Code of Practice for On-farm Biogas Production and Use (Piggeries)

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

1.1 Purpose and scope

The aim of the Code of Practice (CoP) is to establish rural biogas schemes as an accepted agricultural practice and part of good farm management. The CoP therefore outlines boundaries for on-farm biogas schemes that align with the spirit of this CoP. This may include feedstock limitations (such as feedstocks of non-agricultural origin (e.g. municipal organic waste), technology limitations (such as pressures) and scale limitations).

The CoP is comprehensive, and covers off on aspects of biogas production and recovery, handling and transmission, as well as biogas quality improvements and biogas utilisation. However, a core focus is on pig flush manure digestion in covered anaerobic ponds, as well as the biogas handling and any upgrading necessary for utilisation in flares, boilers and electricity generators.

The CoP has only a fringe focus on alternative digestion technology (such as heated tank digesters), alternative substrates (such as waste feeds, deep litter manure etc) and alternative biogas use options and their associated biogas quality improvements (such as biogas to transport fuel etc).

Development of this CoP incorporates international best practice, and Australian regulations and standards for on-farm production and use of biogas. While all attempts have been made to identify relevant regulatory requirements, it is the responsibility of operators to ensure that they address all State regulatory requirements. The document is aligned with the revised Australian Standard 5601 for gas installations (2010).

The CoP builds on, but does not correct or limit, existing guidelines and regulations in the following (but not limited to) areas:

a) Feedstock handling – remains based on best on-farm practice of manure management;
b) Structural design of ponds/tanks – remains based on existing guidelines and regulation; and
c) Safety/operation of biogas generators and boilers – remains based on existing gas appliance regulation.

Since work beyond these (and further) associated guidelines is outside the scope of work for the CoP, specific references for further information are provided.

1.2 Structure

The structure of the CoP has been developed along Standardisation Guide 006, Rules for the Structure and Drafting of Australian Standards guidelines. The elements are written at a level relevant for on-farm biogas. Figure 1.1 illustrates the flow of a biogas plant project from planning, design, construction, on to operations and maintenance. Health and safety, and environmental protection, forms part of each block in the project flow. As cross-cutting themes relevant to each step of the project flow, the segregation enables risk focus on these important components and allows modular updating of the CoP (i.e. ability to revise a single component and not the entire CoP).

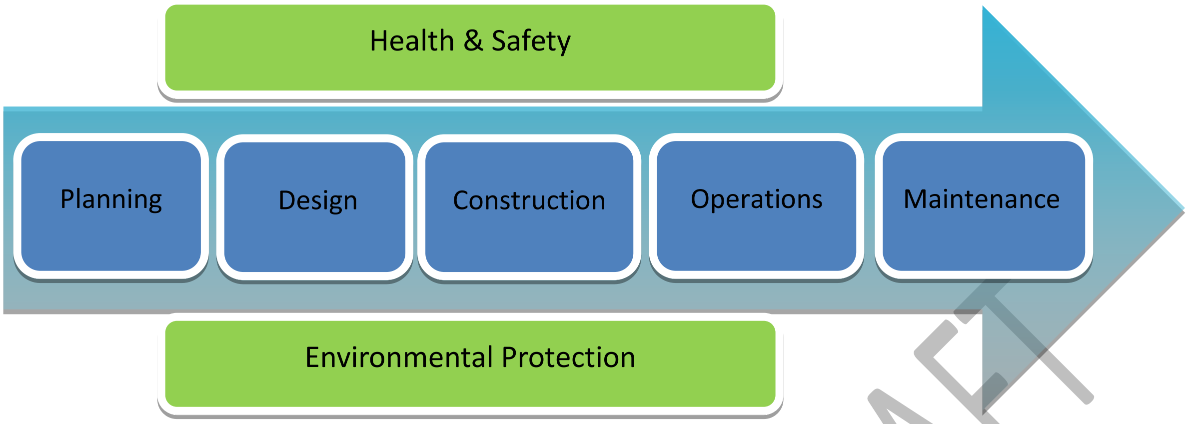


Figure 1.1 Biogas plant project flow

As a result, the essentials of the CoP cover:

a) design and construction;
b) health and safety;
c) environmental protection; and
d) operation and maintenance.

1.3 Biogas basics

A biogas plant comprises structures for the production, storage, movement, handling and utilisation of biogas. Figure 1.2 illustrates a schematic covered anaerobic pond (CAP) biogas plant digesting flush manure, which is the most relevant type of biogas plant for the Australian pork industry. Effluent is collected in the pig sheds and pumped or drained into the anaerobic pond, with or without prior separation of coarser waste solids. The anaerobic pond provides an oxygen free environment, where a community of anaerobic micro-organisms break down dissolved and colloidal waste solids into biogas and inorganic nutrients. This process is also known as anaerobic digestion.

The pond cover at the top of a covered anaerobic pond serves to capture and store the biogas produced. The gas blower moves biogas from the CAP to a flare to be burned off or to onsite biogas utilisation equipment via biogas conditioning devices (e.g. coolers for water removal or filters for gaseous biogas contaminant removal). Biogas can be used for heating applications (e.g. boilers) or for electricity generation and/or combined heat and power (CHP) applications. Combined heat and power applications based on reciprocating motor generators will be the main biogas utilisation pathways for Australian pork farms. The glossary of terms that follows provides a description of the various components and processes in the biogas plant.

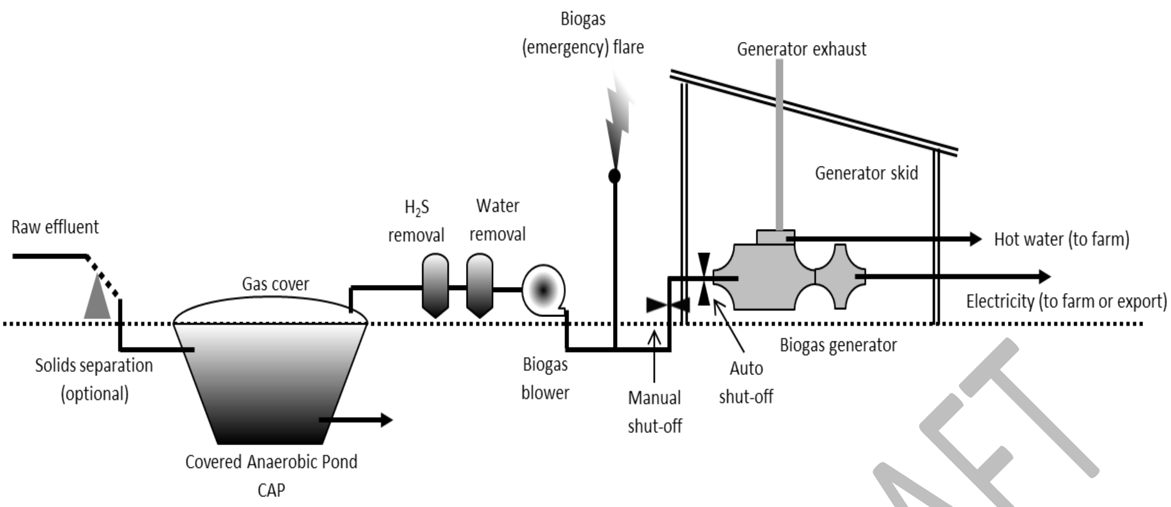


Figure 1.2 Covered anaerobic pond biogas plant

1.4 Glossary of terms

1.4.1 Shall

Indicates that an action is mandatory.

1.4.2 Should

Indicates a recommendation.

1.4.3 May

Indicates the existence of an option.

1.4.4 Anaerobic Digestion (AD)

The biological process by which organic matter (e.g. manure) is broken down in the absence of oxygen, producing raw biogas and other by-products (i.e. liquid and solid digestate).

1.4.5 Anaerobic Pond (AP)

A dam/earthen structure that uses anaerobic micro-organisms to treat the effluent. Digestible waste solids are converted to mineral nutrients, water and biogas. To minimise oxygen exchange, these ponds/lagoons are usually quite deep (typically 2 metres or deeper).

1.4.6 Biogas - composition and properties

Biogas is the mixture of gases that is produced when bio-degradable organic matter is digested by bacteria in the absence of oxygen (i.e. anaerobic digestion). Biogas consists essentially of methane (typically 60 – 70% where manure is the main feedstock), carbon dioxide (typically 30 – 40% where manure is the main feedstock), hydrogen sulphide (200 – 3,000 ppm 0.02% to 0.30% vol.), and traces of ammonia, hydrogen, nitrogen, and carbon monoxide. Raw biogas is generally saturated with water vapour at temperature (e.g. ~50g/m^3 = >6% vol. at 40°C). Therefore condensation will occur where raw biogas is cooled to below its moisture saturation temperature.

	Biogas
Heating value (kWh/m³)	6
Density (kg/m³)	1.2
Density ratio to air	0.9
Ignition temperature (°C)	700
Explosion range (% vol.) in air	6-12
Theoretical air requirement (m³/m³) to form flammable mixtures	5.7
Methane (CH_4) %	60-70
Carbon dioxide (CO_2) %	30-40
Hydrogen sulphide (H_2S) % by volume	0.02-0.30

Source: German Agricultural Occupational Health and Safety Agency, 2008.

1.4.7 Biogas plant

Means the equipment and structures comprising the system for producing, storing, handling and utilising biogas.

1.4.8 Biogas scrubbing or conditioning

Is the partial or total removal of non-methane trace and by-gases, such as hydrogen sulphide (H_2S), water and ammonia (NH_3), from biogas to improve the biogas quality for subsequent use. Biogas scrubbing is particularly important for preventing damage to more sensitive biogas utilisation equipment, such as reciprocating motor generators.

1.4.9 Buffer distance

The distance provided between the piggery complex or reuse areas and sensitive natural resources (e.g. bores, watercourses and major water storages) as an important secondary measure for reducing the risk of environmental harm.

1.4.10 CHP unit

A combined heat and power (CHP) unit simultaneously generates electricity and heat.

1.4.11 Co-digestion

Refers to the AD of additional biodegradable feedstocks in an AD system together with the main substrate, i.e. manure. The intent is to maximise the production of biogas and utilisation of the installed plant. For pond biogas plant on pig farms, options for co-digestion are limited to liquid/fluid feedstocks such as distillery waste or spoiled feed.

1.4.12 Co-generation

Energy conversion process, whereby more than one utility is derived from a particular energy resource such as biogas. Biogas co-generation typically entails electricity generation with the simultaneous recovery of generator waste heat in the form of hot water.

1.4.13 Collection

Collection is defined as the system through which manure feedstock is brought to the digester. The collection system may consist of pipes, open channels and/or pumps.

1.4.14 Contaminant

A contaminant is a foreign unwanted substance (biological, chemical or physical) in a material (e.g. feedstock, biogas).

1.4.15 Covered Anaerobic Pond (CAP)

Is an Anaerobic Pond fitted with an impermeable cover which captures biogas produced for odour and GHG emission control and to make biogas available as an energy resource. Covers can be either perimeter fixed or floating.

1.4.16 Cryophilic/psychrophilic temperatures

Refers to the AD process operation below 30°C.

1.4.17 Desludging

Removing settled solids from an effluent pond.

1.4.18 Digestate

A by-product of the AD process which can be used as an effective fertiliser or soil conditioner.

1.4.19 Digester (reactor, fermenter)

For the purposes of this CoP, digester refers to a covered anaerobic pond where microbial breakdown of the feedstock occurs.

1.4.20 Electrical contractor

Means a suitably qualified and experienced person who carries out the business of performing electrical work for others. Work includes installation, alteration, repair or maintenance of an electrical installation, and includes work of a class prescribed by regulation.

1.4.21 Emergency service

Means an ambulance, fire, police or other emergency service.

1.4.22 Environmental Management Plan (EMP)

An EMP focuses on the general management of the whole farm, taking into account the environment and associated risks. It should document design features and management practices; identify risks and mitigation strategies; include ongoing monitoring to ensure impacts are minimised; and processes for continual review and improvement.

1.4.23 Equipment

Includes fittings, fixtures, appliances and devices.

1.4.24 Explosive limits

If the concentration of biogas in air (volume ratio) is between the lower explosive limit (LEL) and the upper explosive limit (UEL), the mixture is flammable. The explosion range of biogas is where ignition of combustible gas when mixed with air occurs and lies between the explosive limits. For biogas in air, LEL of 6% and UEL of 12% (German, 2008).

1.4.25 Feedstock

The feedstock (sometimes also known as substrate or input) for anaerobic digestion consists of (a mix of) digestible organic materials.

1.4.26 Flares

Engineered device for the safe combustion of biogas that does not yield any usable energy benefit.

1.4.27 Gas fitter

Means a person with appropriate qualifications and authorisation who carries out the business of performing gas fitting including installation, alteration, repair or maintenance of gas system and includes work of a class prescribed by regulation.

1.4.28 Gas storage

Container or membrane bag in which the biogas is temporarily stored.

1.4.29 Gastight

The condition of a gas installation or gas pipework in which any leakage of gas is at a sufficiently low rate that no hazard is likely to ensue.

1.4.30 GHG

Greenhouse gas(es) are gases with a global warming potential.

1.4.31 IEC

The International Electro-technical Commission through the IEC Ex is an international certification scheme that rates explosion hazards. It covers both equipment certification and zone classification. Certificates issued under this scheme are accepted by all member countries including Australia.

1.4.32 Kilowatt hour (kWh)

Key measure of (electrical) energy. 1 kWh = 3.6 MJ.

1.4.33 Liquid manure storage

Containers (includes tanks and ponds) either in-ground or above ground, in which liquid manure, slurry, or the digestate is stored.

1.4.34 Manure

Animal faeces plus urine and may contain spent bedding, waste feed and water.

1.4.35 Mesophilic temperature

Refers to the AD process operation around 30 - 45°C.

1.4.36 NEGP

Refers to the National Environmental Guidelines for Piggeries, Second Edition (Tucker et al., 2010).

1.4.37 Nutrient

A food essential for cell, organism or plant growth. In the context of this CoP, pertains to a fertiliser nutrient essential for plant growth, such as phosphorus, nitrogen and potassium.

1.4.38 On-farm/farm

An area of land and its buildings used for growing crops and rearing animals, typically under the control of an owner or manager.

1.4.39 Permeability

Ability of a material to allow the passive transmission of liquids or gases through micro or macro pores or other openings contained in its structure without undergoing structural transformation.
For most components of a biogas plant, low permeability for liquids and gases is desired, so as to prevent the uncontrolled release of feedstock, digestate or biogas to the environment.

For pond liners constructed from compacted clay or synthetic materials, a maximum permeability of 1×10^{-9} m/s = 31.5 mm/yr is desired or regulated.

1.4.40 Receptor

Receptor person or site that receives, and is sensitive to, community amenity impacts, including a residential dwelling, school, hospital, office or public recreational area.

1.4.41 Reuse areas

Are land areas where (by-) products such as digestate are spread for the purpose of using the nutrients and water they contain for crop or pasture growth.

1.4.42 Risk assessment

A risk assessment is a process of identifying hazards: followed by an analysis or evaluation of the risk associated with that hazard. Finally, determining appropriate ways to eliminate or control the hazard.

1.4.43 Setbacks

A setback is the minimum required distance between any two points of interest. In locating a biogas plant, the setback is the distance between a piece of infrastructure included in on-farm biogas plant and a point of interest in the surroundings. Applicable infrastructure may include pre-storage and handling facilities, the digesters themselves, biogas conditioning and utilisation equipment, as well as solid liquid separation equipment, composting/storage facilities for separated solids, and post-storage of liquid digestate. The infrastructure related to biogas plant is similar to agricultural waste storage facilities, on-farm storage facilities, silos and on-farm petroleum storages.

1.4.44 Separation distance

The distance provided between the piggery complex and sensitive receptors (e.g. residences, recreational areas, towns etc) as an important secondary measure for reducing the risk of negative amenity impacts. Separation distances are measured as the shortest distance between the piggery complex and the nearest part of a building associated with the receptor site land use.

1.4.45 Sludge

The accumulated solids separated from effluent by gravity settling during treatment and storage.

1.4.46 State

Means an Australian State or Territory.

1.4.47 Supernatant

Is the liquid lying or floating above a sediment or settled precipitate (i.e. sludge). Therefore in the context of this CoP, it is the upper, solids-poor, liquid phase formed when effluent is allowed to settle out solids.

1.4.48 Standard gas conditions

Refers to the temperature and pressure conditions biogas volumes have to be converted to, using the general gas equation, for comparison reason, e.g. for the CFI methodology et al. Standard gas conditions in the context of this CoP refer to a temperature of 15°C and a pressure of 101.325 kPa (NGER, 2012).

1.4.49 Thermophilic temperatures

Refers to the AD process operation at temperatures between 45°C and 70°C.

1.4.50 Type B appliance

Refers to a gas appliance (including a second-hand appliance) that has a maximum hourly input rate exceeding 10 mega joules, and includes any components and fittings downstream of and including the appliance manual shut-off valve for which a Gas Work Authorisation may need to be obtained from a State Gas authority, but is neither a Type A appliance nor a mobile engine. Type A gas appliances are mainly domestic and light commercial appliances which are mass produced. They are defined in AS/NZS 5601 as an appliance for which a certification scheme exists.

1.4.51 Waste discharges

Are categorised as solid waste discharges, effluent, or air emissions.

1.4.52 Zones

Potentially explosive areas are classified into zones according to the probability of the occurrence of a potentially explosive atmosphere. Australia uses AS 60079.10 – Explosive Gas atmosphere and uses IEC definitions for classifying zones.

Disclaimer:
NB: The terminologies and meanings described in the glossary are intended to represent meanings in the Australian context. The wording is intended to be generic and any representation to other than that described is unintended.

1.5 Risk matrix

The CoP is compiled in a risk-based format and a risk matrix is illustrated in the next table. The document has been prepared in accordance with good professional practice and all reasonable care has been taken to ensure that the information contained in this report is complete and accurate. The contents of this CoP shall not be a substitute for independent professional advice. Those planning to progress an on-farm biogas project are advised to contact their local government authority, the office of the gas regulator, country fire service and environment protection authority in their respective State early on in the planning process, in order to define requirements.

Table 1.1 Biogas project risk matrix

Project Element	**Risk Description**	**CoP Reference**
Design and construction		
Pre-project considerations	a) Unrealistic expectations from producers b) Unviable/unrealistic projects c) Inappropriate designs/project for a specific context	2.2
Design consideration	a) Reducing the risks of unintended biogas release causing safety problems, e.g. reducing fire, explosion and intoxication risk via basic design b) Reducing the risk of interference by unauthorised personnel c) Reducing operational costs and effort	2.3
AD - Feedstock and storage	a) Envisaged digester type is appropriate for given feedstock b) Inappropriate material ending up in biogas plant leading to system failure or secondary environmental risk c) Feedstock losing biogas production potential prior to entering the digester	2.4.1
AD - Construction material	Using inappropriate materials on biogas plant components leading to equipment failure and reduced service life	2.4.2
AD - Digester design	a) Farmers building digesters inappropriate for their feedstock and situation b) Digesters being built which are a safety or environmental risk c) Digesters being built which have excessive maintenance requirements and reduced service life	2.4.3
Biogas use - Considerations	Farmers following a sub-optimal (too complex) route to biogas utilisation	2.5.1
Biogas use - Equipment	a) Biogas utilisation equipment becoming a hazard b) Biogas utilisation equipment creating a hazardous environment	2.5.2
Biogas use - Flares	Direct venting of biogas into the atmosphere	2.5.3
Biogas conveyance - Pipelines	a) Using inappropriate materials on biogas plant components in contact with biogas leading to equipment failure and reduced service life b) Operating pipelines which (start to) leak biogas	2.6.1
Biogas conveyance - Storage	a) Biogas storage systems that are inappropriate for the situation b) Biogas storage which is a safety or environmental risk	2.6.2
Biogas conveyance - Conditioning	a) Issue of biogas condensate being overlooked, developing into a problem b) Unconditioned biogas being used and slowly destroying biogas equipment	2.6.3

Project Element	Risk Description	CoP Reference
	c) Employed biogas conditioning systems becoming a safety risk or releasing an excessive amount of odour or GHG emissions	
Health and safety		
Biogas safety	a) Biogas methane is a flammable gas, that can form explosive gas mixtures in air ➔Fire and explosion risk b) The trace gas hydrogen sulphide (H_2S) contained in biogas is corrosive and toxic and can cause adverse human (and animal) health effects at moderately low, but on-going exposure, as well as cause acute, and potentially lethal poisoning, at higher exposure ➔ Intoxication (poisoning) risk c) Biogas release in inadequately ventilated spaces can displace oxygen, potentially leading to asphyxiation of humans and animals ➔ Asphyxiation risk	3.1
Workplace health and safety	Non-biogas specific health and safety issues, such as fall, entanglement, electrical etc not being recognised and managed around the biogas plant	3.2
Environmental protection		
Feedstock management	a) Imported material introducing new risks to the operation, including contamination with foreign, problematic or toxic materials as well as novel biosecurity risks b) Imported materials complicating nutrient (and salt) management at the farm	4.3
Effluent/digestate management	a) Unintended fugitive (leakage) or b) Concentrated (catastrophic failure) waste (nutrient) discharges from the digester and associated (manure, digestate) storage facilities c) Overall nutrient volumes being estimated wrongly d) Nutrient concentrations in digestate supernatant and sludge being estimated wrongly, leading to underutilisation of the nutrient value in digestate or follow up problems where digestate (components) have been applied excessively	4.4
Air emissions	That the operation of a biogas plant leads to a substantial increase in the amount of air pollutants emitted from the site	4.5
Flares	Release of non-combusted biogas into the atmosphere	4.5.1
Noise	Minimise the impact of noise into the immediate environment	4.5.2
Odour control	Odours becoming a nuisance	4.5.3
GHG management	That a biogas plant underperforms regarding possible GHG emission reductions	4.5.4
Solid waste discharge	That potentially hazardous materials required for the proper operation of a biogas plant (e.g. generator motor oil, biogas filter media) do not become new environmental risks	4.6

Project Element	Risk Description	CoP Reference
Operation and maintenance		
Commissioning and start-up	a) Unfinished/untested biogas plants commencing operation b) Start-up issues leading to bacteria community collapse and acidic waste c) Special risk of explosive gas mixture being formed during start-up phase	5.1
Digester operation and microbes	a) Digesters becoming overloaded and unstable b) Biogas quality declining c) Solids conversion rate and overall biogas recovery from feedstock declining	5.2
Biogas conditioning and upgrading	a) Biogas scrubbers working ineffectively leading to downstream problems due to low gas quality b) Gas flow blockages	5.3
Biogas utilisation - Boilers	a) Boiler becoming a safety risk b) Biogas use becoming inefficient	5.4.1
Biogas utilisation - Co-gen operations	a) Reduced working life of generator due to lack of maintenance or inappropriate biogas quality b) Generators working with suboptimal electrical conversion efficiency c) Generators causing excessive air pollutant emissions	5.4.2

2.0 Design and Construction

2.1 Definitions

The operation of an on-farm biogas plant is an agricultural activity aimed at reducing the environmental impact of farming, and is strongly integrated with waste and energy management objectives associated with adding value to normal farming operations. An on-farm biogas plant is therefore primarily not an energy generation and export facility. It is part of normal (good) farming activities, not a standalone energy business.

An on-farm based biogas installation in the meaning of this CoP pertains to installations that:

a) Recover biogas from agricultural waste and by-products (primarily manures) and other agricultural biomass;
b) Are not linked to natural gas supply and any distribution infrastructure;
c) Does not produce more than 500 m^3 raw biogas per hour;
d) Does not compress or convey or store raw biogas at pressures exceeding 7 bar(g) in any part of the installation (700 kPa, AS/NZS 60079.10.1:2009) .

2.2 Pre-project considerations

What risks does this section aim to manage/avoid:

a) Unrealistic expectations from producers b) Unviable/unrealistic projects c) Inappropriate designs/project for a specific context

Agricultural biogas plants may be planned based on two general approaches:

a) Bottom-up – This planning paradigm sees biogas technology as an extension of existing farming operations, and wants to derive additional value (e.g. energy, GHG credits etc) from existing (waste) resources and also reduce the adverse impacts of existing operations (e.g. odour and GHG emissions, visual appearance etc)
b) Top-down – A planning paradigm where a specific outcome is required (e.g. energy independence or GHG neutrality of a particular operation), and biogas technology is one option for achieving this outcome either partially or fully.

The bottom-up approach offers more flexibility and will, for the vast majority of pig farms, be the planning paradigm of choice. Therefore, the available manure feedstock (volume, composition, location, seasonality of production) will determine the layout of most biogas plants on Australian piggeries. There are numerous on-farm anaerobic digestion technology and biogas utilisation design options. Appropriate and comprehensive planning will ensure the selection of the most appropriate technology for each part/aspect of the biogas plant.

Project planning should follow the steps of:

a) Feedstock evaluation: The first phase of the biogas project is feedstock evaluation and management which involves handling the feedstock and preparing it for digestion. Since for the majority of projects, this will primarily or solely be (flush) manure, biogas feedstock management will simply become an extension of farm manure management, while digestion facilities will be an extension of manure management facilities. The management of digestate will similarly be integrated with existing farm waste management. As covered anaerobic pond (CAP) biogas plants do not alter the quantities and flows of manure nutrients, compared to conventional liquid manure handling systems, questions regarding digestate nutrient value, nutrient re-use and nutrient land application limits will remain outside the scope of this CoP, as these issues need to be clarified as part of normal farm operations regardless of the existence of a biogas project. For farms that rely heavily on evaporative water losses from their pond system for effluent management, the reduction of evaporative water loss due to the use of a CAP needs to be compensated with additional uncovered pond capacity or intensification of effluent recycling or effluent land application.

b) Biogas technology selection - Digester configuration: Digester technology selection should only be "as complex as necessary and should be as simple as possible". Various digester designs are suitable for agricultural operations increasing in complexity from CAPs, plug-flow and heated mixed digesters to upflow anaerobic sludge blanket (UASB) digesters. The covered pond is the most common in Australia and described further in Section 12.3 of NEGP. In most cases CAPs offer the best value for money and are attractive for pork producers due to their low maintenance requirements and cost. More complex digester set-ups are generally only required where additional aims (e.g. the co-digestion of off-farm by-products), need to be achieved.

c) Biogas technology selection - Biogas uses: Biogas utilisation should target on-site needs (import substitution) over energy exports and high value application over low value applications. For the vast majority of Australian piggeries, this indicates the use of biogas in a CHP unit for the generation of electricity and heat in the form of hot water.

d) Biogas technology selection - Biogas conveyance and conditioning: Biogas conveyance and conditioning operations should be a consequence of the decisions made on preceding steps b and c.

Regarding engineering planning for b, c and d, these should be seen as linked, but independent parts of a biogas project as much as possible. The potential discharges from flares, boilers and biogas upgrading or from cogeneration equipment, shall be considered during the planning of a biogas project. Since technical solutions for effective management of these potentially adverse effects of a biogas plant are available, these should not be used to influence the design of a biogas plant to a great extent.

The following represents a checklist of considerations for a good biogas plant design:

a) Availability of suitably qualified technical support;
b) Appropriate level of complexity;
c) Corrosion resistance;
d) Appropriate level of automation;
e) Feedstock and digestate conveyance by gravity as much as possible;
f) A safe design including appropriate infrastructure (emergency flare) and procedures (training) to mitigate the risk of harm to humans and the environment;
g) Equipment fail safe devices throughout including emergency flare and heat dump;
h) Digester size appropriate for the current and/or projected future volume and nature of waste to be dealt with;
i) Biogas storage for maximising value of biogas utilisation;
j) Biogas handling equipment including pipe work, valves, blower;

k) Appropriate biogas utilisation equipment - electricity generating equipment or boilers;
l) Control and monitoring equipment;
m) Environmental management; and
n) Access to and handling of sludge and treated effluent.

2.3 Design considerations

What risks does this section aim to manage/avoid:

a) Reducing the risks of unintended biogas release causing safety problems, e.g. reducing fire, explosion and intoxication risk via basic design
b) Reducing the risk of interference by unauthorised personnel
c) Reducing operational costs and effort

Gas safety regulations are summarised in Annex A: Australian Regulators.

2.3.1 Plant layout

The infrastructure related to the biogas plant is similar to agricultural waste storage facilities, on-farm storage facilities, silos and on-farm petroleum storages. Section 6 of NEGP provides guidance for piggeries on recommended buffer distances for surface water and groundwater and separation distances for community amenity. In addition, Section 10 provides guidance on preventing releases to surface water and groundwater. A farm biogas plant generally will not be in a public place so consideration to access to dangerous goods is controlled, however closeness to the farm boundary may be a consideration.

In order to reduce operational cost, planning of the digester location shall seek to maximise the use of gravity flow. All digester siting and sizing considerations need to take easy access with heavy machinery into account in order to enable simple maintenance of the plant.

2.3.2 Biogas safety

Planning of the plant layout shall allow for the easy handling and use of the biogas and includes the layout of biogas blowers, gas storage, electrical installation, and earth points. Biogas generated during anaerobic digestion is flammable; therefore appropriate setback shall be established. Furthermore, it is recommended to reduce the zone rating of various parts of the plant through appropriate design decision. For example, using an uncovered pond rather than a rigid digestate holding tank downstream from the digester (pond) can eliminate a Zone 1 environment (see Table 2.1 for zone definitions). Similarly, the use of open skids or well-ventilated shelters with no more than three walls (Annex C: Example of Adequately Vented Shelter) housing biogas use equipment can reduce the extent, rating or occurrence of hazardous zones associated with the biogas plant. Considering the climatic conditions in Australia, the installation of biogas-use equipment on open skids or similar is generally recommended.

In order to assist planning, hazardous area classification is a method of analysing and classifying the environment where an explosive atmosphere is present or is expected to be present. This allows the proper selection of equipment, particularly electrical equipment, to be installed or used in that environment. Hazardous area classification is performed in the following way:

a) the type of hazard is defined (i.e. gas or dust or a combination of gases and dusts).
b) the probability of an explosive atmosphere actually occurring is assessed (release frequency and duration, i.e. continuous, primary or secondary grade of release).

The aim therefore is to exclude viable ignition sources from explosive atmospheres by nominating setbacks around potential point sources of emitted biogas (e.g. pressure release valves or vents).

Table 2.1 Hazardous zone definition

<u>AS/NZS 60079.10 EXPLOSIVE GAS ATMOSPHERES</u> (Replaces AS 2430.3.1)
Explosive gas atmospheres are subdivided into zones as follows:
ZONE 0 - In which an explosive atmosphere is present continuously, or is expected to be present for long periods, or for short periods which occur at high frequency. (More than 1000 hours per year)
ZONE 1 - In which an explosive gas atmosphere can be expected to occur periodically or occasionally during normal operation. (More than 10 hours per year but less than 1000 hours per year)
ZONE 2 - In which an explosive gas atmosphere is not expected to occur in normal operation and when it occurs is likely to be present only infrequently and for short duration. (Less than 10 hours per year)

Source: AS/NZS 60079.10 Explosive Gas Atmospheres - for the full definitions refer to the Standard.
Note – Zone 0 is practically never present with biogas plants during normal operations.

In Australia, hazardous zone classification follows AS/NZS 60079.10, which details specific zoning examples for biogas equipment (e.g. blowers, meters, sampling ports, etc) with a focus on wastewater treatment installations, which are recommended to be used for agricultural biogas plants as well. Although AS/NZS 60079.10 remains the official document for Australia, this CoP recommends the biogas plant hazardous zone classification established by the German Agricultural Occupational Health and Safety Agency (2008), which is more stringent but easier to apply in a farming context. Detailed zone classification examples for various parts of an agricultural biogas plant can be found in Annex D: Examples of Zone Classification. However, for a typical Australian CAP-based biogas plant with the biogas use equipment located on an open skid (or shelter with no more than three walls), the zone classification can be greatly simplified; namely:

a) A spherical space 3 metres around any gas carrying part of the plant (i.e. tightly sealed CAP cover without service openings, gas transfer pipeline, gas meter, gas blower) is classified as Zone 2;
b) Vent pipes, including blow down (exhaust) pipes of over pressure and pressure release valves (which have to extend to at least 3 metres vertically above the ground or structure (shelter roof, CAP cover etc)) are classified as Zone 1 internally, Zone 1 in a spherical space 1 metre around the outlet point as well as classified as Zone 2 for 2 metres around all Zone 1 spaces.

Where explosion-proof equipment (e.g. biogas blower) is supplied to be installed at an agricultural biogas plant, it shall be certified to IEC or Australian standards via an acceptable certification scheme

While the hazardous zone classification is a helpful tool, and the use of explosion proof equipment according to zone requirements is easy to follow and control during the initial construction phase, measures have to be taken to prevent the accidental introduction of an ignition source (i.e. open flame), and particularly non-explosion proof electrical equipment/tool into a hazardous zone of the biogas plant in the long run. Staff training is important in this regard. It is further recommended to erect a security fence around all biogas-carrying parts of the biogas plant, particularly the covered anaerobic pond, at a setback distance equal or greater to the extent of the hazardous zone around the gas carrying parts of the plant (i.e. >3 metre (Zone 2) for most parts of the biogas plant). Such a fence can also prevent damage to sensitive parts of the biogas plant (i.e. the pond cover) by stock or wild animals.

2.4 *Anaerobic digester*

2.4.1 Feedstock and storage

What risks does this section aim to manage/avoid:

a) Envisaged digester type is inappropriate for given feedstock
b) Inappropriate material ending up in biogas plant leading to system failure or secondary environmental risk
c) Feedstock losing biogas production potential prior to entering the digester

Key considerations for feedstock are:

a) Feedstock liquid manure
- Gas yields are directly related to the amount of biodegradable organic solids loaded into the digester. Organic matter content and the percentage of dry matter is an important factor for different digester systems:
    - CAPs can cope with relatively dilute wastes, although benefit from moderately high solids concentrations (smaller footprint). Highly concentrated wastes > 5-7% solids content can lead to acidification and hydraulic problems with pond type digesters.
    - If concentrated wastes with >5-7% solids is envisaged to be digested, a heated digester should be considered.
- Animal manures that contain antimicrobial products or strong disinfectants or cleaning agents may need to be discarded or diluted. Acclimatisation of the bacteria in the digester to antibiotics and some disinfectants is usually possible.

b) Handling and storage
- NEGP recommends the collection and transfer of effluent from shed to treatment facilities with minimal odour generation and no releases to surface water or groundwater. This aligns with maximising biogas production where longer collection intervals or storage of feedstock allows aerobic and possibly anaerobic decomposition to occur, reducing the amount of biogas production that is possible.
- Closed pits or tanks can be established when storage is needed prior to digestion, however storage prior to digestion should be minimised wherever possible.

c) Contaminants
- All feedstock should be free of foreign materials such as plastic, sand and rocks that can block pipelines, pumps etc associated with biogas plants. Screens, sand traps and pro-active management can reduce problems associated with foreign materials to a minimum.

d) Other on-farm wastes
- A wide range of other on-farm wastes and by-products such as spoiled feed etc can be co-digested with manure. However co-digestion is not allowed to overload the digester or interfere with the hydraulics of the system (liquid becoming too thick). Co-digestion of more solid on-farm wastes usually cannot be accomplished with CAPs, but only with engineered tank digesters.

e) Off-farm materials

- Off-farm materials intended for co-digestion with farm wastes carries much higher risks than on-farm feedstocks regarding biosecurity hazards and chemical contamination (e.g. heavy metals).
- Reducing the risk associated with such materials requires careful management, which is outside the scope of this CoP. In particular the use of high risk materials, such as municipal organic waste, for biogas co-digestion cannot be considered good agricultural practice and is therefore not covered by this document.

2.4.2 Construction material

What risks does this section aim to manage/avoid:

Using inappropriate materials on biogas plant components leading to equipment failure and reduced service life

Material components of a biogas plant are exposed to harsh conditions. Both raw effluent and digestate is corrosive. Even low levels of the trace gas hydrogen sulphide (H_2S), usually found in concentrations from 0.02 to 0.30 % in agricultural biogas, can be very corrosive to some materials in contact with biogas. Other parts of the biogas plant, such as the pond cover, are additionally exposed to intense UV radiation and heat during summer. Therefore, all materials used for a biogas plant need to be selected carefully.

For components of the biogas plant that are in contact with manure or digestate, but not necessarily biogas (e.g. pond or tank structures):

Table 2.2 Materials in contact with manure

Material Status	Material List
Recommended	All plastics (PVC piping only if UV resistant, PVC shall not be used for pond liners or covers), Most stainless steel, Clay, Concrete
Not recommended	Copper, Steel other than stainless steel

Components of the biogas plant that are in contact with biogas (e.g. pond cover) should also be corrosion resistant (refer to 2.6.1 for biogas corrosion resistant materials).

2.4.3 Digester design

What risks does this section aim to manage/avoid:

a) Farmers building digesters inappropriate for their feedstock and situation b) Digesters being built which are a safety or environmental risk c) Digesters being built which have excessive maintenance requirements and reduced service life

The physical configuration of the digester affects biogas production efficiency, retention time and homogeneity of feedstock. Digester sizing needs to take into account appropriate solid and hydraulic retention times as well as organic and solids loading rates. Both are temperature and feedstock dependent, indicating that engineered tank digesters can be operated with higher loading rates and shorter solids and hydraulic retention times than unheated pond digesters.

As part of good agricultural practice, all on-farm biogas plants shall seek recovery of the maximum available biogas potential contained in the feedstock (up to 85% are regularly achieved), not least in order to prevent uncontrolled methane, and associated GHG, emissions from effluent treatment and handling downstream from the CAP. Achieving a high reduction in feedstock solids concentration is a simple way of ensuring an equivalent or higher utilisation of the available biogas potential.

In addition to organic loading rates, solids and hydraulic retention times and appropriate solids reduction rates, which are all temperature influenced and hence climate dependent for CAPs, sizing also needs to consider optimum sludge removal intervals. Sludge removal may be frequently/on-going (i.e. weekly or monthly basis) or on an annual or multi-year basis. The most suitable sludge removal interval will often be determined by factors unrelated to farm effluent management, such as the need/opportunity for sludge nutrient re-use, or the availability of equipment and labour for de-sludging. The optimum sludge removal interval therefore needs to be determined on a farm individual basis, but sludge accumulation rates, and the expected amounts of pond volume taken up by stored sludge, need to be factored into pond sizing.

Organic loading rates of more than 0.3 $kgVS/m^3/day$ and hydraulic retention times of < 30 days are not recommended for CAPs, other than for very hot climates and/or where desludging is carried out on a very regular basis. General pond sizing information is available from Table 12.1 of NEGP (suggested large anaerobic pond capacities for different climates, desludging frequencies and pre-treatment options).

CAPs accumulate rainwater on the cover surface that needs to be managed. However, in very dry regions of Australia, rainwater may not need to be managed due to high evaporation rates. An array of rainwater guidance pipes directing rainwater to a removal pump is a practical means of managing rainwater. Recovered rainwater can often be reused as flush water within the piggery. Where CAPs are constructed as a retrofit of an existing structure rather than an additional feature of the waste treatment system, evaporative water losses can be reduced requiring correction measures. For retrofit ponds on piggeries that heavily rely on evaporative water losses for effluent management, establishing a simple water balance is recommended.

All CAPs, digestate storage structures and effluent collections systems need to be tightly sealed to avoid effluent seepage. A permeability requirement of 1×10^{-9} m/s applies to all structures as part of good agricultural practice and as a legal requirement in most states of Australia.

Furthermore all structures need to be structurally sound and place no environmental risk in accordance with Section 12.1 (design of effluent treatment ponds) of NEGP. A bypass effluent pipeline to downstream processing (i.e. secondary pond) is also required for re-use, emergency and maintenance situations.

To prevent unintended pressure or vacuum build up, all digesters shall be fitted with a hydraulic pressure relief and vent stack or mechanical or electronically controlled equivalent.

2.5 Biogas utilisation

2.5.1 Biogas use considerations

What risks does this section aim to manage/avoid:

Farmers following a sub-optimal (too complex) route to biogas utilisation

Biogas is a versatile renewable energy resource. This versatility makes selection of the optimum use of biogas complex, and the optimum biogas use can only be decided on a case by case basis. While biogas flaring is an appropriate low cost and effective means for reducing farm odour and GHG impact, it does not yield any further energy benefit. Wherever practical, the use of biogas for boiler, generator or transport fuel applications is therefore encouraged. Table 2.3 provides an overview of the relative advantages regarding GHG mitigation, gross value and technical complexity of various biogas utilisation pathways.

Table 2.3 Substitution values for various energy applications of 1.5 m3 biogas = ~ 1 m3 CH4 (Approximate costs AUD)

Substitute	GHG Mitigation	Gross Value	Complexity
~ 1m³ Natural gas boiler fuel	~ 2 kg CO_{2eq}	$0.20 – 0.50 Location specific	Simple, cheap and easy
~ 1.4 L LPG boiler fuel	~ 2.2 kg CO_{2eq}	$0.60 – 0.80	Simple, cheap and easy
1.5 – 3 kg Coal (Lig – SB) Boiler fuel	3.3 – 3.6 kg CO_{2eq}	$0.07 – 0.25 Location specific	Quite simple and cheap technology
3 – 3.5 kWh electricity	NZ: 0.6 – 0.7 kg CO_{2eq} AU: 2.7 – 3.2 kg CO_{2eq}	$0.12 – 0.20 export $0.30 – 0.60 own use	Modestly complex Modestly expensive
0.9 – 1.05 L Transport fuel (Diesel/petrol)	2.4 – 2.7 kg CO_{2eq}	$1.00 – 1.20 NZ & AU (no tax)	Complex to organise Relatively expensive technology

Source: Heubeck, S. 2010, value indications based on year 2010.

On-farm biogas plants shall seek to maximise the substitution of energy imports, rather than produce the maximum amount of exportable energy. For most Australian piggeries this will mean that a CHP unit, producing electricity for on-farm consumption as well as waste heat in the form of hot water for on-site heating purposes, is the best option. Only for piggeries with a very large and constant heat requirement (hot water or steam) may the use of biogas as boiler fuel be a better option.

If an on-site CHP unit is to be run in parallel with the existing power supply system (grid synchronous), or will be configured to export (partial) amounts of electricity, contact with the local distribution network will have to be established early on in the planning phase of the on-farm biogas project. The complexity and effort (in particular regarding connection and electrical safety systems) for connecting distributed generators to the local grid vary between Australian states. There are strict requirements that have to be met and each operator shall satisfy the requirements of their local electricity distribution network.

2.5.2 *Biogas use equipment*

What risks does this section aim to manage/avoid:

a) Biogas utilisation equipment becoming a hazard
b) Biogas utilisation equipment creating a hazardous environment

CHP equipment should be designed by qualified professionals and installed in accordance with Australian Standards, the manufacturer's specifications and applicable legislation to meet regulatory Safety Standards and Electrical Safety requirements.

Biogas appliances need to have the new Gas Safety Certification Mark as shown in Figure 2.1.

Figure 2.1 Gas Safety Certification Mark

In some states, on-farm biogas plants are likely to be determined to be using a Type B appliance even if they do not exceed the 10MJ/h consumption trigger point requirement simply because there is no Australian Gas Association approval scheme for biogas plants.

Shutoff valves - A shutoff valve shall be installed in the gas line in front of each biogas use equipment. The valves shall automatically close when the biogas-use equipment stops working. The gas-tightness[1] of the intermediate space shall be checked regularly.

Additionally consideration shall be given to the following safety measures:

CHP generator cut-off switches - It shall be possible to shut off the combined heat and power unit at any time by using an illuminated switch located outside of the generator skid/shelter. The switch shall be labelled permanently and be easily visible with "Emergency Shut-off Switch for Combined Heat and Power Unit" and shall be accessible.

Cut-off for the gas supply - It shall be possible to shut off the gas supply to the heating and/or power unit, in the open, outside of the generator skid/shelter as close to the CHP unit room as possible. The on and off position shall be labelled. The same requirements apply also to electrically-operated shutoff valves.

2.5.3 Flares

What risks does this section aim to manage/avoid:

Direct venting of biogas into the atmosphere

All biogas plants should include an emergency flare on-farm to avoid the direct venting of biogas into the atmosphere. The flare should be installed with the capacity to accept all biogas from the digester and associated structures during an emergency situation or maintenance period, and over a reasonable combustion period. By routing the biogas through a flare, it is combusted and the risk of adverse odour and GHG impact is greatly reduced.

Biogas from on-farm biogas plant usually has a high methane content (>50% CH_4), which (if at an appropriate pressure) will provide a high level of flame stability, enabling the use of electric ignition systems and the use of flares without pilot fuels. In some situations, it is necessary to use flares that rely on pilot fuels (such as LPG which will require a permit in some States) for ignition or flame stabilisation.

[1] Reference AS 5601 - definition of 1.6.50 'gastight'.

While there are two types of flares (open and enclosed), an open flare may be sufficient due to the intermittent use of flares associated with most on-farm biogas plants. Open flares generally are less costly than enclosed flares and have a simpler design but may be less effective at controlling emissions. They also have considerable heat loss and therefore are usually elevated for worker safety. On the other hand, enclosed flares may be beneficial for rural fire safety (see discussion on flares and rural fire safety at end of this section).

Flares should be designed by a qualified professional and installed in accordance with the manufacturer's specifications and applicable legislation. Operators should consult with the Safety Authority regarding biogas flare requirements (e.g. diameter, stack height, etc), inspections and approvals.

For more information on the design of the flare burner management systems refer to AS 3814 Industrial and Commercial Gas-fired Appliances. However, in line with best practice principles, the following shall be provided as a minimum on any flare system:

a) The location of the flare shall be such that in the event of unburnt gas being vented, it will not cause a hazard;
b) To minimise fire risk, a biogas flare needs to be installed outside hazardous zones established by other parts of the biogas plant, and shall be installed with a setback of at least 6 metres from any building or potentially flammable structure (i.e. grain silo) (German, 2008) as well as any gas carrying part of the biogas plant (other than the biogas transfer pipeline);
c) The materials selection for all valves and components shall be compatible with biogas and the associated leachate or condensates;
d) The provision of a flame arrester at the flare inlet or the provision of a temperature sensor to initiate a shutdown if there is the presence of heat at the flare inlet. The use of a fusible link can also be used for this function and is the preferred option;
e) The provision of a safety shut off system for the gas;
f) The electrical installation to be compliant with AS 3000 Electrical installations;
g) The flare ignition system shall work continuously during operation. Alternatively, the flare can be fitted with a flame monitoring system that automates gas shut off, self-check and re-ignition;
h) Where a blower is required, it is to be compliant with the hazardous zone rating, earthing requirements of the gas blower and the flare system to be assessed;
i) Specifically for flares associated with CAPs operating under negative pressure, the extraction system shall have some form of pressure and/or oxygen control to ensure that no excessive amounts of oxygen are induced into the gathering system;
j) To prevent access to the flare by unauthorised persons and animals, the installation of a security fence is recommended. However shut off valves and other safety features need to remain easily accessible.

Flares and rural fire safety

The use of a biogas flare (including emergency flare) may be affected by rural fire regulation, such as total fire bans. Rules and regulation are set by the local fire authority and differ considerably between states across Australia. It is therefore the responsibility of the biogas plant operator to consult with the local fire authority about the status of a biogas flare before it is installed. The risk profile of open flares may be reduced by installing shields around the burner tip of the flare and/or locating the flare on a hard surface pad. Providing sufficient biogas buffer storage can help to avoid operation of a flare for short periods of time during total fire bans. Furthermore, exemptions may be obtained from the local fire authority.

2.6 Biogas conveyance

2.6.1 Biogas transfer pipelines

What risks does this section aim to manage/avoid:

a) Using inappropriate materials on biogas plant components in contact with biogas leading to equipment failure and reduced service life
b) Operating pipelines which (start to) leak biogas

All components in contact with biogas should be corrosion resistant. Biogas pipelines should be labelled as carrying a fuel gas and colour coded yellow.

Table 2.4 Biogas resistant materials

Material Status	Material List
Recommended	Plastics except PVC and PP (PVC piping only if UV resistant, PVC not for pond liners or covers, PP for pond liners and covers only if no fat is present in effluent), Most stainless steel, Aluminium.
Not recommended	Copper, Steel other than stainless steel, Brass, Traditional butyl rubber.

Biogas pipeline design shall take into account the required transfer volume flow-rates, distances and pressures as well as material compatibility with corrosive biogas and resistance to UV and thermal degradation. The focus of on-farm biogas pipeline installations is therefore on Polyethylene (PE) pipelines and is recommended that on-farm installations comply with AS 4130: 2009 Polyethylene (PE) Pipes for Pressure Applications. Other relevant Australian piping standards are shown in Table 2.5.

Table 2.5 Australian piping standards

Standard	Description
AS 2885 (2008)	Pipelines—Gas and liquid petroleum - applies to steel pipelines and associated piping and components that are used to transmit single-phase and multi-phase hydrocarbon fluids, such as natural and manufactured gas, liquefied petroleum gas, natural gasoline, crude oil, natural gas liquids and liquid petroleum products.
AS 4041 (2006)	Pressure Piping - sets out minimum requirements for the materials, design, fabrication, testing, inspection, reports and pre-commissioning of piping subject to internal pressure or external pressure or both. Specific requirements are given for piping constructed of carbon, carbon-manganese, low alloy and high alloy steels, ductile and cast iron, copper, aluminium, nickel, titanium and alloys of these materials.
AS 4130 (2009)	Polyethylene (PE) pipes for pressure applications - specifies requirements for polyethylene pipes for the conveyance of fluids under pressure. Such fluids include, but are not restricted to, water, wastewater, slurries, compressed air, and fuel gas. Fuel gas includes natural gas, liquefied petroleum gas (LPG) in the vapour phase and LPG/air mixtures.

Over and above these requirements, it is recommended that as part of good agricultural practice, on-farm biogas pipeline installations shall:

a) Be operated at pressures no more than 100 kPa (1bar) (AS/NZS 60079.10) for transfer distances of less than 4,000 metres;

b) All components of the plant including pipe work and fittings need to be suitable for the pressures and temperatures involved as well as the corrosive nature of untreated biogas, unless it has been conditioned to remove H_2S;
c) The pipeline shall be installed by a person who is aware of the risks associated with the facility and the precautions required. Where installed by a farmer, safety checks such as pressure tests by a competent person such as a licensed gasfitter shall be carried out before the plant is commissioned;
d) All piping components including bends, reducer, etc that may be subjected to pressure above atmospheric pressure shall have a pressure relief valve fitted or vents capable of maintaining a pressure no greater than the maximum working pressure of the system being protected;
e) Blowers used for biogas conveyance need to have an appropriate safety rating (e.g. IEC category) for the zone in which they are installed;
f) Biogas blowers do not heat the biogas to temperatures exceeding the pipeline manufacturers' temperature specifications;
g) Biogas transfer pipelines shall have provisions for condensate removal and be installed with a constant minimum slope of 2% to prevent the accumulation of condensate in biogas pipelines at any given time, or shall be fitted with biogas dryers.

2.6.2 Biogas storage

What risks does this section aim to manage/avoid:

a) Biogas storage systems that are inappropriate for the situation
b) Biogas storage which is a safety or environmental risk

CAPs generally provide sufficient biogas storage to accommodate short maintenance periods or facilitate advanced biogas usage, such as peak demand generation on a day/night or weekday/weekend basis.

For situations where additional biogas storage is required, pressure free membrane bags offer the best solution in a farm application. Membrane bags need to be fitted with condensate removal and over-pressure release valves, and are to be located in the open, attached to the ground and protected from wind damage by a suitable net, mesh or other restraining system. Refer to 2.3.2 for zone classification and setback requirement for a gas membrane storage bag.

2.6.3 Conditioning

What risks does this section aim to manage/avoid:

a) Issue of biogas condensate being overlooked, developing into a problem
b) Unconditioned biogas being used and slowly destroying biogas equipment
c) Employed biogas conditioning systems becoming a safety risk or releasing an excessive amount of odour or GHG emissions

Raw biogas may need to be conditioned before it can be transferred or utilised depending on its intended use. The purity requirements increase with different applications from boiler fuel to generator fuel to vehicle fuel.

Biogas from anaerobic digestion is commonly saturated with water. Most biogas utilisation processes require relatively dry gas, so drying is often necessary. Water vapour is a problem, as it may condense into water or ice when passing from high pressure to lower pressure. This may result in corrosion issues and clogging of fittings in the gas conveyance system (such as a flame arrestor).

For all applications, the formation of condensate in transfer pipelines needs to be prevented or managed. For short biogas transfer pipelines working at moderately high pressures located in frost free areas, acceptable condensate management may be achieved via the installation of water knock-out vessels and automatic draining in conjunction with adequate pipeline grades.

Alternatively, biogas needs to be dried to prevent the build-up of condensate in transfer pipelines, which may lead to blockages and operational problems. Annex B: Biogas Conditioning Methods lists appropriate biogas drying methods, of which active biogas cooling (refrigeration) will be the most relevant for Australian on-farm installations. All biogas drying equipment needs to have an appropriate safety rating for the respective zone environment. The target moisture level in the dried biogas (dew point) should be several °C below the minimum ground or air temperature environment, through which the transfer pipeline has to move the dried biogas to the biogas use equipment.

While non-condensing boilers with sufficiently high exhaust gas temperature or boilers made from inert materials can be successfully operated on dry raw biogas, generator applications generally require a reduction in corrosive biogas compounds, particularly H_2S, according to the manufacturer's specifications. As part of good agricultural practice, the amount of corrosive biogas compounds does therefore need to be reduced for generator applications. Annex B lists several appropriate biogas scrubbing methods, which differ in regards to removal efficiency, capital expenditure, operating expenses and level of automation.

For most Australian piggery biogas plants, solid state filter materials based on active carbon or iron hydroxide are likely to be most appropriate. Solid state filters need to be fitted with condensate drains, should be installed with easy machinery access in mind, and should not be exposed to high biogas pressures (i.e. it is recommended to install these filters on the suction side of biogas blowers used for biogas conveyance). All vessels and fittings need to be constructed from inert materials.

Condensate recovered from biogas driers and scrubbers needs to be dealt with appropriately, since it may be rich in contaminants such as H_2S. Recycling this condensate back into the effluent system, either into the digester or downstream treatment ponds, can be a sensible option in many cases.

Biogas CO_2 removal is only required for specialist applications like biogas vehicle fuel, and therefore falls outside the scope of this CoP.

3.0 Health and Safety

3.1 Biogas safety

What risks does this section aim to manage/avoid:

Several properties of biogas are relevant to health and safety: a) Biogas methane is a flammable gas, that can form explosive gas mixtures in air ➔Fire and explosion risk b) The trace gas hydrogen sulphide (H_2S) contained in biogas is corrosive and toxic and can cause adverse human (and animal) health effects at moderately low, but on-going exposure, as well as cause acute, and potentially lethal poisoning, at higher exposure ➔ Intoxication (poisoning) risk c) Biogas release in inadequately ventilated spaces can displace oxygen, potentially leading to asphyxiation of humans and animals ➔ Asphyxiation risk

A wide range of design features (see Section 2.3), management practices (see Section 5.0), protective equipment and training can be employed to minimise these biogas-specific risks and make on-farm biogas production and use a safe and low risk undertaking.

Gas safety regulations are summarised in Annex A.

Table 3.1 lists a number of Australian Standards that incorporate components of safety management that should be utilised.

Table 3.1 Australian Standards covering gas safety management

Standards	Description
AS 3814 (2010)	Industrial and Commercial Gas-fired Appliances - provides minimum requirements for the design, construction and safe operation of Type B appliances that use town gas, natural gas, simulated natural gas, liquefied petroleum gas, tempered liquefied petroleum gas or any combination of these gases either together or with other fuels.
AS 1375 (1985)	Industrial Fuel Fired Appliances Code - sets out the safety principles relating to the design, installation, and operation of industrial appliances that involve the combustion of gas or oil, or other fuel in air suspension, or the generation of combustible vapours in such appliances. It is clear that both open and enclosed flares are industrial appliances that involve the combustion of gas, so AS 1375 is applicable to both.
AS 5601.1 (2010)	Gas Installations – General Installations. This Standard contains the mandatory requirements and means of compliance for the design, installation and commissioning of gas installations that are associated with the use or intended use of fuel gases such as natural gas, LP Gas, biogas or manufactured gas.
AS 3000 (2007)	Electrical installations (known as the Australian/New Zealand Wiring Rules). This Standard sets out requirements for the design, construction and verification of electrical installations, including the selection and installation of electrical equipment forming part of such electrical installations.
AS/NZS 60079.10.1	Explosive atmospheres - Classification of Areas - Explosive gas atmospheres This standard sets out requirements for the classification of areas where flammable gas or vapour risks may arise. It is designed to assist with the proper selection and installation of equipment for use in hazardous areas.

3.2 *Workplace health and safety*

What risks does this section aim to manage/avoid:

Non-biogas specific health and safety issues, such as fall, entanglement, electrical etc not being recognised and managed around the biogas plant

Safe Work Australia (2011) provides a workplace framework which has been adopted in this section.

3.2.1 Managing risks

Anaerobic digestion involves hazards that can negatively impact human health and the environment. It is important that proper precautions are taken to reduce the risks associated with these facilities.

All individuals working with the biogas plant should receive training that includes system components, normal operation, emergency operations and maintenance.

a) Open flames shall not be permitted within 6 metres of the biogas plant (German, 2008). Operators shall ensure that appropriate signage is in place (e.g. no smoking, no unauthorised entry).
b) The operator of the digester should perform a weekly inspection that includes checking for cracks, tears, or points of distress on the digester, the presence of an odour, and signs of feedstock or gas leakage.
c) Preventative maintenance should be conducted in accordance with the component manufacturer's recommendations.
d) Biogas is highly explosive when mixed with air. It can also displace oxygen and cause asphyxiation. Beware of biogas and air temperature differentials as this can result in biogas (and its components) being both lighter and heavier than air. Therefore, all buildings associated with the biogas plant should be well ventilated and alarms and gas-detection devices should be used when work is carried out in poorly ventilated, enclosed areas of the biogas plant.
e) Motors, wiring and lights used within hazardous zones need a safety rating appropriate for the zone to prevent fire and explosion; this includes non-specialist tools and equipment such as handheld lights and cordless drills.
f) Operators should be familiar with the safety precautions regarding manure pits, manure gas, and confined spaces (Refer to Confined Spaces Code of Practice (Safe Work Australia, 2011a)).

3.2.2 Information, training and instruction

Comply with induction and ongoing employee training requirements.

Unattended facilities associated with the biogas plant should be locked to limit risk to individuals unfamiliar with the surroundings and to ensure that the plant continues to operate efficiently. Visitors to a biogas plant should be escorted at all times and are not to operate any switches, controllers, or other electrical functions, including light switches.

3.2.3 General working environment

Guidelines for general working environment identifies hazards specific to biogas plants (US EPA, 2011):

a) electrical system;

b) mechanical system;
c) maintenance work and shutdown;
d) accident prevention signage;
e) fall protection;
f) drowning; and
g) entanglement hazard.

Electrical system

Work on the electrical systems shall be performed only by a suitably qualified electrical worker with reference to AS 3000.

Mechanical system

In the event of a mechanical failure, workers should generally refer to the manufacturer manuals to troubleshoot the issue. Manufacturer manuals for mechanical machinery should therefore be sourced and be on-hand. Only appropriately qualified persons should be permitted to repair mechanical equipment.

Operators should use lock-out/tag-out procedures during all mechanical equipment repairs. To avoid mechanical failures, the operator, with support from the manufacturer, should develop a preventative maintenance manual for the site. This shall include isolation of electrical supply where appropriate. The intent of lock-out/tag-out mechanisms of protection is that the locked system should only be unlocked by the person who locked it out in the first place.

Maintenance work and shutdown

The following suggestions outline how a shutdown of a biogas plant can be achieved. Depending on the system employed, a checklist can be formulated that considers the operating state of the plant based on various conditions.

These hazards are considered separately to normal operating instructions:

a) Stop the feedstock supply into the digester and bypass effluent temporarily to downstream processing (i.e. secondary pond). The quantity of the feedstock removed shall not be greater than the quantity of generated gas in the digester in order to prevent a potentially hazardous atmosphere. For pond digesters, this is particularly relevant during desludging operations. If the quantity of feedstock removed can become greater than the quantity of gas generated, the digester is locked against the gas capturing system, and the connection to the atmosphere is created, (e.g. by emptying the sealing liquid supply). By adding air, a potentially explosive atmosphere can develop in the digester. Ignition sources shall be avoided. Replacing removed sludge with equal volumes of water or digestate from a storage structure is an appropriate measure for avoiding air back-flow under the pond cover;
b) The digester shall be blocked from the gas capturing system in order to avoid a backflow of gas;
c) Before entry into, and while in the digester, it shall be guaranteed that the danger of asphyxiation, fire, and explosion has been safely prevented by sufficient ventilation and that sufficient breathable air is present. This may necessitate the full removal of gas collection membranes from ponds or digesters;
d) Operating equipment (e.g. pumps and agitators) shall be secured to prevent being switched on (lock-out procedures);

In principle, wherever possible, maintenance and work platforms, as well as operating parts of agitators, pumps, and purging devices, shall be placed at ground level.

Accident prevention signage

Accident prevention signs and tags should be visible at all times when work is being performed where a hazard may be present and should be removed or covered promptly when the hazards no longer exist. These should include signage to toxic and flammable gases, burn hazards, noise, personal protective equipment requirements, and restricted access areas. Also, caution signs should be designed to be understood by non-English speakers.

Fall prevention

When possible, employees should perform maintenance work at ground level.

Fall protection, such as guardrails, a safety harness, and self-retracting lifelines, should be used when an employee is above the 1.3 metre threshold. When ladders are used to access elevated equipment, they should be secured and supervised at all times. Once the ladder is no longer needed, it should be removed.

Drowning

Liquid manure storage structures pose a drowning risk. People traffic around manure storage structures should therefore be minimised, and access for unauthorised persons should be prevented. If work around manure storage structures has to be carried out, having more than one person on the job is recommended. Individuals attempting to rescue a drowning individual should never enter a manure storage structure (liquid tanks and ponds) because they could also be overcome by the poor air quality. Where a drowning potential exists, ring buoys, ropes, or ladders should be readily available for rescue purposes.

Although CAP covers are often rigid enough to support the weight of an adult, a pond cover shall not be considered as an adequate means for preventing drowning. On the contrary, people traffic on or near covers should be discouraged and prevented. A fence restricting unauthorised persons' entry to the hazardous zone (see 0) around gas carrying parts of the biogas plant (3 metres distance), can often serve the dual purpose of reducing drowning risk for humans and animals.

Similar security fences are recommended for uncovered liquid manure storage/treatment structures. Furthermore, post signs similar to the one shown, can help to warn people of the dangers associated with liquid manure storage structures.

Entanglement hazard

To reduce the entanglement risk (pumps, mixers, drive shafts, and other machinery due to nip points and other moving parts), all equipment safety guards should be in place and individuals should tie back long hair and avoid wearing loose-fitting clothing, accessories or jewellery.

3.2.4 First aid

The First Aid Code of Practice (Safe Work Australia, 2012) provides information on using a risk management approach to tailor first aid to suit the circumstances of the workplace, while also providing guidance on the number of first aid kits, their contents and the number of trained first aiders that are appropriate for some types of workplaces. However, there is a need to determine if the model Code of Practice has been approved in a particular jurisdiction by checking with the relevant regulator in your State.

Risk management is used with the following four steps:

a) identifying hazards that could result in work-related injury or illness;
b) assessing the type, severity and likelihood of injuries and illness;
c) providing the appropriate first aid equipment, facilities and training; and
d) reviewing first aid requirements on a regular basis or as circumstances change.

Refer to First Aid Code of Practice Appendix A and B for sample templates (Safe Work Australia, 2012).

3.2.5 Emergency plans

An operator conducting a business shall ensure that an emergency plan is prepared for the workplace that provides procedures to respond effectively in an emergency.

The emergency procedures shall include:

a) an effective response to an emergency situation;
b) procedures for evacuating the workplace;
c) notification of emergency services at the earliest opportunity;
d) medical treatment and assistance; and
e) effective communication between the person authorised by the operator conducting the business or undertaking to co-ordinate the emergency response and all persons at the workplace.

Refer to business.gov.au publication *Emergency Management & Recovery Plan Template* for an emergency plan template (business.gov.au, 2012).

3.2.6 Personal protective equipment

The provision of appropriate personal protective equipment (PPE) is recommended together with employee education on how it should be used. For example the plant is required to supply noise protection devices, such as earplugs, to employees and visitors who are exposed to high noise levels. Signs should be posted indicating "hearing protection is required in this area". In areas where hot surfaces and materials can cause burns, signs should be posted indicating "caution: hot surfaces or materials".

Where there is biohazard risk such as contact with micro-organisms, including viruses, bacteria or fungi, it may result in infectious diseases, dermatitis or lung conditions (SWA, Confined Spaces, 2011). Encourage the use of PPE to minimise dust inhalation, absorption through the skin and thorough washing of exposed areas.

4.0 Environmental Protection

4.1 Definitions

Most agricultural biogas plants will be add-ons to existing manure handling and treatment facilities, and in themselves are inherently able to enhance the environmental protection aspects of modern agriculture (e.g. by reducing fugitive odour and GHG emissions). Nonetheless, biogas plants can generate discharges (solid waste discharges, effluent or air emissions) of their own, which need to be carefully managed. These include:

a) Anaerobic digestion process – there are no waste discharges from this process but there is the potential for air emissions in the event of a catastrophic structural failure.
b) Stack/tailpipe emissions – from co-generation engines (diesel or gas), boiler and flare.
c) Used oil and filter – co-generation engines.
d) Spent scrubber media.

4.2 Environmental protection and fire safety agencies

Annex A, Table 7.2, provides a list of State authorities and legislation on environmental protection relevant for biogas plants.

Fire Safety (including periods of Total Fire Ban) require permits where flares are used. Refer to Section 2.5.3 for more details.

4.3 Feedstock management

What risks does this section aim to manage/avoid:

a) Imported material introducing new risks to the operation, including contamination with foreign, problematic or toxic materials as well as novel biosecurity risks b) Imported materials complicating nutrient (and salt) management at the farm

The importation of off-farm feedstock for co-digestion may be associated with biosecurity risks, as well as the potential for contaminant imports, including heavy metals and organic contaminants.

For imported digester feedstocks, the plant operator needs to ensure that:

a) The feedstock does not pose a biosecurity risk to livestock or humans;
b) The feedstock is free of problematic contaminants such as heavy metals; and
c) The fertilizer nutrients (and salt) contained in the imported feedstock is recorded and added to farm nutrient budgets where appropriate.

For on-farm biogas feedstocks, the key outcomes to good practice of manure management in NEGP Sections 10, 11, 12 and 13 apply, in particular:

a) Effluent is collected and moved from conventional sheds to treatment facilities or reuse areas, with minimal odour generation and no releases to the surface water or groundwater; and
b) Effluent treatment systems that are designed, constructed and managed to effectively reduce the volatile solids in effluent, without causing odour nuisance or adverse impacts on water resource.

4.4 Effluent/digestate management

What risks does this section aim to manage/avoid:

a) Unintended fugitive (leakage) b) Concentrated (catastrophic failure) waste (nutrient) discharges from the digester and associated (manure, digestate) storage facilities c) Overall nutrient volumes being estimated wrongly d) Nutrient concentrations in digestate supernatant and sludge being estimated wrongly, leading to underutilisation of the nutrient value in digestate or follow up problems where digestate (components) have been applied excessively

Please refer to NEGP Sections 10, 11, 12, 13 and 14. This provides an overview of Effluent Management (collection and treatment), Solids Separation Systems, Solid By-products Storage and Treatment Areas and Reuse Areas.

Additional points for consideration:

a) Although AD may theoretically reduce the nitrogen (N) content of manure during digestion (by single digit % figures), it is assumed that no nutrient reduction (as a total) does occur for the purpose of compiling farm nutrient budgets. Analogous for farms that also import feedstock, the rule of import feedstock nutrient content = net addition to farm nutrient budget shall apply;
b) Farmers need to be aware that following AD, fertiliser nutrients are more plant available (pro's and con's);
c) For pond systems, some of the potential nutrient flow splitting between supernatant and sludge can occur. While for potassium (K), and with some qualifiers nitrogen, these splits may be almost irrelevant, farmers need to be aware of the potential for phosphorous (P) accumulation and high P concentrations in pond sludge. Therefore, this has consequences for nutrient recycling back to land. For example the risks of trace nutrient concentration in pond sludge (particularly copper [Cu] and zinc [Zn]) can cause complications such as the issue of sludge application to sheep grazed pastures.

4.5 Air emissions

What risks does this section aim to manage/avoid:

That the operation of a biogas plant leads to a substantial increase in the amount of air pollutants emitted from the site

All biogas equipment needs to be operated in accordance with the manufacturers' specifications to minimise air emissions.

For the production of biogas, operators should be aware of the following:

a) Expected chemical composition of the raw biogas;
b) The biogas conditioning methods that will be utilised to remove contaminants from the raw biogas;
c) Expected discharge levels from the utilised biogas conditioning methods (use manufacturer information and/or real data from the plant to address all potential discharges).

For the co-gen unit, operators should be aware of the following:

a) Expected H_2S concentration in the biogas when it reaches the co-gen unit; and
b) Expected discharge levels from utilised co-gen method. Stack tests from comparable units is the preferred method, otherwise manufacturer information, emission factors (from EPA) or mass balance, could also be used as appropriate with justification for rationale.

4.5.1 Flares

What risks does this section aim to manage/avoid:

Release of non-combusted biogas into the atmosphere

For biogas flaring, operators should be aware of the following:

a) Type of flare;
b) Capacity of the flare;
c) Fuel types to be burned (e.g. % biogas);
d) Expected annual flare operation time; and
e) The points in the gas stream at which biogas can be directed towards the flare.

Refer to Section 2.5.3 for guidance on avoiding venting of biogas into the atmosphere.

4.5.2 Noise

What risks does this section aim to manage/avoid:

Minimise the impact of noise into the immediate environment

Careful siting and separation from sensitive land uses will minimise the likelihood of noise to nearby receptors.

Engineering/design options for consideration include:

a) Installation of mufflers on equipment;
b) Use of noise barriers and/or insulated walls.

4.5.3 Odour control

What risks does this section aim to manage/avoid:

Odours becoming a nuisance

The hydrogen sulphide portion of the biogas may also be a source of odour if not managed properly. It is very important the biogas remains within the anaerobic digestion system and associated works with controls (e.g. flares in place to avoid direct venting to atmosphere). During an outage of the main biogas appliance, a flare may be used to manage odour.

4.5.4 GHG management

What risks does this section aim to manage/avoid:

That a biogas plant underperforms regarding possible GHG emission reductions

Biogas capture and use is an eligible activity under the Carbon Farming Initiative (CFI). To be eligible, the biogas plant shall need to be a Recognised Offsets Entity (Carbon Farming Initiative, 2013a) and shall use an approved CFI methodology (Carbon Farming Initiative, 2013b). The References section provides hyperlinks to relevant website pages of the Australian Department of Climate Change and Energy Efficiency.

4.6 Solid waste discharge

What risks does this section aim to manage/avoid:

> That potentially hazardous materials required for the proper operation of a biogas plant (e.g. generator motor oil, biogas filter media) do not become new environmental risks

Management of generator motor oil:

a) Either in fully enclosed sumps that can store the entire oil volume that may leak or in rooms with oil skimming bottom drains;
b) Disposal contract for used generator motor oil needs to be in place and be presented upon request from the EPA.

Management of spent biogas filter media:

a) Some biogas filter media can be recycled on-farm (e.g. iron sponge or active carbon). These should be preferred over materials that cannot be safely disposed of without causing harm to humans or the environment (e.g. chemical absorbents or ZnS);
b) For materials requiring off-site disposal, a management plan/contract similar to motor oil needs to be in place.

5.0 Operation and Maintenance

5.1 Commissioning and start-up

What risks does this section aim to manage/avoid:

a) Unfinished/untested biogas plants commencing operation b) Start-up issues leading to bacteria community collapse and acidic waste c) Special risk of explosive gas mixture being formed during start-up phase

Prior to biogas plant start-up (first filling), all digester ponds/tanks need to undergo a testing/check regime. This includes:

a) Checking of all gas containing equipment such as liner and cover welds for tightness;
b) Checking of all biogas carrying pipelines, biogas scrubbing vessels, biogas blowers including connection pieces for gas tightness (e.g. pressure test by competent person);
c) Inspection of pipeline liner penetration for tightness;
d) For concrete tanks, checking of all penetrations (mixer shafts etc) for tightness;
e) For heated digesters, checking the digester heating system, circulation pumps etc; and
f) Checking of the cover seal and anchor for tightness for both concrete tanks and pond covers.

Prior to feedstock being introduced, CAPs and tank digesters need to be filled with start-up liquid to fulfil two functions - providing a pH buffer for initial acid formation from the feedstock as well as anaerobic bacteria flora as seed. For digesters primarily digesting manure, an active bacteria flora can be established spontaneously provided sufficient water buffer can prevent a low pH from occurring. Over ten days' worth of manure feed should be provided as initial clean/recycled water buffer. The more non-manure material a digester is going to process, the more important seeding with active bacteria sludge will become.

Farmers need to be aware that during digester start-up, an especially problematic gas mixture will form in the gas space above the feedstock. Biogas air mixtures are explosive within a mixing range of 6% to 12% biogas in air. During digester start-up, the air under the gas cover will transition through this explosion window as biogas production begins and biogas will crowd out the residual air under the cover.

The formation of the volatile biogas air mixture during the start-up phase needs to be minimised for all biogas plants. Deflating covers prior to filling with feedstock, as well as filling empty digester space with water prior to waste solids introduction, is an appropriate way of reducing the enclosed volume, where a volatile gas mixture can form.

Purging the enclosed air with the addition of dry ice (frozen CO_2) is another appropriate way for reducing the volume and duration of existence of a volatile gas mixture during start up.

Extreme care needs to be taken during the initial commissioning of gas flares and other biogas use equipment. The weak and potentially explosive biogas air mixture from under the cover should be vented for several days, until the biogas air ratios are safely above the upper explosive limit, before ignition sources like flares or generators can be connected to the biogas supply line. During the initial start-up phase, the risk of burn back and explosion can be extreme, particularly for tank digesters containing a lot of volatile biogas air mixture under the cover.

5.2 Digester operation and microbes

What risks does this section aim to manage/avoid:

a) Digesters becoming overloaded and unstable
b) Biogas quality declining
c) Solids conversion rate and overall biogas recovery from feedstock declining

A biogas plant is operated in such a way that nutrient availability (choice of feedstock) and internal digester environment (pH, digester temperature, ammonia concentration, etc) favour the species of microbes and the synergistic effect that maximises the methane yield. Although the process is fairly robust, it is very important that the delicately balanced conditions are kept stable to achieve the best possible methane production. Frequent and/or substantial changes to important conditions, such as the feedstock composition, are detrimental to biogas production, and by extension, counterproductive to the economic viability of the operation.

Key measures to consider in digester operation are:

a) The daily feeding regime of any type of digester needs to ensure that design solids loading rates are not exceeded and hydraulic retention times are not reduced;
b) Shock loadings shall be avoided as much as possible;
c) For pond digesters, stratification within the pond needs to be maintained (e.g. by buffering shock loads/flows);
d) Avoid the use of anti-microbials;
e) For ponds, solids carry over should be monitored regularly (e.g. monthly); and
f) For all digesters, digestate pH should be logged regularly (e.g. weekly) as declining pH are a good indicator of digester over loading, reduced hydraulic retention time (HRT) or loss of active volume (i.e. due to sludge build up for ponds or due to improper mixing for mixed digesters).

The mixture of bacteria can be considered as comprising two main groups: the acid-formers that convert organic material to simple acids such as lactic and acetic; and the methane formers that convert acids to methane and carbon dioxide. It is important that the two groups work together. When the process is in balance, the digester contents will be in the neutral to slightly alkaline range of pH 7- 7.5.

5.3 Biogas conditioning and upgrading

What risks does this section aim to manage/avoid:

a) Biogas scrubbers working ineffectively leading to downstream problems due to low gas quality
b) Gas flow blockages

Some dust and oil particles from the blowers may be present in the gas. These particles have to be filtered out using 2 to 5μm filters made of paper or fabric, which will need to be replaced at regular intervals as part of normal maintenance. The replaced filters will constitute a non-hazardous solid waste discharge.

Depending on biogas conditioning/upgrading method chosen, several maintenance tasks need to be carried out:

a) Regular and scheduled biogas quality analysis is beneficial for all biogas conditioning/upgrading methods to evaluate effectiveness and ensure sufficient gas quality for downstream use;
b) For iron sponge scrubbers, condensate pH needs to be logged regularly (i.e. bi-monthly). Acidic condensate indicates a reduced H_2S removal efficiency necessitating rejuvenation or filter material exchange;
c) For biological scrubbers, air injection volumes need to be metered and logged regularly and if H_2S levels in the raw biogas change, adjusted accordingly;
d) Water levels in pressurised water scrubbers need to be monitored;
e) Bio-film growth needs to be monitored in all biogas conditioning devices and coolers, particularly for systems that include air injection;
f) Condensate knock-out vessels need to be maintained and regularly drained/checked; and
g) Biogas scrubbers producing condensate or working with water as well as biogas refrigeration dryers need to be frost protected.

5.4 Biogas utilisation

5.4.1 Boilers

What risks does this section aim to manage/avoid:

a) Boiler becoming a safety risk
b) Biogas use becoming inefficient

a) Boilers need to be maintained in accordance with the manufacturer's specifications.
b) Internal boiler surfaces need to be checked for corrosion twice per year.
c) Condensate formation in flue gas stack needs to be monitored. If it is a regular occurrence, operating temperatures need to be increased (fuel air ratio) or the stack needs to be sleeved with a corrosion resistant liner.

5.4.2 Co-gen operations

What risks does this section aim to manage/avoid:

a) Reduced working life of generator due to lack of maintenance or inappropriate biogas quality
b) Generators working with suboptimal electrical conversion efficiency
c) Generators causing excessive air pollutant emissions

The following suggestions are for the operator's consideration depending on the sophistication of their equipment - to be entered into a maintenance checklist:

a) Depending on the contents of hydrogen sulphide, the lubrication properties of the motor oil can be reduced, or deposits at pistons, bushings, and valves can cause abrasive processes (increased wear). Both effects can lead to substantial damage. Therefore, the gas quality shall be monitored. Through appropriate gas conditioning, the contaminants can be removed in order to prevent damage and premature wear. The manufacturer's specification shall be followed;
b) With pilot injection engines, too small a quantity of pilot fuel can lead to an insufficient cooling of the injection valves. Therefore, the injection valves shall be checked every 1200 to 1500 operating hours and changed, if necessary. Dripping injection valves lead to serious damage at the pistons and bushings. This can result in potentially serious engine problems;

c) Temperature measurement with an alarm trigger is an effective method to monitor the respective combustion chamber temperatures for each cylinder. This way, damage due to overheating can be prevented through timely shut off;
d) Gas motors can be adapted to lower quality gas with lower methane content through changes of the ignition point. Here, a knocking of the engine is generally not expected (biogas has a high knock resistance), unless the system is operated in a bivalent mode with liquid gas;
e) Motors suited for biogas also have small amounts of non-ferrous metals (piston rod bearing bushing, oil cooler, camshaft bearing etc) and therefore are susceptible to acids. If the specified gas and oil qualities are not maintained, the motors can fail long before the scheduled major overhaul;
f) With increasing acid content, the motor oil loses its lubrication properties. Therefore, it is recommended that oil analyses adapted to the operating conditions be performed, with determination of the TAN value (total acid number). The results should be documented, and the intervals should be adapted accordingly;
g) The exhaust system should be constructed from welded (not inserted or clamped) stainless steel pipes. Exhaust gas lines shall lead the exhaust gases away hazard free. A distance of at least 20cm to combustible building materials shall be maintained;
h) Feed and return lines of lubrication oil of the turbo charger should be checked regularly for tightness through visual controls.

If the manufacturer does not specify service intervals for gas motors, the following shall be performed:

a) Every 20,000 operating hours – a partial reconditioning (check: cylinder head, turbo air cooler, piston rod bearings, pistons, and running bushings; replace depending on wear); and
b) Every 40,000 operating hours – a fundamental reconditioning, with replacement of all wearing parts (generators, agitators, and separators shall be included).

For pilot injection motors:

a) Every 15,000 operating hours – a partial reconditioning; and
b) Every 30,000 operating hours – a fundamental overhaul.

Air filters need to be exchanged within the manufacturer's recommended exchange interval - same for oil filters.

Ignition system needs to be checked monthly and spark plugs need to be changed following the manufacturer's guidelines (i.e. annually).

5.5 Monitoring and record keeping

The key to successful biogas plant operation is in knowing the system and being able to look back and evaluate the performance. To do this, it is necessary to keep records of the operation and maintenance (for digester operation, see Section 0, for biogas conditioning, see Section 0, for biogas utilisation see Section 0) and to evaluate these records as a routine exercise.

Each operator should establish and maintain a written record of the monitoring activities.

6.0 References

Standards Australia references:

AS 1375, 1985. Industrial Fuel Fired Appliances Code.

AS 2885, 2008. Pipelines—Gas and Liquid Petroleum.

AS 4041, 2006. Pressure Piping.

AS 4130, 2009. Polyethylene (PE) Pipes for Pressure Applications.

AS 3814, 2010. Industrial and Commercial Gas-fired Appliances.

AS 5601, 2010. Gas Installations.

AS 2430.3.1, 2004. Classification of hazardous areas.

AS 3000, 2007. Electrical installations.

AS 1596, 2002. The Storage and Handling of LP Gas.

AS 60079.10.1, 2009. Landfill gas, sewerage treatment and sewerage pumping plants. Clause 8.1 of Annex ZA.

BC Ministry of Environment, (2010). On-farm Anaerobic Digestion Waste Discharge Authorization Guideline.

Bourke, Dennis A. (June 2001). Dairy Waste Anaerobic Digestion Handbook, Options for Recovering Beneficial Products From Dairy Manure.

Carbon Farming Initiative, (2013a). Undertaking a CFI project, Department of Climate Change and Energy Efficiency, Accessed 5 March 2013.
http://www.climatechange.gov.au/government/initiatives/carbon-farming-initiative/handbook/project.aspx

Carbon Farming Initiative, (2013b). Methodology determinations, Department of Climate Change and Energy Efficiency, Accessed 5 March 2013.
http://www.climatechange.gov.au/government/initiatives/carbon-farming-initiative/methodology-development/determinations.aspx

Davidson, AA, (2010). A Review of Australian Regulations and Standards for the Handling and Treatment of Biogas, Prime Consulting International (Australia) Pty Ltd.

Business.gov.au, (2012). Emergency management & recovery plan template, Accessed 2 December 2012.
http://www.business.gov.au/Howtoguides/Thinkingofstartingabusiness/Whatplanningtoolscanhelpme/Pages/Emergencymanagementplantoolsguides.aspx

Hyam & Mitchell, (1997). Environmental Resolve, The Environment Council (UK), Anaerobic Digestion of farm and food processing residues – Good Practice Guidelines.

German Agricultural Occupational Health and Safety Agency, 2008. Safety Rules for Biogas Systems.

Heubeck, S. (2010). "Biogas Use Options" Conference presentation at Bioenergy Australia 2010 Conference; 10th December 2010, Sydney, Australia.

National Greenhouse and Energy Reporting (Measurement) Determination 2008, accessed 21 December 2012 at http://www.comlaw.gov.au/Details/F2012C00472

Office of Gas Safety, (2005). Gas Safe, Draft Landfill/ Biogas Flare Systems Guidelines.

Petroleum and Gas (Production and Safety) Act 2004 Victoria Gas Safety (Gas Installation) Regulations 2008 - 165/2008, 18/01/2009 001 (Latest Version).

Safe Work Australia, 2011. Model Work Health and Safety Regulations: Model Regulations, 4 November 2011.

Safe Work Australia, 2012. First Aid in the Workplace Code of Practice. Draft March 2012.

Safe Work Australia, 2011a. Confined Spaces Code of Practice, December 2011.

Standards Association of New Zealand. (1987a). Code of Practice for the Production and Use of Biogas, Farm Scale Operation: Part 1 Production of Biogas, Publication No. NZS 5228, Wellington, New Zealand.

Standards Association of New Zealand. (1987b). Code of Practice for the Production and Use of Biogas, Farm Scale Operation: Part 2 Uses of Biogas, Publication No. NZS 5228, Wellington, New Zealand.

Skerman, Alan, (2005a). Earth pad preparation requirements for deep litter pig production systems and solids waste stockpile and composting areas.

Standards Australia, 2012. Standards Development – SG-006 – Rules for the structure and drafting of Australian Standards, version 2.4, 3 April 2012.

Tucker, RW, McGahan, EJ, Galloway, JL and O'Keefe, MF, (2010). National Environmental Guidelines for Piggeries - Second Edition, APL Project 2231, Australian Pork Ltd, Deakin, ACT, Australia.

United States Environment Protection Agency, (2011). (AgStar) Common Safety Practices for On-farm Anaerobic Digestion Systems.

Victoria Environment Protection Authority, (2012). Regulatory Impact Statement for the Environment Protection (Scheduled Premises and Exemption) Regulations 2007; New Exceptions.

Annex A: Australian Regulators

Table 7.1 Summary of State gas safety agencies

State	Regulation	Certifying Authority	Notes
NSW	Gas Supply (Consumer Safety) Regulation 2012	Department of Planning – Hazards Unit Work Cover Authority, Department of Fair Trading	For further information, refer to *Part 6 – Gas installations (not supplied from a gas network)* to ensure the correct testing and certification requirements are completed, where biogas installations operating under 200 kPa are regulated.
QLD	Petroleum and Gas (Production and Safety) Regulation 2004	Office of Energy, Department of Natural Resources and Mines	Further information and application forms for a Gas Work Authorisation (Industrial Appliances) and a Gas Work Authorisation (servicing) can be sourced from the regulator.
VIC	Victoria Gas Safety (Gas Installation) Regulations 2009 **001**	Energy Safe Victoria	For further information refer to Energy Safe Victoria – to Schedules 7, 8, 9, 10, 11 and 12.
TAS	Gas Safety Regulations 2002	Workplace Standards Tasmania, under the Department of Justice - Office of the Director of Gas Safety	A Safety Management Plan pursuant to Sec 77 of the Gas Act 2000 and Regulation 46 (d & g) of the Gas Safety Regulations 2002 is required for an on-farm biogas installation. The pertinent document is the *Guideline for the preparation of a submission for the acceptance of Gas Installation (major) "safety management plan."*
SA	Gas Regulations 1997	Office of the Technical Regulator, Department of Transport, Energy and Infrastructure	While safety and technical issues involving gas installations are covered under Part 4 of the Gas Regulations 1997, neither the Act nor Regulations are applicable to an on-farm biogas facility in South Australia, unless an LPG pilot light is being used.
WA	Gas Standards (Gas fitting and Consumer Gas Installations) Regulations 1999	Energy Safety WA, Department of Consumer and Employee Protection	Gas Standards Act 1972 and the subordinate legislation the Gas Standards (Gas fitting and Consumer Gas installations) Regulations 1999 do not cover on-farm biogas where an operator produces and consumes biogas on the same site (unless piped to a neighbouring farm).
NT	Dangerous Goods Regulations 2010	NT Work Health and Electrical Safety Authority	The applicable legislation is Part 3 of the Regulations 'Class 2 dangerous goods (gases)'. Furthermore, the general licensing requirements for the manufacture and storage of dangerous goods, is covered in Section 3 and 4, respectively, of the Regulations.

Table 7.2 Summary of State environmental authorities

State	Regulation	Competent Authority	Notes
NSW	Protection of the Environment Operations (Clean Air) Regulation 2010	Department for Environment, Climate Change and Water	Part 4 of the Regulation which covers the Emission of Air Impurities from Activities and Plant is limited to particulate emissions from flares with a larger capacity than those most likely to be installed on farms.
QLD	Environmental Protection Regulation 2008	Queensland Department of Environment and Heritage Protection	Requires a licence for any "Environmentally Relevant Activity" (ERA) listed in the Regulation. For biogas flaring, a fuel burning licence is required for all equipment with a fuel burning capacity of 500 kg/h or more, as per ERA 15 in the Regulation. For installations not requiring a licence, the general intention of the Act is to be complied with and all reasonable practicable measures taken to prevent environmental harm.
VIC	Environment Protection (Scheduled Premises and Exemptions) Regulations 2007 and State Environment Protection Policy (SEPP) (Air Quality Management)	Environment Protection Authority (EPA) Victoria	EPA works approval is required but a new exemption from a discharge control licence is provided for gas fired boilers and turbines of a rated capacity of not more than 20MW (Victoria EPA, 2012).
TAS	Environment Protection Policy (Air Quality) 2004	Environmental Protection Authority within the Department of Primary Industries, Parks, Water and Environment	No licence required for on-farm biogas as it is under the threshold of burning combustible matter of one tonne or more per hour. However, compliance with the Policy is required as its Schedule 1 specifies 'in-stack concentrations that would normally be expected to be achievable using accepted modern technology.'
SA	Environment Protection Regulations 2009	Environmental Protection Authority	Fuel Burning licence under the Act has a minimum threshold limit of 5MW. It is not applicable to biogas flares as the largest on-farm biogas flare has maximum heat out output of 4.4MW. With no licence requirement, flaring shall still comply with the air quality impact assessment requirements included in EPA 386/06 which requires that the combustion process adequately disperses nitrous oxide and other pollutants that may be detrimental to human health, and may be applied differently depending on the proximity to residential areas.
WA	Environmental Protection Regulations 1987	Environmental Protection Authority	Farm-scale biogas plants do not meet the threshold criteria.
NT	Waste Management and Pollution Control Act 2009	Natural Resources, Environment, The Arts and Sport (NRETAS)	On-farm biogas emissions are not regulated.

Source: Davidson (2010).

Annex B: Biogas Conditioning Methods

Table 8.1 Water vapour removal methods

Water Vapour Removal Method	Technical Description	Contaminants Introduced to Biogas or Digestate	Waste Discharges	Advantages and Disadvantages
Passive gas cooling	A piece of biogas pipeline with condensate drains is installed underground. Biogas piped underground for a short period of time is cooled. Cooling condenses some water vapour from the biogas which is collected.	No contaminants introduced.	Condensate water can carry substantial amounts of dissolved H_2S. Condensate needs to be handled with care to avoid odour nuisance and gas intoxication. Condensate can be recycled back into the digester pond.	Pro: • Simple construction • Minimal maintenance Con: • Only partial water removal • Condensate needs to be managed
Refrigeration (active gas cooling)	Heat exchangers are used to cool the biogas to desired dew point. Water vapour condenses, and is removed from the heat exchanger assembly through drain valves or separators. Cooling source can be cold (bore) water, or a refrigeration machine.	No contaminants introduced.	As above (passive cooling).	Pro: • Near complete removal of water vapour possible • Automated process • Moderately complex setup Con: • Moderate investment costs • Potentially parasitic energy consumption • Condensate to be managed
Absorption	Glycol or hygroscopic salts absorb water as biogas is directed through the drying medium. Drying medium is regenerated by drying it at a high temperature.	No contaminants introduced.	Process is regenerative but eventually the drying media will have to be replaced. Hygroscopic salts will result in a non-hazardous solid waste stream.	Pro: • Near complete removal of water vapour possible • No liquid condensate handling Con: • Process is hard to automate • Maintenance requirements

Water Vapour Removal Method	Technical Description	Contaminants Introduced to Biogas or Digestate	Waste Discharges	Advantages and Disadvantages
				• Ongoing costs for absorption media exchanges • Relatively large reactor vessels required
Adsorption	Silica gel or aluminium oxide adsorbs water as biogas is directed through the medium. Drying medium is regenerated by drying it at a high temperature at high pressure (otherwise air needs to be injected for regeneration).	No contaminants introduced.	Process is regenerative but eventually the drying media will have to be replaced, which will result in a non-hazardous solid waste stream.	Same as above (absorption)

Source: Based on BC Ministry of Environment, 2010.

Table 8.2 Hydrogen sulphide (H_2S) removal methods

Removal Method	Technical Description	Contaminants Introduced to Biogas or Digestate	Waste Discharges	Advantages and Disadvantages
Biological oxidation	Air is injected into the gas headspace above the digesting feedstock in the digester. The target is 2-6% air in the biogas. Sulphur oxidising bacteria will consume air derived oxygen to converts H_2S to elemental sulphur (S) and water.	Nitrogen is introduced to the biogas with air injection. Excess air may drive the H_2S oxidisation process to produce sulphuric acid instead of elemental sulphur.	No direct discharges. Sulphur (and sulphuric acid) is fully buffered in the digestate and is therefore not discharged.	Pro: • Low investment costs • Low operational costs and minimal maintenance Con: • Only partial H_2S removal with variable results possible • Air injection leads to N_2 dilution of biogas (more pumping effort, etc) • Malfunctioning air injection equipment can create an explosive gas mixture under the biogas cover.
Iron chloride dosing	Liquid iron chloride solution is injected directly into the feedstock mixing tank. Normal dosing is 4g/litre feedstock. H_2S is converted and contained in the feedstock as $Fe_2(SO_4)_3$. Has the added positive effect of reducing odour.	While chloride ions are introduced to the system, they remain in the digestate where they cause no problem.	No direct discharges. Added chloride does not result in chloride – related combustion discharges.	Pro: • No structural addition to biogas plant required Con: • Only partial H_2S removal with variable results possible • Ongoing cost for chemical purchase • Very high overall costs with dilute feedstocks such as piggery flush manure
Water scrubbing	Create a solution of H_2S in water by feeding the biogas through a counter flow of water. Normally only used in combination with water scrubbing biogas upgrading technologies.	No contaminants introduced.	The process can be designed as a regenerative process, in which case scrubbing water discharge would be significantly reduced.	Pro: • Very high biogas purity achievable • Simultaneous removal of CO_2 and other trace contaminants • Automated system

Removal Method	Technical Description	Contaminants Introduced to Biogas or Digestate	Waste Discharges	Advantages and Disadvantages
			If the process is regenerative the desorbed gas will be vented out through an absorption filter of active carbon, iron hydroxide or iron oxide type (see next items in the table). The desorbed gas that passes through the filter constitutes an air discharge.	Con: • Very high investment costs • Parasitic energy consumption • Very high biogas purity rarely needed for on-farm biogas uses
Activated Carbon	Raw biogas flow is led through an activated carbon filter, often impregnated with potassium iodine (KI) or sulphuric acid (H_2SO_4). This method is usually used in combination with and subsequent to, ventilation of air into the biogas (see biological oxidation). H_2S is converted to elemental sulphur (S).	No contaminants introduced.	Regeneration of the activated carbon will result in air emissions however this activity will most likely occur off-site at a specialised facility. Activated carbon is listed as a Dangerous Good.	Pro: • High biogas purity achievable • Simultaneous removal of other trace contaminants • Relatively cheap and simple reactor required Con: • Ongoing costs for active carbon purchases • Some maintenance required
Iron Hydroxide or Oxide	Biogas is passed through a media composed of woodchips and iron oxide or hydroxide. H_2S reacts to form iron sulphide. Less common media are rust coated steel wool or pelleted “red mud” (a by-product of aluminium production).	No contaminants introduced.	This process is often regenerative, but eventually the filter media will have to be replaced. Depending on the filter media used, the spent media may constitute a hazardous waste and shall be disposed of accordingly. Note: FeS is pyrophoric – can spontaneously combust.	Pro: • High biogas purity achievable • Relatively cheap and simple reactor required Con: • Ongoing costs for media purchases • Some maintenance required • Fire risk if regeneration is not managed carefully
Sodium Hydroxide	Biogas bubbled in a NaOH solution forms	No contaminants introduced.	Scrubbing water containing sodium	Pro: • High biogas purity

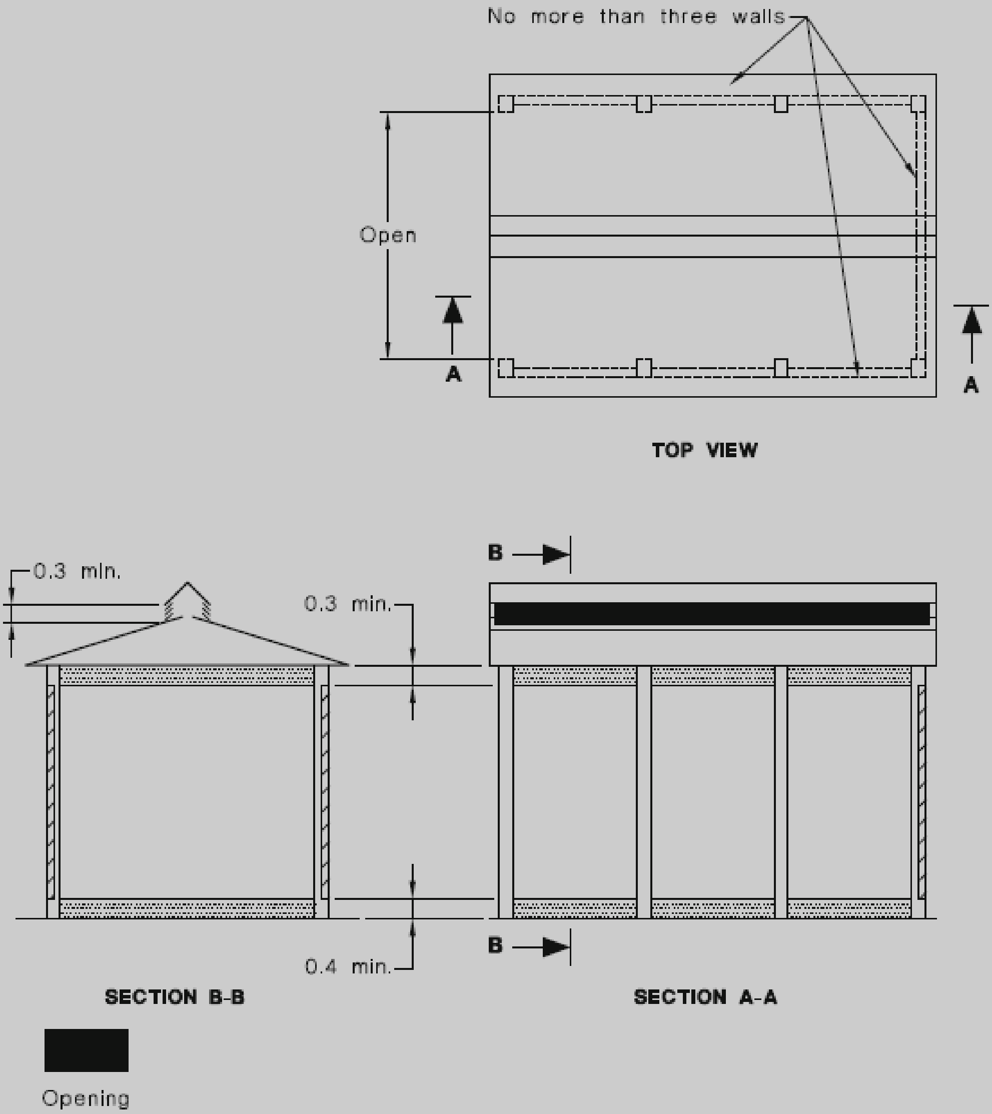
Removal Method	Technical Description	Contaminants Introduced to Biogas or Digestate	Waste Discharges	Advantages and Disadvantages
	sodium sulphide or sodium hydrogen sulphide.		sulphide or sodium hydrogen sulphide. Caustic solutions are frequently dangerous goods. The spent material may or may not be. The process requires less scrubbing agent (NaOH solution) compared to pure water scrubbing but the process cannot be regenerative.	achievable Con: • Ongoing costs for media purchases • Moderately complex reactor required • Some maintenance required • Health and safety risk with handling caustic substances • Biogas needs to be compressed to moderate pressure for bubbling through solution (or liquid needs to be recirculated) indicating parasitic energy consumption

Source: Based on BC Ministry of Environment, 2010.

Annex C: Example of Adequately Vented Shelter

Table ZA.1 – Ventilation criteria

	Adequate ventilation	Inadequate ventilation
1 Open-air (Note 1)	An open-air situation with natural ventilation, without stagnant areas, and where vapours are rapidly dispersed by wind and natural convection. Air velocities should rarely be less than 0.5 m/sec and should frequently be above 2 m/s*	Natural ventilation limited by topography, nearby structures, weather conditions Artificial ventilation may be necessary to meet adequate ventilation and this is normally easily achieved
2 Sheltered structures (Note 2)	(a) Within a structure having no more than three walls (See Figure ZA.2) and where all walls have continuous or virtually continuous ventilation openings along their full length comprising not less than 0.4 m high effective opening at the bottom, 0.3 m high effective opening at the top of the walls and 0.3 m virtually continuous effective opening at the highest part of the roof	Structures having less wall and roof ventilation than that given in (a). Structures that have a low profile or are extensive
	(b) A structure having effective openings equal to at least 10% of wall surface in all walls at both top and bottom of all sides, and 0.3 m continuous, or virtually continuous effective opening at all ridges of the roof	Structures having less wall and roof ventilation than that given in (b) Structures that have a low profile or are extensive
	(c) For LP Gas cylinder filling (other than in situ), a structure having no more than two closed walls	—
* Typically air velocities of not less than 0.5 m/s would suffice.		
NOTE 1 – Where air movement is limited due to topographical features, other nearby structures or unusual meteorological conditions, artificial ventilation may be required by the provision of suitably located fans to improve the ventilation in order to achieve adequate ventilation (see AS 1482 for further guidance). NOTE 2 – The ventilation criteria noted are generally applicable to small or medium structures with medium to large sources of potential release. For small sources of release, large structures or highly buoyant gases, alternative criteria may be applicable.		



Dimensions in metres

Figure ZA.2 – Example of shelter which may be treated as an adequately ventilated location

Source: AS/NZ 600079.10.1:2009 page 69-70.

Annex D: Examples of Zone Classification

Appendix 9

Examples Zone Classification

System Part	Type of Impermeability	Zone 1	Zone 2
General			
Around: System parts, equipment parts, connections	Equipment and system parts with operational gas outlet	1 m around the outlet point	2 m around Zone 1
	tight	–	3 m around system part
	permanently tight	–	–
Examples			
Burst safety device that in normal operation seals securely		–	3 m around system part
Outlet opening of exhaust lines		1 m around outlet opening	2 m around Zone 1
Service Opening			
If the service openings are not opened during normal operation	With operational gas outlet	1 m around the outlet point	2 m around Zone 1
	tight	–	3 m around system part
	permanently tight	–	–
Gas Storage			
Around: Simple membrane storage out in the open			3 m from above
Simple membrane domes on digester containers and storage			3 m to the side
Around ventilation and exhaust openings of vapour-sealed gas storage rooms			2 m downward at 45° gradient
Double membrane domes with digester containers and storage, if the through-flow leads the diffusing biogas sufficiently diluted (<< 10% LEL) from the gas storage, and the exiting air is continuously monitored.		–	–

Appendix 9

System Part	Type of Impermeability	Zone 1	Zone 2
Condensate Separator			
Room that contain the condensate collector. With open water locks, formation of a hazardous, possibly explosive atmosphere must be anticipated as a result of puncture or drying out of the water locks, or as a result of faulty operation: a) with the discharge in closed rooms without ventilation – **Zone 0 in the entire room**			
b) with the discharge in closed rooms with natural ventilation		Entire room	1 m around openings of the enclosed room
c) closed drainage system, locks with double locking devices or automatic drainage For the total space, 1 m around openings of the enclosed room.		–	–
Solid Substance Dosing			
If during normal operation, forced submersed supply is guaranteed.		–	–

Dimensioning of the Area of Zone 1

A spherical area with a radius of 1 m around is considered an area of Zone 1 (see also, TRBS 2152) such as system parts, equipment parts, connections, sight glasses, pass-through, service openings at the gas storage and at the gas-carrying part of the digester container and around the outlet openings of exhaust lines, if an operational outlet of biogas must be anticipated.

The radius of 1 m applies in the case of natural ventilation.

Under normal operating conditions, releases into closed rooms must be avoided. If possible, the entire room is Zone 1.

Appendix 9

Dimensioning of the Areas of Zone 2

Gas-Carrying System Parts

A spherical area with a radius of 3 m around system parts classified as impermeable are considered areas of Zone 2 such as equipment parts, connections, pass-through, service openings, as well as burst plates. The radius of 3 m applies in the case of natural ventilation. Closed rooms are entirely areas of Zone 2 (see also, TRBS 2152).

A spherical shell with a radius of 2 m thickness around system parts not classified as impermeable are considered areas of Zone 2, such as equipment parts, connections, sight glasses, pass-through, service openings, and at the gas-carrying part of the digester container, as well as around the outlet openings of exhaust lines, if these have an operational outlet of biogas.

Gas Storage

If the membrane storage is stored out in the open or housed in a room ventilated all around, the area of Zone 2 encompasses the periphery of 3 m upwards and to the side, and 2 m downwards with a 45° gradient. In the case of housing the membrane storage in a vapor-tight and, therefore, extensively gas-tight room, Zone 2 encompasses the interior of the gas storage room and the periphery of 3 m around the ventilation and exhaust opening upwards and to the sides; the extent downwards amounts to 2 m with a 45° gradient.

Vapour-tight rooms can be rooms constructed with, e.g.:

- brickwork walls with trim
- concrete walls
- walls whose coating consists of non-combustible and spackled plates
- standardized containers with metal walls

Note

Around system parts that are permanently impermeable, according to TRBS 2151, Section I 1.3.2.2 (see Appendix 10), there is no zone

Appendix 9

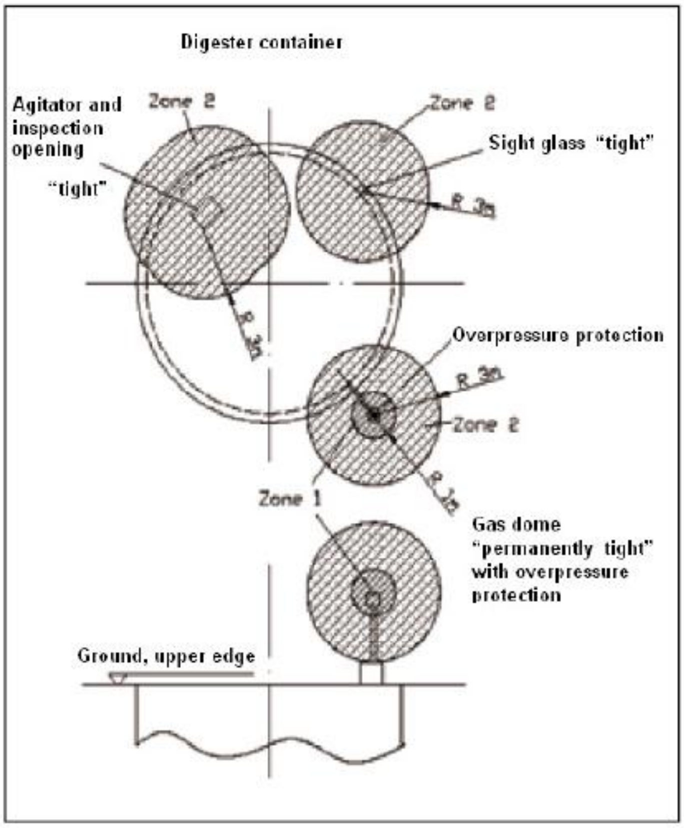
Double Membrane (Support Air)

No zone is present around the outer membrane and in the intermediate space between the two membranes if the through flow sufficiently thins (< 10% LEL) the biogas diffusing from the gas storage and leads it off in a targeted manner, and the air that is being discharged is continuously monitored according to the maintenance plan (manufacturer specification).

A ring-shaped potentially explosive atmosphere can occur around the transition to the digester if the connection is not implemented in a permanently impermeable manner.

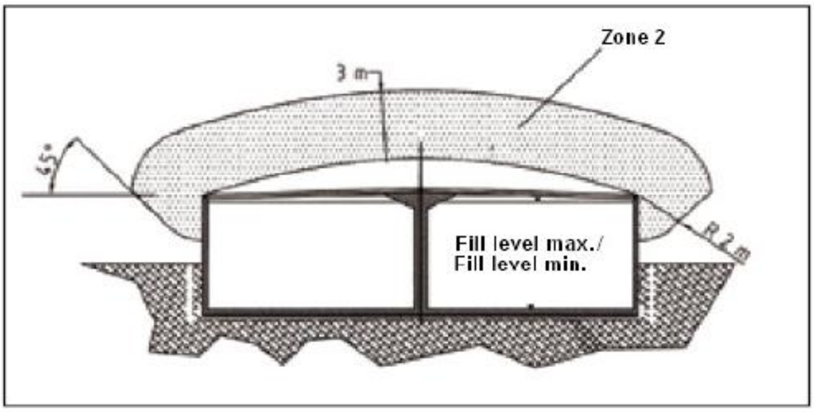
If it is not possible to prevent backflows into the support air blower, these are to be implemented according to 94/9/EU.

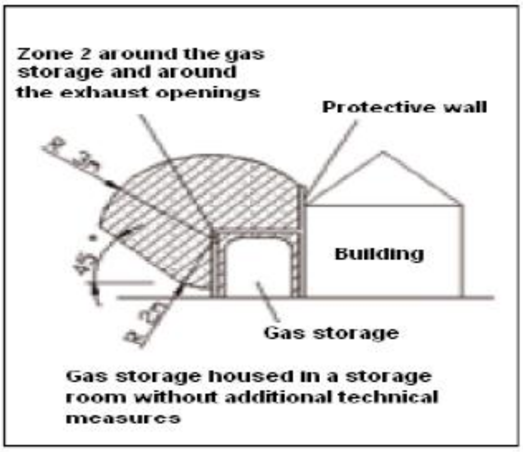
Example – Biogas System, Top View with Permanently Tight System Parts

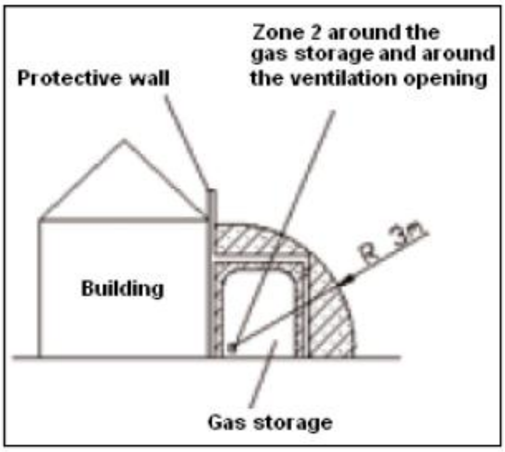


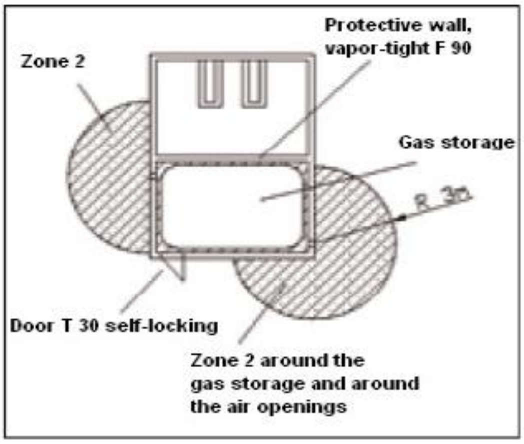
Appendix 9

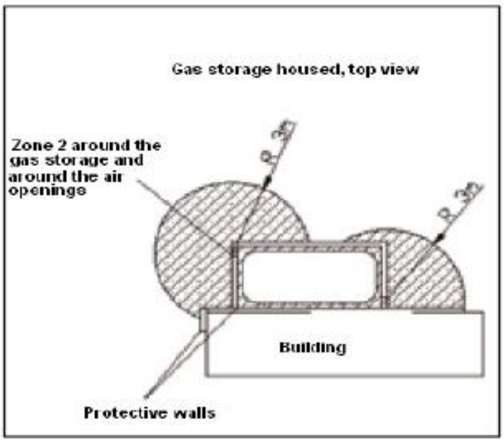
Example – Housed Gas Storage (Storage Room Without Further Technical Measures)











Source: German Agricultural Occupational Health and Safety Agency, 2008.