non-combustible material.

Image 14: Knockout pot in biogas train

5.3.2 Biogas system: Blower to the flare

1. The biogas system downstream of the blower should be designed and installed in accordance with AS 3814-2009 (industrial & commercial gas-fired appliances) and must comply with the safety requirements of AS 1375-1985 (SAA Industrial fuel-fired appliances code). The mechanical installation must be certified by a licensed gas fitter.

2. Aspects of the design of this part of the biogas system depend in the relevant Australian Standards on the anticipated biogas fuel load – for example for the nature of the safety shut off valves. For

lighter-than-air (biogas) gas rates, large meat processing plants and independent renderers treating a high proportion (>80%) of their raw wastewater through CALs, the biogas rate can be expected to fall into the range 5 – 20 GJ/h. Smaller meat processing plants will typically be less than 5 GJ/hour.

3. Biogas combustion units, such as flares, boilers and cogeneration units, are classified as a Type B appliance. The design of the flare-burner management system is required to comply with AS 3814-2009 (industrial & commercial gas-fired appliances). Imported flares must obtain Australian approval for use.

4. Electrical services at the biogas train to comply with AS 3000 Electrical installations and be certified by a registered electrician. Electrical equipment should be either located outside any hazardous area (e.g. Zones 1 or 2), or be compatible with operation in the designated hazardous zone.

5. Stainless steel pipeline construction is recommended for biogas piping downstream of the blower.

6. All components of the biogas system especially safety shut off valves, blowers, meters and burner management system items should be rated for operation with moist biogas, hydrogen sulphide, ammonia and other components likely to be present unless downstream of biogas conditioning equipment.

7. Monitoring of biogas methane content and flow is recommended. Typical methane levels for biogas generated by meat processing CALs are 65 – 75% v/v. Independent render plants may generate biogas of lower quality (usually 60 – 65% v/v). Biogas with methane content less than 20%v/v is non-flammable. The biogas blower should be designed to alarm at 30% v/v and trip at 25% v/v to prevent flare flame-out.

8. The following components must be supplied in the flare system:

    - An appropriate flame arrestor must be provided at the flare inlet and between points of use (gas engines, boilers, etc) and the blower
    - A suitable safety shut off system for the biogas appropriate to the expected biogas rate
    - Interlocking of methane content to trip the biogas flare if methane content falls too low (see 7 above)
    - Automatic ignition system
    - A blower management system which avoids drawing a negative pressure on the CAL cover (which risks drawing in oxygen into the biogas). Where a single blower operates more than one CAL, care is needed to ensure the management system maintains positive pressure under all covers.

9. The biogas flare should be installed to handle the entire design flow of biogas anticipated from the CALs to ensure that it is safely incinerated in the event of problems disrupting its use in boiler or genset systems. This avoids the necessity to hold excessive biogas volumes under the CAL cover and/or vent large volumes through over-pressure devices.

10. Care should be taken siting the biogas flare relative to the CAL. The biogas flare must be sited at separation distances from release sources that comply with AS/NZ 60079.10.1:2009 Explosive atmospheres – Classification of areas. For general flare location, a minimum distance of 6 metres from the CAL is generally recommended. Special consideration is required where the CAL is built with a significant height above natural ground level, to prevent the heat plume from the flare affecting the cover in wind conditions which might push the plume towards the CAL.

11. It is preferred to site blowers and compressors in open environments to minimise risk of biogas accumulation. Where these items are in an enclosed room, electrical equipment should at minimum be suitable for operation in a Zone 2 (gases) area. The room should be equipped with a methane gas detection system designed to alarm at 20% LEL and a suitable device to alarm at an appropriate level for H_2S per local regulations. Automatic shutdown of equipment should occur at 40% LEL. See Section 5.5 for more recommendations for enclosures.

5.3.3 Biogas system: Genset buildings

The use of biogas for generation of electricity on-site has led to the installation of generator sets, usually installed in enclosed structures for the purpose of noise control and security reasons. This poses a unique risk of explosion of released gas within the enclosure, and amplification of blast pressure in comparison to open structures.

1. Consideration should be given to the appropriate siting of gen-set facilities, both for on-site impacts and for off-site impacts in the event of an explosion.
2. If practicable, where noise control and other factors permit, at least 2 sides of any genset enclosure should be open to allow dispersion of any gas releases. This will minimize any explosive effects and would generate a low-pressure flash fire rather than an explosion.
3. Strict controls on ignition sources and personnel access within any enclosure is essential, as is the reliability of ventilation systems.
4. The use of ventilation systems, interlocks and gas detection are critical to ensure that initial biogas release events cannot propagate to an explosive situation.
5. Ventilation systems must be designed such that they effectively disperse any gas releases. It is likely that any ventilation system will not be able to handle a large, instantaneous release of gas. Using simple enclosed volume turn-overs can deal with fugitive emissions but would not be truly effective on acute events such as a line rupture.
6. See Section 5.5 for more recommendations for enclosed buildings.

5.4 Operation

The risk associated with biogas hazards is reduced by safe operating practices, which can be formulated in the Safety Management Plan for the facility (See Section 5.9).

5.4.1 General safe operating practices: Infrastructure protection

The following safe operating practices are recommended to protect the infrastructure associated with the CAL from damage:

1. Cover inflation. Covers should not be inflated more than 2 metres above top of wall (TOW) during normal operation. Excessive inflation increases the risk of damage and/or hazardous biogas releases. Inflation of more than 2 metres above TOW should be regarded as abnormal operation and risks significant cover stress in moderate wind conditions, weighting pipe dislocation and may increase the severity of any biogas release in the event of damage. This was a contributing cause to the Rivalea incident in 2011. If significant storage of biogas is desired (for example to carry biogas over a weekend), purpose built gas storage systems are available and are a safer option.
2. Operating a CAL under vacuum (negative pressure) should be avoided unless specifically designed to do so. Negative pressures under the cover risk oxygen and nitrogen ingress.

3. Regular inspection of the overpressure relief system for blockages and other issues. The regularity should reflect the likelihood of problems occurring. For example, where pre-treatment of effluent is rudimentary and/or scum is observed accumulating under the cover, the inspection should be at least weekly.

4. Regular inspection of the CAL cover, the anchor perimeter and the biogas line should be conducted at least weekly to check for:

    - biogas leaks
    - physical damage to the cover (for example animal damage, tears around spears or stormwater removal sumps, etc) or piping
    - excessive foam or crust in outlet weirs
    - structural deterioration of the cover
    - excessive stormwater sitting on the cover
    - unusual movement or dislocation of weighting pipes or system.

Any damage must be reported to the appropriate company official immediately to ensure the problems are rectified promptly.

5. Accumulated stormwater should be removed as quickly as possible to reduce the risk of cover damage and interference with overpressure relief systems, inlets and outlets. This is particularly a concern in areas of very high rainfall intensity (mm/hr), such as Queensland and the Northern Territory.

6. Condensate accumulation in the biogas train should be regularly removed, preferably by automatic devices, to prevent blockages and corrosion.

7. Sharp or heavy objects on the cover should be avoided to minimise the risk of accidental rupture or holing of the cover.

8. Human traffic on the cover should be minimised. Double thickness walkways, preferably using textured HDPE or similar material, can be helpful to permit access to critical areas.

9. Vehicular traffic in the area should be minimised and the speed strictly controlled to avoid loss of the vehicle and occupants into the deep tanks and/or damage to the CAL components from collision with the vehicle (for example the vehicle hitting the biogas piping).

10. During total fire ban days it is recommended not to operate the flare except when the flare is a totally enclosed type.

5.4.2 General safe operating practices: Working on the CAL cover

From time to time, personnel need to access the floating CAL cover for maintenance or monitoring reasons. While the likelihood of cover failure (e.g. splitting) is very low, the severity associated with a person falling through the cover is high. For this reason, access onto the cover should be minimised and any access treated with due care. An appropriate hazard analysis is recommended prior to entry. Most sites have their own safety requirements in this regard.

The following list of safe operating practices is recommended as a minimum to protect personnel working on the cover and reduce the risk to human health and safety. They can be organised as Work Instructions as required. This list is not intended to remove the need for a facility to perform its own safety analysis.

1. Access to the CAL and biogas train area must be limited to authorized persons only.
2. Authorised persons must be trained to understand the potential hazards existing in, on and near the CAL and associated infrastructure, the correct procedures to adopt when working on the CAL cover and the appropriate procedures in the event of an emergency.
3. Footwear and clothing must not contain sharp components that might damage the cover.
4. Access to the cover should only proceed after careful inspection of the cover to ensure that it is structurally sound and contains no areas of deep water on the cover (since the water may flow rapidly towards persons on the cover as they depress the cover).
5. Access to the cover should be avoided when inflation is substantial (for example more than 2 metres above TOW).
6. Any equipment carried on to the cover must not be excessively heavy or possess surfaces, protrusions or edges likely to damage the cover.
7. Heavy equipment or packages should not be dropped from standing height on to the cover surface since the impact may damage the plastic.
8. A personal gas detector capable of detecting methane and H_2S should be worn by personnel working on the cover of a CAL.
9. The possession of mobile phones, laptops and other electronic equipment on the cover must be carefully considered for its potential as an ignition source.
10. Opening a sample/inspection port on the cover should only be performed when the surrounding cover area is at the water level to avoid excessive biogas release. If the cover is inflated above water level near the port, the biogas train should be activated to reduce the biogas inflation before opening the port (this may require several hours).
11. A spotter located off the cover and equipped with communication equipment to contact emergency contacts should be present when persons are working on the cover.
12. Care should be taken near wet areas to avoid slippage injury.
13. Care should be taken to avoid heat stress if working on the cover for long periods of time. In Australian conditions, the cover temperature can be very hot and radiate a substantial heat load to the person.
14. It is essential that any 'Hot' work carried out on the CAL cover be strictly controlled and consideration given to the likelihood of ignition of biogas releases.

Note that some companies have elected to ban work on covers.

5.4.3 General safe operating practices: Working near the CAL

Under normal operation, biogas concentrations beyond the edge of the CAL cover are likely to be negligible since the system is tightly sealed. Extensive experience with open surface anaerobic ponds used by the industry for decades has found them relatively safe even with vehicular traffic on the pond walls.

Nevertheless, the confinement of the biogas under the cover and in biogas piping means that there is the possibility of local release in the event of a problem. The following safe operating practises will reduce the risk to human health and safety for personnel working near the CAL. They can be organised as Work Instructions as required. This list is not intended to remove the need for a facility to perform its own safety analysis.

1. Access to the CAL and biogas train area must be limited to authorized persons only.
2. Authorised persons should be trained to understand the potential hazards existing in the CAL and associated infrastructure, the correct procedures to adopt when working in the CAL zone and the appropriate procedures in the event of an emergency.
3. A personal gas detector capable of detecting methane and H_2S should be worn by personnel working near a CAL.
4. The possession of mobile phones, laptops and other electronic equipment near the CAL must be carefully considered for its potential as an ignition source.
5. Inlet and outlet pits must be designated a confined space and covered to prevent unauthorised access. Appropriate safety precautions must be implemented prior to access.
6. Opening any valve or piping accessing the contents of the CAL must be performed with extreme caution. These may include:
    - Emergency biogas venting mechanisms
    - Sludge removal piping valves
    - Biogas condensate drain valves

There is a significant risk of the rapid release of biogas in these situations with the release potentially rising towards the head of the person working the release mechanism. Under these circumstances, there is a heightened risk of asphyxiation and injury.

7. It is essential that any 'Hot' work carried out near CALs be strictly controlled and consideration given to the likelihood of ignition of biogas releases.

5.5 Unodourised biogas risks

Biogas produced from anaerobic breakdown of meat processing wastewater is typically offensively odorous since the bacteria are degrading Sulphur-containing meat proteins. Hydrogen sulphide levels are typically between 200 – 2,000 ppm and sometimes higher. The lowest level measured to date in meat processing biogas has been 70 ppm.

It is a legal requirement to odorise gases supplied to users so that gas releases (leaks) are immediately detectable. The requirements of the odorant under the Gas Safety (Gas Quality) Regulations are that the odorised gas must:

- have an odour which is distinctive and unpleasant, and
- have an odour level that is discernible at one-fifth of the LEL of the gas.

Typically, an odorant mixture comprising for example tetrahydrothiophene (commonly 'thiolane') and tert-butyl mercaptan is added to the gas at level between 7 – 14 ppm. In Queensland the Petroleum & Gas Regulation 2004 prescribes the addition of ethyl mercaptan at 25 g/tonne of liquid LPG. These odorants typically have an odour threshold of less than 1 ppb with a recognition threshold of about 1 ppb.

Hydrogen sulphide has very similar human odour recognition thresholds to these commonly used odorants with a recognition threshold of 4.7 (ISU (2004). It meets both requirements of an odorant as described by the Gas Safety Regulations. Consequently, the detection of biogas releases by humans is as certain as if typical odorants had been added.

Where biogas is to be used rather than simply flared, the relevant State regulations should be checked in regard to any need for odourisation. Since H_2S is not a recognised odorant, and is not added to the biogas, State authorities will consider biogas 'unodorised'.

In most cases, the use of unodourised biogas within an enclosure on the industrial site is permissible subject to State guidelines. For example in Queensland, these include:

1. The enclosure containing the equipment must be protected by interlocked forced ventilation and equipment shutdown systems which are adequately designed, installed, commissioned and operational prior to initiation of the unodourised biogas feed to the equipment. Ventilation must comply with AS 5601:2010 Sections 5:13 and 6.4.
2. Gas detection and shutdown systems must be adequately designed, installed, commissioned and operational prior to initiation of the unodourised biogas feed to the equipment.
3. Gas alarm must be activated at any level exceeding 20% of the LEL level (~1%v/v methane). Automatic equipment shutdown and evacuation procedures must be initiated at 40% LEL.
4. Induction and orientation of relevant staff shall ensure they are fully cognisant of the dangers of unodourised gas.
5. Safety warning signs must be placed at appropriate locations on site, including on pipe work, to warn of the possible presence of unodourised gas.
6. Written procedures for commissioning, maintenance and ongoing operation of the gas supply system must reflect the unodourised nature of the gas and be made available to the relevant staff.
7. The installer, commissioner and/or maintenance personnel shall have suitable equipment and the necessary training to ensure safety in dealing with the unodourised nature of the gas during the construction, commissioning, operational and maintenance phase of the project.
8. Maintenance, testing and recording procedures are established to ensure the functional integrity of the gas detection system.
9. A scheduled system and record of manual leak surveys is to be followed, requiring discovered leaks to be repaired immediately and a 'close-out' audit process implemented.

Clearly many of these guidelines can be considered redundant for biogas from meat processing plants since hydrogen sulphide is an equally effective odorant and is always present at levels readily detectable by the human olfactory system at levels of dilution at the 20% LEL.

5.6 Construction phase

The risks from biogas during construction are negligible where:

- the pond is filled with clean water (from clean stormwater, bore or well treated effluent) to enable the fitting of the pond cover
- Other established CALs or anaerobic systems are not present in the vicinity.

Often the quantity of clean water required to fill the pond for cover fitting exceeds supply and wastewater must be used. In this instance, the organic concentration in the water should be minimized to limit anaerobic action and biogas release. Experience has shown that methanogenic activity is slow to occur in the first 3 – 4 weeks, by which time the cover is usually complete.

The biogas train and flare and all cover overpressure devices should be installed within 2 weeks of wastewater being put into a new CAL. This ensures that suitable protection against odour emissions and biogas discharge to the open environment are minimised.

The commissioning of the biogas train and flare may require longer operation of the CAL since it usually requires at least 4 – 6 weeks for sufficient quantities of biogas to be generated.

The initial biogas should be vented since it may contain a high proportion of oxygen and nitrogen due to air trapped under the cover during installation.

5.7 Decommissioning phase

Significant biogas production in an established anaerobic system to which effluent supply has ended will cease rapidly. While significant volumes of biogas are being produced, it will be necessary to continue operating the biogas train to ensure its safe destruction.

After this time, some small quantities of biogas may continue to be produced due to sludge and scum or crust digestion. These quantities should be sufficiently low as to allow their safe dispersion through the overpressure relief systems in the cover.

Access to the area should be limited to only authorised personnel in view of the risks posed by the deep water-filled tank.

5.8 Emergency situations

A risk assessment performed as part of MLA/AMPC industry Project A.ENV.0160 found that the key hazards in regard to biogas are related to biogas releases and possible fires and explosions. The most serious impacts are related to:

1. Large releases of biogas from CALs, for example by a significant rupture of the cover when over-inflated
2. Explosion impacts from enclosed space ignition of biogas in generator set installations.

These are covered below. The impact of biogas releases from small leaks in the cover, or from releases from biogas transmission pipelines between the CAL and flare are considered low due to the low operating pressures in the system.

5.8.1 Large releases from CALs

In a large biogas release, a significant quantity of methane and carbon dioxide escapes the cover as a plume, whose shape depends on many factors including the orientation of the release point in reference to the ground plane and the pressure under the cover.

The most probable releases are likely to be due to:

- over-pressure in the CAL leading to large release via the overpressure protection system
- a significant rupture or tear in the CAL cover

- a significant failure of gas tightness in the cover anchoring system.

The larger the rupture and the higher the pressure under the cover, the larger the release rate will be. Release modelling suggests that large-scale releases in the case of orientations above 20°C above the horizontal are buoyant and disperse rapidly with little impact at the ground level.

In contrast, large gas releases from the cover that are near horizontal in orientation (for example from a puncture in the cover near the cover anchorage point in an over-inflated CAL exhibiting 'whale-back' form) can have significant ground interaction and travel substantial distance at ground level. This form of release poses:

- a suffocation and H_2S toxicity hazard to personnel and animals
- a flash fire risk with sufficient energy to seriously injure or kill personnel nearby.

In the event of a large release with a near horizontal orientation:

1. An immediate exclusion zone of at least 50 metres should be declared around the CAL.
2. All personnel and animals should be evacuated from an area within at least 100 metres of the release point.
3. All potential ignition sources within 50 metres of the release point including vehicles, mobile phones, electronic controls, stormwater removal pumps, biogas flare etc should be deactivated
4. The exclusion zone should be maintained until the gas release has reduced the pressure under the cover to less than 50 Pa.
5. Access to the damaged CAL (once the cover pressure has fallen to less than 50 Pa) should be only by authorised persons equipped with suitable gas monitoring and other personal safety equipment to assess repair.
6. Wastewater flow to the damaged CAL should be minimised until repairs are affected to the extent that this is practicable.

5.8.2 Enclosed space ignition

The impacts of an explosion of biogas in an enclosed building are sufficiently severe to warrant careful attention to ensuring that the risk is mitigated through the use of well-designed ventilation systems, interlocks and gas detection so that the initial biogas release event is unable to propagate to an explosive situation.

5.9 Safety management plan

A site-specific safety management plan (SMP) should be developed covering the risks and management associated with the biogas system. Some States, such as Queensland and WA have prescriptive safety management plan requirements with clear guidelines as to the content of the SMP.

All meat processing plants have formal workplace health & safety management systems in place and as much as practicable, the biogas SMP should be consistent and integrated within this system.

This guideline recommends the following minimum inclusions in a biogas system SMP:

1. A description of the biogas system including plant layout, a process flow diagram, a scaled map indicating distance to nearest receptors and location of critical isolation equipment.

2. The organisational structure and safety appointees and responsibilities. Some States have specific requirements regarding responsibilities pertaining to biogas installations.
3. Operator(s) of the system.
4. A formal safety or risk assessment of the biogas system. This should include hazard identification, assessment of possible risks and associated control measures to eliminate or minimise the risk as low as reasonably practicable. This can be informed by the risk assessment performed as part of this guideline (See Section 4).
5. Documented standard operating and maintenance procedures. All meat processing sites operate formal WHS systems which can be expanded to include the CAL and biogas train. This should include interactions with external contractors who may need to work on or near the system so that all work is performed in a controlled and safe manner.
6. Description of control systems. These should be clearly identified and the personnel responsible trained in their use.
7. Emergency response procedures. These identify the response required for given events, allocate responsibilities and identify equipment, evacuation areas and training required.

Anaerobic wastewater systems and the ancillary biogas train and flare are complex systems coupling a complex microbiological biogas production system with in most cases complex biogas flaring systems. Day to day operation of wastewater treatment plants at many meat processing plants is often a part responsibility allocated to staff positions vulnerable to high turnover.

The effect of human failures can be significant, as key contributors to loss of containment, either at the design phase of the system, or through poor training and poor procedural practice. It is vital that these human factors be expressly considered and managed within a facility to minimize the hazard potential.

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APPENDICES

Appendix 1 - Definitions

The following commonly used definitions may be of use. Many are selected from Australian Standard 3814-2009.

Term	Definition
TYPE B APPLIANCE	An appliance, with gas consumption in excess of 10MJ/h, for which a certification scheme does not exist. NOTE: A Type A appliance when used in an industrial/commercial application for which it was not intended is considered to be part of a Type B appliance. An example of this is a certified direct-fired space heater used as the heating/ventilating device in a spray/bake paint booth.
AUTO-IGNITION TEMPERATURE (AIT)	The lowest temperature at which the rate of self-heating of a gas-air mixture exceeds the rate of heat loss to the surroundings, thus causing the mixture to ignite.
ATMOSPHERIC BURNER	A system where all of the air for combustion is produced by the inspirating effect of the gas or the natural draught in the combustion chamber or the combination of the two without mechanical assistance.
AUTOMATIC BURNER	A burner system that, on starting, follows a self-acting sequence that has been manually or automatically initiated, to provide gas and ignition to the burner without any intermediate manual operation.
BIOGAS	The gas resulting from anaerobic bacterial breakdown of organic material.
BIOGAS TRAIN	The equipment associated with the carriage, conditioning and preparation of biogas for burning in flares or other uses.
BURNER OFF CYCLE	A normal cessation of operation occurring when a pre-determined operation condition is reached and the operation of the burner to provide the application of heat is no longer required. The equipment is placed into a safe stand-by condition ready to restart on demand Or A shut down to a safe stand-by condition in response to an incorrect condition signal resulting from a fault that is unlikely to be hazardous or is likely to be self-rectifying so that normal restarting is permissible when the fault has cleared.
CERTIFIED/CERTIFICATION	Assessed by a certifying body and having a certificate number to demonstrate compliance with a relevant Standard and/or other acceptable safety criteria.
CERTIFYING BODY	A body acceptable to the technical regulator that provides assurance of compliance of appliances and components with relevant Standards and other accepted safety criteria.
CHP	Combined heat and power plant which through the combustion of biogas generates heat and electrical energy.
DAMPER	An adjustable device for controlling: (a) Air flow in a forced or induced draught air system (b) The flow of flue products in a flue system (c) The recirculation of air, flue gases or process gases, or (d) The flow of any other fluids.
FAIL-SAFE	A feature that ensures absence or malfunction of any critical control or safety component, system, signal or function will not result in an unsafe condition.
FLAME ABNORMALITY	A flame condition that results in flame lift, floating, light back, appreciable yellow tipping, carbon deposition or objectionable odour.
FLAME DETECTOR	A device that is sensitive to flame properties and initiates a signal when flame is detected.
FLAME ESTABLISHMENT PERIOD	The period that begins when the fuel valve is energised and ends when the flame safeguard system is first required to supervise that flame.

Term	Definition
FLAME FAILURE RESPONSE TIME	The time taken for the flame safeguard to detect loss of flame and de-energize the safety shut-off valve.
FLAME PROVING PERIOD	The supervised period immediately following the flame establishment period and before any further operation other than shutdown is permitted.
FLAME SAFEGUARD	A safety device that automatically cuts off the gas supply if the actuating flame is extinguished.
FLAME SAFEGUARD SYSTEM	A system consisting of a flame detector (s) plus associated circuitry, integral components, valves and interlocks, the function of which is to shut off the fuel supply to the burner(s) in the event of ignition failure or flame failure.
FLARE	An engineered unit which safely combusts biogas and air mixtures to destroy its methane content and odorous components.
GAS CONSUMPTION	The rate of energy consumed by an appliance under specific conditions and expressed in multiples of joules per hour, for example, megajoules per hour (MJ/h) or gigajoules per hour (GJ/h).
IGNITION TEMPERATURE	The lowest temperature at which heat is generated by combustion faster than heat is lost to the surroundings, and combustion thus becomes self-propagating.
INTERMITTENT PILOT	A pilot that is automatically ignited each time the burner is started, and which is automatically extinguished with the main burner.
INTERRUPTED PILOT	A pilot that is automatically ignited each time the burner is started, and which is automatically extinguished at the end of the main flame establishment period.
LOWER EXPLOSIVE LIMIT (LEL)	The lowest percentage of gas in a mixture of gas and air in which the combustion can be self-sustaining at standard temperature (15°C) and pressure (101.325 kPa absolute) conditions.
PERMANENT PILOT	A pilot that is intended to be permanently alight while the appliance is in service and that is controlled independently of the main burner.
PILOT	A permanently located burner independent of the main burner, small in relation to it, and arranged to provide ignition for the main burner.
POSITION-PROVING SYSTEM	A means of checking that the safety shut-off valves and vent valves of a double block and vent safety shut-off system are in the correct position.
PROGRAMMABLE ELECTRONIC SYSTEM (PES)	A system based on one or more central processing units (CPUs) connected to sensors and/or actuators, for the purpose of control, protection or monitoring.
PURGE (OR PURGING)	With respect to an appliance means the removal of combustibles.
SAFETY SHUT OFF SYSTEM	An arrangement of valves and associated control systems that shuts off the supply of gas, when required, using a device that senses an unsafe condition
SAFETY SHUT OFF SYSTEM, DOUBLE BLOCK AND VENT	A safety shut off system that incorporates two safety shut off valves in series, with the space between the two valves automatically vented. These valves are interlocked so that when the safety shut off valves are closed, the vent valve is open and vice versa.
SAFETY SHUT OFF VALVE	An automatic shut off valve that meets the requirements of AS 4629 and is used to shut off gas supply to an appliance when a signal is generated indicating the approach of an unsafe condition.
STANDARD GAS CONDITIONS	The temperature and pressure values at which biogas volumes are calculated. Typically for biogas, standard gas conditions are 15°C, and a pressure of 1 atmosphere (101.3 kPa).
VENT LINE	A pipe that is connected to a gas pressure regulator, relief valve or a double block and vent safety shut off system and will convey gas to a safe location
VENT VALVE, DOUBLE BLOCK AND	A valve in the vent line of a double block and vent safety shut off system that automatically opens when de-energised and automatically closes when energised.

Term	Definition
VENT SAFETY SHUT OFF SYSTEM	
ZONES	Potentially explosive areas are classified on the basis of zones according to the probability of the presence of a potentially explosive area. In Australia, the appropriate standard is AS/NZ 60079.10:2009 *Explosive atmospheres – Classification of areas*.